ISSN 0031-0301, Paleontological Journal, 2017, Vol. 51, No. 3, pp. 313–325. © Pleiades Publishing, Ltd., 2017.
Original Russian Text © N.B. Gibshman, A.S. Alekseev, 2017, published in Paleontologicheskii Zhurnal, 2017, No. 3, pp. 86–96.

Marine Algal Flora of the Late Viséan (Early Carboniferous) of the Moscow Basin

N. B. Gibshman[a, *] **and A. S. Alekseev**[a, b, c, **]

[a]*Borissiak Paleontological Institute, Russian Academy of Sciences, Profsoyuznaya ul. 123, Moscow, 117997 Russia*
[b]*Department of Paleontology, Geology Faculty, Moscow State University, Russia*
[c]*Kazan Federal University, Kremlyovskaya ul. 18, Kazan, 420000 Tatarstan, Russia*
**e-mail: nilyufer@bk.ru*
***e-mail: aaleks@geol.msu.ru*

Received July 10, 2014

Abstract—New data on the taxonomic composition of the algal flora of the Late Viséan of the Moscow Basin are discussed based on newly collected material. The algal assemblage comprises 24 taxa, 14 taxa identified to species, nine identified to genus, and one taxon not positively identified. Representatives of the genera *Anthracoporella*, *Anthracoporellopsis*, *Asphaltina*, *Asphaltinella*, *Asteroaoujgalia*, and *Zidella* are recorded for the first time from the Upper Viséan of the Moscow Basin. The large geographic ranges of these benthic calcareous algae suggest a relatively free exchange of the floral elements of the Late Viséan Moscow Basin with the remote basins of North America and the Paleotethys in the Aleksinian and Mikhailovian time. The new data fill an important gap in the current state of knowledge of Late Viséan marine algae.

Keywords: Algae, Carboniferous, Late Viséan, taxonomy, Moscow Basin, Russia

DOI: 10.1134/S0031030117020071

INTRODUCTION

Taxonomic studies of the Late Viséan and Serpukhovian foraminifers of the Moscow Basin, mainly associated with biostratigraphic research, have revealed the presence of a considerable number of taxa of calcareous algae, previously unknown from this region, but which suggest that they played a large role in the benthic communities. This paper discusses the taxonomy and morphology of the Late Viséan algal flora of the Moscow Basin.

HISTORICAL BACKGROUND

Möller (1879; 1880) was the first to describe Late Viséan algae from the Moscow Basin, as three species of Foraminifera *Nodosinella index* (Ehrenberg, 1854), *N. lahuseni* Möller, 1879, and *N. tenuis* Möller, 1879. To characterize their skeletons, Möller used the terms proposed by Brady (1876) for describing foraminifers of the genera *Nodosaria* Ehrenberg, 1854 and *Nodosinella* Brady, 1876, such as shell, chambers, septa, shell wall, and perforations for interconnecting between interiors of chambers. The Carboniferous limestones with remains of algal flora, studied by Möller, were sampled by Struve (1886) in the Kaluga, Tula, and Ryazan regions. Möller studied all objects extracted from the matrix and in thin sections, in which sections of skeletons were correctly oriented relative to their axes of symmetry. It should be noted that Ehrenberg (1854; see explanation of pl. 37, section 11) found *Nodosaria index* in a piece of brown chert from the Tula region, containing *Spirifer mosquensis*. The drawing of this sample shows a ventral valve of a spiriferid brachiopod with a sinus, which quite probably belongs to the Middle Carboniferous– Early Permian genus *Choristites*. This suggests that the type material examined by Ehrenberg had a younger age, but all subsequent authors used for reference descriptions and figures published by Möller for the Late Viséan taxa.

Two of the species described and figured by Möller (1879, pp. 111–115, pl. 5, figs. 5–8), later became the type species of new genera. *Nodosinella lahuseni* Möller, 1879 was designated the type species of the genus *Palaeoberesella* Mamet, 1974, and *Nodosinella index* (Ehrenberg, 1854) Möller, 1879a was designated the type species of the genus *Exvotarisella* Elliott, 1970.

Calcareous algae of the Lower Carboniferous of the Moscow Basin were studied as a separate group of fossil organisms in the course of the lithological study of the carbonate rocks of the Aleksinian–Venevian substages (Shvetsov and Birina, 1935). As a result, a new genus and species, *Calcifolium okense* Shvetsov et Birina, 1935, were described. In addition, these authors recognized two other groups of algae: "tubu-

Fig. 1. Location of sections on a geological map with no Meso-Cenozoic deposits shown: (1) Novogurovsky Quarry, (2) Zaborie Quarry, (3) Boreholes 39, 41, 42 on the Oka River 2.5 km south of the Zaborie Quarry.

lar” and “spongious Dasycladaceae” (Shvetsov and Birina, 1935, pp. 22–23).

Tubular specimens were tentatively identified as algae. Both groups were briefly characterized, and some, for example tubular specimens, were illustrated with photographs (Shvetsov and Birina, pl. 4, fig. 9).

Rauser-Chernousova (1948) who studied the foraminifers of the Moscow Basin, distinguished more than seven kinds of Early Carboniferous algae and problematic remains, examined by V.P. Maslov: *Calcifolium okense*, *Calcifolium* sp. (in the distribution tables, but in the text is called *C. punctatum* Maslov), dasycladid alga A, dasycladid alga B, *Donezella*-lile algae, spongiomorphids type A, spongiomorphids type B, and some other remains. Unfortunately these specimens were not described or figured, hence it is not possible to establish precisely what the above names refer to.

Species of the genus *Nodosinella* were later re-identified as algae (Rauser-Chernousova, 1948). The stratigraphic distribution of the algae and algae-like remains is studied in five most complete sections: Erino, Aleksin, Kurakovo-Khomyakovo, Biekhovo, and Zaborie.

A new species, *Calcifolium punctatum,* was established based on material from the Lower Carboniferous of the Moscow Basin, whereas *C. okense* was described in detail and its thallus was reconstructed (Maslov, 1956a). At the same time (Maslov, 1956a) the genus *Calcifolium* Shvetsov et Birina was assigned to green algae (Chlorophyta), family Codiaceae. Almost simultaneously Maslov (1956b) described two rare species found in the Tulian Regional Substage of the Moscow Basin and two species as incertae sedis: *Aphanocapsites granulosus* Maslov, 1956 and *Stipulella fascicularis* Maslov, 1956.

Later calcareous algae were identified along with foraminifers without being taxonomically studied (Makhlina et al., 1993; Gibshman, 2003; Kabanov, 2003; Vevel et al., 2007; Ivanova, 2009). Species of the genera *Koninckopora* Lee, 1912, *Ungdarella* Maslov, 1956, *Sphinctoporella* Mamet et Rudloff, 1972 (=*Kulikia* Golubtsov, 1961) and *Girvanella* Nicholson et Etheridge, 1878 were recorded for the first time in the Lower Carboniferous of the Moscow Basin.

In recent years a bed-by-bed biostratigraphic study of the Upper Viséan deposits of the Moscow Basin and foraminifers from these deposits resulted in recognition of almost all known taxa of algae and several new taxa including *Asteroaoujgalia gibshmanae* Brenckle (Gibshman et al., 2009), *Asphaltina cordillerensis* Mamet in Petryk et Mamet and *Asphaltinella horowitzi*.

Mamet et Roux (Gibshman and Alekseev, 2013a, 2013b). Thus, before this study, the total taxonomic composition of the late Viséan algal flora of the Moscow Basin consisted of only 15 taxa.

MATERIALS AND METHODS

This paper is based on approximately 500 transparent petrographic thin sections (2.5 × 2.5 cm). They are represented by limestone (over 100 samples) from the Novogurovsky Quarry in the Tula Region (Gibshman et al., 2009) and boreholes 39, 41 and 42, drilled near the railway bridge on the Oka River near Serpukhov and located at a small distance from one another (Alekseev et al., 2013; Gabdullin et al., 2013; Kabanov et al., 2013, 2016) (Fig. 1).

The thin sections were studied using a Carl Zeiss microscope equipped with a Nikon photographic camera (lens ×10 or ×2.5 for the largest specimens). Images were merged using Adobe Photoshop CS3 software. The scheme of the subdivision of the Lower Carboniferous of the southern wing of the Moscow Syneclise (Makhlina et al., 1993; emended by Kabanov et al., 2016) was accepted as the stratigraphic basis for this paper.

The algal flora and problematics were identified by comparing specimens found in the Moscow Basin with previously described taxa (Shvetsov and Birina, 1935; Maslov, 1956a; Mamet and Roux, 1974, 1975, 1978; Brenckle et al., 1982; Roux, 1985; Chuvashov et al., 1987; Ivanova, 1988, 2013; Bogush et al., 1990; Skompski, 1996; Mamet, 2006). A review by Mamet (1991) summarizing nearly 140 diagnoses of Carboniferous algal genera and giving their species composition and geographic ranges was used for comparing the taxonomic diversity of the algal flora of the Moscow Region.

The shell structure was examined in the same way as for the Paleozoic foraminifers (Rauser-Chernousova and Gerke, 1971; Loeblich and Tappan, 1987). Both of these groups inhabited shallow water basins in similar environments, and their skeletons underwent similar diagenetic processes after burial, but the calcareous wall usually retained its original structure.

The taxonomy of Paleozoic algae and algae-like organisms is still debated (Brenckle et al., 1982; Chuvashov et al., 1987; Bogush et al., 1990; Skompski, 1996; Mamet, 2006; Ivanova, 2013), and therefore we did not assign the genera to higher taxa, and their characterization is given in alphabetical order. However, it should be said that most of the taxa identified are usually assigned to green algae, Chlorophyta (Maslov, 1956a; Mamet, 2006; Ivanova, 2013).

The collection studied is housed in the Paleontological Institute, Russian Academy of Sciences (PIN), no. 5547.

TAXONOMIC COMPOSITION OF THE ALGAL FLORA

In the studied sections, the remains of most algae are scarce. Only *Calcifolium* thalli are abundant in the Aleksinian, Mikhailovian, and Venevian regional stages, and can even be rock-forming. In the Mikhailovian, the genera *Anthracoporellopsis* Maslov, 1952, *Asphaltina*, *Asphaltinella* Mamet et Roux, 1978, *Exvotarisella*, and *Palaeoberesella* are reasonably frequent. After processing the limestone samples from the same sections for conodonts, the insoluble residue left over often contains tubular segmented skeletons of algae of the family Palaeoberesellaceae (genera *Exvotarisella*, *Palaeoberesella*, and *Kamaena* Antropov, 1967), which are resistant to the acetic acid used.

In total, the algal flora assemblage from the Late Viséan Basin of the Moscow Region contains 24 taxa of algae and problematics belonging to 23 genera. Of these, only the genus *Calcifolium* is represented by two species, and one morphotype is provisionally assigned to the genus *Stacheoides* Cummings, 1955. Most taxa are studied based on a small number of specimens, whereas species of the *Anthracoporellopsis*, *Asphaltina*, *Asphaltinella*, *Calcifolium*, *Exvotarisella* and *Palaeoberesella* are most common.

Most taxa of calcareous algae established in the Moscow Basin have repeatedly been described in the Russian literature (e.g., Bogush et al., 1990; Ivanova, 2013), and therefore are only briefly characterized in this paper.

***Anthracoporella* sp.** (Pl. 12, fig. 18). The genus *Anthracoporella* Pia, 1920 is represented by one fragment of a thallus found in the Mikhailovian Regional Stage (Borehole 42, depth 23.0 m, thin section 2). The thallus is large (up to 0.7 mm long), subcylindrical, round in cross-section, unsegmented, of varying diameter (170–255 μm); wall thickness 34 μm. The calcareous cover is evenly perforated (pore diameter is less than 17 μm) along the entire wall.

***Anthracoporellopsis machaevi* Maslov, 1956** (Pl. 12, figs. 7, 11–16). The thallus is tubular, irregular in shape. The central canal (90–200 μm in diameter) is subdivided by thick (ca. 20 μm) septa. It gives rise to multidirected marginal canals. The walls of the central canal and the branches are unevenly thick (about 20 μm), perforated by dichotomously branching pores of varying sizes (up to 8 μm) and mainly evenly spaced apart. The radial cylindrical pores alternate with wide, lenticular pores. The septa between the cylindrical pores are perforated by irregularly spaced micropores. This species is common in the Lower Carboniferous and is abundantly found in the Mikhailovian Regional Stage (Borehole 39, depth 20.5 m; Borehole 42, depth 32.0 and 23.0 m) and is considerably less common in the Venevian Regional Stage (Borehole 42, depth 20.25 m).

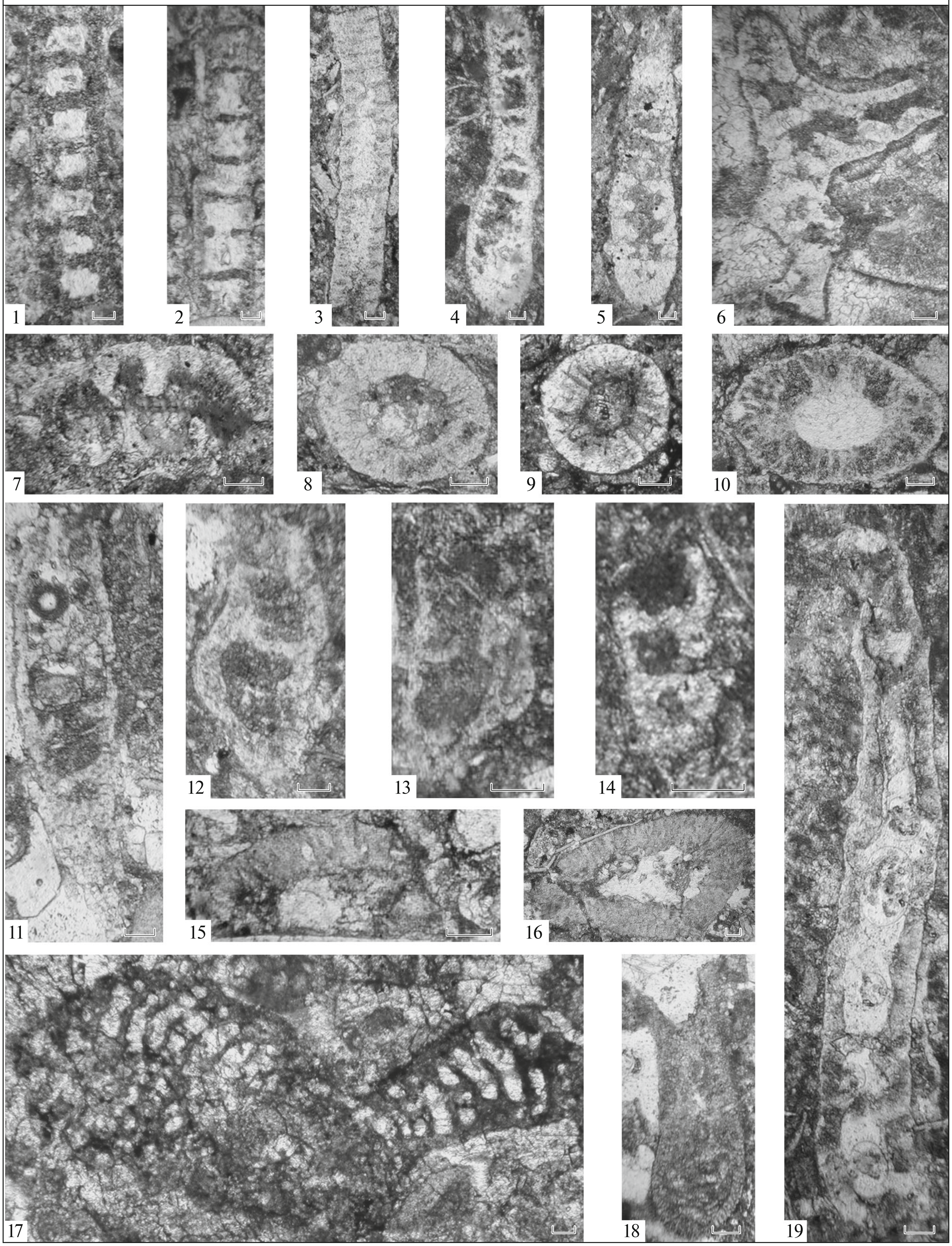
***Aphanocapsites granulosus* Maslov, 1956.** Very small (30–50 μm) round cells (?), irregularly arranged in a colony size up to 0.5 mm, with a thick wall, possibly of cyanobacterial origin (Mierzejewski, 1991). These algae are described by Maslov (1950b) from the Tulian Regional Stage of the Moscow Region with indicating the locality.

***Asphaltina cordillerensis* Mamet in Petryk et Mamet, 1972** (Pl. 13, figs. 1–4). The thallus is encrusting, composed of segmented tubes subdivided by constrictions into several compressed, convexo-concave oval segments. The segments form large (up to 2 mm) monolayered or multilayered crusts (Fig. 2). The thallus wall is two-layered. The inner layer is thick (0.4–0.5 μm), light, porcelaneous, whereas the outer layer is thin (2–3 μm), dark, similar to the surrounding micritic matrix.

The developments of the thallus in this species can be studied based on the material from the Moscow Basin. The formation of the encrusting crust was preceded by a stage of a straight, weakly segmented tube composed of convexo-concave segments. Later segments encrusted the substrate and built a multi-layered thallus of adjacent oval segments. The concave side of the segments is directed towards the substrate (Fig. 2).

Brenckle et al. (1982) suggested that the outer layer in *A. cordillerensis* was not an original part of the thallus, but either had bacterial origin, or represented relicts of micritization. In the Moscow Basin specimens, the thin dark outer layer was not observed in some areas of the segments if they were recrystallized (Pl. 13, fig. 1), and in other specimens if present, it is reasonably thin (less than 2 μm).

Plate 12



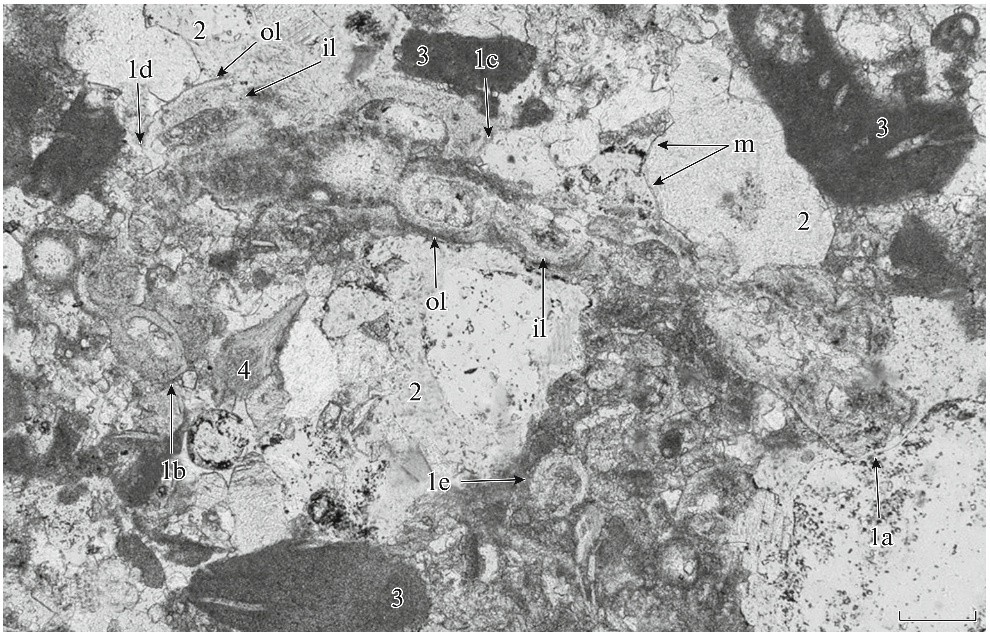


Fig. 2. Large-grained limestone (rudstone), specimen PIN, no. 5547/1, photograph, no. 4492; Oka River, Borehole 39, depth 20.5 m, thin section 2; Upper Viséan, Mikhailovian Regional Stage: (1) longitudinal section of a thallus of *Asphaltina cordillerensis* Mamet: (a, b) single row of oval segments; (c, d) crust accumulation of segments of a round convexo-concave shape; (e) fragments of destroyed thallus; (ol) outer wall layer; (il) inner wall layer; (2) fragments of crinoids; (3) thallus of *Calcifolium okense* Shvetsov et Birina; (4) bryozoan. Micritic cement (m) is observed as a very thin layer (<0.01 mm) around several large crinoidal remains. Scale bar 500 μm.

Explanation of Plate 12

Figs. 1 and 2. *Kamaena* aff. *delicata* Antropov: (1) specimen PIN, no. 5547/12, photograph, no. 4147; tangential section; (2) specimen PIN, no. 5547/13, photograph, no. 4155; longitudinal section, slightly oblique; Oka River, Borehole 41, depth 32.5 m, thin section 1; Aleksinian Regional Stage.

Figs. 3, 4, 8. *Palaeoberesella lahuseni* (Möller): (3) specimen PIN, no. 5547/14, photograph, no. 5034; longitudinal section; Oka River, Borehole 42, depth 35.8 m, thin section 1; Mikhailovian Regional Stage; (4) specimen PIN, no. 5547/15, photograph, no. 4508; longitudinal section, oblique; Oka River, Borehole 39, depth 20.5 m, thin section 3; Mikhailovian Regional Stage; (8) specimen PIN, no. 5547/16, photograph, no. 5032; Oka River, Borehole 42, depth 35.8 m, thin section 1; Mikhailovian Regional Stage.

Figs. 5, 6, 9. *Exvotarisella index* (Ehrenberg) Möller: (5) specimen PIN, no. 5547/17, photograph, no. 5287; longitudinal section; Oka River, Borehole 42, depth 44.3 m, thin section 1; Aleksinian Regional Stage; (6) specimen PIN, no. 5547/18, photograph, no. 0321; longitudinal section, note the dichotomous branching of the thalom; Oka River, Borehole 42, depth 46.5 m, thin section 1; Aleksinian Regional Stage; (9) specimen PIN, no. 5547/19, photograph, no. 5280; cross-section; Oka River, Borehole 42, depth 44.3 m, thin section 1; Aleksinian Regional Stage.

Figs. 7, 11–16. *Anthracoporellopsis machaevi* Maslov, note variations in the diameter of the thallus, direction of belts, and shape of the pores: (7) specimen PIN, no. 5547/20, photograph, no. 4685; fragment of a central canal; Oka River, Borehole 42, depth 209.25 m, thin section 2; Mikhailovian Regional Stage; (11) specimen PIN, no. 5547/21, photograph, no. 4685, longitudinal section, demonstrates differently oriented belts; (12) specimen PIN, no. 5547/22, photograph, no. 4692; longitudinal section; (13) specimen PIN, no. 5547/23, photograph, no. 5007; longitudinal section; (14) specimen PIN, no. 5547/24, photograph, no. 5008; longitudinal section; Oka River, Borehole 39, depth 20.5 m, thin section 2; (15) specimen PIN, no. 5547/25, photograph, no. 5008; fragment of the transverse section of the central canal demonstrates dichotomous branching of pores; Oka River, Borehole 42, depth 32.8 m, thin section 2; (16) specimen PIN, no. 5547/26, photograph, no. 5037; cross-section of a central canal; Oka River, Borehole 42, depth 34.8 m, thin section 1; Mikhailovian Regional Stage.

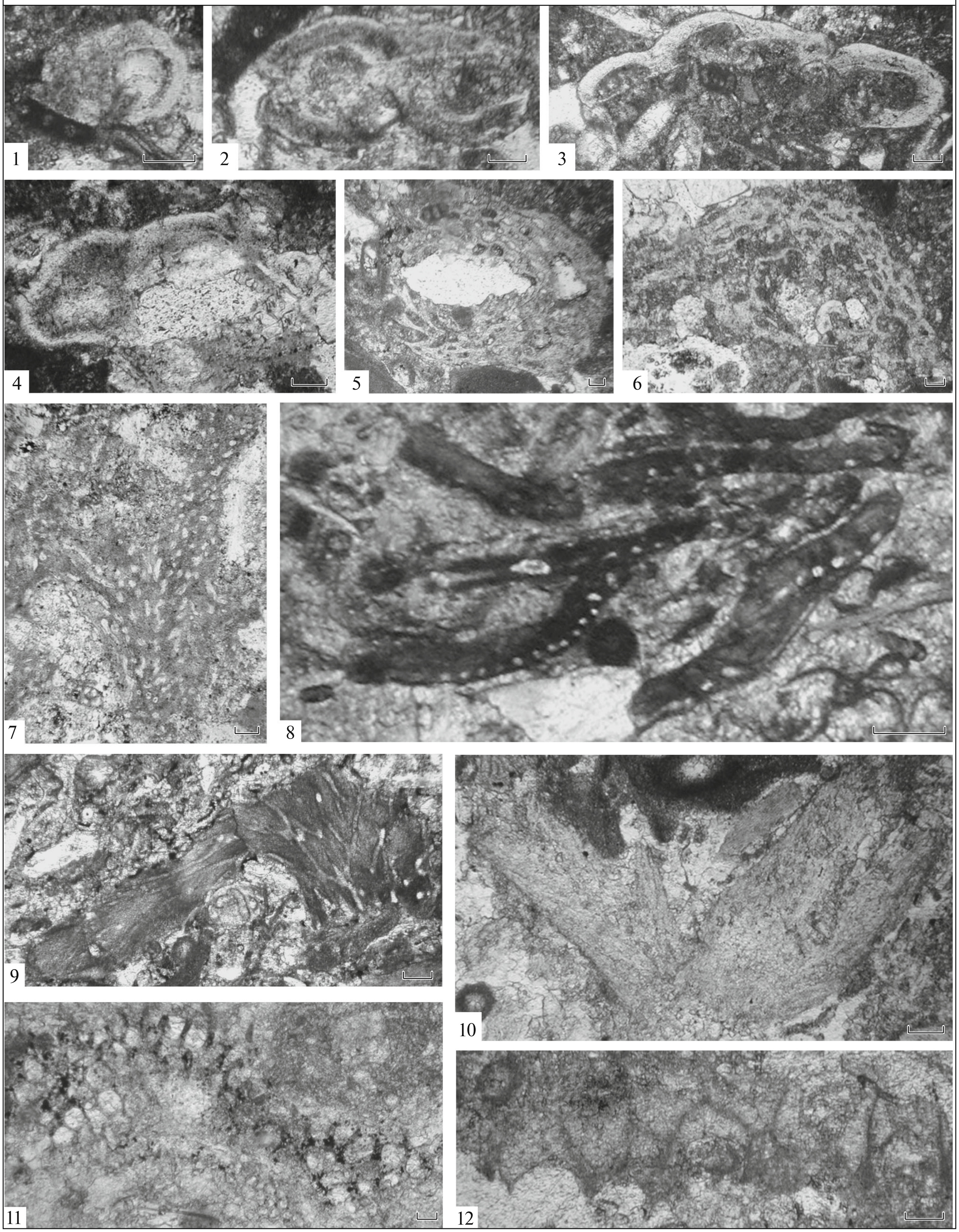
Figs. 10 and 19. *Zidella* sp.: (10) specimen PIN, no. 5547/27, photograph, no. 5185; cross-section; Oka River, Borehole 42, depth 32.2 m, thin section 2; Mikhailovian Regional Stage; (19) specimen PIN, no. 5547/28, photograph, no. 5258; longitudinal section; Oka River, Borehole 42, depth 19.4 m, thin section 2; Venevian Regional Stage.

Fig. 17. *Asteroaoujgalia gibshmanae* Brenckle, specimen PIN, no. 5547/29, photograph, no. 0167; half of oblique section; Novogurovsky Quarry, Bed 15, Sample 14/3, thin section 3; Mikhailovian Regional Stage.

Fig. 18. *Anthracoporella* sp., specimen PIN, no. 5547/30, photograph, no. 5145; longitudinal section; Oka River, Borehole 42, depth 23.0 m, thin section 2; Mikhailovian Regional Stage.

Scale bar 100 μm.

Plate 13



The understanding of the origin of the dark microgranular layer in *A. cordillerensis* is contributed by information from the limestones of the Mikhailovian Regional Stage studied in Borehole 39 (Fig. 2). The host rock is coarse-grained algal bioclastic rudstone. The micritic black matrix, as a very thin, hardly visible film, is observed only in segments constituting the thallus of *A. cordillerensis*, and sometimes around fragments of skeletons of unidentifiable echinoderms. All other bioclasts, and especially grains of algae *Calcifolium okense*, are entirely clear, strongly re-crystallized, and not covered by micrite. Thus, it is possible that there algae were associated with bacteria. The inconsistent presence of the micritic coating (as termed by Mamet, 2006), was probably connected with the inability of bacteria to resist active hydrodynamics during deposition of the carbonate sediment. At the same time, this encrusting, in Mamet's opinion, was what enabled the excellent preservation of specimens of *A. cordillerensis*. If this is accepted, the opinions of Brenckle et al. (1982) and Mamet (2006) do not contradict our hypothesis of the biotic connection between the alga *A. cordillerensis* and bacterial colonies. However, a more detailed examination of the bacterial layer using high-resolution equipment is necessary to confirm this hypothesis. *A. cordillerensis* is more common in the Mikhailovian Regional Stage (Borehole 39, depth 20.5 m; Borehole 42, depth 32.0 and 23.0 m), whereas they are scarce in the Aleksinian and Venevian regional stages.

Asphaltinella horowitzi **Mamet et Roux, 1978** (Pl. 13, figs. 5, 6). The species is represented by 22 specimens (10 specimens from Borehole 39, depth 20.5 m and the same number from Borehole 42, depth 23.0 m, 2 specimens from the Novogurovsky Quarry). In the Mikhailovian Regional Stage these algae produce mass accumulations, and are scarce in the Aleksinian and Venevian regional stages. The thallus is encrusting, pillar-shaped or entangled, irregular in size (from 0.3 to >1 μm), composed of thin singular hyaline threads, groups of parallel entwisted four–five threads, or represents an oval or spherical ball (Fig. 3).

Asteroaoujgalia gibshmanae **Brenckle, 2004** (Pl. 12, fig. 17). This species was described for the first time from the Upper Viséan of northwestern China (Brenckle, 2004), and was later found in the Visean of the Peri-Caspian [identified as *Chantonia* ex gr. *maslovi* by Akhmetshina et al. (2007)]. It is represented by three specimens from the Mikhailovian Regional Stage (Novogurovsky Quarry, Bed 15, Sample 14/3; Oka River, Borehole 42, depth 24.0 m). The thallus is large (up to 1.7 mm), composed of wide radial branches (the length from the base to the terminal part is 600–800 μm), attached to the axis. The inner cavity of the branches is subdivided by horizontal septa (10–40 μm thick) into low chambers, which also contain vertical septa. The wall of the thallus (40 μm thick) is of complex structure. The external part of the wall and radial septa are composed of dark microgranular calcite. The inner part or spaces between the radial septa are composed of sparit.

Calcifolium okense **Shvetsov et Birina, 1935** (Pl. 13, figs. 8, 9). The thallus consists of a cylindrical tubular siphon (up to 0.6 mm long), with thin dichotomizing tubes of inconsistent size extending from it. Inside the tubes there are branching canals (about 10 μm in diameter), filled with light calcite with dark bands. Bands of light calcite are uninterrupted, branching, arranged in a single row or in several rows with interrupted light bands. This algal species is abundant not only in the Upper Viséan of the Moscow Basin, but also in other regions of Eurasia. Calcified remains of the thallus of this species are considerably less common in the Serpukhovian limestones.

Calcifolium punctatum **Maslov, 1956** (Pl. 13, fig. 7). This is a considerably less common species. It is dis-

Explanation of Plate 13

Figs. 1–4. *Asphaltina cordillerensis* Mamet in Petryk et Mamet: (1) specimen PIN, no. 5547/31, photograph, no. 5115; cross-section of a segment; Oka River, Borehole 42, depth 23.0 m, thin section 1; Mikhailovian Regional Stage; (2) specimen PIN, no. 5547/32, photograph, no. 4678; longitudinal section of a plate composed of two segments; Oka River, Borehole 39, depth 20.5 m, thin section 2; (3) specimen PIN, no. 5547/33, photograph, no. 5109; longitudinal section plate composed of three segments; Oka River, Borehole 42, depth 23.0 m, thin section 1; (4) specimen PIN, no. 5547/34, photograph, no. 5133; monolayered crust overgrowing a pelmatozoan grain; Oka River, Borehole 42, depth 23.0 m, thin section 2.

Figs. 5 and 6. *Asphaltinella horowitzi* Mamet et Roux: (5) specimen PIN, no. 5547/35, photograph, no. 4393; longitudinal section; Oka River, Borehole 39, depth 20.5 m, thin section 2; (6) specimen PIN, no. 5547/36, photograph, no. 4697; oblique section, Oka River, Borehole 39, depth 20.5 m, thin section 3; Mikhailovian Regional Stage.

Figs. 7. *Calcifolium punctatum* Maslov, specimen PIN, no. 5547/37, photograph, no. 4331; longitudinal section; Oka River, Borehole 41, depth 15.6 m, thin section 2; Venevian Regional Stage.

Figs. 8 and 9. *Calcifolium okense* Shvetsov et Birina: (8) specimen PIN, no. 5547/38, photograph, no. 0113; cross-section; Novogurovsky Quarry, Bed 7/16, thin section 1; (9) specimen PIN, no. 5547/39, photograph, no. 5053; longitudinal section; Oka River, Borehole 42, depth 32.0 m, thin section 2; Mikhailovian Regional Stage.

Fig. 10. *Ungdarella uralica* Maslov, specimen PIN, no. 5547/40, photograph, no. 5161; longitudinal section; Oka River, Borehole 42, depth 50.0 m, thin section 3; Aleksinian Regional Stage.

Figs. 11 and 12. *Koninckopora* sp.: (11) specimen PIN, no. 5547/41, photograph, no. 0112; longitudinal section; Novogurovsky Quarry, Bed 6, thin section 1; Mikhailovian Regional Stage; (12) specimens PIN, no. 5547/42, photograph, no. 4306; longitudinal section; Oka River, Borehole 41, depth 16.7 m, thin section 1; Venevian Regional Stage.

Scale bar 100 μm.

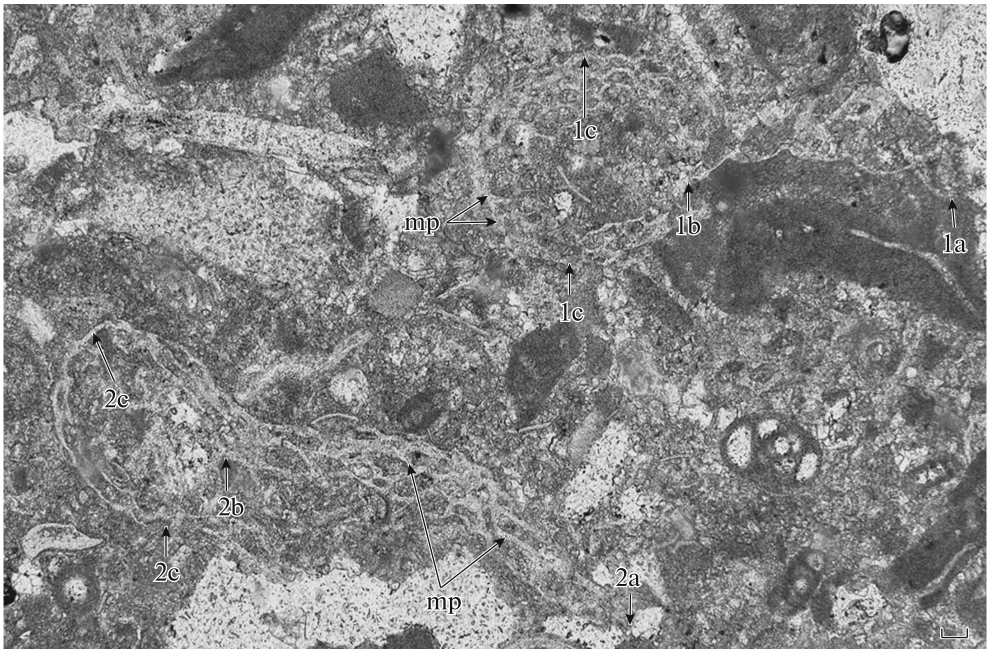


Fig. 3. Two specimens of *Asphaltinella horowitzi* Mamet et Roux in one thin section demonstrate growth stages, specimen PIN, no. 5547/2, photograph, no. 4995; Oka River, Borehole 39, depth 20.5 m, thin section 2; Upper Viséan, Mikhailovian Regional Stage; stages: (1a, 2a) filamentous; (1b, 2b) reticulate; (1c, 2c) spheroid; the wall is perforated by micropores (mp) filled by black micrite. Scale bar 500 μm.

tinguished from *C. okense* by the shape of the siphon, which represents a tube with relatively regular constrictions; the light calcite grains are arranged as a mosaic.

***Claracrusta* sp.** (Fig. 4h). This taxon, assigned to the genus *Claracrusta* Vachard in Vachard et Montenat, 1981, is represented by a single specimen found in the Mikhailovian Regional Stage in the Novogurovsky Quarry (Bed 16, Sample 9/11). The thallus is laminated, about 3 mm long and 0.2–0.3 mm wide, fibrous, composed of tightly fused branching threads with rare irregular constrictions.

***Exvotarisella index* (Ehrenberg, 1854) Möller, 1879** (Pl. 12, figs. 5, 6, 9).

The thallus is cylindrical and calcified (length up to 1.5 mm, diameter 0.3–0.4 mm), irregular in shape and dichotomously branching. The central cavity is subdivided by thick belts into the sub-square segments. The thallus is perforated by pores. Microspores are scattered along the outer contour between the belts (less than 1 μm). This species is abundant in the Upper Viséan of the Moscow Region; over 20 specimens are known from the Aleksinian, whereas over 20 specimens come from the Aleksinian–Venevian Regional Stages (Borehole 39, depth 20.5 and 24.5 m; Borehole 41, depth 24.5, 28.8, 38.0, and 38.8 m; Borehole 42, depth 19.4, 24.8, 41.0, and 44 m).

***Fasciella kizilia* R. Ivanova, 1973** (Fig. 4i). One poorly preserved specimen of this species was found in the Venevian beds in the Novogurovsky Quarry (Bed 24, Sample 13/43). The thallus is tubular (860 μm long, 230 μm wide), composed of clearly delimited layers of inconsistent thickness, enveloping one another. This species is widespread in the Upper Viséan, Serpukhovian, and Bashkirian in the Urals and other regions (Ivanova, 1973; Bogush et al., 1990).

***Fourstanella* sp.** (Fig. 4g). The genus *Fourstanella* Cummings, 1955 is represented by one specimen found in the Mikhailovian Regional Stage (Borehole 39, depth 20.5 m). The thallus (diameter 280 μm) is composed of regular indistinct numerous cell filaments (up to 26 μm in diameter), which are tightly adjacent in parallel to one another and are separated by transverse walls (6 ŋm thick), oblique to the axis. The cells are semi-square or square in outline.

***Girvanella* sp.** (Fig. 4f). One specimen of the genus *Girvanella* Nicholson et Etheridge, 1878 was found in the Aleksinian in the Novogurovsky Quarry (Bed 1, Sample 1/1).

The colony (620 μm long, 200 μm wide) is composed of the entwisted, rarely branching threads of consistent thickness (33 μm) with a distinct dark cover over a lighter lumen.

***Kamaena* aff. *delicata* Antropov, 1967** (Pl. 12, figs. 1, 2). The genus *Kamaena* Antropov, 1967 was established based on the material from the Upper Famennian of the Volga River (Antropov, 1967). In the Lower Carboniferous of the Moscow Basin, this genus is represented by several poorly preserved specimens (Borehole 41, depth 32.5 m; Aleksinian

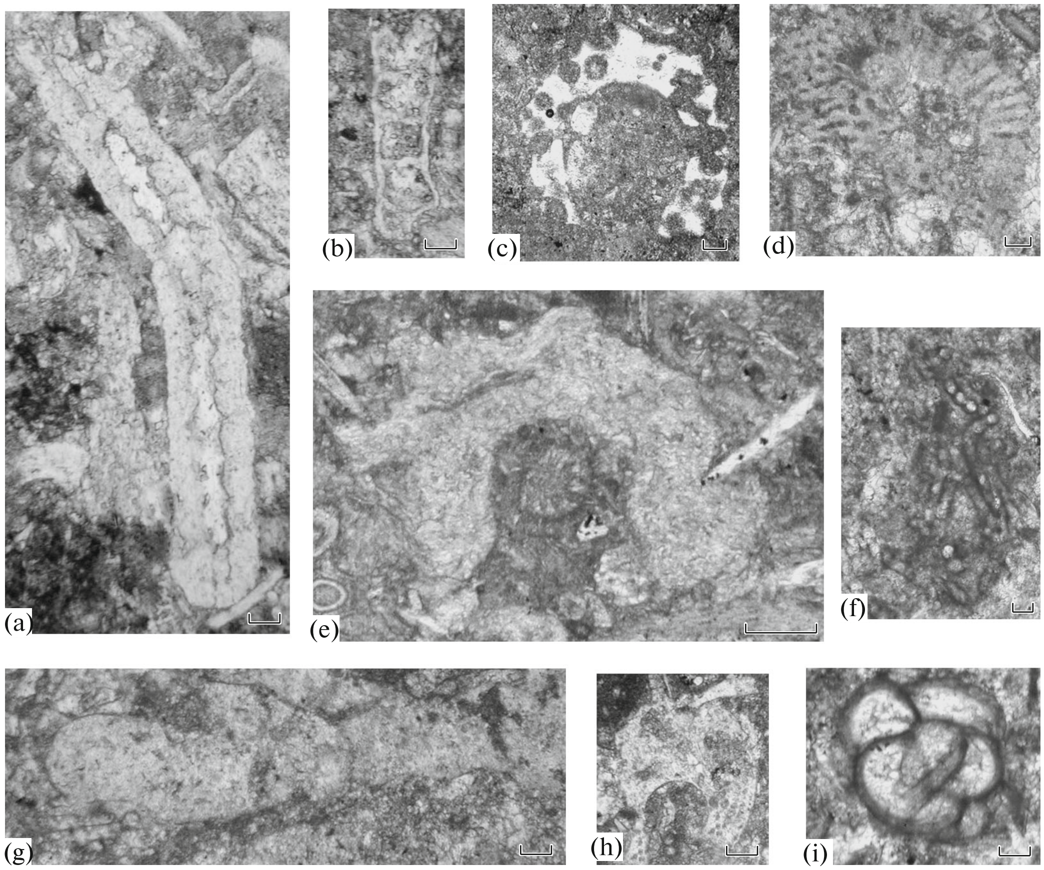


Fig. 4. Association of rare Late Viséan taxa of algal flora of the Moscow Basin: (a) *Pseudokamaena* sp., specimen PIN, no. 5547/3, photograph, no. 4387; longitudinal section; Oka River, Borehole 39, depth 38.8 m, thin section 2; Aleksinian Regional Stage; (b) *Kamaenella* sp., specimens PIN, no. 5547/4, photograph, no. 4420; longitudinal section; Oka River, Borehole 39, depth 34.4 m, thin section 2; Aleksinian Regional Stage; (c) *Kulikia rozovskaiae* (Mamet et Roux) R. Ivanova, specimen PIN, no. 5547/5, photograph, no. 5224; Oka River, Borehole 42, depth 22.0 m, thin section 3; Mikhailovian Regional Stage; (d) *Stacheoides*? sp., specimen PIN, no. 5547/6, photograph, no. 0051; oblique section; Novogurovsky Quarry, Bed 23, Sample 40, thin section 2; Venevian Regional Stage; (e) *Claracrusta* sp., specimen PIN, no. 5547/7, photograph, no. 0111; encrusting a foraminiferal test; Novogurovsky Quarry, Bed 1, thin section 1; Aleksinian Regional Stage; (f) *Girvanella* sp., specimen PIN, no. 5547/8, photograph, no. 0076; oblique section; Novogurovsky Quarry, Bed 1, thin section 1; Aleksinian Regional Stage; (g) *Fasciella kizilia* R. Ivanova, specimen PIN, no. 5547/9, photograph, no. 0133; Novogurovsky Quarry, Bed 24, Sample 13/43, thin section 4; Venevian Regional Stage; (h) *Fourstanella* sp., specimen PIN, no. 5547/10, photograph, no. 5007; cross-section; Oka River, Borehole 39, depth 20.5 m, thin section 2; Mikhailovian Regional Stage; (i) *Salebra* sp., specimen PIN, no. 5547/11, photograph, no. 0081; oblique section; Novogurovsky Quarry, Bed 1, thin section 1; Aleksinian Regional Stage. Scale bar 100 (a–d, f–i) and 500 (e) μm.

Regional Stage). The inner cavity of the tubular skeleton is subdivided into segments of infrequent belts occurring perpendicularly to the wall. The calcareous wall and belts are perforated by simple straight pores.

***Kamaenella* sp.** (Fig. 4b). The genus *Kamaenella* Mamet et Roux, 1974 is represented by several specimens found in the Aleksinian and Mikhailovian regional stages. Of these, a specimen from the Aleksinian Regional Stage (Borehole 39, depth 34.4 m) is the best preserved. This is a fragment 480 μm long and 126 μm in diameter, subdivided into semi-square segments with rare belts oblique to the walls of the tubular thallus. The wall and belts are of the same thickness (13 μ m), are perforated by simple straight pore.

***Koninckopora* sp.** (Pl. 13, figs. 11, 12). Representatives of the genus *Koninckopora* Lee, 1912 are also rare in sections of the Moscow Basin. One specimen was found in the Novogurovsky Quarry (Bed 6, Mikhailovian Regional Stage), and the second in the Venevian Regional Stage (Borehole 41, depth 16.7 m). The thallus is large in size and is variously shaped, composed of light-colored cells arranged in a row or irregularly scattered. The cell walls are thick, perforated by pores. The thin outer layer is dark.

***Kulikia rozovskaiae* (Mamet et Roux, 1975) R. Ivanova, 1999** (Fig. 4c). This species is represented by only a few rather poorly preserved specimens found in the Mikhailovian Regional Stage (Borehole 42, depth 22.0 m, thin section 3). The thallus (0.6 mm) is polygonal, with a thin (20 μm) microgranular wall. The cavity of the central inner canal is smooth is approximately half of the diameter of the thallus. In the cross-section, the dark-colored sporangia are arranged in a circle in a single row. Mamet and Roux (1975) described this species based on the material which he probably received from S.E. Rozovskaya from the core of a borehole drilled without any indication of a collection depth or regional Stage. Makhlina et al. (1993) figured identical specimens as *Sphinctoporella* sp. from the Tulian Regional Stage Voronezh Anteclise. We support the opinion of Ivanova (1999, 2013) and Berchenko and Sukhov (2012) that the genus *Sphinctoporella* Mamet et Rudloff, 1972 is a junior synonym of the genus *Kulikia* Golubtsov, 1961 (Golubtsov, 1961).

Palaeoberesella lahusenii **(Möller, 1879) Mamet et Roux, 1974** (Pl. 12, figs. 3, 4, 8). The thallus is cylindrical (up 1 mm long and ca. 0.3 mm in diameter), straight and curved, subdivided by rectangular septa into segments rounded-rectangular in shape; the segment height is close to the inner diameter of the cylinder. The thallus wall and septa and perforated by thin pores along the entire length. These algae are sometimes rock-forming and form algal mats in the deposits of the Mikhailovian Regional Stage (Gibshman et al., 2009).

Pseudokamaena **sp.** (Fig. 4a). The genus *Pseudokamaena* Mamet in Petryk et Mamet, 1972 is represented by a single well-preserved specimen found in the Aleksinian Regional Stage (Borehole 39, depth 34.4 m). The inner cavity of the tubular thallus (1.1 mm long, 0.17 mm in diameter) subdivided into evenly sized round segments by thick short belts not reaching the middle of the central cavity. The wall is thick, with constrictions.

Salebra **sp.** (Fig. 4e). The genus *Salebra* Bogush, 1976 is very uncommon; one specimen is found in the Aleksinian Regional Stage in the Novogurovsky Quarry (Bed 1, Sample 1). Its diameter is 200 μm, the cell diameter is 80 μm, and the wall thickness is 13 μm. Species of this genus have a skeleton consisting of paired central tube surrounded by a bunch of tubules, which form bubble-like extensions in the cortex (Bogush, 1976). Most authors consider this group as problematic, although its assignment to algae cannot be excluded (Bogush and Brenckle, 1983).

Stacheoides**? sp.** (Fig. 4d). A single poorly preserved specimen from the Venevian in the Novogurovsky Quarry (Bed 23, Sample 40) is tentatively assigned to the genus *Stacheoides* Cummings, 1955 emend. Petryk et Mamet, 1972. It represents a thallus consisting of rectangular or oval, tightly adjacent cells 0.4 mm wide, 0.4 mm high, with threads 26 μm thick.

Stipulella fascicularis **Maslov, 1956.** Remains belonging to this species were found by Maslov (1956b) in the Tulian deposits in the southwestern Moscow Basin, with no exact locality or stratigraphic position indicated. We did not find similar specimens, but limestones of the Tulian Regional Stage were not exposed in the sections studied (apart from Borehole 42). According to Maslov (1956b), the colony was rounded, in the shape of slightly angular lumps, composed of cells 50 μm long, assembled in bundles. The outer membrane of the cells are dark, thin (3–5 μm), the lumen is light (5–7 μm in diameter). The algal nature of these structures is doubtful.

Ungdarella uralica **Maslov, 1956 (**Pl. 13, fig. 10). The threads occur at an acute angle to the outer and inner surface of the thallus. This species of *Ungdarella* Korde, 1951 is common in the Upper Viséan beds of the Moscow Basin. Russian authors consider Maslov (1950) to be the author of this genus, although he published the generic name without any included species, and without verbal descriptions of its characters, or figures. Thus, this name as published in 1950 is a *nomen nudum*. Korde (1951) gave a nomenclaturally valid description of this taxon (although ascribed to Maslov (1951). Korde is therefore the author of the genus *Ungdarella* with the type species *U. conservata* Korde, 1951, as correctly indicated by Mamet (1991, p. 433). Maslov (1956) tried to rectify the situation and published a description of this genus and it type species in a separate paper and in a monograph (Maslov, 1956a, b), which was accepted by other Russian authors as a correct nomenclatural act establishing Maslov's authorship, but according to the International Code of Botanical Nomenclature, Korde remains the correct author for this generic name.

Zidella **sp.** (Pl. 12, figs. 10, 19). The genus *Zidella* Saltovskaya, 1984, originally described from the Viséan described from the Viséan beds of Tajikistan (Saltovskaya, 1984), is represented by two specimens (Borehole 42, depth 19.4 m, thin section 2, Venevian Regional Stage; Borehole 39, depth 35.0 m, thin section 1, Aleksinian Regional Stage). The genus is characterized by a cylindrical thallus up to 1.5 mm, about 0.2 mm in diameter, often curved and unbranching. The central portion of the thallus is wide and clearly delineated. The wall is thick (50 μm), irregularly calcareous and porous. The pores are thin, of varying length, perpendicular to the axial part of the thallus.

CONCLUSIONS

The Late Viséan algal flora of the Moscow Basin, presently comprising 24 species of 23 genera, is somewhat impoverished compared to the synchronous floras of other marine basins (Mamet, 1992). For instance, more diverse Viséan associations are known from British Columbia (Canada), where 41 species were established (Mamet, 2006); 26 genera are found in the Urals in the Upper Viséan only (Ivanova, 1988, 2013, 2014). The relatively low taxonomic diversity suggests that species existing in the Moscow Basin migrated here from other basins with the onset of a large-scale transgression in the Aleksinian (Kabanov et al., 2013, 2016).

The most favorable condition for the growth of algae with a calcareous skeleton were in the Mikhailovian (17 genera), when frequent sea-level oscillations that resulted in the formation of "*Stigmaria* limestones" (paleosols) led to the formation of large shoals, in which algae and other organisms produced a considerable amount of carbonate material. In the Venevian the diversity of algae began to decrease (11 genera), which could be associated with the deepening of the marine basin and the lower level of illuminance. This deepening is supported by a considerable increase of conodont content in the limestone, and appearance among them comparatively deep-water taxa (Gibshman et al., 2009; Kabanov et al., 2016). In the Serpukhovian, the diversity and abundance of algae decreased even more. The Late Viséan algae known in the Moscow Basin are also recorded in the basins of North and South America, Western and Eastern Europe, Western Kazakhstan, Central Asia, North America, and Australia. This suggests a reasonably free exchange between the Late Viséan marine basins, allowing a wide exchange of faunistic and floristic elements. Further detailed study of the Early Carboniferous algal flora of the Moscow Basin is likely to be useful for remote correlations, along with foraminifers and conodonts.

Despite the apparent geographic isolation of the Late Viséan shallow-water marine Moscow basin, the algal flora inhabiting it consisted of genera of wide geographic distribution, and their taxonomic diversity was comparable to that of many other marine basins.

ACKNOWLEDGMENTS

We are grateful to the reviewers for valuable comments, to M.A. Naumcheva (PIN) for her aid with figures, and to M.K. Emelyanova (PIN) for consultations on computer graphics.

The study was partly supported by the Russian Foundation of Basic Research, project nos. 14-05-00774 and 15-05-00214 and the subsidy of the Russian Government to support the Program of Competitive Growth of Kazan Federal University among the World's Leading Academic Centers.

REFERENCES

Akhmetshina, L.Z., Gibshman, N.B., Kuandykov, B.M., Uskova, N.A., Kononets, V.I., Baimagambetov, B.K., Kukhtinov, D.A., and Degtyareva, L.V., *Atlas paleontologicheskikh ostatkov, mikrofatsii i obstanovok osadkonakopleniya famensko-kamennougol'nykh otlozhenii Prikaspiiskoi vpadiny (Kazakhstanskaya chast') (Atlas of Fossil Remains, Microfacies, and Depositional Environments of the Famennian–Carboniferous Sediments of the Kaspian Depression, Kazakhstan Part)*, Almaty: AktyubNIGRI, 2007.

Alekseev, A.S., Gibshman, N.B., Gabdullin, R.R., Mamontov, D.A., Bershov, A.V., Kabanov, P.B., Naumov, S.S., and Samarin, E.N., Biostratigraphy of the upper Viséan sediments (Lower Carboniferous) in the Oka River valley near Serpukhov (Moscow oblast), *Paleostrat-2013. Godichn. sobranie (nauchn. konf.) sektsii paleontologii MOIP i Moskovskogo otd. Paleontol. ob-va. Moskva, 28–30 yanvarya 2013 g. Progr. i tezisy dokl.* (Paleostrat-2013. Annual Meeting (Scientific Conference) of the Paleontology Division of the Moscow Society of Naturalists and the Moscow Branch of the Paleontological Society at the Russian Academy of Sciences: Moscow, January 28–30, 2013: Program and Abstracts), Alekseev, A.S., Ed., Moscow: Paleontol. Inst. Ross. Akad. Nauk, 2013, pp. 6–7.

Antropov, I.A., *Devonian and Lower Carboniferous (Tournesian) algae from the central part of the eastern Russian platform, Iskopaemye vodorosli SSSR (Fossil Algae of the USSR)*, Moscow: Nauka, 1967, pp. 118–125.

Berchenko, O.I. and Sukhov, O.A., On the validity of distinguishing of some early Carboniferous genera of *Dasycladates* algae of the Aciculelleae Bassoullet et al. tribe (Chlorophyta), *Al'gologiya*, 2012, vol. 22, no. 4, pp. 402–409.

Bogush, O.I., Early Carboniferous fossils of uncertain systematic position, *Paleontol. Zh.*, 1976, no. 4, pp. 103–109.

Bogush, O.I. and Brenkl, P.L., Salebridae, a new family of uncertain systematic position from the Lower Carboniferous of the USSR and United States, in *Stratigrafiya i paleontologiya devona i karbona* (Stratigraphy and Paleontology of the Devonian and Carboniferous), Yuferev, O.V., Ed., Tr. Inst. Geol. Geofiz. Sib. Otd. Akad. Nauk SSSR, vol. 483, Moscow: Nauka, 1983. pp. 103–118

Bogush, O.I., Ivanova, R.M., and Luchinina, V.A., *Izvestkovye vodorosli verkhnego famena i nizhnego karbona Urala i Sibiri (Calcareous Algae of the Upper Famennian and Lower Carboniferous of the Urals and Siberia), Tr. Inst. Geol. Geofiz. Sib. Otd. Akad. Nauk SSSR*, vol. 745, Novosibirsk: Nauka, 1990.

Brady, H.B., *A Monograph of Carboniferous and Permian Foraminifera (the Genus Fusulina Excepted), Palaeontogr. Soc. Monogr.*, London: Palaeontogr. Soc., 1876.

Brenckle, P.L., Marshal, F.C., Waller, S.F., and Wilhelm, M.H., Calcareous microfossils from the Mississippian Keokuk Limestone and adjacent formations, upper Mississippi River Valley: their meaning for North American and intercontinental correlation, *Geol. Paleontol.*, 1982, vol. 15, pp. 47–88.

Brenckle, P.L., Late Viséan (Mississippian) calcareous microfossils from the Tarim basin of western China, *J. Foramin. Res.*, 2004, vol. 34, no. 2, pp. 144–164.

Chuvashov, B.I., Luchinina, V.A., Shuiskii, V.P., Shaikin, I.M., Berchenko, O.I., Ishchenko, A.A., Saltovskaya, V.D., and Shirshova, D.I., *Iskopaemye izvestkovye vodorosli (morfologiya, sistematika, metody izucheniya)* (Fossil Calcareous Algae: Morphology, Systematics, and Methods of Study), Dubatolov, V.N., Ed., Tr. Inst. Geol. Geofiz., Sib. Otd. Akad. Nauk, vol. 674, Novosibirsk: Nauka, 1987.

Cummings, R.H., New genera of Foraminifera from the British Lower Carboniferous, *J. Washington Acad. Sci.*, 1955, vol. 45, no. 1, pp. 1–8.

Ehrenberg, C.G., *Zur Mikrogeologie. Einundvierzig Tafeln mit über viertausend Grossentheils colorirten Figuren, gezeichnet vom Verfasser*, Leipzig: Verl. von Leopold Voss, 1854.

Elliott, G.F., Calcareous algae new to the British Carboniferous, *Palaeontology*, 1970, vol. 13, no. 3, pp. 443–450.

Gabdullin, R.R., Alekseev, A.S., Bershov, A.V., Kabanov, P.B., Naumov, S.S., Samarin, E.N., and Kozlova, G.K., A sequential stratigraphic interpretation of Upper Viséan sediments from the southern Moscow Syneclise (Serpukhov district of Moscow oblast), *Paleostrat-2013. Godichn. sobranie (nauchn. konf.) sektsii paleontologii MOIP i Moskovskogo otd. Paleontol. ob-va. Moskva, 28–30 yanvarya 2013 g. Progr. i tezisy dokl.* (Paleostrat-2013. Annual Meeting (Scientific Conference) of the Paleontology Division of the Moscow Society of Naturalists and the Moscow Branch of the Paleontological Society at the Russian Academy of Sciences: Moscow, January 28–30, 2013: Program and Abstracts), Alekseev, A.S., Ed., Moscow: Paleontol. Inst. Ross. Akad. Nauk, 2013, p. 26.

Gibshman, N.B., Foraminifers from the Serpukhovian Stage stratotype, the Zabor'e Quarry site (Moscow region), *Stratigr. Geol. Correlation,* 2003, vol. 11, no. 1, pp. 36–60.

Gibshman, N.B. and Alekseev, A.S., Marine algoflora of the Late Viséan (Early Carboniferous) of the Moscow Basin: Taxonomy and biogeography, *Vodorosli v evolyutsii biosfery. Mater. I Paleoal'gologicheskoi konf. 25–28 fevralya 2013 g.* (Algae in the Evolution of the Biosphere: Proc. 1st Paleoalgological Conf., Moscow, February 25–28, 2013), Moscow: Paleontol. Inst. Ross. Akad. Nauk, 2013a, pp. 20–23.

Gibshman, N.B. and Alekseev, A.S., Paleobiogeographical relationships of algoflora in the Late Viséan (Early Carboniferous) of the Moscow Basin, *Sistematika organizmov. Ee znachenie dlya biostratigrafii i paleobiogeografii. Mater. LIX sessii Paleontol. ob-va pri RAN (1–5 aprelya 2013 g., Sankt-Peterburg)* (Systematics of Organisms: Its Significance for Biostratigraphy and Paleobiogeography: Proc. 59th Session of the Paleontol. Soc. at the Russian Academy of Sciences, April 1–5, 2013, St. Petersburg), Bogdanova, T.N., Ed., St. Petersburg: VSEGEI, 2013b, pp. 36–37.

Gibshman, N.B., Kabanov, P.B., Alekseev, A.S., et al., Novogurovsky Quarry. Upper Viséan and Serpukhovian, in *Type and Reference Carboniferous Sections in the South Part of the Moscow Basin. Field Trip Guidebook of Int. Field Meeting of the I.U.G.S. Subcommission on Carboniferous Stratigraphy "The Historical Type Sections, Proposed and Potential GSSP of the Carboniferous in Russia," Moscow, August 11–12, 2009*, Alekseev, A.S. and Goreva, N.V, Eds., Moscow: Paleontol. Inst. Ross. Akad. Nauk, 2009, pp. 13–45.

Golubtsov, V.K., *Kulikia, a new genus of calcareous algae from the Viséan Stage, Paleontologiya i stratigrafiya BSSR. Sb. 3 (Paleontology and Stratigraphy of the BSSR. Collection of Papers No. 3)*, Fursenko, A.V., Ed., Minsk: Akad. Nauk BSSR, 1961, pp. 348–353.

Ivanova, R.M., A contribution to the stratigraphy of the Middle and Upper Viséan sediments on the eastern slope of the southern Urals, *Kamennougol'nye otlozheniya vostochnogo sklona Yuzhnogo Urala: Magnitogorskii sinklinorii: Sbornik po voprosam stratigrafii. №15* (Carboniferous Sediments on the Eastern Slope of the Southern Urals: Magnitogorsk Synclinorium: Collection of Papers on Problems of Stratigraphy. No.15), Ivanov, A.N., Ed., Tr. Gorno-Geol. Inst. Akad. Nauk SSSR, Ural. Fil., Sverdlovsk: Ural. Fil. Akad. Nauk SSSR, 1973, pp. 18–86.

Ivanova, R.M., *Calcareous algae in the Viséan Stage of the Urals, Biostratigrafiya i litologiya verkhnego paleozoya Urala. Sb. nauch. trudov (Biostratigraphy and Lithology of the Upper Paleozoic of the Urals. Collection of Scientific Papers)*, Chuvashov, B.I., Ed., Sverdlovsk: Ural. Otd. Akad. Nauk SSSR, 1988, pp. 5–18.

Ivanova, R.M., Foraminifers of the Venevian and Tarusian regional stages of the Moscow Basin in the Venev Monastyr' and Bekhovo sections and the boundary between the Viséan and Serpukhovian stages, *Tipovye razrezy karbona Rossii i potentsial'nye global'nye stratotipy. Yuzhnoural'skaya sessiya: Mater. Mezhdunar. polevogo soveshch. "Stratotipicheskie razrezy, predlagaemye i potentsial'nye TGSG karbona v Rossii", Ufa–Sibai, 13–18 avgusta, 2009 g.* (Carboniferous Type Sections in Russia and Potential Global Stratotypes: Southern Urals Session: Proceedings of the International Field Meeting "The Historical Type Sections, Proposed and Potential GSSP of the Carboniferous in Russia," Ufa–Sibai, 13–18 August, 2009), Puchkov, V.N., Ed., Ufa: OOO DizainPoligrafServis, 2009, pp. 206–211.

Ivanova, R.M., *Izvestkovye vodorosli karbona Urala (Calcareous Algae in the Carboniferous of the Urals)*, Yekaterinburg: Redakts.- Izd. Otd. Ural. Otd. Ross. Akad. Nauk, 2013.

Ivanova, R.M., Biostratigrafical Significance of Calcareous Algae in the Carboniferous of the Urals, *Tr. Inst. Geol. Geokhim. Ural. Otd. Ross. Akad. Nauk*, 2014, vol. 161, pp. 27–31.

Kabanov, P.B., Serpukhovian Stage stratotype in the Zabor'e Quarry. Part 1: Lithofacies characterization, *Stratigr. Geol. Correlation*, 2003, vol. 11, no. 1, pp. 18–35.

Kabanov, P.B., Alekseev, A.S., Gabdullin, R.R., Gibshman, N.B., Bershov, A.V., Naumov, S.S., and Samarin, E.N., Progress in sequence stratigraphy of upper Viséan and lower Serpukhovian of the southern Moscow Basin, Russia, *Newsl. Carboniferous Stratigr.*, 2013, vol. 30, pp. 55–65.

Kabanov, P.B., Alekseev, A.S., Gibshman, N.B., Gabdullin, R.R., and Bershov, A.V., The upper Viséan–Serpukhovian in the type area for the Serpukhovian Stage (Moscow Basin, Russia): Part 1. Sequences, disconformities, and biostratigraphic summary, *Geol. J.*, 2016, vol. 51, no. 2, pp. 163–194.

Korde, K.B., New genera and species of calcareous algae from the Carboniferous sediments of the Northern Urals, *Tr. Mosk. Ob-va Ispyt. Prir. Otd. Geol.*, 1951, vol. 1, pp. 175–182.

Lee, G.W., The British Carboniferous Trepostomata, *Great British Geol. Surv. Mem.*, 1912, vol. 1, no. 3, pp. 135–195.

Loeblich, A.R. and Tappan, H., *Foraminiferal Genera and Their Classification*, New York: Van Nostrand Reinhold, 1987.

Makhlina, M.Kh., Vdovenko, M.V., Alekseev, A.S., Byvsheva, T.V., Donakova, L.M., Zhulitova, V.E., Kononova, L.I., Umnova, N.I., and Shik, E.M., *Nizhnii karbon Moskovskoi sineklizy i Voronezhskoi anteklizy (Lower Carboniferous of the Moscow Syneclise and Voronezh Anteclise)*, Tikhomirov, S.V., Ed., Moscow: Nauka, 1993.

Mamet, B.L., Carboniferous calcareous algae, in *Calcareous Algae and Stromatolites*, Riding, R, Ed., Berlin, Heidelberg: Springer-Verlag, 1991, pp. 371–451.

Mamet, B.L., Paléogéographie des algues calcaires marines carbonifères, *Can. J. Earth Sci.*, 1992, vol. 29, no. 1, pp. 174–190.

Mamet, B.L., Taxonomy of Viséan marine calcareous algae, Fernie, British Columbia (Canada), *Riv. Ital. Paleontol. Stratigr.*, 2006, vol. 112, no. 3, pp. 323–357.

Mamet, B. and Rudloff, B., Algues carbonifères de la partie septentrionale de l'Amérique du Nord, *Rev. Micropaléontol.*, 1972, vol. 15, no. 2, pp. 75–114.

Mamet, B.L., Sur deux Dasycladacées carbonifères des Cordillères nord-américaines, *Rev. Micropaléontol.*, 1974, vol. 17, no. 1, pp. 38–44.

Mamet, B.L. and Roux, A., Sur quelques algues tubulaires scalariformes de la Téthys paléozoïque, *Rev. Micropaléontol.*, 1974, vol. 17, no. 3, pp. 134–156.

Mamet, B.L. and Roux, A., Dasycladacées dévoniennes et carbonifères de la Téthys occidentale, *Rev. Esp. Micropaleontol.,* 1975, vol. 7, no. 2, pp. 245–295.

Mamet, B.L. and Roux, A., Algues viséennes et namuriennes du Tennessee (États-Unis), *Rev. Micropaléontol.*, 1978, vol. 21, no. 2, pp. 68–97.

Maslov, V.P., *Iskopaemye izvestkovye vodorosli SSSR* (Fossil Calcareous Algae of the USSR), Shtreis, N.A., Ed., Tr. Inst. Geol. Nauk Akad. Nauk SSSR, vol. 160, Moscow: Akad Nauk SSSR, 1956a.

Maslov, V.P., On a new fossil family of red algae and two new genera of blue-green algae coming from the Carboniferous, *Dokl. Akad. Nauk SSSR,* 1956b, vol. 107, no. 1, pp. 151–154.

Maslov, V.P., The significance of red algae for the stratigraphy of the USSR, *Dokl. Akad. Nauk SSSR,* 1950, vol. 70, no. 1, pp. 75–78.

Mierzejewski, P., Algal nature of the Ordovician presumed polychaete eggs, *Acta Palaeontol. Pol.*, 1991, vol. 36, no. 1, pp. 83–86.

Möller, V., Die Foraminiferen des russischen Kohlenkalks, *Mém. Imp. Acad. Sci. St. Pétersbourg, Sér. 7,* 1879, vol. 27, no. 5, pp. 1–172.

Möller, V.I., *Foraminifery kamennougol'nogo izvestnyaka Rossii (Foraminifers of the Carboniferous Limestone of Russia), Mater. Geol. Rossii*, vol. 9, St. Petersburg: Tipogr. Imp. Akad. Nauk, 1880.

Nicholson, H.A. and Etheridge, R., *A Monograph of the Silurian Fossils of the Girvan District, Ayrshire, with Special Reference to Those Contained in the "Gray Collection,"* Edinburgh, London: Blackwood, 1878, pp. 1–341.

Petryk, A.A. and Mamet, B.L., Lower Carboniferous algal microflora, southwestern Alberta, *Can. J. Earth Sci.*, 1972, vol. 9, no. 7, pp. 768–802.

Pia, J., *Die Siphoneae verticillatae vom Karbon bis zur Kreide*, Verh. Zool. Bot. Ges. Wien, vol. 11, no. 2, Wien: Zool.-Bot. Ges., 1920.

Pia, J., Die wichtigsten Kalkalgen des Jungpaläozoikums und ihre geologische Bedeutung. in *Compte rendu du deuxième Congrès pour l'avancement des études de Stratigraphie Carbonifère (Herleen 1935),* Maestricht: drukk. Gebrs. van Aelst, 1937, vol. 2, pp. 765–856.

Rauser-Chernousova, D.M., Stratigraphy of the Viséan Stage in the southern part of the Moscow Basin based on foraminiferan fauna, in *Stratigrafiya i foraminifery nizhnego karbona russkoi platformy i priural'ya* (Stratigraphy and Foraminifers of the Lower Carboniferous of the Russin Platform and Urals Region), Menner, V.V., Ed., Tr. Inst. Geol. Nauk Akad. Nauk SSSR, vol. 62, Geol. Ser. no. 19, Moscow: Akad. Nauk SSSR, 1948, pp. 3–40.

Rauser-Chernousova, D.M. and Gerke, A.A., *Terminologicheskii spravochnik po stenkam rakovin foraminifer (Glossary of Terms Used in Describing Foraminiferal Shell Walls)*, Moscow: Nauka, 1971.

Roux, A., Introduction à l'étude des algues fossiles paléozoïques (de la bactérie à la tectonique des plaques), *Bull. Centres Rech. Explor.-Prod. Elf-Aquitaine*, 1985, vol. 9, no. 2, pp. 465–699.

Saltovskaya, V.D., Some calcareous algae from the Paleozoic of Tadjikistan, in *Novye vidy iskopaemoi fauny i flory Tadzhikistana (New Species of the Fossil Fauna and Flora of Tadjikistan)*, Dushanbe: Inst. Geol. Akad. Nauk Tadzh. SSR, 1984, pp. 141–160.

Shvetsov, M.S. and Birina, L.M., *K voprosu o petrografii i proiskhozhdenii okskikh izvestnyakov raiona Mikhailov-Aleksin (On Petrography and Origin of the Oka River Limestones in the Mikhailov–Aleksin Region), Tr. Mosk. Geol. Tresta*, vol. 10, Moscow: ONTI NKTP SSSR, 1935.

Skompski, S., Stratigraphic position and facies significance of the limestone bands in the subsurface Carboniferous succession of the Lublin Upland, *Acta Geol. Pol.*, 1996, vol. 46, nos. 3–4, pp. 171–268.

Struve, A., Ueber die Schichtenfolge in den Carbonablagerungen in südlichen Theil des moskauer Kohlenbeckens, *Mém. Imp. Acad. Sci. St. Pétersbourg, Ser.* 7, 1886, vol. 34, no. 6, pp. 1–108.

Vachard, D. and Montenat, Ch., Biostratigraphie, micropaléontologie, et paléogéographie du Permien de la région de Tezak (Montagnes Centrales d'Afghanistan), *Palaeontography*, 1981, vol. 178B, pp. 1–88.

Vevel', Ya.A., Shishlov, S.B., and Zhuravlev, A.V., Facies and biostratigraphy of the Viséan–Serpukhovian sediments in the Polotnyanyi Zavod Section (southwestern Moscow Syneclise), in *Verkhnii paleozoi Rossii: stratigrafiya i paleogeografiya. Mater. Vseross. konf., posvyashch. pamyati prof. V.G. Khalymbadzhi. 25–27 sentyabrya 2007 g.* (Upper Paleozoic of Russia: Stratigraphy and Paleogeography. Proc. All-Russia Conf., Dedicated to the Memory of Prof. V.G. Khalymbadzhi. September 25–27, 2007), Kazan: Kazansk. Univ., 2007, pp. 51–54.

Translated by S. Nikolaeva