

# Stratigraphy of Upper Cretaceous and Cenozoic Deposits of the Bakchar Iron Ore Deposit (Southwestern Siberia): New Data

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**Abstract**—The results of complex palynological and microfaunistic studies of Upper Cretaceous and Cenozoic deposits of the Bakchar iron ore deposit are presented. Geochronologically, the age of the deposits varies from Campanian to Quaternary. It was established that the Slavgorod, Gan'kino, and Jurki (?) formations contain four biostratons in the rank of beds with dinocysts and three biostratons in the rank of beds with spores and pollen. The Cenozoic continental deposits contain four biostratons in the rank of beds, containing spores and pollen. As a result of the study, a large stratigraphic gap in the Cretaceous–Paleogene boundary deposits, covering a significant part of the Maastrichtian, Paleocene, Ypresian, and Lutetian stages of the Eocene, was established. The remnants of a new morphotype of heteromorphic ammonites of genus *Baculites* were first described in deposits of the Slavgorod Formation (preliminarily, upper Campanian). The distribution features of the different palynomorph groups in the Upper Cretaceous–Cenozoic deposits in the area of study due to transgressive-regressive cycles and climate fluctuations were revealed.

**Keywords:** biostratigraphy, biofacies, Upper Cretaceous, Cenozoic, Bakchar iron ore deposit, Tomsk oblast, palynology, dinocysts, baculites

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## INTRODUCTION

In the central part of Western Siberia is the largest in Russia iron ore basin. Sedimentary iron ores are distributed within the territory of the Ob River middle reaches and its tributaries: Ket', Chaya, Parabel', Vas-yugan, Tym, and Vakh. The Bakchar iron ore deposit (Tomsk oblast) is one of the well-explored areas in the southern (Ob) part of the iron ore basin (Fig. 1). The ores comprise three horizons, which, together with country rocks, constitute the unified genetic complex called the oolite iron ore formation (Shatsky, 1957; Kazanskii, 1960; Babin, 1964; Nikolaeva, 1967). The section is represented by alternations of shallow-marine and alluvial-delta iron ore beds with partings of marine and continental deposits. The sequence of the iron formation is as follows: the Narym Horizon at the base, attributed to Turonian–Santonian (?) on the basis of marine foraminifera and macrofauna; the middle Kolpashevo Horizon, attributed to the late Santonian–Maastrichtian; the upper Bakchar Horizon, attributed to the Paleogene (see biostratigraphic data in (Nagorsky and Zaichenko, 1957; Kazanskii, 1960, 1963; Babin, 1964; Belous et al., 1964; Podobina and Babin, 1976)).

In 2009, scientific researchers at the Institute of Petroleum Geology and Geophysics (Siberian Branch,

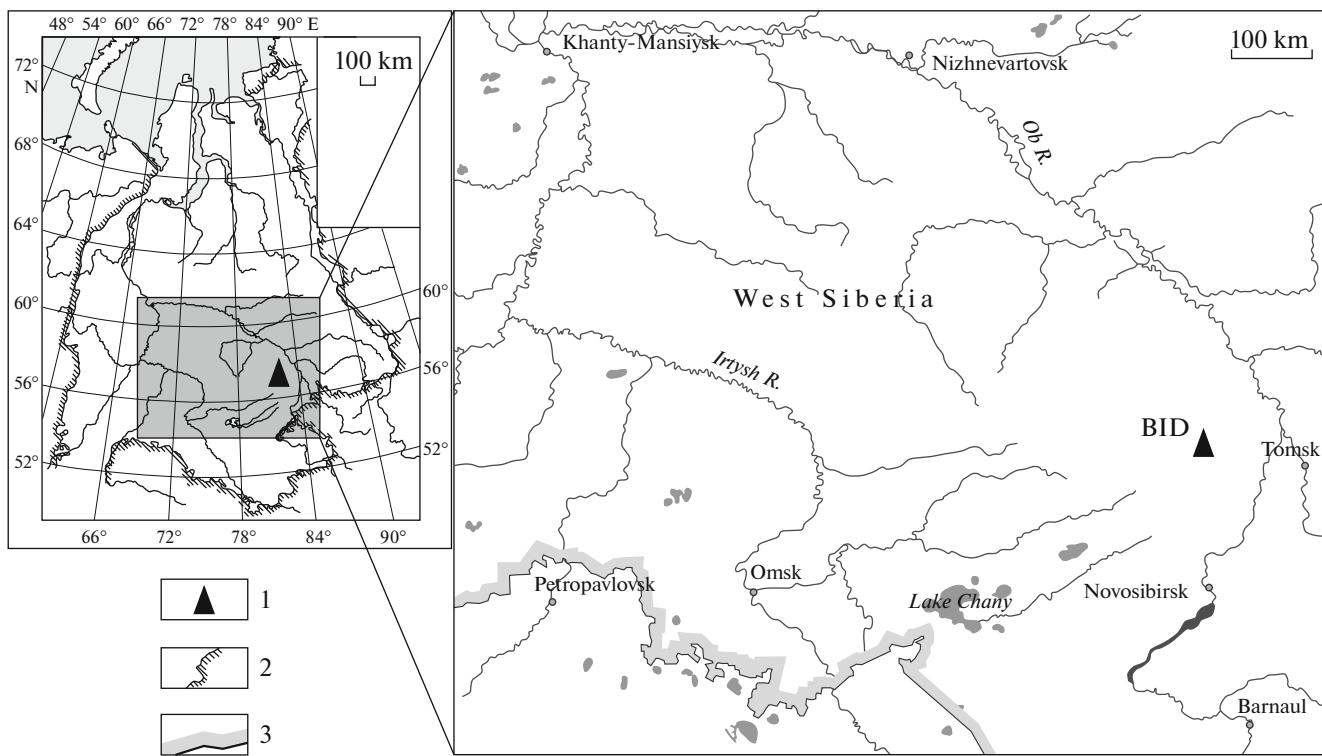
Russian Academy of Sciences, Novosibirsk, Russia) studied the core material from several boreholes drilled within the Bakchar iron ore deposit. The first results based on the paleomagnetic and preliminary palynological data were reported in (Gnibidenko et al., 2015).

This work aims to highlight biostratigraphic and biofacies data obtained on the basis of palynological and macrofaunistic studies of Upper Cretaceous and Cenozoic deposits uncovered in several boreholes at the Bakchar iron ore deposit.

## MATERIALS AND METHODS

The core material for biostratigraphic studies were obtained from eight boreholes which open the Upper Cretaceous deposits (B-114, B-124, B-103, B-119, B-118, B-107, B-129, B-101). In addition, the Cenozoic deposits were studied in one borehole (B-114) (Fig. 2).

**Palynological analysis.** The material for palynological studies was extracted from the core samples from Boreholes B-114 (45 samples), B-124 (29 samples), B-103 (2 samples), and B-119 (3 samples). The samples were treated following the procedure adopted in the Laboratory of Paleontology and Mesozoic and Cenozoic Stratigraphy of the Institute of Petroleum



**Fig. 1.** Locality of the studied boreholes. (1) Locality of boreholes; (2) boundary of the West Siberian Plain; (3) state border of the Russian Federation. BID—Bakchar iron ore deposit.

Geology and Geophysics using potassium pyrophosphate for the removal of clay particles and cadmium heavy liquid with a specific gravity of 2.25 to separate the sludge into mineral and organic constituents. For microphotography, preparations on a gelatin-glycerin base were used.

In order to count the palynological spectra, the total of all microphytofossils (spores, pollen of terrestrial plants, dinoflagellate cysts, acritarchs, prasinophytes, and freshwater microscopic algae similar to modern Zygemataceae) was taken as 100%. In order to estimate the contents of the various components, 200–300 grains as a minimum were calculated.

In order to select palynomorph complexes, the first occurrence of them, disappearance of the taxa, and their proportions were taken into consideration. For biofacies studies, diagrams characterizing the ratio between terrestrial and marine microphytofossils and the contents of acritarchs, prasinophytes, freshwater algae, microforaminifers, and various dinocyst morphotypes were compiled. To determine the ratio of terrestrial (spores and pollens, freshwater algae) and marine (microphytoplankton) palynomorphs, the contents of all groups were taken as 100%. When calculating the percentage of taxa in the microphytoplankton composition, a set of only dinocysts, acritarchs, and prasinophytes was taken as 100%.

**Macrofaunistic analysis.** For macrofaunistic study, the collection of heteromorphic ammonites of the

genus *Baculites* collected from borehole cores B-101 (1 sample), B-103 (5 samples), B-107 (13 samples), B-118 (1 sample), B-119 (10 samples), and B-129 (1 sample) was used. In total, 31 specimens were studied. The material used was largely represented by fragments of inhabited camerae and phragmocones, as well as shell imprints.

The investigation of the collection of baculites was focused on studying cross sections of shells, as well as sculpture and structure of the suture lines.

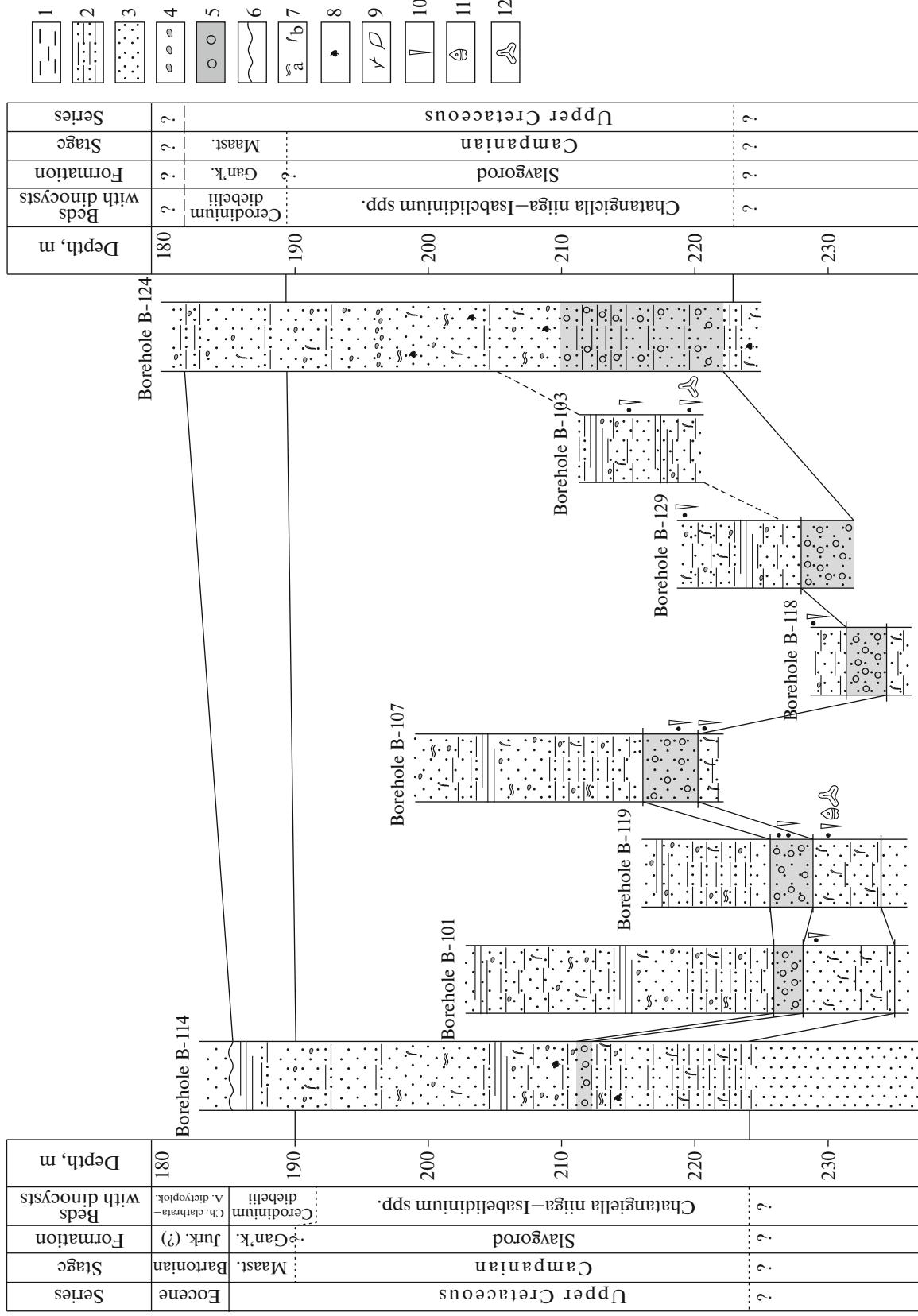
The studied collection of baculites (no. 976) is stored at the Central Siberian Geological Museum (CSGM) at the Institute of Geology and Mineralogy, Siberian Branch, Russian Academy of Sciences (Novosibirsk).

## UPPER CRETACEOUS AND CENOZOIC STRATIGRAPHY

### *Palynological Analysis*

The most complete sequence of Upper Cretaceous and Cenozoic deposits, which was the main aim of our stratigraphic study, is revealed in Borehole B-114.

The lower part of the section (interval 224–250 m) is represented by loose inequigranular sands with clay interbeds and brownish gray, often unsorted grains of gravel. There are horizontal ichnofossils and small coalified plant detritus (CPD), dark brown and black,



**Fig. 2.** Correlation of Upper Cretaceous deposits studied in core sections at the Balkchar iron ore deposit. (1) Clays; (2) sandy mudstones; (3) sandstones; (4) pebbles; (5) iron ore beds; (6) gap; (7) horizontal; (8) vertical; (9) coalified plant detritus; (10) baculites; (11) dynocysts; (12) palynological assemblages. Abbreviations: Maast.—Maastrichtian, Gan'k.—Gan'kino, Jurk.—Jurk. Charlesownia clathrata, A. diktyoplak.—Arenospaera diktyoplakum.

which is sometimes concentrated in very thin interbeds. Two samples from this interval contain no plant microfossils.

From a depth of 223.6 m (Sample 3), the studied samples contain both diverse terrestrial and marine palynomorphs. On the basis of their qualitative and quantitative variations in the composition of Upper Cretaceous deposits, two dinocyst assemblages and a spore and pollen assemblage were identified. Similar palynostratigraphic units were established in Borehole B-124.

**Chatangiella niiga–Isabelidinium spp. Beds** (B-114, int. 190–224 m; B-124, int. 188–224 m; B-119, depth of 230.4 m) (Figs. 3, 4).

**Lithology.** Sandstones, inequigranular, often coarse-grained, greenish gray to gray; mudstone interbeds at the base. An iron ore bed in intervals of 211–212 m (Borehole B-114) and 210.1–223 m (Borehole B-124) is represented by inequigranular sandstone, with a large amount of goethite and hydrogoethite oolites. Up the section, weakly cemented sandstones, inequigranular, gray to brownish gray, with pebbles, small CPD and rare interbeds of schistose dark gray clays. The entire stratum is bioturbated.

**Dinocysts.** The assemblage is characterized by *Chatangiella niiga*, *Ch. vnigrii*, *Trityrodinium suspectum*, *Laciadiinium arcticum*, *L. rhombiforme*, *Alterbidinium acutulum*, *Microdinium ornatum*, *Isabelidinium microarmatum*, *I. rectangulatum*, *Cladopyxidium* sp., *Dinogymnium* spp., etc. In addition, such species as *Chatangiella* spp., *Ch. serratula*, *Ch. bondarenkoi*, *Ch. tripartita*, *Ch. ditissima*, *Ch. spectabilis*, *Odontochitina operculata*, *Glyphanodinium facetum*, *Dinogymnium acuminatum*, *D. albertii*, *D. sibiricum*, *Hystrichosphaeridium tubiferum*, *Rhiptocorys veligera*, *Microdinium kustanaicum*, and *Eisenackia* sp. were identified.

The aforementioned assemblage was correlated with the Campanian assemblage from *Chatangiella niiga* Beds in Ust'-Yenisei and Khatanga districts (Lebedeva, 2006). It is similar to the assemblage from *Chatangiella manumii*–*Chatangiella vnigrii* Beds identified in the core material from Borehole 8 of Russian-Polyansky district (Omsk deflection) (Lebedeva et al., 2013). The Campanian complexes of dinocysts were studied in sections of the polar part of the Cis-Uralian Foredeep (Lebedeva, 2005, 2007), Kushmurun (Northern Kazakhstan) (the Late Campanian dinocyst assemblage was dated on the basis of the occurrence of *Placenticeras meeki* (Boehm); Vasil'eva, 2005; Vasil'eva and Levina, 2007), the Semba Peninsula in Kaliningrad oblast (the dinocyst assemblage was dated on the basis of the occurrence of nannoplankton; Aleksandrova and Zaporozhets, 2008a, 2008b), and the Lower Volga region (dinocysts assemblage was dated on the basis of the occurrence of foraminifers and radiolarians; Aleksandrova et al., 2012). The dinocyst complexes in all the above-cited works were compared with Campanian dinocyst assem-

blages in North America and Europe, including sections calibrated with respect to planktonic foraminifera, belemnites, and nannoplankton (Kirsch, 1991; Odin and Lamaurelle, 2001; Slimani, 2001; etc.). Although the dinocyst assemblages from Boreholes B-114 and B-124 are less diverse, the occurrence of species such as *Chatangiella niiga*, *Ch. vnigrii*, *Ch. ditissima*, *Alterbidinium acutulum*, *Laciadiinium rhombiforme*, *L. arcticum*, *Microdinium kustanaicum*, *Dinogymnium* spp., *Isabelidinium* spp., and *Spongodinium delitiense* indicates Campanian, even probably late Campanian, age of deposits in the studied intervals.

Campanian deposits in the area of study (Kolpashchevo facial area) are attributed to the Slavgorod Formation (Reshenie..., 1991). According to this, deposits in the interval of 190–224 m (B-114) can be attributed to this formation.

**Cerodinium diebelii Beds** (B-114, int. 185–190 m; B-124, int. 183–188 m).

**Lithology.** Sandstone, inequigranular, weakly cemented, gray to greenish gray, brown surface, with numerous pebbles and brownish to brown, unsorted sand and gravel grains, sometimes clusters of small lenses. The layers of schistose dark gray clays.

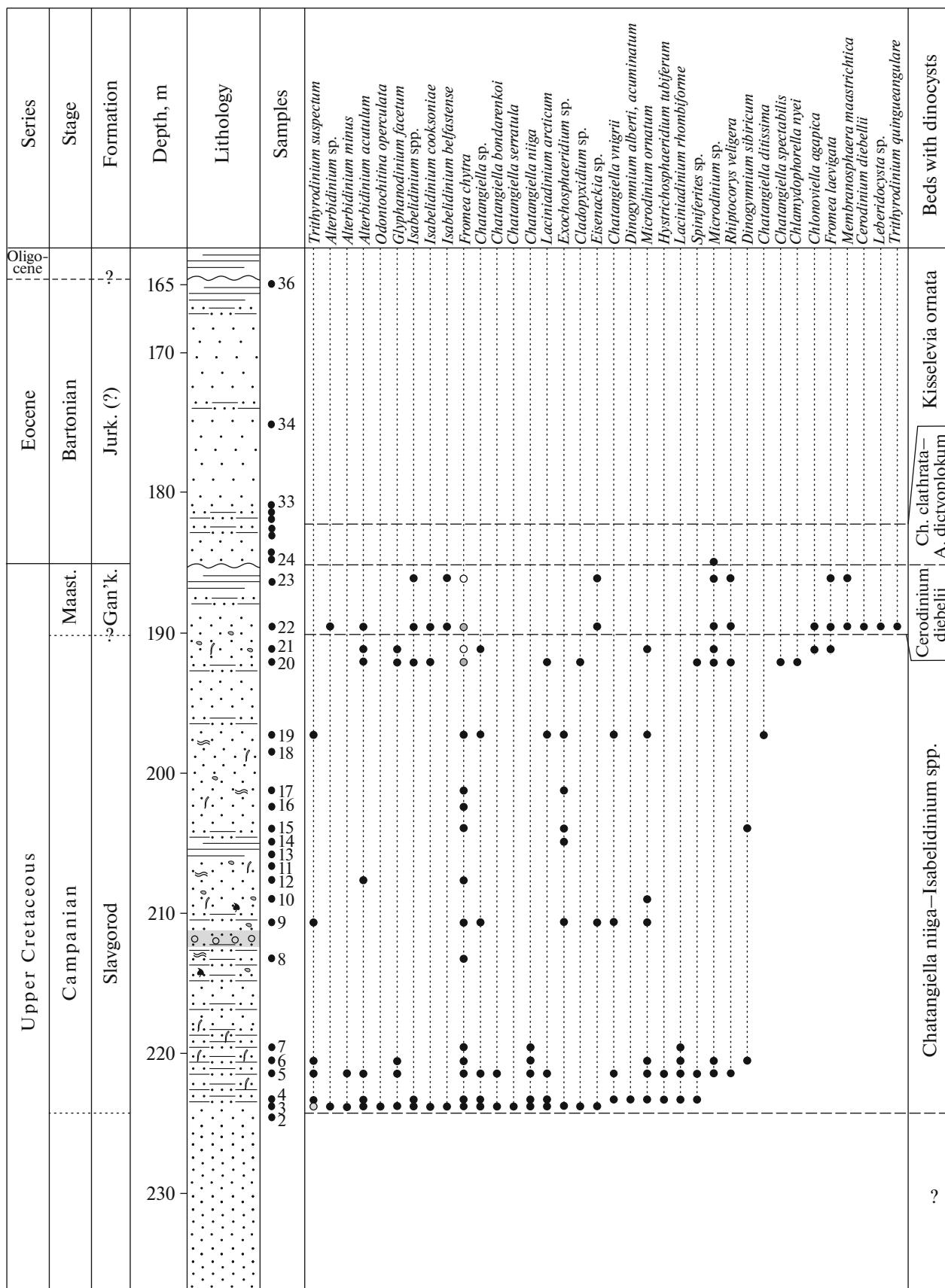
**Dinocysts.** The number of *Chatangiella* decreases. *Fromea chytra*, *Membranosphaera maastrichtica*, and *Cladopyxidium* spp. are in abundance. There are new species: *Cerodinium diebelii* and *Palaeocystodinium golzowense*.

The joint occurrence of *Cerodinium diebelii*, *Palaeocystodinium golzowense*, *Cladopyxidium* spp., and *Trityrodinium quingueangulare* is typical of Lower Maastrichtian deposits in Belgium (Slimani, 2001), Germany (Kirsch, 1991), the North Sea (Schiøler and Wilson, 1993), the Semba Peninsula (Aleksandrova and Zaporozhets, 2008a, 2008b), etc., dated on the basis of different fossil groups. The dinocyst assemblage from *Cerodinium diebelii* Beds is similar to the like-named assemblage in Borehole 8 drilled in the Russko-Polyansky district (Lebedeva et al., 2013), although this assemblage is less diverse. This gives a reason to attribute the studied core intervals in B-114 and B-124 to the lower Maastrichtian (Gan'kino Formation).

The taxonomic spore–pollen composition of terrestrial plants in both boreholes is similar. According to this, they were combined into a unified palynocomplex (PC) (Fig. 5).

**Beds with PC-1** (B-114, int. 185–223.6 m; B-124, int. 182–224.2 m). The content of spores of mosses and ferns is 9–19%; the pollen contents of gymnosperms and angiosperms are 20–37% and 25–54%, respectively.

Spores are dominated by *Leiotriletes* spp., *Gleicheniidites* spp., and *Laevigatosporites ovatus*. Common components are *Cyathidites* sp., *Stereisporites* spp., *Lycopodiumsporites* sp., Polypodiaceae (bean-shaped, ornamented), and *Osmundacidites* sp.; related components are *Ornamentifera echinata*, *Taurocuspites reduncus*,



**Fig. 3.** Distribution of dinocysts in the section of Cretaceous and Paleogene deposits in Borehole B-114. Abbreviations: A. dictyoplokum—Areosphaeridium diktyoplokum. See legend in Fig. 2.

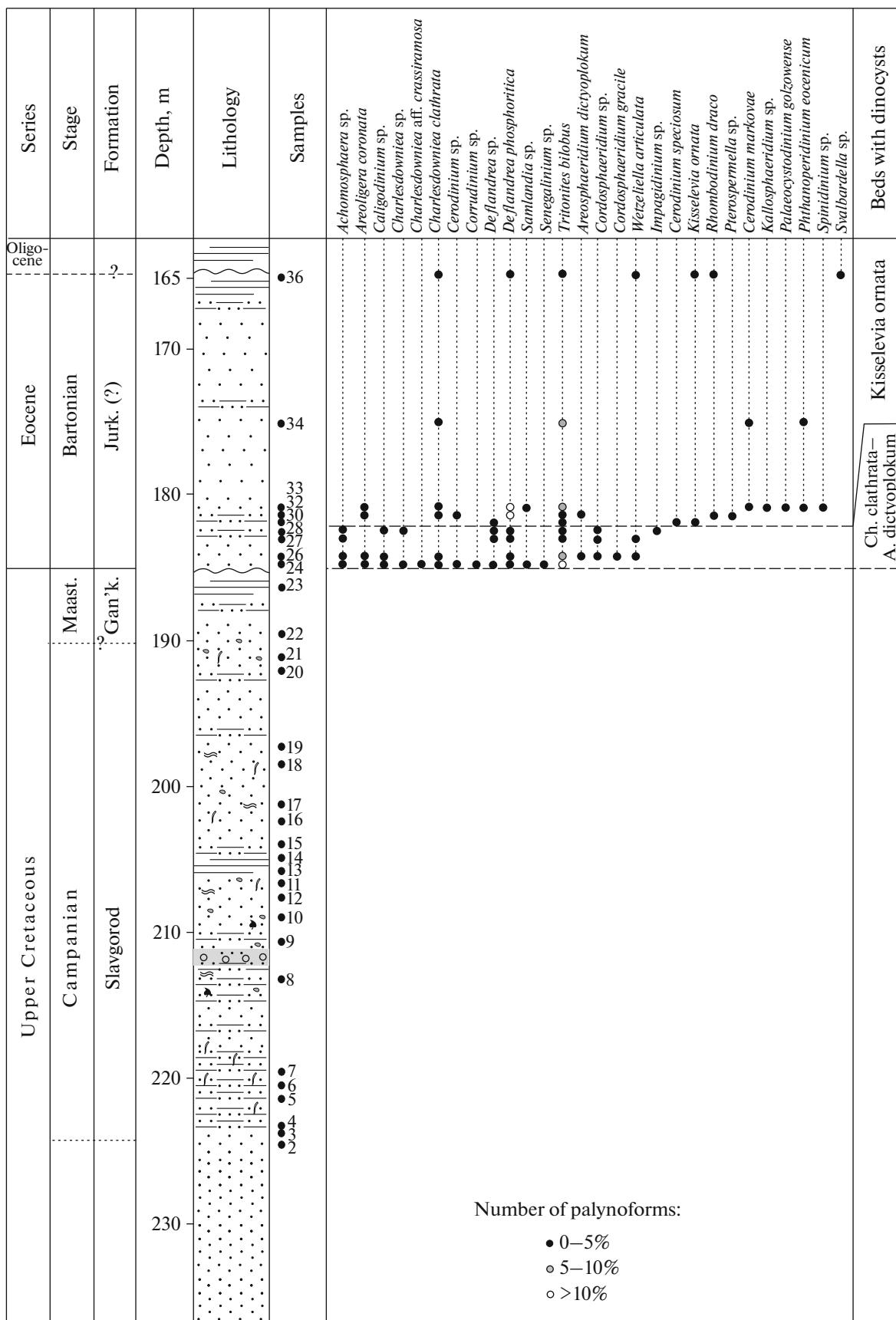
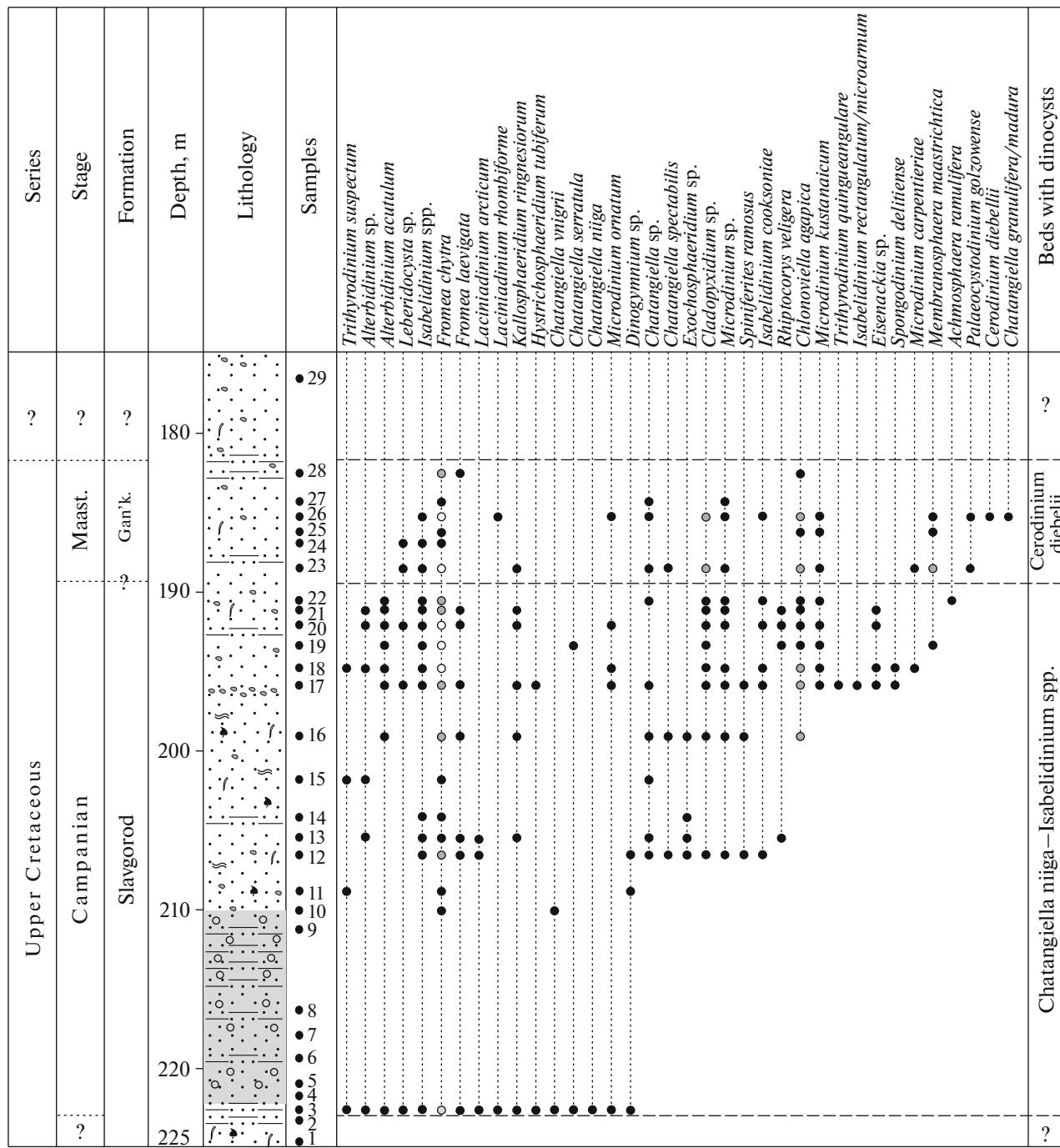


Fig. 3. (Contd.)



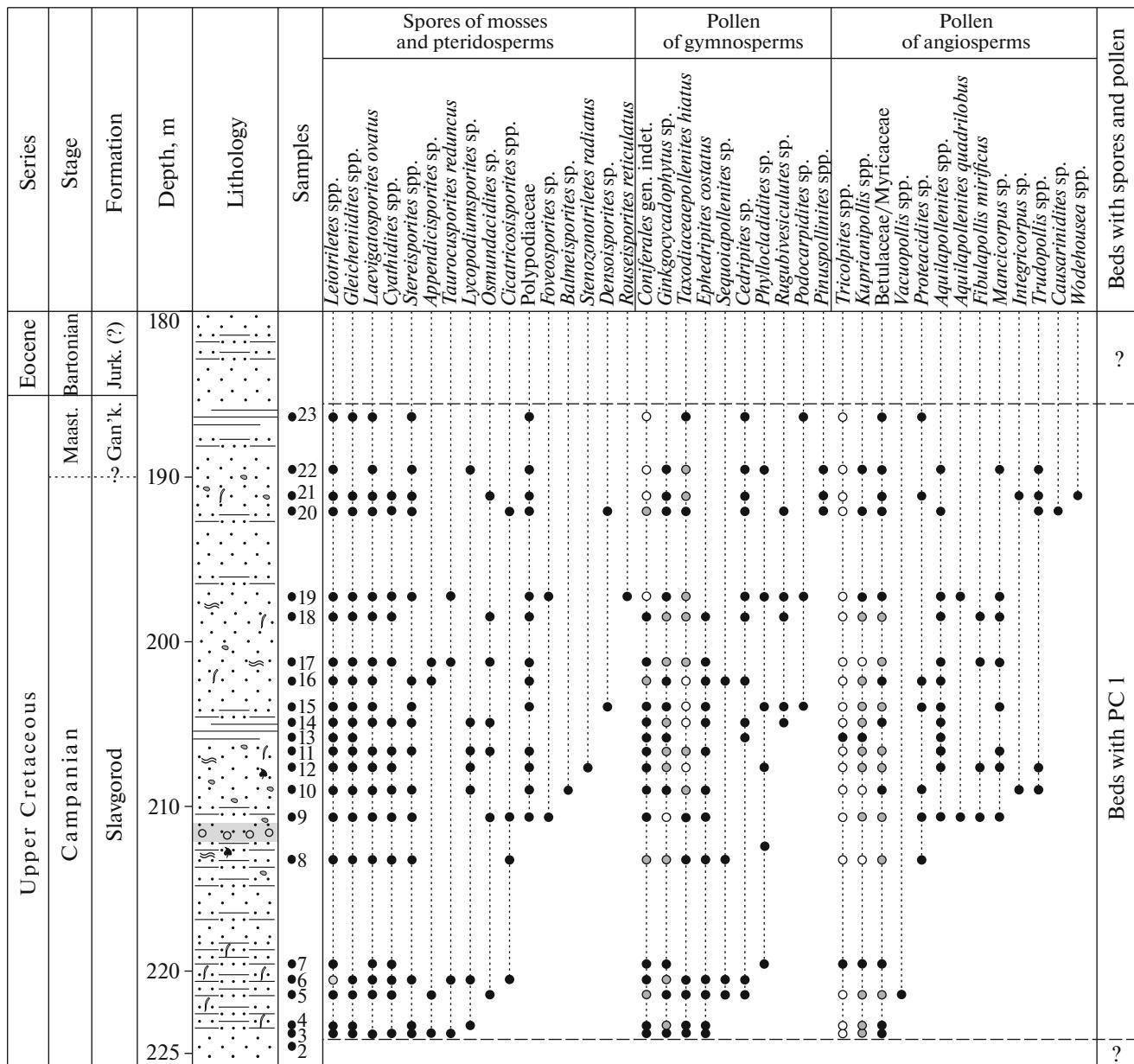
**Fig. 4.** Distribution of dinocysts in the core section of Cretaceous deposits of Borehole B-124. See legend in Fig. 2.

*Appendicisporites* sp., *Cicatricosisporites* sp., *Stenozonotriletes radiatus*, *Matonisporites* sp., *Camarozonosporites insignis*, *Velosporites* sp., *Baculatisporites comamensis*, *Rouseisporites reticulatus*, etc.

The pollen of gymnosperms is represented by poorly preserved saccate pine pollen, as well as *Taxodiaceapollenites hiatus*, *Ginkgocycadophytus* sp., *Ephedripites costatus*, *Pinuspollenites* spp., *Podocarpidites* spp., *Phyllocladidites* sp., *Cedripites* sp., and *Sequoiapollenites* sp.

The angiosperm pollen composition is dominated by *Tricolpites* spp., *Kuprianipollis* sp., and the pollen of betuloid-myricoid type. There are also such species as *Retitricolpites* spp., *Vacuopollis* sp., *Trudopollis* sp., *Trudopollis protrudens*, *Proteacidites* sp., *P. tumidiporis*, *Aquilapollenites* sp., *A. quadrilobus*, *A. unicus*, *Orbiculapollenites lucidus*, *Mancicorus* sp., *Wodehouseia* sp., and *Triorites harrisii*.

Owing to a low diversity of spore and pollen composition, the identified palynocomplex is unrepresent-



**Fig. 5.** Distribution of spores and pollen in Cretaceous deposits exposed in the section of Borehole B-114. See legend in Fig. 2.

able, but, in general, it corresponds to the Campanian–Maastrichtian palynocomplex of the Slavgorod and Gan'kino formations (SPK X–XI (3); Reshenie..., 1991).

Higher horizons in the B-114 section are composed of Cenozoic marine (int. 165–185 m) and continental (int. 0–165 m) deposits with a total thickness of 185 m. Two dinocysts complexes and six palynocomplexes were identified.

Marine deposits (int. 165–185 m) are represented mainly by alternating pale gray thinly laminated clays and sands. The basal part (int. 179.5–183 m) is composed of fine-grained, brown-gray sandstone with

horizontal and oblique ichnofossils, filled with clay material, with numerous “glandular” oolites.

**Charlesdownia clathrata–Areosphaeridium diktyoplokum Beds** (B-114, int. 182.9–185 m) (Fig. 3). Dinocysts constitute from 5 to 8% of the total number of palynomorphs. They are poorly preserved, often represented by fragments. The following taxa were identified: *Areoligera coronata*, *Achomosphaera* sp., *Areosphaeridium diktyoplokum*, *Caligodinium* sp., *Cerodinium* sp., *Charlesdownia clathrata*, *Ch. aff. crassiramosa*, *Cordosphaeridium* sp., *C. gracile*, *Corrudinium* sp., *Impagidinium* sp., *Deflandrea phosphoritica*, *Wetzeliella articulata*, *Samlandia* sp., *Spiniferites* sp., *Senegalinium* sp. Most of the taxa of this complex are

characteristic of Ypresian (Early Eocene), while they continued to exist during the Middle–Late Eocene. The first occurrence of *Areosphaeridium diktyoplokum* in Western Siberia is correlated with the boundary of nannoplankton zones NP12/NP13 (Iakovleva and Aleksandrova, 2013). Thus, the age of deposits in int. 182.9–185 m can vary in a wide range, namely, from Early (not older than late Ypresian) to Late Eocene. However, data on spores and pollen obtained from this interval suggest Middle Eocene age of the deposits (see below).

**Beds with *Kisselevia ornata*** (B-114, int. 165–182.1 m). Dinocysts are represented by single *Areoligeria coronata*, *Cerodinium speciosum*, *C. markovae*, *Cerodinium* sp., *Charlesdowniea clathrata*, *Rhombodium draco*, *Areosphaeridium diktyoplokum*, *Samlandia* sp., *Spinidinium* sp., *Palaeocystodinium golzowense*, *Phthanoperidinium eocenicum*, *Kisselevia ornata*, *Kallosphaeridium* sp., *Wetzelilla articulata*, *Wetzelilla* sp., *Svalbardella* sp., *Deflandrea phosphoritica*, *Deflandrea* sp. (Fig. 3). Only the interval of 181–181.7 m shows a sharp increase in *Deflandrea phosphoritica* (over 60% in the microphytoplankton composition).

The occurrence of *Kisselevia ornata* at a depth of 182.1 m and its presence in a sample from a depth of 165 m (Fig. 3) are of importance for stratigraphic study, as this taxon has a limited distribution in the Northern Hemisphere and is the index species of the like-named biozone in Western Siberia (Iakovleva and Aleksandrova, 2013). It is possible to compare the *Kisselevia ornata* Zone with an interval of the *Rhombodium perforatum* Zone in Western Europe (38.2–39.5 Ma; interval of NP17 Zone; Iakovleva and Aleksandrova, 2013). This makes it possible to attribute these deposits to the Bartonian (Middle Eocene).

Other microphytoplankton forms in the interval of 185–165 m are represented by acritarchs *Tritonites bilobus* (Fig. 6) and single prasinophytes (*Pterospermella* sp., *Leiosphaeridia* sp.).

**Beds with *Castanopsis pseudocingulum*—*Castanea crenataeformis*—*Nyssa crassa*** (B-114, int. 182.9–185 m) (Fig. 6). Spores in the assemblage are rare and belong to Polypodiaceae, Lycopodiaceae, and *Osmunda* sp.

More than 50% of the PC is represented by the pollen of gymnosperms, which is dominated by species of the family Pinaceae (up to 53.5%): *Pinus* s/g *Diploxyylon*, *P. s/g Haploxyylon*, and *Pinus* spp.

The angiosperms are dominated by tricolporate pollen grains (Plate I): dominant is *Castanopsis pseudocingulum* (up to 20.6%), and subdominants are *Castanea crenataeformis* (up to 13%) and *Quercus gracilis* (up to 12%), as well as pollen of formal taxa, such

as *Tricolporopollenites* (*T. cingulum*, *T. pseudocingulum*, *T. liblarensis*) and *Rhoipites* (*Rh. pseudocingulum* and *Rh. granulatus*). Such angiosperms as *Fothergilla* sp., *Corylopsis* sp., *Triporopollenites plicoides*, *Triporopollenites* sp., *Triatriopollenites* sp., *Tilia* sp., *Quercus sparsa*, *Q. conferta*, *Comptonia* sp., *Juglans* sp., *Nyssa crassa*, *Nyssa* sp., *Liquidambar* sp., and *Platycaryapollis* sp. occur in minor amounts.

The assemblage with such pollen composition bears the features of the Middle Eocene regional palynozone of *Castanea crenataeformis*—*Castanopsis pseudocingulum*—*Platycaryapollis trisolutionis* (PC-7) (Unifitsirovannyе..., 2001). However, owing to the predominance of *Castanopsis pseudocingulum* and a large participation of *Quercus gracilis* and various *Tricolporopollenites* and *Rhoipites*, this assemblage is similar to the *Castanopsis pseudocingulum*—*Rhoipites pseudocingulum*—*Quercus gracilis*—*Tricolporopollenites liblarensis* palynocomplex, identified by I.A. Kulkova in the core section of Borehole 37 (Ob–Irtysh interfluvium), together with the dinocyst assemblage of the *Kisselevia ornata* Zone (*Microfitofossilii*..., 1988; Unifitsirovannyе..., 2001). In addition, the identified PA contains *Nyssa crassa*, a characteristic species of the regional palynozone of *Castanopsis pseudocingulum*—*Nyssa crassa* (PC-8) (Unifitsirovannyе..., 2001). Thus, if the dinocyst-based age of deposits in the interval of 182.9–185 m can vary in a wide range (end of Early Eocene–Late Eocene), then the age based on spores and pollen can be within the limits of late Lutetian–early Bartonian.

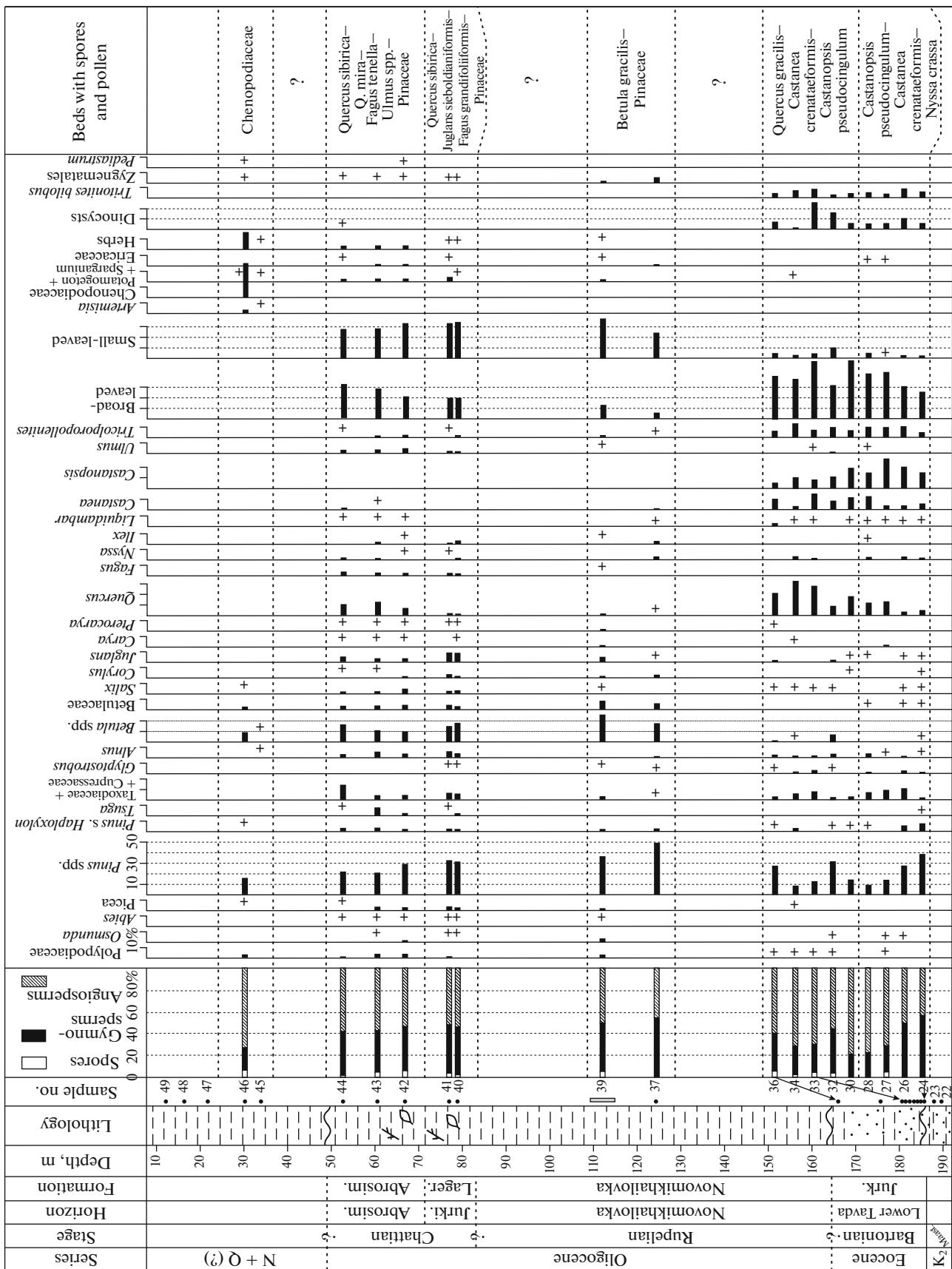
**Beds with the *Quercus gracilis*—*Castanopsis pseudocingulum*—*Castanea crenataeformis* palynocomplex** (B-114, int. 165–182.1 m). Spores are rare; there are single *Osmunda* sp., Polypodiaceae, and *Sphagnum* sp.; there are single *Hydropteris indutus* spores at a depth of 165 m.

Gymnosperms are of minor importance (from 20 to 40%) and are dominated by the pollen of various pines (*Pinus*). Taxodiaceae, *Glyptostrobus*, *Sequoia*, and *Podocarpus* occur in small amounts.

The PC is dominated by angiosperms with *Quercus gracilis* (up to 23.5%) as a dominant, and *Castanopsis pseudocingulum* (10.3%) and *Castanea crenataeformis* (15.6%) as subdominants. Stable components of the spectra are *Quercus graciliformis* and various *Tricolporopollenites* and *Rhoipites*.

The palynocomplex identified on the basis of predominance of *Quercus gracilis* can be correlated with the complex of the regional palynozone *Quercus gracilis*—*Rhoipites granulatus* (PC-9), attributed to the upper level of the Bartonian (Unifitsirovannyе..., 2001).

**Fig. 6.** Palynological diagram (pollen, spores, and microphytoplankton) of Cenozoic deposits exposed in Borehole B-114. Abbreviations: K<sub>2</sub>—Upper Cretaceous; Maast.—Maastrichtian; Jurk.—Jurki; Lager.—Lagerny Sad; Abrosim.—Abrosimovka; N + Q (?)—Neogene—Quaternary. A sampling interval is shown for Sample 39 (109–114 m). See legend in Fig. 2.



There is a high degree of probability that deposits exposed in the interval of 165–185 m can be correlated with the lower part of the Jurki Formation representing regressive sandy facies of the Tavda Sea (*Unifitsirovannyе..., 2001*).

A series of Cenozoic continental deposits is exposed in the interval of 0–165 m. For palynological analysis, samples were collected in several intervals: int. 109–123.5 m (schistose brown clay), int. 78–52 m (clay with abundance of plant residues and imprints of leaves), and int. 29.9–33 m (clay deposits).

**Beds with the *Betula gracilis*–*Pinaceae palynocomplex*** (B-114, int. 109–123.5 m). Spores in this PC occur in small amounts (5%) and are represented by Polypodiaceae, *Sphagnum* sp., *Gleichenia* sp., and *Osmunda* sp.

Gymnosperms are abundant and diverse (44–55%). They are dominated by pollen of various pines (up to 53%); Taxodiaceae, *Glyptostrobus*, *Abies* sp., *Podocarpus* sp., and *Tsuga* sp. occur in small amounts.

The proportion of the pollen of angiosperms in the PC is up to 50%. The pollen of the family Betulaceae (*Betula gracilis* and *Betula* spp., up to 30%) is in predominance. The pollen of broad-leaved trees is extremely poor, especially at a depth of 123.5 m, where there are rare *Tricolporopollenites* spp., *Plicapollis* sp., *Interpolis* sp., and *Castanea crenataeformis*, probably redeposited from underlying deposits. Up the section (int. 109–114 m, Sample 39), the composition of broad-leaved species is supplemented by less abundant *Juglans sieboldianiformis*, *Carya* sp., *Pterocarya* sp., and *Ulmus* sp.

The PC contains green algae: *Ovoidites* sp., *Botryococcus* sp., *Tetrapidites* sp. (the proportion of *Tetrapidites* sp. in the palynospectrum at a depth of 123.5 m is 5%).

According to the dominant role of the *Betula* pollen and the occurrence of index species *Betula gracilis* and *Juglans sieboldianiformis*, this palynocomplex is compared with the assemblage of the regional palynozone *Betula gracilis*, *Juglans sieboldianiformis* (PC-13) (*Unifitsirovannyе..., 2001*). One can suggest that deposits in the interval of 109–123.5 m were formed in the second half of the Early Oligocene (Rupelian Age)

and they probably belong to the Novomikhailovka Formation.

**Beds with the *Quercus sibirica*–*Juglans sieboldianiformis*–*Fagus grandifoliiformis*–*Pinaceae palynocomplex*** (B-114, int. 76–78 m).

The proportion of spores in this PC is small; they belong to the family Polypodiaceae (*Osmunda*, rare *Sphagnum* and *Lycopodium*).

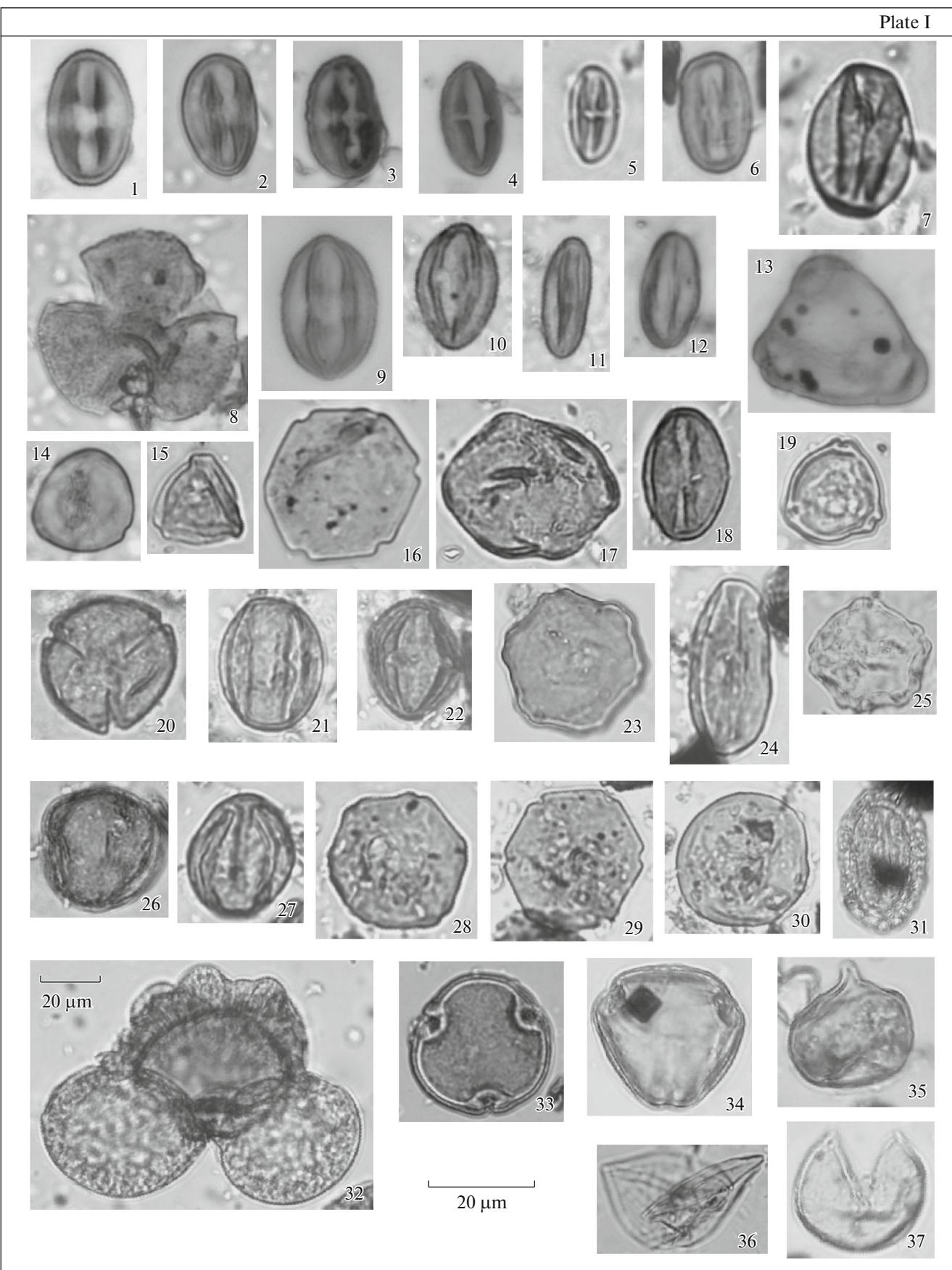
The pollen of gymnosperms (up to 44%) plays an important role in the spectra. The diverse Pinaceae pollen is represented by various *Pinus* of subgenera *Haploxyylon* and *Diploxyylon* (~32%), Taxodiaceae and Cupressaceae (5–6% in total), and also *Picea* sp., *Abies* sp., *Podocarpus* sp., *Tsuga crispa*, *Tsuga* sp., *Taxodium* sp., and *Glyptostrobus*.

A slight predominance of the pollen of angiosperms (52–53%) is noted in the palynospectra (Fig. 6). The pollen contains components of broad-leaved warm temperate flora: *Juglans sieboldianiformis*, *Juglans polyporata*, *Juglans* sp., *Quercus sibirica*, *Quercus* sp., *Fagus grandifoliiformis*, *Fagus* sp., *Pterocarya* sp., *Ulmus* sp., *Carya* sp., *Tilia* sp., *Corylus* sp., and *Carpinus* sp. with a significant proportion of small-leaved flora of the family Betulaceae (*Betula* spp., *Alnus* sp.). The pollen of subtropical plants of *Nyssa* sp. and *Ilex* sp. occur commonly in small amounts.

The *Quercus sibirica*–*Juglans sieboldianiformis*–*Fagus grandifoliiformis*–*Pinaceae palynocomplex* is correlated with a similar palynocomplex in the Upper Oligocene deposits of the Lagerny Sad Formation (Aleksandrova, 1979; Goloverov et al., 1984), as well as with the palynozone *Pterocarya stenopteroides* (PC-14), a part of the regional palynozone *Fagus grandifoliiformis*, which was identified at the Upper Oligocene (Chattian Stage) (*Unifitsirovannyе..., 2001*). In the interval of 76–78 m, the Lagerny Sad Formation is probably exposed.

**Beds with the *Quercus sibirica*–*Q. mira*–*Fagus tenella*–*Ulmus* spp.–*Pinaceae palynocomplex*** (B-114, int. 52–66 m). This complex is similar in composition to that identified in the interval of 76–78 m. However, it is characterized by an increase in proportion of the pollen of the genus *Quercus* (up to 11%), as well as a more diverse composition of the pollen of broad-leaved flora: *Quercus sibirica*, *Q. mira*, *Quercus* sp.,

**Plate I.** Pollen from Cenozoic deposits in the Borehole B-114 section. (1, 2) *Tricolporopollenites pseudocingulum*: (1) Sample 26, depth of 184.4 m; (2) Sample 24, depth of 185.0 m; (3) *Rhoipites granulatus*, Sample 26, depth of 184.4 m; (4, 5) *Castanopsis pseudocingulum*: (4) Sample 36, depth of 165 m, prep. 1; (5) Sample 24, depth of 185.0 m, prep. 1; (6) *Tricolporopollenites cingulum*, Sample 24, depth of 185.0 m, prep. 1; (7) *Quercus sparsus* Mart, Sample 24, depth of 185.0 m, prep. 1; (8) *Fothergilla* sp., Sample 24, depth of 185.0 m; (9) *Tricolporopollenites* sp., Sample 32, depth of 181.7 m, prep. 1; (10) *Tricolporopollenites* sp., Sample 24, depth of 185.0 m; (11, 12) *Quercus gracilis*: (11) Sample 36, depth of 175.0 m; (12) Sample 24, depth of 185.0 m, prep. 1; (13) *Triatriopollenites* sp., Sample 24, depth of 185.0 m; (14) *Platycaryapollis* sp., Sample 24, depth of 185.0 m; (15) *Triporopollenites pliocoides*, Sample 24, depth of 185.0 m, prep. 1; (16) *Juglans* sp., Sample 32, depth of 181.7 m; (17) *Liquidambar* sp., Sample 24, depth of 185.0 m; (18) *Quercus conferta*, Sample 30, depth of 182.1 m; (19–30, 32–35) pollen from Sample 44, depth of 52.0 m: (19) *Betula gracilis*, (20) *Quercus* sp., (21) *Q. forestdalensis*, (22) *Rhus* sp., (23) *Pterocarya* sp., (24) *Quercus sibirica*, (25) *Alnus* sp., (26) *Fagus grandifoliiformis*, (27) *Fagus* sp., (28, 29) *Juglans sieboldianiformis*, (30) *Carya* sp., (32) *Cedrus* sp., (33) *Tilia tomentosiformis*, (34) *Nyssa* sp., (35) *Taxodium* sp.; (31) *Ilex* sp., Sample 42, depth of 66.0 m; (36) *Glyptostrobus* sp., Sample 42, depth of 66.0 m; (37) *Taxodiaceae*, Sample 42, depth of 66.0 m. For all images, the scale bar is 20  $\mu\text{m}$ .



*Fagus tenella*, *F. grandifoliiformis*, *Fagus* sp., *Juglans sieboldianiformis*, *J. polyporata*, *Juglans* sp., *Pterocarya* sp., *Ulmus* sp., *Carya* sp., *Tilia* sp., *Corylus* sp., *Carpinus* sp., *Diervilla* sp., *Castanea* sp., *Liquidambar* sp.

This PC is correlated with the palynozone Quercus sibirica, *Ulmus* crassa (PC-15), a part of the regional palynozone Pinaceae–Taxodiaceae, characterizing the Abrosimovka Horizon and the like-named formation. The latter are conditionally attributed to the level of the Aquitainian Stage–Lower Burdigalian Stage of the Miocene in the modern stratigraphic scheme (*Unifitsirovannye...*, 2001). However, the data obtained in recent years suggest that deposits with PC-15 should be attributed to the Upper Oligocene (Zykin, 2012; Volkov et al., 2016.). On a planetary scale, there was a significant warming during the second half of the Late Oligocene (Zachos et al., 2001). Therefore, it is quite logical that in Western Siberia the Abrosimovka Horizon crowns the complete sequence of Oligocene deposits formed under the relatively warm climatic conditions (Merkulova, 1971; Panov, 1971; Kuzmina and Volkov, 2008; Volkov et al., 2016.). Thus, we assume that the deposits in interval of 52–66 m accumulated during the second half of the Late Oligocene (the second half of the Chattian Stage). Given that the upper part of the Lagerny Sad Formation in the Tom' lithofacial region has palynological features similar to those of the overlying Abrosimovka Formation (Goloverov et al., 1984), it is possible that, in the interval of 52–66 m, we deal with the upper part of the Lagerny Sad Formation or the Abrosimovka Formation.

The interval of 52–66 m (Sample 44) contains single dinoflagellate cysts *Pseudokomewuia* aff. *granulata* (Plate II, figs. 6, 7). The first occurrence of this taxon within the Tom' lithofacies area extends the area of its habitat in Western Siberia. In addition, this taxon has a wide stratigraphic distribution. *Pseudokomewuia granulata* was first described in the Upper Oligocene deposits of China (He, 1984). The similar *Pseudokomewuia* aff. *granulata* is characteristic of the Miocene of North America (Batten et al., 1999) and Northern Europe (Dybkaer, 2004). In Western Siberia, small amounts of *Pseudokomewuia* aff. *granulata* were found in the pollen spectra from the upper Novomikhailovka Formation of the Lower Oligocene and in the Jurki, Turtas, and Abrosimovka formations of the Upper Oligocene (Gnibidenko et al., 2011; Kuzmina and Volkov, 2004; Kuzmina, 2014; Kuzmin et al., 2015; Volkova et al., 2016).

**Beds with PC Chenopodiaceae** (B-114, int. 29.9–33 m). The palynocomplex is dominated by pollen of herbaceous plants (>55%). The spores are represented by *Sphagnum* and Polypodiaceae.

The pollen grains of arboreal plants are presented by *Pinus* spp. (18%), *Betula* spp. (6%), Betulaceae (2.6%), *Picea* sp. (1.7%), and *Salix* sp. (<1%).

The palynocomplex is dominated by the pollen of the family Chenopodiaceae (36.5%). There are also the pollen grains of families Asteraceae, Brassicaceae, Fabaceae, Ranunculaceae, and Polygonaceae, as well as genera *Artemisia*, *Thalictrum*, and *Potamogeton*.

There are Zygomaticales *Ovoidites* sp. and *Tetrapidites* sp., green algae *Pediastrum boryanum*, and spores of soil fungi *Glomus* sp.

The first occurrence of the palynospectra with a predominance of Chenopodiaceae pollen is noted in the sequence of the continental Cenozoic of Western Siberia in the Pavlodar Horizon of the Upper Miocene; they occur higher in the section in the Pliocene–Eopleistocene and Neopleistocene deposits (*Unifitsirovannaya...*, 2000; *Unifitsirovannye...*, 2001). The deposits in the interval of 29.9–33 m contain no remnants of macro- and microfauna, so the age of these deposits varies in a wide range, namely, from Late Miocene to Pleistocene.

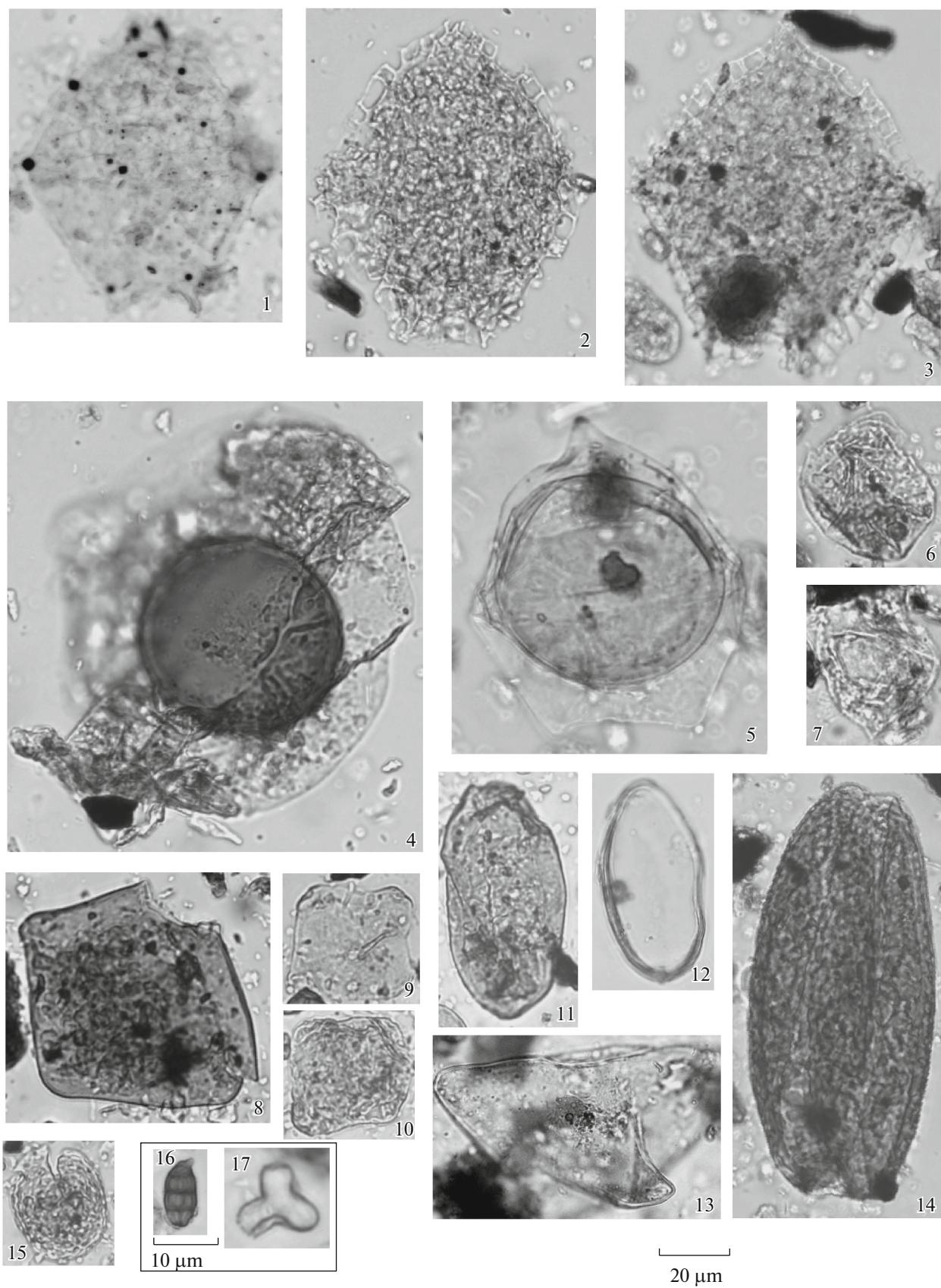
#### Macrofaunistic Analysis

Baculites in the area of the Bakchar iron ore deposit were found in core sections of Boreholes B-101, B-103, B-107, B-118, B-119, and B-129. The Upper Cretaceous sequence studied in these boreholes is similar to that described in Boreholes B-114 and B-124 (Fig. 2).

The lower part of the section is represented by loose sands (B-101, int. 235.1–235.6 m; B-119, int. 234.5–235.8 m). Higher in the section, sand are overlain by greenish gray to gray inequigranular sandstones, often with traces of mud eaters (B-101, int. 228.3–235.1 m; B-107, int. 220.2–221.9 m; B-118, int. 234.9–236.2 m; B-119, int. 229.4–234.5 m). At depths of 229.4 m (B-101), 220.6 m (B-107), and 230.4 m (B-119), sandstones contain remains of baculites. Higher in the section is iron ore formation, represented by brown assorted sandstones with abundance of goethite–hydrogoethite oolites (B-101, int. 226.0–228.3 m; B-107, int. 215.8–220.2 m; B-118, int. 231.6–234.9 m; B-119, int. 225.7–229.4 m; B-129, int. 228–232 m). The oolitic sandstones contain baculites at depths of

**Plate II.** Microphytoplankton from Cenozoic deposits (Eocene, Oligocene) exposed in Borehole B-114. (1) *Kisselevia ornata*, Sample 36, depth of 165 m, prep. 2; (2, 3) *Charlesdowniea clathrata*, Sample 24, depth of 185.0 m, prep. 1; (4) *Thalassiphora pelagica*, Sample 30, depth of 182.1 m; (5) *Deflandrea phosphoritica*, Sample 30, depth of 182.1 m; (6, 7) *Pseudokomewuia* aff. *granulata*, Sample 44, depth of 52.0 m; (8, 13) *Planctonites* spp. (Zygomaticaceae); (8) Sample 44, depth of 52.0 m; (13) Sample 42, depth of 66.0 m; (9, 10) *Tetrapidites* sp., Sample 44, depth of 52.0 m; (11, 12) *Ovoidites* sp., Sample 44, depth of 52.0 m; (14) *Ovoidites emarginatus*, Sample 44, depth of 52.0 m; (15) *Patellaria* (?) sp. (Zygomaticaceae), Sample 44, depth of 52.0 m; (16) nonpollen palynomorph, Sample 24, depth of 185.0 m; (17) *Tritonites bilobus*, Sample 24, depth of 185.0 m. For all images, except for figs. 16, 17, scale bar is 20 µm. For figs. 16, 17, scale bar is 10 µm.

Plate II



219.2 m (B-107) and 226.6 and 227 m (B-119). Iron ore sandstones are overlapped by alternating gray to brownish gray inequigranular sandstones and dark gray silty clays with inclusions of quartz gravel-pebble material (B-101, int. 203.6–226 m; B-103, int. 211.2–220.4 m; B-107, int. 199.5–215.8 m; B-118, int. 229.8–231.6 m; B-119, int. 215.5–225.7 m; B-129, int. 219–228 m). Baculites were selected mainly from the clay layers at depths of 215 m and 219.4 m (B-103), 229.9 m (B-118), and 219.2 m (B-129). The overlying Upper Cretaceous deposits contain no baculites.

Because of poor preservation of the material, we were not able to identify the species of baculites from the Bakchar iron ore deposit. For this reason, the structure of their left blade line, the most important species character for baculites, is unstudied.

However, a comprehensive comparison of cross section and sculptures of remnants of shells and their imprints from various borehole core sections showed that all of them belong to the same morphological group, which is characterized by the unique ontogeny of the shell shape and the same structure of sculpture. For example, baculites at the early stages of ontogeny are represented by shells with a broad and flat dorsal side and convex lateral sides, converging to a rounded and fairly narrow ventral side (Plate III, figs. 3a, 4a). At the late stages of ontogeny, the dorsal side becomes convex, while the lateral sides become flattened and subparallel; along the ventral side, there appears a distinct rounded keel, limited by longitudinal grooves (Plate III, figs. 1b, 1d, 2b, 2d). The shell surface is smooth, with only crescent-type striae of growth (Plate III, figs. 1a, 3a, 3d).

The aforementioned unique morphological features of shells of Bakchar baculites allow us to attribute them to an independent morphotype *Baculites* sp. A.

The stratigraphic distribution of Bakchar baculites was established by studying the core section of Borehole B-119. It was established that, at a depth of 230.4 m, greenish gray inequigranular sandstones contain remnants of *Baculites* sp. A in association with the Campanian, probably late Campanian, assemblage of dinocysts from *Chatangiella niiga*–*Isabelidinium* spp. Beds. This find probably suggests the late Campanian age of these ammonites. Given the above, as well as limited distribution of baculites in sections, mainly in the depth interval of 215–230.4 m, with similar lithological features, one can use them for dating and correlation of country deposits at least within a given area of the paleobasin. For example, despite the fact that there are no data on palynoflora, macrofauna, and microfauna, or they are incomplete (B-119), deposits with *Baculites* sp. A, which are exposed in Boreholes B-101, B-103, B-107, B-118, B-119, and B-129, date back to the Campanian, presumably Late Campanian.

## BIOFACIES ANALYSIS

The deposits uncovered in Boreholes B-114 and B-124 contain spores and pollen of terrestrial plants and marine and freshwater microscopic algae. The biofacies analysis allows us to make some conclusions about the conditions of formation of these deposits. Diagrams of quantitative contents of different groups of microphytوفossils in Upper Cretaceous deposits were constructed (Fig. 7). The spore–pollen diagram based on the quantitative data on palynomorphs (Fig. 6) was constructed for Cenozoic deposits. A diagram of quantitative content of microphytoplankton in the Cenozoic part of the section was not constructed because of incompleteness of the material.

In terms of lithology, the Upper Cretaceous deposits uncovered in boreholes drilled at the Bakchar iron ore deposit are related to shallow-marine and coastal-marine sandy-silty deposits with horizons of oolitic ores (Nagorsky and Zaichenko, 1957; Kazanskii, 1963; Babin and Zaltsman 1970; Kontorovich et al., 2014) (Fig. 8). According to Rudmin (2014), these sand and silt clastic deposits belong to the neritic facies.

The study of different facies sections of Upper Cretaceous deposits of Siberia made it possible to reveal the patterns of facies confinement and indicator properties of individual groups of palynomorphs, morphotypes and taxa dinocysts (Lebedeva, 2008, 2010). These data, together with the published materials, were used to interpret the data obtained from the studied borehole core sections.

The distribution of the following groups and individual taxa were traced in the composition of microphytoplankton: cavate cysts: *Trityrodinium*, *Alterbidinium*, *Odontochitina*, *Spinidinium*, *Isabelidinium*, *Chatangiella*, *Leberidocysta*, *Cerodinium*; proximate, proximo-horata: *Rhyptocorys*, *Microdinium*, *Eisenackia*, *Glyphanodinium*, *Circulodinium*, *Laciadiinium*, *Cladopyxidium*; horata: *Spiniferites*, *Exochosphaeridium*, *Hystrichosphaeridium*; holocavate: *Chlonoviella*, *Chlamydophorella*, *Membranisphaera*; prasinophytes: *Leiosphaeridia*, *Pterospermella*, *Cymatiosphaera*; the genus *Paralecaniella*; acritarchs: *Micrhystridium*, *Leiofusa*, *Veryhachium*, *Polygonium*; freshwater algae: *Shizosporis*, *Ovoidites*; microforaminifers.

On the basis of qualitative and quantitative changes in groups and taxa in the core section of Borehole B-114, three palynomorph assemblages were identified (Fig. 7).

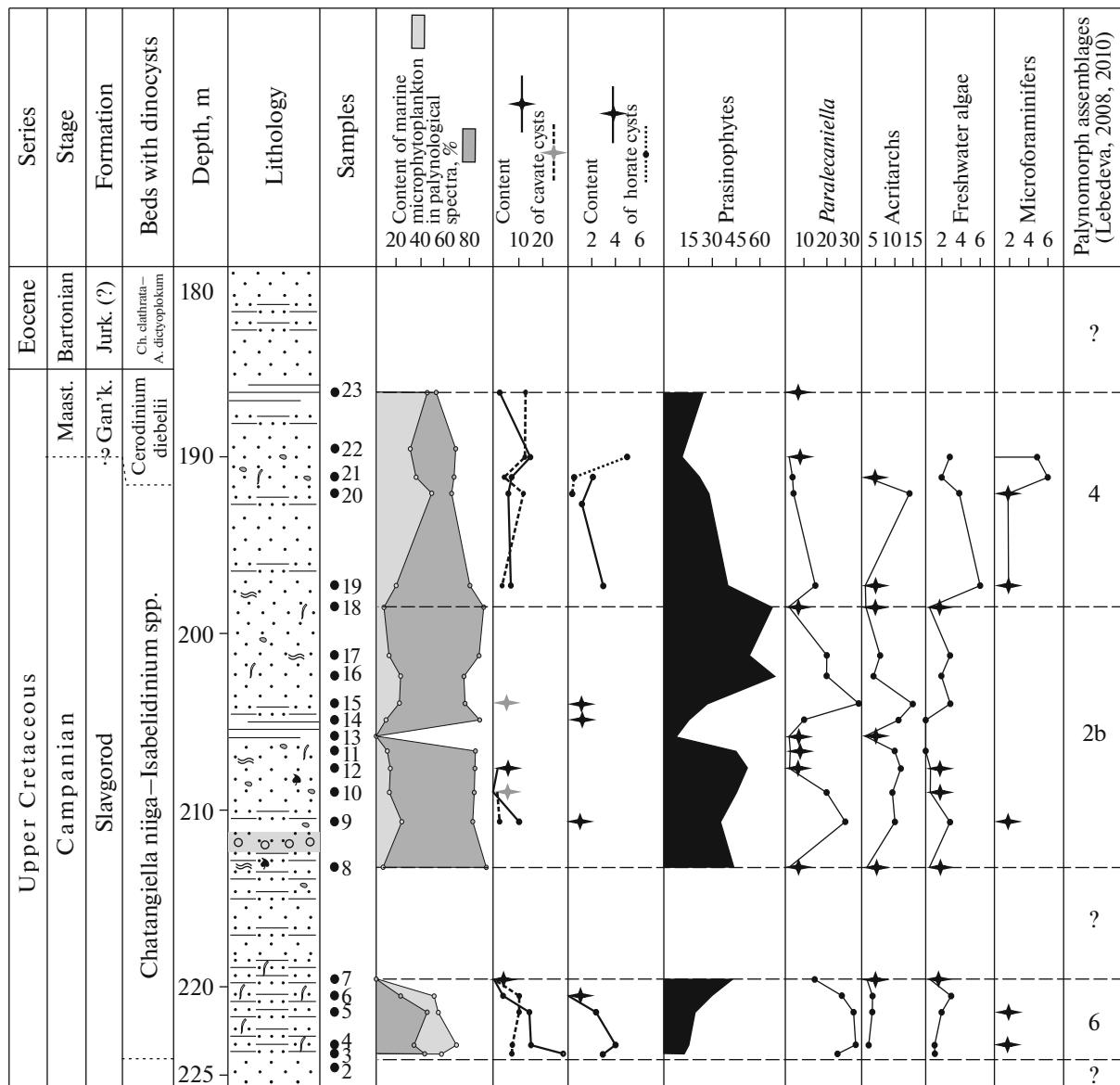
**Interval of 219.7–224.5 m.** The assemblage is characterized by predominance of marine microphytoplankton (60–80%). Dinocysts are dominated in turn by cavate (Samples 3–5) and proximate forms (Sample 6). The content of horata dinocysts is 4–6%. Holocavate dinocysts are absent. Prasinophytes amount to 15–45%; the genus *Paralecaniella* is 20–40%. Acritarchs and freshwater algae are less abundant (2–3%); microforaminifers are rare.

According to the ratio between the different palynomorph groups, this assemblage corresponds to

Plate III



**Plate III.** Baculites from Upper Cretaceous deposits of the Bakchar iron ore deposits. Images show full-size shells. On all images: (a) lateral view, (b) ventral view, (c) dorsal view, (d) cross section, (e) shell imprint. (1–5) *Baculites* sp. A: (1) Sample no. 976/39, TSSGM; Western Siberia, Tomsk oblast, Borehole B-129, depth of 219.2 m; Upper Cretaceous, upper Campanian, Slavgorod Formation; (2) Sample no. 976/35, TSSGM; Western Siberia, Tomsk oblast, Borehole B-119, depth of 227 m; the same age; (3) Sample no. 976/16, TSSGM; Western Siberia, Tomsk oblast, Borehole B-107, depth of 219.2 m; the same age; (4) Sample no. 976/17, TSSGM; the same locality and age; (5) Sample no. 976/18, TSSGM; the same locality and age.



**Fig. 7.** Proportions of different groups of microphytofossils in the core section of Borehole B-114. Environments of formation of palynomorphs (Lebedeva, 2008, 2010): assemblage 6, sublittoral with normal marine salinity; assemblage 2b, sublittoral with active hydrodynamics and varying degrees of desalination; assemblage 4, sublittoral with normal marine salinity and significant influence of the transport of sediments from the shore. See legend in Fig. 2.

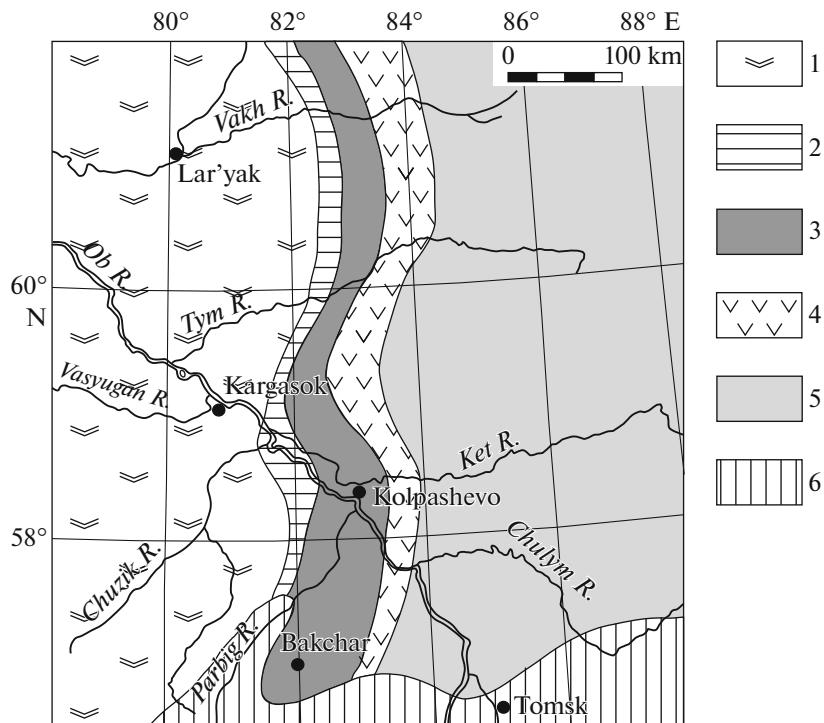
assemblage 6, characterizing conditions of the sublittoral zone with normal marine salinity (Lebedeva, 2010), but differs from it in a higher number of shells of the genus *Paralecaniella*, which is due to their existence in the coastal environment under possible stressful conditions and high hydrodynamic activity (Brinkhuis and Schiøler, 1996; Lebedeva and Zverev, 2003).

**Interval of 198.2–213.5 m.** This assemblage is dominated by spores and pollen of terrestrial plants. Dinocysts are rare. The microphytoplankton is dominated by prasinophytes (40–60%). *Paralecaniella* (up

to 40%) and acritarchs (up to 15%) are in abundance. Freshwater algae amount to 2–6%.

A similar composition and ratio between microphytofossils are typical of assemblage 2b, indicating the conditions of the sublittoral environment with active hydrodynamics and varying degree of desalination (Lebedeva, 2010).

**Interval of 186.8–197.5 m.** The assemblage is dominated by spores and pollen of terrestrial plants. However, the quantity and diversity of dinocysts increases (to 40–60%). In some samples collected in Borehole B-114, marine microphytoplankton dominates (Fig. 7). Cavate and proximate cysts occur in



**Fig. 8.** Lithological-facies zones of the Kolpashevo Horizon of the iron ore formation (modified after Kazanskii, 1963). (1) Zone of marine deposits; (2) zone of marine glauconite, predominantly sandy, deposits; (3) zone of shallow-marine and coastal-marine deposits with iron ore beds; (4) zone of littoral sands; (5) zone of continental deposits; (6) no sediments.

approximately equal proportions. The contents of prasinophytes, *Paralecaniella*, and freshwater algae decrease; acritarchs disappear. In Samples 20–22, the amount of microforaminifer shells increases to 6%.

The assemblage identified is similar to assemblage 4, characterizing the conditions of the sublittoral environment with normal marine salinity, which was significantly affected by the transport of sediments of the shore. The latter is manifested, for example, in the predominance of terrestrial plant remains (Lebedeva, 2010). The study results of facies distribution in microforaminifer complexes demonstrate that they are characteristic of moderate and relatively deep parts of the open (off-shore) sea zone (the depth varies from 60 to 100 m) (Lebedeva and Nikitenko, 1998, 1999).

Thus, a change revealed in the sequence of palynomorph assemblages points to marine regression in the Campanian that was manifested in the sedimentation conditions of deposits of the Slavgorod Formation. The same pattern is traced in the core section of Borehole B-124. According to (Kazanskii, 1963), the ore genesis process in the Kolpashevo Horizon (Campanian–Maastrichtian) within the Bakchar iron ore field area developed under somewhat different conditions than that in the Kolpashevo area owing to more intense tectonic movements. The shallowing of the Late Cretaceous sea in late Campanian–Maastrichtian time led to formation of a complex profile of the coastal shelf. According to data by Kazanskii (1963),

there are marks of this regression at the boundary between the Slavgorod and Gan'kino formations. However, the sequence of microphytofossil assemblages indicates a transgressive trend at the Campanian–Maastrichtian boundary. Thus, detailed stratigraphic and biofacies studies made it possible to clarify the time of the regressive phase of development of a sea basin within the limits of the Bakchar iron ore deposit.

The Cenozoic interval in the core section of B-114 has the following features.

The proportion of microphytoplankton in the palynocomplex of the Middle Eocene interval of the core section (int. 182.9–185 m) is low, from 9 to 16%, with predominance of acritarchs *Tritonites bilobus* (up to 60%, Fig. 6). The predominance of terrestrial palynomorphs (pollen and spores), a large number of acritarchs, and occurrence of rare dinocysts made it possible to reconstruct the shallow coastal conditions with low salinity.

The palynocomplex at the top of the Middle Eocene (int. 165–182.1 m) is characterized by a predominance of terrestrial palynomorphs (mainly, pollen of angiosperms) and an insignificant number of acritarchs *Tritonites bilobus*. This composition of palynomorphs together with the frequent occurrence of peridiniod dinocysts allows one to establish the coastal shallow-water depositional environment of their existence, a lower degree of salinity in a paleo-

sin, and sediment transport from the shore (Iakovleva and Aleksandrova, 2014). The occurrence of microspores of fern *Azolla* (*Hydropteris indutus*) in this PC also points to the low degree of salinity of surface waters of a paleobasin (Zaporozhets and Akhmetiev, 2013).

The composition of palynocomplexes from the Oligocene part of the core section (int. 52–123.5 m) makes it evident that the accumulation of sediments occurred in continental shallow basins, surrounded by Turgaian vegetation (Volkova and Kuzmina, 2005). The systematics of spores and pollen of terrestrial vegetation indicates moderately warm and humid climatic conditions.

Dinocysts *Pseudokomewuia* aff. *granulata* found in the interval of 52–66 m (upper part of the Lagerny Sad Formation or Abrosimovka Formation) are in association with terrestrial palynomorphs and conjugates. The occurrence of Zygnumatales (*Ovoidites*, *Tetrapidites*, etc.) in all the spectra is evidence of the deposition in a shallow, well-heated freshwater basin (Fedorova et al., 1989). Modern conjugates mainly live in fresh water and, sometimes, in slightly saline, brackish water environments (Fedorova et al., 1989). This gives grounds to consider dinocysts *Pseudokomewuia* aff. *granulata* as inhabitants of freshwater basins, although we cannot exclude their occurrence in brackish waters.

The composition and structure of the Neogene–Quaternary pollen spectra in samples collected at a depth of 29.9 m make it possible to assume the existence of forest-steppe landscapes and development of the post-Turgaian vegetation. Compared to the Oligocene Epoch, the climate was more continental, dry, and cold.

## CONCLUSIONS

Comprehensive palynological and macrofaunistic studies of Upper Cretaceous and Cenozoic deposits in several boreholes drilled within the Bakchar iron ore deposit (Tomsk Region) were performed. As a result, four biostratons in the rank of beds with dinocysts and seven biostratons in the rank of spore and pollen zones were identified and the age of deposits varying from Campanian to Quaternary was substantiated. Dinocysts in this area were studied for the first time.

It was found that the boreholes investigated exposed deposits of the Slavgorod, Gan'kino, Jurki, Novomikhailovka, Lagerny Sad, and, probably, Abrosimovka formations and Upper Miocene (?)–Quaternary deposits. The boundary between the Slavgorod and Gan'kino formations is conditional since there are no lithological data for confirmation. This is possibly due to a gap at the Campanian–Maastrichtian boundary, the presence of which is not confirmed by palynological data, but it is assumed from paleomagnetic correlations (Gnibidenko et al., 2015).

A large stratigraphic gap in the Cretaceous–Paleogene boundary deposits covering a significant part of the Maastrichtian, the Paleocene, and the Ypresian and Lutetian stages of the Eocene was established.

Shell remnants of an unusual morphotype of the genus *Baculites* were discovered for the first time. The joint occurrence of baculites and dinocysts made it possible to determine the range of the stratigraphic distribution of these heteromorphic ammonites, which covers, probably, the upper part of the Campanian. On the basis of the data obtained on the stratigraphic distribution of baculites, the country deposits exposed in some boreholes in the area of the Bakchar iron ore deposits, which were not previously characterized by palynological and macrofaunistic studies, were dated and correlated.

Specific trends in the distribution of the different assemblages of microphytofossils or morphotypes of dinocysts in the studied Upper Cretaceous and Cenozoic deposits caused by transgressive–regressive cycles and climate changes were revealed. On the basis of biostratigraphic data and the biofacies analysis, the time of the regressive phase of the basin development in this area resulting from local tectonic movements were clarified (Kazanskii, 1963). The traces of the shallowing of the Late Cretaceous sea were established in studied core sections in the middle part of the Slavgorod Formation. The transgression trend is recorded in the Campanian–Maastrichtian boundary deposits.

Thus, the palynological and macrofaunistic data obtained allowed us to supplement and refine the biostratigraphy of the Upper Cenozoic deposits of the Bakchar iron ore deposit and on the basis of microphytofossils to obtain new data on the depositional environments, which can be used further for paleogeographic reconstructions.

## LIST OF TAXA

### Dinoflagellate cysts:

*Achomosphaera ramulifera* (Deflandre) Evitt

*Alterbidinium acutulum* (Wilson) Lentin et Williams

*Alterbidinium minus* (Alberti) Lentin et Williams

*Areoligera coronata* (Wetzel) Lejeune-Carpentier

*Areosphaeridium diktyoplokum* (Klumpp) Eaton

*Cerodinium diebelii* (Alberti) Lentin et Williams

*Cerodinium speciosum* (Alberti) Lentin et Williams

*Cerodinium markovae* (Vozzhennikova) Lentin et Williams

*Charlesdowniea clathrata* (Eisenack) Lentin et Vozzhennikova

*Charlesdowniea* cf. *crassiramosa* (Williams et Downie) Lentin et Vozzhennikova

*Chatangiella bondarenkoi* (Vozzhennikova) Lentin et Williams

*Chatangiella ditissima* (McIntyre) Lentin et Williams  
*Chatangiella granulifera* (Manum) Lentin et Williams  
*Chatangiella madura* Lentin et Williams  
*Chatangiella niiga* Vozzhennikova  
*Chatangiella serratula* (Cookson et Eisenack) Lentin et Williams  
*Chatangiella spectabilis* (Alberti) Lentin et Williams  
*Chatangiella vignieri* (Vozzhennikova) Lentin et Williams  
*Chlamydophorella nyei* Cookson et Eisenack  
*Chlonoviella agapica* Lebedeva  
*Cordosphaeridium gracile* (Eisenack) Davey et Williams  
*Deflandrea phosphoritica* Eisenack  
*Dinogymnium acuminatum* Evitt et al.  
*Dinogymnium albertii* Clarke et Verdier  
*Dinogymnium sibiricum* (Vozzhennikova) Lentin et Williams  
*Fromea chytra* (Drugg) Stover et Evitt  
*Fromea ?laevigata* (Drugg) Stover et Evitt  
*Glyphanodinium facetum* Drugg  
*Hystrichosphaeridium tubiferum* (Ehrenberg)  
 Deflandre  
*Isabelidinium belfastense* (Cookson et Eisenack)  
 Lentin et Williams  
*Isabelidinium cooksoniae* (Alberti) Lentin and Williams  
*Isabelidinium microarmatum* (McIntyre) Lentin et Williams  
*Isabelidinium rectangulatum* Lebedeva  
*Kallosphaeridium ?ringnesiorum* (Manum et Cookson) Helby  
*Kisselevia ornata* Vozzhennikova  
*Laciadiinium arcticum* (Manum et Cookson)  
 Lentin et Williams  
*Laciadiinium rhombiforme* (Vozzhennikova) Lentin et Williams  
*Membranosphaera maastrichtica* Samoilovitch  
*Microdinium carpentieriae* Slimani  
*Microdinium kustanaicum* Vozzhennikova  
*Microdinium ornatum* Cookson et Eisenack  
*Odontochitina operculata* (Wetzel) Deflandre et Cookson  
*Palaeocystodinium golzowense* Alberti  
*Pseudokomewia granulata* He  
*Pseudokomewia aff. granulata* He  
*Rhombodinium draco* Gocht  
*Rhiptocorys veligera* (Deflandre) Lejeune-Carpenter et Sarjeant  
*Phthanoperidinium eocenicum* (Cookson et Eisenack)  
 Lentin et Williams

*Spongodinium delitiense* (Ehrenberg) Deflandre  
*Thalassiphora pelagica* (Eisenack) Eisenack et Gocht  
*Trithyrodinium quingueangulare* Marheinecke  
*Trithyrodinium suspectum* (Manum et Cookson)  
 Davey

**Acritarchs:**

*Tritonites bilobus* Marshall et Partridge

**Green algae:**

*Ovoidites emarginatus* Lubomirova  
*Pediastrum boryanum* (Turpin) Meneghini

**Spores of mosses and pteridophytes:**

*Baculatisporites comaumensis* (Cookson) Potonie  
*Camarozonosporites insignis* Norris  
*Hydropteris indutus* Kondinskaja  
*Laevigatosporites ovatus* Wilson et Webster  
*Ornamentifera echinata* (Bolchovitina) Bolchovitina  
*Rouseisporites reticulatus* Pocock  
*Stenozonotriletes radiatus* Chlonova  
*Taurocuspores redunctus* (Bolchovitina) Stover

**Pollen of gymnosperms:**

*Ephedripites costatus* Bolchovitina  
*Taxodiaceae pollenites hiatus* (Potonie) Kremp  
*Tsuga crispa* Zaklinskaja

**Pollen of angiosperms:**

*Aquilapollenites quadrilobus* Rouse  
*Aquilapollenites unicus* (Chlonova) Chlonova  
*Betula gracilis* Panova  
*Castanea crenataeformis* Samigulina  
*Castanopsis pseudocingulum* (Potonie) Boitzova  
*Fagus grandifoliiformis* Panova  
*Fagus tenella* Panova  
*Fibulapollis mirificus* Chlonova  
*Juglans sieboldianiformis* Vojcel  
*Juglans polyporata* Vojcel  
*Nyssa crassa* Panova  
*Orbiculapollis lucidus* Chlonova  
*Pterocarya stenopterooides* Vojcel  
*Proteacidites tumidiporis* Samoilovitch  
*Quercus conferta* Boitzova  
*Quercus forestdalensis* Traverse  
*Quercus gracilis* Boitzova  
*Quercus graciliformis* Boitzova

- Quercus mira* Panova  
*Quercus sibirica* Panova  
*Quercus sparsa* Martynova  
*Rhoipites granulatus* (Frederiksen) Boitzova  
*Rhoipites pseudocingulum* (Potonie) Potonie  
*Tilia tomentosiformis* Panova  
*Tricolporopollenites cingulum* (Potonie) Thomson et Pflug  
*Tricolporopollenites liblarensis* (Potonie) Thomson et Pflug  
*Tricolporopollenites pseudocingulum* (Potonie) Thomson et Pflug  
*Triporopollenites plicoides* Zaklinskaja  
*Triorites harrisii* Couper  
*Trudopollis protrudens* Pflug

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