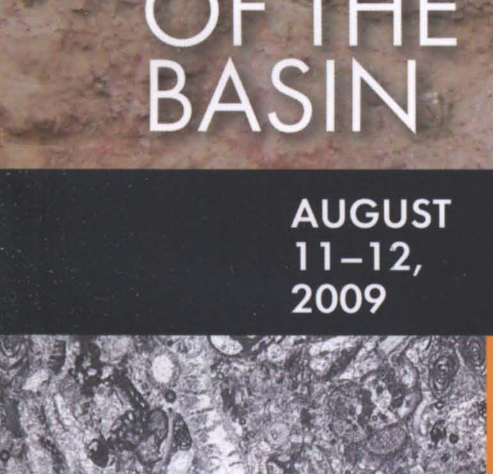
TYPE AND REFERENCE CARBONIFEROUS SECTIONS IN THE SOUTH PART OF THE MOSCOW BASIN

AUGUST
11–12,
2009

FIELD TRIP GUIDEBOOK

of International 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

Edited by

Alexander S. Alekseev

Nataliya N. Goreva

SCCS

MOSCOW, 2009

Russian Academy of Sciences
Branch of Earth Sciences
Branch of Biological Sciences

Borissiak Paleontological Institute of RAS

Institute of Geology, Ufa Scientific Centre of RAS

Geological Institute of RAS

Moscow State University

Karpinsky Russian Geological Research Institute

Academy of Sciences of the Republic of Bashkortostan

Interdepartmental Stratigraphical Committee of Russia

I.U.G.S. Subcommission on Carboniferous Stratigraphy

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Alekseev A.S., Goreva N.V. (Eds.). Type and reference Carboniferous sections in the south part of the Moscow Basin. Field trip guidebook of International 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. Moscow: Borissiak Paleontological Institute of Russian Academy of Sciences, 2009. 147 p.

The descriptions and biostratigraphic analyses of the most important type and reference sections of the Serpukhovian, Moscovian, Kasimovian, and Gzhelian stages are represented. The foraminifers, conodonts, Rugosa corals and some other fossil groups are illustrated. For geologists and paleontologists who study Carboniferous stratigraphy, paleontology and mineral resources, for students and teachers of field practices of Moscow universities.

Алексеев А.С., Горева Н.В. (ред.). Типовые и опорные разрезы карбона южной части Подмосковья. Путеводитель экскурсии Международного полевого совещания Подкомиссии по каменноугольной стратиграфии Международного союза геологических наук «Исторические типовые разрезы, предложенные и потенциальные Глобальные стратотипические разрезы и точки карбона в России». Москва, 11–12 августа 2009 г. М.: ПИН РАН, 2009. 147 с.

В путеводителе приведены описания и биостратиграфическая характеристика типовых и опорных разрезов серпуховского, московского, касимовского и гжельского ярусов. Изображены наиболее важные представители фораминифер, конодонтов, ругоз и ряда других групп ископаемых. Предназначен для геологов и палеонтологов, изучающих стратиграфию и палеонтологию каменноугольной системы, минеральные ресурсы, а также может быть использован студентами и преподавателями московских вузов на учебных геологических практиках.

Издание осуществлено при финансовой поддержке Отделения биологических наук РАН

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The Organizing Committee of the SCCS Field Meeting
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GUROVOBETON
Heidelberg Cement Group

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DOMODEDOVO PLANT OF BUILDING CONSTRUCTIONS AND MATERIALS

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Организационный комитет Полевого совещания Международной подкомиссии по каменноугольной стратиграфии глубоко признателен многим организациям и лицам, которые способствовали осуществлению Подмосковной экскурсии

ГУРОВО-БЕТОН
Предприятие группы *Гейдельберг Цемент Груп*

Полдников Николай Николаевич, *генеральный директор*
Сверчков Сергей Иванович, *начальник горного цеха*

ДОМОДЕДОВСКИЙ ЗАВОД СТРОИТЕЛЬНЫХ МАТЕРИАЛОВ И КОНСТРУКЦИЙ

Шелегия Теймураз Георгиевич, *генеральный директор*
Трусов Иван Васильевич, *главный инженер*

ВОСКРЕСЕНСКЦЕМЕНТ
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INTRODUCTION

GEOLOGICAL SETTING AND CARBONIFEROUS STRATIGRAPHY OF MOSCOW BASIN

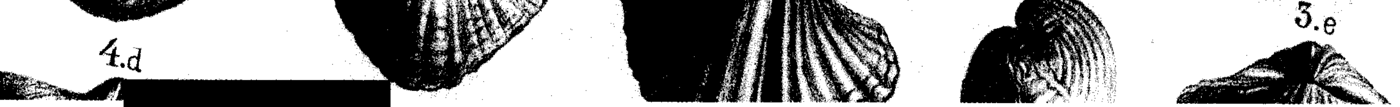
A.S. Alekseev[1,2]

[1]Moscow State University, Geological Faculty, Department of Paleontology,
119991 Moscow, Leninskie Gory, Russia. E-mail: aaleks@geol.msu.ru

[2]A.A. Borissiak Paleontological Institute of Russian Academy of Sciences,
117997 Moscow, Profsoyuznaya st. 123, Russia

The Moscow is situated on the southern margin of the Moscow Syneclise, a large depression in the sedimentary cover of the Precambrian East European craton (Fig. 1). South of the Moscow the coal bearing middle Visean unit have been widely distributed and this area known from the XIX century as the Moscow Coal Basin (Fig. 2). The syneclise is formed of the Vendian, Middle Devonian to the Lower Triassic sediments. The crystalline basement near the Moscow lies at the average depth of 1.5 km. The Moscow Graben (or aulacogene) to the south of the city is narrow (25–30 km) latitudinally oriented depression with faulted north and south margins filled with terrigenous Neoproterozoic (Riphaen and lower Vendian) rocks. The basement inside the graben subsided to the depth 2.5–3.5 km.

Most of the sedimentary cover (1.5 km) consists of carbonate Upper Devonian and Carboniferous sequences with minor clastic intervals. The Middle and Upper Carboniferous marine carbonates are exposed in the environs of the Moscow in the few outcrops and limestone quarries. These strata are overlain by the Middle and Upper Jurassic sands and clays, continental Bajocian and Bathonian and marine Callovian – Tithonian, up to 50–60 m thick. The thickness and stratigraphic completeness of the Jurassic succession increase in the pre-Jurassic river paleovalleys, especially in Main Moscow Valley. The Cretaceous sediments preserved from erosion only in the highest sites. Lower Cretaceous is shallow-water marine and lagoonal siliciclastic, Upper Cretaceous is clays, sands and siliceous rocks. The Cretaceous sediments are well preserved in the southernmost part of the Moscow on the Teply Stan Hills (Teply Stan and Yasenevo, highest point of the Moscow, 256 m above sea level) and northward of the Russian capital on the Klin-Dmitrov Hills. The Lower Cretaceous, up to 80 m thick, is mainly represented by shallow-marine, deltaic and alluvial sands with phosphorite nodules at the some horizons. The regionally developed terminal Albian Paramonovo Formation (up to 40 m) consists of silitic clays with abundant radiolarians (Alekseev et al., 1996a). The Upper Cretaceous strata include Cenomanian sands with phosphate nodules, Upper Turonian to Upper Santonian (or Lower Campanian) marine siliciclastics with inoceramids and radiolarians.



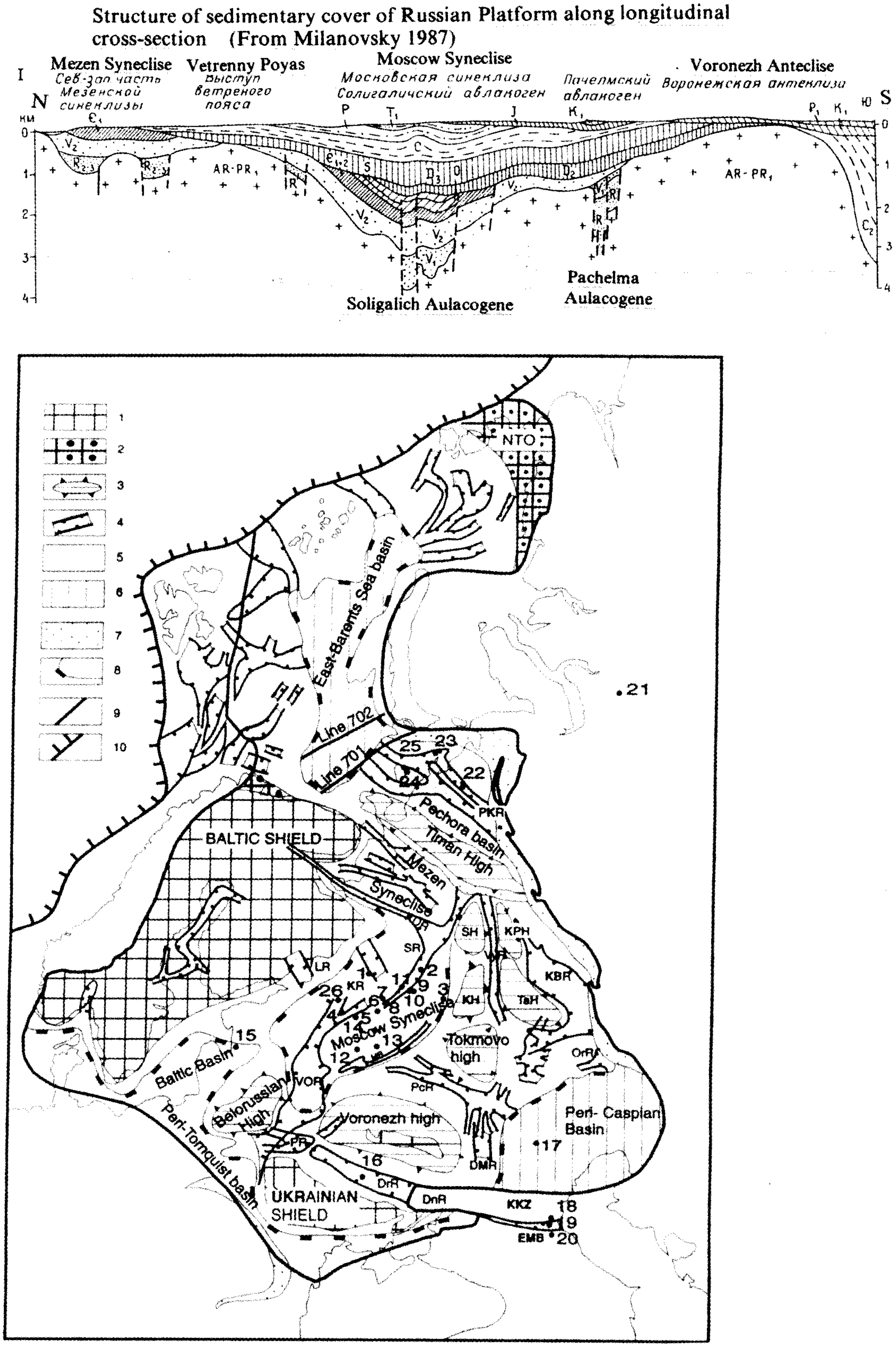

Structure of sedimentary cover of Russian Platform along longitudinal cross-section (From Milanovsky 1987)

Fig. 1. Main sedimentary basins of the East European Platform (Nikishin et al., 1996) and structure of sedimentary cover along longitudinal (north–south) cross-section (Milanovsky, 1987)

Fig. 2. Schematic geological map of the pre-Mesozoic of the south part of the Moscow Syneclise and location of the most important type and reference sections (modified from Yablokov, 1975). 1 – Lower Permian, Asselian (P_1as); 2, 3 – Upper Carboniferous: 2 – Gzhelian (C_3g); 3 – Kasimovian (C_3k); 4–8 – Middle Carboniferous: 4–7 – Moscovian: 4 – Myachkovian ($C_2m\check{c}$); 5 – Podolskian (C_2pd); 6 – Kashirian ($C_2k\check{s}$); 7 – Vereian (C_2vr); 8 – Bashkirian, Melekessian, Aza Group (C_2as); 9–12 – Lower Carboniferous: 9 – Upper Serpukhovian, Protvian (C_1pr); 10 – Upper Visean and Lower Serpukhovian (Tarusian and Steshevian) (C_1ok+sr); 11 – Middle Visean, Bobrikian (C_1jp); 12 – Tournaisian (C_1t); 13 – Upper Devonian, Famennian (D_3fm); 14 – buried valley filled with estuarine and fluviatile sediments of the Bashkirian Aza Group; 15 – type and reference sections in outcrops, numbers on the map: 1 – Stshelkovo; 2 – Gzhel; 3 – Afanasievo; 4 – Peski; 5 – Myachkovo; 6 – Podolsk; 7 – Stshurovo; 8 – Lopasnya River; 9–13 – Kashira and Gory area; 14 – Skniga River; 15 – Vereia; 16 – Nevezhino; 17 – Alyutovo; 18 – Protva River, Rostsha; 19 – Tarusa; 20 – Venev; 21 – Mikhailov; 22 – Aleksin; 23 – Tula; 24 – Novomoskovsk (Bobriki); 25 – Cherepet River; 26 – Plavsk; 27 – Zaborie; 28 – Dashkovka; 29 – Domodedovo; 30 – Rusavkino; 16 – bore-hole reference sections

The all older rocks are covered by Quaternary glacial and alluvial-glacial terrigenous sediments with 7 till bodies. The Middle Pleistocene Moscow Glaciation has extended as far as southern outskirts of the Moscow.

Carboniferous stratigraphy

The Carboniferous of the Moscow Basin is very well known worldwide because it upper part being composed of the shallow-water marine carbonates containing diverse assemblages of the macro- and microfossils, unlike Western European coal bearing Westphalian and Stephanian.

During the Carboniferous the Moscow Basin occupied a position not far from the paleoequator, moving slowly to the north, in the western marginal part of the vast Russian epicontinental sea (Fig. 3). The Moscow Basin is the type area of the global Serpukhovian, Moscovian, Kasimovian and Gzhelian stages. There are two, major gaps in the Carboniferous succession: late Tournaisian-early Visean, and the entire Bashkirian.

The older summaries of the Moscow Basin Carboniferous stratigraphy belongs to Nikitin (1890), Shvetsov (1938), Danshin (1947), Ivanova and Khvorova (1955), Makhlina and Shick (1979), Wagner et al. (1979), Einor (1996) etc.

The accepted official Carboniferous regional stratigraphic scale for the Russian Platform was ratified in 1988 and published by Kagarmanov and Donakova (1990). The description of Mississippian (Lower Carboniferous) stratigraphy was published by Makhlina et al. (1993). The more detail stratigraphic scale for Moscovian Stage (Middle Pennsylvanian) was proposed on the basis of new stratigraphical and paleontological studies (Makhlina et al., 2001a,b). Revision of the stratigraphy of the Kasimovian and Gzhelian stages (Upper Pennsylvanian) is still in progress. The modern Carboniferous stratigraphic scale includes 33 regional substages and more than 60 formations, which provide a firm chronostratigraphic framework (Alekseev et al., 1996b; Alekseev et al., 2004) (Fig. 4). Recently it was integrated in the global Devonian-Carboniferous-Permian correlation chart (Menning et al., 2006).

The biostratigraphy is mainly based on foraminiferal and conodont zonations which are discussed in the stop descriptions. The Mississippian foraminiferal assemblages contain many elements widely distributed in Eurasia paleoequatorial belt, Pennsylvanian ones are more endemic. In the conodont assemblages the shallow-water taxa dominate, but in the Upper Visean and Serpukhovian cosmopolitic elements are predominate. The Pennsylvanian conodont assemblages on the genus level are cosmopolitic, but species composition is more restricted, although many taxa occur in the America, China and Japan.

Only limited paleomagnetic information is available (Khramov et al., 1974). Chemostratigraphic studies were began only recently and their results published for brachiopod oxygen and carbon ratios (Mii et al., 2001).

Mississippian. The Mississippian (Lower Carboniferous) succession is represented by three main sedimentary sequences: lower Tournaisian, middle Tournaisian, and middle Visean-Serpukhovian, each separated by unconformities which could be related to glaciation episodes in the South Hemisphere (Fig. 5). The Upper Visean-Serpukhovian shallow-water carbonate body up to 60–80 m thick in total is most widely distributed, but topmost Serpukhovian strata removed by erosion during Bashkirian hiatus.

Pennsylvanian. The Pennsylvanian (Middle and Upper Carboniferous) is cyclic (Makhlina et al., 1997) shallow-water carbonate succession that was formed under the strong influence of glacio-eustatic sea-level fluctuations. In southwestern part of the Moscow Basin subsurface a long (800 km) and deep (up to 100 m) paleovalley filled with alluvial and estuarine late Bashkirian clastic sediments was studied by drilling. It reflects sea-level rise after Early Bashkirian maximum glaciation in the Gondwana. The Moscovian, second stage of the Russian Middle Carboniferous series, composed by basal red-colored unit (Vereian Substage) with several minor cycles which changes onto cyclic Moscovian–Gzhelian carbonate succession up to 180 m thick.

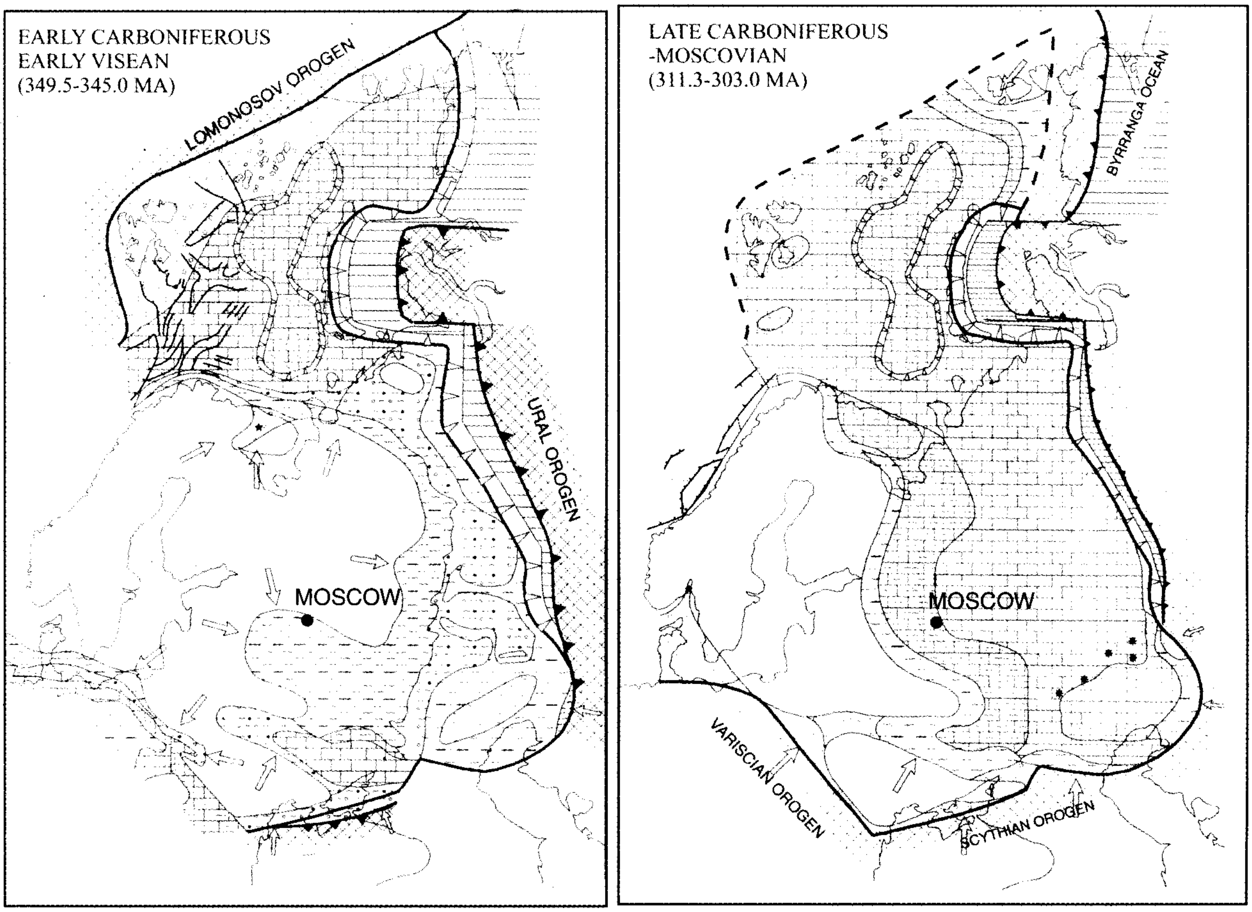


Fig. 3. Paleogeography of the East European Platform during the Early and Middle Visean (regression) and Moscovian (transgression) (from Nikishin et al., 1996)

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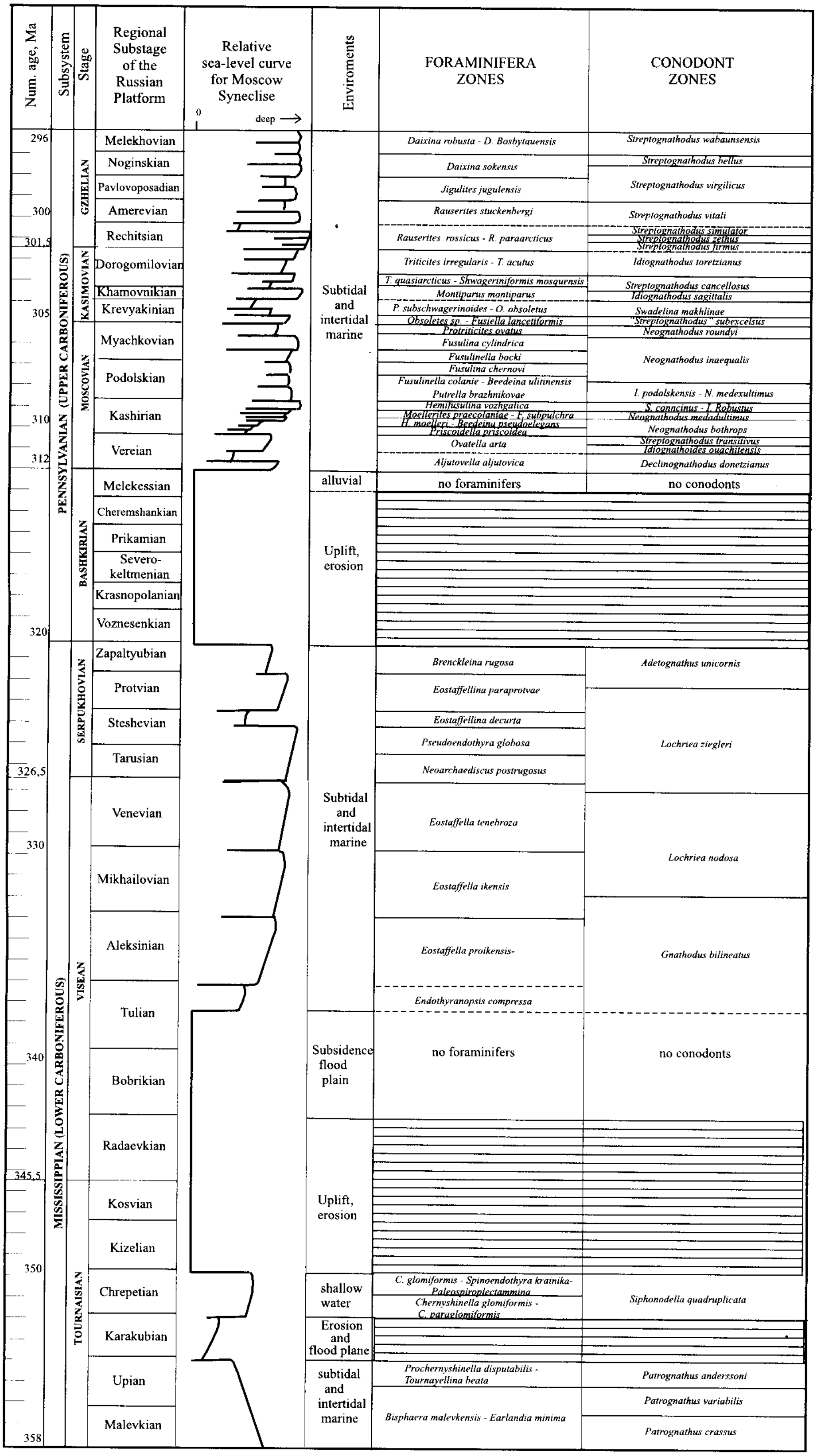

Fig. 4. Stratigraphic subdivision of the Carboniferous System in the Moscow Basin (modified from Alekseev et al., 2004)

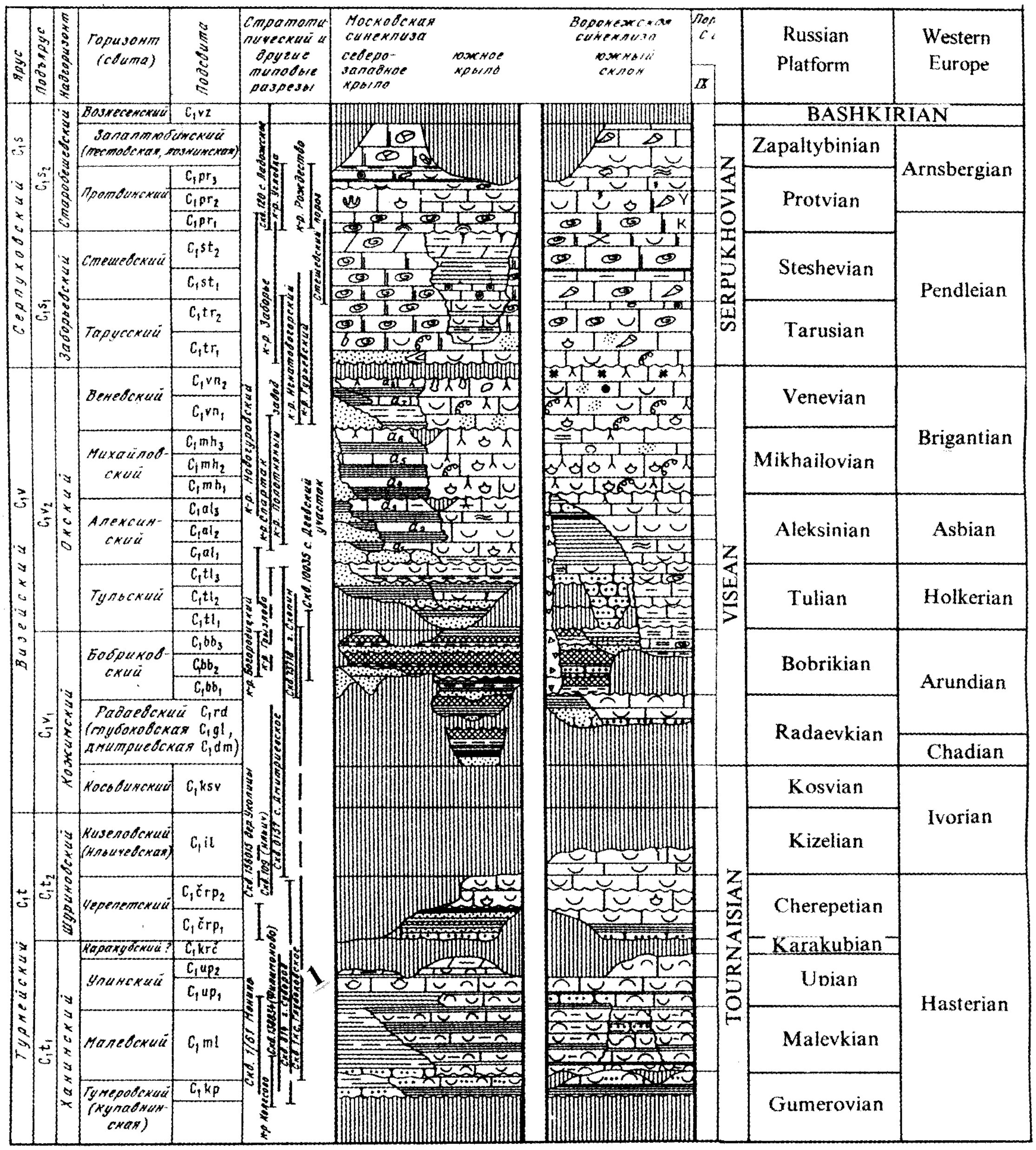

Fig. 5. Stratigraphic subdivision, lithological complexes and correlation of the Lower Carboniferous of the Moscow Syneclise and Voronezh Anteclise (combination from Makhlina et al., 1993 and Makhlina, 1996)

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August 11 • STOP 1

NOVOGUROVSKY QUARRY

UPPER VISEAN AND SERPUKHOVIAN

N.B. Gibshman[1], P.B. Kabanov[2], A.S. Alekseev[1,3], N.V. Goreva[4], M.A. Moshkina[1]

[1]A.A. Borissiak Paleontological Institute of Russian Academy of Sciences,
117997 Moscow, Profsoyuznaya st. 123, Russia

[2]Tyumen Oil Scientific Center, TNK-BP,
Tyumen, Russia

[3]Moscow State University, Geological Faculty, Department of Paleontology,
119991 Moscow, Leninskie Gory, Russia. E-mail: aaleks@geol.msu.ru

[4]Geological Institute of Russian Academy of Sciences,
110017 Moscow, Pyzhevsky per. 7, Russia. E-mail: goreva@ginzas.ru

The Novogurovsky Quarry (originally published as Gurovo Quarry; Belskaya, 1975; Belskaya et al., 1984) is located 144 km to the south of Moscow, in the Tula Region, 54°29' N and 37°19' E in WGS84 coordinates (Fig. 1). The quarry exposes horizontally bedded late Visean (Okian; Shvetsov, 1938) and Serpukhovian limestones, marls, shales, and marly dolostones. The quarry face progresses over years as the quarry actively operates the Visean-Tarusian limestone for macadam. The Novogurovsky section is one of numerous abandoned and active quarries operating Upper Visean-Serpukhovian limestones in northern Tula and eastern Kaluga areas. The advantage of Novogurovsky over neighbour quarries is the broad stratigraphic range from Aleksinian up to Protvian, at places terminating in basal Vereian (Middle Pennsylvanian, Moscovian) beds (Fig. 2). The Okian-Serpukhovian succession of the type Serpukhovian area is notably rich in fossils and contains parallel unconformities which are particularly distinct in the Mikhailovian and Venevian part of the succession ("rhizoid limestones"; Osipova, Belskaya, 1965; Hecker, Osipova, 2007).

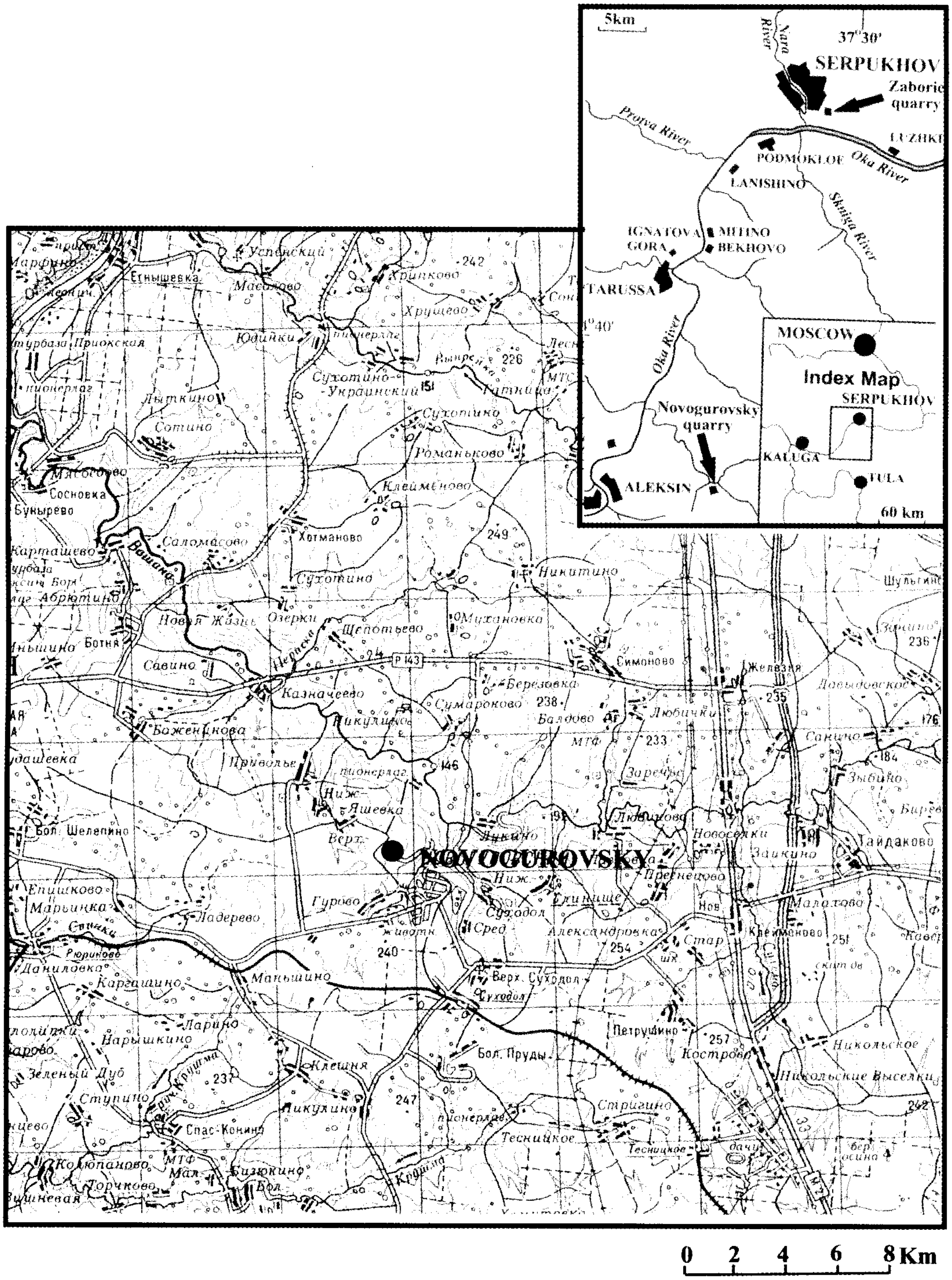


Fig 1. Location of the Novogurovsky quarry and other mentioned Serpukhovian sections

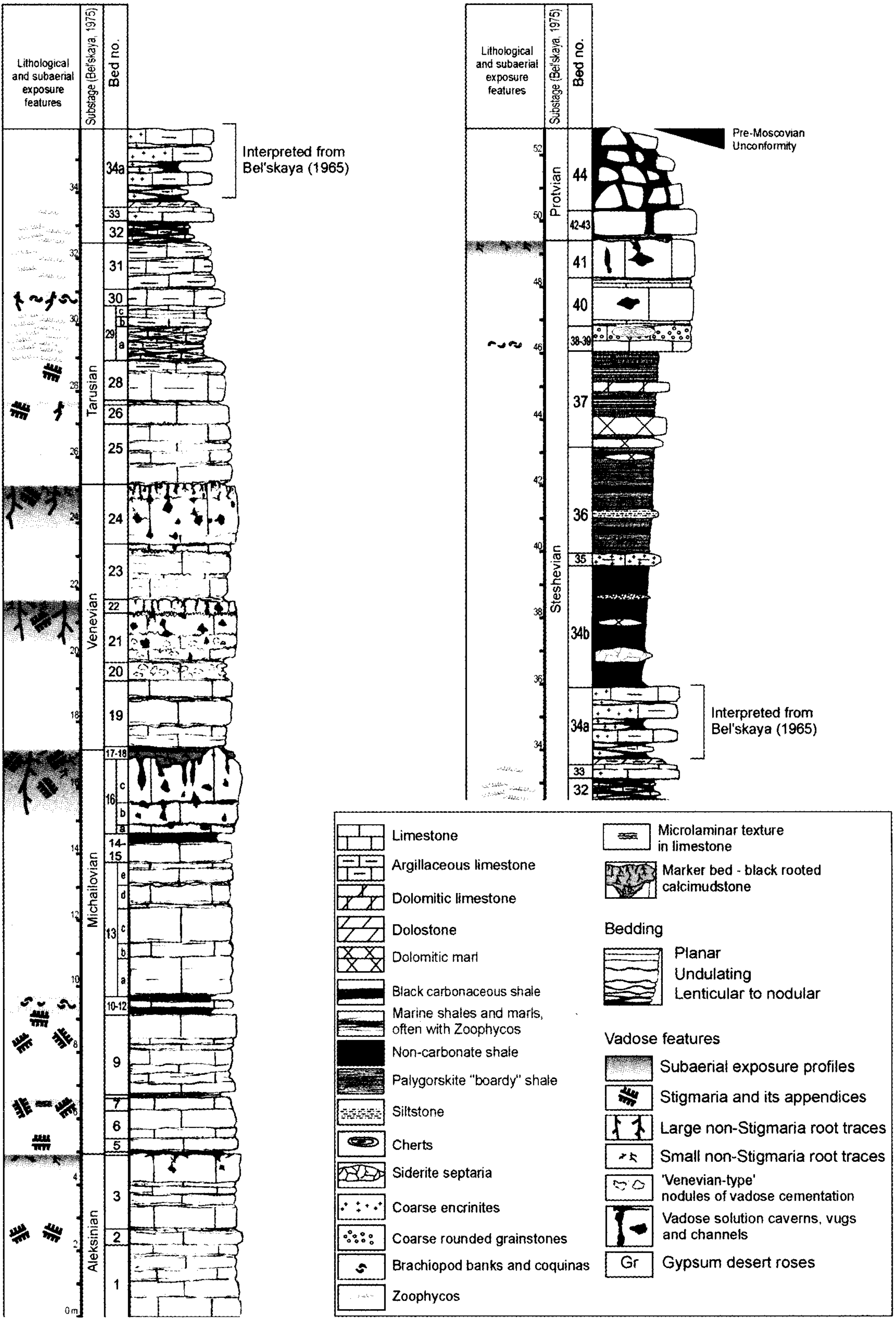


Fig. 2. Columnar section of the Novogurovsky quarry and it subdivision into regional substages

Historical review

The original subdivision of the Visean and Serpukhovian strata of the Moscow Basin is based on lithology, traceable beds, and fossils (Shvetsov, 1922, 1932; Shvetsov et al., 1935). Osipova and Belskaya (1965, 1975) emphasized significance of marker beds, in particular "rhizoid limestones" which are small-scale karst (phytokarst) subaerial exposure profiles. The stratigraphy, brief macro- and micropaleontological characterization, and local correlation of the Novogurovsky section has been published by Belskaya (1975; Belskaya et al., 1984) and Makhlina and Zhulitova (1984). Subsequently this section was regarded in several publications (Makhlina et al., 1993; Osipova, Hecker, 2005; Hecker, Osipova, 2007).

The bed-by-bed log on Fig. 2 is a result of the field study and sampling of quarry faces by P.B. Kabanov and N.B. Gibshman from 2000–2001. The authors agreed to use P.B. Kabanov's bed subdivision. N.B. Gibshman collected 63 samples for microfaces, algae, and foraminifers. Two hundred thins sections have been examined totally, most of them 2.5 × 2.5 cm in size. Several large (over 12 cm^2) thin sections have been made. Each bed has been examined in at least three thin sections. The bed 25 from the Serpukhovian base has been scrutinized in 8 small thin sections from sample 14/40. Totally 288 digital images of microfossils and microfacies including 40 images from bed 25 have been taken, some of them are placed on Plates 4 and 5. The thin section collections and images of N.B. Gibshman and P.B. Kabanov are available in the Laboratory of Protistology of A.A. Borissiak Paleontological Institute of RAS. Microfacies section in bed descriptions consider the available thin sections and thus may not be representative for the entire bed.

The subdivision of the section into regional substages accepted according to Belskaya (1975), although firm opinion that "rhizoid limestones" are nice marker beds is overestimation, because up to now the real biostratigraphical control of the correlations played only limited role.

Section description

Upper Visean
Aleksinian Substage

1. Limestone, pale gray, thick-bedded (0.2–0.5 m), massive bioclastic, mostly fine-grained, monotonous, beds harder and darker (more cemented), divided by thick moderately compacted interbeds of pale yellowish gray porous limestone. Scattered brachiopods and other macrofossils occur. ***Microfacies***: wackestones and packstones foraminiferal with ostracode, echinoderm, bryozoan, and brachiopod bioclasts, with algae *Scalebra* sp. and *Girvanella* sp. ***Foraminifers***: *Earlandia vulgaris*, *Pseudoammodiscus* sp., *Forshia mikhailovi*, *Endothyraniopsis compressa*, *Cribrospira rara*, *Endostaffella* spp., *End. discoidea*, *Omphalotis omphalotis*, *Endothyra similis*, *Priscella prisca*, *Archaediscus moelleri*, *Paraarchaediscus* spp., *P. convexus*, *Planoarchaediscus spirillinoides*, *Eostaffella* sp., *Palaeotextularia longiseptata*, *Consobrinella consobrina*, *Tetrataxis* sp. Thickness over 2.2 m.

2. Limestone, brownish gray, relatively hard, monolithic, with numerous brachiopods and *Stigmaria*, capped by mottled yellowish marl (0.1 m) with collapsed brachiopods and *Stigmaria*. Top is apparently conformable. Thickness 0.35–0.4 m.

3. Limestone, pale gray, thick-bedded (0.1–0.6 m), massive, fine to coarse-grained bioclastic, with thinner beds in the middle (0.1–0.15 m), hard and darker beds are divided by moderately compacted interbeds of soft lighter-colored limestone. Macrofossils: brachiopods, tabulatomorphs, rugose corals, and calcareous sponges. The upper 0.7–0.8 m made of hard gray, purplish in top, massive limestone with obscure bioclastic texture, penetrated from top by scattered solution channels and caverns. The top gently undulated, ferruginized, partly bleached, at places with black mottles and dark marly rootlet casts. Some subsurface caverns are floored with dark gray marl. ***Microfacies***: wackestone bioclastic with fragments of pelmatozoans, bryozoans, brachiopods, ?bivalves, and ostracodes, rich in *Archaesphaera*, with algae *Asphaltinella* sp. ***Foraminifers***: *Endothyranopsis crassa*, *Globoendothyra globula*, *Janischewskina minuscularia*, *Palaeotextularia* sp., *Koskinotextularia* sp., *Endotaxis* sp., *Neoarchaediscus parvus*, *Archaediscus nanus*, *Parastaffella* sp., *Eostaffella proikensis*, abundant *Endostaffella delicata* and *End. discoidea*, rare *Pseudoammodiscus* sp. and *Rectocornuspira* sp. Thickness 1.4 m.

Mikhailovian Substage

4. Shale fissile, mottled, ginger to dark brownish gray, partly coaly (rich in fine coal detritus), with large (>1 cm) elongated plant fragments on fissility planes. Thickness 0.05–0.1 м.

5. Limestone, gray to yellowish gray, fine-grained, massive to weakly brecciated, upper 10 cm with thin (<1 cm) horizontal channel structures having regularly spaced upright branches to underlying bed. Typical *Stigmaria* also present. ***Microfacies***: wackestone-packstone bioclastic (pelmatozoans, brachiopods, bivalves, ostracodes, ?serpulids), with archaespheres and kamaenid algae. ***Foraminifers***: *Endothyranopsis crassa*, *Bradyina rotula*, *Omphalotis minima*, *O. omphalotis*, *O. frequentata*, *Mirifica mirifica*, *Pojarkovella nibelis*, *Parastaffella struvei*, *P. sublimis*, *Endostaffella asymmetrica*, *Eostaffella proikensis*, *E. mosquensis*, *Neoarchaediscus parvus*, *Palaeotextularia longiseptata*, *Dainella tuimasensis*, *Forshia subangula*. Thickness 0.4 m.

6. Limestone, gray, massive, consists of two beds divided by softer compacted limestone interbed. Upper bed with thick shelled brachiopod banks and solution vugs, from top penetrated by Stigmaria. Top is probably conformable, usually sticking to base of bed 7. ***Microfacies***: wackestone-packstone bioclastic. ***Foraminifers***: assemblage close to bed 5. Thickness 0.8 m.

7. Limestone, bluish to brownish gray, distinct by crincled lamination broken by discrete black-stained *Chondrites*, *Planolites*, and *Teichichnus* traces, carrying *Stigmaria* rhizophores and penetrated by spar-filled *Stigmaria* appendices. Desiccation features (brecciated laminae) are locally present. Some bedding planes have pavements of monotonous (one species) small brachiopods and bivalves. In top, bioturbation takes over lamination and limestone is affected by dark-colored argillation mottles. ***Microfacies***: wackestone-packstone bioclastic. Thickness 0.35 m.

8. Shale calcareous, dull violet gray, with collapsed brachiopod fragments and other bioclasts. Thickness 0.07 m.

9. Limestone, gray, massive, indistinctly bedded (hard dark gray beds and softer pale gray interbeds), textures micritic to bioclastic. Frequent gigantoproductid brachiopods. The upper bed relatively hard, massive, penetrated by infrequent *Stigmaria*. Grading to bed 10 via pinkish fissile brachiopod-rich marl. ***Microfacies***: algal packstones-?boundstones with mass *Palaeoberesella* sp. and *Kamaena* sp. ***Foraminifers***: *Endostaffella* sp., *Earlandia vulgaris*, *Endothyranopsis* sp., *Eogloboendothyra parva*, *Globoendothyra globula*, *Endostaffella asymmetrica*, *Eostaffella ikensis*, *E.* sp., *E. mosquensis*, *Archaediscus moelleri*, *Palaeotextularia longiseptata*, *Cribrostomum* sp., Textulariidae. Thickness 2.3 m.

10. Shale, brownish black, carbonaceous, pinkish marl at the base. ***Microfacies***: packstones-rudstones bioclastic, essentially algal with *Koninkopora* sp. and *Palaeoberesella* sp. ***Foraminifers***: *Earlandia vulgaris*, *Globoendothyra globula*, *Omphalotis minima*, *Bradyina rotula*, *Eostaffella ikensis*, *Parastaffella* sp., *P. struvei*. Thickness 0.1–0.15 m.

11. Limestone hard, brownish gray, massive, rich in *Gigantoproductus* and other productid brachiopods. Thickness 0.25 m.

12. Shale gray, sticky, weakly carbonaceous, in top black carbonaceous, with gypsum (selenite) veins/layers in basal part. Top and base are conformable. Thickness 0.15 m.

Plate 1

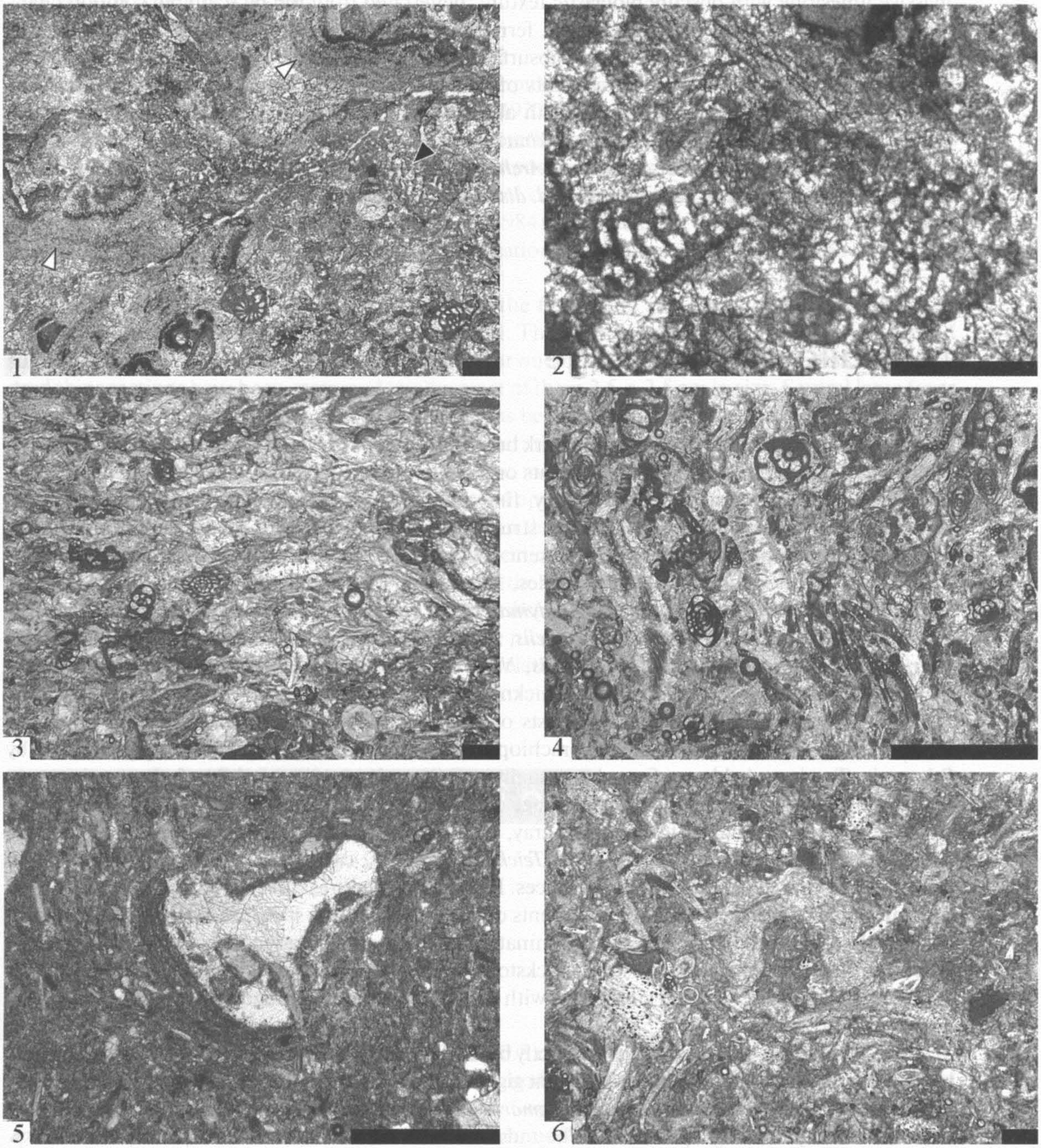


Plate 1. Upper Visean algae and microfacies of Novogurovsky Quarry, scale bars 0.4 мм. Fig. 1. Recrystallized and cemented packstone with *Asteroaoujgalia gibshmanae* Brenckle, 2004 (black arrow); note layered vadose pendant cements (white arrows); dark red staining of cements and bioclasts is due to Fe^{3+} mineral impregnation, base of bed 15. Fig. 2. The same thin section, *A. gibshmanae* Brenckle, 2004, random section. Fig. 3. Algal packstone to ?boundstone with intertwined *Palaeoberesella* aff. *P. lahuseni* (Möller, 1879), sample 5/12, top of bed 9. Fig. 4. Foraminiferal-algal packstone to baffletone with algae *Calcifolium okense* Shvetsov and Birina, 1935 and *Pseudokamaena* aff. *P. armstrongi* Mamet, 1974 and foraminifers *E. ikensis*, *G. globula*, abundant archaesphaers, sample 7/16, bed 13c. Fig. 5. Fine-grained bioclastic wackestone with micrite-enveloped skeletal (algal?) mould, sample 13/41, bed 23. Fig. 6. Bioclastic wakestone/packstone, fusulinoid test in the centre encrusted by alga *Claracrusta* sp, sample 9/11, bed 16c

13. Limestone thick-bedded, brownish gray, massive, with *Gigantoproductus*, *Multithecopora* and other macrofossils. Tabulates especially frequent in upper part. Bedding weak, defined by softer and lighter-colored, moderately compacted limestone interbeds. Fissile marl is in top. ***Microfacies***: packstones bioclastic, largely algal (*Calcifolium okense* and *Kamaena* sp.). ***Foraminifers*** abundant: *Earlandia vulgaris*, *Endothyranopsis sphaerica*, *E. crassa*, *Globoendothyra globula*, *Omphalotis chariessa*, *O. omphalotis*, *O. minima*, cf. *Bradyina rotula*, *Eostaffella ikensis*, *E. mosquensis*, *E. proikensis*, *Parastaffella propinqua*, *P.* spp., Archaediscidae, *Palaeotextularia longiseptata*, *Climacammina simplex*, cf. *Cribrostomum* sp., Textulariidae. Thickness 0.25 m.

14. Limestone, gray, hard, with darker brownish gray dispersed mottles of preferential sparitic cementation-recrystallization, rich in macrofossils: calcareous sponges, *Multithecopora*, solitary and colonial Rugosa, chaetetids, and brachiopods. Top conformable. Thickness 0.6 m.

15. Shale brownish gray, calcareous, fissile, with three laterally persistent seams of black carbonaceous shale. Numerous *Gigantoproductus*. Carbonaceous seams lack macrofossils. Thickness 0.25 m.

16. Limestone hard, brownish gray to gray, notably karsted from top. The lower 0,9 m with diverse macrofossils and at least two overcompacted carbonaceous shale seams separating subbeds 3a, 3b, and 3c. Vadose features increase to the top: solution vugs, small caverns, lapies, uneven sparitic cementation (Plate 3, fig. 3, 6); many karst voids empty or floored by ocher colored clay; upper 30 cm with dark gray micritic-microsparitic mottles and laminae replacing primary texture, some solution cavities geopetally filled by dark gray marl apparently infiltrated from bed 17. ***Microfacies***: Dominantly packstones with local algal baflestones (Plate 3, fig. 6). ***Foraminifers*** (Sample 9/11): *Eostaffella tenebrosa*, *Howchinia bradyana*, *Earlandia vulgaris*, *Spinothyra pauciseptata*, *Bradyina rotula*, *Endothyranopsis sphaerica*, *Endostaffella* spp., *Archaediscus moelleri*. Thickness 2.2 m.

17. Limestone, black to dark gray, argillaceous (saponitic at Malinovka; Fig. 3; data of T.V. Alekseeva, Soil Science Institute of RAS, Pushchino), grading up to marl, syngenetically brecciated and densely penetrated by *Stigmaria* (Plate 3, fig. 4), contains internal karst surfaces. Macrofossils: ostracods and unidentified nacre debris found in neighbor localities (Fig. 3). No typical marine macrofossils. Palustrine origin is most probable. Top conformable to weakly paraconformable, marked by recurrence of marine bioclasts in bed 18. Thickness: thickens in karren depressions to 0.6 m and pinches out on highs (Plate 3, fig. 3).

18. Marl calcareous, gray, compacted, bioclastic. Thickness < 0.2 m.

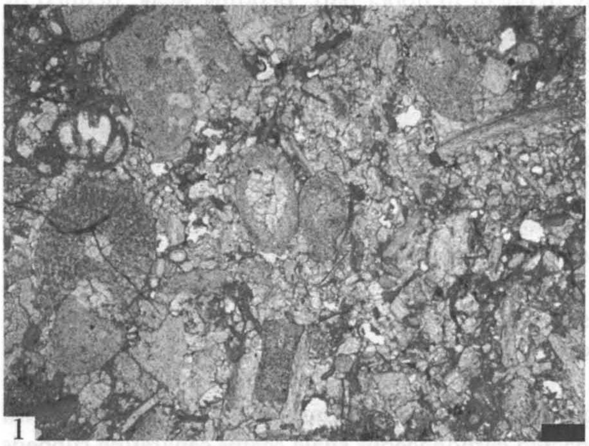
Venevian Substage

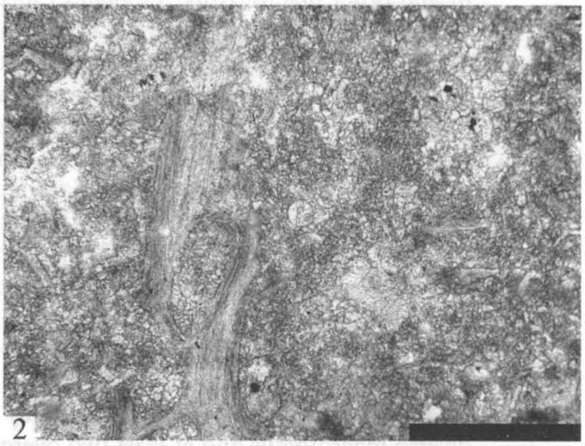
19. Limestone gray, massive, thick-bedded (0.6–0.8 m), moderately hardening upward, unevenly cemented and penetrated by rare tubular structures supposedly of root origin. ***Microfacies***: Packstones and wackestones bioclastic. Top is gradational. ***Foraminifers***: *Pseudoammodiscus* sp., *Earlandia vulgaris*, *Forshia prisca*, *Spinothyra pauciseptata*, *Bradyina rotula*, *Endothyranopsis sphaerica*, *Parastaffella propinqua*, *P.* spp., *Howchinia bradyana*, *Omphalotis samarica*, *O. omphalotis*, "*Endostaffella*" *asymmetrica*, *End. discoidea*, *Climacammina* cf. *simplex*, *Archaediscus gigas*, *A. moelleri*, *Neoarchaediscus akchimensis*, *Asteroarchaediscus baschkiricus*, *Eostaffella ikensis*, *E.* cf. *tenebrosa* (?). Thickness 2.0 m.

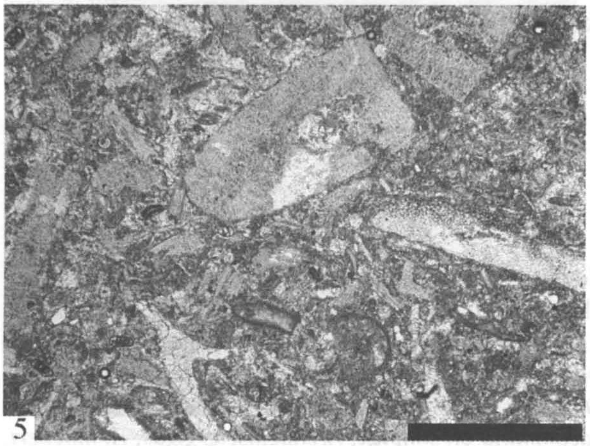
20. Limestone, gray, massive, bioclastic, mottled. Characteristic "venevian mottles" are hard and darker isodiametric to irregular-shaped patches of vadose cementation-recrystallization surrounded by softer and paler porous limestone. Top is conformable, marked by pinkish gray marl. Thickness 0.6–0.65 m.

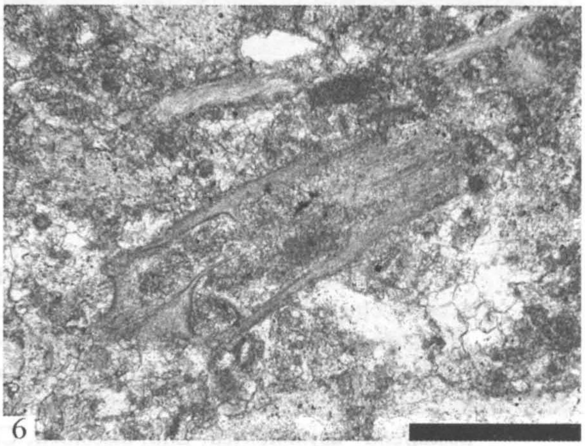
21. Limestone hard, gray, bioclastic, rich in *Calcifolium*, prominently mottled ("venevian mottles") to brecciated, with numerous solution vugs and small caverns (up to 10 cm in diameter). ***Microfacies***: primary textures refer to packstones and grainstones bioclastic with algae *Calcifolium okense*, *Scalebra* sp., and kamaenids. ***Foraminifers***: *Mikhailovella gracilis*, *Endothyranopsis sphaeri-*

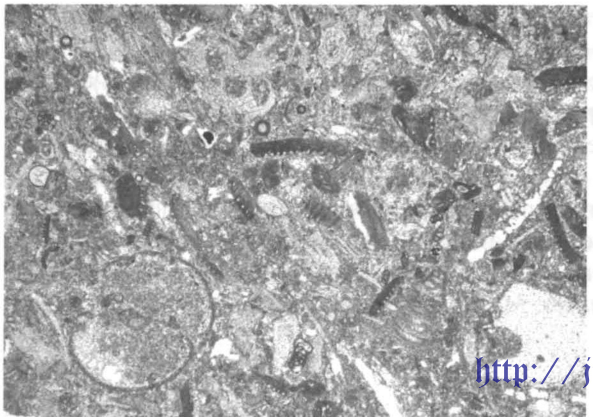
Plate 2











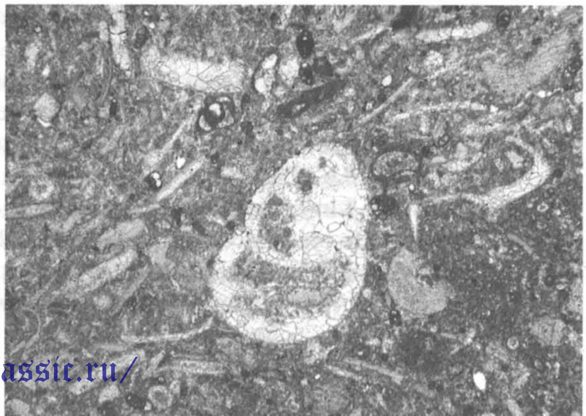
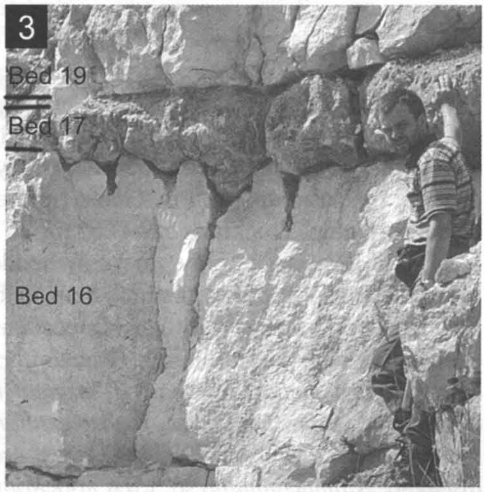
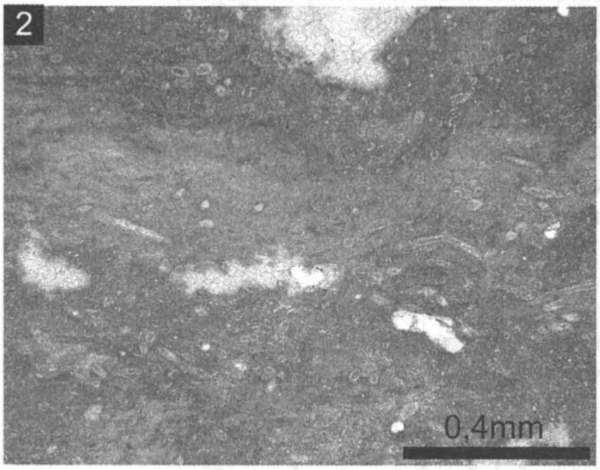
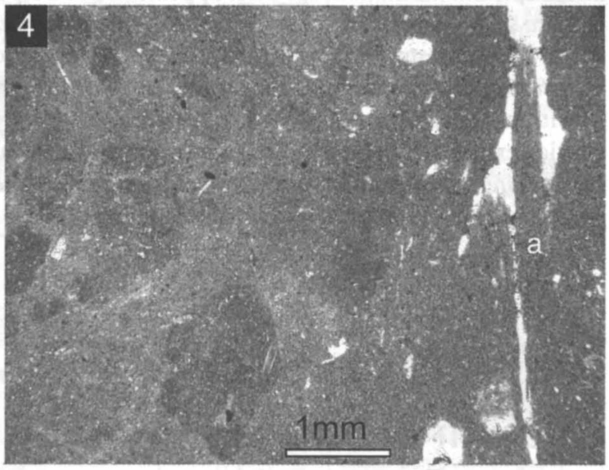


Plate 2. Serpukhovian and Venevian microfacies of the Novogurovsky Quarry, scale bars 0.4 мм. Figs. 1, 2. Upper Tarusian (sensu Belskaya 1975): 1 – echinoderm-crinoidal-brachiopod matrix-poor rudstone/packstone with intergranular compaction, sample15/44, base of bed 28; 2 – wackestone with clotted marl matrix and a bryozoan, sample16/48, bed 29c. Fig. 3. Steshevian: crinoid-brachiopod-molluscan wackestone, uncompacted, sample 19/51 from base of bed 32. Figs. 4–6. Protvian: 4 – bryozoan-pelmatozoan-brachiopod rudstone/packstone, sample 24/62, base of bed 38; 5 – matrix-poor pelmatozoan-brachiopod packstone, black impregnation may represent pyritization, sample 28/62, bed 44; 6 – finer-grained bioclastic wackestone, same thin section. Figs. 7, 8. Venevian: 7 – bioclastic wackestone with *Calcifolium okense* and diverse skeletal assemblage, sample 13/43, bed 24; 8 – bioclastic wackestone with spar-filled gastropod mould, echinoderms, pelmatozoans, brachiopods and abundant smaller foraminifers, sample 10/32, base of Venevian

Plate 3







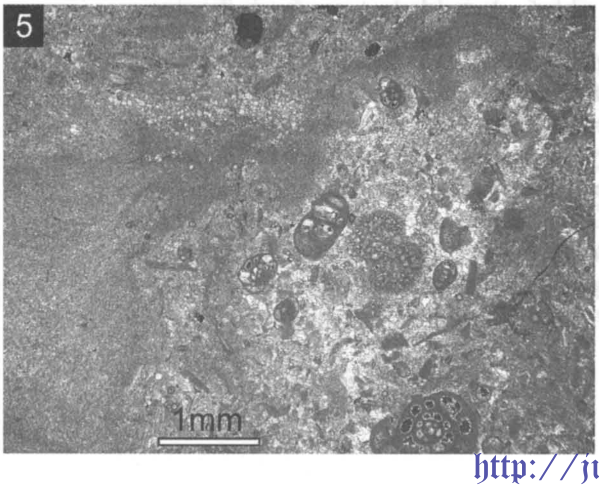


Plate 3. Late Visean unconformities. (Fig. 1 from Forino Quarry, Figs. 2–6 from Novogurovsky Quarry). Fig. 1. Pseudomicrokarst ("rhizoid limestone") in Venevian top, tape in centimetres. Fig. 2. "Rhizoid limestone" in thin section showing cloudy micritic-microsparitic texture, spar-cemented vugs, and relics of primary bioclastic algal texture, sample 12/38, top of bed 22. Figs. 3–6. Mikhailovian/Venevian unconformity: 3 – lapie karren in top of bed 16 unconformably covered by black *Stigmaria* limestone (bed 17); 4–6 – thin sections in plane polarized (PPL) and crossed polarized (XPL) light: 4 – synsedimentary brecciated mudstone texture rooted by *Stigmaria* appendices (a), sample GUR-17kr, bed 17, PPL; 5 – clouds and laminae of vadose micritization-microsparitization replacing foraminiferal packstone/grainstone, sample GUR-16top, top of bed 16, XPL; 6 – vadose sparitic cement in *Calcifolium* bafflestone, same sample, PPL

ca, *Omphalotis omphalotis*, *O. samarica*, *Globoendothyra globula*, *Janischewskina minuscularia*, *Spinothyra pauciseptata*, *Endostaffella* sp., *Loeblichia paraammonoides*, *Eostaffella ikensis*, *E. proikensis*, *E. mosquensis*, *Paraarchaediscus* sp., *Archaediscus moelleri*, *Pseudoammodiscus priscus*, *Parastaffella struvei*, *Mediocris* sp., *Cribrostomum* sp., *Cr.* ex gr. *eximium*, *Palaeotextularia longiseptata*, *P. breviseptata*, Textulariidae. Thickness 0.60–0.65 m.

22. Limestone hard, mottled brown, unevenly bedded and stylolitized, piped by subvertical solution-enlarged root channels up to 1 cm in diameter. These channels sometimes impart columnar appearance to the bed. Texture is secondary microcrystalline, cloudy to vaguely laminar, obscuring primary bioclastic fabric. Phytokarst (microkarst) known previously as "rhizoid limestone". Top is disconformable. Thickness 0.6–0.65 m.

23. Limestone, gray, unevenly bedded, mottled. Cementation-recrystallization mottles are more dispersed and less distinct than in beds 20–21. Bedding defined by compacted horizons. Strongest compaction (up to stylobreccia and flaser marl) occurs in 0.2 m below top. ***Microfacies***: packstones algal-foraminiferal. ***Foraminifers***: *Parastaffella composita*, *Endothyranopsis sphaerica*, *E. crassa*, *Endostaffella discoidea*, "*E.*" *asymmetrica*, *E. parva*, *E.* spp., *Planoendothyra* sp., *Consobrinella consobrina*, *Cribrostomum* sp., *Palaeotextularia longiseptata*, *Globoendothyra globula*, *Parastaffella* sp., *Howchinia bradyana*, *Archaediscus gigas*, *Arch. cornuspiroides*, *Neoarchaediscus parvus*, *Paraarchaediscus* sp., *Climacammina* sp. First appearance of Serpukhovian forms "*Millerella*" *tortula*, *Rectoendothyra* sp., *Planoendothyra* sp., *Endothyra phrissa*, *Janischewskina* cf. *delicata*. Thickness 1.7 m.

24. Limestone hard, brown, darkening to the top. Lower 0.3 m is coarse bioclastic, rich in *Calcifolium*. To the top the bed evolves to "rhizoid limestone" very similar to bed 22 (Plate 3, fig. 1) with bleached walls of phytokarst pipes and cloudy micrite-microsparite replacing primary bioclastic texture (Plate 3, fig. 1). In top limestone columnar to brecciated. Top is disconformable. ***Foraminifers***: presence of Serpukhovian *Janischewskina* cf. *delicata*, *Planoendothyra* sp., *Endothyra phrissa*, along with typical Visean forms. Thickness 1.8 m.

Serpukhovian Stage

Tarusian Substage

25. Limestone, gray, massive, monotonous, thick-bedded (0.3–0.5 m), fine to medium-grained, bioclastic. Top stylolitized, conformable. ***Microfacies***: packstones bioclastic, algal-foraminiferal, with algae *Calcifolium okense*. ***Foraminifers***: *Endothyranopsis sphaerica*, *Bradyina rotula*, *Omphalotis* sp., *Janischewskina* cf. *typica*, *Endostaffella discoidea*, *End. asymmetrica*, *End. delicata*, *Omphalotis* sp., *Consobrinella consobrina*, Textulariidae, *Climacammina* sp., *Eostaffella ragushensis* (?), *E. ikensis*, *Archaediscus gigas*, *Arch. krestovnikovi*, *Arch. nanus*, *Paraarchaediscus* sp., *Palaeotextularia longiseptata*, *Planoendothyra spiriliniformis*, *Bradyina* ex gr. *cribrostomata*, *Janischewskina delicata*, *Eostaffella mirifica*, "*Millerella*" *tortula*, *Endothyra phrissa*, *Pseudoendothyra globosa*. Thickness 1.8 m.

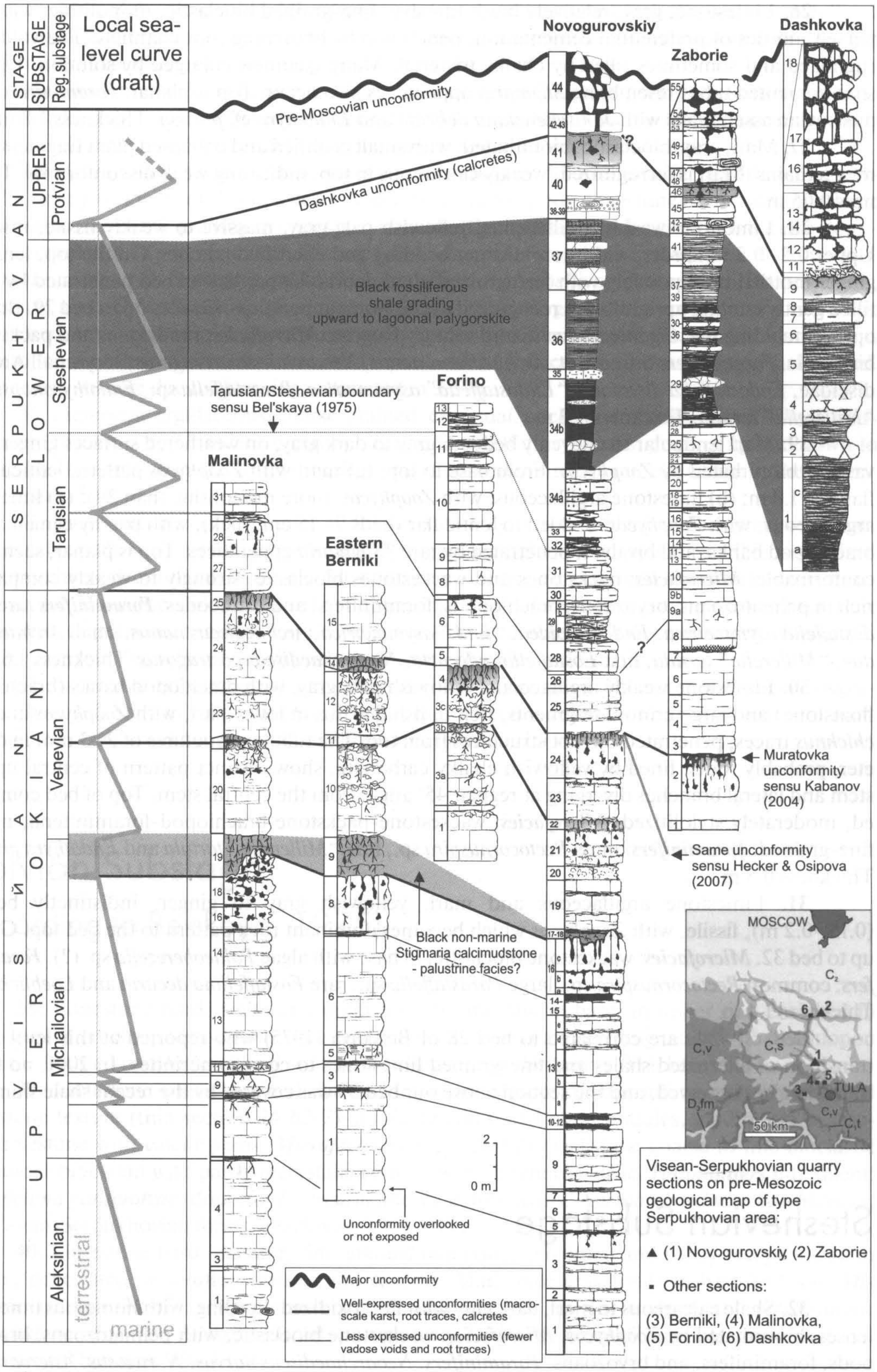


Fig. 3. Unconformity-based correlation of Upper Visean–Serpukhovian sections in Serpukhovian type area (logged by P. Kabanov in 1999–2007). See Fig. 2 for main legend

26. Limestone, gray, relatively hard, massive, fine-grained bioclastic, monolithic, with dispersed mottles of preferential cementation, penetrated by branching root channels. The voids ferruginized and sometimes filled by chalky material. Many channels enlarged by solution. Upright spar-cemented tubes resembling *Stigmaria* appendices also occur. Top is planar. ***Foraminifers***: Serpukhovian assemblage with *Janischewskina delicata* and *Endothyra* cf. *phrissa*. Thickness 1.8 m.

27. Marl, gray, bioclastic, bioturbated, with small coalified and collapsed plant fragments and root remains. Marl is ferruginized, weakly calcareous in top, indicating weak disconformity. Thickness 0.05 m.

28. Limestone weakly argillaceous, yellowish pale gray, massive to weakly fissile, micritic. Upper 0.2–0.3 m harder, with more distinct bedding and chertified patches. On the top, lenses of ginger mottled marl possibly with ferruginized plant debris. Upper half of bed penetrated by spar-filled gently curving upright tubes recognized as *Stigmaria* appendices. Grades up to bed 29. Brachiopods including few *Gigantoproductus* and solitary Rugosa. ***Microfacies***: mudstones and packstones bioclastic. ***Foraminifers*** infrequent: *Archaediscus nanus*, *Neoarchaediscus rugosus*, very small Archaediscidae, *Endostaffella discoidea*, "*Endostaffella*" *asymmetrica*, *Parastaffella* sp., *Endothyranopsis* sp., "*Millerella*" *tortula*. Thickness 1.2 m.

29. Marl lenticular to unevenly bedded, gray to dark gray, on weathered surfaces ginger, pervasively bioturbated by *Zoophycos*. From base to top: (a) marl with *Zoophycos* pattern, lenticular to flaser – 1.0 m; (b) limestone argillaceous, with *Zoophycos*, more monolithic than 29a; (c) limestone argillaceous, with *Zoophycos*, bedded to lenticular (beds 7–15 cm thick), with patchy cementation, brachiopod banks, and bivalves, penetrated by rare ?*Stigmaria* appendices. Top is planar, seemingly conformable. ***Microfacies***: packstones and wackestones bioclastic, strongly to weakly compacted, rich in pelmatozoans, bryozoans, brachiopods, foraminifers, and ostracodes. ***Foraminifers*** rare: *Endostaffella asymmetrica*, *End. discoidea*, "*End.*" *asymmetrica*, *Archaediscus nanus*, small *Archaediscidae*, "*Millerella*" *tortula*, first *Eostaffellina decurta*, *Neoarchaediscus postrugosus*. Thickness 1.65 m.

30. Limestone weakly argillaceous, yellowish pale gray, with brachiopod banks (brachiopod floatstone) and large crinoid fragments, rich in fish detritus in lower part, with *Zoophycos* and *Teichichnus* traces, penetrated by root structures from top. The tubular structures of 2–3 mm in diameter, probably roots, lined by yellowish chalky carbonate, show distinct pattern of central upright stem and lateral branches diverging at regular 45° angle from the central stem. Top of bed compacted, moderately stylolitized. ***Microfacies***: wackestone-packstone brachiopod-foraminiferal, mostly fine-grained. ***Foraminifers***: mass *Rectocornuspira* sp., rare "*Millerella*" *tortula* and *Endothyra phrissa*. Thickness 0.5 m.

31. Limestone argillaceous and marl, yellowish gray to ginger, indistinctly bedded (0.15–0.2 m), fissile, with *Zoophycos* which becomes dominant rock pattern to the bed top. Grades up to bed 32. ***Microfacies***: wackestone bioclastic, in base with algae *Palaeoberezella* sp. (?). ***Foraminifers***: common *Rectocornuspira* sp., large *Parastaffella* sp., rare *Eostaffellina decurta* and *Loeblichia* sp. Thickness 1.4 m.

Beds 31–34a are correlated to bed 28 of Belskaya (1975) who reported at this level facies transition of alternated shales and fine-grained limestones to coarse encrinites. In 2001, no facies transition was observed, and the section above our bed 33 was covered by the recent shale slumps.

Steshevian Substage

32. Shale calcareous to marl, dark gray with Fe^{3+} oxidized mottling, with numerous limestone lenses, bioturbated by *Zoophycos*. ***Microfacies***: wackestone bioclastic, with pelmatozoans, brachiopods, foraminifers, and bryozoans. ***Foraminifers***: *Neoarchaediscus parvus*, *N. rugosus*, *Asteroarchaediscus bashkiricus*, *Archaediscus krestovnikovi*, rare *Planoendothyra* sp. Thickness 0.65 m.

33. Limestone, dark gray, hard, fine-grained, massive, with smooth top and base, with spar-filled "eyes" (fenestrae or vugs), monolithic to weakly bedded, superficially looking closely similar to bed 28 of the Zaborie section. ***Microfacies***: wackestone-packstone bioclastic with recrystallized pelmatozoan, and brachiopod bioclasts; matrix unevenly recrystallized. ***Foraminifers*** common, but low-diversity: *Cepekia cepeki* and *Loeblichia minima*. Thickness 0.35 m.

34a. (Interpreted from Belskaya, 1975). Limestone argillaceous, gray, fine-grained, intercalated by shales, rich in diverse small brachiopods, grading laterally to coarse-grained crinoidal limestones. Thickness 1.5–3.5 m. In 2001, lenses of cherty spiculite were found on top of bed 33.

34b. Clay, black, sticky, with nodules of soft dark gray dolomitic marl, bioturbated (*Chondrites*?), with pavements of thin-shelled low-diversity brachiopods, fenestrate bryozoans, and large crinoid stem fragments, grading in upper part to harder fissile shale. Brachiopods: mass monodominant accumulations (pavements) of *Eomarginifera lobata* (J. Sowerby), *E. longispina* (J. Sowerby), *Composita ambigua* (J. Sowerby), small rhynchonellids, *Ambocoelia* sp., sometimes *Unispirifer* sp., and inarticulate *Orbiculoidea* sp. Presence of *Dictyonema*-like graptolites are indicated. The bed bioturbated: small curved vermiform burrows and probably *Chondrites*. Abundance of fossils drops down to top. Laminated siltstone lenses and septate siderite concretions occur in upper half of bed. Thickness is obscure due to slumping, estimated in 3.5 m.

35. Limestone argillaceous, coarse-grained, crinoidal, packstones-rudstones with black non-carbonate matrix, with abundant brachiopods and fenestellid bryozoans, grading up and down to shales. The bed was observed in one locality and supposedly pinches out elsewhere in the quarry. Thickness 0.15 m.

36. Shale soft, becoming harder and fissile ("boardy") to top, black to dark gray, with scattered brachiopods and fenestellid bryozoans, with gypsum (selenite) veins with small lenses of bioclastic brachiopod-crinoidal limestone. Siltstone gray, selenite cleaved, with hummocky cross stratification. Lenses of gray dolomitic marl in upper part of bed. ***Microfacies*** (sample 22/60): packstone coarse grained pelmatozoan-brachiopod, with non-rounded grains and opaque matrix. ***Foraminifers***: very rare tests including *Eostaffellina* aff. *decurta*. Thickness 0.15 m.

37. Dolomitic marl, yellowish gray, chertified and ferruginized, alternated with shale palygorskitic, "boardy", steel to yellowish gray. The upper marl bed is relatively hard, with lenses of non-dolomitized syringoporid corals and brachiopods. Thickness 2.9 m.

Protvian Substage

(according to Belskaya, 1975)

38. Limestone hard, white and pinkish white, micritic in base, in upper part enriched in thick-shelled brachiopods (*Gigantoproductus* and other forms) and grading laterally to brachiopod coquina. The bed is stylolitized and compacted elsewhere in the quarry. Thickness 0.3 m.

39. Limestone coarse-grained, karsted from pre-Moscovian unconformity, with oncoidal grainstone texture (thin section 24/62-2) and large ellipsoidal chert nodules, grading up to micritic limestone with calcite veins. ***Microfacies*** (sample 24/62): packstone coarse to fine bioclastic echinoidal-bryozoan with partly recrystallized matrix, with rare red algae. ***Foraminifers*** infrequent: *Eostaffellina paraprotvae*, doubtful *E. decurta* and *E. shartimiensis*, *Asteroarchaediscus baschkiricus*, few Visean-Serpukhovian forms. Thickness 0.30–0.45 m

40. Limestone hard, massive, fine-grained bioclastic, cemented and partly recrystallized to sparite, penetrated by solution fissures and caverns. Marls pale gray fissile in base and top. ***Microfacies*** (sample 24/63): wackestone bioclastic with oncoids, indefinite algae, and foraminifers. ***Foraminifers***: very rare *Eostaffellina* aff. *paraprotvae*, *Endotaxis brazhnikovae*, *Asteroarchaediscus bashkiricus*. Thickness 0.9–1.1 m.

41. Limestone massive, micritic with eye observation and in thin section, with bivalve and bellerophontid moulds and small vermiform root channels. Upper part of bed contains hard brownish gray cementation mottles densely penetrated by root channels and sometimes syngenetically brecciated. In top these mottles coalesce to discontinuous crust. Top unevenly compacted, at places with gently undulating solution sculpture and small (<10 cm) solution pockets. Thickness 0.7 m.

Protvian Substage

(according to sequence analysis by Kabanov)

42. Marl fissile, yellowish, weathered. Thickness < 0.1 m.

43–44. Karst breccia of yellowish pale gray to white limestone. Bedding mostly lost. Relatively continuous bed of limestone massive, recrystallized bioclastic, is preserved in base (bed 43). ***Microfacies***: packstones bioclastic, with foraminifers, pelmatozoan, bryozoan, and brachiopod bioclasts. Some bioclasts are moderately micritized. Matrix unevenly recrystallized. ***Foraminifers***: *Endothyranopsis sphaerica*, *Archaediscus longus*, *Endotaxis brazhnikovae*, "*Endostaffella*" *asymmetrica*, *Archaediscus krestovnikovi*, *A. moelleri*, *Eostaffellina decurta*, *Rectoendothyra* sp., doubtful *Eostaffella mirifica*, and unidentified staffellids. Thickness up to 4 m.

Pennsylvanian Subsystem

Bashkirian Stage

45. Vysokoe Formation: Clay mottled red, ocher and gray, filling breccia interstices, often as illuvial skins on limestone blocks and in caverns – paleosol. In Dashkovka section (Fig. 3) Vysokoe paleosol reveals smectitic composition (Kuznetsova et al., 2004).

Biostratigraphic analysis

Foraminifera (Fig. 4; Plates 4–6). Sixty-two rock samples were probed for foraminifers, 160 transparent thin sections prepared, and 288 microphotographs of foraminifers and microfacies taken. At least three thin sections (2.5 x 2.5 cm) were made for each rock sample.

Foraminifers were found in most beds of the section exposed by the Novogurovsky Quarry. Foraminifers are absent in bed 22 (sample 12/38), and in beds 29–31 they occur in very low numbers and has very low taxonomic diversity. Beds represented by terrigenous rocks were not studied.

Despite the absence of foraminifers in some beds, the differences in taxonomic diversity and number of representatives of each taxon, and variable coverage of the stratigraphic column by samples (Fig. 4) the section contains seven levels with very considerable changes in foraminiferal assemblages. Hence, seven biostratigraphic units are recognized on the Upper Visean and Serpukhovian beds of the Novogurovsky Quarry section based on the index foraminiferan species of the General Carboniferous Stratigraphic Scale of Russia (Kulagina et al., 2003; Kulagina, Gibshman, 2005). They are based on the successive changes in the assemblages of the following foraminiferan zones and subzones: *Endothyranipsis compressa*, *Endothyranopsi crassa–Archaediscus gigas* Zone with three

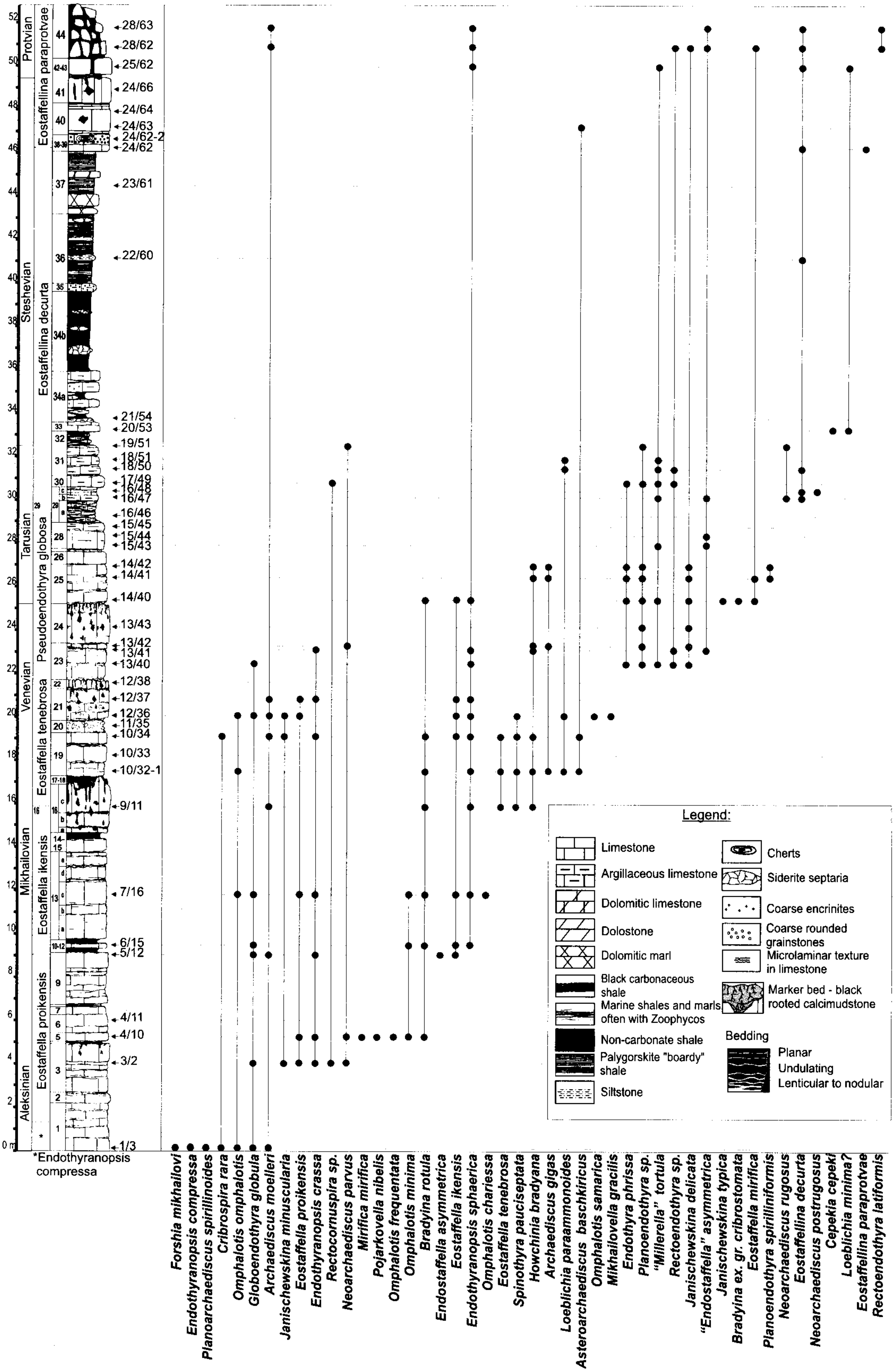


Fig. 4. Ranges of the most significant species of foraminifers in the succession of the Novogurovsky quarry

Plate 4

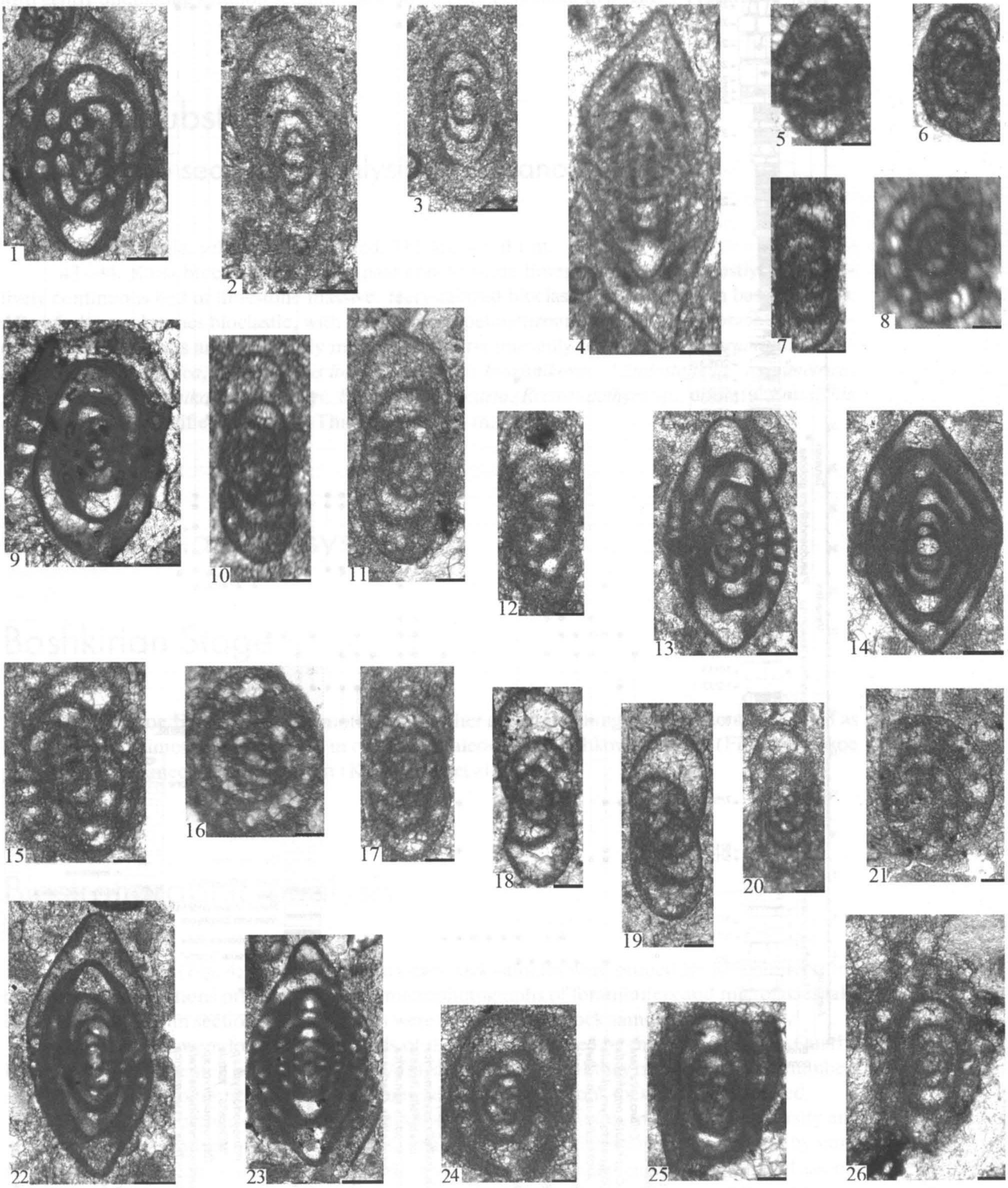


Plate 4. Photomicrographs of the biostratigraphic significant Fusulinidae from the Upper Visean and Serpukhovian strata, the Novogurovsky Quarry (magnification ×100 except for otherwise indicated). Figs. 1, 9. *Eostaffella ikensis* Vissarionova: 1 – diagonal section in axis direction, bed 9, sample 5/12; 9 – diagonal secton normal to coiling axis, bed 14, sample 3, × 70. Fig. 2, 3. *Eostaffella proikensis* Rauser, close to complete axial section, bed 3, sample 3/2, ×70. Fig. 4. *Eostaffella*

tenebrosa Vissarionova, high section normal to coiling axis, bed 16, sample 9/11, ×70. Figs. 5, 6, 8. "*Endostaffella*" *asymmetrica* Rozovskaya: 5– axial section, bed 23, sample 13/41; 6 – axial section, bed 28, sample 15/43; 8 – sagittal section, bed 23, sample 13/41. Figs. 7, 10–12, 17–20. "*Millerella*" *tortula* Zeller: 10 – axial section, bed 31, sample 18/51; 11 – bed 23, sample 13/40; 7 – diagonal section normal to coiling axis, bed 23, sample 13/40; 12 – diagonal section normal to coiling axis, bed 28, sample 15/43; 17 – diagonal section normal to coiling axis, bed 29b, sample 16/47; 18, 19 – diagonal sections normal to coiling axis, bed 25, sample 14/40; 20 – diagonal secton normal to coiling axis, bed 31, sample 18/50. Figs. 13, 14. *Eostaffella ragushensis* Ganelina: 13 – diagonal section normal to coiling axis; 14 – axial section, bed 25, sample 14/40, ×70. Figs. 15, 16, 21. *Eostaffellina decurta* (Rauser): 15 – axial section, bed 29b, sample 16/47; 16 – diagonal secton normal to coiling axis, bed 29a, sample 16/46; 21 – tangention section, bed 29c, sample 16/48. Figs. 22, 23. *Eostaffella mirifica* Brazhnikova: 22 – axial section; 23 – high section – axial direction, ×70. Figs. 24–26. *Eostaffellina paraprotvae* (Rauser): 24 – axial section; 25, 26 – axial section, slightly deflected, beds 38–39, sample 24/62.

subzones: (1) *Eostaffella proikensis* Subzone, (2) *Eostaffella ikensis* Subzone, (3) *Eostaffella tenebrosa* Subzone (Visean Stage – partly) and three zones: *Pseudoendothyra globosa* Zone, *Eostaffellina decurta* Zone, *Eostaffellina paraprotvae* Zone (Serpukhovian). The exact position of the boundaries of the zones and subzones is not identified because of the incomplete sample coverage (Fig. 4).

Endothyranopsis compressa Zone (bed 1, sample 1/3, bottom of the quarry). The assemblage of the *End. compressa* Zone, apart from the index species, contains *Forshia mikhailovi* Dain, *Cribrospira rara* Rauser, *Omphalotis omphalotis* (Rauser and Reitlinger), *Globoendothyra globula* (Eichwald), *Planoarchaediscus spirillinoides* (Rauser), *Archaediscus moelleri* Rauser, which are typical of the *End. compressa* Zone of the Tulian Substage.

Endothyranopsis crassa–Archaediscus gigas Zone, *Eostaffella proikensis* Subzone (beds 2–9, samples 3/2–4/11). The *E. proikensis* Subzone is recognized based on the appearance of the index species *E. proikensis* Rauser in association with *Endothyranopsis crassa* (Brady), *Bradyina rotula* (Eichwald), and on the considerable renewal of the assemblage, general increase in diversity due to the appearance of *Bradyina rotula* (Eichwald), *Janischewskina minuscularia* (Ganelina), *Neoarchaediscus parvus* (Rauser), *Mirifica mirifica* (Rauser), *Pojarkovella nibelis* (Durkina), *Omphalotis minima* (Rauser and Reitlinger), *O. frequentata* (Ganelina) which are typical of the *E. proikensis* Zone of the Aleksinian Substage.

Endothyranopsis crassa–Archaediscus gigas Zone, *Eostaffella ikensis* Subzone (beds 9–16a, 16b, samples 5/12–7/16). The *E. ikensis* Subzone is recognized based on the first appearance of the index species *E. ikensis* Vissarionova in association with *Endothyranopsis sphaerica* (Rauser, Belyaev and Reitlinger), and higher – *Omphalotis chariessa* (Conil and Lys). Apart from newly appeared taxa, the assemblage contains many species continuing from the preceding zone (Fig. 4), which are typical of the *E. ikensis* Subzone of the Mikhailovian Substage.

The impoverished composition of newly appeared assemblage of the *E. ikensis* Subzone largely resulted from the incomplete sampling of the section. Therefore, the true taxonomic diversity of the foraminifers of this subzone remains uncertain.

Endothyranopsis crassa–Archaediscus gigas Zone, *Eostaffella tenebrosa* Subzone (beds 16c–22, samples 9/11–12/38). The *E. tenebrosa* Subzone is recognized based on the first appearance of the index species *E. tenebrosa* Vissarionova in association with *Howchinia bradyana* (Howchin), *Spinothyra pauciseptata* (Rauser), and *Loeblichia paraammonoides* Brazhnikova, *Archaediscus gigas* Rauser, *Asteroarchaediscus baschkiricus* (Krestovnikov and Teodorovich), *Omphalotis samarica* (Rauser), *Mikhailovella gracilis* Ganelina slightly higher up. The assemblage of the *E. tenebrosa* Subzone, in contrast to that of the underlying zone, is taxonomically diverse. Apart from new species, it contains almost all species of the two preceding subzones, which is typical of the *E. tenebrosa* Subzone of the Venevian Substage.

In the upper part of the *E. tenebrosa* Subzone (bed 21, sample 12/37), the taxonomic diversity of foraminifers sharply decreases (due to the presence of cherty facies), and upward in the section (bed 22, sample 12/38), foraminifers completely disappear, and their niche becomes occupied by algae (Plate 1, fig. 4). The quantity of algae became so large that they form the rock matrix (Plate 1,

Plate 5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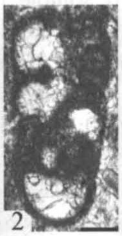
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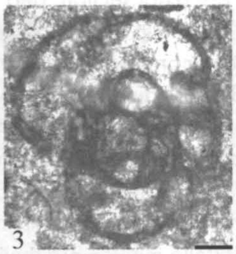
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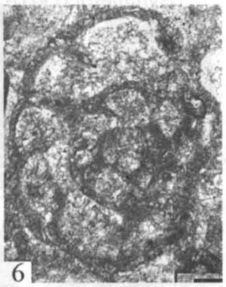
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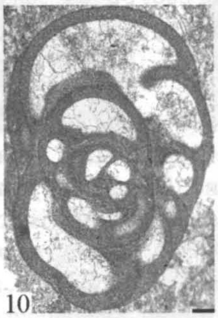
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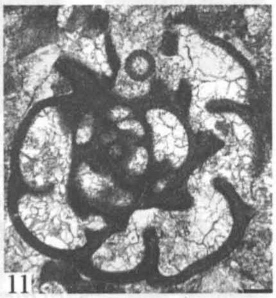
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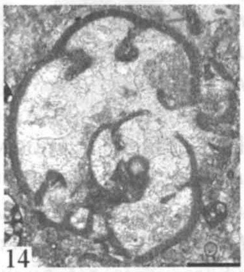
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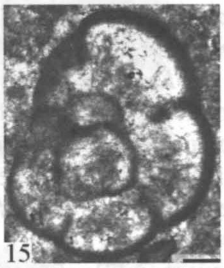
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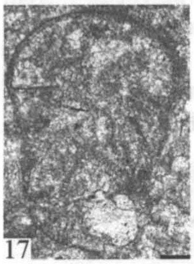
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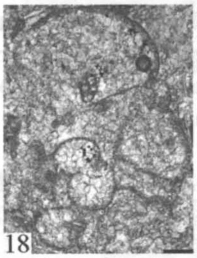
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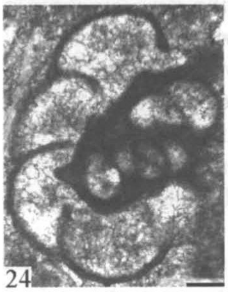
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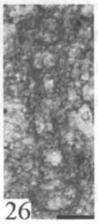
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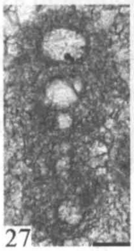
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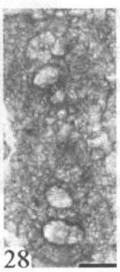
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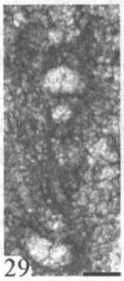
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Plate 5. Photomicrographs of the biostratigraphic significant foraminifera from the Upper Visean and Serpukhovian strata, the Novogurovsky Quarry. Fig. 1. *Forshia mikhailovi* Dain, axial section, bed 1, sample 1/3, ×30. Fig. 2. *Mikhailovella gracilis* Ganelina, axial section, bed 21, sample 12/36, ×100. Fig. 3. *Endothyranopsis compressa* (Rauser and Reitlinger), axial section, bed 1, sample 1/3, ×50. Figs. 4, 6. *Endothyranopsis crassa* (Brady): 4 – axial section, bed 3, sample 3/2, ×40; 6 – sagittal section, bed 6, sample 4/11, ×40. Fig. 5. *Endothyranopsis sphaerica* (Rauser, Belyaev and Reitlinger), axial section, bed 5, sample 4/10, ×40. Fig. 7. *Pojarkovella nibelis* (Durkina), axial section, bed 5, sample 4/10, ×50. Fig. 8. *Omphalotis omphalotis* (Rauser and Reitlinger), incomplete axial section, bed 5, sample 4/10, ×30. Fig. 9. *Omphalotis samarica* (Rauser), axial section, bed 21, sample 12/36, ×70. Fig. 10. *Omphalotis frequentata* (Ganelina), axial section, bed 5, sample 4/10, ×70. Fig. 11. *Omphalotis chariessa* (Conil and Lys), axial section, bed 13c, sample 7/16, ×70. Fig. 12. *Bradyina rotula* (Eichwald), sagittal section, bed 14, sample 14/3, ×25. Fig. 13. *Janischewskina typica* Mikhailov, sagittal section, bed 25, sample 14/40, ×15. Fig. 14. *Mirifica mirifica* (Rauser), sagittal section, bed 5, sample 4/10, ×70. Fig. 15. *Cribrospira rara* Rauser, sagittal section, bed 1, sample 1/3, ×50. Fig. 16. *Spinothyra pauciseptata* (Rauser), sagittal section, bed 21, sample 12/36, ×70. Figs. 17, 18. *Janischewskina delicata* (Malakhova): 17 – axial section, bed 25, sample 14/40, ×40; 18 – sagittal section, bed 25, sample 14/41, ×40. Figs. 19, 20. *Planoendothyra spirilliniformis* Brazhnikova and Potievskaya, axial sections, bed 24, sample 13/43, ×100. Figs. 21, 24, 25. *Endothyra phrissa* Zeller: 21, 25 – axial section, ×100; 24 – sagittal section, ×70; bed 25, sample 14/40. Figs. 22, 23. *Loeblichia paraammonoides* Brazhnikova: 23 – axial section, bed 19, sample 10/32, ×100; 22 – diagonal section, bed 31, sample 18/51, ×100. Figs. 26–29. *Cepekia cepeki* Vašiček and Ružička: 26–28 – axial sections; 29 – tangential section, all from the bed 33, sample 20/53, ×100. Figs. 30, 31. *Rectoendothyra latiformis* Brazhnikova: 30 – longitudinal section, bed 30, sample 19/51; 31 – bed 36, sample 22/60.

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fig. 3). A similar event of complete, although short-term disappearance of foraminifers is observed around the Visean-Serpukhovian boundary everywhere in the Moscow Basin and the Central Russian Basin (Kagarmanov, Donakova, 1990). This event as also recorded during the bed-by-bed study of the type Serpukhovian section in Zaborie (Gibshman, 2003).

Pseudoendothyra globosa Zone (beds 23–29a, samples 13/40-2–16/47). The *Ps. globosa* Zone is recognized based on the considerable renovation of the assemblage due to the appearance of many new taxa: "*Millerella*" *tortula* Zeller, *Janischewskina delicata* (Malakhova), *J. typica* Mikhailov, *Planoendothyra spirilliniformis* Brazhnikova and Potievskaya, *Rectoendothyra* sp., *Endothyra phrissa* Zeller, "*Endostaffella*" *asymmetrica* Rozovskaya, *Eostaffella mirifica* Brazhnikova, typical of the *Ps. globosa* Zone in the Tarusian Substage in the Zaborie Quarry. The appearance of new, typical Serpukhovian taxa was accompanied by the return of some previously existing taxa, commonly found in the preceding Upper Visean zones. A high diversity (Fig. 4) in the *Ps. globosa* Zone continues, almost unchanged, up to the top of bed 25 (sample 14/42).

The index species *Ps. globosa* Rozovskaya was not found, but we had one section of the test of this species (randomly orientated), which was difficult to identify positively.

Eostaffellina decurta Zone (beds 29b–middle 36, samples 16/47–24/62). The *E. decurta* Zone is recognized based on the first appearance of the index species *E. decurta* (Plate 4, fig. 15), while *Loeblichia* sp., *Neoarchaediscus postrugosus* (Reitlinger), *N. rugosus* (Rauser), *Cepekia cepeki* Vašiček and Ružička, and *Rectocornuspira* sp. appear slightly higher up. It is noteworthy that the index species, after its entry, is found in two successive samples higher up in the section, and after an interval of absence is present up to the top of the Serpukhovian (Fig. 4).

Apart from the newly appeared taxa, the assemblage includes several Serpukhovian species continuing from the *Ps. globosa* Zone (Fig. 4). The assemblage of the *E. decurta* Zone is distinct in the sharp decrease of the number of taxa continuing from the Upper Visean, and in the very low number of both Visean and Serpukhovian taxa. The populations at some levels (bed 33, sample 20/55) are composed only of numerous *C. cepeki* (Plate 6, figs. 26–29) and occasional *Loeblichia* sp.

Eostaffellina paraprotvae Zone (beds 38–44, samples 24/62–28/63). The *E. paraprotvae* Zone is recognized, provisionally, based on the first appearance of the index species *E. paraprotvae* (Rauser) (Plate 4, figs. 24–26), three specimens of which have been found in the beds 38–39 only. Apart from the index species, the assemblage contains the newly appeared *Rectoendothyra latiformis* Brazhnikova and occasional tests of *Eostaffellina decurta* (Rauser), "*Millerella*" *tortula* Zeller, and

Plate 6

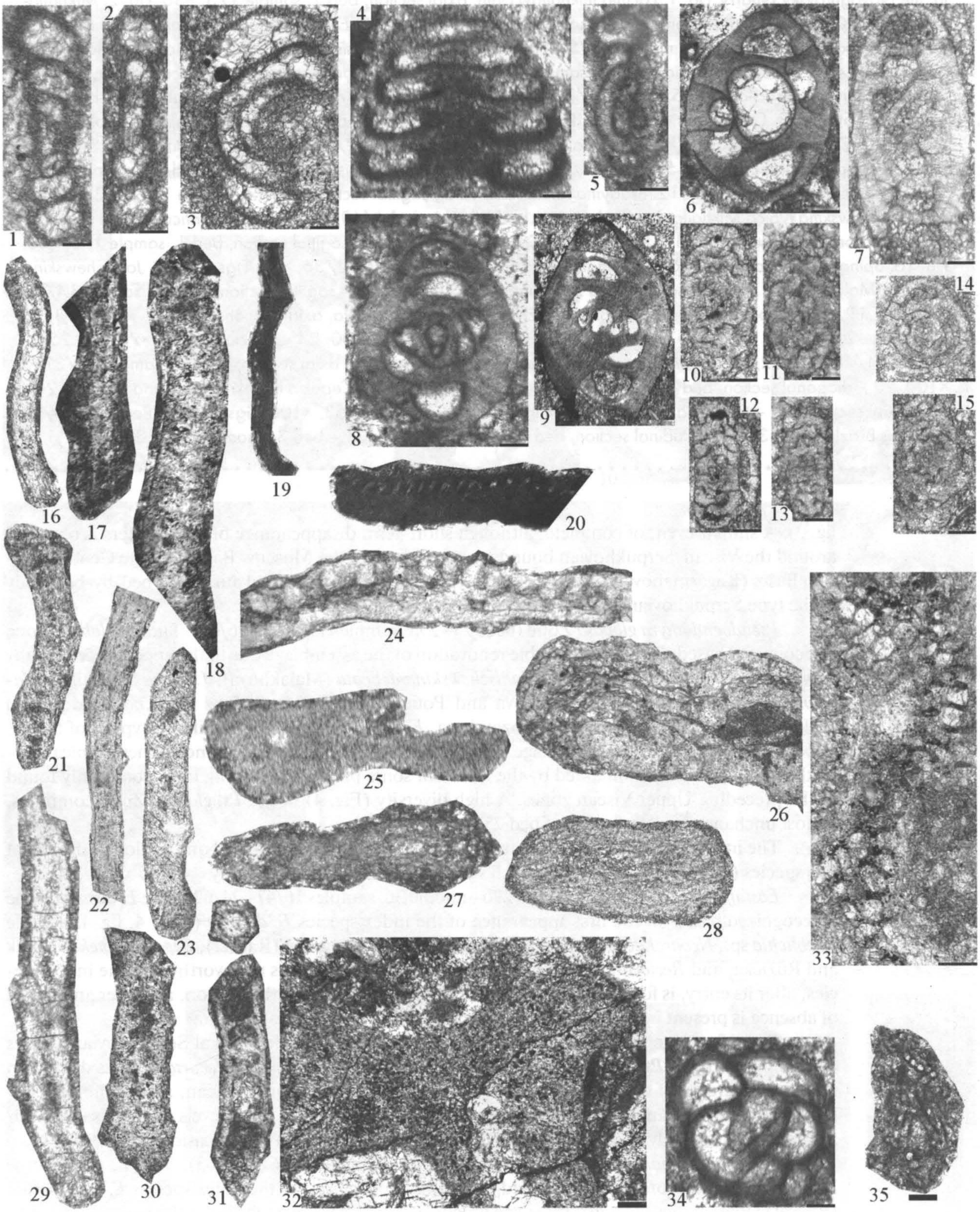
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Plate 6. Photomicrographs of the selected foraminifera and some the most representative algae in the Upper Visean and Serpukhovian strata, the Novogurovsky Quarry. Figs. 1–3. *Rectocornuspira* sp.: 1,2 – axial sections; 3 – sagittal section, bed 30, sample 17/49, ×100. Fig. 4. *Howchinia bradyana* (Howchin), axial section, bed 16c, sample 9/11, ×100. Fig. 5. *Planoarchaediscus spirillinoides* (Rauser), axial section, bed 1, sample 1/3. ×100. Figs. 6, 8. *Archaediscus moelleri* Rauser: 6 – high section in axis direction; 8 – diagonal section in axis direction, bed 1, sample 1/3, ×70. Fig. 7. *Archaediscus krestovnikovi* Rauser, axial section, bed 32, sample 19/51, ×100. Fig. 9. *Archaediscus gigas* Rauser, axial section, bed 19, sample 10/32, ×40. Figs. 10, 11. *Neoarchaediscus rugosus* (Rauser): axial sections, bed 32, sample 19/51. ×100. Fig. 12, 13. *Neoarchaediscus parvus* (Rauser): axial sections, bed 32, sample 19/51, x100. Figs. 14, 15. *Asteroarchaediscus baschkiricus* (Krestovnikov and Teodorovich): 14 – random section; 15 – axial section, bed 32, sample 19/51, x100. Figs. 16, 17, 21, 22, 31. Kamaenids – strong recrystallised: 16 – bed 23, sample 13/40; 17 – bed 1, sample 1/3; 21 – bed 26, sample 14/42; 22 – bed 28, sample 15/44; 31 – bed 44, sample 28/62, ×50. Figs. 18, 23, 24, 30. *Palaeoberesella* sp.: 18 – bed 1, sample 1/3; 23 – bed 31, sample 18/50; 24 – bed 9, sample 5/12; 30 – bed 44, sample 28/62, ×50. Figs. 19, 20. *Calcifolium okense* Shvetsov and Birina, bed 21, sample 12/36, x100. Figs. 25, 27, 28, 32. *Ungdarella uralica* Maslov: 25 – bed 23, sample 13/40, x100; 27, 28 – beds 42–43, sample 25/62, ×30; 32 – bed 14, sample 3, ×50. Fig. 26. *Shartymophycus fusus* Kulik, 1973 / *Fasciella kizilia* Ivanova, 1973, bed 14, sample 3, ×50. Fig. 29. *Praedonezella cespeformis* Kulik, beds 42–43, sample 25/62, ×100. Fig. 33. *Koninkopora* sp.: beds 10–12, sample 6/15, ×50. Fig. 34. *Salebra* sp., bed 1, sample 1/3, ×100. Fig. 35. *Girvanella* sp., bed 1, sample 1/3, ×50.

occasional Late Visean and Serpukhovian taxa (Fig. 4). The assemblage is strongly impoverished taxonomically.

Although the section in the Novogurovsky Quarry was examined and sampled only provisionally, it shows great potential for foraminiferal-based biostratigraphy of the Visean and Serpukhovian.

The foraminiferan-based zonal biostratigraphy showed instances of discrepancies in the stratigraphic position of some foraminiferal zones and Upper Visean and Serpukhovian substages – regional units, earlier discussed by Belskaya (1975).

(1) The first appearance of the index species *Eostaffella tenebrosa*, usually restricted to the Venevian, was fixed in the upper third of the Mikhailovian.

(2) A distinct and diverse Serpukhovian foraminiferal assemblage appeared in the section of the Novogurovsky Quarry approximately in the upper third of the Venevian (Upper Visean).

(3) The index species *Eostaffellina decurta*, usually restricted to the Steshevian, appeared for the first time in the Tarusian.

(4) The index species *Eostaffellina paraprotvae*, normally restricted to the Protvian, appeared in this section in the upper third of the Steshevian.

(5) The index species for the Protvian, *Eostaffellina protvae*, has not been recorded in the Novogurovsky Quarry.

Conodonts (Fig. 5; Plates 7–9). Conodonts from the Novogurovsky section were studied only preliminary. More than 100 samples of lower weight (normally 100–200 g, 29 kg in total) collected for lithological (P.B. Kabanov) and foraminiferal (N.B. Gibshman) studies were processed. The collection counted more 1740 conodont elements.

In the Aleksinian, Mikhailovian and Lower Venevian limestones conodonts are scarce. They are absent or only few elements were recovered with calculated conodont abundance up to 25 specimens/kg. In this interval taxa with ramiform elements dominated [*Synclydognathus geminus* (Hinde) and *Kladognathus tenuis* (Branson and Mehl)]. Also in the Aleksinian (bed 1) Visean *Lochriea commutata* (Branson and Mehl) occurs. In the lower Mikhailovian top of the bed 7 with *Stigmaria* appendicies contains shallow-water assemblage with *Cavusgnathus* sp. and *Hindeodus cristulus* (Youngquist and Miller), and *Mestognathius bipluti* Higgins in the top of bed 9. First deeper water *Gnathodus bilineatus* (Roundy) found in the top of the Mikhailovian in the bed 16.

Important shift in conodont abundance occurs in the lower part of upper Venevian cycle (bed 23). Conodont elements become much more common (up to 90 specimens/kg) and first appearance of *Lochriea ziegleri* Nemirovskaya, Perret and Meischner proposed as potential marker for the lower

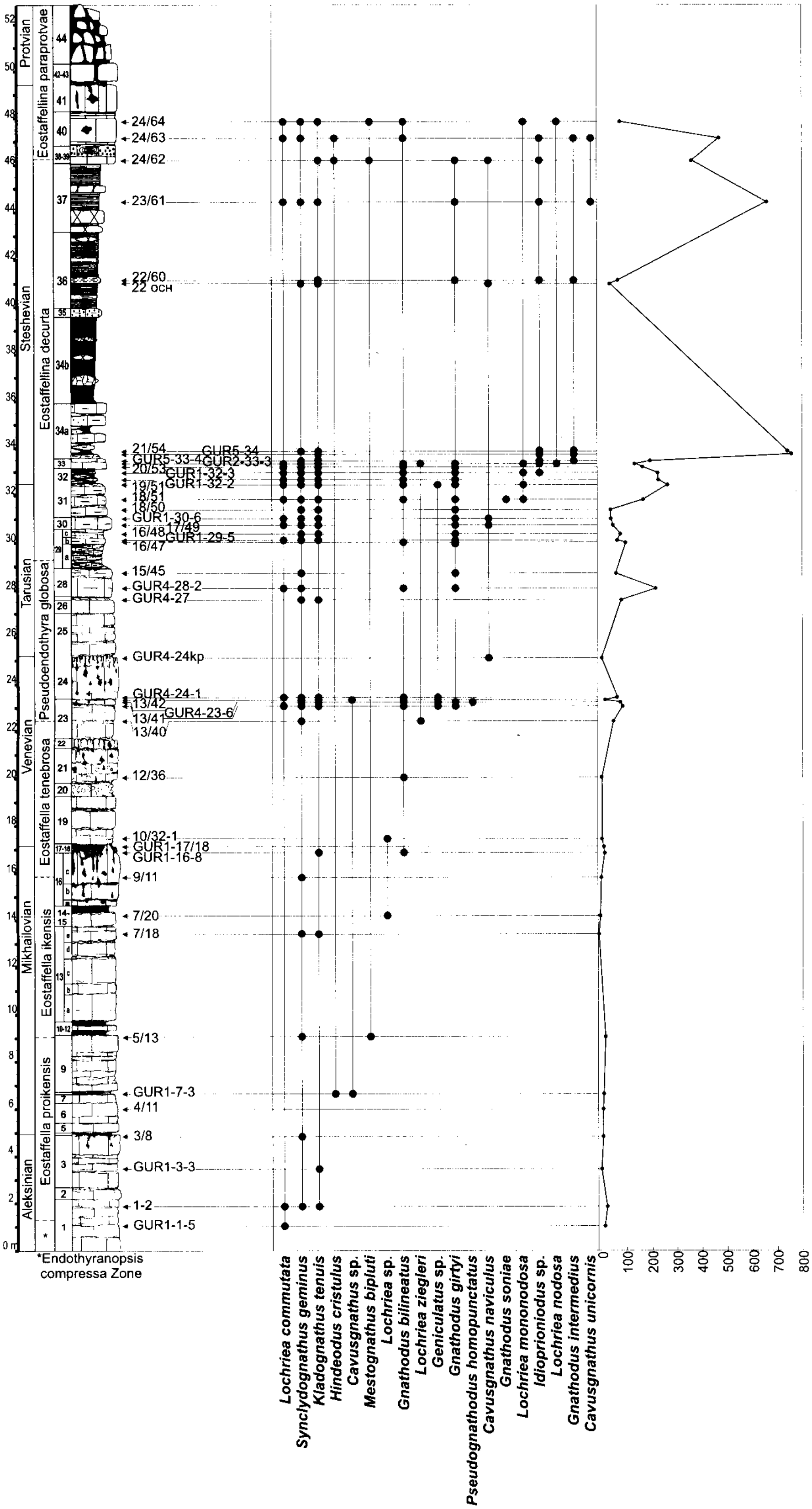

Fig. 5. Ranges of the conodonts and their abundance (specimens/kg) in the succession of the Novogurovsky quarry

Plate 7

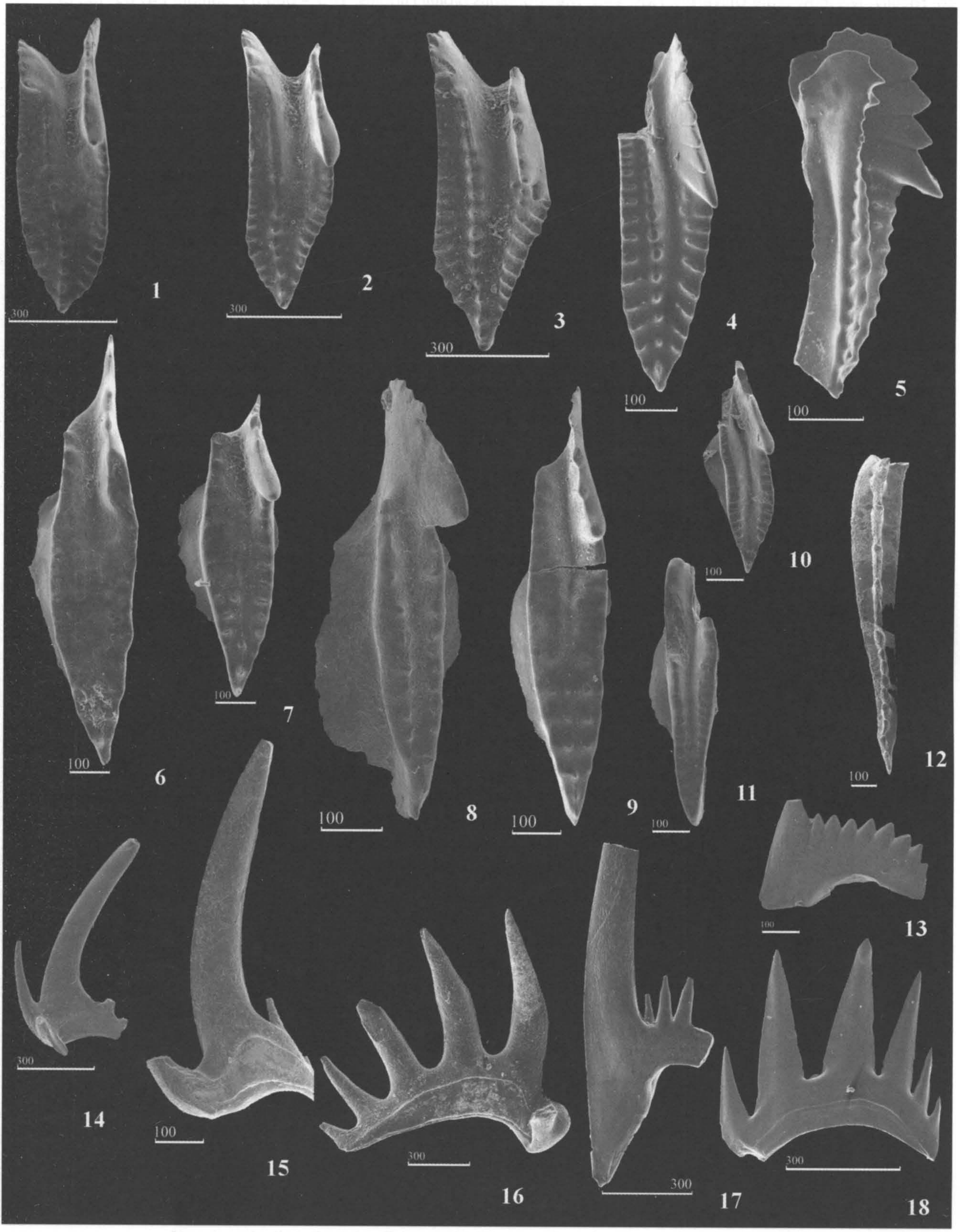
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Plate 7. Conodonts from the Novogurovsky section. Collection is stored in Department of Paleontology, Geological Faculty, Moscow State University. Figs. 1–5. *Mestognathus bipluti* Higgins: 1–3 – bed 39, sample 24/62, top of the Steshevian or base of the Protvian; 4, 5 – top of the bed 9, sample 5/13, Mikhailovian. Figs. 6–9. *Cavusgnathus naviculus* (Hinde): 6, 7 – bed 39, sample 24/62, top of the Steshevian or base of the Protvian; 8, 9 – bed 30, sample 17/49, Tarusian. Figs. 10, 11. *Cavusgnathus unicornis* Youngquist and Miller, bed 40, lower part, sample 24/63, uppermost Steshevian or basal Protvian. Fig. 12. *Geniculatus* sp., bed 23, sample GUR2-23-6, Venevian. Fig. 13. *Hindeodus cristulus* (Youngquist and Miller), bed 40, lower part, sample 24/63, uppermost Steshevian or basal Protvian. Figs. 14–18. *Kladognathus tenuis* (Branson and Mehl): 14 – S element, bed 32, lower part, basal Steshevian; 15 – Pa-Pb element, bed 1, sample 4A, Aleksinian; 16 – Pa-Pb element, bed 1, sample Dno 1-2, Aleksinian; 17 – M element, bed 29, sample GUR3-29-5; 18 – Pa-Pb element, bed 29, sample GUR3-29-5, Tarusian

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boundary of the Serpukhovian Stage (Skompski et al., 1995; Nemyrovska, 2005) fixed. This species has first appearance at the same level in the Lanshino section, 40 km to the north.

In the Tarusian and Steshevian as in the Zaborie section (lectostratotype of the Serpukhovian Stage) conodonts are numerous and high diverse. Besides abundant *Synclydognathus* and *Kladognathus* elements such species as *Lochriea commutata* (Branson and Mehl), *L. mononodosa* (Rhodes, Austin and Druce), *L. nodosa* (Bischoff), *Gnathodus bilineatus* (Roundy), and *G. girtyi* Hass are common. *Cavusgnathus naviculus* (Hinde) occurs in the Tarusian at few levels. The lowermost Steshevian (beds 32 and 33) differs by the domination of *Gnathodus girtyi* Group. Form bed 33 upwards *Kladognathus* dominate over *Synclydognathus*. The upper Steshevian black shales were sampled only at few levels, but conodont assemblage is the same as in its base.

Topmost Steshevian (Lower Protvian according to Belskaya, 1975) white limestone contains abundant deeper water conodont assemblage of *Gnathodus bilineatus* (Roundy), *Lochriea mononodosa* (Rhodes, Austin and Druce), *L. nodosa* (Bischoff), but together with shallow-water *Mestognathus bipluti* Higgins and *Cavusgnathus unicornis* Youngquist and Miller.

Composition of the Upper Visean and Serpukhovian conodont assemblages in the Novogurovsky section is identical to those from other sections in the southern part of the Moscow Basin: Zaborie, Mitino, Lanshino, Aleksin (Barskov et al., 1971; Barskov, Alekseev, 1979; Nikolaeva et al., 2002). No endemics among conodonts were found and taxonomic composition of the assemblages is very close to Upper Visean and Serpukhovian ones everywhere: in England (Higgins, 1975), Germany (Nemirovskaya et al., 1994), Spain (Nemyrovska, 2005), Poland (Skompski, 1996), South Urals (Kulagina et al., 1992).

The studied interval in the Novogurovsky section belongs to Visean-Lower Serpukhovian *Gnathodus bilineatus bilineatus* Zone s.l. The index subspecies was found also in older Upper Tulian limestone (Makhlina et al., 1993). The younger subspecies *G. bilineatus bollandensis* Higgins and Bouckaert typical for Arnsbergian occurs only in the mid-Protvian interval in the subsurface. The upper Venevian and upward could separated as *Lochriea ziegleri* Zone.

Other groups. The ostracods are very abundant in the Upper Visean and Serpukhovian rocks of the Novogurovsky section. Their mainly smooth valves are visible on the limestone crush surfaces. The only preliminary data available (Kochetova, Zianakaeva, 2005). The most diverse assemblage was found in the Mikhailovian: *Shishaella subsymmetrica* Kochetkova, *S. unicornis* Zanina, *Hollinella* cf. *radiata* (Jones and Kirkby), *Kirkbyia pristina* Zanina, *Amphissites mosquensis* Pozner, *Knoxiella posneri* Egorov, *Jonesina bivesiculosa* Pozner, *J. craterigera* (Jones and Kirkby), *J. janischewskyi* Pozner, *Glyptopleura concentrica* Pozner, *Kirkbyella undulata* Zanina, *Cavellina phillipsiana* (Jones and Hall), *C. forschi* Pozner, *C. attenuata* (Jones and Kirkby), *Microcheilinella extuberata* Samoilova and Smirnova, *Pseudobythocypris pediformis* (Bradfield), *Scrobicula scrobiculata* (Jones, Kirkby and Brady), *Bairdia distracta* (Eichwald), *B. donetziana* Gorak, *Acratia rostrata* Zanina, *Bairdiocypris bilobatus* (Münster), *B. fabulina* (Jones and Kirkby), *Macrocypris lenticularis* Cooper etc. Among these species *Glyptopleura concentrica* Pozner and *Cavellina forschi* Pozner occur only in the Mikhalovian (Samoilova, 1979).

The Venevian assemblage is reduced in diversity: *Healdia* aff. *kudrjavtzewi* Pozner, *Microcheilinella shiloi* Bless, *Scrobicula scrobiculata* (Jones, Kirkby and Brady), *Bairdia legumen* (Jones

Plate 8

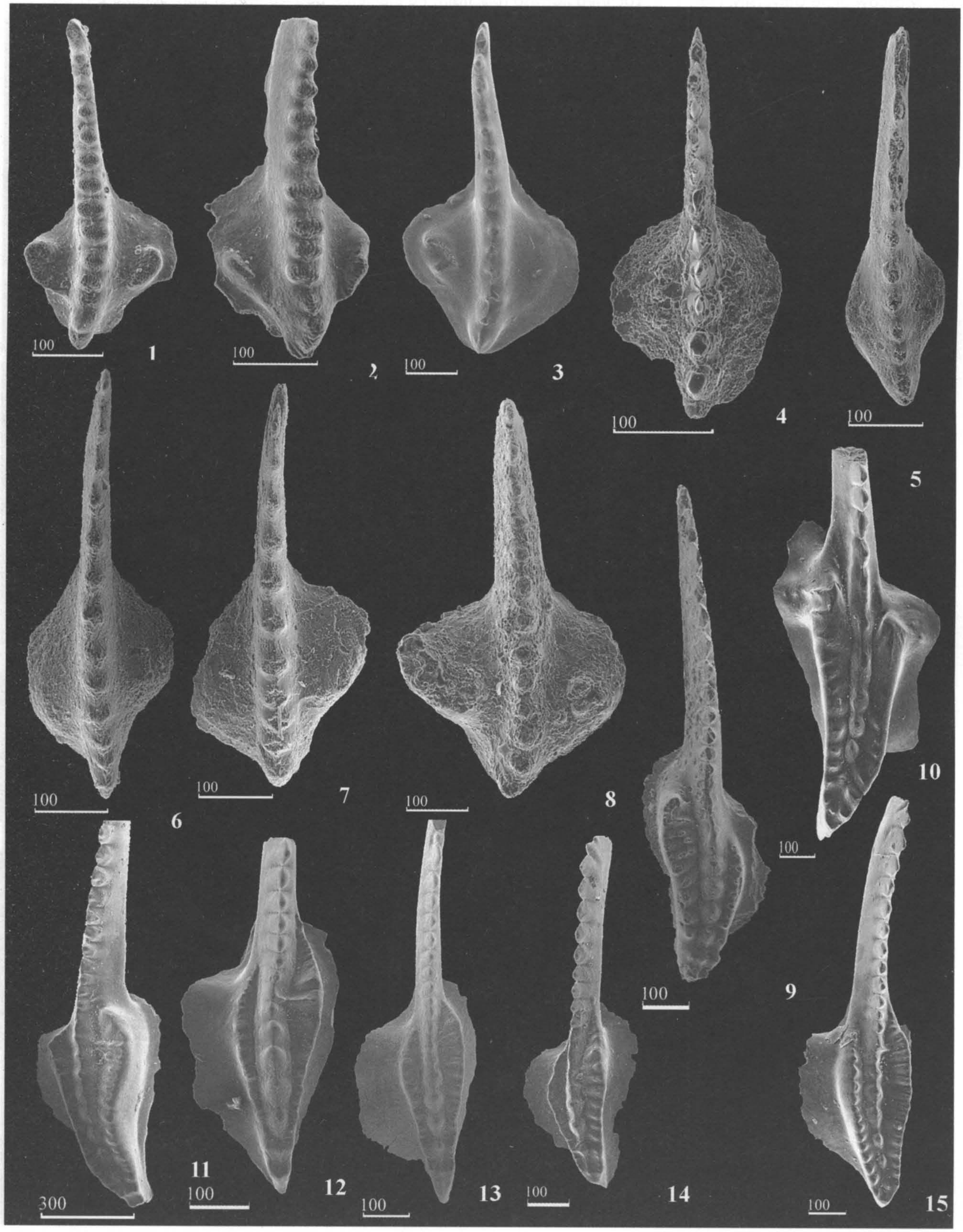
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Plate 8. Conodonts from the Novogurovsky section. Collection is stored in Department of Paleontology, Geological Faculty, Moscow State University. Figs. 1, 2. *Lochriea nodosa* (Bischoff), Pa elements, bed 40, upper part, sample 24/64, uppermost Steshevian or basal Protvian. Fig. 3. *Lochriea mononodosa* (Rhodes, Austin and Druce), bed 32, lower part, sample 19/51, basal Steshevian. Figs. 4–7. *Lochriea commutata* (Branson and Mehl): 4 – bed 23, sample 12/41, Venevian; 5 – bed 15, sample 7/20, Mikhailovian; 6 – bed 1, lower part, sample 4A, Aleksinian; 7 – bed 1, lower part, sample 3, Aleksinian. Fig. 8. *Lochriea ziegleri* Nemirovskaya, Perret and Meischner, bed 23, sample 13-40-2, Venevian. Figs. 9–11. *Gnathodus intermedius* Globensky: 9, 11 – bed 36, sample 22/60, middle Steshevian; 10 – bed 34, sample GUR5-34-1f, basal Steshevian. Figs. 12–15. *Gnathodus girtyi* Hass: 12 – bed 32, lower part, sample 19/51, basal Steshevian; 13, 14 – bed 30, sample 17/49, top of the Tarusian; 15 – bed 34, sample GUR5-34-1f, basal Steshevian

and Kirkby), *B. angulata* Pozner, *Acratia* aff. *praetypica* Pozner, *Bairdiocypris fabulina* (Jones and Kirkby), and *Macrocypris lenticularis* Cooper.

The Tarusian limestone contains only few ostracods: *Dorsoobliquella ovalis* Kochetkova and *Bairdia alta* Jones and Kirkby. The Steshevian assemblage is also impoverish: *Kirkbya lessnikovae* Pozner, *Amphissites urei* Jones, *Scrobicula scrobiculata* (Jones, Kirkby and Brady), and *Macrocypris lenticularis* Cooper.

Ostracod assemblages contain mainly endemic species widely distributed in the southern and western parts of the Russian Platform with admixture of the some taxa described from the Great Britain Dinantian.

Calcareous sponges are present in the Novogurovsky succession: *Siderospongia sirensis* Trautschold, and chaetetids.

Corals (mostly Rugosa) are minor component of the late Visean and Serpukhovian biota (Belskaya, 1975). The Aleksinian contains *Syringopora reticulata* Goldfuss, *Lithostrotion junceum* (Fleming), *Dibunophyllum* sp. and others. In the Mikhailovian limestones corals are more abundant including large *Lithostrotion* and *Lonsdaleia*, but in the Venevian their abundance becomes lower: *Syringopora* sp., *Lithostrotion junceum* (Fleming), *Koninckophyllum volgense* Dobrolyubova, *Dibunophyllum bipartitum* (McCoy), *Palaeosmilia murchisoni* (Milne Edwards and Haime). The large solitary *Caninia inostranzevi* Stuckenberg found in the lower Steshevian.

The large shells of the gigantoproductid brachiopods are most spectacular in the Upper Visean: *Gigantoproductus submaximus* (Bolkhovitinova), *G. sinuatus* (Sarycheva) in the Aleksinian; *G. giganteus* (Martin), *G. striatosulcatus* (Shvetsov), *Moderatoproductus moderatus* (Shvetsov) and *Striatifera striata* (Fischer) in the Mikhailovian. In the Venevian and Tarusian gigantoproductids seriously decrease in the abundance. For the upper Tarusian and lower Steshevian small productid brachiopods are more typical: *Productus concinnus* J. Sowerby, *Antiquatonia costata* (J. Sowerby). *A. khimenkovi* (Janishevsky), and spiriferids *Martinia glabra* (Martin), "*Fusella*" etc. This transition from large and thick shelled gigantoproductid communities to small shelled productids and smooth spiriferids and athyridids may reflect cooling of the waters, high input of the terrigenous clastics because some glacial episode.

For the black clays in the lower part of the Steshevian the mass accumulations of small brachiopods *Eomarginifera lobata* (J. Sowerby), *E. longispina* (J. Sowerby) and *Composita ambigua* (J. Sowerby). Their shells commonly with two valves flattened and crushed due to compaction occur in millions that born the special name for this marker basal Steshevian rock "Lobatovye gliny" (Lobata Clays).

Molluscs are not abundant, but large bivalves and nautiloids (*Domatocers* etc) occur at the some levels.

The common and sometimes rock forming component especially in the Mikhailovian and Venevian is vermicular calcareous algae *Calcifolium okense* Shvetsov and Birina.

Plate 9

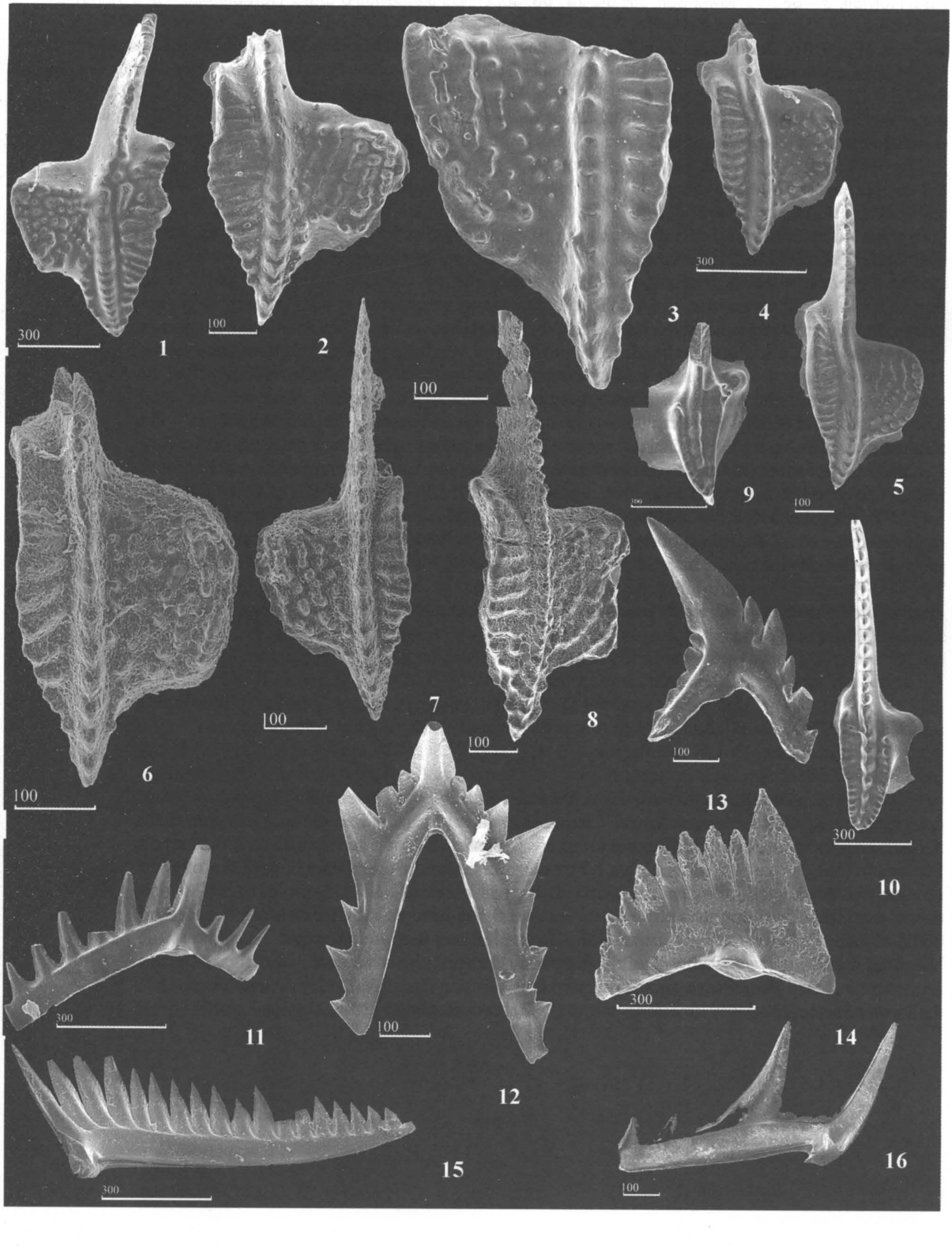
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Plate 9. Figs. 1–8. *Gnathodus bilineatus* (Roundy): 1, 2 – bed 40, upper part, sample 24/64, uppermost Steshevian or basal Protvian; 3 – bed 40, lower part, sample 24/63, uppermost Steshevian or basal Protvian; 4, 5 – bed 32, lower part, sample 19/51, basal Steshevian; 6, 7 – bed 23, sample 13/41, Venevian; 8 – bed 23, sample GUR2-23-6, Venevian. Figs. 9, 10. *Gnathodus soniae* Rhodes, Austin and Druce, bed 34, sample GUR5-34n, basal Steshevian. Fig. 11. *Idioprioniodus* sp., Pa element, bed 29, sample GUR3-29-5, Tarusian. Figs. 12–16. *Synclydognathus geminus* (Hinde): 12 – S element, bed 29, sample GUR3-29-5, Tarusian; 13 –Pb element, bed 29, sample GUR3-29-5, Tarusian; 14 – Pa element, bed 23, sample GUR2-23-6, Venevian; 15 – M element, bed 1, sample Dno1-2, Aleksinian; 16 – S element, bed 1, lower part, sample 4A

Sequence analysis

The Upper Visean and Serpukhovian carbonate succession are cyclic in the southern part of the Moscow Basin and the Aleksinian, Mikhailovian and Venevian regional substages were established primary as major cycles separated by extremely shallow water black "rhizoid limestones" of the paleosol origin. The Aleksinian looks as one cycle, Mikhailovian – 4 cycles, Venevian – 2 cycles. The Tarusian and Steshevian (Serpukhovian) substages do not contain "rhizoid limestones", but also are cyclic (Kabanov, 2004). The Steshevian shale cycle terminated in calcretized limestones of Dashkovka paleosol which traditional were included in the younger Protvian Substage. The thickness of each cycle is variable, changes from less than 1 m up to 10–15 m.

Quite probable that the Stshevian shales, palygorskitic in the upper part, but with normal marine fauna, reflect high input of clastics from the western land. This shift could be resulted from growth of humidity during the mid-Serpukhovian deglaciation interval in the Southern Hemisphere. The Mid-Serpukhovian warming recently was identified in the Central Europe Upper Silesian Basin close to the Pendleian-Arnsbergian boundary (Gastaldo et al., 2009).

Correlation

In the Moscow Basin the individual substages of the Upper Visean and Serpukhovian are correlated using black "rhizoid limestone" being as a marker horizon. It is more or less correct for Aleksinian and Mikhalovian, but boundary intervals of the Venevian and Tarusian, Tarusian and Steshevian look as more transitional that born controversies of the correlational models. Common opinion that thicknesses of individual substages are very constant on the distances of 50–150 km do not confirmed by modern biostratigraphic markers. For example, M. Hecker (Osipova Hecker, 2005; Hecker, Osipova, 2007) considered that in the Zaborie section lowermost beds are not the Venevian, but belong to lower cycle of the Tarusian. But from the other side the interval of clayey limestone included in the Novogurovsky section into Tarusian (Belskaya, 1975) we have to correlate with lower Steshevian clayey limestone part of the Zaborie section (Fig. 3).

Visean/Serpukhovian boundary in Moscow Basin

The Serpukhovian Stage was formally proposed by Nikitin (1890). He did not designate a stratotype section, but he wrote that "...Podmokloe, Zaborie, Luzhki, Sknizhka River may be considered as the most typical and most fossiliferous localities of this stage ..." (Nikitin, 1890, p. 14). The outcrops mentoined by Nikitin have not existed for a long time, except for the section in the Zaborie quarry in the southern margin of the Serpukhov. This section is accepted as lectostratotype of the Serpukhovian Stage. The Zaborie quarry was not active during long time, but access to outcrops in it was opened. During Working Group of the SCCS field meeting in 1998 participants have been visited Zaborie quarry. However the quarry excavation despite of protests of many scientists and local "greens" later began to use as a waste storage. The Novogurovsky section situated in type area of the Serpukhovian Stage in 50 km to south of the Zaborie even more complete and may serve as its hypostratotype.

The lithostratigraphic boundary of the Upper Visean and Serpukhovian coincides with sea level fall at limit of the Venevian and Tarusian substages marked by "rhizoid limestone" paleosol, but correlation of this level is controversial (see above).

The Visean-Serpukhovian boundary strata contain fossils of different groups of the benthic fauna (foraminifers, sponges, corals, brachiopods, echinoderms), ammonoids are scarce. The latter were not found in the Venevian, but few specimens of *Cravenoceras shkolini* Morozov, *C. crassum* Ruzhencev and Bogoslovskaya occur in the upper Tarusian of the Zaborie section. The lower Steshevian in this section contains *Cravenoceras shimanskyi* Ruzhencev and Bogoslovskaya and *C. scoticum* Currie (Shkolin, 2000). Genus *Cravenoceras* is typical for the *Uralopronorites–Cravenoceras* Genozone of the Pendleian.

The lower Serpukhovian foraminiferal zone is *Pseudoendothyra globosa* Zone, but index species is very rare in the Moscow Basin. The more useful species are *Neoarchaediscus postrugosus* and "*Millerella*" *tortula* which permit correlation with the upper Chesterian of the USA (base of the Hombergian; Kulagina et al., 2008). In the Novogurovsky section the latter species was found together with conodont *Lochriea ziegleri* in the bed 23 of the upper Venevian.

The conodont species *Lochriea ziegleri* was proposed as potential marker of the base of the global Serpukhovian (Skompski et al., 1995). The first appearance of this species in the Moscow Basin has been shown in the upper Venevian of the Lanshino section very close to the Serpukhovian lower boundary. In the Novogurovsky section *L. ziegleri* was found at the same level. According to Shvetsov (1938), Venevian fauna is transitional between Okian (Upper Visean) and Serpukhovian and selection of *L. ziegleri* as marker of the Serpukhovian base will not affect seriously the Russian stratigraphic nomenclature.

One of the potential GSSPs for the Serpukhvian Stage is the Verkhnyaya Kardailovka section in the South Urals (Nikolaeva et al., 2005) where ammoinoids, foraminifers, ostracods, radiolarians and conodonts occur in deep water succession and where lineage *L. nodosa – L. ziegleri* could be traced. Another candidate is deep water Nashui section in the South China (Qi, Wang, 2005; Richards and Task Group, 2008). However *L. ziegleri* not found yet in the North America that is not happy for the intercontinental correlation.

Acknowledgments

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ADDENDUM

ZABORIE SECTION LECTOSTRATOTYPE OF SERPUKHOVIAN STAGE

P.B. Kabanov[1], **N.B. Gibshman**[2], **I.S. Barskov**[2,3],
A.S. Alekseev[2,3], **N.V. Goreva**[4]

[1]Tyumen Oil Scientific Center, TNK-BP,
Tyumen, Russia

[2]A.A. Borissiak Paleontological Institute of Russian Academy of Sciences,
117997 Moscow, Profsoyuznaya st. 123, Russia

[3]Moscow State University, Geological Faculty, Department of Paleontology,
119991 Moscow, Leninskie Gory, Russia. E-mail: aaleks@geol.msu.ru

[4]Geological Institute of Russian Academy of Sciences,
110017 Moscow, Pyzhevsky per. 7, Russia

The description of the Zaborie section given below is abrigaded text of recent publications (Gibshman, 2003; Kabanov, 2003, 2004) with addition on conodonts written by I.S. Barskov, A.S. Alekseev and N.V. Goreva. The brachiopods were identified by A.V. Shatulin (unpublished master thesis in the Department of Paleontology, Moscow State University, 2002), nautiloids – by I.S. Barskov, gastropods – by A.V. Mazaev, fishes – by O.A. Lebedev.

Historical review

Shvetsov (1932) published the geological column of that locality, its description, and photographs of the section in his later works (Shvetsov, 1940, 1948). One more column characterizing the Zaborie section was published by Rauser-Chernousova (1948, p. 29). The section base was likely situated at that time in a lower part of the Tarusian (in bed 3 or 4), and the top was at the level of beds 26–28 of the currently exposed succession.

Osipova and Belskaya (1965a, 1967, 1975; Osipova et al., 1972) who investigated lithology, facies, and fossil content of Serpukhovian Stage in the vicinity of Serpukhov, for the Zaborie section published its characterization without bed-by-bed description and columns of particular exposures. Schematic columns of that section have been published later (Barskov and Alekseev, 1979; Makhlina et al., 1993; Skompski et al., 1995).

Section description

The Zaborie Quarry is situated 2 km away from the left bank of the Oka River in southeastern outskirts of Serpukhov near the Mirnyi Settlement (54°54' N, 37°27' E, Fig. 1). The quarry is out of mining now (Fig. 2). The used numeration of beds from the base upward is that of Barskov and Goreva (see in Barskov and Alekseev, 1979; Skompski et al., 1995).

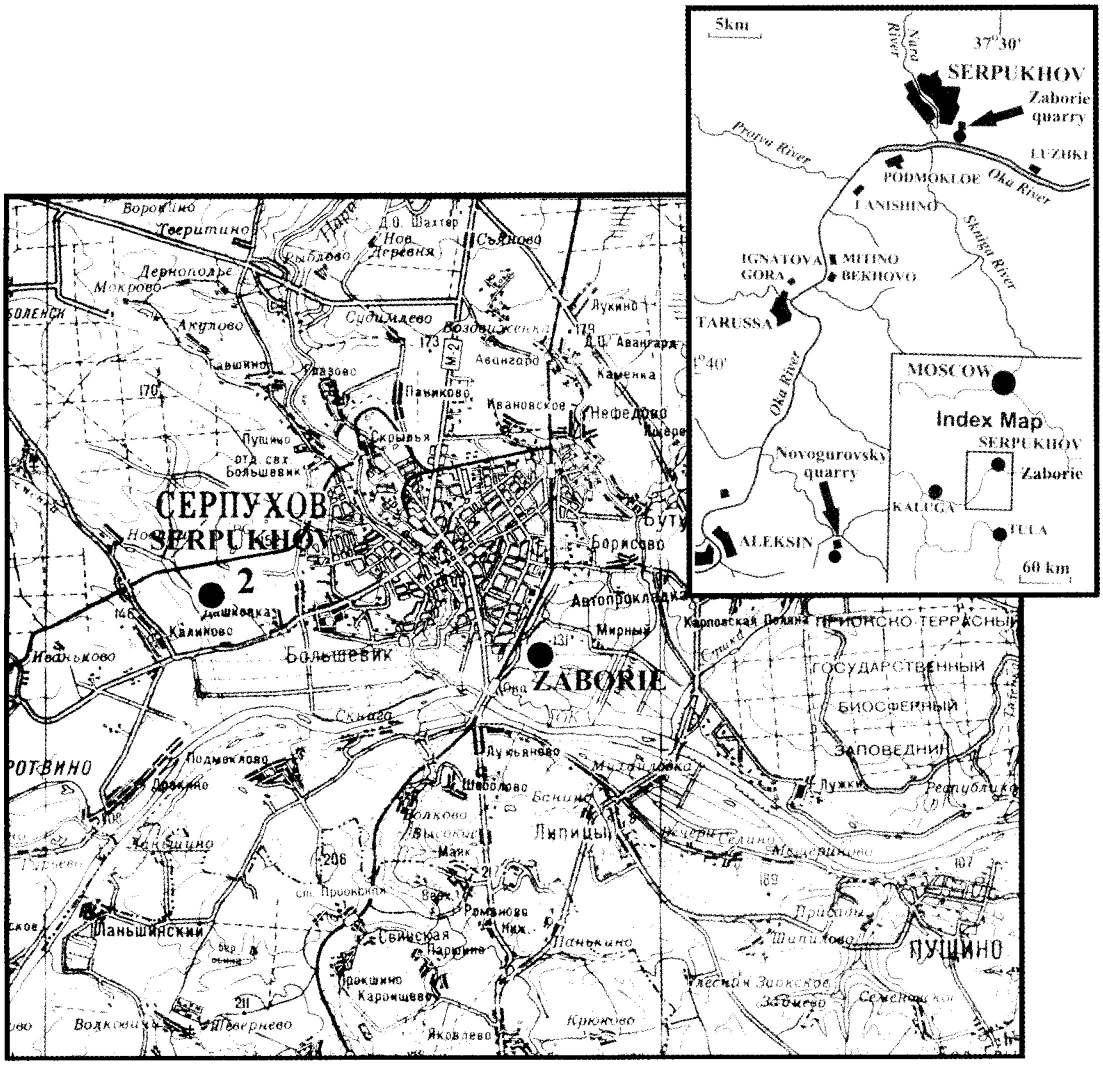


Fig 1. Location of the Zaborie section

Fig. 2. Panoramic view on the Zaborie quarry

Visean Stage
Venevian Substage

First Bench

Member 1

1. Gray fine-grained limestone that has been exposed on the quarry bottom.

An interval of talus (1 m), and lower 1.3 m of the currently exposed section (bed 2).

2. Karstified inhomogeneous mottled limestone with diverse dissolution caverns, rhizocretions of the first root horizon, and microscopic indications of fresh-water diagenesis. All the rocks represent the Muratovo paleokarst profile. ***Microfacies***: packstone and wackestone-packstone of foraminifer-ostracod composition; rocks are fine-grained and bioturbated. Thickness 1.3 m.

Serpukhovian Stage
Tarusian Substage

Member 2

3. Two plates of cream-gray limestone, which are nearly equal in thickness. Abundant biomolds and aggregates of large brachiopod fragments are characteristic. ***Microfacies:*** fine-grained packstone-wackestone with local areas of compaction microtextues. In a dark central spot of the upper plate, the rock corresponds to coarse-grained bioclastic *Calcifolium* wackestone-packstone. Moderately abundant *Zoophycos* occurs. Brachiopods *Gigantoproductus giganteiformis* (Lisitsyn). Thickness 0.55 m.

4. Gray homogeneous bioturbated limestone similar to that of bed 3 with *Stigmaria* appendicies in top. A rather distinct mottling. The second root horizon with *Stigmaria* appendices, the long subvertical channels of about 10 mm in diameter, which are sometimes empty, with a halo of weak alterations in surrounding rock. The channels are characteristic of the entire thickness of bed 4. They are identical to appendices of some *Stigmaria* beds. Brachiopods *Productus subcarbonarius* Sarycheva, *Latiproductus* sp., *Pugnax pugnus* (Martin), *Martinia glabra* (Martin), nautiloids *Loxoceras* sp., *Rayonnoceras giganteus* (Sowerby). Thickness 0.8 m.

Member 3

5. Hard light-gray limestone more porous and soft near the base, where dark *Zoophycos* bands are abundant. Dark mottles with biomolds after molluscan shells are confined to the upper bed part. ***Microfacies:*** wackestone-packstone locally enriched in coarse skeletal fragments. Brachiopods *Gigantoproductus giganteiformis* (Lisitsyn), *Ovatia*? 0 (Sarycheva), *Antiquatonia costata* (Sowerby). Thickness 0.6 m.

6. Gray, comparatively hard limestone with local darker and blurred, horizontally extended mottles. The rock is softer and micrific near the base. Swirling bioturbation patterns of irregular arrangement are interrupted by *Zoophycos* mottles. Transition to Bed 7 is gradual with stylolites. Microfacies inhomogeneous polybioclastic to micrite texture consists of dense wackestone areas and accumulations of skeletal material corresponding to inequigranular or coarse-grained packstone. The distinguished single channels with peloid-grumous geopetal filling differ from surrounding mass in their color and texture. It is likely that these tubes are former openings left by roots. Since undisputable microscopic traces of roots have not been established between the aforementioned "root horizons", the tubes in question penetrated deep in sediment from the third root horizon. Brachiopods *Rhipidomella michelini* (Eveille), *Latiproductus* cf. *latiexpansus* (Sarycheva), *Leiothyridina okensis* Grunt, *Spirifer* aff. *pseudotrigonalis* Semikhatova, *Dielasma curvatum* Chernyshev; fishes *Stethacanthus* cf. *obtusus* (Trautschold), *Thrinacodus* cf. *ferox* (Turner). Thickness 1.3 m.

7. Light gray limestone with yellow mottles and abundant diverse macrofossils, which form the framework of rock in places of their clustering. Biomolds after diverse molluscan shells, brachiopods (representing mostly the genera *Productus*, *Antiquatonia*, *Eomarginifera*, and *Composita*), and bryozoans are abundant. Intact shells are rather frequent, representing about a half of skeletal remains. Many brachiopods occur in situ or are insignificantly displaced. Macrofossil remains are cemented by grainy micritic limestone with sporadic *Zoophycos* traces. ***Microfacies:*** the brachiopod-molluscan floatstone-rudstone with abundant Siphonophycaceae thalli and sporadic trilobite remains. Shreds of rusty foliated marl are locally preserved on the surface, but in general, this level experienced the late diagenetic alteration. The contact between beds 7 and 8 is locally marked by black smeary clay, ferruginous concretions (probably decomposed pyrite), and secondary cavities half-filled with brown and loose ferruginous lumpy clay that presumably is a weathering product of foliated marl. Brachiopods *Avonia youngiana* (Davidson), *Productus* sp.; gastropods *Bellerophon attenuatus* Eichwald, *Pseudozygopleura rugifera* Phillips, *P. exigiuum* Koninck, *Phanerotrema monticola* (Eichwald), *Straparollus pileosidens* Phillips, *Straparollus* (*Euomphalus*) *crotalostomus* McCoy, *Monulonia automaria* Phillips; fishes "*Cladodus*" *exiguus* (St. John and Worthen). Thickness 0.2 m.

Member 4

8. Comparatively hard limestone with small vugs (0.5–1 mm) and indistinct horizontal mottles, which locally exhibit a sedimentary lamination that is outlined by subhorizontal orientation of allochems. Owing to absence of *Zoophycos*, the rock looks homogeneous, nearly massive. Under microscope, it reveals the upward transition from basal polybioclastic packstone-wackestone of variable grain size to homogeneous fine-grained kamaenid packstone. The boundary between beds 8 and 9 is conventionally placed at the concentration level of rhizocretions in the third root horizon (see below). Fishes *Stethacanthus* cf. *obtusus* (Trautschold). Thickness 1.2 m.

9. Massive limestone lighter in color than that of bed 8 and locally displaying either a sedimentary lamination or bioturbation; near the top, proportion of clay admixture is somewhat higher. A lower half of the bed (layer 9a) is amalgamated with bed 8 to represent a single thick plate. Its upper portion 0.5 m thick (layer 9b) corresponds to another plate that again shows appearance of rare

Zoophycos. ***Microfacies:*** foraminiferal-bioclastic wackestone lacking compaction signs and enriched in Kamaenidae and small biomolds after molluscan shells. Chaetetids, solitary Rugosa occur. Thickness 1.1 m.

The third root horizon is marked by occurrence of rhizoconcretions and rhizocretions of variable orientation, which are up to 3–4 cm in diameter and locally preserve appendices branching under normal angle from the main stem. Around rhizomorphs, there are developed dark haloes and spots with microchannels and vugs, which have alveolate-tubercular walls. In addition, a vertical section in the lover part of bed 9 exhibits a series of parallel imprints oriented under angle of about 45°, which resemble whips and represent appendices of *Stigmaria* of the second type after Hecker (1980).

Steshevian Substage

Following Shvetsov (1948), many researchers (Rauser-Chernousova, 1948; Barskov and Alekseev, 1979; Makhlina et al, 1993) place the boundary between Tarusaian and Steshevian in the Zaborie section at the level of transition from monolithic blocky limestones of Member 4 to thick-bedded clayey limestones and marl of Member 5. Osipova and Belskaya (1965a) likely attributed to the Tarusian the basal limestone beds of the Steshevian, which bear accumulations of *Dibunophyllum bipartitum* McCoy.

Member 5

10. Gray homogeneous clayey limestone; the rock is bedded, bearing *Zoophycos*. ***Microfacies:*** floatstone-wackestone with molluscan, crinoid, and brachiopod clasts of variable size. Some skeletal particles are micritized at the surface. Chaetetids, gastropods, bivalves, fishes "*Acanthodes*" cf. *dublinensis* Stauffer, *Thrinacodus* cf. *ferox* (Turner). Thickness 1.0 m.

Second Bench

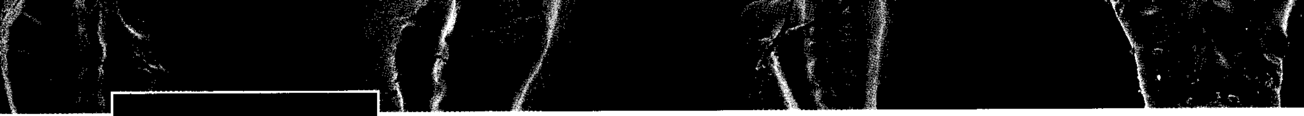
11–13. Rusty-gray limestone (reddish near the top); the rock is clayey, micrific, and fissile, displaying abundant *Zoophycos* traces. Lenticular and other accumulations of large shelly fragments (mostly of brachiopods) likely represent bioturbated storm concentrates. ***Microfacies:*** bioclastic mudstone with admixture of silty quartz grains and neomorphic spiny structures (sponge spicules?). Some bioclasts are silicified. Dispersed dolomite rhombs and crystal-molds (cavities after dolomite crystals) are characteristic of this and higher beds. Thickness 0.8 m.

14. Reddish gray fissile marl with *Zoophycos* and abundant fish remains; the rock with laminae, lentils, and other segregations of bioclasts. Some bioclasts are silicified. Boundaries with beds 13 and 15 are marked by thin laminae of compact clay. ***Microfacies:*** fine- to coarse-grained bryozoan-brachiopod floatstone and wackestone. Thickness 0.4 m.

15. Mottled marl; the rock with abundant *Zoophycos* traces is reddish gray with dark gray mottles extended parallel to bedding. Many bioclasts are silicified, and the rock is compacted and fissile in general. In the basal interval, lenses of less compact gray limestone are bounded at the top by tubercular surface with postsedimentary extension cracks produced under lithostatic pressure or in response to syneresis. These lenses likely represent the firmground. ***Microfacies:*** polybioclastic wackestone with segregations of neomorphic bioclasts and/or biomolds with sparite filling, some of which originated after molluscan shells. Thickness 0.55 m.

16. Above the basal foliated lamina of calcareous clay, the rock corresponds to banded *Zoophycos* marl of brownish gray color. Limestone in the middle is darker and hard, almost lacking bands and slightly compacted. It grades downward and upward into marl resembling a kind of bed concretion. Many bioclasts are silicified. Cavities with alveolate walls seem to be formed after sedimentary structures (maybe after gypsum nodules), which moved aside sediment by growth. ***Microfacies:*** ostracod-crinoid-brachiopod wackestone with frequent conodonts. Thickness 0.75 m.

17. Ocherous foliated calcareous clay with aggregates of bioclasts and *Zoophycos*. Brachiopods *Echinoconchella elegans* (McCoy). Thickness 0.1–0.15 m.



18. Gray clayey hard limestone with swirling bioturbation patterns and *Zoophycos*. Near the top, thin fucoids (up to 5 mm in diameter) with alteration haloes are sometimes filled in with sparry calcite. ***Microfacies:*** fine-grained bioclastic packstone-wackestone with neomorphic segregations of spiny appearance (sponge spicules?) and biomolds after molluscan shells. Between beds 18 and 19, there is a lamina of foliated clay (<0.05 m). Thickness 0.25 m.

19. Gray clayey limestone that is moderately fissile, soft, and sometimes banded owing to ferruginous coloration of *Zoophycos* traces. The rock is enriched in detritus of fish remains. The bed is split in two plates 0.25 and 0.3 m thick. ***Microfacies:*** fine-grained bioclastic wackestone reveals micritization of some echinoderm clasts and presence of scarce algae remains. Thickness 0.55 m.

20. Banded *Zoophycos* limestone that is lighter in color and harder than that of bed 19; the rock encloses lenses of coarse bioclastic material. In the middle of the bed, there are dark gray mottles. Brachiopod accumulations and solitary rugoses occur in the bed, the upper portion of which reveals presence of rare rhizocretions. Fenestrae and vugs of various scale, which could be related in origin to plant roots, are half-filled with sparry calcite. ***Microfacies:*** wackestone-floatstone composed of crinoid-brachiopod size-variable clasts and bearing abundant biomolds after thin-shelled bivalves and gastropods, and also rare Siphonophycaceae. Solitary Rugosa occur. Thickness 0.75 m.

Member 6

21. Gray limestone; in the lower portion, the rock is yellowish gray, clayey and softer, displaying the compaction fissility and bearing *Zoophycos*, abundant brachiopods, solitary rugoses, and other macrofossils. In the upper half of the bed, limestone is hard, lacking compaction signs, and yielding brachiopod and gastropod shells. Small rhizocretions (up to 2 cm in diameter) are developed below the top. Biomolds after molluscan shells are filled in with sparite that forms sometimes the shell pseudomorphs. Rhizocretions with dark femiginate haloes are lined inside with loose white or ochreous carbonate. Small (up to 5–8 cm) dissolution cavities are locally confined to rhizocretions. ***Microfacies:*** crinoid-brachiopod floatstone and wackestone with abundant conodonts and dispersed rhombohedric cavities after dolomite crystals about 50 mcm across. In the lower part of the bed, laminae of shelly and shelly-bioclastic concentrates (brachiopod rudstones) have sharp, sometimes erosional lower boundaries. These features are characteristic of sediments deposited under influence of storm roiling and redeposition. Abundant solitary Rugosa, nautiloids, gastropods, brachiopods *Composita ambigua* (J. Sowerby), *Eomarginifera lobata* (J. Sowerby). Thickness 0.55 m.

22. Dark gray clay that is foliated, smeary, and soapy grades upward into marly shale. Transitions to beds 21 and 23 are gradual. The diverse ichnocoenosis includes *Zoophycos* and/or *Teichichnus*, *Planolites*, and *Vermichnus*. Abundant brachiopods and fish detritus are confined to bedding planes. Elongated convex accumulations of bioclasts likely represent coprolites of fishes. Solitary Rugosa, fishes "*Acanthodes*" cf. *dublinensis* Stauffer. Thickness 0.1 m.

23. Gray to dark gray clayey and bituminous hard limestone with diverse trace fossils (*Planolites*, *Zoophycos*, and/or *Teichichnus*), which are easily detectable owing to selective black coloration. The upper boundary is even and distinct. ***Microfacies:*** ostracod and crinoid-brachiopod floatstone-wackestone with size variable clasts and frequent conodonts. Admixture of fine-grained quartz has been detected near the top. Gastropods *Bellerophon* sp., *Naticopsis* sp., nautiloids *Loxoceras* sp., fishes "*Acanthodes*" cf. *dublinensis* Stauffer. Thickness 0.15–0.2 m.

24. Dark gray to black soapy clay; transitions to beds 23 and 25 are gradual. Thickness 0.1 m.

25. Reddish gray limestone with *Zoophycos* and rhizocretions. Rhizocretions have dark gray dens haloes, and some of them seem to be enlarged by dissolution. Characteristic of haloes are clusters of narrow (3–4 mm and less) undulating tubular structures, which likely represent appendices of rhizocretions, being of the same generation with the latter. In mottles, there are well-preserved casts of gastropods. Near the base and top, the bed is colored lighter and slightly fissile in contrast to its massive non-compacted middle interval. ***Microfacies:*** brachiopod wackestone-floatstone with biomolds after gastropod shells. Large skeletal fragments are irregularly distributed, and many of them reveal the silification. Rare solitary Rugosa, gastropods, brachiopods *Eomarginifera lobata* (J. Sowerby), *Composita ambigua* (J. Sowerby). Thickness 0.7 m.

26. Grayish brown limestone; the bed is cherry in the upper portion, clayey, moderately silicified, very hard, and lacking porosity. Abundant brachiopod shells create the rock framework. The dominant form is *Eomarginifera lobata* (J. Sowerby). Under microscope, the rock corresponds to brachiopod floatstone-rudstone with abundant conodonts and biomolds after molluscan shells. Abundant nautiloids, brachiopods *Eomarginifera lobata* (J. Sowerby), *Antiquatonia khimenkovi* (Janishewsky). Thickness 0.35 m.

Member 7

27. Brown to dark gray mudstone with accumulations of bioclasts and brachiopod shells near the base (some brachiopods are buried *in situ*). Long crinoid columnals occur as well. Bioclasts decrease in size upward, where their accumulations are absent. Transition to bed 26 is gradual. Abundant brachiopods *Eomarginifera lobata* (J. Sowerby), *Antiquatonia khimenkovi* (Janishewsky), *Composita ambigua* (J. Sowerby), fishes *Bransonella lingulata* Ivanov and Ginter, fragment of tree trunk. Thickness 0.2–0.25 m.

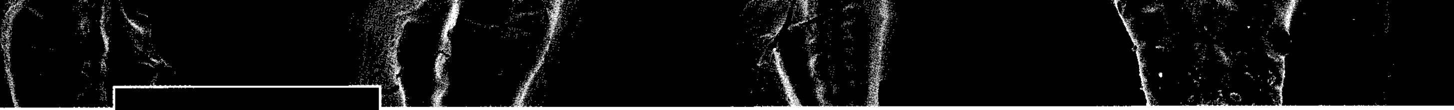
28. ("Tarusa Marble"). Dark gray and massive bituminous limestone; the rock is homogeneous and bioturbated. Small (0.2–0.3 cm in diameter) branching fucoids sometimes reveal a transverse sculpturing, but their origin is unclear. Fish detritus is concentrated closer to the base. Visible at the top is gradual transition to black foliated mudstone. *Zoophycos* seems to be a dominant ichnofossil. ***Microfacies:*** two textural types are distinguishable. The first one corresponds to medium-grained bioclastic packstone-wackestone that bears rather abundant foraminifers and spines filled in with sparite (sponge spicules?), shows presence of Kamaenidae occurring as single specimens, and has a considerably dolomitized matrix with cavities of the early generation filled in with coarse-grained sparite. The second variety is algal-brachiopod wackestone-packstone less porous and dolomitized to a lesser extent. In the last case, a considerable part of skeletal remains (more than a half) is represented by Kamaenidae. Thickness 0.2 m.

Third Bench

29. ("*Lobata* clay"). Black, very plastic and smeary fissile clay with interlayers and lenses enriched in brachiopod shells, mostly of species *E. lobata* and *Composita ambigua* (J. Sow.), and also in other macrofossils. Accumulations of graptolites (genus *Dictyonema*) are characteristic of the upper interval. At present, only the upper half of the bed is exposed. According to description of Barskov and Goreva, the bed includes discontinuous interlayers of barite and limonite nodules of a complex cavernous-septate structure, which can be found now in the talus. Thickness 2.6 m.

30–41. Black clay plastic below and getting fissile upward, especially in beds 39 and 41. Clay grades into dark gray to violet shales, which do not get soaked and are splitting into broad plates resembling cardboard shreds. Rocks of the member are rich in palygorskite. Clay and shales are intercalated with thick (up to 0.4 m) interlayers and lentils of gray dolomitic marl. Macrofossil assemblages from clay and shales are of a low diversity, consisting predominantly of one-two brachiopod species (*E. lobata* and *Antiquatonia khimenkovi* or large spiriferids of genera *Fusella* and *Unispirifer*). Abundant detritus of fish remains and graptolites of the genus *Dictyonema* are dispersed up to the bed 41, inclusive. Trace fossils in all rock types (dolomitic marl, clay, and shales) are represented by small abundant fucoids and by *Zoophycos* and *Teichichnus*. In bed 37 abundant brachiopods were found: *Schelwienella crenistria* (Phillips), *Orthotetes hindi* Thomas, *Syringothyris elongata* North, "*Spirifer*" *russiensis* Shvetsov, *Pleuropugnoides pleurodon* (Phillips), *Camarophoria crumena* (Martin), *Actinoconchus adepressorius* (Einor), *Composita ambigua* (J. Sowerby), *Dielasma* cf. *attenuatum* (Martin). Bed 39 contains brachiopods *Avonia youngiana* (Davidson), *Antiquatonia khimenkovi* (Janishewsky), *Buxtonia scabricula* (Martin), "*Spirifer*" cf. *gamma* (Semikhatova), "*Spirifer*" cf. *lujkiensis* (Semikhatova), *Composita ambigua* (J. Sowerby). Thickness 7.6 m.

42. Greenish gray palygorskite marl of fissile to flaggy structure; the rock yields abundant macrofossils, predominantly brachiopods. Fenestellid bryozoans resembling *Dictyonema* forms are frequent, but true representatives of this graptolite genus have not been found. Thickness 0.4 m.



Protvian Substage (traditional)

Member 8

43. Pinkish silicified clayey limestone with thin (3–5 mm) laminae and lenses of oncoid calcarenite; visible in thin sections are fragments and intraclasts of microlaminated (stromatolitic) cruststone. Bioturbation signs are invisible. Many clasts are transformed into peloids and rounded. Thin-walled ostracod shells, usually strongly deformed, are frequently distinguishable in oncoid cores. Thickness 0.1 m.

44. Clayey fissile limestone; the rock is strongly silicified. Thickness 0.05 m.

45. Light beige clayey limestone with cherty bands; the rock grades upward into fissile marl. ***Microfacies:*** bioclastic-oncoid mudstone and wackestone with size-variable lenses of oncoid grainstone-rudstone. As a rule, these lenses rest on the erosion surface and grade upward into wackestone; some erosion surfaces are covered by thin microlaminated films with syngenetic drying cracks. Primary interstitial porosity of grainstone-rudstone is cemented by equant sparite. The thickest (0.1–0.15 m) and extended lens of Siphonophycaceae-peloid-oncoid grainstone-rudstone is situated 0.35 m above the base. The gentle indistinct cross bedding is noticeably in the lens. The primary lamination is almost lacking signs of bioturbation, but laminae are frequently deformed and disrupted. Thickness 0.8 m.

46. Yellow ferruginized and silicified limestone; the rock is finely brecciated, corresponding to the calcareous duricrust of the Dashkovo paleosol. Rhizocretions in the duricrust represent the *fifth root horizon*. Thickness 0.3–0.5 m.

Protvian Substage (according to sequence analysis by Kabanov)

Member 9

47. Greenish brown palygorskite clay; the rock is fissile, yielding large ostracods. Thickness 0.1–0.15 m.

48. Indistinctly granular, relatively monolithic limestone with rusty stains and *Zoophycos* structures; the rock yields mollusks, brachiopods, and other macrofossils. Calcite druses related in origin with the pre-Moscovian karstification are characteristic of the upper part. Near the top, there are subvertical twisting fucoids. The topmost portion is composed of foliated clay laminae. ***Microfacies:*** fine-grained, bioclastic, intensively bioturbated packstone and wackestone. Thickness 0.55 m.

49. Slightly clayey compact limestone with *Zoophycos* and large abundant bellerofontid gastropods. ***Microfacies:*** bioclastic, predominantly brachiopod wackestone-packstone. Larger clasts (>1–2 mm) form segregations and lenses with the rudstone texture, which are depleted in micritic material and separated from each other by areas of clayey wackestone. The concentrations probably exemplfy remnants of basal graded storm concentrates, which have been disintegrated by bioturbation. Thickness 0.15 m.

50. Greenish gray clayey and hard flaggy limestone; an almost continuous chain of black chert nodules replace locally the entire bed. Thickness 0.1 m.

51. Limestone consisting of alternating monolithic and nodular interlayers. ***Microfacies:*** mudstone or ostracod-brachiopod wackestone and to floatstone in places of concentrated shells. Solitary Rugosa, brachiopods *Antiquatonia* cf. *kremenskensis* Sarycheva, *Echinoconchus punctatus* (Martin), *Syringothyris cuspidata* (Martin). Thickness 1.2 m.

Member 10

52. Yellow ferruginized plastic clay; white calcareous flour seen locally near the top is likely related in origin with development of the pre-Moscovian weathering crust. Thickness 0.3 m.

53. Greenish yellow marl and clay; these rocks of flaggy to foliated structure are silicified and locally transformed into banded chert. Gentle wavy microlamination visible in a single thin section exemplifies alternation of fine-grained peloid calcarenite and mudstone laminae up to 1–3 mm. Rosette-like inclusions of coarse-crystalline sparite are clearly visible against the background of recrystallized primary texture. Thickness 0.3–0.4 m.

54. Light yellow thick-bedded limestone; the rock indistinctly granular below grades upward into the micritic and bears chaetetids. A thin section from the lower granular portion exemplifies peloid-bioclastic bioturbated packstone-grainstone. Chaetetids, bivalves, crinoids. Thickness 1.0 m.

Middle Carboniferous Bashkirian Stage

Vysokoe Formation

55. Red and brown silty clay with limestone breccia; together with the karstified limestone of the Protvian, the rocks are attributed to the pre-Moscovian weathering profile.

Cyclic analysis

(1) The section is divided into 10 members corresponding to consecutive stages in development of the regional paleobasin (Fig. 3). The basal Member 1 (1.3 m) of karstified bioclastic wackestones and packstones is terminal one in the Venevian. The members 2 to 6 characterizing the lower 13 m thick interval of the Serpukhovian correspond to the Tarusian and to the lower half of the Steshevian. Rocks of the former are represented by gray bioturbated micrite-bioclastic limestones, which are overlain by the lower Steshevian clayey limestone and marl beds with clay intercalations. The established microfacies correspond to bioclastic wackestone, packstone, and floatstone. *Zoophycos* distinctly prevail over others in the ichnocoenosis. Rounded clasts and high energy facies are almost absent, except for infrequent intercalations of storm sediments, which appear near the base of the Steshevian. The Member 7 (8.15 m) or facies of the “Steshevo Lagoon” are represented by black plastic clay that yields an oligodominant assemblage of macrofossils. The clay grades upward into flaggy palygorskite shales with intercalations of early diagenetic marl. The upper 6-m-thick interval of the section (upper Steshevian and lower Protvian) is composed of light-colored limestones with marl and clay interlayers, which had been intensively altered at the time of the pre-Moscovian weathering episode. Member 8 (1.25 m) crowning the Steshevian is represented by oncoid-ostracod laminite with recurrent marl and limestone laminae, and by calcrete at the top. The Protvian interval (4.85 m) includes Member 9 of bioturbated sediments with *Zoophycos* (relatively deep-water mudstones, wackestones, and packstones) and Member 10 of highly weathered flaggy marls and micritic to peloid-bioclastic limestones, which seem to be of a shallower genesis.

(2) Four to five levels of shoaling and three profiles of subaerial exposition, all formerly unknown, are distinguished in the section (Kabanov, 2004). Member 3 has a hummocky upper surface that most likely represented a hardground, though it could be of subaerial origin as well. The confident shoaling levels bear rhizocretions of presumably plants and exhibit marks of minor subaerial al-

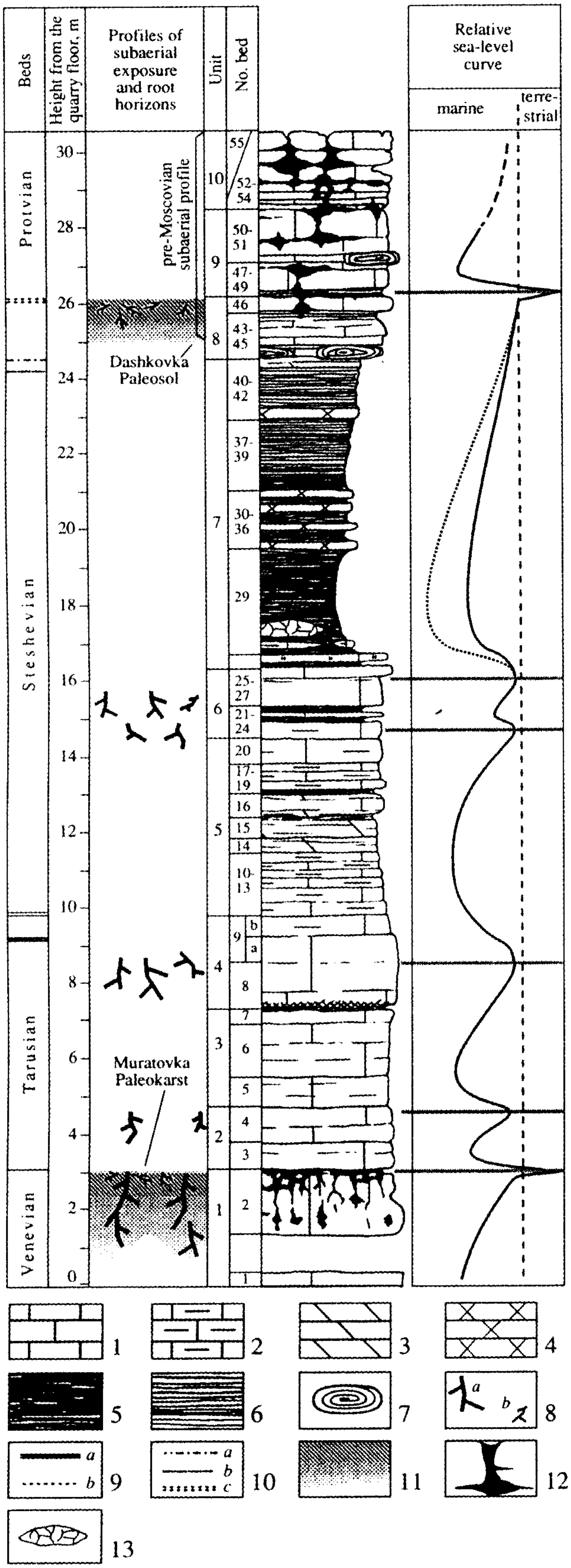


Fig. 3. The Zaborie section. Subaeral exposure profiles, rooted horizons and relative sea-level curve. 1 – limestone; 2 – clayey limestone; 3 – calcareous marl; 4 – dolomitic marl; 5 – soft shale; 6 – palygorskite shale; 7 – cherts; 8 – root traces and *Stigmaria*: a – large, b – small; 9 – Tarusian/Steshevian boundary: a – after Shvetsov, 1948 and Makhlina et al., 1993; b – after Kabanov, 2003; 10 – Steshevian/Protvian boundary: a – after Makhlina et al., 1993; b – after Barskov and Alekseev, 1979; c – after Kabanov, 2003; 11 – subaerial exposure profiles; 12 – pre-Moscovian subaerial complex; 13 – barite-limonite concretions

terations. Above the *first root horizon* corresponding to the Muratovo paleokarst, the shoaling levels in the lower third and near the top of the Tarusian and in the middle of the Steshevian are represented by the *second*, *third*, and *fourth root horizons*, respectively. Surfaces of subaerial expositions do not occur above these levels. Member 4 (2.3 m) enclosing the third root horizon is distinctive because of transition to packstone with abundant algal remains of the Kamaenidae, partially preserved microlamination, and absence of *Zoophycos*. Two other levels are lacking considerable changes in biofacies. The fourth level may correspond to a couple of closely spaced root horizons. The *fifth root horizon* includes rhizocretions of the Dashkovo paleosol. It is likely that shoaling levels can be found as well in the uppermost, highly altered limestone beds of the Protvian.

(3) Following the cyclostratigraphic principle of defining boundaries of local and regional subdivisions, it seems reasonable to place the Tarusian-Steshevian boundary at the level of maximum shoaling inside Member 4, i.e., 1.1m below that placed formerly at the base of Member 9. The Steshevian-Protvian boundary is suggested to be at the top of the Dashkovo paleosol, the level of which is 1.25 to 1.65 m higher than that of formerly accepted boundary.

(4) The earlier assumed lagoonal origin of the Steshevian clayey sequence (Osipova and Belskaya, 1965a) seems doubtful for its lower portion at least. In the alternative model suggested here, the

bituminous clay beds of the sequence are interpreted as sediments accumulated below pycnocline and wave base level in a basin with density-stratified water column.

(5) The origin of graded storm deposits persistently appearing near the Steshevian base in the Zaborie and Novogurovsky sections cannot be explained by the facies variability. In the terminal Steshevian, there are intertidal laminites with indications of storm impact. If the appearance level of storm deposits could be traceable in other sections of the study region, then, taking into account the indications of aridity growth during the Serpukhovian (Osipova and Belskaya, 1977), we may characterize the regional climatic changes as a transition from the humid wind-free climate of the Okian-Tarusian time to the subsequent period of arid climate and enhanced atmospheric circulation that resulted in development of storm events. It is also probable that paleoclimatic changes recorded in the section reflect development of the Gondwana glaciation and glacioeustatic control of sea-level fluctuations.

Biostratigraphical analysis

Foraminifers (Fig. 4). Foraminifers characterize a greater part of the Zaborie section, being missing from an upper part of the Steshevian only. Their impoverished assemblages are typical of the lower and upper thirds of that horizon as well (beds 13, 14, 19–26, and 29).

Variations in abundance and diversity of foraminifers reflect impacts of microfacies factor, sedimentation environments, and energy parameters of their habitat medium. The most diverse assemblages are confined to beds 3–6, 48, and 49 of medium-grained bioclastic wackestone and packstone, which accumulated in shallow-water calm settings, and to beds 2a, 8 and 28 of medium-grained grainstone and algal-bioclastic packstone deposited in a shallow zone with intermediate to high energy.

The assemblages are impoverished in algal boundstone (beds 8, 28) and in sediments, which accumulated in periods of highly changeable and unstable environments (beds 2b, 3a, 19–27), and when the high influx of terrigenous material (beds 10–14, 19–27) was characteristic of sedimentation settings.

The increased diversity of cosmopolitan Serpukhovian forms in bed 15, where they associate with abundant sponge spicules and juvenile ammonoids, reflects a moment, when the basin was deep and well connected with the open sea.

Irrespective of microfacies changes, there are four levels, across which taxonomic renewals in foraminiferal assemblages were most significant. These levels separate five biostratigraphic units of foraminifers: *Eostaffella tenebrosa* Zone, *Neoarchaediscus postrugosus* Beds, and three successive *Pseudoendothyra globosa*, *Eostaffellina decurta*, and *Eostaffellina* "*protvae*" zones.

Eostaffella tenebrosa Zone. Its lower boundary is undetectable. The zone yields foraminiferal species *Endothyranopsis sphaerica* (Rauser and Reitlinger), *Janischewskina typica* Mikhailov, *Bradyina rotula* Eichwald, *Howchinia bradyana* (Howchin), *Loeblichia paraammonoides* Brazhnikova, *Eostaffella tenebrosa* Vissarionova, *Neoarchaediscus* ex gr. *rugosus* (Rauser), *Asteroarchaediscus baschkiricus* (Krestovnikov and Teodorovich), and *Climacammina* sp., all typical of the uppermost Visean in the Moscow region. This unit corresponds to an upper part of the Venevian.

Neoarchaediscus postrugosus Beds. The lower boundary is established at the level, where the diversity of typical late Visean foraminifers distinctly decreases. The assemblage consists of *Endothyranopsis sphaerica* (Rauser and Reitlinger), "*Endostaffella*" *asymmetrica* Rozovskaya, *Archaediscus krestovnikovi* Rauser, *A. nanus* Rauser, and *Eostaffella tenebrosa* (?) Vissarionova, which are inherited from the Venevian and associate with newcomers *Neoarchaediscus postrugosus* (Reitlinger), *N. akchimensis* (Grozdilova and Lebedeva), and "*Millerella*" *tortula* Zeller frequent in the Tarusian of the studied section.

The unit is distinguished at the Tarusian base (bed 3 only) and demonstrates a gradual transformation of foraminiferal assemblages by transition from the Venevian to Tarusian, i.e., across the Visean-Serpukhovian boundary. However that *Pseudoendothyra globosa* Rozovskaya appearing in bed 4 may occur as well in bed 3.

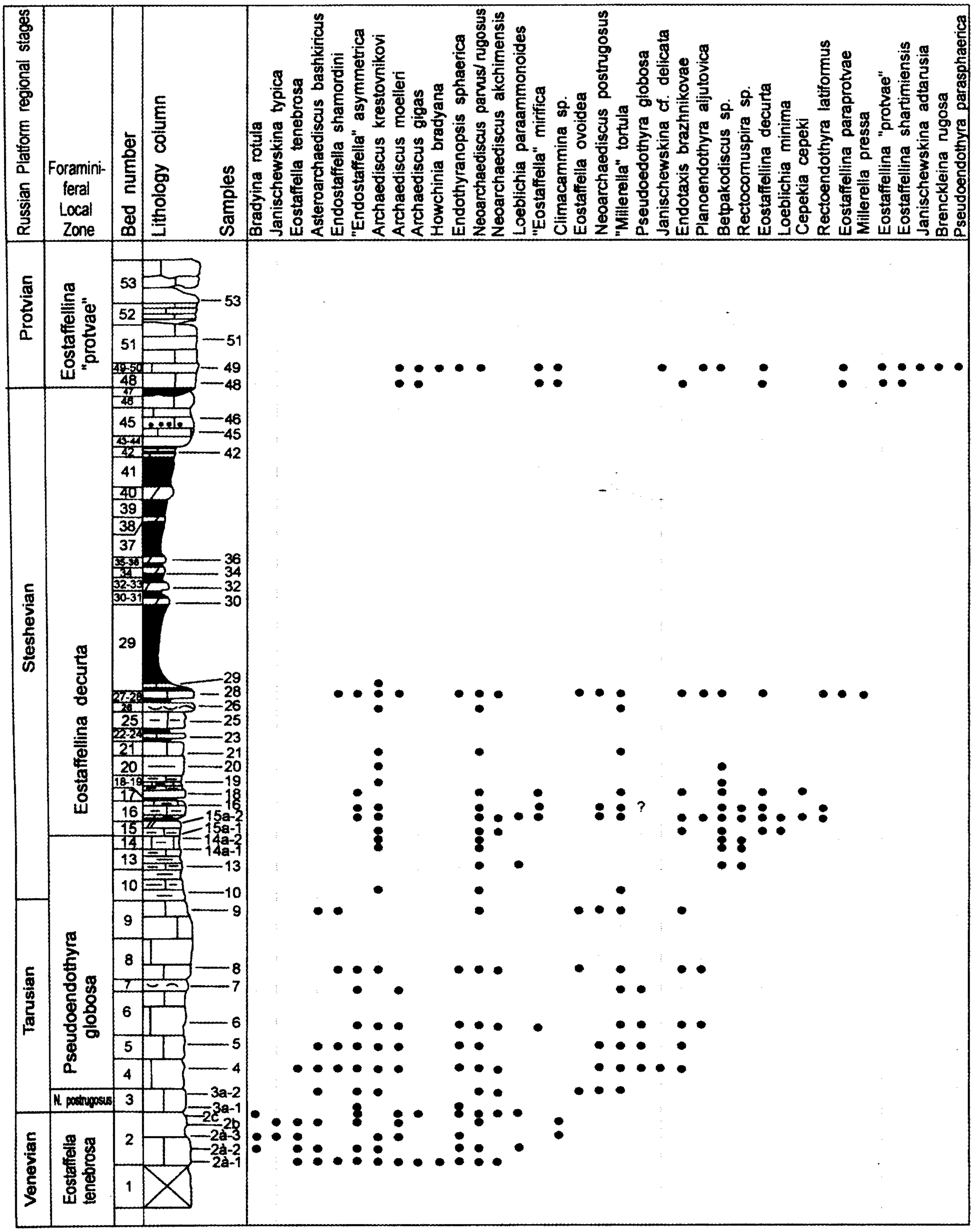


Fig. 4. Ranges of the important foraminifers in the Zaborie section

Pseudoendothyra globosa Zone. The lower unit boundary is placed at the appearance level of *Pseudoendothyra globosa* Rozovskaya in bed 4, and the upper one coincides with the first occurrence level of *Eostaffellina decurta* (Rauser) in bed 15. Three foraminifer taxa of the *Pseudoendothyra globosa* Zone, which appear at the commencement time of Serpukhovian in the *N. postrugosus* Beds, associate with newly appearing forms. In addition to index species, the latter are represented by *Planoendothyra* sp. (*P.* aff. *minima*), *Janischewskina* cf. *delicata* Malakhova, *Endothyra phrissa* (Zeller), and *Endotaxis brazhnikovae* (Bogush and Yuferev). "*Eostaffella*" *mirifica* Brazhnikova and *Planoendothyra aljutovica* (Reitlinger) appear in this assemblage slightly higher, and all taxa associate with *Betpakodiscus* sp. near the upper unit boundary. Thus, the unit reveals a successive increase in diversity of foraminifers.

The newly appearing taxa of Serpukhovian coexist in the unit with typical late Visean forms known from underlying strata. Most frequent among the latter are *Endothyranopsis sphaerica* (Rauser and Reitlinger), "*Endostaffella*" *asymmetrica* Rozovskaya, *Archaediscus* ex gr. *moelleri* Rauser, *A. krestovnikovi* Rauser, *A. nanus* Rauser, and *Neoarchaediscus* ex gr. *rugosus* (Rauser).

The assemblage is very diverse, with a gap in bed 7, up to the bed 8, where index species has not been encountered however. Above the last bed, diversity of foraminifers decreases down to four species.

The zone corresponds to the greater portion of the Tarusian (except for bed 3) and also spans the lower interval of the Steshevian (beds 4–14 of the latter). Thus, both boundaries of the unit do not coincide with the accepted delimitation levels of the indicated horizons.

Eostaffellina decurta Zone. The lower unit boundary marks the appearance level of its index species. First tests of the latter have been detected at the base of bed 15 (Sample 15a-l). The foraminiferal assemblage characteristic of the zone includes many forms present in the underlying unit. Taxa appearing here in addition to index species are *Rectoendothyra latiformis* Brazhnikova, *Loeblichia minima* Brazhnikova, and *Cepekia cepeki* Vašiček and Ružička. Foraminifers are most diverse near the zone base. Their diversity significantly decreases in the middle portion, and the upper interval (bed 28) demonstrates again the diversity increase. First appearance of *Eostaffellina paraprotvae* (Rauser) and *Millerella pressa* Thompson is recorded in the last interval that also demonstrates the recurrent occurrence of many taxa typical of the Serpukhovian and upper Visean, e.g., *Endothyranopsis sphaerica* (Rauser and Reitlinger), *Endothyranopsis crassa* (Brady), and many archaediscids.

The peculiar composition of the assemblage was controlled by unstable sedimentation environments and persistent changes in their habitat medium. The index species has not been encountered in beds 19–26 and 29–46.

The described zone corresponds to the greater part of the Steshevian (beds 15–47). Its upper boundary cannot be defined with a proper confidence, because foraminifers are either scarce in, or missing from beds 30–47 constituting the upper portion of the Steshevian.

Eostaffellina "protvae " Zone. The lower boundary of the unit, is the first occurrence level of index species in bed 48.1. The zonal assemblage of high taxonomic diversity is considerably renewed, incorporating seven new foraminiferal taxa in addition to index species. Its characteristic late Serpukhovian forms are *Eostaffellina shartimiensis* (Malakhova), *E. subsphaerica* (Ganelina), *Brenckleina rugosa* (Brazhnikova), *Deckerella* sp., *Pseudoendothyra parasphaerica* Reitlinger, *Eostaffella umbilicata* Kireeva, new species *Janischewskina adtarusia (Gibshman, Baranova, 2007)*, and *Eostaffellina paraprotvae* (Rauser) that appears first below in bed 28. Rare specimens of *Eostaffellina decurta* (Rauser) still occur at this level.

Taxa typical of the Upper Visean and once again appearing in the unit are *Endothyranopsis* ex gr. *crassa* (Brady), *E. sphaerica* (Rauser and Reitlinger), *E. intermedia* (Rauser), *Howchinia bradyana* (Howchin), and "*Eostaffella*" *parastruvei* Rauser. Representatives of the genus *Eostaffella* are abundant (*E. ovoidea* Rauser). Tests of *Archaediscus moelleri* Rauser prevail among archaediscids. Another characteristic form is *Climacammina* sp., but "*Millerella*" *tortula* Zeller, *Neoarchaediscus postrugosus* (Reitlinger), and *N. akchimensis* (Grozdilova and Lebedeva) have not been encountered. *N.* ex gr. *rugosus* (Rauser) and *Betpakodiscus* occur as single specimens.

The zone corresponds to the Protvian. Its assemblage looks rather mature and demonstrates the diversity increase of the genus *Eostaffellina* from bed 48 to bed 49. Similar assemblages are known from other sections of the Moscow syneclise (Fomina, 1977). Species *Brenckleina rugosa* (Brazhnikova) appearing in bed 49 and unknown in the Donets basin below the upper portion of the Protvian is typical of

the Zapaltyubian (Aizenverg et al., 1983). Besides the Donets basin, *Brenckleina rugosa* is known from the uppermost Chesterian of the North America and occurs in sections of southern Illinois from the base of the Menard Limestone up to the boundary with the Grove Church Shale (Brenckle, 1990).

Conodonts (Fig. 5; Plates 1–3). Conodonts are abundant in the Zaborie section and it was sampled by I.S. Barskov and N.V. Goreva very densely (every 0.2–0.3 m, more 90 samples in total). The conodont collection counted more 6000 elements. Conodonts are scarce in the lowermost (Venevian) beds, abundant in the lower Steshevian, relatively rare in the upper Steshevian shales and only few levels were productive in the Protvian interval.

The most common elements belong to *Synclydognathus* and *Kladognathus*. The latter dominate under *Synclydognathus* from the bed 15 upward. The relativley deep-water *Gnathodus bilineatus* (Roundy) occurs in the uppermost Venevian (bed 2, sample 26) and lower Tarusian (beds 3–6), lowermost (beds 10–14) and upper lower (bed 25) Steshevian, and lower Protvian (beds 48 and 49). The background taxon is *Gnathodus girtyi* Group which occurs throughout the section. Species of the genus *Lochriea* are not very common, occur sporadically and represented mainly by juvenile forms. The shallow-water *Cavusgnathus* and *Mestognathus* present at several levels: middle part of the bed 8, beds 15–24 and especially abundant in the bed 42. In the Protvian bed 51 (sample 51a) only *Kladognathus* and *Windsorgnathus windsorensis* Globensky occur that is typical for high salinity facies. Another interesting element is *Vogelgnathus*. The lower Steshevian (beds 11–25) contains *V. campbelli* (Rexroad) in the most of samples, but only in few specimens. The younger species *V. postcampbelli* (Austin and Husri) was found only in the topmost Steshevian bed 42.

The first appearance of *Lochriea ziegleri* (Nemirovskaya et al.) occurs in the bed 3, i.e in the accepted base of the Tarusian. It was found also in the bed 5, few specimens in lower Steshevian and Protvian. *Lochriea cruciformis* is more common (beds 5, 6, 16–28, 48). So, first appearance of *Lochriea ziegleri* (Nemirovskaya et al.) in the Zaborie section is close to that in the Novogurovsky and Lanshino. We cannot exclude that even some part of the higher Tarusian in the Zaborie could be Venevian also because lower Steshevian clayey limestones (beds 10–20 or up to bed 25) are correlatives of the Tarusian interval in the Novogurovsky section.

Acknowledgments

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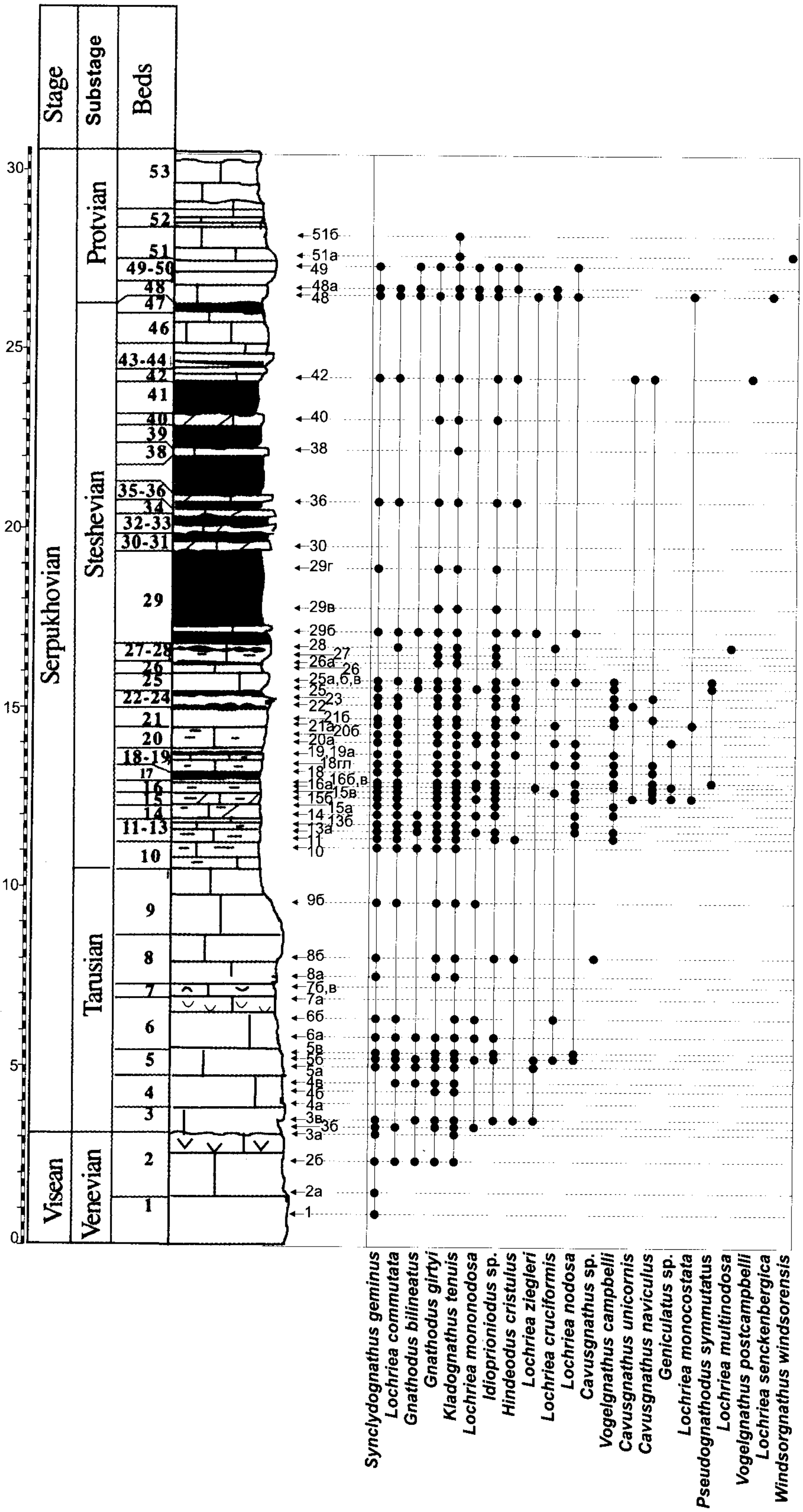

Fig. 5. Ranges of conodonts in the Zaborie section

Plate 1

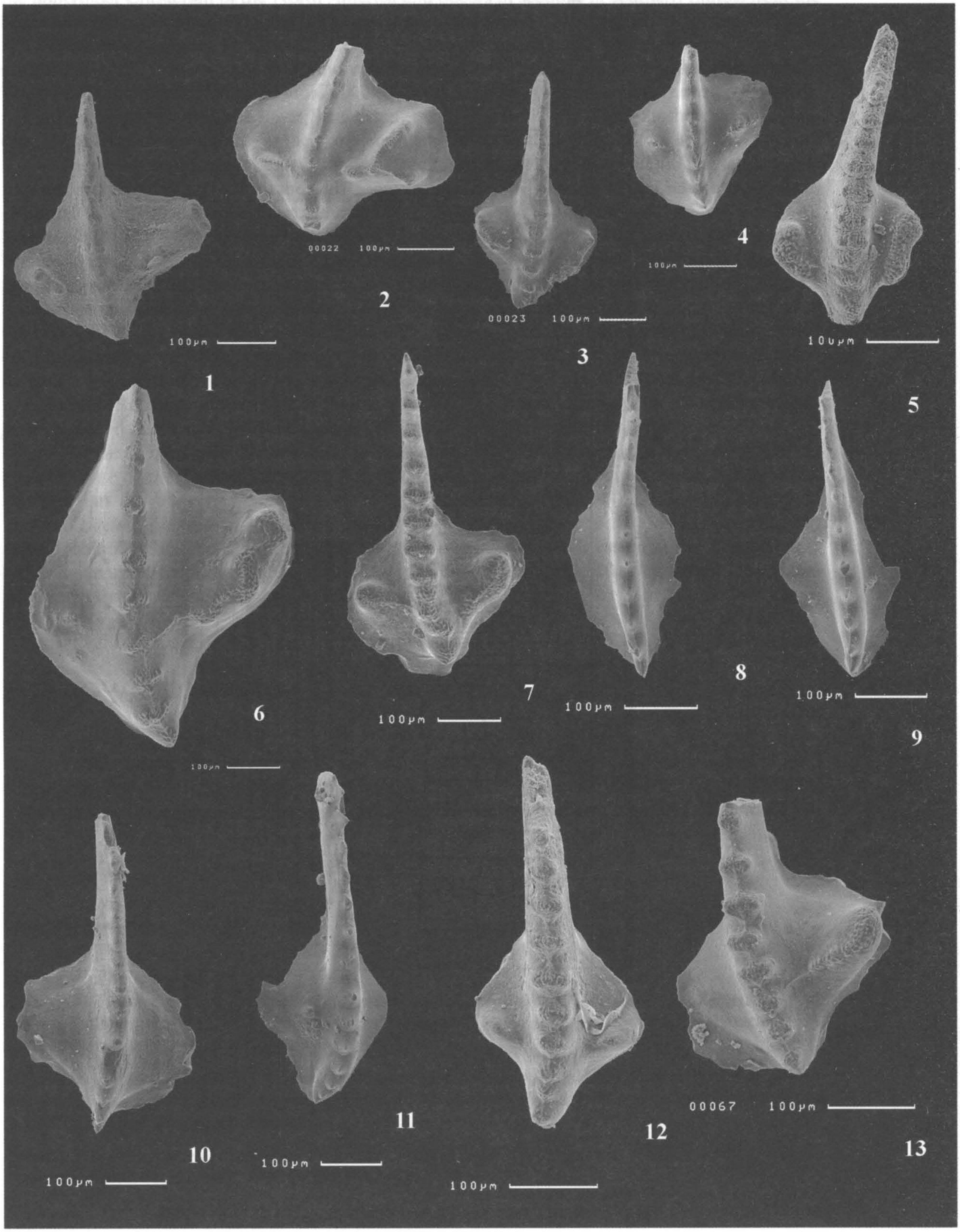
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Plate 1. Conodonts from the Zaborie section, genus *Lochriea*. Collection is stored in Department of Paleontology, Geological Faculty, Moscow State University. Figs. 1, 2. *Lochreia ziegleri* Nenirovskaya, Perret and Meischner: 1 – sample 5A; 2 – sample 5B; Tarusian. Figs. 3–5, 12. *Lochreia nodosa* (Bischoff): 3 – sample 5B; Tarusian; 4 – sample 13A; Steshevian; 5 – sample 48; 12 – sample 48; Protvian. Figs. 6, 7. *Lochreia cruciformis* (Clarke): 6 – sample 5B; Tarusian; 7 – sample 48; Protvian. Figs. 8–10. *Lochreia commutata* (Branson and Mehl): 8, 9 – sample 13A; Steshevian; 10 – sample 48; Protvian. Figs. 11. *Lochreia mononodosa* Rhodes, Austin and Druce, sample 16A; Steshevian. Figs. 13. *Lochreia monocostata* Pazukhin, sample 48; Protvian

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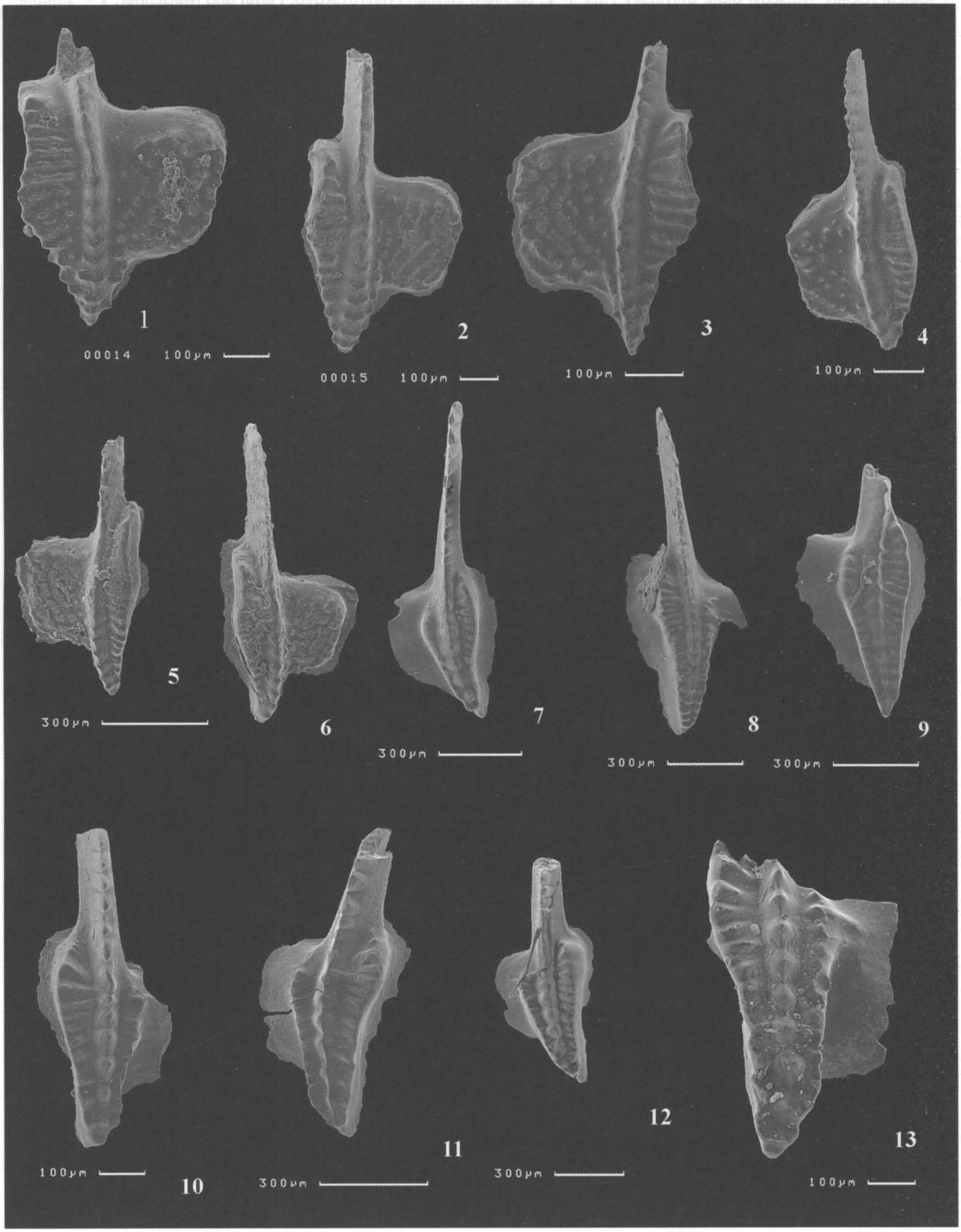
Plate 2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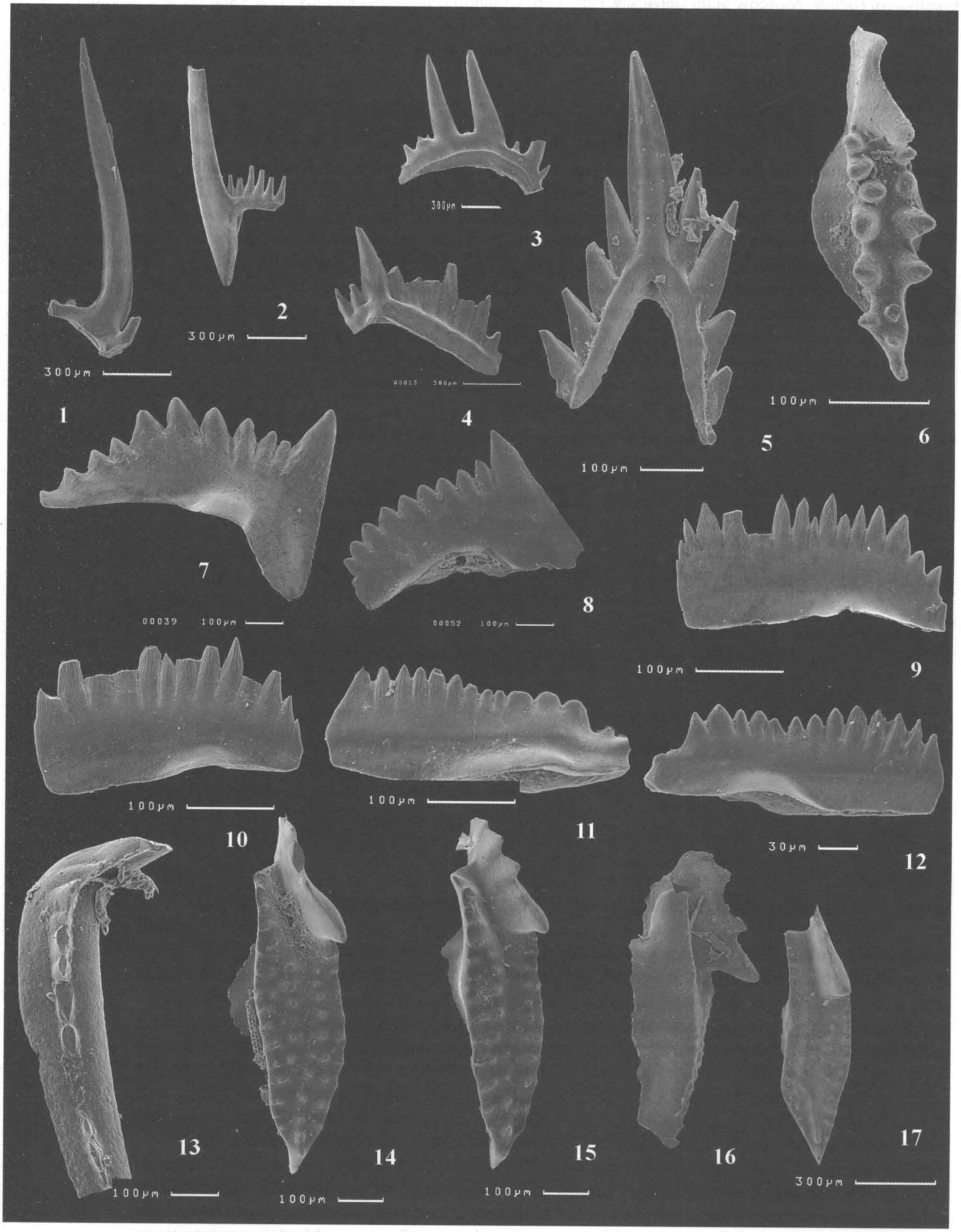
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Plate 2. Conodonts from the Zaborie section, genus *Gnathodus*. Collection is stored in Department of Paleontology, Geological Faculty, Moscow State University. Figs. 1–6. *Gnathodus bilineatus* Roundy: 1, 2 – sample 5A; Tarusian; 3, 4 – sample 13A; Steshevian; 5, 6 – sample 48; Protvian. Figs. 7–12. *Gnathodus girtyi* Hass: 7–9 – sample 36; Steshevian; 10 – sample 5B; Tarusian; 11, 12 – sample 13A; Steshevian. Fig. 14. *Gnathodus intermedius* Globensky, sample 48; Protvian

Plate 3. Conodonts from the Zaborie section, genera *Kladognathus, Idiopriniodus, Synclydognathus, Hindeodus, Windsorgnathus, Vogelgnathus, Geniculatus, Cavusgnathus*, and *Mestognathus*. Collection is stored in Department of Paleontology, Geological Faculty, Moscow State University. Figs. 1–3. *Kladognathus tenius* (Branson and Mehl): 1 – S element, 2 – M element, all from the sample 36; upper Steshevian; 3 – Pa-Pb element, sample 16A; lower Steshevian. Fig. 4. *Idioprioniodus* sp., sample 36; upper Steshevian. Figs. 5, 7 – *Synclydognathus geminus* (Hinde): 5 – S element, sample 5A; Tarusian; 6 – Pa element, sample 16A; Steshevian. Fig. 6. *Windsorgnathus windsorensis* Globensky, sample 51A; Protvian. Fig. 8. *Hindeodus cristulus* Youngquist and Miller, sample 42. Figs. 9, 10. *Vogelgnathus campbelli* (Rexroad), sample 16A; lower Steshevian. Figs. 11, 12. *Vogelgnathus post campbelli* Austin and Husri, sample 42; upper Steshevian. Fig. 13. *Geniculatus* sp., sample 16A; lower Steshevian. Figs. 14, 15. *Cavusgnathus naviculus* (Hinde), sample 16B; lower Steshevian. Fig. 16. *Cavusgnathus unicornis* Youngquist and Miller, sample 42; upper Steshevian. Fig. 17. *Mestognathus bipluti* Higgins: sample 42; upper Steshevian

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DOMODEDOVO SECTION NEOSTRATOTYPE OF MOSCOVIAN STAGE AND MYACHKOVIAN SUBSTAGE

N.V. Goreva[1], T.N. Isakova[1], A.S. Alekseev[2], P.B. Kabanov[3], O.L. Kossovaya[4]

[1]Geological Institute of Russian Academy of Sciences,
110017 Moscow, Pyzhevsky per. 7, Russia

[2]Moscow State University, Geological Faculty, Department of Paleontology,
119991 Moscow, Leninskie Gory, Russia. E-mail: aaleks@geol.msu.ru

[3]Tyumen Oil Scientific Center, TNK-BP,
Tyumen, Russia

[4]Karpinsky Russian Geological Research Institute,
199106 Sankt-Petersburg, Sredny pr. 74, Russia

The Moscovian Stage, upper stage in the Russian middle series of the Carboniferous System has long history.

The "Moskowishes Terrain" has been firstly defined as a stratigraphic unit in rank of system by famous Russian mineralogists and chemist Rudolph Hermann in 1832, but besides the genuine Carboniferous strata he included in it much younger (Jurassic) deposits. Helmersen in 1841 proposed threefold subdivision of the Carboniferous in the Moscow Basin. The uppermost unit was named as "Upper Stage of the Mountain Limestone with *Spirifer mosquensis*". Rouillier and Murchison in 1845 used term "Moscow Limestone with *Spirifer mosquensis*", but only Nikitin (1890) gave to this interval formal name "Moscovian Stage". Up to 1926 the Moscovian Stage embraces also the modern Kasimovian Stage.

The historical stratotype of the Moscovian Stage destroyed. Large quarries mined white limestone from the XV century to the mid-1970th in vicinity of the Myachkovo Village on the right and left banks of the Moskva River southeast of the Moscow not exist now. It is reason why the Domodedovo quarry succession that easy is correlated bed by bed with Myachkovo one is considered as neostratotype of the Moscovian Stage and its uppermost Myachkovian Substage now.

Historical review

The Domodedovo quarry is relatively new excavation operating from the beginning of the XX century. More or less complete descriptions with lists of fusulinids and smaller foraminifers belong to Rauser-Chernousova and Reitlinger (1954), Shick and Ilkhovsky (1975), and Makhlina et al. (2001a). Fusulinids, conodonts, corals, bryozoans, ammonoids, brachiopods, and fish remains from this section were illustrated and partly described recently (Makhlina et al., 2001b). Recently Lazarev (2007, 2008) described two new brachiopod species which occur in Domodedovo section. Study of fusulinids distribution in the boundary interval between Moscovian and Kasimovian (Davydov 1997) and correlation with the succession of the Las Llacerias section of the Cantabrian Mountains in the Spain (Villa et al., 1997) were important steps in the progress of the Carboniferous stratigraphy. Quantitative paleoecological analysis of the fusulinid assemblages from the Domodedovo section by Baranova is available in the unpublished PhD thesis (2008). Cyclicity and paleosol horizons were studied by Baranova and Kabanov (2003), Kabanov (2003, 2005), Kabanov and Baranova (2007).

The quarry was demonstrated to participants of the 8th International Congress on Carboniferous Stratigraphy and Geology under the name “Gorki Leninskie” (Yablokov, 1975) and as “Domodedovo section” during the field trip “Carboniferous deposits of the Moscow Syneclise” of the 27th International Geological Congress (Makhlina, Shick, 1984).

Section description

Right slope of the Pakhra River valley in the northern vicinity of Domodedovo Town, 15 km the south of the Moscow. Quarry belongs to the company “Domodedovo Plant of Building Materials and Constructions”.

The quarry occupied almost destroyed by mining the Rybushkin Ravine. The geographical coordinates 55°28' N, 37°47.5' E. (Fig. 1). The Myachkovian Substage of the Moscovian Stage and basal Kasimovian strata in its traditional meaning are exposed in the quarry. The type area of the Moscovian Stage is located in the vicinity of the Myachkovo Village at the confluence of the Pakhra and Moskva rivers, in 15 km to the west-northwestward of the Domodedovo quarry. Presently it is only available complete Myachkovian outcrop close to the Moscow. Limestone that is mined in the quarry is used for lime production and restoration of old buildings in the Moscow City.

The number of quarry benches decreases towards the Pakhra River from four to two in concordance with lowering of quarry wall and thickening of the Jurassic and Quaternary overburden deposits (Fig. 2). The most complete south-western sector of the quarry is 100 m width and contains Kasimovian basal beds. This part has been acquired as a local nature reserve.

The description given below is based on the studies conducted by M.Kh. Makhlina, A.S. Alekseev and N.V. Goreva, I.S. Barskov and P.B. Kabanov. We used numeration of the beds proposed by Kabanov. The Domodedovo section includes the complete Myachkovian (Korobcheevo, Domodedovo, and Peski formations) and Suvorovo Formation of the Krevyakinian (lowermost Kasimovian). In 1970th above Suvorovo also lower part of the Voskresensk Formation was opened, but later these highest strata were destroyed by quarry activity. The Suvorovo Formation is preserved only in an erosional remnant less than 100 m width.

In the Domodedovo quarry the Carboniferous beds are overlain by the Upper Oxfordian black clays with rare ammonites and radiolarians (Ermolinskoe Formation) or Pleistocene sands.

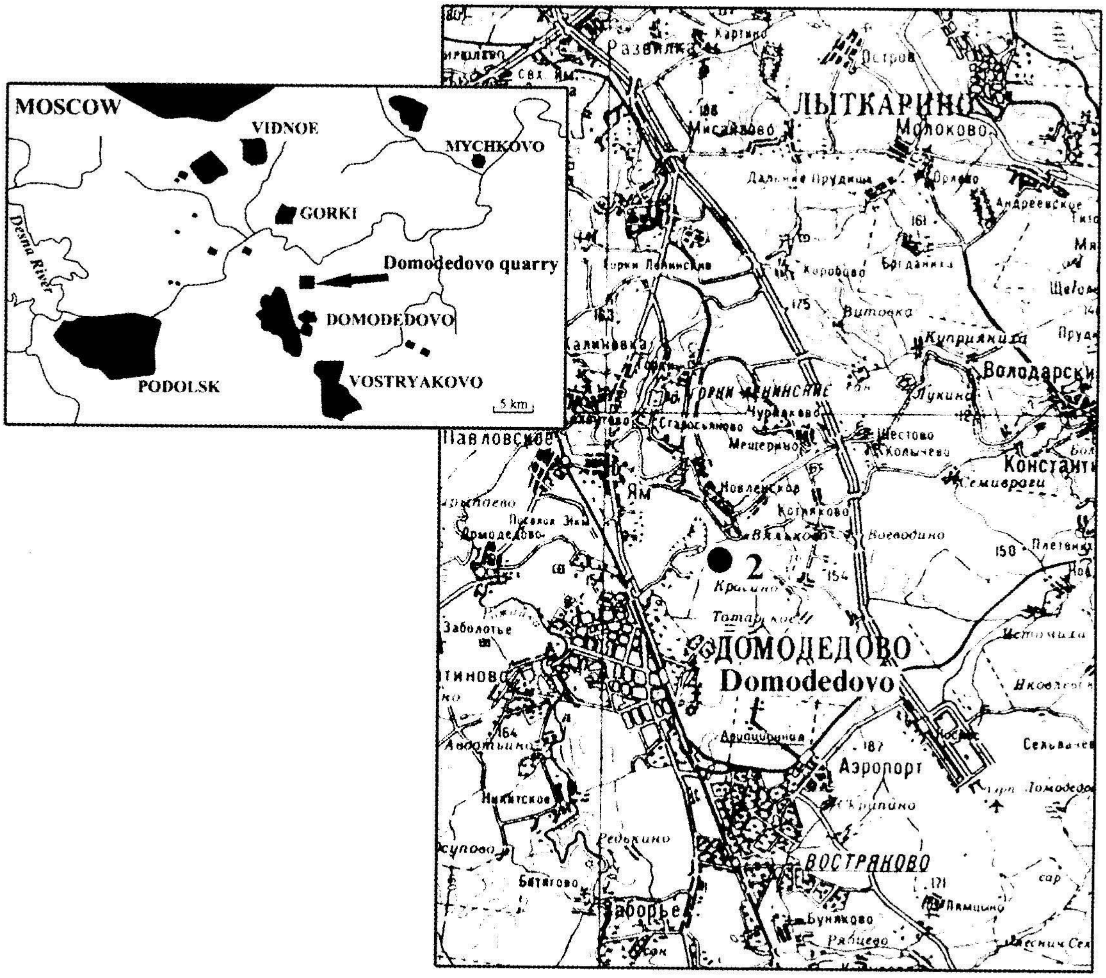


Fig. 1. Location of the Domodedovo section

Fig. 2. General view on the Domodedovo Quarry

Moscovian Stage

Podolskian Substage

Stshurovo Formation

First bench

1. Limestone, white, massive, wackestone-packestone, in most of sites transfer into dolomite green-gray with voids from crinoids, brachiopods and with silicified brachiopod *Choristites* and *Zoophycos*. Thickness 0.2 m.

2. Limestone, yellow and gray, spotted, grainstone, coarse-grained, with *Zoophycos*. Thickness 0.15 m.

3. Dolomite, light-green, clayey, cavernous, with wackestone relics. Thickness 0.6 m.

Myachkovian Substage

Korobcheevo Formation

Lower Member

4. Clay, brown, carbonate, with brachiopod and crinoids bioclasts. Thickness 0.15 m.

5. Limestone, white and light gray, coarse-grained (grainstone) with *Choristites*, fusulinids and black silicified echinoid spines. Along the cliff it changes into dolomite. Thickness 2.3 m.

6. Dolomite, yellow-gray, clayey, spotted, with abundant small cavities of leaching. Thickness 0.6–0.8 m.

Second bench

7. Limestone, yellow-green, intensively clayey, dolomitized, wackestone, with *Zoophycos*. Thickness 0.15 m.

8. Limestone, white in thick layers. The boundaries between layers are marked by the streaks of dissolution or calcareous clay. In the lower part of the bed (up to 1 m) the coarse bioclastic limestone (packstone-grainstone) contains common colonial rugose corals, chaetetids, and brachiopods. Above limestone (0.4–0.5 m) bioclastic, alternation of rudstone, grainstone and packstone, with diverse coral assemblage and Chaetetidae. The siliceous nodules of the different sizes from small to loaf-like (up to 3 m length) are distributed in the bed. Sometimes coral colonies are overturned and broken (0.4–0.6 m). Rugose corals: *Petalaxis* (*P.*) *stylaxis* (Trautschold), *Cystophorastraea molli* (Fischer), *Ivanovia* (*Ivanovia*) *freieslebeni* (Fischer), *Ivanovia* (*I.*) sp. 1. The next layer is limestone bioclastic with small bioclasts, dolomitized, limonitized (0.25–0.4 m). Rugose corals and chaetetids are abundant, among them solitary *Bothrophyllum* aff. *trautscholdi* Stuckenberg was found. Thin layer (0.2–0.3 m) of coarse-grained packstone-grainstone separated below and above by the stylolites do not contains corals. The last layer is limestone massive, thin- and medium-grained wackestone-packstone (thickness 0.5–0.65 m) with abundant micropores. The corals are very rare *Bothrophyllum conicum conicum* (Fischer). The top of the bed is rough irregular with sub-vertical channels of dissolution. The stylolites are developed along the boundary between beds 8 and 9. The total thickness of the bed 8 2.5–2.6 m.

Upper Member

9. Limestone, white and yellow-white, massive in four thick layers: (1) crinoid-foraminiferal limestone, grainstone-rudstone, with silicification of the detritus and bioclasts (0.15–0.2 m); (2) limestone, bioclastic, fine-grained, coarse-grained at the base, packstone, with brachiopod shells *Choristites* and streaks of dissolution (0.7 m). The layer of foliated clay (up to 1 cm) subdivides this layer from overlaying one; (3) limestone, massive, thin-grained with earthy fracture and detritus, wackestone (0.3 m). There are streaks of dissolution covered by the film of the green clay at the top; (4) limestone white massive, polybioclastic, wackestone at the base, packstone-grainstone in the upper part (0.7 m). The total thickness of the bed 1.9 m.

10. Limestone, white and yellow, massive, fine-grained grainstone, well sorted, porous. Thickness 0.2–0.3 m.

11. Limestone, yellow (ferruginous), brecciated, coarse, medium and fine-grained, with small foraminifers and micro-grained cement. Bed contains abundant moulds of gastropods, bivalves, nautiloid cephalopods. Also brachiopods, chaetetids, solitary Rugosa are common. The rock is micritic and weakly silicified. Thickness 0.15–0.2 m.

Beds 10 and 11 are cut by two generations of vertical channels of dissolution. The first generation represents by the subvertical large canals with brown coating on the walls, diameter up to 5 cm. Second one – subvertical channels (burrows?) with constant diameter about 3 mm, obviously of biogenic origin.

12. Limestone, light gray, wackestone-packstone, small foraminiferal with silicieous nodules in the upper part of the bed. Thickness 0.8 m.

13. Limestone, light gray, ochreous, medium- and fine-grained, grainstone, partly cross-bedded. The limestone algae-bioclastic badly sorted and contains large pebbles of the micritized limestone. The bed is penetrated by sub-vertical channels with length 10–15 cm and diameter up to 1 cm. The stylotites are observed. The top of the bed is flaggy. Thickness 0.4 m.

Third bench

Domodedovo Formation

Lower Member

14. Dolomite, brown and yellow, thin-grained. At the base of the bed there is ferruginous rottenstone with quartz geodes and dolomitized limestone with stylolites. The rest part of the bed is represented by light-yellow cavernous dolomite. The dolomite bears thin lamination (thickness of the beds up to 5 mm). Thickness 1.0–1.1 m.

15. Dolomite, light yellow. It is weakly bedded and cavernous in the lower part and massive in the upper part (0.4 m). This dolomite is a marker bed of the lower part of the third bench of the quarry. Thickness 0.6 m.

16. Dolomite (strongly dolomitized limestone), light-brown, cavernous with relics of the variable unrounded bioclasts. In 15 cm above the layer base the small (up to 6 cm) chert nodules which bear the numerous bioclasts relics. Thickness 0.65 m.

17. Limestone dolomitized, yellow, bioclastic, grainstone, vaguely, cross-bedded with the lenses of the fine-grained one. Limestone contains Chaetetidae and fragments of the colonial corals. Thickness 0.5–0.6 m.

18. Limestone dolomitized, white, fine- and middle-grained, porous. Limestone is penetrated by numerous subvertical canals of dissolution. In the lower part the large chaetetid skeleton up to 0.5 m in diameter found. Thickness 0.35 m.

19. Clay, calcareous, yellow-green, with corroded bioclasts, sometimes with thin (1–2 cm) limestone lenses. This clay contains abundant large and thick tablets and flakes of black biotite and transparent possible sanidine crystals. It could be the altered volcanic tuff. The biotite and sanidine (?) occur also in material of the top bed 18 and the base of the bed 20. Thickness 0.05–0.1 m.

20. Limestone, yellow-white, dolomitized in some spots, middle- and coarse-grained, fine-grained at the base, packstone-wackestone, at the some levels the rock become calcarenite. It is possible, that this bed is pseudobreccia. The flattened Chatetidae skeletons occur in the upper part of the bed. Thickness 1.15 m.

Upper Member

21. Limestone, yellow-white, middle- and coarse-grained grainstone with silicified crinoids, gastropods and brachiopods fragments. The dome-shaped Chaetetidae skeleton was found. Thickness 0.3 m.

22. Dolomite massive, light yellow. This bed is often wedge out laterally. Thickness 0.2 m.

23. Clay calcareous, yellow-green, thin-bedded (flaglike) with corroded crinoidal columnals and echinoderm spines. Thickness 0.05 m.

24. Limestone, white, soft, bioclastic microporous, packstone with peloids, brecciated with *Zoophycos* burrows in the top. Thickness 0.5 m.

25. Limestone, light-gray, coarse-grained and fine-grained, grainstone with brachipods, bryozoans and algae, in the upper part with numerous streaks of dissolution and *Zoophycos* burrows. Thickness 0.2 m.

26. Clay calcareous, flaglike with well preserved bioclasts. Among bioclasts there is a whole cup of crinoid (0.05 m). It is overlayed by limestone clayey, crinoidal and smaller foraminiferal with brachiopod fragments, rudstone-grainstone ("Gorokh"). The layers are divided by foliate clay and penetrated by dissolution streaks. Thickness 0.2 m.

27. Limestone, white, muddy, micro-grained in the base, brecciated. The stylolites occur in the top. *Zoophycos* burrows and bryozoans are common. There are relics of erosion surfaces which are covered by coarse detritus. Nautiloids *Mosquoceras shimanskyi* Kabanov were found. Thickness 0.7 m.

28. Limestone, brown-gray, is represented by the set layers of intercalation of micro-grained, fine-grained and middle-grained lithologies, mudstone at the bottom and packstone in the top. Limestone partly stylolitized, irregularly silicified. The crinoids and fish remains occur. Thickness 0.4 m.

29. Clay spotty, red and brown, with angular fragments of limestone, often completely dissolved with origin of black shadows. The clay sometimes contains numerous extracted from the limestone bioclasts. It is paleosol topclay. Above the uplifts of the bed 28 top, clay is not preserved. Thickness 0–0.25 m.

Fourth bench (Fig. 3)

Peski Formation

Lower Member

30. Dolomite, yellow, thin-grained, clayey, in lenses, and represent the dolomitized material of the bed 31. Thickness 0.0–0.7 m.

31. Limestone conglomerate, so called "Fish Bed" laterally turned into bioclastic marl. Conglomerate consists of marl-cemented calcareous sand, gravel and pebbles (up to 10 cm in diameter) of stromatolitic fine- and thin-grained limestone reworked from underlying beds. Some pebbles reach up to 20 cm in diameter, but they are flattened. In the upper part the amount of pebble decrease and conodonts and fish remains mostly represented by sharks appear: *Symmorium occidentalis* (Leidy), *Stetacanthus* cf. *S. proclivus* St. John and Worthen, *S. fulliri* St. John and Worhten, *Polyrhizodus concavus* Trautschold, *Cochliodus triangularis* Trautschold, *Deltodus concha* (Trautschold), *D. circlinans* Trautschold, *D. laminaris* (Trautschold), *Solenodus crenulatus* Trautschold, *Pranunodus specularis* Trautschold, *Lagarodus angustus* (Romanovsky). Thickness 0.25–0.4 m.

32. Limestone, white, massive, poly-bioclastic, wackestone with common fusulinids. The grains of gravel size occur rare at the base. The bed is laminated by the thin interlayers of gray clay into separate layers. Rare *Choristites* and conodonts occurs. Thickness 1.1–1.4 m.

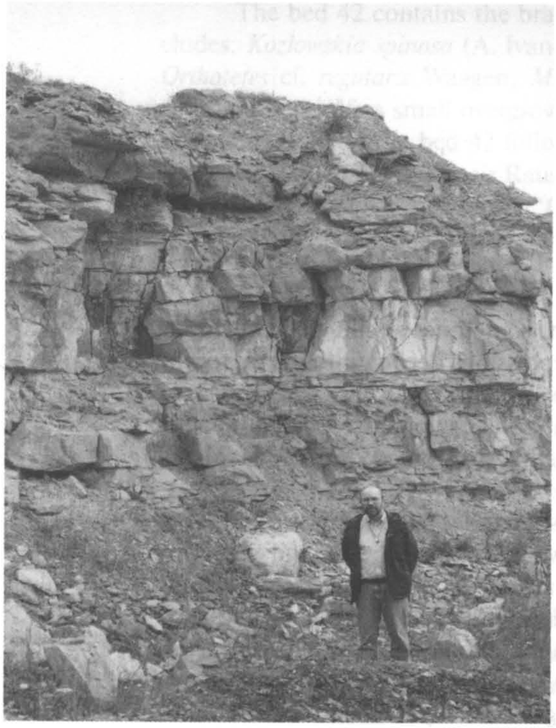


Fig. 3. Peski Formation in the Domodedovo section

33. Limestone, white, crinoid-foraminiferal, strongly porous. Limestone includes rounded more compacted intraclasts which reaches in diameter 5–6 cm. The multidirectional lamination is visible in the upper part of the bed. In the Turaevo quarry (Myachkovo) in the top of the bed the sublatitudinally oriented mega-ripple was observed. The width of waves up to 0.25 m, the height is 0.15 m and the distance between the waves is 1–1.5 m. In the Domodedovo quarry the top of the bed is also irregular, wavy, with the amplitudes of waves up to 5 cm. Limestone contains rounded and scattered brachiopod valves *Orthotetes plana* A. Ivanov, solitary rugose corals *Bothrophyllum conicum moribundum* Kossovaya, moulds of dentaliids, Nautiloidea, and hollows from dissolved gastropods (mainly *Bellerophon*). Fusulinids: *Fusulina mosquensis* Rauser and Safonova, *F. quasicylindrica* Lee and Chen, *F. mjachkovensis* Rauser, *F. pakhrensis* Rauser, *F. fortissima* Rauser, *F. cylindrica cylindrica* Fischer, *F. cylindrica domodedovi* Rauser, and others. Thickness 0.4–0.6 m.

Middle Member

34. Marl, light-green, thin-bedded, includes thin (up to 5 cm) lenticular layers of the clayey limestone. Sometimes laterally this marl is substituded by clayey dolomite. Limestone contains conodonts. Thickness 0.2–0.3 m.

35. Limestone, white, bioclastic, thick-laminated. Sometimes thin interlayers of green clay occur between some limestone ledges. The crinoid-fusulinid limestone deposited at the top is eroded rather often along the strike. Fusulinids: *Fusulina cylindrica cylindrica* Fischer, *F. quasicylindrica* (Lee), *F. quasifusulinoides* Putrja, *F. fortissima* Rauser, *Fusulinella bocki* Möller, *F. pseudobocki ovoides* Lee and Chen, *F. rara* Shlykova, *Protriticites* sp., *Praeobsoletes* (?) *burkemensis* (Volozhanina), *P.* (?) *tethydis* (Igo). Conodonts occur rather rare. Thickness 3.1 m.

Upper Member

36. Limestone clayey or marl. green-gray, lenticular bedded, clotted with variably directed cross-lamination with brachiopods, conodonts and osctracods. Small pebbles of bioclastic limestone occur in the middle part. Brachiopods: *Choristites* and *Linispinus* cf. *tyazhinensis* Lazarev. Thickness 0.3 m.

37. Limestone breccia, marl-cemented, green-gray, situated in the lower part (0.4–0.5 m) consists of acute-angle fragments of thin-grained limestone. In the upper part (0.2 m) limestone gray, pellet-foraminiferal ("Gorokh") with conodonts and fragments of *Linispinus* cf. *tyazhinensis* Lazarev brachiopod shells. The top of the bed is penetrated by trace fossils and irregular. Thickness 0.7 m.

Kasimovian Stage
Krevyakinian Substage

Suvorovo Formation

Lower Member

38. Clay, spotted, greenish gray to red in the lower part, sometimes swelling and declining laterally. Maximal increase of thickness reach 20 cm. In the depressions deepen into the top of the underlying bed 37 the weakly rounded limestone pebbles (up to 10 cm thick) occur. Macrofossils or not reworked bioclasts are lacking. The clay mineral composition is characterized by dominating montmorillonite (84%) with the admixture of the paradioctahedral hydromica (16 %). Macro and microfossils are absent. Thickness 0–0.2 m.

39. Dolomite, yellow or brown, massive, fine grained, sometimes silicified (Turaevo Dolomite). It became clayey in the upper part. Its basal 0.3 m somewhere contains bivalve and gastropod moulds, the main upper part is clayey, any macrofossils are lacking. The basal surface is slightly rough, with the net of ridges forming coarse-cellular surface. These ridges closely resemble desiccation crack casts on the surface of the underlying clay. Sometimes the top of dolomite demonstrates rather small (5–7 cm in diameter with thickness up to 2–3 cm) lenses of the partly dolomitized primary rock represented by crinoid-brachipod limestone with algae. Usually the bed thickness comprises 0.9–1.1 m. One place demonstrates reaching 1.5–1.7 m up because of dolomitization front moving up accompanied by diagenetic changes of the overlaying beds.

Lower part of dolomite contains monospecific assemblage of *Adetognathus lautus* (Gunnel). This species is typical for the extremely shallow water environments with salinity deviating from normal one. The middle and upper parts contain morphotypes of conodonts *Idiognathodus delicatus* Gunnel s.l. and "*Streptognathodus*" *subexcelsus* Alekseev and Goreva identical those known in overlaying "Garnasha".

Fifth bench

40. Clay, yellow-brown, green when fresh. Thickness 0.02–0.03 m.

41. Limestone, light gray to white, weakly clayey, packstone, with numerous *Zoophycos* orientated along the bedding surface. Some layers are enriched by thin-valve brachiopods, including *Neochonetes carboniferus* Keyserling. Black dendrites of manganese oxide are characteristic. Among brachiopods follows species are distinguishes: *Linoproductus* cf. *ovalis* A. Ivanov (probably *Linispinus crassus* Lazarev), *Admoskovia alekseevi* Lazarev, *Hystriculina*? sp. Fusulinids are rare in this bed and includes: *Schubertella mjachkovensis* Rauser, *Fusiella typica ventricosa* Rauser, *Fusiella typica typica* Lee and Chen, *F. lancetiformis* Putrja, *Obsoletes*? sp. The group of specialists on fusulinids which is under supervising of Solovieva studied the problem of the middle-upper Carboniferous boundary, determined *Obsoletes* sp., *Schubertella sphaerica sphaerica* Suleimanov, *Fusulina* sp., etc. in this bed. Thickness 0.4 m.

42. The intercalation of the green and violet calcareous clay, marl, and bioclastc limestone. The latter represents the tempestites. The individual layers can not be well traced laterally, but this unit, so-called "Garnasha" is subdivided into three parts (bottom-up):

a) Clay calcareous, green and violet, marl and bioclastic limestone. Thickness 0.9 m.

b) Marl and clayey limestone, violet or red-gray with green spots. The greenish-gray crinoid-brachiopod limestone occurs in the upper part of the unit. The sharp and rough surface resembling the erosional one is visible here and there. Thickness 0.6 m.

c) Marl, greenish-gray with sharp thin layers of light-gray crinoid-, small foraminiferal, and brachiopod limestone. Limestone contains very high abundance of conodont elements (up to 700 specimens/kg). Thickness 0.9 m.

The bed 42 contains the brachiopod remains rather often. The brachiopod assemblage includes: *Kozlowskia spinosa* (A. Ivanov), *Admoskovia alekseevi* Lazarev, *Linispinus crassus* Lazarev, *Orthotetes* cf. *regularis* Waagen, *Meekella* ex gr. *eximia* (Eichwald), *Choristites sowerbyi* Fischer. Among foraminifers small overgrowing forms are dominated and fusulinids are extremely rare. In the middle part of the bed 42 following species were distinguished: *Schubertella obscura* Lee and Chen, *Ozawainella mosquensis* Rauser and *Obsoletes* ? sp. Solovieva and others (Anonymus, 1985) mentioned the occurrence in the "Garnasha" *Obsoletes* ex gr. *dagmarae* Kireeva, *Protriticites pseudomontiparus*, *Fusulinella pseudoschwagerinoides* and *F.* ex gr. *schwagerinoides*. The total thickness 2.4–2.5 m.

Upper Member

43. Limestone, white and light-gray, strongly porous and cavernous bioclastic small foraminiferal-intraclastic, grainstone, irregularly cemented ("Sharsha"). The distinct variably directed gentle cross-lamination is well visible in the upper part of the bed. Intraclasts of the same limestone (up to 5–7 cm in diameter) and moulds of the bivalves and gastropods occur on some levels. Some surfaces are incrusted by stromatolite crust. The sharp erosional surface is observed between cross-bedded part and thin grained lower part of the bed. The limestone bears rare imprints of *Admoskovia* sp. (brachiopods).

Conodont elements is distributed irregularly in this bed. Some levels demonstrate high concentration because of the post mortal sorting. The amount of conodonts here is very high and reaches more then 200 specimens/kg (sample D-7). Thickness 1.3 m.

Voskresensk Formation

The rocks of the Voskresensk Formation were destroyed in 1980th. But they were studied and sampled for conodonts by A.S. Alekseev.

44. Limestone conglomerate, completed from greenish-gray limestone with abundant gravel and pebble of gray limestone. Conglomerate overlays the rough surface of the limestone of the Suvorovo Formation (Bed 43). The bottom contains flat blocks of the underlying light-gray and dark-gray limestone. Thickness of the blocks is from 5–7 cm, up to 20–30 cm in diameter. It also includes large (up to 10 cm) elongate and flattened pebbles of limestone of two types: light-gray and dark-gray and chert nodules. Limestones in pebbles belong to the group of thin-grained, mostly small foraminiferal with peloids and intraclasts. The upper part of the bed contains first *Swadelina makhlinae* (Alekseev and Goreva). Thickness 0.3 m.

45. Clay calcareous, violet and reddish-brown with green spots and interlayers. Conodonts: *Idiognathodus trigonolobatus* Barskov and Alekseev, *Swadelina makhlinae* (Alekseev and Goreva). Thickness 0.1 m.

46. Limestone, light-gray thin-grained with rare pebbles of dark-gray limestone. Conodonts: *Idiognathodus trigonolobatus* Barskov and Alekseev, *Swadelina makhlinae* (Alekseev and Goreva). Thickness 0.1 m.

47. Clay calcareous, greenish-gray with thin lenticular layers of limestone. Thickness 0.3 m.

48. Limestone, white and light-gray thin-grained with rare remains of crinoids, brachiopods and small foraminifers. The rounded fragments of gray limestone occur at the bottom. Bed consists of two layers subdivided by thin (2–3 cm) interlayer of green clay. Earlier this bed was assigned to the Ratmirovo Formation, but the more precise investigations and the conodont data disprove this statement. Visible thickness 0.2 m.

Biostratigraphical analysis

Foraminifers (Figs. 4, 5; Plates 1, 2). Foraminifers occur in every formation, but abundantly only at a few levels. The distribution of the foraminifers in the section is compiled on the basis of the re-study of the samples and thin sections collected in different years by M.N. Solovieva, N.B. Gibshman, T.A. Nikitina, T.V. Filimonova, and T.N. Isakova. The published data of Davydov (1997) was also used.

The assemblage of fusulinids from the Stshurovo Formation was obtained from two samples (sample 2 – collection of Gibshman and sample 1943 – collection of Solovieva). The species which occur only in the Podolskian include: *Kamaina siviniensis* (Rauser), *K. aspera* (Chernova), *Fusulina innae* Rauser, *Fusulinella vozhgalensis devexa* Rauser, *Taitzehoella librovitchi* (Dutkevich), *Neostaffella cuboides* (Rauser). Two of them – *Fusulina innae* Rauser and *Neostaffella cuboides* (Rauser) – also occur into the overlaying Myachkovian.

Lower and middle parts of the Korobcheevo Formation contain the fusulinid assemblage which is typical for *Fusulinella bocki* Zone. Assemblage (samples 1944, 1945, 1946 – collection of Solovieva and sample 3 – collection of Gibshman) includes taxa of "*Fusulinella bocki* Group": *Fusulinella bocki bocki* Möller, *Fusulinella bocki pauciseptata* Rauser, *Fusulinella pseudobocki pseudobocki* Lee and Chen, *Fusulinella pseudobocki ovoides* Rauser. In general the assemblage of fusulinids is variable and includes: *Fusulinella fluxa* Lee and Chen, *Fusulinella vozhgalensis molokovensis* Rauser, *Fusulinella helenae* Rauser. The occurrence of *Neostaffella sphaeroidea* (Ehrenberg) and *Neostaffella cuboides* (Rauser) is also characteristic for the Korobcheevo Formation. The genus *Fusulina* is represented by *F. truncatulina* Thompson.

Fusulinid assemblage of the upper part of the Domodedovo Formation (sample 1947 – collection of Solovieva; samples 5 and 15 – collection of Gibshman) includes both species transient from the underlying Korobcheevo Formation and the firstly appeared ones. The essential part of the assemblage is represented by *Fusulinella* ex gr. *F. bocki* Möller. The renovation of the fusulinid assemblage deals with the appearance of the stratigraphycally important "*Fusulina cylindrica* Fischer Group", represented by *Fusulina quasicylindrica* Lee and Chen and some firstly appeared taxa: *Fusulina pakhrensis* Rauser, *Fusulina mjachkovensis peskensis* Rauser, *Hemifusulina bocki* Möller, *Pulchrella eopulchra* Rauser. The all mentioned taxa are included in the assemblage of the *Fusulina cylindrica* Zone (Makhlina et al., 2001b). Zonal assemblage was found in the Upper Member of the Domodedovo Formation. The lower part of the Domodedovo Formation lacks of fusulinids. Thus, in the Domodedovo section the upper part of the Domodedovo Formation is correlated with the Myachkovian *Fusulina cylindrica* Zone.

Fusulinids are very abundant and diverse in the Peski Formation. The Lower Member of the Peski Formation includes assemblage with domination of the "*Fusulina cylindrica* Group" – *Fusulina cylindrica cylindrica* Fischer, *F. cylindrica domodedovi* Rauser, *Fusulina quasicylindrica* Lee and Chen, *Fusulina mosquensis* Rauser, and *Fusulina mjachkovensis mjachkovensis* Rauser. The assemblage includes *Fusulina pakhrensis* Rauser that occurs also in the underlying deposits. Genus *Fusulinella* is represented by *Fusulinella mosquensis* Rauser and Safonova only. As a whole the composition the assemblage from the lower part of the Peski Formation is typical for the *Fusulina cylindrica* Zone.

The renovation is fixed in the Middle Member of the Peski Formation by the appearance of new taxa – *Protriticites ovatus* Putrja, *P. parvus* Kireeva and *Praeobsoletes timanicus* (Volozhanina), *P. pauper* (Volozhanina) which were identified by Davydov (samples 1/21 and 1/22). The diversity of genus *Fusulinella* increases substantially. The assemblage includes earlier appeared *Fusulinella bocki bocki* Möller, *F. bocki pauciseptata* Rauser, *F. pseudobocki ovoides Rauser*, and also *F. rara* Shlykova (samples 7 and 11, collection of Gibshman; sample 38, collection of Nikitina; sample M9, collection of Filimonova).

The generic assignment of some forms can not be defined unequivocally because of the bad preservation of the wall structure. By the other morphological features the forms under consideration can be assigned to *Fusulinella* or *Protriticites*. They are considered here as debatable *Fusulinella* (?) – *Protriticites* (?).

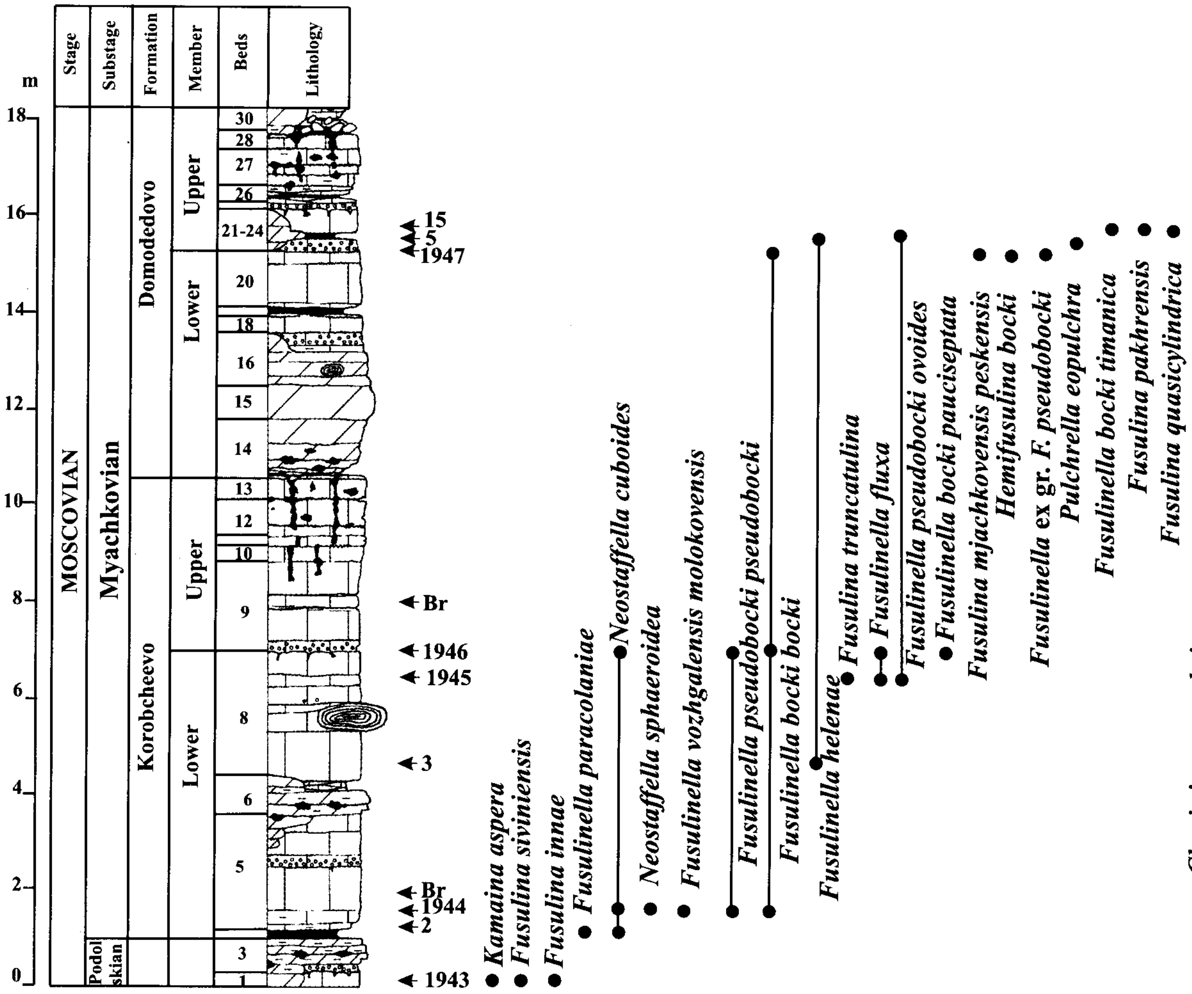


Fig. 4. Distribution of the fusulinids and brachiopods in the Upper Moscovian and Lower Kasimovian strata of the Domodedovo section (lower part)

By the appearance of the above mentioned assemblage the fusulinid *Praeobsoletes burkemensis – Protriticites ovatus* Zone (Davydov, 1997) was recognized in the upper Peski Formation. So, the *Praeobsoletes* and *Protriticites* appear in the upper half of the Peski Formation. However the identification of the representatives of these genera seems to be unclear because of the bad preservation of structure of fusulinid shells.

The validity of the genus *Praeobsoletes* is doubtful. The investigation of the type material of this genus made by Baranova (2005, p. 15) had shown that genus "*Praeobsoletes* represents the mixture of the representatives of *Fusulinella* and *Protriticites* s.l.". Hereupon the upper part of the Myachkovian was defined as *Protriticites ovatus* Zone (Makhlina et al., 2001b). The lower boundary of the zone is distinguished by the appearance of index-species at the base of the Middle Member. Thus, Peski Formation is corresponded to two fusulinid zones: Lower Member coincides with upper part of the *Fusulina cylindrica* Zone, Middle and Upper members are correlated with *Protriticites ovatus* Zone.

The Suvorovo Formation contains the impoverished fusulinid assemblage which occurs mostly in the Lower Member. The assemblage lacks typical *Fusulina* and *Fusulinella*. There are single specimens with three or four incomplete whorls, provisionally defined as ?*Fusulinella* or transitional ?*Fusulinella* – ?*Protriticites*. The specimen with double primary chamber was found. The renovation

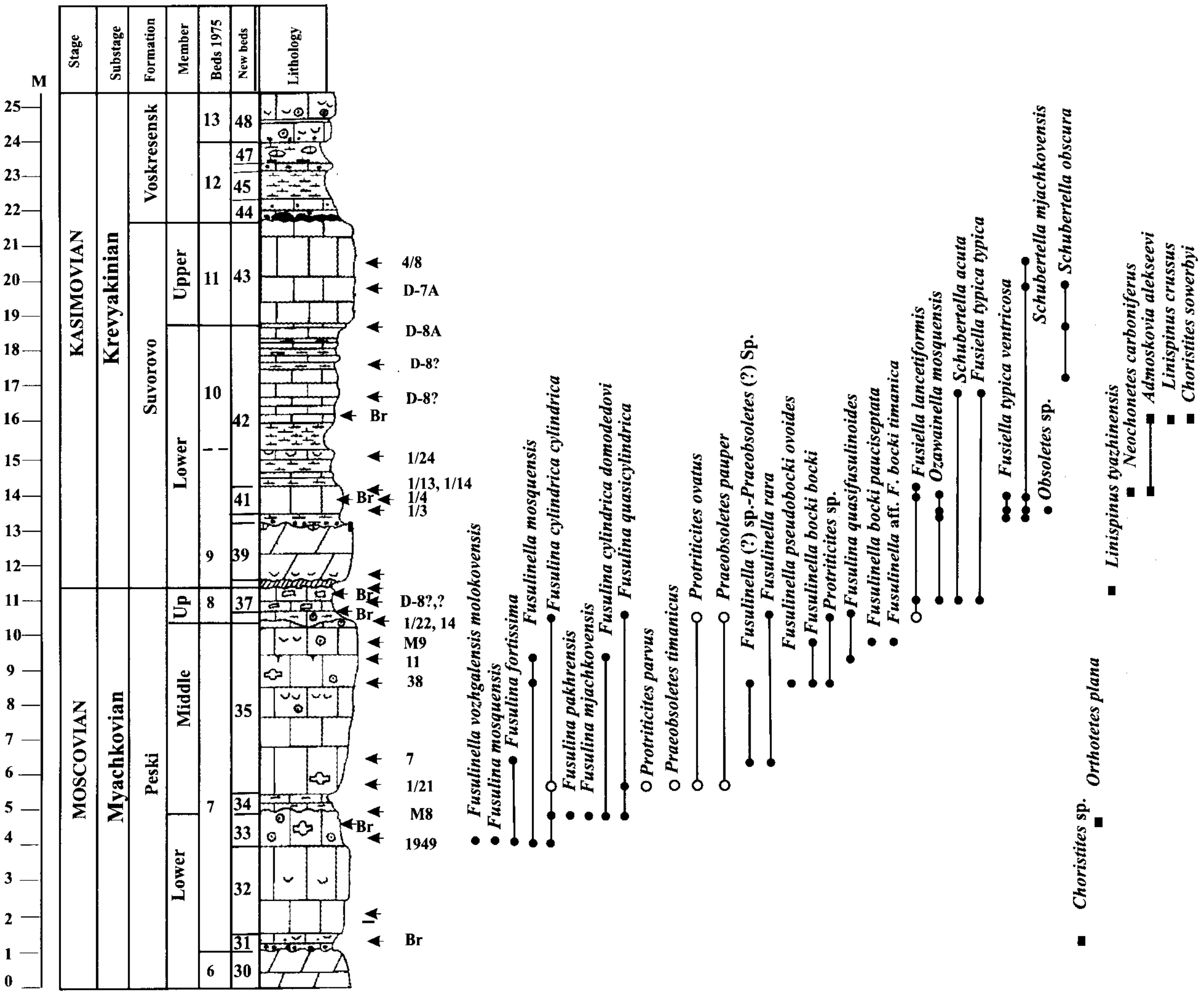


Fig. 5. Distribution of the fusulinids and brachiopods in the Upper Moscovian and Lower Kasimovian strata of the Domodedovo section (upper part)

of assemblage is distinguished by the appearance of *Obsoletes* sp. accompanied by dominant *Fusiella*, *Schubertella* and *Ozawainella* species. In the Upper Member of the Suvorovo Formation fusulinids are nearly absents excluding rare and scarce *Schubertella mjachkovensis* Rauser and *Schubertella* sp. Beds with *Obsoletes* sp. and *Fusiella lancetiformis* were distinguished in the Lower Member of the Suvorovo Formation in the Domodedovo section (Makhlina et al., 2001b). The assemblage includes *Obsoletes* sp., *Fusiella lancetiformis* Putrja, *F. typica ventricosa* Rauser, *Schubertella mjachkovensis* Rauser and some others.

Foraminifers of the Voskresensk Formation were studied in the thin sections made from the samples on conodonts (collection of Alekseev, samples D-5B, D-4B, D-2B). The deposits of the Voskresensk Formation contain the assemblage of smaller foraminifers with the wide stratigraphic ranges. The mass accumulations are formed by overgrowing *Palaeonubecularia* sp., *Tolypammina* sp., *Ammovertella* sp., *Glomospira* sp. Moreover *Globivalvulina* sp. presents rather often, and *Brunsiella* sp. is rarely fixed. Fusulinids are absent.

Conodonts (Figs. 6, 7; Plates 3, 4). More than 50 levels with conodonts identified in the Domodedovo section, above 5500 conodont elements were extracted, but mainly from the Moscovian/Kasimovian boundary interval.

Plate 1

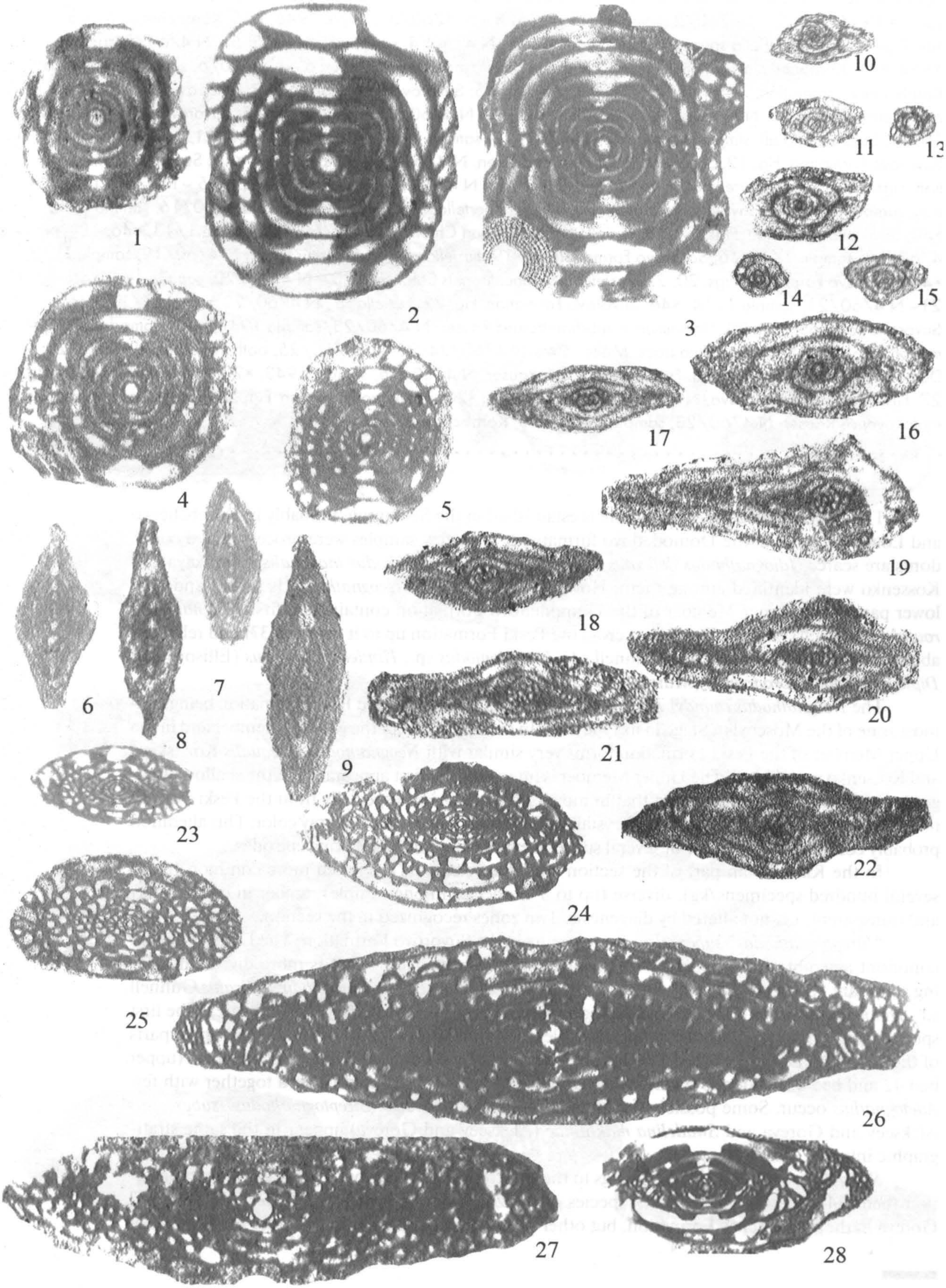


Plate 1. Fusulinids from the Domodedovo section. Collection is stored in the Laboratory of Micropaleontology, Geological Institute of Russian Academy of Sciences, Moscow. Figs. 1–3. *Neostaffella cuboides* (Rauser): 1 – N 4760/1, sample 1944, ×35; 2 – N4760/2, sample 1946, ×35; 3 – N 4760/3, sample 1946, ×35; Korobcheevo Formation. Figs. 4, 5. *Neostaffella sphaeroidea* (Ehrenberg): 4 – N 4760/4, sample 1944, ×35; 5 – N 4760/5, sample 1944, ×35; Korobcheevo Formation. Figs. 6, 7. *Ozawainella mosquensis* Rauser: 6 – N 4760/6, sample 1945, ×45; Korobcheevo Formation; 7 – N 4760/7, sample 1/14, ×45; Suvorovo Formation. Figs. 8, 9. *Ozawainella* ex gr. *O. mosquensis* Rauser: 8 – N 4760/8, sample 1/13, ×45; 9 – N 4760/9, sample 1/3, ×45; Suvorovo Formation. Figs. 10, 11. *Schubertella* aff. *simplex* Lange: 10 – N 4760/10, sample 1/13, ×40; 11– N4760/11, sample 1/4, ×40; Suvorovo Formation. Fig. 12. *Schubertella lata* Lee and Chen, N 4760/12, sample 1/13, ×40; Suvorovo Formation. Figs. 13–15. *Schubertella obscura* Lee and Chen: 13 – N 4760/13; 14 – N 4760/14; 15 – N 4760/15, all from sample 1/4, ×40; Suvorovo Formation. Fig. 16. *Schubertella mjachkovensis* Rauser, N 4760/16, sample 1/13, ×40; Suvorovo Formation. Figs. 17, 18. *Fusiella typica* Lee and Chen: 17 – N 4760/17, sample 1/13, ×46; 18 – N 4760/18, sample 1/4, ×46; Suvorovo Formation. Fig. 19. *Fusiella* aff. *lancetiformis* Putrja, N 4760/19, sample 1/13, ×46; Suvorovo Formation. Figs. 20, 21. *Fusiella praelancetiformis* Safonova: 20 – N 4760/20, sample 1/4, ×46; 21– N 4760/21, sample 1/14, ×46; Suvorovo Formation. Fig. 22. *Fusiella* sp., N 4760/22, sample 1/13, ×46; Suvorovo Formation. Fig. 23. *Hemifusulina subrhomboides* Rauser, N 4760/23, sample 1947, ×20; Domodedovo Formation. Figs. 24, 25. *Hemifusulina bocki* Möller: 24 – N 4760/24; 25 – N 4760/25, both from sample 1947, ×20; Domodedovo Formation. Fig. 26. *Fusulina siviniensis* Rauser, N 4760/26, sample 1943, ×20; Stshurovo Formation. Fig. 27. *Fusulina aspera* Chernova, N 4760/27, sample 1943, ×20; Stshurovo Formation. Fig. 28. *Fusulinella vozhgalensis molokovensis* Rauser, N 4760/28, sample 1944, ×20; Korobcheevo Formation

The *Neognathodus inaequalis* Zone is established in the Stshurovo, probably in Korobcheevo and Lower Member of the Domodedovo formations. Only few samples were processed and conodonts are scarce. *Idiognathodus delicatus* Gunnell s.l. and *Neognathodus inaequalis* Kozitskaya and Kossenko were identified among them. However in beds 16–21 *Neognathodus* is absent and only lower part of the Upper Member of the Domodedovo Formation contains the first *Neognathodus roundyi* (Gunnell) (sample D-23) that cross the Peski Formation up to it top (bed 37) and relatively abundant *Idiognathodus delicatus* Gunnell s.l., *Idioprioniodus* sp., *Hindeodus minutus* (Ellison) and *Diplognathodus coloradoensis* (Murray and Chronic).

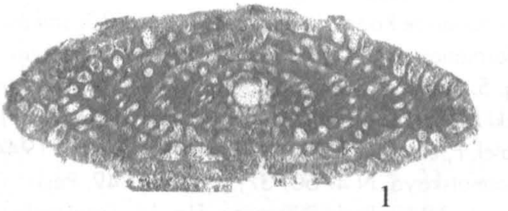
The *Neognathodus roundyi* Zone covers also total thickness of the Peski Formation being topmost zone of the Moscovian Stage in its type area. In the upper part of the Middle Member and in the Upper Member of the Peski Formation forms very similar with *Neognathodus inaequalis* Kozitskaya and Kossenko were found. The Upper Member is interval of the first appearance of the shallow-water genus *Adetognathus*. It is important that in most of Myachkovian, especially from the Peski Formation, conodont elements are altered, recrystallized, corroded, and often has gray color. This alteration probably could be consequence of several subaeral expositions and weathering episodes.

In the Kasimovian part of the section conodont elements are much more common (up to several hundred specimens/kg), diverse (up to 8–9 species in one sample), amber in color, glassy and transparent, i.e. not altered by diagenesis. Two zones recognized in the section.

"*Streptognathodus*" *subexcelsus* Zone occurs in the Suvorovo Formation. The Lower Member conodont assemblage lost typical Moscovian genus *Neognathodus*, but it is more diverse including abundant "*Streptognathodus*" *subexcelsus* Alekseev and Goreva, *Idiognathodus delicatus* Gunnell s.l., *Hindeodus minutus* (Ellison) and *Diplognathodus coloradoensis* (Murray and Chronic). The first specimens of "*Streptognathodus*" *subexcelsus* Alekseev and Goreva found in middle and upper parts of the "Turaevo Dolomite" (bed 39). In the upper part of the Lower and in Upper members (upper bed 42 and bed 43) endemic species *Idiognathodus fischeri* Alekseev and Goreva together with few *Adetognathus* occur. Some possibly transitional specimens between "*Streptognathodus*" *subexcelsus* Alekseev and Goreva and *Swadelina makhlinae* (Alekseev and Goreva) appear in the same stratigraphic interval.

Swadelina makhlinae Zone belongs to the Voskresensk Formation. The shales of this formation (beds 44–47) contain the index species of the zone. No *Idiognathodus fischeri* Alekseev and Goreva in the Voskresensk Formation, but other species are the same as in the older zone.

Plate 2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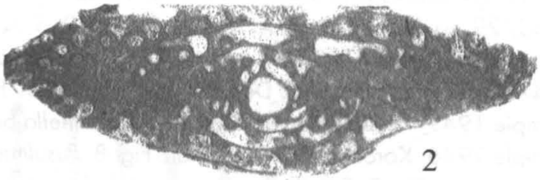
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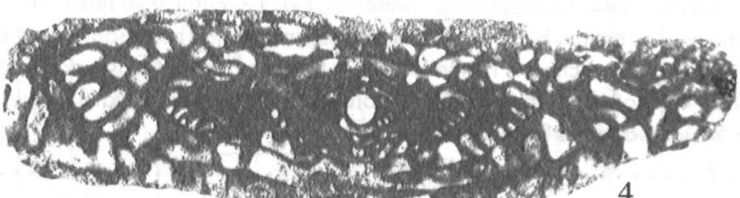
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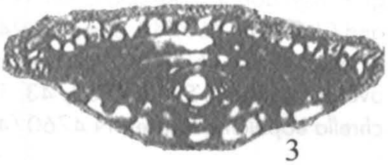
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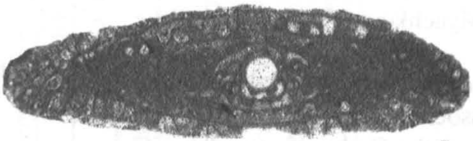
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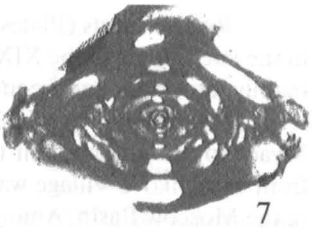
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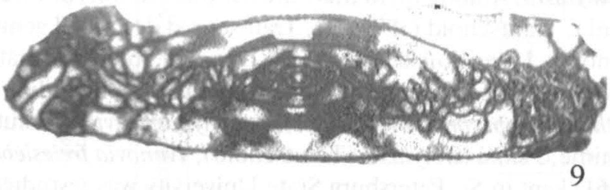
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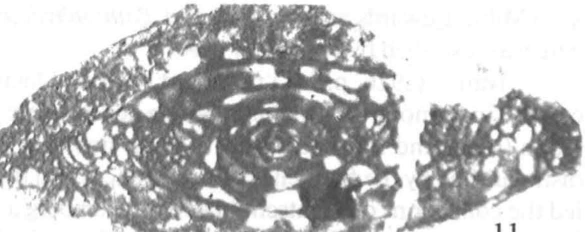
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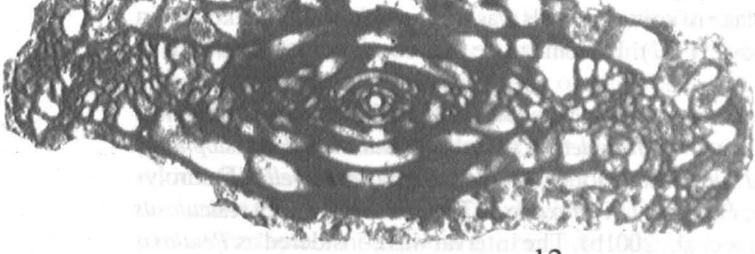
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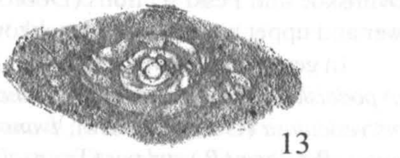
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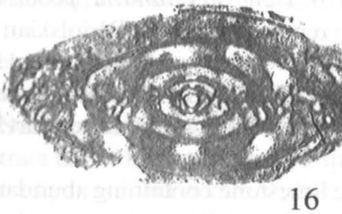
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Plate 2. Fusulinids from the Domodedovo section, for all magnification is ×20. Collection is stored in the Laboratory of Micropaleontology, Geological Institute of Russian Academy of Sciences, Moscow. Fig. 1. *Fusulina mosquensis* Rauser, N 4760/29, sample 1949; Peski Formation. Figs. 2, 3. *Fusulina innae* Rozovskaya: 2 – N 4760/30, sample 1949; Peski Formation; 3 – N 4760/31, sample 1943; Stshurovo Formation. Fig. 4. *Fusulina mjachkovensis peskensis* Rauser, N 4760/32, sample 1947; Domodedovo Formation. Fig. 5. *Fusulina cylindrica* Fischer emend. Möller, N 4760/33, sample 1949; Peski Formation. Figs. 6, 7. *Fusulinella bocki* Möller: 6 – N 4760/34, sample 1944; 7 – N 4760/35, sample 1946; Korobcheevo Formation. Fig. 8. *Fusulinella* cf. *F. cumpani* Putrja, N 4760/36, sample 1944; Korobcheevo Formation. Fig. 9. *Fusulinella mosquensis lyskovensis* Dalmatskaya, N 4760/37, sample 1949; Peski Formation. Fig. 10. *Fusulinella* cf. *rara* (?) Shlykova, N 4760/38, sample 1949; Peski Formation. Fig. 11. *Fusulinella* ex gr. *F. pseudobocki* Lee and Chen, N 4760/39, sample 1944; Korobcheevo Formation. Fig. 12. *Fusulinella fluxa* Lee and Chen, N 4760/40, sample 1946; Korobcheevo Formation. Figs. 13, 14. *Fusulina truncatulina* Thompson: 13 – N 4760/41; 14 – N 4760/42, both from sample 1945; Korobcheevo Formation. Figs. 15, 16. *Fusulinella pseudobocki ovoides* Rauser: 15 – N 4760/43; 16 – N 4760/44, both from sample 1945; Korobcheevo Formation. Fig. 17. *Pulchrella eopulchra* Rauser, N 4760/45, sample 5; Domodedovo Formation

Rugose corals (Plates 5, 6). Myachkovian rugose corals in the Moscow Basin become known in the late thirties of the XIX century. Among the principal sites the Myachkovo Village is one of the mainly important and frequently cited in publications.

Myachkovo, Novlinskoe, and Domodedovo sections are located in the same facial belt of the Myachkovian and content the typical Myachkovian rugose coral association. Collection of corals from Myachkovo Village was mentioned in the pioneer publications on the Carboniferous deposits of the Moscow Basin. Among them there are the publications of Fischer de Waldheim (1830–1837), Eichwald (1861), Trautschold (1879). H. Trautschold described genus *Bothrophyllum* keeping in the modern taxonomy. Later Stuckenberg (1888) studied abundant material from the Myachkovo and Novlinskoe. He described (here in modern nomenclature including results of the Ivanovsky (1987) revision): *Bothrophyllum conicum* (Fischer), *Axophyllum cavum* (Trautschold), *A. konincki* Milne Edwards and Haime, *Petalaxis stylaxis* (Trautschold), *Ivanovia freieslebeni* (Fischer). The collection of Eichwald (1861) kept in St. Petersburg State University was restudied by Fedorowski and Gorianov (1973) and from the vicinity of the Myachkovo Village they redescribed two species: *Petalaxis mcoyanus* (Milne Edwards and Haime) and *Bothrophyllum conicum* Trautschold. Collection of Stuckenberg was restudied by Ivanovsky (1987).

Ivanov (1926, p. 147) proposed two coral facies in the Korobcheevo Formation of the Moscow basin. Among colonial corals two genera were mentioned: *Petalaxis* and *Phillipsastrea*. Both facies (outer and inner relatively to coast line) are similar by taxonomical compositions, but were distinguished by the frequency of occurrences and the size of colonies. Dobrolyubova (1935) restudied the collections of Trautschold and Stuckenberg and with addition of new specimens described of Myachkovian colonial corals. Later assemblage of solitary corals was reported from Myachkovian in Novlinskoe and Peski sections (Dobrolyubova, 1937). It seems to be that corals were found both in lower and upper parts of the Myachkovian.

In general the lower part of the Myachkovian in the Moscow Basin includes *Ivanovia* (*Ivanovia*) *podolskiensis* Dobrolyubova, *Ivanovia* (*Ivanovia*) *freieslebeni* (Fischer), *Ivanovia* (*Procystophora*) *densivesiculosa* (Dobrolyubova), *Ivanovia* (*I.*) *expansa* (Dobrolyubova), *Donastraea bella* (Dobrolyubova), *Petalaxis* (*P.*) *stylaxis* (Trautschold), *Petalaxis* (*P.*) *flexuosus* (Trautschold), *P.* (*P*) *vesiculosus* (Dobrolyubova) (Kossovaya, 1998; Makhlina et al., 2001b). The interval was considered as *Petalaxis* (*P.*) *vesiculosus* Beds (Makhlina et al., 2001b). *Ivanovia* (*Ivanovia*) *podolskiensis* Dobrolyubova and *Petalaxis* (*P.*) *stylaxis* (Trautschold) are also reported from the Podolskian (Makhlina et al., 2001b).

The presence of corals in the Domodedovo quarry was mentioned by Ivanova and Khvorova (1955, p. 143). In the guidebook (Yablokov, 1975) the corals *Petalaxis stylaxis* (Trautschold) and *Lonsdaleiastraea freieslebeni* (Stuckenberg) were shown in the lower part of the Domodedovo section.

The first occurrence in the bioclastic limestone containing abundant colonies and chaetetids is located in 0.4 m above the base of the Korobcheevo Formation (samples D-1-94-0, D-94-0, D-5

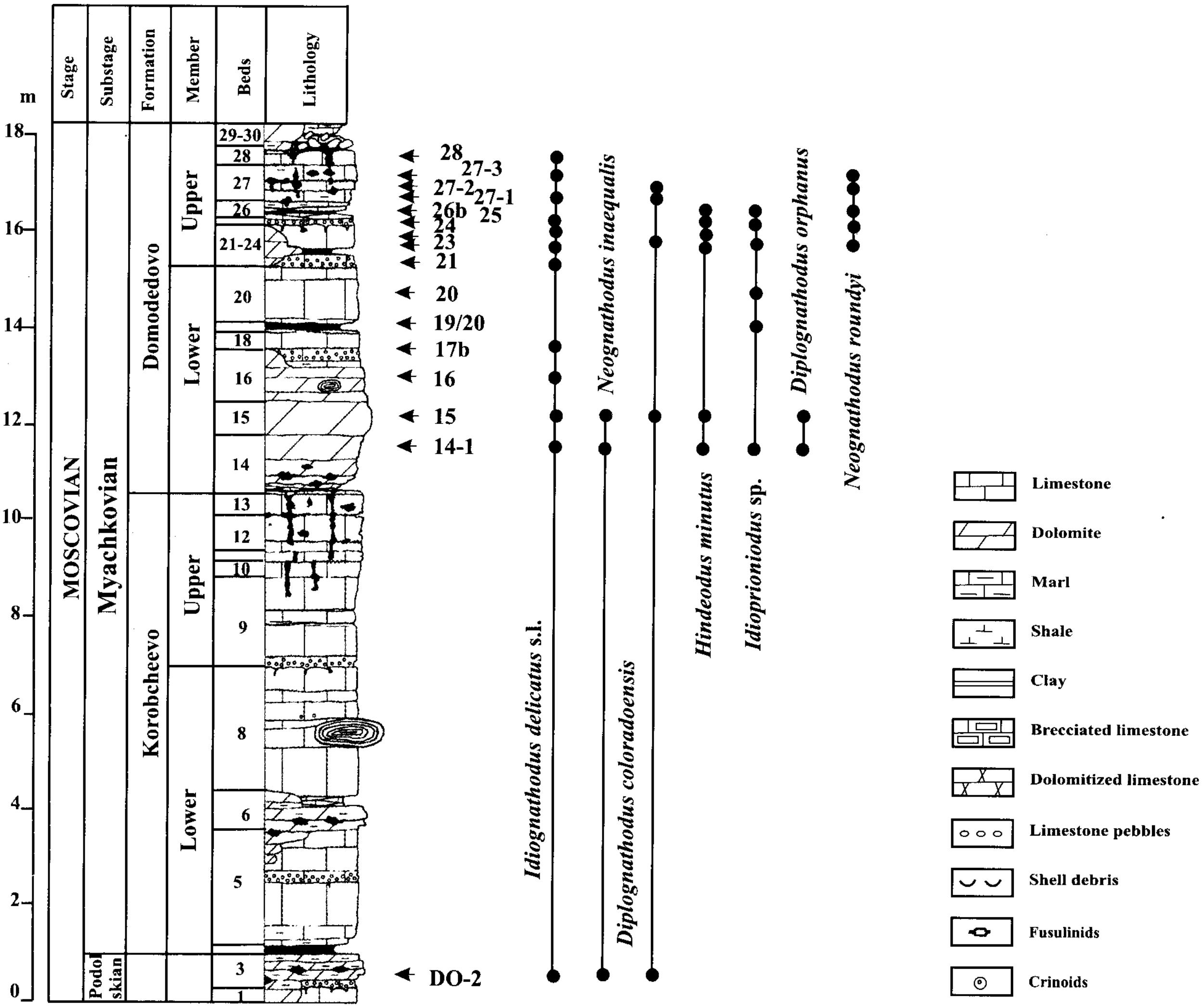

Fig. 6. Distribution of the conodonts in the Upper Moscovian and Lower Kasimovian strata of the Domodedovo section (lower part)

and others). The preservation is rather bad especially of *Bothrophyllum* and *Petalaxis*. Colonies have spherical, flattened, and rarely lamellate forms. Lamellate forms are more typical for *Cystophorastraea* Dobrolyubova. Chaetetids grew on the upper surface of rugose colonies and sometimes penetrated in the inner part of the *Petalaxis* calyx.

Cerioid *Petalaxis* is predominant and represented by only *P.* (*P.*) *stylaxis* (Trautschold). Astreoid colonies belong to *Cystophorastraea molli* (Fischer), *Ivanovia* (Ivanovia) *freieslebeni* (Fischer), *Ivanovia* (*I.*) sp. 1. Small solitary bothrophyllids of the bad preservation were found in the upper part of the layer. In 1 m above the boundary the base of the next layer includes small quasi-colonies of *Bothrophyllum* aff. *trautscholdi* Stuckenberg (sample D-1-94-1). Colonies are similar with type specimens by the growth form and chain position of the corallites (Stuckenberg, 1888, p. 16). They differ by essentially smaller size. Colonial corals sometime formed bioherms up to 0.5–1 m high and Korobcheevo sequence rich in corals is well traceable in the Moscow Basin and is considered as a marker unit, observed in Stshurovo, Podolsk, Korobcheevo, Starye Peski, and in other sites.

In the overlaying strata of the Domodedovo Formation corals are represented by only solitary *Bothrophyllum*. Rare and badly preserved *Bothrophyllum conicum conicum* (Fischer) were found in 2 m above the base of the lower member of the Korobcheevo Formation (Plate 2, figs. 7–8).

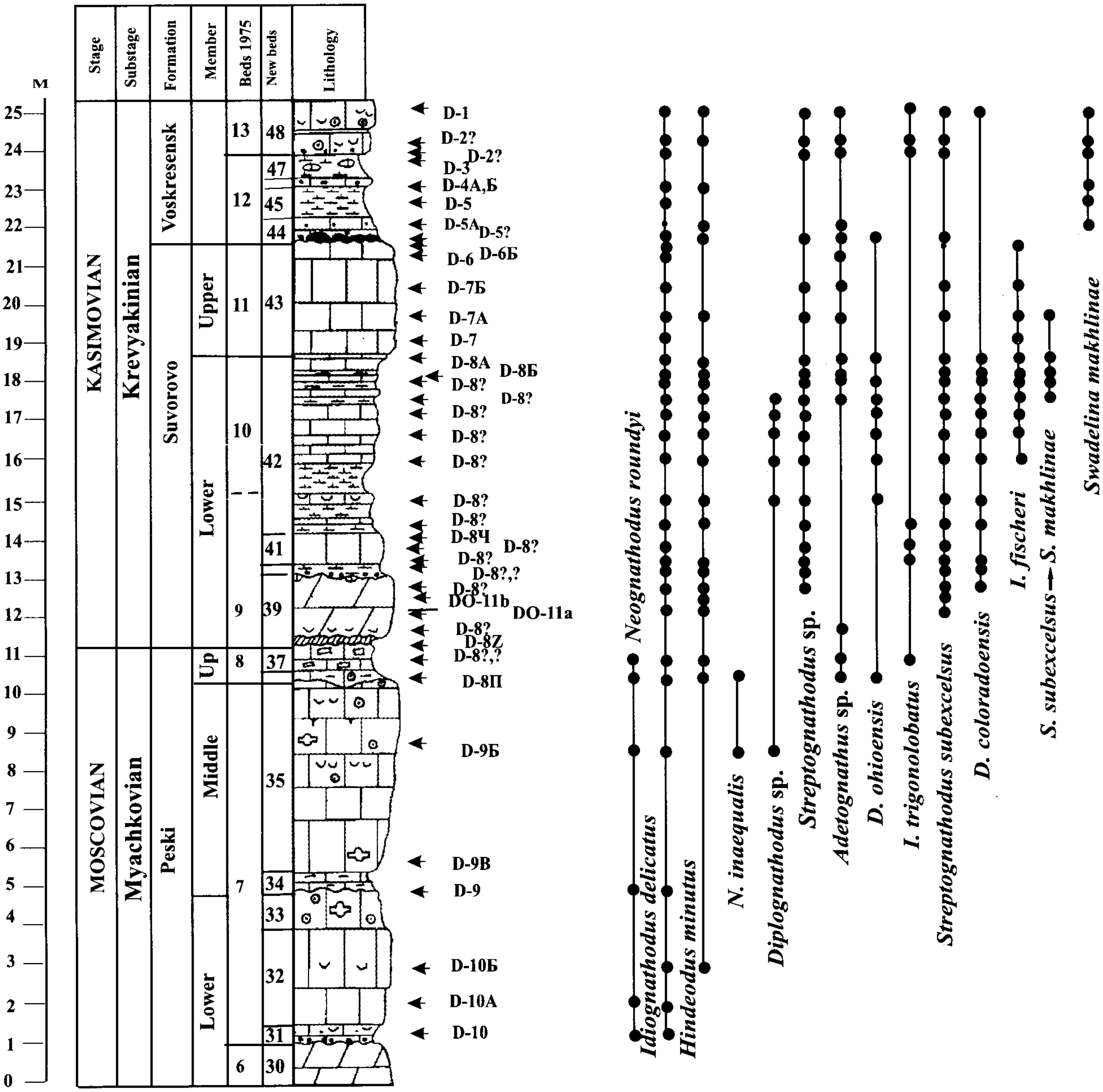

Fig. 7. Distribution of the conodonts in the Upper Moscovian and Lower Kasimovian strata of the Domodedovo section (upper part)

The Peski Formation contains very rare solitary Rugosa. They were found in the bed 33 (Lower Member) and include two forms of *Bothrophyllum*: *B. conicum moribundum* Kossovaya and *B.* sp. 1. For both taxa the reduction of the axial structure is typical. Specimens of *B.* sp. 1. were also found in the talus debris of the Peski Formation in the Afanasievo Quarry. The arrangement of rather long minor septa limited by the width of dissepimentarium is typical. The appearance of forms with reduction of axial structure was used for distinguishing of the *B. conicum moribundum* Beds (Makhlina et al., 2001b).

The overlying deposits of the Suvorovo and Voskresensk formations in the Domodedovo do not content corals.

Sequence analysis

The Domodedovo, Peski and Suvorovo formations are third order sequences (cyclothems) bordered by paleosols. The Korobcheevo Formation is the upper regressive part of the major Stshurovo–Korobcheevo Sequence. The top of the Korobcheevo is Ysupovo paleosol, top of the Domodedovo is Konev Bor paleosol and top of the Peski – Achkasovo paleosol (Baranova, Kabanov, 2003). The highstand systems tracts represented by shaly intervals often with tempestitic limestone beds and with increase of the conodont abundances. Every cyclothem demonstrates several minor sequences (up to 4) reflecting relatively small sea-level fluctuations.

Chemostratigraphy

Stable isotope studies were carried out on few stratigraphic levels in the Domodedovo section (Alekseev et al., 1998). 14 samples of bulk wackestones and 4 fragments of the prismatic layer of the brachiopod *Choristites* (without cathode luminescence control) were analyzed on oxygen and carbon isotopic composition. The oxygen in the carbonates is relatively heavy (-4.9 – -2.45‰ δ^{18}O PDB) and shows only minor fluctuations across the section. Some shift to the more light ratios take place at the Peski Formation base (from -3.23 to -4.65‰ δ^{18}O). The positive oxygen anomaly (-1.51‰ δ^{18}O) is found in the thin limestone interlayer within the clay of the bed 19 containing volcanic material. The brachiopod shell material and rock matrix has very similar ratios (-3.37 – -3.11‰ δ^{18}O). Obviously all Moscovian and Lower Kasimovian carbonates were diagenetically altered.

Isotope composition of carbon is typical for marine carbonates and shows clear trend. In the uppermost Podolskian and the Korobcheevo Formation of the Myachkovian the carbon is heavy (+1.61 - +2.2‰ δ^{13}C PDB), but Domodedovo Formation demonstrates continuous decrease of the ratio up to -1.72 – -1.69‰ δ^{13}C in the Peski Formation (beds 35 and 37). The Suvorovo limestones contain more heavy carbon (-0.97 – -0.42‰ δ^{13}C). Brachiopod calcite of uppermost Podolskian and Lower Myackovian has close isotopic ratios and only in bed 32 (base of the Peski Formation) it shows very heavy carbon (+4.34‰ δ^{13}C). The trend to more light carbon in the Peski and Suvorovo formations could be explained by more prominent subaerial exposures and fresh water diagenesis during that time.

Conservation

Erosional remnant with Kasimovian strata about 100 m long and space below it in the southwestern sector of the quarry were registered as local natural reserve, but its status need to be formally confirmed in the Moscow Region Government. The owner reserved scientifically most important part of the quarry and do not permit mining there. The access for scientists and students is free.

Plate 3

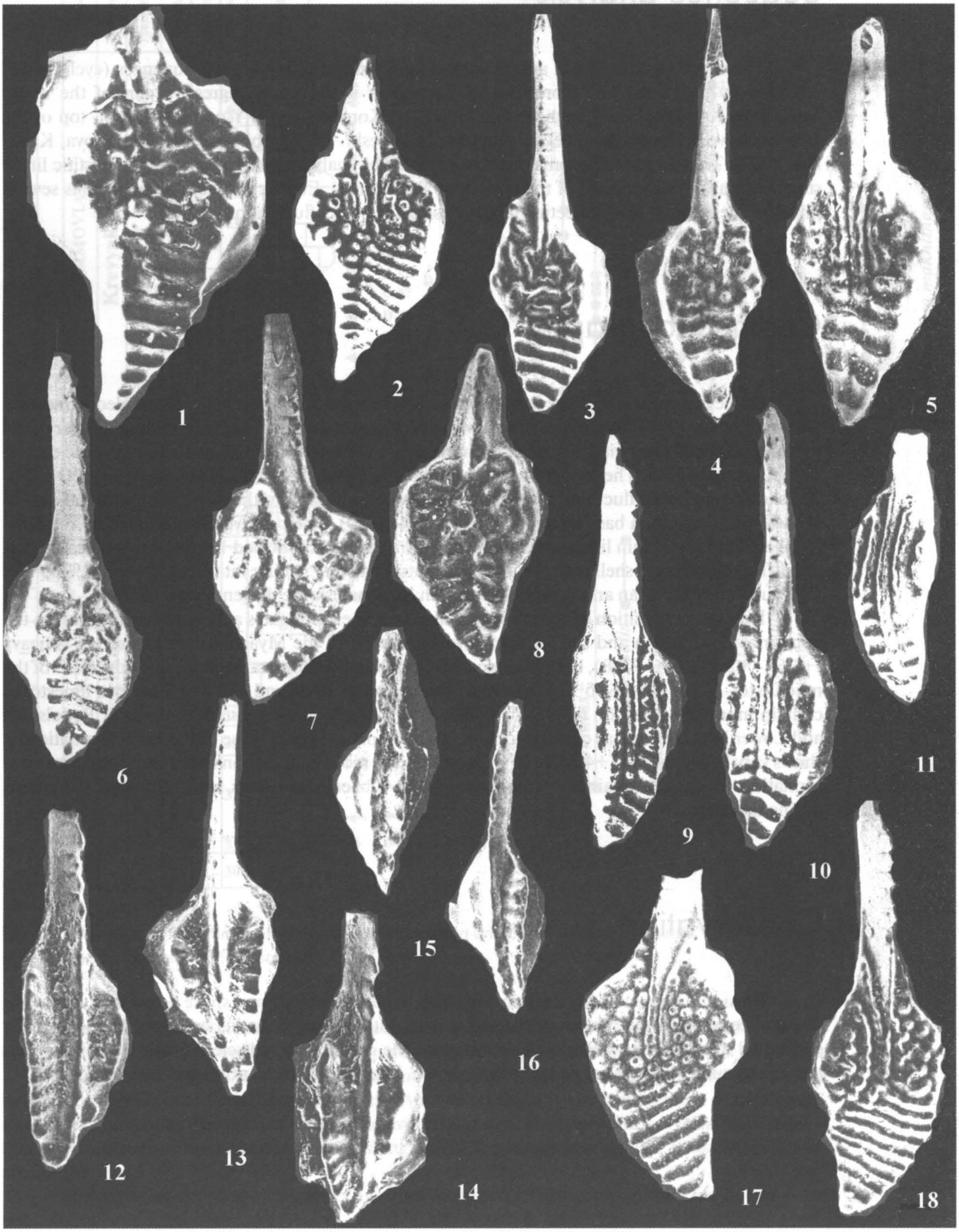

Plate 3. Pa elements of conodonts from the Domodedovo section. Collection is stored in Department of Paleontology, Geological Faculty, Moscow State University. Figs. 1, 2. *Idiognathodus trigonolobatus* Barskov and Alekseev: 1 – sample D-2Б, bed 48, × 50; 2 – sample D-2Б, bed 48, × 50; Voskresensk Formation. Figs. 3–8. *Idiognathodus fischeri* Alekseev and Goreva: 3 – sample D-5Б, bed 44, ×60; 4 – sample 8Г, bed 42, ×60; 5 – sample D-7A, bed 43, ×90; 6 – sample D-7A, bed 43, ×60; 7 – sample D-8Г, bed 42, ×60; 8 – sample D-7A, bed 43, × 65; Suvorovo Formation. Figs. 9–11. *Streptognathodus* sp.: 9 – sample D-8T, bed 40, ×100; 10 – sample D-7A, bed 43, ×90; Suvorovo Formation; 11 – × 110, bed 48, sample D-1; Voskresensk Formation. Figs. 12–14. *Neognathodus* aff. *inaequalis* Kozitskaya and Kossenko: 12 – sample D-8П, bed 36, ×100; 13 – sample D-8П, bed 36, ×100; 14 – sample D-8П, bed 36, ×100; Peski Formation. Figs. 15, 16. *Neognathodus roundyi* (Gunnell): 15 – sample D-8П, bed 36, ×110; 16 – sample D-8П, bed 36, ×110; Peski Formation. Figs. 17, 18. *Idiognathodus delicatus* Gunnell: 17 – sample D-8Ф, bed 41, ×65; 18 – sample D-8C, bed 39, ×65; Suvorovo Formation

Acknowledgment

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Plate 4

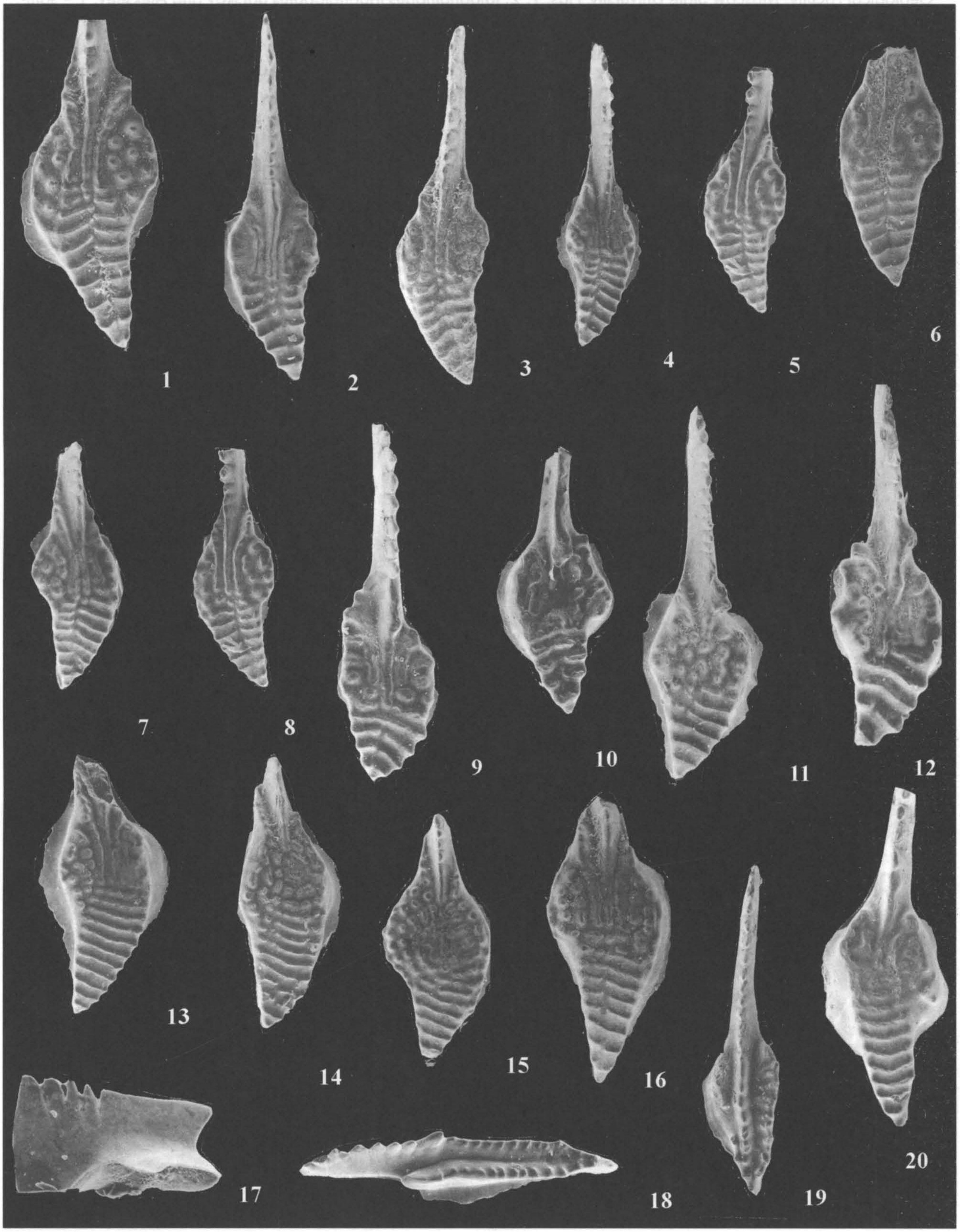

Plate 4. Pa elements of conodonts from the Domodedovo section. Collection is stored in Department of Paleontology, Geological Faculty, Moscow State University. Figs. 1–8. "*Streptognathodus*" *subexcelsus* Alekseev and Goreva: 1–5, 7, 8 – sample D-8Д, bed 42, ×60; 6 – sample DO-11Б, bed 39, ×80; Suvorovo Formation. Figs. 9–12. *Idiognathodus fischeri* Alekseev and Goreva: 9, 11, 12 – sample D-8Д, bed 42, ×60; 10 – sample D-7A, bed 43, × 60; Suvorovo Formation. Figs. 13–16. *Idiognathodus delicatus* Gunnell: 13, 14 – sample D-8Ш, bed 42, ×60; 15 – sample D-7A, bed 43, ×60; 16 – sample D-8E, bed 42, ×60; Suvorovo Formation. Fig. 17. *Diplognathodus coloradoensis* (Murray and Chronic), sample D-8E, bed 42, ×110; Suvorovo Formation. Fig. 18. *Adetognathus lautus* (Gunnell), sample D-7A, bed 43, ×60; Suvorovo Formation. Fig. 19. *Neognathodus roundyi* (Gunnell), sample D-10, bed 31, ×70; Peski Formation. Fig. 20. *Idiognathodus* sp., sample D-8M, bed 37, ×50; Peski Formation

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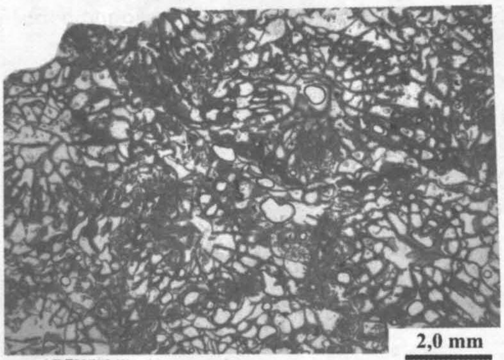
Plate 5



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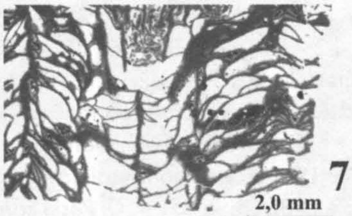

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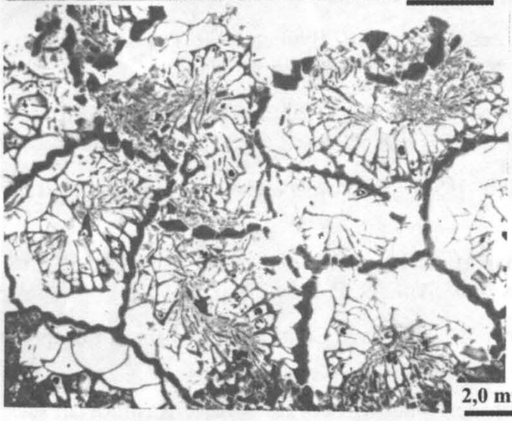

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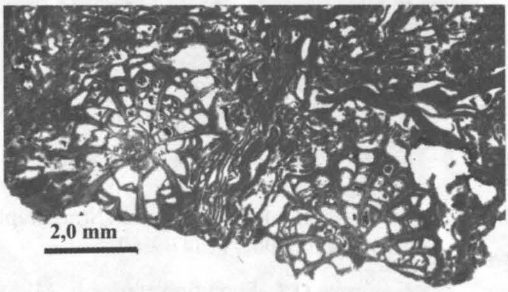

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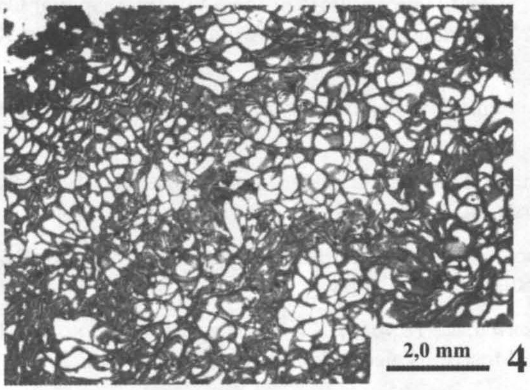

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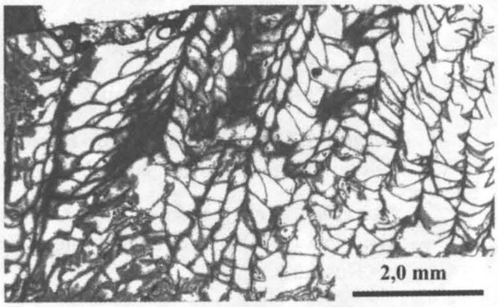

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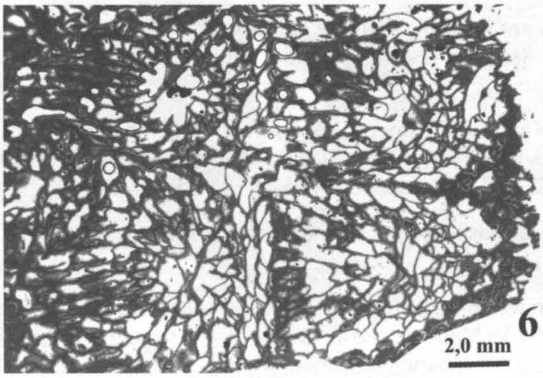

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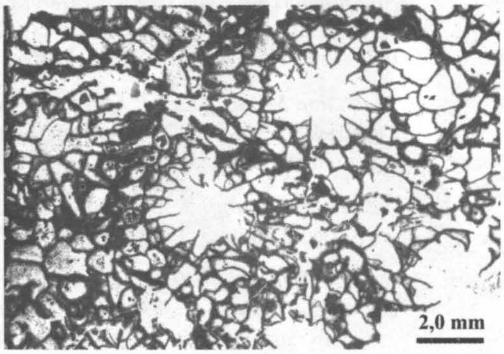

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Plate 6


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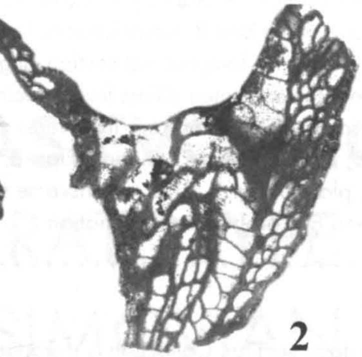
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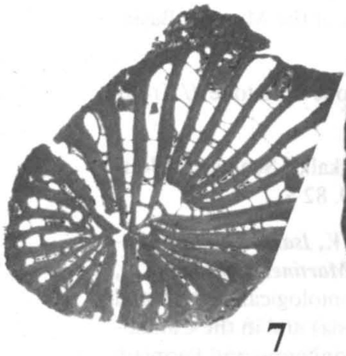
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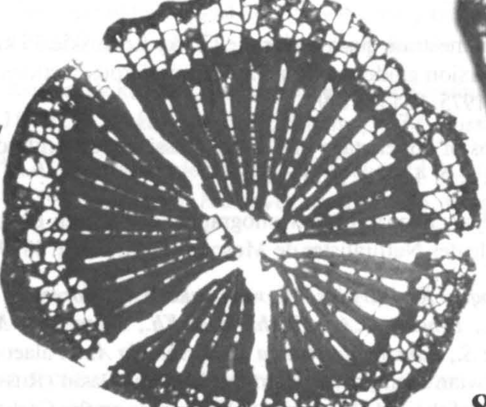
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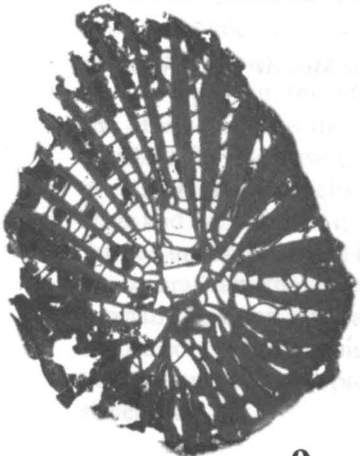
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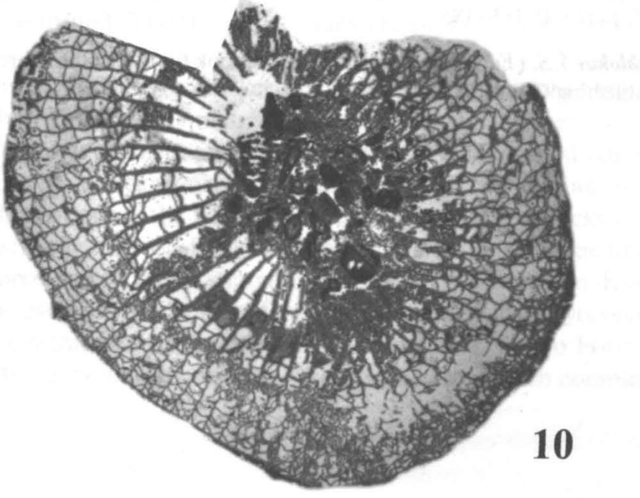
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Plate 5. Colonial Rugosa corals from the Domodedovo section. Collection is stored in Karpinsky Russian Geological Research Institute, Sankt-Petersburg. Figs. 1, 2. *Ivanovia* (*I.*) *freieslebeni* (Fischer): 1 – transverse section of colony; 2 – longitudinal section, specimen 1-94-0-7, lower part of the bed 8; Korobcheevo Formation. Fig. 3. *Petalaxis* (*P.*) *stylaxis* (Trautschold), specimen 94-0b-2, lower part of the bed 8; Korobcheevo Formation. Figs. 4, 5. *Cystophorastraea* aff. *molli* (Fischer): 4 – transversal section of the colony, 5 – longitudinal section, slightly off centre, specimen 1-94-0a-1, lower part of bed 8; Korobcheevo Formation; the specimen differs from specimens described by Dobrolyubova by shorter minor septa. Figs. 6, 7. *Ivanovia* (*I.*) *freieslebeni* (Fischer): 6 – transverse section of colony, 7 – longitudinal section, specimen 1-94-8-9, lower part the bed 8; Korobcheevo Formation. Figs. 8, 9. *Ivanovia* (*I.*) sp. 1. [= *Ivanovia* (*I.*) *freieslebeni* (Fischer) in Dobrolyubova, 1935, plate 5, fig. 1, 2]: 8 – transverse section of colony, 9 – longitudinal section, specimen 1-94-0-10, lower part of the bed 8; Korobcheevo Formation

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Plate 6. Solitary Rugosa corals from the Domodedovo section. Collection is stored in Karpinsky Russian Geological Research Institute, Sankt-Petersburg. Figs. 1, 2 *Bothrophyllum* aff. *trautscholdi* Stuckenberg: 1 – transverse sections, ×8; 2- longitudinal section, specimen 1-94-1-3a, lower part of the bed 8, ×8; Korobcheevo Formation. Corallite from the quasi-colony. Figs. 3–6. *Bothrophyllum* aff. *trautscholdi* Stuckenberg: 3 – transverse section of the calyx; 4 – longitudinal section, specimen 1-94-1-3b, lower part of the bed 8, ×8; 5 – transverse section of the young stage, ×10; 6 – longitudinal section, ×8, specimen 1-94-2, upper part of the bed 8; Korobcheevo Formation. Fig. 7, 8. *Bothrophyllum conicum conicum* (Fischer): 7 – transverse section of the young stage, specimen 1-94-2/5, ×4; 8 – transverse section of the young stage, specimen 1-94-2/6, ×4; upper part of the bed 8, Korobcheevo Formation. Figs. 9, 10. *Bothrophyllum* sp. 1: 9 – transverse section of the young stage; 10 – transverse section of the adult stage, specimen D-33, ×5; bed 33, Peski Formation

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August 12 • STOP 2

AFANASIEVO SECTION
NEOSTRATOTYPE OF KASIMOVIAN STAGE

A.S. Alekseev[1,4], N.V. Goreva[2], T.N. Isakova[2], O.L. Kossovaya[3]

[1] Moscow State University, Geological Faculty, Department of Paleontology,
119991 Moscow, Leninskie Gory, Russia. E-mail: aaleks@geol.msu.ru

[2] Geological Institute of Russian Academy of Sciences,
110017 Moscow, Pyzhevsky per. 7, Russia

[3] Karpinsky Russian Geological Research Institute,
199106 Sankt-Petersburg, Sredny pr. 74, Russia

[4] A.A. Borissiak Paleontological Institute of Russian Academy of Sciences,
117997 Moscow, Profsoyuznaya st. 123, Russia

The Afanasievo section is located approximately 90 km southeast of the Moscow and about 5 km southwest of the Voskresensk on the right bank of the Moskva River (Fig. 1). Geographical coordinates 55°16' N, 38°40' E. The quarry is about 2 km wide and total length of its scarp is more than 7 km and northern part is now recultivated. The studied sections are situated in the western part of the quarry.

At present, the Afanasievo section in the “Voskresenskcement” Quarry on the right bank of the Moskva River is the only section where the Krevyakinian and Khamovnikian substages are accessible. For this reason, this section selected as a neostratotype of the Kasimovian Stage (Makhlina et al., 2001a) that included the Suvorovo and Voskresensk formations of the Krevyakinian Substage and the Ratmirovo and Neverovo formations of the Khamovnikian Substage. These rocks were formed under the strong influence of glacio-eustatic sea-level fluctuations and main lithologic units are separated by the several palaeosol horizons and minor stratigraphic gaps. The Moscovian-Kasimovian transition interval at the Afanasievo section contains fusulinids, brachiopods, bryozoans, rugose corals, fish remains, ammonoids, ostracods, and conodonts. Also in the Neverovo Formation present such well-preserved paleontological rarities, as ophiuroids and asteroids with complete skeletons.

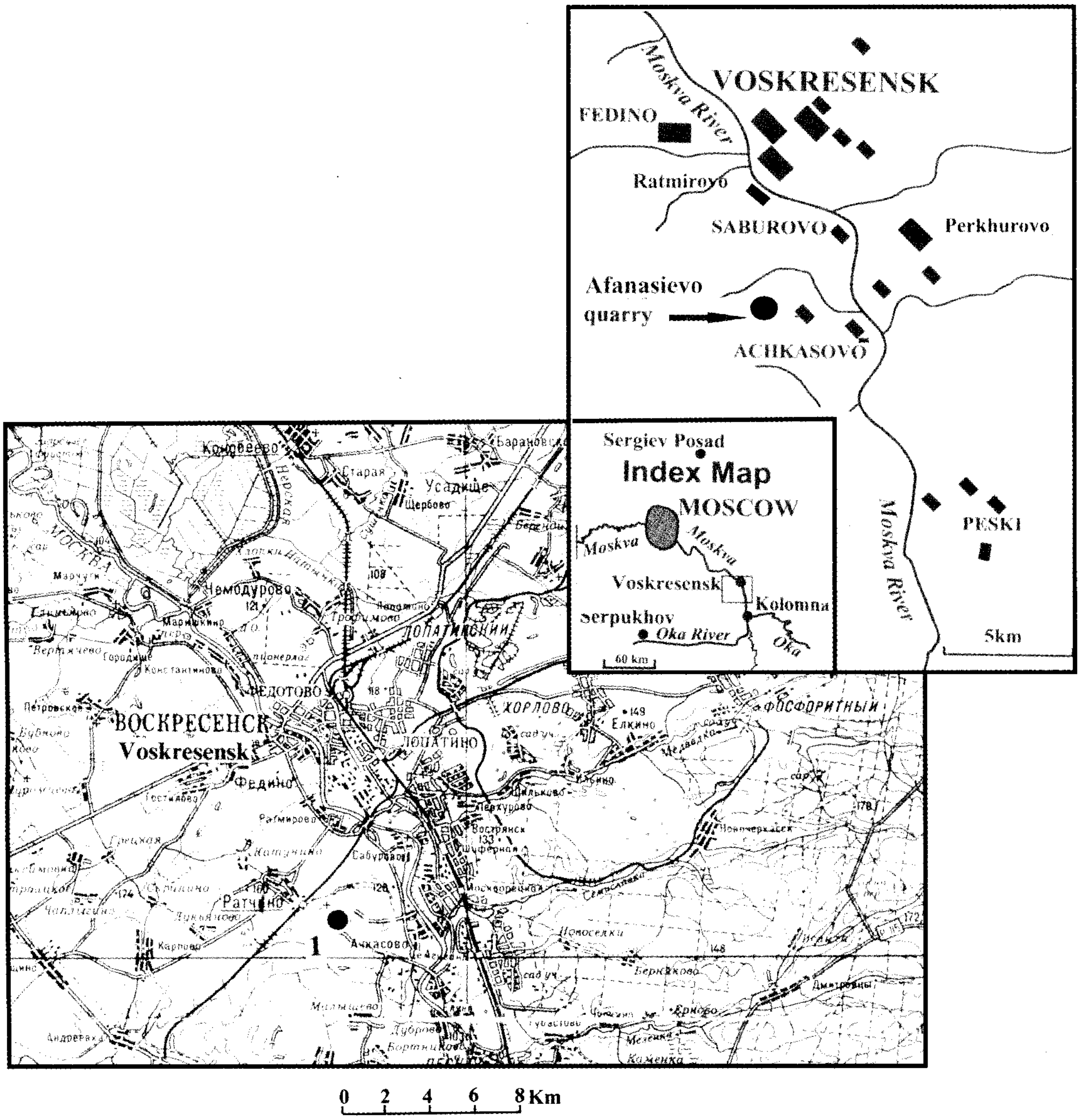


Fig. 1. Location of the Afanasievo section in the Moscow Basin

Historical review

The Kasimovian Stage was established by Ivanov (1926) under the name *Tegulifera* (later *Teguliferina*) Horizon (regional substage) as lowermost subdivision of the Upper Carboniferous (according to threefold Russian classification). Danshin (1947) have been replaced paleontological name into geographical Kasimovian Horizon and Teodorovich (1949) gave it the stage rank. The Kasimov is town on the Oka River in the Ryazan Region where Oka-Tsna Swell (uplifted tectonic structure) crossed by the river and shows Carboniferous deposits among younger rocks. A few outcrops of the Kasimovian strata were known during 1920–1940th in this area without detail description and paleontological publications. The type area of the Kasimovian Stage is lower stream of the Moskva River near the Voskresensk where rich fauna was described beginning of XIX century. But the stratotype formally was no designated by Ivanov, Danshin or Teodorovich.

The Kasimovian Stage was accepted as official stage of the Carboniferous System in the Soviet Union Stratigraphic Scale of 1951, withdrawn from it in 1962 and returned in 1974.

Numerous quarries existed around of the Voskresensk dounstream on Moskva River, they provided abundant paleontological material described in many publications, but most of them stopped their operations in 1970th. Ivanova and Khvorova (1955) published only composite section description for the Voskresensk area.

Only active quarry is Afanasievo now. Its columnar section and conodont distribution with illustrations of some conodont species were published by Barskov and Alekseev (1979). There are description of the Myachkovian and lowermost Kasimovian strata (Peski and Suvorovo formations) in Makhlina et al. (2001a), and illustrations of the fusulinids, conodonts, brachiopods, and bryozoans in Makhlina et al. (2001b). Davydov (1997) published fusulinid characteristics of the Afanasievo section together with illustrations of many taxa, but position of the studied samples to the detail lithostratigraphic subdivision accepted in this guidebook is not reliable. Alekseev and Goreva (2007) show conodont distribution in the Afanasievo section and Goreva et al. (2007) published summary of biostratigraphic works on this outcrop.

Section description

The succession at the Afanasievo section (Figs. 2, 3) starts with limestones of the uppermost Moscovian (Upper Myachkovian) Peski Formation (up to 5 m thick), which are overlain by 12 m of shallow-water carbonates of the Krevyakinian Substage (Suvorovo and Voskresensk formations) and the lower part (7 m) of the Khamovnikian Substage (Ratmirovo and basal, lower and middle parts of Neverovo formations). Fluctuations in sea level, as a result of glacial eustacy, influenced the deposition of this sequence; marine units are separated by minor stratigraphic gaps of uncertain durations, subaerial exposures, and palaeosol horizons.

The description given below has been compiled from data collected by Makhlina (1970 and 1971), Alekseev and Goreva (1993–2006), and Kabanov (1990–1998).

Moscovian Stage
Myachkovian Substage

Peski Formation

Lower Member

0. Clay, green in its lower part, but violet and black in upper part, fissile, with small limestone gravel, in some places dolomitized. The clay is overlay on the irregular top of the Domodedovo Formation limestone. Thickness up to 0.15 м.

1a. Dolomite massive, yellow, with moulds some fossils at the base. Thickness 0.4 m.

1b. Dolomite clayey violet and red. Thickness 0.6 m.

1c. Dolomite green-gray and yellow-gray, hard, contains sparse dissolution voids, with thin (2–3 cm) layer of the green clay in the top. Thickness is not constant, sometimes increase up to 1.1 m.

1d. Limestone, white and light-gray, bioclastic. Thickness 0.4 m.

1e. Limestone, light-gray, coarse-grained (grainstone), with abundant crinoid debris and fusulinid shells. Thickness 0.5 m.

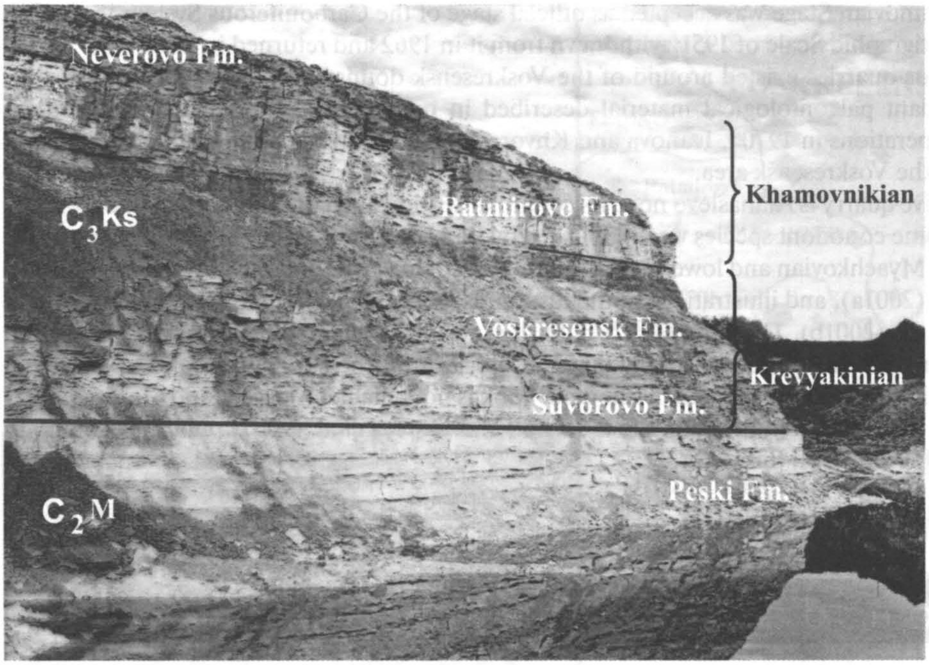


Fig. 2. Afanasievo quarry – neostratotype of the Kasimovian Stage, general view on the outcrop

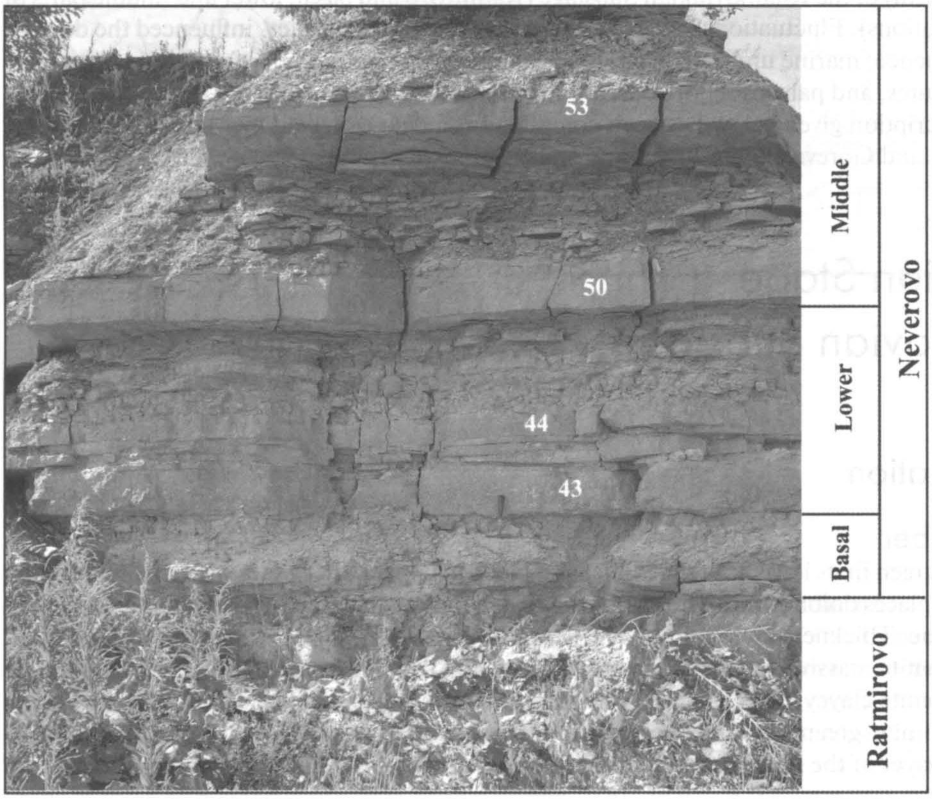


Fig. 3. Upper part of the Afanasievo section, uppermost Ratmirovo and Neverovo formations

Middle Member

2. Limestone, white and light-gray with a light greenish hue, massive, fine-grained, with crinoid ossicles, brachiopod shells, the foraminifers *Fusulinella* (?) – *Protriticites* (?) sp., *Fusulina* ex gr. *F. cylindrica* (Fischer emend Möller), *Hemifusulina stabilis* Rauser and Safonova and conodonts. Thickness 0.7–0.8 m.

3. Marl, green-gray, with thin interbeds of pink bioclastic marl and lenses of bioclastic limestone with echinoid spines. The conodont assemblage is the same as in bed 2. Thickness 0.15 m.

4. Limestone, light-gray, nearly white, finely porous, bioclastic, mostly crinoids with fine debris of brachiopod shells. In the upper part of the limestone there are clasts of recrystallized coarse-grained limestone. Limestone contains the foraminifers *Fusulinella* ex gr. *F. pseudobocki* Lee and Chen, *F. mosquensis* Rauser and Safonova, *Hemifusulina bocki mosquensis* Rauser, *Fusulinella*? sp., *Fusulina* sp., *Fusiella typica ventricosa* Rauser, *Ozawainella mosquensis* Rauser, *Oz. angulata* (Colani), *Oz.* aff. *Oz. palentina* Villa and Ginkel, *Eostaffella* sp. and the conodonts. Thickness 0.5 m.

5. Limestone, clayey, with interlayers of marl. Lower part of the limestone is green colored and upper part is brick-red. Limestone contains mostly crinoidal detritus, rare *Choristites* and productid shells (brachiopods), and echinoid spines. Lower boundary is indistinct and very gradual. The upper boundary is much clearer. The fusulinid assemblage includes *Fusulina mosquensis* Rauser, *F. quasicylindrica* (Lee), *F. pakhrensis* Rauser, *Fusiella praecursor* Rauser, *Schubertella gracilis* Rauser. Conodonts in this bed are rather abundant. Thickness 0.3 m.

6. Limestone, white with greenish tint, crinoidal, which includes the remains of the brachiopod *Choristites*, solitary corals, conodonts and the foraminifers *Fusulinella* ex gr. *F. bocki* Möller, *F. fluxa* Lee and Chen, and numerous *Ozawainella angulata* (Colani), *Oz.* aff. *Oz. palentina* Villa and Ginkel. Thickness 0.7 m.

7. Limestone, light-gray, massive, lumpy, contains brachiopods, crinoids, algae and foraminifer detritus. Lenses of limestone containing gastropods and brachiopods also present. The shells are replaced by chalcedony. The green-gray calcareous clay with abundant *Zoophycos* burrows is characteristic of the lower part of the bed. The thickness of clay varies from a few millimeters up to a few centimeters. Conodonts are not found. Thickness 0. 8 m.

Upper Member

8. Limestone, light-gray and gray, thin-bedded, often cross-bedded. Limestone includes rare brachiopod shells and crinoids fragments. A thin layer of green clay (up to 1 cm) marks the lower part of the bed. The upper part of the bed includes gray and yellow-brown siliceous concretions and dark-brown stromatolitic crusts. The top of the bed is intensively eroded, compacted and considerably brecciated in depressions in course of karstification. Thickness 0.4–0.5 m.

Kasimovian Stage
Krevyakinian Substage

Suvorovo Formation

Lower Member

9. Shale, calcareous, with green and brick-red spots. The clay includes pebbles and large (up to 10–15 cm) angular gray and dark-gray limestone blocks. The bed overlies a strongly eroded and karstified surface of cross-bedded limestone of the Upper Member of the Peski Formation. Thickness 0.05– 0.2 m.

10. Dolomite, yellow or light brown (the so called "Turaevo Dolomite") bearing small empty caverns. At the top it has a reddish color and becomes slightly clayey. Thickness 1.5 m.

11. Clay, purple-red, plastic, possibly calcareous, possessing gray spots. Thickness 0.02–0.05 m.

12. Limestone, light-gray, slightly greenish, crinoidal, bearing *Zoophycos* trace fossils ("Verkhozem"). Limestone includes the foraminifers *Protriticites subschwagerinoides* Rozovskaya, *Fusulinella* ex gr. *F. pseudobocki* Lee and Chen, *Fusulinella* (?) – *Obsoletes* (?) sp., *Fusulina kljasmica* Gryzlova, *Ozawainella* cf. *Oz. nikitovkensis* (Brazhnikova), *Oz. mosquensis* Rauser, *Schubertella mjachkovensis* Rauser, *Fusiella typica ventricosa* Rauser and the conodonts. Thickness 0.35 m.

13. Shale and marl, greenish-gray, containing interlayers of greenish-gray, partly coarse-grained, crinoidal limestone with brachiopod shells ("Garnasha"). The bed contains 4 such interlayers of 5–6 cm in thickness. Conodonts are abundant. The occurrence of *Adetognathus lautus* (Gunnell) is characteristic of the upper part of the bed. Thickness 1.95 m.

Upper Member

14. Limestone, white, and white-gray with vertical solution channels at the top. Limestone is weakly leached and bioclastic ("Sharsha"). The lower part of the bed is mudstone, clotted, and possesses a nodule-like structure. The limestone is penetrated by stylolites and solution cavities after gastropods and rare fine gray limestone pebbles also are present. Rare conodonts. Thickness is 1.15 m, but along the quarry it is reduced up to 0.6 m due to ancient erosion of its top.

In the other parts of the quarry, especially in the southwestern direction, nearly all strata between the top of the Peski Formation and "Sharsha" limestone are secondary dolomitized. The "Turaevo Dolomite" is not recognized here. The bed, which consists of clayey (red, yellow and green) dolomitic marls and dolomitic clay, is 4–4.5 m thick. Sometimes the middle part of the dolomite shows remnants of the original lithology without secondary changes. In a few other places the higher dome-like dolomite doms nearly reach the bottom of the "Sharsha" limestone. The depressions between dome-like dolomite bodies filled up the typical sequence of "Garnasha" is outcropped.

Voskresensk Formation

15. Conglomeratic marl, green-gray with red spots and numerous limestone pebbles that concentrated predominantly at the base of the bed. Bed 15 overlies an erosional surface on the top of the "Sharsha" limestone. Pebbles vary from the small and angular to large (up to 10 cm in the diameter) and rounded. The conodonts occur sporadically. Thickness 0.25 m.

16. Limestone, light-gray, medium-grained, rarely with pebbles of black limestone up to 1 cm in diameter. Some pebbles have a brown-gray color and reach 3–4 cm. In the upper part of the bed the limestone is more coarse-grained, very porous, with numerous internal molds of bivalves and gastropods. The rock is cut by thin (5 mm) vertical dissolution canals filled with greenish clay. Brachiopods are represented by the shells of *Enteletes* and *Neochonetes*. The conodonts are rare. The top of the bed is compacted and covered by black coating. Thickness 0.35 m.

17. Marl, greenish-gray clayey thin bedded. In some places it has been altered to a yellow-green plastic clay. The rock is more compact and calcareous in the upper part of the bed. Thickness 0.25 m.

18. Limestone, greenish-gray coarse-grained and gravelly, containing crinoidal fragments, fusulinids, and small pebbles of black and gray limestone. Rare large (up to 10 cm in the diameter) flattened pebbles of light-brown color also are present. In some areas the limestone becomes slightly clayey. Vertical burrows extending from above are filled in with green clay material. The fusulinid assemblage includes *Protriticites subschwagerinoides* Rozovskaya, *P. pseudomontiparus* Putrja, *P. formosus* Volozhanina, *P. longus* Volozhanina, *Fusulina mosquensis* Rauser, *F. quasicylindrica* (Lee), *F. pakhrensis* Rauser, *Quasifusulina longissima praecursor* Rauser and some forms similar to *Obsoletes* ex gr. *O. obsoletus* (Schellwien), *O. magnus* Kireeva, *Endothyra* sp., *Schubertella obscura compressa* Rauser, *Fusiella lancetiformis* Putrja. Among conodonts the *Idiognathodus trigonolobatus* Barskov and Alekseev has been distinguished. Thickness 0.1 m.

19. Clay purple-red, silty. At the bottom clay is plastic and greenish-gray. Silt admixture increases in the upper part of the bed. Conodonts are rare. The conodont *Swadelina makhlinae* (Alekseev and Goreva) appears at the middle part of the bed. Thickness 0.5 m.

20. Dolomitic marl, speckled, brick-red and light-brown, hard. The thin layers of greenish-gray silty marl with thickness up to 1 cm were found at two levels (15 cm and 30 cm above the base). Conodonts are rather abundant. Thickness 0.7 m.

21. Marl, speckled green and red, including lenses of clayey crinoidal limestone. Greenish-gray friable siltstone bearing echinoid spines occurs at the base of the bed. The latter is very enriched by conodont elements (more then 600 specimens/kg). Thickness 0.3 m.

22. Limestone, greenish-gray, thin-bedded, clayey with abundant *Zoophycos* trace fossils and conodonts. In its upper part the limestone contains numerous productid brachiopods shells. Thickness 1.2 m.

23. Clay, green and blue-green, thin-bedded, some interlayers are dolomitized, iron stained along the fractures. Very thin seams of the clayey limestone also were observed. Small burrows are filled with green and yellow iron stained material. Small crinoid columnals also are present. In the clay conodonts are numerous. Thickness 0.07–0.1 m.

24. Dolomite clayey. At the base dolomite is violet-red. The color changes into brick-red upwards. The dolomite is strongly iron stained, but the color is lighter in some parts. Small burrows occur in the dolomite. Thickness 0.4 m.

25. Shale silty, at the base (2–3 cm) it is greenish-gray, in the middle part – the color changes into purple-red. Clay is slightly dolomitic. The upper part of the bed consists of the gray clayey silt (5–7 cm). The uppermost part of the bed is represented by dolomitic marl (2–3 cm). Thickness 0.2 m.

26. Shale, brick-red, hard, calcareous. In the lower part of the bed the color is purple. Thickness 0.3 m.

27. Siltstone, green-gray, partly yellow-green, friable. Some parts are harder because of carbonate cementation. Thickness 0.02–0.05 m.

28. Shale, purple-red and brick-red, slightly dolomitic, sometimes with green spots. Thickness 0.6 m.

29. Siltstone, greenish-gray, spotted. Spots are dark colored. The lower and upper surfaces are rough. Conodonts are rare. Thickness 0.02–0.03 m.

30. Marl, clayey, brick-red, spotted. Conodonts are rare. Thickness 0.1 m.

31. Shale, brick- to cherry-red. In the middle the bed contains a thin seam of highly calcareous greenish-gray clay, which changes into clayey crinoidal limestone along strike. Conodonts are not numerous. Thickness 0.3 m.

32. Greenish-gray and brick-red shale. Three thin green-gray irregular traceable layers of coarse-grained limestone (from 2–3 to 5 cm) are observed within the shale. Conodonts are not numerous. Thickness 0.3 m.

33. Shale, brick-red and green-gray, spotted. Some layers are very silty. Shale includes thin lenses (up to 2 cm) of coarse-grained limestone containing crinoid and bryozoan bioclasts. Thickness 0.3 m.

Khamovnikian Substage

Ratmirovo Formation

34. Limestone, light-gray, nearly white, fine-grained. Lower part includes relatively abundant crinoidal bioclasts. Limestone usually is subdivided into 3 or 4 layers, with thickness near 10 cm each. Layer surfaces are emphasized by very thin seams of the green clay. Thickness 0.3 m.

35. Limestone, light-gray and nearly white, very fine grained, with a porcelain-like structure characterized by conchoidal fractures. Numerous fine gray dendrites of manganese oxides are developed along the fissures. Limestone includes both rare small crinoids and lens-like accumulations of various other bioclasts together with gastropod and bivalves molds and coral *Bothroclisia* sp. Very thin layers of green clay and subvertical canals 1 cm in diameter filled with green clay occur in the upper part of the bed. The vertical cracking has resulted in destruction of the bed and formation of isometric rock fragments. Thickness 0.8 m.

36. Limestone, light-gray and white, fine-grained, with porcelain-like structure. The limestone is similar to that of the underlying bed, but differs in the occurrence of distinct crinoidal lenses also containing gastropods and bivalves molds. Thickness of lenses is 5 cm and their length is up to 20 cm. Thickness 0.1–0.15 m.

37. Limestone, light-gray and nearly white, fine-grained with porcelain-like structure and earthy fracture. Limestone is cracked into numerous solution channels filled by green clay. A thin seam of green clay occurs at the bottom. Rare shells of pectinid bivalves and small dissolution caverns occur in the limestone. Thickness 0.15 cm.

38. Limestone, light gray and white, fine-grained, with small (near 1 mm) dissolution caverns, brecciated. Some fragments have a rough shape formed as a result of sub-vertical solution by canals usually free of sediment material. Some canals bear the inner longitudinal elevations which are similar to root imprints. Thickness 0.2 m.

Neverovo Formation

Basal Member

39. Limestone, light-gray or white, crinoidal, fine-grained, crossed by subvertical oblique canals filled with green clay. The contact with underlying bed is sharp and rough. The top of the bed is iron stained. Limestone includes *Montiparus paramontiparus* Rozovskaya, *Protriticites* transition to *Montiparus*, *Protriticites pseudomontiparus* Putrja, *P. subschwagerinoides* Rozovskaya, *P. subovatus* Bensh. Thickness 0.1 m.

40. Clay green, thin-bedded. In the upper part the clay grades into thin-bedded marl. Thickness 0.015–0.03 m.

41. Limestone, yellow-gray, slightly clayey, thin-bedded with earthy fracture. Thickness of layers is 3–5 cm. The depositional surface is emphasized by green clayey sediment. The limestone includes rare crinoidal bioclasts and tabulate and solitary rugose corals. The upper part of the bed bears *Zoophycos* trace fossils. Thickness 0.25 m.

42. Marl, light- to coffee-brown, thin bedded. A thin (2–3 cm) layer of green clayey marl occurs at the bottom. At about 10 cm upward from the bottom the marl includes small lenses of crinoid-brachiopod grainstone. Brachiopods are represented by *Neochonetes* shells. In the upper 10 cm the marl changes into yellow-gray medium-grained mostly crinoidal clayey limestone containing small fragments of brachiopods. Near the top of the bed the rock is cut by oblique solution canals 3–4 cm in diameter. The rock is often altered into dust. The bed contains *Montiparus paramontiparus* Rozovskaya, *Protriticites* transition to *Montiparus*, *Protriticites pseudomontiparus* Putrja, *P. subschwagerinoides* Rozovskaya, *P. subovatus* Bensh. Thickness 0.25 m.

Lower Member

43. Limestone, light-gray, hard, from coarse- to medium-grained. It crops out as a massive ledge, easily visible in the section. Gray limestone including rare large (up to 5 × 20 cm) pebbles at the bottom. In the upper part of the limestone there are fewer clasts of carbonate rocks. Limestone in this part is much more clay-rich and includes rounded crinoid fragments. Rare fusulinids were found: *Montiparus* (?) sp., *Protriticites subovatus* Bensh. Thickness 0.25 m.

44. Limestone, greenish-gray, slightly clayey, fine-grained, thin-bedded (thickness of the layers 2–7 cm). Brick-red calcareous clay separates the limestone layers. Some layers contain accumulations of crinoid fragments which increase in the middle part of the bed. Abundant carbonate rock clasts occur. An *Orthotetes* sp. shell (brachiopod) was found at the bottom of the bed. Thickness 0.2 m.

45. Limestone, light-gray, or sometimes slightly yellowish, massive. In the lower part it is medium-grained, containing mostly crinoid fragments. The upper part is fine-grained and practically without bioclasts. The upper surface is wavy and rough. Numerous oblique hollow canals with a diameter up to 7 mm extend down from the upper surface. The canal walls are iron stained and bear longitudinal ribbing. Sometimes canals extend to the bottom of the bed. Thickness 0.15 m.

46. Limestone, light-gray, slightly yellowish, thin bedded, fine-grained showing a conchoidal fracturing. Limestone looks as brecciated via numerous mostly vertical canals with stains of green clay. Thickness 0.15 m.

47. Limestone, yellow-gray, clayey, fine-grained, wavy-bedded with *Zoophycos* trace fossils. Thickness 0.1 m.

48. Shale, yellow or light-brown, thin-bedded, calcareous, containing lenses of more calcareous material. Thickness 0.05 m.

49. Limestone, light-gray, medium- to coarse-grained, mostly crinoidal with echinoid remains and shells of the brachiopod *Admoskovia ivanovorum* Lazarev. This limestone, which sometimes is subdivided into two layers, forms a traceable layer with a thickness of 5 to 10 cm. The limestone is overlain by brick-red clay with a greenish tint. The shale contains brachiopod shells of the same species. The shale is overlain by yellow-gray, medium- or coarse-grained fine-porous limestone possessing a large number of brachiopod shells. The limestone is pierced by burrows filled with green clay (from 0 to 5 cm). This limestone is overlain by a layer of brick-red shale with green spots. At the top the shale includes a thin (up to 5 mm) seam of gray fine-grained limestone (0.05 m). The total thickness of the bed 0.3 m.

Middle Member

50. Limestone, light-gray cropping out as a single prominent hard layer visible as an easily traceable cliff along the whole quarry. Three parts are recognizable: (1) a lower part (0.1 m) composed of light-gray limestone with a yellowish tint, containing lenses of crinoid fragments, brachiopod shells, scaphopod molds, and solitary rugose corals *Bothrophyllum conicum robustum* Dobrolyubova (up to 3–5 cm); (2) the main part of the bed composed of crinoidal wackstone grading into coarse-grained crinoidal grainstone with *Quasifusulina dagmarae* Putrja, *Q. longissima* (Möller), *Q. eleganta* (Shlykova) and (3) an uppermost part composed of thin-bedded, non-resistant clayey limestone bearing abundant *Zoophycos* trace fossils. Total thickness of the bed 0.3 m.

51. Limestone, greenish-gray, clayey, wavy-bedded, fine- and medium-grained. Clay is concentrated along the layer surfaces. *Zoophycos* trace fossils are abundant. The uppermost part is comprised of the seam of crinoidal grainstone. Thickness 0.15 m.

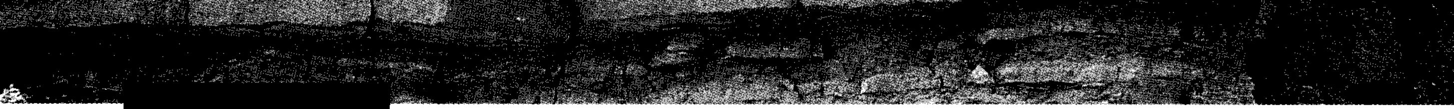
52. Shale, brick-red, with green spots and two layers of limestone. The lower layer is greenish-gray, coarse-grained, crinoidal with lenticular bedding. This limestone contains brachiopod remains (0.15 m). It is overlain by brick-red clay (0.1 m) containing abundant brachiopods including *Kozlowskia borealiformis* Lazarev, *Neochonetes carboniferus* Keyserling, *Enteletes* sp., and *Admoskovia* sp. The lower layer of limestone is light-gray and greenish, slightly clayey and thin-bedded. The lower part of this layer is more coarse-grained and contains crinoid fragments, but upward the rock becomes finer-grained. The second layer of limestone is light-gray and greenish, slightly clayey and thin-bedded. It contains crinoids in its lower part and becomes finer-grained upwards. The basal erosion surface of this (second) layer is rough. In the upper part the layer grades into clay (0.1 m). At the top there is light-brown clay containing thin (up to 1 cm) lenses of gray fine-grained limestone (0.1 m). Total thickness of the bed 0.75 m.

53. Limestone, light-gray, crinoidal, coarse-grained, easily visible as a separate layer. The size of grains decreases in the upper part of the bed. Rare tabulate corals are present. Among Rugosa *Bothrophyllum conicum robustum* Dobrolyubova and *Fomichevella* n. sp. 1 found. Thickness 0.25 m.

54. Shale, brick-red with green spots, includes thin seams of bioclastic tempestitic limestone with abundant brachiopods and bryozoans. The bed yields brachiopods *Enteletes* sp. and *Neochonetes* sp. and bryozoans. Thickness 0.15 m.

55. Limestone, greenish-gray coarse-grained. Rugosa corals *Bothrophyllum conicum robustum* Dobrolyubova, *Fomichevella* n. sp. 1 and *Bothrophyllum rareseptatum* occur in the bed. Thickness 0.05 m.

56. Shale, brick-red with green spots. Thickness 0.5 m.



57. Intercalation of greenish-gray coarse-grained limestones and brick-red clays. Limestone, gray and greenish-gray, coarse-grained, microporous, similar to "Gorokh". This rock includes a lot of rounded bioclasts. Large (1–2 cm) primary voids (?) are common. There are numerous *Enteletes* sp., and *Kozlowskia* sp. (brachiopods), *Montiparus montiparus* (Ehrenberg emend. Möller), *M. subcrassulus* Rozovskaya, *M. paramontiparus paramontiparus* Rozovskaya, *M.* ex gr. *M. umbonoplicatus* (Rauser and Belyaev), *Quasifusulina longissima* Möller, *Q. eleganta* Shlykova (fusulinids) and bryozoans in the limestone. Thickness 0.3 m.

58. Marl, yellowish light-brown, thin-bedded. Thickness 0.05 m.

59. Limestone, gray and greenish-gray, coarse-grained, similar to" Gorokh". Sometimes limestone is splitted up into two layers. Limestone contains *Montiparus montiparus* (Ehrenberg emend. Möller), *M. subcrassulus* Rozovskaya, *M. paramontiparus mesopachus* Rozovskaya, *M.* cf. *umbonoplicatus* (Rauser and Belyaev). Thickness 0.15 m.

60. Marl, greenish-light-brown and brown, thin-bedded, sometimes clotted. Thickness 0.1 m.

61. Limestone, greenish- and yellowish-gray, fine-medium-grained. Thickness 0.1 m.

62. Marl, yellowish-light-brown, with thin lenses of the bioclastic limestone. Marl contains rare shells of *Kozlowskia borealiformis* Lazarev (brachiopods). Thickness 0.3 m.

Biostratigraphical analysis

Fusulinids (Figs. 4, 5; Plates 1, 2). Twelve levels with fusulinids were distinguished. Most characteristic species are illustrated on Plates 1 and 2. A fusulinid assemblage containing *Hemifusulina* and rare *Fusulina* occurs in the Peski Formation. Stratigraphically upward this assemblage is replaced by frequent *Fusulina cylindrica* Fischer, *F. mosquensis* Rauser, *F. quasicylindrica* Lee, and forms of the *Fusulinella fluxa* (Lee and Chen) Group. Several morphotypes were considered as *Fusulinella* (?) – probable *Protriticites* (?) sp. (Plate 1, figs. A–C).

In the unified stratigraphic scheme for the Russian Platform, the Krevyakinian corresponds to the *Protriticites pseudomontiparus–Obsoletes obsoletus* Zone. The base is recognized by sharp changes in the fusulinid assemblage compared to the fusulinid assemblage of the Myachkovian. *Neostaffella* and *Hemifusulina* do not cross the Myachkovian/Krevyakinian boundary. The Suvorovo Formation contains a sparse fusulinid assemblage, which includes stratigraphically important genera and the species *Protriticites subschwagerinoides* Rozovskaya (Plate 1, fig. D) and forms identified as ?*Obsoletes* ex gr. *O. obsoletus* (Schellwien). This assemblage also contains species with a wide stratigraphic range, such as *Fusiella typica ventricosa* Rauser, *Schubertella gracilis* Rauser, and *Ozawainella mosquensis* Rauser.

The lower part of the Voskresensk Formation contains an abundant fusulinid assemblage characterized by typical forms of *Protriticites*: *Pr. pseudomontiparus* Putrya (Plate 1. fig. G); *Pr. formosus* Volozhanina (Plate 1, fig. J); *Pr. longus* Volozhanina, *Obsoletus magnus* Kireeva, and *O.* ex gr. *O. obsoletus* (Schellwien). It should be noted that some researchers (van Ginkel and Villa, 1999) do not regard *Obsoletes* as a valid genus.

Fusulinids of the Basal Neverovo (Khamovnikian Substage) are represented by a single assemblage at the bottom (sample 5-39, Fig. 3). Characteristic forms such as *Protriticites* [*P. pseudomontiparus* Putrja (Plate 1, fig. H), *P. subschwagerinoides* Rozovskaya, *P. subovatus* Bensh (Plate 1, figs. K, L)] are typical in wall structure. Rare forms with transitional wall structure from *Protriticites* to *Montiparus*, and a few *Montiparus paramontiparus* Rozovskaya discovered also (Plate 2, figs. N, O).

Among fusulinids, only *Protriticites subovatus* occurs in the basal part of the Lower Member of the Neverovo Formation. Numerous *Quasifusulina* [*Q. longissima* (Möller), Plate 2, fig. A; *Q. eleganta* Shlykova, Plate 2, fig. B; *Q. dagmarae* Putrja are predominating forms] and *Ozawainella* appear at the bottom of the Middle Member of the Neverovo Formation. *Montiparus montiparus*

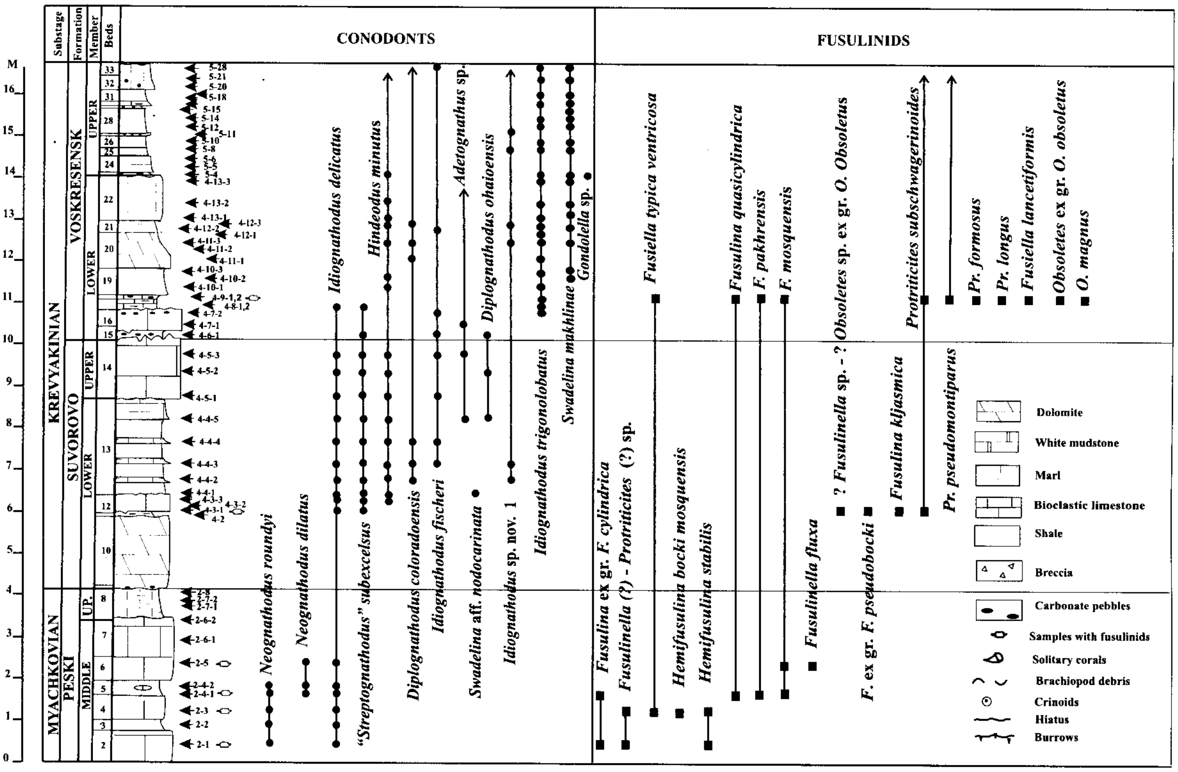


Fig. 4. Distribution of conodonts and fusulinids in the uppermost Moscovian and Krevyakinian interval at the Afanasievo section

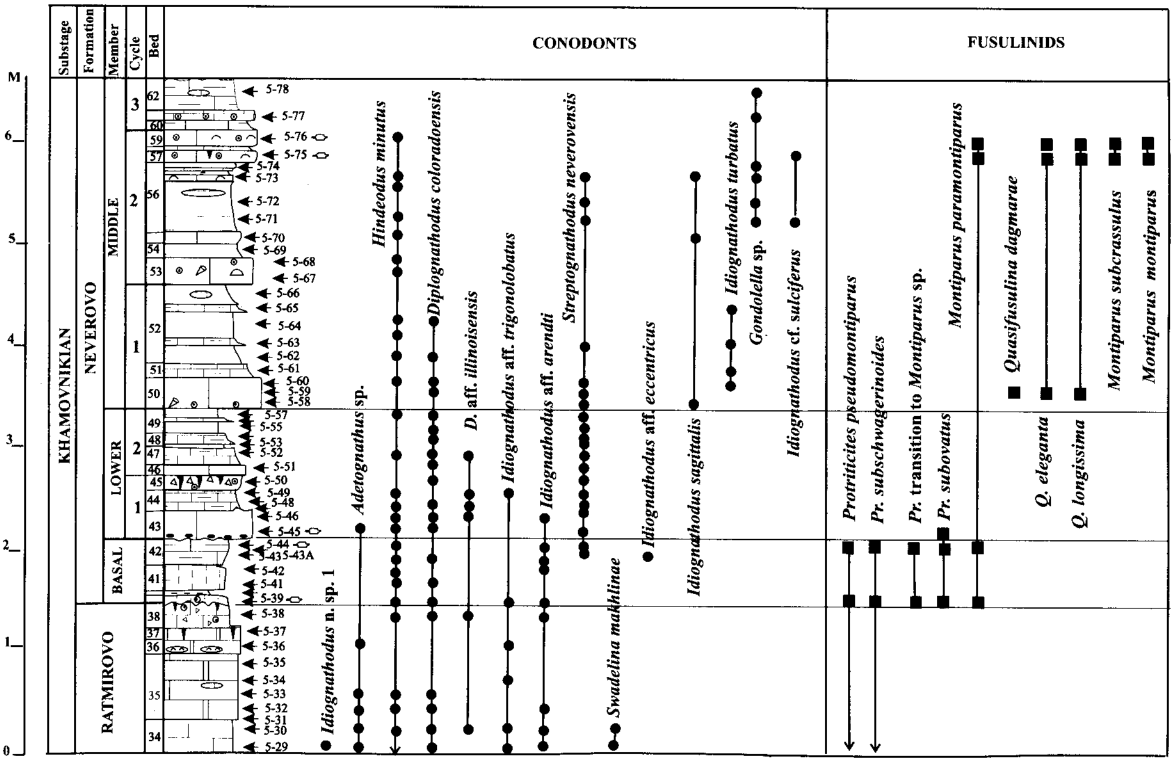


Fig. 5. Distribution of conodonts and fusulinids in the Khamovnikian interval at the Afanasievo section

Plate 1

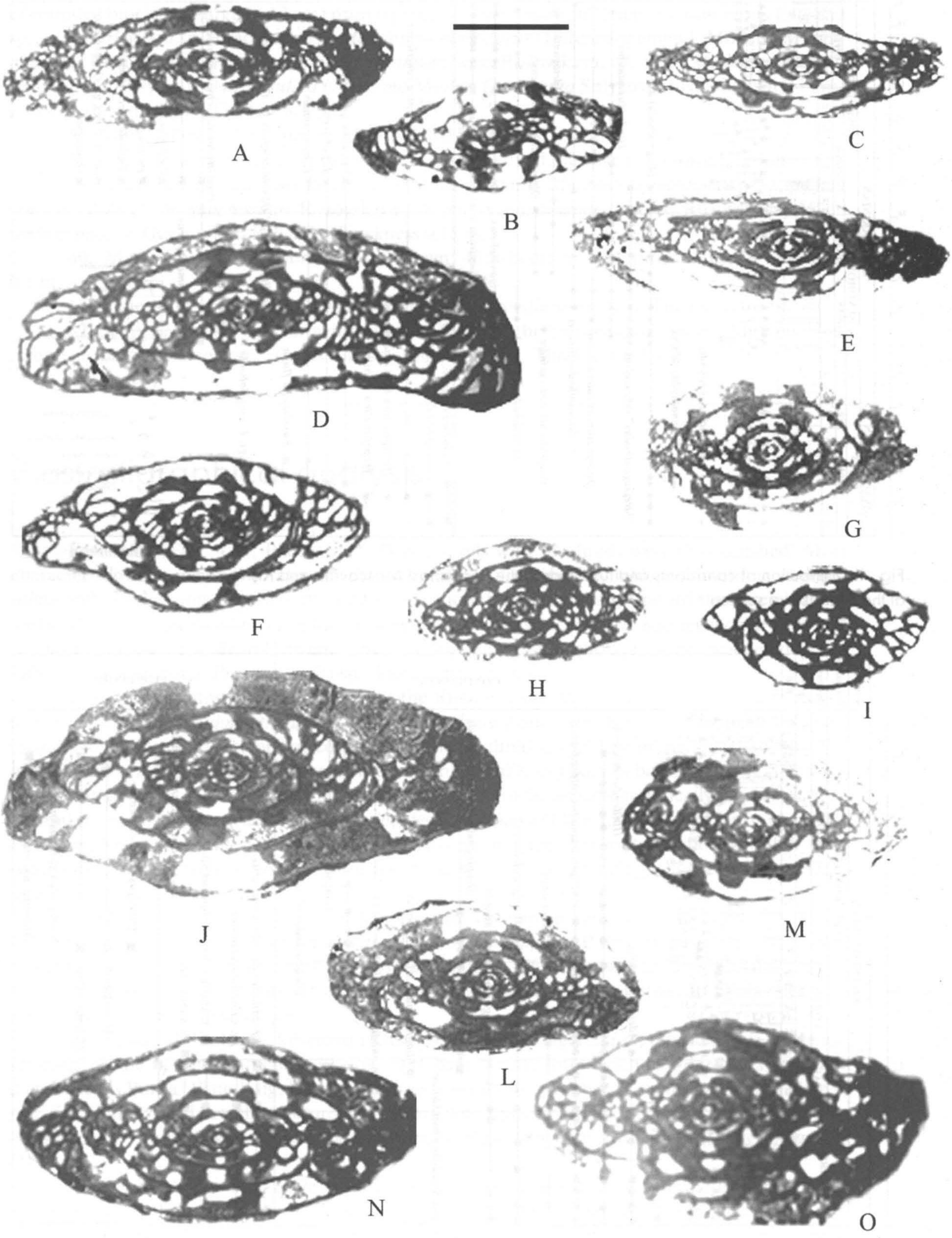


Plate 1. Fusulinids of stratigraphical importance from the Afanasievo section, scale bar represents 100 µm. Collection is stored in Laboratory of Micropaleontology, Geological Institute of Russian Academy of Sciences, Moscow. Figs. A–C. *Fusulinella* (?) sp. – *Protriticites* (?) sp.: A – sample 2-3; B, C – sample 2-1; Peski Formation. Fig. D. *Protriticites subschwagerinoides* Rozovskaya, sample 4-3-1; Lower Suvorovo Formation. Fig. E. *Protriticites longus* Volozhanina, sample 4-9-1; Lower Voskresensk Formation. Figs. F–I. *Protriticites pseudomontiparus* Putrja: F, I – sample 5-39; basal Neverovo Formation; G – sample 4-9-1; Lower Voskresensk Formation; H – sample 5-44; basal Neverovo Formation. Fig. J. *Protriticites formosus* Volozhanina, sample 4-9-1; Lower Voskresensk Formation. Figs. K, L. *Protriticites subovatus* Bensh, sample 5-39; basal Neverovo Formation. Fig. M. *Montiparus* sp., sample 5-44; basal Neverovo Formation. Figs. N, O. *Montiparus paramontiparus* Rozovskaya, sample 5-39; basal Neverovo Formation

(Ehrenberg emend. Möller) (Plate 2, fig. F) and *M. subcrassulus* Rozovskaya (Plate 2, figs. I, J, K, L, M, P, Q, R, S) occur 2.5 m above base of the Middle Member. *Montiparus* morphotypes are highly variable.

Conodonts (Figs. 4, 5; Plates 3, 4). A total of 115 samples were collected from this section for conodonts. Each sample weighed 2 to 5 kg. Seventy-two levels with conodonts were distinguished in the Afanasievo section, from the upper part of the Peski Formation (Moscovian) up to the middle part of the Neverovo Formation (Kasimovian). More than 11000 conodont elements were recovered, an average of 100–120 elements/kg.

The Middle Member of the Peski Formation contains typical late Moscovian condont assemblage of *Neognathodus roundyi* (Gunnell), *N. dilatus* (Stauffer and Plummer), and *Idiognathodus delicatus* s.l. Gunnell, but no conodonts in the Upper Member.

The conodont assemblage of the basal Krevyakinian is essentially different from the Myachkovian one. The difference is pronounced in the complete disappearance of *Neognathodus*, along with the appearance of *Streptognathodus* and *Swadelina* in the basal Krevyakinian. Conodont elements sharply increase in abundance in the Kasimovian relative to the Upper Moscovian, and may exceed 500 specimens/kg. The "Turaevo Dolomite" do not sampled in Afanasievo, but in Domodedovo section it contains "*Streptognathodus*" *subexcelsus* Alekseev and Goreva.

Characteristic species of the Suvorovo Formation are "*Streptognathodus*" *subexcelsus* Alekseev and Goreva (Plate 3, figs. A–D), *Idiognathodus fischeri* Alekseev and Goreva (Plate 3, figs. F, G), and rare *Swadelina nodocarinata* (Jones) (Plate 3, fig. E). The Voskresensk Formation is dominated by *Swadelina makhlinae* (Alekseev and Goreva) (Plate 3, figs. K–N) and *I. trigonolobatus* Barskov and Alekseev (Plate 3, figs. H–J). The appearance of *Gondolella* at the bottom of the upper part of the Voskresensk Formation reflects a short deepening episode. A very significant form was found in the upper part of the Suvorovo Formation, but it is more abundant and more advanced in the middle and upper parts of the Voskresensk Formation. We identified this form as *Idiognathodus* n. sp. 1 (Plate 4, figs. C–F). The stratigraphic distribution of these species allows establishment of two conodont zones: the lower one of "*S*". *subexcelsus* corresponding to the Suvorovo Formation and the upper one of *S. makhlinae* corresponding to the Voskresensk Formation (Alekseev and Goreva, 2000, 2007).

The assemblage of conodonts in the Ratmirovo Formation of the Khamovnikian Substage is sparse and includes mainly shallow-water *Adetognathus* along with *Hindeodus*, *Diplognathodus* and rare *Idiognathodus* aff. *I. arendti* Barskov and Alekseev and *Idiognathodus* aff. *I. trigonolobatus* Barskov and Alekseev. In the base of the Ratmirovo Formation, along with *Swadelina makhlinae* (Alekseev and Goreva) forms occur that looks similar to *Idiognathodus* n. sp. 1.

The lower part of the basal Neverovo Formation contains similar conodont assemblages. *Streptognathodus neverovensis* Goreva and Alekseev (Plate 4, figs. G, H, I, K) first appears in the uppermost basal Neverovo Formation. Along with abundant *Hindeodus* and *Diplognathodus*, there are forms similar to *I. arendti* Barskov and Alekseev, and *I. eccentricus* (Ellison). The Lower member of the Neverovo Formation contains abundant *Streptognathodus neverovensis* along with common *Hindeodus* and *Diplognathodus* and rare *Idiognathodus* aff. *I. arendti* and *Idiognathodus* aff. *I. trigonolobatus*.

The first appearance of *Idiognathodus sagittalis* Kozitskaya (Plate 4, figs. M) is fixed at the base of the Middle Neverovo Formation (bed 50), where it occurs with *Idiognathodus turbatus* Ross-

Plate 2

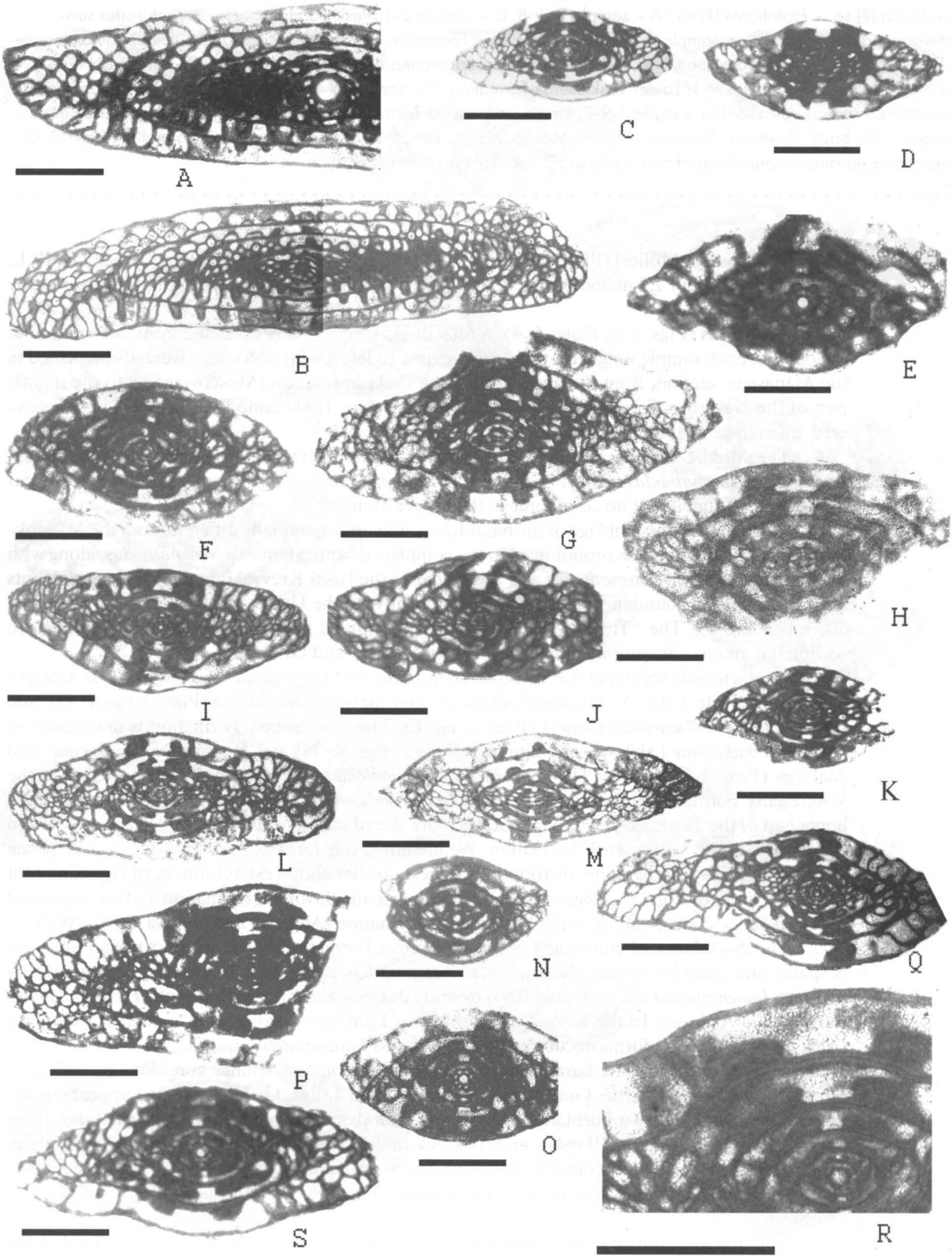


Plate 2. Fusulinids of stratigraphical importance from the Afanasievo section, scale bar represents 100 μm. Collection is stored in Laboratory of Micropaleontology, Geological Institute of Russian Academy of Sciences, Moscow. Fig. A. *Quasifusulina longissima* (Möller), sample 5-75; Middle Neverovo Formation. Fig. B. *Quasifusulina eleganta* Shlykova, sample 5-76; Middle Neverovo Formation. Figs. C–E. *Montiparus montiparus* (Ehrenberg emend. Möller): C–E – sample 5-76; F – sample 5-75; Middle Neverovo Formation. Fig. G. *Montiparus paramontiparus* Rozovskaya, sample 5-75; Middle Neverovo formation. Figs. H, N, O. *Montiparus* sp.: H, N – sample 5-76; O – sample 5-75; Middle Neverovo Formation. Figs. I–M, P–S. *Montiparus subcrassulus* Rozovskaya, sample 5-76; Middle Neverovo Formation

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coe and Barrick, 2009 (Plate 4, figs. L, O) and *Streptognathodus neverovensis*. The appearance of *Gondolella* in the upper part of the Middle Neverovo Formation reflects the progressive deepening of the marine basin. The stratigraphic distribution of these conodont species establishes *Idiognathodus sagittalis* Zone in this interval (Alekseev and Goreva, 2000, 2007). Also important event is occurrence of *Idiognathodus swadei* Rosscoe and Barrick in the upper part of the Middle Member (sample 5-74).

The appearance of *Idiognathodus sagittalis* has recently been proposed as one of the best index fossils for defining the base of the Kasimovian in the global stratigraphic scale (Villa and Task Group, 2005). A form that can be interpreted as the ancestor of *Idiognathodus sagittalis* (or *I. turbatus*) was found in the upper part of the Suvorovo Formation, but it is more abundant and more advanced in the middle and upper parts of the Voskresensk Formation. We identified these forms as *Idiognathodus* n. sp. 1 (Plate 4, figs. B, D–F). This lineage can be considered as a prospect for fixing the GSSP at the level of the first appearance of *Idiognathodus sagittalis*. It is significant that *Idiognathodus sagittalis* (as *I. delicatus*) and *Streptognathodus neverovensis* (as *S. elegantulus*) were found together in the Oeumri Formation of the South Korea (Park, 1996).

Macrofauna (Fig. 6; Plate 5). The studied interval of the Afanasievo section is also characterized by a diverse macrofauna of rugose corals, brachiopods, bryozoans, and other groups.

Rugose corals occurred at six levels. In comparison with the abundant early Myachkovian colonial corals of the Family Petalaxidae, the uppermost Myachkovian-Krevyakinian rugose assemblage is taxonomically impoverished. A sparse rugose assemblage in the Krevyakinian Substage includes only a few taxa that survived the diversity decrease during the late Myachkovian. Middle part of Suvorovo Formation contants rare specimens of *Bothrophyllum* n. sp. 1 originally described Dobrolyubova as *Bothrophyllum pseudoconicum* (Dobrolyubova, 1940, p. 32, plates 10–11). The well developed caninomorphic mature stages, wide zone of dissepiments together with long minor septa are the distinguishing features of a new species (Kossovaya, in progress). The Ratmirovo Formation and lower part of the Neverovo Formation contain rare specimens of Rugosa. A few corals *Bothroclisia* sp. 1 (Plate 5, figs. M–P) resembling *Bothrophyllum flexuosum* Dobrolyubova (Dobrolyubova and Kabakovich, 1948) were found in the upper part of bed 35 of the Ratmirovo Formation. Corals are more diverse in the Middle Neverovo Formation. *Bothrophyllum conicum robustum* Dobrolyubova, 1940 are rather abundant in beds 50, 53, and 55 of the Middle Neverovo Formation (Plate 5, figs. A–E). According to the original description this species was reported from the "*Teguliferina* Horizon" (Dobrolyubova, 1940, p. 30, plates VI–VIII). The diversity increases in the upper part of the Middle Neverovo Formation. In addition to *Bothrophyllum conicum robustum* Dobrolyubova, small forms of this genus are represented by *Bothrophyllum rareseptatum* Dobrolyubova (Plate 5, figs. K, L). The small quasi-colonies of *Fomichevella* sp. 1 (= *Campophyllum* aff. *parvulum* Dobrolyubova, 1948) often disintegrated into isolated corallites were also found in beds 53 and 55 (Plate 5, figs. F–J, Q, R). The main difference of the Neverovo *Bothrophyllum* assemblage in comparison with Myachkovian one is the progressive development of the "caninomorphic" features replacing the complex axial structure in the mature stages of corals. The assemblage found in the Neverovo Formation is also recognizable in the other occurrences in the Moscow basin (Medvedka River) and the Oka-Tsna Swell (Stsherbatovka section).

The Lower and especially Middle members of the Neverovo Formation are characterized by abundant and diverse brachiopod assemblages, but without typical Moscovian *Choristites sowerbyi* Fischer Group. *Admoskovia ivanovorum* Lazarev, *Neochonetes carboniferus* (Keyserling), *Kozlowskia*

Plate 3

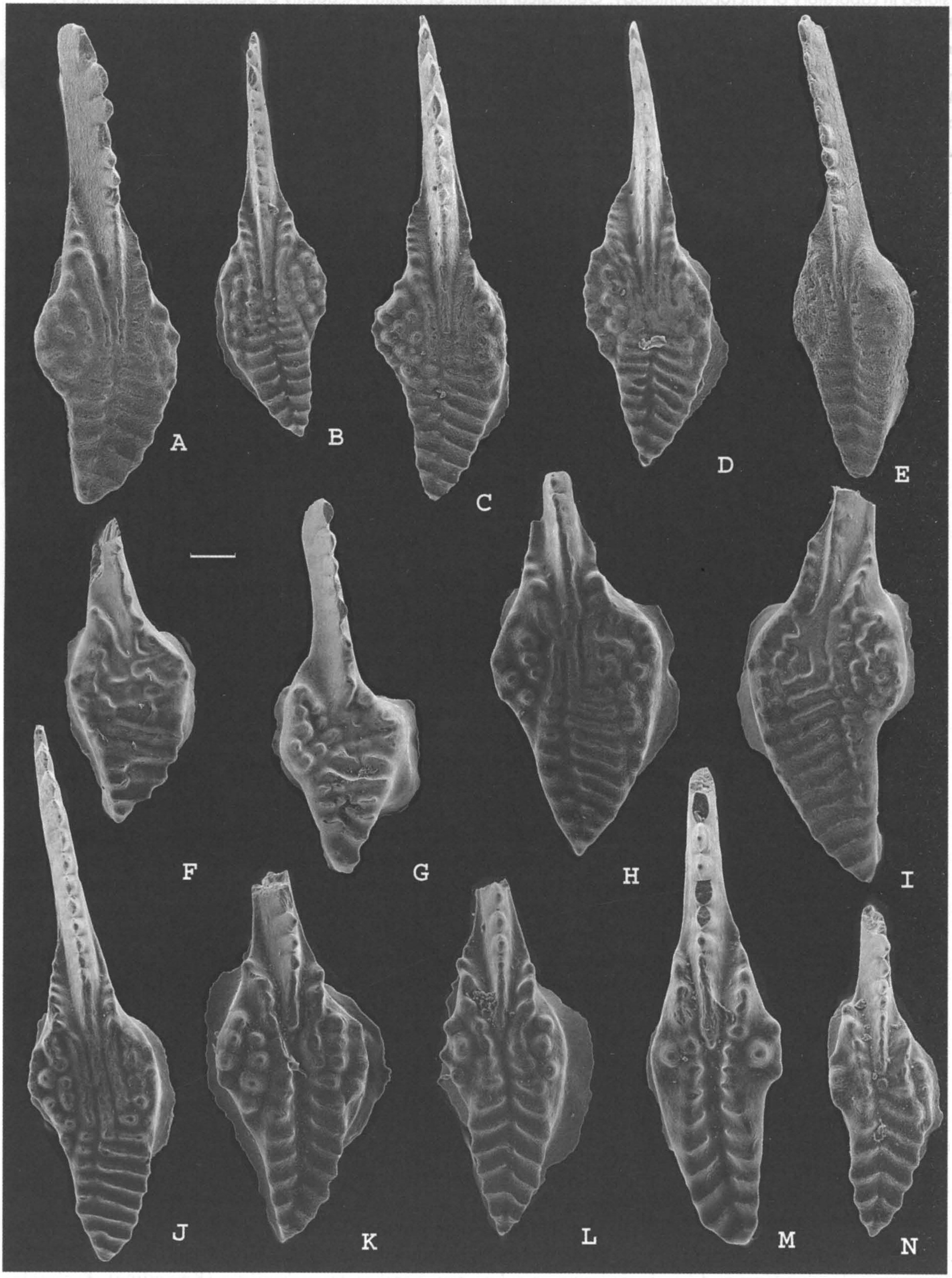

Plate 3. Pa conodont elements of stratigraphical importance from the Afanasievo section, scale bar represents 100 μm. Collection is stored in Department of Paleontology, Geological Faculty, Moscow State University. Figs. A–D. *"Streptognathodus" subexcelsus* Alekseev and Goreva: A, B – sample 4-3-3; C, D – sample 4-4-3; Suvorovo Formation. Fig. E. *Swadelina nodocarinata* (Jones), sample 4-4-1; Suvorovo Formation. Figs. F, G. *Idiognathodus fischeri* Alekseev and Goreva: F – sample 5-28; Upper Voskresensk Formation; G – sample 4-4-3; Lower Suvorovo Formation. Figs. H–J. *Idiognathodus trigonolobatus* Barskov and Alekseev: H, I – sample 4-9-2; J – sample 4-11-3; Voskresensk Formation. Figs. K–N. *Swadelina makhlinae* (Alekseev and Goreva): K – sample 5-4; L – sample 4-12-1; M, N. – sample 4-11-3; Voskresensk Formation

borealiformis Lazarev and other species were found in one meter above the base of the Lower Member of the Neverovo Formation.

R.V. Goryunova (Makhlina et al., 2001b) reported the bryozoans *Crustoporella alekseevi* Gorjunova, *Rectifenestella constans* (Shulga-Nesterenko) and *Polyporella martis* (Fischer) from the Voskresensk shales, and *Pseudorhabdomeson polygonium* Gorjunova and *Crustoporella sakharovensis* Gorjunova were collected at 0.5 and 4 m above the Neverovo Formation base (Fig. 4). Bryozoans are abundant in the Lower Kasimovian strata, but especially common in the Middle Neverovo Formation where large and fragile fenestellid skeletons sometimes cover depositional surfaces in shales by dense pavements.

Two ammonoid species, *Gonioglyphioceras gracile* (Girty) and *Eoschistoceras unicum* (Miller and Owen), were collected from the Suvorovo and the Ratmirovo formations respectively (Makhlina et al., 2001b; Shkolin, 1998).

Abundant ostracods occur at many levels in the Kasimovian shale intervals, but they were studied by Oderov (1998) and later by Strezh et al. (2006) only from some samples (Fig. 6).

Sequence analysis

Most of the formations are sequences of third order (cyclothems) with duration no less than 400 Ka. They separated by hiatuses of unclear time span and arid paleosol horizons. The especially prominent paleosols are in the tops of Peski and Suvorovo formations. The Ratmirovo Formation looks as lowstand system tract for transgressive and highstand Voskresensk Formation. However they are separated by disconformity without paleosol horizon and basal conglomerate. The Neverovo Formation consists of several sequences: basal, lower, and middle (Heckel et al., 2007). Each sequence begins with transgressive limestone and continues into highstand shales. These cycles are very clear in changes of conodont abundance – highstand intervals contain high concentrations of the conodont elements. The most important disconformity is at the base of Lower Member of the Neverovo Formation. The first appearances of *Idiognathodus sagittalis* and *I. turbatus* coincide with highstand intervals.

Chemostratigraphy

Data on oxygen and carbon isotope ratios derived from the Afanasievo carbonates are unsuitable because of diagenetic alteration during repeated changes of sea-level (W. Buggisch, personal communication). Minor cyclic variations in the oxygen isotope values from the phosphatic matter of conodonts reflect glacio-eustatic fluctuations (unpublished data by M. Joachimski et al.) and may be useful for distant correlations.

Plate 4

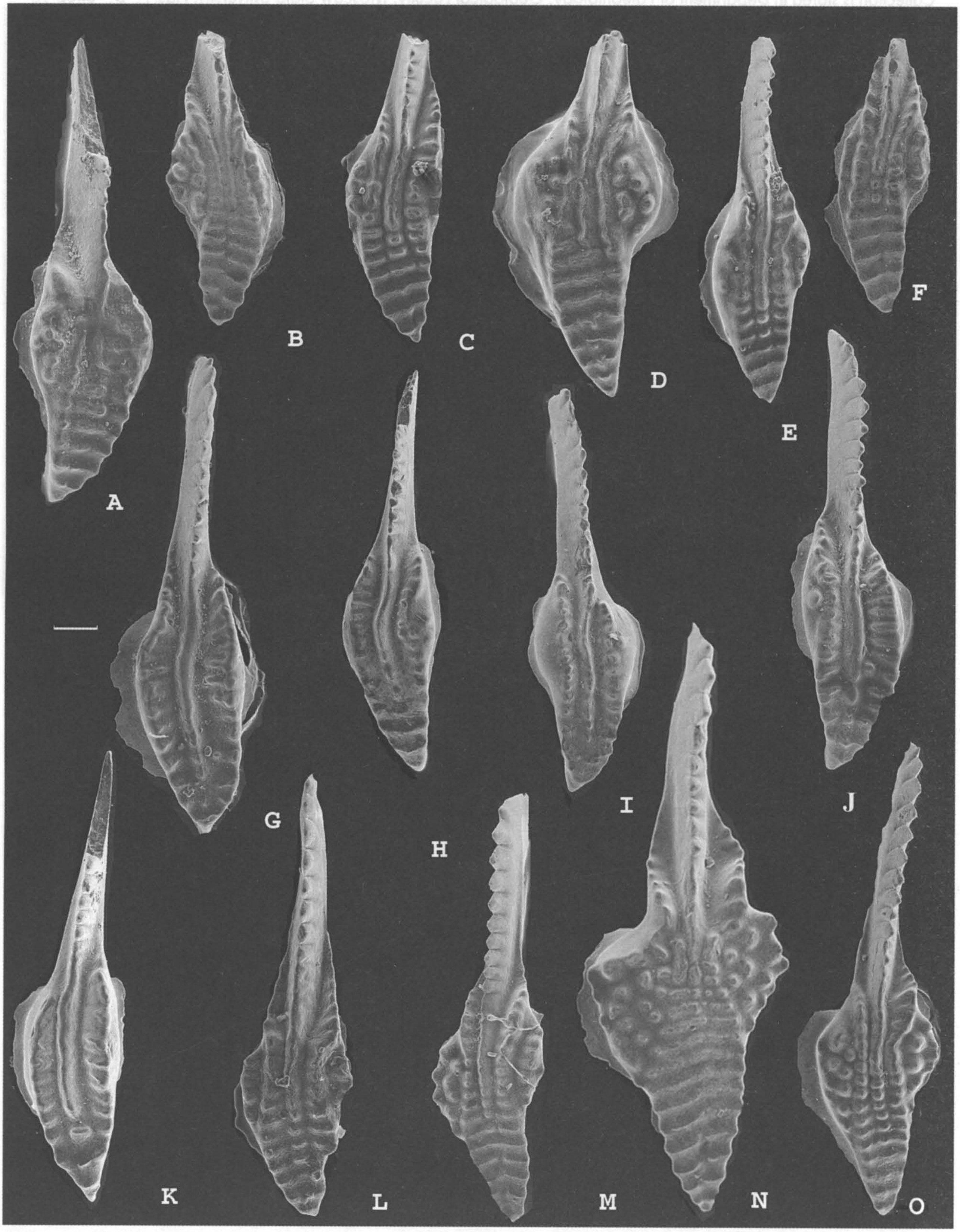

Plate 4. Pa conodont elements of stratigraphical importance from the Afanasievo section, scale bar represents 100 µm. Collection is stored in Department of Paleontology, Geological Faculty, Moscow State University. Fig. A. *Idiognathodus* aff. *I. eccentricus* (Ellison), sample 5-43; basal Neverovo Formation. Fig. B. "*Streptognathodus*" *subexcelsus* Alekseev and Goreva, sample 4-4-3; Lower Suvorovo Formation. Figs. C–F. *Idiognathodus* n. sp. 1: C – sample 5-12; Upper Voskresensk Formation; D – sample 5-8; Upper Voskresensk Formation; E – sample 4-11-3; Lower Voskresensk Formation; F – sample 4-12-2; Lower Voskresensk Formation. Figs G–K. *Streptognathodus neverovensis* Goreva and Alekseev: G – sample 5-48; H – sample 5-56; I – sample 5-54; J – sample 5-48; K – Sample 5-50; Lower Neverovo Formation. Fig. L, O. *Idiognathodus turbatus* Rosscoe and Barrick: L – sample 5-60; O – sample 5-61; Middle Neverovo Formation. Fig. M. *Idiognathodus sagittalis* Kozitskaya, sample 5-74; Middle Neverovo Formation. Fig. N. *Idiognathodus swadei* Rosscoe and Barrick, sample 5-74; Middle Neverovo Formation

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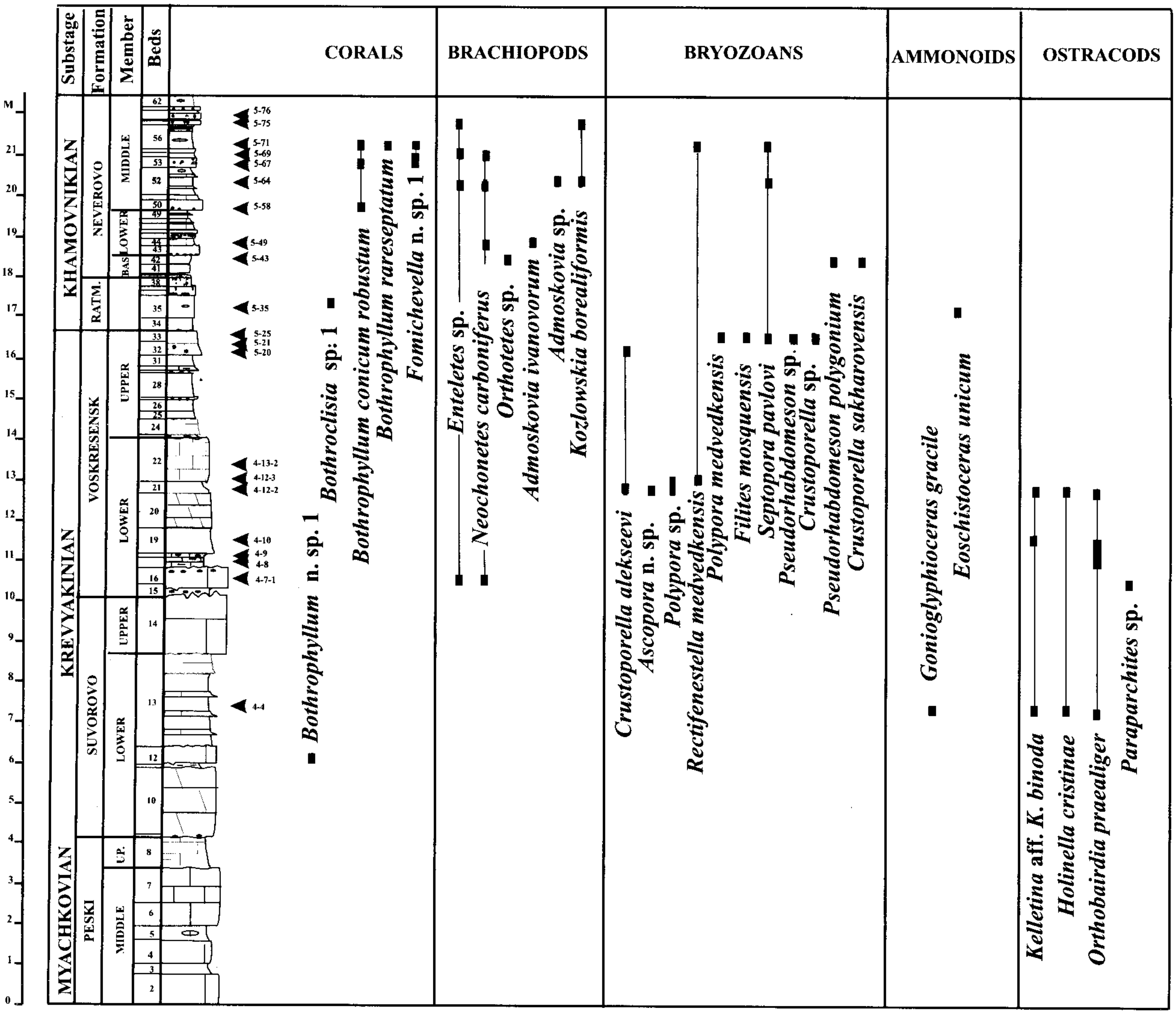

Fig. 6. Distribution of corals, bryozoans, brachiopods, ammonoids and ostracods at the Afanasievo section

Plate 5

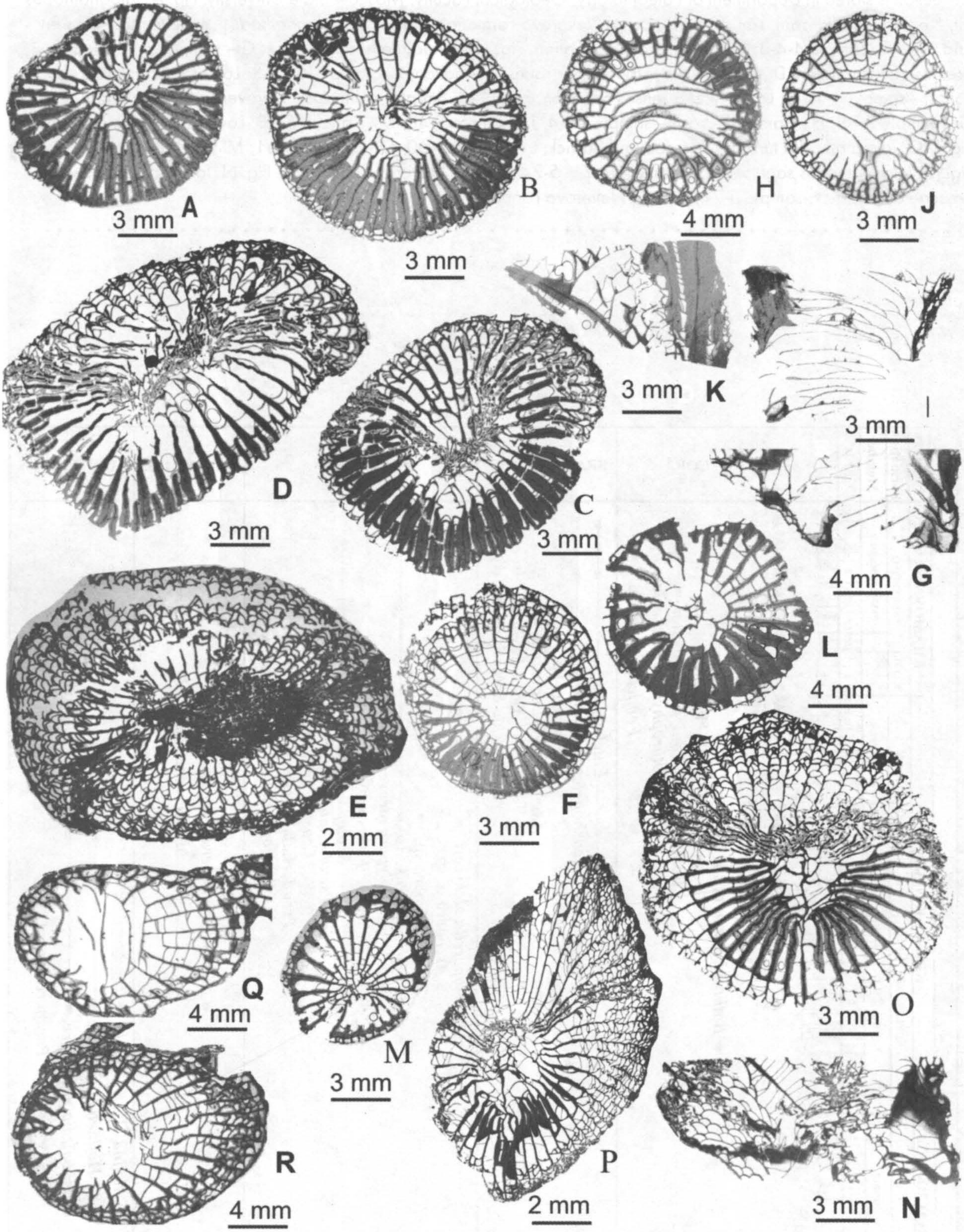
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Plate 5. Rugose corals from the Afanasievo section. Collection is stored in Karpinsky Russian Geological Research Institute, Sankt-Petersburg. Figs. A–E. *Bothrophyllum conicum robustum* Dobrolyubova: A, B – successive transversal sections of the late neanic stage; C–E – successive transversal sections of the mature stage, bed 55, specimen 5-21-3; Middle Neverovo Formation. Figs. F–J, Q, R. *Fomichevella* n. sp. 1: F – transversal section of the mature stage, G – longitudinal section, bed 57, specimen 5-23-3; H, J – transversal section of the mature stage, I – longitudinal section, bed 57, specimen 5-23-2; Q – transversal section of mature stage, bed 57, specimen 5-23-6; R – transversal section of mature stage, bed 57, specimen 5-23-10; Middle Neverovo Formation. Figs. K, L. *Bothrophyllum rareseptatum* Dobrolyubova: K – longitudinal section, L – transversal section of the mature stage, bed 57, specimen 5-23-5; Middle Neverovo Formation. Figs. M–P. *Bothroclisia* n. sp. 1: M – transversal section of the late neanic stage, N – longitudinal section, bed 35, specimen 5-35-1; O, P – successive mature stages, bed 35, specimen 5-35-2; Ratmirovo Formation

Comparison with other potential Kasimovian GSSP

No proposed GSSP sections for the Kasimovian Stage besides Afanasievo. The Afanasievo section can be considered as a possible candidate for the GSSP of the Kasimovian Stage. Advantages of this section are as follows: (1) geographic accessibility, (2) refined characterization by conodonts and fusulinids, and (3) diverse macrofauna and high potential for correlation with Eurasian sections. The disadvantages of this section are (1) shallow-water facies, (2) erosional unconformities of uncertain duration between all formations.

Conservation

The Afanasievo Quarry is active now and its authorities protect most important part of the quarry bench in non operating area where Neverovo formation with first appearances of conodonts *I. sagittalis*, *I. turbatus* and fusulinid genus *Montiparus* could be studied with easy.

Lower boundary of the Kasimovian

The position of the lower boundary of the Kasimovian in the type area has been the subject of numerous revisions (Makhlina et al., 2001a). In the late 1970th, the Middle-Upper Carboniferous boundary was established in the type region at the base of the Suvorovo Formation of the Krevyakinian Substage (top of the "Turaevo Dolomite", now lowermost Suvorovo). This level was conventionally placed at the base of the fusulinid Zone *Protriticites pseudomontiparus–Obsoletes obsoletus*, which is the lower zone of the Upper Carboniferous in Russia, and was firstly distinguished by Semikhatova (1947) in Donskaya Luka as the "sub-*Triticites*" beds. Intense studies during the last decade have been made: (1) to define event markers for the lower boundary of the Kasimovian, (2) to locate sequences where reliable phylogenetic successions were preserved, and (3) to find where a GSSP for this boundary could be established.

It was discovered that the conodont *Idiognathodus sagittalis* has a high potential for the recognition and correlation of the lower boundary of the Kasimovian. The short range and worldwide dis-

tribution of this species make its first appearance a good marker for the boundary. *I. sagittalis* occurs in the Donets Basin (Ukraine) (Kozitskaya et al., 1978), Moscow Basin and South Urals (Russia) (Alekseev and Goreva, 2007), Cantabrian Mountains in Spain (= *Idiognathodus* aff. *sagittalis*, pl. 2, fig. 16 in Méndez, 2002), northern Canada (= *Idiognathodus* aff. *claviformis* Gunnell, pl. 22.1, figs. 5, 6 in Orchard, 1984), South Korea (= *Idiognathodus delicatus*, figs. 4.1, 4.2 in Park, 1996), and South China (Wang and Qi, 2002). The distinctive morphological characters do it easy to be identify. At the Afanasievo section it appears first in the base of the Middle Member of the Neverovo Formation (mid Khamovnikian), i.e. much higher than the base of the Kasimovian that was established in the USSR in 1971.

The supposed ancestor of *I. sagittalis* appears in the Suvorovo Formation and similar morphotypes become relatively abundant and more advanced in the Lower and Upper members of the Voskresensk Formation. We named it as *Idiognathodus* n. sp. 1. This evolutionary line is promising for establishing the GSSP at the level of first appearance of *I. sagittalis*. If this species will selected as a marker, the Kasimovian base will be approximately coincident with the first appearance of the fusulinid genus *Montiparus*.

We thought that *Idiognathodus* sp. nov. A (Barrick et al., 1996) is the same or very close species to *Idiognathodus sagittalis*. Recently Rosscoe and Barrick (2009) named this taxon as *Idiognathodus turbatus* and do not recognized *I. sagittalis* in the American collections. However holotype of *I. sagittalis* is right element, in original description only few specimens figured that born some difficulties in the identification. By our opinion, *I. turbatus* also present in the Moscow Basin (Plate 2, fig. L) and South Urals lowermost Kasimovian conodont assemblages (as some morphotype previously identified as *I. sagittalis*) and could be considered as the alternative marker for the base of the Kasimovian Stage.

The Task Group to establish the Moscovian and Kasimovian and Kasimovian-Gzhelian boundaries (Villa and Task Group, 2008) reached agreement to focus work on *Idiognathodus sagittalis* Kozitskaya and *I. turbatus* Rosscoe and Barrick as potential biostratigraphic markers of the base of the Kasimovian. The Afanasievo section can be considered as a possible candidate for the GSSP of the Kasimovian Stage because both discussed conodont taxa occur together with fusulinid *Montiparus*.

Acknowledgment

The description of the Afanasievo section was corrected and updated with financial support from the Russian Foundation for Basic Researches, projects 06-05-64783 and 08-05-00828.

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August 12 • STOP 3

GZHEL SECTION

STRATOTYPE OF THE GZHELIAN STAGE

A.S. Alekseev[1,4], N.V. Goreva[2], T.N. Isakova[2], O.L. Kossovaya[3],
S.S. Lazarev[4], A.E. Davydov[4]

[1]Moscow State University, Geological Faculty, Department of Paleontology,
119991 Moscow, Leninskie Gory, Russia. E-mail: aaleks@geol.msu.ru

[2]Geological Institute of Russian Academy of Sciences,
110017 Moscow, Pyzhevsky per. 7, Russia

[3]Karpinsky Russian Geological Research Institute,
199106 Sankt-Petersburg, Sredny pr. 74, Russia

[4]A.A. Borissiak Paleontological Institute of Russian Academy of Sciences,
117997 Moscow, Profsoyuznaya st. 123, Russia

The Gzhelian Stage – one of the seven stages of the Carboniferous system – was named by Nikitin in 1890 and became in 1951 by official stage in the General Stratigraphic Chart of the USSR. The Gzhelian Stage is subdivided into four regional substages. They are (from below) Dobryatinian, Pavlovoposadian, Noginskian, and Melekhovian. Each of these substages is corresponded to one provincial or local fusulinid zone and several zones on conodonts.

The lithostratigraphic subdivision of the Gzhelian in the southern part of Moscow Syneclise (or Moscow Basin) was created by Danshin (1947). Ivanova and Rozovskaya (1967), and later Makhlina et al. (1979) published more complete description of Gzhelian lithostratigraphy. In the type region the lower lithological boundary of the stage was marked at top of the variegated shales and dolomites of the Troshkovo Formation (Dorogomilovian) or between *Triticites* (*Triticites*) *irregularis* – *T.* (*T.*) *acutus* and *Triticites* (*T.*) *rossicus* – *Triticites* (*Rauserites*) *paraarcticus* zones (Makhlina et al., 1979).

The historical stratotype of the Gzhelian is located in the Ramenskoe District of the Moscow Region nearby the railway station Gzhel between Rechitsy and Troshkovo villages. Only lower part of the stage is outcropped here. However the formal lower boundary of the stage is not visible in the quarry and its characteristics is available only from reference borehole 6k and other wells drilled in this area (Makhlina, 1975).

Historical review

In 1890 outstanding Russian geologist S.N. Nikitin subdivided the upper part of the Carboniferous in the Moscow Basin into two stages – Moscovian (lower) and Gzhelian (upper). In contrast with the contemporaneous terrestrial coal-bearing succession of the Western Europe the Gzhelian strata in the Moscow Basin are the marine carbonates with abundant fossils and they traceable in far distance around the East European Platform and in other regions of the World. Gzhelian Stage was based by the occurrence of the specific assemblage of macrofossils (mainly brachiopods) found in the layers outcropped in the small quarries existed at the end of the XIX century near the Gzhel and Rusavkino villages and studied by Nikitin (1890b). This site is located in the south-east from the Moscow within the south limb of Moscow Syneclise. The series of outcrops in the quarries near the Rechitsy Village is considered as a Gzhelian stratotype. Here Nikitin (1890a, site 508, p. 148) observed "brown-yellow clayey dolomite limestone alternating with the layers of sandy marl of the same color and containing the abundant fauna specific for Moscow Basin". In the more western quarries this limestone (2 m) is underlined by the white dense limestone with visible thickness near 2 m. Similar characteristics to this section was later given by Danshin (1947, p. 211–212), Smirnov (1930, p. 125), Ivanova and Khvorova (1955, p. 209–212), V.A. and A.A. Aprodov (1963). Danshin attributed these strata to Rusavkino Formation of the *Omphalotrochus* Horizon (old name for the Gzhelian). The most comprehensive description of stratotype was done by Makhlina and Ivanova (1975) in the field trip Guidebook published to the VIII International Congress on Carboniferous Stratigraphy and Geology.

Ivanova and Rozovskaya (1967) raised the rank of the Rusavkino Formation to regional substage, but later the latter was renamed into Rechitsian Substage (Makhlina et al., 1979). The name Rusavkino was considered as belonging to formation. In Unified Chart of the Carboniferous of the Russian Platform (Kagarmanov, Donakova, 1990) the name Rechitsian was replaced by Dobryatinian, because it joined the previously separate Rechitsian and Amerevian substages belonging to the single fusulinid zone.

Based on the recent drillings within the territory of the Moscow City (Alekseev et al., 1998) and investigation of the Rusavkino section it was discovered that the Rusavkino Formation consists of five lithological units. Some of these units are separated by hiatuses of unknown duration. These five units are grouped into three members. The Lower and Middle members of the Rusavkino Formation are constituted by shallow-water limestones and clays which is overlaid by white mudstone showing an erosion surface at the top. The Upper member (unit 5) overlays the middle one with distinct disconformity.

In December 2007 the International Subcommission on Carboniferous Stratigraphy accepted the decision on the establishing of the lower boundary of the Gzhelian Stage at the level of the first appearance of the conodont *Idiognathodus simulator* (s.s.) (Villa and Task Group, 2007; Heckel et al., 2008; Villa et al., 2009). In the Moscow Basin this event was established in the lower part of the Upper Member of the Rusavkino Formation (unit 5), in 5–6 m (Moscow City) and 14 m (Gzhel) above the traditional boundary of the Kasimovian and Gzhelian stages (Alekseev, Goreva, 2007).

Section description

The Gzhelian stratotype is a part of the old quarry scarp with height of 5–6 m located in to the west from the Rechitsy Village near by the railway station "55th km". Geographical coordinates are 55°36'38.8" N, 38°25'22.9" E (Fig. 1). The absolute altitude of the bottom of section is about 132 m. In the northern wall of the quarry in the distance of 50 m there is the outcrop of upper part of the Rusavkino Formation (Fig. 2).

Fig. 2. General view of the Gzhel section. Sharp erosional boundary between white mudstones (unit 4 of the Rusavkino Formation) and yellow-brown dolomites and limestones (unit 5 of the Rusavkino Formation)

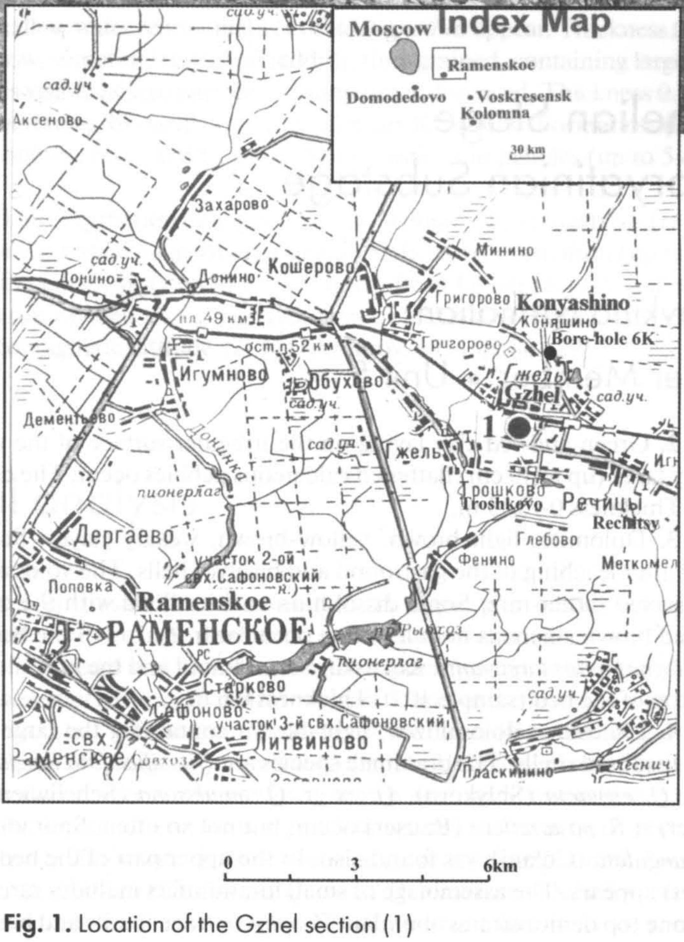

Fig. 1. Location of the Gzhel section (1)

Kasimovian Stage
Dorogomilovian Substage

Rusavkino Formation

Middle Member • upper part • Unit 4

1. Limestone, white, fine-grained (mudstone) porcelain-like at the top, with stylolites. The limestone is strongly fractured and contents varicolored chert nodules of predominant spherical shape (up to 15 cm in diameter). Scarce brachiopods, gastropod moulds, and rather numerous silicified solitary rugose corals occur in this bed. Conodonts *Streptognathodus firmus* Kozitskaya and *S.* aff. *S. vitali* Chernykh, *Hindeodus minutus* (Ellison) were found in the lower part of the limestone. Visible thickness is up to 2 m, but the lower part of the bed is covered by debris. Makhlina and Ivanova (1975) estimated the thickness of her beds 1 and 2 as equal to 2.8–3.0 m. The borehole 95 drilled in few hundred meters to the west from Gzhel outcrop showed 2.7 m for bed 1. In old quarry which was active in 1960th and 1970th and situated southward of the Gzhel railway station the visible thickness of the white limestone reached up 3.2 m. In the Rusavkino section (22 km to the north-west from Gzhel) white limestone of bed 1 has thickness less than 1 m and in some sites wedge out completely as a result of erosion during major sea level fall marked by residual clay of the bed 2.

Gzhelian Stage
Dobryatinian Substage

Rusavkino Formation

Upper Member • Unit 5

2. Green and red clay laying on the irregular surface of the white limestone. Sometimes in the clay large (up to 10 cm) flattened calcareous pebbles occur. The clay blows out laterally along the strike. Thickness 0–0.15 m.

3. Dolomite, light-brown, yellow-brown, weakly clayey. Some levels content cavities appeared after leaching of the gastropod and bivalve shells. The voids after fusulinid shells dissolution are observed rather rare. Some dissolution cavities filled with the calcite and quartz crystals. The flattened brown siliceous nodules often occur near the top of the bed. Conodonts *Adetognathus* sp. and *Idiognathodus toretzianus* Kozitskaya were found and the juvenile specimen of *I. simulator* occur at the top of the bed (sample 103). Thickness 0.6 m.

4. Limestone dolomitized, light-brown containing the large amount of the large and easy visible fusulinid shells. The dominate species are *Quasifusulina longissima* (Möller), *Q. ultima* (Kanmera), *Q. eleganta* (Shlykova), *Q.* ex gr. *Q. tenuissima* (Schellwien). Also *Rauserites paraarcticus* (Rauser) и *R. postarcticus* (Rauser) occur, but not so often. Sporadic *Ozawainella* sp., probably, ex gr. *O. angulata* (Colani) was found also. In the upper part of the bed single *Rauserites* sp. (*R.* aff. *R. rossicus*) appears. The assemblage of small foraminifers includes rare *Textularia* and *Tuberitina*. The limestone top demonstrates abundant *Zoophycos* trace fossils and brachiopod shells. The conodonts in this bed are numerous: *Idiognathodus toretzianus* Kozitskaya, *Streptognathodus pawhuskaensis* (Harris and Hollingsworth) and *Idiognathodus simulator* (Ellison). Thickness 0.5 m.

5. Limestone, yellow-gray with visible green glauconite grains and numerous conodont elements of *Streptognathodus pawhuskaensis* (Harris and Hollingsworth), *Idiognathodus tersus* Ellison, *I. simulator* (Ellison). Among them the deep-water genus *Gondolella* appears. Foraminifers are rare and their assemblage includes *Quasifusulina* sp. (*Q.* ex gr. *Q. longissima*), *Ozawainella* sp., *Textularia* sp. Thickness 0.1 m.

6. Limestone, yellow-gray, bioclastic, weakly dolomitized. The abundant elongated and curved light-gray and brown siliceous concretions with white cover are typical for this bed. Their diameter is 5—7 cm. The concretions are orientated mainly sub-vertically and resembles the fillings of the burrows. Sometimes the thin (up to 1cm) layer of green clay is visible at the bottom of limestone. Abundant conodonts are represented by the same species as in the bed 5. In the upper part of the bed the spicules of the siliceous sponges appear. Thickness 0.4 m.

7. Yellow-brown marl and clayey limestone with characteristic wave-like bedding. It contents numerous silicified brachiopods, bryozoans, and corals. The spicules of siliceous sponges found in the rock show the often aggregation in bunches. Because of the subsistent amount of spicules the rock can be called by spiculite. This spiculitic (equivalent of beds 7 and 8) event traced from north vicinity of the Moscow to the eastern margin of the Moscow Region and in Vladimir Region on distance about 200 km. Thickness 0.4 m.

8. Clay, green-brown partly compacted into shale with thin (5—7 cm) lenticular layers of yellow-brown coarse-grain tempestite limestone. The latter contains numerous bryozoans, brachiopods, solitary rugose corals, fragments of crinoid stems. The fossils are often silicified, the sponge spicules are numerous. This bed is characterized by mass accumulation of the fusulinid shells belonging to *Rauserites rossicus* (Schellwien). Among them there are few *Rauserites paraarcticus* (Rauser) и *R. postarcticus* (Rauser). The assemblage of conodonts became impoverished with relative dominance of *Idiognathodus tersus* Ellison. The sparse shallow water representatives of *Adetognathus* appear. Thickness 0.8 m.

9. Limestone, brown-yellow, sometimes gray and reddish, thin-grained, containing large (up to 20 cm) siliceous concretions. It is visible as separate blocks, sometimes displaced. Thickness 0.3 m.

The Carboniferous is overlaying by sands of the Callovian Kriushino Formation (Middle Jurassic) with sparse limonitic oolites, reworked Carboniferous fossils, and pebbles (up to 5 cm) of chert and quartz.

Carbonates of the Rusavkino Formation changes up in the sequence by terrigenous (red clays with few sandstone and limestone interbeds) lagoonal or deltaic Stshelkovo Formation (up to 15 m) which could be studied in brick quarries situated in 1.5 km north from Gzhel section, but boundary between both formations is not opened there. The red clays of Stshelkovo Formation show the reverse magnetization with paleomagnetic latitude 17° N (Khramov, 1974, p. 86—89).

Biostratigraphical analysis

Fusulinids (Fig. 3, plates 1, 2). Fusulinids were found in the upper part of the section (beds 4—8). Four levels with fusulinids were distinguished, but only in two of them they are common. One level is in the middle part of the bed 4 and includes abundant *Quasifusulina longissima* (Möller) (sample 104). The numerous *Rauserites rossicus* (Schellwien) were found in the lower part of the bed 8 (sample 112) where they co-occurred with scarce *Rauserites postarcticus* (Rauser), *R. paraarcticus* (Rauser), single *Ozawainella* sp. (*O.* ex gr. *O. angulata* Colani) and *Textularia* sp. The vertical fusulinid distributions in the section demonstrate presence of two ecological assemblages replacing each other upwards. The first (lower) one in beds 4 and 5 integrates the numerous population of *Quasifusulina* dominated over the *Rauserites*. This assemblage includes *Quasifusulina longissima* (Möller), *Q. ultima* (Kanmera), *Q. eleganta* (Shlykova), *Q.* ex gr. *Q. tenuissima* (Schellwien), *Rauserites postarcticus* (Rauser), *R. paraarcticus* (Rauser), *R.* sp. (*R.* aff. *rossicus* (Schellwien)), *Textularia* sp. and single *Ozawainella* sp. ex gr. *O. angulata* (Colani). The second (upper) assemblage in bed 8 includes the rich population of *Rauserites*. The species *Rauserites rossicus* (Schellwien) is the absolute dominant of this assemblage. *R. postarcticus* (Rauser) and *R. paraarcticus* (Rauser) are minor components. However taxonomic diversity of fusulinids in this section is relatively impoverished.

Rozovskaya (unpublished report, 1966) identified in borehole 95 from depth 8.0 m (variegated marl with limestone pebbles, Unit 3 of the Rusavkino Formation) and 8.3–8.4 m (gray limestone, the same unit) late Kasimovian fusulinid assemblage of *Triticites secalicus* Say, *T. irregularis annuliferus* Rauser, *T. noinskyi plicatus* Rozovskaya, *T.* ex gr. *schwageriniformis* Rauser, *Fusulinella pulchra* var. *mesopachus* Rauser, *Fusulinella usvae* Dutkevich. Similar assemblage was mentioned by Rozovskaya and Kulikova (printed columnar section distributed among participants of the Moscow Basin field trip in 1975) from Unit 1 of the Rusavkino Formation (borehole 6k, depth 32.0–34.5 m): *Psudofusulinella usvae* (Dutkevich), *P. pulchra* (Rauser and Belyaev), *Triticites schwageriniformis bellus* Rozovskaya, *T. schwagerinifromis mosquensis* Rozovskaya, *T. paraschwageriniformis* Rozovskaya, *Rauserites* cf. *procullomensis* Rozovskaya, *R. condensus* Rozovskaya, but also with *Rauserites stuckenbergi* Rauser. The presence of the last species was reason why Gzhelian lower boundary was shown at the depth 34.5 m in base of the Rusavkino Formation. The thin sections studied by Rozovskaya and Kulikova were not traced in the available collections.

The Gzhel section is a *locus typicus* for *Rauserites rossicus* (Schellwien) which discussed recently as one of the potential markers of the Gzhelian lower boundary. In 1908 Ernst Schellwien described the new variety *Fusulina alpina* var. *rossica* (Schellwien, taf. XV, fig. 5–12; taf. XVI, fig. 1, 2). Following changes of the taxonomical status of *F. alpina* var. *rossica* (Rauser-Chernousova, 1938; Davydov, 1990; Rauser-Chernousova et al., 1996) allow consider *F. alpina* var. *rossica* as a separate species. The available and recently collected specimens of this species from bed 8 show the differentiation of the population. The groups corresponding to forms *typica*, *regularis* and *atypica* are distinguished (Isakova, Ueno, 2007; Isakova, 2008). Each group is characterized by the specific morphological features, distinguishing them from the other ones. But there are some specimens with transitional features, so that the limits between groups are changeable and flexible. Thus we have to take into the account the polymorphic status of this species when using it as a marker of the Gzhelian global boundary.

Recently Davydov et al. (2008) described Schellwien's specimens of *R. rossicus* from the Donets Basin as *R. rossicus rossicus* (Schellwien, 1908) and specimens from Gzhel as *R. rossicus gzhelicus* (Bensh, 1962). Davydov illustrated from Gzhel section several specimens named them as *R. rossicus gzhelicus*. However Isakova and Ueno designated the Gzhel specimen as lectotype for species *R. rossicus*, not for subspecies. It means that selection by Davydov et al. the Donets Basin specimen as lectotype for *R. rossicus rossicus* is invalid. Bensh (1962, p. 188) proposed "*Triticites rossicus* subsp. *gzhelicus* (Schellwien)", but do not mentioned any type specimen for it. In synonymy list she put only specimens from Gzhel section. Later Bensh never used name *R. rossicus gzhelicus* prefer to stop on the species level. Probably *R. rossicus* concept need to be revised much deeper. Villa and Ueno (2002) who commented subspecies and types problem in *R. rossicus* s.l. for the first time, do not considered the subspecies as valid.

Conodonts (Fig. 4, plates 3–5). This section contains 19 levels with conodonts (Fig. 4). There were found about 2000 conodont elements. A few *Streptognathodus firmus* Kozitskaya distinguishing the zone of the same name have been found at the base of the bed 1 (Unit 4, Middle Member). The lower part of the Unit 5 (bed 3) contains mostly shallow-water *Adetognathus* and sparse *Idiognathodus toretzianus* Kozitskaya. The single right juvenile Pa element of *Idiognathodus simulator* (Ellison) recovered from top of bed 3 (sample 103). The remarkable renovation of the conodont taxonomical composition was established from the level of the sample 104 where *Streptognathodus pawhuskaensis* (Harris and Hollingsworth) and *Idiognathodus tersus* Ellison has first appearance. The number of conodont elements increases sharply in sample 105. Sometimes the abundance of conodonts is above 200 specimens/kg. The typical specimens, although uncommon, of *Idiognathodus simulator* (Ellison) appear at this level.

The upper part of the Unit 5 contains the impoverished conodont assemblage with predominate *Idiognathodus tersus* Ellison together with shallow-water *Adetognathus* and *Diplognathodus*.

The similar succession of conodonts is demonstrated by borehole 6k, but at depth 23.0–23.5 m (the base of unit 4, Middle Rusavkino) and 26.4–26.7 m (unit 3 of the Middle Rusavkino) *Streptognathodus zethus* Chernykh and Resetkova occurs together with *S. firmus* Kozitskaya.

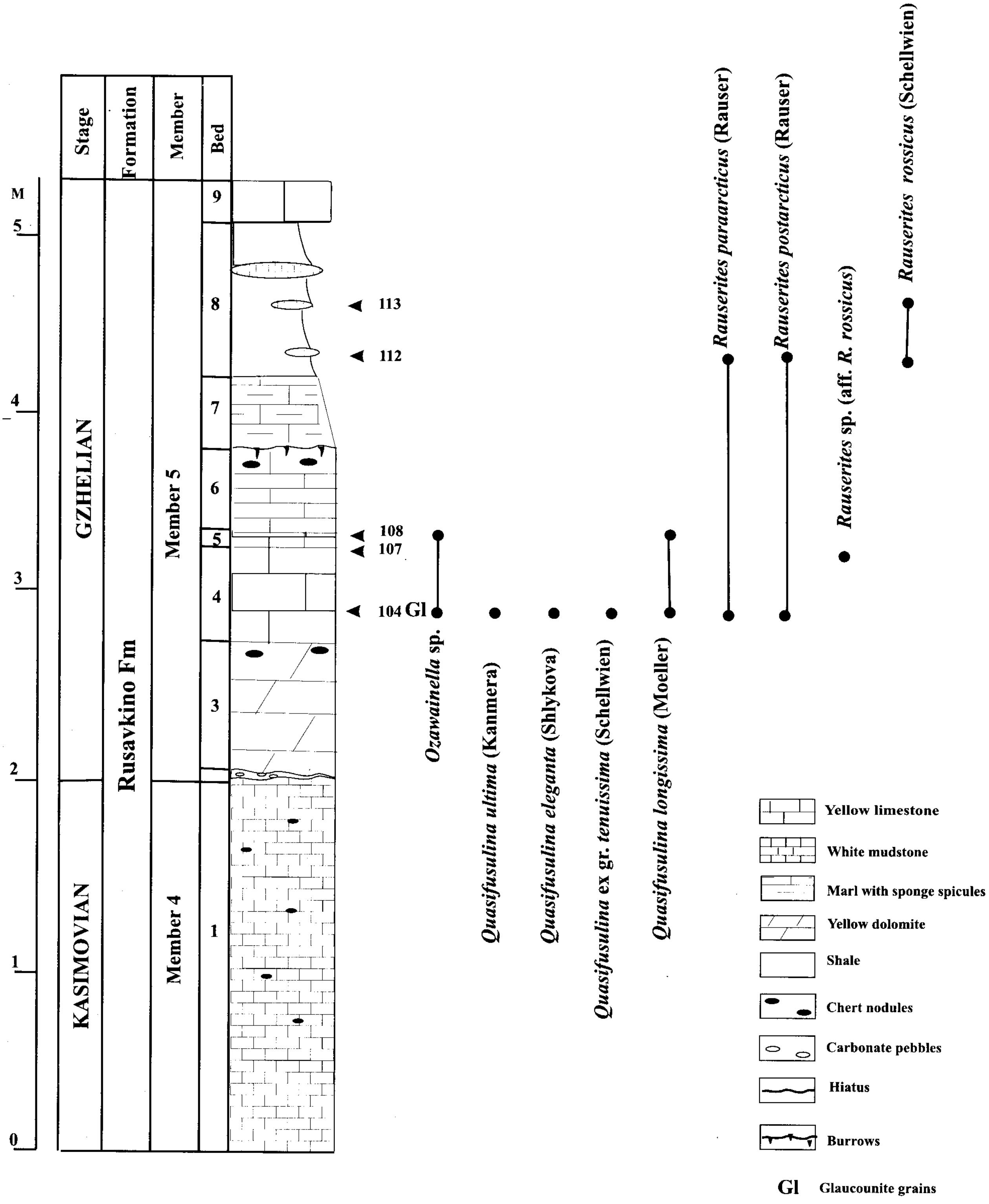

Fig. 3. Distribution of fusulinids in the Gzhel section

Plate 1

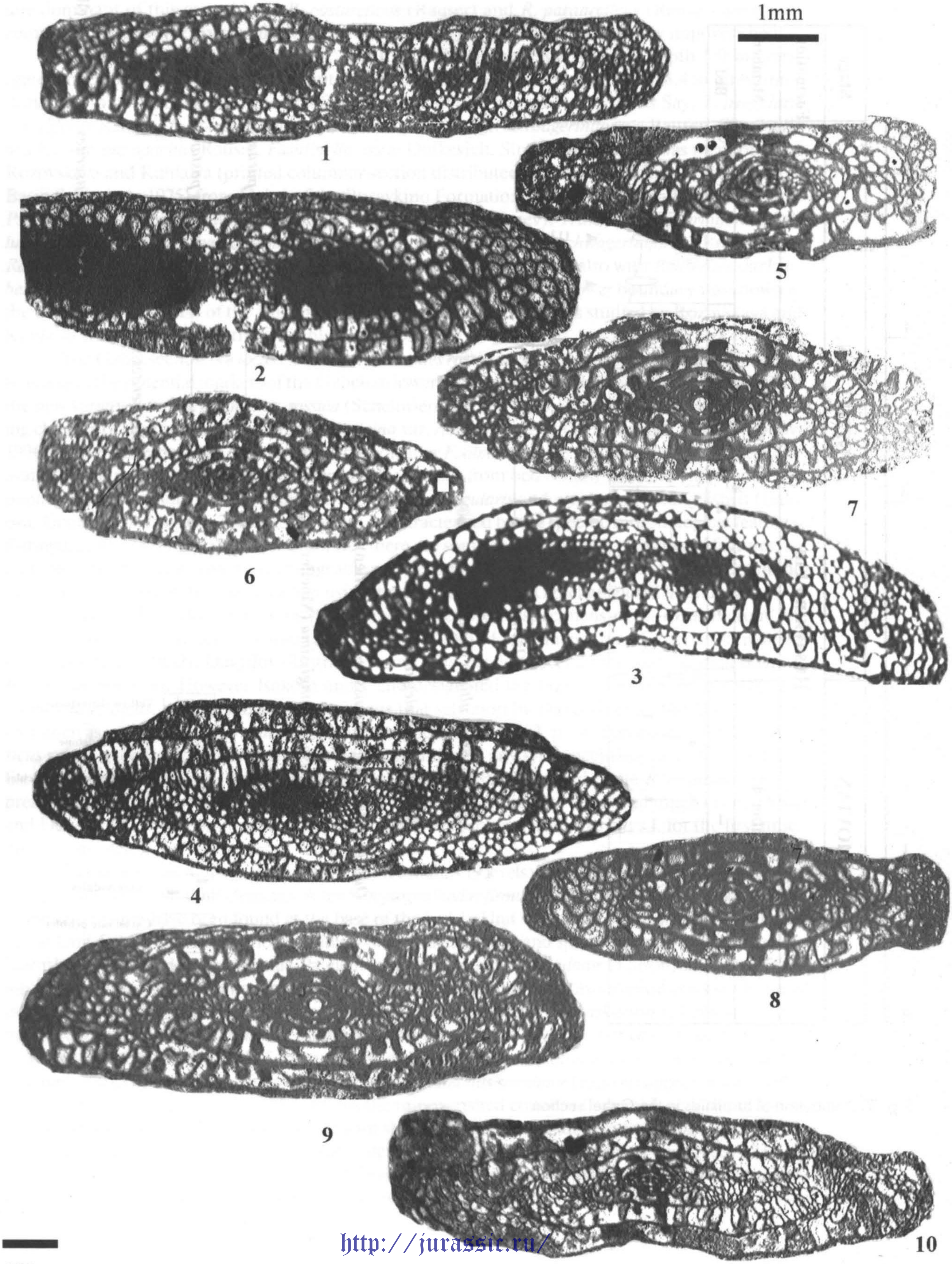

Plate 1. Fusulinids from the Gzhel section, lower assemblage, all besides fig. 10 are from bed 4, sample 104, x20. Collection is stored in Laboratory of Micropaleontology, Geological Institute of Russian Academy of Sciences, Moscow, number 4790. Figs. 1, 2. *Quasifusulina longissima* (Möller): 1 – №4790/1; 2 – №4790/2. Fig. 3. *Quasifusulina ultima* (Kanmera), №4790/3. Fig. 4. *Quasifusulina* ex gr. *Q. tenuissima* (Schellwien), №4790/4. Figs. 5, 8, 9. *Rauserites postarcticus* (Rauser): 5 – №4790/5; 8 – №4790/6; 9 – №4790/7. Figs. 6, 7. *Rauserites paraarcticus* (Rauser): 6 – №4790/8; 7 – №4790/9. Fig. 10. *Rauserites* sp. (*R.* aff. *R. rossicus* Schellwien), №4790/10, upper part of bed 4, sample 107

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The first appearance of *I. simulator* marks the lower boundary of the conodont zone bearing the same name and the base of the Gzhelian in its new definition (Heckel et al., 2008). The short range and wide geographical distribution allows consider the first appearance of the species as a good tool for correlation of this boundary. Now *I. simulator* group is well studied (Barrick et al., 2008) and occurs in many marine sections of the Upper Pennsylvanian both in Northern America and Eurasia. The level of the first appearance of this species was proposed for definition of the base of the Gzhelian Stage in the Moscow Basin (Barskov et al., 1980; Alekseev, Goreva, 2007) and the Urals (Chernykh, Reshetkova, 1988; Chernykh, Chuvashov, 2006).

Diverse assemblage of *I. simulator* morphotypes occurs in the Gzhel section, but typical left Pa elements as identified by Barrick et al. (2008) are scarce, dominate forms with straight platform and with very shallow furrow. Right elements are much more abundant. Possible that several species rank taxa could be separated from this population.

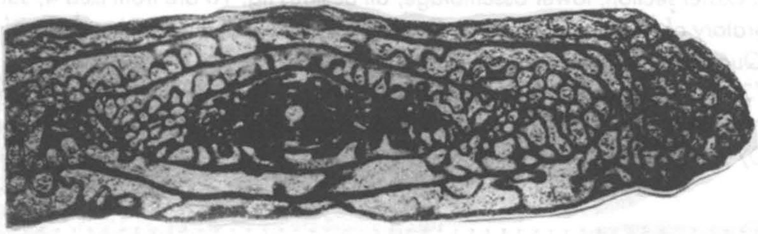
The assemblage of the *I. simulator* Zone is very specific and well recognizable. Besides the index species it includes *Streptognathodus pawhuskaensis* (Harris and Hollingsworth), *Idiognathodus tersus* Ellison, *I. toretzianus* Kozitskaya, *I. luganicus* Kozitskaya, *I. sinistrum* Chernykh, and *Gondolella bella* Stauffer and Plummer.

The lower boundary of the Gzhelian has to be shifted inside of the Rusavkino Formation (close to the base of its Upper Member). Despite the new boundary position is located somewhat above the base of the Rusavkino Formation this will not seriously affect the regional and interregional correlations.

The conodonts collected in the stratotype of the Rusavkino Formation nearby the Rusavkino Village and from borehole 6k, drilled northward the Gzhel railway station near the Konyashino Village have been re-studied additionally. Our recent investigation shows that *Idiognathodus* aff. *simulator* (= *I. eudoraensis* Barrick et al., 2008) considered as a possible ancestor of *I. simulator*, appears in the Moscow Basin succession in Troshkovo Formation (Dorogomilovian, Kasimovian Stage) and occurs rarely also in the Lower and Middle members of the overlaying Rusavkino Formation. The level of the first appearance of *Idiognathodus simulator* (top of bed 3 or mid of bed 4) is close to the first appearance of *Rauserites rossicus* (Schellwien) in the base of bed 8 (distance about 1.2 m).

Rugose corals (Plate 6). Stuckenberg (1888) described Gzhelian rugose corals collected near by the villages Rusavkino and Gzhel. The most comprehensive study was made by Dobrolyubova (1940). She proposed the new diagnosis for genus *Gshelia* Stuckenberg and the new genus name *Pseudobradyphyllum* for *Zaphrentis nikitini* Stuckenberg. Dobrolyubova described four species from the Rusavkino and Gzhel sections: *Cyathaxonia cornu* Michelin var. *orientalis* Dobrolyubova, *Pseudobradyphyllum nikitini* (Stuckenberg), *P. serpens* Dobrolyubova, *Gshelia rouilleri* Stuckenberg. As a result of the revision of the Stuckenberg's collection the neotypes of *Gshelia rouilleri* Stuckenberg and *Pseudobradyphyllum nikitini* Stuckenberg were selected (Ivanovsky, 1987). But the neotype of *Gshelia* is the mature stage only, so it is not sufficient for identification of this species. A difference between early and mature stages is the most remarkable feature of this genus (and species). The early ontogenetic stage of *Gshelia rouilleri* Stuckenberg demonstrates presence of columella, but the mature stage is a typical "caninomorphic type" bearing no axial structure. Caring out a revision of Eichwald (1861) collection Fedorowski and Gorianov (1973) assigned some specimens from Myachkovian (Upper Moscovian) to *G. rouilleri*. Also these specimens are in early ontogenetic stage and demonstrate the connection of cardinal septa with columella that contradicts the diagnosis of

Plate 2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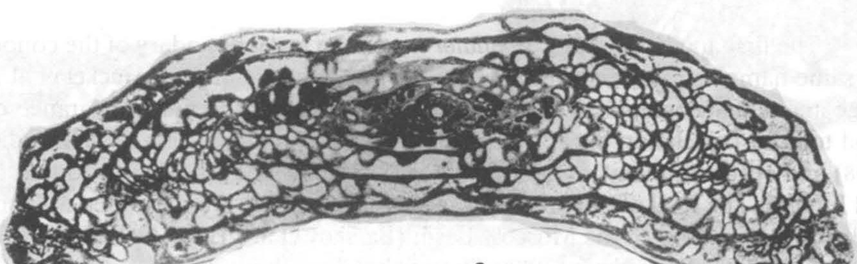
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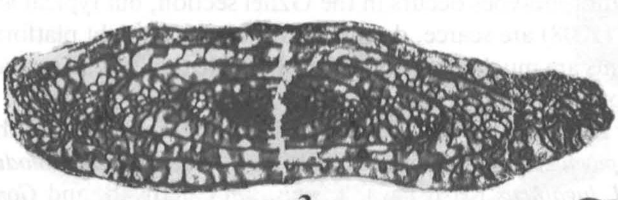
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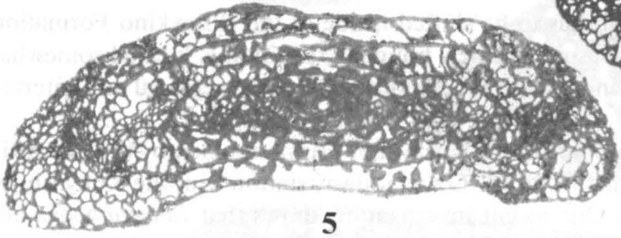
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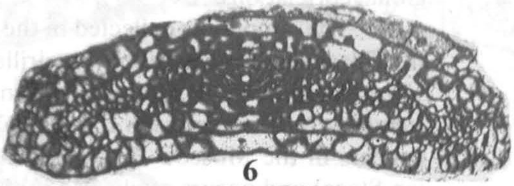
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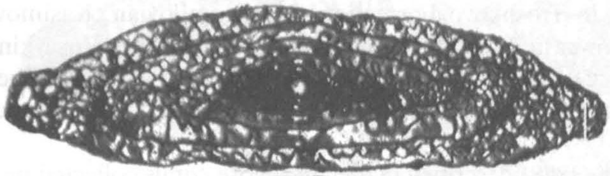
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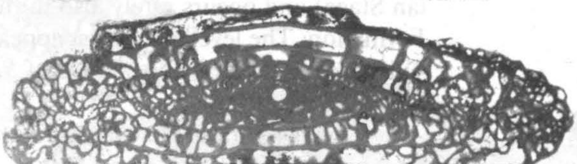
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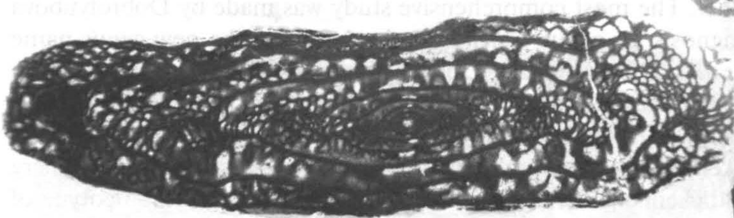
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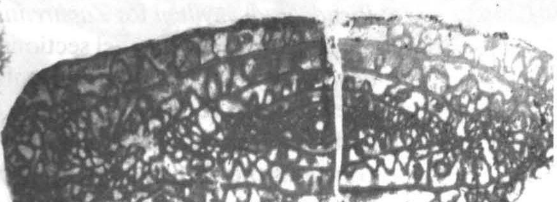
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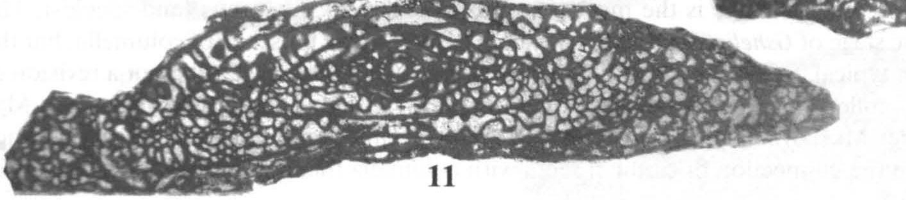
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Plate 2. Fusulinids from the Gzhel section, all specimens (besides figs. 1 and 2) are from bed 8, sample 112, x10. Collection is stored in Laboratory of Micropaleontology, Geological Institute of Russian Academy of Sciences, Moscow. Figs. 1, 2. *Rauserites rossicus* (Schellwien). Lectotype, designated by Isakova and Ueno (2007), photo from Schellwien, 1908, x 13,5. Figs. 3–7. *Rauserites rossicus* (Schellwien) forma *typica*: 3 – №4790/11; 4 – №4790/12; 5 – №4790/13; 6 – №4790/14; 7 – №4790/15. Figs. 8–10. *Rauserites rossicus* (Schellwien) forma *regularis*: 8 – №4790/16; 9 – №4790/17; 10 – №4790/18. Fig. 11. *Rauserites rossicus* (Schellwien) forma *atypica*, №4790/19

G. rouilleri. The absence of mature stages does not allow observe the transition to "caninomorphic" structure and we do not consider the Myachkovian specimens as *G. rouilleri* Stuckenberg.

Ivanova and Khvorova (1955, p. 210) assigned the mentioned list of species to bed 10 of the upper part of the Gzhel-Rusavkino composite section (= bed 8 in this paper). It was added by *Gshelia rouilleri breviseptata* Dobrolyubova and Kabakovich (1948). However latter subspecies occurs only in the contemporaneous strata of the Oka-Tsna Swell (100 km to the east). Later the part of the specimens assigned to *Gshelia rouilleri breviseptata* Dobrolyubova and Kabakovich was included in *Arctophyllum intermedium* (Toula) (Fedorowski, 1975). *Pseudobradyphyllum nikitini* (Stuckenberg) was assigned to *Paracaninia* (Weyer 1980; Iljina, 1984), but because of the difference in early ontogeny we leave this species in *Pseudobradyphyllum* (Plate 6, fig. 1–6).

The appearance of *G. rouilleri* is considered as a marker feature for the lower part of the Gzhelian. It is rather widespread geographically and occurs in the lower Gzhelian in different regions. In East European Platform it is known from Gzhel section and was also found in Dyukino and Melekhovo quarries (Oka-Tsna Swell). Its upper limit of stratigraphical range is not clear now, but data from the Oka-Tsna Swell supposed it duration up to Upper Gzhelian including *Daixina sokensis* fusulinid Zone (O.L. Kossovaya, unpublished data). *G. rouilleri* is also known from the Yablonevyi Ovrag section (Samarskaya Luka, Volga River), where it is occurs from *Rauserites stuckenbergi* Zone to *Daixina sokensis* Zone (Kossovaya, 1986). In the Orel section (Middle Urals) it was found in the lower Gzhelian also. Because of its stratigraphical value, the species was included in zonal succession on rugose corals (Koren, 2006) as a basal zone of Gzhelian in its traditional understanding. The precise data supported the appearance of *G. rouilleri* at the beds 7 and 8 (see above) that is close to the first appearance of *I. simulator*. In spite of the some uncertainty of its first appearance, *Gshelia rouilleri* is considered as a marker coral taxon for the lower Gzhelian.

Other macrofaunal groups (Plates 7, 8). Beds 7 and 8 contain diverse macrofossil assemblage: bivalve *Exochorhynchus curtus* Astafieva-Urbajtis; gastropods *Omphalotrochus canaliculatus* (Trautschold), *O. kalitvaensis* (Likharev), *Straparollus* (*Euomphalus*) *moniliformis* (Romanovsky), *Platyceras* (*Orthonychia*) *egorovi* (Mazaev), *Retshitsella egorovi* Mazaev, *Stegocoelia gzheliensis* Mazaev, *Goniasma gzheliensis* Mazaev; several taxa of nautiloids; trilobite *Ditomopyge ivanovi* (Weber); 37 species of bryozoans revised recently by Morozova and Lisitsyn (2002) including *Tabulipora maculosa* Nikiforova, *Goniocladia subpulchra* Shulga-Nesterenko, *Mackinneyella subornamentata* (Shulga-Nesterenko), *Rhombotrypella subcomposita* Shulga-Nesterenko and others; brachiopods (Plate 8) *Gemmulicosta gjeliensis* (Ivanov), *Duartea pseudoartiensis* (Stuckenberg), *Spiriferella gjeliensis* Stepanov, *Gjelispinifera gerasimovi* E. Ivanova, *Gypospirifer poststriatus* (Nikitin), *Choristites supramosquensis* (Nikitin), *Hustedia pseudocardium* (Nikitin), *H. remota* (Eichwald), *Stenoscisma gjelis* Lazarev, *Laioporella modesta* E. Ivanova, *Cleiothyridina gzheliensis* Grunt, *Neochonetes dalmanoides* (Nikitin), *Chonetinella uralica* (Möller), *Lissochonetes geinitzianus* (Waagen), *Paramesolobus ivanovae* Afanasieva, *Kozlowskia borealis* (Ivanov), *Calliprotonia sterlitamakensis* (Stepanov) etc; crinoid *Belashovicrinus gjelensis* Arendt and Zubarev; echinoid *Archaeocidaris nikitini* Faas.

The ammonoid Gonioloboceras goniolobum (Meek) and some other cephalopod taxa mentioned as found in bed 7 of the Gzhel section (Shkolin, 1998).

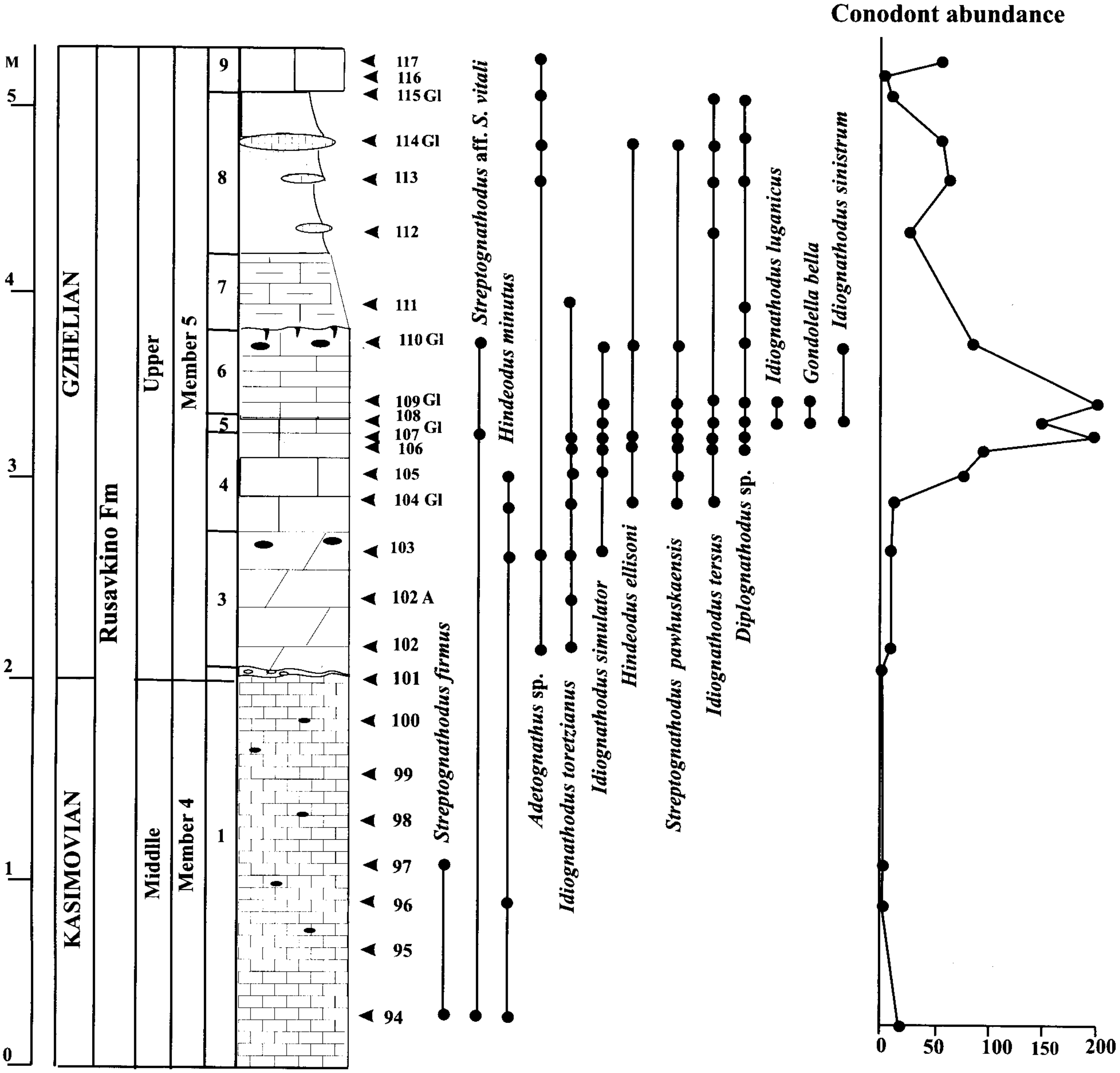

Fig. 4. Distribution of conodonts in the Gzhel section and their abundance (specimens/kg)

Sequence analysis

White limestone of the bed 1 reflect lowstand system tract of the lower sequence of the Rusavkino Formation. The hiatus between beds 1 and 2 with paleosol horizon is important boundary of the third order sequence. The new sequence consists of transgressive system tract (beds 3 and 4), maximum flooding surface (bed 5 and lower bed 6) with reduced accumulation rate and appearance of deep-water conodont *Gondolella*, and regressive system tract (beds 7 and 8). The first appearance datum of *I. simulator* coincides with transgressive tract with acme close to maximum flooding surface.

Chemostratigraphy

Limited information on oxygen and carbon isotope composition of bulk rock are available (unpublished data by Buggisch et al.) and on oxygen isotope ratios in phosphatic material of conodont elements (unpublished data by Joachimski et al.).

Comparison with other potential Gzhelian GSSP

Only proposed section as potential GSSP for the global Gzhelian Stage is Usolka section on the South Urals in the Bashkiria (Chernykh et al., 2006a,b; Davydov et al., 2008). The Usolka section is deep water and looks as continuous that did it much promised than Gzhel section. It contains abundant conodonts, but only at distant levels. Fusulinids occurs rarely and much higher than proposed boundary level on the first appearance of "*Streptognathodus simulator*" (Davydov et al., 2008). The taxonomic conceptions of "*S. simulator*" and its ancestor "*S. praenuntius*" Chernykh were based on right Pa elements, not on left Pa elements as in case of true *I. simulator* and *I. eudoraensis* Barrick et al. However apparatus of *I. simulator* Group includes asymmetrical right and left Pa elements that prevent simple solution of this identification problem. Recently Davydov et al. (2008) illustrated from the Usolka section the left elements (text-fig. 11, C and E) which are true *I. simulator* (Ellison). Macrofossils do not present in the Kasimovian-Gzhelian boundary interval of the Usolka section instead of the Gzhel section where they are abundant. It is obvious that the Usolka section has important potential, but need to be restudied on centimeter basis.

Conservation

The type Gzhelian exposure is a natural reserve in the Moscow Region and its renovated protection status is under official registration.

Acknowledgment

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Plate 3

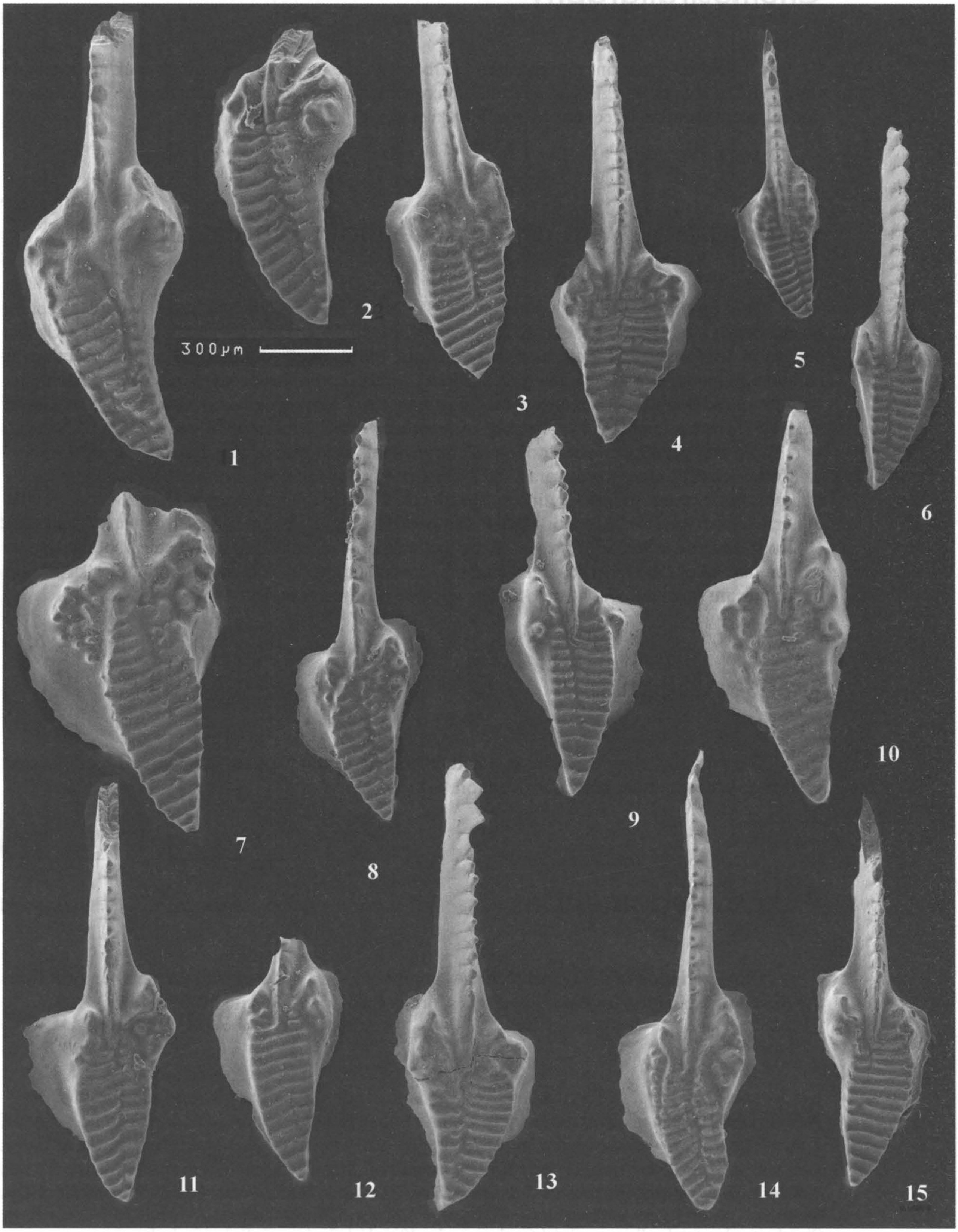

Plate 3. Pa elements of conodonts from the Gzhel section. Scale bar represents 300 μm. Collection is stored in Department of Paleontology, Geological Faculty, Moscow State University. Figs. 1–7, 9, 10, 12–15. *Idiognathodus* ex gr. *I. simulator* (Ellison): 1–7 – bed 5, sample 108; 9, 10, 12–15 – bed 6, sample 110. Figs. 8, 11. *Idiognathodus simulator* (Ellison), bed 6, sample 110

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Plate 4

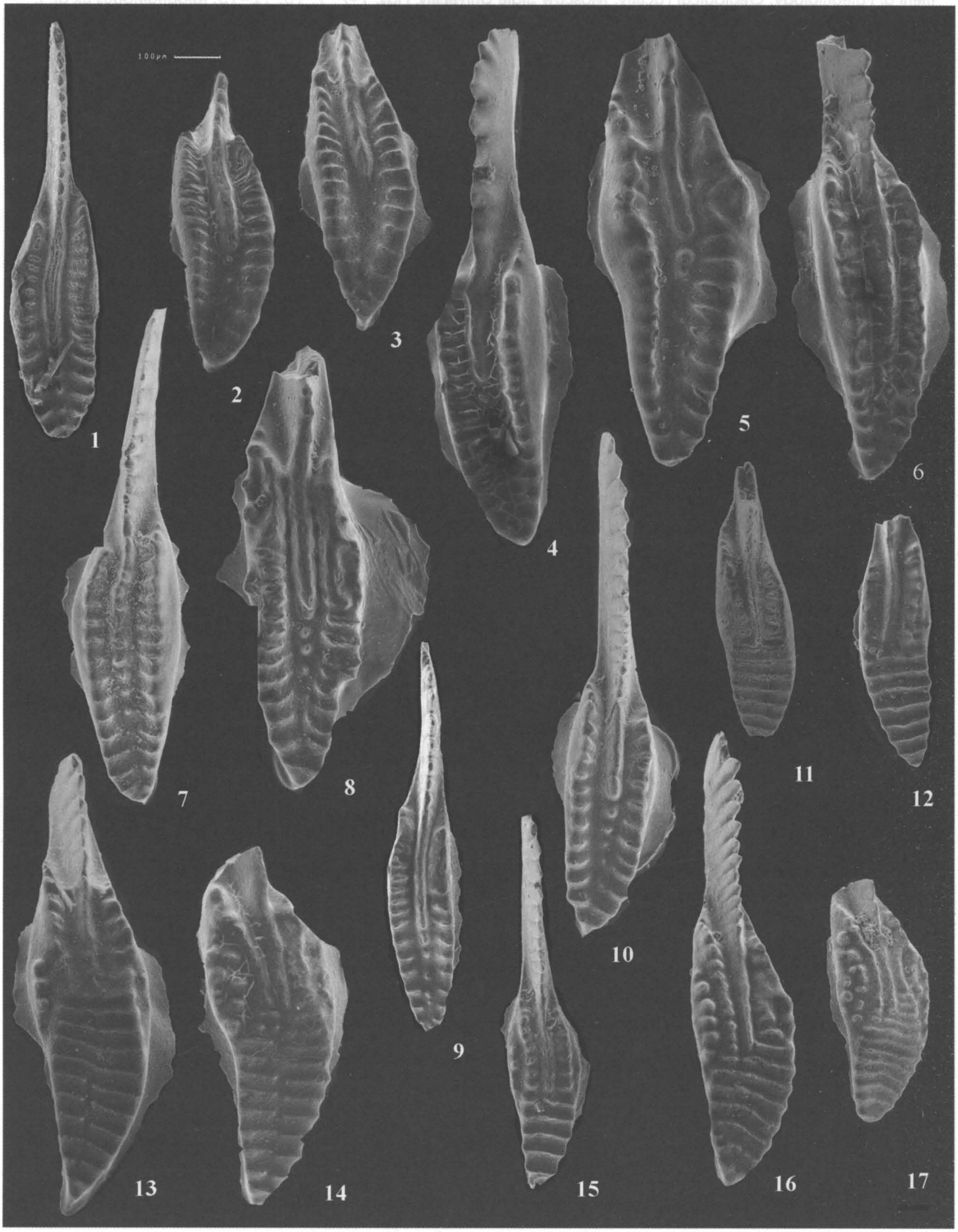

Plate 4. Pa elements of conodonts from Gzhel section. Scale bar represents 100 μm. Collection is stored in Department of Paleontology, Geological Faculty, Moscow State University. Fig.1. *Streptognathodus firmus* Kozitskaya, bed 1, sample 94. Figs. 2–5. *Streptognathodus pawhuskaensis* Harris and Hollingsworth; bed 4: 2, 5 – sample 106; 3 – sample 104; 4 – sample 107. Figs. 6–10. *Streptognathodus* aff. *S. vitali* Chernykh: 6 – bed 4, sample 107; 7, 8, 10 – bed 6, sample 110; 9 – bed 1, sample 96. Figs. 11, 12. *Idiognathodus tersus* Ellison: 11 – bed 4, sample 104; 12 – bed 8, sample 112. Figs. 13, 14, 16, 17. *Idiognathodus toretzianus* Kozitskaya: 12, 13, 16 – bed 4, sample 105;17 – bed 4, sample 104. Fig. 15. *Idiognathodus* sp., bed 3, sample 103

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Plate 5

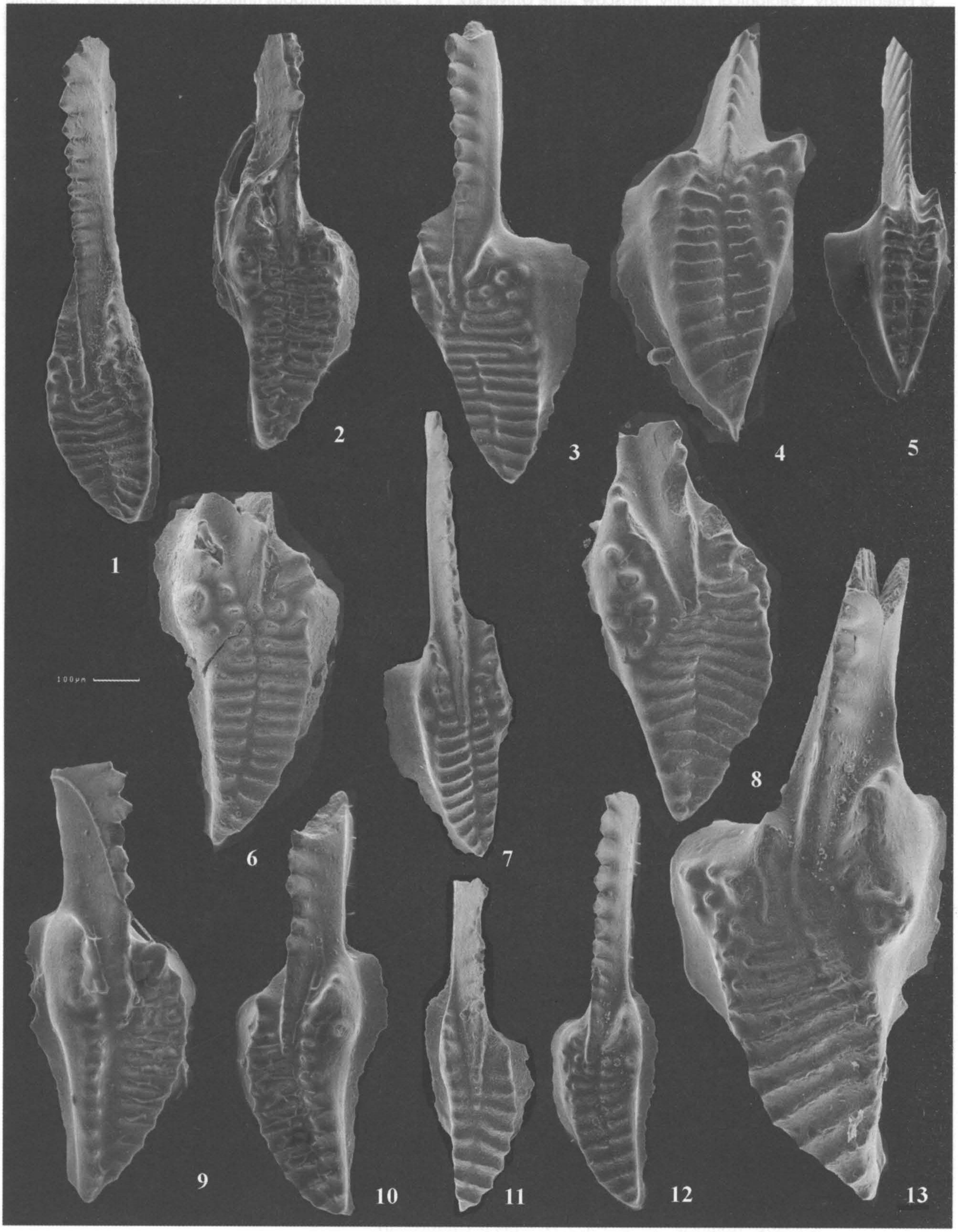

Plate 6


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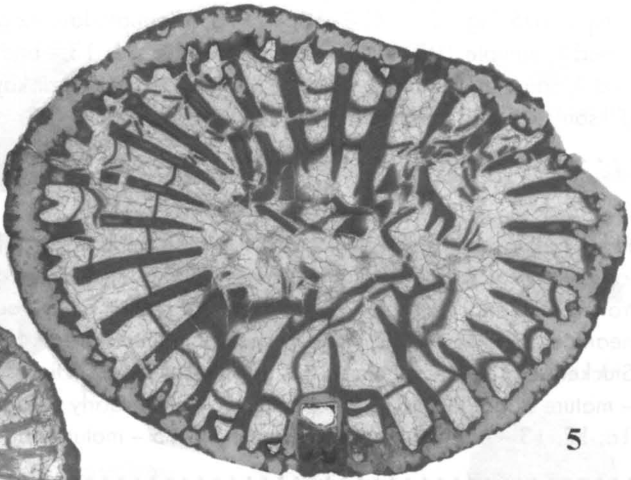
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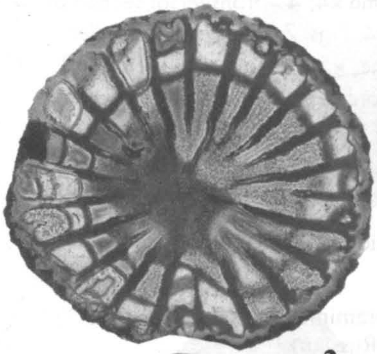
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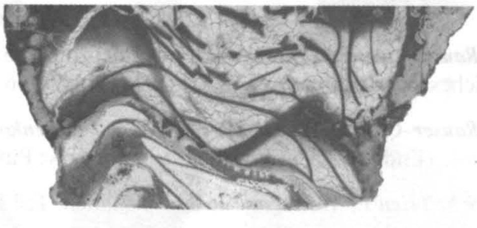
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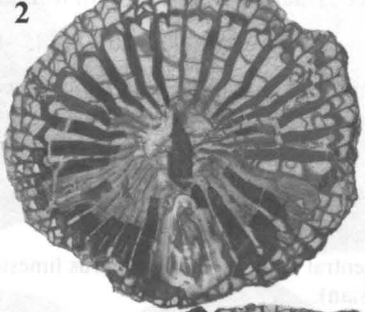
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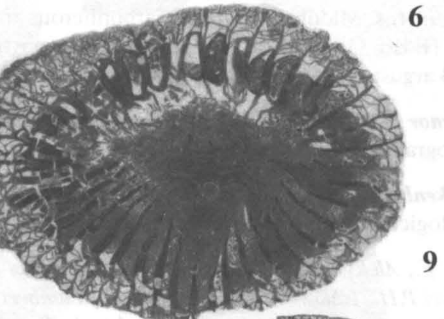
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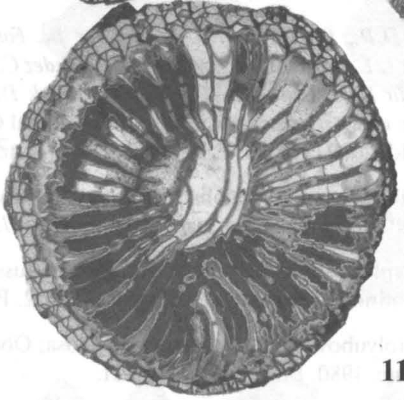
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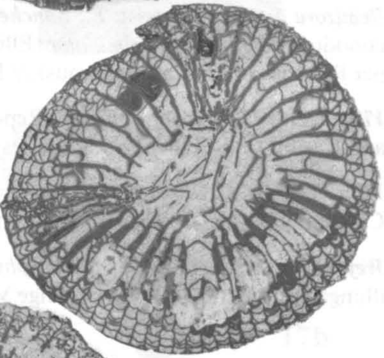
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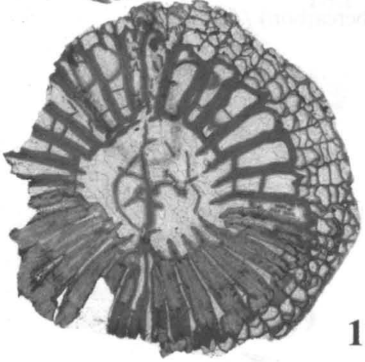
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Plate 5. Pa elements of conodonts from the Gzhel section. Scale bar represents 100 μm. Collection is stored in Department of Paleontology, Geological Faculty, Moscow State University. Fig. 1. *Idiognathodus toretzianus* Kozitskaya, bed 4, sample 105. Figs. 2, 3, 6, 8–10, 12, 13. *Idiognathodus* ex gr. *I. simulator* (Ellison): 2, 12 – bed 4, sample 107; 3, 6, 8 – bed 5, sample 108; 9, 10 – bed 4, sample 106; 13 – bed 6, sample 110. Fig. 4. *Idiognathodus sinistrum* (Chernykh), bed 4, sample 108. Fig. 5. *Idiognathodus luganicus* Kozitskaya, bed 4, sample 106. Fig. 7, 11. *Idiognathodus simulator* (Ellison): 7 – bed 5, sample 108; 11 – bed 3, sample 103

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Plate 6. Rugose corals from the Gzhel section, all specimens from bed 7. Collection is stored in Karpinsky Russian Geological Research Institute, Sankt-Petersburg. Figs. 1–6. *Pseudobradyphyllum nikitini* (Stuckenberg): 1–5 – specimen 39, transversal serial sections: 1, 2 – transversal section of the young stages, x5; 3 – the same x4; 4 – transversal section of neanic stage, x4; 5– transversal section of mature stage, x4; 6 – longitudinal section, x4. Figs. 7–15. *Gshelia rouilleri* Stuckenberg: 7–9 – specimen 38, transversal serial sections: 7 – early ontogenetic stage, x5; 8 – late neanic stage; 9 – mature stage, x2; 10, 11 – specimen 50: 10 – early ontogenetic stage; 11 – late neanic stage; 12–15 – specimen 1a: 12, 13 – early ontogenetic stages; 14–15 – mature stages, x2

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Plate 7

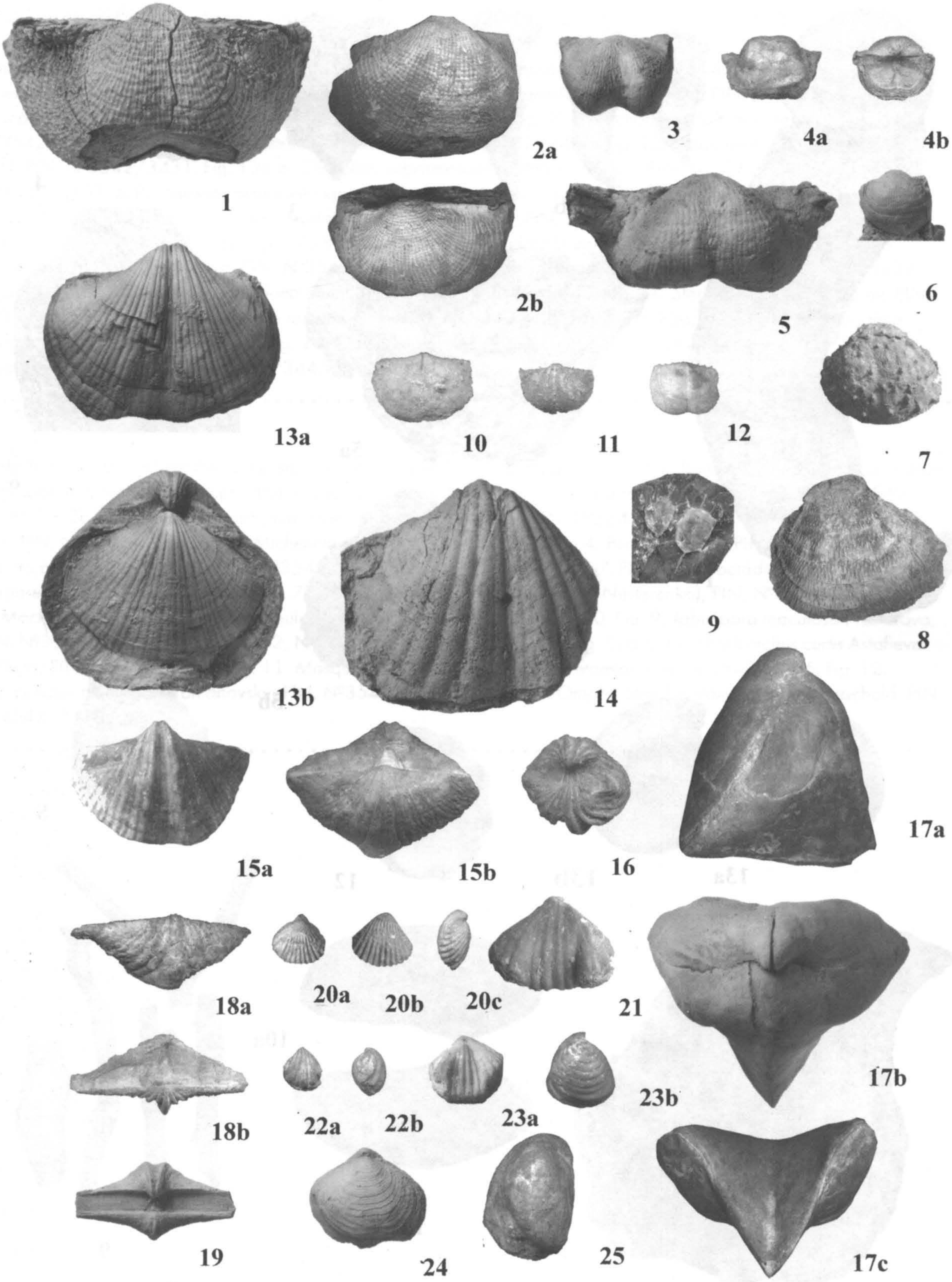
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Plate 8.

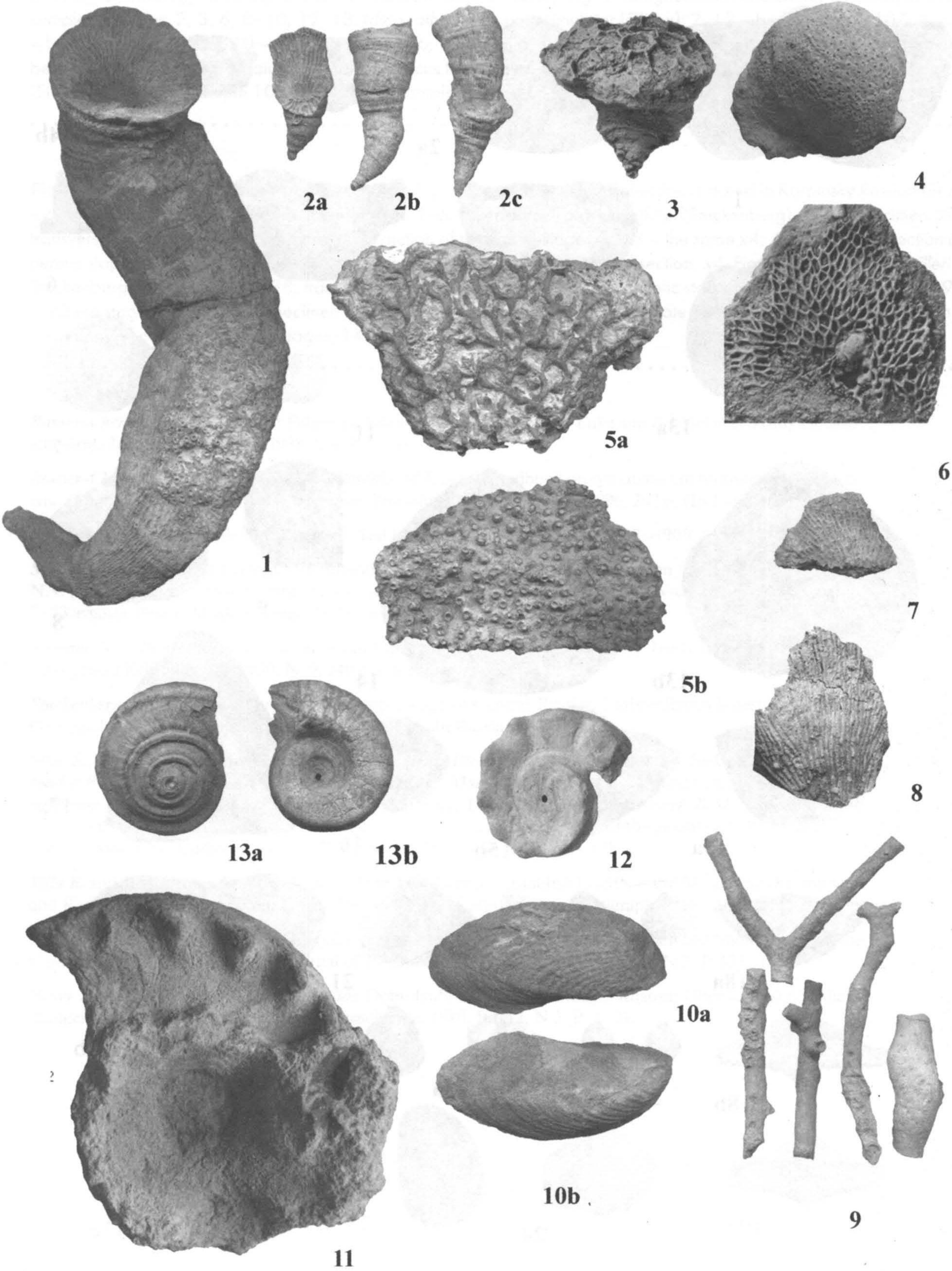

Plate 7. Brachiopods from the Gzhel section, beds 7, 8. Collection is stored in A.A. Borissiak Paleontological Institute of Russian Academy of Sciences (PIN), Moscow, number 3542. Fig. 1. *Gemmulicosta gjeliensis* (Ivanov), PIN, №3542/3419. Fig. 2a,b. *Admoskovia* sp., PIN, №3542/3420. Fig. 3. *Duartea pseudoartiensis* (Stuckenberg), PIN, №3542/3421. Fig. 4a,b. *Kozlowskia borealis* (Ivanov): 4a – PIN, №3542/3422; 4b – PIN, №3542/3423. Fig. 5. *Chaoiella boliviensis* (d'Orbigny), PIN, №3542/3424. Fig. 6. *Striapustula* sp., PIN, №3542/3425. Fig. 7. *Krotovia tuberculata* Möller, PIN, №3542/3426. Fig. 8. *Calliprotonia sterlitamakensis* (Stepanov), PIN, №3542/3427. Fig. 9. *Leptalosia gracilis* (Ivanov and Ivanova), PIN, №3542/3428. Fig. 10. *Neochonetes dalmanoides* (Nikitin), PIN, №3542/3429. Fig. 11. *Chonetinella uralica* (Möller), PIN, №3542/3430. Fig. 12. *Lissochonetes geinitzianus* (Waagen), PIN, №3542/3431. Fig. 13a,b. *Choristites supramosqensis* (Nikitin): 13a – PIN, №3542/3432; 13b – PIN, №3542/3433, д. Русавкино, гжельский ярус, русавкинский горизонт. Fig. 14. *Brachythyris ufensis* Tschernyschev, PIN, №3542/3434. Fig. 15a,b. *Gypospirifer poststriatus* (Nikitin), PIN, №3542/3435. Fig. 16. *Callispirina ornata* (Waagen), PIN, №3542/3436. Fig. 17a,b,c. *Camerisma pyramidata* Lazarev, PIN, №3542/3437. Fig. 18a,b. *Laioporella modesta* E. Ivanova, PIN, №3542/3438. Fig. 19. *Paeckelmanella gjeliensis* E. Ivanova, PIN, №3542/3439. Fig. 20a,b,c. *Hustedia pseudocardium* (Nikitin), PIN, №3542/3440. Fig. 21. *Stenoscisma gjelis* Lazarev, PIN, №3542/3441. Fig. 22a,b. *Hustedia remota* (Eichwald), PIN, №3542/3442. Fig. 23a,b. *Rhynchopora variabilis* Stuckenberg, PIN, №3542/3443. Fig. 24. *Cleiothyridina gjeliensis* Grunt, PIN, №3542/3444. Fig. 25. *Dielasma moelleri* Tschernyshev, PIN, №3542/3445

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Plate 8. Macrofauna from the Gzhel section, beds 7 and 8. Collection is stored in A.A. Borissiak Paleontological Institute of Russian Academy of Sciences (PIN), Moscow, number 3542. Fig. 1. *Gshelia rouilleri* Stuckenberg, PIN, №3542/3400. Fig. 2a,b,c. *Pseudobradyphyllum nikitini* Dobrolyubova: 2a – PIN, №3542/3401; 2b – PIN,№3542/3402; 2c – PIN, №3542/3403. Fig. 3. *Michelinia* sp., PIN, №3542/3404. Fig.4. *Pemmatites* sp., PIN, №3542/3405. Fig. 5a,b. *Aulopora* sp.: 5a – PIN, №3542/3406; 5b – PIN, №3542/3407. Fig. 6. *Goniocladia pulchra* Shulga-Nesterenko, PIN, №3542/3408. Fig. 7. *Shulgapora postabundans* (Shulga-Nesterenko), PIN, №3542/3409. Fig. 8. *Mackinneyella subornamentata* (Shulga-Nesterenko), PIN, №3542/3410. Fig. 9. *Tabulipora maculosa* Nikiforova, PIN, №3542/3411, №3542/3412, №3542/3413, №3542/3414. Fig. 10a,b. *Exochorhynchus curtis* Astafieva-Urbajtis, PIN, №3542/3415. Fig. 11. *Mosquoceras tschernyschewi* (Tzwetaeva), PIN, №3542/3416. Fig. 12. *Euomphalus moniliferus* Romanovsky, PIN, №3542/3417. Fig. 13a,b. *Omphalotrochus canaliculatus* Trautschold, PIN, №3542/3418.

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APPENDIX

Papers presented to SCCS Field Meeting

Pennsylvanian sphinctozoan habitats from the Cantabrian Mountains, northern Spain

Hans-Georg Herbig[1], Sebastian Rautenberg[2]

[1]Institut für Geologie und Mineralogie, Universität zu Köln,
Zülpicher Str. 49a, D-50674 Köln, Germany, herbig.paleont@uni-koeln.de

[2]sebastianrautenberg@gmx.net

"Sphinctozoans" are segmented sponges of polyphyletic origin. After a Cambro-Ordovician radiation, they remained rare faunal elements until the absolute acme of that morphological group in Permo-Triassic times. Nowadays, only the taxon *Vaceletia crypta* remains. According to literature, sphinctozoans are completely missing in the Late Devonian and Mississippian (Senowbari-Daryan 1990; Senowbari-Daryan et al., 2002). This strongly points to paraphyletic relations of early/middle Palaeozoic and late Palaeozoic taxa. From the Pennsylvanian seven genera of that mostly rare fossils are known from Texas, the Cantabrian Mountains, the Southern Alps and Manchuria.

Pennsylvanian sphinctozoan sponges from the Cantabrian Mountains are surprisingly common in some localities and inhabited different environments. Taxonomic descriptions from that region were given from Steinmann (1882), who created the taxon based on material sampled by Barrois (1882) (see Truyols et al. 1980). Modern descriptions are from Graaff (1969), García-Bellido Capdevila (2001) and García-Bellido et al. (2004). We studied the localities mentioned by García-Bellido unless otherwise stated.

In the Sierra Corisa Limestone Member (upper part of Vergaño Formation, late Myachkovian, late Moscovian – Villa in García-Bellido et al., 2004) northeast of Vergaño (Pisuerga-Carrión Unit, northern Palencia) the sponges form true sphinctozoan marls, few meters in thickness. They are part of a 22 m thick transgressive succession composed of marls, thin beds of intercalated bioturbated sandy bioclastic wackestone to calcareous sandstone and a single, metric sandstone horizon in the upper part. The succession follows above an erosional unconformity at the top of the lowermost limestone unit of the Sierra Corisa Member. Sphinctozoans mostly miss in sandy, up-section increasingly fossiliferous marl in the lower third of the succession. They are most common in limonitic marl in the middle third, and miss again in fusulinid marl and few intercalated fusulinid wackestone beds above. The succession is overlain by breccious phylloid algal limestone, which up-section becomes bedded (middle limestone unit of the Sierra Corisa Member).

In the lower part of the Demués section (lower Demués Formation, Krevyakinian, lower Kasimovian – Merino-Tomé et al., 2006) southwest of the village of Demués (northern sector of the Picos de Europa Unit) sphinctozoans thrive in a 14 m thick interval of a similar mixed carbonate-siliciclastic facies, although up to 4.5 m thick limestone intervals are conspicuous. Sphinctozoans are common within the non-sandy, metric marl units; occurrence within certain bioclastic *Anthracoporella* or *Archaeolithophyllum* bearing wackestone and floatstone is at least partly due to tempestitic reworking from the marls. This is evidenced by erosional bases of the limestones, normal grading and, within the floatstone, by intraclasts. However, sphinctozoan-bearing *Anthracoporella* wackestone with further sponges, fenestellid bryozoans, trilobites and ostracodes apparently represents a parautochthonous organism community in more calcareous facies, as evidenced from similar facies from northern Palencia (see below).

In both localities the delicate *Amblysiphonella barroisi* and *A. carbonaria* with diameters rarely exceeding 10 mm and slender specimens of *Discosiphonella mamillosa* predominate. According to García-Bellido et al. (2004) stem diameters of *D. mamillosa* in marly facies range mostly from 6 to 20 mm. In certain horizons, especially in the Demués section, the tiny *Sollasia ostiolata* becomes more common.

Within the marls and the intervening sandy bioclastic wackestone beds at Vergaño a filter feeding community consisting of sphinctozoans, other demosponges and hexactinellid sponges (for taxonomy of body fossils see García-Bellido Capdevila, 2001, 2002; García-Bellido and Rigby, 2004), brachiopods, bryozoans and crinoids, and grazing organisms (gastropods, echinoids) predominate. Algae are rare. Abundant phylloid green algae or fusulinids excluded the growth of sphinctozoans. In Demués, the same filter feeding and grazing community is observed. However, the ancestral red alga *Archaeolithophyllum*, which tolerates fine-grained siliciclastic influx (Minwegen, 2001) is commonly associated, although its increasing abundance reduced sphinctozoan abundance. Toomey (1979) showed the importance of *Archaeolithophyllum* as a pioneer organism for the settlement of a sphinctozoan-bearing filter feeding community, since it acts as a prostrate growing, binding organism, encrusting and stabilizing soft grounds. In more calcareous facies, sphinctozoans are also associated with the aspondyl, stick-like growing dasycladacean *Anthracoporella*, which due to similar growth form apparently was not a successful competitor for space. Like in Vergaño, growth of phylloid green algae excluded the growth of sphinctozoans. This appears to be related to the erect, leaf-shaped and shadow-casting growth and high reproduction rate of those algae, which mostly occur in oligospecific to monospecific mass occurrences (Forsythe et al., 2002; see already Toomey, 1979). However, nutrient level and interrelated turbidity have to be taken as the primary account since increasing oligotrophic and less turbid waters favour the growth of autotrophic organisms. Also fusulinids probably contained photosymbionts and can thus be considered a proxy for episodes of low nutrient supply (Brasier, 1995).

The habitats of both localities are comparable in spite of minor age and facies differences. Envisaged are muddy, low energetic lagoons, which developed during a transgression and received fine-grained siliciclastic material from riverine influx. The reconstruction fits well into the delta-platform system reconstructed by Graaff (1971). Similar sponge-bearing settings are also known from modern environments (e. g. Nasese intertidal platform near Suva, Fiji; Pohler, Herbig, 2004). The lagoons of Vergaño and Demués were settled by moderately diverse communities of filter feeding and grazing organisms. With the fading of detrital sand input, sphinctozoans started to invade the lagoon and occasionally formed dense sponge meadows. In Demués, in more calcareous parts of the lagoon, sphinctozoans apparently were intermingled with the dasycladacean *Anthracoporella*. In the same locality, *Archaeolithophyllum* encrusted the soft bottom and provided a suitable substrate for sphinctozoan attachment. However, in Vergaño sphinctozoans were apparently attached to other invertebrate skeletons and even rooting in soft substrate cannot be excluded. Within the marls, the organisms were parautochthonously preserved. However, all could be reworked during higher energetic events, mixed with biota and carbonate mud of an adjacent platform, and finally enriched in tempestitic wackestone or floatstone. Continuing transgression caused lowered nutrient levels and appearance of photozoans (fusulinids, phylloid algae). Oligotrophic environments, shade-casting erect growth and rapid reproduction of phylloid algae were the reasons for the disappearance of the sphinctozoans.

The locality of Ándara (predominantly reddish breccioid-nodular upper member of the Picos de Europa Fm., Myachkovian, latest Moscovian – Sanchez de Posada et al., 1993) southeast of the village of Sotres (central sector of the Picos de Europa Unit) is located within a several hundred m thick, extended carbonate platform succession without siliciclastic influence. Sphinctozoans occur on the bedding planes of massive, white, cream-coloured and reddish limestone with breccioid texture within a 30 x 50 m sized area. A section could be not logged and randomly sampled thin-sections reveal complex mottled structures of bioturbated and afterward condensed bioclastic micritic rudstone. It is mostly composed of not oriented, often densely packed, strongly fragmented sphinctozoans, brachiopods/bivalves, gastropods, echinoderms and minor bryozoans. Algae and foraminifers are rare. The matrix is rich in sponge spicules, filaments and microbioclasts. Large sphinctozoans of *Discosiphonella mammillosa* prevail, reaching more than 20 cm in length and stem diameters up to 4.2 cm (Barcía-Bellido et al., 2004). Few still bigger *Discosiphonella maior* as well as smaller *Amblysiphonella* species are associated. According to the localized occurrence, sphinctozoans were apparently associated with spicular sponges and echinoderms in a buildup. The characteristic association of filter feeders, rarity of algae, micritic matrix and condensation textures favour a position below wave base and low sedimentation rates. Intermittently occurring, intraclast-bearing phylloid algal grainstone and floatstone are of low biodiversity. They do not bear sphinctozoans and confirm the mutual exclusion of these taxa. The algal-rich facies could be interpreted as a capping facies developing on top of the sphinctozoan buildup in agitated shallow water. A similar setting of phylloid algal boundstones on top of a pelmatozoan-bryozoan-brachiopod buildup was described from the Picos de Europa Formation in the valley of the Rio Deva at La Hermida (Minwegen, 2001).

Within the Casavegas Syncline (Pisuerga-Carrión Unit, northern Palencia) lower Kasimovian calcareous debrisflow deposits called Urbaneja Limestone occur within the Upper Ojosa Formation. An outcrop at the road to Lores exposes these strata in a thickness of almost 100 m (Wagner, Varker, 1971). Few olistolithic limestone blocks of slightly older age (Lores Limestone, base of Upper Ojosa Formation, Myachkovian, Uppermost Moscovian), occur north of Areños in a low road cut (Wagner, Varker, 1971; Minwegen, 2001). The outcrop at the road to Lores yielded quite abundant sphinctozoans, among those large and branched *Discosiphonella mammillosa* (van de Graaff in Wagner and Varker, 1971, p. 575). Facies of the mostly dark limestone clasts is diverse, but micritic matrix predominates. Like elsewhere, sphinctozoans are associated with filter feeding organisms, in places also with *Archaeolithophyllum* and *Anthracoporella*, but not with phylloid green algae. From the road cut north of Areños Minwegen (2001) described a micritic sphinctozoan boundstone (?) with abundant small sphinctozoans, which are covered by thin microbial crusts; demosponges, fistuliporid and fenestellid bryozoans, and gastropods are associated. *Anthracoporella* boundstones occur in another limestone block in that locality. The reworked limestone clasts of both localities allow reconstruction of a low energetic, carbonate-dominated lagoonal setting, which seems to be similar to the sphinctozoan-Anthracoporella facies of Demués.

Summing up, upper Moscovian-lower Kasimovian sphinctozoans from the Cantabrian Mountains are unexpected diverse, abundant, and inhabited varied environments, in spite of the "new" occurrence of that paraphyletic taxon after the extended Upper Devonian-Mississippian gap. They were constantly part of a suspension feeding community including other sponge taxa, crinoids, bryozoans and brachiopods. They did not live in oligotrophic agitated shallow-water populated by photozoans (fusulinids, phylloid algae). Three habitats are obvious.

(1) Predominantly delicate to slender sphinctozoans, in places forming dense meadows, lived in eutrophic, marly lagoons. They were attached to skeletal hard parts of invertebrates or rooted in soft bottom. In more calcareous, but still eutrophic lagoonal setting, the ancestral red alga *Archaeolithophyllum* acted as sediment binder and formed a stable substrate for sphinctozoan growth.

(2) Slender to large sphinctozoans dwelled in low energetic, carbonate dominated lagoonal settings intermingled with the stick-like growing dasycladacean *Anthracoporella*. They might form sphinctozoan-*Anthracoporella* boundstones.

(3) Predominantly large sphinctozoans dwelled in buildups below wave base on an extended carbonate platform. Sedimentation rates and probably also nutrient influx was low.

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Numerical Calibration of the Early Carboniferous (Mississippian) Time Scale

Manfred Menning[1], **Dieter Weyer**[2]

[1]Deutsches GeoForschungsZentrum Potsdam, Telegrafenberg C128,
D-14 473 Potsdam, Germany, e-mail: menne@gfz-potsdam.de

[2]Loewestr. 15, D-10 249 Berlin, Germany, e-mail: dieter.weyer@t-online.de

Several time indications can be used to construct a numerically calibrated time scale:
– Radio-isotopic age determinations (RIADs),
– climatically induced sedimentary cycles of Milankovich-duration,
– weighted average thicknesses,
– graphic correlation.

The variable interpretation and combination of these indications leads to variable time scales whose precession also depends from precise biostratigraphic control. Thus, each time scale is a model.

The composite time scale of Menning et al. (2000) has been carefully balanced, as far as data allows, to remove unnecessary, artificial compression and expansion of time intervals, biozonations and depositional events. The time scales of the Stratigraphische Tabelle von Deutschland 2002 (STD 2002), the Devonian-Carboniferous-Permian Correlation Chart 2003 (DCP 2003), and Weyer and Menning (2006) corresponds to that of Menning et al. (2000) which was extended at its base to a compromise age of 358 Ma (Fig. 1). The Mississippian time scales of the STD 2002 and GTS 2004 (Geologic Time Scale 2004; Gradstein et al., 2004) are close to each other whereas some ages are markedly different to those in Haq and van Eysinga (1987), the Geologic Time Scale 1989 (GTS 1989; Harland et al., 1990) and in Gradstein and Ogg (1996).

Weyer and Menning (2006) have documented and standardized 20 RIADs (364–319 Ma) from Central and West Europe (12), Australia (4), Asia (1), and North America (3). These data are related to the Belgian resp. British substages and to standard biozones as accurately as possible and are shown in relation to the time scale of the STD 2002 / DCP 2003:

1. The confidence rectangles of the RIADs 7, 8, 9, 14, 17, and 18 lay on the regression line of the STD 2002. Thus, they are consistent to the STD 2002. Such "older" RIADs were used to construct the scale.

2. The error rectangles of the RIADs 10, 11, 12, 13, 15, and 19 are inconsistent to the STD 2002. Using them, the ages of the stage boundaries Visean-Serpukhovian and Serpukhovian-Bashkirian would became younger and the duration of the Visean Stage would be extended and, vice versa, the duration of the Late Carboniferous would be reduced.

3. The STD 2002 / DCP 2003 age of ca. 358 Ma for the Devonian-Carboniferous boundary (DCB) is a compromise between the ca. 354 Ma age for the DCB, based on U-Pb SHRIMP dates (Claoué-Long et al.,1993), and the ca. 362 Ma age for the DCB, based on U-Pb ID-TIMS dates (Tucker et al., 1998). An age of 360.7 ± 0.7 Ma has been derived for the DCB from U-Pb ID-TIMS dating of two metabentonites (360.2 ± 0.7 Ma for bed 70, Early *Siphonodella duplicata* Zone, and 360.5 ± 0.8 Ma for bed 79, late part of the *Siphonodella sulcata* Zone) taken from the Hasselbach auxiliary global stratotype section in the Rhenish Slate Mts. (Rheinisches Schiefergebirge) (Trapp et al., 2004). Using the probable, though unsure FAD of *Siphonodella sulcata* in bed 84 of this section, and its thickness, the age of the DCB is estimated at ca. 361.4 ± 0.7 Ma (Weyer and Menning 2006). This age is totally consistent with the Re-Os isochrone age of 361.3 ± 2.4 Ma for the DCB from the Jura Creek, Alberta, Canada (Selby and Creaser 2005). Thus, an age of sligthly >360 Ma is optimal for the DCB, whereas ages between 354 Ma to 359 Ma were favoured during the last 15 years.

4. The 320 Ma age for the Early-Late Carboniferous boundary (Menning et al., 2000; STD 2002; DCP 2003) is based on the $^{40}Ar/^{39}Ar$ date of 324.6 Ma for the Jaklovec Member in Upper Silesia (Lippolt et al., 1984), close to the Pendleian-Arnsbergian boundary (intra-Namurian A) (Menning et al., 2000: Fig. 6). The $^{40}Ar/^{39}Ar$ age of 319.5 Ma for the Poruba Member (Lippolt et al., 1984), within the Middle Arnsbergian (Menning et al., 2000: Fig. 6), is indicative of a younger age for this boundary, and an age of ca. 318 Ma was suggested for this boundary (Weyer and Menning 2006).

5. The Early-Late Carboniferous boundary (intra Namurian A) is between 320 Ma and 317 Ma. Thus, the Mississippian, with duration of ⩾40 Ma, is twice as long than the Pennsylvanian. For a long time the duration of the Pennsylvanian was overestimated, mainly because of the tremendous thicknesses of coal-bearing deposits in the United States and Europe.

6. Mostly, the ages of the STD 2002 / DCP 2003 are rounded to the nearest 0.5 Ma in order to avoid estimates of questionable accuracy, whereas ages rounded to 0.1 Ma in the GTS 2004 with error bars of ± 0.4 Ma to ± 2.8 Ma for the Devonian to Permian stage boundaries suggest an improved accuracy. In contrast, in the STD 2002 / DCP 2003 questionable ages and positions of stratigraphic boundaries are marked by arrows.

7. The duration of the ammonoid zones of Central Europe and the British Isles varies significantly in the latest Devonian to earliest Late Carboniferous time (Fig. 1). The large majority of zones are no longer than 0.5 Ma in average. It yields one of the best time resolutions of the Phanerozoic. Only 5 zones are longer than 1 Ma. However, in the early Visean of Central Europe there is a time span of ca. 10 Ma without data. It corresponds approximately to the conodont zones *Gnathodus texanus* and *Gnathodus praebilineatus* (Fig. 1).

8. The continuous use of the time scale of the STD 2002 / DCP 2003 is recommended (Fig. 1) despite of the above mentioned small modifications.

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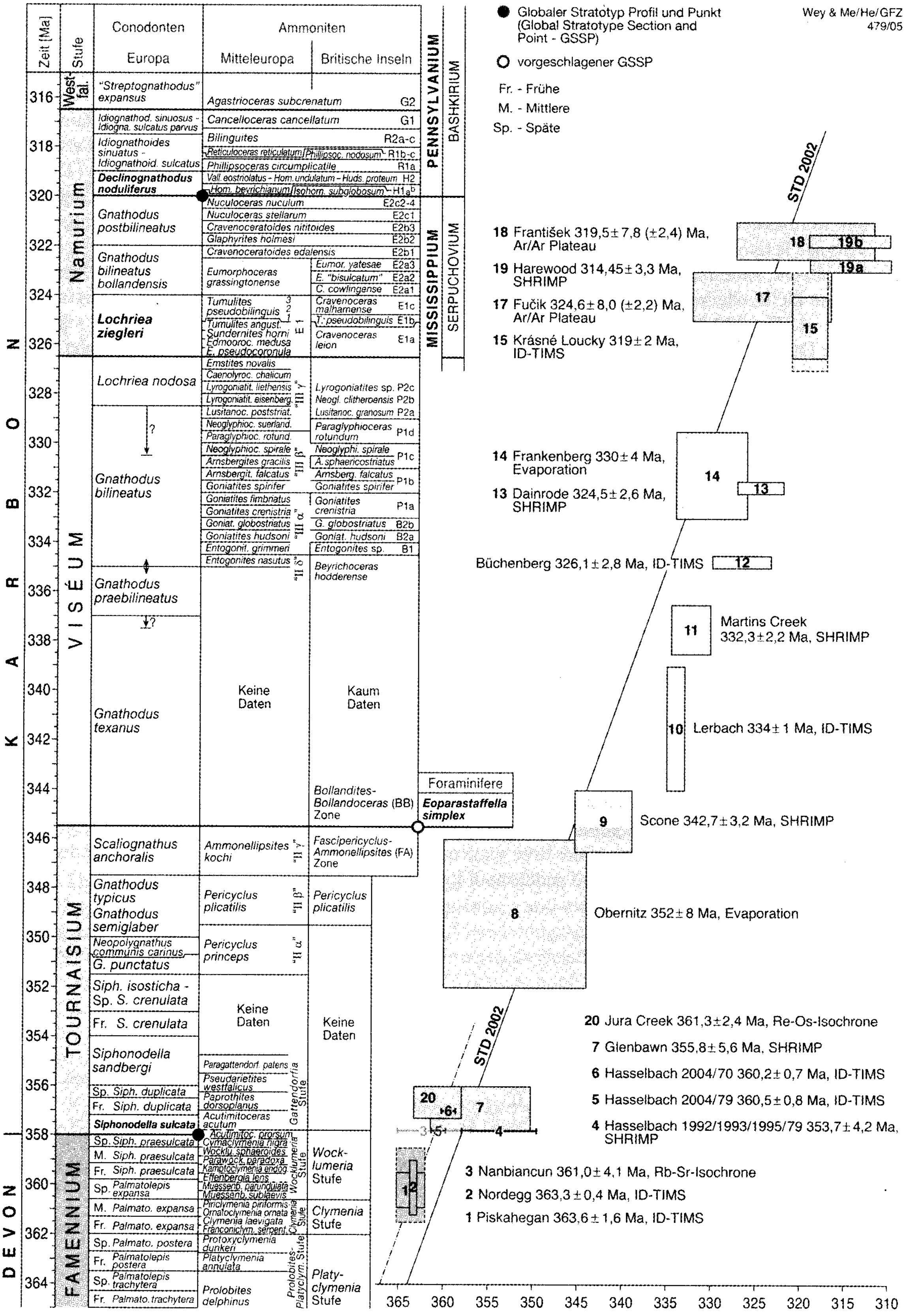
Zeit [Ma]
Stufe
Conodonten
Europa
Ammoniten
Mitteleuropa
Britische Inseln
PENNSYLVANIUM
BASHKIRIUM
MISSISSIPPIUM
SERPUCHOVIUM
Westfal.
Namurium
VISÉUM
TOURNAISIUM
FAMENNIUM
KARBON
DEVON
"Streptognathodus" expansus
Agastrioceras subcrenatum G2
Idiognathod. sinuosus - Idiogna. sulcatus parvus
Cancelloceras cancellatum G1
Idiognathoides sinuatus - Idiognathoid. sulcatus
Bilinguites R2a-c
Reticuloceras reticulatum/Phillipsoc. nodosum R1b-c
Phillipsoceras circumplicatile R1a
Declinognathodus noduliferus
Vall. eostriolatus - Hom. undulatum - Huds. proteum H2
Hom. beyrichianum/Isohom. subglobosum H1a^b
Nuculoceras nuculum E2c2-4
Gnathodus postbilineatus
Nuculoceras stellarum E2c1
Cravenoceratoides nititoides E2b3
Glaphyrites holmesi E2b2
Cravenoceratoides edalensis E2b1
Gnathodus bilineatus bollandensis
Eumorphoceras grassingtonense
Eumor. yatesae E2a3
E. "bisulcatum" E2a2
C. cowlingense E2a1
Lochriea ziegleri
Tumulites pseudobilinguis
Tumulites angust.
Sundernites horni
Edmooroc. medusa
E. pseudocoronula
E 1
Cravenoceras malhamense E1c
T. pseudobilinguis E1b
Cravenoceras leion E1a
Lochriea nodosa
Emstites novalis
Caenolyroc. chalicum
Lyrogoniatit. liethensis
Lyrogoniatit. eisenberg.
Lusitanoc. poststriat.
Neoglyphioc. suerland.
Paraglyphioc. rotund.
Neoglyphioc. spirale
Arnsbergites gracilis
Arnsbergit. falcatus
Goniatites spirifer
Goniatites fimbriatus
Goniatites crenistria
Goniat. globostriatus
Goniatites hudsoni
Entogonit. grimmeri
Entogonites nasutus
"III γ"
"III β"
"III α"
"II δ"
Lyrogoniatites sp. P2c
Neogl. clitheroensis P2b
Lusitanoc. granosum P2a
Paraglyphioceras rotundum P1d
Neoglyphi. spirale P1c
A. sphaericostriatus
Arnsberg. falcatus P1b
Goniatites spirifer
Goniatites crenistria P1a
G. globostriatus B2b
Goniat. hudsoni B2a
Entogonites sp. B1
Beyrichoceras hodderense
?
Gnathodus bilineatus
Gnathodus praebilineatus
Gnathodus texanus
Keine Daten
Kaum Daten
Bollandites-Bollandoceras (BB) Zone
Foraminifere
Eoparastaffella simplex
Scaliognathus anchoralis
Ammonellipsites kochi
"II γ"
Fascipericyclus-Ammonellipsites (FA) Zone
Gnathodus typicus
Gnathodus semiglaber
Pericyclus plicatilis
"II β"
Pericyclus plicatilis
Neopolygnathus communis carinus
G. punctatus
Pericyclus princeps
"II α"
Siph. isosticha - Sp. S. crenulata
Fr. S. crenulata
Keine Daten
Keine Daten
Siphonodella sandbergi
Paragattendorf. patens
Sp. Siph. duplicata
Pseudarietites westfalicus
Fr. Siph. duplicata
Paprothites dorsoplanus
Siphonodella sulcata
Acutimitoceras acutum
Gattendorfia Stufe
Sp. Siph. praesulcata
Acutimitoc. prorsum
Cymaclymenia nigra
M. Siph. praesulcata
Wocklu. sphaeroides
Parawock. paradoxa
Fr. Siph. praesulcata
Kamptoclymenia endog.
Effenbergia lens
Sp. Palmatolepis expansa
Muessenb. parundulata
Muessenb. sublaevis
Wocklumeria Stufe
Wocklumeria Stufe
M. Palmato. expansa
Piriclymenia piriformis
Ornatoclymenia ornata
Fr. Palmato. expansa
Clymenia laevigata
Franconiclym. serpent.
Clymenia Stufe
Clymenia Stufe
Sp. Palmato. postera
Protoxyclymenia dunkeri
Fr. Palmatolepis postera
Platyclymenia annulata
Sp. Palmatolepis trachytera
Prolobites delphinus
Fr. Palmato. trachytera
Prolobites-Platyclym. Stufe
Platyclymenia Stufe
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● Globaler Stratotyp Profil und Punkt (Global Stratotype Section and Point - GSSP)
○ vorgeschlagener GSSP
Wey & Me/He/GFZ 479/05
Fr. - Frühe
M. - Mittlere
Sp. - Späte
STD 2002
18 František 319,5±7,8 (±2,4) Ma, Ar/Ar Plateau
19 Harewood 314,45±3,3 Ma, SHRIMP
17 Fučik 324,6±8,0 (±2,2) Ma, Ar/Ar Plateau
15 Krásné Loucky 319±2 Ma, ID-TIMS
18
19b
19a
17
15
14 Frankenberg 330±4 Ma, Evaporation
13 Dainrode 324,5±2,6 Ma, SHRIMP
14
13
Büchenberg 326,1±2,8 Ma, ID-TIMS
12
11
Martins Creek 332,3±2,2 Ma, SHRIMP
10
Lerbach 334±1 Ma, ID-TIMS
9
Scone 342,7±3,2 Ma, SHRIMP
8
Obernitz 352±8 Ma, Evaporation
STD 2002
20 Jura Creek 361,3±2,4 Ma, Re-Os-Isochrone
7 Glenbawn 355,8±5,6 Ma, SHRIMP
6 Hasselbach 2004/70 360,2±0,7 Ma, ID-TIMS
5 Hasselbach 2004/79 360,5±0,8 Ma, ID-TIMS
4 Hasselbach 1992/1993/1995/79 353,7±4,2 Ma, SHRIMP
3 Nanbiancun 361,0±4,1 Ma, Rb-Sr-Isochrone
2 Nordegg 363,3±0,4 Ma, ID-TIMS
1 Piskahegan 363,6±1,6 Ma, ID-TIMS
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1
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365
360
355
350
345
340
335
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325
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315
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Fig. 1.

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Conodont biostratigraphy of the Naqing (Nashui) section in South China: candidate GSSPs for both the Serpukhovian and Moscovian Stages

Yuping Qi[1], Xiangdong Wang[1], Zhihao Wang[1], H. Richard Lane[2], Barry C. Richards[3], Katsumi Ueno[4] and John R. Groves[5]

[1]Nanjing Institute of Geology and Paleontology, the Chinese Academy of Sciences,
Nanjing, 210008, P. R. China

[2]National Science Foundation of USA,
Arlington, VA, 22230, USA

[3]Geological Survey of Canada,
Calgary, Alberta T2L 2A7, Canada

[4]Department of Earth System Science, Faculty of Science, Fukuoka University,
Fukuoka 814-0180, Japan

[5]Department of Earth Science, University of Northern Iowa,
Cedar Falls, IA 50614, USA

In the Carboniferous, the endemism of biota, the strong glacial-eustatic control over sedimentation and consequent widespread disconformities hamper the selection of acceptable GSSPs for the Carboniferous stages, including the Serpukhovian, Moscovian, Kasimovian and Gzhelian. Those relatively deeper-water, carbonate-slope and basinal sections can be served as potential candidate sections for GSSPs. The Naqing Section, which was formerly named as the Nashui section in Luosu, Luodian, Guizhou Province, South China, is such a slope facies section. More detailed biostratigraphy of both foraminifers and conodonts mainly for the two GSSPs of the Serpukhovian Stage and the Moscovian Stage have been carried out in last year. The sedimentary study for the two stages has also being carried through with centimeters sampling.

Very abundant conodonts are found from both the Visean-Serpukhovian (V/S) boundary interval (28 species including one new species representing 6 genera) and the Bashkirian-Moscovian (B/M) boundary interval (31 species representing 9 genera). Three conodont zones occur at Naqing in the V/S boundary interval including, in ascending order, *Gnathodus bilineatus*, *Lochriea nodosa*, and *Lochriea ziegleri* zones in an about 20 m interval. It is proposed herein that the FAD of *L. ziegleri* from the evolutionary lineage *L. nodosa–L. ziegleri* at 60.60 m above the base of the Naqing section could serve as the best marker for the base of the Serpukhovian. And four conodont zones are found in the Bashkirian-Moscovian boundary interval, in ascending order, the *Streptognathodus expansus*, *Diplognathodus coloradoensis*, *Diplognathodus ellesmerensis* and *Gondolella donbassica–G. clarki* zones in an about 15 m interval. We tentatively propose a new definition for the base of the Moscovian Stage, which is the FAD of *Diplognathodus ellesmerensis* from the conodont lineage *Diplognathodus coloradoensis–D. ellesmerensis* at 173.00 m above the base of the Naqing section in South China. This boundary approximately coincides with the entry of the fusulinid *Profusulinella*, making it easier for a global correlation.

More detailed foraminifer biostratigraphy and sedimentary research in the Naqing section are underway. A comparable section, the Yashui section, which is shallow water facies and is about 50 km north of the Naqing section, was selected to be studied in order to establish a correlation to the slope facies. The Yashui section contains abundant foraminifers and rugose corals among which the foraminifer *Neoarchaediscus postrugosus* is important because its first appearance marks the base of the Serpukhovian Stage in its type section in Zaborye Quarry, Moscow Basin, Russia. The successions of foraminifers and rugose corals will be taken out in near future.

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"The historical type sections, proposed and potential GSSP of the Carboniferous in Russia"

August 11–12, 2009

Alexander S. Alekseev, Nataliya N. Goreva, Editors

ТИПОВЫЕ И ОПОРНЫЕ РАЗРЕЗЫ КАРБОНА ЮЖНОЙ ЧАСТИ ПОДМОСКОВЬЯ

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Подкомиссии по каменноугольной стратиграфии
Международного союза геологических наук
«Исторические типовые разрезы, предложенные и потенциальные
Глобальные стратотипические разрезы и точки карбона в России»

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