A.P. Karpinsky Russian Geological Research Institute
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Lower Carboniferous of the St. Petersburg region (northwestern Russia)

Guidebook of pre-Congress field trip
August 8–10, 2015

A.P. Karpinsky Russian Geological Researcn Institute
St. Petersburg State University

LOWER CARBONIFEROUS OF THE ST. PETERSBURG REGION (NORTHWESTERN RUSSIA)

AUGUST 8–10, 2015

A FIELD GUIDEBOOK

of XVIII International Congress on the Carboniferous and Permian

E d i t e d b y

Yury V. Savitsky
Olga L. Kossovaya
Irina O. Evdokimova

A u t h o r s

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Authors

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On the cover:
the sketch by Roderick I. Murchison 'The Gurmaya Hills, South Urals, approaching from the Steppes' (Murchison et al., 1845)

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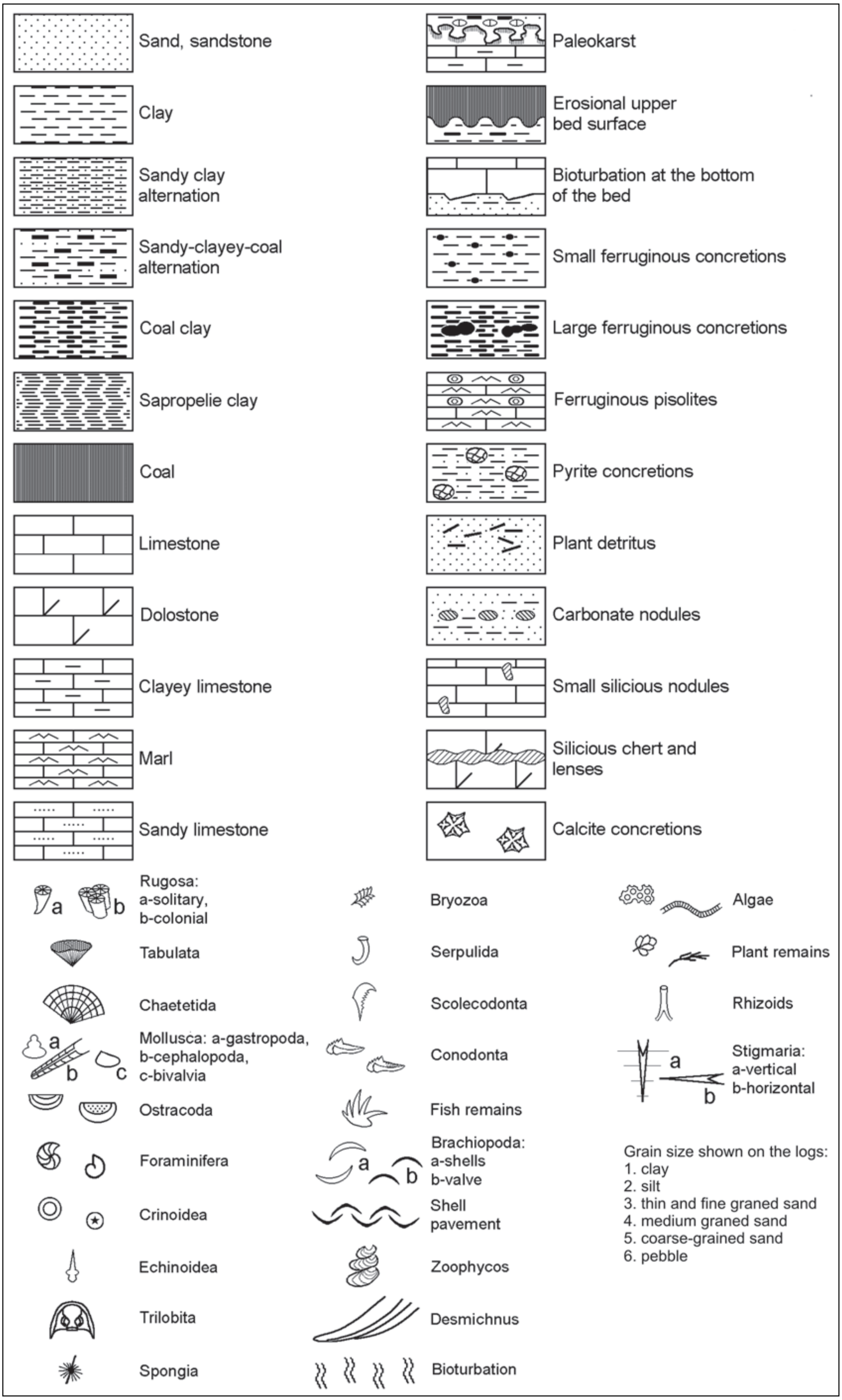
Sand, sandstone
Clay
Sandy clay alternation
Sandy-clayey-coal alternation
Coal clay
Sapropelie clay
Coal
Limestone
Dolostone
Clayey limestone
Marl
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Bioturbation at the bottom of the bed
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Rhizoids
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Grain size shown on the logs:
1. clay
2. silt
3. thin and fine graned sand
4. medium graned sand
5. coarse-grained sand
6. pebble

INTRODUCTION

Lower Carboniferous deposits are distributed within a wide area of the northwestern part of the Moscow basin. They have been known for many years as the source of mineral deposits of bauxite, brown coal, and other industrial minerals, including fireproof clays and building materials as the most important.

The geologic investigation of these Lower Carboniferous deposits began more than 200 years ago. Many well-known geologists and academicians such as S. G. Gmelin, S. F. Olivieri, G. P. Gelmersen, R. Murchison, E. Verneuil, N. P. Barbot de Marni, E. Eichwald, A. A. Inostrantsev, and P. A. Zamyatchensky made the first step in the geological investigation of the region, laid the foundation of the stratigraphy of the Lower Carboniferous strata of the northwestern part of the Moscow basin.

However, much extensive geological work was done on these deposits over a 30–60 year period of the last century. The significance of these works is difficult to overestimate. During this time detailed investigation of many sections was carried out by many workers (Yanishevsky, 1936; Forsh, 1935; Hecker, 1938a; Sokolov, 1944, 1946, 1959). The stratigraphical chart of the Lower Carboniferous deposits was constructed (Bogdanova, 1929; Sokolov, 1939, 1941; Kotlukov, Yanishevsky, 1948), features of cyclic sedimentation and variability of the lithological complexes was documented, and data on facies composition and sedimentation regimes were found (Bruns, 1935, 1939; Vishnyakov, 1940; Ulmer, 1935, 1946). A major breakthrough was the work on the paleontological documentation of the ages of the various strata and their correlation with the southern part of the Moscow syneclise (Yanishewsky, 1935, 1937, 1954; Zhelezkova, 1938; Pozner, 1951; Ganelina, 1951; Shlykova, 1951). Also, paleoecological investigation was first carried out in our country (Hecker, 1938b; 1940).

These important geological investigations of the Lower Carboniferous strata of this area provided the main data that supported the publication of geological maps of 1:200 000 scale, delineating the whole area of Lower Carboniferous rock distribution (Sammet, 1959; Kofman, 1960; Aleksandrova, Sverbenkova, 1960; Ostrometskaya, 1963). Knowledge of the geology of the region was summarized in a multi-authored monograph entitled “Geology of the USSR, v. 1, Leningrad, Pskov and Novgorod regions” (ed. Selivanova and Kofman, 1971). The structure and stratigraphy of the Lower Carboniferous deposits in this region are still of great interest at the present time because of the revisions of stage subdivisions and their boundaries in the International Stratigraphical Scale, and auxiliary problems of regional and world wide stratigraphical correlation.

Last decade investigations of the Lower Carboniferous deposits of northernwest flank of the Moscow syncline have been focused on the details of the stratigraphic subdivision and lithofacies characteristics (Savitsky, Kossovaya Vevel, Leontyev, 2005; Savitsky, Kossovaya, Vevel, Evdokimova, 2006, Savitsky, Kossovaya Vevel, 2007). Choosing of markers and tracing the stage boundaries of the International Stratigraphic Chart has led to the refinement of the position of the Serpukhovian–Visean boundary in the section along the Msta River (Savitsky, Kossovaya Vevel, Evdokimova, 2012; Savitsky, 2013).

The purpose of this guidebook is to document several key sections of the Upper Visean – Serpukhovian deposits that are located in the Novgorod district. They are most important for understanding the history, sedimentation and features of stratification within the entire northwestern area of the Moscow basin. The combination of easy access, slight diagenetic alteration, and abundant faunal remains (foraminifers, porifers, cnidaria, ostracodes, bivalves, brachiopods, crinoids, conodonts, vertebrates and trace fossils) permit these sections to be considered as significant in the understanding of Carboniferous stratigraphy. The authors have taken as their task the modern precise stratigraphical documentation (litho- and biofacies, paleontological data), but the traditional nomenclature of the stratigraphical subdivisions is kept.

GEOLOGICAL SETTING OF THE NORTHWESTERN PART OF THE RUSSIAN PLATFORM

The region of the geological excursion is situated in the northeastern part of the Moscow basin (Russian platform) (Fig. 1). Sedimentary cover of this region includes Late Proterozoic – Paleozoic deposits overlying the Archaean – Proterozoic dislocated crystalline granite-gneiss basement. Total thickness of the sedimentary cover is more than 1500 m. The sedimentary depositional sequence thickens to the south-southeast with a regional dip at a slight angle in the same direction. In the south part of the area the Late Paleozoic deposits are also exposed.

The oldest sedimentary rocks overlying the basement are of Vendian age and consist of sandy-silt and clay (thickness about 140m). The Cambrian strata are characterized by sandy-silt-clay of Lower Cambrian age and sandstone of Middle Cambrian age (thickness about 200m). The Lower and Middle Ordovician deposits are represented by varigrained quartz sandstone with phosphatic brachiopod shells, "Dictyonema" graptolite shales, and a carbonate-clay unit (thickness about 300 m).

The Middle and Upper Devonian sequence consists of siliciclastic-carbonate deposits overlying the Ordovician sequence with a remarkable erosional unconformity (thickness about 700 m). Lower Carboniferous deposits complete the Paleozoic succession and overly the erosional surface of the Devonian rocks. The erosional surface of the Devonian deposits is marked by deep grooves or depressions.

Locally, Tournaisian and Lower Visean terrigenous deposits fill in the depressions in the pre-Carboniferous relief. Upper Visean and Serpukhovian deposits are represented by a wide variety of marine and non-marine lithofacies consisting of various kinds of siliciclastic-clay and siliciclastic-carbonate rocks (thickness about 160 m).

Glacial and fluvioglacial Quaternary unconsolidated deposits of variable thickness cover the whole area. Pre-Quaternary deposits are exposed along the incised river valleys.

STRATIGRAPHY OF THE LOWER CARBONIFEROUS DEPOSITS OF THE NORTHWESTERN PART OF THE MOSCOW BASIN

The Lower Carboniferous sequence present in the north-western part of the Moscow basin consists of Tournaisian, Visean and Serpukhovian deposits exposed in numerous outcrops of varying thickness in river valleys and quarries. Such age deposits also have been recognized in numerous boreholes made in this area. A wide variety of lithofacies including both terrestrial and shallow-water shelf sequences reflect frequent change of depositional environment. One of the reasons for the variable sedimentary regime is the distinct eustatic control of the depositional processes on the marginal part of the epicontinental Moscow basin.

In accordance with the relevant Regional Stratigraphic Chart, Lower Carboniferous deposits are subdivided into formations that are chronologically correlated to the regional substages of the Russian platform. The correlation with International Stages is debatable and ambiguous because of insufficient correlation criteria (Fig. 2).

LOWER CARBONIFEROUS, TOURNAISIAN STAGE

Gumerovian – Upian Regional Substages

Koegoshcha Formation. The Koegoshcha Formation consists of limy wax-like thin-bedded clays, partly silty or sandy with limy seams, dolostone, dolomitic marlstone, and fine-grained quartz sand (thickness up to 18m). The Koegoshcha Formation contains the spores: *Tumulispora malevkensis* (Kedo) Turnau, *Vallatisporites pusillites* (Kedo) Dolby et Nev., *Reticulatisporites tschernischensis* (Jushko) Oshurkova, *Cyclogranisporites rugosus* (Naum.) Oshurkova, *Apiculatisporis rarispinosus* (Jushko) Oshurkova (Kofman, 1989, Oshurkova, 2003). Here and below, nomenclature is presented in accordance to the modern one for sporae dispersae.

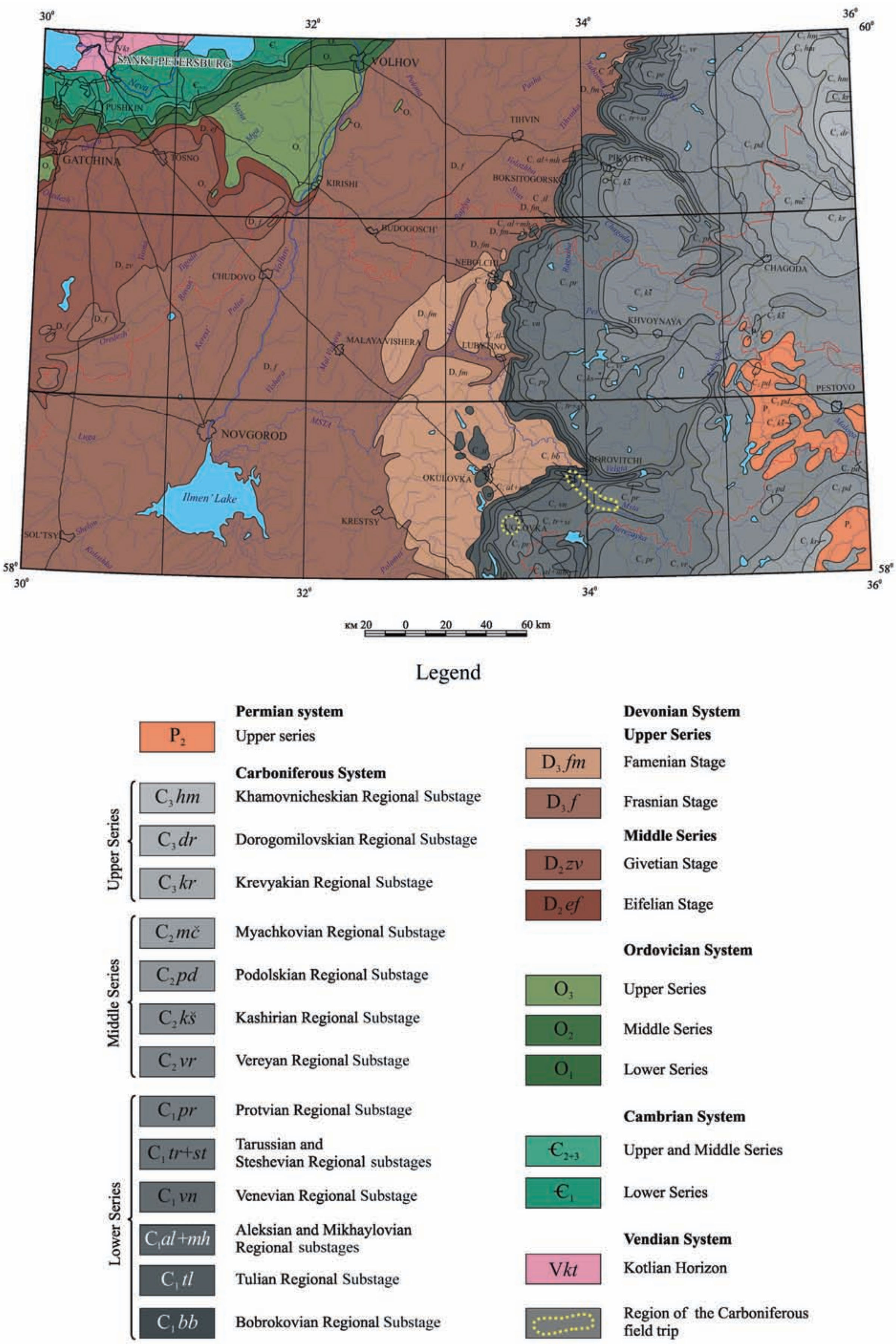


Fig. 1. Geological map of northwestern part of Moscow Basin

VISEAN STAGE, LOWER SUBSTAGE

Radaevkian Regional Substage

Kremnitsa Formation. The Kremnitsa Formation is represented by variegated kaolinite clays and siallitic-like rocks with an insignificant sandy-silt admixture and numerous small plant remains (thickness 7m). These deposits have unconformable lower and upper boundaries. They are considered as the lower part of the residual soil generated on the pre-Visean rocks. Their age is not well determined and is tentatively based on the paleogeographical history of the region.

Bobrikian Regional Substage

Bobriki Formation. The Bobriki Formation is represented by an intercalation of sandy-clayey and coal-clayey deposits containing kaolinite-clay seams, fine-grained quartz sand and brown coal lenses of insignificant thickness. The formation is of limited distribution and fills in depressions and isolated cavities of the pre-Visean relief (thickness 3–10 m). The spore assemblage includes: *Vallatisporites variabilis* (Waltz) Oshurkova, *V. valleculosus* (Waltz) Oshurkova, *V. intermedius* (Waltz) Oshurkova, *Densosporites goniacanthus* (Waltz) Byvsch., S*tenozonotriletes glabrum* Naum., *Ambitisporites pumilus* (Waltz) Oshurkova, *Cincturasporites sulcatus* (Waltz) Hacq. et Barss, *Potoniespores tenuisulcatus* (Waltz) Oshurkova, *Anulatisporites tersus* (Waltz) Pot. et Kr., *Euryzonotriletes planus* Naum., *E. macrodiscus* (Waltz) Isch., *Knoxisporites literatus* (Waltz) Playf., *Cincturasporites trivialis* (Kedo et Jushko) Oshurkova, *Punctatisporites platyrugosus* (Waltz) Sulliv., *Lycospora pusila* (Ibr.) Som., *Tripartites incisotrilobus* (Naum.) Pot. et Kr., et al. (Salamon and Vanreflit, 1966; Kofman, 1989, Oshurkova, 2003).

VISEAN STAGE, UPPER SUBSTAGE

The Visean deposits extend almost continually from the Valdai Hills to Onega Lake. The succession contains multiple intercalations of marine and terrestrial deposits and is subdivided into two parts. The lower part is characterized by sandy, clayey-coal sediments and bauxites, and the upper part is represented by mixed siliciclastic-carbonate rocks. To the north, the siliciclastic deposits become predominant and consist of successive cycles of sand and clay intercalating with limestone beds. The limestone beds are used as markers and are traceable up to tens of kilometers. They permit the definition of lateral facies transitions at isochronous levels. The specific terminology (a_1, a_1, etc.) assigned to the limestone sequence proposed by Bogdanova (1929) is used for regional correlation.

Tulian Regional Substage

Tikhvin Formation. This formation has been well studied because of the discovery of bauxite, fireproof clay and brown coal (thickness reaches 50m). The composition and thickness of the Tikhvin Formation is determined by the paleo-relief features and marginal marine paleoenvironments indicated in the sedimentary record in the northwestern part of the Moscow basin. This formation is stratigraphically unconformable with the underlying deposits and is represented by three distinct units.

The lower unit is represented by deposits consisting of carbonaceous sand, siltstone, sandy clay, and coal clay with thin layers of brown coal and lignite (thickness 60–70m in the deep depressions). In the Borovichi area the unit includes carbonaceous clay intercalated with limestone layers. The various limestone beds contain *Parastaffella struvei* (Moeller), poorly-preserved *Eostaffella*, *Endothyra*, rare *Archaediscus*, *Hyperammina*, and representatives of the Paleotextulariida (Kofman and Goryansky, 1971).

The middle unit is represented by fireproof clays and bauxite rocks (*kaolinite clay - bauxite complex*) that are distributed on the slopes of the pre-Visean uplifts (thickness varies from 1 to 25–30 m). These deposits accumulated in the troughs and valleys of the paleoerosional system and on the slopes of bay-like depressions.

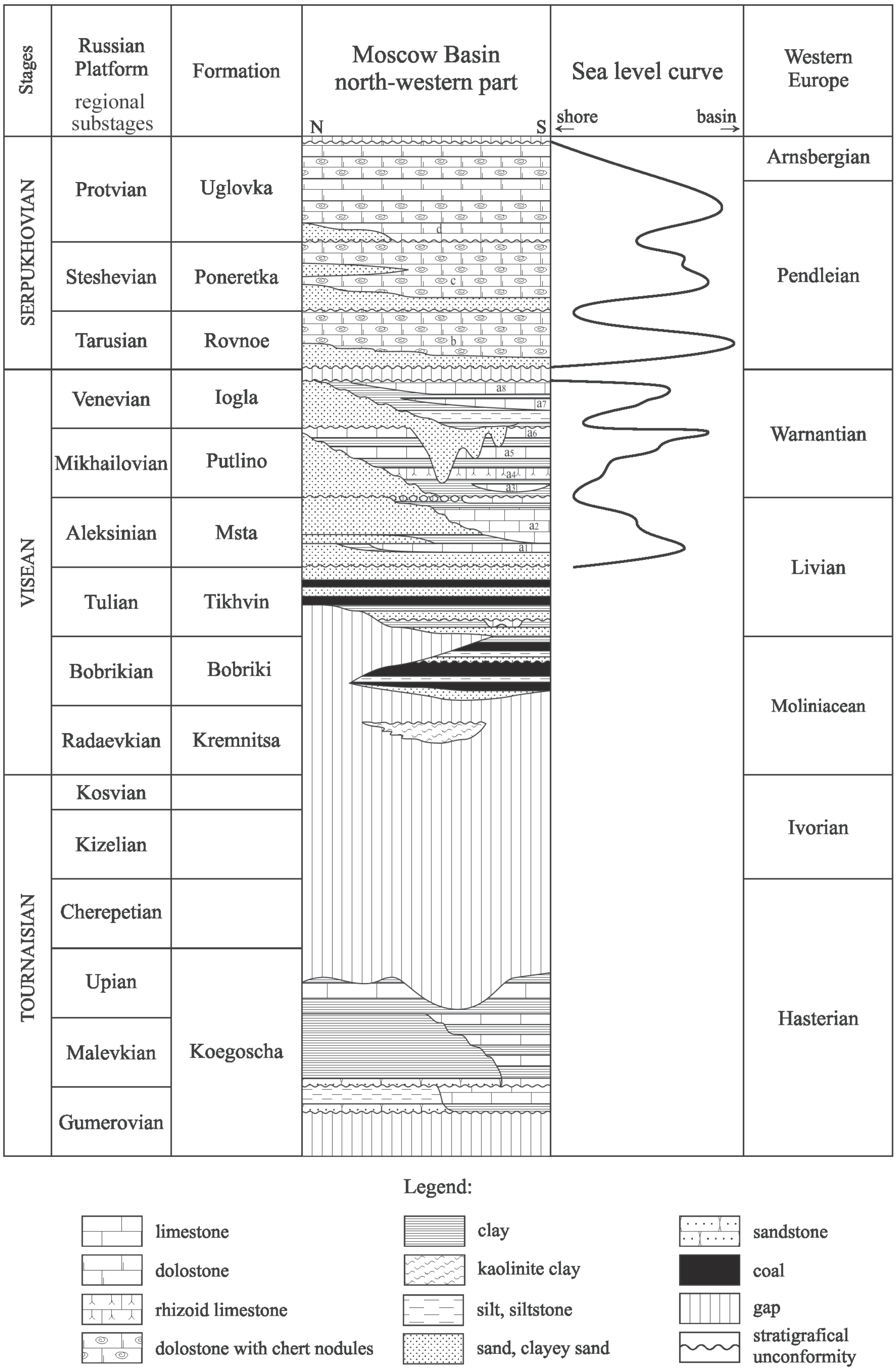


Fig. 2. Stratigraphic subdivision, lithological complexes and correlation of the Lower Carboniferous of the Moscow Basin

The upper unit of the Tikhvin Formation is represented by clayey-coaly-sandy-deposits covering the underlying rocks with an erosional unconformity (thickness varies from 7 to 30 m). The unconformity is considered to be an isochronous level separating the Lower Tulian from the

Upper Tulian. The gray plastic fireproof clays, mostly kaolinite, rarely hydromica or beidellite, and brown coals are widely distributed. Quartz sand seams and lenses rarely occur.

Aleksinian Regional Substage

Msta Formation. The basal part of the Msta Formation is represented by sandy-clayey deposits with a significant lower erosional boundary (thickness 20–25 m). Upwards it is characterized by the organogenic and clayey Limestones a_1 and a_2, that are separated by a gray sandy-clayey unit.Foraminifers, ostracods, brachiopods, bryozoans, crinoids, vertebrate remains, and conodonts occur in the limestones (Fig. 3).

The upper surfaces of the limestones are characterized by traces of horizontal bioturbation. *Zoophycos* traces are more distinctive in the upper part and on the upper surface of Limestone a_2. The Limestone a_2 is overlain by 30 cm of a carbonate-clay unit. Above this unit there is thin limestone layer (3 cm) showing an extensive erosional unconformity. Based on the occurrence of limestone pebbles, erosional pockets, and reworked conodonts, the unconformity is traceable outside of the stratotype region. The significance of this unconformity is considered to be one of high correlation potential (Aristov, Savitsky, and Fedorova, 1999; Savitsky, Ivanov, and Orlov, 2000).

The lithofacies of the formation changes about 30 km to the north-west of the town of Borovichi where the siliciclastic deposits become predominant and the limestones (except Limestone a_1) totally disappear from the succession.

The most typical organic remains present in the limestones are foraminifers, ostracods brachiopods, and conodonts: foraminifers – *Earlandia elegans* (Rauser et Reitlinger), *Omphalotis samarica* (Rauser), *Endothyranopsis crassa* (Brady), *Archaediscus moelleri gigas* Rauser, *Eostaffella mosquensis* Vissarionova, *Mediocris mediocris* (Vissarionova); rugose corals – *Paleoasmilia murchisoni* (Milne Edwards et Haime), *Siphonodendron junceum* (Fleming); ostracods – *Amphissites umbonatus* (Eichw.), *Am. urei* (Jones), *Janischewskya digitata* Batalina, *J. longiscula* Zanina, J. levigata Posner, *Bairdia hisingeriformis* (Posner), *Kirkbya lessnikovae* Posner, *K. volginoensis* Posner, *Youngiella naviculata* Posner, *Scrobicula scrobiculata* (Jones, Kirkby et Brady), *Kindlella bituberculata* (McCoy), *K. legibilis* (Zanina), *Shishaella porrecta* (Zanina), *Cavellina quasiattenuata* Egorov, *C. recta* (Jones, Kirkby et Brady), *Knoxiella posneri* Egorov, *Jonesina fastigata* (Jones et Kirkby), *Borovitchella egorovi* Gramm; brachiopods – *Chonetes parvus* Janischewsky, *Avonia yungiana* (Davidson), *Buxtonia scabricula* (Martin),*Semiplanus semiplanus* (Schwetzov), *Gigantoproductus inflatus* (Sarycheva), *G. striatosulcatus* (Schwetzov), conodonts – *Gnathodus bilineatus bilineatus* (Roundy), *G. girtyi girtyi* Hass, *Cavusgnathus naviculus* (Hinde), *Mestognathus beckmanni* Bisch., and *Mestognathus bipluti* Higgins.

Mikhailovian Regional Substage

Putlino Formation. The Putlino Formation is characterized by interlayered limestone, clay, siltstone and sand (thickness varies from 10–23m). The succession includes Limestones a_3–a_6 that are represented by crinoid-foraminiferal-algal packstone with large shells of the Gigantoproductidae.

Abundant horizontally, vertically, or obliquely orientated rizophores of *Stigmaria* are present in this sequence of rocks. Numerous worm traces (*Rhizocorallium*, *Vermichnus, Zoophycos*) also can be seen at the base of the Limestones a_5 and a_6. The top of each of the Limestones a_4–a_6 is often characterized by an erosional surface bearing locally deep scours filled in with alluvial clayey-sandy-coal sediments.

Limestone a_6 is the most prominent one among the limestones of the Okian Series and can be traced in outcrops more than 200 km. It can be traced continuously to the north from the village of Lubytino. All underlying limestones are represented by persistent lenses that are intermittent in the succession.

The fauna of the Putlino Formation is abundant and varied. It includes: foraminifers – *Parastaffella sagittaria* Schlykova, *Tetrataxis media* Vissarionova, *Bradyina rotula* (Eichwald), *Janischewskina calceus* Ganelina, *J. typica* Mikhaulov, *Palaeotextularia longiseptata magna* Lipina;

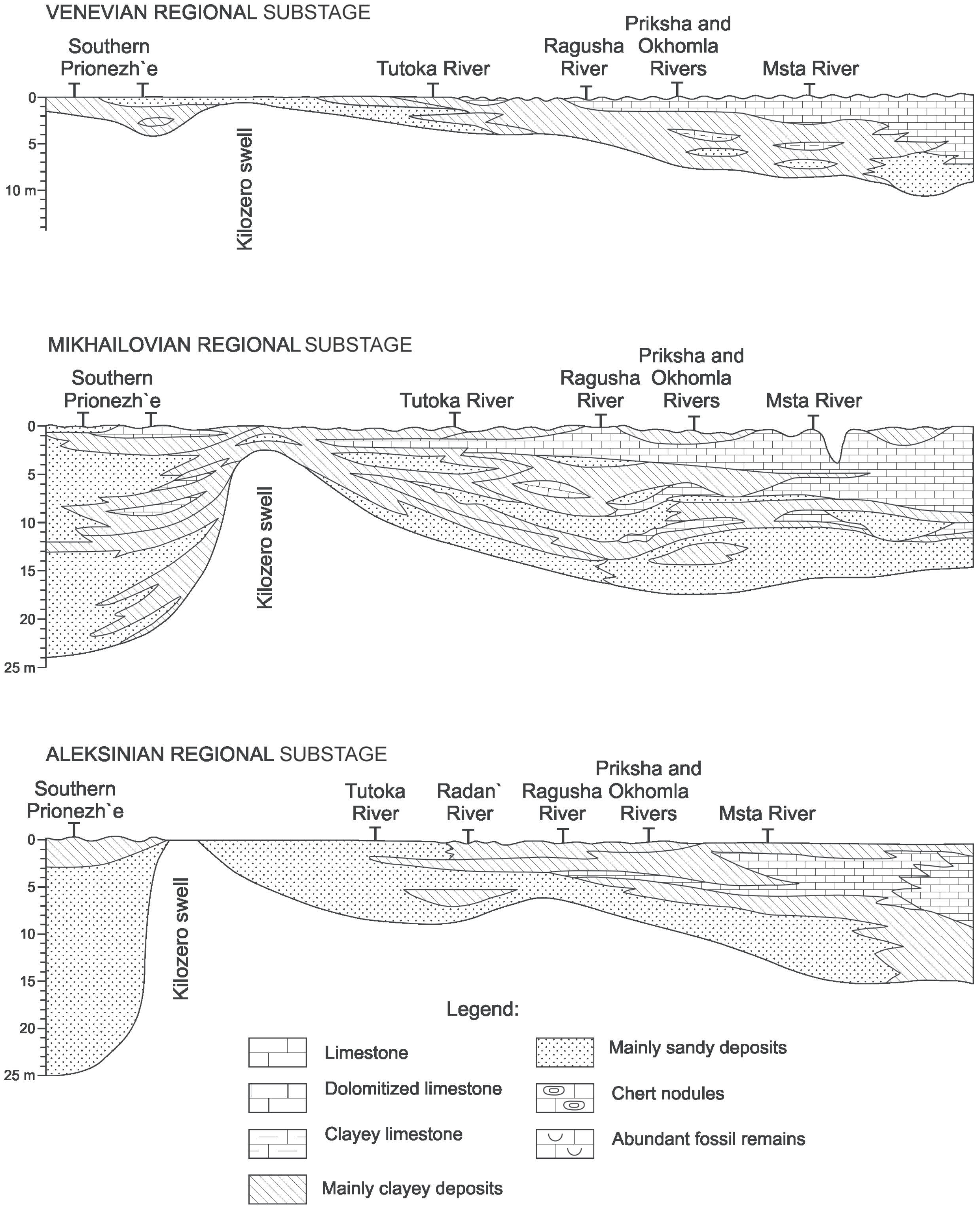


Fig. 3. Litho-facies profiles of the Upper Visean deposits of the northwestern part of the Moscow Basin (based on Osipova, Belskaya, 1969 with authors additions)

rugose corals – *Actinocyathus floriformis* (Martin), *Siphonodendron intermedium* (Milne Edwards et Haime); ostracods – *Glyptopleura concentrica* Posner, *Bairdiacypris fabulina okensis* (Posner), *Paraparchites galbus* Posner, *Cavellina forschi* Posner, *Bairdia korzenewskajae* Posner, *B. mandelstami* Posner, *B. brevis jonesi* Posner; brachiopods – *Datangia moderata* (Schw.), *G. striatosulcatus* (Schw.), *G. giganteus* (Sowerby), *Linoproductus wischnjakovi* (Janishevskiy); conodonts – *Gnathodus girtyi girtyi* Hass, *Cavusgnathus naviculus* (Hinde), and *Mestognathus bipluti* Higgins.

Venevian Regional Substage

Iogla Formation. Deposits of the Iogla Formation overlap the erosional surface of the Putlino Formation and are represented by alternation of the sandy-clayey and coaly rocks, and limestones (thickness varies from 1–2 to 15 m). In the type section on the Msta River the lower part of the succession contains a loosely consolidated clayey rizoid chalk-like limestone bed characterized by the occurrence of numerous brachiopod shells (Limestone a_7). It is overlain by a siliciclastic unit separating Limestone a_7 from the foraminiferal-algal-crinoidal Limestone a_8. Its upper surface is characterized by a karst-like development of vertical canal-like hollows. Outside of the limits of the type area, Limestone a_8 occurs as intermittent discontinuous lenses. The erosional surface of the top of Limestone a_8 reflects a significant regional unconformity. Deposits of the Iogla Formations contain: algae remains – *Calcifolium okense* (Schwetzov et Birina); foraminifers – *Endothyranopsis crassus* (Brady), *E. sphaerica* (Rauser et Reitlinger), *Forschiella prisca* Mikhailov; ostracods – *Jonesina bivesiculosa* Posner, *J. janischewskyi* Posner, *Janischewskya levigata* Posner, *Cavellina recta* (Jones, Kirkby et Brady), *Glyptopleura spinosa* (Jones et Kirkby), *G. plicatul*a Posner, *Bairdiacypris distracta* (Eichwald), *Monoceratina yungiana* (Jones et Kirkby), and *Posneratina jonesi* (Posner); brachiopods – *Gigantoproductus janischewskii* (Sarytcheva), *Gigantoproductus striatosulcatus* (Schwetzow), *Datangia moderatoconvexa* (Janischewsky), *Gigantoproductus okensis* (Sarycheva); conodonts – *Cavusgnathus naviculus* (Hinde).

SERPUKHOVIAN STAGE

Tarusian Regional Substage

Zaboryevian Series

Rovnoe Formation. The Rovnoe Formation is subdivided into two parts (maximum thickness 12 m). The lower part consists of mostly silty clays and clayey sands with thin lenses of brown coal. The upper part is considered as Unit b, a term proposed by Bogdanova (1929), and is represented by a single limestone. This unit has no visible lamination, and consists of micritic and bioclastic partly dolomitized limestone including layers of silica nodules. The bedding surfaces are bioturbated by *Zoophycos*. Numerous thin shell brachiopods and other invertebrates occur in pocket-like accumulations and seams. Brachiopods, bivalves, ostracods and foraminifers are dominant. The fauna includes: foraminifers – *Eostaffella tenebrosa* Vissarionova, *E. infulaeformis* (Ganelina), *Palaeotextularia longiseptata crassa* Lipina, *Asteroarchaedscus rugosus* (Rauser) *Cribrostomum communis* Moeller, *Haplophragmella fallax* Rauser et Reitlinger; ostracods – *Bairdia legumen* (Jones et Kirkby), *Microcheilinella inflata* (Jones et Kirkby); brachiopods – *Pulsia janischewskii* Sokolskaja., *Meekella thomasi* Janischewsky, *Schuchertella rovnensis* Janischewsky, *Chonetes dalmanianus* Koninck, *Eomarginifera praecursor* (Muir-Wood), *Antiquatonia prikschiana* (Janischewsky), *Spirifer pseudotrigonalis* Semichatova., *Martinia angulisinuata* Janischewsky, *Pugilus pugiliformis* (Janischewsky); cephalopods – *Megapronorites sakmarensis* Ruzhentzev.; conodonts – *Gnathodus girtyi girtyi* Hass, *G. bilineatus bilineatus* (Roundy), *Lochriea ziegleri* Nemirovskaya, Perret et Meischner, *L. cruciformis* (Clarke), *L. nodosa* (Bischoff) and *L. mononodosa* Rhodes, Austin et Druce.

The carbonate unit is considered as an important marker in the section of the Lower Carboniferous deposits of the region. Its top is an erosional surface characterized by a paleosoil and indicates the pre-Steshevian interruption of sedimentation (Fig. 4).

Steshevian Regional Substage

Poneretka Formation. The base of the Poneretka Formation consists of loose fine-grained sand and siltstone followed by medium to thick-bedded bioclastic limestone (thickness about 35 m). The limestone is dolomitized to a variable degree and include repetitive layers with silica nodules. This limestone was considered as Unit c by Bogdanova (1929). Numerous moulds and imprints of faunal elements are present. Trace fossils are characterized by simple horizontally and vertically oriented holes, and *Zoophycos*. To the north from Borovichi the carbonate unit

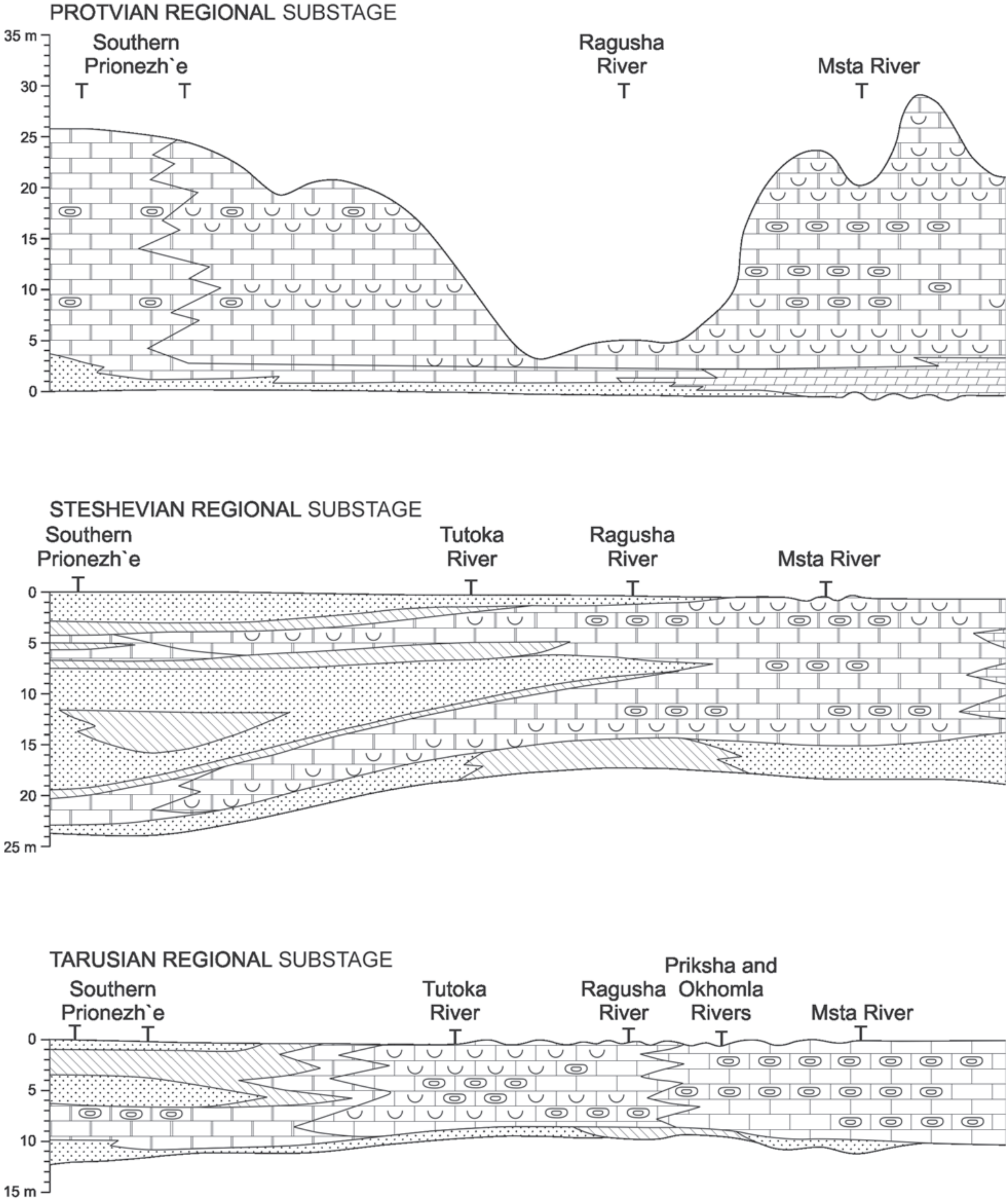


Fig. 4. Litho-facies profiles of the Serpukhovian deposits of the northwestern part of the Moscow Basin (based on Osipova, Belskaya, 1969 with authors additions)

is subdivided by a sandy clayey interval (thickness 1–4 m). Thus, in places the nature of the formation changes and the sandy clayey carbonate rocks are repeated twice.

The fauna is represented by: foraminifers *Eostaffella ikensis* Vissarionova, *E. parastruvei* Rauser, Vissarionova, *Endathyronopsis crassus* (Brady), *Endothyra bowmanii* Phillips, *Cribrostomum bradyi* Moeller, *Archaediscus* ex gr. *chernoussovensis* Mamet; tabulate and rugose corals: *Chaetetes rossicus* Sokolov, *Actinocyathus borealis* (Dobrolyubova), *Actinocyathus crassiconus subcrassiconus* (Dobrolyubova); ostracods – *Amphissites mosquensis* Posner, *Scrobicula cincinnata* Posner, *Hollinella* *sokolovi* Posner, *Janischewskya steschovensis* Posner, *J. pleschakovi* Posner, *Healdia kudrjavtzevi* Posner; brachiopods – *Chonetes papilionaceus* (Phillips), *Striatifera explanata* Janischewsky, *Striatifera striata* (Fischer), *Striatifera lata* Janischewsky, *Gigantoproductus superior* Janischewsky, *Antiquatonia khimenkovi* (Janischewsky), *Latiproductus latissimus* (Sowerby), *Spirifer multicostatus* Schwetzov; conodonts – *Gnathodus bilineatus bilineatus* (Roundy), *Cavusgnathus unicornis* Youngquist et Miller, *Vogelgnathus campbelli* (Rexroad).

Protvian Regional Substage

Lesnovian Series

Uglovka Formation. The Uglovka Formation is represented by carbonate deposits everywhere in the region studied. It consists of yellowish dolomite and strongly recrystallized silicified limestone considered as Unit d by Bogdanova (1929) (thickness about 45m). It overlies the limestone of the Poneretka Formation. The bottom is marked by an erosional surface and the top is strongly eroded. To the north from Borovitchi, the limestone and dolomite at the base of the Uglovka Formation are replaced by a thin interval (0.1–0.3 m) of sandy-clayey rocks. This interval includes sandy and silty clays with interbedded quartz and mica sands. The fauna is often recrystallized and is represented by: foraminifers – *Eostaffella protvae* Rauser, *E. subsphaerica* Ganelina, *Climacamina gracilis* (Moeller), *Bradyina cribrastomata* Rauser et Reitlinger; rugose corals – *Corwenia rugosa* (Mc Coy), *C. densivesiculosa* Dobrolyubova; brachiopods – *Echinoconchella elegans* (M`Coy), *Gigantoproductus superbus* Sarycheva, *Latiproductus latiexpansus* (Sarytcheva), *Antiquatonia khimenkovi* (Janischewsky), and *Striatifera lata* (Janischewsky).

BIOSTRATIGRAPHICAL REVIEW

Foraminifers, Chaetetidae, Cnidaria, ostracodes, and brachiopods are the more abundant faunal groups found in the Lower Carboniferous deposits of the northwestern part of the Moscow basin. The palaeontological dating of the local and regional stratigraphical subdivisions is based mainly on the results of the investigation of these groups. Plant remains, Porifera, bivalves, gastropods, cephalopods, scolecodonts, crinoids are of lesser importance. Special palaeontological works dealing with the fauna and flora of the Lower Carboniferous strata of this area are not numerous despite the wide usage of the palaeontological data for geological correlation.

Most publications dealing with the fossil remains of this area were published in the middle of the last century. The most important among them are papers on foraminifers by Mikhailov (1935a, 1935b, 1939a, 1939b), Ganelina (1951, 1956), and Shlykova (1951); on chaetetides by Sokolov (1939a, 1939b); on rugose corals by Karaeva (1935) and Dobrolyubova (1958); on gastropods by Vostokova (1955), on brachiopods and bivalves by Yanishewsky (1954, 1960); and on ostracodes by Pozner (1951). Some publication on conodonts, ichnofauna, and ostracodes (Savitsky, Ivanov, and Orlov, 2000), and also on rugose corals appeared recently (Hecker, 1997, 2002; Poty and Hecker, 2003). Some data on plant remains also have been published recently (Snigirevsky, 1994; Snigirevsky & Orlova, 2000, 2003, 2004)

The data presented in the following review is based on the bed-by-bed study of the key sections that are the first to be published.

Foraminifers. The subdivisions and correlation of the Upper Visean and Serpukhovian (Lower Carboniferous) deposits of the Moscow basin have always been traditionally based on a scheme that was accepted for the central part of the Moscow basin. According the foraminifers data (Lipina & Reitlinger, 1970; Decisions, 1990), the Aleksinian Regional Substage is considered equivalent to the range of the Eostaffella proikensis – Archaediscus gigas Zone, the Mikhailovian Regional Substage is considered equivalent to the Eostaffella ikensis Zone, and the Venevian Substage is considered equivalent to the Eostaffella tenebrosa – Endothyranopsis sphaerica Zone. The Tarusian and Steshevian regional substages are considered equal to the Pseudoendothyra globosa – Neoarchaediscus parvus Zone, and the Protvian Regional Substage is considered equivalent to the Eostaffellina protvae Zone. These foraminiferal zones have been interpreted as assemblage zones. They were established by the assemblage of species or by the characteristic features of the assemblage, and they do not reflect the precise stratigraphical distribution of the index species. They are considered mainly as the indicators of the paleoenvironments rather than markers of geological age. That's why the revision of the taxonomical composition of these units in the stratotype sections presents difficulties with the boundary definitions (Makhlina, Vdovenko, Alekseev, and al., 1993; Gibshman, 2003; Kulagina, Gibschman, & Pazukhin, 2003).

Up to the present time, a detailed investigation of the Lower Carboniferous sections in the northwestern region of the Moscow basin has not been carried out. The results proposed in this guidebook are the first data on the systematic measuring and sampling of these substage intervals.

The foraminifer assemblage of Limestones a_1 and a_2 of the Msta Formation includes more than 100 species that are characteristic of the Upper Visean. The genus *Parastaffella* is represented mainly by the *P. struvei* (Moell.) group. The genus *Eostaffella* is characterized by the occurrence of the *E. mosquensis* Vissarionova group, but *Eostaffella* species with a rounded periphery also occur along with them. The genus *Endothyranopsis* is very abundant and is represented by numerous specimens of *E. crassus* (Brady) and *E. compressus* (Rauser et Reitlinger). The genus *Globoendothyra* includes a large number of species: the *G. globulus* (Eichw.) group, *G. numerabilis (*Vissa.), *G.* aff. *G. inconstans* (Grozd. et Leb.), and others. The genus *Omphalotis* is known by rare specimens of *O. samarica* (Rauser) and *O.* sp. Archaediscidae of the *A. krestovnikovi* Rauser group are also abundant. Large archaediscids (*A. moelleri* Rauser, *A. itinerarius supressa* Schlykova, *A. mellitus* Schlykova, *A. operosus* Schlykova, *A. magna* Schlykova) occur rather commonly, but more rarely than *A. moelleri gigas* Rauser. Rare *Paraarchaediscus* and some specimens of *Archaediscus* similar with *Permodiscus syzranicus* Tchernyscheva also occur. The genus *Mikailovella* is represented by only the species *M. grasilis* (Rauser.). The assemblage also includes following taxa: *Haplophragmella*, *Cribrospira* (*C.* aff. *mikhailovi* Raus, *C. sp*.), *Endothyra (E.)* aff. *granularis* Rosovskaya, *E. tatianae* Ganelina; *E. (Similisella), Eotuberitina*, *Mediocris*, *Endostaffella,* and large *Earlandia*. The Palaeotextulariida are characterized by following genera: *Palaeotextularia* (with one – and two-layer wall) and *Cribrostomum*. Rare representatives of *Pseudoammodiscus*, *Tetrataxis*, *Valvulinella, Forschia*, *Climacammina?*, *Lituotubella (Lituotubella* ex gr. *L. glomospiroides* Rauser) also occur.

As a whole, the assemblage is characterized by a mixed composition containing a large number of species characteristic for the *Endothyranopsis compressus – Archaediscus krestovnikovi* Zone (the Tulian Regional Substage). This assemblage includes in part species typical for the *Endothyranopsis crassus – Archaediscus gigas* Zone. The interval of the distribution of this assemblage is equivalent to the Aleksinian, Mikhailovian and Venevian regional substages. The foraminiferal assemblage of the Putlino Formation (Limestones a_3, a_4, a_5, and a_6) is represented by more than 80 species.

The foraminiferal association of Limestone a_3 is similar in taxonomical composition with the previous one, but it is impoverished both in the number of specimens and species. It is characterized by fewer archaediscids represented by the *A. krestovnikovi* Rauser group and rare *Paraarchaediscus pauxillus* Schlykova. Less commonly *Endothyranopsis* sp. and scarce *Globoendothyra* ex gr.*G. globula* (Eichwald) occur. *Mediocris*, *Endostaffella* and *Eostaffella* (ex gr. *E. mosquensis*) have also been found.

In Limestone a_4 the species composition of foraminifers is similar to the assemblage from Limestone a_3, but it is enriched by new genera and species characteristic for the Eostaffella ikensis Zone of the Mikhailovian Regional Substage. The genus *Janischewskina* and star-shaped *Asteroarchaediscus baschkiricus* (Krestovnikov. et Theodorovich) appear first. However, the archaediscids are diminished in number. Among the eostaffellids, *E*. ex. gr. *E. ikensis* Vissarionova, scarce *Eostaffellina* (?) *irenae* (Ganelina), rare *Endothyranopsis sphaerica* (Rauser et Reitlinger) and *Brunsia* sp. occur. Large *Omphalotis* ex gr. *O. omphalota* (Raus. et Reitl.) and *O. minima* (Raus. et Reitl.) also occur. *Bradyina rotula* (Eich.) and *B.*ex gr. *B. rotula* (Eich.) became abundant. *B. flosuculus* Ganelina and *B.* aff. *B. modica* Ganelina also have their first appearance.

Limestone a_5 contains a rich and variable assemblage of the Mikhailovian Regional Substage.

Janischewskina (*J.* sp., *J. calceus* Gan., *J. typica* Mikh.) is distributed throughout the entire thickness. *Endothyranopsis crassus* (Brady), large *Omphalotis* (*O. sp., O. omphalota* (Rauser et Reitlinger)), abundant *Bradyina* and *Forschia* (*F.* sp., *F. mikhailovi* Dain, *F.* ex gr *F. parvula* Raus.) occur.

With respect to the foraminiferal content, Limestone a_6 is similar with previous one, but differs by less diversification, possibly because of insufficient preservation of the fauna.

The Iogla Formation includes Limestones a_7 and a_8, however, foraminifers are known only from Limestone a_8 The assemblage of the Iogla Formation is similar to the previous one. Differences seen are characterized by the co-occurrence of *Endothyranopsis* crassus (Brady) together with *E. sphaerica* (Rauser et Reitlinger); frequent *Bradyina* (ex gr. *B. rotula* (Eichw.) and rare *B. flosuculus* Ganelina. *Janischewskina* ex gr.*J. typica* Mikhailov and *J.* ex gr. *J. rovnensis* Ganelina occur. Advanced *Janischewskina* with a thin wall also appears. The appearance of *Forschiella prisca* Mikhailov, characteristic for the Venevian Regional Substage has been recorded (Ganelina, 1956) and also there is a mass accumulation of the alga *Calcifolium okense* Schwetzov et Birina.

The foraminiferal assemblage of the Limestone b was found in the Rovnoe Formation. It is correlated to the Tarusian Regional Substage (Makhlina, Vdovenko, Alekseev et al., 1993) and is characterized by a very depleted assemblage in which Late Visean species are dominant. Rare *Earlandia*, *Palaeotextularia*, *Climacammina*, *Archaediscus*, *Endostaffella*, *Mediocris*, *Eostaffella*, *Janischewskina,* and rare Asteroarchaediscus occur. The data obtained do not allow the determination of the precise stratigraphical position of the assemblage.

Rugose corals. Investigation of rugose corals from the Lower Carboniferous deposits of the northwestern part of the Moscow basin was started in the 19th century by the expedition of Murchison carried out in 1840. Material collected by him was given to Lonsdale (1845) for determination. Lonsdale identified two species of *Actinocyathus* from outcrops on the outskirts of Borovichi. Both these species belong to *A. borealis* (Dobrolyubova) (Poty & Hecker, 2003). Stuckenberg (1904) continued the study of Lower Carboniferous corals of the Russian Platform. Later Ivanovsky (1987) restudied this collection (CNIGR museum, St. Petersburg, coll. 44), of which only the species *Actinocyathus rossicus* (Stuckenberg) is now available in this collection.

In the years 1932–1933, Karaeva (1935) studied an abundant collection of rugose corals that had accumulated to that time. She distinguished typical assemblages by using the numbers of the different limestone beds proposed by Bogdanova (1929). She subdivided the assemblages for the units a, b, c, and d, and also distinguished coral assemblages for the 1–6 layers of unit a (Karaeva, 1935). She proposed a preliminary correlation with the coral zonation adopted at that time for the Carboniferous succession in the Franco-Belgian basin. Hecker (1940) included corals in his bed-by bed description of Limestone a and he also made some observations about the affinities of the ecological pattern of coral distribution. The next step in coral investigations of the strata in this area, which was not finished by Karaeva in spite of her plan to compare the corals of the Borovitchi region and northern part of the area, was done by Dobrolyubova (1958).

Many specimens of rugose corals have been collected from the outcrops along the Msta River, the Ragusha and Tutoka rivers, and the Uglovka Quarry during students geological field work, some short field trips, and in the preparation of this guidebook. According to the previous data and also supported by our recent sampling, Limestone a_2 contains rare solitary *Palaeaosmilia murchisoni* (Milne Edwards et Haime). Hecker's fasciculate *Siphonodendron junceum* (Fleming) also appears at this level in the succession on the Msta River and occurs in Limestone a_2. We found this species in the middle-upper part of Limestone a_2 at the Vittsy rapids of the Msta River (Plate 3) together with *Palaeosmilia murchisoni* (Milne-Edwards et Haime). Thus, the Aleksinian Regional Substage corresponding to Limestones a_1–a_2 of the Msta Formation is characterized by presence of *Siphonodendron junceum* (in a_2 near the Vittsa rapids in our collection), *Palaeosmilia murchisoni* (the same outcrops), and *Orionastraea rareseptata* Dobrolyubova (near the village of Vittsy, Hecker, 2002). A *Siphonodendron–Palaeosmilia* assemblage was also found in outcrops of the Msta Formation along the Priksha River (Stop 9). *S. junceum* is widespread in the Upper Visean of the Urals (Kozhim section) outside of the region studied. In the stratotype region of the Visean Stage this form is reported from Cf6(γ), the middle part of the Warnantien (Poty, 1981), and up to the end of Warnatien (Poty, 1984).

The Mikhailovian Regional Substage, represented in the region studied by the Putlino Formation, contains the genus *Actinocyathus* in Limestone a_4. *Siphonodendron* occurs rather rarely and representatives of the genus were found in Limestone a_6 (Ragusha River) and differ from *S. junceum* by well developed minor septa. Similar specimens were considered by Dobrolybova (1958) as *S. junceum* (Fleming) (plate 19, fig.4), but they seem to be belong to *S. intermadium* (Milne Edwards et Haime). This species appears earlier in the Livian and in the Tulian of the Moscow basin and ends at Cf6(δ), a little earlier than *S. junceum*. A rather rich assemblage of *Siphonodendron* is known in contemporaneous deposits outcropping along the Priksha River.

In our collections, the first *Actinocyathus* was found in Limestone a_4 at the Kamenka River outcrops 15cm below the top of the limestone. This species is considered to be *A. floriformis floriformis* (Martin). Dobrolyubova (1958) described *Actinocyathus floriformis floriformis* (Martin) from the long interval from the Aleksinian to the Protvian, and mentioned that corals from Limestone a_4 are not typical. In the revision by Poty and Hecker (2003) of part of this material, mostly Serpukhovian, the latter species was referred to *Actinocyathus borealis* (Dobrolyubova). They considered *A. floriformis floriformis* as a first representative of the genus in the phylogenetic chart of the "*floriformis*" group. Specimens from our collections differ from *A. borealis* by their smaller size and the type of dissepiments, and are considered to be *A. floriformis floriformis*. *Actinocyathus* also occurs in Limestone a_6 in the outcrops along the Priksha River.

Actinocyathus continues to the Tarusian Regional Substage, but this genus is mostly abundant in the Steshevian Regional Substage (unit c) where some colonies reach a length of 70cm. Our collections have been recently enlarged by specimens from the Gverstka outcrop (Stop 7) and from new levels from the Mokraya Poneretka River area (Stop 9).

In spite of the fact that the stratigraphic interval bearing these colonial corals is nearly the same, they differ in their taxonomic composition. In the upper part of the Poneretka Formation, the Mokraya Poneretka outcrop (bed 13), *Actinocyathus borealis* (Dobrolyubova) with wide dissepiments and *A. osipovae* (Dobrolyubova) were identified. Both *A. osipovae* and corals found in the Gverstka outcrop (stop 6) belong to another phylogenetic lineage (collection made in 2005). The latter species has very large corallites (max d – 2.5 cm), bear a rather complicated inner structure and is considered to be *Actinocyathus crassiconus subcrassiconus* (Dobrolyubova).

The Protvian boundary is characterized by colonial coral bioherms or large *Lithostrotion* colonies. The exact species determination is not possible because of very poor preservation, but the level is very useful as a lithostratigraphic marker. The assemblage of corals in the Protvian Regional Substage (Uglovka Formation) is very different. There, Actinocyathus colonies occur rarely, and numerous fasciculate Corwenia appear (collection made in 2005). *Corwenia rugosa* (McCoy) was found in a silicified limestone in the Malyi Porog outcrop (Stop 8) and *C. densivesiculosa* Dobrolyubova is known from the Uglovka Quarry (lower floor) (Stop 10).

Brachiopods. Species of the Order Productida are the main component of the Upper Visean – Serpukhovian brachiopod associations, but species referred to the Rhynchonellida, Spiriferida, Athyrida also occur.

According to the modern stratigraphical scheme, the Gigantoproductus – Semiplanus Genozone corresponds to the Aleksinian, Mikhailovian and Venevian regional substages. The brachiopod assemblages are characterized by a remarkable similarity of the taxonomic composition. Some differences established among the assemblages of these regional substages seem to be ecological ones. Beds with *Datangia praemoderata* correspond to the Aleksinian Regional Substage. The assemblage occurs in Limestones a_1 and a_2 of the Msta Formation and consists mainly of thin-bedded shells of *Chonetes parvus* Janischewsky, *Avonia yungiana* (Davidson), *Buxtonia scabricula* (Martin), *Semiplanus semiplanus* (Schwetzow), *Gigantoproductus gigant*eus (Martin), *Datangia praemoderata* (Sarytcheva), *Productus concinnus* Sowerby, *Pugnax pugnus* (Martin), *Pricodothyris lineata* (Martin), *Composita trinuclea* (Hall), and *Composita ambigua* (Sowerby).

Beds with *Datangia moderata* correspond to the Mikhailovian Regional Substage. They contain mainly thick-shelled gigantoproductids: *Semiplanus semiplanus* (Schwetzov), *Gigantoproductus giganteus* (Martin), *Gigantoproductus inflatus* (Sarytcheva), *Gigantoproductus janischewskii* (Sarytcheva), *Gigantoproductus striatosulcatus* (Schwetzow), *Datangia moderatus* (Schwetzow), *Gigantoproductus crassus* (Martin), and lesser abundant *Avonia yungiana* (Davidson), *Buxtonia scabricula* (Martin), *Productus concinnus* Sowerby, *Pugilus rossicus* Sarytcheva, *Pricodothyris lineata* (Martin), *Echinoconchus punctatus* (Martin), and *Echinoconchella elegans* (M'Coy). These species range in the interval from Limestone a_3 up to Limestone a_6 of the Putlino Formation. A more variable and abundant assemblage is characteristic for Limestone a_4, above which the composition and quantity of the assemblage is restricted.

Beds with *Datangia moderatoconvexa* correspond to the Venevian Regional Substage. They are characterized by a depleted brachiopod assemblage containing *Semiplanus semiplanus* (Schwetzov), *Gigantoproductus janischewskii* (Sarytcheva), *Gigantoproductus striatosulcatus* (Schwetzow), *Datangia moderatoconvexa* (Janischewsky). This assemblage is known from Limestone a_7 in the lower part of the Iogla Formation.

The Serpukhovian Stage corresponds to the Gigantoproductus–Latiproductus Genozone that is subdivided into three parts: An assemblage of thin-shelled small brachiopods, distinctly different from the underlying one, can be distinguished at the base of the zone (corresponding to Limestone b in the Rovnoe Formation). It consists of *Schuchertella rovnensis* Janischewsky, *Pulsia janischewskii* Sokolskaja, *Isogramma germanicum* Paeckelmann, *Meekella thomasi* Janischewsky, *Chonetes dalmanianus* Koninck, *Avonia yungiana* (Davidson), *Buxtonia scabricula* (Martin), *Echinoconchus punctatus* (Martin), *Echinoconchella elegans* (M'Coy), *Ovatia tenuistiatus* (Verneuil), *Pugilus pugiliformis* (Janischewsky), *Antiquatonia prikschiana* (Janischewsky), *Eomarginifera praecursor* (Muir-Wood), *Spirifer pseudotrigonalis* Semichatova, *Pricodothyris lineata* (Martin), *Composita trinuclea* (Hall), and *Dielasma attenuatum* (Martin). To the north of the key-section (Msta River, village of Rovnoe), the diversity is reduced and some thick-shelled forms appear. *Latiproductus priscus* (Sarytcheva), *Striatifera stiata* (Fischer), and *Striatifera lata* (Janischewsky) have been found. *Gigantoproductus giganteus* (Martin) and *G. striatosulcatus* (Schwetzow) as transitional species from the underlying deposits also occur. A clear-cut distinction of the assemblages is connected with the facial differentiation of the beds. These beds are correlated with the Tarusian Regional Substage.

The middle part of the Zone corresponds to the Poneretka Formation (Limestone c) and the Steshevian Regional Substage. It includes mainly transitional taxa that also occur in the underlying deposits. *Striatifera explanata* (Janischewsky), *Gigantoproductus superior* (Janischewsky), *Gigantoproductus superbus* (Sarytcheva), *Latiproductus latissimus* (Sowerby), *Antiquatonia khimenkovi* (Janischewsky), *Martinia angulisinuata* Janischewsky are known from the Poneretka Formation.

The brachiopod assemblage found in the upper part of the Gigantoproductus – Latiproductus Zone has been identified at the base of the Uglovka Formation (Limestone d). It is remarkably impoverished and contains *Echinoconchella elegans* (McCoy), *Latiproductus irregularis* (Janischewsky), *Latiproductus latiexpansus* (Sarytcheva), *Striatifera lata* (Janischewsky), *Striatifera magna* (Janischewsky), *Antiquatonia khimenkovi* (Janischewsky), and *Dielasma avellana* (Koninck). It corresponds to the Protvian Regional Substage.

Conodonts. Conodonts of the Aleksinian Regional Substage are very abundant and taxonomically variable. In spite of their part in the oryctocoenosis is not remarkable, their constant occurrence allows them to be considered as one of the main components of the Aleksinian ecosystem. They belong to the *Cavusgnathus – Mestognathus* biofacies that is characteristic for nearshore and lagoonal paleoenvironments. The generic association includes: *Mestognathus*, *Gnathodus*, and *Cavusgnathus*. They are found in lagoonal clay and nearshore bioclastic limestone with abundant shell benthos.

Conodont assemblages including species of the genus *Mestognathus* are widespread in Western Europe, but are lesser known in Canada. Some occurrences are known in the USA (Utah and Alaska), Australia, North Africa and Malaysia. Within the Western Urals and on the Asian Continent similar associations have been found in the Donetz basin and in the southern part of the Moscow basin.

In the Msta Formation, which corresponds with the Aleksinian Regional Substage, the Mestognathus beckmanni and M. bipluti conodonts zones can be identified. The interzonal boundary is well recognizable in Limestone a_1. Near this level in the upper part of the M. beckmanni zone, there is a thin interval that contains forms transitional from *M. beckmanni* to *M. bipluti* together with zonal species. The transitional forms emphasize the change in the evolutional line within the Mestognathus lineage. The zonal assemblage of the M. beckmanni Zone includes: *Mestognatus beckmanni* Bischoff, *Cavusgnathus unicornis* Youngquist et Miller, *Cavusgnathus naviculus* (Hinde), *Gnathodus girtyi girtyi* Hass, *Synclydognathus geminus* (Hinde), and *Kladognathus tenuis* (Branson et Mehl).

The assemblage of the M. bipluti Zone includes (besides the species mentioned above): the index-species – *Mestognatus bipluti* Higgins, and also *Cavusgnathus charactus* Rexroad, *Hindeodus cristulus* (Youngquist et Miller), *Hindeodus penescitulus* Rexroad et Collins, *Gnathodus girtyi collinsoni* Rodes Austin et Druce, *Gnathodus girtyi simplex* Dunn, *Gnathodus bilineatus bilineatus* (Roundy), and *Gnathodus* aff. *G. texanus* Roundy.

Conodonts in the Mikhailovian and Venevian regional substages are rare and have no significant difference between their assemblages. *Cavusgnathus* species are dominant and their remains occur sporadically, mainly in the clay deposits that cover and underly the Limestones (a_4, a_5, a_6, and a_8) that are widespread in the area. The conodont assemblages reflect more the biofacies changes rather than the chronological ones. The assemblage consists of: *Cavusgnathus naviculus* (Hinde), *Gnathodus girtyi girtyi* Hass, *Gnathodus girtyi simplex* Dunn, *Synclydognathus geminus* (Hinde), *Kladognathus tenuis* (Branson et Mehl), and very rare *Mestognatus bipluti* Higgins.

The Tarusian Regional Substage is characterized by the distribution of *Lochriea* and *Cavusgnathus* species, and subspecies of *Gnathodus girtyi* that form the distinctive assemblages in the carbonate part of the Rovnoe Formation (Limestone b). The slight change in comparison with the previous assemblage in taxonomical composition is connected with the appearance of open-marine facies that influenced all representatives of the biota.

Cavusgnathus naviculus (Hinde), *Kladognathus tenuis* (Branson et Mehl), *Hindeodus cristulus* (Youngquist et Miller), and *Synclydognathus geminus* (Hinde) that are characteristic for near shore and lagoonal deposits appear at the base of Limestone b. The following taxa complete the above assemblage: *Cavusgnathus unicornis* Youngquist et Miller, *Gnathodus girtyi girtyi* Hass, *Gnathodus bilineatus bilineatus* (Roundy), *Lochriea ziegleri* Nemirovskaya, Perret et Meischner, *L. cruciformis* (Clarke), *L. nodosa* (Bischoff), *L. mononodosa* Rodes, Austin et Druce, and *G. symmutatus* Rodes, Austin et Druce. This assemblage is more typical for deep-water paleoenvironments.

The level of the appearance of *L. ziegleri* Nemirovskaya, Perret et Meischner that was considered as a possible marker of the Serpukhovian boundary by many researchers is found 0.8 m from the base of the Limestone b and 1.5 m from the base of the Rovnoe Formation.

There are few data on the conodonts of the Steshevian and Protvian regional substages in the northwestern part of the Moscow basin. The upper part of the Poneretka Formation (Steshevian Regional Substage) contains *Cavusgnathus unicornis* Youngquist et Miller and *Vogelgnathus campbelli* (Rexroad).

GEOLOGICAL EXCURSIONS

The observations of a series of natural outcrops describing various intervals of the Visean – Serpukhovian (Lower Carboniferous) deposits of the northwestern part of the Moscow basin is presented in this guidebook. Most of the outcrops are located in the Novgorod District about 350 km to the south-east of the city of Saint Petersburg. Some outcrops are exposed in the middle part of the Msta River in the vicinity of the town of Borovichi (Fig. 5).

The youngest Serpukhovian deposits known in the territory can be seen in the quarries near the Uglovka settlement (Fig. 30).

Fig. 5. Location of the stops in the middle part of the Msta River. Scale 1:100000

Stop 1 Carbonate build-ups in the lower part of the Visean Stage

Tikhvin Formation in its main part consists of sandy-clay-coal sediments. In the lower part deposits include lenses of carbonate rocks. The most significant outcrops are located in the stream of the Msta River within the city of Borovichi. Limestones are interpreted as carbonate build-ups (mud mounds), presumably of algal-bacterial origin (Fig. 6). They were formed in coastal conditions with periodic exposure (Dronov, Savitsky, 2003). Formerly they were considered to be the remains of the pre-Visean carbonates conserved under the erosion surface of the Tikhvin Formation.

Fig. 6. Round-shape mud-mounds in the Msta River

1. The limestone lenses are in the form of isometric in plan and convex upward. The diameter is 3–7 meters. Thickness is up to 1.5 m. Nine isolated mud-mounds were found in the stream of the Msta River.

2. Mud-mounds are composed by light gray to white, and the in some parts, micritic pink limestone with complex internal structure. Limestone bears intergrowths of newaly formed calcite forming fenestral structure (Fig. 7). This structure is also known as loferite structure (Fisher, 1964). It is developed in tropical climate under supralittoral conditions with periodic exposure and dehydration of carbonate mud (Shinn, 1983).

3. In thin sections micrite consists of the thin dendritic tubules (similar with Orthonella) or Girvanella-like fouling. The laminar structure resembling stromatolite and clotty-peloidal-oncolite structure also occur (Fig. 8).

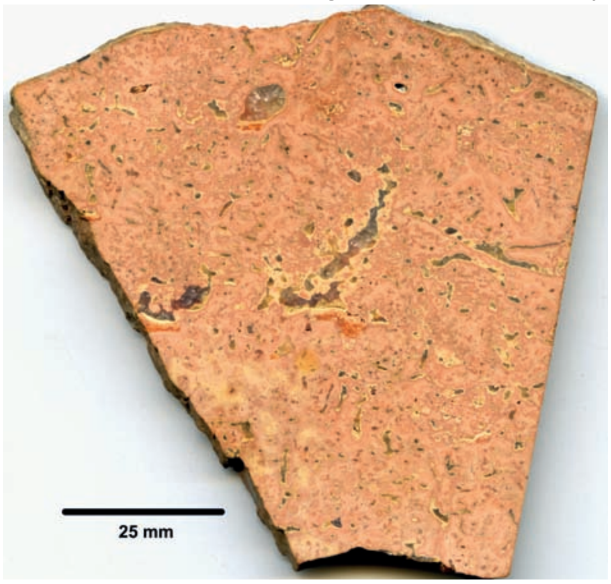


Fig. 7. Fenestral structure of the mud mounds on the left bank of the Msta River

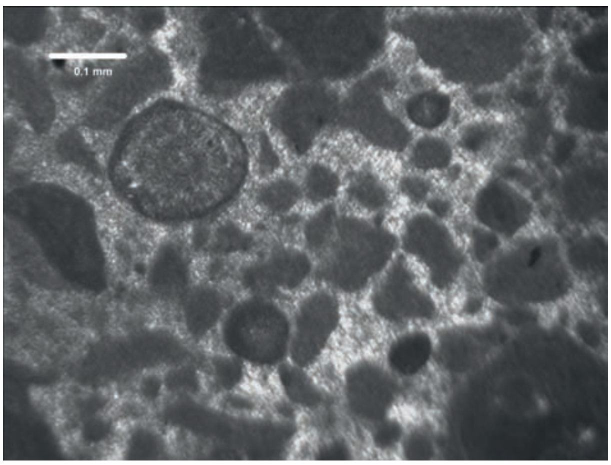


Fig. 8. Peloidal and oncoid microfabrics in the Msta build-ups

Stop 2 Aleksinian deposits near the threshold Vitzy

Outcrop is located on the left bank of the Msta River in 250–300 m downstream of the threshold Vitzy. It is the reference sections of the Msta formation (Fig. 9). A similar section can be observed on the right bank (Fig. 10).

Aleksinian Substage

Msta Formation (Fig. 11)

1. Gray thin-bedded clay interbedded with fine-grained silica sand containing carbonaceous inclusions. Thickness 1.4 m.

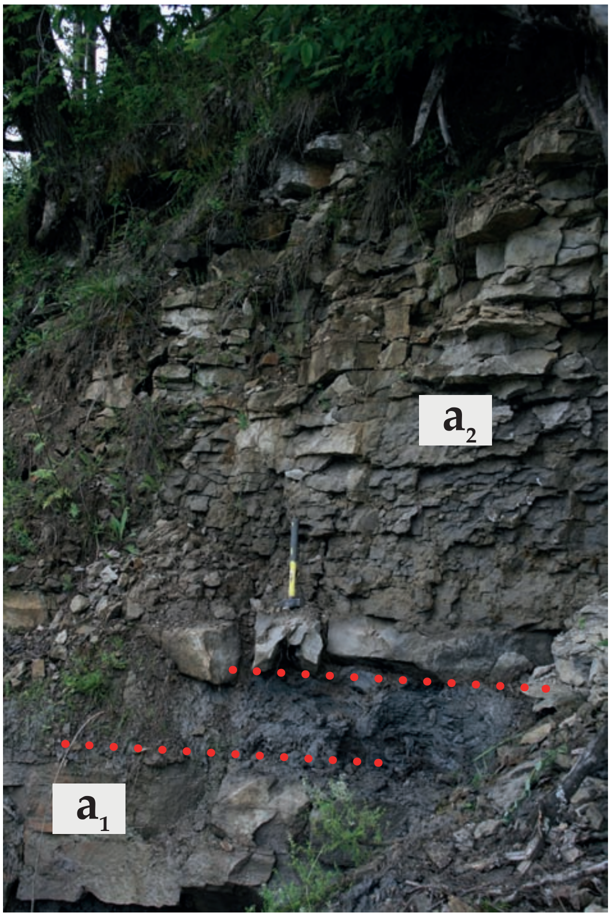


Fig. 9. Outcrop of the Msta Formation (limestones a_1 and a_2) on the left bank of the Msta River

2. Gray- and dark gray organogenic crinoid-foraminiferal limestone a_1, with traces of bioturbation and coal inclusions. Limestone includes remains of tetracorals, mollusks, brachiopods *Semiplanus semiplanus* (Schwetzov), *Gigantoproductus giganteus* (Martin), ostracods, bryozoans, and others. Thickness 59 cm.

3. Gray calcareous and kaolinite-hydromicous clays, thin laminated with numerous remains of ostracods *Paraparchites suborbiculatus* (Münster), *Shishaella porrecta* (Zanina), *Scrobicula scrobiculata* (Jones, Kirkby & Brady), *Youngiella naviculata* Posner, *Amphissites mosquensis* Posner, *Amphissites urei* (Jones), *Kegelites helenae* (Posner), *Kindlella bituberculata* (M'Coy), *Kirkbya lessnikovae* Posner, *Kirkbya volginoensis* Posner, *Cavellina quasiattenuata* Egorov, *Cavellina recta* (Jones, Kirkby & Brady), *Bairdia hisingeriformis* Posner, *Bairdiacypris distracta* Eichwald, *Egorovitina kirsanovi* Gramm, *Healdia cornuta* Posner, *Healdianella darwinuloides* Posner and bryozoans. Thickness 21 cm.

4. Gray organogenic limestone a_2, medium- and thin-bedded. It contains the remains of crinoids, foraminifera, brachiopods, and conodonts. Numerous traces of *Zoophycos* also occur. Thickness 2.62 m.

Fig. 10. Outcrop of the Msta Formation (limestone a_2) on the right bank of the Msta River

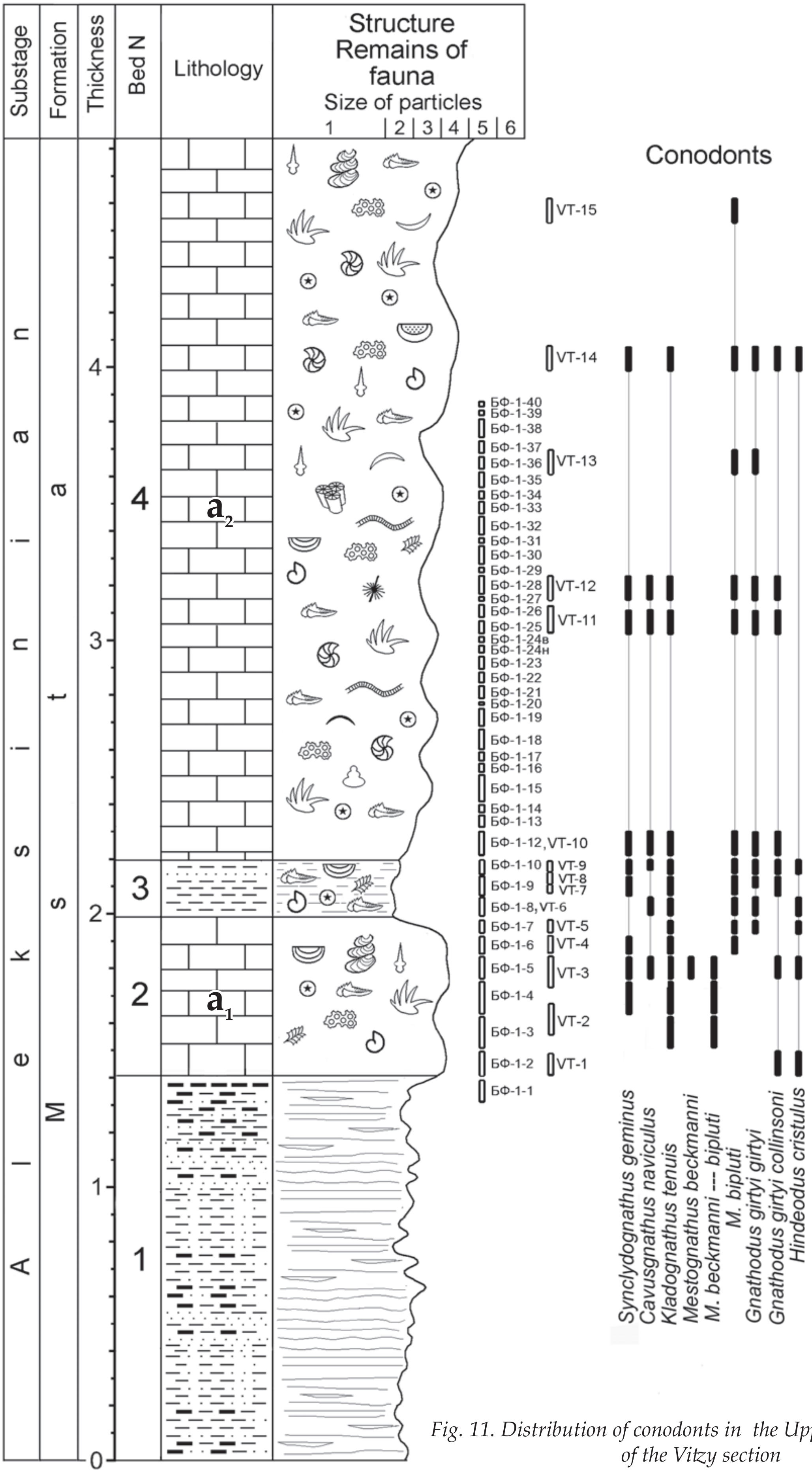


Fig. 11. Distribution of conodonts in the Upper Visean deposits of the Vitzy section

STOP 2 A SECTION OF THE UPPER VISEAN DEPOSITS, LEFT BANK OF THE KRUPA RIVER

At this stop, deposits associated with the first Late Visean transgression will be examined. The section is located in the southern outskirts of the town of Borovichi on the left bank of the Krupa River about 1.2 km upstream from its junction with the Msta River. Of historical interest is the fact that the first shaft for brown coal production was made in 1786 in this region. Also the first excavation of fireproof kaolinite clay was started here. Until now the remains of shaft linings and talus are visible at the mouth of the Krupa River. The sources of both types of raw materials are the terrestrial deposits of the Tikhvin Formation of the Late Visean. The upper part of this formation is visible in the outcrop to be examined (Fig. 12). The first appearance of marine sedimentation in the region can be seen at this section and it is considered as a key outcrop of the Msta Formation.

Fig. 12. Outcrop of the Msta Formation (limestones a_1 and a_2) on the left bank of the Krupa River

The section below is measured up from the shore line (Fig. 13):

Tulian Regional Substage
Tikhvin Formation
1. Brown humus, durain coal.
Thickness 0.15m.

2. Clay, gray sandy with coalified plant and *Stigmaria* remains, and pyrite concretions in the lower part. The upper surface is eroded and bears signs of ferrigenous impregnation.
Thickness 3.0 m.

Aleksinian Regional Substage
Msta Formation
3. Clay yellow strongly sandy. Thickess 0.1 m.
4. Sand quartz fine-grained brown, ferriginate. Thickness 0.5 m.
5. Sand white quartz fine-grained. Thickness 1.2 m.
6. Clay gray sandy, kaolinite. Thickness 1.2 m.

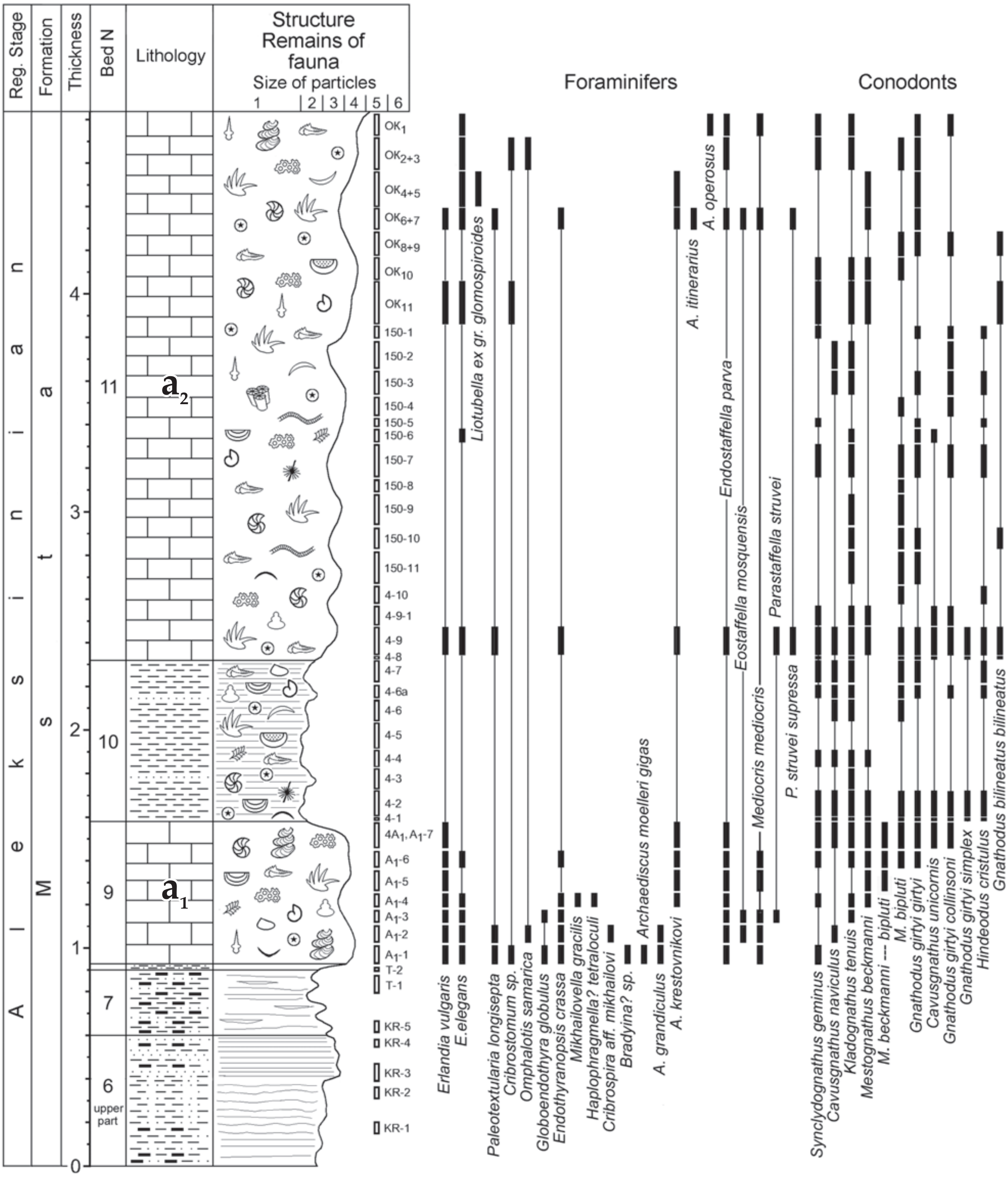


Fig. 13. Distribution of foraminifers and conodonts in the Upper Visean deposits of the Krupa Section

7. Clay gray coaly with lenses or impurities of quartz sand. Thickness 0.3 m.

8. Sand clayey quartz brownish-gray thin-layer. Thickness 0.03 m.

9. Limestone (a_1), gray clayey, algal foraminiferal-crinoidal wack- or packstone with remains of molluscs, bryozoans, brachiopods, ostracodes, conodonts, and fish remains. The base of the limestone is quartzose and cross-bedded, and the top is slightly clayey with *Zoophycos* traces (Fig. 8). Faunal remains include: ostracodes *Bairdia alta* Jones et Kirkby, *Amphissites mosquensis* Posner, *Bairdiacypris distracta* (Eichwald), *Microcheilinella subcorbuloides* Posner, *M. intumescens* Posner; brachiopods *Schellwienella* cf. *rotundata* Thomas, *Semiplanus semiplanus* (Schwetzov), *Gigantoproductus* cf. *giganteus* (Martin), *Productus concinnus* Sowerby, *Pugnax* cf. *P. pugnus* (Martin). The base of the Mestognathus bipluti conodont zone is recognized in the upper part of the bed. Thickness 0.65 m.

10. Clay gray carbonaceous-kaolinite-hydromicous, thin-layered with thin lenses of quartzose sand. Clay contains abundant ostracodes, small brachiopods, bryozoan colonies, and crinoid segments. Conodonts and fish remains also are present. The assemblage, exceptional by its preservation and taxonomic diversity, includes: ostracodes *Healdianella darwinuloides* Posner, *Egorovitina kirsanovi* Gramm, *Glyptopleura barjatinensis* Samoilova et Smirnova, *Scrobicula scrobiculata* (Jones, Kirkby, et Brady), *Amphissites umbonatus* (Eichwald), *Amphissites* helenae Posner, *Amphissites* urei (Jones), *Janischewskya digitata* Batalina, *J. longiscula* Zanina, *J. levigata* Posner, *Bairdia hisingeriformis* (Posner), *Kirkbya lessnikovae* Posner, *K. volginoensis* Posner, *Youngiella naviculata* Posner, *Scrobicula corrugata* Zanina, *S. levis* Samoilova et Smirnova, *Kindlella bituberculata* (McCoy), *K. legibilis* (Zanina), *Shishaella porrecta* (Zanina), *Cavellina quasiattenuata* Egorov, *C. recta* (Jones, Kirkby et Brady), *Knoxiella posneri* Egorov, *Jonesina fastigata* (Jones et Kirkby), and *Borovitchella egorovi* Gramm. Brachiopods are represented by separated valves of *Chonetes parva* Jan., *Buxtonia scabricula* (Mart.), *Productus concinnus* Sowerby, *Camarotoechia pleurodon* (Phillips), *Phricodothyris lineata* (Martin). Thickness 0.74 m.

11. Limestone (a_2) light-gray flaggy foraminiferal-crinoidal pack-wackstone with numerous *Zoophycos* traces. At the base the limestone has well cemented calcarenite structure. Gradually upwards the nature of the limestone changes, and it becomes porous and chalky as a result of disintegration and leaching of the organic remains. The faunal assemblage includes: brachiopods *Chonetes parva* Janischewsky Thickness 2.6 m.

The top of limestone is covered by Quaternary deposits.

Stop 3 Section of the Aleksinian/Mikhailovian boundary beds

The outcrop to be examined is located on the right bank of the Msta River between the villages of Putlino and Shibotovo. The depositional succession at this stop stratigraphically extends the section at Stop 2 and Stop 2a (Figs 14, 15, 16, 17).

Aleksinian Regional Substage
Msta Formation

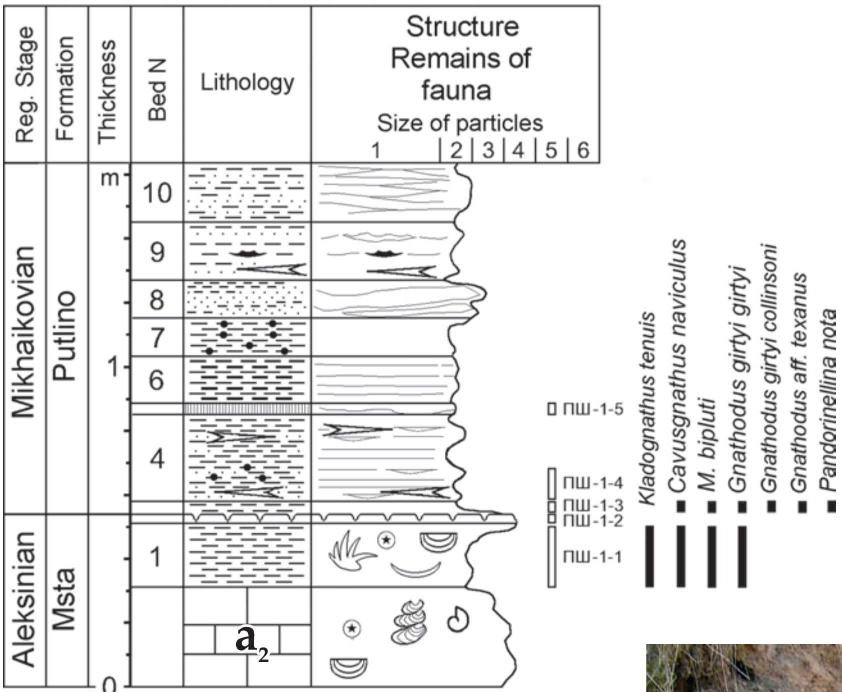


Fig. 14. The boundary deposits of the Msta and Putlino formations located between the villages of Shibotovo and Putlino, right bank of the Msta River

1. Clay calcareous, kaolinite – hydromicous with abundant invertebrate detritus such as foraminifers, ostracodes, and brachiopods. The contact with the underlying Limestone a_2 gradational without a visible break. Clay contains conodonts *Cavusgnathus naviculus* (Hinde), *Gnathodus girtyi girtyi* Hass, *Gnathodus girtyi collinsoni* Rhodes, Austin et Druce, *Kladognathus tenuis* (Branson et Mehl), *Mestognatus bipluti* Higgins.

Thickness 0.2 m.

2. Limestone yellowish-gray bioclastic, polydetrital, clayey. Limestone overlays clay with sharp contact. The top is eroded and has a deep channel penetrating into the bed.

Thickness 0.03 m.

Mikhailovian Regional Substage
Putlino Formation

3. Clay calcareous lilac-gray with abundant invertebrate detritus. The top is beige colored. The transition into the overlying bed is distinguished by the disappearance of detritus and a less colored surface. Clay contains reworked ostracodes *Amphissites umbonatus* (Eichwald), *Kindlella bituberculata* (McCoy), *Healdianella darwinuloides* Posner, *Egorovitina kirsanovi* Gramm, *Scrobicula scrobiculata* (Jones, Kirkby et Brady), *Scrobicula corrugata* Zanina, *Amphissites urei* (Jones), *Am. mosquensis* Posner. This level is also characterized by reworked conodont elements. Redeposition

Fig. 15. The boundary deposits of the Msta and Putlino formations located between the villages of Shibotovo and Putlino, right bank of the Msta River

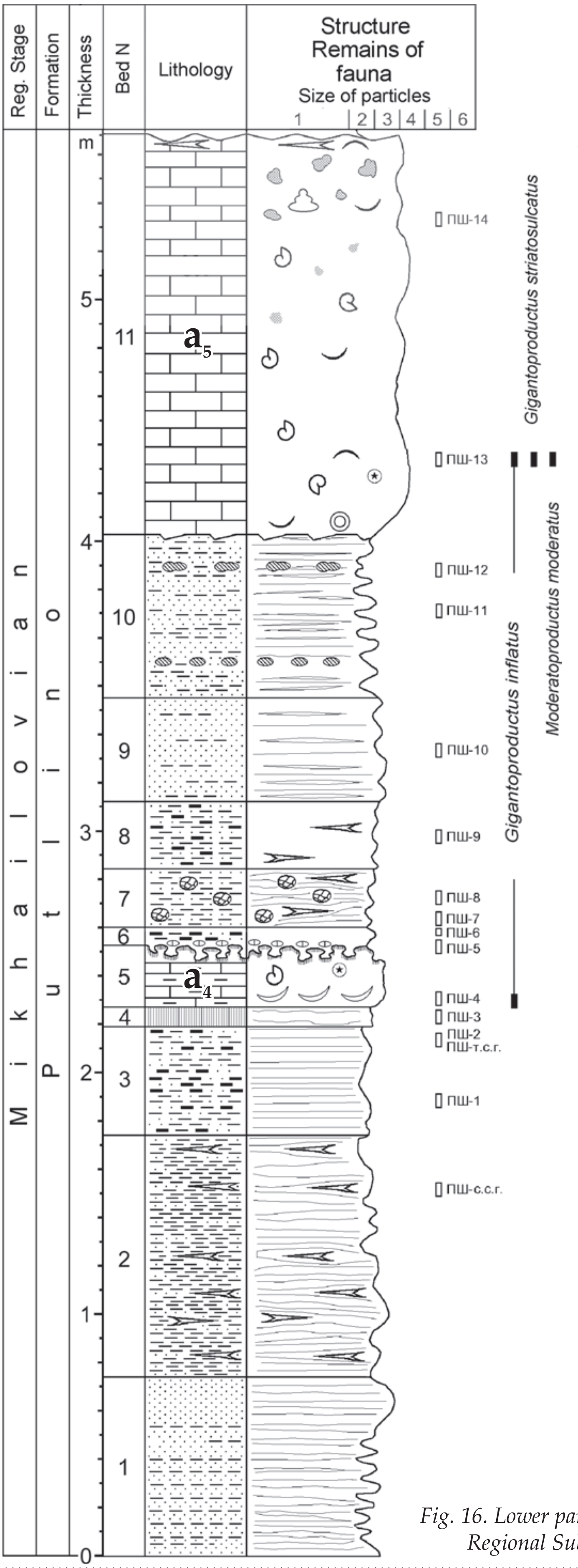


Fig. 16. Lower part of the Putlino Formation (Mikhailovian Regional Substage), right bank of the Msta River

is proved by the change of color of the conodont elements. They are also partly nodulized. The assemblage consists of *Cavusgnathus naviculus* (Hinde), *Gnathodus girtyi girtyi* Hass, *Mestognatus bipluti* Higgins, *Gnathodus* aff. *texanus* Roundy, *Pandorinellina nota* Kononova et Migdisova. Redepositional interval is between late Famennian – Visean.

Thickness 0.04 m.

4. Clay gray with rare len-ses of fine quartzose sand and with numerous coalified plant remains, *Stigmaria*, and concretions – pebbles consisting of pyritized carbonaceous-clayey sediments. Thickness of lenses is under 0.5 cm.

Thickness 0.27 m.

5. Lenslike layer of gypsiferous and pyritized brown coal.

Thickness 0.04 m.

6. Clay dark – gray coaly.

Thickness 0.14 m.

7. Clay brownish-gray with limonite concretions. Thickness 0.12 m.

8. A pair of quartzose sand lenses forming an imbricate structure. The bottom of the lower lens is ferruginous. Thickness of the lower lens is 5 cm, upper one 7 cm. They are separated by 1cm of clay that is similar to the clay of bed 7.

Thickness 0.12 m.

9. Clay brownish-gray with lenses of fine grained quartzose sand. Plant detritus and numerous small (under 2 cm) siderite concretions are concentrated at the bottom of the bed. Thickness 0.18 m.

10. Clay gray with lenses of light-gray, whitish quartzose sand.

Thickness 0.15 m.

Above bed 10, 2.5 m of slope is covered and bedrock is visible in the cleaned ditch (Fig. 10). This part of the section repeatedly exposed by trenches and boreholes along the Msta River, consists of sandy-clay alternation. Bioclastic limestone (a_3) occurs to the northeast from Borovichi only along the Kamenka River.

Thickness of the limestone is up to 0.4 m.

Fig. 17. Lower part of the Putlino Formation (Limestone a_5), right bank of the Msta River

11 (1). Sand quartzose- micaceous light-gray yellowish. At 50 cm below the top there is a slight clay impurity that forms a downwardly directed thin light blue- gray lenses.
Thickness over 0.7 m.

12 (2). Clay light-gray, bluish sandy with abundant remains of *Stigmaria* and leaflike plant detritus. The orientation varies, but large rhizoids are distributed mainly horizontally.
Thickness 1 m.

13 (3). Clays dark-gray weakly quartzose with ferruginous concretions enriched by great amount of finely-dispersed carbonaceous material. Transition into overlying coal extends more than 0.15 m.
Thickness 0.45 m.

14 (4). Coal brownish dull ferruginous pyritized. Thickness 0.08 m.

15 (5). Limestone (a_4) brownish-gray clayey bioclastic, separated from the coal by a layer of dark-gray clay (3-5 mm). Limestone contains large shells of *Gigantoproductus inflatus* Sarytcheva, oriented with the convex side towards the bottom of the bed. Upper surface of the bed is eroded and wavey with the depressions filled in by brownish-gray clay. Thickness 0.22–0.25 m.

16 (6). Clay-carbonaceous brownish-gray and black, originating from the accumulation of plant remains and squeezed fragments of *Stigmaria* into a brownish clayey mass. Small pebbles of foraminiferal - detrital limestone occur at the base of the bed. The top is clearly ferruginous.
Thickness 0.04–0.08 m.

17 (7). Intercalation of lens-like clayey-sandy layers characterized by irregularly distributed plant detritus, pyrite and siderite concretions. Thickness 0.24 m.

18 (8). Sands clayey gray with coaly inclusions and large fragments of *Stigmaria* oriented horizontally. Thickness 0.28 m.

19 (9). Sand quartzose-micaceous light yellow microgranular with thin elongate lenses of violet clay. Thickness 0.43 m.

20 (10). Sand clayey violet-gray banding and ferruginous intercalations with thin elongate clay lenses. Irregularly shaped carbonate concretions are present 0.1 m above the base.
Thickness 0.68 m.

21 (11). Limestone (a_5) bioclastic gray with abundant concentrations of ostracodes and foraminifers. Lower part of the limestone is porous and ferruginous. Upper part is leached. Limestone contains braciopods *Moderatoproductus moderatus* (Schw.) *Gigantoproductus striatosulcatus* (Schw.), *Gigantoproductus inflatus* Sar.; *Moderatoproductus moderatus* (Schw.).
Thickness 1.65 m.

Stop 4 Depositional succession of the Mikhailovian and lower part of the Venevian regional substages

The outcrop is located in the north outskirts of the village of Iogla on the right bank of the Msta River (Fig. 18). The most continuous succession and characteristic features of the Putlino Formation of the Mikhailovian Regional Substage are visible upstream for more than 400 m along the river banks of the Msta River. The section was measured from the base of the outcrop (Fig. 19).

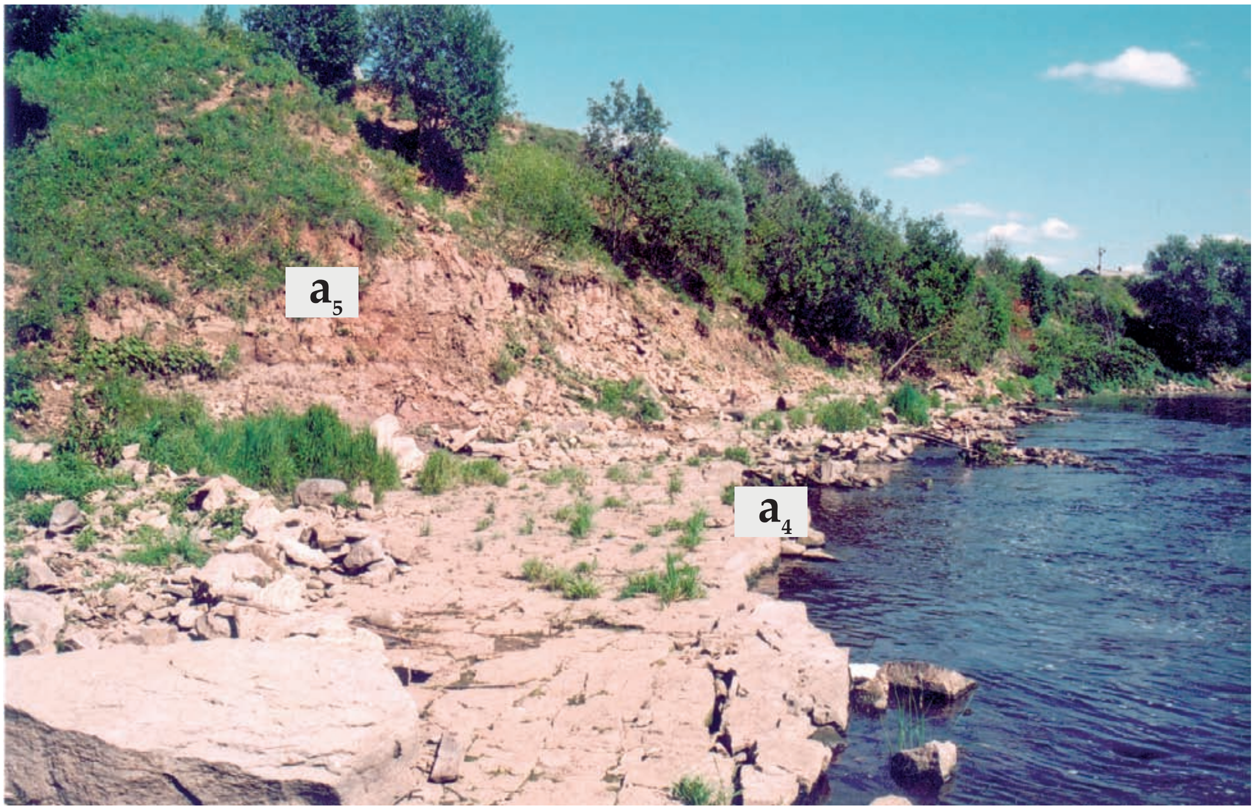


Fig. 18. Putlino Formation near the village Iogla

Mikhailovian Regional Substage
Putlino Formation

1. Dull-banded brownish coal with pyrite concretions Thickness 0.14 m.

2. Clay dark-gray, black sapropelic, monochromatic without visible lamination. This clay contains abundant incrusted (or replaced by pyrite) remains of porifera, rugosa, ostracodes, bivalves, gastropods, bryozoans, and crinoids. Various zones of pyritization are present. Thickness 0.17 m.

3. Clay asphaltic-gray or gray-back with thin (up to 2mm) layers of quartzose sand, phyto-detrital with nest-like assemblages of separated valves or whole shells of bivalves and brachipods along with other invertebrates. Shells of *Pugilus rossicus* Sarytcheva are present in life position (Fig. 20). Thickness 0.14 m.

4. Unconsolidated brownish-black clayey limestone with a large number of bioclasts. The limestone is characterized by earthy chips. The amount of carbonate material increases towards the top. Large Productidae oriented with their convex shell downwards can be seen in the upper part of the bed. Thickness varies from 0.20 to 0.30 m.

5. Limestone (a_4) gray and dark-gray, bioclastic, brachiopod-foraminiferal packstone. The limestone is penetrated by vertically and obliquely distributed autochthonous *Stigmaria* with widespread rhizoids (Fig. 21). The top of the limestone is eroded. Its wavy surface is covered by a yellow-red ferruginous rind. The rock is composed of numerous shell fragments. Brachiopods

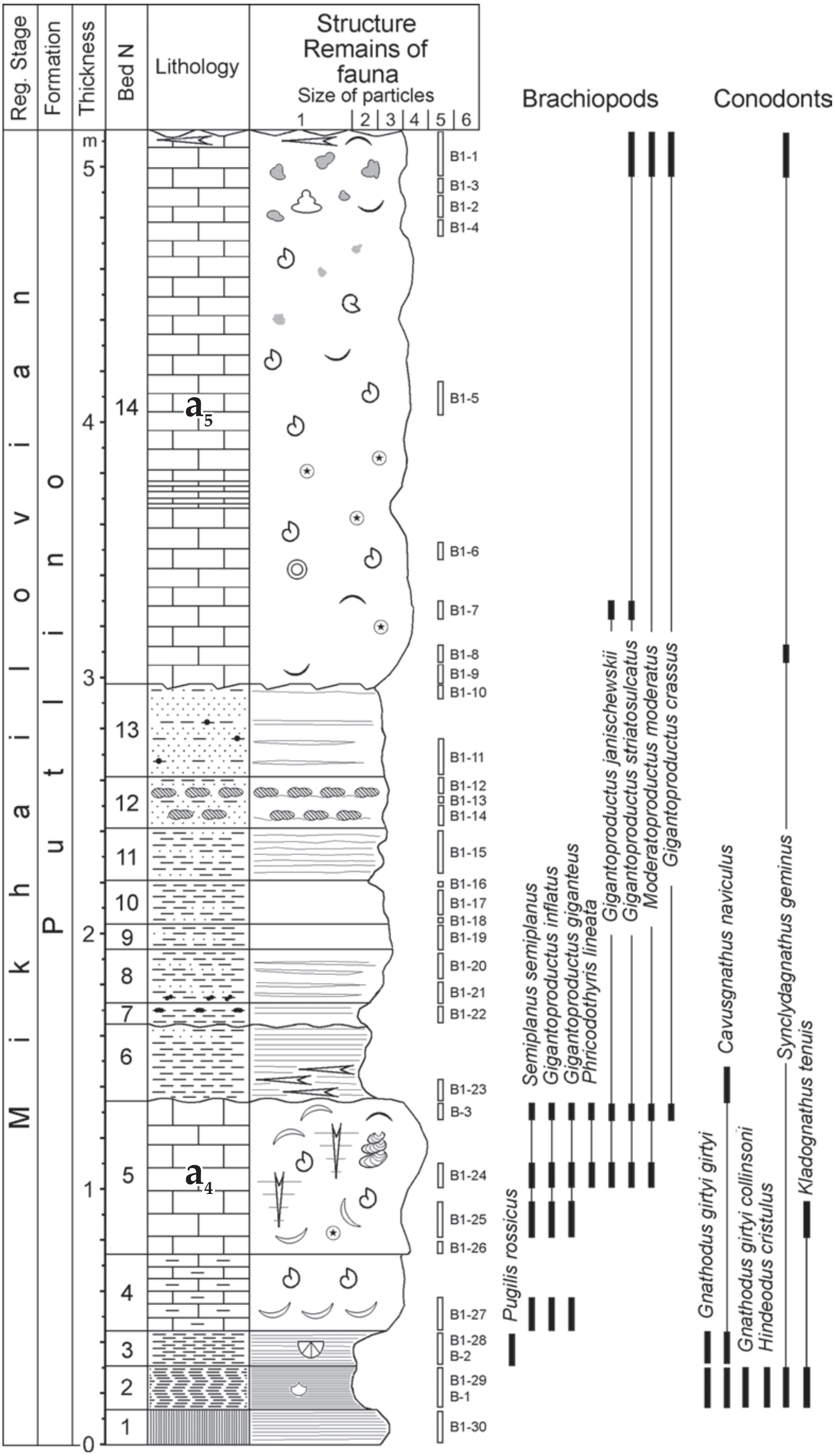


Fig. 19. Brachiopod and conodont distribution in the outcrop near the mouth of the Varushenka River, right bank of the Msta River

Fig. 20. Pugilus rossicus Sarytcheva found in the clay at the base of the Limstone a_4

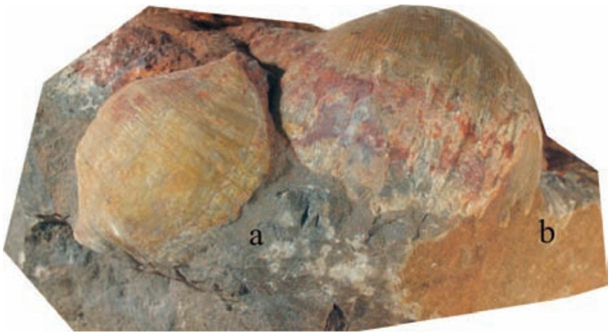


Fig. 22. Brachiopods Semiplanus semiplanus (Schwetzov) (a) and Gigantoproductus inflatus (Sarytcheva) (b) at the top of the Limstone a_4

Fig. 21. Stigmaria from the Limstone a_4

Gigantoproductus and small foraminifers predominate. Ostracodes, crinoids, gastropods, bivalves also are present. Accumulations of brachiopods form a few levels. There are mostly brachiopod shells in upside down position at the top of the bed – with the convex pedicle valve oriented upwards (Fig. 22). The shells are oriented irregularly in the middle of the bed and they occur in life position at the bottom. The bed contents numerous *Zoophycos* traces (Fig. 23), more in the lower and upper parts. As a whole, the bed appears as a single unit, but is broken by vertical and oblique cracks. Thickness 0.60 m.

6. Clay dark-gray sandy coaly with numerous remains of large *Stigmaria* fragments up to 30 cm long and with diameters up to 3cm. Thickness 0.30 m.

7–8. Clay gray-raspberry, raspberry-red subdivided by thin lens-like gray sandy-clayey layers, with limonite iron concretions at the top. Concretions have an elongated lensoid shape. The lower eroded surface is wavy. Thickness 0.29 m.

9–11. Intercalation of lens-like layers of gray-light blue clay, and red and light yellow fine grained quartzose sand. Rocks bear irregularly distributed large brownish-yellow spots – traces of decomposed limonite. Composition of sandy and clayey components varies widely. Thickness 0.47 m.

12–13. Sand quartzose micaceous fine grained violet with thin rare layers-lenses of light blue-gray clay (silt). There are siderite-calcite concretions of irregular shape in the lower part of the unit. Clay layers are thin lensoid. They often contain thin impregnation of limonite-goethite concretions – nodules. The boundaries of beds are clear with wavy flame-like contours. The contact with overlying bed is distinct and sharp. Thickness 0.56 m.

14. Limestone (a_5), mainly crinoidal-foraminiferal packstone, gray and brownish-gray bioclastic with abundant foraminifers, ostracodes, brachopods, and crinoids. Rugose corals,

Taxa	26	25	24	7	6	5	4	3	2	1
Endothyra (Similisella) similis Rauser et Reitlinger	+			+	+					
Endothyranopsis ex gr. *crassa* (Brady)	+	+	+							
Asteroarchaediscus baschkiricus (Krest. et Theod.)	+	+								
Globoendothyra ex gr. *globulus* (Eichwald)	+	+							+	
Palaeotextularia spp.	+	+	+	+		+	+	+	+	
Earlandia vulgaris (Rauser et Reitlinger)	+	+	+	+	+		+	+	+	+
Earlandia elegans (Rauser et Reitlinger)	+	+		+	+	+	+	+	+	
Archaediscus krestovnikovi Rauser	+	+								
Parastaffella struvei (Moeller)		+	+	+	+	+	+	+	+	
Endothyranopsis compressa (Rauser et Reitlinger)		+	+							
Bradyina sp.		+	+	+	+	+	+		+	
Bradyina flosuculus Ganelina		+								+
Globoendothyra inconstans (Grozdilova et Lebedeva)		+	+							
Omphalotis sp.		+			+					
Parastaffella ex gr. *struvei* (Moeller)		+		+						+
Eostaffella mosquensis Viss.		+	+							
Endothyra bowmani Phillips		+	+						+	
Eostaffellina irenae (Ganelina)		+								
Endothyranopsis crassa (Brady)		+	+	+	+					
Cribrostomum sp.		+			+		+	+	+	
Climacammina sp.		+	+		+			+	+	+
Bradyina ex gr. *rotula* (Eichwald)		+	+	+				+	+	+
Archaediscus moelleri Rauser		+	+		+					
Endothyranopsis crassa umbonata (Ganelina)			+							
Globoendothyra globulus (Eichwald)			+		+			+		
Omphalotis minima (Rauser et Reitlinger)			+							
Haplophragmella sp.			+	+	+	+			+	
Eostaffella ikensis Vissarionova			+					+		
Eostaffella ex gr. *ikensis* Vissarionova			+							
Bradyina rotula (Eichwald)			+	+	+					
Bradyina aff. modica (Ganelina)			+							
Cribrospira sp.			+	+		+	+	+		
Janischewskina sp.				+			+	+	+	
Globoendothyra numerabilis (Vissarionova)				+			+	+		
Lituotubella glomospiroides Rauser				+			+			
Omphalotis omphalota (Rauser et Reitlinger)				+			+			
Forschia sp.				+			+	+	+	
Haplophragmella ex gr. *tetraloculi* Rauser					+					
Archaediscus itineraries supressa Schlykova					+					
Forschia mikhailovi Dain					+		+		+	+
Eostaffella ex gr. *galinae* Ganelina							+			
Cribrospira panderi Moeller								+		
Eostaffella ex gr. *raguschensis* Ganelina								+		
Archaediscus ex gr. *moelleri* Rauser								+		
Cribrostomum fortis Durkina								+		
Archaediscus operosus Schlykova								+		
Forschia ex gr. *parvula* Rauser								+	+	
Janischewskina calceus Ganelina								+		
Parastaffella sagittaria Schlykova									+	
Janischewskina minuscularia (Ganelina)									+	
Janischewskina typica Mikhailov										+

Text-fig. Distribution of foraminifers in the limestones a_4 and a_5 of the Putlino Formation (Section B1)

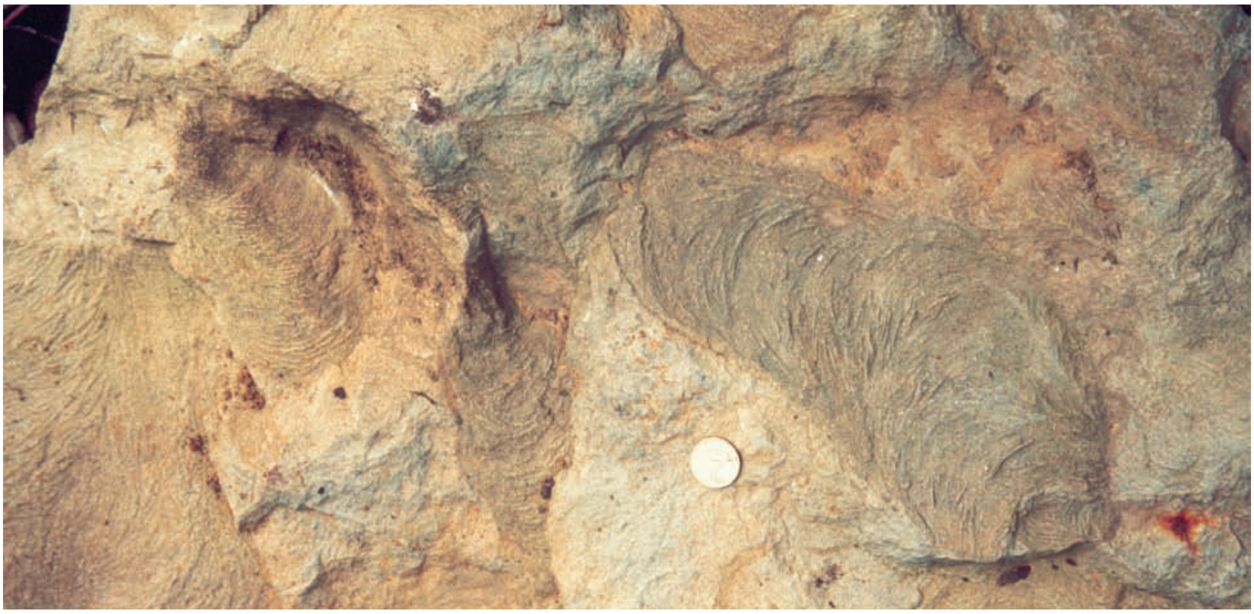


Fig. 23. Zoophycos traces in the Limstone a_4

bivalves and gastropods are also present. The limestone is whitish at the top with gray-violet spots. In the most outcrops the limestone is typically solid and massive. The bottom has *Rhizocorallium* traces (Fig. 24). The top surface is hummocky and is characterized by features of subaerial exposure and ferruginous impregnation. Large horizontally oriented *Stigmaria* with rhyzoides are present in the upper part of the bed. The bed is subdivided in the middle part by thin (up to 4cm) bioclastic very soft limestone. The limestone can be divided into plates covered by thin black scum and ornamented by an imbricate covering of shells and detritus parallel to bedding. Thickness up to 2.30 m.

Gradually going down to the water-level this limestone forms the main rapids of the Msta River locally called the Iogla rapids. The following deposits are visible upstream along the river (Fig. 26).

15. Clay lead-gray, gray-violet sandy with rare short lenses (1–3 cm) and thin (2–5 mm) layers of yellowish hydromicous fine grained sand. Amount of hydromica increases to the top. Hydromica occurs in a rectangular plate shape (0.2–1.0 mm). In the lower part of the unit coalified and partially pyritized plant remains.

Thickness 1.3 m, to the south it is reduced up to 1.0 m.

16. Limestone (a_6) light-gray bioclastic foraminiferal. The limestone is dolomitized at the base (up to 14cm) with abundant traces of *Rhizocorallium* and *Vermichnus* (Fig. 25). The overlying part (up to 65cm) is yellow-gray soft and unconsolidated with banding. The latter is marked by hydromica and locally appears breccated. The uppermost part (up to 2.2 m) is a deeply and irregularly eroded. The top surface is covered by a ferruginous crust.

Thickness up to 3.10 m.

This limestone is of most interest because of the existence of erosional remnants of fluid flow of the Venevian. One such erosional remnant can be seen near the water-fall called Varushenka. Its length is about 50 m with a relief depth of over 2 m. The deepest erosional remnant can be seen near the Iogla rapids where the Limestone a_6 is absent for a great distance.

The overlying deposits of the Iogla Formation of the Venevian Regional Substage extend the section and fill in the erosional depression in Limestone a_6.

Venevian Regional Substage

Iogla Formation

17. Gray-brownish sandy clay with coalified plant detritus occuring in the depression of the relief. Thickness from 0 to 0.50 m.

Fig. 24. The bottom of the Limstone a_5*, showing the traces of Rhizocorallium and Vermichnus*

Fig. 25. The bottom of the Limstone a_6*, showing the traces of Rhizocorallium and Vermichnus*

18. Gray-light blue clay with a greenish tint. This clay is lighter than the clay in bed 17. Thickness from 0 to 0.40 m.

19. Coaly and sandy alternations characterized by thin rhythmical intercalation of coal and sand. Coal is brownish-black, flaggy, thin-layered. Sand is yellow-white fine grained quartz. Coal seams reach up to 0.5cm, sand seams are about 0.1–0.2 cm. This unit directly overlies the limestone in places. Thickness up to 0.80 m.

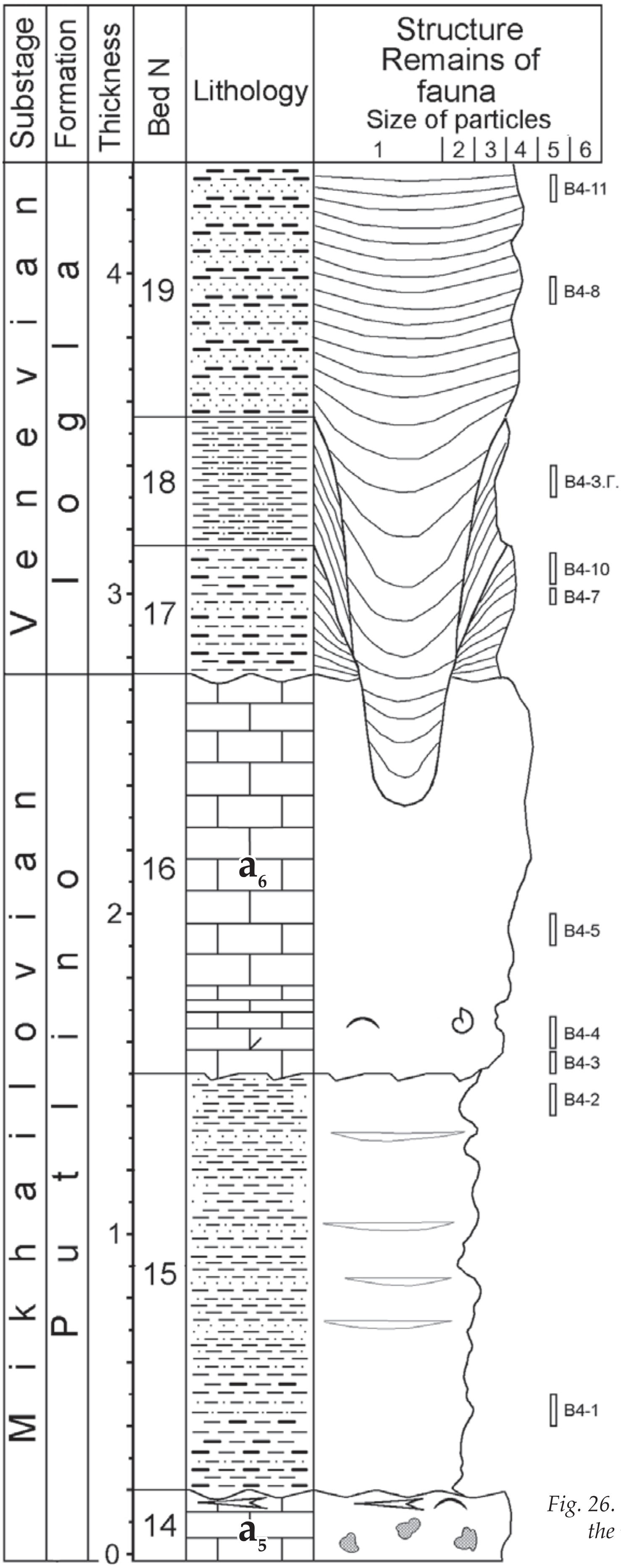


Fig. 26. The upper part of the Putlino Formation near the waterfall (photo) of the Varushenka River (small gully)

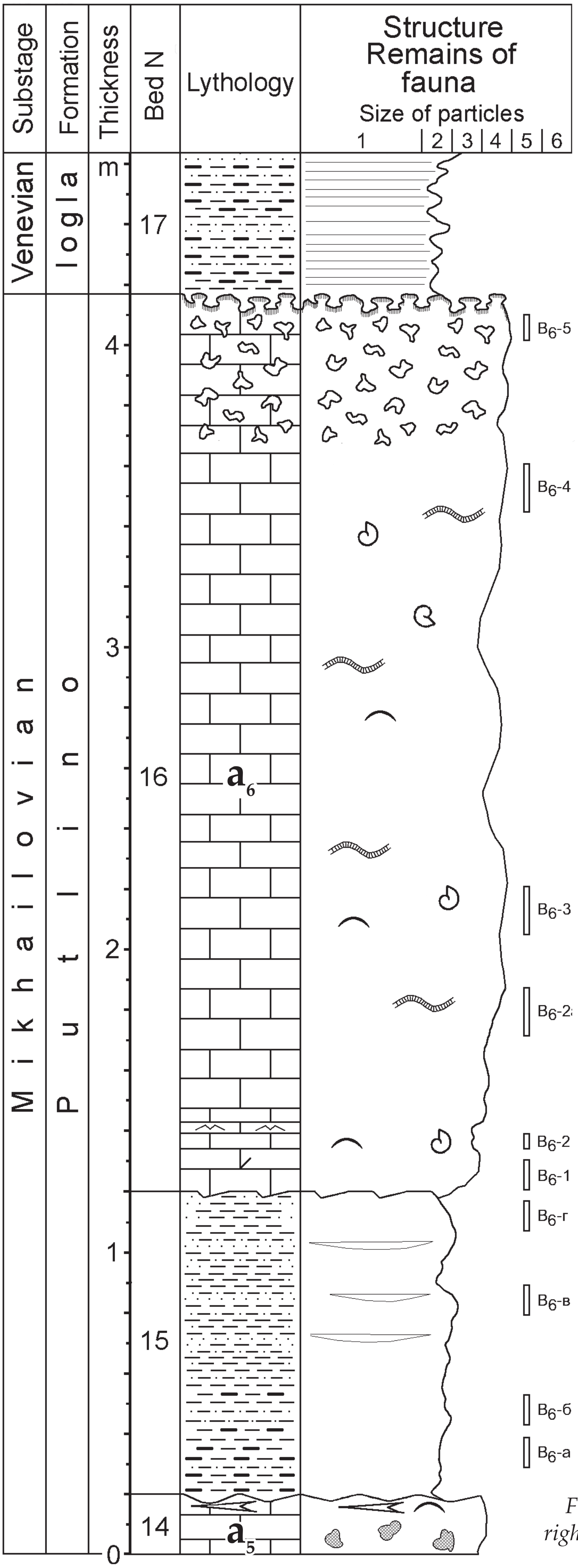


Fig. 27. The upper part of the Putlino Formation, right bank of the Msta River upstream of mouth of the Varushenka River

Stop 5 — Depositional sequence of the Venevian Regional Substage

The section is located on the right bank of the Msta River in the middle part of the village of Iogla near the main rapids. Limestone a_6 has been totally removed, probably by fluvial stream erosion, for a distance of about 400 m. The depth of erosion is about 3.5 m. Sandy-clayey deposits of the Iogla Formation fill in the resulting depression. The section includes the depositional succession from the top of Limestone a_5 to Limestone a_7. The outcrop is situated from the shoreline to the river bluff.

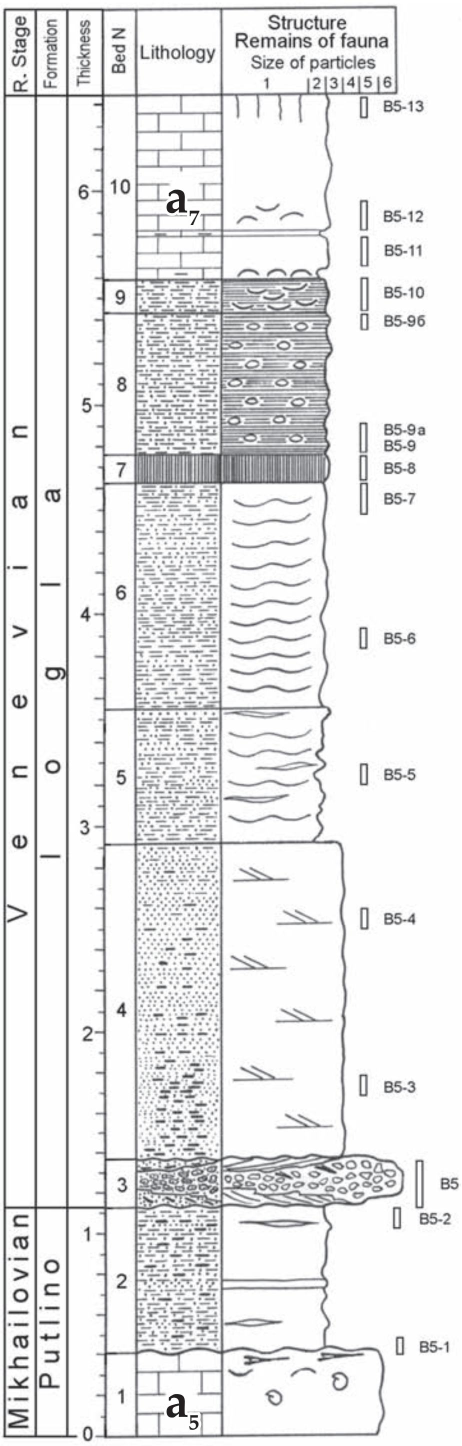


Fig. 28. Section of the Venevian Regional Substage near the main rapid near the village of Iogla (large gully)

The following deposits are exposed on the top of Limestone a_5 that is covered by a hummocky ferruginous crust (from the bottom to the top) (Fig. 28):

Mikhailovian Regional Substage

Putlino Formation

1. Dark-gray and gray clay with dark yellow lenses of fine-grained sand or silt containing about 30% clay. Some lenses are cemented by iron hydroxide and are similar to nodules. The top of the bed is an erosional surface. Thickness 0.7 m.

Venevian Regional Substage

Iogla Formation

2. Sand and conglomerate deposits overly the wavy top of bed 1 and consist of three units whose thickness and composition vary within a short distance both laterally and vertically.

The lower unit consists of slightly inclined fine-grained quartzose unconsolidated sand and sandstone containing fine coaly plant detritus. The rock changes into a light gray sandy clay within a distance of 30–40 cm along strike.

Thickness varies from 2.5 to 7 cm, maximal thickness – 0.12 m.

The middle unit is a conglomerate containing clay and sand pebbles cemented by fine-grained sandy-clayey rock. Siderite pebbles are also present. The cement is yellow-brownish and the color of the clay and sand is light gray. The sizes of the pebbles can be as much as 2cm, but usually they range from 0.8–1.0 cm. The clay and sand contain a large amount of flakey hydromica. The general aspect of the cement resembles the siliciclastic layer between Limestones a_5 and a_6 near the waterfall Varushenka. Thickness varies from 8 to 16 cm. The upper unit consists of a thin layer of gray clay (1–2 cm) grading upwards into horizontally or slightly inclined quartzose sand and sandstone with vertically orientated coaly plant remains. Large fragments of *Stigmaria* (up to 30cm) are located directly on the conglomerate. Plants remains are orientated at a sharp angle to the bedding surface. Cavities of Stigmaria are filled in by sand transitional to clay. The top of the unit is wavy and covered by thin coaly gravel and gray clay. Thickness of the upper unit 0.22 m.

3. Quartzose, slightly clayey light yellow sand enriched by numerous coaly inclusions that emphasize the slightly inclined cross-bedding. Sand overlies the undulating erosional surface of the underlying bed. Thickness 1.50 m.

4. Interbedded light blue-gray and gray-yellow sand and clay. Rocks have a lens-like shape and indistinct intra-stratal boundaries (Fig. 29). Thickness 0.6 m.

5. Light-blue clay with lenses of fine-grained silt. Clay becomes darker to the top of the bed. Thickness 1.1 m.

6. Brownish thin-bedded dull coal, slightly brighter chips. Ferrugination and pyritization developed on the intra-stratal surfaces. Pyrite concretions of rather isometric shape up to 3–5 cm are characteristic. Thickness 0.12 m.

7. Brownish-gray silty thin-bedded clay containing ostracodes. Lower contact is sharp. Upper contact is gradational with the overlying bed. The bed contains abundant dispersed fine coaly matter that is easily seen on the intra-stratal surfaces in the form of uniformly distributed flakes on the surface. Thickness 0.7 m.

8. Clay, limey, slightly greenish, the color becoming lighter to the top. Clay is characterized by thin-bedded alternation of clayey-silt and sandy-clay. The bed contents large numbers of brachiopod molds, and also ostracodes: *Jonesina bivesiculosa* Posner, *Bairdiacypris distracta* (Eichwald), *Janischewskya levigata* Posner, *Cavellina recta* (Jones, Kirkby et Brady), *Jonesina janischewskyi* Posner, *Gliptopleura spinosa* (Jones et Kirkby), *G. plicatul*a Posner, *Monoceratina yungiana* (Jones et Kirkby), and *Posneratina jonesi* Posner. Thickness 0.15 m.

9. Light-gray clayey soft limestone full of brachopod shells: *Gigantoproductus striatosulcatus* (Schwetzov) and *Datangia moderata* (Schwetzov). Brachiopods are oriented with the convex pedicle valve towards the top of the bed. Thickness 0.05 m.

10. Light-yellowish or white soft clayey Limestone (a_7), represented by wackstone and floatstone bearing abundant ostracodes and brachiopods. At the base of limestone large shells of *Gigantoproductus giganteus* (Martin), *Datangia moderata* (Schwetzov), *Datangia moderatoconvexa* (Janischewsky) occur in living position – on the convex pedicle valves. They are distributed more irregularly in the middle and upper parts, but the position of the shells, similar to living ones, is predominant. Conodonts (B5–12) are known from the base of the limestone: *Cavusgnathus unicornis* (Hinde) and *Synclidagnathus geminus* (Hinde). Micritization is well developed in the whole bed. Spots of finely dispersed pyrite occur at the top. Their origination is connected with recrystallization and replacement of the abundant rhizoids of *Stigmaria*.

Incomplete thickness 0.8 m.

This unit is covered on the top by brown loam of glacial origin.

Fig. 29. Section of the Venevian Regional Substage near the main rapid near the village of Iogla (large gully)

The succession changes about 170 m upstream from the described outcrop. The eroded and ferruginous top of Limestone a_6 is exposed within 2 m of the shore line. The overlying deposits belong to the Iogla

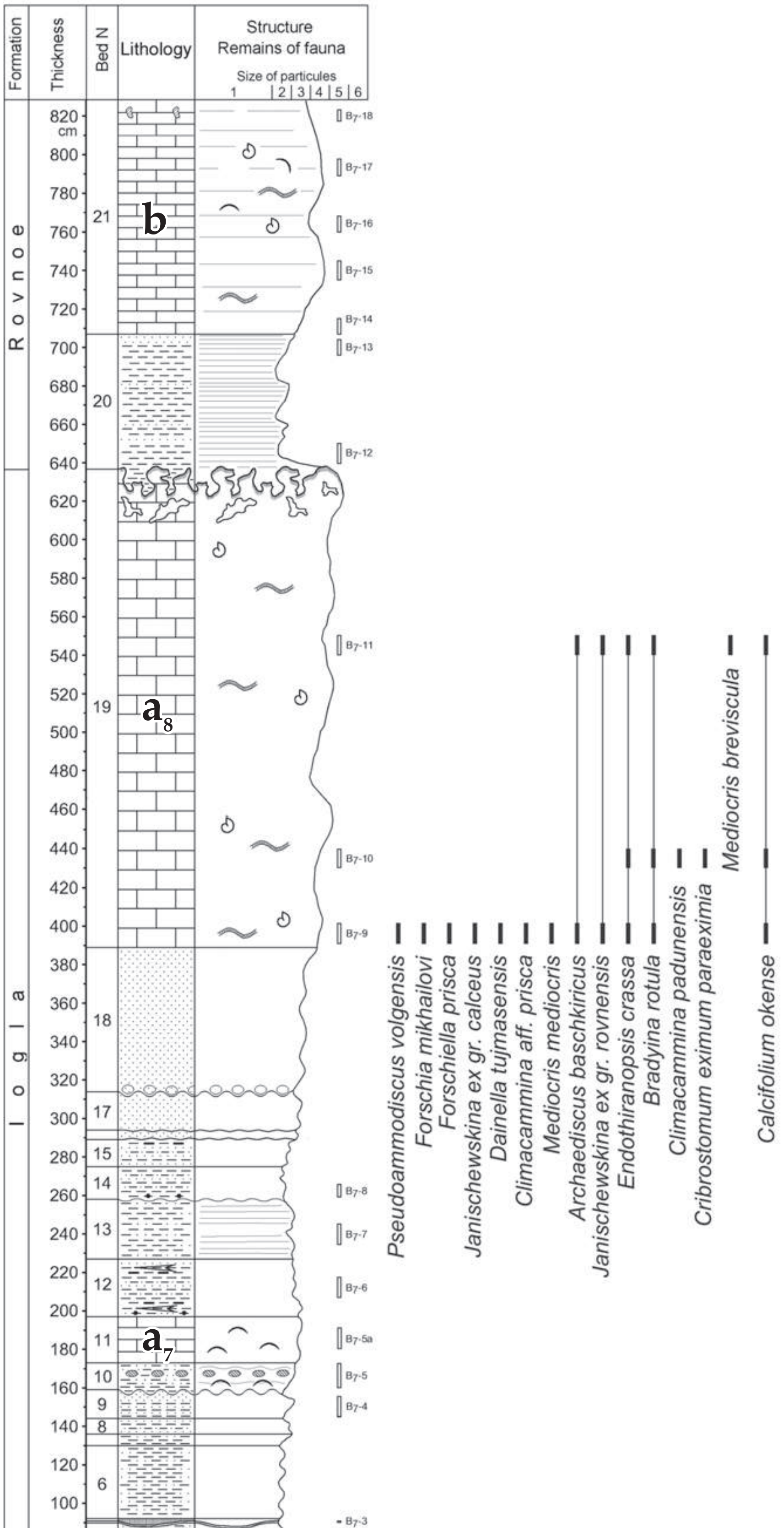


Fig. 30. Section of the Iogla and upper part of the Rovnoe formations on the right bank of the Msta River (village of Iogla). Right part of the picture shows the distribution of foraminifers

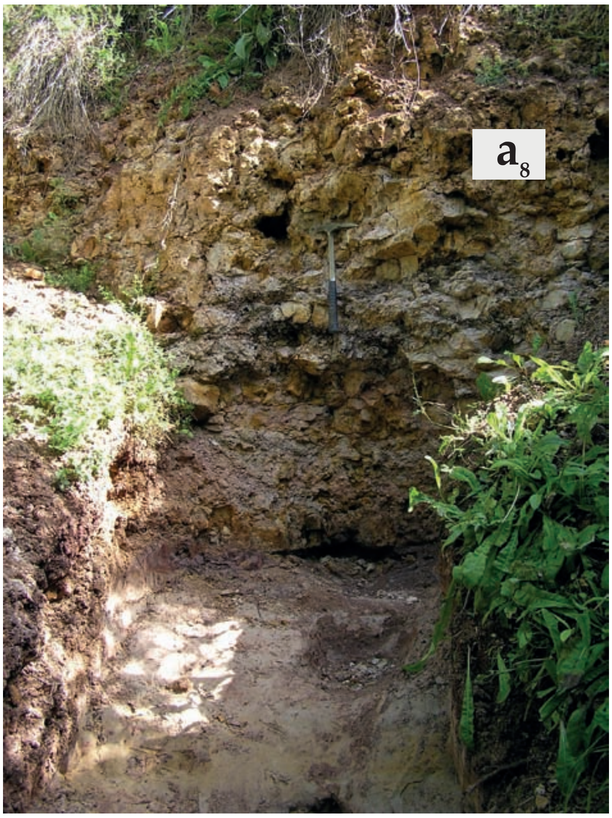


Fig. 31. Upper part of the Iogla Formation, light-gray sands and limestone a_8

Fig. 32. Lower part of the Iogla Formation, clays and Llimestone a_7

Formation of the Venevian Regional Substage (Fig. 30):

1. Light-gray greenish clay containing isometric limestone pebbles (size 1.5–2.0 cm) at the base. Composition of the clay includes iron hydroxide appearing as yellow-red spots in the clay at the top of the bed.
Thickness 0.4 m.

2. Sandy clay with abundant ferruginous (oxidation of pyrite) remains of plant roots showing vertical and sub-vertical orientation. A layer of loose round ferruginous concretions (size up to 2 cm) is located at the base of the bed. A 2cm layer of violet clay distinctly marks the bottom of the bed.
Thickness 0.2 m.

3. Lens-like layer of dark-yellow-gray sandy clay. Thickness 0.06 m.

4. Brownish-gray sandy clay. It overlies bed 3, or bed 2, if bed 3 is eroded.
Thickness 0.01–0.02 m.

5. Brown-black coal with gradational contact to bed 4. The top is strongly ferruginous.
Thickness 0,01–0,03 m.

6. Brownish-red, gray-brownish thin-bedded clay. Silt interlayers emphasize the lamination. Thickness 0.4 m.

7. Gray clay with a gradual contact with the underlying one. The top is marked by a thin ferruginous crust.
Thickness 0.06 m.

8. Thin-bedded intercalation of yellowish-gray fine-grained quartzose sand with violet-gray clay. Surfaces of the sand layers are emphasized by ferrugination. Thickness of sand layers up to 1cm, clay layers up to 4 cm.
Thickness 0.1 m.

9. Alternation of greenish-yellow clayey sand with lenticular layers of gray-violet clay. Thickness of separate sand layer is up to 3 cm, clay layers – up to 0.8 cm.
Thickness 0.15 m.

10. Yellow gray carbonate-clay with fine carbonate pebbles. The sizes of pebbles usually around 1cm. Lower boundary is characterized by an erosional surface with eroded pockets. Shells of *Gigantoproductus striatosulcatus* Schwetzov are present.
Thickness varies from 0.14 m to 0.22 m.

11. Yellow-gray clay with visibly jointed limestone (Fig. 32). The contact with underlying bed is gradational.
Thickness from 0,18 to 0,24 m.

Fig. 33. Palaeokarst in the Limestone a_8 (detritus, vertical borings)

Fig. 34. Limestone a_8 on the right bank of the River Msta (southern limit of the village of Iogla)

12. Gray sand with violet spots of iron sulfide. Sand contains large *Stigmaria* remains oriented with the bedding. Thickness 0.3 m.

13. Gray-violet, brownish horizontally laminated clay. The bottom surface is undulating and wavy with ferrugination at the bottom reaching 0.5 cm in thickness. Top irregular and wavy. Thickness 0.3 m.

14. Clayey quartose fine-grained sand. Ferruginous pebbles – concretions occur at the base of the bed. The top is covered by a ferruginous crust. Thickness 0.2 m.

15–16. Alternation of thin lenticular layers of sand and clay. Towards the top the deposits become fine sand. The color of these beds is gray-yellow-brownish with red and violet spots. Ferruginous weathered plant remains are present. Thickness 0.2 m.

17. Light-gray fine-grained homogenous quartzose sand. The top is wavy with traces of erosion and weak ferrugination. Thickness 0.2 m.

18. Alternation of unconsolidated fine-grained quartzose light-gray sand with yellow stripes of sand that have iron hydroxide and are of the same composition and color, but are more consolidated. Pebbles of the underlying bed occur at the bottom. The top is strongly brown with isometric spots of iron hydroxide decomposition. Thickness 0.75 m.

19. Gray bioclastic karst Limestone (a_8). Its texture is typcally a foraminiferal-algal packstone. It is characterized by dissolution, is partly friable and unstratified. The visible structure resembles breccia (Figs 31, 33, 34). Traces of borings extend through 1.5 m. Foraminifers and the alga *Calcifolium okense* Schwetzov are abundant. Visible thickness 2.0 m.

The continuation of this section can be seen 400 m upstream on the Msta River. The deposition sequence includes:

Tarusian Regional Substage

Rovnoe Formation

20. Thin-bedded alternation of gray-violet clay and gray fine-grained quartzose sand overlying the eroded and ferruginous top of Limestone a_8. Thickness 0.7 m.

21. Gray quartzose fine-grained sand containing iron hydroxide grains. The top is covered by a ferruginous crust. Thickness 0.03 m.

22. Bioclastic thin-bedded Limestone (b). This limestone contains abundant detritus including thin shells of small brachiopods, bivalves and gastropods, crinoid columnals, and the alga *Calcifolium*. Some parts of the rocks bear early diagenetic silicification in the form of nodules or elongate lenses. Visible thickness 2.5 m.

Stop 6

Section of the "Rovnoe Limestone" of the Tarusian Regional Substage, Serpukhovian Stage

The section is located on the right bank of the Msta River in the village of Rovnoe. Outcrops of limestone are exposed along the river bank in a continuous belt of about 300 m (Fig. 35). The strata, known as the "Rovnoe Limestone" consists of limestone with chert nodules. In the first stratigraphical chart of the Lower Carboniferous subdivisions of the north-western part of the Moscow basin, this strata was mentioned as unit b (Bogdanova, 1929). This section was first described by Yanishewsky (1936). Faunal remains are abundant with predominance of brachiopods, foraminifers, gastropods, bivalves, and crinoids. The diversity of remains gives high biostratigraphic significance of this section for the stratigraphy of the Serpukhovian Stage (Yanishewsky, 1954, 1960; Vostokova, 1955). Later this was further enhanced by the discovery of the cephalopod *Megapronorites sakmarensis* Ruzhentzev (Osipova and Bel'skaya, 1962) and conodonts of the Lochriea ziegleri Zone (Savitsky, 1999).

This outcrop is typical of the upper part of the section that is thick. Starting at the shore line, the following deposits are exposed (Fig. 36):

Tarusian Regional Substage

Rovnoe Formation

1. Light-yellow bioclastic soft limestone consisting of an accumulation of unconsolidated fine detritus. Microstructure shows partly neomorphic bioclastic packstone and wackstone with strongly disintegrated organic remains. Bioclasts are oriented mainly horizontally with thin shells of brachiopods, bivalves, crinoids, small foraminifers, and conodonts present. The first

Fig. 35. Outcrops of the limestone b on the right bank of the Msta River near the village of Rovnoe

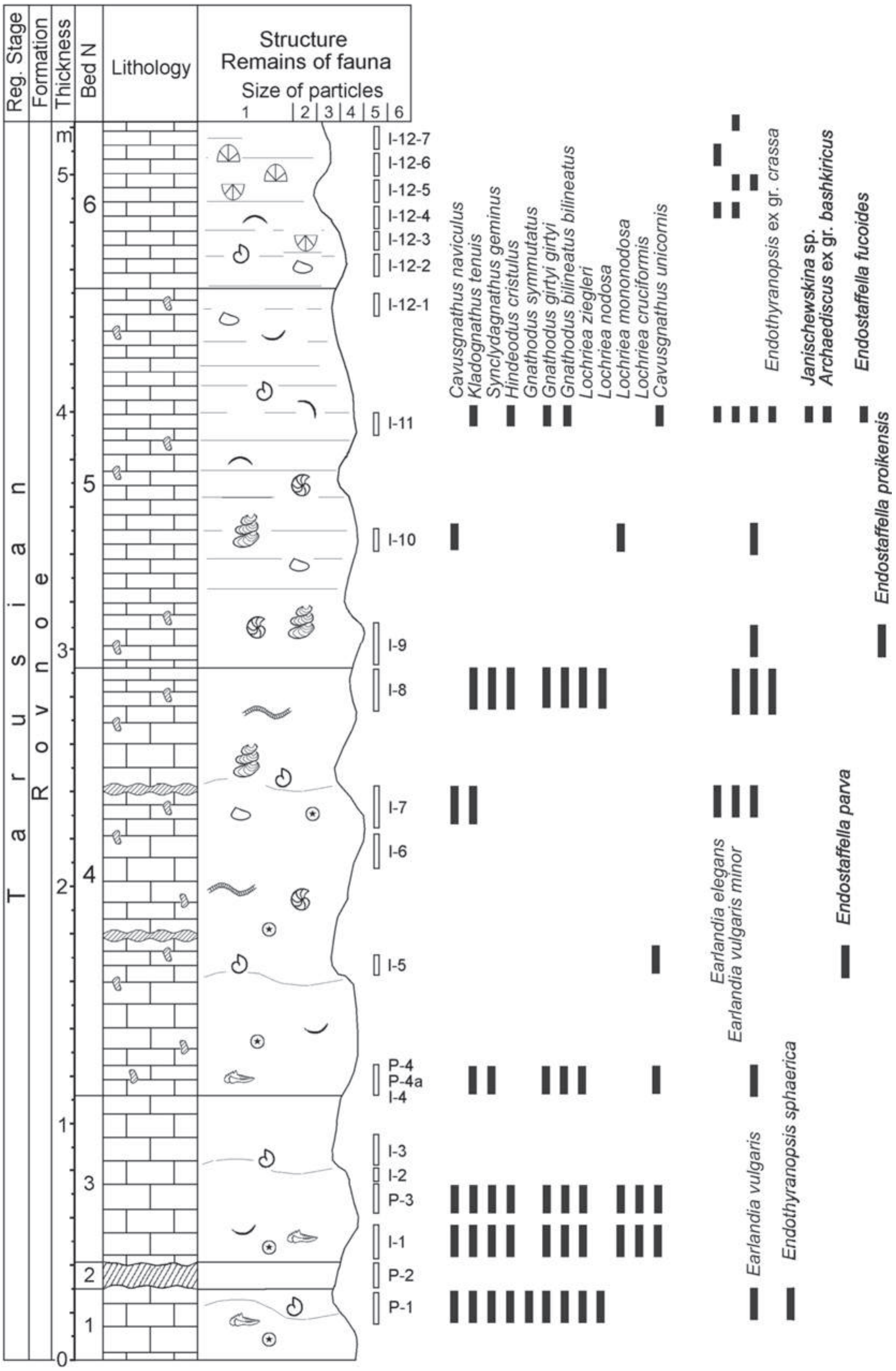


Fig. 36. Distribution of foraminifers and conodonts in the upper part of the Rovnoe Formation (Tarusian Regional Substage)

appearance of the conodont *Lochriea ziegleri* Nemirovskaya, Perret et Meischner was found at the top of the unit at the contact with overlying bed. Visible thickness 0.3 m.

2. Silicious chert, laminated in the lower part, traceable along the bedding planes. Thickness 0.12 m.

3. Light-gray flaggy homogenous foraminiferal-bioclastic carbonate packstone. Traces of Zoophycos are characteristic for the top of the bed. Thickness 0.7 m.

4. Alternation of light-yellow unconsolidated bioclastic limestone, including siliceous nodules, with light-gray biomicritic solid limestone. A large diversity of faunal remains is present, but they are mainly broken and whole specimens are rarely found. Biomicritic limestone is also present to a lesser extent with abundant brachiopods with well-preserved thin shells: *Ovatia tenuistriata* (Verneuil), *Pugilis pugiliformis* (Janishewsky), *Antiquatonia prikschiana* (Janishewsky), *Avonia youngiana* (Davidson), *Isogramma germanica* (Paeckelman.), and *Schuchertella rovnensis* Janishewsky. Numerous foraminifers, ostracodes, bivalves, crinoids, rare trilobites, and conodonts are present. Gray silicious nodules are also present and form thin lenses (thickness up to 5–7 cm). Thickness 1.8 m.

5. Light-gray flaggy bioclastic, partly solid, but also partly unconsolidated limestone, intensely bioturbated wackstone, with chert nodules. Faunal detritus and shells are irregularly distributed and concentrated in separate places. Wilkingia shells occur rather commonly and some are in vertical position (in situ). Zoophycos traces are widespread.

Thickness 1.6 m.

6. White bioclastic packstone , thinly laminated at the base with an abundant monotaxonomic accumulation of the brachiopod *Schuchertella rovnensis* (Janishevskyi), orientated along the bedding (Fig. 37). Visible thickness 0.7 m.

The last unit is covered by Quaternary deposits.

Fig. 37. Brachiopod Schuchertella rovnensis (Janishevskyi) from the Rovnoe Formation (Tarusian Regional Substage)

Stop 7 Section of the Steshevian Regional Substage and lower part of the Protvian Regional Substage

This section is located on the right bank of the Msta River in the southern outskirts of the village of Rovnoe. Outcrops of dolomitized limestone and secondary dolomite with siliceous nodules can be seen for about 1 km downstream on the banks of the Msta River. These strata belong to the Poneretka and Uglovka formations of the Serpukhovian Stage (Fig. 38). The first rather complete description of this section was presented by Yanishewsky (1936). This section was used by several well-known workers for the detailed study of an excellent example presenting unique palaeoecological and palaeoichnological data of the invertebrata and vertebrata of the Lower Carboniferous (Hecker 1940, 1980; Belskaya and Osipova 1965, 1969, 1970, 1977).

The following deposits are exposed above the shore line at this locality (Fig. 39):

Fig. 38. Outcrops of the Poneretka Formation on the right bank of the Msta River

Steshevian Regional Substage

Poneretka Formation

1. Thin-bedded alternation of colorful clay with layers of sandy clay and quartzose sand. The contact with the underlying "Rovnoe Limestone" is under water.

Thickness about 1.5 m.

2. Gray-violet thin horizontally-bedded quartzose sand with large plates of hydromica. Lamination is emphasized by gray-violet or cherry-red ferrugination stripes. Rocks contain dispersed limonite and hydro goethite formed as scattered dark-gray nodules. Thin wavy lenses of white-green clay and a thin wedge-shaped series of cross-bedded sands appear in the upper part of the bed.

Thickness 1.30 m.

3. Yellow-gray quartzose carbonate sand with violet spots and stripes. Sand is penetrated by the vertical burrows of organisms.

Thickness 0.16–0.18 m.

4. Gray-violet, dolomitic horizontally-bedded sand. Upper 10–12 cm of the bed is strongly ferruginated dolomitized yellow limestone. Thickness 0.9 m.

5. Yellowish-gray dolomitized solid limestone with red spots. At the bottom, the limestone contains abundant large shells of brachiopods oriented along the bedding: *Striatifera striata* (Fischer), *Latiproductus latissimus* (Sowerby), and also small shells of *Dielasma* sp. and *Athyris* sp. The bed is penetrated by vertical or oblique rounded burrows. Thickness 0.2 m.

6. Dolomitized dark-gray massive silicified limestone with red ferrugination spots. *Zoophycos* burrows are widespread. Remains of solitary and colonial corals, ostracodes, brachiopods, and crinoids are present. The brachiopod assemblage includes: *Gigantoproductus superior* (Janischewsky). Thickness 0.4 m.

7. Dolomitized massive light-gray porous limestone. Pores are developed by the leached remains of foraminifers, bivalves, brachiopods, and crinoids. Thickness 0.3–0.4 m.

8. Dolomitized yellow thin-bedded limestone. Rocks are strongly unconsolidated and are friable, floury without features of jointing. Thickness 0.15 m.

Beds 5–8 correspond to the beds 10a, 10b, 10c, and 10d of Yanishewsky (1936).

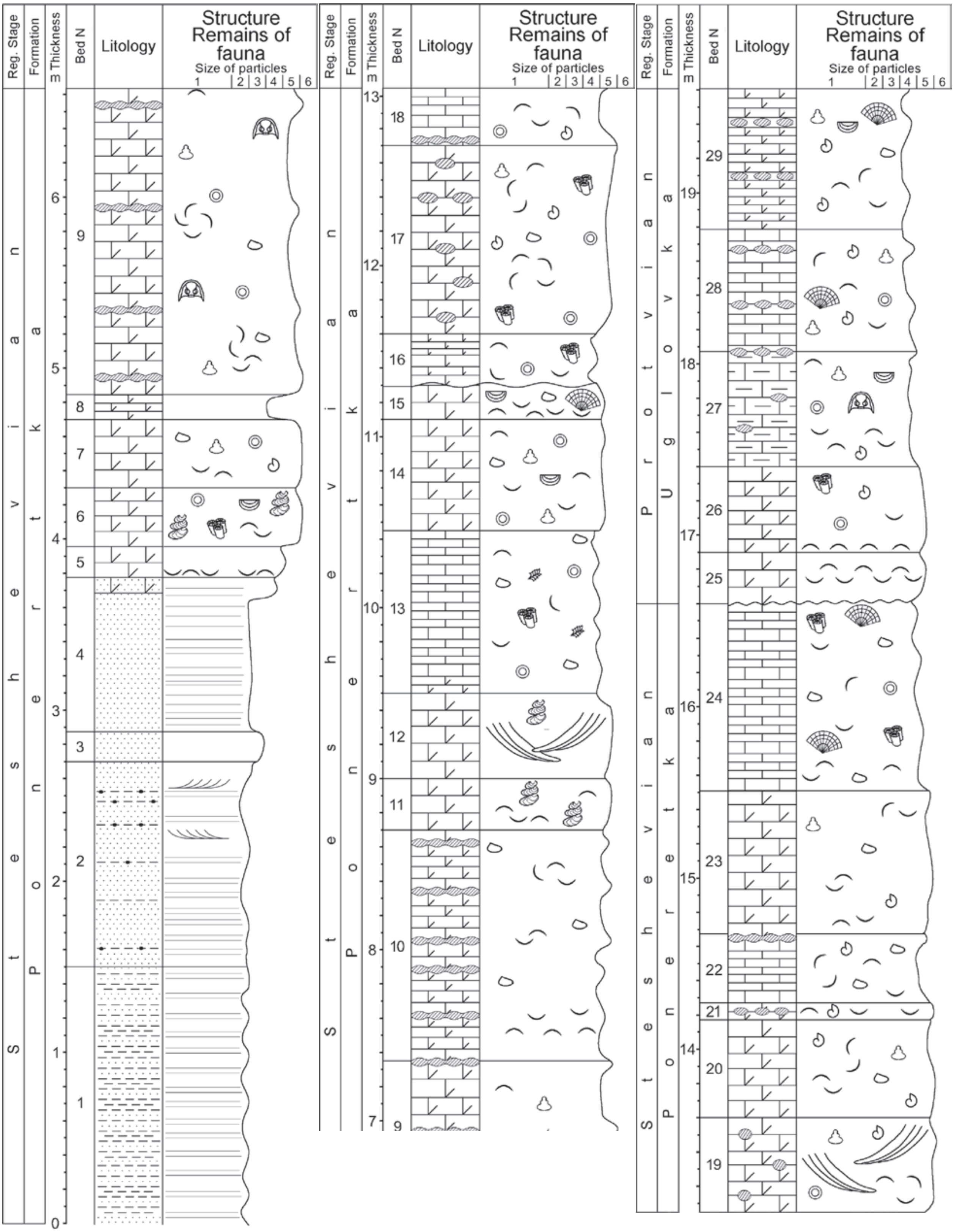


Fig. 39. Section of the Steshevian and Protvian deposits on the right bank of the Msta River

Fig. 40. Stigmaria from the Poneretka Formation

9. Alternation of thick-bedded dolomitized limestone with layers of siliceous chert. Limestone is gray massive, polydetritic, sometimes unconsolidated to flour. Remains of trilobites, bivalves, brachiopods, and crinoids are distributed as nest-like accumulations and are represented as internal molds or imprints. This unit contains six intervals of siliceous chert. Siliceous oval chert nodules are gray-brown surrounded by thick white rind and are from 5 to 20 cm thick.

Thickness of the unit is 2.5 m.

10. Alternation of medium-bedded dolomitized limestone with chert. Light yellowish-gray bioclastic, partly unconsolidated, friable, containing imprints and molds of brachiopods: *Striatifera lata* Janischevsky, *Antiquatonia prikschiana* (Janischewsky), and *Ovatia tenuistriata* (Verneuil). Bivalves are also present. Gray chert nodules occur at five levels. Thickness of the chert layers varies from 10 to 40cm. Thickness of the unit is from 1.0 to 1.55 m.

Beds 9 and 10 correspond to beds 11 and 12 of Yanishewsky (1936).

11. Gray dolomitized thick-bedded limestone with numerous borrows of *Zoophycos* and imprints of large brachiopods *Gigantoproductus superior* (Janischewsky).

Thickness 0.3–0.35 m.

12. Light-gray cavernous dolomitized intensively bioturbated limestone with numerous burrows, of *Zoophycos* and oblique burrows of *Desmichnus porschnniakovi* Hekker. The latter densely penetrate the bed and occur as branches spreading from the base.

Thickness up to 0.5 m.

Beds 11 and 12 correspond to bed 13 of Yanishewsky (1936). Bed 12 correlates with bed 14 of Hekker (1980).

13. Intercalation of medium to thin-bedded white bioclastic limestone. They mainly consist of crinoid fragments and brachiopods, but corals, bivalves, and bryozoans also occur. A layer of unconsolidated strongly dolomitized limestone, decomposed to gray-yellow or greenish dolomite flour 10cm thick is present at the base of the unit. Thickness 1.0 m.

This bed corresponds to bed 14 of Yanishewsky (1936).

14. Dolomitized brown-yellow bioclastic porous limestone. Numerous faunal remains

are leached and occur in the form of voids and molds. Ostracodes, gastropods, bivalves, and crinoids are present in this bed. The lower 13 cm of the bed is penetrated by oblique burrows of *Desmichnus*, increasing upward from the base of the bed. Thickness up to 0.7m.

15. Dolomitized bioclastic limestone containing foraminifers, ostracodes, bivalves, brachiopods, and also crinoid fragments. Bed contains convexo-plane, dome-shaped colonies of Chaetetida. The top is wavy. The bed sometimes pinches out laterally.

Thickness 0–0.3 m.

Beds 14 and 15 correspond to bed 15 of Yanishewsky (1936).

16. White-gray bioclastic dolomitized medium to thin flaggy limestone. Contains primarily crinoid and brachiopod shell fragments. Colonial rugose corals are also common. Limestone overlies the wavy irregular surface of bed 14 or 15. Thickness from 0.2 to 0.4 m.

This bed corresponds to bed 16 of Yanishewsky (1936).

17. Pink-gray massive dolomitized limestone with chert nodules. Chert nodules are distributed throughout the entire thickness of the bed and are oriented obliquely to the bottom and developed in the burrows of *Teichichnus.* Abundant invertebrate remains are represented by external molds and imprints of brachiopods, burrowing bivalves, gastropods, colonies of Chaetetida`and Rugosa, and crinoids. Fauna occurs in dense pockets.

Thickness 1.1 m.

This bed corresponds to bed 17 of Yanishewsky (1936).

18. Thin-flaggy light-gray bioclastic limestone with chert nodules of cylindrical shape, located at the bottom of the bed. Thickness 0.3 m.

19. Limy dolomite brownish-yellow-gray, bioclastic with nest-like accumulations of bivalves, gastropods, and brachiopods, some occurring in growth position. The bed is penetrated by oblique *Desmichnus* burrows. Round-shaped siliceous nodules are present.

Thickness 0.5 m.

20. Brownish-gray bioclastic dolomitized medium bedded flaggy limestone.

Thickness 0.6 m.

21. White-gray dolomitized thin bedded flaggy bioclastic limestone with siliceous nodules developed along the bedding. Thickness 0.1 m.

22. White-gray, medium bedded flaggy bioclastic limestone with gray-brown large elongate chert nodules at the top. Thickness 0.4 m.

Beds 18–22 correspond to bed 18 of Yanishewsky (1936).

23. Dolomitized brown-gray massive limestone containing numerous large brachiopods *Gigantoproductus superior* (Janischevsky) in the form of molds and imprints of valves

Thickness 0.8 m.

Bed 23 corresponds to the bed 19 of Yanishewsky (1936).

24. White medium bedded flaggy bioclastic friable limestone, characterized by abundant Chaetetida colonies of sub-spherical shape, colonies of *Syringopora*, rugose corals *Actinocyathus* and *Diphyphyllum*, and large brachiopods *Gigantoproductus superior* (Janischevsky). The top is characterized by an undulating erosional surface covered by a micritic crust.

Thickness 1.1 m.

Bed 24 corresponds to bed 20 of Yanishewsky (1936).

Protvian Regional Substage

Uglovka Formation (Fig. 41)

25. Greenish-gray dolomitized siliceous limestone with abundant brachiopod valves *Spirifer multicostatus* Schwetzov, *"Productus" crassicostatus* Janischewsky, *"Productus" percostatus* Janischevsky oriented along the bedding. Thickness 0.3 m.

Bed 25 corresponds to bed 21a of Yanishewsky (1936).

26. Yellow-gray medium bedded flaggy dolomitized bioclastic friable limestone with a thin accumulation layer of shellstone containing valves of *Latiproductus latissimus* (Sowerby). The top of the limestone also contains re-crystallized *Lithostrotion* colonies characterized by compressed corallites oriented along the bedding. Thickness 0.5 m.

Bed 26 corresponds to bed 21-b of Yanishewsky (1936).

27. Beige-yellow clayey limestone with small chert nodules and abundant molds of valves of brachiopods *Striatifera lata* Janischevsky, *Striatifera magna* Janischevsky, *Gigantoproductus superior* (Yanischevsky), and *Antiquatonia khimenkovi* (Yanischewsky). Ostracodes, bivalves and gastropods are also present in the bed and a layer of chert nodules marks the top.

Thickness 0.7 m.

Bed 27 corresponds to bed 21-c of Yanishewsky (1936).

28. Light-gray medium bedded flaggy limestone with thin layers of chert nodules and isolated valves of the brachiopods *Striatifera lata* Janischevsky and *Latiproductus latissimus* (Sowerby), fragments of Chaetetida colonies and gastropod shells.

Thickness 0.7m.

Bed 28 corresponds to bed 22-a of Yanishevsky (1936).

29. Beige-yellow medium to thin bedded flaggy bioclastic partly unconsolidated limestone with small chert nodules irregularly distributed within the bed. Remains of foraminifers, Chaetetida, bivalves and brachiopods occur in the form of molds and imprints.

Thickness 0.8 m.

Bed 29 corresponds to bed 22-b of Yanishevsky (1936).

This bed is covered by the thin glacial till.

Fig. 41. Outcrops of the Uglovka Formation in the Gverstka quarry

Stop 8

Serpukhovian deposits near the village of Malyi Porog

Lengthy exposures of Serpukhovian limestone are well exposed in this easily accessible outcrop (Fig. 42). They represent the Steshevian/Protvian boundary interval. This section practically repeats the upper part of the previous one, but here the rocks are better exposed and fauna is more abundant. The abundant faunal elements in the lower part of this unit (uppermost bed of the Poneretka Formation) are characterized by Chaetetidae and rugose corals that are dominant. The wide and persistent distribution of this assemblage was the reason to assume the reef genesis of this bed (Yanishevsky, 1935; 1937). However, the specific taxonomical composition and absence of visible bioherms suggest only optimum environments rather a reef genesis (Osipova, 1997).

Fig. 42. Deposition of the Uglovka Formation near the village of Malyi Porog

Stop 9 Section of the Steshevian deposits (Poneretka Formation)

This section is located on the left bank of the Msta River near the mouth of the Poneretka River. The Poneretka River is a karst river developed within a karstic valley (Fig. 43). This section is a key one for the understanding of the structure and composition of the Serpukhovian Stage.

The following deposits are represented from the bottom to the top at the cliff of the Msta River (Fig. 44):

Fig. 43. Poneretka River

Steshevian Regional Substage

Poneretka Formation

1. Gray monotonous dolomitized limestone with well-developed bedding-plane partings, three beds of thickness 10–12 cm.

Thickness 0.35 m.

2. Layer of white bedded chert easily traceable along strike and characterized by constant thickness. The top is slightly wavy.

Thickness 0.07 m.

3. Two beds of gray monotonous dolomitized limestone. The lower bed is yellow, solid, and well-exposed in relief, with an accumulation of the brachiopods *Schuchertella* and *Striatifera* oriented along the bedding at the bottom. The upper bed is an friable finely grained clastic limestone, smooth in relief, with a thickness of 20 cm.

Total thickness 0.44 m.

4. White bedded and nodular chert. Thickness 0,1 m.

5. Gray friable dolomitized limestone with irregularly distributed white chert nodules in layers up to 10cm thick mainly occurring in the upper part of the bed. Thickness 0,35 m.

6. Alternation of white-gray monotonous medium bedded flaggy dolomitized limestone. In some places the limestone has disintegrated to sand. Limestone has lenticular layers of gray chert. Thickness 0.35 m.

Beds 1–6 correspond to bed 11 of Yanishewsky (1936).

7. Alternation of white slightly silicified medium bedded flaggy limestone and lenses of siliceous chert. Bioclastic limestone with an accumulation of shell remains, mostly brachiopods along the bedding. Foraminifers and gastropods also are present. Thickness 1.9m.

Bed 7 corresponds to bed 12 of Yanishewsky (1936).

8. Gray dolomitized thick-bedded bioclastic limestone with *Desmichnus* burrows oriented obliquely to the bottom and extending through the entire thickness. The bed is locally unconsolidated and the top is wavy. Thickness 0.4 m.

Bed 8 corresponds to bed 13 of Yanishewsky (1936).

9. Alternation of medium to thin bedded flaggy white bioclastic limestone containing crinoid and brachiopod remains. Ostracodes and lamellar *Chaetetida* also occur.

Thickness 0.9 m.

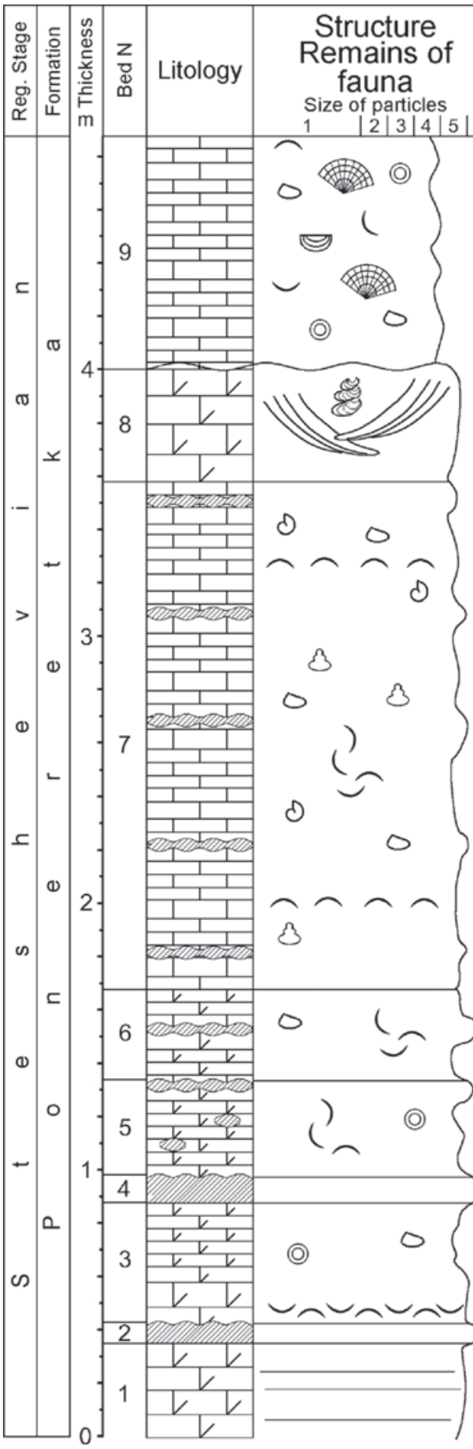
Bed 9 corresponds to bed 14 of Yanishewsky (1936).

10. Gray-brown massive dolomite with traces of erosion and vertical borings. The top is roughly wavy represented as furrows and ripples. Thickness 0.5 m.

11. Gray dolomitized bioclastic limestone. Abundant organic remains are leached and replaced. An accumulation of brachiopod and gastropod shells occurs at the bottom, some in growth position Thickness 0.5 m.

Beds 10 and 11 correspond to bed 15 of Yanishewsky (1936).

12. Limestone, dolomitized, medium to thick bedded, light-gray, consisting mainly of



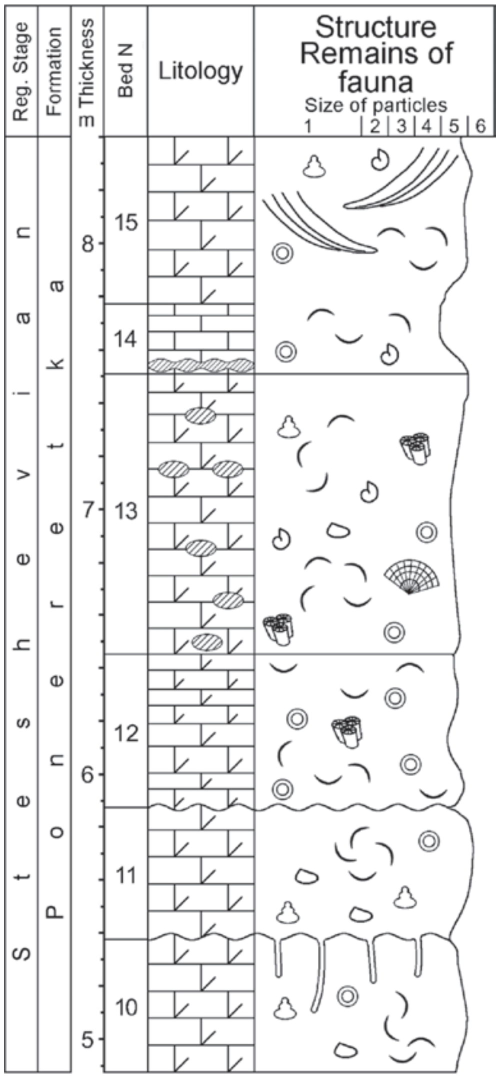


Fig. 44. The Upper Steshevian deposits in the mouth of the Poneretka River

crinoid fragments and brachiopod shells. Colonial rugose corals are common. The bed overlies the irregular wavy surface of bed 11. Thickness 0.6 m.

Bed 12 corresponds to bed 16 of Yanishewsky (1936).

13. Gray massive dolomitized limestone with brown-gray chert nodules of cylindrical shape. *Teichichnus* burrows are obliquely oriented to the bottom. Burrows crossing the entire bed are often filled by chert. Numerous invertebrate remains are represented by external molds and casts of Gigantoproductidae, burrowing bivalves, gastropods, Chaetetidae and rugose colonies, and crinoids in accumulations. Thickness 1.1 m.

Bed 13 corresponds to bed 17 of Yanishewsky (1936).

14. Thin-flaggy yellow-white bioclastic poly-detrital limestone with chert nodules of cylindrical shape. Thickness 0.3 m.

15. Yellow-gray bioclastic dolomitized thick-bedded limestone containing whole shells of bivalves, gastropods, cephalopods, brachiopods, coral colonies and irregularly accumulated unsorted bioclasts. Oblique *Desmichnus* borrows cut across the limestone. Thickness 0.6 m.

Beds 14 and 15 correspond to the lower part of bed 18 of Yanishewsky (1936).

The bed is covered by clay loam.

Stop 10

Section of the upper part of the Protvian Subregional Substage

The younger Serpukhovian deposits (in comparison with the outcrops observed on the Msta River) can be seen in the quarries in the Uglovka settlement (Fig. 45). The limestone of the Uglovka Formation corresponded to the Protvian Substage is over-covered by Quaternary glacial deposits. The younger deposits of the Serpukhovian Stage is not known in the territory. The thickness of the Uglovka Formation established by drilling data reaches 40 m. Uppermost 8–10 m of the Uglovka Formation is visible in the quarries.

The studied section is situated in the south-western part of the quarry, about 500–700 m north of the active Uglovka quarry (Fig. 46).

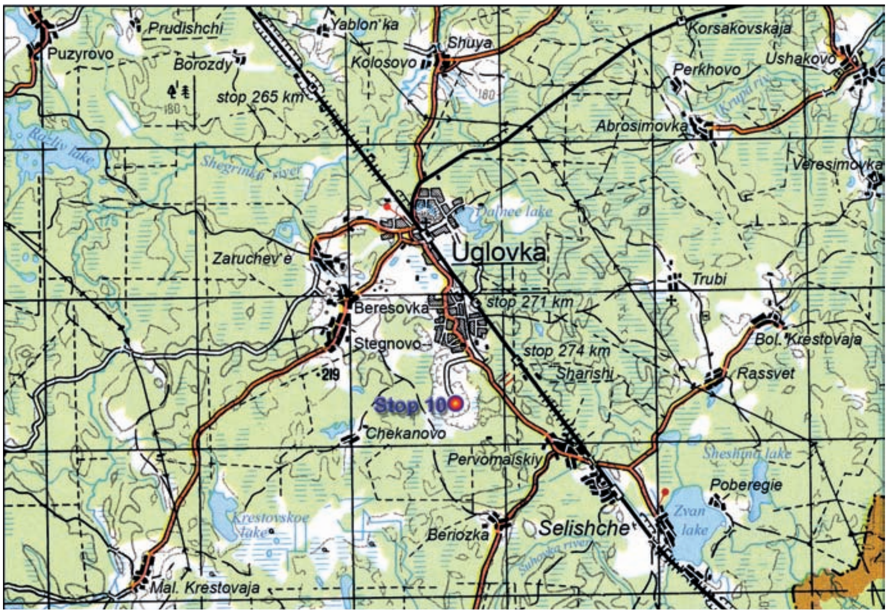


Fig. 45. Location of the Uglovka quarry in the vicinity of the village of Uglovka. Scale 1:200 000r

Fig. 46. Outcrop of the Uglovka Formation in the Uglovka quarry

Protvian Regional Substage

Uglovka Formation

Exposed at the bottom of the quarry (Fig. 47):

1. Dome shaped chaetetid bioherm, which is composed of white massive biogenic boundstone, yielding numerous overturned chaetetid colonies. Massive colonies reach 20 cm in diameter. Inter-colonial spaces are filled with wacke-packstone. Visible size is 10x10 m. Foraminiferids and brachiopods occur. Visible thickness 1.0 m.

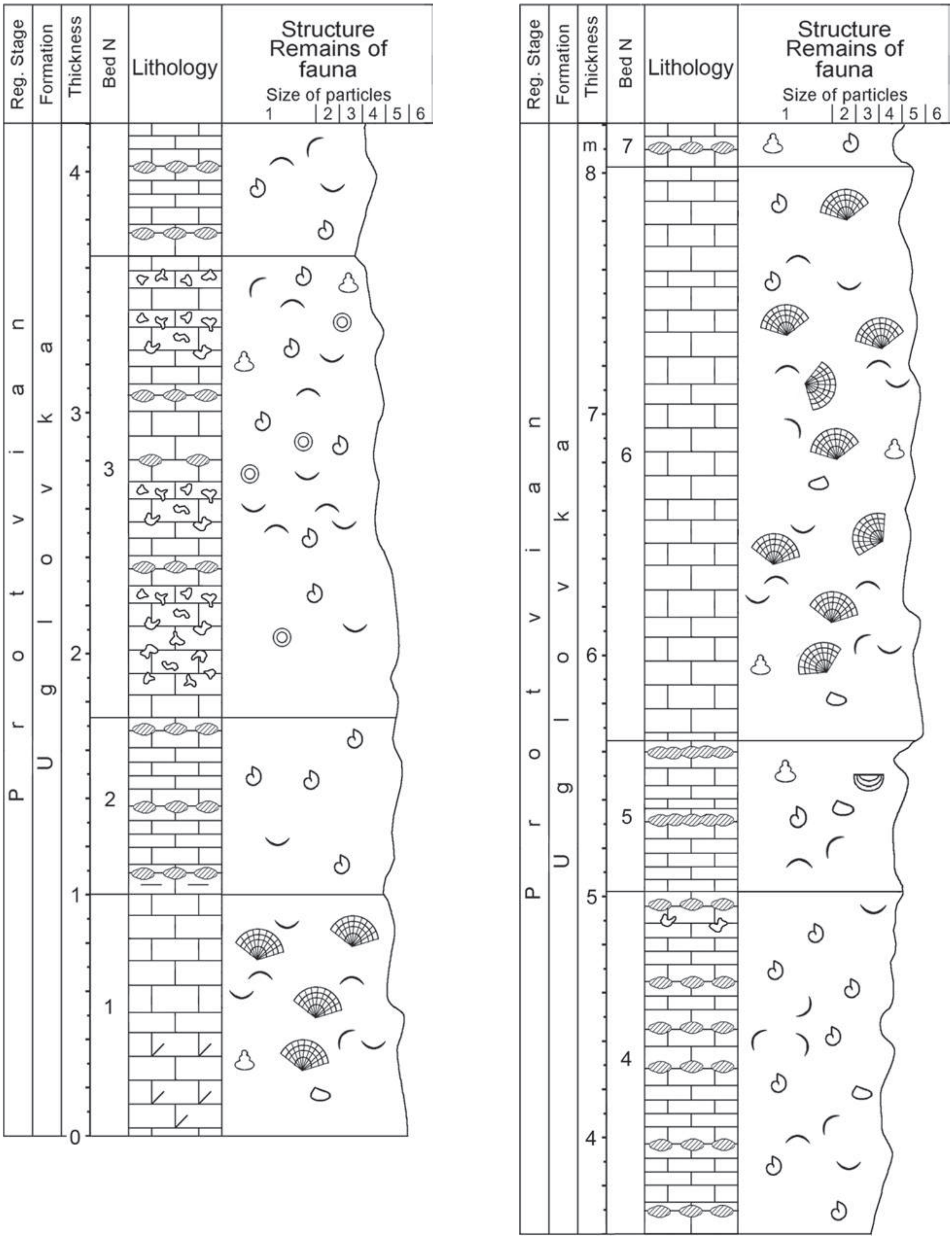


Fig. 47. Section of the Protvian deposits in the Uglovka quarryr

2. Secondary altered limestone unit with chert nodules (20x40 cm). The whitish-gray or white micritic limestone includes small calcitic geodes. Silicification and traces of dissolution are visible. Cherty nodules are decompacted and demonstrate a brecciated structure. Towards the top, cavernousity of rocks increases. Thickness from 0.40 to 0.63 m.

3. Light gray cavernous biogenic wacke-packstone with chert nodules of elliptic shape. These periodically distributed cavernous layers bear karstic features (Fig. 49). The upper part is dominated by a foraminiferous limestone yielding shell detritus and sporadically complete brachiopod shells of Latiproductus laticostatus (Yan.) (Fig. 50). The unit is subdivided into cleavage middle-thick layers. Thickness 1.90 m.

4. Light gray foraminiferal bedded limestone (up to 12 cm), including layers of silicious cherts. Their dark gray elongate seams are distributed in the lower part of layers. Cavernosity increases towards the top of the unit. Thickness 1.43 m.

5. Bioclastic, light grey to yellowish coloured limestone with abundant foraminifers, ostracods and gastropods. The unit is subdivided into two parts by silicification, emphasizing a lithologic boundary. Thickness from 0.40 to 0.62 m.

6. A massive unit of white, laminated limestone. At the base a foraminiferal-detritic wackstone predominates, followed by a recrystallized sparite with abundant *Chaetetes* colonies, which are irregularly orientated. Thickness of individual layers ranges from 60–70 cm. In the upper part, deposits are penetrated by vertical dichotomous karst channels. Thickness of separate layers varies from 40 to 70 cm. The unit shows a dome-like biohermal shape.
Thickness from 3.0 to 2.2 m.

7. Light yellowish coloured wacke-packstone Visible thickness 0.3 m.

Fig. 48. Rugose colony of the Actinocyathus genus

Fig. 49. Dissolution traces (paleosoils) in limestone of the Uglovka Formation

Fig. 50. Productid brachiopods of the Laticostatus genus in limestone of the Uglovka Formation

Fig. 51. Gastropods from the Uglovka Formation

REFERENCES

Aristov, A.S., Savitsky, Y.V., Fedorova, E.V., 1999. Conodonts from the deposits of Late Visean epicontinental basin (northwestern part of the Russian Platform) // Dokl. AN, t. 366, № 1, pp. 72–75. (In Russian).

Belskaya, T.N., Osipova, A.I., 1977. Dependence of the structure and composition of deposits from paleorelief in northwest of Moscow Syneclise // Litologia I Poleznye iskopaemye, № 2, pp. 36–47. (In Russian).

Bogdanova, Z.A., 1929. On the section of the Lower Carboniferous deposits of the western and northwestern part of the Moscow basin // Izvestia geol. Comiteta, t. 48, № 10.(In Russian).

Bruns, E.P., 1935. To lithology of the sandy-clay unit of C_1^{hn} of Borovichi district // Izv. Leningrad geologo-gidrogeodezich. tresta, № 2–3(7–8), pp. 52–64. (In Russian).

Bruns, E.P., 1939. The main features of structure and sedimentology of sandy-clay (coal-bearing series) of C_1^{hn} of the Leningrad District // Lower Carboniferous deposits of the northwestern part of the Moscow basin. Sb. Leningradskogo geologich. Upravlenia, № 3, pp. 5–32. (In Russian).

Dobrolyubova, T.A., 1958. Lower Carboniferous colonial tetracorals of the Russian Platform //Trudy of the Paleontological Istitute, v. LXX, Izd. ANSSSR, M., 224 p.(In Russian).

Dronov A.V., Savitsky Y.V., 2003. Organogenic carbonate structures at the base of the Oka series (Visean) in the north-west of Moscow syncline. Abstracts. PALEOSTRAT 2003, Moscow, p. 5.

Fischer A.G., 1964. The Lofer cyclothem of the Alpine Triassic. Kansas Geol. Survey Bull. 169, pp. 107–149.

Forsh, N.N., 1935. New data on the structure of the Okian deposits of the Borovichi and Tikhvinian districts and significance of this issue for problem for C_1. // Izv. Of Leningrad Geologo-Geodez. tresta, № 2–3 (7–8), pp. 18–33.(In Russian).

Ganelina, R.A., 1951. Eostaffells and Millerells of the Visean and Namurian of the western part of the Moscow basin // Stratigraphy and microfauna of the Lower Carboniferous of the western part of the Moscow basin. Sbornik statei /Edited by Fursenko A.B. M.- L., pp. 179–210. (In Russian)

Ganelina, R.A., 1956. Foraminifers of the Visean deposits of the northwestern regions of the Moscow basin // Microfauna SSSR. M., pp. 61–183. (Trudy VNIGRI, N.S.; Vyp. 98). (In Russian)

Goryansky, V.Y., Kofman, V.S., 1979. Modern ideas on stratigraphy and lithologo-facies features of the Carboniferous deposits of the northwestern part of the Russian Platform and Kola Peninsula // Paleontological characteristics of the main subdivisions of the Carboniferous system. M., Nauka, pp. 247–252. (Eight International Geological Congress on the stratigraphy and geology of the Carboniferous system, Proceedings, v. 3, Moscow, 8–13, September, 1975). (In Russian).

Hecker, R.F., 1938a. To organization of the palaeoecological study of the Lower Carboniferous deposits of the Leningrad district//Materialy po regional'noi I prikladnoi geologii Lenoblasti I Karelskoi ACCP, 1938, sb. №2, pp. 3–15. (In Russian)

Hecker, R.F., 1938b. Section of the "unit of alternation (a)"Oka Fromation of the Lower Carboniferous along the Msta River // Materialy po regional'noi I prikladnoi geologii Lenoblasti I Karelskoi ACCP, 1938, sb. № 2, pp. 15–22. (In Russian)

Hecker, R.F., 1940. Results of the Carboniferous palaeoecological expedition in 1934 –1936 year // Tr. PIN, t. IX. M.- L. Izd. ANSSSR, pp. 105–122.

Hecker, R.F., 1980. Traces of invertebrates and Stigmaria in the marine deposits of the Lower Carboniferous in the Moscow Syneclize // Tr. PIN, v. 178. M., "Nauka", 84 p.

Hecker, M.R., 1997. Evolution, ecology and variability of the Actinocyathus d' Orbigny 1849 (Rugosa) in the Moscow Basin during the latest Visean and Serpukhovian // Boll. Real Sociedad Espanola de Historica Natural, Seccion Geologica, 91 (1–4), pp. 107–115.

Hecker, M., 2002. Revision of Orionastraea Smith, 1917 (Rugosa) from the Lower Carboniferous (Uppermost Visean) of the Moscow Basin, and comments on pattern of variability, evolution andrange of the genus in eastern Europe and in British Isles // Cologuios de Paleontologia, 53, pp. 3–20.

Iwanowski, A.B., 1987. Rugosa, described by A.A. Stuckenberg (1888–1895). Nauka, Moscow. 45 p. (In Russian).

Kabanov P.B., Alekseev A.S., Gibshman N.B., Gabdullin R.R., Berschov A.V., 2014. The upper Visean-Serpukhovian in the type area for Serpukhovian Stage (Moscow Basin, Rassia): Sequencis, disconformites, and biostratigraphic summary // GEOLOGICAL JOURNAL / Geol. J. Published online in Wiley Online Library (wileyonlinelibrary.com). DOI: 10.1002/gj.2612

Karaeva, M.V., 1935. Significance of the coral fauna for the stratigraphy of the Lower Carboniferous of the Leningrad District // Izv. Leningr. Geologo-Gidro-Geodezich Tresta, № 2–3 (7–8), pp. 36–38.

Kofman, B.S., 1989. Carboniferous System // Geological map of SSSR. List O–(35), 36 – Leningrad. Explanatory note/ Edited by V.P. Kirikov, L. (In Russian).

Lonsdale, W., 1845. Appendix A. Description of some characteristic Paleozoic corals of Russia // Murchison, R.I., de Verneuil, E., Von Keyserling, A.The geology of Russia in Europe and the Urals Mountains. London, Paris, v. 2, № 3, pp. 1–20.

Mikhailov, A.V., 1935a. Foraminifers of the Oka Formation of the Borovichi District // Izv. Leningrad Geologo-Gidro-Geodezich. Tresta, № 2–3 (7–8), pp. 33–36. (In Russian).

Mikhailov, A.V., 1935b. To the problem of the phylogeny of the Carboniferous foraminifers // Izv. Leningrad Geologo-Gidro-Geodezich. Tresta, № 2–3 (7–8), c. 38–42. (In Russian).

Mikhailov, A.V., 1939. To the characteristics of the Lower Carboniferous genera of territory of SSSR // Lower Carboniferous deposits of the northwestern part of the Moscow basin. Sb. Leningrad Geol. Upravlen. , № 3, pp. 47–62. (In Russian).

Mikhailov, A.V., 1939. About Palaeozoic Ammodiscidae // Lower Carboniferous deposits of the northwestern part of the Moscow basin. Sbornik. Leningrad Geol. Upravlen. , № 3, pp. 63–69.

Orlova, O.A., Snigirevsky, S.M., 2000. First findings of the fern leaves in the Upper Visean deposits of the northwestern part of Moscow Syneclise // Materialy simposiuma posv. pamyati S.V. Meiena (1935–1987). GEOS, pp. 157–158. (In Russian).

Orlova, O.A., Snigirevsky, C.M., 2003. Late Visean Lyginopteridophyta from the vicinity of town of Borovichi (Novgorod Region). Calamopityales//Paleontological Journal, № 6, pp. 105–111. (In Russian).

Orlova, O.A., Snigirevsky, C.M., 2004. Late Visean Lyginopteridophytes from the vicinity of the town of Borovichi (Novgorod Region). 2. Lyginopteridales and Medullosales // Paleontological Journal, № 4, pp. 104–109. (In Russian).

Oshurkova, M.V., 2003. Morphology, classification and description of form-genera of Late Paleozoic miospores. St. Petersburg, VSEGEI, 377 p. (In Russian).

Osipova, A.I., 1997. Corals “reefs” in the Lower Carboniferous of the Moscow syneclise // Reefogenous build-ups in the Paleozoic of Russia. M.”Nauka”, pp. 89–96. (In Russian).

Osipova, A.I., Belskaya, T.N., 1962. Facies and paleogeigraphy of Serpukhovian time in the Moscow basin // Litologia I poleznye iskopaemye, № 5, pp. 3–17. (In Russian).

Osipova, A.I., Belskaya, T.N., 1965. About Venevian Horizon of the southern part of the Moscow basin // Izvestia Vuzov. Geologia I razvedka, № 11, pp. 33–44. (In Russian)

Osipova, A.I., Belskaya, T.N., 1969. Lithological-Paleoecological maps of the Moscow Syneclise in Visean and Namurian ages, map 52 // Atlas of lithological-paleogeographical maps of the USSR. Volume II, Edited by V.M. Pozner. (In Russian).

Osipova, A.I., Belskaya, T.N., 1970. Paleoecological criteria for determination of the epigenetic changes of the carbonate rocks (for instance of the Lower Carboniferous deposits of the Russian Platform) // Litologia I poleznye iskopaemye, № 2, pp. 107–129. (In Russian).

Poty, E., Hecker, M.R., 2003. Parallel evolution in European rugose corals of the genus Lonsdaleia Mc Coy, 1849 (Lower Carboniferous) // Bulletin de l’Institute Royal Des Sciences Naturelles de Belcique, Science De La Ferre, 73: 109–135.

Pozner, V.M. 1951. Ostracodes of the Lower Carboniferous of the western part of the Moscow basin // Stratigraphy and microfauna of the Lower Carboniferous of the western part of the Moscow basin. Sbornik statei / Edited by Fursenko A.B. M.- L., pp. 5–108. (In Russian)

Salomon, A.P., Vanderflint, E.K., 1966. Stratigraphy of the sandy-clay unit of the Lower Carboniferous of the Moscow coal basin //Materials on geology and ore-deposits of the northwest of RSFSR. № 5, L., Nedra. (In Russian)

Savitsky, Y.V., 1999. Lower Carboniferous conodonts of the “Rovnoe limestone” //VestnikSPbGU, ser. 7, vyp. 3, № 21, pp. 72 – 76. (In Russian).

Savitsky, Y.V., Ivanov, A.O., Orlov, A.N., 2000. Atlas of the micro-remains of the Lower Carboniferous of the northwestern part of the Moscow basin (ostracods, conodonts, vertebrate remains). Part 1. Msta and Putlino Formations. SPb: Izdatelstvo S. Petersburgskogo Universiteta, 88 p. (In Russian).

Savitsky Y.V., Kossovaya O.L., Vevel Y.A., Leontyev D.I., 2005. Lower Carboniferous key-sections of the northwestern part of the Moscow basin. 6th Baltic Stratigraphical Conference. Guidebook of pre-conference field trip. St. Petersburg. 95 p.

Savitsky Y.V., Kossovaya O.L., Evdokimova I. O. Vevel Y.A, 2006. New data on biostratigraphy of the Upper Visean and Serpukhovian deposits of the north-west flank of the Moscow syncline // Bulletin of St. Petersburg State University. Ser. 7. Geology, geography. Vol. 1, p. 94–101. (In Russian)

Savitsky Y.V., Kossovaya O.L., Vevel Y.A., 2007. X International Congress on Fossil Cnidaria and Poriefera. Guidebook of pre-conference field trip. St. Petersburg, VSEGEI, 90 p.

Savitsky Y.V., Kossovaya O.L., Evdokimova I. O., Vevel Y.A., 2012. The reference section of the Lower Carboniferous along the Msta River. / Guidebook of pre-conference field trip. 21-24 September 2012. III All-Russian Conference "Russian Upper Paleozoic: regional stratigraphy, paleontology, geological- and bio-events" St. Petersburg., "VSEGEI" Publishing House. 55 c. (In Russian)

Savitsky Y.V., 2013. Psephytoliths in the Lower Carboniferous of the northwest flank of the Moscow syncline: composition, structure, origin // Sedimentary basins, sedimentation and post-sedimentary processes in geological history / Proceedings of the VII All-Russian lithological meeting. Novosibirsk, III, p. 50–53. (In Russian)

Shinn E.A., 1983. Birdseyes, fenestrae, shrinkage pores, and loferites: A reevaluation // J. Sed. Petrol., 53, pp. 619–628.

Shlykova, T.I., 1951 Foraminifers of the Visean and Namurian stages of the Lower Carboniferous of the western part of the Moscow basin //Stratigraphy and microfauna of the western part of the Moscow basin. Sbornik statei /Edited by Fursenko A.B., M.- L., pp. 109–178. (In Russian).

Snigirevsky, S.M., Orlova, O.A., 2001. Some new findings of the lycopods and sphenopsids in the Visean deposits of the northwestern part of the Moscow basin. Abstracts of IV meeting deducated to A.N. Krishtofovitch, Sankt-Petersburg, pp. 38–39. (In Russian)

Sokolov, B.S., 1939. Stratigraphical significance and types of the cross bedding of the Carboniferous in USSR // Dokl. AN SSSR, t. XXII, № 4. (In Russian)

Sokolov, B.S., 1939. Significance of Rugosa и Tabulata corals in the stratigraphy of the C_1 of the Moscow basin // Dokl. AN SSSR, t. XXV, № 2. (In Russian)

Sokolov, B.S., 1940. Sandy-clay deposits of the Lower Carboniferous of the Moscow Basin // Sovetskaya Geologia, № 5–6, pp. 145–152. (In Russian)

Sokolov, B.S., 1941. Stratigraphical scheme of the northern part of the Moscow basin // Izvestia ANSSSR, ser.geol., № 2, pp. 13–22. (In Russian)

Sokolov, B.S., 1944. New data on stratigraphy and paleogeography of the north of the Moscow basin (Ljubytino District) // Uchenye Zapisky of Leningrad University, ser. Geolog.-Pochv. nauk, vyp. 11, № 70, pp. 112–136.

Sokolov, B.S., 1946. Lower Carboniferous of the Vytegra District. The main features of stratigraphy and paleogeography of the northern part of the Moscow basin // Uchenye Zapisky of Leningrad University, ser. Geolog.-Pochv. nauk, vyp. 14, № 93, pp. 223–258. (In Russian)

Sokolov, B.S., 1959. Materials on stratigraphy and paleogeography of the Tikhvin district // Uchenye Zapisky of Leningrad University, ser. Geolog. nauk, vyp. 10, № 263, pp. 173–189. (In Russian)

Stuckenberg, A.A., 1904. Anthozoen und Bryozoen des Unteren Kohlenkalkes von Central –Russland // Trudy Geologicheskogo komiteta, novaya seria. V. 14, 67 p.

Ulmer, A.E., 1935. To lithostratigraphy of the Lower Carboniferous of the northwestern part of the Moscow basin // Izv. Leningr. Geologo-gidro-geodezicheskogo tresta, № 2–3 (7–8), pp. 42–52. (In Russian)

Ulmer, A.E., 1946. Lower Carboniferous deposits of the Moscow basin. Gosgeolizdat. (In Russian)

Vostokova, B.A., 1955. Lower Carboniferous gastropods "Rovnoe Limestone" // Voprosy palaeontologii, v. II, pp. 70–81. (In Russian)

Yanishevsky, M.E., 1935. To a problem of the stratigraphy of the Lower Carboniferous of the Leningrad District // Izvestia Leningrad geologo-gidro-geodezich. Tresta, № 2–3 (7–8), pp. 5–18. (In Russian)

Yanishevsky, M.E., 1936. The brief report about the work of 1935 year. // Uchenye zapisky Leningradskogo Universiteta, ser.geol.-pochv.-geograf., issue 3, v. II , № 10, pp. 80–95. (In Russian).

Yanishevsky, M.E., 1937. Carboniferous deposits //Articles to the geological map of the south part of the Leningrad District, c. 64–83. (In Russian)

Yanishevsky, M.E., 1946. Uglovkian Horizon and its connection with the upper part of the Lower Carboniferous succession along the Msta River // Uchenye zapisky Leningradskogo Universiteta, ser.geol.-pochv. nauk, issue 14, № 93, pp. 191–195. (In Russian)

Yanishevsky, M.E., 1954. Brachiopod fauna of the Lower Carboniferous of the Leningrad District. L. (In Russian)

Yanishevsky, M.E., 1960. Lower Carboniferous Pelecypoda of the northwestern part of the Moscow basin // Voprosy paleontologii, t. III, pp. 9–81. (In Russian)

Yanishevsky, M.E, Kotlykov, V.A., (eds), 1948. Geology of SSSR, Leningrad, Novgorod and Pskov districts //Min. geol. SSSR, M.-L., 808 p. (In Russian)

Zhelezkova, V.N., 1938. To issue of brachiopod fauna and stratigraphical position of the unit b of the Lower Carboniferous deposists // Materialy po region. and prikladnoi geologii Lenoblasti i Karel'skoi ASSR, sb. № 2, pp. 23–34. (In Russian).

EXPLANATIONS OF PALAEONTOLOGICAL PLATES

Plate I

Fig. 1. Earlandia elegans (Rauser et Reitlinger): Msta River, village of Iogla, base of Limestone a_8, sample B7-9; Iogla Formation, Venevian Regional Substage, Upper Visean.

Fig. 2. Earlandia vulgaris (Rauser et Reitlinger): Krupa River, Limestone a_1, sample A1-3; Msta Formation, Aleksinian Regional Substage, Upper Visean.

Fig. 3. Deckerella? sp., *Climacammina* ? sp.: Krupa River, Limestone a_2, sample OK-3; Msta Formation, Aleksinian Regional Substage, Upper Visean.

Fig. 4. Climacammina sp.: Krupa River, Limestone a_2, sample OK-2α1; Msta Formation, Aleksinian Regional Substage, Upper Visean.

Fig. 5. Climacammina aff. *prisca* Lipina: Msta River, village of Iogla, base of the Limestone a_8, sample B7-9; Iogla Formation, Venevian Reg. Sudstage, Upper Visean.

Fig. 6. Cribrostomum sp.: Krupa River, Limestone a_2, sample OK-3; Msta Formation, Aleksinian Regional Substage, Upper Visean.

Fig. 7. Palaeotextularia longiseptata Lipina: Krupa River, Limestone a_2, sample A2-4-9; Msta Formation, Aleksinian Regional Substage, Upper Visean.

Fig. 8. Tetrataxis sp.: Krupa River, Limestone a_1, sample A1-4B; Msta Formation, Aleksinian Regional Substage, Upper Visean.

Fig. 9. Valvulinella sp.: Krupa River, Limestone a_2, sample OK-6; Msta Formation, Aleksinian Regional Substage, Upper Visean.

Fig. 10. Lituotubella glomospiroides Rauser: Krupa River, Limestone a_2, sample OK-4; Msta Formation, Aleksinian Regional Substage, Upper Visean.

Fig. 11. Haplophragmella tetraloculi Rauser: Msta River, middle part of the Limestone a_4, sample B1-24α; Putlino Formation, Mikhailovian Regional Substage, Upper Visean.

Fig. 12. Archaediscus moelleri Rauser: Krupa River, Limestone a_1, sample A1-1; Msta Formation, Aleksinian Regional Substage, Upper Visean.

Fig. 13. Archaediscus gigas Rauser: Krupa River, Limestone a_1, sample A1-1; Msta Formation, Aleksinian Regional Substage, Upper Visean.

Fig. 14. Archaediscus mellitus Schlykova: Krupa River, Limestone a_2, sample OK-4; Msta Formation, Aleksinian Regional Substage, Upper Visean.

Fig. 15. Archaediscus magna Schlykova: Krupa River, Limestone a_2, sample OK-6; Msta Formation, Aleksinian Regional Substage, Upper Visean.

Fig. 16. Archaediscus aff. *operosus* Schlykova: Krupa River, Limestone a_2, sample OK-1; Msta Formation, Aleksinian Regional Substage, Upper Visean.

Fig. 17. Archaediscus grandiculus Schlykova: Krupa River, Limestone a_1, sample A1-1; Msta Formation, Aleksinian Regional Substage, Upper Visean.

Fig. 18. Archaediscus itineraries supressa Schlykova: Krupa River, Limestone a_1, sample A1-1; Msta Formation, Aleksinian Regional Substage, Upper Visean.

Fig. 19. Archaediscus krestovnikovi Rauser: Krupa River, Limestone a_2, sample a2-4-9-α2; Msta Formation, Aleksinian Regional Substage, Upper Visean.

Fig. 20. Endostaffella parva (Moeller): Krupa River, Limestone a_1, sample 4A1β; Msta Formation, Aleksinian Regional Substage, Upper Visean.

Fig. 21. Mediocris mediocris (Vissarionova): Krupa River, Limestone a_1, sample A1-3B; Msta Formation, Aleksinian Regional Substage, Upper Visean.

Fig. 22. Eostaffella ex gr. *mosquensis* Vissarionova: Krupa River, Limestone a_1, sample A1-2Б; Msta Formation, Aleksinian Regional Substage, Upper Visean.

Fig. 23. Eostaffella ex gr. *mosquensis* Vissarionova: Krupa River, Limestone a_1, sample A1-1; Msta Formation, Aleksinian Regional Substage, Upper Visean.

Fig. 24. Eostaffella ikensis Vissarionova: Varushenka River, upper part of the Limestone a_5, sample BA5-к2; Putlino Formation, Mikhailovian Regional Substage, Upper Visean.

Fig. 25. Parastaffella concinna Schlykova: Krupa River, Limestone a_2, sample A2-4-9α1; Msta Formation, Aleksinian Regional Substage, Upper Visean.

Fig. 26. Parastaffella struvei (Moeller): Krupa River, Limestone a_2, sample OK-3; Msta Formation, Aleksinian Regional Substage, Upper Visean.

Fig. 27. Bradyina sp.: Msta River, upper part of the Limestone a_5, sample B1-1Б; Putlino Formation, Mikhailovian Regional Substage, Upper Visean.

PLATE I

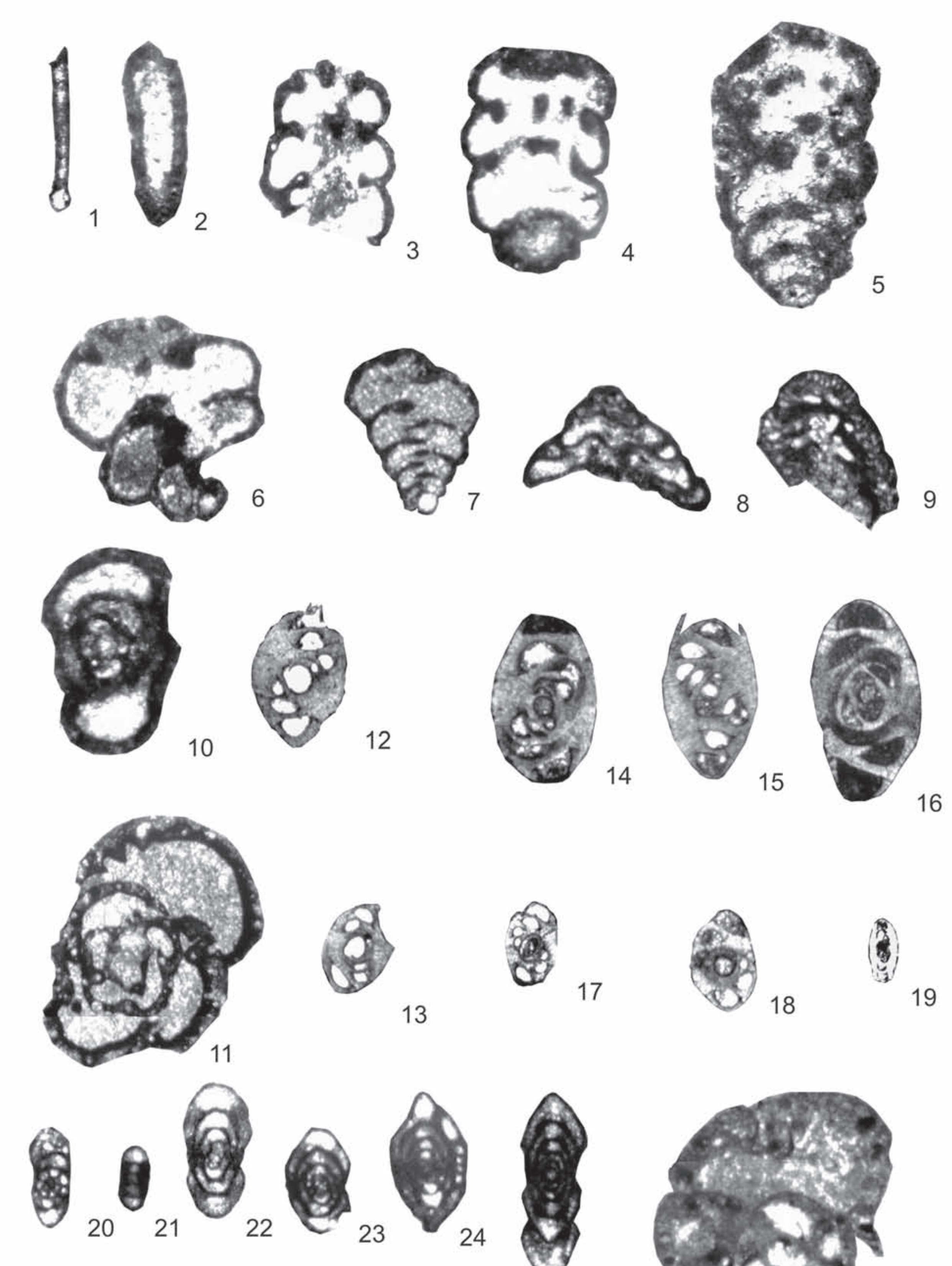


Plate II

Fig. 1. Bradyina flosuculus Ganelina: Msta River, village of Iogla, Limestone a_8, sample 8-0-1; Putlino Formation, Mikhailovian Regional Substage, Upper Visean.

Fig. 2. Bradyina rotula (Eichwald): Msta River, middle part of the Limestone a_4, sample B1-24β; Putlino Formation, Mikhailovian Regional Substage, Upper Visean.

Fig. 3. Cribrspira panderi Moeller: Msta River, Limestone a_5, sample B1-3β; Putlino Formation, Mikhailovian Regional Substage, Upper Visean.

Fig. 4. Forschiella prisca Mikhailov: Msta River, village of Iogla, Limestone a_8, sample 8-0-1; Putlino Formation, Mikhailovian Regional Substage, Upper Visean.

Fig. 5. Forschiella prisca Mikhailov: Msta River, Limestone a_5, sample B1-4α; Putlino Formation, Mikhailovian Regional Substage, Upper Visean.

Fig. 6. Mikhailovella gracilis (Rauser): Krupa River, Limestone a_1, sample A1-4A; Msta Formation, Aleksinian Regional Substage, Upper Visean.

Fig. 7. Endothyra ex gr. *bowmani* Phillips: Krupa River, Limestone a_1, sample A1-3A; Msta Formation, Aleksinian Regional Substage, Upper Visean.

Fig. 8. Globoendothyra globula (Eichwald): Msta River, middle part of the Limestone a_4, sample B1-24α; Putlino Formation, Mikhailovian Regional Substage, Upper Visean.

Fig. 9. Omphalotis minima (Rauser et Reitlinger): Varushenka River, Limestone a_6, sample B6-3B; Putlino Formation, Mikhailovian Regional Substage, Upper Visean.

Fig. 10. Omphalotis ex gr. *omphalota* (Rauser et Reitlinger): Msta River, base of the Limestone a_5, sample B1-7; Putlino Formation, Mikhailovian Regional Substage, Upper Visean

Fig. 11. Endothyranopsis compressa (Rauser et Reitlinger): Krupa River, Limestone a_1, sample A1-2Б; Msta Formation, Aleksinian Regional Substage, Upper Visean.

Fig. 12. Endothyranopsis crassa (Brady): Krupa River, Limestone a_1, sample A1-1; Aleksinian Regional Substage, Upper Visean.

Fig. 13. Endothyranopsis sphaerica (Rauser et Reitlinger): Varushenka River, Limestone a_6, sample B6-3β; Putlino Formation, Mikhailovian Regional Substage, Upper Visean.

Fig. 14. Janischewskina sp.: Msta River, upper part of the Limestone a_5, sample B1-3β; Msta Formation, Aleksinian Regional Substage, Upper Visean.

Fig. 15. *Janischewskina* ex gr. *rovnensis* (Ganelina): Msta River, base of the Limestone a_8, sample B7-9; Iogla Formation, Venevian Regional Substage, Upper Visean.

Fig. 16. *Mirifica mirifica* (Rauser): Msta River, base of the Limestone a_8, sample B7-9; Iogla Formation, Venevian Regional Substage, Upper Visean.

Plate II

Plate III

Figs 1–2. Siphonodenron junceum (Fleming): 1 – transverse section through colony, x2, 2 – longitudinal section through one of the corallites, x2; Msta River, rapid of Vitzy, Limestone a_2; Msta Formation, Aleksinian Regional Substage, Upper Visean.

Fig. 3. Actinocyathus floriformis floriformis (Martin): x3,5; transversal section; Kamenka River, Limestone a_4, 15 cm below the top; Putlino Formation, Mikhailovian Regional Substage, Upper Visean.

Figs 4–5. Actinocyathus borealis (Dobrolyubova): 4 – transversal section x3,5; 5 – longitudinal section, x3; Mokraya Poneretka Section, base of the bed 13, sample 13-1; Poneretka Formation, Steshevian Regional Substage, Lower Serpukhovian.

Figs 6–7. Actinocyathus osipovae (Dobrolyubova): x3. 6 – transversal section; 6 – longitudinal section; left bank of the Msta River, Mokraya Poneretka Section, base of the bed 13, sample 13-2; middle part of the Poneretka Formation, Steshevian Regional Substage, Lower Serpukhovian.

Figs 8–12. Actinocyathus crassiconus subcrassiconus (Dobrolyubova): x 2. 8–10 – transversal sections of the different corallites; 11, 12 – longitudinal sections, showing very complicate axial structures; right bank of the Msta River, ”Gverstka” Section; middle part of the Poneretka Formation, Steshevian Regional Substage, Lower Serpukhovian.

Plate III

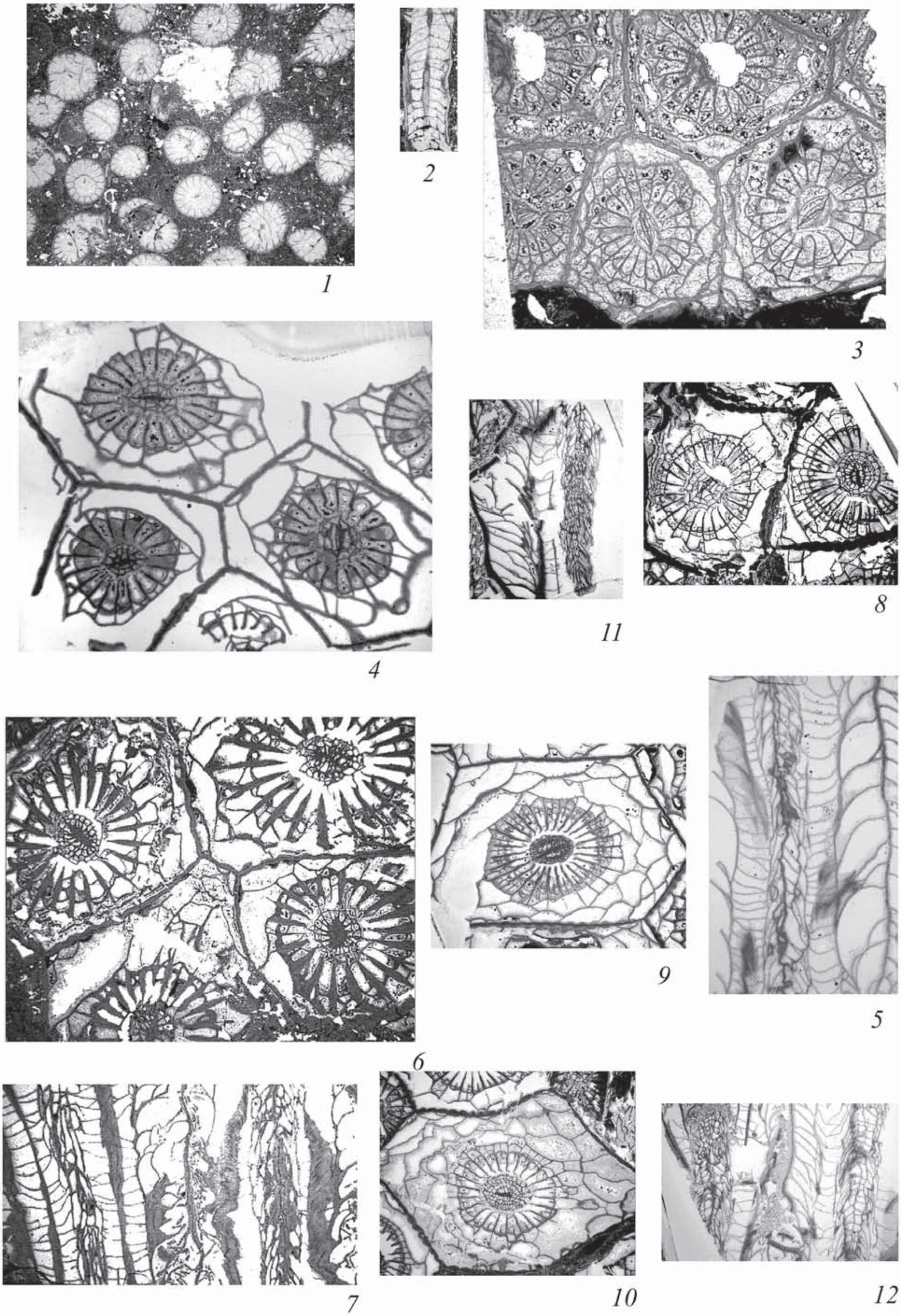


Plate IV*

Fig. 1. Cavusgnathus unicornis Youngquist et Miller: x110, Msta River, village of Rovnoe, sample P-4A, Iogla Formation, Venevian Regional Substage, Upper Visean.

Fig. 2. Cavusgnathus naviculus (Hinde): x85, Krupa River, sample 4-6A, clay between the limestones a_1 and a_2, Msta Formation, Aleksinian Regional Substage, Upper Visean.

Fig. 3. Hindiodus cristulus Youngquist et Miller: x200, Krupa River, sample 4-6A, clay between the limestones a_1 and a_2, Msta Formation, Aleksinian Regional Substage, Upper Visean.

Fig. 4. Gnathodus aff. *bilineatus* (Roundy): x85, Krupa River, sample 4-9, the base of the Limestone a_2, Msta Formation, Aleksinian Regional Substage, Upper Visean.

*) a – upper view; b – lateral view; c – lower view

Plate IV

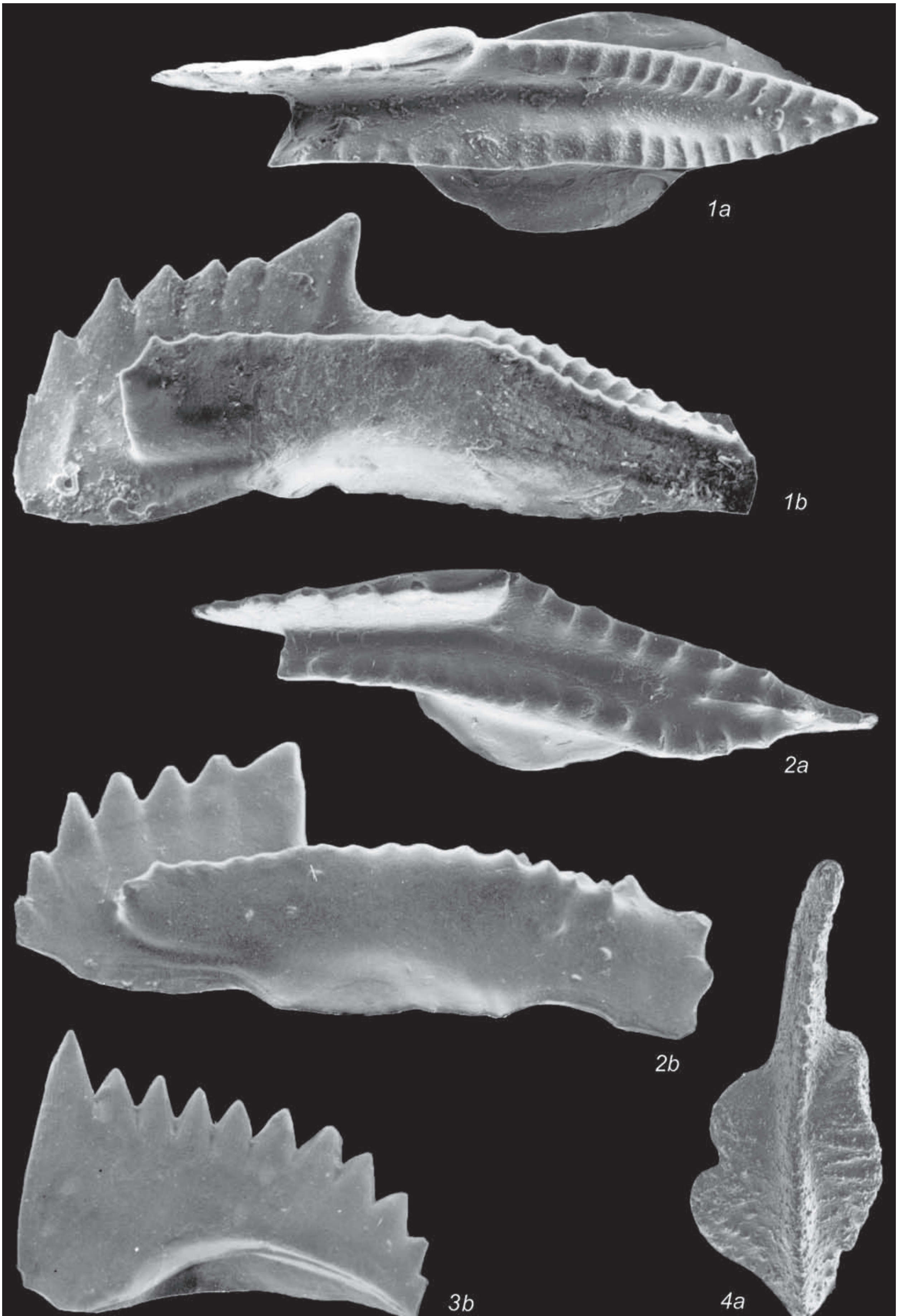


Plate V*

Figs 1, 4. Gnathodus girtyi girtyi Hass: x85. 1 – Krupa River, sample OK-2-3, Limestone a_2, Msta Formation; 4 – Krupa River, sample 4-9, base of the Limestone a_2, Msta Formation, Aleksinian Regional Substage, Upper Visean.

Fig. 2. Gnathodus girtyi collinsoni Rhodes, Austin et Druce: x85, Krupa River, sample 4-9, base of the Limestone a_2, Msta Formation, Aleksinian Regional Substage, Upper Visean.

Fig. 3. Clydagnathus cavusformis Rhodes, Austin et Druce: x250, Kamenka River, sample БФ2-31, clay under the Limestone a_3, base of the Putlino Formation, Mikhailovian Regional Substage, Upper Visean.

*) a – upper view; b – lateral view; c – lower view

PLATE V

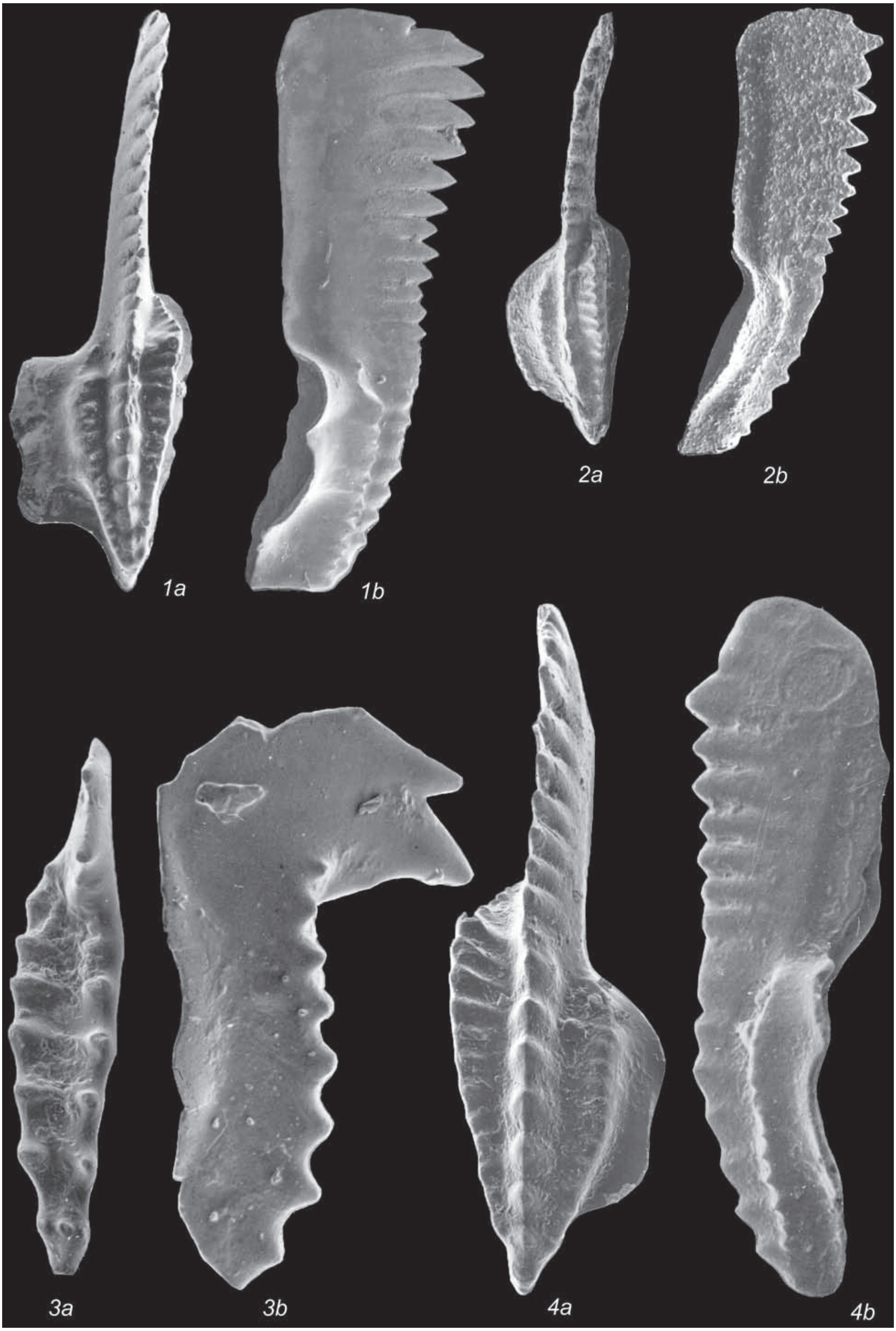


Plate VI*

Figs 1, 3, 5. Cavusgnathus naviculus (Hinde): 1, 3 – x50 and x90 correspondingly, Krupa River, sample 4-9, base of the Limestone a_2, Msta Formation, Aleksinian Regional Substage, Upper Visean; 5 – x90, Krupa River, sample 4-6A, clay between the limestones a_1 and a_2, Msta Formation, Aleksinian Regional Substage, Upper Visean.

Fig. 2. Cavusgnathus charactus Rexroad: x80, Kamenka River, sample БФ2-31, clay under the Limestone a_2, base of the Putlino Formation, Mikhailovian Regional Substage, Upper Visean.

Fig. 4. Spathognathodus scitulus (Hinde): x80, Krupa River, sample A1/1, base of clay above the Limestone a_1, Msta Formation, Aleksinian Regional Substage, Upper Visean.

Fig. 6. Gnathodus girtyi girtyi Hass: x75, Kamenka River, sample БФ2-39, clay under the Limestone a_4, Putlino Formation, Mikhailovian Regional Substage, Upper Visean.

*) a – upper view; b – lateral view; c – lower view

Plate VI

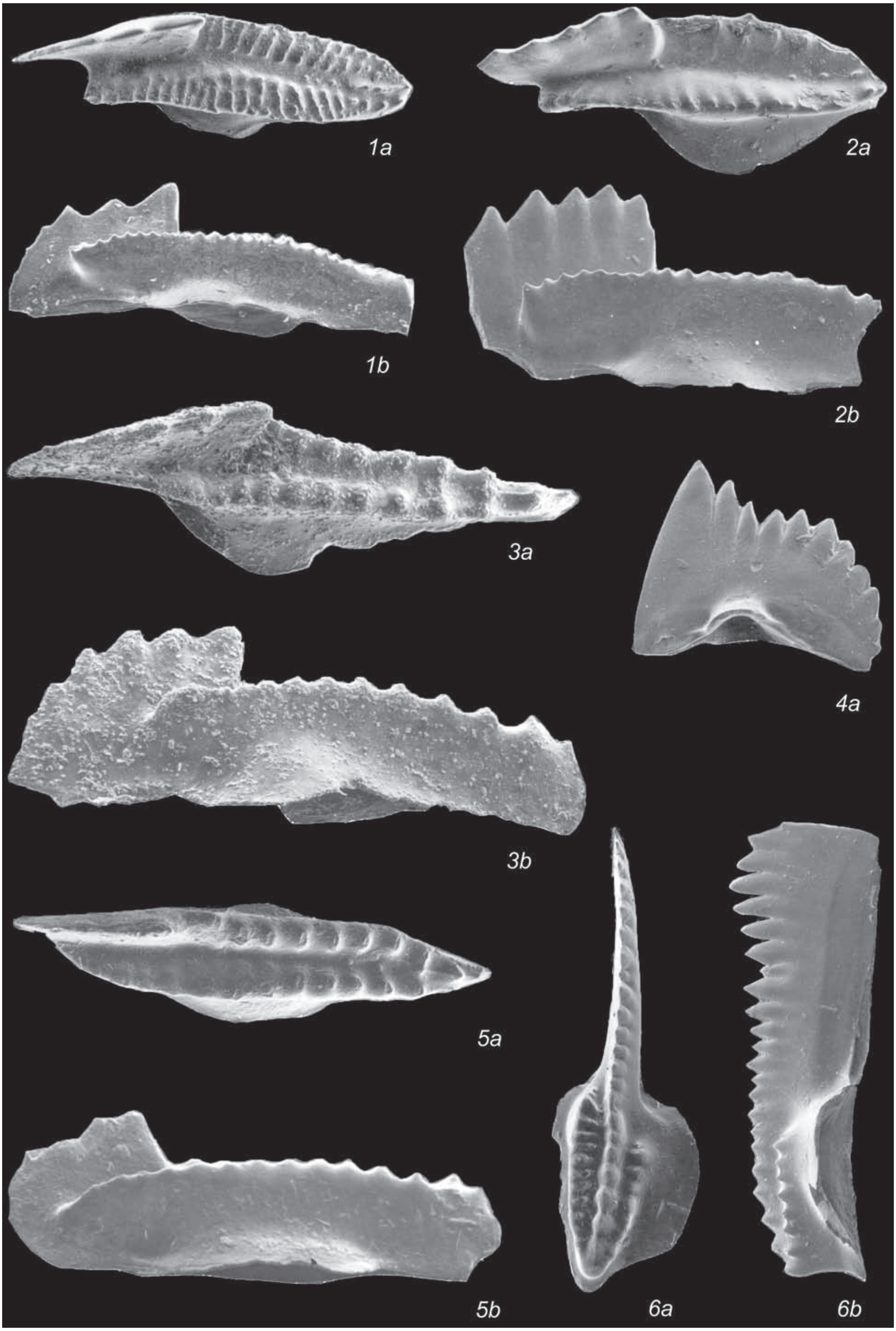


Plate VII*

Figs 1–3. Mestognathus bipluti Higgins: 1 – x 80, Krupa River, sample 4-6A, clay between the limestones a_1 and a_2, Msta Formation, Aleksinian Regional Substage, Upper Visean; 2, 3 – x200 and 80 correspondingly, Kamenka River, sample БФ2-25, clay at the top of the Msta Formation, Aleksinian Regional Substage, Upper Visean.

Fig. 4. Mestognathus beckmanni Bischoff: x80, sample БФ2-5, clay between the limestones a_1 and a_2, Msta Formation, Aleksinian Regional Substage, Upper Visean.

*) a – upper view; b – lateral view; c – lower view

Plate VII

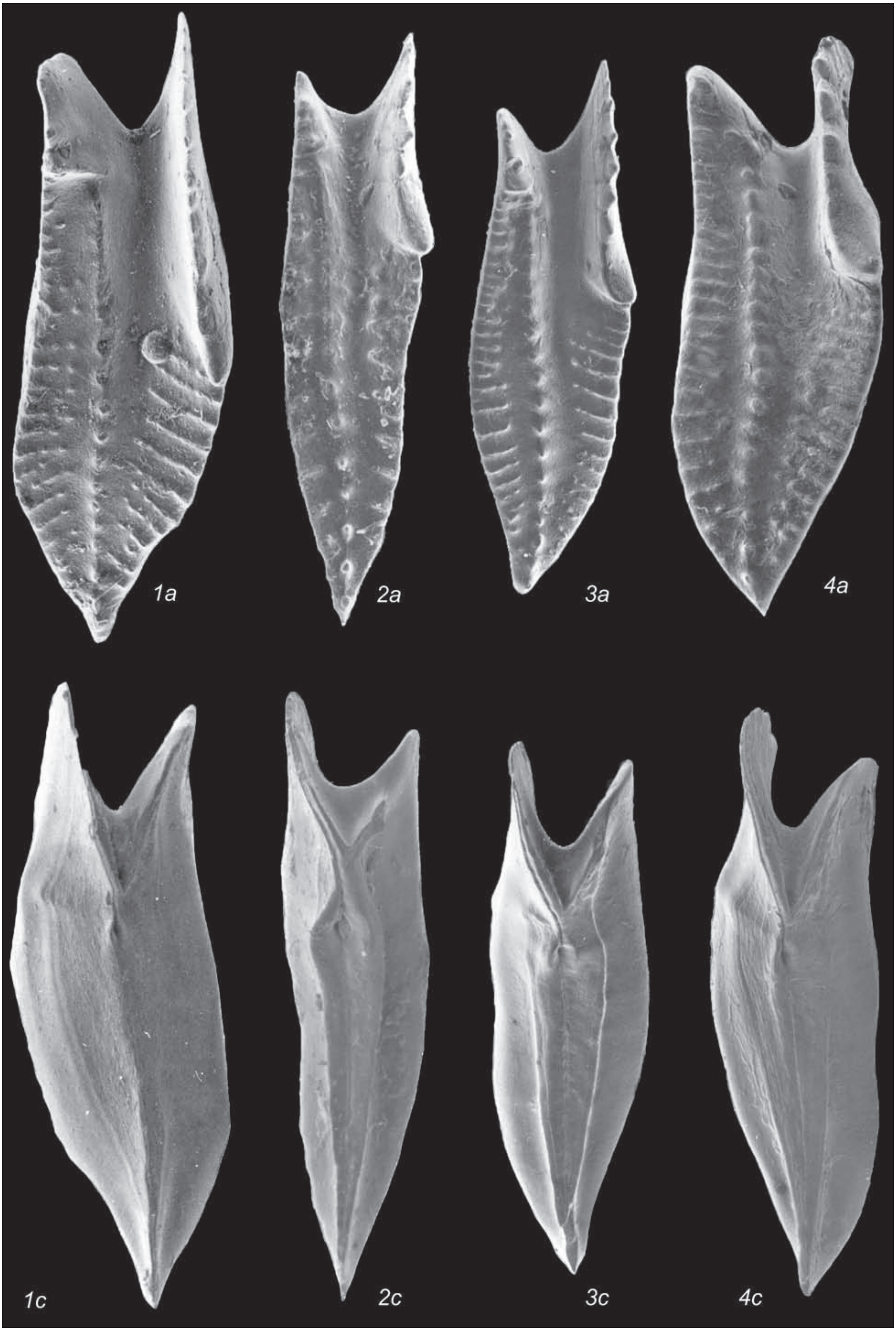


Plate VIII*

Figs 1–3. Mestognathus bipluti Higgins: side position of the specimens, shown on the plate VII, fig. 1 – x 80, 2 – x200, 3 – x80.

Fig. 4. Mestognathus beckmanni Bischoff: side position of the specimen, shown on the plate VII, fig. 4 – x80.

Fig. 5. Mestognathus bipluti Higgins: x80, Krupa River, sample 4-6A, clay between the limestones a_1 and a_2, Msta Formation, Aleksinian Regional Substage, Upper Visean.

*) a – upper view; b – lateral view; c – lower view

Plate VIII

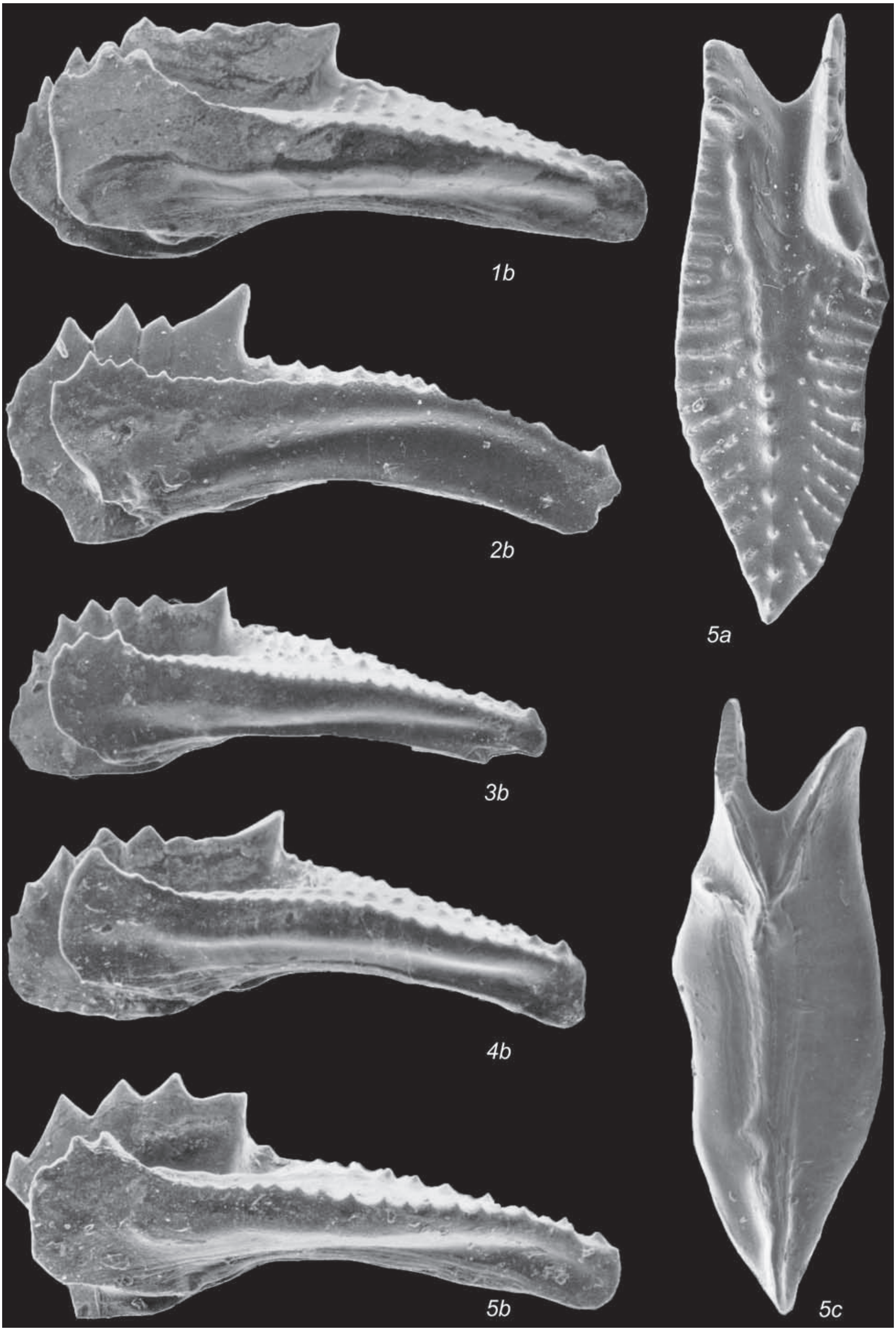


Plate IX*

Fig. 1. Cavusgnathus naviculus (Hinde): x160, Krupa River, sample 4-6A, Msta Formation, top of the Limestone a_1, Aleksinian Regional Substage, Upper Visean.

Fig. 2. Gnathodus girtyi girtyi Haas: x90, Msta River, "Rovnoe Limestone"-b, Sample R-1, Rovnoe Formation, Tarusian Regional Substage, Lower Serpukhovian.

Fig. 3. Lochriea mononodosa Rodes, Austin et Druce, x160: Msta River, "Rovnoe Limestone"-b, Sample R-3, Rovnoe Formation, Tarusian Regional Substage, Lower Serpukhovian.

Fig. 4. Gnathodus bilineatus bilineatus (Roundy), x160: Msta River, "Rovnoe Limestone"-b, Sample R-3, Rovnoe Formation, Tarusian Regional Substage, Lower Serpukhovian.

Fig. 5. Lochriea nodosa (Bischoff): x160, Msta River, "Rovnoe Limestone"-b, Sample R-1, Rovnoe Formation, Tarusian Regional Substage, Lower Serpukhovian.

Fig. 6. Lochriea ziegleri Nemirovskaya, Perret et Meischner: x125, Msta River, "Rovnoe Limestone"-b, Sample R-1, Rovnoe Formation, Tarusian Regional Substage, Lower Serpukhovian.

*) a – upper view; b – lateral view; c – lower view

Plate IX