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Some lower Famennian (Upper Devonian) cyrtospiriferid brachiopods from the Volhyn-Podillian plate (western Ukraine)

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Деякі циртоспіроферодні брахіоподи нижнього фамену (верхній девон) Волино-Подільської плити (захід України)

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This study provides the first documentation of lower Famennian spiriferide brachiopods from the Volhyn-Podillian plate in western Ukraine, specifically from the Lokachi, Torchyn, Kowel', and Velyki Mosty boreholes in the Volhyn and Lviv regions. The examined assemblage comprises three species: *Cyrtospiriferinae* gen. indet., *Tornatospirifer* sp., and *Cyrtiopsis?* sp. Albeit with some uncertainty regarding the latter genus, this marks the first record of these genera in Ukraine, thereby extending the palaeobiogeographic distribution of the subfamily *Cyrtiopsinae*.

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Introduction

The Devonian Period was a time of significant evolutionary advancements and ecological shifts within the marine part of the biosphere. Among the numerous marine invertebrates that flourished during this period, brachiopods were particularly abundant and diverse, thriving in shallow-water tropical and subtropical marine environments (Ma and Day, 1999; Curry and Brunton, 2007; Alroy, 2010). Consequently, brachiopods have been widely considered valuable biostratigraphic markers and are crucial for understanding the changes that occurred during the Devonian. However, during the Late Devonian interval, their diversity declined through multiple pulses of extinction, particularly around the Frasnian–Famennian (F–F) boundary (McGhee, 1996; Racki and House, 2002; Huang et al., 2018). Although it is evident that brachiopods experienced severe losses at the F–F boundary, the extent of the crisis’s impact on brachiopod diversity and the dynamics of their post-extinction recovery remain poorly understood in many study areas. This lack of understanding is particularly true for the brachiopods from the Volhyn–Podillian area in western Ukraine. The Famennian spiriferides from this area were first examined by Samsonowicz (1950), who recovered two species from the Busk borehole near Lviv and identified them as *Spirifer archiaci* Murchison, 1840 and *S. murchisonianus* Verneuil, 1845. Regrettably, the illustrations were not accompanied by detailed serial sections or morphological descriptions, which preclude a definitive assignment of these species. Pomyanovskaya (1974, 1991) conducted a more detailed study on the stratigraphic distribution of the Upper Devonian brachiopods from boreholes in the Volhyn–Podillian plate. She reported the presence of 75 species, but did not provide any illustration or description of the brachiopods. Unfortunately, the current location of the material examined in the aforementioned studies is unknown. Despite these taxonomic studies, as well as more recent work by O. Kotlyar (Kotlyar, 1980, 2011, 2021; Kotlyar et al., 2013), the taxonomy and biostratigraphy of the Upper Devonian brachiopod assemblages from Ukraine remain largely undocumented. This is especially true for the cyrtospiriferid species of the Frasnian–Famennian critical interval.

The prime objective of this contribution is to assess the taxonomy of three cyrtospiriferid species (*Cyrtospiriferinae* gen. indet., *Tornatospirifer* sp., and *Cyrtiopsis?* sp.) described herein from the lower Famennian recovery interval of the Volhyn–Podillian plate.

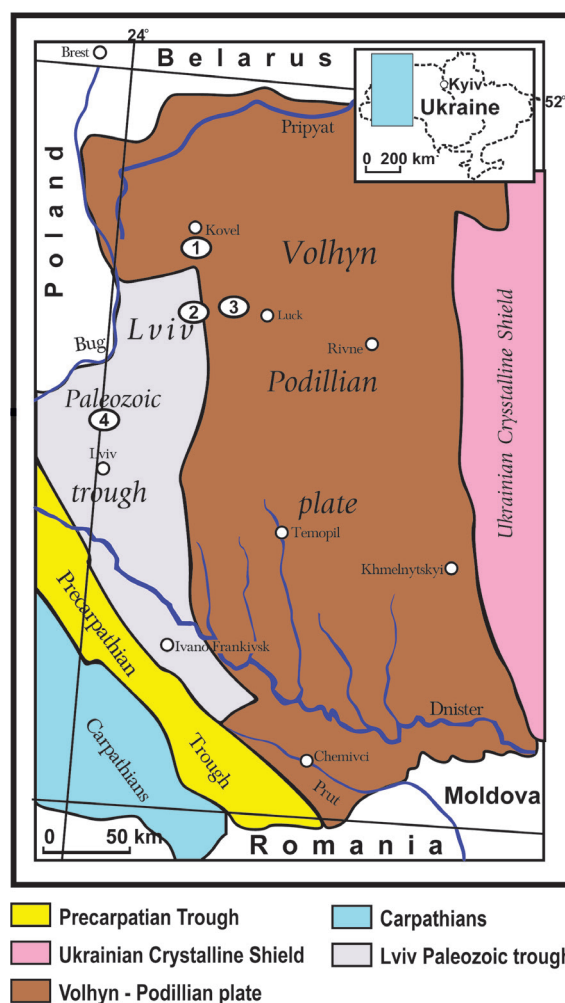


Fig. 1. Geographical location of the Volhyn–Podillian plate and its tectonic zonation. Boreholes with brachiopod species described in this paper: 1 – The Kovel’ borehole area; 2 – The Lokachi borehole area; 3 – The Torchyn borehole area; 4 – The Velyki Mosty borehole area

Stratigraphy and geological setting

The study area is located in the south-western segment of the East European Platform (Fig. 1). Here, the Famennian strata form an elongated monocline between the north-western blocks of the Ukrainian Shield (so-called Kovel’ projection of the foundation) and the Carpathian Geosyncline. The western submerged part of this monocline represents Lviv Paleozoic trough (or depression). Two distinct Famennian regional stratigraphic units, the Kowelian and Novovolhynian regional stages, were distinguished in this area by Kotlyar (2021). The lower Famennian Kowelian regional stage includes the Sadovian Horizon. The latter could be correlated with the *triangularis* to *crepida* conodont zones and possibly partly to the *rhomboidea* Zone (Drygant, 2010). The lower part of the Sadovian Horizon is characterized by a succession of marine facies represented by nodular limestones and marlstones. Based on limited materials only from ten boreholes we consider the iden-

tification of any brachiopod zones to be currently incorrect. The lower part of the Sadovian Horizon may be correlated with the Zadonskian Horizon of the East European Platform (*triangularis* to *crepida* conodont zones), whereas its upper part correlates with the Eletzian Horizon (*rhomboidea* conodont Zone). The middle and upper Famennian Novovolhynian regional stage is characterized by regressive succession of subcontinental rocks (sandstones and siltstones with rare marlstone lenses). Litovezhian, Zakhidny-Bugian and Volodymir-Volhynskian horizons were recognized within this regional stage (Kotlyar, 2021). These strata are dated only by palynological data (Ivanina, 2018). The brachiopod specimens examined in this study were recovered from the Sadovian Horizon.

Material and methods

The brachiopod specimens illustrated and investigated herein come from the Lokachi and Torchyn boreholes, located west of the city of Lutsk, and the Kowel' borehole area, situated close to the town of Kowel', as well as the Velyki Mosty borehole area, located north of the city of Lviv (see Fig. 1). Most of the specimens, recovered from boreholes, are either partially preserved, represented by single disarticulated valves, or are corroded. The internal morphology of specimens was investigated by using the standard technique of serial sections and acetate peels. The fossils were photographed with a camera Panasonic DMC-ZC1 with Leica-Lumix optics after being coated with ammonium chloride.

Repositories and abbreviations: All illustrated material is stored in the Department of Palaeontology and Stratigraphy of Palaeozoic Sediments of the Institute of Geological Sciences of the National Academy of Sciences of Ukraine, Kyiv (IGS NASU).

Systematic palaeontology

The supraspecific classification of this study follows the one suggested by Carter et al. (1994) and Johnson (2006).

Order Spiriferida Waagen, 1883

Suborder Spiriferidina Waagen, 1883

Superfamily Cyrtospiriferoidea Termier & Termier, 1949

Family Cyrtospiriferidae Termier & Termier, 1949

Subfamily Cyrtospiriferinae Termier & Termier, 1949

Cyrtospiriferinae gen. indet.

Pl. 1, Fig. 1a–c

Material. Two incomplete ventral valves from the Lokachi-4 borehole, depth interval 475–480 m; one in-

complete ventral valve presumably representing this species comes from the lower part of the Sadovian Horizon in the Velyki Mosty-1 borehole, depth interval 1390–1394 m; two incomplete ventral valves come from the upper part of the lower Famennian in the Kowel'-5448 borehole, depth 117.7 m and the Kowel'-5447 borehole, depth 272 m, and one ventral valve with high interarea from the latter borehole, depth 305 m; three fragments of the ventral valves come from the same borehole, depth interval 330–334 m; two incomplete ventral valves and one dorsal valve presumably belonging to this species were found in same borehole at depth interval 377–378 m; one ventral valve comes from the Lokachi-6 borehole, depth 618 m and two fragments of ventral valves from the same borehole, depth interval 718–722 m.

Remarks. The specimens consist of poorly preserved, medium-sized (up to 40 mm in width, 33 in length and 23 mm in thickness) ventral valves, which are markedly inflated with flanks sloping steeply towards the lateral commissures and posteriorly hemipyramidal in lateral profile. The cardinal extremities are acute. The specimens are widest at the hinge line and have a prominent umbo terminating with a straight to inclined, acute beak. The ventral interarea is very high, nearly catacline, with a narrow delthyrium (height/width ratio of three to four). The sulcus is poorly preserved, becoming perceptible starting at the midlength and more prominent towards the anterior margin. Ornamentation is preserved only on the left flank of the illustrated specimen and consists of low, flattened, simple costae, which become progressively thicker anteriorly. The examined material is assigned to the subfamily Cyrtospiriferinae rather than Cyrtiopsinae, based on its wide hinge line and acute cardinal extremities. It is worth noting that the nearly catacline ventral interarea and the markedly high and narrow delthyrium are more indicative of the genus *Tenticospirifer* Tien, 1938, as revised by Ma and Day (2000), than *Cyrtospirifer* Nalivkin in Fredericks, 1924, as revised by Ma and Day (2003). However, representatives of *Tenticospirifer* generally display smaller shells and are known only from the Frasnian strata. A better comparison of this material to the aforementioned genera is hampered due to the insufficiency of our material. Therefore, from the generic viewpoint, these specimens are left in open nomenclature pending the collection of better-preserved material.

Occurrence. Sadovian Horizon, lower Famennian, *triangularis-crepida* zones, northern part of the Volhyn-Podillian plate, Ukraine.

Subfamily Cyrtiopsinae Ivanova, 1972

Genus *Tornatospirifer* Serobyanyan et al., 2022

Type species: *Cyrtiopsis senceliae armenica* Abrahamyan, 1974 (by original designation)

Tornatospirifer sp.

Pl. 1, Figs. 2–3; Fig. 2

Material. Two complete shells and four ventral valves from the Torchyn-201 borehole, depth interval 310–319 m; two ventral valves from the Kowel'-5447 borehole, depth interval 334–338 m and one ventral valve from the depth interval 310–315 m; one ventral valve from Lokachi-1 borehole, depth interval 498–500 m.

Description. Shell medium-sized (up to 29 mm in width, 24 mm in length and 16 mm in thickness), wider than long, markedly ventribiconvex, rounded

subpentagonal in outline, widest at about mid-length; cardinal extremities obtuse or slightly mucronate (although these features are not well-preserved in the specimens we examined); anterior commissure uniplicate.

Ventral valve strongly inflated, with convex flanks sloping moderately towards lateral commissures; umbo inflated, prominent; beak unobserved (due to poor preservation); interarea apsacline, triangular, moderately high, well-defined, slightly concave; delthyrium relatively wide, covered by pseudodeltidium formed by several distinct plates with a minute foramen at its top; sulcus relatively wide, moderately deep, originating from beak, widening and becoming deeper anteriorly, round-bottomed at front; tongue relatively high, wide, subtriangular to subcircular in outline.

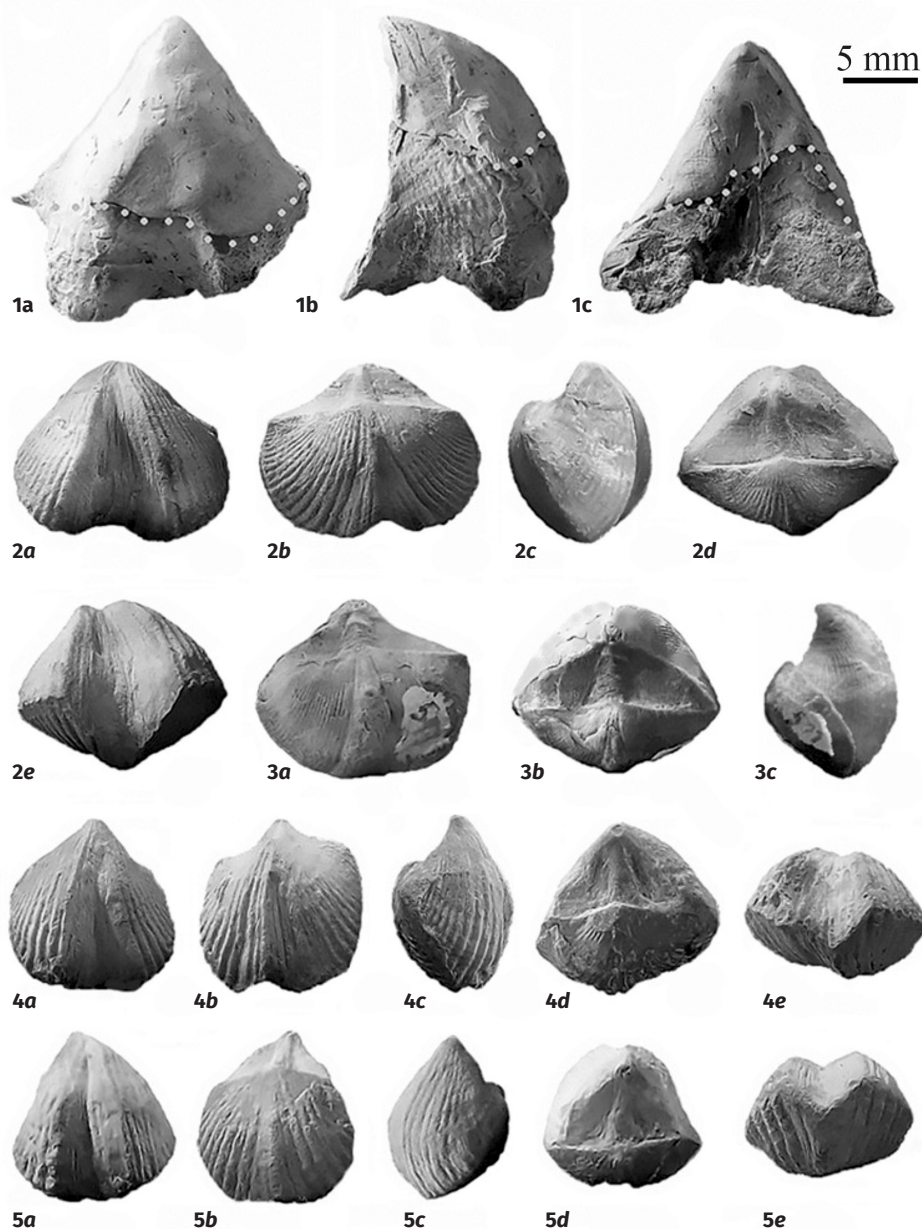


Plate 1. Lower Famennian cyrtospiriferid brachiopods from the Volhyn-Podillian plate: 1a–c – *Cyrtospiriferinae* gen. indet. from the Lokachi-4 borehole, depth 446 m. Specimen IGS NASU-573/2, incomplete ventral valve in oblique anterior, oblique lateral and posterior views. Apical part restored with plasticine (the boundary between the fossil and the reconstructed part of the shell is shown by a dashed line). 2a–3c – *Tornatospirifer* sp. IGS NASU-578/2, partly exfoliated specimen from the Kowel'-5447 borehole (depth 334 m) in oblique ventral, dorsal, oblique lateral, posterior and oblique anterior views (2a–e). IGS NASU-577/1, partly exfoliated specimen from the Torchyn-201 borehole (depth interval 310–319 m) in dorsal, posterior and lateral views (3a–c). 4a–5e – *Cyrtiopsis?* sp. from the Lokachi-3 borehole, depth 635 m. IGS NASU-566/5, almost complete specimen in oblique ventral, dorsal, oblique lateral, posterior and anterior views (4a–e). IGS NASU-566/6, partly exfoliated specimen in oblique ventral, dorsal, oblique lateral, posterior and anterior views (5a–e).

Dorsal valve moderately inflated with convex flanks sloping gently to moderately towards lateral commissures, rounded rectangular in outline; interarea linear, nearly flat, orthocone; fold relatively wide, well-defined, moderately high, originating from beak, widening and becoming relatively higher anteriorly, round-topped at front.

Ornamentation of up to 29 rounded, simple, flattened, low ribs on each flank becoming thicker anteriorly; in sulcus and on fold, up to 14 ribs, increasing by bifurcation, much narrower than those present on flanks; ribs twice as wide as interspaces on the entire shell.

Ventral valve interior (Fig. 2) with long, subparallel to slightly divergent dental plates; delthyrial plate short; central and lateral apical cavities large and poorly filled in by callus; teeth small, subrectangular.

Dorsal valve interior unobserved due to deficient preservation.

Remarks. Serobyán et al. (2022) erected the genus *Tornatospirifer*, designating *Cyrtiopsis senceliae armenica* Abrahamyan, 1974, as the type species, primarily based on specimens from the Lesser Caucasus that feature a short delthyrial plate. They noted that among all genera attributed to the subfamily Cyrtiopsinae Ivanova, 1972, a delthyrial plate is observed only in the genus *Pseudocyrtiopsis* Ma and Day (1999). This genus was created to include species that resemble *Cyrtiopsis* Grabau, 1923, but differ by having a wide hinge line and a delthyrial plate. Although Ma and Day (1999), and later Gourvenec and Carter (2007), assigned *Pseudocyrtiopsis* to the subfamily Cyrtiopsinae, Serobyán et al. (2022) explained that due to its wide hinge line, the latter genus should be re-assigned to the

subfamily Cyrtospiriferinae, according to Johnson's (2006) classification. Thus, *Tornatospirifer* Serobyán et al., 2022, rather than *Pseudocyrtiopsis* Ma and Day, 1999, appears to be the only genus in the subfamily Cyrtiopsinae that possesses a delthyrial plate.

The material examined in this study displays a brachythyrid shell and also possesses a short delthyrial plate, and is therefore assigned to the lower Famennian genus *Tornatospirifer*. Additionally, it is worth noting that the ornamentation of our specimens appears to be variable. Some specimens (e.g., IGS NASU 578/2; Pl. 1, Fig. 2) exhibit coarser and fewer ribs on the flanks compared to others (e.g., IGS NASU 577/1; Pl. 1, Fig. 3), which display more numerous and finer ribs. Currently, it is difficult to determine whether these variations are due to palaeoecological factors or if the examined material includes both a nominal species and a subspecies, given the insufficiency of material. Therefore, these differences are considered here as expressions of intraspecific variability, pending the collection of additional specimens. The Ukrainian material, particularly the specimens with finer ribs, appears to be close to *Tornatospirifer armenicus* (Abrahamyan, 1974), but differs from the latter in their smaller size, less convex shell, and deeper sulcus. Comparing the internal morphology and micro-ornamentation of these species is challenging due to the poor state of preservation of the Ukrainian specimens. Consequently, the insufficiency of our material precludes a definitive identification at the species level.

Occurrence. Sadovian Horizon, lower Famennian, *triangularis-crepida* conodont zones, northern part of the Volhyn-Podillian plate, Ukraine.

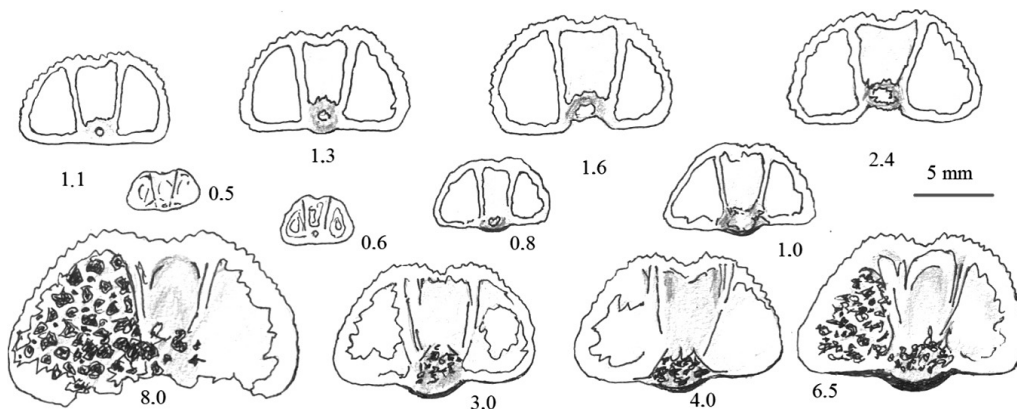


Fig. 2. Transverse serial sections of *Tornatospirifer* sp. (IGS NASU-578/5), Kowel'-5447 borehole, depth 310 m. Numbers refer to distance in mm measured from the top of the ventral umbo

Genus *Cyrtiopsis* Grabau, 1923

Type species: *Cyrtiopsis davidsoni* Grabau, 1923 (by subsequent designation by Grabau, 1931)

Cyrtiopsis? sp.

Pl. 1, Figs. 4–5; Fig. 3.

Material. Lokachi-3 borehole, depth interval 645–649 m: 28 complete to nearly complete shells and 55 fragments of shells and single valves, including 10 juvenile specimens; Lokachi-4 borehole, depth interval 498–500 m: two juvenile specimens; Velyki Mosty-13 borehole, depth 1124 m: two ventral valves.

Description. Shell medium-sized (reaching 16 mm in width, 18 mm in length and 10 mm in thickness), longer than wide to as wide as long, ventribiconvex, widest at about mid-length or slightly anteriorly; cardinal extremities obtuse or rounded (although the latter are poorly preserved in our examined material); anterior margin nearly straight to emarginate; anterior commissure uniplicate.

Ventral valve inflated with convex flanks sloping moderately towards lateral commissures; highest in the posterior third of the valve, then decreasing progressively towards anterior margin; umbo inflated; beak unobserved; interarea triangular, high, well-defined, high and apsacline; delthyrium relatively wide, closed by a pseudodeltidium (?), with a minute foramen near the apex; sulcus well-defined, moderately deep, originating from beak, widening and becoming deeper anteriorly, flat- to slightly round-bottomed at front; tongue wider than high, subtriangular in outline.

Dorsal valve slightly inflated, subquadrangular to subtrapezoidal in outline, with flanks sloping gently to moderately towards the lateral commissures; interarea linear, flat to slightly concave, orthocline; fold moderately low, originating from beak, round-topped at front.

Ornamentation of up to 16 coarse ribs on each flank (4–5 ribs per 5 mm at anterior margin near sul-

cus and fold), becoming coarser anteriorly; in sulcus and on fold, up to 8 ribs, increasing by bifurcation, narrower than those present on flanks; ribs twice as wide as interspaces on the entire shell; micro-ornament not preserved.

Ventral valve interior (Fig. 3) with relatively thin, long, intrasinal or subsinal dental plates, slightly divergent posteriorly then becoming subparallel anteriorly; delthyrial plate absent; central and lateral apical cavities large and poorly filled in by callus. Dorsal valve interior (Fig. 3) with ctenophoridium; spiral cones not preserved in the sectioned specimens.

Remarks. The external and internal features observed in the studied specimens, such as the medium-sized brachythyrid shell, obtuse or rounded cardinal extremities, ventribiconvex profile, nearly subparallel to slightly divergent dental plates, absence of a delthyrial plate, and presence of a ctenophoridium, indicate affinities to the genus *Cyrtiopsis* Grabau, 1923, as revised by Ma and Day (1999). However, it is doubtfully assigned to this genus, since representatives of *Cyrtiopsis* generally display a very broad sulcus with rounded lateral boundaries and fine ribs, in contrast to the clearly defined sulcus and coarse ribs observed in the Ukrainian material. Moreover, most *Cyrtiopsis* species possess a supported ctenophoridium, whereas in our specimens, it is unsupported. Additionally, further comparison with other *Cyrtiopsis* species is currently hampered by the poor state of preservation of the Ukrainian specimens, which prevents determination of important taxonomic features such as micro-ornament and type of pseudodeltidium. Thus, this assignment appears to be the most satisfactory at this stage, pending the collection of additional material to enable a more confident identification.

Occurrence. Sadovian Horizon, lower Famennian, *triangularis-crepida* conodont zones, northern part of the Volhyn-Podillian plate, Ukraine.

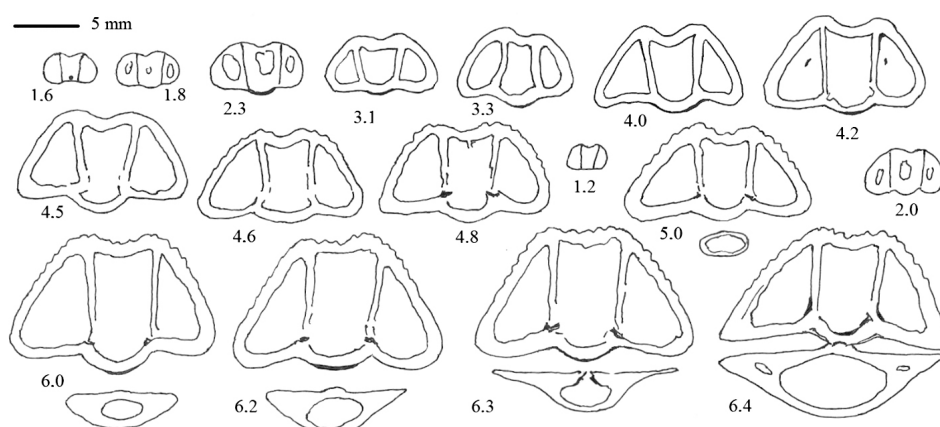


Fig. 3. Transverse serial sections of *Cyrtiopsis?* sp. (IGS NASU-566/15), Lokachi-3 borehole, depth 645 m. Numbers refer to distance in mm measured from the top of the ventral umbo

Conclusions

The taxonomic assessment of brachiopods collected from the drilling cores of the Lower Famennian strata of the Volhyn-Podillian plate has led to the identification of three cyrtospiriferide species: *Cyrtospiriferinae* gen. indet., *Tornatospirifer* sp., and *Cyrtiopsis?* sp. This study represents the first documentation of the genera *Tornatospirifer* and *Cyrtiopsis?* (albeit with some uncertainty regarding the latter) not only in the Volhyn-Podillian plate but also across the entire territory of Ukraine. These findings underscore the significance of studying the lower Famennian strata of the Volhyn-Podillian plate for understanding the diversity within the subfamily Cyrtiopsinae and shedding light on the recovery of brachiopods following the Frasnian-Famennian crisis. However, further investigations

of the Ukrainian material are urgently needed to refine our understanding of the taxonomy and biostratigraphy of Upper Devonian brachiopod assemblages.

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У цьому дослідженні вперше задокументовано нижньофаменські циртоспірiferоїдні брахіоподи із Волино-Подільської плити на заході України, зокрема зі свердловин Локачинської, Торчинської, Ковельської та Великомоствської площ буріння у Волинській та Львівській областях. До складу вивченого комплексу входять три види: *Cyrtospiriferinae* gen. indet., *Tornatospirifer* sp. і *Cyrtiopsis?* sp. Незважаючи на певну невизначеність щодо останнього роду, це перший опис та зображення представників цих родів в Україні, що розширює наше уявлення про палеобіогеографічне поширення підродина Cyrtiopsinae.

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