

Early Ordovician foraminifers from the Lava River Section, northwestern Russia

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ABSTRACT: Recent studies on the biostratigraphy and fauna of the Lower Ordovician successions of the Russian part of Baltoscandia have shown for the first time that agglutinated foraminifers are very numerous in the deposits of the lower part of the Latorp Russian Regional Stage in the vicinity of St. Petersburg, northwestern Russia. These forms were discovered in a classic section exposed on the left side of the Lava River canyon in the northern outskirts of the village of Vassilkovo. The lower part of the Latorp Regional Stage is represented in this section by unlithified sands and clays of the Lakity Member of the basal part of the Leetse Formation and corresponds to the upper part of the Hunneberg Regional Stage of Baltoscandia. The clay beds of the Lakity Member encompass the upper part of the *Paroistodus proteus* and lower part of the *Prioniodus elegans* conodont zones and correspond to the *Tetragraptus phyllograptoides* graptolite zone. Foraminifers from the Lakity Member were collected from strata belonging to both of the above mentioned conodont zones and are represented by monothalamous agglutinated foraminiferal tests of a new species of a new genus *Lakites ordovicus* n. gen., n. sp., new species of the genus *Amphitremoida*: *A. asperella* n. sp., *A. laevis* n. sp., *A. longa* n. sp., *A. orbicularis* n. sp., and *A. rugosa* n. sp. (family Hippocrepinellidae), a new genus and species *Lavella cucumeriformis* n. gen., n. sp. of the family Saccamminidae, and one specimen assigned to the genus *Arenosiphon*? of the family Hippocrepinidae. The finding of representatives of the genus *Amphitremoida* (emended herein), previously known only from the Middle Ordovician to the Lower Carboniferous (Tournaisian) permits the extension of the range of this genus down into the Lower Ordovician.

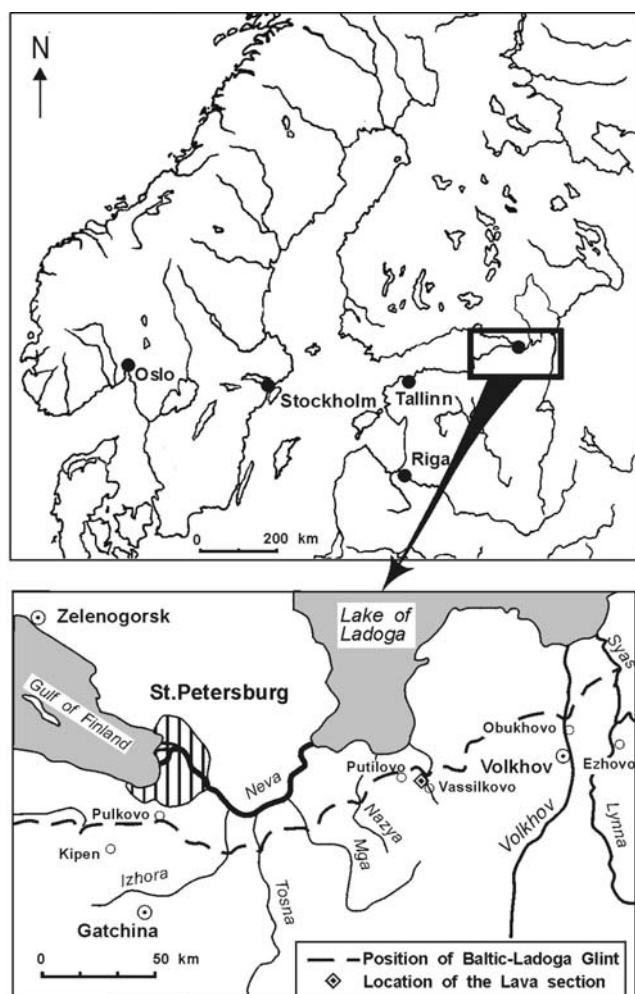
INTRODUCTION

Recent studies on the biostratigraphy and fauna from Lower Ordovician rocks exposed at localities near St. Petersburg, Russia have shown for the first time that the Lower Ordovician deposits (Latorp Regional Stage) contain numerous monothalamous agglutinated foraminifers. No Early Ordovician foraminifers have been previously described from this area of northwestern Russia. Bykova (1956) first noted their presence in Ordovician deposits of the Soviet Baltic region (former Soviet Union). In her paper, in a table of distribution of foraminifers through Ordovician and Silurian, she noted the following species of foraminifers for the Lower Ordovician deposits: *Cornuspira*? sp., *Cochleatina plavinensis* gen. and sp. n. (now these forms are assigned to the Bryozoa), *Lagena cylindrica* Smith and *L. aranea* n. sp. (it is our opinion that Bykova's generic assignment is incorrect). However, in the description of these forms, in the heading "distribution and age", Bykova wrote that all of these species occur only in the Middle Ordovician. If there was a typographical mistake in the table and indeed they are of Middle Ordovician age, then the presence of foraminifers in Lower Ordovician strata in northwestern Russia is first demonstrated here. In Baltoscandia (herein considered to include northwestern Russia, Sweden, Norway, northern Germany, Estonia, Lithuania and Latvia), foraminifers are known from the *Didymograptus bifidus* graptolite Zone of the Lower Llanvirnian (Middle Ordovician) of northwestern Germany (Reigraf and Niemeyer 1996), and Caradoc and Ashgill strata (British Series) of the upper part of the Middle and lower part of the Upper Ordovician of the former East Prussia (Eisenack 1954, 1967). Recently, new data about Cambrian foraminifers has

appeared (Cherchi and Schroeder 1985; Culver 1991, 1994; Culver et al. 1996; Zhigulina 1999; McIlroy et al. 2001; Scott et al. 2003). Faunas described in these papers include monothalamous foraminiferal tests of the genera *Luekatiella* Mens and Zhigulina 1999, *Sorosphaera* Brady 1879, *Hemisphaerammia* Loeblich and Tappan 1955, *Psammospaera* Schulze 1875, tubular tests of the genera *Ammodiscus* Reuss 1862, *Glomospira* Rzehak 1885, *Turritella* Rhumbler 1904, *Tolypammia* Rhumbler 1875, *Platysolenites* Eichwald 1860, *Spirosolenites* Glaessner 1979, and multichambered forms such as "Haplophragmoides-like" and "Ammobaculites-like" genera. In our material only monothalamous foraminifers are present that are not similar to those forms described from the Cambrian. Thus, our data support the first appearance of the genus *Amphitremoida* Eisenack 1938 and new genera *Lakites*, and *Lavella* in the Lower Ordovician.

GEOLOGICAL SETTING AND STRATIGRAPHY

The general area of study is about 100km east of St. Petersburg where deposits of the Lower and Middle Ordovician crop out along the Lava River canyon, in the well-known Putilovo Quarry, and in the other several natural outcrops between the Nazya River to the west and the village of Kipuja (near the town of Volkhov) to the east (text-fig. 1). All foraminifers were collected from a classic section exposed on the left side of the Lava River canyon (Section 6817, St. Petersburg area) mentioned and described for the first time by Raymond (1916). It is the most well exposed section in the area where a succession of strata of the Varangu (Upper Tremadocian) and Latorp (Lower Arenig in British Series) Regional Stages is naturally exposed on the left



TEXT-FIGURE 1
Maps of the St. Petersburg area showing the Lava River section.

side of the Lava River canyon in the northern outskirts of the village of Vassilkovo (text-fig. 1). In some previous papers, the location of this section is also given as located on the right side of the Lava River canyon in the southern outskirts of the village of Gorodishche (Tolmacheva et al. 2001; Pronina-Nestell and Tolmacheva 2003). Detailed lithologic studies of the Lava River section and paleontological data of some fossil groups were recently published by Magi et al. (1989), Dronov et al. (1995, 1998), and Tolmacheva et al. (2001). The approximately 3m thick sequence through the Latorp Stage is represented by the Leetse Formation that is divided into four members (or Beds) in ascending order: Lakity, Mäeküla, Vassilkovo and Päite (text-fig. 2). Foraminifers appear to be restricted to strata of the Lakity Member.

The stratigraphic interval of the Latorp Stage of Russia corresponds to the interval of the Hunneberg and Billingen Regional stages in Sweden. The subdivision of the Lower Ordovician strata there into Hunneberg and Billingen stages was originally introduced by Tjernvik and based on the distribution of a trilobite fauna (Tjernvik 1956). Later, Tjernvik (Tjernvik and Johansson 1980) inserted the trilobite *Megistaspis* aff. *estonica* Zone (so-called Transitional beds) as a basal zone of the Billingen Stage. Studies on trilobite and conodont distribution

in several sections throughout Sweden have shown that the lower boundary of the *M. aff. estonica* Zone closely correspond to the lower boundary of the conodont *Prioniodus elegans* Zone (Löfgren 1985, 1993; Maletz et al. 1995). In the East Baltic region (herein considered to be Estonia and northwestern Russia) where trilobites are not well studied or are even absent, the Hunneberg/Billingen boundary traditionally follows lithological changes from the glauconitic clay of the Lakity Beds to the glauconitic sand of the Mäeküla Beds, and are thus placed within the lower part of the *Prioniodus elegans* Zone (Dronov et al. 1995; Tolmacheva et al. 2001).

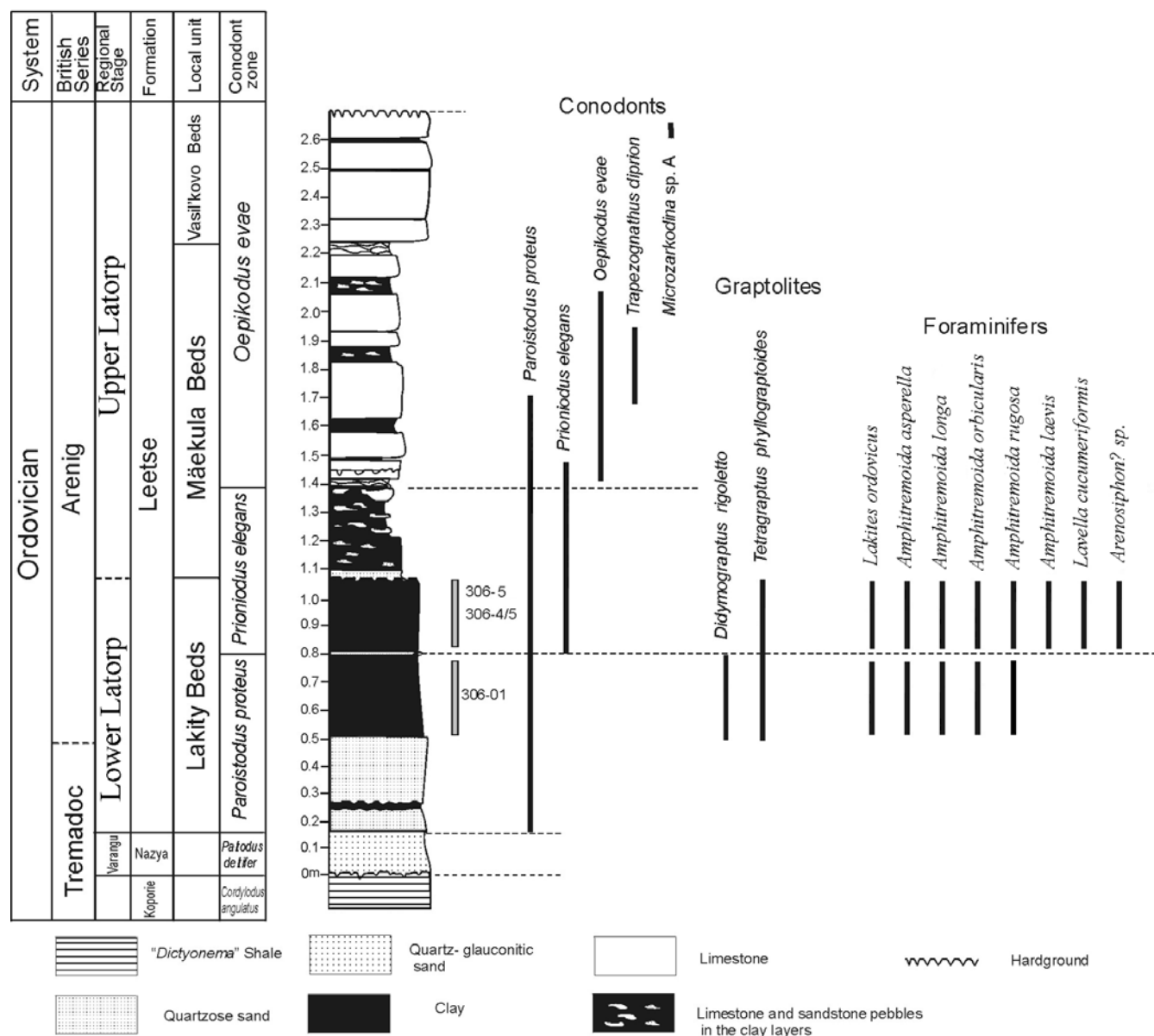
The Lakity Beds in the St. Petersburg area consist of a basal bed of fine to medium grained, quartzose glauconitic sand and an overlying greenish gray, silty clay, in total about 1.15m thick. In the Lava River section the lowermost layer of the Lakity Beds (text-fig. 2) is represented by glauconitic, clayey dark green sand (thickness 0.32m) with subhorizontal and oblique burrows, and containing numerous conodonts diagnostic for the upper part of the *Paroistodus proteus* Zone. The overlying layer about 0.28m thick consists of greenish gray clay with conodonts also of the upper *Paroistodus proteus* Zone, and also the graptolite species *Didymograptus rigoletto* Maletz, Rushton and Lindholm, and *Tetragraptus phyllograptoides* Strandmark. The uppermost layer is 0.26m thick and is represented by greenish gray clay in the lower part of the unit and brownish gray clay in the upper 10cm. It is separated from the underlying unit by a discontinuity surface and a very thin basal bed of fine-grained glauconitic sand. Such small-scale discontinuities indicating subtle stratigraphic breaks have been called "paracontinuities" (Conkin and Conkin 1974, Conkin et al. 1998). This unit contains conodonts of the *Prioniodus elegans* Zone and numerous graptolites *Didymograptus* aff. *protobalticus* Mosen and *Tetragraptus phyllograptoides* Strandmark. The lower boundary of the clayey layer in the middle part of the Lakity Member coincides with the lower boundary of the *Tetragraptus phyllograptoides* Zone of Baltoscandia (text-fig. 3). This stratigraphic level is considered to be a local lower boundary of an as yet unnamed second Stage of the Ordovician defined by the first appearance of *Tetragraptus approximatus* Nichol森 in the international stratigraphic scheme.

The overlying Mäeküla Member, belonging to the upper part of the Latorp Stage, consists of sand and sandstone cemented by carbonate, and limestone in its uppermost part. It contains a conodont assemblage of the uppermost *Prioniodus elegans* conodont Zone and *Didymograptus balticus* graptolite Zone.

In a sequence stratigraphic context, the interval of the Latorp Stage has been considered to represent a third order sequence (Dronov and Holmer 1999). The lower siliciclastic part of the section has been equated with a transgressive system tract whereas the upper carbonate part of the section is regarded as a highstand system tract demonstrating successive shallowing upward.

MATERIAL

The distribution of conodonts, graptolites, linguloid brachiopods and other fossils through the Lakity Beds of the Lava section were reported recently (Tolmacheva et al. 2001). The clay beds of the section were resampled for this study. Several samples of about 2kg each were collected from the lower and upper parts of the clay layer (samples 306-01, 306-4/5, and 306-5) in order to obtain a representative collection of foraminifers. The lithology of the section and log with the distribution of samples



TEXT-FIGURE 2

Stratigraphic column strata of the Latorp Regional Stage exposed on the left side of the Lava River with distribution of foraminifers, selected graptolites and conodonts.

collected is shown on text-fig. 2. More than 150 well preserved specimens were picked from the 0.5-0.25mm fraction of the residues. Fifty-three tests of the foraminifers were studied with a Scanning Electron Microscope (SEM) to examine the ultrastructure of the test wall and structure of an aperture. Also 21 thin sections of individual specimens of the genus *Amphitremoida* and one section of the genus *Lavella* were made to examine the wall structure of the tests.

CHEMICAL COMPOSITION OF FORAMINIFERAL TESTS


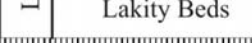

Two tests of the genera *Lakites* and *Amphitremoida* were analyzed in the Isotope Center of All Russian Scientific Research Geological Institute (VSEGEI) to establish the mineral composition of the test wall by SEM CAMSCAN MX 2500 with EDX

(Oxford CANSCAN Instrument). The foraminiferal tests are composed of small mineral grains that are usually not larger than 8-10µm. Three mineral types of grains were found (text-figs. 4, 5). Quartz grains are rare, strongly rounded and are approximately 3-5µm in size. K-feldspar grains are more common, are usually square, flat and typically larger than the quartz grains (5-10µm in length). The products of K-feldspar degradations, muscovite and sericite, are among the most common grains and compose more than 95% of foraminiferal tests.

PALEONTOLOGY

Foraminifers

Foraminifers are represented by numerous and well-preserved monothalamous agglutinated tests, mostly of new species. They

System	International Series	International Stages	British Series	Baltoscandia				Lithostratigraphy				
				Swedish stages	Conodont zones	Graptolites zones	East Baltic reg. stages	St. Petersburg region the Lava River section				
Ordovician	Middle	Not distinguished	Arenig	Volkhov	<i>Baltoniodus navis</i>	<i>Didymograptus hirundo</i>	Volkhov					
					<i>Baltoniodus triangulatus</i>	<i>Pseudophyllograptus angustifolius elongatus</i>						
	Lower			Tremadocian	Tremadoc	Billingen	<i>Oepikodus evae</i>		<i>Phyllograptus densus</i>	Upper Substage	Leetse Fm.	Päite Beds
							<i>Prioniodus elegans</i>		<i>Didymograptus balticus</i>			Vassilkovo Beds
		Hunneberg	<i>Paroistodus proteus</i>			<i>Didymograptus balticus</i>	Lower Substage	Mäeküla Beds				
						<i>Tetragraptus phyllograptoides</i>		<i>Hunnegraptus copiosus</i>	Lakity Beds			
	Ceratopyge	<i>Paltodus deltifer</i>	<i>Kiaerograptus supermus</i>	Varangu								
						Pakerort	<i>Cordylodus angulatus</i>	<i>Rhabdinopora flabelliformis s.l.</i>	Pakerort			

TEXT-FIGURE 3

Correlation chart for the Lower/Middle Ordovician lithostratigraphic units of the Lava River section.

are very numerous in the clay layer of the Lakity Member; commonly their numbers are more than several hundreds per 1kg of sediment. In contrast, in the clay layers of the Mäeküla Member foraminifers are more rarely found, whereas their occurrence was not noted in the sandy part of the section. Five new species: *Lakites ordovicus*, *Amphitremoida asperella*, *A. orbicularis*, *A. longa* and *A. rugosa* are present in the lower part of the clay of the Lakity Member and extend to the upper part of the clay. The species *Amphitremoida laevis*, *Lavella cucumeriformis*, and *Arenosiphon?* sp. appear for the first time in the upper part of the clay. The appearance and distribution of foraminifers in the Lava River section coincides with the appearance and distribution of graptolite species of the *Tetragraptus phyllograptoides* Zone in this section (text-fig. 2).

Conodonts

Because the conodont biostratigraphy and taxonomic composition of conodonts from the Latorp Stage of the Lava River section was reported earlier (Tolmacheva et al. 2001), we only briefly summarize the main features of the conodont assemblages from the clayey interval of the Lakity Member. Conodonts from the clay are well preserved, thermally unaltered and very abundant throughout the interval. They are very diverse taxonomically with 23-27 species in the assemblage. Four species from the upper *Paroistodus proteus* Zone - *Drepanodus arcuatus* Pander, *Drepanoistodus forceps* (Lindström), *Paroistodus proteus* (Lindström), and *Oelandodus elongatus* (Lindström) constitute up to 90% of the entire assemblage. *Baltoniodus deltatus* (Lindström), *Oelandodus elongatus* (Lindström), *Paracordylodus gracilis* Lindström, *Periodon primus* Stouge and Bagnoli, *Tropodus* cf. *T. comptus* Branson and Mehl, *Tripodus* sp., *Scandodus furnishii* Lindström, *Diaphorodus* sp., *Paroistodus parallelus* (Pander), *Stolodus stola* (Lind-

ström), *Decoriconus peselephantis* (Lindström), *Cornuodus longibasis* (Lindström), *Paltodus subaequalis* Pander and *Protoprioniodus simplicissimus* McTavish are strongly varying in number from less than 1% up to 5-10%. *Protoprioniodus simplicissimus* McTavish, *Semiacontiodus* sp., *Parapanderodus* sp., *Fahraeusodus* sp. and *Prioniodus robustus* (Lindström) are always represented in numbers less than 1% of the assemblage.

The base of the *Prioniodus elegans* Zone is defined by the first appearance of the nominate taxon, which is quite rare in the boundary interval and becomes more abundant in the uppermost part of the clay. *Paroistodus proteus*, *Drepanoistodus forceps*, and *Drepanodus arcuatus* remain the dominant species of this zone. *Scolopodus rex* Lindström, *Protopanderodus rectus* (Lindström), *Oistodus lanceolatus* Pander and *Jumudontus gananda* Cooper first appear within the basal part of the *Prioniodus elegans* Zone.

SYSTEMATIC DESCRIPTIONS

The system proposed by Cavalier-Smith (1998) is used for higher protozoan taxa and the system proposed by V. Mikhalevich (1995, 1998) is used for higher foraminifer taxa and for monothalamous foraminifers. The holotypes and paratypes of all described taxa of foraminifers are deposited in the Department of Paleobiology of the Uppsala University, Uppsala, Sweden under numbers PMU In 63 and from PMU In 375 to PMU In 418. The collection of conodonts is deposited under numbers PMU In 137, 142, 143, 146-148, 150, 151, 153-157, 172, 190-191, 343 and from PMU In 419 to PMU In 433.

Components	Quartz grains	K-feldspar grains	Muscovite and sericite grains			
SiO ₂	100%	66.75%	50.38%	56.07%	60.60%	60.97%
Al ₂ O ₃		16.97%	37.37%	28.28%	26.57%	22.32%
K ₂ O		16.28%	10.78%	10.18%	7.98%	8.70%
MgO			0%	1.69%	1.84%	2.27%
Na ₂ O			1.02%	0%	0%	1.48%
FeO			0.45%	2.87%	2.49%	0%
TiO ₂			0%	0.45%	0.52%	0.55%
CuO			0%	0.46%	0%	2.07%

TEXT-FIGURE 4

Chemical composition of mineral grains of foraminiferal tests of the genera *Lakites* and *Amphitremoida*.

Kingdom PROTOZOA Goldfuss 1818, emend. Owen 1858
 Subkingdom NEOZOA Cavalier-Smith 1993, emend. Cavalier-Smith 1997
 Phylum FORAMINIFERA (D'Orbigny 1826) Eichwald 1830 stat. nov. Margulis 1974
 Class ASTORRHIZATA Saidova 1981, emend. Mikhalevich 1995
 Subclass ASTORRHIZANA Saidova 1981
 Order ASTORRHIZIDA Haeckel 1894
 Family **HIPPOCREPINELLIDAE** Loeblich and Tappan 1984, emend. Mikhalevich 1995

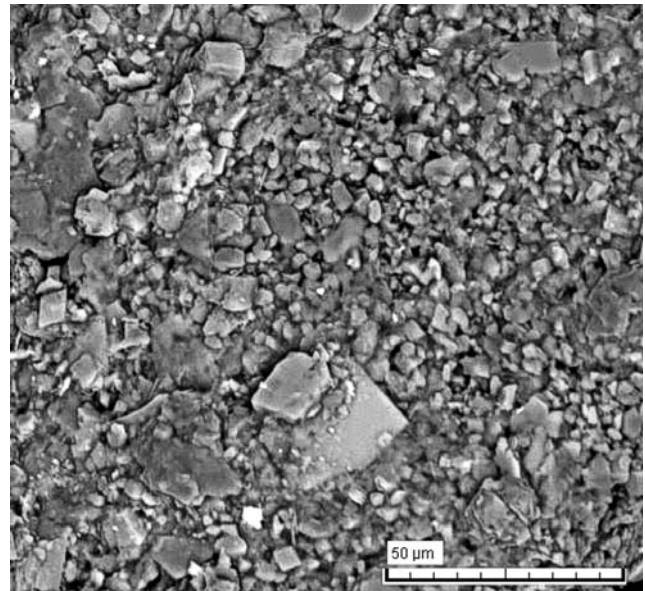
Diagnosis is given after Mikhalevich (1995): Test elongate, fusiform, externally sometimes with transverse wrinkles reflecting periodicity of growth; wall agglutinated throughout, thick, finely grained, friable with large amounts of light cement; two apertures as rather small subcircular openings at constricted or semi-closed ends of test.

Genera: *Hippocrepinella* Heron-Allen and Earland 1932 (Holocene); *Crespinitella* Rauser and Reitlinger 1993 (Early Permian); *Amphitremoida* Eisenack 1938 (= *Croneisella* Dunn 1942; *Pachyammia* Eisenack 1967) (Early Ordovician, Latorp Regional Stage, *Tetraraptus phyllograptoides* graptolite Zone – Early Carboniferous, Tournaisian); *Astrorhizinulla* Saidova 1975 (Holocene), and *Lakites* n. gen. (Early Ordovician, Latorp Regional Stage, *Tetraraptus phyllograptoides* graptolite Zone).

Genus ***Lakites*** Nestell and Tolmacheva n. gen.

Type species: *Lakites ordovicus* n. sp.; Russia, east of St. Petersburg, the northern outskirts of the village of Vassilkovo, Lava River canyon; Leetse Formation, Lakity Member; Lower Ordovician, Latorp Regional Stage, *Tetraraptus phyllograptoides* graptolite Zone.

Description: Test free, monothalamous, stick-shaped, straight or slightly curved, elongate, slightly inflated in middle part and narrowing to both ends, sometimes compressed, or twisted at one of the ends, one apertural end narrower than other end, on narrowest end there is small collar, two apertures one at each end, aperture round in shape, sometimes one of them plugged, wall agglutinated, white in color, densely cemented, composed of fine grains of muscovite and sericite, rare grains of K-feldspar and single quartz grains, surface smooth or slightly rough.



TEXT-FIGURE 5

SEM microphotograph in back-scattered electrons regime of the outer surface of the test of the genus *Lakites*. Two square grains are K-feldspar grains, the rest are muscovite and sericite grains.

Etymology: After the Lakity Member.

Composition of the genus: Monotypic.

Discussion: Based on the stick-shaped and elongate test, the genus *Lakites* is similar to the genus *Bathysiphon* M. Sars 1872 (Sars 1872, Loeblich and Tappan 1988). The test of the new genus differs from it by having an inflated middle part that narrows to the apertural ends, an absence of constrictions resulting from periodic growth, and a densely cemented finely grained wall consisting of muscovite and sericite, rare grains of K-feldspar and single quartz grains and not sponge spicules. It differs from the genus *Crespinitella* Rauser and Reitlinger 1993 (Rauser-Chernousova and Reitlinger in Vdovenko et al. 1993) by the lack of constrictions and narrower test.

Range: Lower Ordovician, Latorp Regional Stage, *Tetraraptus phyllograptoides* graptolite Zone.

Lakites ordovicus Nestell and Tolmacheva n. sp.

Plate 1, figures 1-4, plate 10, figure 1

Agglutinated foraminifer TOLMACHEVA et al. 2001, fig. 9, 9.

Description: Test free, monothalamous, stick-shaped, straight or slightly curved, elongate, slightly inflated in middle part and narrowing to both ends, sometimes compressed, or twisted at one of the ends, one apertural end narrower than other end, on narrowest end there is small collar, two apertures one at each end, rounded in shape, sometimes one of them plugged, wall agglutinated, white in color, densely cemented, composed of fine grains of muscovite and sericite, rare grains of K-feldspar and single quartz grains, smooth or sometimes surface slightly rough because of inclusions of glauconite grains (Pl. 1, fig. 4). Dimensions in mm: test length (L) 0.76 – 1.0, width (W) 0.12 – 0.15, in compressed specimens width increases up to 0.2, form ratio L/W 5.0 – 6.3, width of wide apertural end 0.05 – 0.078, of

TABLE 1
List of described taxa.

<i>Lakites</i> Nestell and Tolmacheva, gen. n.
<i>Lakites ordovicus</i> Nestell and Tolmacheva, n. sp.
<i>Amphitremoida asperella</i> Nestell and Tolmacheva, n. sp.
<i>Amphitremoida laevis</i> Nestell and Tolmacheva, n. sp.
<i>Amphitremoida longa</i> Nestell and Tolmacheva, n. sp.
<i>Amphitremoida orbicularis</i> Nestell and Tolmacheva, n. sp.
<i>Amphitremoida rugosa</i> Nestell and Tolmacheva, n. sp.
<i>Lavella</i> Nestell and Tolmacheva, n. gen.
<i>Lavella cucumeriformis</i> Nestell and Tolmacheva, n. sp.
<i>Arenosiphon?</i> sp.

narrow end 0.035 – 0.07; corresponding dimensions of holotype 0.78, 0.15, 5.2, 0.07, 0.063.

Designation of types: The specimen illustrated on plate 1, figure 1 is designated as the holotype (no. PMU In 375) and the specimens illustrated on Pl. 1, figure 3 (no. PMU In 63) and on figure 4 (no. PMU In 377) are paratypes; Russia, east of St. Petersburg, the northern outskirts of the village of Vassilkovo, Lava River canyon; Leetse Formation, Lakity Member; Lower Ordovician, Latorp Regional Stage, the holotype (no. 375) and paratype (no. 377) – the lower part of the *Prioniodus elegans* conodont Zone, and paratype (no. 63) – the upper part of the *Paroistodus proteus* conodont Zone.

Etymology: After the Ordovician System.

Material: Five specimens from sample 306-4/5, ten from sample 306-5 and five from sample 306-01.

Discussion: Given in the description of the genus.

Occurrence: The same as the holotype and paratypes.

Genus ***Amphitremoida*** Eisenack 1938, **emend.** Nestell and Tolmacheva herein

Synonymy: *Croneisella* Dunn 1942; *Pachyammina* Eisenack 1967; *Thurammina* Brady 1879 (part.); *Lagena* Walker and Jacob 1798 (part.); *Ordovicina* Eisenack 1938 (part.)

Type species: *Amphitremoida citroniforma* Eisenack 1938, from glacial drift boulders, the Baltic Province; Ordovician, equivalent in age to the Lyckholm Formation (Stage F₁ of Estonia). According to a recent Ordovician scheme of the eastern Baltic region, the Stage F₁ corresponds to the Nabala, Vormsi and Pirgu stages of the Upper Caradoc – Lower Ashgill of the British Series (Mannil and Meidla 1994).

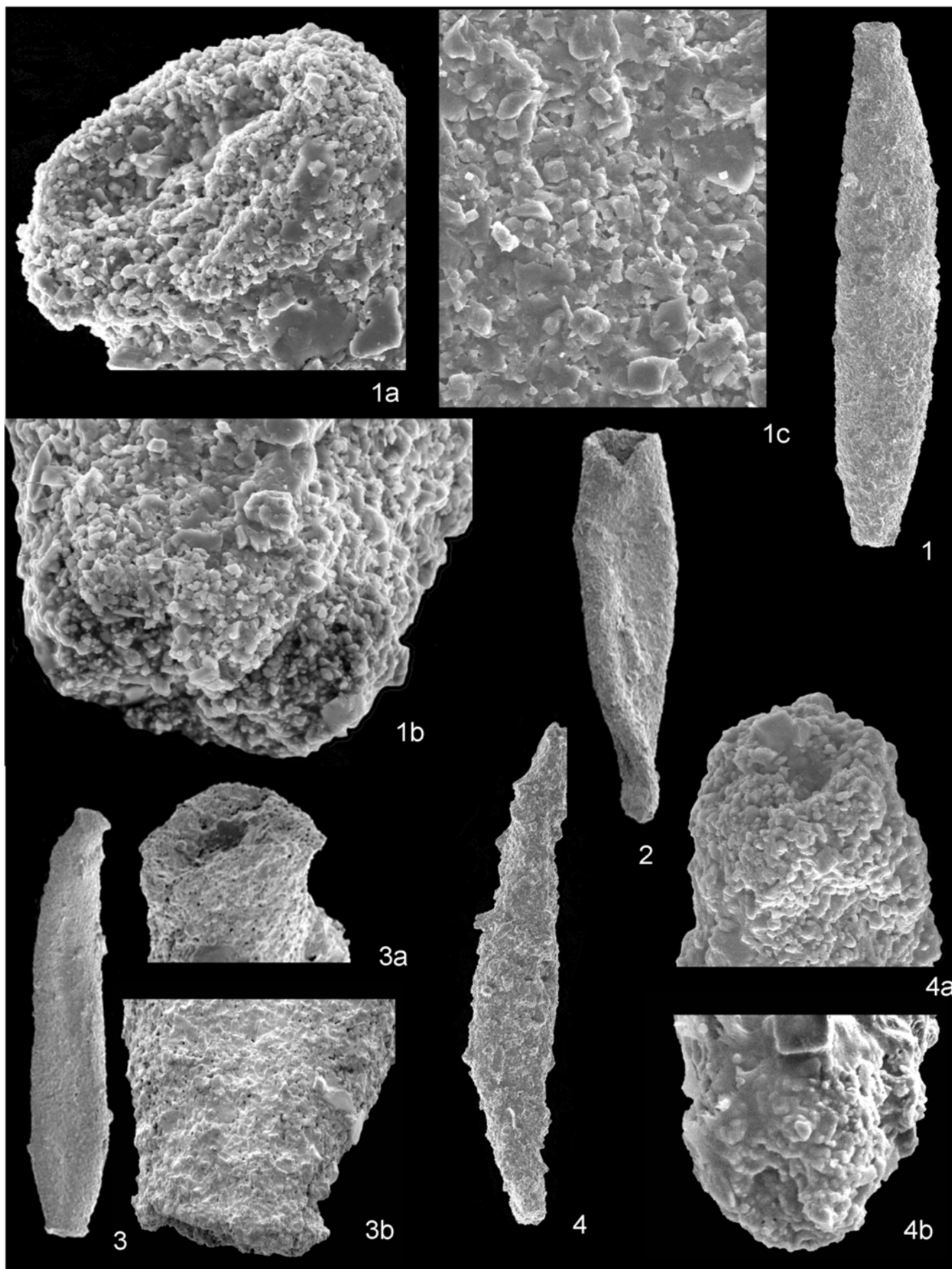
Description: Test free; monothalamous; fusiform, oval, lemon-shape, rounded, sometimes globular; symmetrical or asymmetrical, sometimes twisted, inflated in middle part, surface of test smooth or with transverse wrinkles expressed to a different degree; test has two apertures one at each end; sometimes apertures located on distinct necks; in most cases one aperture semi-closed or closed completely; shape of aperture varies from rounded, oval to slit-like; wall agglutinated, white or yellowish in color, densely cemented, not perforate, consists of finely or medium-grained muscovite, sericite, K-feldspar and quartz.

Discussion: The genus *Amphitremoida* (type species *A. citroniforma*) was first described by Eisenack (1938) from glacial boulders that the author considered to be of Silurian age and found along a beach on the Samland Peninsula, East Prussia. He assigned to this genus monothalamous agglutinated foraminifers with tests of lemon - or spindle-shape and with two apertures, one at each end and located on small nipple-like projections. Later, Eisenack (1954) redescribed the genus after studying additional material and expanded the specific diagnosis of the type species. He also corrected the age range of the ge-

PLATE 1

1-4 *Lakites ordovicus* Nestell and Tolmacheva n. sp.

- | | |
|--|---|
| <p>1 no. PMU In 375, holotype, SEM ×150: 1a – view of the upper apertural end, 1b – view of the lower apertural end, SEM ×750, 1c – wall structure, SEM ×1500; sample 306-4/5, the lower part of the <i>Prioniodus elegans</i> conodont Zone.</p> <p>2 no. PMU In 376, view of twisted and broken test, SEM ×129; sample 306-01, the upper part of the <i>Paroistodus proteus</i> conodont Zone.</p> | <p>3 no. PMU In 63, paratype, SEM ×107: 3a – view of the upper apertural end, SEM ×502, 3b – view of the lower apertural end, SEM ×491; sample 306-01, the upper part of the <i>Paroistodus proteus</i> conodont Zone.</p> <p>4 no. PMU In 377, paratype, SEM ×150: 4a – view of the upper apertural end, 4b – view of the lower apertural end, SEM ×1000. Sample 306-4/5, the lower part of the <i>Prioniodus elegans</i> conodont Zone.</p> |
|--|---|



nus to be equivalent to the Lychholm Formation (Stage F₁ of the Estonian Ordovician). In recent Ordovician correlations the Lychholm Formation (Stage F₁) corresponds to the quite long time interval of three stages in Estonia (Nabala, Vormsi and Pirgu) of the Upper Caradoc – Lower Ashgill in the British Series (Mannil and Meidla 1994). At the same time that Eisenack (1954) redescribed the genus, he also described a new species *Amphitremoida? pachythea*, conditionally assigning it to the genus *Amphitremoida* based on the absence of apertures in the tests, but noting the shape of the test and structure of the wall is similar to the genus *Amphitremoida*. Later, Eisenack (1967) erected the new genus *Pachyammina*, choosing *A.? pachythea* as the type species. According to Eisenack, the main difference between the genera *Pachyammina* and *Amphitremoida* is the presence of a thick wall and the absence of apertures in the genus *Pachyammina*. Based on these premises, Eisenack included all foraminiferal tests in his Ordovician fauna that did not have apertures in the new genus, although their shapes vary from spherical to oval, some of sausage or cucumber shape, and even polyhedral. He described the sausage shaped tests as the new species *Pachyammina longa* and the polyhedral forms as *P. polyedrica*. In order to describe the new species Eisenack used some medium, possible glycerin, to make the tests translucent. However, by doing this, internal structures, including apertures, could not be seen. In addition to describing the new species of the genus *Pachyammina*, Eisenack (1967) also described several new species of the genus *Amphitremoida* using the same method of translucence. Apertures also could not be seen in any of these new species. In this study, Canada balsam was used to make the test of *Amphitremoida asperella* n. sp. (Pl. 10, fig. 2) translucent, and apertures could not be seen either. Thus, for this study, many thin sections of individual specimens of the genus *Amphitremoida* were made. Only one open aperture could be seen in most cases, whereas the other one was closed. An ex-

planation of this apparent closure of one aperture is not known, but it could be connected with the process of reproduction in the species, with feeding, or with the stage of growth of the tests. Arnold (1953) studied variation in living foraminifers using the species *Allogromia laticollaris*, and showed that the number of apertures in this species changes with the growth of the individual. Some young individuals had two, three, and even more apertures, whereas adults possessed only one aperture. According to Arnold (1953), the shape of the tests and number of apertures has taxonomic significance for such monothalamous foraminifers.

Because the type species of the genus *Pachyammina*, *A.? pachythea* has an oval or almost fusiform test shape characteristic for the genus *Amphitremoida*, this species should be included in the genus *Amphitremoida*, and thus the genus *Pachyammina* is a younger synonym of this genus. The species *Pachyammina longa* Eisenack is probably not a foraminifer but, if it is, then it can be assigned to the genus *Stegnammina* Moreman 1930 based on the sausage or stick-shape of the test and lack of apertures. The species *P. polyedrica* Eisenack is considered to possibly be a species of the genus *Thurammina* Brady 1879, also based on the shape of the test.

The genus *Croneisella* established by Dunn (1942) is considered to be a synonym of the genus *Amphitremoida* based on the shape of the test that is characteristic for this genus and also based on the presence of two apertures, one at each end. Based on the same features, the following species are also included in the genus *Amphitremoida*: *Thurammina parvituba* Dunn 1942, *Thurammina foerstei* Dunn 1942, *Thurammina? seminaformis* Dunn 1942, all described by Dunn (1942) from the Silurian of the USA, and also the species “*Lagena*” *panucella* Bykova from the Lower Silurian of Lithuania (Bykova 1956).

PLATE 2

Amphitremoida asperella Nestell and Tolmacheva n. sp., no. PMU In 378, holotype, SEM ×150:

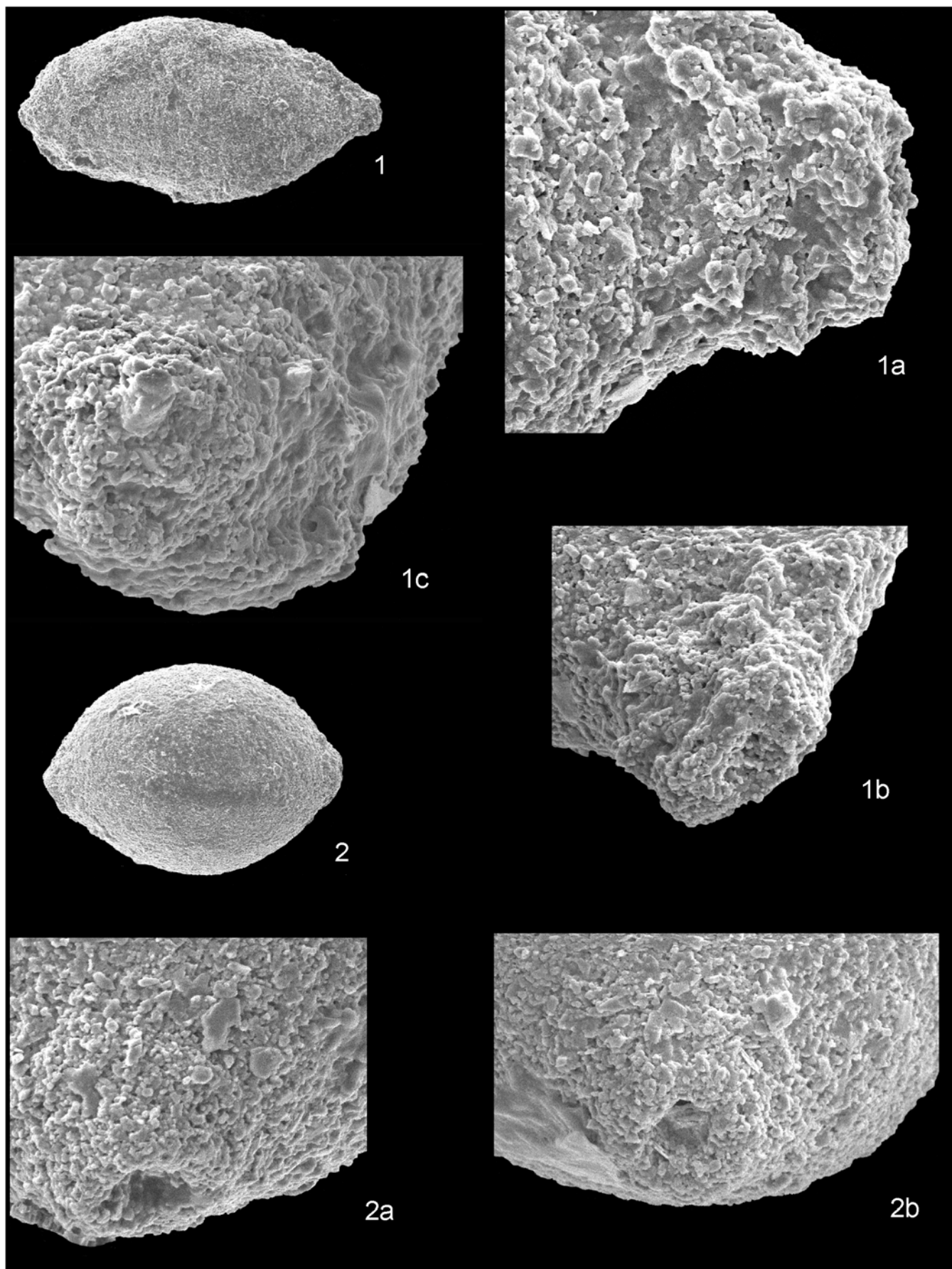
- 1a view showing the elongate apertural neck, SEM ×1000,
- 1b view of the same neck showing semi-closed aperture,

- 1c view of the opposite end showing closed aperture, SEM × 750. Lava River section, Leetse Formation, Lakity Member, sample 306-01; Lower Ordovician, Latorp Regional Stage, the upper part of the *Paroistodus proteus* conodont Zone.

Amphitremoida laevis Nestell and Tolmacheva n. sp., no. PMU In 379, holotype, SEM ×200:

- 2a apertural view of the left side of the test,

- 2b apertural view of the right side of the test, SEM ×750. Lava River section, Leetse Formation, Lakity Member, sample 306-4/5; Lower Ordovician, Latorp Regional Stage, the lower part of the *Prioniodus elegans* conodont Zone.



The species *Amphitremoida tubulosa* described by Eisenack (1967) is probably a radiolarian because in the photo (Eisenack, 1967, pl. 25, fig. 1) one can see the porous wall and two spines characteristic for radiolarians, not for foraminifers.

Composition of the genus: The following species are included in the genus *Amphitremoida*: *A. citroniforma* Eisenack 1938, emend. Eisenack 1954, *A. fusiforma* Eisenack 1967 (with its synonym *A. minuta* Eisenack 1967), *A. tenuissima* Eisenack 1967, *A. elongata* Eisenack 1967, *A. robusta* Eisenack 1967, *A. pachytheca* Eisenack 1954, *A. huffmani* Conkin and Conkin 1964, *A. eisenacki* Conkin and Conkin 1964, *A. kielcensis* Malec 1992 (with its synonym *A. pajchlowae* Malec 1992), *Croneisella typa* Dunn 1942, *Thurammina parvituba* Dunn 1942, *Th. foerstei* Dunn 1942, *Th. seminaformis* Dunn 1942, *Lagena panucella* Bykova 1956, and the new species *Amphitremoida asperella*, *A. laevis*, *A. longa*, *A. orbicularis*, and *A. rugosa*.

Range: Lower Ordovician (Latorp Regional Stage, *Tetragraptus phyllograptoides* graptolite Zone) – Lower Carboniferous (Tournaisian).

***Amphitremoida asperella* Nestell and Tolmacheva n. sp.**
Plate 2, figure 1, plate 10, figure 2

Description: Test free, monothalamous, relatively large, pointed-oval, weakly elongate, apertural end rounded on one side of test with small neck, other apertural end nipple-shaped with distinct neck (height 0.04mm). Two apertures, one at each end, one closed on rounded end (Pl. 2, fig. 1c) and other on opposite end semi-closed and oval shape (Pl. 2, fig. 1b). Wall agglutinated, medium-grained, white in color, its thickness 0.026mm. Surface of test rough. Dimensions in mm: test length (L) 0.51-0.55, width (W) 0.27-0.3, form ratio L/W 1.8-1.9; corresponding dimensions in holotype 0.55, 0.29, 1.9.

Designation of types: The specimen illustrated on plate 2, figure 1 is designated as the holotype (no. PMU In 378); Russia, east of St. Petersburg, the northern outskirts of the village of Vassilkovo, Lava River canyon; Leetse Formation, Lakity Member; Lower Ordovician, Latorp Regional Stage, the upper part of the *Paroistodus proteus* conodont Zone.

Etymology: From the Latin – *asperellus* – slightly rough.

Material: Four specimens from sample 306-01 and one from sample 306-4/5.

Discussion: *Amphitremoida asperella* n. sp. is similar to *A. robusta* Eisenack (Eisenack 1967, p. 265, pl. 25, fig. 11, text-figure 10), but differs from it by larger size, more elongate test (in *A. asperella* L/W 1.8-1.9, in *A. robusta* – 1.35-1.5), pronounced distinct apertural neck on one side and rough surface.

Occurrence: The same as the holotype, and also in the lower part of the *Prioniodus elegans* conodont Zone.

***Amphitremoida laevis* Nestell and Tolmacheva n. sp.**
Plate 2, figure 2, plate 3, figures 1-5, plate 10, figures 4-5

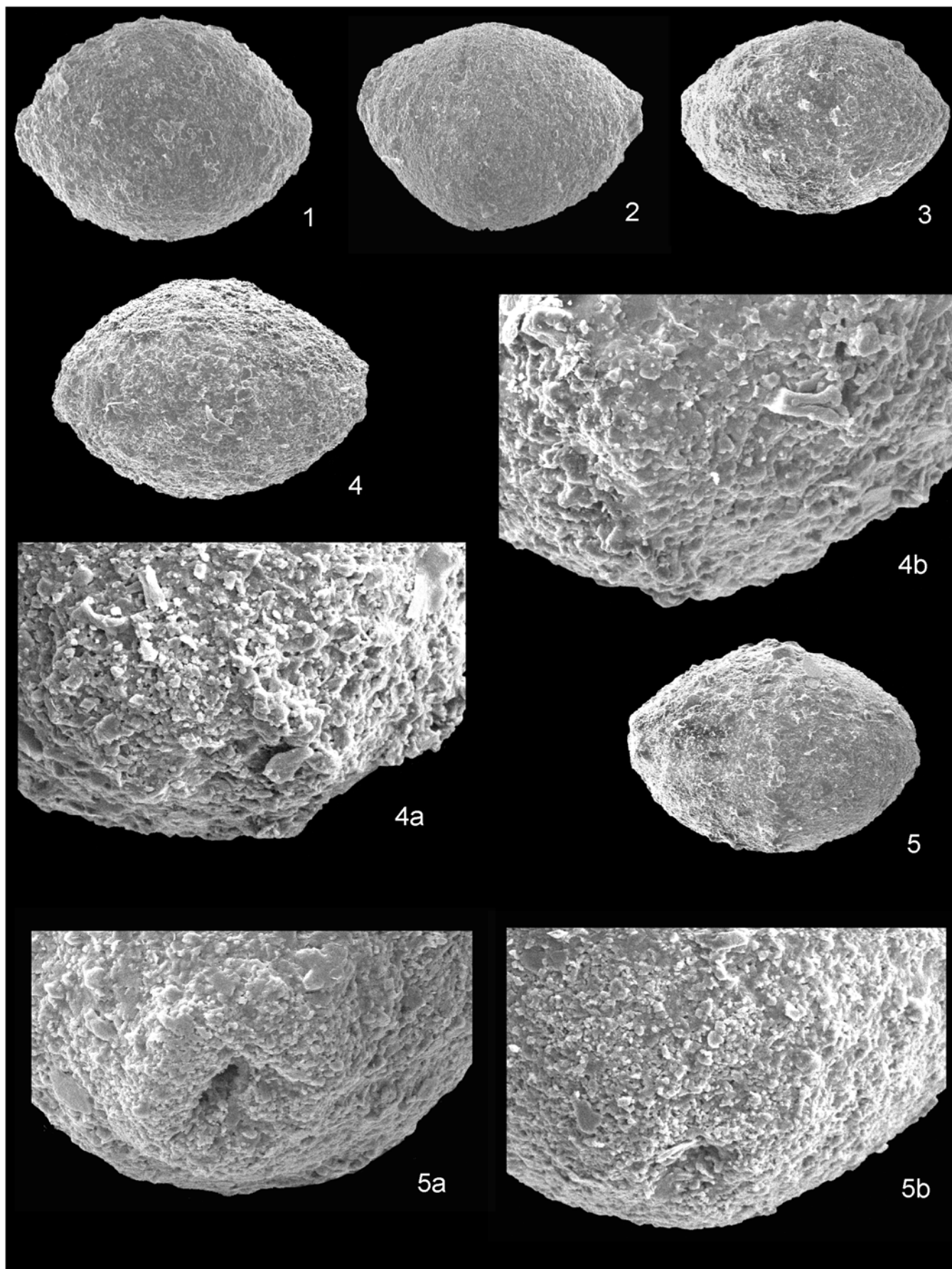
Description: Test free, monothalamous, relatively large, pointed-oval or lemon-shaped, symmetrical or asymmetrical, with short projections on both poles on which the apertures are located. Distinct axial small groove observed in some tests in middle part (Pl. 3, fig. 5). Two apertures, oval shaped, either open (Pl. 2, fig. 2a-b), or closed (Pl. 3, fig. 4a-b). Surface of test smooth or slightly rough. Wall agglutinated, white in color, fine-grained, its thickness 0.027mm. Dimensions in mm: test length (L) 0.270-0.405, width (W) 0.210-0.285, form ratio L/W 1.1-1.4, height of the neck 0.012-0.020, width – 0.04-0.07; corresponding dimensions in holotype 0.34, 0.24, 1.4, 0.02, 0.06.

Variability: The tests of this species vary in asymmetry, in having more or less distinct apertural necks, and in different degrees of inflation.

PLATE 3

Amphitremoida laevis Nestell and Tolmacheva n. sp.

- 1 no. PMU In 380, SEM ×200;
- 2 no. PMU In 381, SEM ×200;
- 3 no. PMU In 382, SEM ×200;
- 4 no. PMU In 383, paratype, SEM ×200: 4a – apertural view of the left end of the test, 4b – apertural view of the right end of the test, SEM ×750;
- 5 no. PMU In 384, paratype, SEM ×200: 5a – apertural view of the left end of the test, 5b – apertural view of the right end of the test, SEM ×750. Lava River section, Leetse Formation, Lakity Member, sample 306-4/5; Lower Ordovician, Latorp Regional Stage, the lower part of the *Prioniodus elegans* conodont Zone.



Designation of types: The specimen illustrated on plate 2, figure 2 is designated as the holotype (no. PMU In 379) and specimens illustrated on Pl. 3, figure 4 (no. PMU In 383) and figure 5 (no. PMU In 384) and Pl. 10, figure 5 (no. PMU In 412) as the paratypes; Russia, east of St. Petersburg, the northern outskirts of the village of Vassilkovo, Lava River canyon; Leetse Formation, Lakity Member; Lower Ordovician, Latorp Regional Stage, the lower part of the *Prioniodus elegans* conodont Zone.

Etymology: From the Latin – *laevis* – smooth.

Material: Twenty-four specimens from sample 306-4/5.

Discussion: *Amphitremoida laevis* n. sp. is similar to *A. fusiforma* Eisenack (Eisenack 1967, p. 253, pl. 25, fig. 3-4) based on the lemon-shaped test, but differs by its larger size and shorter and less projected necks.

Occurrence: The same as the holotype and paratypes.

***Amphitremoida longa* Nestell and Tolmacheva n. sp.**

Plate 4, figures 1-3, plate 10, figure 3

Description: Test free, monothalamous, large, of fusiform shape, elongate, with blunt both ends of test or barely noticeable pointed ends. Two apertures, one at each end, of oval shape, sometimes both completely closed. Surface of test smooth or slightly rough. Wall agglutinated, white in color, fine-grained, its thickness 0.03mm. Dimensions in mm: test length (L) 0.360-0.494, width (W) 0.156-0.182, form ratio L/W 1.9-2.5, usually 2.1; corresponding dimensions in holotype 0.36, 0.17, 2.1.

Variability: Configuration of the apertural ends of the test varies from both ends being blunt to slightly pointed. The latter connects with the closed apertures.

Designation of types: The specimen illustrated on plate 4, figure 1 is designated as the holotype (no. PMU In 385) and figure 2 (no. PMU In 386), and plate 10, figure 3 (no. PMU In 410) as the paratypes; Russia, east of St. Petersburg, the northern out-

skirts of the Vassilkovo village, Lava River canyon; Leetse Formation, Lakity Member; Lower Ordovician, Latorp Regional Stage, the lower part of the *Prioniodus elegans* conodont Zone.

Etymology: From the Latin – *longus* – long.

Material: One specimen from sample 306-01, two specimens from sample 306-4/5 and twenty from sample 306-5.

Discussion: *Amphitremoida longa* n. sp. is similar to the species *Amphitremoida elongata* Eisenack (1967, p. 266, fig. 7) and *A. kielcensis* Malec (Malec 1992, p. 280, pl. 3, fig. 11) based on the elongate and fusiform test. It differs from *A. elongata* by the absence of apertural necks and its smaller form ratio L/W (in *A. elongata* the ratio L/W is 2.4-3.0), and from *A. kielcensis* by its shorter and narrower test.

Occurrence: Lower Ordovician, Latorp Regional Stage, *Tetragraptus phyllograptoides* graptolite Zone of northwestern Russia.

***Amphitremoida orbicularis* Nestell and Tolmacheva n. sp.**

Plate 5, figure 1, plate 6, figures 1-5, plate 10, figures 6-7

Description: Test free, monothalamous, small, of rounded-oval or almost spherical shape, with absence of projections from poles or barely noticeable pointed ends. Two apertures, one at each end, of oval shape, sometimes both completely closed, or one of them semi-closed. Surface of test smooth or slightly rough. Wall agglutinated, white in color, fine-grained, thick, its thickness 0.03-0.04mm. Dimensions in mm: test length (L) 0.250-0.405, width (W) 0.19-0.33, form ratio L/W 1.1-1.2 in spherical forms and 1.25-1.5 in oval forms; corresponding dimensions in holotype 0.32, 0.27, 1.2.

Variability: The range of the shape of the test varies from almost spherical to oval, with an absence of projections from the poles, and barely pointed ends.

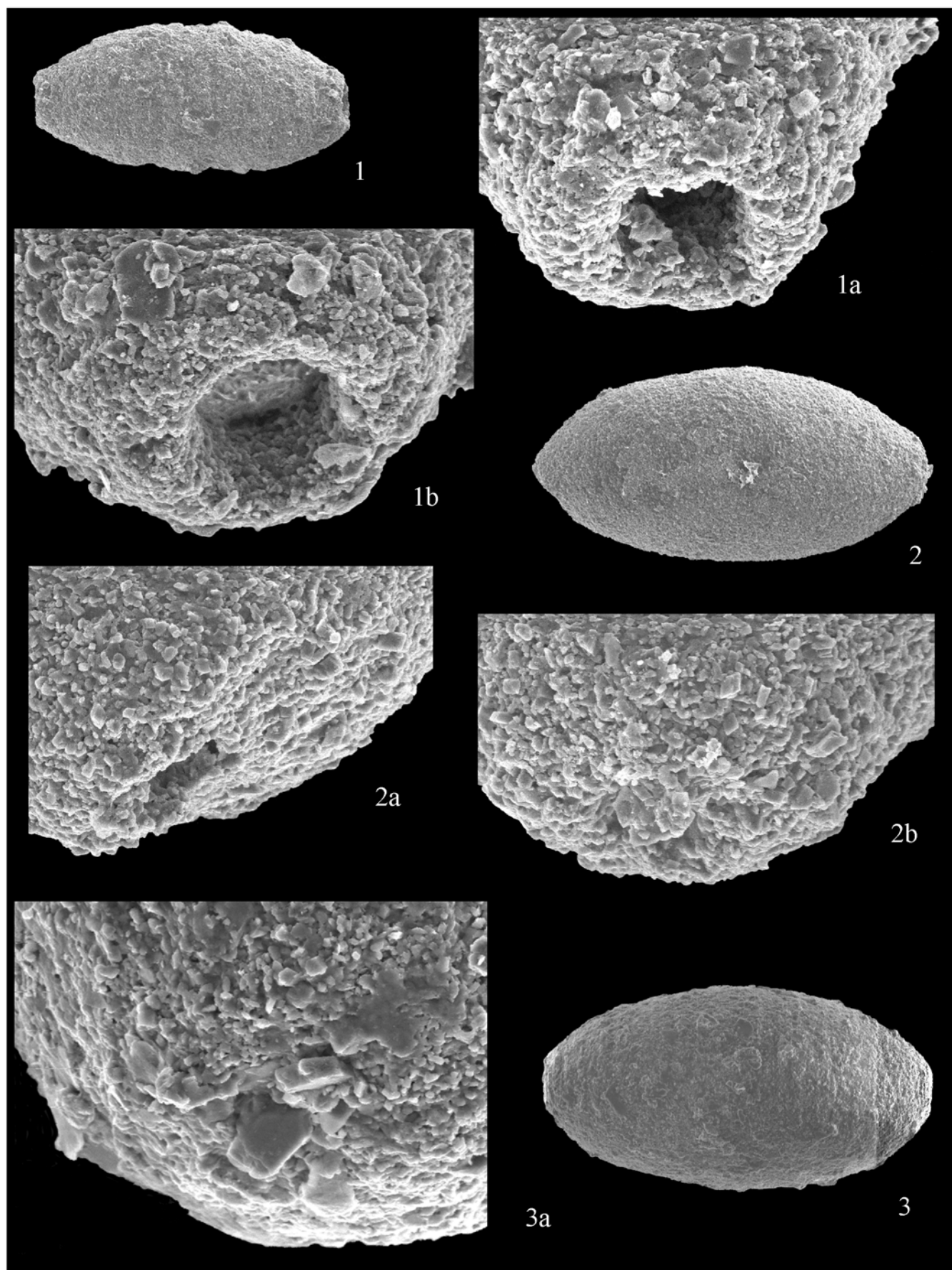
Designation of types: The specimen illustrated on plate 6, figure 1 is designated as the holotype (no. PMU In 389) and specimens

PLATE 4

Amphitremoida longa Nestell and Tolmacheva n. sp.

- 1 no. PMU In 385, holotype, SEM ×200: 1a – apertural view of the right end of the test, 1b – of the left end of the test, SEM ×1000;
- 2 no. PMU In 386, paratype, SEM ×200: 2a – apertural view of the right end of the test, 2b – of the left end of the test, SEM ×1000;

- 3 no. PMU In 387, SEM ×200: 3a – plugged aperture, view of the right end of the test, SEM ×750; Lava River section, Leetse Formation, Lakity Member; Lower Ordovician, Latorp Regional Stage; 1-2 - sample 306-5, 3 – sample 306-4/5, the lower part of the *Prioniodus elegans* conodont Zone.



illustrated on Pl. 5, figure 1 (no. PMU In 388) and Pl. 6, figure 3 (no. PMU In 391) and Pl. 10, figure 7 (no. PMU In 414) as the paratypes; Russia, east of St. Petersburg, the northern outskirts of the village of Vassilkovo, Lava River canyon; Leetse Formation, Lakity Member; Lower Ordovician, Latorp Regional Stage, the lower part of the *Prioniodus elegans* conodont Zone.

Etymology: From the Latin – *orbicularis* – rounded.

Material: Fifteen specimens from sample 306-4/5, eighteen from sample 306-5 and four from sample 306-01.

Discussion: *Amphitremoida orbicularis* n. sp. is similar to *A. huffmani* Conkin and Conkin (Conkin and Conkin 1964, p. 74, pl. 12, fig. 1-7) from the Upper Devonian of Missouri, USA based on the absence of projections from both ends, but differs by its larger size, almost spherical or rounded-oval test shape sometimes with slightly pointed ends, and smaller form ratio.

Occurrence: The same as the holotype and paratypes, and also in the upper part of the *Paroistodus proteus* conodont Zone.

***Amphitremoida rugosa* Nestell and Tolmacheva n. sp.**
Plate 7, figures 1-7, plate 8, figures 1-3, plate 9, figures 1-2, plate 10, figures 8-10

Agglutinated foraminifer TOLMACHEVA et al. 2001, fig. 9, 10-11.

Description: Test free, monothalamous, of fusiform shape, sometimes elongate, with two distinct apertural necks, symmetrical or asymmetrical, sometimes twisted. Apertural necks in shape of short and wide tubes. Two apertures, one at each end, both of rounded shape or one of them of slit-like shape. Sometimes one or both apertures closed completely or semi-closed. Surface of test covered by thin or coarse transverse wrinkles, probably reflecting stages of test growth. Wall agglutinated, tightly cemented (Pl. 8, fig. 3a), fine-grained, thickness of wall 0.015-0.03mm. Dimensions in mm: test length (L) 0.25-0.45, sometimes up to 0.52, width (W) 0.14-0.30, form ratio L/W 1.3-1.9, elongate specimens have form ratio L/W of 2.6, the height of the apertural neck 0.02-0.04, width 0.05-0.07; corresponding dimensions of holotype 0.37, 0.21, 1.76, 0.03, 0.05.

Variability: There are symmetrical and asymmetrical (Pl. 7, fig. 6) tests, twisted (Pl. 7, fig. 4) tests, and the degree of expression of the transverse wrinkles varies from thin to coarse, and also the shape of apertures varies from rounded to oval to slit-like.

Designation of types: The specimen illustrated on plate 7, figure 1 is designated as the holotype (no. PMU In 394) and specimens illustrated on Pl. 7, figure 5 (no. PMU In 398) and Pl. 10, figure 10 (no. PMU In 417) as paratypes; Russia, east of St. Petersburg, the northern outskirts of the village of Vassilkovo, Lava River canyon; Leetse Formation, Lakity Member; Lower Ordovician, Latorp Regional Stage, no. 394, 417 – the lower part of the *Prioniodus elegans* conodont Zone, and no. 398 – the upper part of the *Paroistodus proteus* conodont Zone.

Etymology: From the Latin – *rugosus* – wrinkled.

Material: Thirty-two specimens from sample 306-01, twenty-five from sample 306-4/5, and eight from the sample 306-5.

Discussion: Based on the distinct apertural necks shaped like small tubes and well developed transverse wrinkles *Amphitremoida rugosa* n. sp. differs from all known species of the genus *Amphitremoida*.

Occurrence: The same as the holotype and paratypes.

Class NODOSARIATA Mikhalevich 1992
Subclass HORMOSINANA Mikhalevich 1992
Order SACCAMMINIDA Lankester 1885

Family SACCAMMINIDAE Brady 1884

Diagnosis is given after Mikhalevich et al. (2000): Test free, monothalamous, subspherical or ovoid, rare subtriangular, aperture terminal, single, of rounded, oval or slit-like shape, can be at same level with surface or above it, often on elongate neck, can be surrounded by rim, rarely with entosolenian tube, wall agglutinated.

Remarks: According to Mikhalevich (1995), the family Saccamminidae Brady 1884 was subdivided into six subfamilies

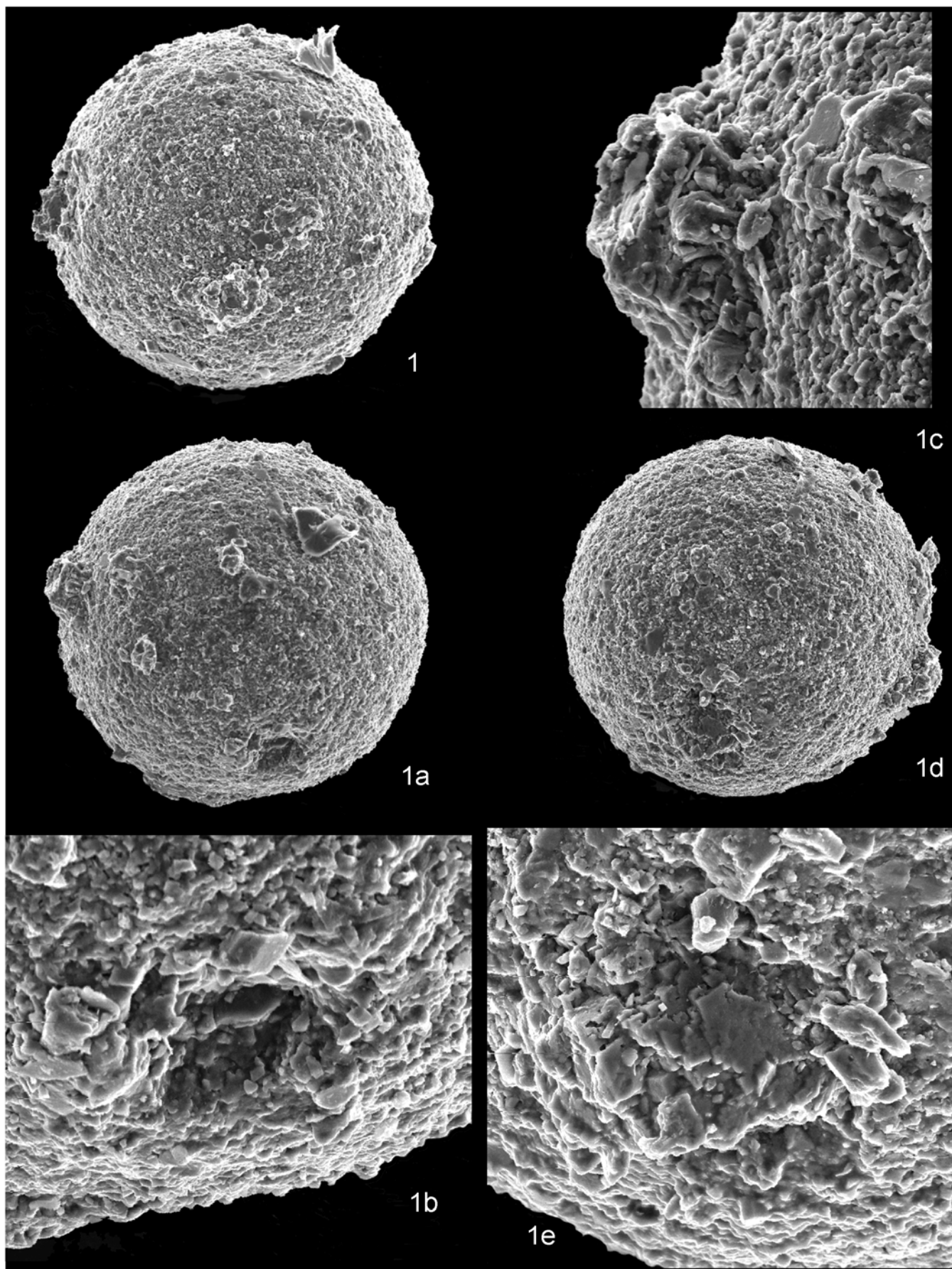
PLATE 5

Amphitremoida orbicularis Nestell and Tolmacheva n. sp., no. PMU In 388, paratype, SEM ×200

1a-b apertural views of the right end of the test, a – SEM ×200, b – SEM ×750,

1c view of outgrowth of the test, SEM ×750,

1d-e apertural views of the left side of the test, d – SEM ×200, e – SEM ×750. Lava River section, Leetse Formation, Lakity Member, sample 306-4/5; Lower Ordovician, Latorp Regional Stage, the lower part of the *Prioniodus elegans* conodont Zone.



and was included in the order Saccamminida of the class Astorhizata. Later, Mikhalevich et al. (2000) assigned the order Saccamminida to the class Nodosariata based on the presence of a single terminal aperture, a characteristic of nodosariids. Of the six subfamilies originally referred to the family Saccamminidae, three of these (Saccammininae, Pilulininae, and Thurammininae) were elevated to family rank. Kaminski (2000) reinstated the genera *Cribrothalammina* Goldstein and Barker 1988, *Marsupulinoides* Bronnimann 1988, and *Saccamminella* Bronnimann, Whittaker and Zaninetti 1992 to the subfamily Saccammininae, and we include them here in the family Saccamminidae.

Genera: *Saccammina* Carpenter 1869 (Silurian – Holocene), *Brachysiphon* Chapman 1906 (Holocene), *Cribrothalammina* Goldstein and Barker 1988 (Holocene), *Hyperamminita* Crespin 1958 (Early Permian), *Lagenammina* Rhumbler 1911 (= *Protonella* Lukina 1969) (Silurian – Holocene), *Marsupulinoides* Bronnimann 1988 (Holocene), *Ovammina* Dahlgren 1962 (Holocene), *Pilulinella* Saidova 1975 (Holocene), *Placentammina* Thalmann 1947 (Cretaceous–Miocene), *Psammodonta* Arnold 1982 (Holocene), *Saccamminella* Bronnimann, Whittaker and Zaninetti 1992 (Holocene), *Sacculinella* Crespin 1958 (Early Permian), *Stomasphaera* Mound 1961 (Lower Silurian), *Technitella* Norman 1878 (Oligocene–Holocene), and *Lavella* gen. n. (Lower Ordovician, Latorp Regional Stage, the lower part of the *Prioniodus elegans* conodont Zone).

Genus ***Lavella*** Nestell and Tolmacheva **n. gen.**

Type species: *Lavella cucumeriformis* n. sp., Russia, east of St. Petersburg, the northern outskirts of village of Vassilkovo, Lava River canyon; Leetse Formation, Lakity Member; Lower Ordovician, Latorp Regional Stage, the lower part of the *Prioniodus elegans* conodont Zone.

Description: Test free, monothalamous, cucumber-shaped, with blunt initial and apertural ends, aperture terminal, simple, small, located in center of apertural surface, of rounded shape.

Surface of test smooth or slightly rough. Wall agglutinated, densely cemented, not perforate, fine-grained, and very thick.

Etymology: After Lava River.

Composition of the genus: Monotypic.

Discussion: Based on its peculiar test shape (like a cucumber) and its thick and densely cemented fine-grained wall, the new genus *Lavella* differs from other known representatives of the family Saccamminidae (sensu Mikhalevich et al. 2000). The genus *Lavella* is similar in shape to tests of the genus *Ovammina* Dahlgren 1962 from which it differs by the absence of an entosolenian tube in the aperture.

Remarks: We include the genus *Lavella* within the family Saccamminidae based on the presence of a terminal and single aperture located in the middle part of the apertural surface, and also in possessing a short unilocular test. Representatives of the family Hippocrepinidae Rhumbler 1895 also possess a single aperture and a unilocular test, but differ from representatives of the family Saccamminidae by their elongate stick-shaped tests with pointed initial ends.

Range: Lower Ordovician, Latorp Regional Stage, the lower part of the *Prioniodus elegans* conodont Zone.

Lavella cucumeriformis Nestell and Tolmacheva **n. sp.**
Plate 9, figure 3, plate 10, figure 11

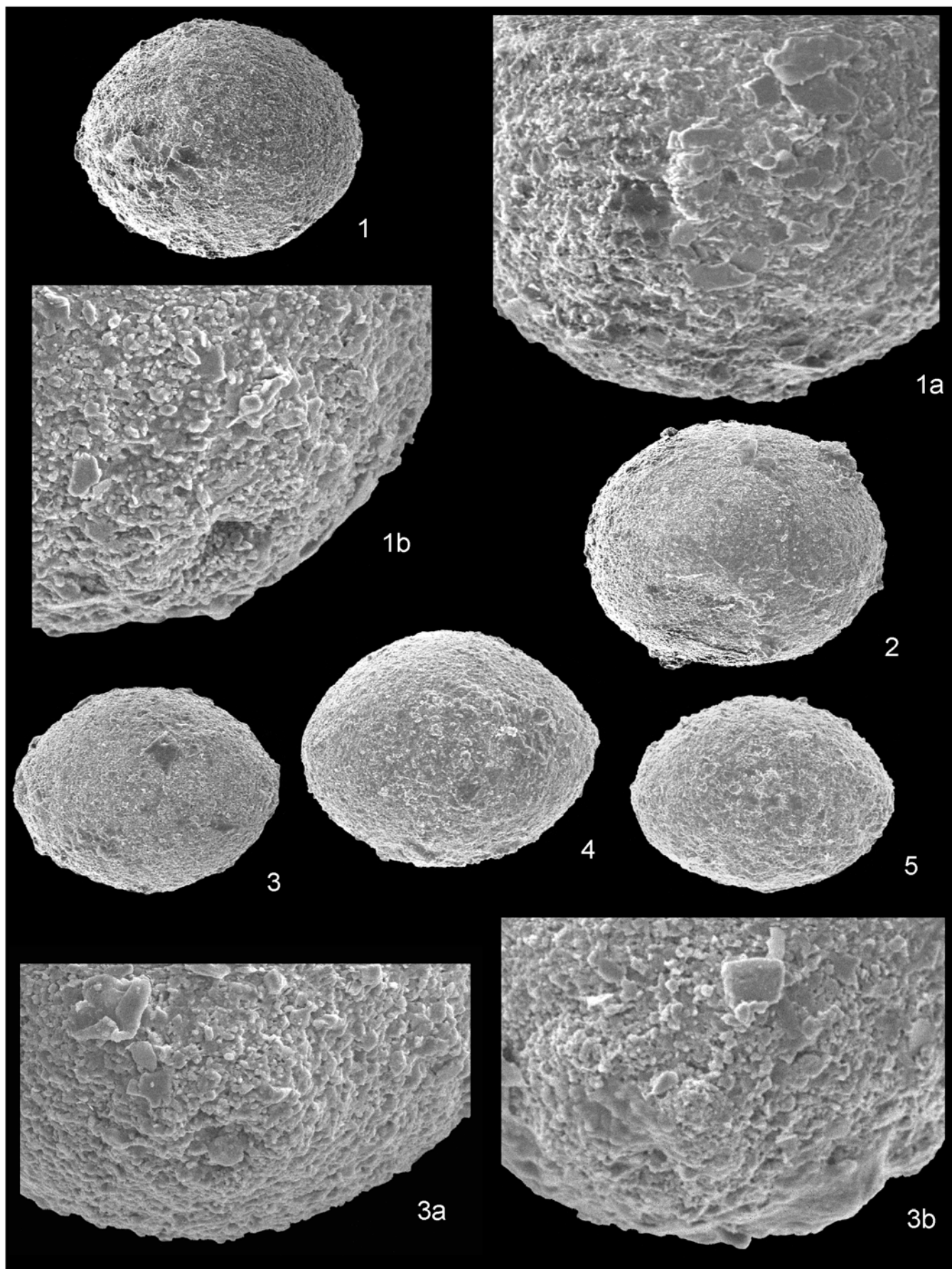
Description: Test free, monothalamous, cucumber-shaped, elongate, initial and apertural ends widely rounded. Surface of test smooth or slightly rough. Aperture terminal, simple, small, of rounded shape, located in center of apertural surface. Wall agglutinated, densely cemented, not perforate, fine-grained, with thickness 0.09mm. Internal cavity narrow, with width 0.17mm. Dimensions in mm: test length (L) 0.36–0.65, width (W) 0.21–0.35, form ratio L/W 1.7–1.85; corresponding dimensions of holotype 0.36, 0.21, 1.7.

PLATE 6

1–5 *Amphitremoida orbicularis* Nestell and Tolmacheva n. sp.

- 1 no. PMU In 389, holotype, SEM ×200: 1a – apertural view of the left end of the test, 1b – apertural view of the right end of the test, SEM ×750;
- 2 no. PMU In 390, SEM ×200;
- 3 no. PMU In 391, paratype, SEM ×200: 3a – apertural view of the left end of the test, 3b – apertural view of the right end of the test, SEM ×750;

- 4 no. PMU In 392, SEM ×200;
- 5 no. PMU In 393, SEM ×200. Lava River section, Leetse Formation, Lakity Member, sample 306-4/5; Lower Ordovician, Latorp Regional Stage, the lower part of the *Prioniodus elegans* conodont Zone.



Designation of types: The specimen illustrated on plate 9, figure 3 is designated as the holotype (no. PMU In 406); Russia, east of St. Petersburg, the northern outskirts of the village of Vassilkovo, Lava River canyon; Leetse Formation, Lakity Member; Lower Ordovician, Latorp Regional Stage, the lower part of the *Prioniodus elegans* conodont Zone.

Etymology: From the Latin - *cucumeriformis* – cucumber-shaped.

Material: Two specimens from sample 306-4/5.

Discussion: Given under the description of the genus.

Occurrence: The same as the holotype.

Order HIPPOCREPINIDA Saidova 1981

Family HIPPOCREPINIDAE Rhumbler 1895

Diagnosis is given after Mikhalevich (1995): Test free, monothalamous, resembles a stick, sometimes tapering up, initial part closed, acute or rounded, rounded in transverse section, oval or square with depressed sides, surface without or with transverse constrictions, aperture terminal, single, small circular or oval in the center of apertural end, or wide rounded opening at end of test, sometimes with small lip, wall agglutinated, finely or coarsely grained.

Subfamily HIPPOCREPININAE Rhumbler 1895

Genera: *Hippocrepina* Parker 1870 (Holocene), *Hyperamminoides* Cushman and Waters 1928 (Upper Carboniferous), *Giraliarella* Crespin 1958 (Permian), *Pseudohyperammina* Crespin 1958 (Lower Permian).

Remarks: Conkin (1954) assigned the genus *Hyperamminoides* to the genus *Hyperammina* Brady 1878. However, the apertures

of these two genera are very different (*Hyperamminoides* has a slit-like aperture and *Hyperammina* has a rounded aperture). Thus, these two genera would be considered distinct in the concept of Mikhalevich's system of foraminiferal classification (Mikhalevich and Debenay 2001).

Subfamily JACULELLINAE Mikhalevich 1995

Genera: *Jaculella* Brady 1879 (Holocene), *Aciculella* Vyalov 1968 (Upper Cretaceous), *Arenosiphon* Grubbs 1939 (Lower Ordovician - Middle Silurian), *Tasmanammina* Gutschik and Wuellner 1983 (Upper Devonian), *Kechenotiske* Loeblich and Tappan 1984 (Upper Carboniferous – Lower Cretaceous), *Sansabaina* Loeblich and Tappan 1984 (Upper Devonian - Permian).

Genus *Arenosiphon* Grubbs 1939

Type species: *Arenosiphon giganteus* Grubbs 1939, Middle Silurian (Niagarian) deposits of Chicago area, Illinois, USA.

Diagnosis is given after Loeblich and Tappan (1988, p. 43): Test free, tubular, elongate, tapering, up to 14mm in length and 1.0mm in diameter, straight or slightly curved; wall agglutinated, with medium to fine quartz grains, firmly cemented, surface roughly finished.

Composition of the genus: The species *Arenosiphon giganteus* Grubbs 1939 (Middle Silurian), *A. minima* Eisenack 1969 (Upper Ordovician, Caradoc), and *Hyperammina? minuta* Moreman 1930 (Lower Ordovician) are included in the composition of the genus.

Range: Lower Ordovician (Moreman 1930) – Middle Silurian (Grubbs 1939).

Arenosiphon? sp.

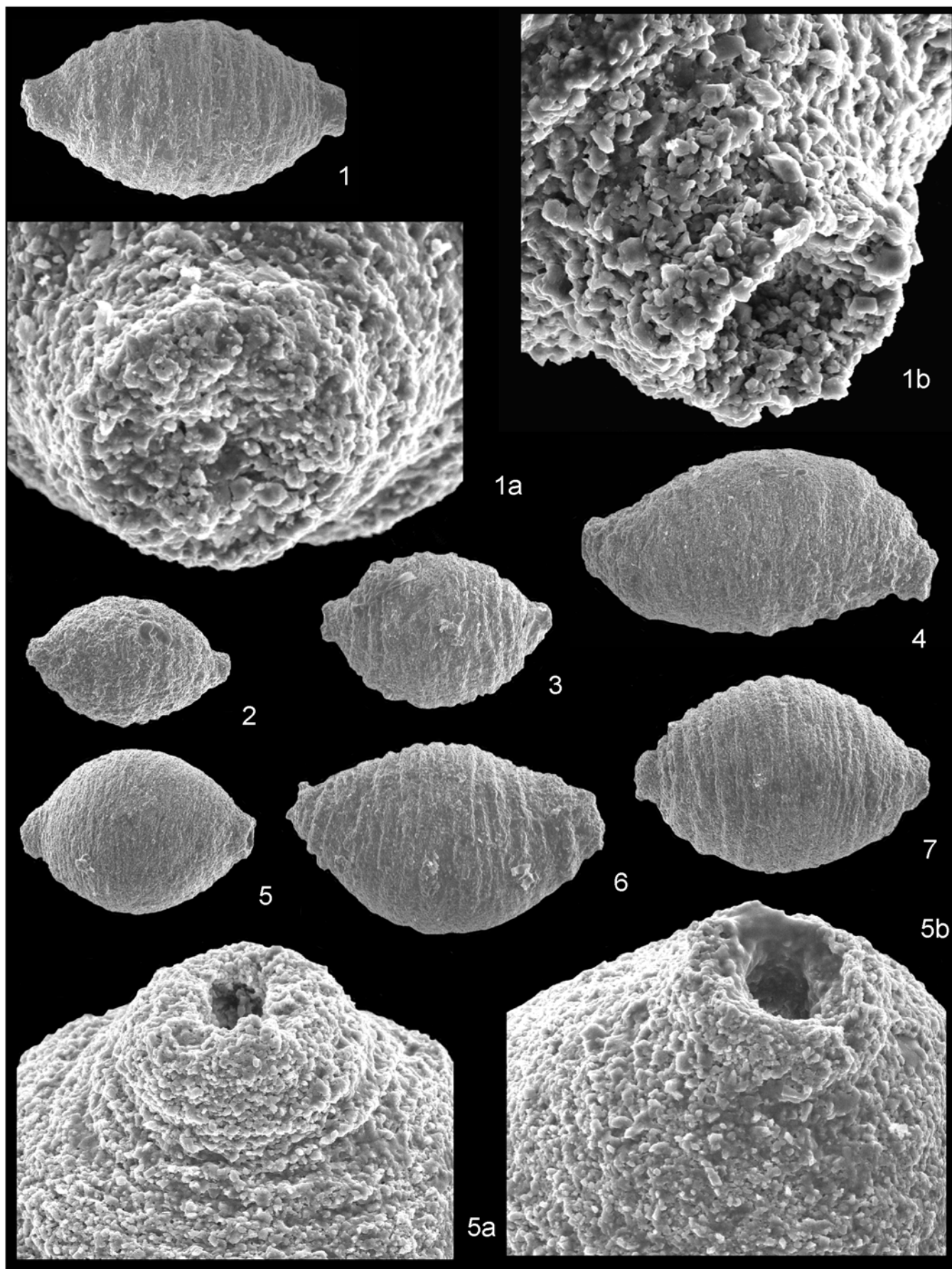
Plate 9, figure 4

PLATE 7

1–7 *Amphitremoida rugosa* Nestell and Tolmacheva n. sp.

- 1 no. PMU In 394, holotype, SEM ×200: 1a – apertural view of the left side of the test, 1b – apertural view of the right side of the test, SEM ×750;
- 2 no. PMU In 395, SEM ×200;
- 3 no. PMU In 396, SEM ×200;
- 4 no. PMU In 397, SEM ×200;

- 5 no. PMU In 398, paratype, SEM ×200: 5a – apertural view of the left side of the test, 5b – apertural view of the right side of the test, SEM ×1000;
- 6 no. PMU In 399, SEM ×200;
- 7 no. PMU In 400, SEM ×200. Lava River section, Leetse Formation, Lakity Member; Lower Ordovician, Latorp Regional Stage. 1, 3, 4, 6, 7 – sample 306-4/5, the lower part of the *Prioniodus elegans* conodont Zone, 2, 5 – sample 306-01, the upper part of the *Paroistodus proteus* conodont Zone.



Description: Test free, monothalamous, stick-shaped, almost cylindrical, with pointed rounded initial end and rounded and compressed apertural end. Aperture terminal, plugged, possibly of oval shape. Wall agglutinated, densely cemented, composed of fine grains. Dimensions in mm: test length (L) 0.650, width (W) 0.125, form ratio L/W 5.2.

Material: One specimen from sample 306-4/5.

Discussion: We have assigned this specimen to the genus *Arenosiphon* Grubbs 1939 conditionally because only one test was found. The described test differs from typical representatives of this genus, *A. giganteus* Grubbs from Silurian deposits of Illinois (Grubbs 1939, p. 544, pl. 61, fig. 1-3) by its smaller size, untapered test, pointed rounded (not pointed) initial end. Based on the shape of the test, this test is similar to that described by Moreman (1930) as *Hyperammina? minuta* from the Arbuckle Limestone (Lower Ordovician), Arbuckle Mountains, Oklahoma. Moreman assigned this species to the genus *Hyperammina* on the basis that “there is a slight constriction just above the closed end which suggests a proloculum” (Moreman 1930, p. 58). In our opinion, the species *H. minuta* should be assigned to the genus *Arenosiphon* and not to *Hyperammina*.

Occurrence: Lower Ordovician, Latorp Regional Stage, the lower part of the *Prioniodus elegans* conodont Zone.

CONCLUSIONS

1) Recent studies on the biostratigraphy and fauna of Lower Ordovician successions of the Russian part of Baltoscandia have shown for the first time that agglutinated foraminifers are very numerous in the deposits of the Latorp Regional Stage in the vicinity of St. Petersburg.

2) One new species of the new genus *Lakites*, five new species of the genus *Amphitremoida* (emend. herein) of the family Hippocrepinellidae, one new species of the new genus *Lavella* of the family Saccamminidae, and one specimen assigned to the genus *Arenosiphon?* of the family Hippocrepinidae are described for the first time.

3) The identification of representatives of the genus *Amphitremoida*, previously known only from the Middle (Rieggraf and Niemeyer 1996) and Upper Ordovician, Silurian and Lower Carboniferous (Conkin and Conkin 1981) permits the extension of the range of this genus down into the Lower Ordovician.

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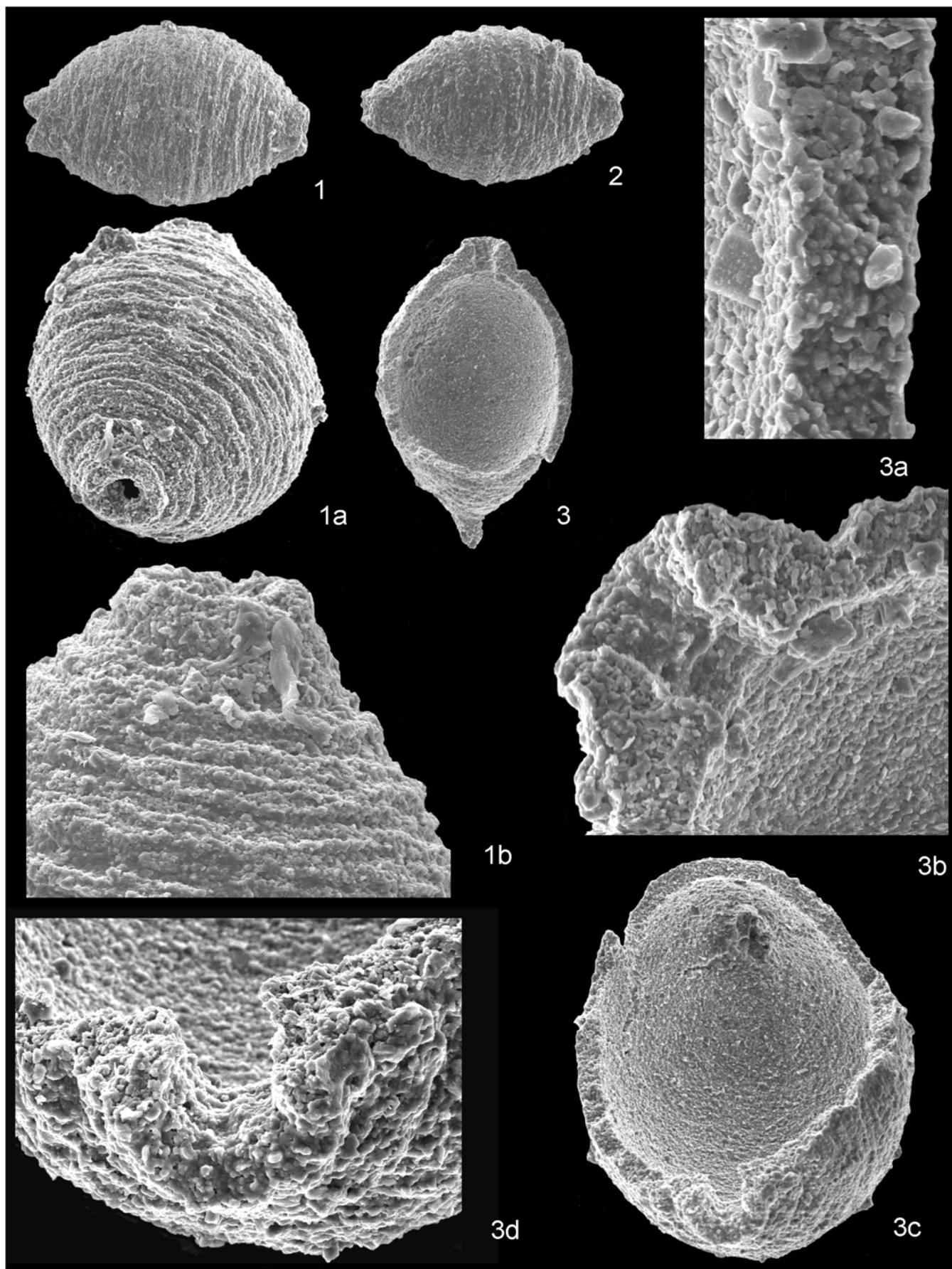
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PLATE 8

1–3 *Amphitremoida rugosa* Nestell and Tolmacheva n. sp.

- 1 no. PMU In 401, SEM $\times 200$: 1a – apertural view of the right side of the test, SEM $\times 200$, 1b – apertural area of the same specimen magnified showing transverse wrinkles, SEM $\times 750$; sample 306-4/5, the lower part of the *Prioniodus elegans* conodont Zone.
- 2 no. PMU In 402, SEM $\times 200$; sample 306-01, the upper part of the *Paroistodus proteus* conodont Zone.

- 3 no. PMU In 403, view of a broken test, SEM $\times 200$: 3a – structure of the agglutinated wall showing a very thin outer organic layer on the right side, SEM $\times 2000$, 3b – cross-section showing interior structural shape of the aperture, SEM $\times 1000$, 3c – test of the opposite end from the aperture showing plugged second aperture, SEM $\times 350$, 3d – exterior view of cross-section of apertural opening, SEM $\times 1000$. Lava River section, Leetse Formation, Lakity Member; Lower Ordovician, Latorp Regional Stage; sample 306-01, the upper part of the *Paroistodus proteus* conodont Zone.

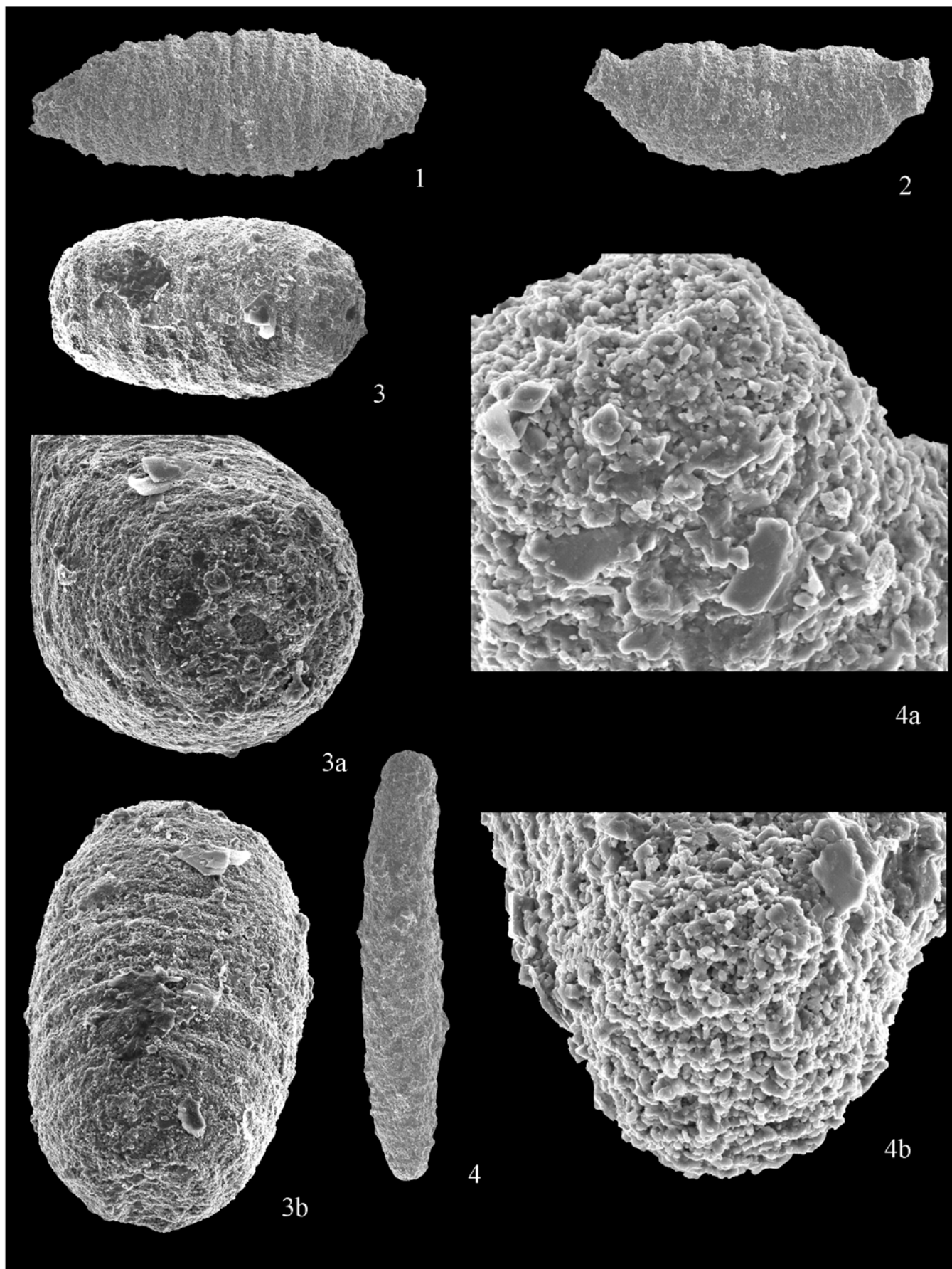


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PLATE 9

1-2 *Amphitremoida rugosa* Nestell and Tolmacheva n. sp.

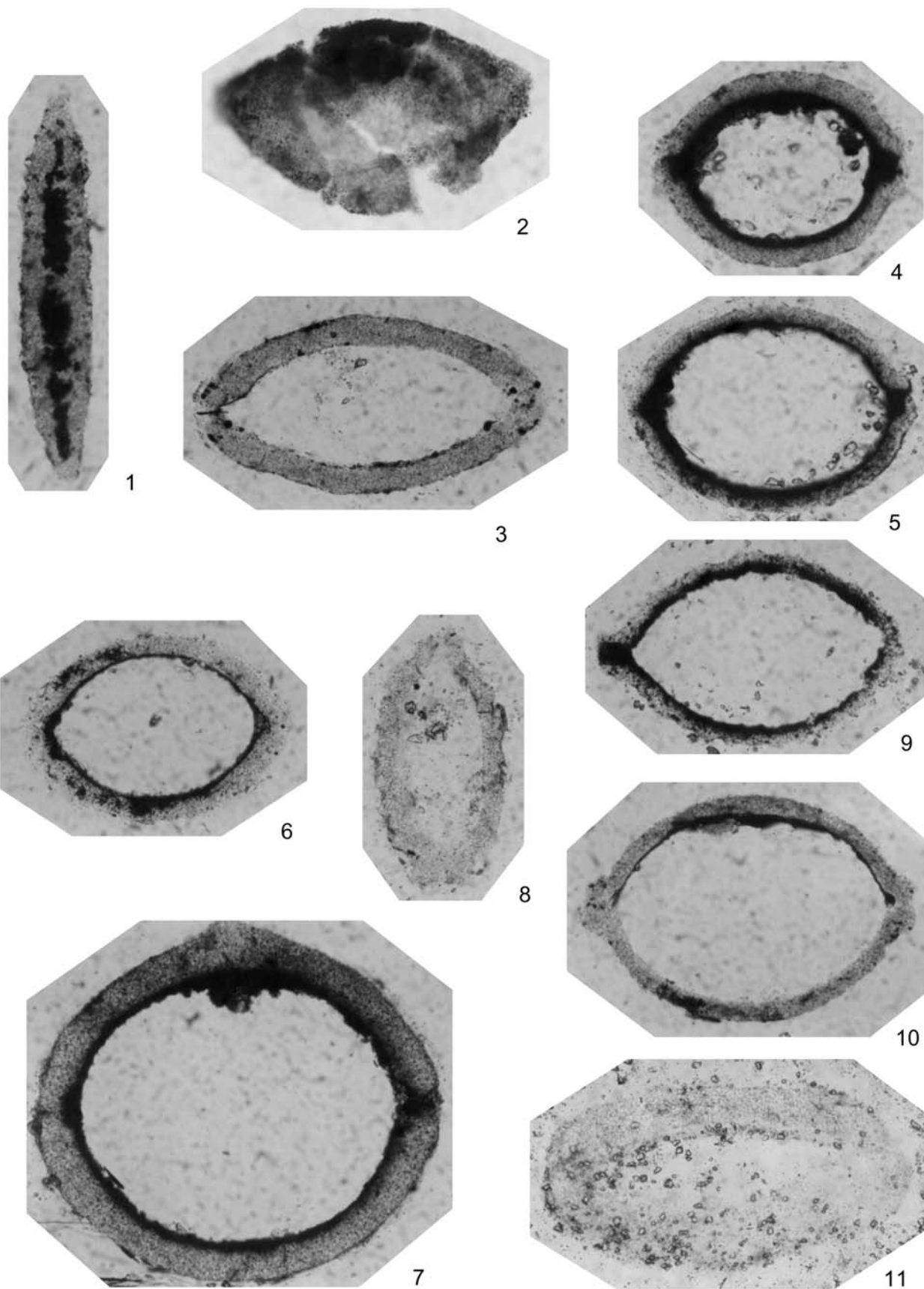
- 1 no. PMU In 404, SEM ×200.
- 2 no. PMU In 405, SEM ×200. Lava River section, Leetse Formation, Lakity Member, sample 306-5; Lower Ordovician, Latorp Regional Stage, the lower part of the *Prioniodus elegans* conodont Zone.
- 3 *Lavella cucumeriformis* Nestell and Tolmacheva n. sp., gen. n., no. PMU In 406, holotype, SEM ×200: 3a – apertural view, SEM ×350, 3b – view of the opposite end from the aperture, SEM ×200. Locality and age are the same as in Fig. 1-2, sample 306-4/5.
- 4 *Arenosiphon?* sp., no. PMU In 407, SEM ×150: 4a – apertural view showing plugged aperture, 4b – opposite view to the apertural end, SEM ×750. Locality, age and sample are the same as in Figs. 1-2.



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PLATE 10

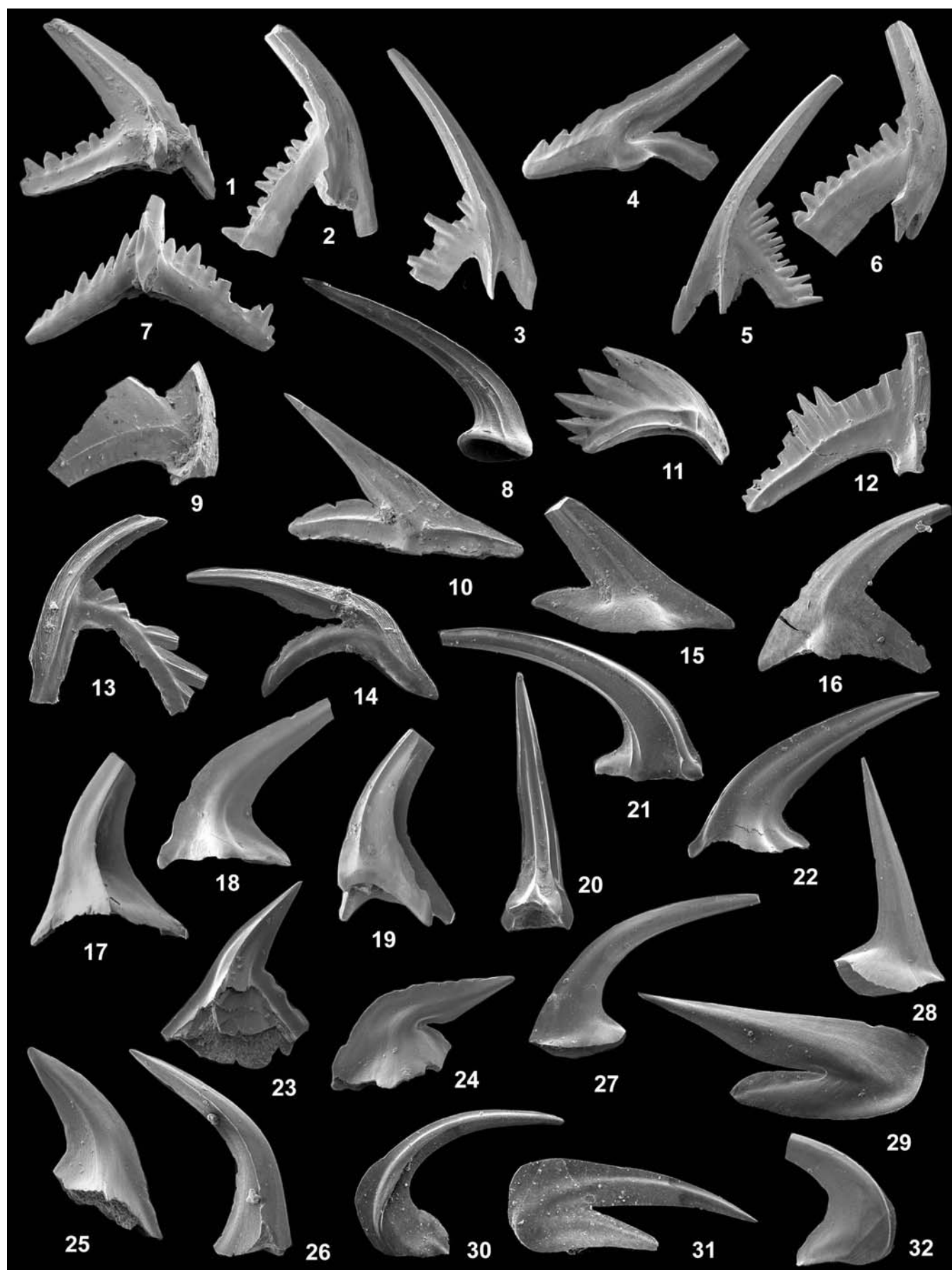
- 1 *Lakites ordovicus* Nestell and Tolmacheva n. sp., no. PMU In 408, the test imbedded in Canada balsam, ×160. Lava River section, Leetse Formation, Lakity Member, sample 306-5; Lower Ordovician, Latorp Regional Stage, the lower part of the *Prioniodus elegans* conodont Zone.
- 2 *Amphitremoida asperella* Nestell and Tolmacheva n. sp., no. PMU In 409, the test imbedded in Canada balsam, ×100. The same locality as in Fig. 1, sample 306-01; the upper part of the *Paroistodus proteus* conodont Zone.
- 3 *Amphitremoida longa* Nestell and Tolmacheva n. sp., no. PMU In 410, paratype, ×160, axial section. The same locality, age, and sample are the same as in Fig. 1.
- 4-5 *Amphitremoida laevis* Nestell and Tolmacheva n. sp., ×160. 4 – no. PMU In 411, 5 – no. PMU In 412, paratype, axial sections. Locality and age are the same as in Fig. 1, sample 306-4/5.
- 6-7 *Amphitremoida orbicularis* Nestell and Tolmacheva n. sp., ×160. 6 – no. PMU In 413, 7 – no. PMU In 414, paratype, axial sections. Locality, age, and sample are the same as in Fig. 1.
- 8-10 *Amphitremoida rugosa* Nestell and Tolmacheva n. sp., ×160. 8 – no. PMU In 416, 9 – no. PMU In 415, 10 – no. PMU In 417, paratype, axial sections. Locality is the same as in Figs. 1. 8 – sample 306-01, the upper part of the *Paroistodus proteus* conodont Zone, 9, 10 – sample 306-4/5, the lower part of the *Prioniodus elegans* conodont Zone.
- 11 *Lavella cucumeriformis* Nestell and Tolmacheva n. gen., n. sp., no. PMU In 418, slightly tangential axial section, ×100. Locality and age are the same as in Fig. 1, sample 306-4/5.



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PLATE 11

- 1-7 *Prioniodus elegans* Pander. 1 – Pa element, no. PMU In 419, SEM x55; 2 – Sd element, no. PMU In 420, SEM x49; 3 – Sb element, no. PMU In 421, SEM x59; 4 – M element, no. PMU In 422, SEM x64; 5 – Sb element, no. PMU In 423, SEM x57; 6 – Sa element, no. PMU In 424, SEM x60; 7 – Pb element, no. PMU In 425, SEM x61. Lava River section, Leetse Formation, Lakity Member, sample 306-4/5; Lower Ordovician, Latorp Regional Stage, the lower part of the *Prioniodus elegans* conodont Zone.
- 8 *Scolopodus rex* Lindström, no. PMU In 426, SEM x45. Locality, age, and sample are the same as in Fig. 1-7.
- 9-10 *Oelandodus costatus* van Wamel. 9 – Pa element, no. PMU In 427, SEM x78; 10 – Sd element, no. PMU In 428, SEM x74. Locality, age, and sample are the same as in Fig. 1-7.
- 11-12 *Fahraeusodus* sp. 11 – P element, no. PMU In 429, SEM x60; 12 – Sc element, no. PMU In 430, SEM x70. Locality, age, and sample are the same as in Fig. 1-7.
- 13-14 *Paracordylodus gracilis* Lindström. 13 – S element, no. PMU In 190, SEM x105; 14 – M element, no. PMU In 191, SEM x97. Lava River section, Leetse Formation, Lakity Member, sample 306-6a (Tolmacheva et al. 2001); Lower Ordovician, Latorp Regional Stage, the upper part of the *Paroistodus proteus* conodont Zone.
- 15 *Paltodus subaequalis* Pander, M element, no. PMU In 343, SEM x45. Lava River section, Leetse Formation, Lakity Member, sample 306-9a (Tolmacheva et al. 2001); Lower Ordovician, Latorp Regional Stage, the lower part of the *Prioniodus elegans* conodont Zone.
- 16 *Oelandodus elongatus* (Lindström), Sc element, no. PMU In 172, SEM x82. Lava River section, Leetse Formation, Lakity Member, sample 306-7a (Tolmacheva et al. 2001); Lower Ordovician, Latorp Regional Stage, the upper part of the *Paroistodus proteus* conodont Zone.
- 17-19 *Tripodus* sp. 17 – ?Pa element, no. PMU In 431, SEM x44; 18 – ?Pb element, no. PMU In 432, SEM x48; 19 – Sd element, no. PMU In 433, SEM x65. Lava River section, Leetse Formation, Lakity Member, sample 306-9a (Tolmacheva et al. 2001); Lower Ordovician, Latorp Regional Stage, the lower part of the *Prioniodus elegans* conodont Zone.
- 20-22 *Tropodus* cf. *T. comptus* Branson and Mehl. 20 – Sd element, no. PMU In 143, SEM x44; 21 – Sc element, no. PMU In 142, SEM x44; 22 – Pa element, no. PMU In 137, SEM x56. Lava River section, Leetse Formation, Lakity Member, sample 306-7a (Tolmacheva et al. 2001); Lower Ordovician, Latorp Regional Stage, the upper part of the *Paroistodus proteus* conodont Zone.
- 23-26 *Baltoniodus deltatus* (Lindström). 23 – Pa element, no. PMU In 156, SEM x70; 24 – M element, no. PMU In 155, SEM x84; 25 – Pb element, no. PMU In 157, SEM x73; 26 – Sd element, no. PMU In 154, SEM x88. Lava River section, Leetse Formation, Lakity Member, sample 306-6a (Tolmacheva et al. 2001); Lower Ordovician, Latorp Regional Stage, the upper part of the *Paroistodus proteus* conodont Zone.
- 27-29 *Drepanoistodus* cf. *D. forceps* (Lindström). 27 – S element, no. PMU In 150, SEM x64; 28 – S element, no. PMU In 153, SEM x62; 29 – M element, no. PMU In 151, SEM x86. Lava River section, Leetse Formation, Lakity Member, sample 306-7a (Tolmacheva et al. 2001); Lower Ordovician, Latorp Regional Stage, the upper part of the *Paroistodus proteus* conodont Zone.
- 30 *Paroistodus parallelus* (Lindström), M element, no. PMU In 146, SEM x95. Lava River section, Leetse Formation, Lakity Member, sample 306-7a (Tolmacheva et al. 2001); Lower Ordovician, Latorp Regional Stage, the upper part of the *Paroistodus proteus* conodont Zone.
- 31-32 *Paroistodus proteus* (Lindström). 31 – M element, no. PMU In 148, SEM x58; 32 – S element, no. PMU In 147, SEM x53. Lava River section, Leetse Formation, Lakity Member, sample 306-7a (Tolmacheva et al. 2001); Lower Ordovician, Latorp Regional Stage, the upper part of the *Paroistodus proteus* conodont Zone.



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