New finding of Cyclida (Crustacea) from Mississippian and not-cyclidan from Permian of Russia

Eduard V. Mychko, Alexander S. Alekseev, Elena L. Zaytseva, Carrie E. Schweitzer, and Rodney M. Feldmann

With 5 figures

Abstract: A new genus and species of cyclidan Magnitocyclus struveae gen. et sp. nov., from the Mississippian of the Urals is described and illustrated. It is the first reliable record of a cyclidan in the Upper Viséan – Lower Serpukhovian of Russia. Petschorocaris kozhimensis, from the Permian of the Pechora Coal Basin (Russia), is not a cyclidan but is apparently the mold of a patella-like gastropod shell.

Key words: Crustacea, Cyclida, Carboniferous, Mississippian, Permian, Russia.

1. Introduction

Cyclidans are enigmatic, extinct crustaceans that had a crab-like carapace, long before the origin of true crabs. The first cyclidans appeared in the Early Carboniferous, survived the Great Permian extinction, and existed until the end of the Late Cretaceous (Maastrichtian). The specific structure of the carapace, a pair of antennal structures, number of legs, markedly reduced abdomen and a horseshoe-shaped array of gill filaments do not support cyclidans being assigned to a previously defined higher taxon (subclass or infra-class) of Crustacea. Therefore, like many previous authors, we consider cyclidans to be in the order Cyclida SCHRAM, VONK & HOF, 1997, within the superclass Multicrustacea REGIER et al., 2010.

The earliest recognition of cyclidans was in the first half of the 19th century. Currently, the order Cyclida includes 6 families, 27 genera and 53 species. Fossils of cyclidans are sporadic and rare, and there were no general studies up until recently. Interest in these extinct crustaceans has erupted, a general morphology and terminology was developed to describe cyclidans (FELDMANN & SCHWEITZER 2019), and then a detailed revision of Cyclida (SCHWEITZER et al. 2020) was conducted.

Remains of cyclidans are known from Europe, Asia, North America, and Madagascar. In the territory of Russia, specimens of cyclidans are very rare and confined to the Middle and Southern Urals. They are represented by Prolatcyclus kindzadza MYCHKO et al., 2019, from the Viséan of the Orenburg Region, Ambocyclus capidulum (CHERNYSHEV, 1933) from the Serpukhovian of the Sverdlovsk Region, Uralocyclus miloradovitchi (KRAMEKAKO, 1961) from the Asselian of the Chelyabinsk Region, and Skuinocyclus juliae MYCHKO & ALEKSEEV, 2018 from the Asselian of the Bashkortostan. There are records in various works about other rare findings of Russian cyclidans, but without details and descriptions (MYCHKO et al. 2019: 81). Therefore, any new discoveries of these fossils are extremely important for understanding their evolutionary history and paleobiogeography.
2. Struve’s cyclidan

A cyclidan carapace was discovered in 2017 in the Department of Paleontology of Lomonosov Moscow State University, in the collection of various fossil arthropods, collected over many years by A.S. Alekseev. It was in a standard size matchbox (Fig. 1a) issued after 1977. The front label has a handwritten inscription “колл. З. Макс. рак??” (= “collection of Z. Max, can­cer??”). Designation “Z. Max” without any doubt is the abbreviated name and surname of Zlata Alexan­drovna Maksimova, an employee of VSEGEI (Vse­soyuzni Nauchno-issledovatelskiy Geologicheskiy Institut, now Karpinsky Geological Research Institute, Saint-Petersburg), a prominent specialist in the study of mainly Devonian trilobites of the USSR. Maksimova did not transfer material on arthropods to A.S. Alek­seev; but in the late 1980s E.S. Levitsky, who studied Devonian trilobites, as well as Cretaceous decapods of the Crimea, kindly lent his collection to A.S. Alekseev upon retirement. It was supposed to contain a box with a cyclidan.

3. Locality

Inside the box, along with the fossil, there is a small blank VSEGEI typographical label (Fig. 1b), intended for labeling collection samples, on the reverse side of which, over the original inscription, made in blue ink and very badly damaged by water, is written in large letters with a ballpoint pen “Struve f. 229 (2 or g, smaller). 1955”. Unfortunately, the symbols of the original text were so blurred that now only a few let­ters and numbers can be recognized more or less confi­dently, so it is not possible to consider the information contained on the label as absolutely reliable. This entry is deciphered quite simply: Struve is the surname of the one who found this specimen. The letter “f” was used in the sample numbers of USSR geologists, and it usually denoted the abbreviated word “fauna”, that is, fossils, and not a rock or mineral sample. The final number is the observation/outcrop number. Unfortu­nately, the last symbol of the number is smaller than the others and its meaning is unclear: it is the num­ber “2” or the letter “г”, which may indicate one of several specimens collected in this outcrop. A similar number is written in black ink (?) on a suitable area of limestone under the carapace of the fossil, and the last character is also smaller, although there is enough space for it, and it most of all resembles the handwritten Cyrillic letter “г” (= “g”).

Natalia Vasilievna Struve, like Z.A. Maksimova, was an employee of VSEGEI, where she was listed in the department that studied igneous complexes in various regions of the USSR. In the 1950s, she worked under the direction of V.M. Sergeievsky on the eastern slope of the Southern Urals, in the Magnitogorsk Synclinorium, describing sections mainly of the Lower Carboniferous volcanogenic strata. Several of her publications on the stratigraphy and volcanism of the Mississippian of this region are known (Struve 1959; Donakova & Struve 1959). Thus, the outcrop in which the cyclid was found, if the information from the label is considered reliable, is undoubtedly located on the eastern slope of the South Urals, Magnitogorsk Synclinorium (Fig. 2), in the territory of the Chelyabinsk or Orenburg regions and the east of the Republic of Bashkortostan.

The Carboniferous deposits of this rather vast area mainly belong to the volcanic Berezovo and Grekhovo formations (Tournasian–Lower Viséan), and the carbonate Kizil Formation (Upper Viséan–lower part of the Bashkirian) (Kulagina et al. 2015).
STRuve handed over the collected fossils to VSEGEI paleontologists for study. In particular, brachiopods collected in the Berezovo and younger Kizil formations were conveyed to L.M. DONAKOVA, who also worked at VSEGEI. Using these collections, Donakova published a number of articles (DONAKOVA 1969; DONAKOVA 1972; DONAKOVA 1974; etc.), but there are no sample numbers among the depicted brachiopod specimens. The only number belonging to the collections of N.V. STRUVE belongs to the holotype of Davidsonina struvei DONAKOVA, 1969, which comes from sample 433, collected in 1953, "Ural Riv-
er” (DONAKOVA 1969: 219). In the Central Research Geological Prospecting Museum (TsNIGR-museum, VSEGEI, St. Petersburg), number 7147 is a collection of N.V. STRUVE of 1950 (information received from the curator of this museum N.M. KADLEC in 2021), in whose field notebook specimens of brachiopods are listed with numbers 224/50, 266/50, 431/50, 431a/50, 567/50, and 654/50 without locations, but with preliminary determinations and ages in the lower-upper Viséan interval. The numbers of the outcrops belonging to STRUVE are three-digit and, apparently, were repeated in different years, which significantly complicates the search for the desired one among them. But it is also possible that the outcrop with the same number was visited several times in different years.

The handwritten Metallogenic Map of the Urals, compiled in 1956 and kept at VSEGEI, shows outcrop number 229, but without any additional character or letter. It is located on the east (left) bank of the Ural River about 1.5 km south of the village of Ershovskiy, not far from the confluence of the Ural and Bolshaya Karaganka rivers. According to the geological map at a scale of 1:200000, sheet N-40-XXXVI, first edition, volcanic rocks of the Upper Tournaisian-Lower Viséan Berezovo Formation are widespread at this place, and in the field of outcrops of the tuff strata there is a sign indicating the presence of fossils here. However, on the map of the second edition of the same sheet, the location of the fossils is shown to the north, on the right bank of the Bolshaya Karaganka river (TEVELEV et al. 2018). In any case, it is impossible to establish the identity of the location indicated on the label and observation point 229 on the STRUVE manuscript map.

4. Age

Despite the fact that the exact place in the Magnitogorsk Synclirion where this cyclidan was found remains unclear, it remains possible to determine its age more accurately than just Carboniferous. The carapace of the cyclidan is located on a small fragment of gray rather durable limestone. From it, it was possible to make one thin section 1.2 × 0.6 cm in size. The rock is peloidal wackestone with rare foraminifers, fragments of echinoderm skeletons, brachiopod shells, a single fragment of bryozoan (?), and other bioclasts (Fig. 3).

The following species of foraminifers were defined: Eotuberitina reitlingerae MIKLUKHO-MAKLAY, 1958; Pachysphaerina dervilei (CONIL & LYS, 1964); Neoarchaesphaera (Elenella) (?) sp.; Vissariotaxis exilis (VISSARIONOVA, 1948); Tetrataxis aff. T. quasiconica BRAZHNIKOVA, 1956; Endothyra obsoleta RAUSER-CHERNOUSOVA, 1948; Monotaxinoides sp. Most of these species and forms have a wide geological distribution. For example, Eotuberitina reitlingerae occurs in the Carboniferous and the Lower Permian, and Pachysphaerina dervilei is known from the Viséan in the Franco-Belgian and Donets basins (BRAZHNIKOVA & VDOVENKO 1973), as well as in the Urals (STEPANOVA 2016).

Vissariotaxis exilis was described by VISSARIONOVA (1948) from the Upper Viséan (Tulian Regional Substage) of the Moscow Basin and is known from the Upper Viséan in western Ukraine (BRAZHNIKOVA 1956). In the Donets Basin, according to M.V. VDOVENKO (VDOVENKO 2000), this species is distributed in C1 ve2–C1 vg zones, correlated with the Tulian, Aleksinian, and partly Mikhailovian regional substages of the East European Platform (ALEKSEEV et al. 2022). On the Voronezh Anteclise, it is fixed at the base of the Upper Viséan (MAKLINA et al. 1993).

The species Tetrataxis quasiconica was described by BRAZHNIKOVA (1956) from the Upper Viséan of the Galicia-Volyn Depression in Ukraine. In terms of shell shape and apical angle, the encountered specimen is closest to the mentioned species, but differs from the holotype in smaller size and more regular shell shape with slightly concave lateral sides. The species Endothyra obsoleta was described by RAUSER-CHERNOUSOVA (1948) from the Mikhailovian of the Moscow Basin and distributed on the East European Platform in the Upper Viséan and Serpukhovian. In the Donets Basin, the distribution of this species is limited to the Upper Viséan substage, C1 ve2–C1 vg zones (VDOVENKO 2000).

Members of the genus Monotaxinoides on the East European Platform, the Donets Basin, and Arctic Canada are found in the interval from the Upper Viséan to Middle Pennsylvanian; in France, this is Upper Viséan–Serpukhovian; in Turkey, the Upper Serpukhovian; in Spain and the countries of Central Asia – Serpukhovian–Pennsylvanian; in North America – Upper Mississippian–Lower Pennsylvanian; in South America – Lower Pennsylvanian (KULAGINA & FILIMOLOVA 2020).

Thus, the foraminifer assemblage found in the limestone with the cyclidan indicates its Upper Viséan or Serpukhovian age and does not correspond to the Upper Tournaisian–Lower Viséan Berezovo Formation of Outcrop 229.
New finding of Cyclida (Crustacea) in Mississippian

Foraminifera from limestone containing the new cyclidan, eastern slope of the South Urals, Magnitogorsk Synclinorium, Upper Viséan – Serpukhovian. a – Pachysphaerina dervillei (Conil & Lys); b – Neoarchaesphaera (Élenella) (?) sp.; c – Eotuberitina reitlingerae Miklukho-Maklay; d – Vissariotaxis exilis (Vissarionova), axial section; e – Earlandia elegans (Rauser-Chernousova & Reitlinger); f – Endothyra obsoleta Rauser-Chernousova, subequatorial section; g – Tetra-taxis aff. T. quasiconica Brazhnikova, axial section; h – Monotaxinoides sp., oblique subequatorial section; i) peloidal wackestone with bioclasts of brachiopods, echinoderms and bryozoans.
5. Systematic paleontology

Superclass Multicrustacea Regier et al., 2010
Order Cyclida Schram, Vonk & Hof, 1997
Family Cyclidae Packard, 1885

Diagnosis: See Schweitzer et al. (2020).

Genus Magnitocyclus nov.

Etymology: By name of type area – Magnitogorsk.

Type species: Magnitocyclus struveae gen. et sp. nov., by original designation.

Diagnosis: Carapace longer than wide, ovate; carapace lobes well-defined: there are posterior axial lobe, posterior median bulge, second pair of lobes, anterior median bulge, first and second pair of lateral lobes, inner lyrate keels and weak axial keel; the surface of the carapace is covered with papillae arranged in rows.

Comparisons: The new genus is allied with the genera of the family Cyclidae, based upon the morphology described by Feldmann & Schweitzer (2019) and Schweitzer et al. (2020). The new genus differs from the type genus Cyclus de Koninck, 1841, from the Mississippian of the British Isles and Belgium by the absence of a thoracic ridge (tr), presence of papillae (pap), a less pronounced axial keel (ak), and absence of a posterior notch (pn). From Prolatycyclus Mychko, Feldmann, Schweitzer & Alekseev, 2019, from the Mississippian of England and Russia the new genus differs by possessing a wider carapace, lack of definition of the outer branchial regions (obr), narrower and smaller posterior axial lobe (pal), smaller second pair of lobes (al 2) and a number of other features. From Uralocyclus Mychko & Alekseev, 2018, from Mississippian–Lower Permian of UK and Russia the new genus differs by having a narrower carapace, lack of separation of outer branchial regions (obr), less convex lobes, the absence of a third pair of lateral lobes (ll 3), and a less wide marginal rim (mr). From Ambocyclus Schweitzer, Mychko & Feldmann, 2020, from the Carboniferous of Ireland and Russia the new taxon differs by bearing pronounced lobes, the presence of papillation (pap), a different form of marginal rim (mr), and the presence of an axial keel (ak). However, the outline of the carapace in new the genus resembles Ambocyclus. From Carabicyclus Schweitzer, Mychko & Feldmann, 2020, from the Mississippian of the British Isles, the new genus differs by its wider carapace, the presence of papillation (pap), and a complex system of lobes in the anterior part of carapace, which are almost absent in Carabicyclus. From Litocyclus Schweitzer, Mychko & Feldmann, 2020, from the Carboniferous of the British Isles and USA the new genus differs by lack of posterior notch (pn), the presence of a second pair of lobes (al 2), very narrow anterior median lobe (al 3), and regular arrangement of papillae (in Litocyclus they are arranged randomly). From Chernyshevine Schweitzer, Mychko & Feldmann, 2020, from the Mississippian of Tajikistan the new genus differs in a shorter axial keel (ak), smaller papillae (pap), and absence of spines on the marginal rim (mr). From Tazawacyclus Schweitzer, Mychko & Feldmann, 2020, from the Mississippian of Japan the new genus differs in its narrower carapace, smaller second pair of lobes (al 2), and absence of a third pair of lateral lobes (ll 3).

Discussion: Apparently the closest genus to Magnitocyclus gen. nov. is Litocyclus. However, the development of the lobes in Litocyclus is comparatively different (see comparison). It is possible that the development of the second pair of lobes and the lack of posterior notch can be considered genus-level characters. It is very interesting that the morphology of the carapace of Magnitocyclus gen. nov. is similar to that of Paraprosopon, described from the Guadalupian of Sicily (Gemmellaro, 1890). However, we do not have the holotype of Paraprosopon reussi Gemmellaro, 1890, which may have been lost and therefore cannot be compared. In a previous revision (Schweitzer et al. 2020), the authors placed Paraprosopon in the Hemitrochiscidae. Apparently this may be wrong, since Paraprosopon has well-defined carapace lobes typical of Cyclidae.

Magnitocyclus struveae gen. et sp. nov. Fig. 4

Etymology: In honor of the author of the discovery – Natalia Vasilievna Struve.

Types: An almost complete carapace, Borissiak Paleontological Institute, Russian Academy of Sciences (Moscow), no. №5871/1, holotype (by monotypy).

Description: Carapace is elongated, ovoid in outline: the posterior part is slightly wider than the anterior part. The ratio of length to width in the anterior part
New finding of Cyclida (Crustacea) in Mississippian (narrowest side) is 1.4; the same ratio in the posterior (widest side) – 1.1. Carapace is highly vaulted with greatest height posterior to mid-length.

Marginal rim (mr) is not well known and is visible only in the posterior of the carapace on the right. Apparently, the mr is not uniformly wide: its greatest width is in the central part of the carapace, and it narrows toward the posterior and possibly the anterior of the carapace. The flat surface of the mr is slightly inclined away from the carapace and is separated from it by a barely perceptible groove.

Anterior median lobe (al 3) is elongated and narrows toward its posterior and anterior margins. On both sides of it there is a pair of large subrectangular lobes (al 2), separated by wide furrows from al 3. Adjacent to these lobes are a pair of even larger subtriangular lateral lobes (ll 2). All of these lobes are flattened.

In the anterior part, the central lobe is separated, consisting of a pair of lateral lobes (ll 1) and a posterior median lobe (al 1) that have merged, so the furrows between these three lobes are not visible. However, obvious furrows between this fused lobe (pair ll 1 + al 1)
are clearly visible with al 2 and ll 2. At the place where it meets the posterior axial lobe (pal), there is a pair of deep pits.

The posterior axial lobe is comparatively large and consists of two parts: a horseshoe-shaped anterior part and narrow posterior conical part. A pair of inner lyrate keels (ilk) are very small and barely noticeable. In outline, they are elongate-ovoid and in width each corresponds to the width of the posterior part of the posterior axial lobe. These lobes are flattened and weakly marked on the carapace. They abut the weak axial keel (ak) that appears to terminate before reaching the posterior margin. This axial keel is slightly convex, bordered by a pair of parallel shallow furrows, slightly tapering towards its anterior end.

The entire surface of the carapace is covered with small papillae (pap). All these papillae are of the same round shape and the same size (about 2 micrometers). They are located densely and not randomly arrayed: in the posterior of the carapace they form dense rows from the second lateral lobes to the axial keel.

**Dimensions:** Length: 8.1 mm; posterior width: 7.3 mm; anterior width: 5.7 mm; height: 4.5 mm.

6. **PIROZHNIKOV’s “cyclidan”**

Recently, a publication by PIROZHNIKOV (1960) was discovered describing species of “cyclidans”, which was not accounted for in the revision of the order Cyclida (SCHWEITZER et al. 2020). The single specimen was discovered by the geologist V.P. Gorsky in 1959 in the Permian deposits of the Pechora Coal Basin, on the left (south) bank of the Kozhim river (10 km from the confluence of the Kos’yu River, Komi Republic, 40 km southwest of the town of Inta).

According to PIROZHNIKOV’s data (1960: 85), the “cyclidan” was discovered in marly sandstones in conjunction with a bivalve assemblage, which indicated the lower part of the Vorkuta Formation (KUZKKOVA et al. 1980) or Kozhrudnetsk Formation (GRUNT et al. 1998: 68). This latter formation corresponds to the lower part of the Ufimian, or to the upper part of the Kungurian of the International Stratigraphic Scale (KOREN 2006: 92).

It is interesting that no reliable records of Kungurian cyclidans are known (SCHWEITZER et al. 2020). Therefore, the finding of cyclidans would significantly expand our understanding of the paleobiogeography of this group of extinct arthropods. However, the fossil described by PIROZHNIKOV (Fig. 5a, b) is a small, rounded, cap-shaped “carapace” (33 × 33 × 22 mm). According to him concentric tubercles are observed on the surface of the “carapace”; the “carapace” consists of three segments, as well as two longitudinal grooves. This single specimen was used to describe the species Petschorocaris kozhimensis PIROZHNIKOV, 1960 and is currently kept in the collection of the TsNIGR-museum in St. Petersburg (No 1/9197).

Upon a detailed study of the specimen, we did not find features characteristic of cyclidans and of general fossil arthropods. On the contrary, we found signs characteristic of cap-shaped gastropods, in particular, of the genus Novlepatea Starobogatov & MAZAEV, 1999 from the Middle Carboniferous to the Lower Permian of Russia. For example, on PIROZHNIKOV’s “cyclidan”, imprints of horseshoe muscle (?), which he took for grooves are visible. The shape and size of the studied “cyclidan” are similar to those in the Novlepatea (Fig. 5d, f). However, PIROZHNIKOV’s “cyclidan” is very poorly preserved (core without shell or carapace material) and it is apparently impossible to unequivocally identify it as belonging to any genus of Gastropoda.

7. **Conclusions**

New findings of cyclidans expand our understanding of the paleobiogeography and evolution of these fossil arthropods. For example, Magnitocyclus struveae gen. et sp. nov. represents the first reliable occurrence of a cyclidan in the Upper Viséan–Lower Serpukhovian of Russia. The morphology similar to Litocyclus allows us to inform the relationships among these cyclidans. Unfortunately, some findings tentatively identified as cyclidans turn out to be completely different fossils. Thus, the “cyclidan” Petschorocaris kozhimensis is apparently the mold of a patella-like gastropod shell.

**Acknowledgements**

The first author is grateful to ALEXEY R. SOKOLOV, director of the TsNIGR-museum (Saint Petersburg) for providing photos of the fossil described by PIROZHNIKOV; ALEXEY V. MAZAEV, senior researcher of the Borissiak Paleontological Institute, Russian Academy of Sciences (Moscow), for various advice on stratigraphic literature; YULIYA V. KOSHELEVA for the drawing of the reconstruction of the new cyclidan.
We sincerely thank GÜNTER SCHWEIGERT (Staatliches Museum für Naturkunde, Stuttgart, Germany) for high-quality and fast review of this work. The research was supported by RSF (project No. 22-14-00258).
References


KRAMARENKO, N.N. (1961): Predstavitel’ Cyclidae (Crustacea) iz nizhnepermishskih otlozheniy Priuralia. – Paleontologicheskiy Zhurnal, 2: 86–89. (In Russian)


New finding of Cyclida (Crustacea) in Mississippian


Manuscript received: June 6th, 2022. Revised version accepted by the Stuttgart editor: June 9th, 2022.

Addresses of the authors:

Eduard V. Mychko, Shirshov Institute of Oceanology, Russian Academy of Sciences, Nahimovskiy prospekt 36, Moscow, 117997, Russia; A.N. Severtsov Institute of Ecology and Evolution, Leninsky Prospect 33, Moscow 119071, Russia; Institute of Living Systems, Immanuel Kant Baltic Federal University, Nevskogo Street 14, Kaliningrad, 236016, Russia; Borissiak Paleontological Institute, Russian Academy of Sciences, Profsoyuznaya St. 123, Moscow, Russia, 117647; e-mail: eduard.mychko@gmail.com

Alexander S. Alekseev, Geological Faculty, Lomonosov Moscow State University, Leninskie Gory 1, Moscow, 119991, Russia; Borissiak Paleontological Institute, Russian Academy of Sciences, Profsoyuznaya St. 123, Moscow, Russia, 117647; e-mail: aaleks.geol@mail.ru

Elena L. Zaytseva, Geological Faculty, Lomonosov Moscow State University, Leninskie Gory 1, Moscow, 119991, Russia; e-mail: ezaitseva@mail.ru

Carrie E. Schweitzer, Department of Geology, Kent State University at Stark, North Canton, Ohio 44720, USA; e-mail: cschweitz@kent.edu

Rodney M. Feldmann, Department of Geology, Kent State University, Kent, Ohio 44242, USA; e-mail: rfeldman@kent.edu

References:


Schweitzer, C.E., Mychko, E.V. & Feldmann, R.M. (2020): Revision of Cyclida (Pancrustacea, Multicrustacea), with five new genera. – Neues Jahrbuch für Geologie und Paläontologie, Abhandlungen, 10.1017/S0022336000039172


