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Corresponding author:
Carrie E. Schweitzer;
Email: cschweit@kent.edu

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New Carboniferous and Permian cyclidans (Multicrustacea: Cyclida) from the Urals (Russia): the unpublished collection of B.I. Chernyshev at the CNIGR museum in St. Petersburg

Eduard V. Mychko[1,2,3,4], Alexander S. Alekseev[4,5] and Carrie E. Schweitzer[6]

[1]Shirshov Institute of Oceanology, Russian Academy of Sciences, Nahimovskiy Prospekt 36, Moscow 117997, Russia
[2]A.N. Severtsov Institute of Ecology and Evolution, Leninsky Prospect 33, Moscow 119071, Russia
[3]Institute of Living Systems, Immanuel Kant Baltic Federal University, Nevskogo Street 14, Kaliningrad 236016, Russia
[4]Borissiak Paleontological Institute, Russian Academy of Sciences, Profsoyuznaya Street 123, Moscow 117647, Russia
[5]Geological Faculty, Lomonosov Moscow State University, Leninskie Gory 1, Moscow 119991, Russia
[6]Department of Earth Sciences, Kent State University at Stark, North Canton, Ohio 44720, USA

Abstract

We describe the findings of cyclidans from the unpublished collection of the famous paleontologist B.I. Chernyshev (1888–1950) in the storage of the Academician F.N. Chernyshev Central Scientific Research Geological Survey Museum (CNIGR museum, St. Petersburg, Russia). These cyclidans were discovered by various researchers in the Carboniferous and Permian of the Urals. They are represented by the following taxa: *Oonocarcinus uralicus* new species, *Uralocyclus feldmanni* new species, *Ambocyclus capidulum* (Chernyshev, 1933), and *Magnitocyclus* (?) sp. indet. The discovery of the new species *Oonocarcinus uralicus* n. sp. greatly expands the geographic and stratigraphic interval of the genus *Oonocarcinus* Gemmellaro, 1890, previously known from the Middle Permian and Triassic. The discovery of *Uralocyclus feldmanni* n. sp. in the Mississippian deposits of the Chelyabinsk Oblast indicates a wide distribution of the genus *Uralocyclus* Mychko and Alekseev, 2018 in the Early Carboniferous, because Carboniferous representatives of this genus were previously known only from Ireland and England. The paper provides an up-to-date list of all known cyclidan occurrences and taxa in Russia.

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Non-technical Summary

We describe the findings of cyclidans from the unpublished collection of the famous paleontologist B.I. Chernyshev (1888–1950) in the storage of the Academician F.N. Chernyshev Central Scientific Research Geological Survey Museum (St. Petersburg, Russia). Cyclidans are extinct, unusual arthropods that are superficially similar to crabs, and can even look like horseshoe crabs or ticks, but are not related to any of these groups. The specimens were discovered by various researchers in the Carboniferous and Permian of the Ural Mountains of Russia. Two new species are named, and two previously known species are reported here. The new findings expand our knowledge of this enigmatic group and will help to decipher their evolutionary history and niche in the ancient ecosystems in which they are found. The paper provides an up-to-date list of all known cyclidan occurrences and taxa in Russia.

Introduction

Cyclidans are an extinct group of crustaceans that existed from the Early Carboniferous (Tournaisian) to the Late Cretaceous (Maastrichtian). Cyclidans are very rare fossils in the geological record, and each of their occurrences is extremely valuable for understanding the diversity and evolution of this group. Externally, cyclidans were morphologically convergent with crabs, but phylogenetically or evolutionarily, they are not related to them or to other decapod crustaceans. They are distinguished in a separate order Cyclida Schram, Vonk, and Hof, 1997, within the superclass Multicrustacea Regier et al., 2010.

Representatives of the cyclidans have an elongate-oval, convex or flattened carapace, often ornamented with numerous and varied sculptural elements. Externally, their carapace, like that of most arthropods, is divided into two bilaterally symmetrical parts. In the anterior (head) part of the carapace are convex lobes, the number and shape of which varies from genus to genus. Most have an anterior unpaired axial lobe, located in the center of the anterior part of the carapace; on both sides of it, there can be paired axial and lateral lobes, up to three or four pairs (Feldmann and Schweitzer, 2019).

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Posterior to the axial lobe of cyclidans is the posterior axial lobe, with a triangular or obovate shape. In some species, numerous transverse ridges diverge from the axial part. Closer to the ventral (sternal) side, the carapace is bordered by a marginal rim. In the posterior part of the carapace and border is a posterior notch (Feldmann and Schweitzer, 2019). However, the last feature is not present in all cyclidan genera. The surface of the entire carapace is often ornamented with numerous tubercles and papillae.

Cyclidans have two pairs of antennae like most crustaceans. On the ventral side, held anterior to the rostrum, there are two pairs of maxillae, short limbs located near the oral region. Posterior to the maxillae are the maxillipeds. Posterior to the maxillipeds are five or six pairs of trunk limbs. Extending posteriorly from the carapace is a pair of caudal rami of unclear function (Feldmann and Schweitzer, 2019). However, spinose caudal rami can be seen in the specimens of *Americlus rankini* (Woodward, 1868) from Scotland attached to the terminal abdominal segment and might have functioned like the cercopods of extant branchiopods (Clark et al., 2020).

Cyclidans lived in a variety of environments: some species are known from relatively deep-sea shelf or shallow-water deposits, and salinity ranged from hypersaline to (possibly) freshwater (Schweitzer et al., 2020). Apparently, all known cyclidans were benthic forms, possibly leading a lifestyle similar to that of crabs (Mychko, 2022a, b).

Interest in this group has been revived. Only recently, a universal morphological terminology was developed for cyclidans (Feldmann and Schweitzer, 2019) as well as a revision of all species and genera (Schweitzer et al., 2020). Since this last work, only a few studies have been published on new finds of cyclidans from various localities around the world (Tang et al., 2021, 2023; Dernov, 2022; Mychko et al., 2022; Pieroni, 2024). Currently, Cyclida consists of six families, 28 genera, and ~55 species.

The first very brief information about the discovery of cyclidans in Russia (former USSR), attributed to the genus *Cyclus* de Koninck, 1842, appeared in the report of the famous Soviet geologist and paleontologist Boris Isidorovich Chernyshev (Fig. 1), which he presented at a meeting of the Russian Paleontological Society on 25 April 1930 (Chernyshev, 1935b). According to Chernyshev, these crustaceans belonged to 'primitive crabs.' In 1931, Chernyshev returned to this topic and on 17 April 1931, at a meeting of the same society, he reported 'his findings' of a number of arthropods, including *Cyclus*, from the Lower Carboniferous of the Urals and Turkestan (Chernyshev, 1935a). A very brief summary of both reports was published in volume 10 of the 'VPO Yearbook' (Chernyshev, 1935b).

In 1933, Chernyshev published descriptions of the first cyclidans (Fig. 2) discovered in the USSR. These were identified as representatives of the genus *Cyclus* from Lower Carboniferous limestones of the Alapaevsk District, Sverdlovsk Oblast in Russia (*Cyclus capidulum* Chernyshev, 1933) and the Lower Carboniferous locality Shurab II on the northern slope of the Turkestan Range in Tajikistan (*Cyclus spinosus* Chernyshev, 1933 and *Cyclus tuberosus* Chernyshev, 1933) (Chernyshev, 1933). The collection for Chernyshev's 1933 paper with the description of cyclidans is stored in the Academician F.N. Chernyshev Central Scientific Research Ggeological Survey Museum (CNIGR museum, St. Petersburg) under number 3694 (Kulikov, 1985, p. 138, 139) and is on display in the 'Paleozoic Hall.'

Later, in the Russian revised edition of the textbook on paleontology by Zittel (1934, p. 899), a very short 'addition' was placed between Phyllocarida and Syncarida in the class Crustacea. Its author should be considered to be Chernyshev, who took part in the revision of the section on arthropods. We cite it in full: "From the Lower Carboniferous, Permian and Triassic, calcareous remains of crustaceans in the form of a cap with tubercles in the head area and a median groove were described. These remains cannot yet receive a sufficiently clear position in the system. They were considered either as the larva of Merostomata or as primitive crabs. Glaessner thinks that these are Phyllocaridae. At present, they are distinguished into a special group Cycloidea Glaessner with the genera *Cyclus* de Kon.—Lower Carboniferous, England, Belgium, Urals, Turkestan. *Halycine* Meyer—Cretaceous and Triassic, Germany. *Oonocarcinus* Gemmellaro (Fig. 1767)—Permian, Sicily; Upper Carboniferous, Urals. *Paraprosopon* Gemmellaro—Permian, Sicily" (Weber et al., 1934, p. 899).

Figure 1. Boris Isidorovich Chernyshev (1888–1950). Photograph from the collections of the Yeisk Museum of History and Local Lore (Yeisk, Russia).

The indication of the presence of *Oonocarcinus* Gemmellaro, 1890 in the 'Upper Carboniferous' of the Urals was of particular interest to us. However, Chernyshev did not provide a description of *Oonocarcinus* representatives from the USSR in subsequent works.

Chernyshev gave an explanation regarding the 'Upper Carboniferous' cyclidans in 1939: "For other regions of the Union, we know crustaceans only in the amount of two species of the genus *Oonocarcinus* from the Urals (they were found in the Eichwald

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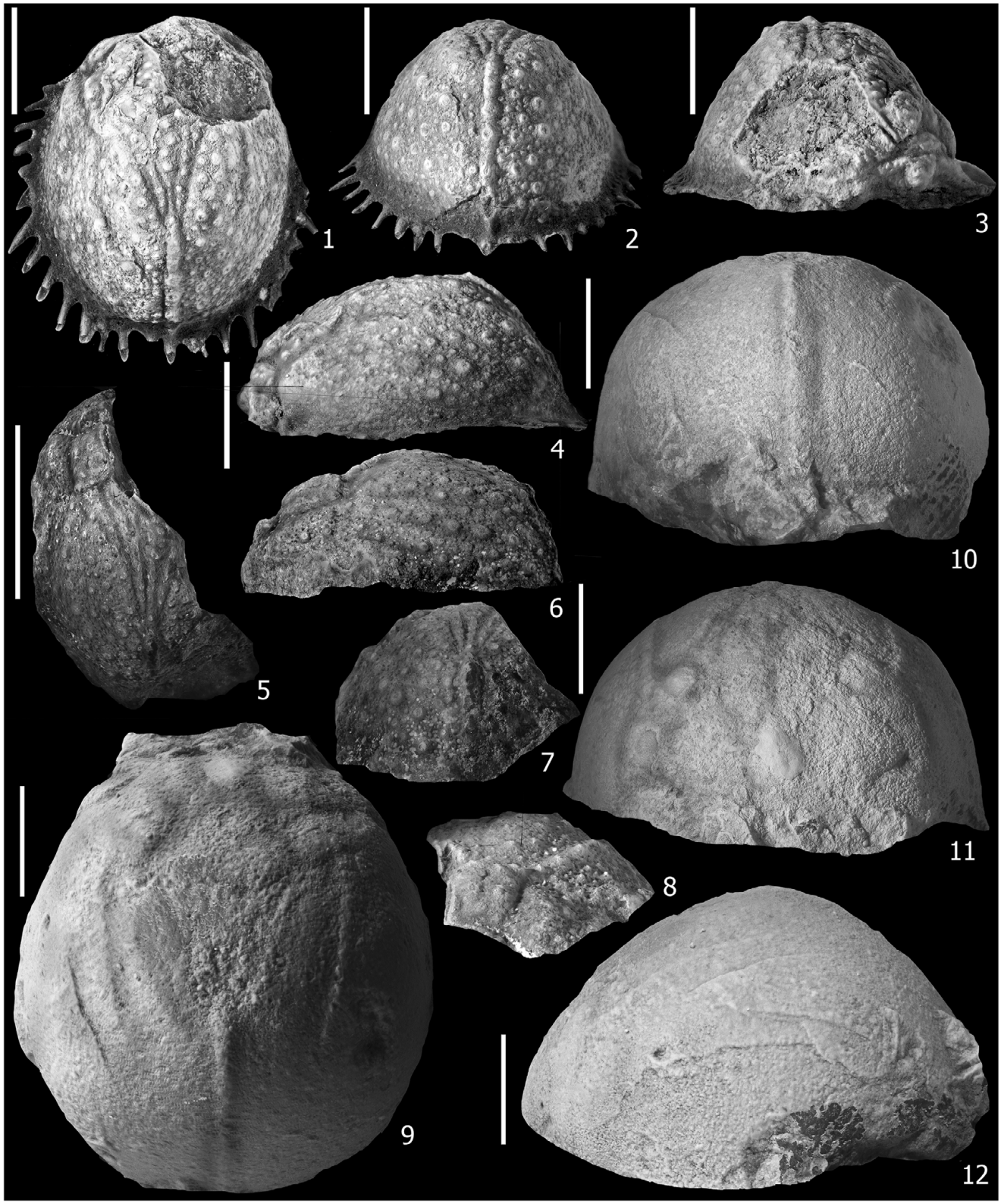

Figure 2. The first cyclidans of the USSR, described by B.I. Chernyshev (1933): (**1–8**) *Chernyshevine spinosus* (Chernyshev, 1933), locality Shurab II, Turkestan Range, Tajikistan, Middle Mississippian (Viséan): (**1–4**) holotype, CNIGR museum no. 12/3694: (**1**) dorsal view; (**2**) posterior view; (**3**) anterior view; (**4**) lateral view; (**5–8**) paratype (holotype of *Cyclus tuberosus* Chernyshev, 1933), CNIGR museum no. 14/3694, incomplete carapace: (**5**) dorsal view; (**6**) lateral view; (**7**) posterior view; (**8**) anterior view; (**9–12**) *Ambocyclus capidulum* (Chernyshev, 1933), holotype, CNIGR museum no. 15/3694, Alapaevsk District, Sverdlovsk Oblast, Russia, Lower Carboniferous limestones, Upper Mississippian (Serpukhovian): (**9**) dorsal view; (**10**) posterior view; (**11**) anterior view; (**12**) lateral view. Scale bars = 2.5 mm.

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collection) and from there one representative of Triopsidae. These extremely interesting forms indicate the age of the strata" (Chernyshev, 1939, p. 141, 142).

Additional information on the cyclidans of the USSR is contained in the 'Atlas of the Index Forms of Fossil Faunas of the USSR, Volume 4, Lower Series of the Carboniferous System,' which was ready for publication in 1937 but not published until 1941; it also belongs to Chernyshev (1941, p. 154): "Very peculiar forms from the Viséan, which have not yet received a definite place in the system and are united in the Cycloidea group, which until recently was generally known almost exclusively from Belgium and England (a small number were found in North America), were first discovered in Fergana on the Shurab River. Later, they were found in the Urals and Novaya Zemlya in a significant number of samples in the same Viséan strata. The Fergana forms with spines are closer to what was known from America, but there are the same ones here as in Europe and the Urals. Forms devoid of spines show similarities with European ones. These forms are so characteristic and so limited in time that they may be good indicators of the age of the deposits which contain them."

Thus, in the hands of Chernyshev back in the 1930s, there were quite a lot of specimens of cyclidans from the Lower Carboniferous and, as it turned out, even the Bashkirian (at that time, it was thought that the younger Serpukhovian and Bashkirian deposits could belong to the Viséan), including from Novaya Zemlya. Unfortunately, Chernyshev never returned to the study of this group.

In the volumes of the Soviet 'Fundamentals of Paleontology' devoted to arthropods, the genus *Cyclus*, defined by Chernyshev, is absent. However, Birshtein (1960, p. 440) included a note in the section on decapod crustaceans with the following content: "The Permian and Triassic crustaceans described by Schafhäultl (1863), Frech (1900) and Trauth (1918) as Brachyura, according to Glaessner (1928) do not belong to Decapoda and should be separated into a special group Cycloidea, approaching on one side Phyllopoda, and on the other – Phyllocarida."

A little time after publication of the 'Fundamentals,' Kramarenko (1961) described a new species of cyclidan, *Cyclus miloradovitchi* Kramarenko, 1961, based on seven well-preserved carapaces from the Lower Permian (Asselian) of 'Kazarmenny Kamen' (or 'Kazarmenny Greben') on the Sim River in the Chelyabinsk Oblast. After this paper, the study of this group of fossils in Soviet/Russian paleontology was forgotten for a long time.

The study of cyclidans from the territory of Russia was resumed almost 60 years later, thanks to the efforts of the authors of this paper. In 2018, we described a new species and genus of cyclidans—*Skuinocyclus juliae* Mychko and Alekseev, 2018 from the Lower Permian of Shakhtau—and established a new genus *Uralocyclus* Mychko and Alekseev, 2018, based on the material collected by Kramarenko (Mychko and Alekseev, 2018). Later, the lead author (EVM) managed to find fossil remains of cyclidans in a recently discovered (and, unfortunately, destroyed by subsequent limestone mining) Konzentrat-Lagerstätten (Mychko et al., 2019a) in the Akkermanovka quarry of the Orenburg Oblast, in the Viséan. The new cyclidans were similar to the species *Prolatcyclus martinensis* (Goldring, 1967) from the Viséan of England, and this material and the English findings served to describe a new species and genus *Prolatcyclus kindzadza* Mychko et al., 2019b.

Several years ago, two of the authors of this paper, together with the late Dr. R.M. Feldmann (Schweitzer et al., 2020), carried out a revision of all known cyclidans in general. In this work, for the first time, all species of these fossils were presented with their classification at the level of families and genera, including using a morphospace analysis. Several new genera were proposed, and the taxonomic affiliation of cyclidans described by Chernyshev (1933) was revised. Thus, the species *Cyclus spinosus* and *Cyclus tuberosus* were synonymized and assigned to the new genus *Chernyshevine* Schweitzer, Mychko, and Feldmann, 2020, named in honor of Chernyshev. The species *Cyclus capidulum* was assigned to the new genus *Ambocyclus* Schweitzer, Mychko, and Feldmann, 2020.

Another species and genus of cyclidan from Russia—*Magnitocylus struveae* Mychko et al., 2022—was described, the only specimen of which came from the Lower Carboniferous of the Urals (Mychko et al., 2022). It was also established there that *Petschorocaris kozhimensis* Pirozhnikov, 1960—the 'cyclidan' described from the Permian (Kungurian) along the Kozhim River (Komi Republic)—is most likely not a cyclidan, but the internal mold of a cap-shaped gastropod shell.

In April 2024, the lead author of this paper (EVM) serendipitously discovered a box with interesting fossil crustaceans while studying the collections at the CINGR museum. This collection (no. 5178) was prepared by Chernyshev in 1936 under the title 'Some Arthropoda from the Paleozoic of the USSR. Silurian-Permian. Collections of Markovskiy, Khodalevich, Reinwald, and others. (Ural, Turkestan, etc.)' and contained numbered but undescribed specimens of ostracods, phyllocarids, and cyclidans with labels (Fig. 3). Apparently, Chernyshev did not have time to describe this collection before moving from Leningrad to Kyïv in 1939. The cyclidans in this collection are represented by five specimens of varying states of preservation and come from the Carboniferous and Permian of the Urals.

Localities and geological setting

The cyclidan specimens found almost 100 years ago were for that time quite accurately tied to sections and had reliable biostratigraphic dating, but most often were simply referred to the Carboniferous. As a result of more recent increases in stratigraphical detail, however, these data are now so imprecise as to make it impossible to establish their age with any accuracy. Nevertheless, we tried to decipher the stratigraphic position of four specimens of Uralian cyclidans, but our placement turned out to be very broad, covering two stages or even stages of adjacent systems. Now that the cyclidans are reported in the literature, more work can help place them more precisely stratigraphically. See Figure 4 for Russian stages and substages, as well as regional stratigraphic terminology used in the discussion.

Shartymka River (Fig 4.5, point c). The primary label of CNIGR museum, no. 12/5178 (Fig. 3) indicates that this specimen was found by Yakovlev (the initials were added later in pencil) on the Shartymka (Shartym) River; the year of collection and number of the outcrop are not indicated. The recent geographical position is Chelyabinsk Oblast, Uy District, right bank of the Shartymka River, the so-called 'Murchison Hill,' 5 km southwest of the village of Pichuginskiy, on the left bank of the Uy River.

According to Librovich (1939, p. 4), Yakovlev collected fossil fauna on the Shartymka River in 1924 for the Geological Committee. Weber (1937) described a number of trilobites collected by Yakovlev in outcrops 35, 38, 23, and 27. There was also unfigured material from outcrops 34, 43, and 58. Observations of the distribution of cyclidans show that they are often associated with trilobites in localities, so in the absence of other information, it is advisable to follow the levels containing them. All available

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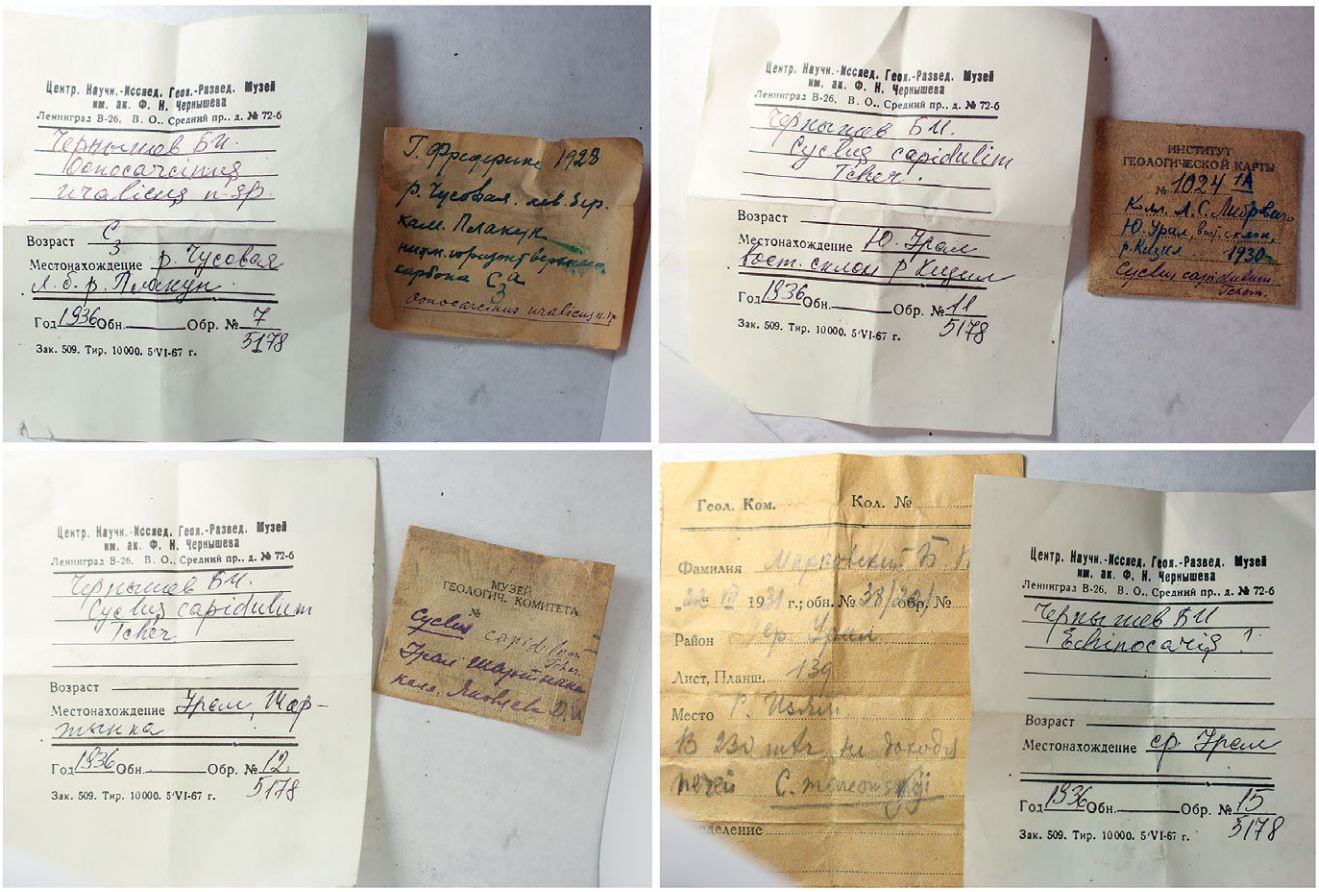

Figure 3. Original labels for cyclidan specimens from unpublished B.I. Chernyshev collection (no. 5178) in the CNIGR museum (St. Petersburg, Russia).

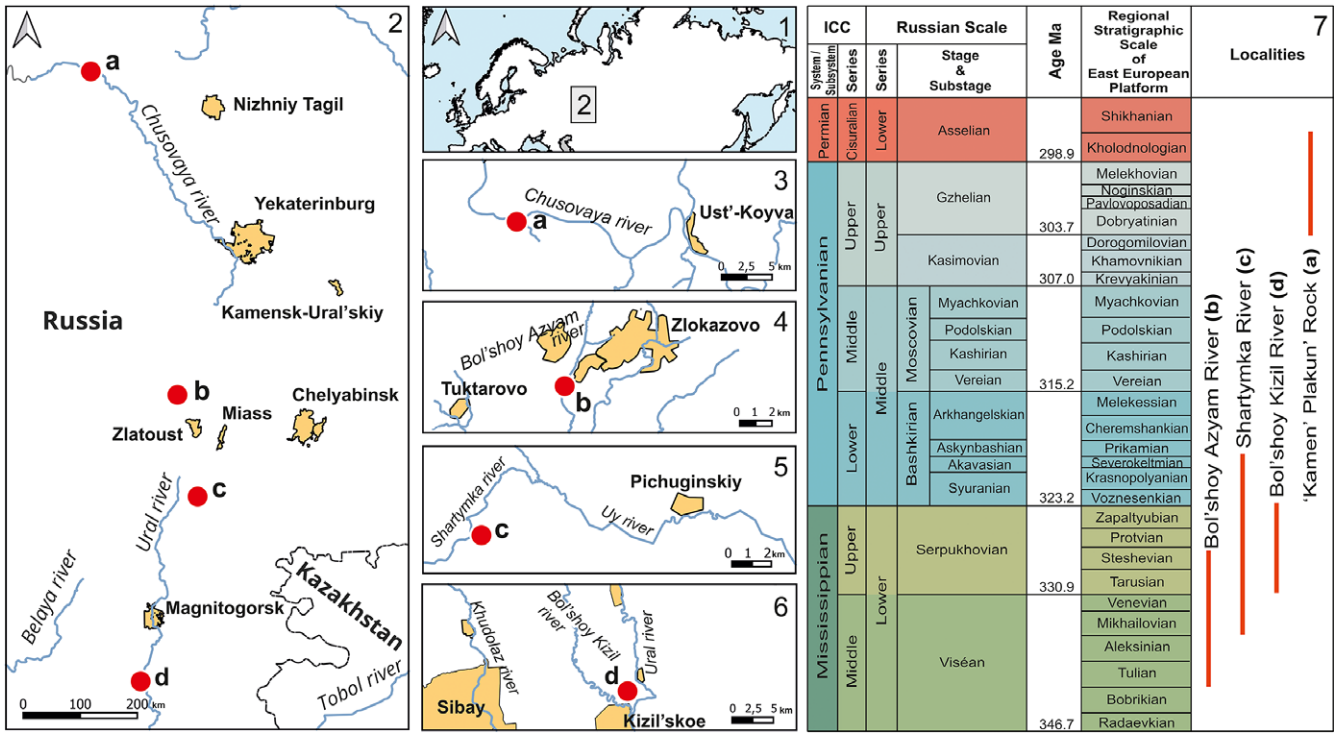

Figure 4. Localities of Chernyshev's cyclidans described herein: (**1**) map of northern Eurasia; (**2**) Middle-Southern Urals and the Cis-Urals; (**3,** a) vicinity of locality of 'Kamen' Plakun' Rock; (**4,** b) vicinity of locality of Bol'shoy Azyam River; (**5,** c) vicinity of locality of Shartymka River; (**6,** d) vicinity of locality of Bol'shoy Kizil River; (**7**) stratigraphic scale of Middle Mississippian–Early Permian (Cisuralian) of East European platform with position of localities (modified from Alekseev et al., 2022).

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information shows that on the Shartymka River, trilobites are present almost only in the upper part of the section, which was identified by Librovich as Horizon 5 or the Upper Shartymka Beds according to Einor (1973), which the latter attributed to the Syuranian Regional Substage of the Lower Pennsylvanian (Bashkirian). Ruzhentsev and Bogoslovskaya (1978, p. 18–20) analyzed the age of the ammonoid assemblages collected in the Upper Shartymka Beds and came to the conclusion that they all correspond to the lower half of the *Bilinguites-Cancelloceras* Genozone, although they do not contain index forms. According to modern interpretation, the lower part of the *Bilinguites-Cancelloceras* Genozone corresponds to the Akavasian Regional Substage of the Lower Pennsylvanian (Bashkirian) (Alekseev et al., 2013, 2022).

However, cyclidans of this morphology have not yet been found anywhere in Bashkirian rocks and this makes the presence of cyclidans in the Upper Shartymka Beds very questionable. At the same time, Librovich (1939, p. 18) indicated the presence of *Cyclus* sp. indet. in outcrop 160, located north of 'Murchison Hill' in the Upper Serpukhovian Horizon 4, together with trilobites. Chernyshev in 1931 at a meeting of the Russian Paleontological Society (Summary…, Chernyshev, 1935b) reported the occurrence of *Cyclus* in the Urals, during which, undoubtedly, he spoke about where they were found. Therefore, the find on the Shartymka River most likely became known to Librovich, and in his 1939 paper, he had in mind precisely the specimen found by Yakovlev. In the upper part of Horizon 4 (Middle Shartymka Beds), Sultanaev collected the assemblages of ammonoids of the *Homoceras-Hudsonoceras* Genozone (Ruzhentsev and Bogoslovskaya, 1978, p. 19, 20) of the Syuranian Regional Substage of the Bashkirian.

The attribution of the outcrop with early Bashkirian ammonoids to Horizon 4 and the general allocation of these 'horizons' is not supported by geological data. In his review of the stratigraphy and paleontology of the Shartymka Carboniferous, Einor (1973) indicated that any extended outcrops of bedded carbonates are absent in the region, and there are many areas with breccias and limestones strongly altered by secondary processes, the position of which in general succession is unclear, with signs of the presence of faults, which makes it impossible to construct a consistent summary section. Einor's group drilled several wells during fieldwork and pits were excavated, but neither their columns nor the determinations in the core (e.g., foraminiferans) were published. This indirectly indicates that the materials of the mining work could not be rationally interpreted. Thus, each outcrop on 'Murchison Hill' must be dated separately, and outcrop 160 with cyclidans could have an age in the range from the Mikhalovian Regional Substage of the Middle Mississippian (Upper Viséan) to the Akavasian Regional Substage of the Lower Pennsylvanian (Bashkirian), which are known in this area (Einor, 1973).

'Kamen' Plakun' Rock (reef) (Fig. 4.3, point a). The label of CNIGR museum specimen no. 7/5178 (Fig. 3) contains fairly detailed information, i.e., that it was found by Fredericks in 1928 on the left bank of the Chusovaya River in the 'Kamen' Plakun' Rock. The age of the beds is indicated as 'lower horizon of the Upper Carboniferous C3a.' Zenchenko (1930) described the 1928 work after participating under the supervision of Fredericks. The faunal list from the 'Kamen' Plakun' Rock contains more than 40 forms, among them *Capulus* sp. indet. (Zenchenko, 1930, p. 1054). In the nineteenth and first half of the twentieth centuries, the genus *Capulus* Montfort, 1810 was often used to refer to Paleozoic cap-shaped gastropod shells, and there is every reason to believe that this name was attributed to the cyclidan found by Fredericks, the carapace of which can easily be confused with a gastropod shell (Mychko et al., 2022).

'Kamen' Plakun' is a rock outcrop on the left bank of the Chusovaya River, ~10 km southeast of the Chusovoy town in Perm Krai between the mouths of the Bol'shaya and Malaya Isakovka rivers, opposite the small Isakovskiy Island. The 'Kamen' (= rocks) on the Chusovaya are high rocky cliffs composed of Carboniferous, often reefal, limestones, with their base submerged, so that they can often only be reached by boat.

The first comprehensive description of the geological structure and stratigraphy of the area surrounding the 'Kamen' Plakun' Rock was given by Nalivkin (1955). The reef limestones of 'Kamen' Plakun' proper are mainly composed of hydractinoids (*Palaeoaplysina* Krotov, 1888), bryozoans, and problematics of *Tubiphytes* Maslov, 1956. At the base of the cliff, the limestones, which were considered to be Upper Pennsylvanian (Upper Kasimovian), contain a fusulinid assemblage: *Triticites* ex gr. *T. arcticus* (Schellwien, 1908), *Triticites petschoricus* Rauser-Chernousova and Belyaev in Rauser-Chernousova, Belyaev, and Reitlinger, 1936, *Triticites* aff. *T. fortissimus* Rauser-Chernousova, 1958, *Triticites* cf. *T. montiparus* var. *kumpani* Putrja, 1940, *Ozawainella* cf. *O. angulata* (Colani, 1924). Brachiopods and bryozoans were also very diverse here. The reef has a height of ~70–80 m in outcrop and a total thickness of ~100–150 m, and according to Nalivkin, it continued to grow during the *Pseudofusulina* and *Schwagerina* biozones, otherwise Late Pennsylvanian (Gzhelian) to Early Permian (Asselian) time, when it expanded significantly.

Later, detailed biostratigraphic studies of the 'Kamen' Plakun' Rock and its vicinity based on the modern stage and zonal division of the Carboniferous were carried out by Shcherbakova and Shcherbakov (1994, 2009). They concluded that the base of the section belongs to the *Triticites stuckenbergi* Biozone (now *Rauserites rossicus* Biozone), which begins the Gzhelian Stage of the Upper Pennsylvanian. However, they did not determine the index species of this zone. The reef body itself covers the entire volume of Gzhelian, but the upper part of the section belongs to the Lower Asselian of the Lower Permian. In the western part of the rock, Asselian limestones descend to the water level in the river and could be sampled.

Because the 'Kamen' Plakun' Rock is a reef structure with a complex relationship of facies and often with nonhorizontal bedding, without information about the exact point of the find, the age of the cyclidan-containing strata can only be determined as Upper Pennsylvanian (Gzhelian)–lowermost Permian (Asselian).

Bol'shoy Kizil River (Fig. 4.6, point d). The label of CNIGR museum no. 11/5178 states that the specimen belongs to the Librovich collection and was found in 1930 on the eastern slope of the southern Urals on the Kizil River, outcrop 1024^{1A}. Undoubtedly, this refers to the Bol'shoy Kizil River, in the lower reaches of which the marine Carboniferous is widespread. The strip of outcrops of the Kizil Formation with a total thickness of ~1,500 m extends along the left bank of the Bol'shoy Kizil River for a distance of ~7 km to the Kizil'skoye Village (Chelyabinsk Oblast), where it flows into the Ural River. The total stratigraphic range of the Kizil Formation covers the interval from the Middle Mississippian (Tulian Regional Substage, Viséan, Holkerian) to approximately the middle of the Lower Pennsylvanian (Bashkirian, Askynbashian Regional Substage) (Kulagina et al., 2009, 2015). The section does not represent a single outcrop, rather a series of outcrops separated by intervals without outcrops.

Unfortunately, Librovich (1933, 1936) did not indicate the numbers of the outcrops in his works on the Carboniferous stratigraphy of the eastern slope of the southern Urals, so it is very difficult to localize the stratigraphic position of this specimen. During his studies, Librovich found many trilobite remains, which were described by Weber (1937). Among them, *Brachymetopus*

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(*Brachymetopus*) *strzeleckii* var. *uralica* Weber, 1937 and several other forms come from outcrop 1023b (Weber, 1937, p. 86), attributed to 'Horizon' 4 or Member 'd' of the Kizil Formation, which, according to modern scales, belongs to the Upper Mississippian (Serpukhovian). The closeness of the numbers of the outcrops with trilobites and cyclidan (1023 and 1024) does not guarantee their coeval age, but the Serpukhovian age of locality 1024[1A] seems more probable than the Lower Pennsylvanian (Bashkirian) one.

Bol'shoy Azyam River (Fig. 4.4, point b). The label of CNIGR museum specimen no. 15/5178 includes 'July 22, 1931, outcrop 38/22. Middle Urals, Izyam River, 230 m before reaching the furnaces. Collector Markovsky.' This river is now called Bol'shoy Azyam, and the location itself was supposed to be on its left bank near the village of Nikolskiy and west of the village of Zlokazovo (Kusa District of Chelyabinsk Oblast). The exact location of the kilns in which charcoal was burned for the Nikolskiy Ironworks is unknown because they have not survived. A geological description with a map of the territory near Zlokazovo has been published, prepared on the basis of the results of geological mapping conducted by Nalivkin and students from Leningrad University in 1926 (Schmidt, 1937). However, this map is inaccurate, because the kilns shown on it were supposed to be located 1.5 km northeast of the settlement, but there were unlikely to be outcrops in this location, judging by modern aerial photographs. Most likely, the kilns were located much closer to the village.

The cyclidan was found together with trilobites collected by Petrenko and Markovsky and described by Weber (1937) as Viséan fossils. Unfortunately, their images were not included in Weber's plates. Information about the collectors (Petrenko and Markovsky) was provided:, furnaces were mentioned, and the outcrop number 22 (on Markovsky's label 38/22). One point was located immediately adjacent to the Nikolskiy plant. Today the outcrops of bioherm limestones are clearly visible on the left bank of the Nikolskiy pond at the western end of the village, where the bank forms a ledge toward the pond, as well as in a small quarry next to the production building.

Outcrops of Lower Carboniferous limestones, often of biohermal structure, have been known near the village of Nikolskiy for quite a long time (Smirnov, 1956); they were even named the Zlokazovsky Reefs (Nalivkin, 1949). In their lower part, the brachiopod *Globosoproductus mirus* (Fredericks, 1926) was found, which is considered characteristic of the Middle Mississippian (Tulian Regional Substage, Middle Viséan) (Litvinovich and Vorontsova, 1983). Above, according to the definitions of Einor (1973), brachiopod assemblages were found containing *Gigantoproductus latissimus* (J. Sowerby, 1822) and *Spirifer bisulcatus* J. Sowerby, 1825, which made it possible to attribute these beds to the "very top of the Upper Viséan" (Smirnov, 1956, p. 133). However, *Gigantoproductus latissimus* also occurs in the Upper Mississippian (lower part of the Serpukhovian) (Litvinovich and Vorontsova, 1991; Aretz et al., 2019).

According to modern studies, the Tulian age (Middle Viséan, Mississippian) of the lower part of the limestone succession, with a thickness of ~150 m, developed near the Nikolskiy, is confirmed by the foraminiferan assemblage determined by Reitlinger (Korolyuk et al., 1991, p. 30). Above are strata composed mainly of algal bioherms of the Middle Mississippian (Aleksinian and Mikhailovian regional substages, Upper Viséan).

The eastern margin of the Ufa Amphitheater (a geological structure) near the village of Zlokazovo is distinguished by a complex thrust-sheet structure, confirmed by drilling wells to a depth of 3 km (Kamaletdinov, 1974). There, Upper Devonian and Lower Carboniferous rocks can alternate at depth. Therefore, their outcrops on the surface can be a mosaic.

Upstream along the Bol'shoy Azyam River, Lower and Middle Pennsylvanian (Bashkirian–Moscovian) terrigenous formations are widespread, as are proximal turbidites containing blocks, pebbles, and even kilometer-sized landslide 'bodies' or tectonic remnants of Viséan and Serpukhovian limestones (Mustafin et al., 1989). The youngest rocks in the upper reaches of the Bol'shoy Azyam River are thick conglomerates of the Abdrezyakovo Formation (Middle Pennsylvanian, Moscovian). The upper reaches of the Bol'shoy Ik River, where Lower Permian terrigenous rocks crop out, are ~10–15 km away, but across a watershed. The possibility of fossil transportation to Nikolskiy from the area of Lower Permian strata development is therefore unlikely.

Taking into account all of the information presented above, the most probable age range of the cyclidan locality is Middle Mississippian (Viséan)–Late Mississippian (Lower Serpukhovian) if we believe the correlation given by Kabanov et al. (2016).

Materials and methods

Repositories and institutional abbreviations. Specimens examined in this study are deposited in the following institutions: Academician F.N. Chernyshev Central Scientific Research Geological Survey Museum (CNIGR museum), St. Petersburg, Russia; Borissiak Paleontological Institute, Russian Academy of Sciences (PIN), Moscow, Russia; Museum of the World Ocean (MWO), Kaliningrad, Russia. Line drawings (Figs. 5-8) and photographic images (Fig. 9) of these specimens illustrate their morphology.

Systematic paleontology

We follow morphological terminology and the Cyclida classification proposed by Feldmann and Schweitzer (2019) and Schweitzer et al. (2020).

Superclass **Multicrustacea** Regier et al., 2010
Order ***Cyclida*** Schram, Vonk, and Hof, 1997
Family **Hemitrochiscidae** Trauth, 1918

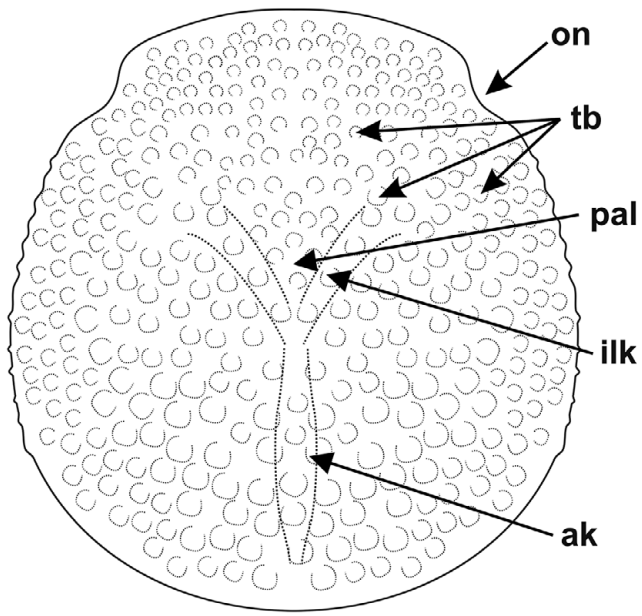

Figure 5. Diagrammatic carapace morphology of *Oonocarcinus uralicus* n. sp.; ak, axial keel; ilk, inner lyrate keel; on, optic notch; pal, posterior axial lobe; tb, tubercles.

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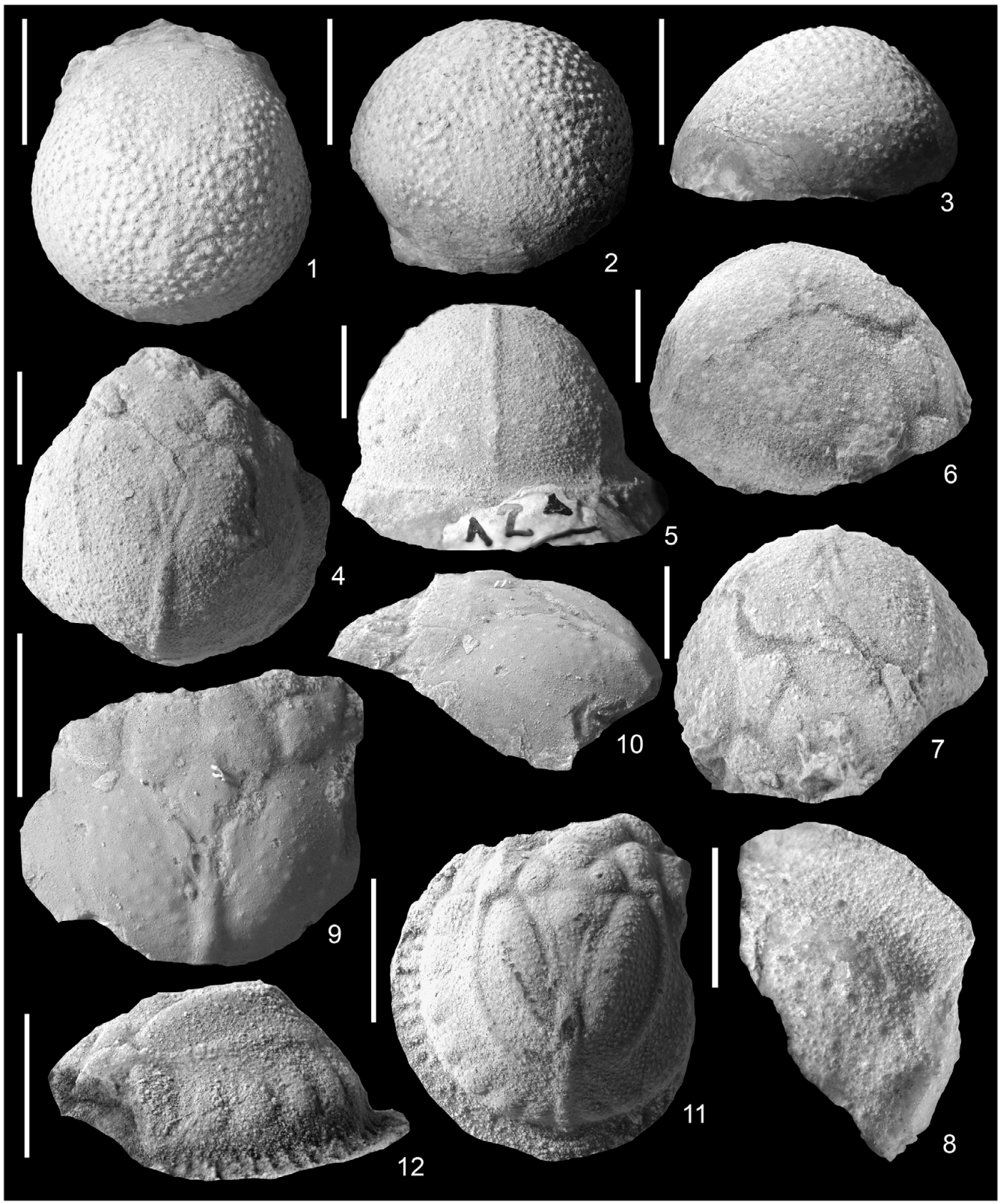

Figure 6. New cyclidans from Chernyshev's undescribed collection (CNIGR museum no. 5178): (**1–3**) *Oonocarcinus uralicus* n. sp., holotype, CNIGR museum no. 7/5178, 'Kamen' Plakun' Rock (reef), Chusovaya River, Chusovskoy District, Perm Krai, Russia, Upper Pennsylvanian (Gzhelian)–Permian (Cisuralian, Asselian): (**1**) dorsal view; (**2**) anterior view with labrum; (**3**) lateral view; (**4–8**) *Ambocyclus capidulum* (Chernyshev, 1933), CNIGR museum no. 12a/5178, right bank of the Shartymka (Shartym) River, right tributary of the Uy River, Chelyabinsk Oblast, Uy District on the border with the Uchaly District of the Bashkortostan, Middle Mississippian (Upper Viséan)–Lower Pennsylvanian (Bashkirian): (**4**) dorsal view; (**5**) posterior view; (**6**) lateral view; (**7**) anterior view; (**8**) CNIGR museum no. 12b/5178, fragment of the counterpart; (**9, 10**) *Magnitocyclus* (?) sp. indet., CNIGR museum no. 11/5178, left bank of the Bol'shoy Kizil River above Kizil'skoe Village, Kizil'skoe District, Chelyabinsk Oblast, Upper Mississippian (probably Serpukhovian): (**9**) dorsal view; (**10**) lateral view; (**11, 12**) *Uralocyclus feldmanni* n. sp., CNIGR museum no. 15/5178, Bol'shoy Azyam River, tributary of the Bol'shaya Arsha River near Zlokazovo Village, Kusa District, Chelyabinsk Oblast, Middle Mississippian (Upper Viséan)–Upper Mississippian (Lower Serpukhovian): (**11**) dorsal view; (**12**) lateral view. Scale bars = 5 mm.

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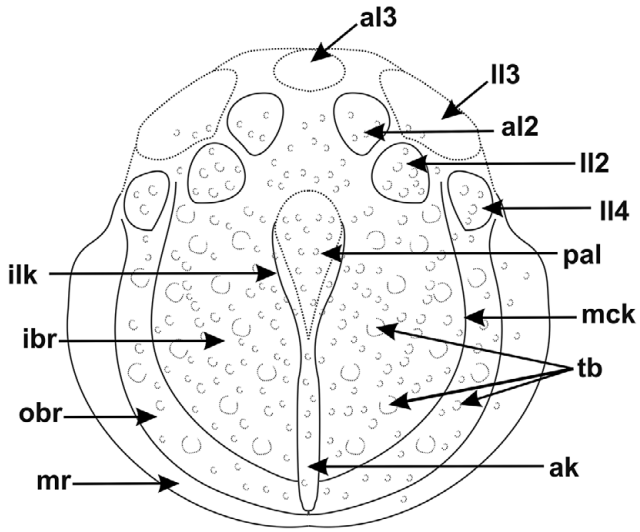

Figure 7. Diagrammatic carapace morphology of *Ambocyclus capidulum* (Chernyshev, 1933); ak, axial keel; al2, second axial lobe; al3, third unpaired axial lobe; ibr, inner branchial region; ilk, inner lyrate keel; ll2, second lateral lobe; ll3, third lateral lobe; ll4, fourth lateral lobe; mr, marginal rim; mck, median concentric keel; obr, outer branchial region; pal, posterior axial lobe; tb, tubercles.

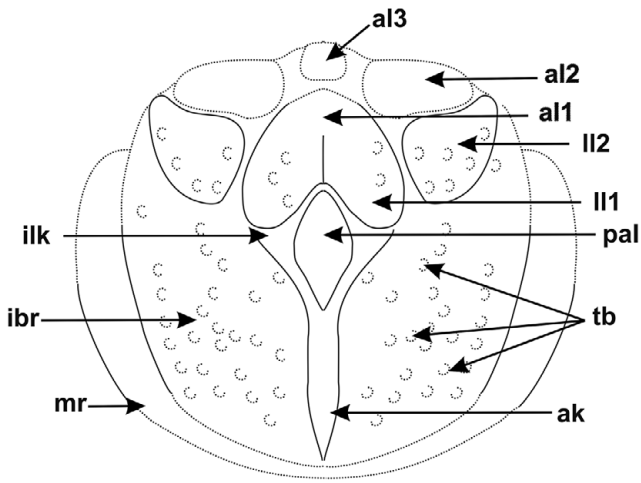

Figure 8. Diagrammatic carapace morphology of *Magnitocyclus* (?) sp. indet.; ak, axial keel; al1, first axial lobe; al2, second axial lobe; al3, third unpaired axial lobe; ibr, inner branchial region; ilk, inner lyrate keel; ll1, first lateral lobe; ll2, second lateral lobe; mr, marginal rim; pal, posterior axial lobe; tb, tubercles.

Diagnosis. See Schweitzer et al. (2020, p. 278).

Genus ***Oonocarcinus*** Gemmellaro, 1890

Type species. *Oonocarcinus insignis* Gemmellaro, 1890, by subsequent designation (Glaessner, 1969).

Other species. *Oonocarcinus puchoviensis* Kittl in Trauth, 1918; *Oonocarcinus uralicus* new species.

Diagnosis. See Schweitzer et al. (2020, p. 282).

Occurrence. Upper Pennsylvanian (Gzhelian)–Lower Permian (Cisuralian, Asselian) to Upper Triassic (Carnian).

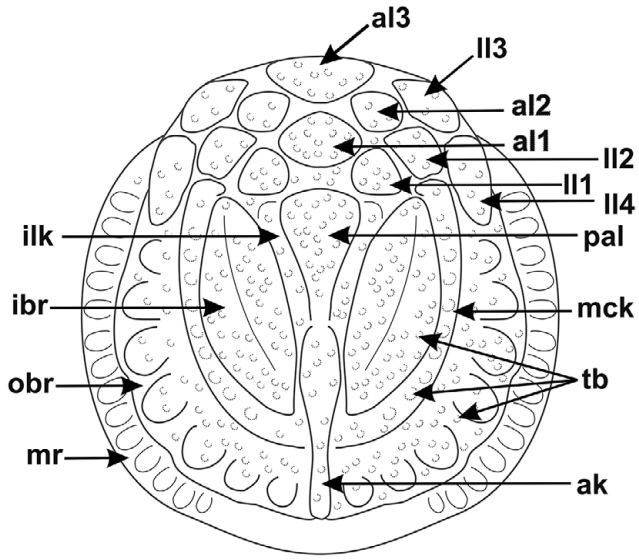

Figure 9. Diagrammatic carapace morphology of *Uralocyclus feldmanni* n. sp.; ak, axial keel; al1, first axial lobe; al2, second axial lobe; al3, third unpaired axial lobe; ibr, inner branchial region; ilk, inner lyrate keel; ll1, first lateral lobe; ll2, second lateral lobe; ll3, third lateral lobe; ll4, fourth lateral lobe; mck, median concentric keel; mr, marginal rim; obr, outer branchial region; pal, posterior axial lobe; tb, tubercles.

Oonocarcinus uralicus new species
Figures 5, 6.1–6.3

1936 *Oonocarcinus uralicus* Chernyshev, on label in collection [nomen nudum].

Holotype. An almost complete carapace, CNIGR museum no. 7/5178; the specimen was discovered by Georgy Nikolaevich Fredericks in 1928.

Diagnosis. Carapace bilaterally symmetrical, ovoid, very strongly domed. Surface of the carapace covered with densely spaced, small tubercles. Posterior part bearng axial keel. Inner lyrate keels barely distinguishable. Carapace anterior regions poorly developed; axial and lateral lobes not differentiated.

Occurrence. 'Kamen' Plakun' Rock (reef), Chusovaya River, Chusovskoy District, Perm Krai, Russia; Upper Pennsylvanian (Gzhelian)–Lower Permian (Cisuralian, Asselian).

Description. The carapace is ovoid, longer than wide, wider in the posterior part than in the anterior, very strongly domed. The entire surface of the carapace is covered with densely spaced small tubercles (tb) of almost equal size. However, in the anterior part of the carapace these tubercles are slightly smaller than in the posterior part. In the posterior part of the carapace, there is a weak longitudinal lobe of the axial keel (ak); in front of it, poorly visible pairs of inner lyrate keels (ilk) diverge to the sides; between them is a small flat swelling of the posterior axial lobe (pal). Anterior regions are poorly developed; axial and lateral lobes are not differentiated. On the sides of the anterior part, there are barely noticeable optic notches (on). The marginal rim (mr) is very narrow, tucked under the carapace.

Etymology. The trivial name is for the territory of the Urals, the locality of the holotype.

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Measurements (in mm). Carapace length 12; posterior width 11; anterior width 6.5; height 7.

Remarks. *Oonocarcinus uralicus* n. sp. is referred to *Oonocarcinus* based upon its ovate, strongly domed carapace, coarsely granular ornamentation, and small orbital notches. All of these are diagnostic for the genus. The sole species of *Hemitrochiscus* Schauroth, 1854, is more circular in shape and possesses distinctive vermiform ornamentation not present on the new species. Species of *Cyclocarcinides* Glaessner, 1969 have distinct, triangular spines along their posterolateral and posterior margins, absent in the new species. *Paraprosopon* Gemmellaro, 1890, has well-defined anterior regions and a very large posterior axial lobe, not seen in the new species. *Skuinocyclus* Mychko and Alekseev, 2018, has much more sparse ornamentation and better defined anterior and lateral lobes than in the new species.

Oonocarcinus uralicus n. sp. differs from *Oonocarcinus insignis* in the wider carapace in the posterior part, as well as in the sculpture, which in *Oonocarcinus insignis* is represented by large tubercles on the posterior and lateral parts and small tubercles on the anterior and dorsal parts. From *Oonocarcinus puchoviensis*, the new species differs in the absence of rows of tubercles located at the marginal rim closer to the ventral side, as well as in larger and densely spaced tubercles over the entire surface of the carapace.

The other two named species of *Oonocarcinus* are known from younger strata: the Middle Permian of Italy (*Oonocarcinus insignis*) and the Upper Triassic of Slovakia (*Oonocarcinus puchoviensis*). Thus, the new species is significantly older than the other known species. It is quite possible that the Uralian species belongs to a different genus; however, we do not observe any obvious generic differences from the type species. These circumstances could be clarified by new finds from transitional regions—the Middle Permian of Crimea and the Upper Permian of the Caucasus—if there are any.

Family **Cyclidae** Packard, 1885

Diagnosis. See Schweitzer et al. (2020).

Genus ***Ambocyclus*** Schweitzer, Mychko, and Feldmann, 2020

Type species. *Cyclus simulans* Reed, 1908, by original designation.

Other species. *Ambocyclus capidulum* (Chernyshev, 1933); questionably *Ambocyclus minutus* (Rogers, 1902).

Diagnosis. See Schweitzer et al. (2020, p. 253).

Occurrence. Lower Mississippian (Tournaisian)–Upper Pennsylvanian (Kasimovian).

Ambocyclus capidulum (Chernyshev, 1933)
Figures 2.9–2.12, 6.4–6.8, 7

1933 *Cyclus capidulum* Chernyshev, p. 21 (Russian), p. 23 (English), pl. 1, fig. 11.
2018 *Cyclus capidulum*; Mychko and Alekseev, p. 25.
2019 *Cyclus capidulum*; Feldmann and Schweitzer, p. 2.
2019b *Cyclus capidulum*; Mychko et al., p. 81.
2020 *Ambocyclus capidulum*; Schweitzer et al., p. 253–255, 297.
2021 *Ambocyclus capidulum*; Tang et al., p. 7.
2022b *Ambocyclus capidulum*; Mychko, p. 33.
2022 *Ambocyclus capidulum*; Mychko et al., p. 75.

Holotype. An almost complete carapace, CNIGR museum no. 15/3694; Alapaevsk District, Sverdlovsk Oblast, Russia; 'Lower Carboniferous limestones,' Upper Mississippian (Serpukhovian).

Occurrence. Right bank of the Shartymka (Shartym) River, right tributary of the Uy River, Uy District (Chelyabinsk Oblast), Russia; Middle Mississippian (Upper Viséan, Ladeinian Regional Substage)–Lower Pennsylvanian (Bashkirian, Akavasian Regional Substage).

Description. The carapace is elongated, dome-shaped, ovoid, strongly vaulted in the longitudinal and transverse directions, the highest approximately in the middle of the length. The posterior margin is somewhat wider than the anterior margin. The posterior margin is steeper than the shallow anterior margin. On the sides of the anterior margin there are small optical notches. The posterior axial lobe (pal) is quite noticeable, but strongly flattened, triangular, and in the anterior part, it disappears. The first pair of lateral lobes (ll1) and the first unpaired axial lobe (al1) are not visible. On both sides of the flattened area in front of the posterior axial lobe (pal), the second pairs of lateral lobes (ll2) and the second pairs of axial lobes (al2) are clearly visible. They are of approximately equal size, quite large, subtriangular, and moderately convex. Lateral to them and closer to the ventral part of the carapace, third lateral lobes (ll3) are located on both sides. The posterior axial lobe (pal) is framed by narrow, but very noticeable, inner lyrate keels (ilk), which flatten out anteriorly and disappear, and posteriorly merge with each other, gradually transforming into a very convex, clearly visible axial keel (ak). This keel extends to the posterior margin and marginal rim (mr). In the central part of the carapace, on both sides of the inner branchial regions (ibr), there are arched median concentric keels (mck). These are very narrow, framed by densely covered tubercles. The marginal rim (mr) is narrow, separated from the carapace by a small constriction. The entire surface of the carapace is covered with tubercles, of two types: very small and larger ones; the larger ones are staggered and rather scattered.

Materials. Holotype and complete carapace (CNIGR museum no. 12a/5178) with a fragment of the counterpart (CNIGR museum no. 12b/5178).

Measurements (in mm). CNIGR museum no. 15/3694: carapace length 10, posterior width 7.7; anterior width 6.2, carapace height 7.; CNIGR museum no. 12a/5178: carapace length 17, posterior width ~16; anterior width ~11, carapace height 13.

Remarks. The new specimen adds to the description of *Ambocyclus capidulum*, because it has better preserved anterior and axial regions. The anterior lobes, the posterior axial lobe, and the inner lyrate keel are more strongly expressed on the new specimen than on the holotype, which can exhibit weathering of these areas.

Genus ***Magnitocyclus*** Mychko et al., 2022

Type species. *Magnitocyclus struveae* Mychko et al., 2022, by original designation.

Other species. None.

Diagnosis. See Mychko et al. (2022, p. 80).

Occurrence. Middle Mississippian (Upper Viséan)–Lower Pennsylvanian (Bashkirian).

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***Magnitocyclus* (?) sp. indet.**
Figures 6.9, 6.10, 8

Occurrence. Left bank of the Bol'shoy Kizil River above Kizil'skoe Village, Kizil'skoe District, Chelyabinsk Oblast, Russia; Upper Mississippian (probably Serpukhovian).

Description. The incomplete carapace is significantly missing the frontal (anterior) part, as well as the lower (supraventral) part. It is elongated in width, weakly dome-shaped, even somewhat flattened, vaulted in the longitudinal and transverse directions, the highest approximately in the middle of the length. The posterior axial lobe (pal) is clearly visible, strongly flattened, rhombic, separated from the inner branchial regions by wide shallow grooves. The anterior edges of this lobe meet the first pair of lateral lobes (ll1). These lobes are quite long, elongated in the longitudinal direction, elliptical, close to each other. They could merge with the first axial lobe (al1) anteriorly, which is absent. Each of the first lateral lobes (ll1) is adjacent to two pairs of lobes on both sides: the second axial (al2) and second lateral lobes (ll2). These lobes are more convex than the first pair of lateral (ll1) ones. Each of the second lateral lobes (ll2) is obovate. From the second axial lobes (al2), only the right fragment of the lobe has been preserved; their shape and size are unknown. On both posterior sides of the posterior axial lobe (pal) are inner lyrate keels (ilk). Toward the posterior edge of the carapace, these keels merge and form a wide, rather convex axial keel (ak). A section of marginal rim (mr) is preserved only on the left side of the carapace. Judging by this, the marginal rim was broad. The surface of the carapace is scattered with rare, large, flattened tubercles located in sparse rows on the internal branchial regions (ibr); such tubercles are also located on the anterior axial and lateral lobes.

Material. An incomplete carapace, CNIGR museum no. 11/5178.

Measurements (in mm). Length >10; posterior width ~9; anterior width ~9; height > 6.

Remarks. The new specimen differs from the type species *Magnitocyclus struveae*, described also from the Mississippian (Upper Viséan–Lower Serpukhovian) of the eastern Urals by having more separated first lateral lobes (in *M. struveae*, they merge into one together with the first axial lobe), a slightly different shape of the second lateral lobes (in *M. struveae*, they widen toward the anterior part of the carapace), a more rhombic posterior axial lobe, more elongated inner lyrate keels, as well as less dense tuberculation on the carapace.

In the Chernyshev collection, this specimen was identified as *Cyclus capidulum* (Fig. 3, upper right). However, upon detailed study, the obvious differences between this cyclidan and *Ambocyclus capidulum* became clear. The carapace is less convex, has a more obvious posterior axial lobe, has the first pair of lateral lobes, wider inner lyrate keels, and does not have smaller tubercles on the carapace as seen on *Ambocyclus capidulum.* At the same time, the missing frontal part does not allow us to attribute it to *Magnitocyclus* with great confidence. In addition, this carapace has the first pair of lateral lobes slightly separated from each other.

Genus ***Uralocyclus*** Mychko and Alekseev, 2018

Type species. *Cyclus miloradovitchi* Kramarenko, 1961, by original designation.

Other species. *Uralocyclus feldmanni* n. sp.; *U. harknessi* (Woodward, 1870); *U. woodwardi* (Reed, 1893).

Diagnosis. See Schweitzer et al. (2020, p. 250, 251).

Occurrence. Lower?–Middle Mississippian (Tournaisian?–Viséan)–Permian (Cisuralian, Asselian).

Remarks. The new species shares most of the diagnostic generic characters with other species of *Uralocyclus*, e.g., well-developed lyrate and median concentric keels, transverse lobes on the outer branchial region, and transverse lobes on the marginal rim. The well-ornamented outer branchial region and marginal rim are particularly diagnostic for this genus.

Uralocyclus feldmanni new species
Figures 6.11, 6.12, 9

Holotype. An almost complete carapace, CNIGR museum no. 15/5178; the specimen was discovered by B.P. Markovsky in 1931.

Diagnosis. Carapace bilaterally symmetrical, ovate, moderately inflated, cap-shaped, laterally bordered by marginal rim, complexly ornamented with various lobes and ridges. Frontal area dissected by large, symmetrical lobes; posterior axial lobe elongate, widest anteriorly, then narrowing, then slightly widening posteriorly, extending into axial keel. First axial lobe diamond-shaped, well defined; second axial lobes and third axial lobe approximately same size and shape as first axial lobe; first lateral lobes approximately same size and shape as first axial lobe but less inflated; second lateral lobe longer than first, diamond- shaped; third lateral lobe elongate, with arcuate keel on lateral margin, granular. Inner lyrate keel weak, outer lyrate keel absent, median concentric keel strong, inner branchial region granular, moderately inflated; outer branchial region with seven ovate, transverse swellings. Marginal rim wide, bearing small oblong swellings, > 12 on each side, reaching margin.

Occurrence. Bol'shoy Azyam River (tributary of the Bol'shaya Arsha River near Zlokazovo Village), Kusa District, Chelyabinsk Oblast, Russia; Mississippian (Upper Viséan or Lower Serpukhovian).

Description. The carapace is rounded, somewhat wider than long, highly vaulted longitudinally and transversely, with the greatest height in the central region, complexly ornamented with various lobes and ridges. Its entire surface is ornamented with flattened tubercles. The frontal margin is not completely preserved; the left part and the third unpaired axial lobe (al3) are missing. The frontal lobes of the carapace are approximately diamond-shaped, nested with each other, all approximately the same size. The third lateral lobes (ll3) are elongated in width and slightly convex. The second axial lobes (al2) are large, larger than the other axial lobes. The first unpaired axial lobe (al1) is diamond-shaped, slightly convex, and descends vertically toward the third axial lobe (al2). Between it and the slightly convex posterior axial lobe (pal) is a flattened area. On either side of it are small first lateral lobes (ll1). The posterior axial lobe (pal) smoothly transitions into a swollen axial keel (ak) that abuts the marginal rim in the posterior part. On both sides of the posterior axial lobe (pal) are narrow inner lyrate keels (ilk). They are separated by distinct grooves from the vaulted inner branchial regions (ibr), which descend vertically to the outer branchial regions (obr). The outer branchial regions (obr) are arched, wide, and separated from the inner branchial region (ibr) by an arched median concentric keel (mck), which in the anterior part widens into triangular lobes and is bounded by the first and second pairs of lateral lobes (ll1 and ll2). The outer branchial regions (obr) bear

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seven lobes, the size of which increases from the posterior to the anterior. The anteriormost lobe is the largest, elongated in length. The marginal rim (mr) is wide, reaching the anterior part and the line of location of the first lateral lobes (ll1). On both sides of the carapace on the marginal rim are small oblong swellings, > 12 on each side, which reach the margin.

Etymology. In honor of our colleague and coauthor, famous American paleontologist, specialist in crustaceans and cyclidans in particular, Professor Emeritus Rodney Feldmann, who passed away in May 2024.

Measurements (in mm). Length 12; posterior width ~9; anterior width 7; height ~7.

Remarks. The new species is similar to the type species *Uralocyclus miloradovitchi* from the Lower Permian of the Urals, but has some differences. For example, the marginal rim of the new species is much wider than that of *U. miloradovitchi* and differs in ornamentation: the oblong swellings on the rim of *U. miloradovitchi* widen and do not reach the edge, whereas in *U. feldmanni* n. sp., these swellings narrow and rest against the edge of the rim. The internal branchial regions of *U. miloradovitchi* are more swollen than those of the new species. Also, the space between the pal and ll2 lobes in the new species is larger than in *U. miloradovitchi.* The new species is also closely related to the Mississippian species *U. woodwardi* and *U. harknessi* but differs in the presence of transverse swellings on the marginal rim. However, *U. harknessi* lacks evidence of a marginal rim, which could be an artifact of preservation.

CNIGR museum no. 15/5178 was classified in the collection by Chernyshev not as a cyclidan, but as a phyllocarid and was conditionally identified as *Echinocaris* Whitfield, 1880 (Fig. 3, lower right). This, apparently, could be due to the slightly different morphology of *Uralocyclus* from other cyclidans and the presence of larger number of lobes than in other genera.

The conservative morphology of species of *Uralocyclus* across time is notable. Such conservatism was noted, for example, for the lobster genus *Hoploparia* M'Coy, 1849, for which dozens of species are known from the Cretaceous to the Miocene (Tshudy and Sorhannus, 2003; Feldmann et al., 2007). Oligocene species of the ghost shrimp *Callianopsis* are very similar to extant species (Schweitzer Hopkins and Feldmann, 1997). Similarly, Eocene species of the squat lobster *Shinkaia* Baba and Williams, 1998 are clearly similar to extant species (Schweitzer and Feldmann, 2008). Among crabs, members of Carpiliidae are remarkably conservative morphologically from the Paleocene to the Holocene (Schweitzer et al., 2018). Thus, the similarities across time in morphology of species of *Uralocyclus* have precedent among other crustacean groups.

Discussion

Cyclidans are a rare extinct crustacean group, and each new discovery expands our knowledge of the diversity, morphology, and evolution of these animals. Thanks to the chance discovery of this undescribed Chernyshev's collection, our knowledge of Russian cyclidans has been expanded with five new finds of four species, two of which are new (Table 1).

Table 1. All known Russian cyclidans.

Species	Locality	Stratigraphy	Specimens	References
Ambocyclus capidulum (Chernyshev, 1933)	Alapaevsk District, Sverdlovsk Oblast	'Lower Carboniferous limestones', Serpukhovian, Upper Mississippian	Holotype CNIGR museum no. 15/3694	Chernyshev, 1933, p. 21; Schweitzer et al., 2020, p. 254
	Shartymka (Shartym) River, right tributary of the Uy River, Uy District (Chelyabinsk Oblast) on the border with the Uchaly District (Bashkortostan)	Upper Viséan (Ladeininsky Substage), Middle Mississippian–Bashkirian (Akavass Substage), Lower Pennsylvanian	CNIGR museum, nos. 12a/5178 and 12b/5178	This study
Uralocyclus miloradovitchi (Kramarenko, 1961)	Kazarmennyy Kamen' Rock, Chelyabinsk Oblast	Asselian, Cisuralian (Lower Permian)	Holotype, PIN no. 1792/5; paratypes PIN nos. 1792/1–4	Kramarenko, 1961; Mychko and Alekseev, 2018; Schweitzer et al., 2020, p. 251
Uralocyclus feldmanni sp. nov.	Bol'shoy Azyam River, tributary of the Bol'shaya Arsha River near Zlokazovo Village, Kusa District, Chelyabinsk Oblast	Upper Viséan (Middle Mississippian)–Lower Serpukhovian (Upper Mississippian)	CNIGR museum no. 15/5178	This study
Skuinocyclus juliae Mychko and Alekseev, 2018	Shakhtau Quarry, Ishimbay District, Bashkortostan	Asselian, Cisuralian (Lower Permian)	Holotype, PIN no. 5610/1	Mychko and Alekseev, 2018; Schweitzer et al., 2020, p. 286
Prolatcyclus kindzadza Mychko et al., 2019b	Akkermanovka Quarry, Novotroitsk District, Orenburg Oblast	Izvestkovy Dol Formation, Viséan, Middle Mississippian	Holotype, MWO 1/59, no. 9868; paratypes, MWO 1/59 nos. 9866, 9867	Mychko et al., 2019b; Schweitzer et al., 2020, p. 250
Magnitocyclus struveae Mychko et al., 2022	Eastern slope of the Urals, Magnitogorsk Synclinorium	Upper Viséan–Lower Serpukhovian, Middle–Upper Mississippian	Holotype, PIN 5871/1	Mychko et al., 2022
Magnitocyclus (?) sp. indet.	Left bank of the Bol'shoy Kizil River above Kizil'skoe Village, Kizil'skoe District, Chelyabinsk Oblast	Probably Serpukhovian, Upper Mississippian	CNIGR museum no. 11/5178	This study
Oonocarcinus uralicus sp. nov.	'Kamen' Plakun' Rock (reef), Chusovaya River, Chusovskoy District, Perm Krai	Gzhelian (Upper Pennsylvanian)–Asselian, (Cisuralian = Lower Permian)	CNIGR museum no. 7/5178	This study

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New discoveries have made it possible to revise the time range of some genera and species of cyclidans. Thus, the stratigraphic distribution of the genus *Oonocarcinus*, the oldest representatives of which were previously known from the middle Permian (Wordian) of Sicily, has been significantly expanded. *Oonocarcinus uralicus* n. sp. extends the origin of the genus into the Late Carboniferous or Early Permian. In addition, the geographic range of the genus is significantly expanded from Sicily to include a Russian locality east of Moscow, in the western Urals.

The most interesting thing is that Chernyshev mentioned the discovery of *Oonocarcinus* in the Urals several times previously (Weber et al., 1934, p. 899; Chernyshev, 1939, p. 141, 142). However, he referred to the fact that these finds came from the collection of von Eichwald. The specimen that we are describing as *Oonocarcinus uralicus* n. sp. was discovered by Fredericks in 1928. It is quite possible that there is another specimen of *Oonocarcinus* in Eichwald's collection.

The discovery of *Ambocyclus capidulum* in the Upper Viséan–Bashkirian of Shartymka (Table 1) expands the geographical distribution of this species, because the holotype (monotype) was previously known from the Serpukhovian 400 km to the north. Also, the carapace from Shartymka provides more information about the morphology of this species than the holotype, because sculpture is preserved on it and some lobes are better represented.

No less important is the discovery of *Uralocyclus feldmanni* n. sp. in the Mississippian deposits of the Chelyabinsk Oblast (Table 1). This discovery allows us to reduce the geographic distance between the type species *U. miloradovitchi*, known from the Permian (Asselian) of the Urals, and two Mississippian species, *U. harknessi* and *U. woodwardi*, discovered in the British Isles. The differences among the four species, despite their different geography and age, are minimal, a pattern well-documented among extinct crustaceans.

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References

Alekseev, A.S., Kossovaya, O.L., and Goreva, N.V., 2013, [Sostoyanie i perspektivy sovershenstvovaniya obshchey shkaly kamennougol'noy sistemy Rossii], *in* Fedonkin, M.A., ed., [Obshchaya stratigraficheskaya shkala Rossii: sostoyanie i perspektivy obustroystva. Vserossiyskaya konferenciya, Moscow, 23–25 May 2013]: Moscow, GIN RAS, p. 165–177. [in Russian]

Alekseev, A.S., Nikolaeva, S.V., Goreva, N.V., Donova, N.B., Kossovaya, O. L., et al., 2022, Russian regional Carboniferous stratigraphy, *in* Lucas, S.G., Schneider, J.W., Wang, X. and Nikolaeva S., eds., The Carboniferous Timescale: The Geological Society, London, Special Publications, **v. 512**, p. 49–117.

Aretz, M., Legrand-Blain, M., Vachard, D., and Izart, A., 2019, Gigantoproductid and allied productid brachiopods from the 'Calcaires à Productus' (late Viséan-Serpukhovian; Montagne Noire, southern France): taxonomy and palaeobiogeographical position in the Palaeotethys: *Geobios*, **v. 55**, p. 17–40, https://doi.org/10.1016/j.geobios.2019.06.007.

Baba, K., and Williams, A.B., 1998, New Galatheoidea (Crustacea, Decapoda, Anomura) from hydrothermal systems in the West Pacific Ocean Bismarck Archipelago and Okinawa Trough: *Zoosystema*, **v. 20**, p. 143–156.

Birshtein, Ya.A., 1960, [Otryad Decapoda. Desyatinogie], *in* Cernyshev, N.E., ed., [Osnovy paleontologii. Spravochnik dlya paleontologov i geologov SSSR. Chlenistonogie – trilobitoobraznye i rakoobraznye]: Moscow, Gosudarstvennoe Nauchno-Tekhnicheskoe Izdatelstvo Literatury po Geologii i Okhrane Nedr, p. 439–456. [in Russian]

Chernyshev, B.I., 1933, [Arthropoda s Urala i drugikh mest SSSR, 7. Predstaviteli roda *Cyclus* iz nizhnego karbona Urala i Turkestana]: Materialy Tsentralnogo Nauchnoissledovatelskogo Geologo-Razvedochnogo Instituta, Sbornik 1, Paleontologia i Stratigrafia, p. 20, 21. [in Russian with English summary]

Chernyshev, B.I., 1935a, [O chlenistonogih s Urala i drugih mestnostey Soyuza], *in* Borisyak, A.A., and Ryabinin, A.N., eds., [Ezhegodnik Vserossiyskogo Paleontologicheskogo Obshchestva], Volume 10, 1931–1933: Moscow–Leningrad, Gosudarstvennoe Ob"edinyonnoe Nauchno-Tekhnicheskoe Izdatel'stvo Narodnogo Komissariata Tyazheloy Promyshlennosti SSSR, Glavnya Redakciya Geologo-Razvedochnoy i Geodezicheskoy Literatury, p. 152. [in Russian]

Chernyshev, B.I., 1935b, [O dvuh vpervye najdennyh v SSSR predstavitelyah redkogo rakoobraznogo, otnosyashchegosya k rodu *Cyclus*], *in* Borisyak, A. A., and Ryabinin, A.N., eds., [Ezhegodnik Vserossiyskogo Paleontologicheskogo Obshchestva], Volume 10, 1931–1933: Moscow–Leningrad, Gosudarstvennoe Ob"edinyonnoe Nauchno-Tekhnicheskoe Izdatel'stvo Narodnogo Komissariata Tyazheloy Promyshlennosti SSSR, Glavnya Redakciya Geologo-Razvedochnoy i Geodezicheskoy Literatury, p. 149. [in Russian]

Chernyshev, B.I., 1939, [Class Rakoobraznye—Crustacea], *in* Gorskiy, I.I., ed., [Atlas Rukovodyashchih Form Iskopaemyh Faun SSSR, Volume **5**, Sredniy i Verhniy Otdely Kamennougol'noj Sistemy]: Moscow–Leningrad, Gosudarstvennoe Ob"edinyonnoe Nauchno-Tekhnicheskoe Izdatel'stvo Narodnogo Komissariata Tyazheloy Promyshlennosti SSSR, Glavnya Redakciya Geologo-Razvedochnoy i Geodezicheskoy Literatury, p. 141–144. [in Russian]

Chernyshev, B.I., 1941, [Class Crustacea, Rakoobraznye], *in* Librovich, L.S., ed., [Atlas Rukovodyashchih Form Iskopaemyh Faun SSSR, Volume **4**, Nizhniy Otdel Kamennougol'noy Sistemy: Moscow–Leningrad, Gosgeolizdat, p. 154–164. [in Russian]

Clark, N.D., Feldmann, R.M., Schram, F.R., and Schweitzer, C.E., 2020, Redescription of *Americlus rankini* (Woodward, 1868) (Pancrustacea: Cyclida: Americlidae) and interpretation of its systematic placement, morphology, and paleoecology: *Journal of Crustacean Biology*, **v. 40**, no. 2, p. 181–193, https://doi.org/10.1093/jcbiol/ruaa001.

Colani, M., 1924, Nouvelle contribution à l'étude des fusulinidés de l'Extrême-Orient: *Mémoires du Service Géologique de l'Indochine*, **v. 11**, no. 1, p. 9–199.

de Koninck, L.G., 1842, B. Cycloides, *in* de Koninck, L.G., ed., Description des Animaux Fossiles qui se Trouvent dan le Terraine Carbonifère de Belgique: Liége, 96 p.

Dernov, V., 2022, The first record of Cyclida (Pancrustacea, Multicrustacea) in the Carboniferous of the Donets Basin, Ukraine: *Collection of Scientific Works of the Institute of Geological Sciences of NAS of Ukraine*, **v. 15**, no. 1, p. 78–85.

Einor, O.L., ed., 1973, [Stratigrafiya i fauna kamennougol'nykh otlozheniy reki Shartym (Yuzhniy Ural)]: L'vov, Poland, Izdatel'stvo pri L'vovskom Fosudarstvennom Universitete, 184 p. [in Russian]

Feldmann, R.M., and Schweitzer, C.E, 2019, The enigmatic Cyclida (Pancrustacea): morphological terminology and family-level classification: *Journal of Crustacean Biology*, **39**, p. 617–633, https://doi.org/10.1093/jcbiol/ruz053.

Feldmann, R.M., Schweitzer, C.E., Redman, C.M., Morris, N.J., and Ward, D. J., 2007, New Late Cretaceous lobsters from the Kyzylkum Desert of Uzbekistan: *Journal of Paleontology*, **v. 81**, p. 701–713. https://doi.org/10.1666/pleo0022-3360(2007)081[0701:NLCLFT]2.0.CO;2.

Frech, F., 1900, Lethaea geognostica: oder Beschreibung und Abbildung der für die Gebirgsformationen bezeichnendsten Versteinerungen. Theil 1, **v. 2**, *Lethaea palaeozoica*: Stuttgart, Schweizerbart, 788 p.

Frederiks, G.N., 1926, [*Daviesiella gigantea* iz Bol'shezemel'skoy tundry i soprovozhdayushchie ee formy]: *Trudy Mineralogicheskogo Muzeya AN SSSR*, **v. 1**, p. 29–46. [in Russian]

Gemmellaro, G.G., 1890, I crostacei dei clacari con *Fusulina* della Valle del Fiume Sosio nella Provincia di Palermo in Sicily: *Memorie della Società Italiana delle Scienze*, **v. 8**, p. 1–29.

Glaessner, M.F., 1928, Zur Frage der ältesten fossilen Krabben: Centralblatt für Mineralogie, Geologie und Paläontologie, Abteilung B, **v. 6**, p. 388–398.

Glaessner, M.F., 1969, Cycloidea, in Moore, R.C., ed., Treatise on Invertebrate Paleontology, Part R, Arthropoda 4, Volume 2: Boulder, Colorado, Geological Society of America (and University of Kansas Press), p. R567–R570.

Goldring, R., 1967, *Cyclus martinensis* sp. nov. (Crustacea) from the Upper Viséan of the Mendip Hills, England: *Palaeontology*, **v. 10**, p. 317–321.

Kabanov, P.B., Alekseev, A.S., Gibshman, N.B., Gabdullin, R.R., and Bershov, A.V., 2016, The upper Viséan-Serpukhovian in the type area for the Serpukhovian Stage (Moscow Basin, Russia), part 1, sequences, disconformities, and biostratigraphic summary: *Geological Journal*, **v. 51**, no. 2, p. 163–194. https://doi.org/10.1002/gj.2623.

Kamaletdinov, M.A., 1974, [Pokrovnye struktury Urala]: Moscow, Nauka, 231 p. (in Russian)

Korolyuk, I.K., Sidorov, A.D., and Shchekotova, I.A., 1991, [Vizejskaya rifogennaya tolshcha Ufimskogo amfiteatra i perspektivy ee neftegazonosnosti], *in* Gromeka, V.I., and Menner, V.V., Rifogennye Zony i ih Neftegazonosnost': Moscow, Institut Geologii i Razrabotki Goryuchih Iskopaemyh (IGiRGI), p. 27–38. [in Russian]

Kramarenko, N.N., 1961, [Predstavitel' Cyclidae (Crustacea) iz nizhnepermskikh otlozheniy Priuralia]: *Paleontologicheskiy Zhurnal*, **v. 2**, p. 86–89. [in Russian]

Krotov, P.I., 1888, [Geologicheskie issledovaniya na zapadnom sklone Cherdynskogo i Solikamskogo Urala]: *Trudy Geologicheskago Komiteta*, **v. 13**, p. 297–537.

Kulagina, E.I., Pazukhin, V.N., Nikolaeva, S.V., Kochetova, N.N., Zainakaeva, G.F., Gibshman, N.B., and Konovalova, V.A., 2009, Serpukhovian and Bashkirian bioherm facies of the Kizil Formation in the southern Urals, *in* Puchkov, V.N., ed., Carboniferous Type Sections in Russia and Potential Global Stratotypes, Proceedings of the International Field Meeting, Southern Urals Session, Ufa-Sibai, 13–18 August 2009: Ufa, Russia, DesignPolygraphService, p. 78–96.

Kulagina, E.I., Nikolaeva, S.V., Gorozhanina, E.N., Kucheva, N.A., Stepanova, T.I., et al., 2015, Carboniferous reference sections: potential candidates for the base of the Serpukhovian GSSP and organic buildups, South Urals, *in* International Congress on the Carboniferous and Permian, 18th, Kazan, Russia, 11–15 August 2015, Field Guidebook of Post-Congress C3 Trip, 16–19 August 2015: St. Petersburg, Svoe Izdatelstvo, 90 p.

Kulikov, M.V., ed., 1985, [Katalog Golotipov Vidov Fauny i Flory, Hranyashchihsya v CNIGRmusee. Vypusk 2, Chast' 1. Paleozoj]: Leningrad, Leningradskaya kartfabrika VSEGEI, 352 p. [in Russian]

Librovich, L.S., 1933, [Osnovnye cherty geologicheskoy istorii Kizilo-Urtazymskogo rajona na Yuzhnom Urale]: *Zapiski Vserossiyskogo Mineralogicheskogo Obshchestva*, **v. 62**, no. 1, p. 71–96. [in Russian]

Librovich, L.S., 1936, [Geologicheskoe stroenie Kizilo-Urtazymskogo rayona na Yuzhnom Urale]: *Trudy Central'nogo Nauchno-Issledovatel'skogo Geologo-Razvedochnogo Instituta*, **v. 81**, p. 1–206. [in Russian]

Librovich, L.S., 1939, [Kamennougol'nye otlozheniya rayonov reki Shartymki i verhoviy reki Urala]: *Trudy Central'nogo Nauchno-Iissledovatel'skogo Geologo-Razvedochnogo Instituta*, **v. 114**, p. 1–43. [in Russian]

Litvinovich, N.V., and Vorontsova, T.N., 1983, [K voprosu o revizii roda *Gigantoproductus* Prentice]: Byulleten' Moskovskogo Obshchestva Ispytatelej Prirody (MOIP), *Otdel Geologicheskiy*, **v. 58**, no. 1, p. 81–94. [in Russian]

Litvinovich, N.V., and Voroncova, T.N., 1991, [Gigantoidnye brahiopody SSSR, ih rasprostranenie i stratigraficheskoe znachenie]: Moscow, *Nauka*, **61** p. [in Russian]

Maslov, V.P., 1956, [Fossil calcareous algae of the USSR]: *Trudy Instituta Geologicheskih Nauk Akademii Nauk SSSR*, **v. 160**, p. 1–301.

M'Coy, F., 1849, On the classification of some British fossil Crustacea with notices of new forms in the University Collection at Cambridge: *Annals and Magazine of Natural History, ser. 2*, **v. 4**, p. 161–179, 330–335.

Montfort, P. [Denys de], 1808–1810), Conchyliologie Systématique et Classification Méthodique des Coquilles, 2 Volumes: Paris, Schoell, **v. 1**, p. lxxxvii + 409 [1808]; **v. 2**, p. 676 + 16 [1810].

Mustafin, Sh.A., Golovchenko, I.M., and Ismagilova, G.M., 1989 (for 1988), [Tektonicheskie ostancy basseyna reki Uraim (Ufimskiy amfiteatr)], *in* Kazanceva, T.T., (ed., [Formirovanie Zemnoy Kory Urala]: Ufa, Russia, Bashkirskiy Nauchnyy Centr Ural'skogo Otdeleniya AN SSSR, p. 56–61. [in Russian]

Mychko, E.V., 2022a, Amazing Cyclidans—the Witnesses of the Great Extinction, Part 1: *Priroda*, **v. 9**, p. 12–23, https://doi.org/10.7868/S0032874X22090022. [in Russian]

Mychko, E.V., 2022b, Amazing Cyclidans—the Witnesses of the Great Extinction, Part 2: *Priroda*, **v. 10**, p. 26–35, https://doi.org/10.7868/S0032874X22100039. [in Russian]

Mychko, E.V., and Alekseev, A.S., 2018, Two new genera of Cyclida (Crustacea: Maxillopoda: Branchiura) from the Cisuralian (Lower Permian) of southern Urals: Neues Jahrbuch für Geologie und Paläontologie, *Abhandlungen*, **v. 289**, p. 23–34, https://doi.org/10.1127/njgpa/2018/0747.

Mychko, E.V., Mazaev, A.V., Davydov, A.E., Gibshman, N.B., Sakhnenko, K. V., and Alekseev, A.S., 2019a, [Akkermanovka-Khabarnoe—new Early Carboniferous Lagerstätt in Russia (South Urals)]: Bulletin of the Moscow Society of Naturalists, *Geological Series*, **v. 94**, p. 46 – 55. [in Russian with English abstract]

Mychko, E.V., Feldmann, R.M., Schweitzer, C.E., and Alekseev, A.S., 2019b, New genus of Cyclida (Crustacea) from Lower Carboniferous (Mississippian, Viséan) of Russia and England and new species of Viséan of Russia: *Neues Jahrbuch für Geologie und Paläontologie, Abhandlungen*, **v. 294**, p. 81–90, https://doi.org/10.1127/njgpa/2019/0847.

Mychko, E.V., Alekseev, A.S., Zaytseva, E.L., Schweitzer, C.E., and Feldmann, R.M., 2022, New finding of Cyclida (Crustacea) from Mississippian and notcyclidan from Permian of Russia: Neues Jahrbuch für Geologie und Paläontologie, *Abhandlungen*, **v. 305**, no. 1, p. 75–85, https://doi.org/10.1127/njgpa/2022/1077.

Nalivkin, V.D., 1949, [Stratigrafiya i tektonika Ufimskogo plato i Yurezano-Sylvenskoy depressii: trudy Vsesoyuznogo neftyanogo nauchno-issledovatel'skogo geologo-razvedochnogo instituta (VNIGRI). Novaya serya. Vypusk 46]. Moscow-Leningrad, Gostoptekhizdat, 206 p. [in Russian]

Nalivkin, V.D., 1955, [Stratigrafiya i facii verhnego paleozoya okrestnostey kamnya Plakuna na r. CHusovoy. Geologicheskiy sbornik (Doklady i stat'i). *Vypusk* **3** (6). L.]: Moscow-Leningrad, Gostoptekhizdat, p. 7–32. [in Russian]

Packard, A.S., 1885, Types of Carboniferous Xiphosura new to North America: *American Naturalist*, **v. 19**, p. 291–294.

Pieroni, V., 2024, The first Cyclida from the Triassic of Italy: *Swiss Journal of Palaeontology*, **v. 143**, no. 1, p. 1–9, https://doi.org/10.1186/s13358-024-00306-9.

Pirozhnikov, L.P., 1960, [Ostatki Cycloidea iz Kazanskogo yarusa reki Kozhim (Pechorskiy kamennougolnyi bassein)]: *Sbornik Statei po Paleontologii i Biostratigraphii*, **v. 17**, p. 85–87. [in Russian]

Putrya, F.S., 1940, [Foraminifers and stratigraphy from the upper Carboniferous sediments of the eastern part of the Donetsk basin]: [*Azov-Black Sea Geological Administration*], **v. 11**. p. 5–146. [in Russian]

Rauzer-Chernousova, D.M., 1958, [High-resolution subdivision of upper Carboniferous section in the Kuibyshev Hydro-electric Power-station area]: [*Transactions of the Geological Institute (Academy of Sciences USSR)*], **v. 13**. p. 121–138. [in Russian]

Rauzer-Chernousova, D.M., Belyaev, G., and Reitlinger, E., 1936, [Upper Paleozoic Foraminifera of the Pechora region]: [*Proceedings of the Polar Commission AS USSR*], **v. 28**, p. 159–232. [in Russian]

Reed, F.R.C., 1893, Woodwardian Museum notes: *Geological Magazine, decade* **3**, v. 10, p. 64–66.

Reed, F.R.C., 1908, A new species of *Cyclus* from the Carboniferous Limestone of Ireland: *Geological Magazine, decade* **5**, v. 5, p. 551–552.

Regier, J.C., Shultz, J.W., Zwick, A., Hussey, A., Ball, B., Wetzer, R., Martin, J. W., and Cunningham, C.W., 2010, Arthropod relationships revealed by phylogenomic analysis of nuclear protein-coding sequences: *Nature*, **v. 463**, p. 1079–1083, https://doi.org/10.1038/nature08742.

Rogers, A.F., 1902, Some new American species of *Cyclus* from the Coal Measures: *Kansas University Science Bulletin*, **v. 1**, p. 269–274.

Ruzhentsev, V.E., and Bogoslovskaya, M.F., 1978, [Namyurskiy etap v evolyucii ammonoidey. Pozdnenamyurskie ammonoidei]: Trudy Paleontologicheskogo Instituta AN SSSR, 167. Moscow, Nauka, 338 p. [in Russian]

https://doi.org/10.1017/jpa.2024.85 Published online by Cambridge University Press

Schafhäutl, K.E., 1863, Süd- Bayerns lethea geognostica. Der Kressenberg und die südlich von ihm gelegenen Hoch alpen, Leipzig, Leopold Voss.

Schauroth, C. von, 1854, Ein Beitrag zur Paläontologie des deutschen Zechsteingebirges: *Zeitschrift der Deutschen Geologischen Gesellschaft*, **v. 6**, p. 539–577.

Schellwien, E., 1908, Monographie der Fusulinen, Teil I (mit Taf 13–20), Nach dem Tode des Verfassers herausgegeben und fortgesetzt von Günter Dyhrenfurth und Hans v. *Staff; Teil 1: Die Fusulinen des russisch-arktischen Meeresgebietes, mit einem Vorwort von Fritz Frech und einer stratigraphischen Einleitung von Hans. v. Staff: Palaeontographica*, **v. 55**, p. 145–194.

Schmidt, M.N., 1937, [Kamennougol'nye otlozheniya rajona Kusinskogo zavoda], *in* Krymgol'c, G.Ya., ed., [Materialy Central'nogo Nnauchno-Issledovatel'skogo Geologo-Razvedochnogo Instituta], Volume 3: Leningrad-Moscow, ONTI NKTP USSR, p. 53–63. [in Russian with English abstract]

Schram, F.R., Vonk, R., and Hof, C.H.J., 1997, Mazon Creek Cycloidea: *Journal of Paleontology*, **v. 71**, p. 261–284, https://doi.org/10.1017/S0022336000039172.

Schweitzer, C.E., and Feldmann, R.M., 2008, New Eocene hydrocarbon seep decapod crustacean (Anomura: Galatheidae: Shinkaiinae) and its paleobiological implications: *Journal of Paleontology*, **v. 82**, p. 1021–1029, https://doi.org/10.1666/08-007.1.

Schweitzer, C.E., Feldmann, R.M., and Karasawa, H., 2018, Systematic descriptions: superfamily Carpilioidea, in Seldon, P.A., ed., Treatise [on Invertebrate Paleontology] Online, Part R (Revised), Volume 1, Chapter 8T2: Lawrence, Kansas, The Paleontological Institute, 24 p. [See http://paleo.ku.edu/tronline/treatiseonline.html].

Schweitzer, C.E., Mychko, E.V., and Feldmann, R.M., 2020, Revision of Cyclida (Pancrustacea, Multicrustacea), with five new genera: Neues Jahrbuch für Geologie und Paläontologie, *Abhandlungen*, **v. 296**, no. 3, p. 245–303, https://doi.org/10.1127/njgpa/2020/0905.

Schweitzer Hopkins, C., and Feldmann, R.M., 1997, Sexual dimorphism in fossil and extant species of *Callianopsis* de Saint Laurent: *Journal of Crustacean Biology*, **v. 17**, no. 2, p. 236–252.

Shcherbakova, M.V., and Shcherbakov, O.A., 1994, [Verhnekamennougol'nye otlozheniya v okrestnostyah kamnya 'Plakun' na reke Chusovoy], *in* Chuvashov, B.I., and Amon, E.O., [Novye Dannye po Stratigrafii Verhnego Paleozoya—Nizhnego Kajnozoya]: Ekaterinburg, Russia, Ural'skoe Otdelenie RAN, p. 41–93. [in Russian]

Shcherbakova, M.V., and Shcherbakov, O.A., 2009, [Kamen' Plakun (polnye razrezy verhnego karbona v rifovoj facii)], *in* Chajkovskiy, I.I., [Geologicheskie Pamyatniki Permskogo Kraya. Enciklopediya]: Perm, Russia, Gornyj Institut Ural'skogo Otdeleniya RAN, p. 93–98. [in Russian]

Smirnov, G.A., 1956, [Ufimskiy amfiteatr. Chast' 1. Stratigraficheskoe opisanie]: Trudy Gorno-Geologicheskogo Instituta Ural'skogo Filiala AN *SSSR*, **v. 25**, p. 1–175. [in Russian]

Sowerby, J., 1822, The Mineral Conchology of Great Britain; or Coloured Figures and Descriptions of Those Remains of Testaceous Animals or Shells, Which Have Been Preserved at Various Times and Depths in the Earth, Volume 4: *London, J. de C. Sowerby*, p. 1–114.

Sowerby, J., 1825, The Mineral Conchology of Great Britain; or Coloured Figures and Descriptions of Those Remains of Testaceous Animals or Shells, Which Have Been Preserved at Various Times and Depths in the Earth, Volume 5: *London, J. de C. Sowerby*, no. **39**, p. 100–168.

Tang, H.Y., Mychko, E.V., Feldmann, R.M., Schweitzer, C.E., Shaari, H., and Sone, M., 2021, *Malayacyclus* gen. nov., the first Southeast Asian Cyclida (Crustacea) from the Early Carboniferous of Terengganu, Malaysia: *Geological Journal*, p. 1–9, https://doi.org/10.1002/gj.4128.

Tang, H.Y., Mychko, E.V., Feldmann, R.M., Schweitzer, C.E., Shaari, H., and Sone, M., 2023, *Validation of* Malayacyclus *Tang, Mychko, Feldmann, Schweitzer, Shaari & Sone, a cyclidan crustacean from the Early Carboniferous of Terengganu*, Malaysia: Zootaxa, **v. 5318**, no. 3, p. 439–440, https://doi.org/10.11646/zootaxa.5318.3.10.

Trauth, F., 1918, Über einige Krustazeenreste aus der alpin-mediterranean Trias: *Annalen des Naturhistorischen Hofmuseums*, **v. 32**, p. 172–192.

Tshudy, D., and Sorhannus, U., 2003, *Hoploparia*, the best-known fossil clawed lobster (family Nephropidae), is a 'wastebasket' genus: *Journal of Crustacean Biology*, **v. 23**, p. 700–711, https://doi.org/10.1651/C-2353.

Weber, V.N., 1937, [Trilobites of the Carboniferous and Permian deposits of the USSR. Issue. 1. Carboniferous trilobites]: Monografii po paleontologii SSSR [Monographs on paleontology of the USSR], Volume 71: Leningrad-Moscow, Main Editorial Office of Geological Exploration and Geodetic Literature, 160 p. [in Russian and English]

Weber, V.N., Lermontova, E.V., Martynov, A.V., and Chernyshev, B.I., 1934, [Tip 8, Arthropoda, Chlenistonogie], *in* K. Cittel', ed., [Osnovy Paleontologii (Paleozoologiya). Chast' 1. Bespozvonochnye. Pererabotano Paleontologami SSSR pod Redakciej A.N. Ryabinina]: Moscow-Leningrad-Groznyj-Novosibirsk, Gosudarstvennoe Ob"edinyonnoe Nauchno-Tekhnicheskoe Izdatel'stvo Narodnogo Komissariata Tyazheloj Promyshlennosti SSSR, p. 880–1026.

Whitfield, R.P., 1880, Notice of new forms of fossil crustaceans from the Upper Devonian rocks of Ohio, with descriptions of new genera and species: *American Journal of Science and Arts, ser.* **3**, v. 19, p. 33–42.

Woodward, H., 1868, Fourth report on fossil Crustacea: British Association Reports, *Norwich Meeting*, **1868**, p. 72–75.

Woodward, H., 1870, Contributions to British fossil Crustacea: *Geological Magazine*, **v. 7**, p. 554–560.

Zenchenko, N.A., 1930, [Geologicheskiy ocherk doliny reki Chusovoj ot derevni Kojvy do kamnya Gladkogo]: *Izvestiya Glavnogo Geologo-Razvedochnogo Upravleniya*, **v. 49**, no. 9, p. 1047–1066. [in Russian with French abstract]

Zittel, K. (revised edited by A.N. Ryabinin), 1934, [Osnovy paleontologii (paleozoologiya). Chast 1. Bespozvonochnye]: Leningrad-Moscow-Groznyj-Novosibirsk, ONTI NKTP USSR, 1067 pp. [in Russian]

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