New brachiopods from the Lower–Middle Ordovician (Billingen–Volkhov stages) of the East Baltic

EVA EGERQUIST

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Two new rhynchonelliformean brachiopods, *Neumania paucicostata* sp. nov. and *Leoniorthis robusta* gen. et sp. nov., are described from the Billingen and Volkhov stages (Lower–Middle Ordovician: Arenig) of the Baltic–Ladoga Klint area. All specimens were washed out from unconsolidated sediments, and were sampled in Tallin, Estonia, and at three localities in St. Petersburg district, Russia. Numerous specimens were found in a large mud mound, the lower part of which is within the *Baltoniodus triangularis* conodont Zone, otherwise usually missing in this area. *L. robusta* is here assigned to the family Orthidae.

Key words: Brachiopoda, Clitambonitidae, Orthidae, Ordovician, Russia, Estonia.

Eva Egerquist [eva.egerquist@pal.uu.se], Department of Earth Sciences, Historical Geology and Palaeontology, Norbyvägen 22, SE-75236, Uppsala, Sweden.

Introduction

Brachiopod faunas of the East Baltic have been investigated and described since the early nineteenth century (e.g., Pander 1830; Eichwald 1860; Lamansky 1905; Öpik 1930, 1932; Rubel 1961). However, recent studies on faunal dynamics and spatial variation (Egerquist 1999; Tolmacheva et al. 2001; Tolmacheva, Egerquist, et al. in press) based on detailed bed-by-bed sampling of the soft marl and limestone layers, as well as investigations of microbially mediated clay mud mounds in the region (Fedorov and Dronov 1998, Fedorov, Dronov, and Zavarzin 1998; Tolmacheva, Fedorov, and Egerquist in press) have yielded new brachiopods as well as samples that have enabled revision of previously poorly known brachiopods (e.g., Egerquist 1999).

In this paper two new rhynchonelliformean brachiopods from the Arenig (Billingen–Volkhov stages) of Estonia and north-western Russia are described: *Neumania paucicostata* sp. nov. and *Leoniorthis robusta* gen. et sp. nov.

Most specimens are from the clay core of a large mud mound, which is located in the central part of Putilovo Quarry. *Neumania paucicostata*, however, is also common in the clays of the bedded succession outside the mud mound. This succession is here referred to as the "standard succession".

Geological setting and distribution

The investigated localities are part of a series of quarries and exposures distributed along the so-called Baltic-Ladoga Klint which extends from the north-western coast of Estonia to the southern shore of Lake Ladoga in Russia (Fig. 1). The Klint forms the northern edge of the Ordovician outcrop area in the East Baltic region (Popov et al. 1989; Dronov et al. 1996), and consists of shallow-water, eastward deepening, Ordovician shelf deposits.

A few specimens of *Leoniorthis robusta* were collected by L. Popov on the western side of Popovka River (locality 716 sample 4). The section here is characterised by quartzose glauconitic sand, calcareous glauconitic sandstone and clay in the lowermost part of the Billingen Stage (Mäekula Member), whereas the upper part (Vassilkovo and Red Dikari members) consists of argillaceous glauconitic limestones with thin intercalations of clay (Rubel and Popov 1994; Pushkin and Popov 1999). The specimens (PMU In 121–127) were found in purple and light green clay in the lower part of the Vassilkovo Member, and are associated with other brachiopods such as *Neumania erecta* (Pander, 1830), *Panderina tetragona* (Pander, 1830), *Ranorthis* sp., *Paurorthis resima* (Rubel, 1961), and *Plectella crassa* (Pander, 1830) (Rubel and Popov 1994).

Two specimens of *Leoniorthis* (PMU In 128, 129) were found at the Suhkrumägi road cut in Tallinn. The sample is from a green clay layer, within limestone beds, of which the lower one is greyish green and rich in glauconite grains. Based on lithology and conodonts, this horizon is considered to belong to the lower Päite Member (T. Tolmacheva personal communication). Associated brachiopods are *Paurorthis* sp., *Panderina* sp., *Ranorthis*? *trivia* Rubel, 1961, *Antigonambonites* sp., and *Orthidium* sp. nov. A few specimens of *Leoniorthis robusta* were also found in the lower part of the standard succession at the Putilovo Quarry. Two of these specimens are from glauconite rich, greyish green, amalgamated clay, from the lowermost Dikari Member (*Oepicodus evae* conodont Zone) (Fig. 2), associated with *Paurorthis*

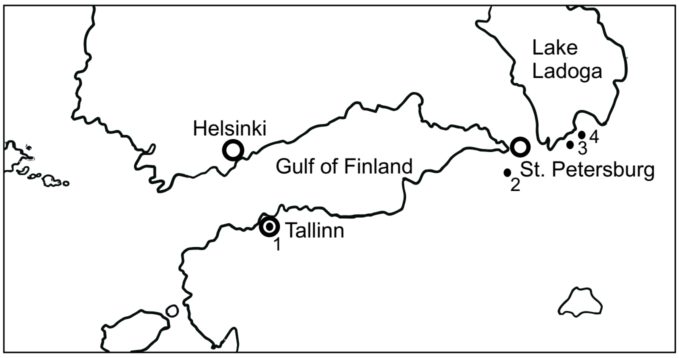

Fig. 1. Location of outcrops. 1, Suhkrumägi; 2, Popovka River; 3, Putilovo Quarry; 4, Lava River.

resima (Rubel, 1961), *Ranorthis*? *trivia* Rubel, 1961, and *Panderina* sp. Two other specimens were found in the upper part of the Dikari Member (*Baltoniodus navis* conodont Zone) together with brachiopods such as *Paurorthis parva* (Pander, 1830), *Ranorthis*? *trivia* Rubel, 1961, *Productorthis aculeata* (Pander, 1830), and *Antigonambonites* sp.

Most of the studied material was collected from the lowermost Middle Ordovician (Volkhov Stage) succession in Putilovo Quarry and from the large mud mound situated in this exposure. However, some samples containing *Neumania paucicostata* are from the Lava River. The Putilovo section (Fig. 2), as well as the section at Lava River, consists of easily recognisable units of calcareous packstones and wackestones with soft clay intercalations and varying content of glauconite. Most of these units can be recognised over a distance of nearly 200 kilometres along the Baltic-Ladoga Klint in Russia and north-western Estonia (Dronov et al. 1998; Dronov et al. 2000). *Neumania paucicostata* occurs in clays from the *Paroistodus originalis* conodont Zone, associated with brachiopods such as *Paurorthis parva* (Pander, 1830), *Ranorthis* sp., *Nothorthis penetrabilis* Rubel, 1961, *Produc-*

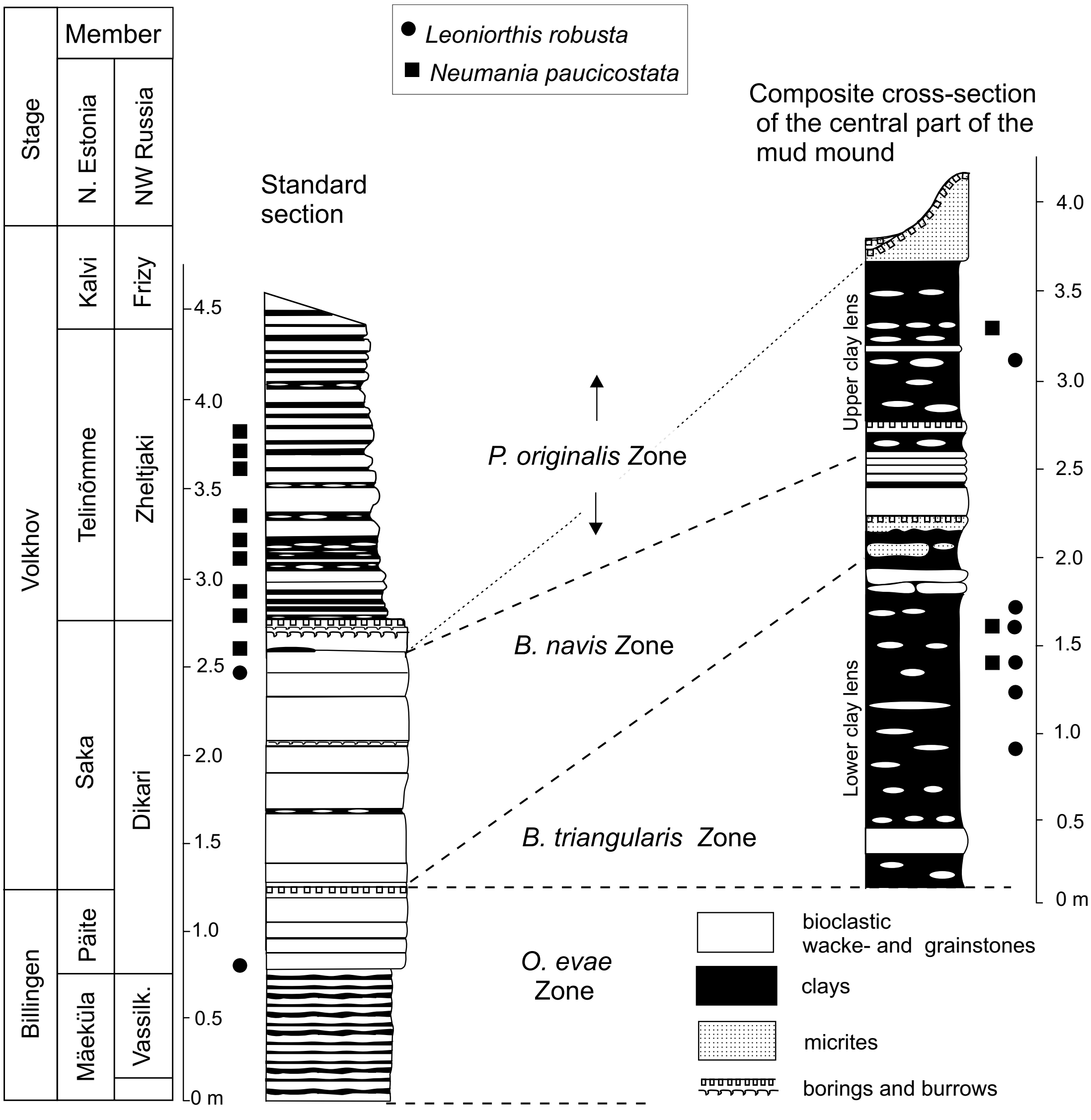

Fig. 2. The standard section in Putilovo Quarry compared with the mud mound section (after Tolmacheva, Fedorov, and Egerquist in press). Levels with occurrences of *Neumania paucicostata* are marked with squares; levels with *Leoniorthis robusta* are marked with circles.

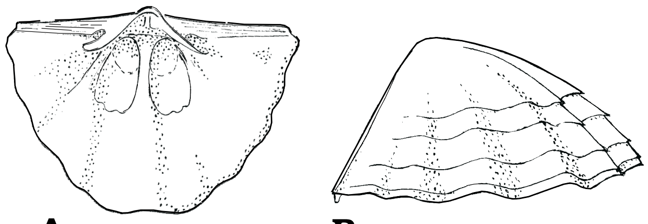

Fig. 3. *Neumania paucicostata*. **A**. Dorsal valve interior showing the anteriorly lobed muscle scars, drawn from specimen PMU In 107. **B**. Lateral view of ventral valve drawn from specimen PMU In 108 (holotype).

torthis aculeata (Pander, 1830), *Antigonambonites planus* (Pander, 1830), *Apomatella ingrica* (Phalen, 1877), and *Ingria nefedyevi* (Eichwald, 1860).

The mud mound is a more or less circular, (about 150 metres in diameter), microbial build-up consisting of two thick clay lenses, of which the lower one sits on top of the distinct hardground surface ("Steklo") that marks the boundary between the Billingen and Volkhov regional stages. The two lenses are covered by micritic crusts and contain numerous limestone pebbles. For more detailed description of the mud mound see Fedorov et al. (1998) and Tolmacheva, Fedorov, and Egerquist (in press). The lower clay lens is within the *Baltoniodus triangularis* Zone, which is otherwise missing in this outcrop. The upper lens is of *Paroistodus originalis* Zone age (Fig. 2) (Tolmacheva, Fedorov, and Egerquist in press). Both new brachiopods have been found in the clays of the mud mound, associated with the same brachiopods that occur in corresponding clays of the standard succession in the quarry.

Systematic palaeontology

All examined material is deposited in the palaeontological collection of the Museum of Evolution, Uppsala University (PMU), Sweden.

Family Clitambonitidae Winchell and Schuchert, 1893
Subfamily Atelelasmatinae Cooper, 1956
Genus *Neumania* Harper, 1981 (in Bruton and Harper 1981)

Type species: *Atelelasma atlanticus* Neuman, 1976: 24; from the Summerford Group (upper Arenig), Newfoundland, Canada.

Neumania paucicostata sp. nov.

Figs. 3, 4.

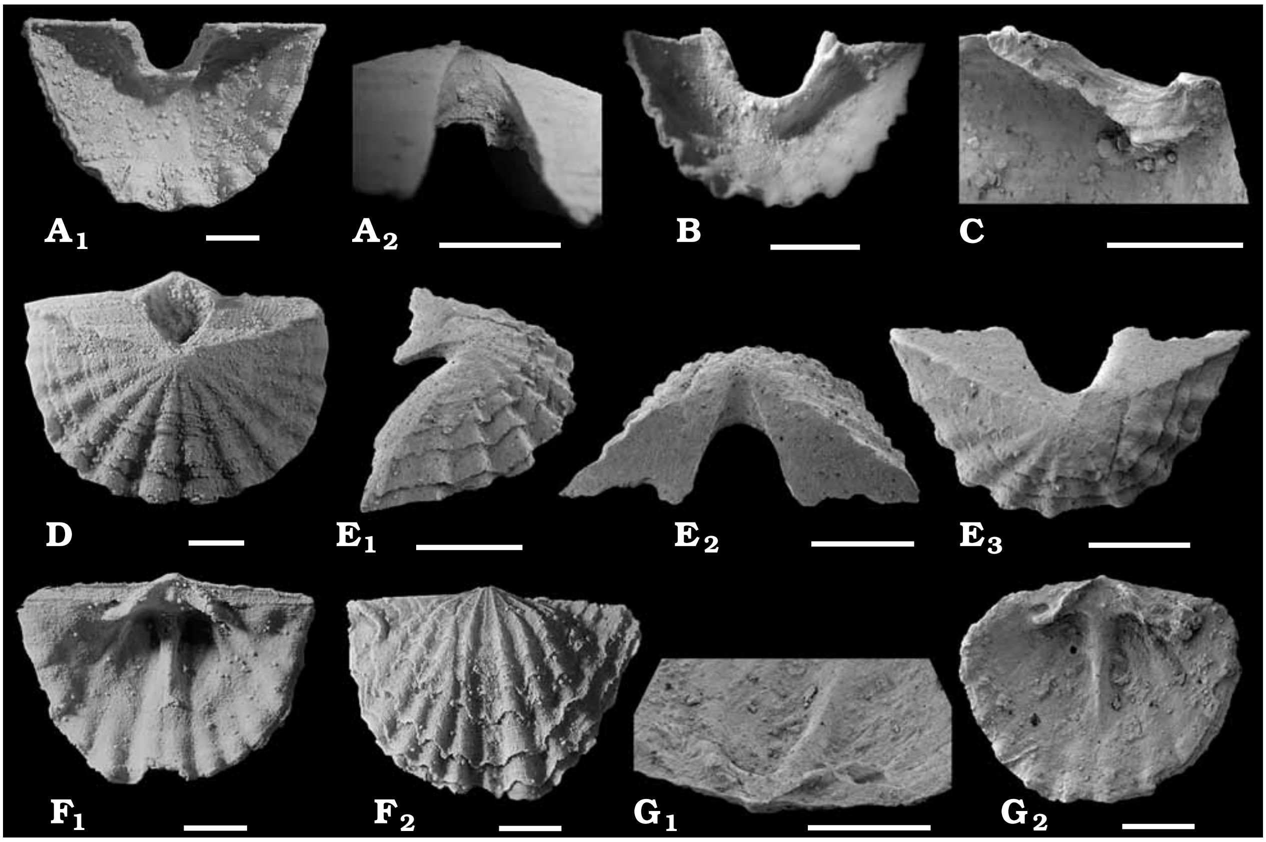

Fig. 4. *Neumania paucicostata* sp. nov. Specimens from Putilovo Quarry. **A**. Holotype PMU In 108; ventral valve interior (A_1), enlargement of the spondylium showing the muscle attachment area (A_2). **B**. PMU In 113, oblique internal view of ventral valve showing the U-shaped spondylium. Note that this specimen does not possess rounded muscle scars as in the holotype. **C**. PMU In 112, enlargement of spondylium on broken ventral valve, slightly oblique view showing the rough muscle attachment area. **D**. PMU In 109, ventral view of conjoined specimen. **E**. Exterior of specimen PMU In 228 in different views. **F**. PMU In 107, dorsal interior and exterior. **G**. PMU In 224; oblique posterior view of cardinalia (G_1), dorsal valve interior (G_2). Scale bars 1 mm.

Table 1. *Neumania paucicostata* sp. nov. Dimensions of figured specimens (in mm).

Specimen	Maximum length	Hinge width	Maximum depth	Length of interarea	Number of ribs along commissure	Number of lamellae
PMU In 108, ventral valve, holotype	3.3	5.3	1.7	2	11	5
PMU In 107, dorsal valve	3.2	4.4	0.7		12	5
PMU In 109, conjoined	3.5/3.9 (ventral/dorsal)	5.2	1.6	1.4	13	5
PMU In 112	3.4	3.6	1.7	1.8	14	10
PMU In 113	2.3	3.5	1	1.5	10	4
PMU In 224	3.7	3.5	0.8		10	8
PMU In 228	2.3	4	1	1.8	10	4

Table 2. *Leoniorthis robusta* gen. et sp. nov. Dimensions of figured specimens (in mm).

Specimen	Maximum length	Maximum width	Hinge width	Maximum depth	Number of ribs along commissure
PMU In 110, dorsal valve, holotype	5.0	7.2	6.0	1.3	25
PMU In 120, dorsal valve	6.1	8.5	8.2	1.5	31
PMU In 111, ventral valve	5.8	7.9	7.0	1.7	27
PMU In 144, ventral valve	8	9	7	3	29
PMU In 145, ventral valve	5.3	7.0	6.7	1.5	26
PMU In 121, dorsal valve	5.2	6.8	6.5	2.0	25
PMU In 122, dorsal valve	4.5	6.0	5.5	1.5	21
PMU In 123, ventral valve	6.2	6.5	5.8	3.0	25
PMU In 125, ventral valve	5	5.5	5.3	2	23

Holotype: PMU In 108 (Figs. 3B and 4A), ventral valve from the standard section in Putilovo Quarry, Zheltjaki Member (local name of bed: Krasnota), lower *P. originalis* conodont Zone.

Paratypes: 17 ventral valves, 11 dorsal valves and 1 articulated specimen (PMU In 107–109, 112–119, 213–230).

Diagnosis.—Ventribiconvex, subtrapezoidal atelelasmatine with procline ventral interarea; ornament coarsely costate with imbricate growth lamellae; spondylium simplex U-shaped.

Description.—Shell up to 4.8 mm long and 7.2 mm wide with maximum width at hinge line; cardinal angles acute to slightly alate; lateral margins straight to convex, anterior margin rounded. Anterior commissure slightly sulcate. Radial ornament coarsely costate with rounded costae which only rarely branch; costae of equal size; one to two costae per mm at the anterolateral margin. Concentric ornament with fine fila (not visible on all specimens) and irregularly arranged, imbricate growth lamellae, which vary in number from three to eight on examined specimens; average number 1.5 per mm valve length.

Ventral valve high, lateral profile with highest point at apex. Interarea plane, procline, sometimes with faint growth lines parallel to hinge line, but also with faint striae parallel to the delthyrial opening; length of interarea on average 35% of width. Delthyrium about as high as wide, open, on some specimens bounded by narrow deltidial plates. Interior surface of valve smooth. Hinge teeth small, simple. Elevated, U-shaped spondylium simplex, supported anteriorly by short rounded septum. Diductor scars rounded anteriorly, not readily distinguished on all specimens; adductor scars weakly impressed.

Dorsal valve moderately convex, with shallow sulcus beginning at umbo, broadening anteriorly. Cardinal extremities depressed. Interarea short, concave, orthocline. Notothyrium closed by chilidium; cardinal process developed as low ridge; dental sockets small. Notothyrial platform almost flush with interarea, well developed with prominent anterior border, merging into narrow median ridge which extends as long as the muscle field. Adductor field impressed, anteriorly lobed, extending half-length of the shell. Anterior adductor scars not readily distinguished from the smaller posterior scars (Fig. 3A). Interior surface of valve smooth, muscle field flanked by two faint, diverging mantle canals.

Discussion.—This clitambonitid species is referred to *Neumania* based on the presence of imbricate growth lamellae and a U-shaped spondylium simplex with impressed muscle scars, a feature which is taken as diagnostic for the genus by Rubel and Popov (1994). The muscle scars are not as clearly distinguished as in the other two species from the East Baltic, *N. erecta* (Pander, 1830) and *N. costata* (Pander, 1830). There is no obvious adductor scar, but a broad and, in some specimens, quite rough surface between the diductor scars probably served as attachment for the adductor muscles. The other two species also have finer radial ornaments than the new species (see Rubel and Popov 1994).

Compared with *Neumania atlanticus* (Neuman, 1976), the new species has larger, rounded costae, wider spaced

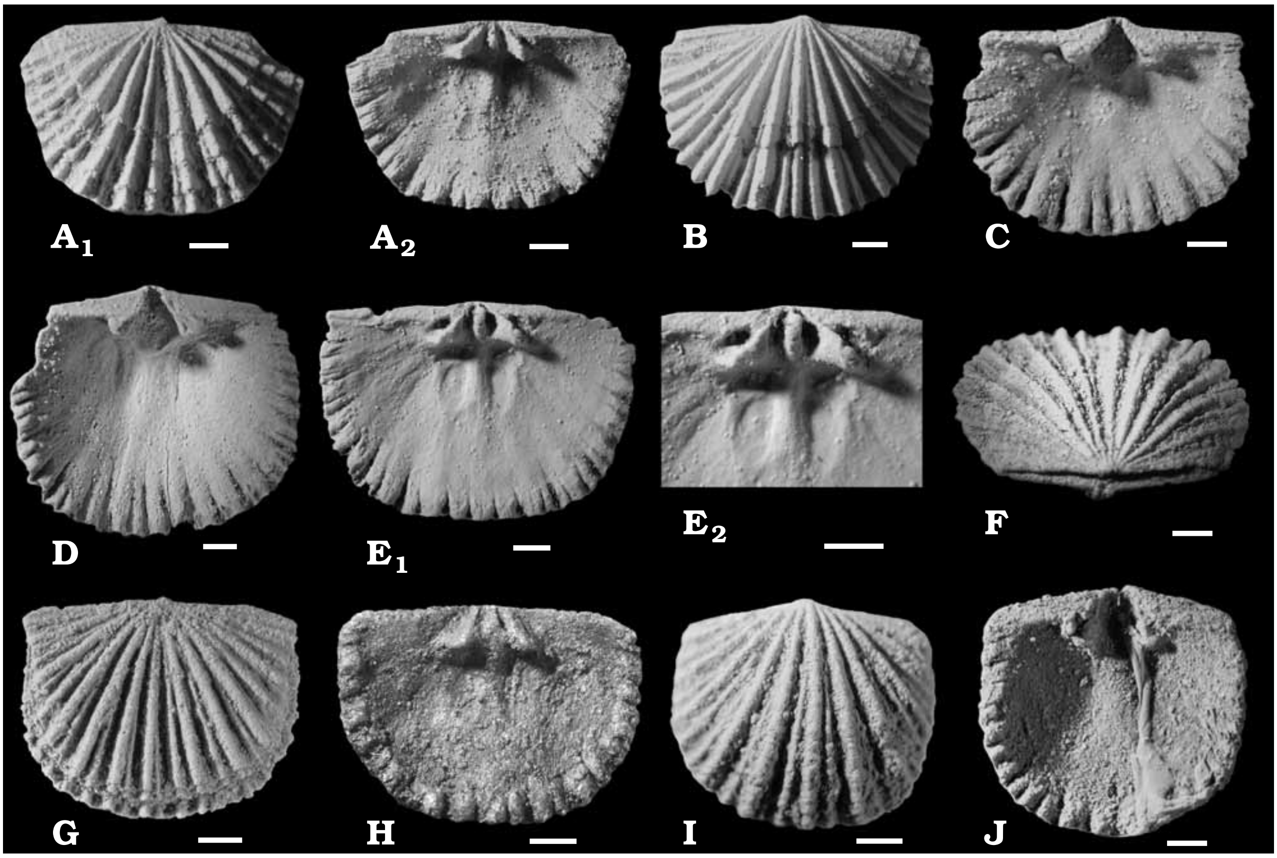

Fig. 5. *Leoniorthis robusta* gen. et. sp. nov. **A–F**. Specimens from Putilovo mud mound. **G–J**. Specimens from Popovka River. **A**. Holotype, PMU In 110, dorsal exterior (A_1) and interior (A_2). **B**. PMU In 111, ventral exterior. **C**. PMU In 145, ventral interior. **D**. PMU In 144, ventral interior. **E**. PMU In 120, dorsal interior (E_1); enlargement of cardinal region (E_2). **F**. PMU In 153, oblique view of hingeline and dorsal valve of conjoined specimen. **G**. PMU In 121, dorsal exterior. **H**. PMU In 122, dorsal interior. **I**. PMU In 125, ventral exterior. **J**. PMU In 123, ventral interior. Scale bars 1 mm.

growth lamellae and less prominent internal structures (see Harper in Bruton and Harper 1981).

The weakly impressed muscle scars somewhat resemble those of *Apomatella* Schuchert and Cooper, 1931, another commonly occurring genus in the area. However, this genus has a more V-shaped spondylium simplex without visible muscle scars.

Distribution.—Upper part of the *B. triangularis* conodont Zone (lower Dikari Member) to the upper *P. originalis* Zone (Zheltjaki Member), found in Putilovo Quarry and at Lava River.

Superfamily Orthoidea Woodward, 1852
Family Orthidae Woodward, 1852
Genus *Leoniorthis* gen. nov.

Derivation of name: In honor of brachiopod specialist Dr. Leonid Popov.

Type and only species: *Leoniorthis robusta* sp. nov.

Diagnosis.—Small orthoid. Radial ornament coarsely costellate with angular ribs; concentric ornament weakly developed. Shell nonpunctate with smooth internal surface. Ventral mantle canal system saccate with moderately divergent vascula media. Dorsal muscle field quadripartite, anterior muscle scar longer than posterior; a thick notothyrial platform continues anteriorly into low median ridge.

Discussion.—This brachiopod is assigned to the family Orthidae on account of its short, curved apsacline ventral interarea and anacline dorsal interarea, the poorly differentiated, broad ventral adductor track slightly longer than diductor scars, and its saccate ventral and pinnate dorsal mantle canal systems. It also has a ridge-like cardinal process, short, stout and moderately divergent brachiophores, and quadripartite dorsal muscle field with anterior scars longer than posterior. The weakly developed concentric ornament and simple, ridge-like cardinal process exclude reference to other possible orthidine families such as the Glyptorthidae Schuchert and Cooper, 1931 and Orthidiellidae Ulrich and Cooper, 1936.

With a recorded maximum width of 9 mm the new brachiopod is much smaller than the other coarsely ribbed genera belonging to this family. *Orthis* Dalman, 1828, *Orthambonites* Pander, 1830, and *Paralenorthis* Havlíček and Branisa, 1980 are distinguished by having costate radial ornament with capillae and rounded costae. *Orthambonites* as well as *Sivorthis* Jaanusson and Bassett, 1993 and *Sulevorthis* Jaanusson and Bassett, 1993 are strongly filate,

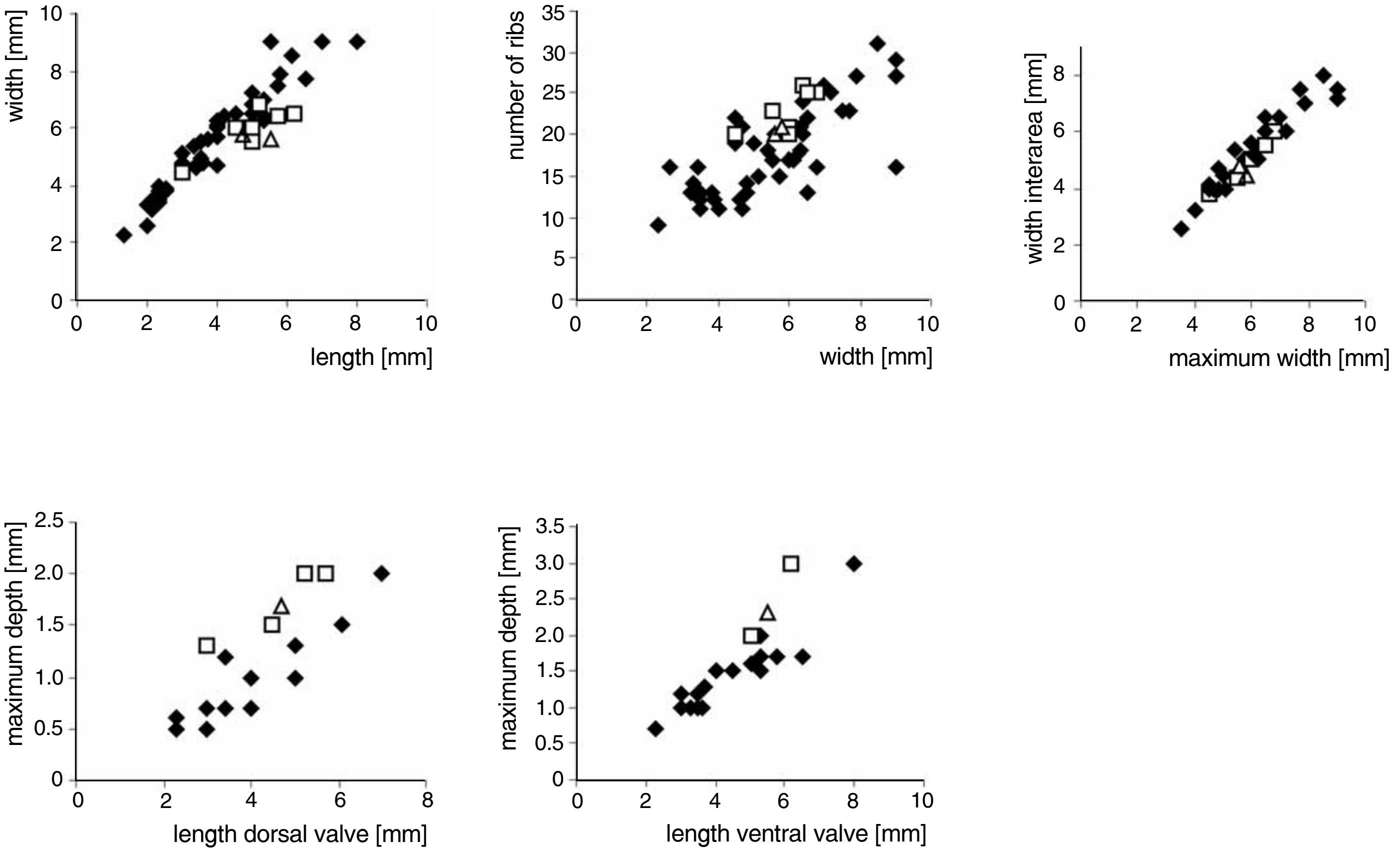

Fig. 6. Bivariate plots of 51 measured specimens of *Leoniorthis robusta*. Solid rhombi represent specimens from Putilovo mud mound, open squares represent specimens from Popovka River, triangles represent specimens from Suhkrumägi road cut.

which is not the case with the new genus. Furthermore, *Sivorthis* differs in having a subcordate ventral muscle field, whilst *Sulevorthis* has a different shaped cardinal process and possesses exopunctae on the sides of the costae.

The Silurian genus *Orthokopis* Baarli, 1995 from Norway shows quite close external resemblance to *Leoniorthis*. However, internal features such as the lack of a notothyrial platform, different development of the dorsal muscle field, and the ribs impressed all over the inner surface of the ventral valve, clearly distinguish *Orthokopis* from the new genus.

The slightly younger (Arenig–Llanvirn) genus *Trondorthis* Neuman, 1974 is also similar to *Leoniorthis* externally, but also in this case the internal structures such as ventral adductor scars terminating anteriorly in an elevated ridge and strongly divergent vascula media distinguish it from the new genus.

Leoniorthis robusta sp. nov.

Fig. 5.

Holotype: PMU In 110 (Fig. 5A), dorsal valve from the upper clay lens of the mud mound in Putilovo Quarry, lowermost *P. originalis* conodont Zone.

Paratypes: 44 specimens from Putilovo Quarry (22 ventral valves, 14 dorsal valves and 8 conjoined specimens, PMU In 110, 111, 120, 130–132, 134–171), 4 dorsal valves and 3 ventral valves from the Popovka River (PMU In 121–127), and 1 dorsal and 1 ventral valve from Tallinn, Estonia (PMU In 128, 129).

Diagnosis.—Moderately ventribiconvex, subrectangular orthide with weakly sulcate anterior commissure. Ventral valve 72% as long as wide and 26% as deep as wide. Dorsal valve 70% as long as wide and 20% as deep as wide. Ventral muscle field suboval, confined to delthyrial cavity by low ridge. Cardinal process forms high, sometimes pointed ridge.

Description.—Up to 9 mm wide and 8 mm long, moderately ventribiconvex and slightly sulcate shell with maximum width at, or slightly anterior to, hinge line; cardinal extremities moderately acute to obtuse. Lateral margins straight to convex, anterior margin rounded. Radial ornament coarsely costellate with triangular ribs, frequently branching into smaller costellae, which flank the coarser first one. Number of ribs per mm shell width varies between 2 and 5, depending on the branching frequency. Concentric ornament consists of irregularly spaced growth lamellae and very faint fila, not visible on all specimens.

Ventral valve on average 72% as long as wide and 26% as deep as wide. Interarea short, about 90% as wide as maximum width of shell, moderately concave, apsacline to orthocline, horizontally striated. Hinge teeth small, pointed, with crural fossettes, dental plates recessive. Ventral muscle field suboval, confined to delthyrial cavity by low ridge, individual muscle scars not readily distinguished, broad adductor track slightly longer than diductor scars; low rounded median ridge anterior to the delthyrial cavity present in some specimens. Interior surface of valve smooth; mantle canal system obscure on most specimens, when visible—saccate with slightly divergent vascula media.

Dorsal valve on average 70% as long as wide and 20% as deep as wide. Interarea short, about 85% as wide as maximum width of shell, planar, anacline, striated horizontally. Cardinal process forms a high, sometimes pointed ridge; brachiophores moderately divergent on thick notothyrial platform, rather short and stout with sharp posterior edges, upper and anterior surfaces blunt. Dorsal muscle field quadripartite, impressed on booth sides of a low, rounded median ridge which extends as long as muscle field; each half of muscle field about twice as long as wide, anterior muscle scar about twice as long as the posterior one (Fig. 5E). Mantle canal system digitate.

Remarks.—This species occurs in the lower part of the Vassilkovo Member (Billingen Stage) at Popovka River and in approximately corresponding layers at the Suhkrumägi road cut in Tallinn, Estonia (both *Oepikodus evae* Zone). In Putilovo Quarry a few specimens are from the *O. evae* and *B. navis* zones in the standard section (Billingen Stage), whereas the majority are from the *B. triangularis* and lower *P. originalis* zones in the mud mound (Volkhov Stage). The specimens from the first two localities differ somewhat from those from Putilovo, mainly in respect to the number of ribs and depth and thickness of the shell (Fig. 6). The nine specimens from Popovka River and Suhkrumägi have on average 4 ribs per mm width, compared with 3 ribs per mm for the Putilovo specimens. They also have on average 29 percent deeper shells than the mud mound specimens. However, these quite small differences are not sufficient to justify separation into two different species; the number of ribs seems to vary a lot also among the mud mound specimens and the thickening of the shell might be due to environmental factors.

Acknowledgements

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