

Microornamentation of *Lioestheria*, *Mimoleaia*, and *Echinolimnadia* (Conchostraca) from the Terminal Permian of Siberia

E. F. Orlova and G. N. Sadovnikov

Moscow State Geological Prospecting University, ul. Miklukho-Maklaya 23, Moscow, 117997 Russia

Received May 15, 2003

Abstract—Previously unknown minute ornamentation patterns of conchostracans are described based on SEM investigation of several collections from the terminal Permian volcanic deposits of the Tunguska Syncline. *Lioestheria* (Lioestheriidae) shows ovaly elongated cells arranged in rows along the growth bands, *Mimoleaia* (Leaiidae) has large polygonal cells with double walls, and *Echinolimnadia* (Echinolimnadiidae fam. nov.) displays a pattern with small polygonal cells bearing small spines along their walls. Diagnoses of genera and species are refined. New data about their distribution are presented.

DOI: 10.1134/S0031030106030075

Key words: Conchostraca, microornamentation, Taimyrian Stage, terminal Permian, Siberia, Russia.

INTRODUCTION

The minute ornamentation of growth bands in conchostracans was already noted in many early studies of the group. But only Novojilov (1952a, 1952b, 1960b) systematized the available data, described several new types and varieties of microornamentation, noted its taxonomic significance, and included the characterization of microornamentation into diagnoses of all families. Microscopic preparation and production of acetate peels made data on the microornamentation available for mass material (Orlova, 1978, 1990), and the SEM study of conchostracans revealed details of several microornamentation types, thus showing that microornamentation may be useful for genus-level identification (Orlova, 1991).

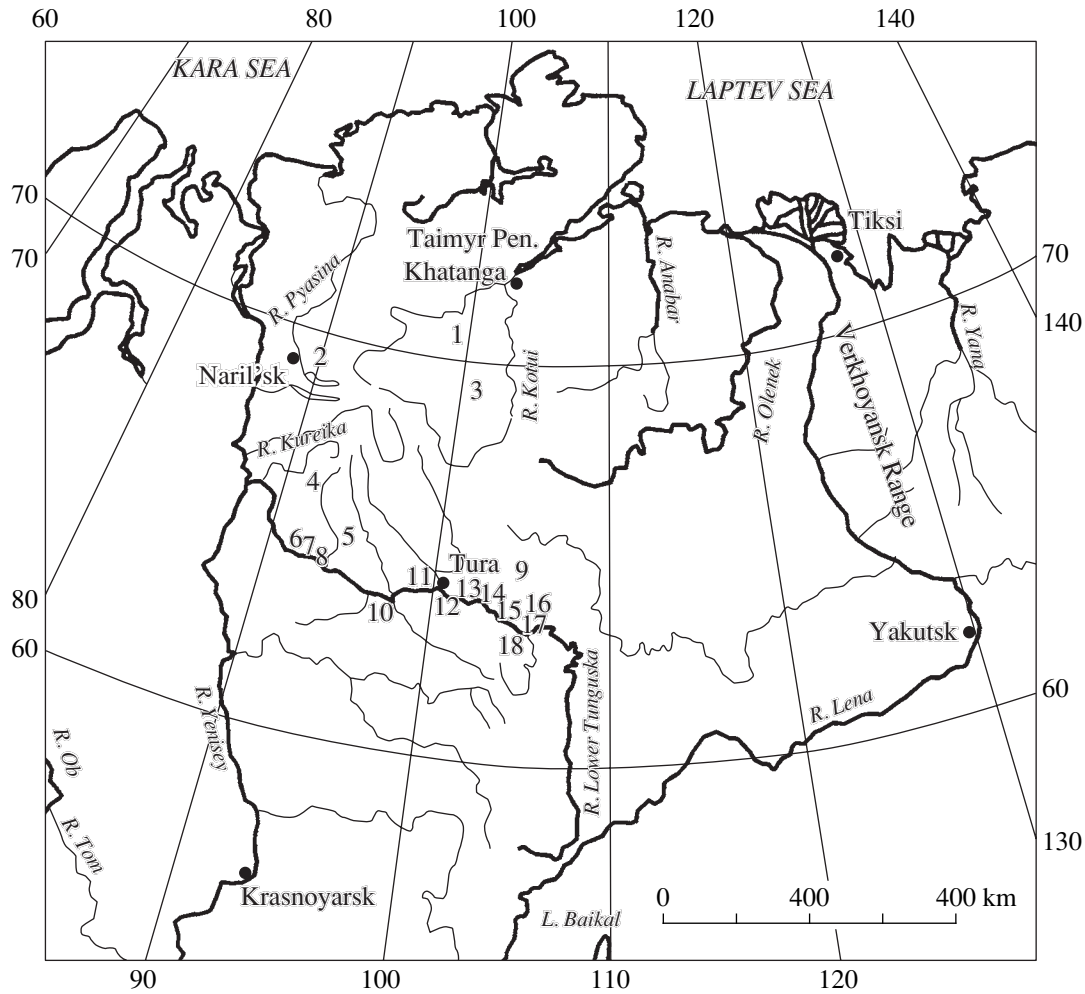
Conchostracans were for the first time found in volcanic deposits of the terminal Permian of Siberia in 1931 by G.V. Uspenskii, who took them for bivalve mollusks. In 1936, L.M. Shorokhov, S.M. Fleishman, and E.N. Freiberg collected conchostracans on the Lower Tunguska River, at the mouth of the Khungtukun River. Lutkevich (1938) identified in this collection *Estheria gutta* Lutk., *E. aequalis* Lutk., *E. subcircularis* Chern., and described the new species, *E. evenkiensis* and *E. tungussensis*. Lutkevich referred to the microornamentation of all these species as finely punctate. Its details were not studied and described. In the revision of the Tungus conchostracans Novojilov (1958) placed *Estheria evenkiensis* in the genus *Lioestheria* and described the microornamentation of *L. evenkiensis* as finely cellular.

The genus *Lioestheria* has an extremely wide stratigraphic distribution from the Devonian up to the Cretaceous. It is known from the equatorial (France), north-

ern (cis-Ural Region, Siberia, Kazakhstan, Mongolia), and southern (Australia) extratropical regions. In the Tunguska Basin, *L. blomi* Nov., *L. ignatjevi* Nov., *L. kostromiana* Nov., *L. propinqua* Nov., and *L. toricata* Nov. are recognized in addition to *L. evenkiensis*.

In the Upper Permian of central Siberia, *L. evenkiensis* is typical of the third, and present in the second and fourth conchostracan assemblages (Orlova, 1999). It is found in the localities Gagarii, Moldaul (the lower Korvunchan Group, Tatarian Stage), Khungtukun-3 and Khungtukun-4, Delimekit-2 (Pirda Formation of the Korvunchan Group, *Mimoleaia mitchelli-Takhtajanodoxa mirabilis* Zone, Taimyrian Stage), Irgakta Yar (Agitkan Formation of the Putorana Group, *Falsisca turaica-Quadrocladus pachyphyllum* Zone, Taimyrian Stage) (figure: 10–12, 15, 17) (Sadovnikov and Orlova, 1990, 1994a, 1994b, 1995, 1998, 1999). Besides the Tunguska Basin and adjacent areas, *L. evenkiensis* is known in the Permian–Triassic Charkabozh Formation of the Pechora Basin (*Resolution...*, 1982).

Lioestheria evenkiensis always co-occurs with other conchostracans, of which *Limnadia vana* Nov., *Rohdendorfiium (Bipemphigus) gennisi* (Nov.), and *Falsisca turaica* Nov. or *F. zavjalovi* Nov. always occur; *Echinolimnadia mattoxi* Nov., *Eulimnadia shorokhovi* Nov., *Cyclotunguzites gazimuri* (Nov.), *Ragozinia leonidi* (Nov.), and *Loxomicroglypta subcircularis* Chern. occur frequently; and *Pseudestheria (P.) novacastrensis* (Mitch.), *Cyclotunguzites mezenensis* Mol., *Glyptoasmussia belmontensis* (Mitch.), *Trigonestheria permiana* (Nov.), *Estheriina aequalis* (Lutk.) (Moldaul), *Sphaerestheria sibirica* Nov. (Khungtukun-3), *Sphaerestheria* sp., and *Notocrypta begitchevi* (Nov.) occur sporadically.



Map of localities of conchostracans. (1) Balagannakh, (2) Noril'sk, (3) Shchadrinka-1, (4) Aldakel, (5) Bugarikta-1, (6) Nizhnyaya Bugarikta-3, (7) Nizhnyaya Bugarikta-2, (8) Nizhnyaya Bugarikta-1, (9) Untun-2, (10) Gagarii, (11) Irgakta Yar, (12) Delimekit-2, (13) Yastrebok-2, (14) Khungtukun-2, (15) Khungtukun-3, 4, (16) Khoorki-1, (17) Moldaul, (18) Iritka-3.

The microornamentation of *L. evenkiensis* has been examined under an SEM microscope using material from localities Irgakta Yar and Moldaul. It is of the cellular type both in larval valves and on growth bands. Cells are fine, usually oval (Pl. 6, figs. 1, 3–5), less often rounded (Pl. 6, fig. 2). The diameter of isodiametric cells is 3.5–5.5 μm ; that of the cells' internal cavity, 2.5–4.5 μm . The elongated cells are 6 to 18 μm (typically 10–12 μm) long and 4 to 14 μm (typically 6–12 μm) wide. The internal cavities of cells are 4–7 μm long and 2.5–5.5 μm wide. Cells are usually 1.3–1.6 times as long as wide. There is an alternation of bands composed of smaller, more elongated cells (6 \times 10 μm) and larger isodiametric cells (10 \times 12 μm). It points to a change in the diameter of cells in different parts of the growth band (Pl. 6, figs. 1, 2a, 3a, 4a). The diameter apparently increases toward the external edge of a growth band. Cells are usually arranged in rows parallel to growth bands with their long axis directed

along bands (Pl. 6, figs. 1, 2a, 3a, 4). Cells alternate in neighboring rows of the form columns typically running obliquely to growth bands but sometimes being almost perpendicular to them. In this case, longitudinal cell rows are not clearly manifested (Pl. 6, fig. 2b). The microornamentation is often absent or poorly expressed on growth bands (Pl. 6, figs. 2a, 3a, 4a). The larval valve bears slightly more isodiametric cells 6–10 μm long and 5–8 μm wide. Their length is no more than 10% greater than their width (Pl. 6, fig. 4). The walls of cells are not clearly delimited; thus, their thickness cannot be measured precisely. It is less than or nearly equal to the diameter of the cell cavity and makes 0.5–3 μm . Sometimes, along with typical cells, much smaller cells with a diameter of 1.5 μm are observed (? pores) (Pl. 6, fig. 1b).

Leaids in Permian volcanic deposits of the Siberian Platform were first discovered by V.A. Khakhlov (personal communication). He reported *Leaia tricarinata* Meek et Worth from the Norilsk Region. This material

was not described and illustrated; therefore, there is no reason to follow the species determination by Khabkhlov. However, there is hardly any doubt that this find really does represent leaiids and, probably, the genus *Mimoleaia*, the type species of which, *Leaia tricarinata*, was later found in this area.

In 1959, V.P. Belozarov collected on the Lower Tunguska River, downstream from the settlement of Tutonchany (figure: 5–8) spheroidal particles, which he took for lapilli. G.N. Sadovnikov revised the material and re-determined it as carbonate concretions nearly always containing remains of conchostracans. These samples and numerous additional collections made by Belozarov and Sadovnikov (1962) have been sent to Novojilov. He described from this material *Mimoleaia belozerovi* Nov., *M. juonae* Nov., *M. mitchelli* (Ether.), *Leaianella paraleidy* (Mitch.), *Teiichium sibiricum* (Nov.), and also *Echinolimnadia mattoxi* Nov., *Cycles-theria detykteica* Nov., *Tripemphigus sibiricus* (Nov.), *Limnadia pygmaea* Nov., and *L. gennadyi* Nov. Later, he partly transferred the latter species to *Megasitum gennadyi* (Nov.), and partly to *Falsisca kanandensis* Nov. The microornamentation of *Mimoleaia* he referred to as fine cellular (Novojilov, 1965a, 1965b). Later, Jones and Chen (2000) have transferred *Mimoleaia mitchelli*, including the specimens illustrated by Novojilov from the Lower Tunguska River, into the genus *Hemicycloleaia*, and synonymized the entire genus *Mimoleaia* under *Hemicycloleaia*, which Tash (1958) in turn considered a synonym of *Leaia*. These actions seem not to have been quite grounded; therefore, we preserve the name *Mimoleaia* for forms with clearly angular valves.

The listed sites are confined to the lower part of the Bugarikta Formation (*Mimoleaia mitchelli*–*Takhtajanodoxa mirabilis* Zone, Taimyrian Stage) (Belozarov and Sadovnikov, 1962; *Geological Map...*, 1981, 1991).

Later, Novojilov determined *Mimoleaia mitchelli* (Ether.) in the Aldakel locality (figure: 4) together with *Echinolimnadia mattoxi* Nov., *Polygrapta laptevi* Nov., and *P. necta* Nov. The two latter species are synonyms of *Rohdendorffium (Bipemphigus) gennisi* (Nov.) (Orlova, 1990). E.F. Orlova determined numerous *Mimoleaia mitchelli* (Ether.) vel *belozerovi* Nov. in the Shadrinka Formation (Shchadrinka-1, figure: 3) in combination with numerous *R. (B.) gennisi* and a single *Limnadia* sp. In the collection of Sadovnikov from the Balagannakh locality discovered by Obonitskaya in 1978, Orlova determined *Mimoleaia* cf. *belozerovi* Nov. together with abundant *R. (B.) gennisi* and sporadic *Tripemphigus hovorkiliensis* Nov. Similarly, the underlying bed of this locality yielded, along with mass *R. (B.) gennisi*, individual *Falsisca turaica* (Nov.). In the collection of V.M. Chalisova from the site Khoorki-1 (figure: 16), Novojilov determined *Mimoleaia* sp., *Hemicycloleaia* sp., *Kaltanleaia* sp. together with *Falsisca turaica* (Nov.), *Megasitum harmonicum* Nov., Lioestheriidae, and Bairdestheriidae; and in the collec-

tion of V.P. Petrov and Yu.I. Ponomarev from the locality Yastrebov-2, *Hemicycloleaia intermediata* (Mitch.).

Leaiids are particularly characteristic of the third conchostracan assemblage of the Siberian Platform (Orlova, 1999). All localities with leaiids are associated with the Korvunchan Group (mainly its upper part) and the lower Putorana Group and belong almost exclusively to the *Mimoleaia mitchelli*–*Takhtajanodoxa mirabilis* Zone of the Taimyrian Stage (Sadovnikov and Orlova, 1990, 1994a, 1994b, 1995, 1998, 1999). Some of the species of Leaiidae listed are local, others are described from upper parts of Upper Permian deposits of the Pechora Basin (Molin et al., 1982; Strok et al., 1984; *Resolution...*, 1990; *Stratigraphical Dictionary...*, 1991) and Australia (Etheridge, 1892; Mitchell, 1925, 1926; Tash, 1979; Tash and Jones, 1979; Jones and Chen, 2000).

Contrary to the cellular microornamentation of Limnadiidae and Lioestheriidae and, especially the striated-costate microornamentation of Bairdestheriidae, which are frequently observed and quite often clearly visible even under a light microscope (Orlova, 1978, 1990), the microornamentation of Leaiids is visible only under a scanning electron microscope and it is extremely rare (Orlova, 1991). Probably, it is caused by a multilayered shell structure (Pl. 7, figs. 2): the sculpture in leaiids is expressed only in one (likely, external) infrequently and poorly preserved layer, whereas, for example, in *Rohdendorffium (Bipemphigus)* all shell layers are sculptured (Orlova, 1990).

Of the Siberian Permian leaiids, it was only possible to study the microornamentation of *Mimoleaia mitchelli* (Ether) from the locality Nizhnyaya Bugarikta-1. Novojilov referred to the microornamentation of leaiids, as well as lioestherids, as fine cellular. However, leaiids have a type quite distinct from lioestherids, namely, coarsely reticulate. Cells of the grid are square to hexagonal, most typically pentagonal, nearly identical in different parts of the shell, with a length of 27–56 μm (usually about 40 μm) and width of 36–90 μm (usually about 55 μm) (Pl. 7, figs. 1, 3). Thus, both in shape and size of cells the sculpture differs strongly from that of *Lioestheria*. Cells at the ventral margin of the valve are more isodiametric (Pl. 7, figs. 3). The ratio of the cell length to its width at the ventral margin is 1–1.6 (on average, 1.3); and in the central part of the valve, 1–2.5 (average 1.4). The thickness of the cell wall is much less than the internal diameter of the cell and makes 2.5–9.5 μm . A magnification of more than $\times 200$ sometimes reveals the two-layered structure of the cell wall (Pl. 7, figs. 3). The width of each layer is 1–2 μm , distance between them, up to 1.5 μm . Internal layers are round in cell corners, making the wall thicker (Pl. 7, figs. 3b). At a magnification more than $\times 2000$, both the walls and inner spaces of cells show minute (0.7–0.9 μm) pitted microornamentation (microstructure?) (Pl. 7, figs. 4, 5).

The genus *Echinolimnadia*, with only one species *E. mattoxi*, was described by Novojilov (1965b) based

on material of Belozherov and Sadovnikov from the same localities near the Tutonchany settlement. Subsequently, Novojilov and Orlova reported this species from localities Aldakel, Khoorki-3, Khungtukun-2, 3 (mentioned above), Delimekit-2, Iritka-3, and Untuun-2. *Echinolimnadia* co-occurs with *Limnadia vana* Nov.; less frequently with *Lioestheria evenkiensis* (Lutk.) and *Rohdendorffium (Bipemphigus) gennisi* (Nov.); sometimes with *Limnadia glabra* (Mitch.), *L. kastiana* Nov., *L. maichatica* Nov., *L. pygmaea* Nov., *Falsisca kanandaensis* Nov., *F. turaica* Nov., *Tripemphigus sibiricus* (Nov.), *Eulimnadia shorokhovi* Nov., *Cyclotunguzites gazimuri* (Nov.), and *Sphaerestheria sibirica* Nov.

All sites with *E. mattoxi* belong to the Taimyrian Stage; Untuun-2 belongs to the *Falsisca turaica-Quadrocladus pachyphyllum* Zone (Agitkan Formation, Putorana Group), the others to the *Mimoleaia mitchelli-Takhtajanodoxa mirabilis* Zone (Pirda and the lower Bugarikta Formation of the Korvunchan Group) (Sadovnikov and Orlova, 1990, 1994a, 1994b, 1995, 1998, 1999). Outside the Tunguska Basin, the genus *Echinolimnadia* is reported from the Admiralteiskaya Formation of Novaya Zemlya along with abundant marine bivalves *Liebea septiger* Tchern. (*Resolution...*, 1990). At least some conchostracans described by Tchernyshev (1934) from the Mal'tsevo Group of the Kuznetsk Basin as *Praeleaia triasiana* Tchern. and then allocated by Novojilov to the genus *Lioleaiina* have radial rows of tubercles (apparently, bases of spines) on the shell and may belong to *Echinolimnadia*.

Microornamentation of *Echinolimnadia* has been examined under an electron microscope using material from the type locality Nizhnyaya Bugarikta-1. It is of the cellular type. Cells are small, irregular penta- or hexagonal, about 10 µm in diameter, isodiametric or very slightly elongated. Length usually exceeds width insignificantly, much more rarely up to 1.5 times. The wall thickness is 1–1.5 µm. Walls of cells on the valve surface bear fine tubercles-spines (corresponding to the apertures on the internal side) that form margins around polygons (Pl. 7, fig. 7).

These observations allow the description of a new family, Echinolimnadiidae, and amendment of the diagnoses of species and genera.

MATERIAL

The specimens here described are housed in the Paleontological Institute of the Russian Academy of Sciences (PIN), collection no. 5091.

SYSTEMATIC PALEONTOLOGY

Superfamily Cyzicoidea Stebbing, 1902

Family Lioestheriidae Raymond, 1946

Genus *Lioestheria* Depéret et Mazeran, 1912

Lioestheria: Depéret and Mazeran, 1912, p. 167; Raymond, 1946 (partim), p. 231; Kobayashi, 1954 p. 131; Novojilov, 1953, p. 1207; 1954b, p. 45; 1959, p. 95; 1960a, p. 240; 1961, p. 44; 1965a, p. 20; Novojilov, 1958, p. 29; Novojilov and Kapel'ka, 1960,

p. 180; Kapel'ka and Novojilov, 1962a, p. 380; 1962b, p. 22; Molin, 1964, p. 77; 1965a, p. 79; 1965b, p. 64.

Estheria (pars): Lutkevich, 1938, p. 160; 1941, p. 10; Novojilov, 1946, p. 180.

Isaura: Raymond, 1946, p. 233 (partim).

Type species. *L. lallyensis* Depéret et Mazeran, 1912; Lower Permian red beds of France.

Diagnosis. Carapace flat, oblong. Dorsal margin expressed only behind larval valve. Anterior part high, posterior part low. Height of valves about two-thirds of their length. Posterodorsal angle absent. Microornamentation of fine oval or rounded cells, closely contacting each other, with rather wide walls.

Species composition. Twenty-seven species: *L. asiatica* Nov., *L. crassa* (Lutk.), *L. pseudolallyensis* Nov. (Devonian of European Russia and Kazakhstan), *L. hakassica* (Nov.), *L. canadensis* Nov. (Devonian of Khakassia and North America), *L. matiewi* Pruv., *L. striata* (Goldf. et Munst.) (Carboniferous of western Europe), *L. cicatricosa* (Lutk.), *L. ellipsoidalis* Nov. et Kap., *L. evenkiensis* (Lutk.), *L. nidymensis* Nov., *L. simplex* Molin, *L. toricata* (Nov.) (Permian of European Russia and Siberia), *L. raashi* Raym. (Permian of the United States), *L. kubaczeki* (Voltz), *L. lallyensis* Depéret et Mazeran (Permian–Triassic of Europe and Siberia), *L. blomi* Nov., *L. jaroslavensis* Nov., *L. quellaensis* Nov., *L. ignatievi* Nov., *L. kostromiana* Nov., *L. angularis* Nov., *L. propinqua* Nov. (Triassic of European Russia and Siberia), *L. inornata* Raym. (Triassic of the United States), *L. kidoi* (Kob.) (Triassic of Japan), *L. shimamurai* (Kob.) (Triassic of Siberia and Japan), *L. imperfecta* Nov. (Cretaceous of Mongolia).

Comparison. The new form differs from the genus *Cornia* in the absence of a convexity reaching from the larval valve to the posterodorsal sector and in the higher anterior part of the shell, whereas *Cornia* has a higher posterior part. From the other genera it differs in the dorsal margin, which is not expressed in front of the larval valve.

Lioestheria evenkiensis (Lutkevich, 1938)

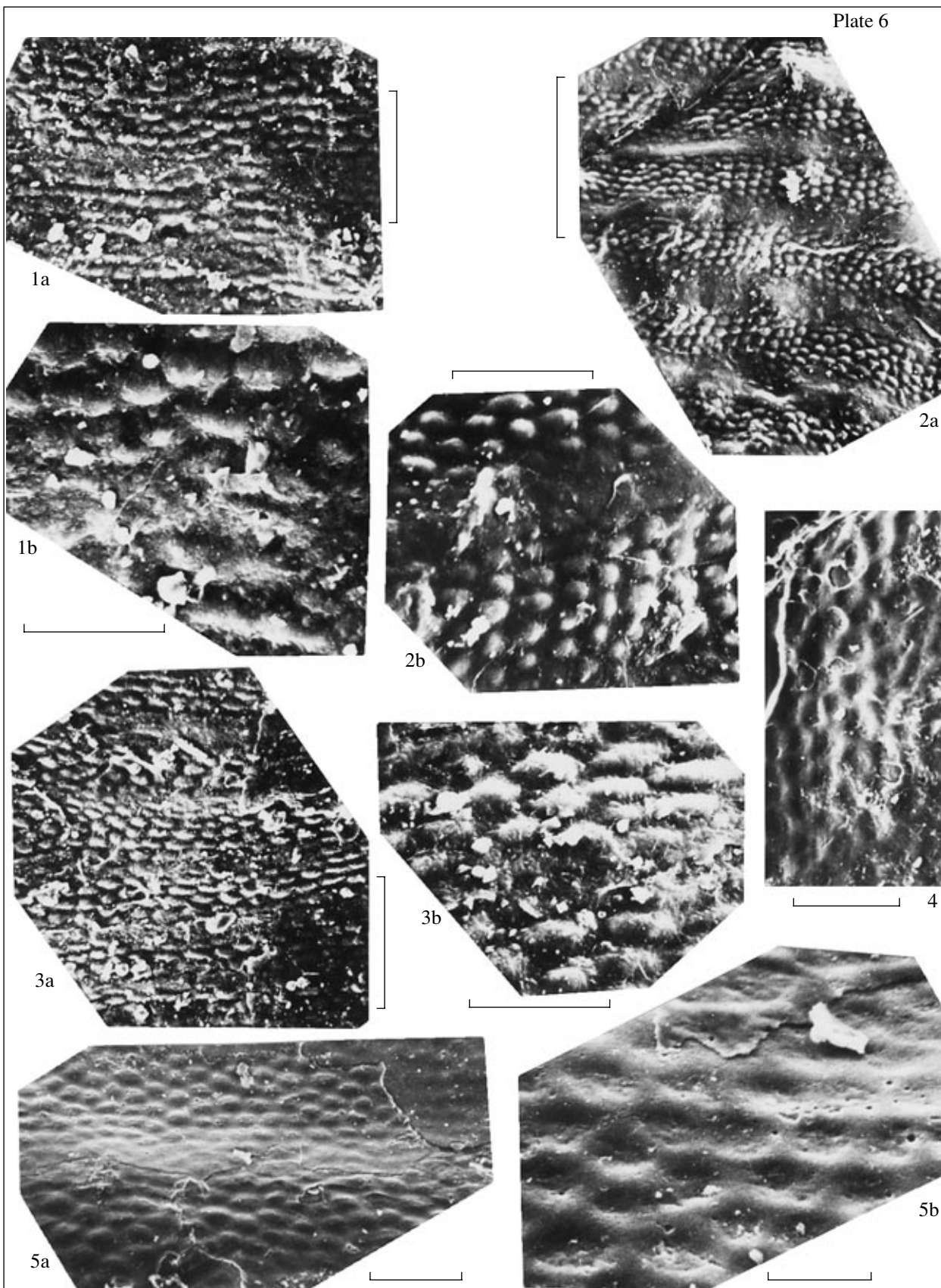
Plate 6, figs. 1–5

Estheria evenkiensis: Lutkevich, 1938, p. 160, pl. 1, figs. 12–14.

Lioestheria evenkiensis: Novojilov, 1958, p. 31, text-fig. 25.

Holotype. The specimen illustrated by Lutkevich (1938, pl. 1, figs. 12–14); Lower Tunguska River, the right bank 3–4 km upstream from the mouth of the Khungtukun River; Taimyrian Stage, Upper Permian.

Description. The carapace is ovate, elongated. The larval valve is small, shifted anteriorly. The dorsal margin is shorter than half of the valve length. The height/length ratio of valves is near three-quarters. The microornamentation is cellular. The cells are oval in cross section, less often rounded, 4–18 µm in size, located in concentric rows along growth bands in alternating order between neighboring rows. The internal



spaces of cells are approximately equal in width to inter-cell distances (walls?).

Measurements. Length, 2.8–3.4 mm; height, 2.4–2.8 mm.

Comparison. Anteriorly shifted larval valve, except for this species, is typical of *L. jaroslavlensis* and *L. nidymensis*. *L. evenkiensis* differs from the former species in the absence of convexity near the apex, and from the latter, in the higher shell, more strongly curved anterior side, and smaller larval valve.

Occurrence. Tatarian and Taimyrian stages of the Tunguska and Pechora basins.

Material. More than 170 specimens from sites Gagarii, Moldaul, Khungtukun River-3, Khungtukun River-4, Delimekit-2, and Irgakta Yar.

Superfamily Leaiioidea Raymond, 1946

Family Leaiidae Raymond, 1946

Genus *Mimoleaia* Novojilov, 1954

Leaia: Meek and Worthen, 1868, p. 441; White, 1883, p. 167; Pruvost, 1914, p. 265; 1919, p. 67; Mitchell, 1925, pl. 41, 42; Chernyshev, 1934 (partim), pl. 1, fig. 8 (below); Vangerow, 1954, p. 1605; Tash, 1958, p. 1099.

Hemicycloleaia: Raymond, 1946, p. 288; Jones and Chen, 2000, p. 230.

Mimoleaia: Novojilov, 1954a, p. 1242; 1956, p. 60; 1965b, p. 55.

Type species. *Leaia tricarinata* Meek et Worthen, 1868; Upper Carboniferous of the United States.

Diagnosis. Carapace with two radial carinae, sometimes with additional carina along dorsal margin, with more or less angular posterior part and rounded anterior sector. Microornamentation coarsely reticulate. Cells of grid angular, square to hexagonal, typically pentagonal. Internal spaces of cells much wider than their very thin walls.

Species composition. Twelve species: *M. tricarinata* Meek et Worthen, *M. minima* (Pruvost), *M. asiatica* Nov., *M. boltoni* (Raymond), *M. normalis* (Raymond) (Carboniferous of Europe and the United States), *M. karagandica* Nov. (Carboniferous of Kazakhstan), *M. rossica* Nov. (Permian of European Russia), *M. belozeroi* Nov., *M. inusitata* Nov., *M. magnifica* Nov. (Permian of Siberia), *M. mitchelli* (Etheridge) (Permian of Australia and Siberia), and *M. ovata* (Mitch.) (Permian of Australia).

Comparison. The genus is distinct in the weakly expressed angularity of the valves and the anterior sector being always rounded rather than angular.

Mimoleaia mitchelli (Etheridge, 1892)

Plate 7, figs. 1–5

Leaia mitchelli: Etheridge, 1892, p. 307; Mitchell, 1925, pl. 41, figs. 1, 2.

Mimoleaia mitchelli: Novojilov, 1956, pl. 11, figs. 3; 1965b, pl. 6, figs. 1–3.

Hemicycloleaia mitchelli: Jones and Chen, 2000, text-fig. 7h (non text-figs. 7a–7g, 7i, 7k).

Holotype. The specimen illustrated by Mitchell (1925, pl. 41, figs. 1, 2); Australia, New South Wales; Upper Permian, Belmont Beds.

Description. The carapace bears two radial carinae. The anterior and posterior valves are of equal height. The posterodorsal angle is close to 90°. The maximal curvature of the anterior margin is above its midpoint. The dorsal margin is either weakly or not thickened. The carinae are straight and equally wide. Their angles with the dorsal margin are 80°–85° and 37°, respectively. The microornamentation is coarsely reticulate. Cells are square to hexagonal, more often pentagonal, almost isodiametric, about 40 μm long and about 55 μm wide. The thickness of cell walls is much less than the internal diameter of cell.

Measurements. Length, 5.4–7.5 mm; height, 3.8–4.8 mm.

Comparison. From the related *M. belozeroi* and *M. ovata* this form differs in the position of the curvature of the anterior margin above its midpoint; from *M. boltoni* and *M. normalis*, in a convex posterior margin; from other species, in a straight anterior carina.

Distribution. Tatarian and Taimyrian stages of the Tunguska and Pechora basins.

Material. More than 65 specimens from localities Aldakel-1, Balagannakh, Bugarikta-1, Nizhnyaya Bugarikta-1, 2, 3, Khoorki-1, Shchadrinka-1, and Yas-trebok-2.

Family Echinolimnadiidae Orlova, fam. nov.

Type genus. *Echinolimnadia* Novojilov, 1965.

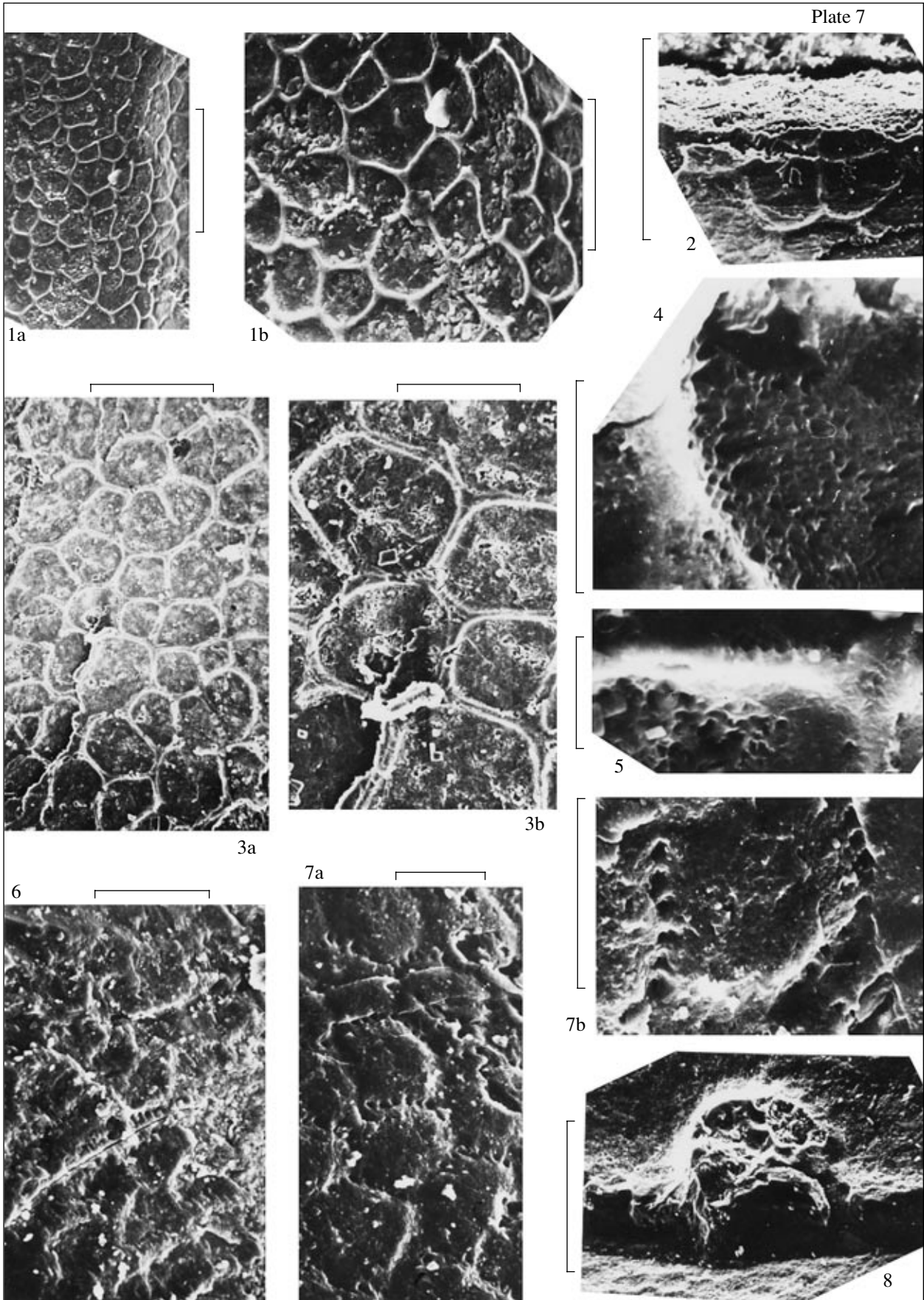
Diagnosis. Conchostracans with radial rows of spines, large larval valve and polygonal-cellular microornamentation with wide cell inner spaces and narrow walls with numerous small spines.

Composition. Type genus.

Comparison. Radial rows of spines or tubercles are known in the genus *Igorvarentsovia* Novojilov placed in the family Leaiidae. Similar structures are observed at least in some specimens from the Kuznetsk Basin, referred to *Leaianella triasiana* (Tchern.). The microornamentation of the former genus is insuffi-

Explanation of Plate 6

Figs. 1–5. *Lioestheria evenkiensis* (Lutkevich); (1) specimen PIN, no. 5091/1, oval cells of the posterior part of valve; (2) specimen PIN, no. 5091/1, oval and rounded cells on growth bands; (3) specimen PIN, no. 5091/1, oval cells of posteroventral part of shell; (4) specimen PIN, no. 5091/2, oval cells near the growth band; (5) specimen PIN, no. 5091/2, oval and rounded cells of larval valves; (1–3, 5) Moldaul; Khungtukun or Putorana horizons, Taimyrian Stage; (4) Irgakta Yar; lower Putorana horizon, Taimyrian Stage, Irgakta Formation. Scale bars 10 μm in Figs. 1b, 2b, 3b, and 5b; 35 μm in Fig. 4; 50 μm in Figs. 1a, 3a, 5a; and 100 μm in Fig. 2a.



Explanation of Plate 7

Figs. 1–5. *Mimoleaia mitchelli* (Etheridge); (1) specimen PIN, no. 5091/3, reticulate microornamentation of the central part of shell; (2) specimen PIN, no. 5091/3, shell on a fracture; (3) specimen PIN, no. 5091/3, reticulate microornamentation of ventral part of shell; (4, 5) specimen PIN, no. 5091/3, thin microornamentation (a microstructure?) in the central part of shell; Nizhnyaya Bugarikta-1, Khungtukun Horizon, Taimyrian Stage, lower parts of the Bugarikta Formation.

Figs. 6–8. *Echinolimnadia mattoxi* Novojilov; (6, 7) specimen PIN, no. 5091/4, polygonal microornamentation; (8) specimen PIN, no. 5091/5, base of a spine on the distal side of a growth band. Locations and age are the same. Scale bars 1 μm in Fig. 7; 10 μm in Figs. 2, 6, 8–10; 50 μm in Figs. 5 and 11; and 100 μm in Figs. 1, 3, and 4.

ciently known. It resembles the microornamentation of leaiids but may turn to be closer to echinolimnadiids. Features of sculpture and microornamentation of the genus are sufficient for allocation of a new, so far monotypic, family. Other genera with radial spine rows may be included into the genus after their microornamentation has been studied in sufficient detail.

Genus *Echinolimnadia* Novojilov, 1965

Echinolimnadia: Novojilov, 1965b, p. 54; 1970, p. 132.

Type species. *Echinolimnadia mattoxi* Novojilov, 1965.

Diagnosis. Dorsal margin long, archlike. Larval valves large. Distal margins of growth bands with spines forming several radial rows. Microornamentation of cellular type. Cells fine, usually hexagonal, with wide inner spaces and narrow walls carrying small spines.

Species composition. Type species.

***Echinolimnadia mattoxi* Novojilov, 1965**

Plate 7, figs. 6–8

Echinolimnadia mattoxi: Novojilov, 1965b, p. 54, pl. 4, figs. 1–6; pl. 5, figs. 1–4; 1970, p. 132, fig. 118, pl. 5, figs. 1–8.

Holotype. The specimen illustrated by Novojilov (1965b, pl. 4, fig. 1); Lower Tunguska River, right bank at the mouth of the Nizhnyaya Bugarikta River; Taimyrian Stage, Upper Permian.

Description. The distal margins of growth bands bear spines forming six radial rows, one of which runs along the dorsal margin. The cells are of hexagonal or rarely pentagonal shape, about 10 μm in diameter, isodiametric or just slightly elongated. The length is less than half again the width. The wall is 1–1.5 μm thick.

Measurements. Length, 4.2–6.0 mm, height, 2.6–3.4 mm.

Occurrence. Taimyrian Stage of the Tunguska and Kuznetsk basins and Novaya Zemlya.

Material. More than 350 specimens from sites Aldakel-1, Bugarikta-1, Delimekit-2, Iritka-3, Nizhnyaya Bugarikta-1, 2, 3, Untuun-2, Khoorki-3, and Khungtukun-2, 3, 4.

CONCLUSIONS

Detailed study of the microornamentation patterns in the conchostracans of Siberia, including the use of acetate peels and SEM microscopy, allowed us to add

new features to the characterization of taxa. The genus *Lioestheria* and species *L. evenkiensis* show elongated oval cells arranged in rows parallel to growth bands; the genus *Mimoleaia* and species *M. mitchelli* display a pattern with large polygonal cells with double walls; the genus *Echinolimnadia* and species *E. mattoxi* show fine polygonal cells with numerous small spines along their walls. The latter genus has been placed in a separate family, Echinolimnadiidae fam. nov.

APPENDIX**LOCATION OF SITES WITH CONCHOSTRACANS**

Sites are listed in alphabetic order. Numbers in parentheses correspond to numbers in Fig. 1. Locations are followed by names of discoverers and year of discovery.

Aldakel (4), the western slope of the Aldakel Range, on the water divide between the upper reaches of the Tutonchana and Severnaya rivers (I.M. Malovetskaya, 1963); Balagannakh (1), the right bank of the lower reaches of the Maimecha River opposite the mouth of the Balagannakh River (E.K. Obonitskaya, 1978); Bugarikta-1 (5), Bugarikta River (1 km from the mouth), the left-bank tributary of the Tutonchana River, 30 km from the mouth (V.P. Belozarov and G.N. Sadovnikov, 1959); Gagarii (10), the left bank of the Lower Tunguska River, opposite Gagarii Island, 22 km downstream from the mouth of the Taimura River (L.M. Shorokhov, 1936); Delimekit-2 (12), the left bank of the Lower Tunguska River, 1.5 km downstream from the mouth of its right-bank tributary, the Delimekit River, about 100 km upstream from the Tura settlement (A.P. Stepanov, 1966); Irgakta Yar (11), the right bank of the Lower Tunguska River, opposite Irgakta Island, downstream from the Tura settlement (V.P. Belozarov, 1965); Iritka-3 (19), the left bank of the Iritka River (the left-bank tributary of the Lower Tunguska River upstream from the Tura settlement), 15 km from the mouth (G.N. Sadovnikov, 1987); Moldaul (17), the right bank of the Lower Tunguska River, 1 km downstream from the mouth of the Moldaul River (=Mol'daul', Mul'daul'), upstream from the Tura settlement (E.F. Orlova and G.N. Sadovnikov, 1987); Nizhnyaya Bugarikta-1 (8), the right bank of the Lower Tunguska River, 3 km upstream from the mouth of the Nizhnyaya Bugarikta River, 26.5 km downstream from the mouth of the Tutonchana River (V.P. Belozarov and

G.N. Sadovnikov, 1959); Nizhnyaya Bugarikta-2 (7), the left bank of the Nizhnyaya Bugarikta River, 1.5 km from the mouth, 29.5 km downstream from the mouth of the Tutonchana River (V.P. Belozarov and G.N. Sadovnikov, 1959); Nizhnyaya Bugarikta-3 (6), the right bank of the Lower Tunguska River, 0.3–0.4 km upstream from the mouth of the Nizhnyaya Bugarikta River, 29 km downstream from the mouth of the Tutonchana River (V.P. Belozarov and G.N. Sadovnikov, 1959); Norilsk (2), vicinities of Norilsk (precise location, author, and year of discovery are unknown); Untuun-2 (9), 10 km from the mouth along the Untuun River, the left-bank tributary of the Kochechumo River that meets the Lower Tunguska River at the Tura settlement (M.M. Levitan, 1966); Khoorki-1 (16), the right bank of the Khoorki River, the right-bank tributary of the Pirda River (the left-bank tributary of the Eika River), 46 km from the mouth (V.M. Chalisov, 1966); Khoorki-3 (18), 0.9 km from the mouth of the Nizhnyaya Bugarikta, the right-bank tributary of the Khoorki River (see Khoorki-1) (B.P. Markevich, 1965); Khungtukun-2 (14), the right bank of the Lower Tunguska River, 4.9 km upstream from the mouth of the Khungtukun River, which is located 70 km upstream from the Tura settlement (G.N. Sadovnikov, 1968); Shchadrinka-1 (3), the right bank of the Kureika River, 0.8 km upstream from the mouth of the Shchadrinka River (a right-bank tributary of the Kureika River within its headwaters), 21 km downstream of Lake Anam (G.N. Sadovnikov and Nesterov S.A., 1971); Khungtukun River-3, 4 (15), the right bank of the Lower Tunguska River, 4.2 and 3.1 km upstream from the mouth of the Khungtukun River, which is located 70 km upstream from the Tura settlement (Uspenskii, 1931); Yastrebok-2 (13), the right bank of the Lower Tunguska River, 6.5 km downstream from the mouth of the Nizhnii Kochechumo River (Yastrebok Rapids), upstream from the Tura settlement (V.P. Petrov and Yu.I. Ponomarev, 1967).

REFERENCES

1. V. P. Belozarov and G. N. Sadovnikov, "Stratigraphy of the Korvunchanskaya Series in the Lower Nizhnyaya Tunguska River Basin," Tr. Vses. Aerogeol. Tresta, No. 8, 24–42 (1962).
2. Ch. Depéret and P. Mazeran, "Les Estheria du Permien d'Autun," Bull. Soc. Hist. Nat. d'Autun, No. 25, 165–173 (1912).
3. J. R. Etheridge, "On *Leaia mitchelli*, Etheridge, Fil., from the Upper Coal Measures of the Newcastle District," Proc. Linn. Soc. N. S. Wales, Ser. 2 7, 307–310 (1892).
4. *Geological Map of the USSR at a Scale of 1 : 1000000 (New Series): Sheet R-48.49 (Baikit)* (Nedra, Leningrad, 1981).
5. *Geological Map of the USSR at a Scale of 1 : 1000000 (New Series): Sheet Q-48.49 (Aikhal)* (Nedra, Leningrad, 1991).
6. P. J. Jones and Chen Pei-Ji, "Carboniferous and Permian Leaioidea (Branchiopoda: Conchostraca) from Australia: Taxonomic Revision and Biostratigraphic Implications," Rec. Austral. Mus. 52, 223–244 (2000).
7. V. I. Kapel'ka and N. I. Novojilov, "Biostratigraphy of the Paleozoic of the Sayan–Altai Mountain Region: Vol. 3. Upper Paleozoic," Tr. Sibirsk. Nauchno-Issled. Inst. Geol. Geofiz. Miner. Syr'ya, Issue 21, 379–389 (1962a).
8. V. I. Kapel'ka and N. I. Novojilov, "Triassic Conchostraca of Western Siberia," Tr. Sibirsk. Nauchno-Issled. Inst. Geol. Geofiz. Miner. Syr'ya, Issue 22, 19–26 (1962b).
9. T. Kobayashi, "Older Mesozoic Estheriae from Eastern Asia," J. Fac. Sci. Univ. Tokyo, Ser. 2 7 Part 10, 431–442 (1950).
10. T. Kobayashi, "Fossil Estherians and Allied Fossils," J. Fac. Sci. Univ., Tokyo, Ser. 2 9 Part 1, 1–192 (1954).
11. E. M. Lutkevich, "Triassic Estheriae from the Upper Tunguskaya Series," Tr. Arkt. Inst. 101, 155–164 (1938).
12. E. M. Lutkevich, "Phyllopora of the Permian Deposits of the European Part of the USSR," in *Paleontology of the USSR* (Akad. Nauk SSSR, Moscow, 1941), Vol. 5, Part 10, Issue 1 [in Russian].
13. F. B. Meek and A. H. Worthen, "Fossils of the Coal Measures," Geol. Surv. Illinois 3, 1–540 (1868).
14. J. Mitchell, "Description of New Species *Leaia*," Proc. Linn. Soc. N. S. Wales 50 Part 4, 438–447 (1925).
15. J. Mitchell, "The Fossil Estheriae of Australia, Part 1," Proc. Linn. Soc. N. S. Wales 52 Part 2, 105–211 (1926).
16. V. A. Molin, "New Branchiopoda from the Ufimian Stage of the Mezen' River," Paleontol. Zh., No. 1, 76–81 (1964).
17. V. A. Molin, "Upper Permian and Lower Triassic Conchostraca in the Mezen' River Basin," in V. A. Molin and N. I. Novojilov *Conchostraca of the Permian and Triassic of the Northern USSR* (Nauka, Moscow, 1965a), pp. 77–102 [in Russian].
18. V. A. Molin, *Conchostraca of the Lower Triassic of Northern Yakutia* (Nauka, Moscow, 1965b), pp. 57–76.
19. V. A. Molin, A. B. Virbitskas, L. I. Varyukhina, et al., *Paleontological Atlas of the Permian Deposits of the Pechora Coal Basin* (Nauka, Leningrad, 1982) [in Russian].
20. N. I. Novojilov, "New Phyllopora from the Permian and Triassic Deposits of the Nordvik–Khatanga Region," Nedra Arktiki, No. 1, 172–200 (1946).
21. N. I. Novojilov, "A Critical Analysis of the Papers of E.M. Lutkevich on Conchostraca in Connection with His Paper "Stratigraphy of the Upper Permian Deposits of the Kama River Region (the Urals)," Izv. Akad. Nauk SSSR. Ser. Geol., No. 3, 148–152 (1952a).
22. N. I. Novojilov, "New Generic-Level Groups of Conchostraca of the Family Leaidae," Dokl. Akad. Nauk SSSR 85 (6), 1369–1372 (1952b).
23. N. I. Novojilov, "A New Conchostraca Assemblage from the Devonian of the Karatau," Dokl. Akad. Nauk SSSR 91 (5), 1207–1209 (1953).
24. N. I. Novojilov, "Leaids (Conchostraca) from the Carboniferous Deposits of the Karaganda Coal Basin," Dokl. Akad. Nauk SSSR 96 (6), 1241–1244 (1954a).

25. N. I. Novojilov, "Conchostracans of the Jurassic and Cretaceous of Mongolia," Tr. Paleontol. Inst. **48**, 7–124 (1954b).
26. N. I. Novojilov, "Conchostracans—Leaiids," Tr. Paleontol. Inst. **56**, 1–157 (1956).
27. N. Novojilov, "Conchostraca du Permien et du Trias du littoral de la mer des Laptev et de la Toungouzka inférieure," Ann. Serv. Inf. Géol. BRGGM Paris, No. 26, 15–80 (1958).
28. N. I. Novojilov, "New Permian and Triassic Conchostraca from Southern Byelorussia, Cis-Urals Region, and Yakutia," in *Materials for "Fundamentals of Paleontology"* (Moscow, 1959), Issue 3, pp. 84–103 [in Russian].
29. N. I. Novojilov, "Conchostraca from the Lower Triassic of the Yaroslavl Region," in *Regional Studies: Issue 4* (Yaroslavl, 1960a), pp. 216–253 [in Russian].
30. N. I. Novojilov, "Subclass Gnathostraca," in *Fundamentals of Paleontology: Arthropoda—Trilobita and Crustacea* (Gosgeoltekhizdat, Moscow, 1960b), pp. 216–253 [in Russian].
31. N. I. Novojilov, "Devonian Conchostraca," Tr. Paleontol. Inst. **81**, 1–133 (1961).
32. N. I. Novojilov, "Permian and Triassic Conchostraca in the Littoral of the Laptev Sea," in V. A. Molin and N. I. Novojilov *Conchostraca of the Permian and Triassic of the Northern USSR* (Nauka, Moscow, 1965a), pp. 6–44 [in Russian].
33. N. I. Novojilov, *New Conchostraca from the Korvunchanskaya Series of the Nizhnyaya Tunguska River* (Nauka, Moscow, 1965b), pp. 45–56 [in Russian].
34. N. I. Novojilov, *Extinct Limnadioideae* (Nauka, Moscow, 1970) [in Russian].
35. N. Novojilov and V. Kapel'ka, "Crustacés bivalves (Conchostraca) de la série Daido de l'Asie orientale dans le Trias supérieur de Madygen (Kirghizie Occidentale)," Ann. Soc. Géol. Nord **80**, 177–187 (1960).
36. E. F. Orlova, "The Use of Replicas for the Study of Fossil Conchostraca," Paleontol. Zh., No. 3, 124–127 (1978).
37. E. F. Orlova, "New Data on the Conchostraca *Rohden-dorfium* and *Bipemphigus* from the Volcanogenic Permian-Triassic Deposits of the Tunguska Syncline," Paleontol. Zh., No. 1, 66–75 (1990).
38. E. F. Orlova, "The First Results in the SEM Study of the Microsculpture of Conchostracan Carapaces from the Northern Siberian Platform," Dokl. Akad. Nauk SSSR **316** (6), 1476–1478 (1991).
39. E. F. Orlova, "Permian–Triassic Conchostracan Faunas from the North of Central Siberia," Stratigr. Geol. Korrelyatsiya **7** (5), 56–63 (1999) [Stratigr. Geol. Correlation **7** (5), 465–472 (1999)].
40. P. Pruvost, "Découverte de Leiaia dans le terrain houiller du Nord de la France et du Pas-de-Calais," Ann. Soc. Géol. Nord **43**, 254–281 (1914).
41. P. Pruvost, *La faune continentale du terrain houiller du Nord de la France* (Paris, 1919).
42. P. F. Raymond, "The Genera of Fossil Conchostraca—an Order of Bivalved Crustacea," Bull. Mus. Comp. Zool. Harv. Coll. **96** (3), 216–307 (1946).
43. *Resolution of Interdisciplinary Regional Stratigraphic Conference on the Triassic of the East European Platform (Saratov, 1979)* (Tr. Vses. Geol. Inst., Leningrad, 1982).
44. *Resolution of Interdisciplinary Regional Stratigraphic Conference on the Middle and Upper Paleozoic of the Russian Platform (Leningrad, 1988)* (Tr. Vses. Geol. Inst., Leningrad, 1990).
45. G. N. Sadovnikov and E. F. Orlova, "The Age of the Continental Volcanogenic Deposits of the Northern Central Siberia," Izv. Akad. Nauk SSSR, Ser. Geol., No. 3, 58–70 (1990).
46. G. N. Sadovnikov and E. F. Orlova, "The Taimyr Stage—the Terminal Stage of the Continental Permian," Dokl. Akad. Nauk Earth Sci. **338A** (5), 658–661 (1994a).
47. G. N. Sadovnikov and E. F. Orlova, "The Taimyr Stage—the Terminal Stage of the Continental Permian," Dokl. Akad. Nauk Earth Sci. **341A** (3), 149–153 (1994b).
48. G. N. Sadovnikov and E. F. Orlova, "New Data in the Stratigraphy of the Volcanogenic Deposits of the Central Part of the Tunguska Syncline," Stratigr. Geol. Korrelyatsiya **3** (1), 34–42 (1995).
49. G. N. Sadovnikov and E. F. Orlova, "Lower Boundary of Non-Marine Triassic of Siberia," Halle Jb. Geowiss. B, No. 5, 156–157 (1998).
50. G. N. Sadovnikov and E. F. Orlova, "Stratigraphy and the Upper Boundary of the Terminal Permian in Siberia," in *Proceedings of the International Symposium on the Upper Permian Stratotypes of the Volga River Region* (GEOS, Moscow, 1999), pp. 192–197.
51. *Stratigraphical Dictionary of the USSR: New Stratigraphical Subdivisions of the Paleozoic of the USSR* (Nedra, Leningrad, 1991) [in Russian].
52. N. I. Strok, T. E. Gorbatkina, and V. R. Lozovskii, *The Upper Permian–Lower Triassic Deposits of the Moscow Syncline* (Nedra, Moscow, 1984) [in Russian].
53. P. Tash, "Novojilov's Classification of Fossil Conchostracans—a Critical Evaluation: Part 1. Familie Leaiidae," J. Paleontol. **32** (6), 1094–1106 (1958).
54. P. Tash, "Permian and Triassic Conchostraca from the Bowen Basin, Queensland," Bull. Bureau Miner. Res. Austral., No. 185, 33–47 (1979).
55. P. Tash and P. J. Jones, "Carboniferous and Triassic Conchostraca from the Canning Basin, Western Australia," Bull. Bureau Miner. Res. Austral., No. 185, 3–20 (1979).
56. B. I. Tschernyschew, "On Some Branchiopoda from the Kuznetsk Basin," Tr. Leningr. Ob-va Estestvoispyt. **63** (2), 115–125 (1934).
57. E. F. Vangerow, "Eine Leiaia aus dem Aachener Karbon," Glückauf **90** (49–50), 1605–1606 (1954).
58. C. A. White, "The Fossils of Indiana Rock," 13th Annu. Rept. Dept. Nat. Hist., Part 2, 167 (1883).