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The Brachiopod Family Linoproductidae Stehli from the Lower Moscovian of the Middle Carboniferous of the Moscow Region

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Abstract—The phylogeny and taxonomy of the brachiopod family Linoproductidae are revised. The change in the distributional pattern of spines and distinctive structure of the median lobe of the cardinal process are shown to be the main apomorphies in the family evolution. A new subfamily, Linispininae, and the included new genera, *Linispinella* and *Linispinus*, are described. In the nominotypical subfamily Linoproductinae, a new genus *Linoproductoides* and two new species included in this genus are described from the Vereiskian deposits of the Moscow Region. The new species *Linispinus riparius* (Trautschold), *L. longus* sp. nov., and *L. staricensis* (Ivanov) are described from the Kashirskian deposits. Another new species is tentatively described as *"Linoproductus" kabanovi*.

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Key words: brachiopods, Linoproductidae, Middle Carboniferous, Moscovian, Moscow Region.

INTRODUCTION

The stratigraphic part of the title of this paper needs explanation, as the International Subcommission on Stratigraphy has recently tended to raise the rank of the Moscovian stratigraphic interval. Therefore, the subordinated Moscovian subdivisions that for a long time were regarded as subglobal may possibly be withdrawn from the International Stratigraphic Chart as the formal procedures of the nomenclatural typification in stratigraphy that are connected only with the priority principle are still not elaborated, although they were worked out in the biological classification about half a century ago.

In the two previous papers (Lazarev 2003, 2004), a new taxonomic structure of the superfamily Linoproductoidea was introduced and the family Schrenkiellidae was revised, including the description of new genera and species, some of which are from the Moscovian of the Moscow Region. The present paper is devoted to the revision of its sister group, the family Linoproductidae, which is better represented in the Middle and Upper Carboniferous of the Moscow Region. The linoproductids, together with other productids, were first described by Ivanov (1935) 70 years ago and until recently were not revised.

To substantiate the taxonomic structure of supraspecific taxa, it is necessary to go beyond the geographic and chronological limits of the material studied because this is the only way to establish the hierarchy of the studied group more reliably. The main diagnostic feature of the family Linoproductidae that has isolated it since the end of the Famennian is the distinctively arranged radial ornament and bases of spines such that the radial ribs (striae) curve around the bases of spines and the adjoining ribs that approach the spine outnumber those departing from the base of the spine. In the last years another previously ignored taxonomic feature effective with various productoid groups began to be used. It is the pattern of spines on the ventral valve: whether the thicker supporting spines are located in the posterior or anterior region of the valve surface. This feature proved to be very useful as it helped me to understand the evolution of the family Linoproductidae and to substantiate (to diagnose) its taxonomic structure.

Indeed, without any analysis of the arrangement of spines it is almost impossible to find supraspecific differences between the Early Carboniferous and Bashkirian linoproductids and the geologically younger Early Moscovian linoproductids. For example, the period of existence in the Carboniferous of the genus *Ovatia* Muir-Wood et Cooper, 1960 is uncertain. The name of the genus reflects the form and outline of the ventral valve. It is questionable if *Linoproductus ovalis* Ivanov, 1935, which is similar in shape and existed, according to Ivanov (1935), from the Kashira to Neverovo Horizons, should be included in this genus. Now it is clear that Moscovian linoproductids differ from the true Lower Carboniferous *Ovatia* in the sizes of spines on the ears and trail. In *Ovatia*, the last spines on the ears are considerably thinner than the spines on the trail. The Moscovian linoproductids have equally thick spines on the ears and trail.

Initially, the spines differentiated by size with the change of the density of spines in different regions of the ventral valve; the spines on the trail thickened while their density decreased. Probably beginning in the Late Bashkirian, the spines on the ears also became less dense and thus thicker (as on the trail). But it was the subsequent process, and initially the families Schrenkiellidae and Linoproductidae diverge in the location (posterior or anterior region of the valve) of the thickest spines. Earlier I used this feature to assign the subfamily Coopericinae Lazarev to the family Schrenkiellidae but with the minor reservation that linoproductids later could also reduce the spines on the trail and that if such parallelism would be shown in fossils, the subfamily Coopericinae should be placed into the family Linoproductidae (Lazarev, 2004).

Thus, the difference in the arrangement of spines on the ears and trail is more essential feature than the form and outline of the ventral valve because the longitudinally elongated, inflated ("ovate") form repeatedly appeared in the evolution of Linoproductidae. The same is with the relatively coarse ribbed forms (5–8 ribs per 5 mm), thicker spines (more than 1 mm), and the so-called "corrugate" ribbing: as all these features appeared repeatedly in the linoproductid evolution at different stratigraphic levels. That is why the species name "simensis," which was initially used for the Permian species, was later on was used for the various Moscovian (Ivanov, 1935) and Bashkirian (Semichatova, 1964) species.

The cardinal process is also of great taxonomic value for me because its morphogenesis proved to be irreversible. In the initially bilobed cardinal process of the linoproductid genus *Ovatia*, the inner lobes of the myophore of each of the two parts were not fused at the top. In the Vereiskian forms their distal tips fused, a process that was probably entailed with the change in the orientation of the myophore surface towards the commissural plane. The fusion of the myophore tips led to the formation of an almost isometric pit at the base (in the inner surface) of the two lobes. This pit should not be mixed up with the productid cardinal process pit (alveolus), which is located between the median septum and the cardinal process, at the base of the latter. The next stage of the morphogenesis is the transformation of the pit between the fused lobes into the longitudinal groove (slit) internally dividing the median lobe of the cardinal process. The median lobe that was formed as a result of the fusion of two lobes of the cardinal process became longitudinally stretched (elevated) over the lateral lobes. From the Kashirskian Age onward, all linoproductids of the Moscow Region had this type of cardinal process (Lazarev, 1984, fig. 1).

The development of the coarse radial ribs is mainly a species level character, as the number of ribs per unit distance (the most convenient is to count per 5 mm) changed repeatedly in linoproductid evolution. Coarse ribs are usually developed together with thick spines, which are directly related to hydrodynamics and therefore probably with eustatic sea-level changes. However, in fact the inverse correlation took place (Lazarev, 2005). According to lithologists' conclusions, in the Smedva time the rise of sea level corresponded to the existence of a species that had the coarsest ribs in the Early Moscovian, *L. staricensis* Ivanov. The ribs were measured in the middle region of the ventral valve along a 5-mm distance through the place with the coarsest ribs in order to be determined uniquely.

As before, taxonomic features were ranked according to their assumed morphogenesis.

(1) Since the Vereiskian (or probably Late Bashkirian) time, the last spines on the ears reached the maximum width of the spines on the trail and thus the spines equalized in diameter at the base. That corresponds to the origin of *Linispinus*. The initial genus with thinner spines on the ears was named *Linispinella.*

(2) The simultaneous appearance of forms with two rows of spines on the ears (oligomerization of spines). This feature preserved up to the end of the linoproductid evolution and therefore it is valued as the feature of subfamily rank (Linoproductinae). The more conservative branch of linoproductids with three rows of spines or even with a bunch of spines on the ears is distinguished here as the new subfamily Linispininae. It is uncertain whether the Linoproductinae as a continuous evolutionary line rose in the Vereiskian (or even Late Bashkirian) time. The point is that in the Lopasnya time this subfamily is unknown and only in the Smedva time Linoproductinae seems to originate "once more": in *Linispinus staricensis* (Ivanov) both specimens with two or three rows of spines (the third row is poorly developed) occur. The forms with two rows of spines completely separated in the Podolskian Age. Thus, the forms with two rows of spines possibly originated earlier (Vereiskian Age) as a kind of repetition of their later and final establishment in the Podolskian Age. However, for the purpose of convenient diagnostics, the Vereiskian species (new genus) are assigned here to the subfamily Linoproductinae.

(3) The complete fusion of the two lobes of the cardinal process in the Early Kashirskian Age with the subsequent formation of more posteriorly projecting median lobe that is divided from the interior by a longitudinal groove. This median groove is a constant feature of all linoproductids that existed after the Vereiskian time and thus they may be distinguished from the Vereiskian and younger species (Lazarev, 1984). Here the Vereiskian linoproductid species with a pit at the base of the median lobe of the cardinal process are distinguished as the new genus *Linoproductoides.*

MATERIAL

In addition to the type specimens and the material used by Ivanov (1935) and Ivanova (1958), the material collected during the 1970s by E.A. Ivanova,

O.A. Erlanger, A.S. Alekseev, S.V. Rozhnov, P.B. Kabanov, and others is used.

SYSTEMATIC PALEONTOLOGY

Family Linoproductidae Stehli, 1954

Subfamily Linoproductinae Stehli, 1954

Type genus. *Linoproductus* Chao, 1927

Diagnosis. Two rows of slightly diverging spines on the ears of ventral valve.

Generic composition. *Linoproductus* Chao, 1927 and *Linoproductoides* gen. nov.

Remarks. The generic composition of the subfamily will be expanded after the study of the Late Moscovian and Upper Carboniferous linoproductids of the Moscow Region.

Genus *Linoproductoides* Lazarev, gen. nov.

Etymology. From the external similarity to the type genus of the subfamily.

Type species. *L. aljutovensis* sp. nov.

Diagnosis. Cardinal process with incompletely fused internally lobes. Bases of the lobes divided internally with almost isometric pit. Median lobe of the cardinal process not rising noticeably above the lateral lobes.

Species composition. *L. aljutovensis* sp. nov. and *L. aurilongus* sp. nov.

Comparison. The new genus differs from *Linoproductus* in the lobes of the cardinal process being almost equal in height and projecting posteriorly and in the presence of a pit (rather than a median groove) at the base of the inner side of the median lobe of the cardinal process.

Remarks. The new genus has not been recorded from beds younger than the Vereiskian time. In the structure of the cardinal process it is intermediate between *Ovatia* Muir-Wood et Cooper, 1960, which is assigned here to another (new) subfamily, and *Linoproductus*. The median lobe of *Ovatia* is poorly developed and is lower than the lateral lobes as viewed from the valve interior (Muir-Wood et Cooper, 1960, pl. 114, figs. 9–11). The median lobe of *Linoproductus* is better developed and is higher than the lateral lobes (Muir-Wood et Cooper, 1960, pl. 111, figs. 9–13).

As noted above, two rows of spines on the ears seem to appear twice (independently) in the Moscovian; first in the Vereiskian (or as early as the Late Bashkirian) time when the cardinal process was more primitive (*Linoproductoides*). These rows of spines were inherited possibly only by *L. kabanovi* from Nara, which is now assigned to *Linoproductus* based on the structure of cardinal process and two rows of spines on the ears. Later, two rows of spines appeared for a second (and last) time in the Podolskian Age that determined the evolutionary line of Linoproductinae.

Linoproductoides aljutovensis Lazarev, sp. nov.

Plate 9, figs. 3–8

Etymology. From the locality near the village of Al'yutovo.

Holotype. PIN, no. 3542/3172; ventral valve, left bank of the Pronya River near the village of Al'yutovo; Vereiskian Substage; Al'yutovo Formation.

Description. The shell is 2.5–4 cm wide and transversely elongated. The maximum width is situated slightly anterior to the hinge line. The ventral disc is indistinctly defined, about 2 cm long, and slightly shorter than the trail. The longitudinal profile is almost semicircular. The transverse profile is trapezoidal. The venter is flattened or even slightly concave. The lateral slopes are about 70°. The apical angle is from 90° to 100°. The apex of the umbo slightly projects beyond the hinge line. The ears are not very well separated from the lateral slopes. The cardinal angle is about 110°. The dorsal disc is slightly concave. The length of the trail (observed in one specimen) is one-third the length of the disc.

The ribbing is regular. The middle part of the disc bears about 10 ribs, the bend bears 7–9 ribs, and the trail bears 8–9 ribs per 5 mm. The concentric rugae in

Explanation of Plate 9

Figs. 1 and 2. *Linispinella postovata* (Semichatova, 1964): (1) specimen PIN, no. 3869/6, imprint of the dorsal valve; Bashkiria, Simsk District, Zhukova Shishka; (2) specimen PIN, no. 3869/4, ventral valve; Bashkiria, village of Yakh'ya; Bashkirian Stage.

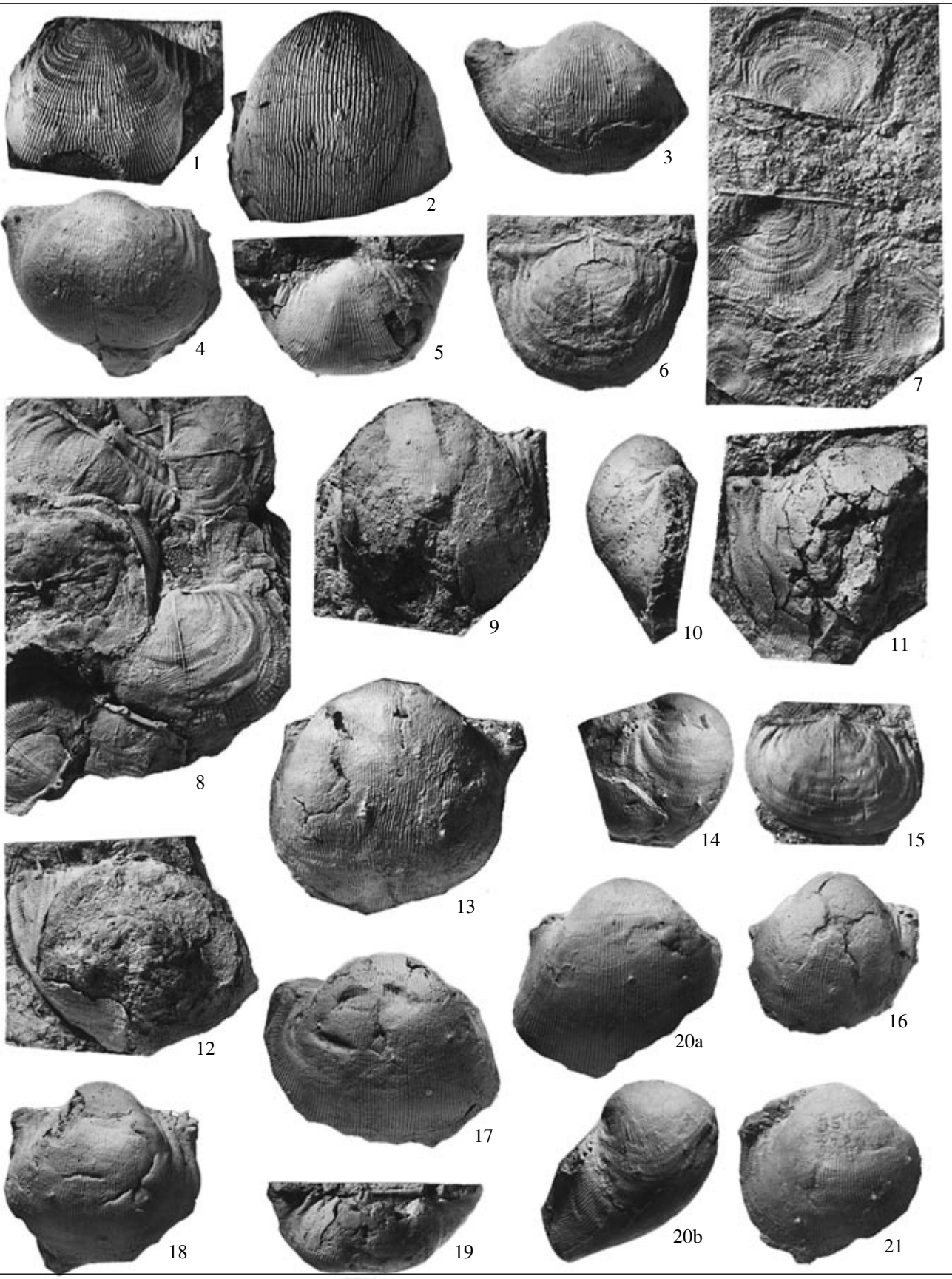
Figs. 3–8. *Linoproductoides aljutovensis* sp. nov.: (3–5) specimens PIN, nos. 3542/1190, 3542/3172 (holotype), and 3542/1189, ventral valves; (6) specimen PIN, no. 3542/1266, interior of the dorsal valve; (7 and 8) specimens PIN, nos. 3542/1267 and 3542/3178, exteriors and interiors of dorsal valves with a few valves of *L. aurilongus* sp. nov.; Pronya River, left bank near the village of Al'yutovo; Vereiskian Substage, Al'yutovo Formation.

Figs. 9–13. *Linoproductoides aurilongus* sp. nov.: (9) holotype PIN, no. 3542/1208, ventral valve; (10–13) specimens PIN, nos. 3542/1333, 3542/1314, 3542/1122, and 3542/3197, ventral valves; Pronya River, left bank near the village of Al'yutovo; Vereiskian Substage, Al'yutovo Formation.

Figs. 14–16. *"Linoproductus" kabanovi* sp. nov.: (14) holotype PIN, no. 3542/3246, almost lateral view of the ventral valve; (15) specimen PIN, no. 3542/3248, interior of the dorsal valve; (16) specimen PIN, no. 3542/3249, ventral valve; Oka River, Koltovo Farm, west of the town of Kashira; Kashirskian Substage, (?) Nara Formation.

Figs. 17–21. *Linispinus riparius* (Trautschold, 1867): (17) holotype PIN, no. 3542/3212; (18–21) specimens PIN, nos. 3542/3211, 3542/3213, 3542/3214, and 3542/3226a; Oka River downstream of the mouth of the Kashirka River, quarry near the village of Gorodishchi; Kashirskian Substage, Lopasnya Formation.

Plate 9



the ventral valve are well developed only near the border between the lateral slopes and ears, disappear at the bases of spines on the ears, and are usually flattened in the middle part of the lateral slopes. The rugae in the ventral valve are located in the anterior region of the disc and in the bend and, unlike the ventral valve, cross the whole disc. The ears bear two rows of spines. The supporting spines 1 mm in diameter appear not earlier than 15 mm, usually 17–18 mm, away from the starting point of growth. The trail bears solitary supporting spines 0.8–1 mm in diameter.

The cardinal process is wide (2.2–2.45 mm), has four poorly defined lobes, and thickens at the base of the cardinal process, which lacks alveoli and encloses the base of the septum. The septum is long and crosses the whole disc. The muscle field is rhombic. The borders of the two pairs of branched adductors are indistinguishable. The papillae in the rim of the disc are absent.

Material. Separated valves from one locality; 15–20 valves can be assigned to this species with certainty.

***Linoproductoides aurilongus* Lazarev, sp. nov.**

Plate 9, figs. 9–13

Etymology. From the Latin *auris* (ear) and *longus* (long).

Holotype. PIN, no. 3542/1208, ventral valve, left bank of the Pronya River near the village of Al'yutovo; Middle Carboniferous, Moscovian, Vereiskian Substage, Al'yutovo Formation.

Description. The shell is about 3.5–5 cm wide, transversely elongated, rounded triangular in outline. The maximum width is near the hinge line. The ventral disc is almost undefined and slightly shorter than the trail. The longitudinal profile of the valve is almost semicircular. The transverse profile is trapezoidal. The venter may be slightly concave. The apical angle is about 100°–110°. The umbo hardly projects beyond the hinge line. The ears are well developed but indistinctly separated from the lateral slopes. The lateral margins of the ears are stretched and rounded. The cardinal angle is 70°–80°. The fold may be developed near the anterior margin of the trail and sometimes it is well pronounced. The dorsal disc is slightly concave and 20–22 mm long. The ratio of the trail length to the disc length cannot be because of broken trails.

The disc usually bears thin (11–12 per 5 mm) ribs. The trail bears 9–10 ribs per 5 mm. Some coarser ribbed specimens bear 7–8 ribs per 5 mm of the trail. The concentric rugae are developed at the bases of the lateral slopes. Closer to the ear endings, they diverge towards the hinge line. The concentric rugae in the dorsal valve. The ears bear two rows of spines. The first row, which is located closer to the hinge line, disappears 17–18 mm away from the starting point of growth. After that one or two spines arise in the second row. Spines of the first row are less than 1 mm in diameter. Spines of the second row became thicker than 1 mm only 20 mm away from the starting point of growth. The last spine 22–23 mm away from the umbo has a diameter of 1.2–1.3 mm. The spines on the trail are 1–1.3 mm in diameter.

The cardinal process is 1.7–1.8 wide, sometimes up to 2 mm, and trifid. A small alveolus or flattening are developed at its base and are bordered with the pair of radial ridges (thickenings). The cardinal ridge runs along the hinge line up to 5 mm and then became blurred. The septum is long, starts near the base of the cardinal process, and terminates near the anterior margin of the disc. The muscle field is poorly pronounced.

Comparison. The new species differs from *L. aljutovensis* in the shape of the shell, laterally stretched ears, fold developed near the anterior margin of the ventral valve, supporting spines (1 mm and more) developed on the ears 20 mm away, and structure of the cardinal process.

Material. Only about 20 separated valves from one locality can be assigned to this species with certainty.

Genus *Linoproductus* Chao, 1927

***"Linoproductus" kabanovi* Lazarev, sp. nov.**

Plate 9, figs. 14–16

Etymology. In honor of the lithologist P.B. Kabanov who collected the material.

Holotype. PIN, no. 3542/3246, deformed ventral valve, Oka River, Koltovo Farmstead, west of the town of Kashira; Middle Carboniferous, Moscovian, Kashirskian Substage, ?Nara Formation.

Description. The shell is rounded triangular, with corpus about 2–3 cm wide. The hinge line is possibly slightly shorter the maximum width. The ventral valve lacks clearly defined sulcus. The venter is flattened. The transverse profile is trapezoidal. The disc in the longitudinal profile is not separated. The dorsal disc is concave and smoothly bends to the trail. The angle between the disc and the trail is obtuse.

The ornamentation is variable. The trail bears 8–9 ribs, sometimes less than 7 ribs per 5 mm. The concentric rugae in the ventral valve are developed only on the ears and slightly enter the lateral slopes. The concentric rugae in the dorsal valve cross the ears near the bend to the trail. The spines on the ears are arranged into two slightly diverging (brought together) rows. The spines are less than 0.7 mm thick. The distance between the axes of the anterior spines is about 1.5 mm. The spines on the trail are irregularly arranged, less than 0.7 mm wide.

The cardinal process is wide and low. The longitudinal groove in the internal surface divides the median lobe into two parts. The alveolus is absent. The cardinal ridges do not deflect from the hinge line and are distinctly separated from the internal surface of the valve.

The muscle field is very wide. The median septum is long.

Comparison. The new species differs from all species from the Moscow Region described as *Linoproductus* in the very thin spines on the ears (thinner than 0.7 mm).

Remarks. P.B. Kabanov, who collected material, believes that these deposits are of the Nara age. His hypothesis is probably correct because this species is unknown from the younger (Lopasnya) deposits where the other species, which are described below, are abundant. This species seems to be the youngest representative of linoproductids with the median lobe of the cardinal process divided internally with the groove.

The generic name is placed in inverted commas because I am in some doubt that the spines on the ears of this species always remained arranged in two rows up to their ends.

Material. Six specimens from the type locality.

Subfamily Linispininae Lazarev, subfam. nov.

Type genus. *Linispinus* gen. nov.

Diagnosis. Ears of the ventral valve bear three or more rows of spines or sometimes cluster of spines with poorly discernible rows.

Generic composition. Three genera: *Ovatia* Muir-Wood et Cooper, 1960, *Linispinella* gen. nov., and *Linispinus* gen. nov.

Comparison. The new subfamily differs from Linoproductinae in the more than two rows of spines on each ear.

Genus *Linispinella* Lazarev, gen. nov.

Etymology. From the Latin *linea* (line, thread) (radial ornamentation as the feature of the rank of superfamily group is intended) and *spinella* (small spine) (accumulation of thin spines on the ears).

Type species. *L. postovata* (Semichatova, 1964); Southern Urals; Middle Carboniferous, Bashkirian.

Diagnosis. Shell medium sized. Corpus about 2.5–3.5 cm wide. Hinge line almost as wide as maximum width of shell. Ears with accumulation of thin (less than 0.6 mm) spines. Trail with more widely spaced but larger (up to 1 mm) spines. Lateral slopes almost lack spines. Dorsal disc flattened, almost as long as disc.

Species composition. Type species.

Comparison. The new genus differs from *Ovatia* in the wider hinge line, very rare (one or two) spines in the lateral slopes, flattened dorsal disc, and (possibly) higher corpus cavity.

Remarks. The new genus resembles its Moscovian descendants in the presence of radial ornamentation and spines on the trail (Pl. 9, figs. 1, 2). The longer dorsal trail (about as long as the disc) and large, flattened, and not curved ears would be additional distinctions of the new genus from linoproductids similar in ornamentation.

Semichatova (1964) described two more species with the generic name *Linoproductus*: *L. silimicus* Sem., which was recently assigned to the genus *Elalia* Lazarev (family Schrenkiellidae) (Lazarev, 2004) and *L. staricensis* Ivanov, which possibly differs from the type species of the new genus only in the more elongated shell. But these two groups of different geologic ages cannot be synonymized not only at the species, but also at the generic level because the pattern of the arrangement of spines (different diameter) on the ears and on the trail, which is accepted in the present paper as the more essential distinction. The topotypes of the "staricensis" species are now assigned to another new genus (see below). Incidentally, the Bashkirian "L. staricensis" (as it was used by Semichatova) is similar in the elongated shell to *L. ovalis* Ivanov from the Moscow Region the Kashirskian representatives of which will be described below as *Linispinus longus* sp. nov.

The type species of the new genus would possibly need to be divided into two or more species if more material were available. Already it is evident that the holotype PIN, no. 3869/3 from the Lower Bashkirian of the Southern Urals, Zilim River, has spines on the trail up to 1.5–1.7 mm in diameter and anterior region of the trail bears 7 spines per 5 mm, while another specimen PIN, no. 3869/5 from the Middle Bashkirian, has spines on the trail less than 1 mm in diameter and the trail bears 8–9 ribs per 5 mm (Semichatova, 1964, pl. 2, fig. 3).

The number of species in the new genus may increase after receiving the information on the spines in different regions of the ventral valve of the Bashkirian species from other regions. Unfortunately, some collections discussed in the previously published papers, e.g., Lapina (1957), now are inaccessible for revision.

Genus *Linispinus* Lazarev, gen. nov.

Etymology. From the Latin *linea* (thread) (radial ornamentation as the feature of superfamily group is intended) and *spina* (spine) (accumulation of thin spines on the ears).

Type species. *Linispinus riparius* (Trautschold, 1867).

Diagnosis. Shell medium sized. Corpus less than 3.5–4 mm wide together with spines that usually cover most of ears being arranged into more than two rows. The third row may be incomplete and consist of one or two spines. Sometimes more than three rows form cluster of spines on ears. Spines widely spaced on trail, with maximum diameter usually no less than 0.8 mm and equal to that of the last spines on the ears. The median lobe of the cardinal process is divided internally with the longitudinal groove.

Species composition. Four species from the Kashirskian and Podolskian deposits of the Moscow Basin and a few species from the Upper Moscovian and Upper Carboniferous of the Moscow Basin that will be described lately.

Comparison. The new genus differs from the Bashkirian *Linispinella* in the thicker spines on the ears and (more important) in the same maximum diameter of the spines on the ears and trail.

Remarks. Most likely the new genus also differs from *Linospinella* in the structure of the cardinal process; however, this structure is still poorly known in the Bashkirian representatives of the genus. The pair of lobes of the cardinal process in the Early and Middle Bashkirian linoproductids possibly remained separated (unfused); i.e., the median lobe of the cardinal process was then unformed.

***Linispinus riparius* (Trautschold, 1867)**

Plate 9, figs. 17–21; Plate 10, figs. 1–3

Productus riparius: Trautschold, 1867, p. 35, pl. 5, fig. 1.

Linoproductus simensis: Ivanov, 1935, p. 46 (pars), pl. 8, fig. 1 (non figs. 3, 8).

Holotype. Lost; a neotype is selected here: PIN, no. 3542/3212, ventral valve, quarry near the village of Gorodishchi, near the mouth of the Kashirka River; Middle Carboniferous, Moscovian, Kashirskian Substage, Lopasnya Formation.

Description. The shell is rounded triangular, rarely trapezoidal in outline because of the diverging lateral slopes of the ventral valve. In the completely preserved trail, the shell is elongated. The corpus (disc) of the shell is 2.5–3.5 cm wide. The hinge line is slightly shorter than the shell maximum width, which is displaced to the shell mid-line. The ventral disc is poorly separated from the trail. The longitudinal profile has an inflated umbonal region, although the umbo only projects slightly beyond the hinge line. The transverse profile is trapezoidal, has a flattened venter, and lacks a clearly defined sulcus. The apical angle is about 100°. The cardinal angle is slightly less than 90°. The dorsal disc is distinctly concave and about 2 cm long. The full length of the trail is unknown. The ratio of the height of the cavity to its length is slightly more than 0.4 ($n = 1$).

The ribbing is relatively thin and usually regular. The trail bears 9–13 ribs per 5 mm, usually 10–12 ribs. The anterior region of the trail usually bears coarser ribs (8–10 ribs per 5 mm). The concentric rugae in the ventral valve are developed only on the ears up to the spines bases and enter the bases of the lateral slopes. The concentric rugae in the dorsal valve may cross the whole disc, especially in its anterior region and in the bend to the trail. The ears originally bear two rows of spines. The second, front row of spines distinctly deviates at an angle of 20°–30° 8–10 mm away from the starting point of growth. Thus, the spines cover most of the ears. Near the lateral margins of the ears, between the diverged rows of spines, there are one or two more spines. The spines are infrequent. The distance between the spine axes is 1–2 mm or, in the lateral regions, up to 2.5 mm . Even the last spines on the ears rarely reach 1 mm thick (usually less than 0.9 mm thick). Spines are infrequent on the trail. The venter usually bears two or three spines that are less than 1 mm thick.

The cardinal process is 2–2.5 mm wide and low. Internally it is trifid because of the fusion of the inner parts into a single longitudinal lobe with the median groove in between. The muscle field is very wide, with branched and indistinctly separated imprints of adductors. The lateral ridges are situated along the hinge line and curve only at the base of the cardinal process where there is usually a pit (alveolus). The median septum is long and crosses almost the whole disc.

Remarks. The remains of the Trautschold collection are stored at the Department of Geological History,

Explanation of Plate 10

All sizes are natural except Fig. 22

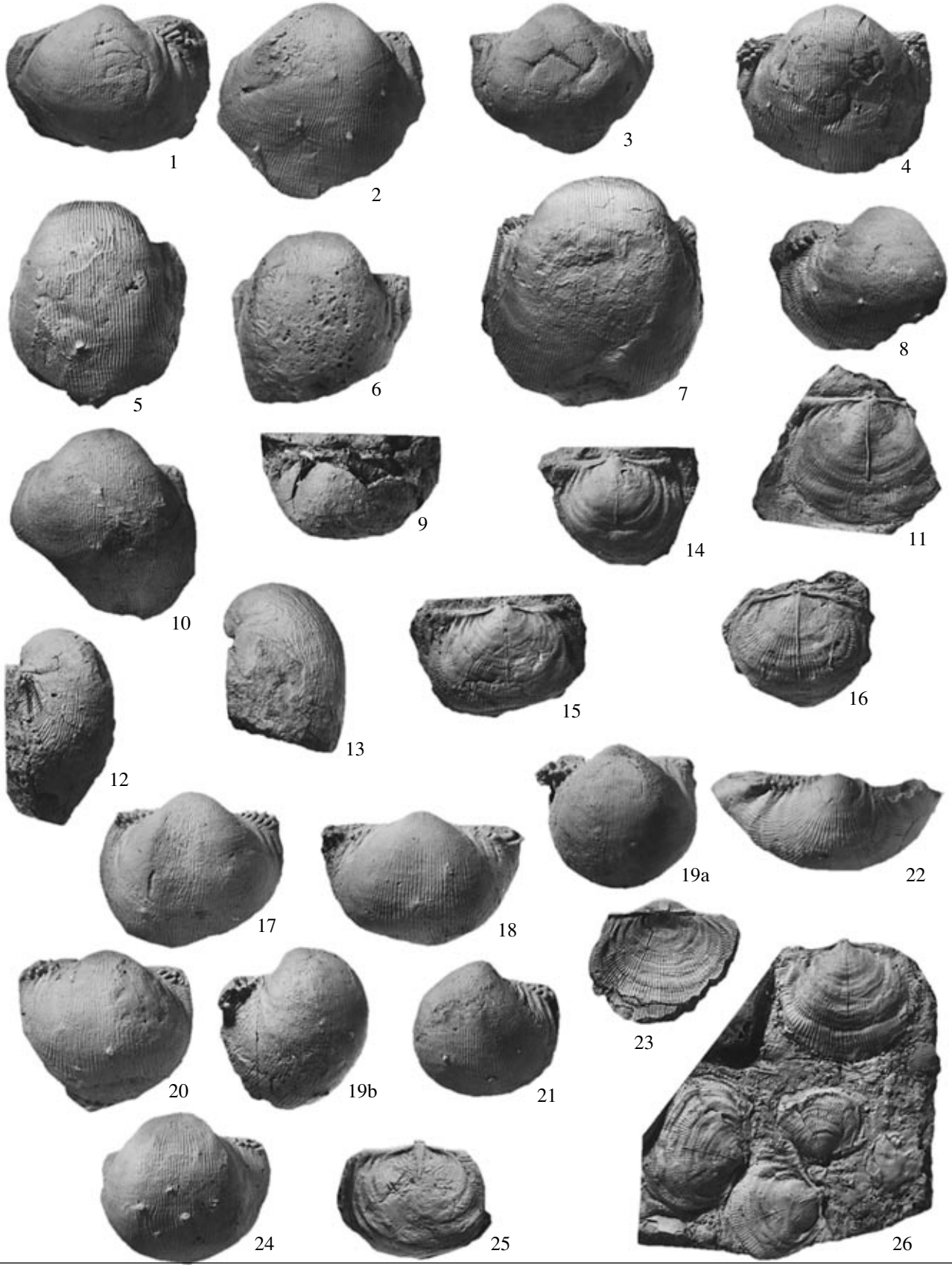
Figs. 1–3. *Linispinus riparius* (Trautschold, 1867): (1) specimen PIN, no. 132/10, ventral valve; town of Kashira; Kashirskian Substage, Lopasnya Formation; (2 and 3) specimens PIN, nos. 3542/3230 and 3542/3218, ventral valves; Oka River downstream of the mouth of the Kashirka River, quarry near the village of Gorodishchi; Kashirskian Substage, Lopasnya Formation.

Figs. 4–16. *Linispinus longus* sp. nov.: (4) holotype PIN, no. 132/236, ventral valve; town of Kashira; Kashirskian Substage, Lopasnya Formation; (5–7) specimens PIN, nos. 3542/3228, 3542/3225, and 3542/3210, ventral valves; Oka River downstream of the mouth of the Kashirka River, quarry near the village of Gorodishchi; Kashirskian Substage, Lopasnya Formation; (8) specimen PIN, no. 3542/3235, ventral valve; (9) specimen PIN, no. 3542/3243, shell with the broken umbo of the ventral valve; Kashirka River; Kashirskian Substage, Lopasnya Formation; (10) specimen PIN, no. 132/255, ventral valve; Kashirka River near the village of Nizhnee Obraztsovo; Kashirskian Substage, Lopasnya Formation; (11–13) specimens PIN, nos. 3542/3241, 3542/3242, and 3542/3254, interior of the dorsal valve and lateral view of two ventral valves; Kashirka River; Kashirskian Substage, Lopasnya Formation; (14–16) specimens PIN, nos. 132/254, 132/253, and 132/252, dorsal valves; Kashirka River, village of Nizhnee Obraztsovo; Kashirskian Substage, Lopasnya Formation.

Figs. 17–25. *Linispinus staricensis* (Ivanov, 1935): (17–21) specimens PIN, nos. 132/19, 132/23, 132/234, 132/20, and 132/248, ventral valves; Volga River, town of Staritsa; Kashirskian Substage, Smedva Formation; (22) specimen PIN, no. 3542/3252, umbonal view of the ventral valve, ×2; (23) specimen PIN, no. 3542/3251, dorsal view of the shell; Kashirka River, right bank near the power line; Kashirskian Substage, (?) Smedva Formation; (24 and 25) specimens PIN, nos. 132/233 and 132/231, ventral and dorsal valves; Kholokhol'nya River (tributary of the Volga River); Kashirskian Substage, (?) Smedva Formation.

Fig. 26. *Linispinus (?) staricensis* (Ivanov, 1935), specimen PIN, no. 132/251, dorsal valves in rock; Kashirka River, village of Nizhnee Obraztsovo; Kashirskian Substage.

Plate 10



St. Petersburg State University, coll. no. 83. However, the only ventral valve, which was figured by the author (pl. 5, fig. 1) and could be selected as holotype, is lost. Fortunately, the main diagnostic features of the species in its modern sense are shown in the figure (shell outline, ribbing, and three rows of spines on the ears).

Ivanov (1935) used the name *Linoproductus simensis* Tschernyschew, which belongs to the species from the Lower Permian of the Urals, for the forms similar in outline and in radial ribbing that occur in the Moscovian of the Moscow Region but, judging from the published specimens, he used it predominantly for the forms from the Kashirskian and Podolskian substages. Lately Ivanova (1958, p. 109) referred the latter forms to *Linoproductus riparius* (Trautschold). The name "simensis" she suggested to use for younger Myachkovskian forms from the Moscow Region. However, the ornamentation of the only specimen of "L. riparius" (from the Kholokhol'nya River) figured in the cited paper (pl. 16, fig. 2) clearly shows that this belongs to *L. staricensis.*

Indeed, *L. riparius* somewhat resembles the Early Permian *"Linoproductus" simensis* Tschernyschew. However, this Urals species is too distinctive in the absence of spines on the trail and well-developed and isolated fold in the anterior region of the trail of the ventral valve. Therefore, the latter species is assigned to another genus and, probably, to another family.

The forms from the Upper Carboniferous of the Donets Basin described by B.K. Licharew using the species name "simensis" (Central Research Geological Prospecting Museum, coll. no. 5462) can belong neither to the Urals species nor to the newly described here species from the Moscow Region. Some specimens from the Donets Basin have only two rows of thin spines on the ears and therefore cannot be assigned even to the genus *Linispinus.*

Occurrence. Middle Carboniferous, Moscovian, Kashirskian Substage, Lopasnya Formation; Moscow Region.

Material. In addition to the material and type specimens discussed in Ivanov's paper (1935), about 70 separated valves (mainly ventral valves) from the Kashirka River banks, including the locality near the village of Gorodishchi (Oka River, east of the mouth of the Kashirka River).

Linispinus longus Lazarev, sp. nov.

Plate 10, figs. 4–16

Linoproductus staricensis: Ivanov, 1935, p. 43 (pars), pl. 8, figs. 10 and 11.

Etymology. From the Latin *longus* (long).

Holotype. PIN, no. 132/236, ventral valve, town of Kashira, "Amerika"; Middle Carboniferous, Moscovian, Kashirskian Substage, Lopasnya Formation.

Description. The shell is longitudinally elongated. The disc is 2–3 cm wide. The ratio of the height of the corpus cavity to its length is about 0.4. The lateral slopes of the ventral valve are steep, slightly diverging but sometimes slightly converging anteriorly to give the shell an egg-shaped outline. The maximum width is probably in the hinge line and remains to the middle of the valve. The ventral disc is not separated from the trail. The umbo is inflated and overhangs the hinge line. The transverse profile is trapezoidal or almost semicircular. The apical and cardinal angles are almost right. The dorsal disc is concave, with the length almost equal to its width. The length of the trail is unknown.

The ribbing is usually regular. There are 8–10 ribs per 5 mm in the posterior part of the trail (after the bend) and 7–9 ribs per 5 mm in the anterior part of the trail. The concentric ornamentation is developed at the bases of the lateral slopes of the ventral valve and on the ears up to the rows of spines. The rugae in the dorsal disc are variously developed and sometimes hardly visible. The spines on the ears are arranged in three rows. The third row appears 12–13 mm away from the starting point of growth. The last spines in rows may be up to 1 mm in diameter. The spines cover almost the whole surface of the ears. The last spines are approximately 5 mm away from the hinge line. The trail bears rare single spines up to 1 mm in diameter.

The cardinal process is trifid, wide, and projects up to 1.5 mm beyond the hinge line. The median lobe is divided internally with the longitudinal groove. The alveolus is developed at the base of the cardinal process. The cardinal ridge is well developed but flattens out at the lateral ends. The median septum is long and almost reaches the disc margins. The posterior adductors are large and branched and the anterior adductors are absent.

Comparison. The new species differs from *L. riparius* in the longitudinally elongated shell, steeper and almost not diverging lateral slopes, well-developed third row of spines on the ears, coarser ribs, and slightly thicker (up to 1 mm) spines.

Remarks. The outline and transverse profile of the ventral valve of *Linispinus longus* are highly variable. Therefore, it is hard to isolate at the species level the forms with wider and more flattened venter of the ventral valve (sometimes even with the sulcus primordium) from the forms with a dome-shaped venter. In shell outline and shape the former are closer to *L. neffedievi* (Vern.) sensu Ivanov (1935) and the latter are closer to *L. ovalis* Ivanov. Ivanov believed that *L. neffedievi* is limited to the Podolskian deposits of the Moscow Region. Lately Ivanova (1949) broadened its distribution to the Kashirskian and Myachkovskian deposits. She also noted (Ivanova, 1958, p. 109) that *L. neffedievi* and *L. ovalis* are probably the same species.

After Volgin (1960, p. 77) selected a specimen from the Vereiskian (Ordynskii) deposits of the Moscow Region (Sokolova Pustyn') as a lectotype of *L. ovalis*, the sense of the "ovalis" species became uncertain. The

point is that the lectotype is represented by the internal mold of the ventral valve and thus the thickness of spines in different parts of the valve and number of rows of spines on the ears are unknown.

Occurrence. Middle Carboniferous, Moscovian, Kashirskian Substage, Lopasnya Formation; Moscow Region.

Material. About 40 specimens from the Lopasnya Formation: about 30 specimens from the localities in the lower reaches of the Kashirka River and on the Oka River near the mouth of the Kashirka River, 6 specimens from the quarry at the town of Zaraisk, and a few specimens from other localities.

***Linispinus staricensis* (Ivanov, 1935)**

Plate 10, figs. 17–26

Linoproductus staricensis: Ivanov, 1935, p. 43 (pars), pl. 8, figs. 10 and 12.

Linoproductus aff. *ufensis*: Ivanov, 1935, p. 45, pl. 7, figs. 6 and 7.

Linoproductus simensis: Ivanova, 1949, pl. 20, fig. 2.

Linoproductus riparius: Ivanova, 1958, pl. 16, fig. 2.

Holotype. Not selected. A lectotype is designated here: PIN, no. 132/3038, ventral valve, Volga River, town of Staritsa; Middle Carboniferous, Moscovian, Kashirskian Substage, Smedva Formation.

Description. The shell is variously shaped. The corpus is 2–3 cm wide. The ventral valve is inflated in the umbonal region, with steep and slightly diverging lateral sides that may slightly converge anteriorly to give the shell an egg-shaped appearance. The venter is sometimes slightly flattened. The sulcus is absent. The apical angle is about 90°. The hinge line is slightly shorter than the maximum width that is in the middle of the shell. The cardinal angle is slightly more than 90°. The dorsal disc is slightly concave, with the width slightly exceeding its length (2.0 cm, $n = 1$). In some longitudinally elongated and relatively small forms the correlation is probably opposite.

The ribbing of the ventral valve is coarse, and regular except for the bases of the spines. There are 8 ribs per 5 mm on the disc, 7–8 ribs on the trail, and anteriorly often 6–7 ribs on the trail. Usually the trail bears 7 ribs per 5 mm. The concentric ornamentation is developed only at the bases of lateral slopes and on the ears up to the bases of spines. In the dorsal valve, the concentric rugae cross the whole valve only in the bend to the trail ($n = 1$). The ears bear two well-developed and slightly diverging rows of spines. One or two additional spines may appear between the rows of spines or in front of them (Pl. 10, figs. 19, 20). As the rows of spines are slightly diverging (slightly deviating from the hinge line), the anterior part of the ears usually lacks spines. The trail usually bears three or four spines 1–1.3 mm in diameter.

The cardinal process is trifid and is located on the horny thickening. The alveolus may be absent. The cardinal ridge is well developed. The posterior adductors are branched. Other features are unknown.

Comparison. The new species distinctly differs from the other species in the uniformly coarse ribbing on the trail (about 7 ribs per 5 mm) and the ribs curving near the relatively thick spines on the trail.

Remarks. The ancestor of *L. staricensis* was probably *L. longus*, which is unknown in the Smedva time. The latter species gave rise to *L. staricensis* with the tendency to coarser ribs and partial reduction of the third row of spines on the ears and to the new Podolskian species that will be described later, and is characterized by the opposite tendency to less coarse ribs and denser spines on the ears. The Smedva time is the period when both ribs and spines in members of the new genus reached their maximum thickness.

Occurrence. Middle Carboniferous, Moscovian, Kashirskian Substage, Smedva Formation; Moscow Region.

Material. In addition to the type specimens discussed in Ivanova's paper (1935), 17 specimens from the Staritsa locality and 5 specimens from the Kholokhol'nya locality (ventral valves and one dorsal valve).

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