Upper Cretaceous calcareous nannofossil biostratigraphy of the East European Platform: A proposed regional zonal scheme and correlation with foraminifera and radiolarian zones

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Abstract

The Upper Cretaceous deposits are broadly distributed over the territory of the East European Platform (EEP), yet they cannot be reliably subdivided on the basis of the calcareous nannofossils using the existing global and provincial zonal schemes due to the rarity or absence of some index species in the East European palaeobiogeographic province. An original regional biostratigraphic scheme for the EEP is proposed, based on the analysis of the stratigraphic distribution of the calcareous nannofossils from the Moscow Basin, the Central Russian Upland and the Ulyanovsk–Saratov trough. The newly proposed scheme is compared to other Upper Cretaceous zonations for the EEP, based on foraminifera and radiolaria.

1. Introduction

The East European Platform, or the East European Province if it is spoken of in the palaeobiogeograhic terms, was a part of the North-Eastern Peri-Tethys in the late Mesozoic (Fig. 1). This region was a dynamically developing province during the Late Cretaceous. The geodynamic

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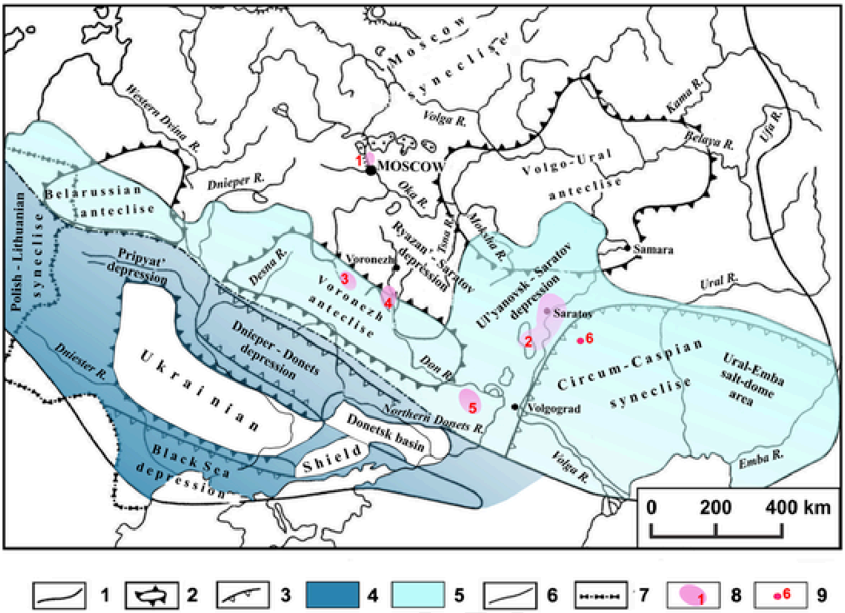


Fig. 1 The distribution of the Upper Cretaceous deposits within the various structural elements of the East European Platform (EEP) and the palaeogeographic zonation of the area: (1) the EEP boundary; (2) shield or high; (3) syncline and depression; (4) Central European palaeogeographic subprovince; (5) Central Russian palaeogeographic subprovince; (6) modern distribution of Upper Cretaceous deposits; (7) state boundary of the EEP and neighboring territories; (8) studied areas: 1—Moscow Basin, 2—Saratov Region, 3—Belgorod Region, 4—Voronezh Region, 5—Rostov Region; (9) Novouzenskaya borehole. *Modified from Olferiev, A.G., Alekseev, A.S., 2003. Biostratigraphic zonation of the Upper Cretaceous in the East European Platform. Stratigr. Geol. Corr. 11(2), 172–198.*

evolution, transgression and regression episodes coupled with reorganization of water passages led to substantial faunal changes in the basin (Alekseev et al., 2005; Baraboshkin et al., 2003; Beniamovskii et al., 2014; Brunet and Cloetingh, 2003; Vishnevskaya and Kopaevich, 2008, 2020).

The Upper Cretaceous biostratigraphy of the East European Platform (EEP) and adjacent regions has been based on the Western European macropaleontological standard (Olferiev and Alekseev, 2005), since the Turonian–Campanian siliceous deposits of the Moscow and Voronezh regions and the Volga Basin (Ulyanovsk, Volgograd and Saratov Regions) are very poorly characterized by the faunal groups traditionally used in the stratigraphy of the Upper Cretaceous, such as inoceramids and belemnites. It has recently become clear that microfossils have a greater potential for subdivision and correlation on the EEP compared to macrofossils (Vishnevskaya et al., 2018), which is due to the ubiquitous presence of microfossils in the Upper Cretaceous sequences.

The depositional history of the North-Eastern Peri-Tethys, and the EEP in particular, was far from being uniform during the Late Cretaceous. While the carbonates prevail in the southern parts of the EEP, the cold Boreal water influenced the siliciclastic sedimentation in the predominantly northern part of the EEP, and terrigenous influx is strongly evident in different parts of the basin (Baraboshkin et al., 2003). The depositional environments obviously affected the preservation potential of certain microorganisms, and in certain instances favored groups with siliceous elements—radiolarians, diatoms and silicoflagellates (Oreshkina et al., 2013; Vishnevskaya, 2010; Vishnevskaya et al., 2018). In some regions, deposits yield only benthic foraminifera, or, infrequently, only calcareous nannofossils (Ovechkina, 2007).

The Upper Cretaceous microfossil biostratigraphy of the central and southern parts of EEP has been traditionally based on the benthic foraminifera, while zonation of the northern and eastern parts of the EEP has been controlled by radiolarians (Vishnevskaya et al., 2018). This approach is backed by a high taxonomic diversity of these groups, and by our ability to trace evolutionary changes in their various phylogenetic lines (Vishnevskaya, 2010; Vishnevskaya and Kopaevich, 2008). On the other hand, there are stratigraphic intervals where the planktonic foraminiferal assemblages become more diverse, contain regional index species and can be reliably used for correlation with established zonal schemes (Vishnevskaya et al., 2018; Vishnevskaya and Kopaevich, 2020).

The calcareous nannofossils are another extremely important stratigraphic tool due to their minute size and generally sub-global geographic distribution. In recent decades, the calcareous nannofossils have been playing one of the leading roles in the biostratigraphy of the Mesozoic and Cenozoic deposits, both offshore and onshore (e.g., Jarvis et al., 2021; Wolfgring et al., 2018).

First descriptions of the calcareous nannofossils from the East European Platform were done more than a century ago by Arkhangelsky (1912). Then there was a big time gap before the nannofossil studies resumed in the 1950s and 1960s (e.g., Bushinskiy, 1954; Lyul'eva, 1967; Shamray, 1963; Shumenko, 1962, 1969; Vekshina, 1959) before the introduction of standard schemes and before a widespread use of the scanning electron microscopy. However, zones and layers established at that time (Dmitrenko, 1985; Dmitrenko et al., 1988; Lipnik and Lyul'eva, 1981; Shumenko, 1974, 1987) were not broadly accepted. The first attempt to consider a detailed regional zonation of the Campanian–Maastrichtian deposits of the EEP was done by Ovechkina (2007), who also thoroughly reviewed the history of the calcareous nannofossil studies on the EEP. She also tested the suitability of global and provincial zonal schemes (Burnett, 1998; Perch-Nielsen, 1985; Sissingh, 1977) for the Upper Cretaceous on the EEP and concluded that an independent regional scheme could resolve the problem of subdivision and broad-scale correlation of these deposits.

An integrated biostratigraphic scheme based on benthic and planktonic foraminifera, radiolarians and nannofossils has been recently proposed for the Upper Cretaceous of the EEP (Vishnevskaya et al., 2018). The calcareous nannofossil subdivisions have been used after the "standard" zonation of Sissingh (1977) with additions of Perch-Nielsen (1985). This nannofossil zonal scale was developed for the sections in Western Europe, Tunisia, Turkey and Oman, and proved to be very convenient and widely used for deposits in the western and southern Tethys. However, some marker species cannot be applied for biostratigraphy of the Upper Cretaceous deposits on the EEP. Thus, for example, warm-water species of *Quadrum*, *Uniplanarius*, *Ceratolithoides* and *Lithastrinus* are rare or completely absent in the EEP. The situation is further exacerbated by diachronism of some calcareous nannoplankton datums. This was noted by Burnett (1998) who concluded that the unified global zonal scheme of the Upper Cretaceous cannot be applied straightforwardly due to the diachronic appearances and disappearances of many index species of the calcareous nannofossils. Therefore, parallel scales for the Boreal, Intermediate, Tethyan and Australian provinces were developed (Burnett, 1998).

The main purpose of the present endeavor is to summarize data that have been obtained during many years of study of the calcareous nannofossils in the EEP deposits, to elucidate the stratigraphic distribution of the calcareous nannofossils in the Upper Cretaceous deposits of the EEP, and to clarify the suitability of certain species as the zonal markers on the EEP and provide a basis for the zonal division of this interval in combination with the foraminiferal and radiolarian zonations as proposed by Vishnevskaya et al. (2018).

2. Material and methods

The present study is based on examination of the calcareous nannofossils, foraminifera and radiolaria from over 700 samples from 19 sections located in a relatively narrow latitudinal strip between 49° and 56°N, in the south and east of the Eastern European Platform: the Moscow Basin (borehole Potanino 2), the Central Russian Upland (Belgorod Region: Belgorod section, boreholes Butovo 100 and Rovenki 614; Voronezh Region: Kolbinskoe, Podgornoe 170 and Podgornoe 171 sections; the Rostov Region: Rossypnoe, Efremovo-Stepanovka, Tarasovskii 1 and Tarasovskii 2 sections) and in the Ulyanovsk–Saratov trough (Saratov Region: Lokh, Klyuchi 1, Klyuchi 2, Teplovka 2, Teplovka 3, Lysaya Gora, Pudovkino and Nizhnyaya Bannovka sections) (Fig. 2).

The samples from the Moscow Basin were provided by A.S. Alekseev (Lomonosov Moscow State University) and the calcareous nannofossils were studied in 52 samples taken every 0.5–1.0 m. Foraminifera and radiolaria were examined in the same samples and the results were published (Olferiev et al., 2000; Ovechkina et al., 2002; Vishnevskaya, 2019).

Five sections in the Saratov Region (Lokh, Klyuchi 1, Klyuchi 2, Teplovka 2 and Teplovka 3) were studied during the 1998 field season, and the results of the study (foraminifera and nannofossil biostratigraphy) were published later (Alekseev et al., 1999; Ovechkina, 2007; Ovechkina and Alekseev, 2005). A total of 161 samples were taken at 0.4–1.0 m intervals from these sections. Samples from the Lysaya Gora, Pudovkino and Nihnyaya Bannovka sections were kindly provided by A.G. Olferiev (Borissiak Paleontological Institute of the Russian Academy of Sciences). The samples were taken at 0.3–3.0 m intervals. A total of 46 samples were studied and results were partly published elsewhere (Ovechkina, 2007; Vishnevskaya et al., 2014).

Samples from the sections in the Belgorod Region were provided by A.G. Olferiev. The Belgorod section and boreholes Butovo 100 and Rovenki 614 were sampled at 0.4–1 m intervals, and a total of 194 samples were studied.

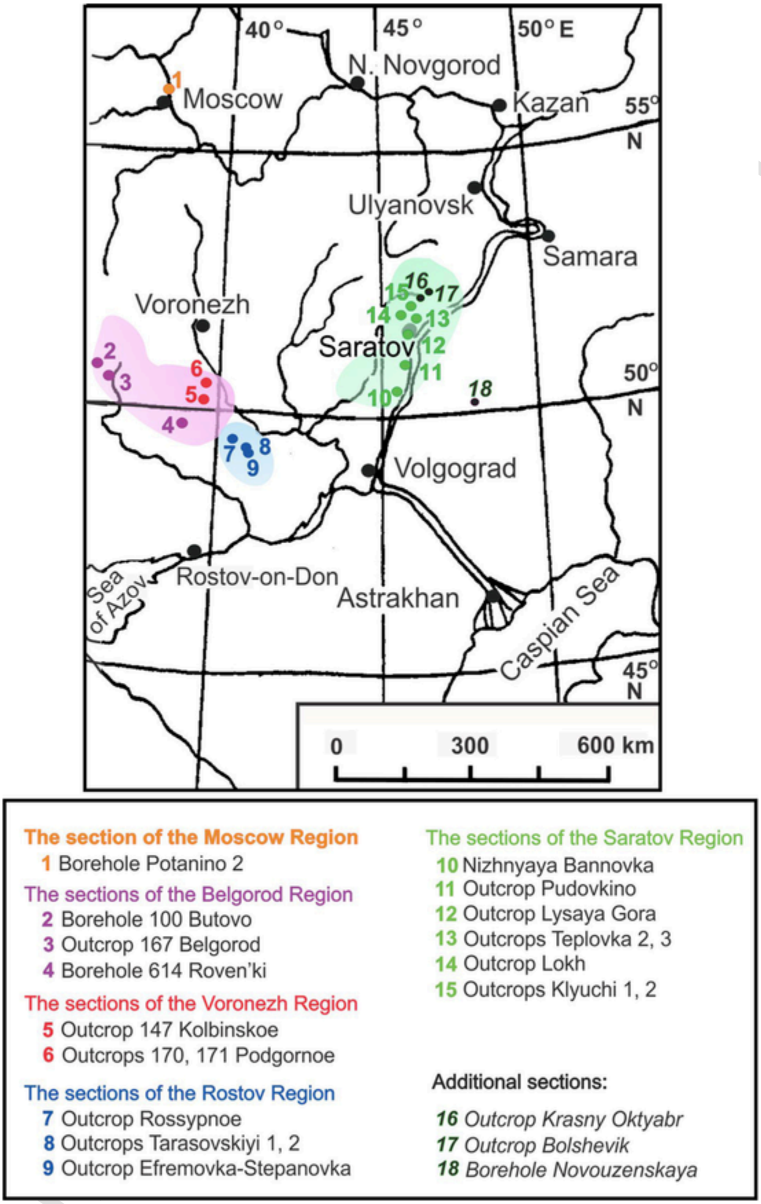


Fig. 2 Location map of studied sections of the EEP.

Samples from the sections in the Voronezh Region were provided by A.G. Olferiev. Samples from the Kolbinskoe, Podgornoe 170 and Podgornoe 171 sections were taken at 0.5–1.0 m intervals, and a total of 88 samples were studied.

The Tarasovskii 1, Tarasovskii 2, Rossypnoe and Efremovo-Stepanovka sections were studied during the 1999 field season in the Rostov Region, and the results of the study (foraminifera and nannofossil biostratigraphy) were published elsewhere (Beniamovskii et al., 2012, 2014; Ovechkina, 2007). These four sections were sampled at 0.3–0.5 m intervals, with the total of 160 samples.

Another three sections in the Saratov Region—Krasny Oktyabr and Bolshevik quarries and the stratotype borehole Novouzenskaya—have been selected as an additional source of information, since these represent most complete Albian/Cenomanian–Maastrichtian sequences in the region (Fig. 2). A thorough lithology and biostratigraphy of these sections based on macro- and microfossil data were published elsewhere (Olferiev et al., 2009a, 2009b, 2014; Ovechkina, 2012).

Foraminifera from the same samples were studied by V·N. Benyamovskiy, L.F. Kopaevich and L.M. Osipova, radiolaria were studied by V.S. Vishnevskaya and L.I. Kazintsova, and belemnites were identified by A.S. Alekseev. The outstanding role of the late A.G. Olferiev should be commended; he was the first to bring together a broad spectrum of specialists in different groups of fauna and flora to study the Upper Cretaceous deposits of the EEP: in the Moscow Region (Ovechkina et al., 2002), Rostov Region (Benyamovski, 2012), along the Volga River (Olferiev et al., 2004, 2007, 2009a, 2009b, 2014; Pervushov et al., 2015), including the section Vishnevoe, where E.A Scherbinina provided identifications of nannofossils (Olferiev et al., 2007), and deposits of the Voronezh anteclise (Olferiev et al., 2005).

2.1 Calcareous nannofossils

The calcareous nannofossils (Figs. 3–34) were studied in permanent smear-slides, which were prepared using the method described by Bown and Young (1998), under a compound microscope Zeiss Axiolab at 1500 × magnification with phase contrast and cross-polarized light. Photographs were taken with an Olympus digital camera attached to the microscope, and the SEM images were taken in the Laboratory of Electron Microscopy of the A.N. Severtsev Institute of Ecology and Evolution

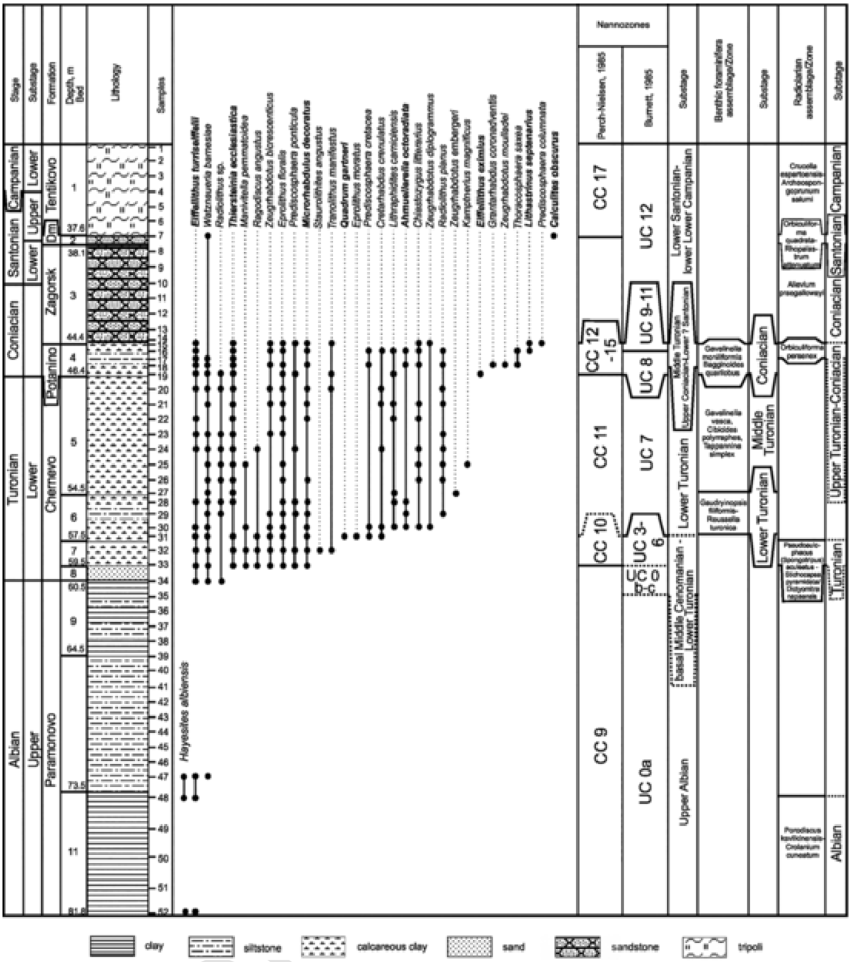


Fig. 3 Stratigraphic distribution of nannofossil species in borehole Potanino 2 (Moscow Basin).

(Moscow, Russia) and at the Electron Microscopy Unit of the University of KwaZulu-Natal (Pietermaritzburg, South Africa).

The calcareous nannofossil taxonomy follows Perch-Nielsen (1985), Bown (1998, 2005) and Burnett (1998).

For biostratigraphy, the standard zonation of Sissingh (1977) with additions of Perch-Nielsen (1985), and the Burnett (1998) for the Boreal Province have been applied.

Abundances of individual calcareous nannofossils species are recorded as follows: abundant (> 10 specimens per one field of view

Fig. 4 Stratigraphic distribution of nannofossil species in Pudovkino section (Saratov Region).

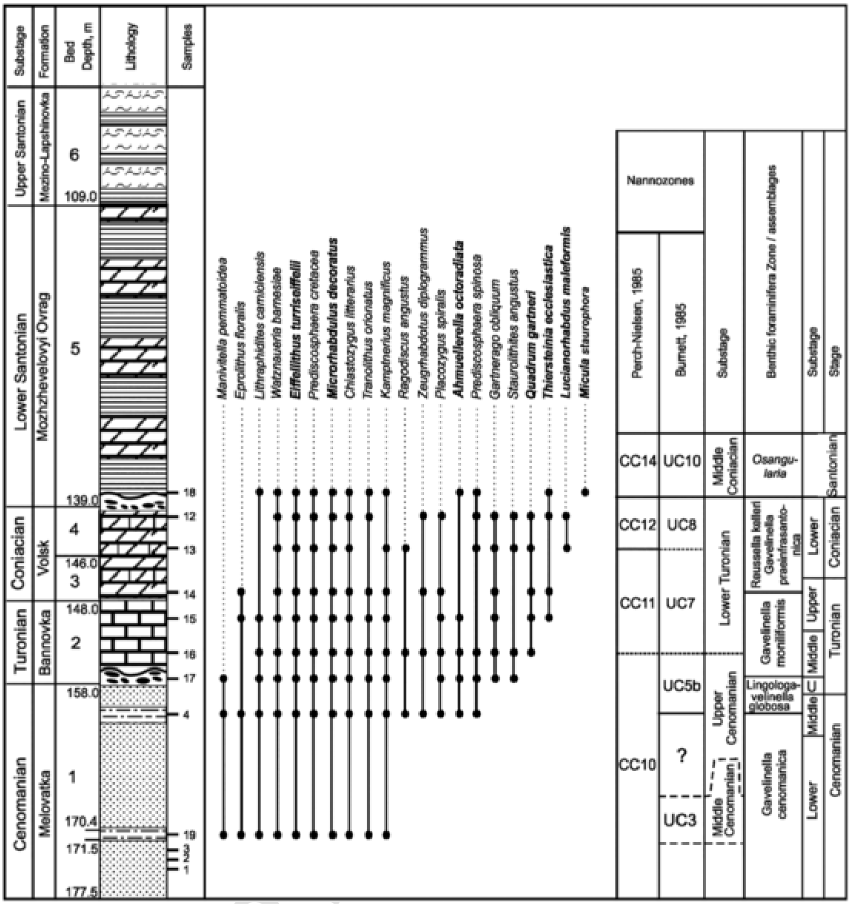


Fig. 5 Stratigraphic distribution of nannofossil species in Nizhnyaya Bannovka section (Saratov Region).

(FOV)), common (> 1–10 specimens per 1 FOV), uncommon/few (1 specimen per 1–10 FOVs), rare (< 1 specimen per 10 FOVs), very rare (1 specimen per slide).

Preservation of calcareous nannofossils has been estimated based on following criteria:

Good—most specimens exhibit little or no secondary alteration, little or no evidence of dissolution and/or recrystallization, primary morphological characteristics only slightly altered, and specimens are identifiable to the species level;

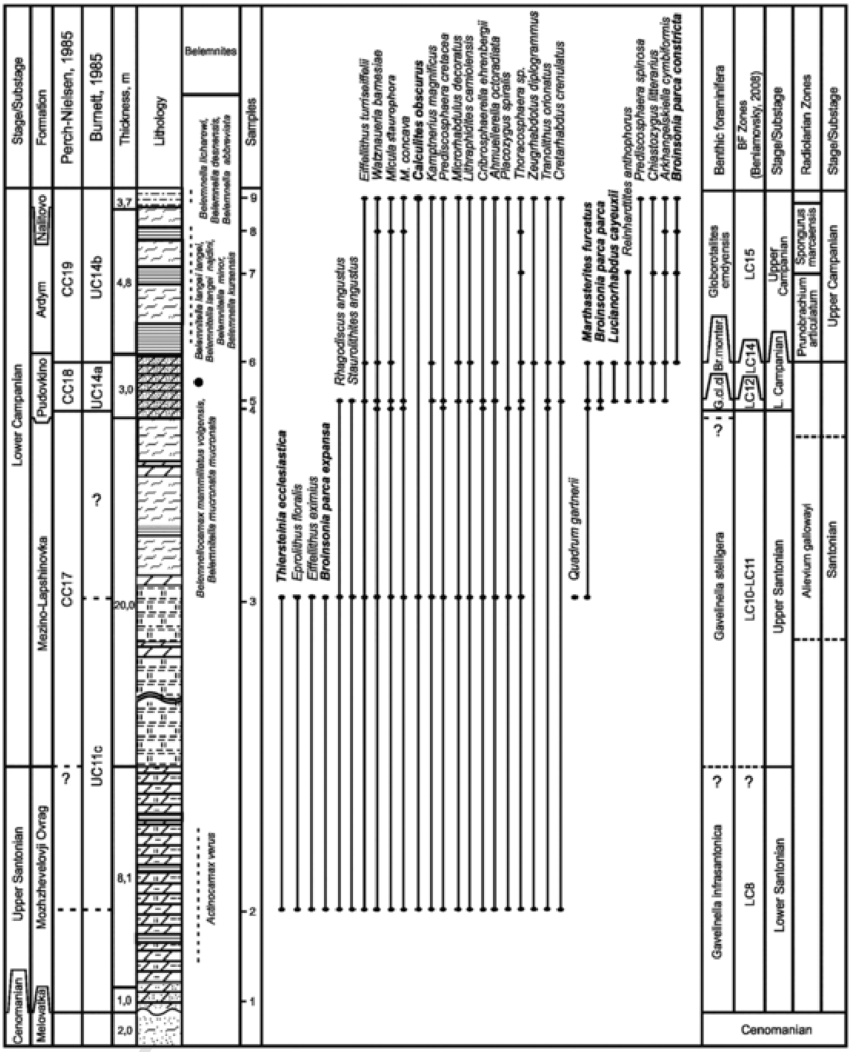


Fig. 6 Stratigraphic distribution of nannofossil species in Lysaya Gora section (Saratov Region).

Moderate—all specimens are easily identifiable to the species level, but exhibit some etching and/or recrystallization from calcite dissolution and/or overgrowth; primary morphological characteristics are somewhat altered;

Poor—identification of species is hampered at the species and/or generic level but possible in some cases; specimens are severely etched

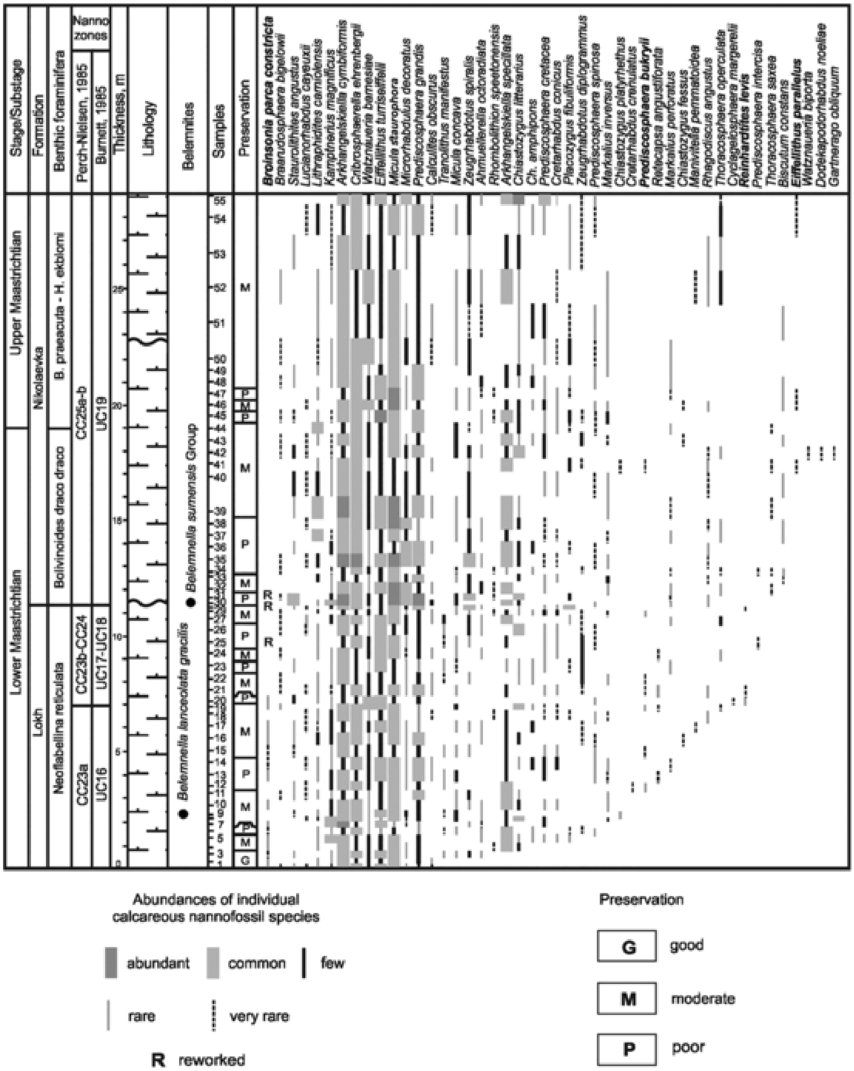


Fig. 7 Stratigraphic distribution of nannofossil species in Lokh section (Saratov Region).

or overgrown, primary morphological characteristics are largely destroyed, fragmentation occurs.

2.2 Foraminifera and radiolaria

Foraminifera and radiolaria were extracted from relatively soft marls and clay-rich limestones using standard micropalaeontological techniques. This involved soaking dry samples in sodium bicarbonate and washing

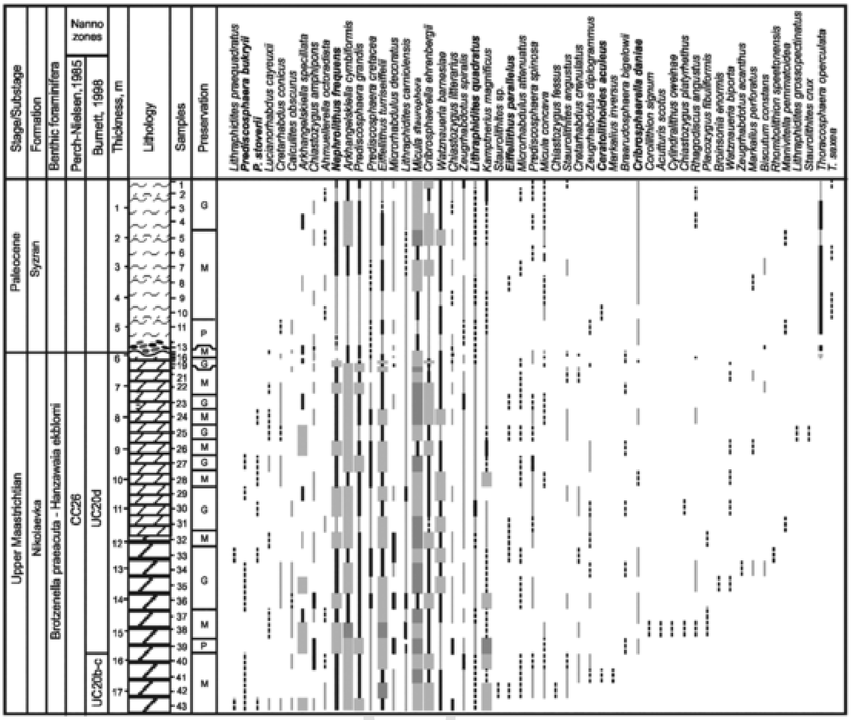


Fig. 8 Stratigraphic distribution of nannofossil species in Klyuchi 1 section (Saratov Region).

the sediment over a 63 μm sieve. Ordinarily, samples of about 200 g were used, but sometimes foraminifers and radiolarians were extracted from smaller amount of rock using the standard elutriation technique: 50–100 g (Efremovo-Stepanovka), 60–180 g (Tarasovskii 2), 70–170 g (Tarasovskii 1) and 90–200 g (Rossypnoe). A total of 160 samples were subjected to this procedure. Relatively hard, silicified rocks (siliceous marls and limestones) of the Moscow and Saratov regions were disintegrated by soaking crushed rock samples with sodium sulphate (Maslakova et al., 1995).

Preservation of foraminiferal tests is very good in soft marls and clay-rich limestones. Many tests have retained their crystallized walls with the original structure. Foraminiferal tests from clastic and hard siliceous rocks are of medium or poor preservation. Species identification has been done on the ≥ 63 μm fraction under a stereo-microscope LEICA MZ12.

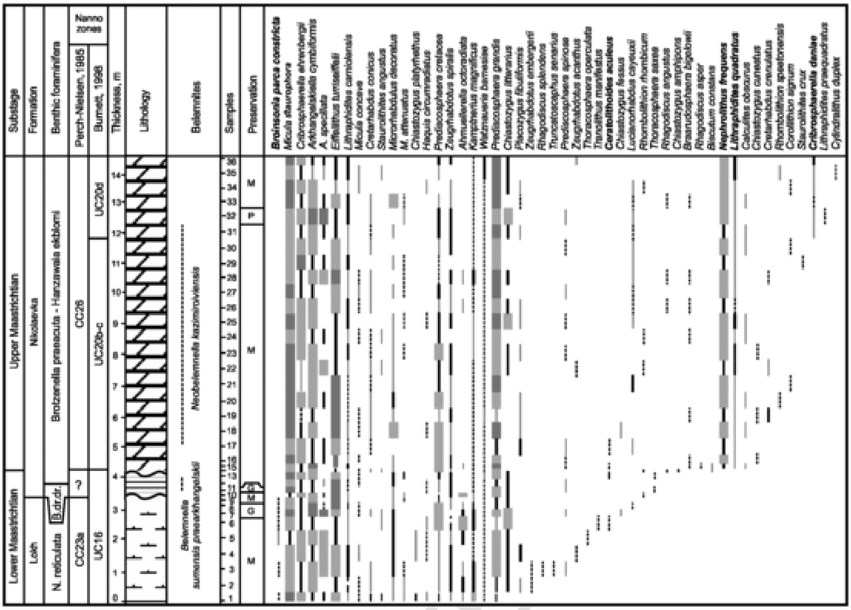


Fig. 9 Stratigraphic distribution of nannofossil species in Klyuchi 2 section (Saratov Region).

Radiolaria were picked from the residue of all fractions and mounted on stubs with double-sided tape and coated with approximately 13 Å of gold for scanning electron microscope (SEM) images.

The foraminifera and radiolaria images were taken with a TESCAN SEM at the Paleontological and Geological Institutes of the Russian Academy of Sciences (Moscow), and with a SCAN JEOL JSM-6480LV SEM at the Department of Petrology, Geological Faculty, Lomonosov Moscow State University (Russia).

The planktonic foraminifera were identified using Huber et al. (2016). The generic system of the benthic foraminifera in this study follows Loeblich and Tappan's (1987), with some additions made according to Beniamovskii (2008a, b) Some species of the Cenomanian benthic foraminifera, earlier attributed to the genus *Gavelinella*, are considered members of the genus *Berthelina* (Tyszka, 2006) in this publication. *Pseudovalvulineria* Brotzen is considered an independent genus comprising the phylogenetic lines *Pseudovalvulineria kelleri* (Myatlyuk)—*P. stelligera* (Marie) for the Middle Turonian–Santonian (Vasilenko, 1954).

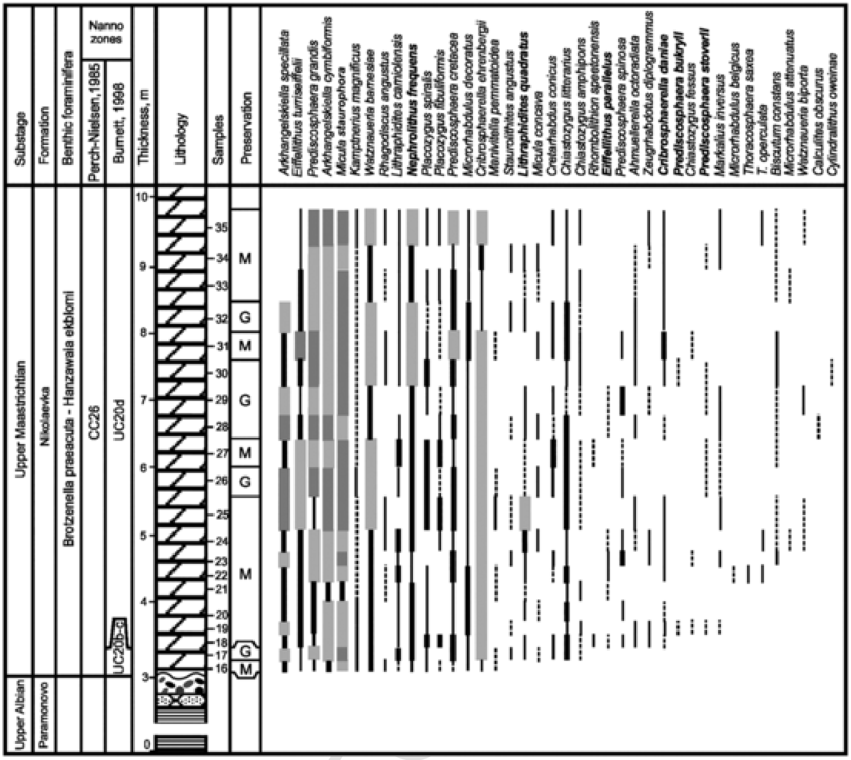


Fig. 10 Stratigraphic distribution of nannofossil species in Teplovka 2 section (Saratov Region).

Most foraminifral zones are subdivided into subzones, which reflect evolutionary or ecological changes of foraminiferal assemblages. In addition to traditional naming after the index species, foraminifral zones receive the following alphanumeric codes—LC1a, LClb, LC2a etc., where LC stands for Late Cretaceous, numerals reflect the sequence of zones starting from the bottom, and lower-case letters denote subzones.

Benthic foraminiferal assemblages (Figs. 35 and 36) have been studied mainly from the central and southern parts of the East European Province, where the greatest numbers of specimens are documented. Stratigraphic intervals of the sections differ from each other by the quantitative ratios of planktonic and benthic foraminifera, including agglutinated and secreting forms. The most important phylogenetic lineages of the benthic foraminifera practically for all upper Cretaceous section are the gavelinellids in a broad sense: *Stensioeina* (especially for the Tur-

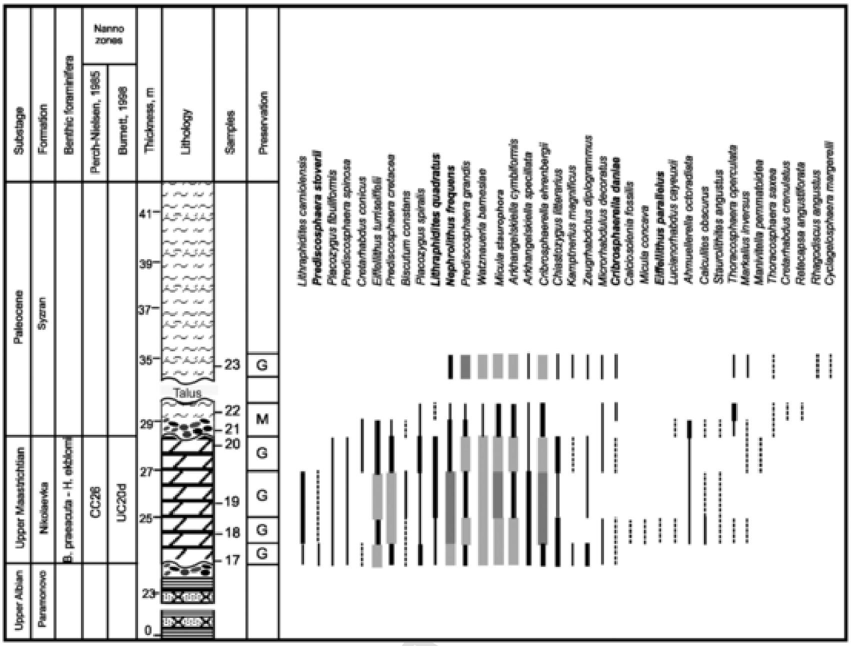


Fig. 11 Stratigraphic distribution of nannofossil species in Teplovka 3 section (Saratov Region).

onian–Santonian), *Bolivinoides* and *Neoflabellina* (for the Santonian–Campanian and Campanian–Maastrichtian). The zonal assemblages have been described in detail by Beniamovskii (2008a, b).

The *Stensioeina* species on the EEP show the evolutionary and stratigraphic sequences during the Turonian–Santonian interval similar to those in North-western Europe (Beniamovskii and Kopaevich, 2016; Beniamovskii and Sadekov, 2005; Walaszczyk et al., 2013). The genus underwent a revision, and a new genus *Protostensioeina* Dubicka and Peryt, 2014, including *Protostensioeina praeexculpta*, *P. emsherica* and *P. granulata* was established for the Late Turonian and Early Coniacian forms (Dubicka and Peryt, 2014; but see also Beniamovskii and Kopaevich, 2016; Kopaevich et al., 2007). Currently, the following events is established on the EEP: (1) *Protostensioeina praeexculpta* appears in the Late Turonian; (2) *P. emsherica* appears in the Early Coniacian and reaches its acme in the Middle–Upper Coniacian (as in the Podgornoe section, see below); (3) *Stensioeina exculpta* marks the Late Coniacian–Lower Santonian; (4) the first record of *Stensioeina incondita* is observed near Lower–Upper Santonian boundary, but its appearance is

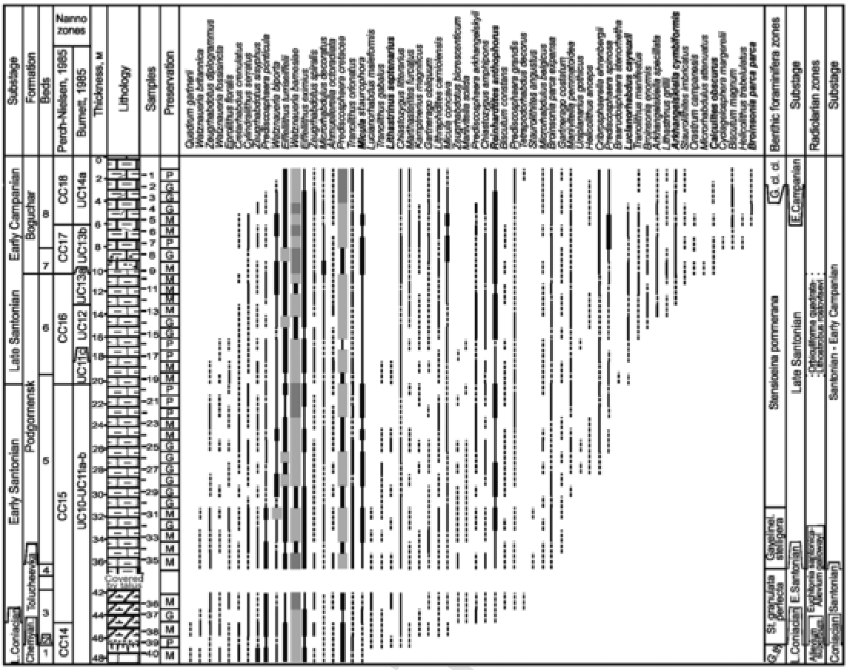


Fig. 12 Stratigraphic distribution of nannofossil species in Podgornoe 171 section (Voronezh Region).

timed to the middle Santonian if a three-fold division of the stage is accepted; (5) *S. pommerana* characterizes the last subzone of the Santonian.

Many zonal benthic foraminifera schemes for the Upper Santonian–Maastrichtian are based on the *Bolivinoides* species. In addition to that, *Bolivinoides* species play a major role in the identification of the Campanian lower boundary, which is the primary challenge of the Upper Cretaceous stratigraphy (e.g., Beniamovskii and Kopaevich, 2016; Hampton et al., 2007). Currently, the following events are established on the EEP: (1) *Bolivinoides strigillatus* appears in the Upper Santonian; (2) the occurrence of *Bolivinoides culverensis* is linked to the position of the Campanian lower boundary; (3) *B. culverensis* evolved into *B. decoratus* during the upper Lower Campanian; (4) the first occurrence of *Bolivinoides miliaris* (or *B. draco miliaris*) marks the upper part of the Upper Campanian, according to Dubicka and Peryt (2012a) this event also mark the end of the *Bostrychoceras polyplocum* ammonite Zone; (5) *Bolivinoides giganteus* appears in the upper part of the Lower Maastricht-

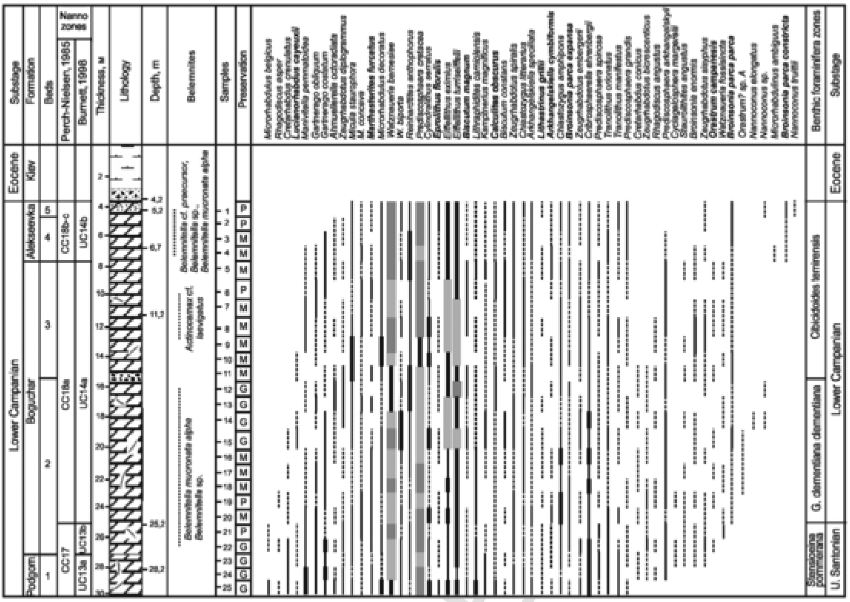


Fig. 13 Stratigraphic distribution of nannofossil species in Podgornoe 170 section (Voronezh Region).

ian, this species is a useful stratigraphical marker for the upper Lower and lower Upper Maastrichtian; (6) *Bolivinoides draco* (*B. draco draco*) is first recorded close to the Lower/Upper Maastrichtian boundary (Dubicka and Peryt, 2012a, b; Vishnevskaya et al., 2018), *B. draco* occurs to the end of the Maastrichtian.

Planktonic foraminifera (Figs. 37–39) can potentially be used to subdivide and correlate sections on the EEP. However, a low taxonomic diversity and the absence of index species do not allow us to utilize them for distinguishing zones here; however, subdivisions in the rank of layers can be recognized. Relatively diverse planktonic foraminifera assemblages are characteristic of the Peri-Caspian depression and sections in the Rostov Region. The sections of the central and eastern parts of the EEP contain poor planktonic foraminifera assemblages, and are dominated by cosmopolitan taxa typical for shallow areas of the boreal and temperate climatic zones. In general, planktonic foraminifera assemblages show some similarity to the associations of the Crimean–Caucasian region and other parts of the North-eastern Tethys area during the Turonian, Santonian/Campanian and Late Maastrichtian (Kopaevich,

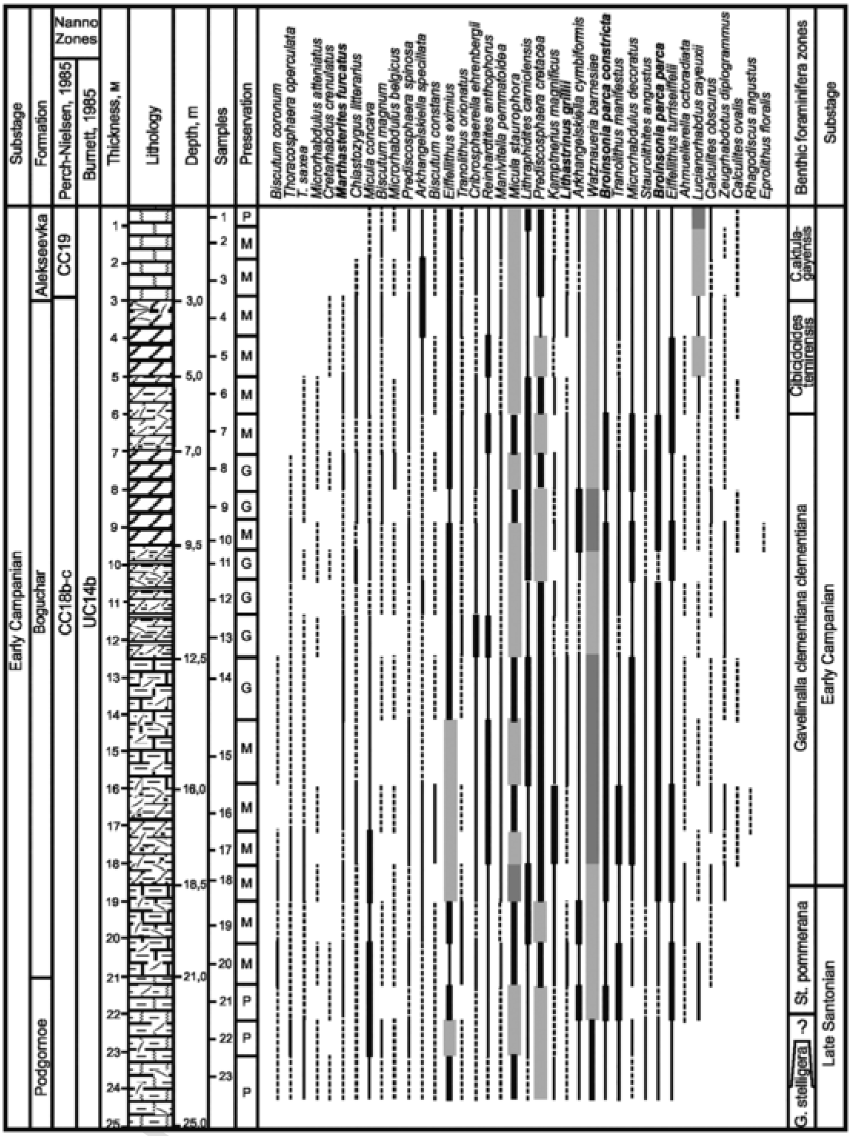


Fig. 14 Stratigraphic distribution of nannofossil species in Kolbinskoe section (Voronezh Region).

2011; Kopaevich and Alekseev, 2019; Vishnevskaya and Kopaevich, 2020).

Identification and stratigraphic distribution of the radiolaria (Fig. 40) follow De Wever et al. (2001) and O'Dogherty et al. (2009). In some

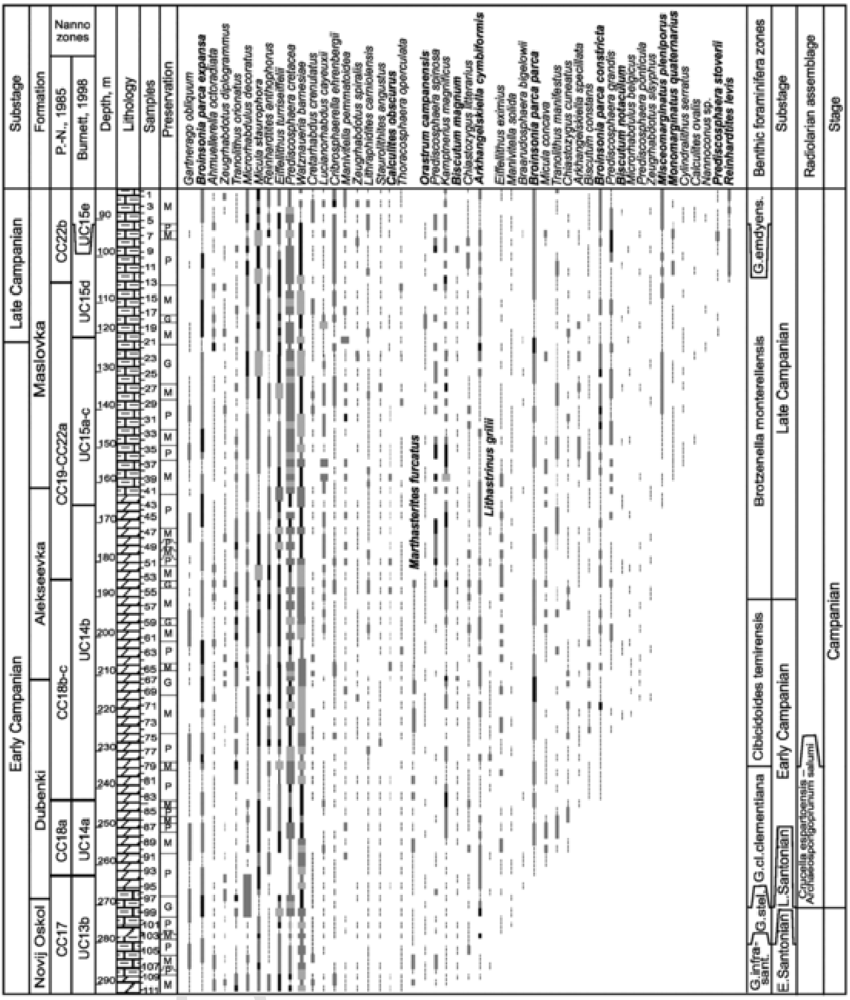


Fig. 15 Stratigraphic distribution of nannofossil species in Butovo 100 borehole (Belgorod Region).

cases, these were modified according to the newest data (Vishnevskaya, 2011, 2015, 2019).

The first appearance (FA) and the last appearance (LA) are “datums” used for global chronological bioevents and referring to the known global record of a species. The first occurrence (FO) or the last occurrence (LO) are used for the local or regional biostratigraphic occurrences of individual species.

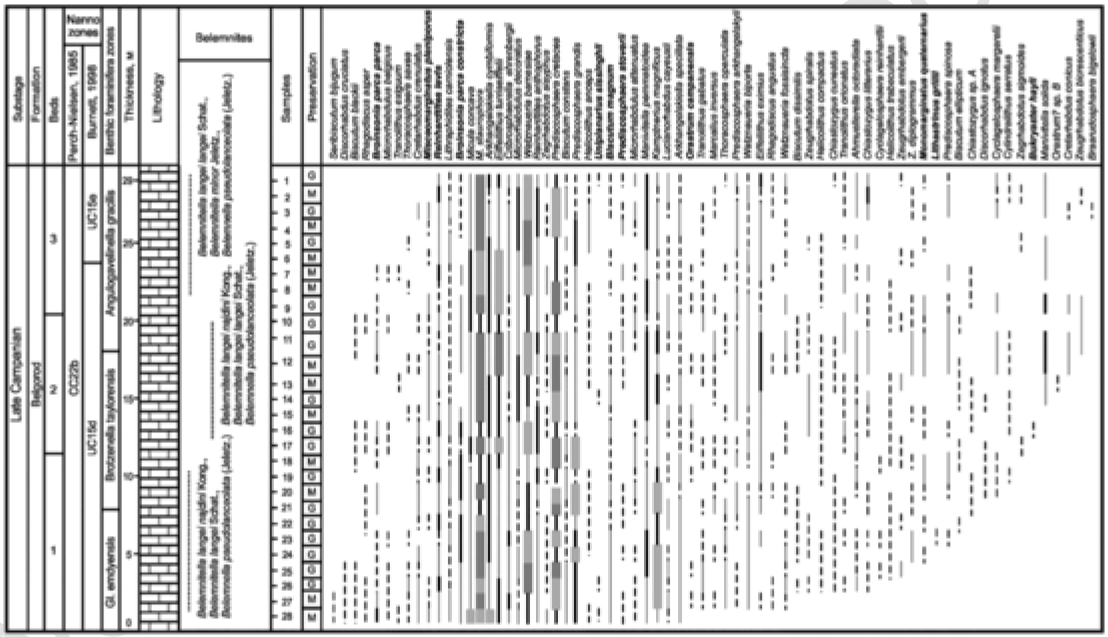


Fig. 16 Stratigraphic distribution of nannofossil species in Belgorod 167 section (Belgorod Region).

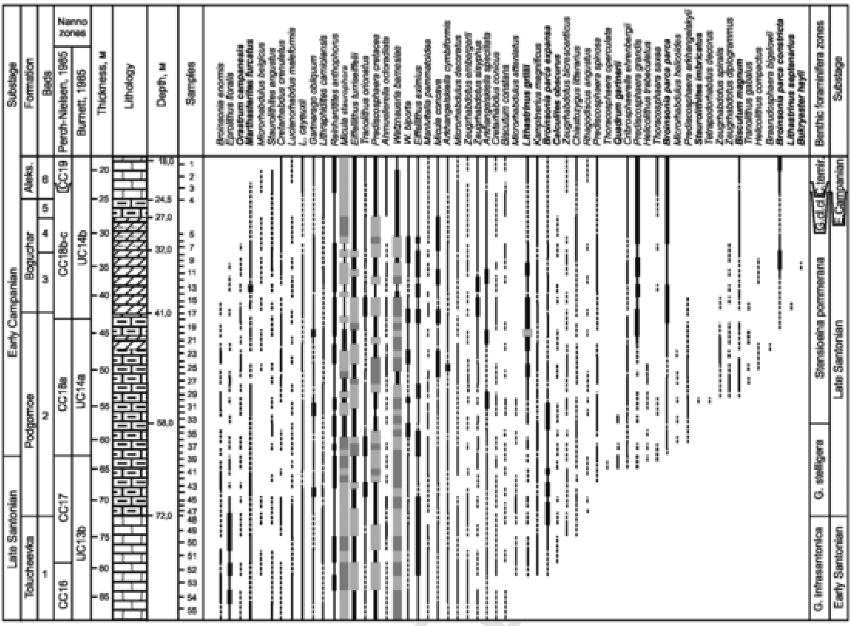


Fig. 17 Stratigraphic distribution of nannofossil species in Rovenki section (Belgorod Region).

3. Geological setting

3.1 General overview

The Upper Cretaceous deposits are widespread in the southern and eastern parts of the EEP. To the north, they are known only in certain areas of the Moscow depression, in the Urals, and in the basin of the Usa River in the Komi Republic (Alekseev et al., 2005; Baraboshkin et al., 2003; Beniamovskii et al., 2014; Olferiev and Alekseev, 2003; Vishnevskaya and Kopaevich, 2020; etc.).

The completeness of the Upper Cretaceous deposits on the EEP is determined by their structural position (Fig. 1), and the most complete sections are confined to synclines within the platform (Olferiev and Alekseev, 2005).

The studied region structurally includes the Voronezh anticline, Volga-Ural anticline, complicated by the Ulyanovsk-Saratov trough, and the northwest margin of the Caspian depression (Fig. 1). This region be-

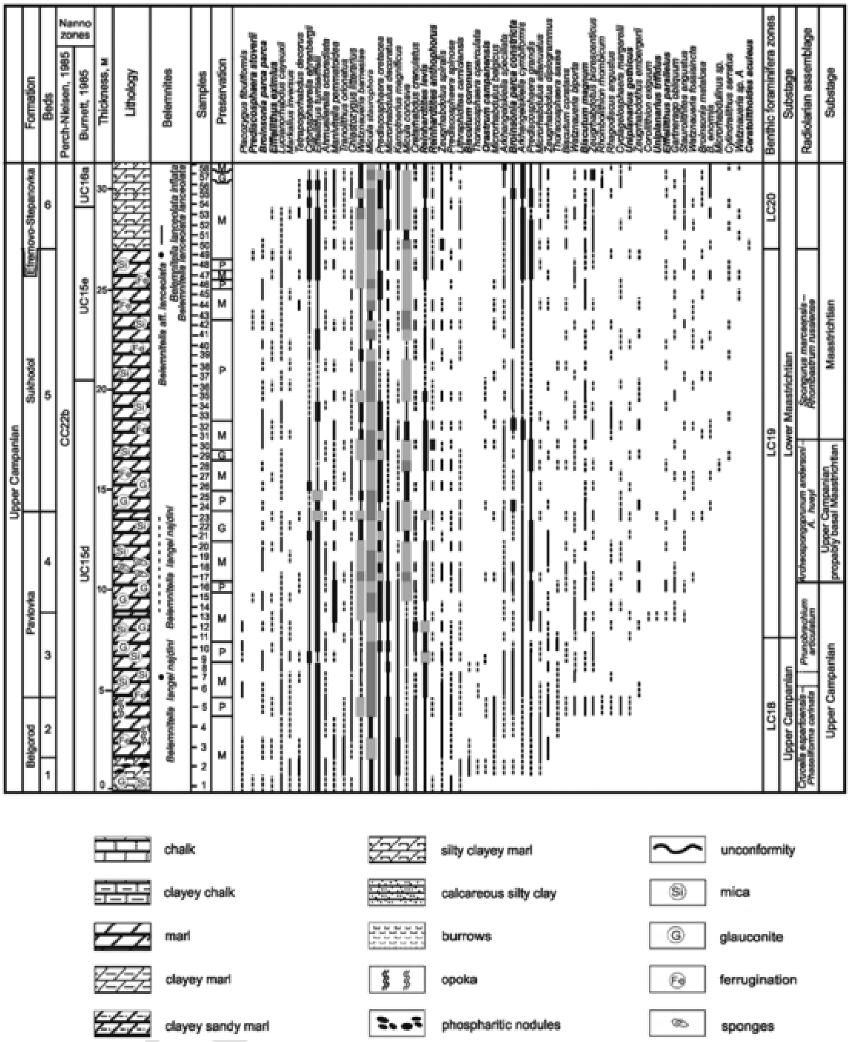


Fig. 18 Stratigraphic distribution of nannofossil species in Rossypnoe section (Rostov Region).

longs to the European paleobiogeographic area (EPO), which occupied the southern part of the middle latitudes of the Western and Eastern Europe in the Late Cretaceous (Naidin, 1986). Within the EPO, several smaller subdivisions are distinguished bounded by sublatitudinal boundaries (Olferiev and Alekseev, 2005). Thus, Christensen (1976) recognizes the southern Central European and northern Central Russian subprovinces within the EPO. The presently studied part of the EEP mainly

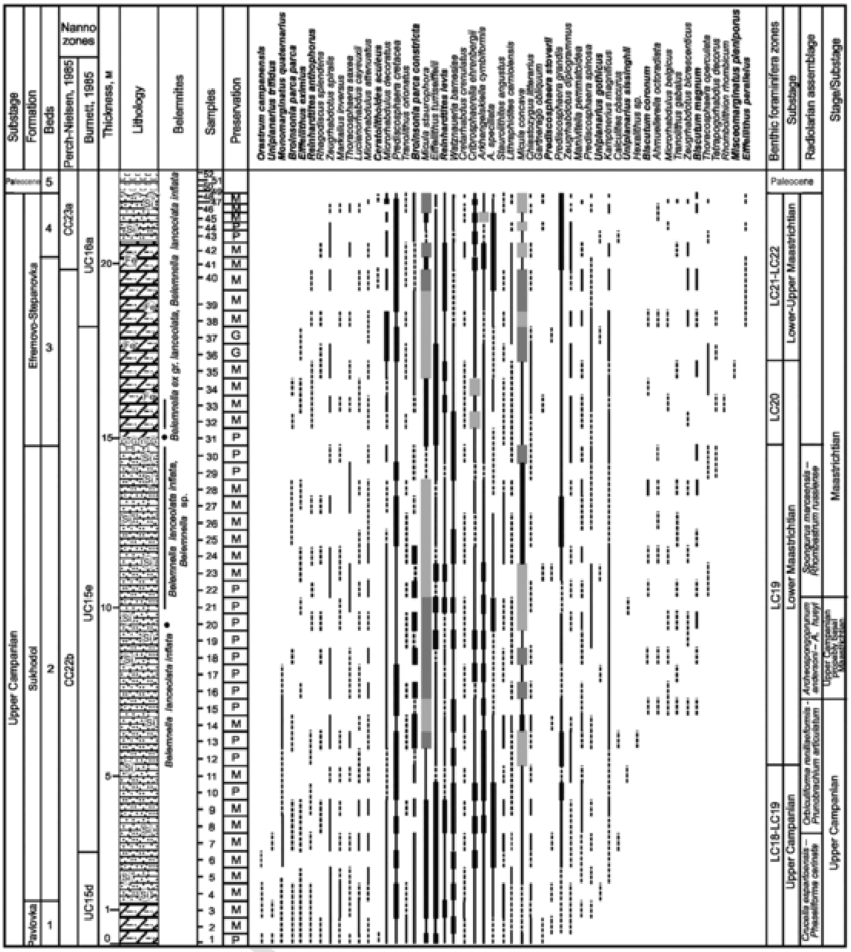


Fig. 19 Stratigraphic distribution of nannofossil species in Efremovo-Stepanovka section (Rostov Region).

occupies the northern part of the EPO, almost entirely within the boundaries of the Central Russian Subprovince.

The Upper Cretaceous sedimentary sheath of the EEP is represented exclusively by marine deposits and as a whole, is characterized by three main types of rocks. Among them, the carbonate deposits predominate and are represented by chalk, limestones and marls. Siliciclastic sediments—flasks, tripoli and spongolites—are quite widespread. Terrigenous sediments represented by sands, sandstones and clays, play a lesser role compared to the Lower Cretaceous deposits.

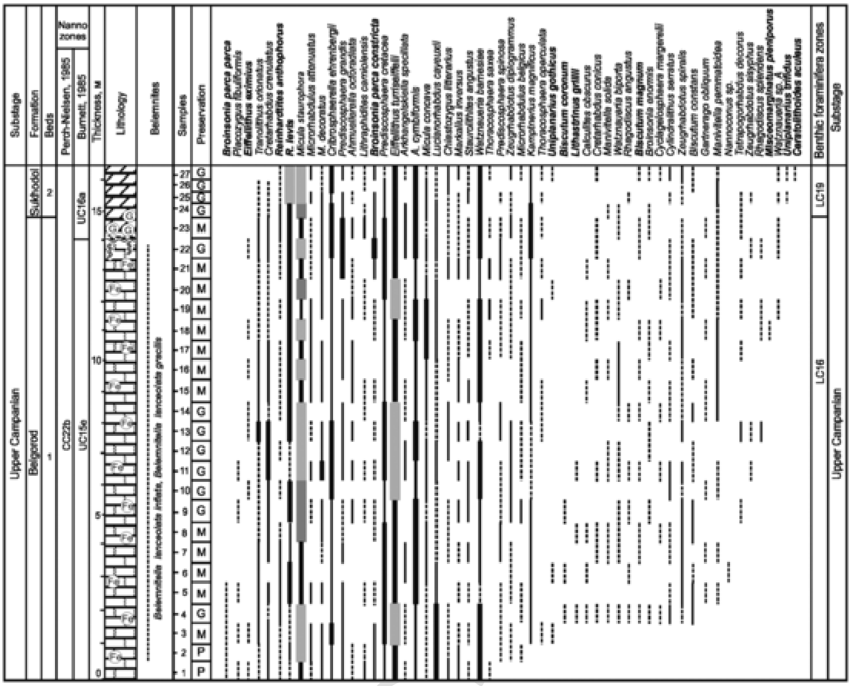


Fig. 20 Stratigraphic distribution of nannofossil species in Tarasovskii 1 section (Rostov Region).

A distinct feature of all Upper Cretaceous deposits in the region is the presence of nodular phosphorites, which are usually dispersed, but locally forming interlayers, especially in the basal horizons of the formations.

The carbonate facies of many areas are characterized by chert concretions, as well as thin interlayers of bentonite clays. In carbonate strata and, to a lesser extent, in siliceous rocks (mainly on the slopes of depressions and on positive structures), hard ground structures are developed.

For biostratigraphic subdivision of the EEP Upper Cretaceous deposits, a regional stratigraphic scheme has been developed by Olferiev and Alekseev (2003, 2005) based on macrofauna (belemnites and inocerams) and microfauna (benthic foraminifera).

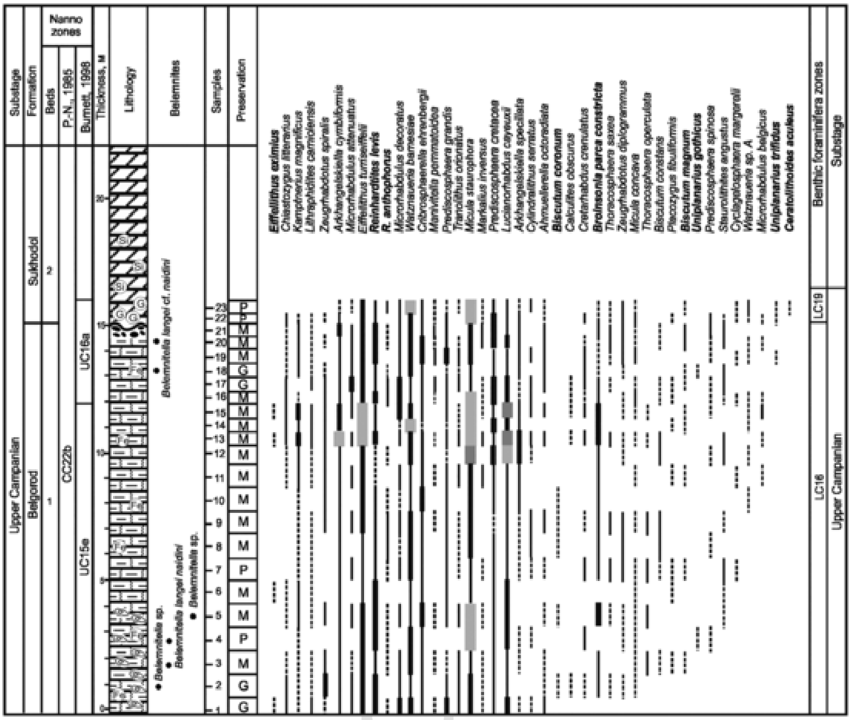


Fig. 21 Stratigraphic distribution of nannofossil species in Tarasovskii 2 section (Rostov Region).

3.2 Lithological description of individual sections

Below are given brief descriptions of sections and boreholes considered in this contribution. Their extended treatment has been published elsewhere, and readers are referred to the relevant sources where appropriate.

3.2.1 Moscow Basin

Borehole Potanino 2 (56°39′N 38°49′E) is located in the north-eastern part of the Klin-Dmitrov Ridge (Fig. 2), within the main field of development of the Upper Cretaceous deposits in northern Moscow Basin (Olferiev et al., 2000). The borehole penetrates the Upper Albian–Upper Santonian/Lower Campanian deposits, with several formations being recognized (Olferiev et al., 2000).

The Paramonovo Formation (Upper Albian; samples 52–35, 81.8–60.5 m) consists of three members (Fig. 3). The lower member (Bed 11, samples 52–48, 81.8–73.5 m) is composed of dark gray and black fine

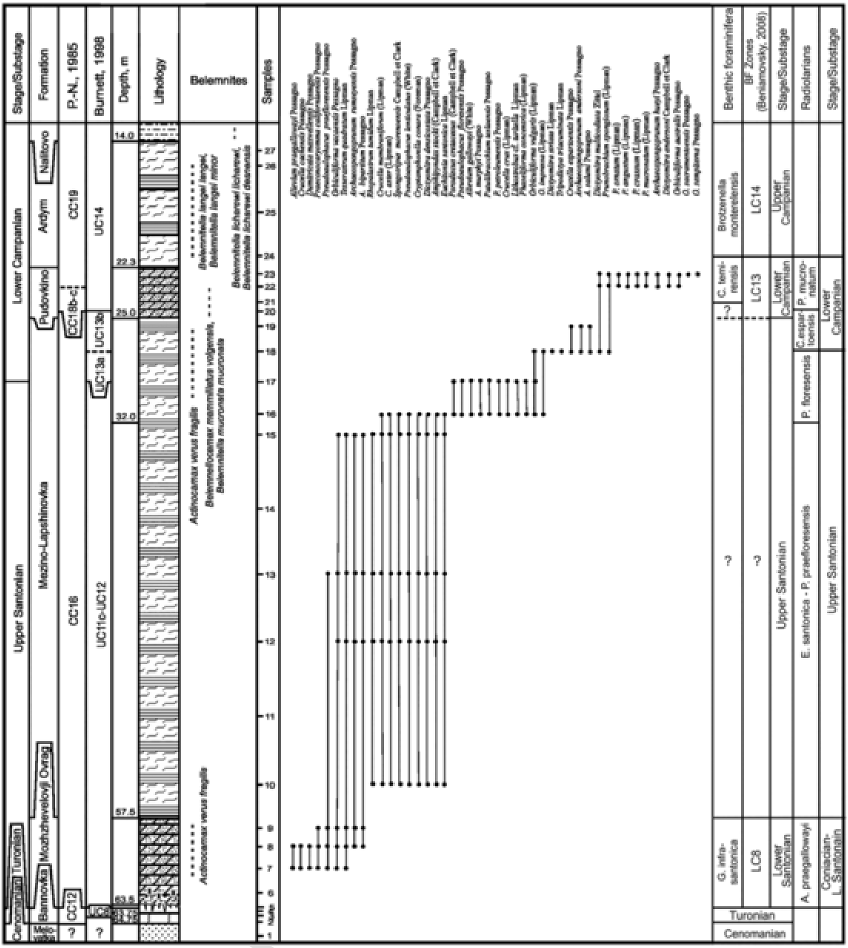


Fig. 22 Stratigraphic distribution of radiolarians in Pudovkino section (Saratov Region) and correlation to foraminiferal and nannofossil zonations.

silty clay with rare *Chondrites*. The middle member (Bed 10, samples 47–40, 73.5–64.5 m) is represented by gray clayey silt, sometimes turning into fine-grained micaceous sand. Frequent *Chondrites* channels are filled with light gray sandy silt or fine-grained sand. The upper member (Bed 9, samples 39–35, 64.5–60.5 m) is similar to the lower member and is composed of dark gray silty clay, heavily bioturbated, with isolated *Chondrites*.

The Chernevo Formation (Turonian; samples 34–20, 60.5–46.4 m) overlaps the Paramonovo Fm. with erosion and a hiatus and is repre-

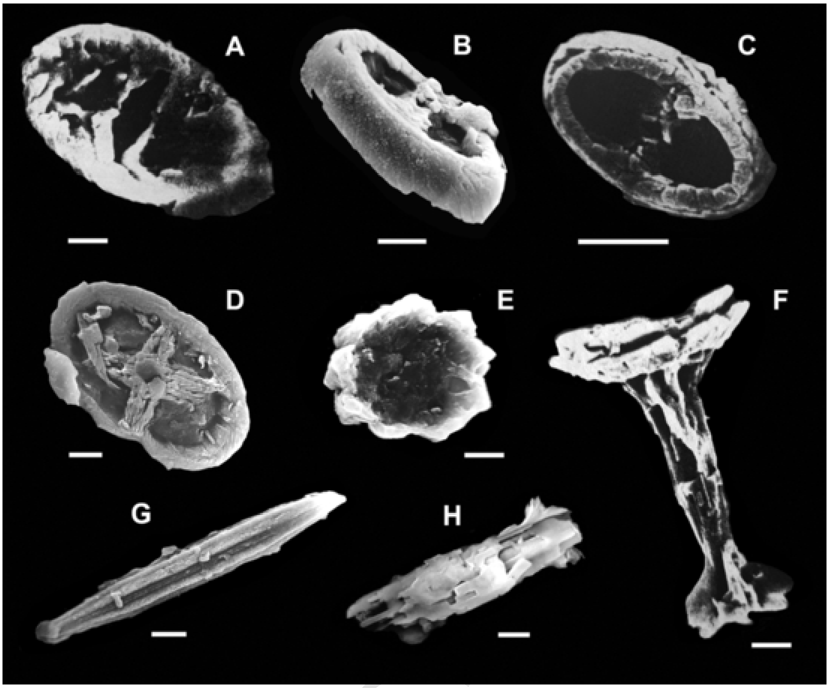
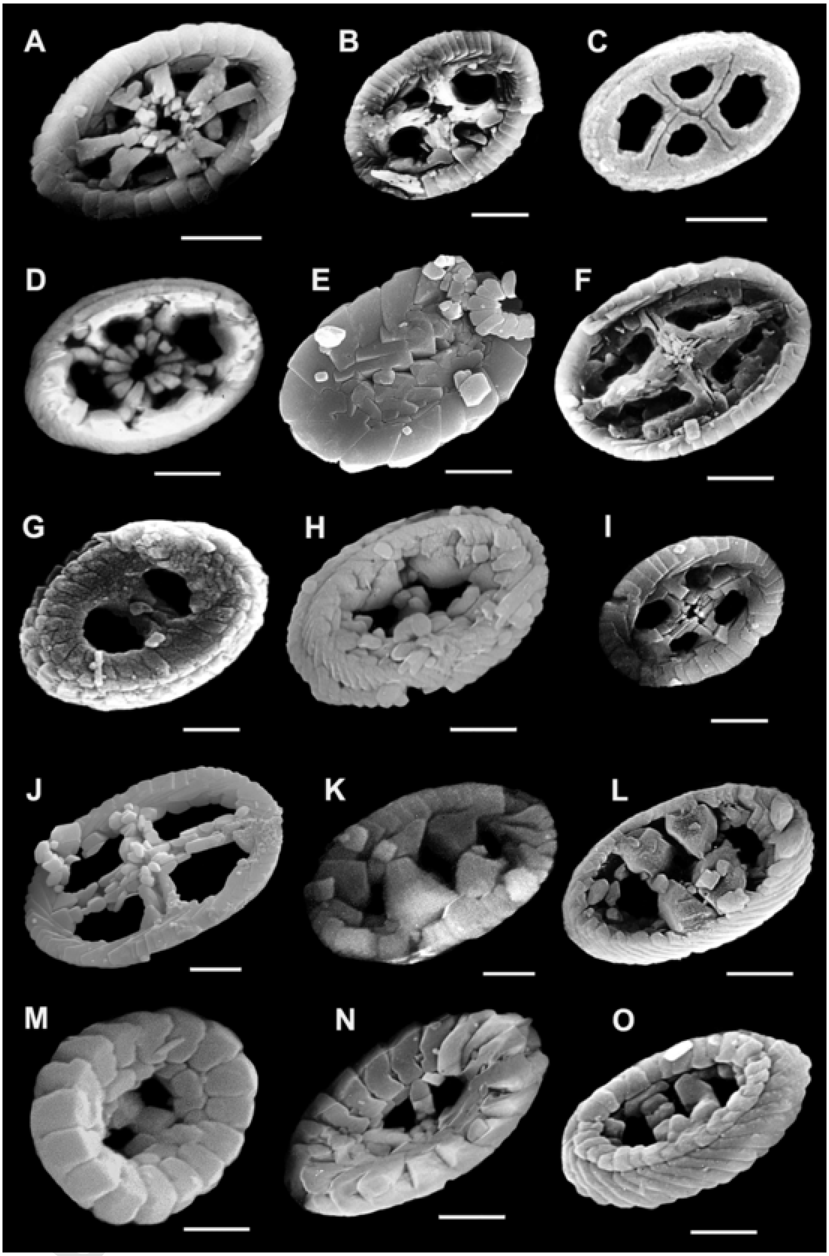


Fig. 23 SEM photographs of selected nannofossil species from the Potanino 2 borehole (Moscow Basin). (A) *Tranolithus manifestus* (sample 32, depth 58.0 m, Bed 7, Chernevo Fm.); (B) *Zeugrhabdotus embergeri* (sample 27, depth 54.4 m, Bed 5, Chernevo Fm.); (C) *Zeugrhabdotus moulladei* (sample 18, depth 45.9 m, Bed 4, Potanino Fm.); (D) *Eiffeltithus turriseiffelii* (sample 47, depth 73.0 m, Bed 10, Paramonovo Fm.); (E) *Eprolithus fioralis* (sample 18, depth 45.9 m, Bed 4, Potanino Fm.); (F) *Prediscosphaera* sp. (sample 18, depth 45.9 m, Bed 4, Potanino Fm.); (G) *Lithraphidites carniolensis* (sample 27, depth 54.4 m, Bed 5, Chernevo Fm.); (H) *Microrhabdulus decoratus* (sample 31, depth 57.1 m, Bed 6, Chernevo Fm.). Scale bars 1 μm.

sented by two members. The lower member (Beds 8–6, samples 34–28, 60.5–54.5 m) begins with a thin (about 1.0 m, 60.5–59.5 m) sandy layer (Bed 8, established from well log data only) and continues with dark gray and black sandy low-calcareous clays of Bed 7 (59.5–57.5 m) with fragments of inoceramids and belemnites. Higher and possibly with a slight hiatus, occur dark gray strongly silty clays or clayey carbonate siltstones overlain by the marl (Bed 6, samples 31–28, 57.5–54.5 m). The base of Bed 6 contains accumulations of fine-grained glauconite-quartz sand, sometimes with coarser grains of quartz; but despite this the con-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tact with the underlying layer is not very clear. The upper member of the Chernevo Fm. (Bed 5, samples 27–20, 54.5–46.5 m) is represented by black weakly calcareous layered clay with thin layers of light gray silt and fine-grained sand, and with unclear imprints of inoceramids.

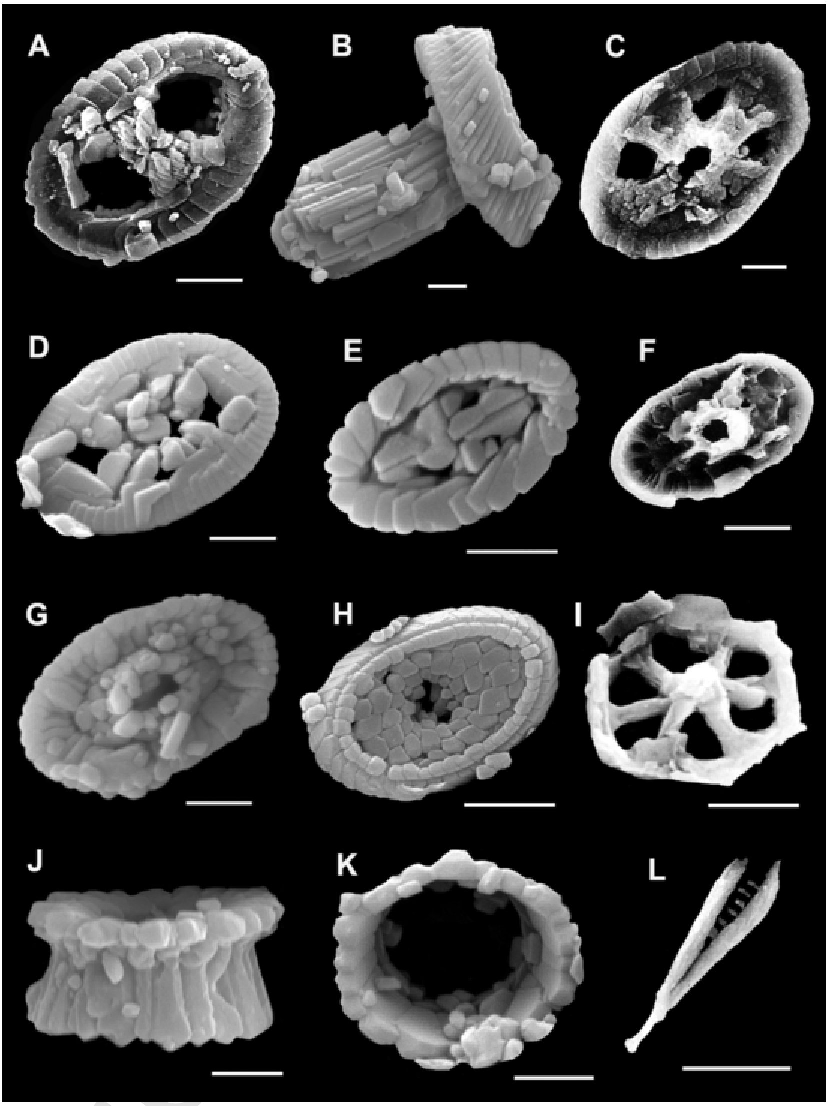
The Potanino Formation (Coniacian; samples 19–15, 46.4–44.4 m) is represented by rough ash-gray, with bluish tint, clayey carbonate siltstones. The contact with the underlying Chernevo Fm. is very clear.

The Zagorsk Formation (Coniacian–Lower Santonian; samples 14–8, 44.3–38.1 m) is represented by sandstones ending with a 0.3 m layer of gray opoka crowned with a hardground.

The Dmitrov Formation (Lower–Upper Santonian; sample 7, 38.1–37.6 m) is represented by the glauconitic sandstones.

The Tentikovo Formation (Upper Santonian–?Campanian) (samples 6–1, 37.6–30.5 m) is composed of light gray fine silty rotten stones, ferruginous and with nests of glauconite at the bottom.

Fig. 24 SEM photographs of selected nannofossil species from the Saratov, Belgorod and Voronezh regions. (A) *Ahmuellerella octoradiata* (Butovo 100 borehole, sample 100/65, Lower Campanian, Alekseevka Fm.); (B) *Chiastozygus amphipons* (Klyuchi 2 section, Nikolaevka Fm., Upper Maastrichtian, sample KL2/16); (C) *Chiastozygus cuneatus* (Klyuchi 2 section, Nikolaevka Fm., Upper Maastrichtian, sample KL2/23); (D) *Chiastozygus* sp. A (Belgorod section, Belgorod Fm., Upper Campanian, sample 21); (E) *Crepidolithus* sp. (Belgorod section, Belgorod Fm., Upper Campanian, sample 28); (F) *Misceomarginatus pleniporus* (Belgorod section, Belgorod Fm., Upper Campanian, sample 28); (G) *Placozygus fibuliformis* (Klyuchi 2 section, Nikolaevka Fm., Upper Maastrichtian, sample KL2/23); (H) *Reinhardtites anthophorus* (Butovo 100 borehole, sample 100/19, Lower Campanian, Maslovka Fm.); (I) *Staurolithites angustus* (Klyuchi 1 section, Nikolaevka Fm., Upper Maastrichtian, sample KL1/43); (J) *Staurolithites imbricatus* (Podgornoe 171 section, Lower Campanian, Boguchar Fm. sample 171/5); (K) *Tranolithus exiguum* (Belgorod section, Belgorod Fm., Upper Campanian, sample 28); (L) *Tranolithus orionatus* (Butovo 100 borehole, sample 100/23, Lower Campanian, Maslovka Fm.); (M) *Zeugrhabdotus bicrescenticus* (Belgorod section, Belgorod Fm., Upper Campanian, sample 28); (N) *Zeugrhabdotus biperforatus* (Belgorod section, Belgorod Fm., Upper Campanian, sample 28); (O) *Zeugrhabdotus diplogrammus* (Butovo 100 borehole, sample 100/97, Upper Santonian, Noviy Oskol Fm.). Scale bars 2 μm.



3.2.2 Saratov Region

3.2.2.1 Pudovkino section

The section is located on the right side of a ravineon the right bank of the Volga River, 40 km south of the Saratov (Fig. 2) and has been described in great detail elsewhere (Ivanov and Pervushov, 1999; Ovechkina, 2004, 2007; Olferiev and Alekseev, 2005; Vishnevskaya et al., 2014). From the bottom up, the following formations are exposed.

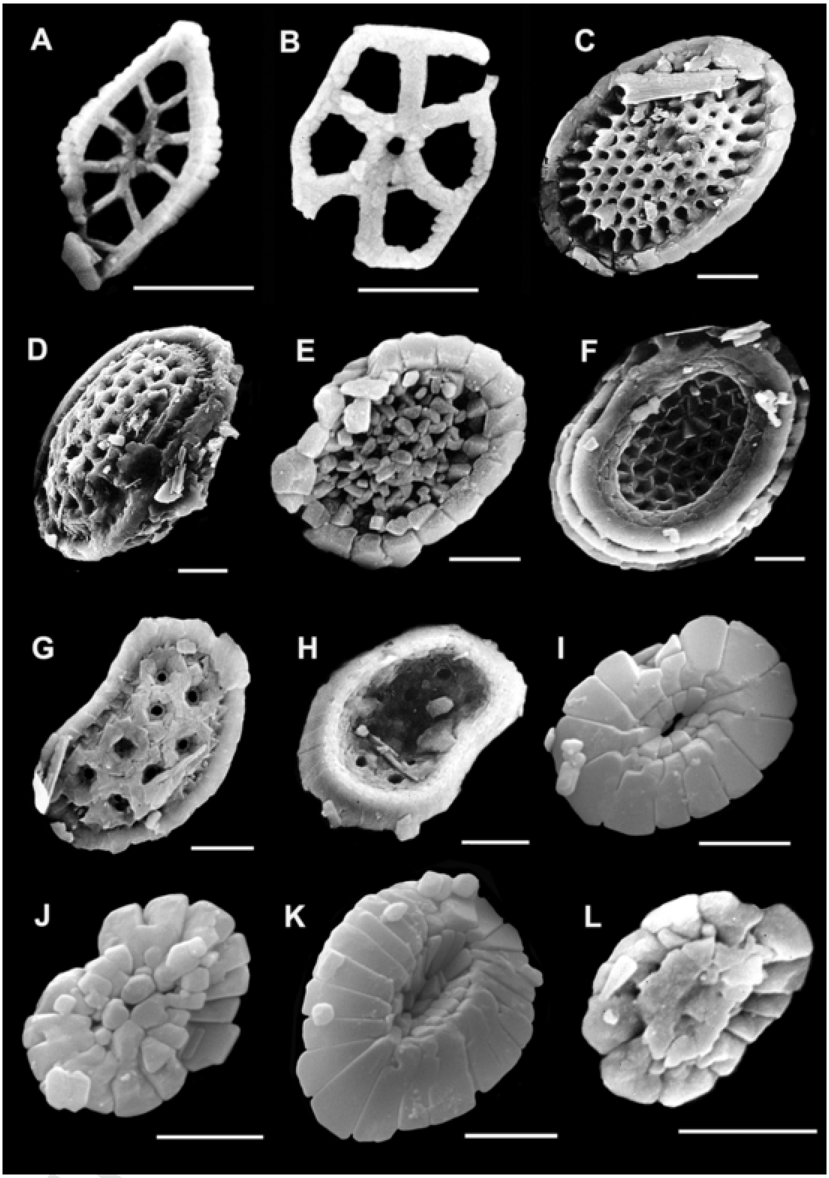
The Turonian Bannovka Formation is represented by sandy chalk with numerous phosphatic nodules, thickness 1–1.2 m (Fig. 4).

The Mozhzhevelovyi Ovrag Formation (Lower Santonian, thickness 8.1 m) contains in its lower part a sponge horizon in otherwise sandy, locally silicified marls. Higher, sandy marls with sponges, inoceramids and belemnites are presented.

The Upper Santonian Mezino-Lapshinovka Formation is represented by two members. Its lower part (thickness 25.5 m) is composed of siliceous marls that become silty towards the top and contain bivalves. The upper part of the formation (thickness 7 m) is represented by siliceous marls alternating with cherty marls that become silty and glauconitic towards the top and contain bivalves and belemnites *Actinocamax verus fragilis* Arkh.

The Lower Campanian Pudovkino Formation (thickness 2.7 m) is represented by unevenly siliceous sandy heavily bioturbated glauconitic greenish gray marls. The lower and middle parts of the formation contain rounded phosphatic fragments (5–12 mm) and numerous sponges. Higher are recorded belemnites *Belemnellocamax mammillatus volgensis* Naidin, *Belemnitella mucronata* (Schloth.) and inoceramids.

Fig. 25 SEM photographs of selected nannofossil species from the Saratov and Belgorod regions. (A) *Zeugrhabdotus spiralis* (Butovo 100 borehole, sample 100/37, Lower Campanian, Maslovka Fm.); (B) *Zeugrhabdotus* sp. (Belgorod section, Belgorod Fm., Upper Campanian, sample 7); (C) *Eiffellithus eximius* (Butovo 100 borehole, sample 100/65, Lower Campanian, Alekseevka Fm.); (D) *Helicolithus anceps* (Belgorod section, Belgorod Fm., Upper Campanian, sample 10); (E) *Helicolithus compactus* (Belgorod section, Belgorod Fm., Upper Campanian, sample 24); (F) *Rhagodiscus angustus* (Klyuchi 2 section, Nikolaevka Fm., Upper Maastrichtian, sample KL2/21); (G) *Rhagodiscus asper* (Belgorod section, Belgorod Fm., Upper Campanian, sample 20); (H) *Rhagodiscus asper* (proximal side; Belgorod section, Belgorod Fm., Upper Campanian, sample 10); (I) *Corollithion exiguum* (Teplovka 3 section, Nikolaevka Fm., Upper Maastrichtian, sample TP3/18); (J) *Cylindralithus serratus* (side-view; Belgorod section, Belgorod Fm., Upper Campanian, sample 11); (K) *Cylindralithus serratus* (general appearance; Belgorod section, Belgorod Fm., Upper Campanian, sample 15); (L) *Calciosolenia fossilis* (Teplovka 3 section, Nikolaevka Fm., Upper Maastrichtian, sample TP3/18). Scale bars 2 μm.



The Upper Campanian Ardym Formation (thickness 8.3 m) is composed by alternating siliceous irregularly calcareous marls and clays with belemnites *Belemnitella langei* Schatsk. and *B. langei minor* Jeletz.

The section ends the Upper Campanian Nalitovo Formation (thickness 14 m), represented by siliceous clays with glauconitic lenses, interlayers and nests in its basal part, as well as with belemnites *Belemnitella licharewi licharewi* Jeletz. and *B. licharewi desnensis* Jeletz.

3.2.2.2 Nizhnyaya Bannovka section

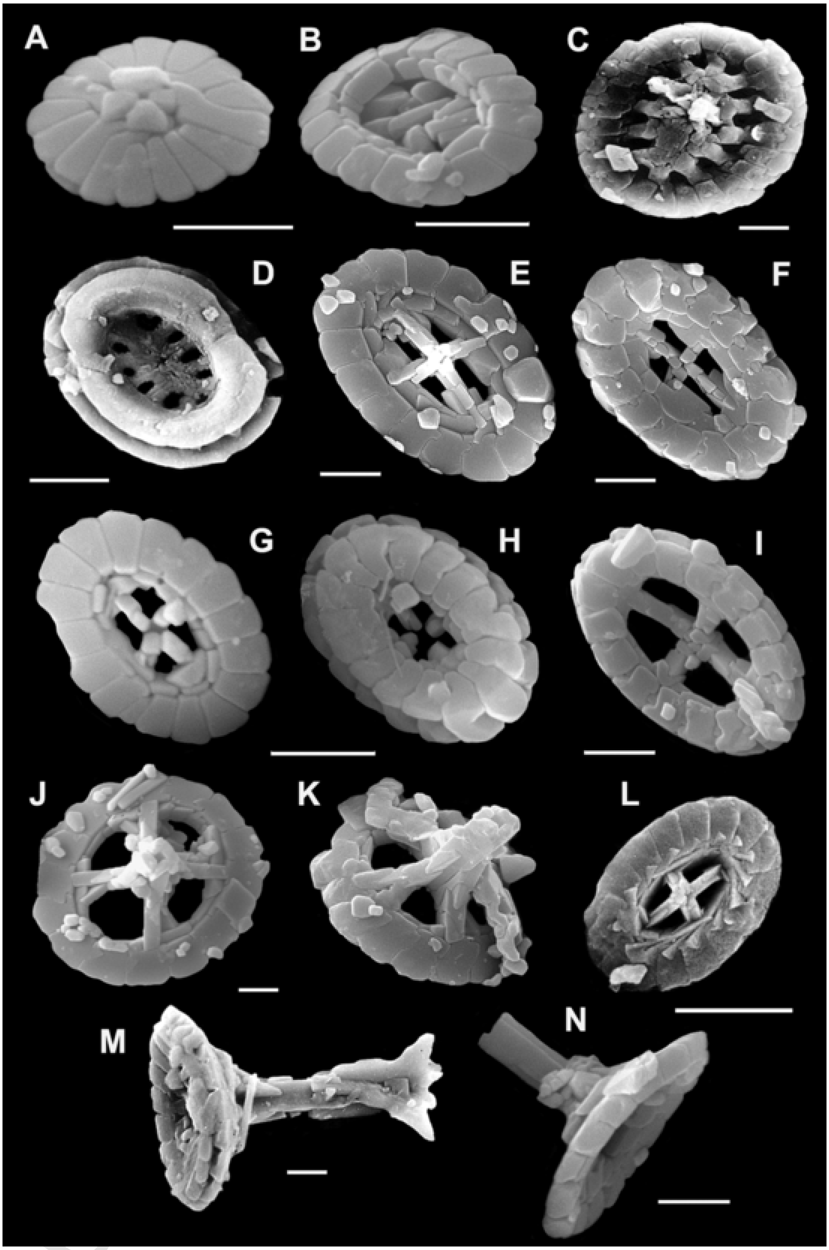
The section is located near the Nizhnyaya Bannovka village on the right bank of the Volga River (Fig. 2) and has been thoroughly described in numerous publications (Akhlestina and Ivanov, 2000; Ivanov and Pervushov, 1999; Olferiev and Alekseev, 2005; Ovechkina, 2004; Vishnevskaya et al., 2014; Guzhikov et al., 2017). The following formations are exposed.

The Cenomanian Melovatka Formation (Bed 1, thickness 19.5 m) is represented by gray-green glauconitic sand (Fig. 5).

The Turonian Bannovka Formation (Bed 2, thickness 10 m) is represented by light gray limestones with numerous inoceramid fragments; higher the limestones become white and chalky with small phosphatic grains.

The Coniacian Volsk Formation (Beds 3 and 4, thickness 9.0 m) is composed of white, sandy chalky marls with inoceramid fragments. At the top, the marls become grayish yellow and slightly silicified (hardground).

Fig. 26 SEM photographs of selected nannofossil species from the Saratov and Belgorod regions. (A) *Rhombolithion rhombicum* (Klyuchi 2 section, Nikolaevka Fm., Upper Maastrichtian, sample KL2/13); (B) *Truncatoscaphus senarius* (Lokh section, Lokh Fm., Lower Maastrichtian, sample L/13); (C) *Cribrosphaerella ehrenbergii* (Teplovka 2 section, Nikolaevka Fm., Upper Maastrichtian, sample TP2/28); (D) *Cribrosphaerella ehrenbergii* (side view; Teplovka 2 section, Nikolaevka Fm., Upper Maastrichtian, sample TP2/28); (E) *Cribrosphaerella ehrenbergii* (Butovo 100 borehole, sample 100/22, Upper Campanian, Maslovka Fm.); (F) *Cribrosphaerella daniae* (proximal side; Klyuchi 1 section, Nikolaevka Fm., Upper Maastrichtian, sample KL1/20); (G) *Nephrolithus frequens* (distal side; Teplovka 2 section, Nikolaevka Fm., Upper Maastrichtian, sample TP2/28); (H) *Nephrolithus frequens* (proximal side; Teplovka 2 section, Nikolaevka Fm., Upper Maastrichtian, sample TP2/28); (I) *Biscutum constans* (Belgorod section, Belgorod Fm., Upper Campanian, sample 19); (J) *Biscutum dissimilis* (proximal side; Belgorod section, Belgorod Fm., Upper Campanian, sample 24); (K) *Biscutum magnum* (Belgorod section, Belgorod Fm., Upper Campanian, sample 19); (L) *Biscutum notaculum* (proximal side; Butovo 100 borehole, sample 100/53, Lower Campanian, Alekseevka Fm.). Scale bars 2 μm.



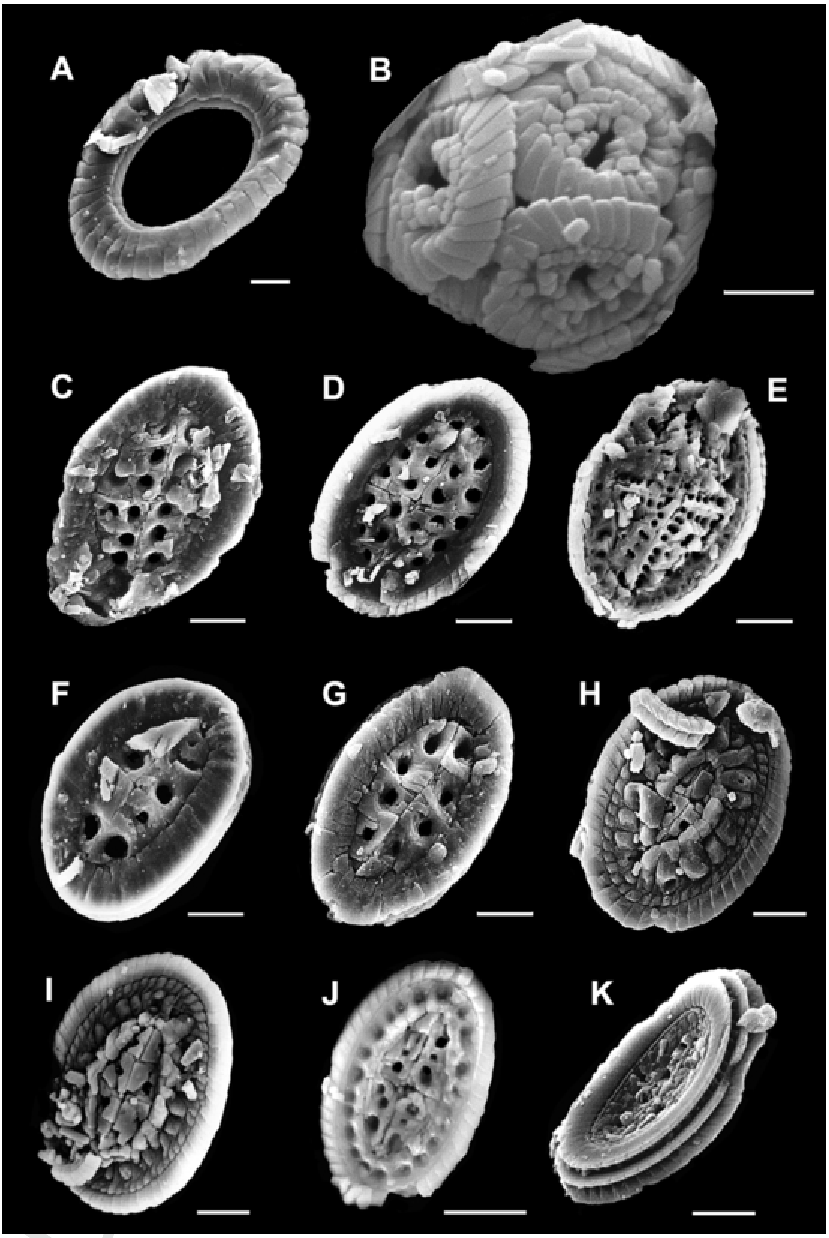
The Lower Santonian Mozhzhevelovyi Ovrag Formation (Bed 5, thickness 30.0 m) is represented by a banded series composed of opoka-like light gray marls and dark clays. At the bottom of the series, there is sponge horizon consisting of siliceous marls and numerous inclusions of phosphorites and phosphatized remains of sponges. In sample 18 just above the sponge horizon, quite rich assemblages of nannofossils and foraminifera have been identified, but there are no nannofossils higher in siliceous marls of the Mozhzhevelovyi Ovrag Fm. and Upper Santonian Mezino-Lapshinovka Fm. (Bed 6, thickness 22.0 m).

3.2.2.3 Lysaya Gora section

The section is located in Saratov (Fig. 2) and has been studied in detail by many researchers (Ivanov and Pervushov, 1999; Ovechkina, 2004, 2007; Vishnevskaya, 2011; Vishnevskaya et al., 2014). The following deposits are exposed from the bottom up in the section. The Cenomanian Melovatka Formation (thickness > 20 m) is represented by, quartz-glauconite, gray-green, fine-grained, silty sand (Fig. 6).

The Lower Santonian Mozhzhevelovyi Ovrag Formation (thickness 8.1 m) is represented in the lowermost part (0.75–1.0 m) by siliceous, sandy, dirty gray marls with abundant glauconite and phosphatic inclusions and phosphatized remains of sponges that form thin irregular interlayers and lenses. Up the section, the terrigenous admixture decreases

Fig. 27 SEM photographs of selected nannofossil species from the Belgorod and Saratov regions. (A) *Discorhabdus cruciatus* (Belgorod section, Belgorod Fm., Upper Campanian, sample 28); (B) *Seribiscutum bijugum* (Belgorod section, Belgorod Fm., Upper Campanian, sample 28); (C) *Cretarhabdus crenulatus* (Teplovka 3 section, Nikolaevka Fm., Upper Maastrichtian, sample TP3/18); (D) *Cretarhabdus crenulatus* (proximal side; Klyuchi 1 section, Nikolaevka Fm., Upper Maastrichtian, sample KL1/43); (E) *Prediscosphaera arkhangelskyii* (distal side; Belgorod section, Belgorod Fm., Upper Campanian, sample 15); (F) *Prediscosphaera arkhangelskyii* (proximal side; Belgorod section, Belgorod Fm., Upper Campanian, sample 15); (G) *Prediscosphaera bukryii* (distal side; Lokh section, Lokh Fm., Lower Maastrichtian, sample L/22); (H) *Prediscosphaera bukryii* (proximal side; Lokh section, Lokh Fm., Lower Maastrichtian, sample L/22); (I) *Prediscosphaera spinosa* (proximal side; Belgorod section, Belgorod Fm., Upper Campanian, sample 26); (J, K) *Prediscosphaera cretacea* (Belgorod section, Belgorod Fm., Upper Campanian, sample 15); (L) *Prediscosphaera stoverii* (Teplovka 2 section, Nikolaevka Fm., Upper Maastrichtian, sample TP2/18); (M) *Prediscosphaera cretacea* (general appearance of rabdolith; Butovo 100 borehole, sample 100/97, Upper Santonian, Noviy Oskol Fm.); (N) *Prediscosphaera* sp. (general appearance of rabdolith; Belgorod section, Belgorod Fm., Upper Campanian, sample 28). Scale bars 2 μm.



and diverse faunal remains (sponges, brachiopods, bivalves and sea urchins) are found. Higher the accumulation of skeletons of siliceous sponges and their fragments, forming the so-called “sponge horizon” is observed. The rest of the formation is composed of clay tripoli with marls, often with thin-shelled bivalves, inoceramids and belemnites *Actinocamax verus* Mill.

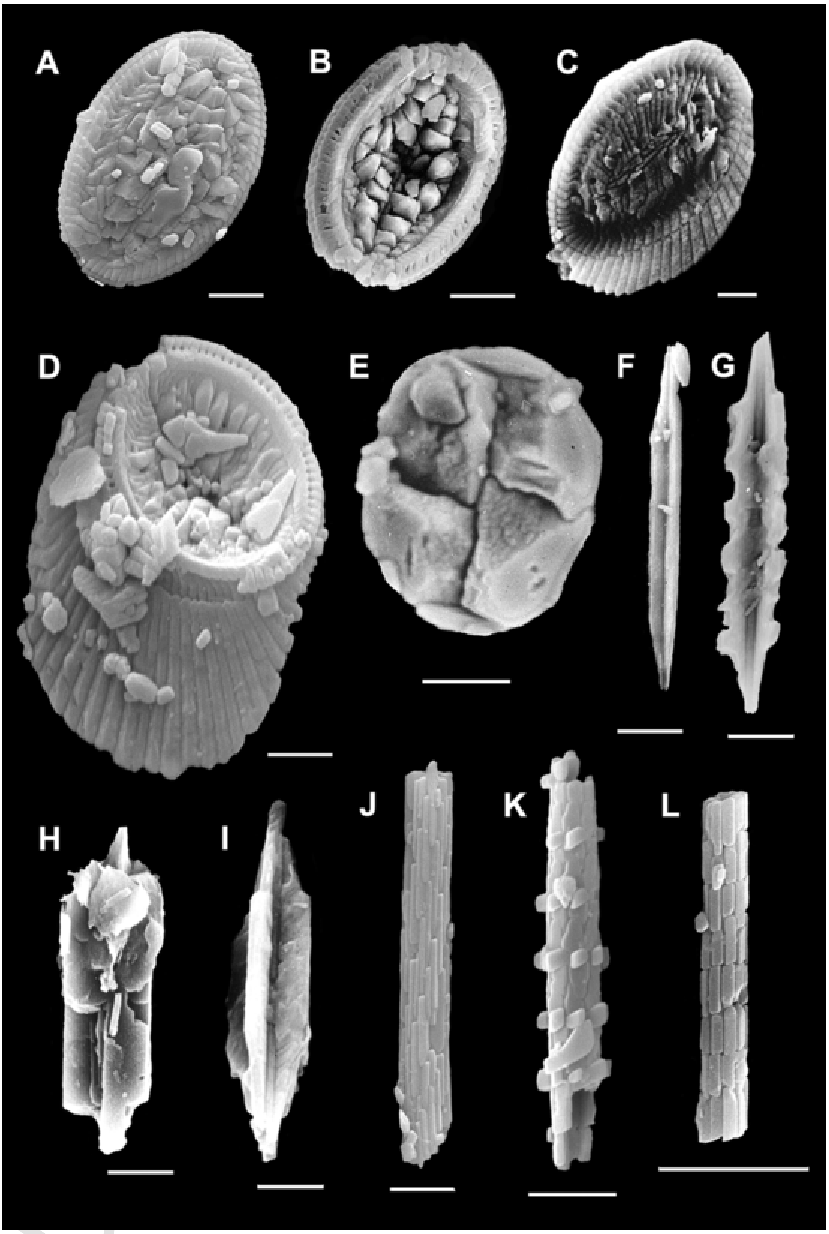
The Upper Santonian Mezino-Lapshinovka Formation (thickness 20 m) is composed of siliceous marls with an uneven degree of calcareousness and with bivalves.

The Lower Campanian Pudovkino Formation (thickness 3 m) is represented by marls, often siliceous and enriched with glauconitic and/or phosphoritic grains, and with abundant sponges, cephalopods and bivalves, including inoceramds and belemnites *Belemnellocamax mammillatus volgensis* Naidin, *Belemnitella mucronata mucronata* Schloth. and etc.

The Upper Campanian Ardym Formation (thickness 4.8 m) is composed of alternating siliceous irregularly calcareous marls and clays with various belemnites *Belemnitella langei langei* Schatz., *B. langei najdini* Kong., *B. langei minor* Jeletz., *Belemnella kursensis* Najd.

The Upper Campanian Nalitovo Formation (thickness 3.7 m) is represented by siliceous clays practically devoid of carbonate material, with rare phosphatic nodules and grains at the base and with belemnites *Belemnella licharewi* Jeletz., *B. desnensis* Jeletz., *B. abbreviata* Mozg.

Fig. 28 SEM photographs of selected nannofossil species from the Belgorod and Saratov regions. (A) *Manivitella pemmatoidea* (Butovo 100 borehole, sample 100/36, Upper Campanian, Maslovka Fm.); (B) *Watznaueria barnesiae* (coccosphera; Belgorod section, Belgorod Fm., Upper Campanian, sample 24); (C) *Arkhangelskiella cymbiformis* (Teplovka 2 section, Nikolaevka Fm., Upper Maastrichtian, sample TP2/18); (D) *Arkhangelskiella specillata* (Lokh section, Nikolaevka Fm., Lower Maastrichtian, sample L/35); (E) *A. specillata* (Teplovka 2 section, Nikolaevka Fm., Upper Maastrichtian, sample TP2/18); (F) *Broinsonia parca parca* (Klyuchi 2 section, Lokh Fm., Lower Maastrichtian, sample KL2/7); (G) *B. p. parca* (Teplovka 2 section, Nikolaevka Fm., Upper Maastrichtian, sample TP2/18); (H) *Broinsonia parca constricta* (Butovo 100 borehole, sample 100/27, Lower Campanian, Maslovka Fm.); (I) *B. p. constricta* (Butovo 100 borehole, sample 100/4, Lower Campanian, Maslovka Fm.); (J) *Broinsonia* sp. (Pudovkino section, sample 22, Lower Campanian, Pudovkino Fm.); (K) *Broinsonia* sp.: (side view of the proximal side; Butovo 100 borehole, sample 100/97, Upper Santonian, Noviy Oskol Fm.). Scale bars 2 μm.



3.2.2.4 Lokh section

The section is located in a quarry and on an adjacent hillside near the Lokh village on the left side of the valley of the Chardym River in the

Saratov Region (Fig. 2). The section was studied by Bondarenko (1975), Alekseev et al. (1999) and Ovechkina (2004, 2007). Two Maastrichtian formations are exposed.

The Lokh Formation (Bed 1, thickness 12 m, samples 1–30) is composed by soft clays, which are grayish brown, strongly calcareous, micaceous, ferruginous and have numerous cracks filled with columnar gypsum (Fig. 7). Numerous burrows and belemnite rostra *Belemnella lanceolata gracilis* (Arkh.) are found.

The Nikolaevka Formation (Beds 2 and 3, total thickness 21.8 m, samples 31–55) is represented by marls, greenish gray, highly sandy and glauconitic in its lower part (samples 31–34, thickness 0.8 m) and yellowish gray, strongly clayey, silty, micaceous and highly carbonate in its upper part (samples 35–55, thickness 21 m). Fragments of bivalves and belemnites *Belemnella sumensis* Jeletz. occur throughout.

3.2.2.5 Klyuchi 1 and Klyuchi 2 sections

The sections are located 0.5 km apart on the southern bank of the Klyuchi River, 1 km upstream of the Klyuchi village, Bazarnyi-Karabulak District (Fig. 2). The sections were described by Alekseev et al. (1999) and Ovechkina (2004, 2007).

Fig. 29 SEM photographs of selected nannofossil species from the Voronezh, Belgorod and Saratov regions. (A) *Gartnerago obliquim* (distal side; Rovenki 614 borehole, Podgornoe Fm., Lower Campanian, sample 614/33); (B) *G. obliquim* (proximal side; Butovo 100 borehole, sample 100/65, Lower Campanian, Alekseevka Fm.); (C) *Kamptnerius magnificus* (Teplovka 2 section, Nikolaevka Fm., Upper Maastrichtian, sample TP2/18); (D) *Kamptnerius magnificus* (Belgorod section, Belgorod Fm., Upper Campanian, sample 24); (E) *Orastrum campanensis* (Belgorod section, Belgorod Fm., Upper Campanian, sample 8); (F) *Lithraphidites carniolensis* (Teplovka 2 section, Nikolaevka Fm., Upper Maastrichtian, sample TP2/18); (G) *Lithraphidites grossopectinatus* (Teplovka 3 section, Nikolaevka Fm., Upper Maastrichtian, sample TP3/18); (H) *Lithraphidites praequadratus* (Klyuchi 2 section, Nikolaevka Fm., Upper Maastrichtian, sample KL2/16); (I) *Lithraphidites quadratus* (Klyuchi 2 section, Nikolaevka Fm., Upper Maastrichtian, sample KL2/16); (J) *Microrhabdulus attenuatus* (Rovenki 614 borehole, Podgornoe Fm., Lower Campanian, sample 614/34); (K) *Microrhabdulus belgicus* (Belgorod section, Belgorod Fm., Upper Campanian, sample 17); (L) *Microrhabdulus decoratus* (Belgorod section, Belgorod Fm., Upper Campanian, sample 23). Scale bars 2 μm.

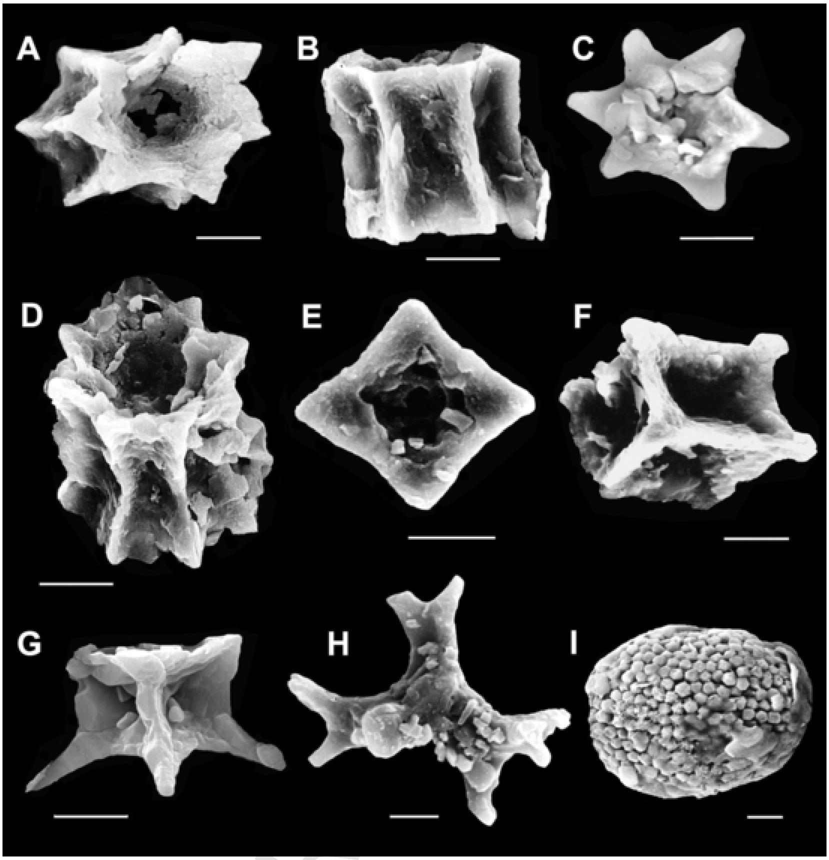
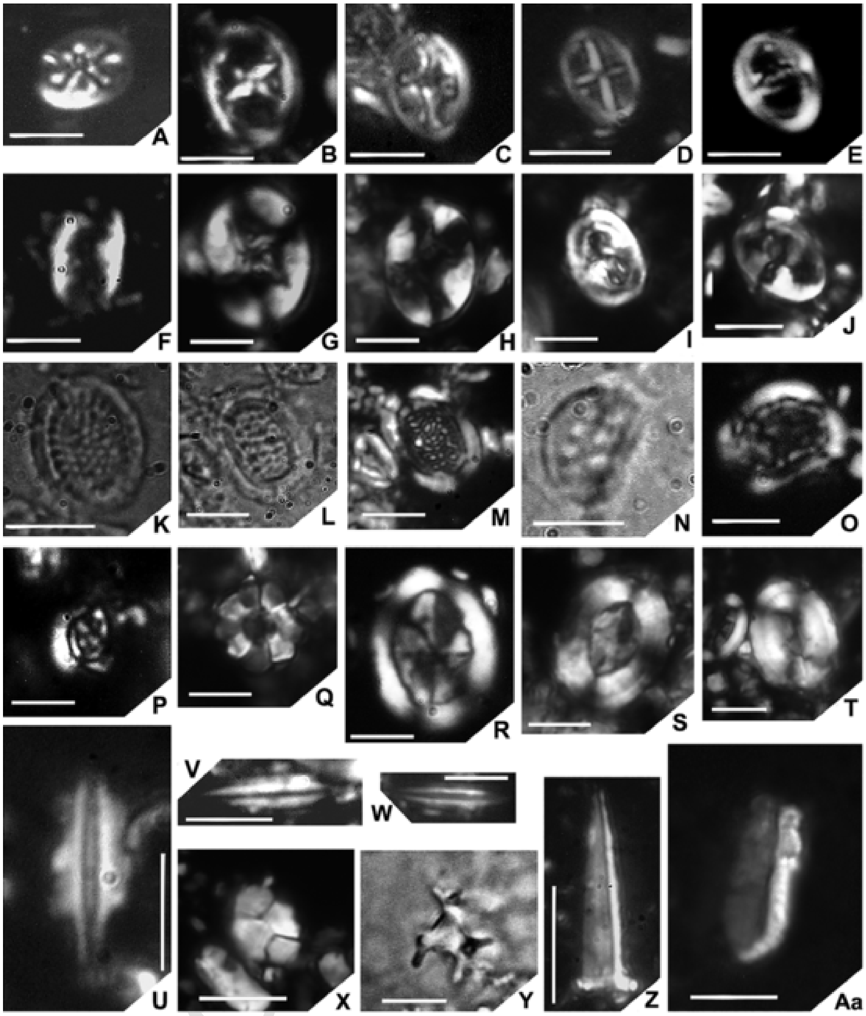


Fig. 30 SEM photographs of selected nannofossil species from the Belgorod and Saratov regions. (A) *Lithastrinus* sp. (general appearance; Lysaya Gora section, sample 5, Lower Campanian, Pudovkino Fm.); (B) *Lithastrinus* sp. (side view; Pudovkino section, sample 23, Lower Campanian, Pudovkino Fm.); (C) *Lithastrinus grillii* (Pudovkino section, sample 22, Lower Campanian, Pudovkino Fm.); (D) *Lithastrinus* sp. (side view; Lysaya Gora section, sample 6, Lower Campanian, Pudovkino Fm.); (E) *Micula concava* (Lokh section, Nikolaevka Fm., Upper Maastrichtian, sample L/53); (F) *Micula staurophora* (Teplovka 2 section, Nikolaevka Fm., Upper Maastrichtian, sample TP2/18); (G) *Micula staurophora* (Belgorod section, Belgorod Fm., Upper Campanian, sample 25); (H) *Marthasterites furcatus* (Butovo 100 borehole, sample 100/76, Lower Campanian, Dubenki Fm); (I) *Thoracosphaera* sp. (Klyuchi 2 section, Nikolaevka Fm., Upper Maastrichtian, sample KL2/18). Scale bars 2 μm.



In Klyuchi 1, the following strata are exposed from the bottom upward.

The Nikolaevka Formation (samples 43–15, total thickness 11.4 m) is represented by marls, which are yellowish, silty, platy, chalky with *Zoophycos* traces at the bottom (Bed 1, samples 43–18, thickness 11.2 m), and greenish gray, with dark gray spots of silicification and chalk fragments in the roof (Bed 2, samples 17–15, thickness 0.15 m) (Fig. 8).

The Paleocene Syzran Formation (Bed 3, samples 14–1, thickness 6 m) is represented by greenish yellow-gray, silty, bioturbated, strongly fractured opokas, with corals, bivalves and gastropods.

In Klyuchi 2, two Maastrichtian formations are exposed (Fig. 9). The Lokh Formation (Bed 1, samples 1–9, thickness 2.8 m) is composed of yellowish gray, highly calcareous clays.

The Nikolaevka Formation (Beds 2 and 3, total thickness 12.2 m) is represented by greenish yellow, oily clays with a phosphatic horizon at the bottom (Bed 2, samples 10–13, thickness 1 m) with belemnites *Belemnella sumensis praearkhangelskii* (Naidin) and by light yellow-gray strongly fractured marls, with glauconitic grains at the bottom and with traces *Zoophycos* and belemnite rostra *Neobelemnella kazimiroiviensis* (Skol.) (Bed 3, samples 14–36, thickness 11.2 m).

No contact with the Paleocene is visible in this section.

3.2.2.6 Teplovka 2 and Teplovka 3 sections

The sections are located in a steep ravine on the left bank of an unnamed stream that flows into the Chardym River, 1 km from the Saratov–Novye Burasy highway (Fig. 2). Both sections were studied by Alekseev et al. (1999) and Ovechkina (2007).

In both sections, the clayey rocks of the Upper Albian Paramonovo Formation are transgressively overlain by the Upper Maastrichtian Nikolaevka Formation (Figs. 10 and 11) represented by light gray, silty, micaceous marls with glauconitic grains at the bottom (thickness 4–6 m), followed by glauconitic greenish gray, clayey, strongly silty sandstone (0.5 m) and red mottled clay (0.07 m) in Teplovka 2. The Cretaceous deposits are overlain by yellow-gray opokas of the Palaeogene Syzran Formation.

3.2.3 Voronezh region

3.2.3.1 Podgornoe 170 section

The section is located 1.2 km WNW of the railway Podgornoe station in the quarry Podgornoe (Fig. 2). The outcrop was described by Olferiev in 1998 (unpubl. materials) and Ovechkina (2007). The following strata are exposed from the bottom upwards.

The Podgornoe Formation (Bed 1, samples 25–23, thickness 3.0 m) is composed of gray to light gray marls, occasionally bioturbated and with gypsum concretions (Fig. 13).

The Boguchar Formation (Beds 2 and 3, total thickness 17.5 m) is represented by homogeneous, and denser compared to underlying marls of the Podgornoe Fm., gray to light gray occasionally bioturbated marls with belemnites *Belemnitella mucronata alpha* Schat. and *Belemnitella* sp. (Bed 2, samples 22–12, thickness 10 m) and gray, weakly bioturbated marls with bivalves and belemnites *Actinocamax* cf. *laevigatus* Arkh. (Bed 3, samples 11–5, thickness 7.5 m).

The Alekseevka Formation (Beds 4 and 5, total thickness 6 m) is represented by less clayey compared to the underlying deposits, lighter, indistinctly platy and slightly ferruginous marls with belemnites *Belemnitella* cf. *praecursor* Stoll., *Belemnitella* sp., *Belemnitella mucronata alpha* Schat. (Bed 4, samples 4–2, thickness 4.5 m) and by gray strongly weathered marls (Bed 5, sample 1, thickness 1.5 m).

3.2.3.2 Podgornoe 171 section

The section is located 4.2 km WNW of the railway station Podgornoe in the quarry Podgornoe (Fig. 2). The outcrop was described by Olferiev in 1998 (unpubl. data) and subsequently published by Ovechkina (2007). The following strata are exposed from the bottom upwards.

The Chernyanskoe Formation (Bed 1, sample 40, thickness 2.0 m) is represented by white soft chalk with abundant and diverse inoceramids (Fig. 12).

The Tolucheevka Formation is represented by three beds, with a thin (2–3 cm) layer of ferruginous and weakly phosphatized chalk, followed by highly calcareous slightly siliceous massive marls (Bed 3, samples 39–36, thickness 6 m), and, after 6 m of talus, by chalky light gray marls with indistinct patches of ferruginization (Bed 4, thickness 3.0 m).

The Podgornoe Formation (Beds 5 and 6, samples 35–9, thickness 22.5 m) is composed of white clayey chalk.

The Boguchar Formation (Beds 7 and 8, total thickness 9.5 m) is represented by chalky light gray marls with vague patches of ferruginization (Bed 7, 1.5 m) and strongly calcareous greenish gray marls, with diffused ferruginous streaks (Bed 8, samples 8–1, 8.0 m).

Kolbinskoe 147 section.

The section is located 3 km east of the village of Kolbinskoe on the right bank of the river Black Kalitva, Voronezh Region (Fig. 2). The outcrop was described by Olferiev in 1999 (unpubl. materials) and Ovechkina (2007). The following strata are exposed from the bottom upwards.

The Podgornoe Formation (Bed 1, samples 23–21, thickness 4.0 m) is represented by clayey, light gray, almost white chalk with indistinct burrows (Fig. 14).

The Boguchar Formation (Beds 2–8, samples 20–4, total thickness 17 m) is composed of greenish gray marls, sometimes with clayey interlayers, with ferruginous marks, often bioturbated, with belemnites *Belemnitella* ex gr. *praecursor* Stoll. (Bed 5), *Belemnitella* ex gr. *praecursor* Stoll., *B.* ex gr. *mucronata* (Schloth.) (Bed 7), *Actinocamax* sp. (Bed 8) and isolated bivalves.

The Alekseevka Formation (Bed 9, samples 3–1, thickness 3.0 m) is represented by white soft chalk with belemnites *Belemnitella mucronata* Schloth.

3.2.4 Belgorod Region

3.2.4.1 Borehole Butovo 100

The borehole is located near the village of Butovo, Yakovlevskiy District, Belgorod Region (50°46′N 36°10′E) (Fig. 2). It was described by Ovechkina and Alekseev (2002).

The borehole penetrates mostly marls (162–292 m) and chalky marls (81–162 m) (Fig. 15). The exposed sequence covers the upper part of the Santonian–lower part of the Upper Campanian.

The Noviy Oskol Formation (samples 111–98, 267.8–292 m) is represented by white and light gray dense chalky marls; at the level of 275–277 m an interlayer of light gray bioturbated marls is exposed.

The Dubenki Formation (samples 97–66, 213–267.8 m) consists of light gray silty, micaceous, bioturbated marls, with pyrite passages up to 2 mm in diameter.

The Alekseevka Formation (samples 65–41, 163–212 m) is represented by is represented by gray, soft, micaceous, weakly bioturbated marls, with burrows filled the pyrite.

The Maslovka Formation (samples 40–1, 82–162 m) consists of white and light gray chalky weakly micaceous marls with the finest burrows.

3.2.4.2 Belgorod 167 section

The section is situated in a quarry on the north-eastern outskirts of the Belgorod city (Fig. 2) and has been studied and described by Naidin (1986), Olferiev in 2000 (unpubl. materials) Ovechkina (2007).

The Belgorod Formation (Beds 1–3, samples 28–1, thickness 30 m) is represented by white chalk, sometimes clayey, with various belemnites:

Belemnitella langei najdini Kong., *Belemnitella langei* Schat., *Belemnella pseudolanceolata* (Jeletz.) (Bed 1), *Belemnitella langei najdini* Kong., *Belemnitella langei langei* Schat., *Belemnella pseudolanceolata* (Jeletz.) (Bed 2) and *Belemnitella langei langei* Schat., *Belemnitella minor* Jeletz., *Belemnella pseudolanceolata* (Jeletz.) (Bed 3) (Fig. 16).

3.2.4.3 Rovenki 614 borehole

The borehole is located in the Rovenki village, Belgorod Region (Fig. 2). The borehole was described in detail by Olferiev in 1998 (unpubl. materials) and Ovechkina (2007). The borehole recovers the following formations.

The Tolucheevka Formation (Bed 1, samples 55–48, 87–72 m) is represented by white clayey homogeneous chalk with detritus and shell fragments in the upper part (Fig. 17).

The Podgornoe Formation (Bed 2, samples 47–18, 72.0–41.0 m) consists of light gray to white chalky marls; in the interval 46.5–45.0 m, marls are calcareous, dense and darker. The bottom contact is indistinct.

The Boguchar Formation (Beds 3–5, samples 18–4, 41.0–24.5 m) is represented by light gray calcareous, slightly siliceous, homogeneous marls (Bed 3, samples 18–8, 41.0–32.0 m), gray siliceous silty marls with thin dark branching layers and pyritized sponge imprints at the bottom (Bed 4, samples 8–5, 32.0–27.0 m) and light gray with fine ochre streaks chalky marls (Bed 5, samples 5–4, 27.0–24.5 m).

The Alekseevka Formation (Bed 6, samples 4–1, 24.5–18.5 m) is composed of white soft chalk.

3.2.5 Rostov Region

Several sections in the Rostov Region were studied and described by Morozov (1962), Zaitsev (2000), Ovechkina (2007) and Beniamovskii et al. (2012, 2014).

3.2.5.1 Rossypnoe section

The section near the Rossypnoye is opened in a cliff on the right bank of the Kalitva River, 2.5 km from the Efremovo-Stepanovka village and 1–1.5 km from the Pavlovka village (Fig. 2). The following formations are exposed.

The Belgorod Formation (Beds 1 and 2, samples 1–5, thickness 5.2 m) is represented by light gray to yellowish light gray marls with spots of ferruginization and with very fine glauconitic and black phosphatic grains in Bed 1 and gray spots of silicification and burrows in Bed 2 (Fig. 18).

The Pavlovka Formation (Beds 3 and 4, samples 6–23, thickness 9 m) is composed of greenish gray to light gray marls, with gray spots of silicification and fine glauconitic grains, with belemnites *Belemnitella langei najdini* (?) Kong (Bed 4).

The Sukhodol Formation (Bed 5, samples 24–49, thickness 13.5 m) is represented by greenish gray, silty and thinly micaceous marls with rare glauconitic grains and isolated belemnite (*Belemnitella* aff. *Lanceolata* (Schlot.)) rostrum in sample 49.

The Efremovo-Stepanovka Formation (Bed 6, samples 50–58, thickness 4.0 m) is represented by light gray, silty marls with high clay content, but with no traces of silicification. The Lower Maastrichtian belemnites *Belemnitella lanceolata inflata* (Arkhangelsky) and *Belemnitella lanceolata lanceolata* (Schlotheim) occur in samples 50–52.

3.2.5.2 Efremovo-Stepanovka section

The section is located on the right bank of the Kalitva River, opposite the bridge (near the old farm), 300 m from the abandoned brick factory (Fig. 2). The following formations are exposed.

The Pavlovka Formation (samples 1–3, thickness 1.3 m) is represented by greenish gray, very clayey, micaceous, sandy marls, with abundant very fine dark green glauconitic grains, locally ferruginous, with belemnite rostra of *Belemnitella* spp. and sponges (Fig. 19).

The Sukhodol Formation (samples 4–30, thickness 13.5 m) is composed of yellowish gray, greenish gray to light gray calcareous silty clays with interlayers of non-carbonate, often weakly siliceous, micaceous clays and light gray to greenish gray siltstones, and with belemnite rostra *Belemnella* ex gr. *lanceolata*, *Belemnella lanceolata inflata* (Arkh.) and *Belemnella* sp.

The Efremovo-Stepanovka Formation (Beds 3 and 4, thickness 7.5 m) is represented by light gray to yellowish gray strongly clayey marls, locally with spots of silicification and ferruginization, higher replaced by calcareous clays, at the base with fine glauconitic grains (Bed 3, samples 31–42, thickness 5.7 m), and by yellowish or greenish gray to gray, non-carbonate or weakly calcareous, irregularly silicified, locally opoka-like, silty clays with a layer of highly clayey silty marls in its middle part (Bed 4, samples 43–48, thickness is 1.8 m). Belemnite rostra *Belemnella lanceolata inflata*, *B.* ex gr. *lanceolata* occur at various levels.

The Paleocene Bed 5 (samples 49–52, thickness 0.5 m) is represented by gray, micaceous opoka, very hard and lacking organic remains.

3.2.5.3 Tarasovskii 1 and Tarasovskii 2 sections

The sections are located on the right bank of the Glubokaya River opposite the Tarasovskii village (Fig. 2). Both sections expose the Belgorod and Sukhodol formations, which may be separated by a hiatus (Figs. 20 and 21).

The Belgorod Formation (thickness 6.8–8.2 m) is represented by white to slightly yellowish dense chalk, with numerous ferruginous and film-like dark brown interlayers of manganese oxide, and with belemnites *Belemnitella lanceolata inflata* (Arkh.), *Belemnitella lanceolata gracilis* (Arkh.) (Tarasovskii 1); *Belemnitella langei najdini* Kong., *Belemnitella* ex gr. *langei* (lower part, Tarasovskii 2), *B. langei* cf. *najdini* Kong. (uppermost part, Tarasovskii 2).

The Sukhodol Formation (thickness 1–4 m) is represented by greenish gray marls, with rare very fine mica and unevenly distributed fine glauconitic grains and inclusions of black ferruginous phosphorites 2–2.5 cm in diameter.

4. Results

4.1 Biostratigraphy

4.1.1 Moscow Basin

Borehole Potanino 2 (56°39′N 38°49′E) drilled near the Potanino village, Pereslavskiy District, Yaroslavl Region, penetrates the Upper Albian to the Upper Santonian and Lower Campanian deposits belonging to the Paramonovo, Chernevo, Potanino, Zagorsk, Dmitrov and Tentikovo formations (Fig. 3).

Due to the rarity of nannofossils, some zonal species are found in only one sample, which does not allow us to establish the levels of FOs and/or LOs of species accurately, so some zonal boundaries are drawn conditionally.

In the northern Moscow Basin, the recorded levels of these species cannot be considered their first appearances, therefore a reliable zonal subdivision of this interval is difficult. At high latitudes, the distribution ranges of warm-water species of nannofossils are generally significantly narrowed compared to those in the tropical and subtropical areas.

4.1.1.1 Paramonovo Formation

The formation consists of two members. The lower member contains a rich assemblage of radiolarians of the Albian *Porodiscus kavilkinensis–Crolanium cuneatum* assemblage, typical for the Paramonovo Fm. of the Moscow Basin, and uncommon calcareous nannofossils; whereas nannofossils are generally extremely rare and radiolarians are absent in the upper member, which may point to the shallowing basin.

Isolated *Eiffellithus turriseiffelii* and *Hayesites albiensis* are found throughout the Paramonovo Fm, starting from its base. *Eiffellithus turriseiffelii* is considered a zonal marker and its first occurrence is fixed at the base of the transitional CC9 Zone of the Late Albian–Early Cenomanian (Perch-Nielsen, 1985; Sissingh, 1977). According to Burnett (1998), the FO of *E. turriseiffelii* marks the lower boundary of the Upper Albian–Lower Cenomanian UC0 Zone as well. The joint presence of *E. turriseiffelii* and *H. albiensis* allows us to establish the Upper Albian UC0a Subzone. This does not contradict the Late Albian age of the Paramonovo Fm. established by foraminifera and radiolarians (Alekseev et al., 1996; Kazintzova and Olferiev, 1997).

The lower member (Bed 11, samples 52–48, depth 81.8–73.5 m) contains a rich assemblage of radiolarians, which may belong to the Albian *Porodiscus kavilkinensis–Crolanium cuneatum* assemblage typical of the Paramonovo Formation of the Moscow Basin.

Calcareous nannofossils were found at the base of the exposed part of the Paramonovo Fm. (sample 52, depth 81.8 m), where isolated *Eiffellithus turriseiffelii* and *Hayesites albiensis* were recorded. These two species were found at the top of the Lower member (sample 48, depth 74.0 m). *Eiffellithus turriseiffelii* is considered a zonal marker and its first occurrence is fixed at the base of the transitional CC9 Zone of the Late Albian–Early Cenomanian (Perch-Nielsen, 1985; Sissingh, 1977). According to Burnett (1998), the FO of *E. turriseiffelii* marks the lower boundary of the Upper Albian–Lower Cenomanian UC0 Zone as well. The joint presence of *E. turriseiffelii* and *H. albiensis* allows us to establish the Upper Albian UC0a Subzone. This does not contradict the Late Albian age of the Paramonovo Fm. established by foraminifera and radiolarians (Alekseev et al., 1996; Kazintzova and Olferiev, 1997).

The middle member of the Paramonovo Fm. presented by clayey silt and contains *E. turriseiffelii* and *H. albiensis* in its base (sample 47, depth 73.0 m). Also at the level of the sample 47 few *Watznaueria barnesiae* appears. The transitional CC9 Zone of the Late Albian–Early Cenomanian by Perch-Nielsen (1985) and the Upper Albian UC0a Subzone by Burnett (1998) are established.

Generally calcareous nannofossils are extremely rare and radiolarians are absent in this member. Perhaps it indicates to shallowing of the basin.

4.1.1.2 Chernevo Formation

The deposits of the Chernevo Fm. overlap the clays of the Paramonovo Fm. with erosion and a hiatus. Olferiev et al. (2000) attributed the Chernevo Fm. to the Turonian. The formation is subdivided into eight beds that are discussed below.

The Early Turonian age of the basal layers of the formation is confirmed by foraminifera *Gavelinella nana* (Akimez) and *Reussella turonica* Akimez. The Middle Turonian age of the overlying part is more precisely dated by the ammonite *Collignoniceras woollgari* (Mantell), belemnites *Goniocamax intermedius* (Arkhangelsky) and bivalve mollusks *Inoceramus lamarcki* Parkinson (Olferiev et al., 2000).

The sandy Bed 8 has yielded only calcareous nannofossils, which are discussed below. The middle part of the clays of Bed 7 contains rare agglutinated foraminifera *Arenobulimina minima* Vassilenko and *A. presli* (Reuss). The diversity of the foraminifera assemblage increases sharply towards the top of Bed 7, with appearing benthic foraminifera with calcareous tests and planktonic foraminifera. The identified assemblage is very similar to the Turonian foraminiferal assemblage of the lower part of the Chernevo Fm. in its stratotype near Chernevo village, Yaroslavl Region (Olferiev et al., 2000).

The Turonian radiolarian assemblage *Pseudoaulophacus (Spongotripus) aculeatus–Stichocapsa pyramidata* or *Dictyomitra napaensis* (Olferiev et al., 2000; Vishnevskaya, 2019; Vishnevskaya and De Wever, 1998) has been also established in Bed 7.

Bed 6 contains the richest foraminifera and calcareous nannofossil assemblages and probably corresponds to the maximum transgression and relative warming of the basin.

The foraminiferal assemblage is dominated by nodosariids *Nodosaria obscura* Reuss, *N. asper* Reuss, *Dentalina communis* d'Orbigny, *D. foliformis* Reuss and planktonic *Hedbergella caspia* (Vasilenko), *H. holrfi*

(Hagn), *H.* aff. *Infracretacea* (Glaessner), *Whiteinella archaeocretacea* (Pessagno) and *W. baltica* (Douglas and Rankin). This assemblage most likely belongs to the interval near the Cenomanian–Turonian boundary–Hedbergella holzli Zone (Beniamovskii, 2008a; Vishnevskaya and Kopaevich, 2020). This is supported by a sharp increase in the number of unkeeled planktonic foraminifera.

The upper member of the Chernevo Fm. (Bed 5, samples 27–20, interval 54.5–46.5 m) contains a noticeably depleted foraminiferal assemblage: *Gyroidinoides nitidus* (Reuss), *Cibicides polyrraphes* (Reuss), *Gavelinella vesca* (N. Bykova) and *Tappanina simplex* (Vassilenko), with isolated *Ataxophragmium initiata* Woloschinova, *Eponides* aff. *Turonicus* Lipnik, *E.* aff. *Karsteni* (Reuss) and *E. coninnus* (Brotzen). The planktonic foraminifera disappear. It is most likely that this interval, with no typical early Turonian foraminifera, can be referred to LC2 (Beniamovskii, 2008a) and the planktonic Hedbergella holzli Zone (Vishnevskaya and Kopaevich, 2020).

Calcareous nannofossils of Bed 8 (sample 34) are very rare, with only *Radiolithus* sp., *Eiffellithus turriseiffelii* and *Watznaueria barnesiae* identified, which allows us to establish the transitional Upper Albian–Lower Cenomanian CC9 Zone according to Perch-Nielsen (1985) or possibly undivided UC0b–c subzones (Burnett, 1998), since *Hayesites albiensis* has not been found.

Up the section, the diversity and abundance of nannofossils is sharply increasing. For the first time in this section, a quite diverse assemblage of nannofossils appears at the bottom of Bed 7 (sample 33, depth 59.5 m): *E. turriseiffelii*, *W. barnesiae*, *Thiersteinia ecclesiastica*, *Ragodiscus angustus*, *Eprolithus floralis*, *Prediscosphaera intercisa*, *Microrhabdulus decoratus*, *Manivitella pemmaioidea* and *Zygodiscus variatus*. *Staurolithites angustus* and *Tranolithus manifestus* are recorded at the level of sample 32.

The nannofossils assemblage reaches its maximum variety in Bed 6 and consists of 18 species in total, with each sample containing 9–12 species and all species from Bed 7 appearing here in addition to *Prediscosphaera cretacea*, *Stradneria crenulata*, *Quadrum gartneri*, *Lithastrinus moratus*, *Chiastozygus litterarius*, *Lithraphidites camiolensis*, *Ahmuellerella octoradiata*, *Zeugrhabdotus diplogrammus* and *Radiolithus planus*.

In Bed 5, the nannofossil assemblage becomes impoverished, although in general it continues to be the same as in Bed 6. Rare *Zeugrhab-*

dotus embergerii (sample 27) and *Kamptnerius magnificus* (sample 25) are recorded.

The interval of samples 33–32 (depths 59.5–58.0 m; Bed 7) belongs to the Late Cenomanian CC10 Zone, which lower boundary is fixed by the FO of *M. decoratus* (sample 33) and the upper boundary is marked by the FO of *Quadrum gartneri* (sample 31). Since the latter species is found in only one sample and we cannot accurately establish the level of its FO, the upper boundary is drawn conditionally in this section.

The interval of samples 31–20 (depths 57.0–47.2 m; Beds 6 and 5) corresponds to the Early–Middle Turonian CC11 Zone. This zone is established from the FO of *Q. gartneri* to the FO of *Lucianorhabdus maleformis*. In the section, its lower boundary is also conditionally fixed, for *Q. gartneri* is recorded only in sample 31. *Lucianorhabdus maleformis* has not been found in the section, but an important species *Eiffellithus eximius* has been recorded in sample 19. Many authors (Čepek and Hay, 1969, 1970; Perch-Nielsen, 1985; etc.) use the FO of *E. eximius* as the top marker of the Quadrum gartneri CC11 Zone. Perch-Nielsen (1979, 1985) considers *L. maleformis* and *E. eximius* interchangeable markers for the base of CC12 Zone; thus, the upper boundary of CC11 Zone in borehole Potanino 2 is tentatively drawn at the appearance of *E. eximius* in sample 19.

According to the Burnett's (1998) scheme, the interval of the samples 33–32 (depths 59.5–58.0 m; Bed 7) may belongs to the undivided UC3–UC6 Zones of the basal Middle–Upper Cenomanian to Lower Turonian. The base of UC3 Zone is fixed by the FO of *Lithraphidites acutus* (Burnett, 1998), but in our material this species is absent. However, another important species *M. decoratus* appears in sample 33. According to Perch-Nielsen (1985), the FO of *L. acutus* roughly coincides with the FO of *M. decoratus.* A recent study of nannofossils from North Israel has shown that *M. decoratus* appears slightly below the FO of *L. acutus* (Ovechkina et al., 2019). In borehole Potanino 2, we conditionally draw the lower boundary of UC3 at the level of the FO of *M. decoratus*. The main zonal markers of UC4–UC5 Zones have not been found here due to the general rarity of nannofossils.

The interval of samples 31–20 (depths 57.0–47.2 m; Beds 6, 5) can be attributed to the Lower Turonian UC7 Zone, which lower boundary is defined by the FO of *Q. gartneri* and upper boundary by the FO of *E. eximius*. In borehole Potanino 2, rare specimens of *Q. gartneri* have been recorded only in sample 31, so we conditionally draw the lower boundary at this level. The upper boundary of the zone is fixed by rare *E. eximius* in sample 19.

4.1.1.3 Potanino Formation

The siltstones of the *Potanino Fm* (samples 19–15, depths 46.4–44.4 m) contain a fairly diverse foraminifera assemblage of the Coniacian age, among which noteworthy are the newly emerging planktonic *Hedbergella caspia* (Vassilenko) and *H. holzli* (Hagn), and diverse benthic foraminifera (Supplementary Material in the online version at https://doi.org/10.1016/bs.sats.2021.09.004). The Coniacian benthic foraminifera assemblage *Gavelinella moniliformis–Bagginoides* quadrilobus has been established.

Radiolarians from borehole Potanino 2 are similar to associations from borehole Chernevo 102 drilled about 30 km southeast of Potanino2, and are referred to the Upper Turonian–Coniacian *Orbiculiforma persenex–Archaeospongoprunum rumseyensis* assemblage belonging to the Turonian–Lower Coniacian *Alievium superbum* zone (Pessagno, 1976; Vishnevskaya, 2010, 2019).

Nannofossils of the Potanino Fm. are poorly preserved, but very diverse, and almost all species pass here from the Chernevo Fm. The appearance of *Eiffellithus eximius* in sample 19, and *Zygodiscus erectus* and *Grantarhabdus coronadventis* in sample 18 should be noted. *Lithastrinus septenarius* has been recorded in the upper part of the formation in samples 15 and 16. The interval of 46.4–44.4 m corresponds to CC12–CC15 Zones of the Late Turonian/early Early Coniacian to late Early Santonian, which cannot be divided further due to the absence of the zonal markers. The base of the CC12 Zone is defined by the FO of *L. maleformis* (Perch-Nielsen, 1985), but is conditionally marked in the section by the appearance of *E. eximius* in sample 19 (see discussion above). The main zonal markers of CC13–CC15 have not been found in the section; the top of the CC15 is defined by the FO of *Lucianorhabdus cayeuxii* (Perch-Nielsen, 1985). This species has not been recorded in our material; however, another zonal marker, *L. septenarius*, is present. Perch-Nielsen (1979, 1985) accepts that the FO of *L. cayeuxii* coincides with the LO of *L. septenarius.* The LO of L. *septenarius* is fixed in sample 14, and the upper boundary of CC15 is conditionally drawn at this level.

According to the Burnett (1998), the lower part of the Potanino Fm. (samples 19–17) belongs to the Lower–Middle Turonian UC8 Zone, the base of which is fixed by the FO of *E. eximius* in sample 19 and its top is marked by the FO of *L. septenarius* in sample 16. Up the section, the interval of samples 16–15 corresponds to the undivided UC9–UC11 Zones of the Middle Turonian/Lower–Middle Coniacian to Upper Coniacian/Lower? Santonian due to the presence of *L. septenarius*. The lower boundary of the UC9 is fixed by the FO of *L. septenarius* and its LO marks the top of UC11 Zone. No other zonal species of UC10–UC11 Zones have been found.

Lithastrinus septenarius appears in CC13, the lower boundary of which is placed in the upper part of the Lower Coniacian (Perch-Nielsen, 1985); thus, our nannofossil records confirm the Early Coniacian age of the Potanino Fm. established by foraminifera. However, Burnett (1998) noted the FO of *L. septenarius* in the Middle Turonian, which makes it difficult to compare the data.

4.1.1.4 Zagorsk Formation

Sandstones of the Zagorsk Fm (samples 14–8, depths 44.3–38.1 m) contain neither foraminifera nor calcareous nannofossils. Rare radiolarians found in the upper part of this formation in Potanino 2 are similar to the radiolarian assemblage of borehole Chernevo 102 and belong to the Coniacian *Alievium praegallowayi* zone (Pessagno, 1976; Vishnevskaya, 2010, 2019).

4.1.1.5 Dmitrov Formation

The glaukonite sandstones of the *Dmitrov Fm* (sample 7, depths 37.6–38.1 m) have yielded the Santonian radiolarian assemblage *Orbiculiforma quadrata–Rhopalastrum attenuatum* (Kazintsova and Vishnevskaya, 2003) or *Orbiculiforma quadrata–Pseudoaulophacus floresensis* of the Santonian *Alievium gallowayi* zone (Pessagno, 1976; Vishnevskaya, 2010, 2019). Nannofossils are absent.

4.1.1.6 Tentikovo Formation

Foraminifera are absent from the rotten stones of the Tentikovo Fm. (samples 6–1, depths 37.6–30.5 m), but radiolarians are very diverse and belong to the Lower Campanian assemblage *Crucella espartoensis–Archaeospongoprunum salumi* that was distinguished in Borehole Potanino 2 (Kazintsova and Vishnevskaya, 2003; Vishnevskaya, 2019).

Calcareous nannofossils are found only at the base of the Tentikovo Fm. in glauconite-enriched deposits. Isolated *Watznaueria bamesae* and *Calculites obscurus* have been recorded insample 7 (37.5 m). According to Perch-Nielsen (1985), the first appearance of *C. obscurus* marks the lower boundary of the transitional Santonian–Campanian zone CC17. The presence of *C. obscurus* in our section suggests that the deposits of the Tentikovo Fm. are not older than the Late Santonian.

4.1.2 Saratov Region

4.1.2.1 Pudovkino section

In sandy marls of the Mozhzhevelovyi Ovrag Fm. (samples 5–9, depths 63.5–57.5 m) the foraminiferal assemblage belongs to the Early Santonian Gavelinella infrasantonica (Ovechkina, 2007) (Fig. 4), later Late Coniacian–Early Santonian Gavelinella infrasantonica–Stensioeina exsculpta exsculpta Zone (Olferiev et al., 2008).

In siliceous marls of the Mezino-Lapshinovka Fm. (samples 10–19, depths 57.5–25.0 m) the foraminiferal assemblage is extremely poor and does not allow establishing its zonal affiliation, but it is most likely to be Late Santonian.

The foraminiferal assemblage of the Pudovkino Fm. (samples 21–23, depths 24.3–22.3 m) belong to the Lower Campanian Cibicidoides temirensis (LC13) Zone (Ovechkina, 2007; Vishnevskaya et al., 2014).

Calcareous marls and clays of the Ardym Fm. (samples 24–27, depths 22.3–14.0 m) have yielded two foraminiferal associations that correspond to the Cibicidoides temirensis Zone in the lower part of the formation and the Brotzenella monterelensis Zone in its upper part.

Marls of the Mozhzhevelovyi Ovrag Fm. in the middle and upper parts are strongly siliceous and contain the *Alievium praegallowayi* radiolarian assemblage, which points to the Coniacian–Lower Santonian Alievium praegallowayi Zone of the Californian zonal scale (Pessagno, 1976) based on the presence of the index species *Alievium praegallowayi* Pessagno. Records of characteristic species *Crucella cachensis* Pessagno and *Dumitricaia maxwellensis* Pessagno (Turonian–Coniacian, rarely to early Santonian) in samples 7 and 8, and *Archaeospongoprunum rumseyensis* Pessagno and *Pseudoaulophacus praefloresensis* Pessagno (Coniacian–Early Santonian) in sample 9 suggest the Coniacian–Early Santonian age (Fig. 22).

In the middle part of the Mezino-Lapshinovka Fm. (samples 10, 12, 13, and 15), a radiolarian assemblage with *Euchitonia santonica* Lipman and *Pseudoaulophacus praefloresensis* has been identified, which age is identified as the early Late Santonian due to the disappearance of *Orbi-*

culiforma vacaensis Pessagno and *Archaeospongoprunum rumseyensis* (Fig. 22).

In the upper part of the Mezino-Lapshinovka Fm. (samples 16, 17), the *Pseudoaulophacus floresensis* assemblage has been established with abundant pseudoaulophacids (*Alievium gallowayi* (White), *A. murphyi* Pessagno). The presence of the index species of the Californian radiolarian Alievium gallowayi Zone (Santonian) established by Pessagno (1976), as well as the disappearance of *Archaeospongoprunum bipartitum* Pessagno, suggest the Late Santonian age of the assemblage.

In the uppermost part of the Mezino-Lapshinovka Fm. (samples 18, 19), a radiolarian assemblage with the index species *Crucella espartoensis* Pessagno has been identified. In California, the Crucella espartoensis Zone corresponds to the Lower Campanian foraminiferal Archaeoglobigerina blowi Subzone (Pessagno, 1976). The assemblage contains *Archaeospongoprunum salumi* Pessagno and *A. andersoni*, which are characteristic of the Early Campanian (Fig. 22).

In Pudovkino Fm, the radiolarian assemblage with *Prunobrachium mucronatum* (Lipman) has been identified in samples 22 and 23. In addition to prunobrachids, *Prunobrachium angustum* (Lipman), *P. crassum* (Lipman) and abundant orbiculiformids characteristic for the Campanian are present here: *Orbiculiforma australis* Pessagno, *O. sacramentoensis* Pessagno, *O. sempiterna* Pessagno. The presence of *Archaeospongoprunum hueyi* Pessagno allows to limit the age of the deposits to the end of the Early–beginning of the Late Campanian.

In the Pudovkino section in the interval 23.4–22.5 m near the top of the glauconitic bed, Kazintsova (2000) proposed to distinguish the Upper Campanian *Prunobrachium articulatum* assemblage or *Prunobrachium angustum* assemblage, based on the similarity of its species composition to the *P. angustum* assemblage from the Lysaya Gora section (Saratov Region) (Olferiev and Alekseev, 2005).

The taxonomic composition of the nannofossil assemblage in the Pudovkino section is rather poor and includes 31 species (Fig. 4) with generally moderate and good in some intervals preservation.

Common *Watznaueria barnesiae*, *Prediscosphaera cretacea*, *Eiffellithus turriseiffelii*, *Micula staurophora*, *M. concava* and less common *Retecapsa crenulata*, *Lithraphidites carniolensis*, *Tranolithus orionatus*, *Microrhabdulus decoratus*, *Staurolithites angustus*, *Ahmuellerella octor-*

adiata, *E. eximius*, *Zeugrhabdotus diplogrammus*, *Kamptnerius magnificus* occur throughout almost the entire section.

The lowermost sample 1 (Melovatka Fm.) has yielded very rare *Zeugrhabdotus acanthus*, *Watznaueria barnesiae* and *R. crenulata*. The last two species have a wide stratigraphic range of distribution, but the FO of *Z. acanthus* is recorded at the base of the Cenomanian (Burnett, 1998; Young et al., 2021). It is impossible to distinguish an exact nannofossil zone here, but most likely the deposits are Cenomanian.

The interval of samples 2–4 (Bannovka Fm.) belongs to the Late Turonian–early Early Coniacian CC12 Zone on the basis of the presence of L. *maleformis* in sample 2. The FO of this species is fixed at the base of the CC12 Zone (Perch-Nielsen, 1985). The lowermost sample of the Bannovka Fm. (sample 2) is characterized by the increased nannofossil diversity. The following species are found here: *Eiffellithus turriseiffelii*, *Pista cretacea*, *S. angustus*, *T. orionatus* (appear in the Albian–Cenomanian); *Anasterias octoradiata* and *M. decoratus* (appear in the Cenomanian); and *Th. ecclesiastica* and *L. maleformis* (appear in the Lower Turonian). It is impossible to distinguish the exact zone, but we can assume that this sample is most likely of the Early Turonian age.

The interval of samples 3–4 (Bannovka Fm.) corresponds to the Lower–Middle Turonian UC8 Zone due to the FO of *Eiffellithus eximius* in sample 3. The FO of *Quadrum gartneri* is also recorded in the sample 3.

Most of the lower part of the section (samples 5–19; Mozhzhevelovyi Ovrag Fm. and Mezino-Lapshinovka Fm.) refers to the Upper Santonian CC16 Zone, since the assemblage contains the zonal marker *L. cayeuxii*, which FO is fixed the base of the CC16 Zone (Perch-Nielsen, 1985).

The interval of samples 20–22 (most of Pudovkino Fm.), belongs to the undivided Lower Campanian CC18b–c Subzones based on the presence of *Br. parca constricta* in sample 20, the FO of this species fixes the lower boundary of the CC18b Subzone. It is impossible to distinguish the CC18a Subzone due to the absence of the zonal species *Br. parca parca*. It is also impossible to establish the CC18c Subzone, since *Ceratolithoides verbeekii*, which FA marks the base of CC18c, is missing.

The upper part of the section (samples 23–27; uppermost part of Pudovkino Fm., Ardym Fm. and Nalitovo Fm.) corresponds to the Upper Campanian CC19 Zone, which base is fixed by the LO of *Marthasterites furcatus* in sample 23.

According to the Burnett's (1998) scheme, some intervals can be subdivided in more detail. The Melovatka Fm. (sample 1) is characterized by a very impoverished nannofossil assemblage (see explanation above), which does not allow us to establish the exact zone. However, the presence of *Zeugrhabdotus acanthus*, which appears at the bottom of the Cenomanian (Burnett, 1998; Young et al., 2021), suggests the Cenomanian age.

Higher, the interval of samples 5–16 (Mozhzhevelovyi Ovrag Fm. and most part of Mezino-Lapshinovka Fm.) refers to the undivided interval of UC11c–UC12 (Sub) Zones of the Upper Coniacian–Lower Santonian/ Lower Santonian–lower Lower Campanian. The FO of *L. cayeuxii* in sample 5 marks the lower boundary of the UC11c Subzone. It is impossible to separate this subzone from the UC12 Zone due to the absence of the index species *Lithastrinus septenarius*, last occurrence of which defines the base of UC12.

The interval of samples 17–18 (upper part of Mezino-Lapshinovka Fm.) refers to the lower Lower Campanian UC13a Subzone based on the FO of *Arkhangelskiella cymbiformis* in sample 17. The top of the UC13a Subzone is fixed by the consistent occurrence of *O. campanensis*; however, this species has not been found in this section. For the Boreal Province, Burnett (1998) noted that the level of consistent *O. campanensis* is slightly below the LO of *Eprolithus floralis*; this event has been recorded in sample 19 (uppermost sample of Mezino-Lapshinovka Fm.) and the base of the UC13b Subzone has been conditionally drawn at this level.

The upper part of the section (samples 20–27; Pudovkino and Ardym Fms.) belongs to the lower Lower Campanian UC14b due to the presence of *Br. parca constricta* in sample 20. It is impossible to recognize the UC14a Subzone due to the absence of the zonal species *Br. parca parca*, which FA defines the lower boundary of this subzone; this suggests a possible hiatus in sedimentation.

4.1.2.2 Nizhnyaya Bannovka section

The main part of the section (samples 19–12) contains a quite diverse assemblage of foraminifera.

In the Melovatka Fm., a quite rich foraminiferal assemblage is identified. Bed 1 (sample 19) is characterized by the presence of *Gavelinella cenomanica* (Brotzen), which places it to the Lower–Middle Cenomanian Gavelinella cenomanica Zone (Fig. 5).

A significantly different assemblage is identified in sample 4 (Bed 1), where *Lingulogavelinella globosa* (Brotzen), *Neobulimina numerosa* (Vassilenko) and many representatives of planktonic *Whiteinella* appear. The foraminifera assemblage corresponds to the Upper Cenomanian Lingulogavelinella globosa Zone or the Upper Cenomanian–Lower Turonian Whiteinella archaeocretacea Zone.

In the Bannovka Fm. (Bed 2; samples 17–15), the foraminifera assemblage is dominated by secreted forms, with the important appearance of *Gavelinella moniliformis*, *G. ammonoides*, *Gyroidinoides nitidus*, etc. These representatives allow us to refer this interval to the Middle Turonian Gavelinella moniliformis Zone. The first forms of *Marginotruncana* appear in the assemblage of the planktic foraminifera.

In the Volsk Fm. (Beds 3, 4; samples 14–12), *Reusella kelleri* and *Gavelinella praeinfrasantonica* appear from sample 14. Possibly this interval correlates to the terminal Turonian or the lower part of the Coniacian.

The Mozhzhevelovyi Ovrag Fm. (lowermost part of Bed 5; sample 18) contains an extremely poor foraminiferal assemblage, among which agglutinated forms predominate. The presence of rare representatives of the genus *Osangularia* suggests that the deposits are not older than Santonian.

Within the Lower Campanian Pudovkino and Ardym Fms, the uppermost Campanian Nalitovo Fm. and Maastrichtian Lokh Fm. the distribution of foraminifera, nannofossils and radiolarians, as well as their zonations and correlation are given by Vishnevskaya et al. (2014) and Guzhikov et al. (2017).

In the Nizhnyaya Bannovka section, the nanofossil assemblage is very impoverishment and consists of 21 species (Fig. 5) with mostly poor, sometimes moderate preservation. *Watznaueria barnesiae*, *Eiffellithus turriseiffelii* and *Prediscosphaera cretacea* dominate in the assemblage.

The interval of samples 19, 4, 17 (Melovatka Fm. and lower part of Bannovka Fm.) refers to the Late Cenomanian CC10 Zone based on the presence of *Microrhabdulus decoratus* in sample 19. *Rhagodiscus angustus*, *Zeugrhabdotus diplogrammus*, *Z. spiralis*, *Ahmuellerella octoradiata* and *Prediscosphaera spinosa* appear at the level of sample 4. *Gartnerago obliquim* and *Staurolithites angustus* are recorded in sample 17.

Higher, the interval of samples 16–14 (Bannovka Fm. and lowermost part of Volsk Fm.) corresponds to the Early–Middle Turonian CC11 Zone due to the presence of *Quadrum gartneri* in sample 16, which FO marks the base of this zone. Characteristic Turonian–Coniacian *Thiersteinia ecclesiastica* appears at the level of sample 15.

The upper part of the Volsk Fm. (samples 13–12) belongs to the Late Turonian–early Early Coniacian CC12 Zone due to the finding of *Lucianorhabdus maleformis* in sample 13. The FO of this species is fixed the base of the CC12.

In sample 18 taken immediately above a horizon with sponges at the base of the Mozhzhevelovyi Ovrag Fm., the nannofossil assemblage belongs to the Late Coniacian–Early Santonian CC14 Zone based on the presence of *Micula staurophora*, which FO fixes the lower boundary of the zone.

According to Burnett's (1998) scheme, sample 19 (Melovatka Fm.) conditionally correlates to the UC3 Zone based on the presence of *Microrhabdulus decoratus*. The base of this zone is established by the FO of *Litraphidites acutus*, which is absent in our material. However, Perch-Nielsen (1985) noted that the FO of *M. decoratus* roughly coincides with the FO of *L. acutus*.

The interval of samples 4, 17 (Melovatka Fm. and base of Bannovka Fm.) is conditionally correlated to the upper part of the Upper Cenomanian UC5b Subzone based on the presence of *Ahmuellerella octoradiata*. Burnett (1998) mentioned that the FO of *A. octoradiata* is roughly placed in the upper part of the UC5b, although some researchers place this datum lower in the Cenomanian (Perch-Nielsen, 1979, 1985).

Sample 16 (Bannovka Fm.) is assigned to the Lower Turonian UC7 Zone, which lower boundary is fixed by the FO of *Quadrum gartneri* and upper boundary by the FO of *Eiffellithus eximius*. In the Nizhnyaya Bannovka section, the base of UC7 is drawn quite confidently by the FO of *Q. gartneri* in sample 16. The top of the zone is difficult to establish, since *E. eximius* has not been found; however, *Thiersteinia ecclesiastica* is recorded in sample 15, the FO of this species is noted at the base of the UC8a Subzone in the Austral Province (Burnett, 1998), so the upper boundary of UC7 conditionally could be drawn at the level of sample 15 by the presence of *Th. ecclesiastica*. Perch-Nielsen (1985) noted that the level of the FO of *Eiffellithus eximius* coincides with the level of the FO of *Lucianorhabdus maleformis* (sample 13) and suggested to use the FOs of *E. eximius* and *L. maleformis* as interchangeable markers for the base of the CC12 (Perch-Nielsen, 1979, 1985).

The uppermost part of the section (sample 18; Mozhzhevelovyi Ovrag Fm.) belongs to the Middle?—Upper Coniacian UC10 Zone based on the presence of *M. staurophora*, which FO is fixed the base of this zone.

4.1.2.3 Lysaya Gora section

Siliceous marls of the Mozhzhevelovyi Ovrag Fm. (sample 2) have yielded the foraminiferal assemblage that belongs to the Lower Santonian Gavelinella infrasantonica Zone (Fig. 6) (Olferiev et al., 2004).

In siliceous marls of the Mezino-Lapshinovka Fm. (sample 3), the foraminiferal assemblage belongs to the Upper Santonian Gavelinella stelligera Zone.

Sandy marls of the Pudovkino Fm. (lower part, sample 4) have brought the foraminiferal assemblage that allows to distinguish the Lower Campanian Gavelinella clementiana clementiana Zone (Ovechkina, 2007) later defined as the Lower Campanian LC12 (Vishnevskaya et al., 2014). Up the section, The Upper Campanian Brotzenella monterelensis Zone has been established in loose glauconitic siliceous marls (sample 5) (Ovechkina, 2007) later renamed as the Upper Campanian LC14 (Vishnevskaya et al., 2014).

In the uppermost part of the Pudovkino Fm. in siliceous marls near the top of the glauconite-rich member, abundant foraminifera *Heterostomella foveolata* (Marssoon), *Arenobulimina puschi* (Reuss), *Neoflabellina praereticulata* Hilterm., *Globorotalites emdyensis* Vass., *Eponides moskvini* (Keller) and *Sitella laevis* (Beissel) have been recorded; they point to the Upper Campanian Globorotalites emdyensis (LC15) Zone.

In the Ardym Fm. the foraminiferal assemblage is represented by *Arenobulimina puschi* (Reuss), *Pseudouvigerina cretacea* Cushman, *Heterostomella foveolata* (Marsson), *Neoflabellina praereticulata* Hilterm. and *Sitella laevis* (Beissel), and belongs to the Upper Campanian Globorotalites emdyensis Zone (Ovechkina, 2004) later defined as the Upper Campanian LC15 (Vishnevskaya et al., 2014).

In Mezino-Lapshinovka Fm. (sample 3), abundant radiolarians have been identified, among which *Alievium gallowayi*, the index species of the Californian radiolarian zone of the Santonian, is present (Fig. 6). Stratigraphically important Late Santonian *Euchitonia santonica* Lipman и *Pseudoaulophacus floresensis* Pessagno are also found.

In the upper part of the Pudovkino Fm. (sample 6), Kazintsova (2000) recorded radiolarians of the Upper Campanian *Prunobrachium* *articulatum* assemblage and Vishnevskaya et al. (2014) recorded the Upper Campanian marker *Prunobrachium articulatum* (Lipman), and other species that constrain age of the assemblage to the early Early Campanian.

At the top of the Ardym Fm. (samples 7 and 8), a radiolarian assemblage with *Spongurus marcaensis* Pessagno is established. The marker species *Eucyrtis cornegiense* Campbell and Clark and *Archaeodictyomitra regina* (Campbell and Clark), as well as *Orbiculiforma campbellensis* Pessagno, *Phaseliforma meganoensis* Pessagno and *Rhombastrum russiense* Vishnevskaya, confirm the Latest Campanian age of the deposits.

The assemblage of nannofossils is rather poor and includes only 31 mostly moderately preserved species (Fig. 6). Common *Eiffellithus turriseiffelii*, *Watznaueria barnesiae*, *Micula staurophora*, *M. concava* and uncommon *Prediscosphaera cretacea*, *P. intercisa*, *Kamptnerius magnificus*, *Cribrosphaerella ehrenbergii*, *Zeugrhabdotus diplogrammus*, *Calculites obscurus*, *Lithraphidites carniolensis*, *Retecapsa crenulata* and *Tranolithus orionatus* occur throughout almost the whole section.

The lower part of the section (samples 2–3; upper part of the Mozhzhevelovyi Ovrag Fm., Mezino-Lapshinovka Fm.) belongs to the transitional Upper Santonian–Lower Campanian CC17 Zone due to the presence of *Calculites obscurus*, which FO marks the base of this zone.

Higher, the interval of samples 4–6 (Pudovkino Fm.) refers to the Lower Campanian CC18 Zone based on the presence of *Br. parca parca* (sample 4), which FO fixes the base of this zone. It is impossible to subdivide CC18 further, since *Br. parca constricta*, which FO defines the base of the CC18b Subzone, is recorded on the same level (sample 6) with the disappearance of *Marthasterites furcatus*, which LO marks the top of the CC18. Also, *Ceratolithoides verbeekii*, which FA defines the base of CC18c, is absent.

The upper part of the section (samples 7–9; Ardym Fm. and Nalitovo Fms) corresponds to the Lower Campanian CC19 Zone based on the disappearance of *M. furcatus* in sample 7.

Accordingto the Burnett's (1998) scheme, the interval of samples 2–3 (upper part of the Mozhzhevelovyi Ovrag Fm. and Mezino-Lapshinovka Fm.) most likely belongs to the UC11c Subzone due to the joint presence of *M. concava* and consistent *C. obscurus*, which are recorded in the middle part of this subzone, near the Coniacian–Santonian boundary (Burnett, 1998). However, the marker species *L. cayeuxii*, which FO fixes the base of UC11c is recorder higher in sample 5.

Up the section, the lower Lower Campanian UC14 Zone with subzones can be establish. The interval of samples 4–5 (Pudovkino Fm.) belongs to the UC14a Subzone based on the presence of *Br. parca parca*. The overlying part (samples 6–9; Ardym and Nalitovo Fms.) refers to the UC14b Subzone duethe presence of *Br. parca constricta* in sample 6.

4.1.2.4 Lokh section

Detailed biostratigraphy of the Lokh, Klyuchi 1 and Klyuchi 2 sections was published elsewhere (Alekseev et al., 1999; Ovechkina, 2007; Ovechkina and Alekseev, 2005).

In clays of the Lokh Fm. (Bed 1, samples 1–30), the foraminiferal assemblage consists of *Globotruncana arca* (Cushman) *Rugoglobigerina rugosa* (Plummer), *Globotruncanella petaloidea* (Gandolfi), *Bolivina incrassata* Reuss, *B. decurrens* Ehrenberg and *Bolivinoides draco miliaris* Hilt. and Koch. The composition of the foraminiferal assemblage indicates the Lower Maastrichtian Neoflabellina reticulata Zone (Fig. 7).

The foraminiferal assemblage from marls of the Nikolaevka Fm. (Bed 2, lower part of Bed 3; samples 31–44) includes *Hedbergella monmouthensis* Olsson, *Bolivinoides draco draco* (Marss.), *Bolivina crassa* Vas. and *Globotruncanella petaloidea* (Gand.). The assemblage is typical for the Lower Maastrichtian Bolivinoides draco draco Zone. *Spiroplectammina kasanzevi* Dain and *Brotzenella praeacuta* (Vas.) appear higher, at the level of 19 m from the base of the Nikolaevka ka Fm., and mark the Upper Maastrichtian Brotzenella praeacuta—Hanzawaia ekblomi Zone.

A rather scarce nannofossil assemblage consists of 46 species (Fig. 7). The preservation of nannofossils is good in the lowermost part of the section (samples 1–3), but it worsens higher up due to secondary alteration. Abundant *Arkhangelskiella cymbiformis*, *Cribrosphaerella ehrenbergii*, *Watznaueria barnesiae*, *Eiffellithus turriseiffelii*, *Micula staurophora*, *Prediscosphaera grandis* and *Microrhabdulus decoratus* distribute throughout the whole section. The assemblage is characteristic of the Maastrichtian, as indicated by the abundant *Arkhangelskiella cymbiformis*, *A. specillata* and *Cribrosphaerella ehrenbergii*.

The lower part of the Lokh Fm. (samples 1–20, 7.3 m) belongs to the transitional latest Campanian–Early Maastrchtian CC23a Subzone based on the constant presence of *Br. parca constricta*, which LO is observed in sample 20. Isolated specimens of *Br. parca constricta* occur even slightly higher in samples 25, 30 and 31; however, there they are considered to be redeposited, since they are exceptionally rare and heavily dissolved. Moreover, single specimens of *Br. parca constricta* are also found in the basal sandstone of the Nikolaevka Fm., where they are clearly redeposited as a result of erosion of older strata.

The upper part of the Lokh Fm. (samples 21–29) is referred to the undivided interval of the Lower Maastrichtian CC23b Subzone and CC24 Zone, due to the absence of *Tranolithus orionatus* and the presence of *Reinhardtites levis* (samples 21, 22, 29), the LO of the latter marking the top of CC24. *Reinhardtites levis* is recorded for the first time in sample 20, but this cannot be considered as its FO, since this species is very rare in the Lokh section. Burnett (1998) noted the relative rarity of *R. levis* in the Boreal Region and recorded its FO at the base of Subzone CC22b.

In the interval of samples 31–55 (Nikolaevka Fm., Beds 2, 3), the nannofossil assemblage consists of 36 species in the lower part of the Nikolaevka Fm. (Bed 2) and is reducing to 31 in the upper part (Bed 3). The entire interval can be assigned to the Upper Maastrichtian CC25a Subzone due to the absence of *Reinhardtites levis* and *Lithraphidites quadratus*. The FA of the latter is marked the base of the CC25b Subzone. *E. parallelus* appears in the sample 40, *Prediscosphaera bukryii* disappears in the sample 41.

According to the Boreal scheme of Burnett (1998), the nannofossil assemblage of the lower part of the Lokh Fm. (samples 1–20) correlates to the upper Lower Maastrichtian UC16 Zone by the presence of *Br. parca constricta*. In the uppermost part of the Lokh Fm. (samples 21–29), the undivided Lower Maastrichtian UC17–UC18 Zones are recognized. The assemblage of the Nikolaevka Fm. (samples 30–55) most likely belongs to the upper Lower Maastrichtian UC19 Zone due to the absence of *R. levis* and *L. quadratus*.

4.1.2.5 Klyuchi 1 section

In the marls of the Nikolaevka Fm. (Beds 1, 2; samples 43–15), a rich foraminiferal assemblage allows to distinguish the uppermost Maastrichtian Brotzenella praeacuta—Hanzawaia ekblomi Zone (Fig. 8) (see Supplementary Material in the online version at https://doi.org/10.1016/bs.sats.2021.09.004).

The nannofossil assemblage consists of 53 species (Fig. 8) with predominantly moderate preservation. Abundant *Arkhangelskiella cymbi-*

formis, *Eiffellithus turriseiffelii*, *Micula staurophora*, *Cribrosphaerella ehrenbergii*, common *Prediscosphaera grandis*, *Watznaueria barnesiae*, *Nephrolithus frequens*, *Prediscosphaera cretacea*, *Lithraphidites carniolensis*, and rare *Kamptnerius magnificus* and *Zeugrhabdotus spiralis* occur throughout the whole section.

In the lower part of the Klyuchi 1 section, the assemblage is essentially identical to the nannofossil assemblage of the upper part of the Klyuchi 2 section and belongs to zone CC26, since *Nephrolithus frequens*is recorded in the lowermost sample 43. Given the proximity of the two sections, which are just 0.5 km apart, they can be correlated more precisely. The FO of *Cribrosphaerella daniae* in sample 39 in Klyuchi 1 corresponds to this datum in sample 31 in the Klyuchi 2 section.

According to Burnett (1998), the interval of samples 43–40 belongs to the undivided Upper Maastrichtian UC20 b–c Subzones based on the presence of *N. frequens* and *L. quadratus* from the lowest sample 43. The interval of samples 39–15 refers tothe UC20d Subzone by the FO of *Cr. daniae*. The subzone UC20c cannot be recognized, since the index species *A. maastrichtiana* that defines the base of this subzone has not been recorded in the section.

Near the erosional top of the Nikolaevka Fm., *Lucianorhabdus cayeuxii*, *Zeugrhabdotus diplogrammus*, *Cretarhabdus crenulatus*, *Braarudosphaera bigelowii* and *Watznaueria biporta* disappear. Most of the species pass into the Paleocene assemblage from the Maastrichtian, but the abundance of nannofossils in the lower part of the Syzran Fm. decreases markedly.

In the Paleogene opokas (samples 14–1), *Thoracosphaera saxea* and *Telesto operculata*—good indicators of unfavorable environments and often very abundant in the basal Paleocene—appear.

4.1.2.6 Klyuchi 2 section

In clays of the Lokh Fm. (Bed 1, samples 1–9), the foraminiferal assemblage consisting of *Rugoglobigerina rugosa* (Plumm.), *Bolivina decurrens* Ehr. and *Hedbergella monmouthensis* Olss. belongs to the Lower Maastrichtian Neoflabellina reticulata Zone (Fig. 9) (Alekseev et al., 1999; Ovechkina, 2007).

In clays of the Nikolaevka Fm. (Bed 2, samples 10–11), the foraminiferal assemblage of *Globotruncnita stuarti* (de Lapp.), *Spiroplectammina kasanzevi* Dain, *Bolivinoides draco draco* (Marss.), *Bolivina incrassata* Reuss, *Globotruncana esnehensis* Nakkady and *G. mariei*

Banner and Blow allows to identify the Upper Maastrichtian Bolivinoides draco draco Zone. Above, at 0.5 m from the base of the Nikolaevka Fm. (samples 12–36) *Sliteria varsoviensis* Gawor-Biedowa, *Brotzenella praeacuta* (Vass.) and etc. appear, which corresponds to the uppermost Maastrichtian Brotzenella praeacuta–Hanzawaia ekblomi Zone.

In the rest part of the Nikolaevka Fm. marls (Bed 3) foraminifera *Hanzawaia ekblomi* (Brotzen), *Planoglobulina brazoensis* Martin, *Pseudotextularia deformis* (Kikoine), *Bolivina crassa* Vas., *Schackoina multispinata* Cush. et Wick. and etc. were identified. This assemblage is typical to the uppermost Maastrichtian Brotzenella praeacuta–Hanzawaia ekblomi Zone.

The nannofossil assemblage of the Klyuchi 2 section is quite rich and consists of 49 species (Fig. 9) with moderate preservation. Abundant *Micula staurophora*, *Cribrosphaerella ehrenbergii*, *Arkhangelskiella cymbiformis*, *A. specillata*, *Eiffellithus turriseiffelii*, *Prediscosphaera grandis*, common *Lithraphidites carniolensis*, *Prediscosphaera cretacea*, *Watznaueria barnesiae*, and rare *Kamptnerius magnificus* and *Zeugrhabdotu spiralis* are found throughout the whole section.

In the interval of samples 1–9 (Lokh Fm.), the nannofossil assemblage is characterized by the presence of *Br. parca constricta* and is essentially identical to the assemblage of the Lokh Fm. in the Lokh section, which makes it possible to recognize the CC23a Subzone here.

Between the Lokh Fm. and the overlying marls of the Nikolaevka Fm., a clay member with a nanofossil assemblage is distinguished, which is similar to the underlying beds and does not allow to identify any certain biozone with confidence. According to the study based on benthic foraminifera (Alekseev et al., 1999), these clays represent a condensed interval covering the upper part of the Lower and lower part of the Upper Maastrichtian. This conclusion is also confirmed by belemnite rostras *Belemnella sumensis praeakhangelskii* Naidin found in talus on the surface of the clay layer, although it is also possible that these rostras were also washed out from the base of the overlying sediments.

The marls of the Nikolaevka Fm. (samples 14–36) are characterized by the presence of *Nephrolithus frequens*, *Lithraphidites quadratus*, *Eiffellithus parallelus* and *Cribrosphaerella daniae*. The first two species appear directly at the base of the formation, whereas *C. daniae* has been first recorded higher (sample 31). The assemblage with *N. frequens* is characteristic of the Upper Maastrichtian CC26 Zone.

According to the Burnett's (1998) scheme, the lower part of the section (samples 1–9; Lokh Fm.) belongs to the Lower Lower Maastrichtian UC16 Zone based on the presence of *Br. parca constricta* and the absence of *R. levis* and *L. quadratus*.

Nephrolithus frequens and *L. quadratus* are recorded from the base of the marls from sample 14. This indicates that these marls are not older than Subzone UC20b. Thus, the interval of samples 14–30 (lower part of Nikolaevka Fm.) refers to the undivided interval of the Upper Maastrichtian UC20b–c Subzones due to the FO of *N. frequens* and the presence of *L. quadratus*. The nannofossil assemblage is still not particularly diverse here, with 37 species. Up the section (samples 31–36), the upper Upper Maastrichtian UC20d Subzone is established due to the FO of *Cribrosphaerella daniae* in sample 31. The assemblage of Subzone UC20d is essentially unchanged and includes 32 species. The subzone UC20c cannot be distinguished, since its marker *Arkhangelskiella maastrichtiana* has not been found.

4.1.2.7 Teplovka 2 section

Detailed biostratigraphy of Teplovka 2 and Teplovka 3 sections was published elsewhere (Ovechkina, 2007).

In marls of the Nikolaevka Fm. (Beds 1–3; samples 16–35), a rich foraminiferal assemblage (see Supplementary Material in the online version at https://doi.org/10.1016/bs.sats.2021.09.004) is typical for the uppermost Maastrichtian Brotzenella praeacuta–Hanzawaia ekblomi Zone (Fig. 10) (Alekseev et al., 1999; Ovechkina, 2007).

In the marls of the Nikolaevka Fm. (samples 16–35), the nannofossil assemblage consists of 40 species (Fig. 10) with generally good preservation. Abundant *Prediscosphaera grandis*, *Arkhangelskiella cymbiformis*, *Micula staurophora*, *Watznaueria barnesiae*, *Nephrolithus frequens*, *Cribrosphaerella ehrenbergii*, common *Eiffellithus turriseiffelii*, *Prediscosphaera cretacea* and few *Lithraphidites carniolensis*, *Microrhabdulus decoratus*, *Kamptnerius magnificus* and *Placozygus fibuliformis* are found throughout the whole section.

Nephrolithus frequens appears at the bottom of the marls of the Nikolaevka Fm. (sample 16) and occurs throughout the section. Therefore, this interval of the samples 16–35 confidently belongs to the upper Upper Maastrichtian CC26 zone. Consequently, the older Cenomanian–lower Upper Maastrichtian deposits completely fall out of the section.

Using the Boreal scheme of Burnett (1998), the lowest two samples (16–17) could be refer to the undivided interval of the Upper Maastrichtian UC20b–c Subzones due to the FO of *N. frequens* and the presence of *L. quadratus*. The absence *L. quadratus* in the lowermost sample can possibly be explained by the relative rarity of the species in the lower part of the section Teplovka2. The subzone UC20c cannot be distinguished, since its marker *Arkhangelskiella maastrichtiana*, which marks the UC20c base, has not been found.

The rest part of the section (samples 18–35) belongs to the Upper Maastrichtian UC20d Subzone based on the FO of *Cribrosphaerella daniae* in sample TP2/18.

4.1.2.8 Teplovka 3 section

In the marls of the Nikolaevka Fm. (samples 17–20), the foraminiferal assemblage belongs to the uppermost Maastrichtian Brotzenella praeacuta–Hanzawaia ekblomi Zone (Fig. 11).

The marls of the Nikolaevka Fm. (samples 17–20) contain a rather impoverishment assemblage of calcareous nannofossils, consisting of 37 very well preserved species (Fig. 11). Abundant *Cribrosphaerella ehrenbergii*, *Arkhangelskiella cymbiformis*, *Micula staurophora*, *Watznaueria barnesiae*, *Prediscosphaera grandis*, *Nephrolithus frequens* and common *Arkhangelskiella specillata*, *Chiastozygus litterarius*, *Kamptnerius magnificus*, *Zeugrhabdotus diplogrammus*, *Cribrosphaerella daniae* and *Microrhabdulus decoratus* occur throughout the whole section.

The following disappearances are recorded: *Placozygus fibuliformis*, *Prediscosphaera spinosa* (sample 20), *Cretarhabdus conicus*, *Eiffellithus turriseiffelii*, *Prediscosphaera cretacea*, *Ahmuellerella octoradiata*, *Calculites obscurus*, *Staurolithites angustus*, *Lucianorhabdus cayeuxii* (sample 21), and *Zeugrhabdotus spiralis*, *Lithraphidites quadratus*, *Chiastozygus amphipons* (sample 22).

The nannofossil assemblage of the Nikolaevka Fm. is characterized by the presence of *Placozygus fibuliformis* and *Prediscosphaera spinosa*. The disappearances of *Ahmuellerella octoradiata*, *Calculites obscurus*, *Staurolithites angustus*, *Lucianorhabdus cayeuxii*, *Cretarhabdus conicus* and *Eiffellithus turriseiffelii* conicide with the boundary of the Nikolaevka and Syzran formations. *Zeugrhabdotus spiralis*, *Lithraphidites quadratus* and *Chiastozygus amphipons* disappear near this boundary.

In the assemblage of the lower part of the Paleocene Syzran opokas, there is a slight decrease in the number of the Late Cretaceous species, and the Paleocene *Thoracosphaera saxea* appears in the sample 21. Reworked *Rhagodiscus angustus*, *Cretarhabdus crenulatus*, *Retacapsa angustiforata* and *Cyclagelosphaera margerelii* are recorded in this part of the section as well.

The deposits of the Nikolaevka Fm. (samples 17–20) can be attributed to the upper Upper Maastrichtian CC26 Zone on the basis of the presence of the index species *Nephrolithus frequens* at the base of the marls (sample 17).

According to the Burnett's (1998) scheme, we can distinguish the upper Upper Maastrichtian UC20d Subzone by the presence of *Cribrosphaerella daniae* starting from the base of the Nikolaevka Fm. in the samples 17.

4.1.3 Voronezh Region

In the Voronezh Region, several sections expose the Upper Coniacian–Lower Campanian Chernyanskoe, Tolucheevka, Podgornoe, Boguchar and Alekseevka formations.

4.1.3.1 Podgornoe 171 section

In the chalk of the Chernyanskoe Fm. (Bed 1, sample 40), the foraminiferal assemblage belongs to the Upper Coniacian Gavelinella thalmanni Zone (Fig. 12) (Kopaevich et al., 2007; Fig. 4). The planktonic foraminiferal assemblages are more diverse in the Chernianskya Formation and consist of *Dicarinella canaliculata* (Reuss), *Marginotruncana pseudolinneiana* Pessagno and *Marginotruncana marginata* (Reuss). In addition, the genera *Planoheterohelix*, *Whiteinella* and *Archaeoglobigerina* sum up to 10%. In the Santonian, only unkeeled taxa and isolated *M. marginata* exist, with the planktonic forms dropping to 7%. *Globigerinelloides asper* (Ehrenberg), the lower Santonian index-species on the East European Platform, is identified in the Tolucheevka Fm. The Upper Santonian index species *Globotruncana bulloides* (Vogler) is absent (Vishnevskaya and Kopaevich, 2020).

Among the radiolarians, the presence of *Alievium superbum* (Squinabol) points to the Coniacian Alievium superbum Zone (Olferiev et al., 2005).

Calcareous, slightly siliceous marls of the Tolucheevka Fm. (Bed 3, samples 39–36) have yielded a quite rich foraminiferal assemblage, which corresponds to the Stensioeina granulata perfecta Zone of the upper Lower Santonian. The co-occurrence of the radiolarians *Alievium gallowayi* (White), *Euchitonia santonica* Lipman and *Archaeospongoprunum bipartitum* Pessagno in Bed 3 indicates the Santonian *Euchitonia santonica–Alievium gallowayi* Zone (Popova-Goll et al., 2005; Vishnevskaya, 2010).

In clayey chalk of the lower part of Bed 5 (samples 35–30; Podgornoe Fm.), the foraminiferal assemblage has been identified as belonging to the Upper Santonian Gavelinella stelligera Zone (see Supplementary Material in the online version at https://doi.org/10.1016/bs.sats.2021.09.004 and Kopaevich et al., 2007; Vishnevskaya and Kopaevich, 2020).

The main part of the section (samples 29–3; Podgornoe Fm., Beds 5, 6; Boguchar Fm., Beds 7, 8) has yielded a rich foraminiferal assemblage, which corresponds to the Upper Santonian Stensioeina pommerana Zone. The radiolarian association from Bed 6 (Podgornoe Fm.) is referred to the *Orbiculiforma quadrata–Lithostrobus rostovtsevi* Zone (Popova-Goll et al., 2005; Vishnevskaya, 2010). In the uppermost part of Bed 8 (samples 2–1; Boguchar Fm.), *Gavelinella clementiana clementiana* (d'Orb.) appears in the foraminiferal assemblage (see Supplementary Material in the online version at https://doi.org/10.1016/bs.sats.2021.09.004), which is thus referred to the Lower Campanian Gavelinella clementiana clementiana Zone.

In the Podgornoe 171 section, the nannofossil assemblage consists of 60 species (Fig. 12) with generally moderate, sometimes good or poor at some levels preservation: abundant *Watznaueria barnesiae*, *Prediscosphaera cretacea* and less abundant *Eiffellithus turriseiffelii*, *Eiffellithus eximius*, *Prediscosphaera intercisa*, *Micula staurophora* throughout the whole section. The general species composition of the assemblage is characteristic of the Santonian and Campanian deposits.

At the base of the section (47.5–45.5 m, samples 40–38; upper part of Chernyanskoe Fm. and lowermost Tolucheevka Fm.), the Upper Coniacian–Lower Santonian CC14 Zone –is recorded due to the presence of *Micula staurophora* and *M. concava*. The following species appear: *Lucianorhabdus maleformis*, *Lithastrinus septenarius* and *Marthasterites furcatus* (sample 39), and *Micula concava* (sample 38).

In the lower part of the section (44.0–20.8 m, samples 37–20; main part of Tolucheevka Fm. and almost the entire Podgornoe Fm.), the Lower Santonian CC15 Zone has been established due to the appearance of the index species *Reinhardtites anthophorus* at the level of sample 37.

The disappearance of *Quadrum gartnerii* coincides with the same level. Within the CC15 Zone, the following nannofossil events are established: the appearance of *Biscutum constans* and *Prediscosphaera grandis*, as well as isolated records of *Tetrapodorhabdus decorus* (sample 36), *Staurolithites angustus*, *Microrhabdulus belgicus* and *Broinsonia parca expansa* (sample 35), *Gartnerago costatum* (sample 34), *Manivitella pemmatoidea* (sample 29), *Uniplanarius gothicus*, *Helicolithus anceps* and *Cribrosphaerella ehrenbergii* (sample 27), and *Prediscosphaera spinosa* (sample 25).

In the upper part of the Podgornoe Fm. (19.8–10.6 m, samples 19–10), the Upper Santonian CC16 Zone has been recognized, which lower boundary is defined by the appearance of *Lucianorhabdus cayeuxii* in sample 19. Within this zone, *Tranolithus manifestus* (sample 15), *Broinsonia enormis* (sample 14), *Arkhangelskiella specillata* and *Lithastrinus grillii* (sample 13), *Arkhangelskiella cymbiformis* (sample 12) and *Staurolithites imbricatus* (sample 10) appear, whereas *Zeugrhabdotus diplogrammus*, *Tranolithus gabalus* and *Lithastrinus septenarius* (sample 17), *Zeugrhabdotus bicrescenticus* (sample 16), *Manivitella solida*, *Watznaueria fossacincta* and *Eprolithus floralis* (sample 15) disappear.

In the upper part of the section (10.0–6.6 m, samples 9–6; lower part of Boguchar Fm.), the transitional Upper Santonian–Lower Campanian zone CC17—has been identified based on the appearance of the zonal species *Calculites obscurus* in sample 9. The appearance of *C. obscurus* coincides with the appearance of *Orastrum campanensis*, and a single record of *Microrhabdulus attenuatus* in the same sample. Rare *Helicolithus trabeculatus*, *Biscutum magnum* and *Cyclagelosphaera margerelii* are recorded at the level of sample 7.

The upper part of the Boguchar Fm. (5.6–1.5 m, samples 5–1) refers to a further undivided Lower Campanian CC18 Zone on the basis of the appearance of marker species *Broinsonia parca parca* in the sample 5. The disappearance of *Biscutum constans* coincides with this level, and the following species also disappear within this interval: *Cretarhabdus crenulatus* (sample 4), *Cylindralithus serratus*, *Prediscosphaera arkhangelskyii* and *Lucianorhabdus cayeuxii* (sample 3), *Zeugrhabdotus sisyphus* and *Helicolithus anceps* (sample 2), *Watznaueria biporta* (sample 1).

Based on the Burnett's (1998) scheme, the Podgornoe 171 section can be subdivided in more detail.

In the lower part of the section (47.5–20.8 m, samples 40–20; Chernyanskoe, Tolucheevka and lower part of Podgornoe Fms.), the presence of *Micula staurophora* marks a further undivided Upper Coniacian–Lower Santonian interval of the UC10–UC11a–b (sub)zones. In the middle part of the Podgornoe Fm. (19.8–18.0 m, samples 19–17), the Upper Santonian subzone UC11c has been established, which lower boundary is fixed by the appearance of *Lucianorhabdus cayeuxii* in sample 19 and upper one –by the disappearance of *Lithastrinus septenarius* in sample 17.

In the upper part of the Podgornoe Fm. (18.9–11.7 m, samples 18–11), the Upper Santonian Zone UC12 is distinguished as the interval between the disappearance of *L. septenarius* in sample 17 and the appearance of *Arkhangelskiella cymbiformis* in sample 12.

In the uppermost part of the Podgornoe Fm. (12.6–10.6 m, samples 12–10), the Lower Campanian Subzone UC13a has been established based on the appearance of the zonal index *Arkhangelskiella cymbiformis* in sample 12.

The lowest part of the Boguchar Fm. (10.0–6.6 m, samples 9–6) belongs to the UC13b Subzone, which base is established by the consistently occurrence of *Orastrum campanensis* from sample 9. The upper part of the Boguchar Fm. (5.6–1.5 m, samples 5–1) refers to the Lower Campanian UC14a Subzone due to the appearance of *Broinsonia parca parca* in sample 5.

4.1.3.2 Podgornoe 170 section

In the interval of the samples 25–21 (29.5–25.6 m, Podgornoe Fm. and lower part of Boguchar Fm., Bed 2), the foraminiferal assemblage points to the Upper Santonian Stensioeina pommerana Zone (Fig. 13). The main part of the Boguchar Fm. (Bed 2; 25.6–16.5 m, samples 21–12) belongs to the Lower Campanian Gavelinella clementiana clementiana Zone due to the FO of *G. clementiana clementiana* at 2 m above the base of this formation (25.2 m). The upper part of the section (samples 11–1; 15.5–4.4 m, Boguchar Fm., Bed 3, and Alekseevka Fm., Beds 4, 5) refers to the Lower Campanian Cibicidoides temirensis Zone.

In the Podgornoe 170 section the nannofossil assemblage consists of 56 species (Fig. 13). The preservation of nannofossils is generally moderate, ranging from good in the lower samples to poor in the upper part of the section. Abundant *Watznaueria barnesiae*, *Prediscosphaera cretacea*, *Eiffellithus turriseiffelii*, *Eiffellithus eximius* and less abundant

Micula staurophora, *Microrhabdulus decoratus*, *Watznaueria biporta*, *Reinhardtites anthophorus*, *Cylindralithus serratus*, *Cribrosphaerella ehrenbergii* are recorded throughout the whole section.

In general, the identified assemblage of nannofossils is characteristic of the Santonian and Campanian.

The lower part of the section (29.5–25.6 m, samples 25–21; the upper part of the Podgornoe Fm. and the lowermost part of the Boguchar Fm.) belongs to the transitional Upper Santonian–Lower Campanian zone CC17 due to the presence of the zonal species *Calculites obscurus*. The following species also appear within this interval: *Cretarhabdus conicus*, *Zeugrhabdotus bicrescenticus*, *Prediscosphaera arkhangelskyii*, *Rhagodiscus angustus* (sample 24), *Cyclagelosphaera margerelii*, *Staurolithites angustus*, *Broinsonia enormis* and *Zeugrhabdotus sisyphus* (sample 23), *Orastrum campanensis* (sample 22) and *Watznaueria fossacincta* (sample 21).

The main part of the section (24.6–8.1 m, samples 20–5; Boguchar Fm.) refers to the Lower Campanian CC18a Subzone, which base is established by the appearance of *Broinsonia parca parca* in sample 20. The disappearance of *Microrhabdulus belgicus* also coincides with this level. Within this subzone, *Rhagodiscus asper* (sample 18), *Cretarhabdus crenulatus* (sample 14), *Cretarhabdus conicus* and *Zeugrhabdotus bicrescenticus* (sample 11), *Lucianorhabdus cayeuxii* (sample 10), *Rhagodiscus angustus* (sample 8) disappear. *Orastrum*? sp. A (Ovechkina, 2007) is recorded in the interval of samples 18–15. Isolated *Nannoconus elongatus* and *N*. sp. appear at the level of sample 14, which probably reflects a brief warming episode.

The uppermost part of the section (7.1–4.4 m, samples 4–1; Alekseevka Fm.) belongs to the undivided Lower Campanian CC18b–c subzones based on the appearance of *Broinsonia parca constricta* in sample 4. It is impossible to separate the CC18c Subzone, since the index species *Ceratolithoides verbeekii* is absent. The level of the appearance of *Br. p. constricta* coincides with the disappearance of *Staurolithites angustus*, *Orastrum campanensis* and *Watznaueria fossacincta*; a single specimen of *Microrhabdulinus ambiguus* has been also found in this sample. In this interval, the following species disappear: *Manivitella pemmatoidea*, *Gartnerago obliquum*, *Broinsonia enormis* (sample 3), *Gartnerago costatum*, *Prediscosphaera arkhangelskyii* (sample 2), *Ahmuellerella octoradiata*, *Zeugrhabdotus diplogrammus* and *Predis-*

cosphaera intercisa (sample 1). A single specimen of *Nannoconus truittii* has been recorded in the uppermost sample 1.

According to the Burnett's (1998) scheme, the Podgornoe 170 section can be subdivided in more detail.

The lower part of the section (29.5–27.5 m, samples 25–23; Podgornoe Fm. and lowermost of Boguchar Fm.) belongs to the Lower Campanian UC13a Subzone according to the presence of the zonal species *Arkhangelskiella cymbiformis* in the lowest sample.

In the lower part of the Boguchar Fm. (26.6–25.6 m, samples 22–21) is referred to the UC13b Subzone based on the persistent appearance of *Orastrum campanensis* from sample 22.

The rest of the Boguchar Fm. (24.6–8.1 m, samples 20–5) belongs to the UC14a Subzone, which lower boundary is fixed by the occurrence of *Broinsonia parca parca* in sample 20.

The uppermost interval (7.1–4.4 m, samples 4–1, Alekseevka Fm.) is assigned to the UC14b Subzone based on the appearance of *Broinsonia parca constricta* in sample 4.

4.1.3.3 Kolbinskoe 147 section

The lowermost part of the section (sample 23; Podgornoe Fm., Bed 1) belongs to the Upper Santonian Gavelinella stelligera Zone (Fig. 14). A rich foraminiferal assemblage has been identified in sample 22; however, its composition does not allow to establish the exact zone.

The rest of the section belongs to the Boguchar Formation, and the following zones have been identified on the basis of corresponding foraminiferal assemblages.

The interval of samples 21–19 (uppermost part of Bed 1, Bed 2) belongs to the Upper Santonian Stensioeina pommerana Zone.

The interval of samples 18–7 (Beds 3–6, lower part of Bed 7) refers to the Lower Campanian Gavelinella clementiana clementiana Zone.

The interval of samples 6–4 (upper part of Bed 7, and Bed 8) has yielded a rich foraminiferal assemblage, with representatives of *Cibicidoides temirensis* (Vass.) appearing at 3 m below the top of the formation (sample 6), which allows to distinguish the Lower Campanian Cibicidoides temirensis Zone.

In the chalk of the Alekseevka Fm. (samples 3–1; Bed 9), a rich foraminiferal assemblage points to the Lower Campanian Cibicidoides aktulagayensis Zone.

In the Kolbinskoe 147 section, the calcareous nannofossil assemblage consists of 38 species (Fig. 14) with mostly moderate and sometimes quite good preservation. Several species groups are recognized: abundant *Micula staurophora*, *Prediscosphaera cretacea*, *Watznaueria barnesiae* and less common *Eiffellithus eximius*, *Reinhardtites anthophorus*, *Lithraphidites carniolensis*, *Broinsonia parca parca*, *Br. parca constricta*, *Microrhabdulus decoratus*, *Eiffellithus turriseiffelii*, *Micula concava*, *Prediscosphaera intercisa*, *P. spinosa*, *Arkhangelskiella specillata*, *A. cymbiformis*, *Cribrosphaerella ehrenbergii*, *Manivitella pemmatoidea*, *Kamptnerius magnificus*, *Lithraphidites grillii*, *Staurolithites angustus*, *Tranolithus manifestus* and *T. orionatus* are found throughout the entire section.

The nannofossil assemblage is generally typical for the Campanian.

Most of the section (interval 23.6–3.5 m, samples 23–4, Podgornoe Fm. and Boguchar Fm.) refers to the undivided Lower Campanian CC18b–c Subzones, since *Br. p. parca* and *B. p. constricta* have been found together in the lowest sample 23. The appearance of the latter subspecies marks the base of the CC18b Subzone. As in other sections, it is impossible to recognize the CC18c Subzone here because of the absence of the warm-water index species *Ceratolithoides verbeekii*. The appearances of *Ahmuellerella octoradiata*, *Lucianorhabdus cayeuxii* (sample 21), *Calculites obscurus* (sample 20), *Zeugrhabdotus diplogrammus* (sample 18) and *Calculites ovalis* (sample 17) are noted. Isolated records of *Rhagodiscus angustus* have been recorded in sample 16 and *Eprolithus floralis* in sample 10. The disappearance of the following species has been recorded in the corresponding samples: *Biscutum coronum* (sample 13), *Thoracosphaera operculata* (sample 7), *Thoracosphaera saxea* and *Microrhabdulus attenuatus* (sample 5).

The upper part of the section (interval 2.4–0.8 m, samples 3–1, Alekseevka Fm.) belongs to the CC19 zone, which lower boundary is established by the disappearance of *Marthasterites furcatus* in sample 3. *Cretarhabdus crenulatus* also disappears at this level, and *Chiastozygus litterarius* disappears in sample 2.

The Burnett's (1998) scheme for the Boreal Province offers little help for the subdividing this section in further detail. In the entire interval, only the Lower Campanian UC14b Subzone can be established, which lower boundary is marked by the appearance of *Br. p. constricta*.

4.1.4 Belgorod Region

4.1.4.1 Butovo 100 borehole

The borehole penetrates the Upper Santonian–lower Upper Campanian Noviy Oskol, Dubenki, Alekseevka and Maslovka formations.

In the Novji Oskol Fm. (samples 111–102, depths 292–280 m,), the identified foraminiferal assemblage is characteristic for the Gavelinella infrasantonica Zone (Fig. 15). In the interval of 280–272 m (samples 102–98) the assemblage of the Gavelinella stelligera Zone was identified.

The interval of samples 98–79 (depths 272–235 m; uppermost part of the Novji Oskol Fm., lower part of Dubenki Fm.) has yielded foraminifers of the Gavelinella clementiana clementiana Zone and radiolarian assemblage of the Campanian Crucella espartoensis–Archaeospongoprunum salumi (Olferiev and Alekseev, 2005).

Up the section, the interval of samples 79–56 depths 235–190.5 m; upper part of Dubenki Fm., lower part of Alekseevka Fm. contains the foraminiferal assemblage of the Cibicidoides temirensis Zone.

The foraminiferal assemblage from in the interval of samples 56–6 (depths 190.5–92 m; upper part of Alekseevka Fm., main part of Maslovka Fm.) indicates the presence of the Brotzenella monterelensis Zone. The uppermost part of the borehole (5–1, depths 92–82 m; uppermost part of Maslovka Fm.) belongs to the Globorotalites emdyensis Zone.

Borehole Butovo 100 was previously studied and described in detail, including lithology by Ovechkina and Alekseev (2002) and re-examined later by Ovechkina (2007).

The identified assemblage of variously preserved nannofossils consists of 50 species (Fig. 15), and is generally characteristic of the Campanian, with abundant *Watznaueria barnesiae*, *Prediscosphaera cretacea*, *Micula staurophora*, *Eiffellithus turriseiffelii* and less abundant *Broinsonia parca expansa*, *Reinhardtites anthophorus*, *Microrhabdulus decoratus*, *Cribrosphaerella ehrenbergii*.

The lower part of the section (samples 111–94, depths 292.0–263.8 m; Noviy Oskol Fm. and lowermost part of Dubenki Fm.) can be attributed to the transitional Upper Santonian–Lower Campanian zone CC17 due to the presence of *Calculites obscurus* starting from the lowest sample 111. In this part of the section, *Marthasterites furcatus*, *Orastrum campanensis*, *Prediscosphaera spinosa*, *Kamptnerius magnificus* (sample 110, depth 290.0 m), *Biscutum magnum*, *Arkhangelskiella cymbiformis*, *Chiastozygus litterarius* (sample 109, depth 288.1 m), *Lithastrinus grillii* (sample 107; depth 286.0 m), *Eiffellithus eximius* (sample 102, depths 280.0 m), and *Manivitella solida* (sample 101, depth 276.0 m) appear. The absence of *Marthasterites furcatus*, the index species of the CC17 Zone, in the lowest sample 111 can be explained by the relative rarity of this species in this section.

Arkhangelskiella cymbiformis is present throughout almost the entire section, from sample 109. Globally, in most areas, the FO of *A. cymbiformis* demarcates the base of the Campanian (Burnett, 1998), as recommended at the Brussels Symposium (Hancock and Gale, 1996). Simultaneously with *A. cymbiformis* in borehole Butovo 100, *Biscutum magnum* appears; the latter is first recorded in the Boreal Realm slightly above the base of the Campanian, almost at the level of the FO of *Broinsonia parca parca* (Burnett, 1998).

The interval of 262.0–186 m (samples 93–54, Dubenki Fm. and lower part of Alekseevka Fm.) is referred to the Upper Campanian CC18 Zone, which lower boundary is fixed by the first appearance of *Broinsonia parca parca* in sample 93 (262.0 m) and upper boundary by the last appearance of *Marthasterites furcatus* in sample 54 (186.0 m). *Broinsonia parca constricta* appears in sample 83 and allows to fix the upper boundary of the CC18a Subzone. Subzones CC18b and CC18c cannot be separated, since the zonal index *Ceratolithoides verbeekii* has not been found.

The upper part of the section opened by borehole Butovo 100 (samples 53–14, depths 182.0–107 m; uppermost part of Alekseevka Fm. and Maslovka Fm.) apparently belongs to the undivided upper Lower–Upper Campanian zones CC19–CC22a. Boundaries within this interval cannot be established due to the absence of *Ceratolithoides aculeus*, *Bukryaster hayii* and *Uniplanarius* spp. The frequent absence or extreme rarity of these species in the Boreal Realm have been noted for decades (Ovechkina, 2007; Perch-Nielsen, 1985). In the Belgorod Region, Shumenko (1974) noted the absence of the species *Quadrum* (currently a junior synonym of *Uniplanarius*), which prevented him from accurately subdividing this interval according to the Sissingh's (1977) scheme.

The uppermost part of the section (samples 13–1, depths 106.0–82 m; upper part of Maslovka Fm.) has been assigned to the Upper Campanian CC22b Subzone on the basis of the appearance of *Reinhardtites levis* in sample 13 (depths 106.0 m).

Sediments of borehole Butovo 100 can be subdivided in more detail using the Burnett's (1998) scheme for the Boreal Realm.

In the lower part of the section (samples 111–94, depths 292.0–263.8 m; Noviy Oskol Fm. and lowermost part of Dubenki Fm.), the Lower Campanian Subzone UC13b is identified based on the co-occurrence of *Arkhangelskiella cymbiformis* and *Orastrum campanensis*.

The interval of 262.0–167.0 m (samples 93–44; Dubenki Fm. and lower part of Alekseevka Fm.) belongs to the Lower Campanian UC14 Zone. The lower boundary of this zone is established by the first appearance of *Broinsonia parca parca* in sample 93 (similarly to that of the CC18 Zone; Sissingh, 1977) and its upper boundary is fixed by the appearance of *Misceomarginatus pleniporus* in sample 43.

The record of *Broinsonia parca constricta* in sample 83 allows to subdivide the UC14 Zone into subzones UC14a and UC14b. The UC14a Subzone corresponds to the lower part of the Dubenki Fm. and the UC14b Subzone corresponds to the upper part of the Dubenki Fm. and most of the Alekseevka Fm.

In the upper part of the section (samples 43–1, depths 165.8–82.0 m; uppermost part of Alekseevska Fm. and Maslovska Fm.), the UC15 Zone has been identified; it can be only partly subdivided into subzones as follows.

The interval of 165.8–122.0 m (samples 43–21) corresponds to the undivided Lower Campanian UC15a–c Subzones. The index species *Cylindralithus biarcus* and *Heteromarginatus bugensis* have not been found, which renders separation of the subzones impossible. In the interval of 120.0–92.0 m (samples 20–6; the upper part of the Maslovska Fm.), the Upper Campanian Subzone UC15d is distinguished, its base being marked by the appearance of *Prediscosphaera stoverii* in sample 20. In the topmost part of the section (samples 5–1, depths 90.0–82.0 m; uppermost part of Maslovska Fm.), the Upper Campanian Subzone UC15e is established, which lower boundary is defined by the disappearance of *Orastrum campanensis*.

4.1.4.2 Belgorod 167 section

4.1.4.2.1 Belgorod Formation In the chalk of Bed 1 (samples 28–21) the identified assemblage of foraminifera allows to distinguish the Globorotalites emdyensis Zone (Fig. 16).

The interval of the samples 21–12 (upper part of the Bed 1, lower part of the Bed 2) contains foraminiferal assemblage belonging to the Brotzenella taylorensis Zone.

In the interval of the samples 12–1 (upper part of the Bed 2 and Bed 3) the identified assemblage of foraminifera belongs to the Angulogavelinella gracilis Zone.

In the Belgorod 167 section, the nannofossil assemblage consists of 69 species (Fig. 16) with generally good, sometimes moderate preservation: abundant *Micula staurophora*, *Arkhangelskiella cymbiformis*, *Eiffellithus turriseiffelii*, *Watznaueria barnesiae* and *Prediscosphaera cretacea*, and less abundant *Reinhardtites levis*, *Micula concava*, *Cribrosphaerella ehrenbergii*, *Microrhabdulus decoratus*, *Reinhardtites anthophorus*, *Prediscosphaera grandis*, *Manivitella pemmatoidea*, *Kamptnerius magnificus* and *Arkhangelskiella specillata*, all recorded throughout the whole section.

The identified assemblage is typical for the Upper Campanian deposits. According to the Perch-Nielsen zonal scheme (Perch-Nielsen, 1985), this assemblage corresponds to the Upper Campanian CC22b Subzone due to the co-occurrence of *Reinhardtites levis* and *Reinhardtites anthophorus*.

The Burnett's (1998) scheme allows a more detailed subdivision of the exposed deposits.

The main part of the Belgorod Fm. (samples 28–7, interval 0.8–23.0 m) belongs to the lower Upper Campanian UC15d Subzone based on the presence of *Misceomarginatus pleniporus*, *Reinhardtites levis* and *Prediscosphaera stoverii*. This subzone is characterized by the predominance of *Micula staurophora*, *Prediscosphaera cretacea* and *Watznaueria barnesiae*; the presence of abundant *Kamptnerius magnificus* and *Prediscosphaera grandis* has been also noted.

At the level of sample 27 (2.0 m), the stratigraphically important *Orastrum campanensis* appears, as well as the *Tranolithus gabalus*, *Markalius inversus*, *Thoracosphaera operculata*, *Prediscosphaera arkhangelskyii*, *Watznaueria biporta*, *Eiffellithus eximius*, *Rhagodiscus angustus* and *Watznaueria fossacincta.*

The general distribution of calcareous nannofossils is given in the Fig. 16. The following occurrences are important *Monomarginatus quaternarius* (sample 24, depth 5.0 m), isolated *Lithastrinus grillii* (sample 23, depth 6.0 m) and *Bukryaster hayii* (sample 16, depth 13.0 m).

In the upper part of the Belgorod Fm. (samples 6–1, depths 24.0–29.0 m), the UC15e Subzone is established, which lower boundary is fixed by the last appearance of *Orastrum campanensis*. This subzone is characterized by the presence of abundant *Eiffellithus turriseiffelii*, *Micula staurophora*, *Prediscosphaera cretacea* and *Watznaueria barnesiae*. The level of disappearance of *Orastrum campanensis* in sample 6 is also associated with the disappearance of *Broinsonia parca parca* and *Microrhabdulus belgicus*. It should be noted, however, that in Northern Europe Burnett (1998) recorded the disappearance of *Broinsonia parca parca* higher in relation to the last appearance of *Orastrum campanensis*, approximately in the middle of the UC15e Subzone. An isolated *Braarudosphaera bigelowii* has been recorded in sample 2 (28.0 m).

4.1.4.3 Rovenki 614 borehole

Foraminiferal assemblages from the borehole allow recognition of the following zones (Fig. 17):

Gavelinella infrasantonica Zone in the clayey chalks of the Tolucheevka Fm. (Bed 1; samples 55–48, depths 87–72 m);

Gavelinella stelligera Zone in the lower part of the Podgornoe Fm. (Bed 2; samples 48–34, depths 72–58 m);

Stensioeina pommerana Zone in the rest of the Podgornoe Fm. (Bed 2) and in the Boguchar Fm. (Beds 3, 4, 5); samples 34–4, depths 58–24.5 m;

Gavelinella clementiana clementiana Zone in the interval of 24.5–22.0 m (lower part of Bed 6, Alekseevka Fm.; samples 4–2);

Cibicidoides temirensis Zone in the interval of 22.0–18.5 m (upper part of Bed 6, Alekseevka Fm.; samples 2–1).

The borehole Rovenki 614 has yielded a quite rich nanofossil assemblage consisting of 58 species (Fig. 17), with sometimes quite good, mostly moderate and poor at some intervals preservation. The assemblage is generally typical for the Upper Santonian–Upper Campanian: abundant *Micula staurophora*, *Eiffellithus turriseiffelii*, *Watznaueria barnesiae*, *Prediscosphaera cretacea* and less abundant *Cretarhabdus crenulatus*, *Reinhardtites anthophorus*, *Watznaueria biporta*, *Eiffellithus eximius*, *Micula concava*, *Arkhangelskiella specillata* are distributed throughout the whole section.

The lowest part of the section (samples 55–52, depths 87.0–80.0 m; Tolucheevka Fm.) belongs to the CC16 Zone due to the presence of *Lucianorhabdus cayeuxii* and L. *maleformis*. This interval in the section is characterized by abundant *Eprolithus floralis*. *Microrhabdulus attenuatus*, *Lithastrinus grillii*, *Kamptnerius magnificus* and *Broinsonia parca expansa* are recorded in the lowermost sample 55.

The interval of 77.5–62.5 m (samples 51–39, upper part of Tolucheevka Fm. and the lower part of the Podgornoe Fm.) belongs to the transitional Upper Santonian–Lower Campanian CC17 Zone based on the first appearance of *Calculites obscurus* in sample 51 (77.5 m). This interval is characterized by abundant *Broinsonia parca expansa* and *Eiffellithus eximius*, which become rarer up the section. Also, the following appearances are recorded: *Zeugrhabdotus bicrescenticus* and *Chiastozygus litterarius* (sample 49), *Rhagodiscus angustus* (sample 47), *Prediscosphaera spinosa* (sample 41), isolated *Thoracosphaera operculata* and *Quadrum gartnerii* and appearance of *Cribrosphaerella ehrenbergii* and *Prediscosphaera grandis* (sample 40), *Helicolithus trabeculatus* and *Thoracosphaera saxea* (sample 39).

The interval of 62.0–45.0 m (samples 38–20, main part of Podgornoe Fm.) belongs to the Lower Campanian CC18a Subzone, which lower boundary is established by the first appearance of *Broinsonia parca parca* in sample 38. *Broinsonia parca constricta* appears in sample 19, which allows to refer the interval 44.0–23.0 m (samples 19–3, upper part of Podgornoe Fm. and Boguchar Fm.) to the undivided CC18b–c Subzones. The absence of the zonal index marker *Ceratolithoides verbeekii* from the assemblage prevents recognition of the CC18c Subzone. Other events in this interval include the appearance of *Microrhabdulus helicoides* and *Prediscosphaera arkhangelskyii* (sample 36), isolated *Staurolithites imbricatus* and *Tetrapodorhabdus decorus* (sample 30), *Zeugrhabdotus spiralis*, *Z. diplogrammus* and *Biscutum magnum* (sample 29), *Tranolithus gabalus* (sample 27), *Helicolithus compactus* (sample 25), *Braarudosphaera bigelowii* (sample 22). A single specimen of *Lithastrinus septenarius* has been found in the sample 16, and *Bukryaster hayii* has been recorded in sample 10.

The interval of 21.0–18.5 m (samples 2–1, uppermost part of Alekseevka Fm.) refers to the Lower Campanian CC19 Zone, which lower boundary is established by the disappearance of *Marthasterites furcatus* in sample 2.

According to the Burnett's (1998) scheme, the deposits of borehole Rovenki 614 can be subdivided as follows.

The lower part of the section (samples 55–39, depths 87.0–62.5 m; Tolucheevsk Fm. and lower part of Podgornoe Fm.) belongs to the Upper

Campanian UC13b Subzone due to the presence of *Arkhangelskiella cymbiformis* and *Orastrum campanensis*; the latter species defines the base of the subzone.

The interval of 62.0–45.0 m (samples 38–20, main part of Podgornoe Fm.) refers to the Upper Campanian UC14a Subzone based on the appearance of *Broinsonia parca parca* in sample 38.

The upper part of the section (samples 19–1, depths 44.0–18.5 m; uppermost part of Podgornoe Fm., Boguchar Fm. and Alekseevka Fm.) is referred to the Lower Campanian UC14b Subzone due to the appearance of *Broinsonia parca constricta* in sample 19.

4.1.5 Rostov Region

The distribution and biostratigraphy of foraminifera and radiolarian in the Rostov Region (Rossypnoe, Efremovo-Stepanovka, Tarasovskii 1, 2 sections) are covered in much detail elsewhere (Beniamovskii et al., 2012, 2014).

4.1.5.1 Rossypnoe section

In the interval of the samples 1–10 (Belgorod Fm., Beds 1, 2, and lower part of Pavlovka Fm., Bed 3), the assemblage of benthic foraminifera belongs to the Upper Campanian Angulogavelinella gracilis LC18 Zone (Fig. 18) (Beniamovskii et al., 2012, 2014).

In the interval of the samples 11–49 (Pavlovka Fm., Bed 4, Sukhodol Fm., Bed 5), the diverse benthic foraminiferal assemblage includes transitional forms between *N. praereticulata* and *N. reticulata* characterizing the Neoflabellina praereticulata/*N. reticulata* (LC19) Zone. According to the zonal scheme of the EEP based on benthic foraminifera, the Maastrichtian begins with the LC19 Zone (Olferiev and Alekseev, 2003, 2005; Vishnevskaya and Kopaevich, 2020).

In the Efremovo-Stepanovka Formation (samples 50–58, Bed 6), a sharp turnover of the foraminiferan assemblage has been observed. Diverse secreted rotaliids and buliminids of the Falsoplanulina multipunctata (= Brotzenella complanata)/Neoflabellina reticulata (LC20) Zone appear.

The Belgorod Fm. (samples 1–6; Beds 1, 2) contains radiolarians of the Upper Campanian *Crucella espartoensis–Phaseliforma carinata* assemblage, which belongs to the Campanian *Crucella espartoensis* Zone (Fig. 18) (Pessagno, 1976; Vishnevskaya, 2010). The radiolarian assemblage is represented by the subtropical Californian species *Theocap-*

somma comys Foreman, *Crucella espartoensis* Pessagno, *Phaseliforma carinata* Pessagno, *P. subcarinata* Pessagno, *Orbiculiforma* ex gr. *sempiterna* Pessagno, *Amphipyndax stocki* (Campbell and Clark) and *Dictyomitra densicostata* Pessagno (Beniamovskii et al., 2012).

In the interval of the samples 8–16 (Pavlovka Fm., Beds 3, 4), radiolarians are represented by members of the Upper Campanian *Prunobrachium articulatum* assemblage. The considered assemblage is similar in taxonomic composition to the subboreal *Prunobrachium articulatum* assemblage from the Upper Campanian of the Saratov Volga region (Vishnevskaya, 2010, 2015).

In the interval of the samples 17–30 (Pavlovka Fm., Bed 4; Sukhodol Fm., Bed 5), the diverse radiolarian *Archeospongoprunum andersoni–Archaeospongoprunum hueyi* assemblage belongs to the uppermost Campanian–lowermost Maastrichtian.

In the interval of the samples 31–49 (Sukhodol Fm., Bed 5) abundant and diverse radiolarians, and common siliceous sponge spicules are also present. The Maastrichtian *Spongurus marcaensis–Rhombastrum russiense* assemblage has been established (Beniamovskii et al., 2012, 2014; Vishnevskaya, 2015).

In the Rossypnoe section, the nannofossil assemblage consists of 56 species (Fig. 18) with poor to very good preservation. Abundant *Watznaueria barnesiae*, *Micula staurophora*, *M. concava*, *Prediscosphaera cretacea*, and less common *Eiffellithus turriseiffelii*, *Reinhardtites levis*, *Cribrosphaerella ehrenbergii* and *Microrhabdulus decoratus* are recorded throughout the whole section. The nannofossils in this outcrop are typical for the Upper Campanian deposits.

According to the Perch-Nielsen's (1985) scheme, the Upper Campanian CC22b Subzone can be distinguished due to the co-occurrence of *Reinhardtites levis* and *Reinhardtites anthophorus*.

According to the Burnett's (1998) scheme, a more detail subdivision is possible with recognition of the UC15 and UC16 zones with their subzones.

The lower part of the section (samples 1–37; Belgorod Fm., Beds 1, 2; Pavlovka Fm., Beds 3, 4; and lower part of Sukhodol Fm., Bed 5) is correlated with the Upper Campanian UC15d Subzone, which lower boundary is established by the appearance of *Prediscosphaera stoverii* in sample 1 and the upper boundary by the disappearance of *Orastrum campanensis* in sample 37. In our material, this subzone is characterized by the presence of abundant *Eiffellithus turriseiffelii*, *Micula staurophora*, *Prediscosphaera cretacea* and *Watznaueria barnesiae*. The stratigraphically important species *Prediscosphaera stoverii* has been recorded only sporadically and *O. campanensis* appears at the level of sample 2. At the level of sample 2, also recorded are *Biscutum coronum*, *Thoracosphaera operculata*, *Microrhabdulus belgicus*, *M. attenuatus*, *Arkhangelskiella specillata*, *A. cymbiformis*, *Broinsonia parca constricta* and *Prediscosphaera grandis*. Further to this, the following species noted: *Zeugrhabdotus diplogrammus* (sample 3), *Thoracosphaera saxea* (sample 4), *Biscutum constans*, *B. magnum*, *Watznaueria biporta*, *Zeugrhabdotus bicrescenticus*, *Rhombolithion rhombicum*, *Rhagodiscus angustus*, *Cyclagelosphaera margerelii*, *Uniplanarius gothicus* (sample 5), *Zeugrabdothus embergerii* (sample 6), *Corollithion exiguum*, *Uniplanarius trifidus*, *Eiffellithus parallelus*, *Gartnerago obliquum*, *Staurolithites angustus* (sample 13), *Watznaueria fossacincta* (sample 17), *Broinsonia matalosa* (sample 22), *B. enormis* (sample 23), isolated *Microrhabdulinus* sp. and *Cylindralithus serratus* (sample 29). *Placozygus fibuliformis* disappears in sample 13.

The overlying interval (samples 38–53; upper part of Sukhodol Fm., Bed 5 and Efremovo-Stepanovka Fm., Bed 6) belongs to the upper Upper Campanian UC15e Subzone, which lower boundary is fixed by the LO of *Orastrum campanensis* and upper boundary by the LO of *Eiffellithus eximius*. This subzone is characterized by the presence of *Reinhardtites anthophorus* and *Broinsonia parca parca* up to sample 51, the latter subspecies disappears approximately in the middle of this subzone according to Burnett (1998). *Watznaueria* sp. A (Ovechkina, 2007) is recorded in sample 45 and *Ceratolithoides aculeus* in sample 50.

It is important to emphasize, the level of disappearance of *Br. parca parca* in sample 51 has been recorded above *O. campanensis* that the Rossypnoe section, which supports the data by Burnett (1998) for the entire Boreal Province.

The upper part of the section (samples 54–58; upper part of Efremovo-Stepanovka Fm.) refers to the upper Upper Campanian UC16a Subzone, which base is marked by the LO of *Eiffellithus eximius* in sample 54. This subzone is characterized by the presence of *Broinsonia parca constricta* and *Uniplanarius gothicus*, the latter disappearing in the middle of the UC16b Subzone. The disappearance of *Lucianorhabdus cayeuxii* and *Markalius inversus* coincides with the level of last findings of the index species. *Tetrapodorhabdus decorus* disappears in the sample 57.

It should be mentioned that Perch-Nielsen (1985) and Burnett (1998) noted that the LO of *Reinhardtites anthophorus* coincides with the level of the LO of *E. eximius*. However, in the Rossypnoe section, *E. eximius* disappears slightly earlier than *R. anthophorus*.

4.1.5.2 Efremovo-Stepanovka section

In the interval of samples 1–11 (Pavlovka Fm., Member 1; Sukhodol Fm., Member 2), a rich foraminiferal assemblage is observed (Fig. 19). This complex is assigned to the LC18–LC19 zones, since it contains both characteristic species and zonal species *Brotzenella taylorensis* and *Angulogavelinella gracilis*; the disappearance of *Pseudogavelinella clementiana laevigata* is also noted in sample 2. Planktonic foraminifera are less abundant compared to the benthic forms and are represented by species of the genera *Archaeoglobigerina*, *Globigerinelloides* and *Heterohelix*.

In the interval of samples 12–30 (Sukhodol Fm., Member 2), a diverse assemblage has been identified with *N. reticulata* appearing from sample 12; this event is typical for the Lower Maastrichtian LC19 Zone.

In clayey marls of the Efremovo-Stepanovka Fm. (Beds 3, 4), the benthic foraminifera assemblage shows significant changes compared to Bed 2. In the interval of samples 31–35 (Bed 3) has been established the Lower Maastrichtian LC20 Zone, since *Falsoplanulina multipunctata* (Bandy) (= *Brotzenella complanata* (Reuss)) and abundant typical *Neoflabellina reticulata*, small *Bolivinoides* forms transitional from *Bolivinoides draco miliaris* Hiltermann and Koch to *B. draco draco* (Marsson) appear in sample 31.

In the interval of samples 36–48 (Beds 3, 4), an assemblage with *Anomalinoides gankinoensis* (Neck.) and *A*. cf. *pinguis* (Jennings) (from sample 36) has been identified; it characterizes the upper part of the Lower Maastrichtian and the Upper Maastrichtian LC21–LC22 Zone of the EEP (Beniamovskii, 2008b).

In clays of Bed 4 (Efremovo-Stepanovka Fm.), the diversity of benthic foraminifera with secreted tests and finely agglutinated trochoid ataxophragmiids sharply decreases. Rare planktonic foraminifera *Globigerinelloides* and *Heterohelix* have been recorded.

It should be emphasized that previous researchers noted a succession of silicified deposits in the upper part of the Cretaceous deposits at the K/T boundary. Possibly this could be interpreted as a result of secondary leaching and silicification of chalky and marly deposits of different age during the Paleocene diagenesis (Beniamovskii et al., 2012, 2014).

Peculiarities of the radiolarian distribution in the Sukhodol Fm. permit recognition of four assemblages (bottom to top) (Fig. 19):

(1) The *Crucella espartoensis–Phaseliforma carinata* assemblage (samples 1–7) consists of zonal species and characteristic taxa *Prunobrachium kenneti* Pessagno, *P. ornatum* Lipman, *Orbiculiforma sempiterna* Pessagno and *Millocercion*? spp.

(2) The *Orbiculiforma renillaeformis–Prunobrachium articulatum* assemblage (upper part of the Upper Campanian) (samples 8–13) is characterized by the appearance of the abundant spongy species *Orbiculiforma renillaeformis* Pessagno, *O*. cf. *campbellensis* Pessagno, *O. sacramentoensis* Pessagno, *Prunobrachium articulatum* (Lipman), *P. spongiosum* Lipman, *P. crassum* (Lipman) and *P. incisum* Kozlova.

(3) At the level of sample 13, the assemblage is changed due to the appearance of new species, among which *Amphipyndax tylotus* Foreman—the zonal species of the Upper Campanian in the Crimea–Caucasus Region (Kopaevich and Vishnevskaya, 2016) should be noted.

(4) The *Archaeospongoprunum andersoni–A. hueyi* assemblage (Upper Campanian, possibly lowermost Maastrichtian) (samples 16–22) consists of the characteristic species *Orbuculiforma campbellensis* Pessagno, *Millocecion echtus* Empson-Morin, *M. acinetos* Foreman, *Patulibracchium delvallensis* Pessagno, *Archaeodictyomitra regina* (Campbell and Clark), *Lithostrobus natlandi* Campbell and Clark, *Dictyomitra andersoni* Campbell and Clark and *Homeoarchicorys eiformigum* Empson-Morin. This assemblage has not been previously known in this region (Beniamovskii et al., 2012, 2014).

(5) The *Spongurus marcaensis–Rhombastrum russiense* assemblage (Lower Maastrichtian) (samples 22–30 up to the formation top) is characterized by the first appearance of the Maastrichtian species *Dictyomitra rhadina* Foreman, *D. tiara* Campbell and Clark and typically Cenozoic *Amphymenium splendiarmatum* Clark and Campbell. This assemblage has also not been previously known (Beniamovskii et al., 2012, 2014; Vishnevskaya, 2010).

Radiolarians continue to occur in this layer, but their preservation is unsatisfactory. Their last finds were recorded at the level of sample 36. In the upper part of the layer (sample 46), sponge spicules are noted, and rare radiolarians and a few coarsely agglutinated foraminifers are recorded at the same level and higher.

The nannofossil assemblage consists of 51 species (Fig. 19). The preservation of nannofossils is changing from poor to moderate, at the level of samples 36–37 the preservation is good. Abundant *Micula staurophora* and *M. concava* and less common *Prediscosphaera cretacea*, *P. grandis*, *Reinhardtites levis*, *Arkhangelskiella specillata*, *A. cymbiformis*, *Eiffellithus turriseiffelii*, *Cribrosphaerella ehrenbergii*, *Watznaueria barnesiae*, *Microrhabdulus decoratus* occur throughout the whole section. The nannofossil species in this outcrop are typical of the Upper Campanian deposits.

The main part of the section (samples 1–40; Pavlovka Fm., Sukhodol Fm. and lower part of Efremovo-Stepanovka Fm.) belongs to the Upper Campanian CC22b Subzone due to the co-occurrence of *R. levis* and *R. anthophorus*.

The upper part of the section (samples 41–48; upper part of Efremovo-Stepanovka Fm.) refers to the latest Campanian to Early Maastrichtian CC23a Subzone, which lower boundary is fixed by the LO of *R. anthophorus*.

According to the Burnett's (1998) scheme, a more detail subdivision is possible with recognition of the UC15 and UC16 zones with their subzones.

The lower part of the section (samples 1–6; Pavlovka Fm. and lowermost part of Sukhodol Fm.) is correlated with the Upper Campanian UC15d Subzone, which base is marked by the FO of *Prediscosphaera stoverii*, and the top—by the LO of *O. campanensis*. Rare representatives of *Pr. stoverii* have been found sporadically. The subzonal marker *O. campanensis* is recorded from the lowermost sample and its last record is made in sample 6.

The overlying interval (samples 7–37; Sukhodol Fm. and lower part of Efremovo-Stepanovka Fm.) belongs to the upper Upper Campanian UC15e Subzone, which lower boundary is fixed by the LO of *O. campanensis* and upper boundary by the LO of *Eiffellithus eximius*. This subzone is characterized by the presence of *R. anthophorus* (up to sample 40) and *Broinsonia parca parca* (up to sample 34), the latter subspecies disappears approximately in the middle of this subzone (Burnett, 1998). As well as this subzone is also notable for the absence of *O. campanensis*. *Uniplanarius trifidus* disappears at the level of sample 7.

The disappearance of *Br. parca parca* (sample 35) is recorded higher compared to *O. campanensis*, similar to the Rossypnoe section; this corroborates data of Burnett (1998) for the entire Boreal Province.

The upper part of the section (samples 38–48; upper part of Efremovo-Stepanovka Fm.) refers to the upper Upper Campanian UC16a Subzone, which base is marked by the LO of *Eiffellithus eximius* (sample 38). This subzone is characterized by the presence of *Br. parca constricta* and *U. gothicus*, the latter species disappears in the middle of the UC16b Subzone. *Eifellithus parallelus* appears in sample 38.

It should be noted that Perch-Nielsen (1985) and Burnett (1998) believed that the LO of *R. anthophorus* coincides with the level of the LO of *E. eximius*. However, in the Efremovo-Stepanovka section, as well as in the Rossypnoe section, *E. eximius* disappears slightly earlier than *R. anthophorus*.

The uppermost part of the section consisting of opoka-like rocks (samples 49–52) contains no calcareous nannofossils.

4.1.5.3 Tarasovskii 1 section

The chalk of the Belgorod Fm. (samples 1–23, Member 1) has yielded rare planktonic foraminifera represented by unkeeled forms. The benthic foraminifera from this interval point to the LC16 Zone of the upper part of the Upper Campanian of the East European Province (Fig. 20) (Beniamovskii, 2008b). This zone is established by the presence of *Coryphostoma* (*Bolivina*) *incrassata* (Reuss) (= *B. kalinini* Vasilenko). The appearance of *Eponides frankei* Brotzen (sample 12) is a stratigraphic benchmark for the upper part of the Upper Campanian LC16 Zone in the East European Province and Mangyshlak (Beniamovskii et al., 2012).

The benthic foraminifera assemblage from sample 24 (Sukhodol Fm., Member 2) is characterized by the appearance of *Angulogavelinella gracilis* (Marsson) and the disappearance of papillate the *Neoflabellina rugosa* group. The extinction of the *N. rugosa* group is a stratigraphic marker of the uppermost part of the Campanian of North-western Europe in the older understanding of the volume of the stage (Beniamovskii et al., 2012; Hiltermann, 1956; Hiltermann and Koch, 1955; Koch, 1977). *Neoflabellina praereticulata* Hiltermann and forms with transitional features from *Neoflabellina praereticulata* to *N. reticulata* (Reuss) appear from the level of sample 25. This phase of the phylogenetic development of the genus *Neoflabellina* corresponds to the LC19 zone of the East European Province.

This section has yielded a quite rich nannofossil assemblage consisting of 55 species (Fig. 20). The preservation of nannofossils varies from mostly moderate and good to poor in the two lower samples. Abundant *Micula staurophora*, *Eiffellithus turriseiffelii* and less common *Prediscosphaera cretacea*, *Arkhangelskiella cymbiformis*, *Reinhardtites levis* and *Watznaueria barnesiae* occur throughout the whole section. The assemblage of the nannofossil species in this section is typical of the Upper Campanian deposits.

According to the Perch-Nielsen (1985) zonation, only the Upper Campanian CC22b Subzone can be recognized in the whole section due to the joint presence of *R. levis* and *R. anthophorus*.

Using the Burnett's (1998) scheme, the sediments of the section can be subdivided further into subzones UC15e and UC16a.

The interval of samples 1–22 (Belgorod Fm.) belongs to the uppermost Campanian UC15e Subzone. The top of this subzone is fixed by the LO of *E. eximius* in sample 22.

This subzone is characterized by the presence of *R. anthophorus* and *Br. parca parca* (up to sample 6); the latter subspecies should disappear approximately in the middle of the subzone (Burnett, 1998), as well as by the absence of *O. campanensis*. The following nannofossil appearances have been observed: *Prediscosphaera spinosa*, *Zeugrhabdotus diplogrammus* and *Microrhabdulus belgicus* (sample 2), *Kamptnerius magnificus*, *Thoracosphaera operculata* and *Uniplanarius gothicus* (sample 3), *Biscutum coronum*, *B. magnum*, *B. constans*, *Lithastrinus grillii*, *Calculites obscurus*, *Cretarhabdus conicus*, *Manivitella solida*, *Watznaueria biporta*, *Rhagodiscus angustus*, *Broinsonia enormis*, *Cyclagelosphaera margerelii*, *Cylindralithus serratus* and *Zeugrhabdotus spiralis* (sample 4), *Gartnerago obliquum* and *Manivitella pemmatoidea* (sample 5), *Tetrapodorhabdus decorus* (sample 9), *Zeugrhabdotus sisyphus* (sample 11), *Rhagodiscus splendens* (sample 13), *Misceomarginatus pleniporus* (sample 18), and *Watznaueria* sp. A (Ovechkina, 2007) (sample 19). *Placozygus fibuliformis* disappears in sample 12.

The upper part of the section (samples 23–27; uppermost part of Belgorod Fm. and Sukhodol Fm.) correlates with the uppermost Campanian UC16a Subzone, which base is marked by the LO of *E. eximius*. This subzone is characterized by the presence of *Br. parca constricta* and *Uniplanarius gothicus*, the latter disappearing in the Boreal Province in the middle of the UC16b Subzone (Burnett, 1998).

Uniplanarius trifidus is recorded in sample 25 and *Ceratolithoides aculeus* in sample 27. The appearance of *C. aculeus* is recorded slightly lower in the subzones UC15b and UC15c according to Burnett (1998). Since these warm-water species are very rarely found in sediments of the Boreal Province (Perch-Nielsen, 1985), their appearances cannot be considered the first in this section.

4.1.5.4 Tarasovskii 2 section

In the lower part of the Belgorod Fm. (samples 1–10; Member 1), a rich assemblage of the benthic foraminifera of the Upper Campanian Zone LC15 has been found (Fig. 21).

The first and usually abundant occurrence of the zonal species *Coryphostoma* (*Bolivina*) *incrassata* (sample 11) is established the younger Zone LC16, which corresponds to the upper part of the Upper Campanian. Noteworthy is a higher appearance of the zonal species *Coryphostoma incrassata* in the Tarasovskii 2 section compared to the Tarasovskii 1 section. However, the general succession of appearances and disappearances of species is preserved in both sections, so the discrepancy is probably due to slight facial differences.

In the Sukhodol Fm. (samples 22–23, Member 2), the association of the benthic foraminifera demonstrates a significant reorganization. Papillate forms of the *Neoflabellina rugosa* group disappear and transitional forms between *N. praereticula* to *N. reticulata* appear. This allows to refer the enclosing deposits to the Upper Campanian–Lower Maastrichtian LC19 Zone. It should be noted that the planktonic forms disappear from the foraminiferal association in this interval, and the taxonomic composition of foraminifera with the calcareous test is sharply depleted (only the discorbiids and lagenids remain), so is diversity of agglutinated foraminifera.

A notable feature of the microfaunal association of the bottom of the Sukhodol Fm. is the appearance of skeletons of radiolarians and spicules of siliceous sponges, which are abundant at this stratigraphic level in the more eastern sections of the Efremovo-Stepanovka and Rossypnoye. As in the Tarasovky 1 section, the Sukhodol Fm. overlies the Belgorod Fm with a hiatus.

In the Tarasovskii 2 section, the identified nannofossil assemblage consists of 42 species (Fig. 21) with mostly moderate, sometimes poor and good preservation. Abundant *Eiffellithus turriseiffelii*, *Watznaueria barnesiae* and *Micula staurophora*, and less abundant *Prediscosphaera* *cretacea*, *Lucianorhabdus cayeuxii*, *Arkhangelskiella cymbiformis*, *Reinhardtites levis*, *Microrhabdulus decoratus*, *Cribrosphaerella ehrenbergii* occur throughout the whole section. The identified assemblage is typical of the Upper Campanian deposits.

According to the Perch-Nielsen (1985) scheme, only the Upper Campanian CC22b Subzone is distinguished based on the joint presence of *R. levis* and *R. anthophorus*.

According to the Burnett's (1998) scheme, the Upper Campanian UC15e and UC16a subzones can be recognized.

Most of the section (samples 1–15; Belgorod Fm.) can be correlated with the uppermost Campanian UC15e Subzone, which top is fixed by the LO of *E. eximius* in sample 16. The assemblage is characterized by the presence of *R. anthophorus* and the absence of *O. campanensis* and *Br. parca parca.* The absence of *Br. parca parca* indicates that the deposits in question belong to the upper part of the UC15e Subzone (Burnett, 1998). The following levels of appearances have been observed: *Biscutum coronum*, *Calculites obscurus*, *Cretarhabdus crenulatus*, *Broinsonia parca constricta*, *Zeugrhabdotus diplogrammus*, *Thoracosphaera saxea*, *Micula concava* (sample 2), *Thoracosphaera operculata*, *Bacisiformum constans*, *Placozygus fibuliformis*, *Biscutum magnum* (sample 3), *Uniplanarius gothicus*, *Prediscosphaera spinosa* (sample 4), *Staurolithites angustus* (sample 5), *Cyclagelasphaera margerelii* (sample 7), *Watznaueria* sp. A (Ovechkina, 2007) (sample 10) and *Microrhabdulus belgicus* (sample 11).

The upper part of the section (samples 16–23; upper part of Belgorod Fm. and lowermost part of Sukhodol Fm.) belongs to the uppermost Campanian UC16a Subzone, which base is recorded by the LO of *E. eximius*. This subzone is characterized by the presence of *Br. parca constricta* and *Uniplanarius gothicus*, which disappears in the middle of the UC16b Subzone.

In this section, as well as in Tarasovskii 1, such warm-water species as *Uniplanarius trifidus* (appears in sample 19) and *Ceratolithoides aculeus* (sample 23) are found only in the upper part of the section (UC16a Subzone), while their first appearances were recorded by Burnett (1998) slightly earlier, i.e. in the UC15b and UC15c Subzones. This can also be explained by the extreme rarity of these forms in the Boreal Province (Burnett, 1998; Perch-Nielsen, 1985).

5. Discussion and conclusions

The first variant of subdivision of the Upper Cretaceous deposits of Western Europe using assemblage zones was presented by Stradner (1963). Stover (1966), Reinhardt (1966) and Bukry (1969) proposed similar assemblage zonation schemes for France and the Netherlands, Western Europe and Texas (USA), and Europe respectively. Čepek and Hay (1969) were the first to propose a zonal scheme based on the interval zones for the Upper Cretaceous sections of Kansas and Alabama (USA). Since then the interval zones became the most popular.

A stable sequence of calcareous nannofossil zonations based on different characteristics of the assemblages, as well as the first occurrence (FO), last occurrence (LO) or acme events, is traced throughout the remaining of the 1960s and early 1970s (Burnett, 1998). These first zonations are now considered obsolete; however, many nannofossil events are used in modern schemes (Burnett, 1998).

The most important Upper Cretaceous nannofossil zonations proposed in the last 50 years have been described in detail by Crux (1982), Perch-Nielsen (1985), Mortimer (1987), Burnett (1998), and Ovechkina (2007) (Fig. 40).

5.1 The suitability of the schemes

To clarify the suitability of the schemes for subdividing the Upper Cretaceous deposits of the East European Platform (EEP), we need to analyze the obtained results using the most detailed scales: the “standard” scheme by Sissingh (1977) in the version of Perch-Nielsen (1985) and the boreal scale by Burnett (1998) (Fig. 40).

The subdivision of the studied sections into zones by benthic foraminifers and according to the scheme proposed by Vishnevskaya et al. (2018) have been used as an external reference, since traditionally the subdivision of the EEP deposits has been established primarily by benthic foraminifers. Needless to say, benthic foraminiferal assemblages are facies-dependent, and in this light, we will try to clarify the nannofossil zonal subdivisions for the EEP.

5.1.1 Sissingh (1977) ***with additions*** Perch-Nielsen (1985)

The Upper Albian–Lower Cenomanian **CC9** Zone is easy to distinguish in the boreholes Potanino 2 and Novouzenskaya (Figs. 41 and 42). Regrettably, this interval is not characterized by foraminifera, and the precise tracing of the FOs of *Eiffellithus turriseiffelii* and *Microrhabdulus decoratus* relative to foraminifera datums is impossible. However, in the borehole Potanino 2, in the lower part of the CC9 Zone, the Albian radiolarian *Pododiscus kavilkinensis–Crolanium cuneatum* assemblage is identified, which confirms the stratigraphical position of the zone.

The Upper Cenomanian **CC10** Zone is also easily recognizable, since the FO of *M. decoratus* is a reliable and solid marker. The FO of *Quadrum gartneri* is also a solid marker, however relatively rare in our material; nonetheless, the FO of *Q. gartneri* is recorded in all three sections (boreholes Potanino 2 and Novouzenskaya, and Nizhnyaya Bannovka section) (Figs. 41 and 42). This zone can be correlated to the Lower Cenomanian Gavelinella cenomanica and Middle–Upper Cenomanian Lingulogavellinella globose zones (Nizhnyaya Bannovka) (Fig. 42). In the borehole Potanino 2, the top of the CC10 Zone coincides with the base of the Lower Tutonian benthic foraminifera assemblage *Gaudryinopsis filiformis–Reussella turonica*. Also, the CC10 Zone can be correlated to the Turonian radiolarian assemblage *Pseudoaulophacus (Spongotripus) aculeatus–Stichocapsa pyramidata* or *Dictyomitra napaensis*.

The **CC11** Zone of the Lower and Middle Turonian can be traced but with some difficulties. The FO of *Lucianorhabdus maleformis* which defines the top of the CC11 Zone is a reliable index; however, it can be relative rare and even absent in some sections on the EEP (borehole Potanino 2) (Fig. 42). An additional and interchangeable marker (FO of *Eiffellithus eximius*) proposed by Perch-Nielsen (1985) can be used to define the upper boundary of the CC11 Zone. The CC11 Zone confidently correlates with the Lower Tutonian benthic foraminifera assemblages *Gaudryinopsis filiformis–Reussella turonica* and *Gavelinella vesca*, *Cibicides polyrraphes*, *Tappannina simplex* (Potanino 2) (Fig. 42). In the Saratov Region (Nizhnyaya Bannovka), the CC11 Zone corresponds to the Middle–Upper Turonian Gavelinella moniliformis Zone and the assemblage with *Reusella kelleri* and *Gavelinella praeinfrasantonica* of the Upper Turonian–Lower Coniacian (Fig. 42).

Establishing the Upper Turonian–Lower Coniacian **CC12** Zone is associated with some difficulties. The recognition of its base is discussed in the previous paragraph. Fixing of the zone's top defined by the FO of *Marthasterites furcatus* can be problematic, since *M. furcatus* is relatively rare and sporadic at high latitudes (Perch-Nielsen, 1985). However, in sequences with frequent sampling, the level of its FO can be established (Bolshevik section and borehole Novouzenskaya) (Figs. 41 and 43). In the Bolshevik section, CC12 correlates with the boundary interval of the Upper Turonian benthic foraminiferal subzones LC5b–LC5c. The FO of *E. eximius* is recorded in the LC5b subzone, the FO of *M. furcatus* is fixed in the LC5c subzone (Fig. 43). In the Nizhnyaya Bannovka section, CC12 corresponds to the Upper Turonian–Lower Coniacian assemblage with *Reusella kelleri* and *Gavelinella praeinfrasantonica* (Fig. 42).

The Lower Coniacian **CC13** Zone can be traced on the territory of the EEP with some difficulties associated with the base of this zone. While its top is easily established based on the FO of *Micula staurophora* (= *Micula decussata*) if the nannofossil assemblage of the section is not impoverished (Bolshevik section and borehole Novouzenskaya) (Figs. 41 and 43). The CC13 Zone correlates with the Upper Turonian LC5c subzone (Bolshevik section) (Fig. 43). In the Nizhnyaya Bannovka section, the FO of *M. staurophora* is recorded in the Upper Turonian–Lower Coniacian foraminiferal assemblage with *Reusella kelleri* and *Gavelinella praeinfrasantonica* (Fig. 42).

The Upper Coniacian–Lower Santonian **CC14** Zone is established, and its base have been already discussed above. The top of CC14 is marked by the FO of *Reinhardtites anthophorus*, which is a reliable marker and is recorded in our material (Podgornoe 171 section and Novouzenskaya borehole) (Figs. 41 and 44). The CC14 Zone correlates with the Middle–Upper Coniacian benthic foraminifera Gavelinella thalmanni Zone (Podgornoe 171 section) (Fig. 44).

The upper Lower Santonian **CC15** Zone is relatively easily established, since its base is defined by the reliable marker *R. anthophorus*, which FO is fixed without any difficulty (Podgornoe 171 and Krasny Oktyabr sections, and borehole Novouzenskaya) (Figs. 41, 43, and 44). The top of the zone is recognized by the FO of *Lucianorhabdus cayeuxii*, which is a solid index and can be easily fixed. However, the FO of *R. anthophorus* shows some diachronism; the CC15 Zone can be correlated with the Middle Coniacian LC7 in the Krasny Oktyabr section, whereas in the Podgornoe 171 section the FO of *R. anthophorus* is fixed in the Stensioeina granulata perfecta Zone, which corresponds to the Upper Santonian LC9 Zone (Beniamovskii, 2008b). In the Podgornoe 171 section, CC15 correlates to the interval of the Stensioeina granulata perfecta Zone (LC9) to the lower part of the Stensioeina pommerana Zone, which corresponds to the Upper Santonian LC11 Zone (Beniamovskii, 2008b).

The **CC16** Zone is easy established in many sequences (Podgornoe 171 and Pudovkino sections, boreholes Rovenki 614 and Novouzenskaya) (Figs. 41, 42, 44, and 45). In the most complete sections Krasny Oktyabr and Bolshevik, this zone is reduced possibly due to a hiatus in the sections. The base of CC16 is fixed by a reliable marker *L. cayeuxii*, which FO is easily detectable. The FO of *L. cayeuxii* also shows some diachronism; in the Pudovkino section, this level is recorded in the Lower Santonian Gavelinella infrasantonica Zone and in the Podgornoe 171 section, in the Upper Santonian Stensioeina pommerana Zone. The top of CC16 is marked by the FO of *Calculites obscurus*.

On the territory of the EEP, the **CC17** Zone is well traced in many sections (Podgornoe 170, Podgornoe 171, Krasny Oktyabr and Bolshevik sections, and boreholes Rovenki 614, Butovo 100, Potanino 2 and Novouzenskaya) (Figs. 41, 42, 43, 44, and 45). This zone is established as the interval from the FO of *C. obscurus* to the FO of *Broinsonia* ex gr. *parca*. The FO of *C. obscurus* is somewhat diachronous; in the borehole Rovenki 614 it appears in the Lower Santonian Gavelinella infrasantonica Zone, and in Podgornoe 171, in the Upper Santonian Stensioeina pommerana Zone.

Sissingh (1977) and Perch-Nielsen (1985) mentioned the FA of *C. obscurus* in the Upper Santonian as a solid and good marker; however, this species demonstrates a remarkable diachroneity across the world (e.g., Burnett, 1998; Ovechkina et al., 2021). Wagreich (1992) noted the FO of *C. obscurus* in the Upper Santonian Sigalia decoratissima Zone in the Austrian Gosau section. In North Europe and Indian Ocean, the first consistent occurrence of *C. obscurus* was noted around the Coniacian/Santonian boundary (Subzone UC11c) (Burnett, 1998). Hampton et al. (2007) recognized the FO of *C. obscurus* in the middle part of the Middle Coniacian in Seaford Head (Southern England). Thierstein (1976) put together *Calculites obscurus* and *Calculites ovalis*, and treated them as the best markers for the Coniancian/Santonian boundary.

The **CC18** Zone is traced quite well in all studied sections. This zone is established as the interval from the FO of *Broinsonia* ex gr. *parca* to the LO *Martasterites furcatus.* The base of the zone is based on the FO of a reliable marker *Broinsonia* ex gr. *parca* and is distinguished in a number of the studied sections (boreholes Butovo 100, Rovenki 614, Novouzenskaya, and Podgornoe 170, Podgornoe 171, Lysaya Gora, Krasny Oktyabr and Bolshevik sections) (Figs. 41–45).

The diachronous nature of the FO of *Br. parca parca* has been also noted in the studied area. In the borehole Rovenki 614, this subspecies is first recorded in the upper part of the Upper Santonian Gavelinella stelligera Zone (Fig. 45); in the Podgornoe 171 section, in the upper part of the Upper Santonian Stensioeina pommerana Zone (Fig. 44); in the Lysaya Gora and Podgornoe 170 sections, it is established in the lowermost part of the Lower Campanian Gavelinella clementiana clementiana Zone (immediately near the boundary of the G. stelligera and G. cl. clementiana zones) (Figs. 42 and 44); in the borehole Butovo 100, in the lower part of the G. clementiana clementiana Zone (Fig. 45); in Krasny Oktyabr and Bolshevik sections, the upper zone of the Lower Campanian LC13 (Fig. 43) (Olferiev et al., 2009b, 2014).

Sissingh (1977) and Perch-Nielsen (1985) accepted the FA of *Broinsonia* ex gr. *parca* in the Campanian as a good marker. Burnett (1998) is also noted that the FA of *B. parca parca* is considered a useful marker for defining the Santonian–Campanian boundary and can be traced globally at all paleolatitudes, in all paleobiogeographical realms and in most geographical settings. However, our data show that the FO of *B. parca parca* demonstrates diachronism; its lowest occurrence has been recorded in the upper part of the Upper Santonian Gavelinella stelligera Zone (within LC10) and its highest occurrence in the upper zone of the Lower Campanian LC13.

Regarding the lowest occurrence of *B. parca parca*, our data confirm findings by Fritsen (1999), when the FO of *B. parca parca* coincides with the FO of *Stensioeina pommerana*, i.e., at the base of the Stensioeina pommerana Zone; nevertheless, Fritsen (1999) defines this interval as the Lower Campanian.

In the practice, the top of the CC18 Zone is established with a certain degree of complexity, since the marker *M. furcatus*, which LO defines this boundary, is rather rare. However, as shown by the study of a number of sections (boreholes Rovenki 614, Butovo 100, Lysaya Gora and Kolbinskoe sections) (Figs. 42, 44, and 45), it is possible to quite accurately establish the level of the LO of this species if a sequence is sampled frequently. In the section Kolbinskoe and borehole Rovenki 614, *M. furcatus* disappears in the Lower Campanian Cibicidoides temirensis Zone, and in the Lysaya Gora section and borehole Butovo 100, in the Upper Campanian Brotzenella monterelensis Zone.

The subdivision of the CC18 Zone into subzones causes a certain difficulty. The lower CC18a Subzone is clearly distinguished in all studied sections (boreholes Rovenki 614, Butovo 100, and Podgornoe 170 section), and is established based on the FO of *Broinsonia parca constricta*.

The FO of *B. parca constricta* also demonstrates certain diachronism. In the borehole Butovo 100, it occurs in the upper part of the Lower Campanian G. clementiana clementiana Zone; in the Podgornoe 170 section, in the upper part of the Lower Campanian Cibicidoides temirensis Zone; in the Lysaya Gora section, in the Upper Campanian Brotzenella monterelensis Zone; in Krasny Oktyabr section, the upper part of the Lower Campanian LC13 Zone, which correlates with the Cibicidoides temirensis and Cibicidoides aktulagayensis zones (Olferiev et al., 2014). Thus, its lowest occurrence has been recorded in the Lower Campanian G. clementiana clementiana Zone (LC12) and the highest in the upper part of the Lower Campanian LC13.

It is impossible to separate subzones CC18b and CC18c, since the lower boundary of the latter is determined by the FO of the warm-water *Ceratolithoides verbeekii*, which is absent in the studied sections.

The base of the **CC19** Zone is established by the LO of *M. furcatus* and, as mentioned above, can be traced in all studied sections, although not always completely reliably.

The situation is more difficult with establishing the **CC20** Zone, which base is defined by the FO of the warm-water *Ceratolithoides aculeus*. This species is very rare in the studied sections and cannot be use in practice on the EEP.

It is also difficult to distinguish the **CC21** Zone, since warm-water representatives of *Quadrum* or *Uniplanarius* have not been found at this stratigraphic level; their FOs mark the base of CC21 (*U. sissinghii*) and the top of the zone (*U. trifidum*). Species of this group of nannofossils are very rare in our sections, and their single finds have been recorded at obviously higher stratigraphic levels (sections Tarasovskii 1 and 2, Rossypnoe, Efremovo-Stepanovka, Belgorod, Krasny Oktyabr and Bolshevik, and Novouzenskaya borehole) (Figs. 41, 43, 45, and 46). The subdivision of the CC21 Zone into subzones is also impossible due to the absence of *Cylindralithus arcuatus*, the FA and LA of which are used to establish the lower and upper boundaries of the CC21b Subzone.

In the studied area, the lower boundary of the **CC22** Zone cannot be fixed reliably, since *U. trifidus*, as noted above, is rare or absent.

The top of the CC22 Zone is marked by the LO of *Reinhardtites anthophorus* and is clearly traced in the Krasny Oktyabr section (lower part of the Lower Maastrichtian LC20a Subzone) and in Efremovo-Stepanovka section—in a younger undivided interval of Lower Maastrichtian LC21 and Upper Maastrichtian LC22 zones (Figs. 43 and 46).

Perch-Nielsen (1985) and then Burnett (1998) believed that the LO of *Eiffellithus eximius* was also confined to the level of LO of *R. anthophorus*. However, our studies (Tarasovskii 1, 2, Rossypnoe, Efremovo-Stepanovka sections, and Novouzenskaya borehole) have shown that *E. eximius* disappears much earlier in the Voronezh anteclise and in the Volga Region, which completely supports the research by Fritsen (1999) (Figs. 41 and 46). Nevertheless, in the Krasny Oktyabr section the levels of the LOs of *E. eximius* and *R. anthophorus* coincide. This raises a question if one of these species is the actual marker.

The lower boundary of the CC22b Subzone is distinguished by the FO of *Reinhardtites levis*, which was found in borehole Butovo 100 in the Upper Campanian Brotzenella monterelensis Zone (LC14), and in Krasny Oktyabr in the Upper Campanian Brotzenella taylorensis Zone (LC17). Starting from this level, the standard scheme of Sissingh (1977) with additions by Perch-Nielsen (1985) again becomes applicable on the EEP.

The lower and upper boundaries of the **CC23** Zone are established as the interval from the LO of *R. anthophorus* to the LO of *Tranolithus orionatus*. The CC23 could be subdivided into two subzones based on the LO of *Br. parca constricta*.

The CC23a is clearly traced in many sections (Efremovo-Stepanovka, Lokh, Klyuchi 2, Bolshevik, Krasny Oktyabr sections, and Novouzenskaya borehole) (Figs. 41, 43, 46, and 47). The base of this subzone has been discussed above. The top of the CC23a is fixed in the Lokh section and the LO of *Br. parca constricta* is recorded in the Lower Maastrichtian Neoflabellina reticulata Zone. Thus, the CC23a is younger in the Rostov Region. The CC23a is established also in the Klyuchi 2 section, but unfortunately the top of the subzone has not been fixed due to the hiatus in sedimentation. In the Lokh section, the established undivided interval of CC23b–CC24 correlates with the Neoflabellina reticulata Zone.

However, the CC23 Zone most confidently can be established in the sections Krasny Oktyabr, and Bolshevik, and in the Novouzenskaya borehole (Figs. 41 and 43). In the Krasny Oktyabr section, CC23a correlates with the lower part of the Brotzenella complanata (LC20) of the Lower Maastrichtian (Olferiev et al., 2014); in the Bolshevik section, this subzone corresponds to the transitional Upper Campanian–Lower Maastrichtian Neoflabellina praereticulata/*N. reticulata* Zone (LC19) and the lower part of the Lower Maastrichtian Brotzenella complanata Zone (LC20).

The CC23b Subzone is clearly recognizable in the Novouzenskaya borehole, Krasny Oktyabr section (as the upper part of the Lower Maastrichtian Brotzenella complanata LC20 and the Bolivinoides draco draco LC21 zones) and in the Bolshevik section (as the Lower Maastrichtian Brotzenella complanata LC20 Zone).

The base of the **CC24** Zone is reliably fixed by the LO of *Tr. orionatus*, which, however, may appear on different levels even in closely located sections. Thus, in the Krasny Oktyabr section the LO of *Tr. orionatus* is recorded in the middle part of the Lower Maastrichtian LC21 Zone, and in the Bolshevik section it is fixed in the middle part of the Lower Maastrichtian LC20 Zone (Fig. 43). The top of the CC24 Zone is marked by the LO of *R. levis*; it has been established in the Lokh section and coincides with the boundary of the Lower Maastrichtian *N. reticulata* (LC19) and Bolivinoides draco draco (LC21) zones (Fig. 47).

Since there is a hiatus in this section (the Lower Maastrichtian Brotzenella complanata Zone (LC20) and possibly the lower part of the Bolivinoides draco draco Zone are missing), the exact level of the LO of *R. levis* cannot be correlated to the benthic foraminifera zones. However, we can correlate the level of the LO of *R. levis* with the benthic foraminifera zones in other sections of the Saratov Region. Thus, the LO of *R. levis* is noted in the upper part of the Lower Maastrichtian LC21 Zone in the Krasny Oktyabr section, and in the lower part of the Lower Maastrichtian LC21 Zone in the Bolshevik section (Olferiev et al., 2009b, 2014).

The base of the **CC25** Zone is recorded by the LO of *R. levis*, and the top is established based on the FO of *Nephrolithus frequens* in the Lokh section, where only the CC25a Subzone has been identified (Fig. 47). This subzone corresponds to the Lower Maastrichtian Bolivinoides draco

draco (LC21) and the Upper Maastrichtian Brotzenella praeacuta Zone (LC22).

In the Krasny Oktyabr and Bolshevik sections and in the Novouzenskaya borehole, the CC25 Zone is complete and the CC25a Subzone and undivided CC25b–c subzones have been established based on the FO of *L. quadratus*, which defines the top of CC25a (Figs. 41 and 43). The absence of *Micula murus*, which FO marks the base of CC25c, does not allow to separate the CC25c subzone in our material.

In the section Krasny Oktyabr, the CC25a Subzone falls into the upper part of the Lower Maastrichtian LC21 Zone and the undivided CC25b–c subzones are referred to the boundary interval between the Lower–Upper Maastrichtian LC21 and LC22 zones. In the section Bolshevik, the CC25a corresponds to the Lower Maastrichtian LC21 and the CC25b–c subzones fall into the uppermost Lower–Upper Maastrchtian LC22 Zone.

The **CC26** Zone is clearly and easily recognizable in many studied sections (Klyuchi 1, Klyuchi 2, Teplovka 2, Teplovka 3, Krasny Oktyabr, Bolshevik, and Novouzenskaya borehole) (Figs. 41, 43, and 47). The base of CC26 is determined by the FO of the index *N. frequens*. The FO of *N. frequens* has been recorded in the Upper Maastrichtian Brotzenella praeacuta/Hanzawaia ekblomi Zone (LC22).

Thus, it is difficult to subdivide the upper part of the Lower and most of the Upper Campanian on the EEP using the scheme by Sissingh (1977) with additions by Perch-Nielsen (1985), due to the absence of zonal index species.

5.1.2 Boreal scale of Burnett (1998)

The use of Burnett's (1998) scale allows a more detailed subdivision of some intervals of the Upper Albian–Maastrichtian.

The FO of *Eiffellithus turriseiffelii* is a good marker for the Upper Albian–Lower Cenomanian **UC0** Zone and reliably defines its base. The FO of *E. turriseiffelii* is readily recorded in our material (boreholes Potanino 2 and Novouzenskaya) (Figs. 41 and 42). The top of the UC0 is marked by the FA of *Corollithion kennedyi*, which, so far, has not been found in our material.

The lower part of the UC0 Zone can be correlated with the Albian *Porodiscus kavilkinensis–Crolanium cuneatum* radiolarian assemblage (Potanino 2 borehole) (Fig. 42).

In the borehole Novouzenskaya, the top of the Lower Cenomanian **UC1** Zone is fixed by the FO of *Gartnerago segmentatum*. On the EEP, *G. segmentatum* is a common species and the level of its FO is fixed without any difficulty.

Thus, it is possible to establish the interval of the Upper Albian–Lower Cenomanian UC0–UC1 zones in our material. In the middle part of this interval, the FO of *Kamptnerius magnificus*, which appears near the base of UC1c according to Burnett (1998), is recorded. Regrettably, the FOs of both *G. segmentatum* and *K. magnificus* cannot be correlated with foraminiferal zones, since benthic foraminifera have not been studied in the Novouzenskaya borehole.

The **UC2** Zone is traced with some difficulty. The base of this zone is discussed above, and its top is defined by the FO of *Lithraphidites acutus*, which has not been found in our material. However, a reliable marker *Microrhabdulus decoratus*, which FO roughly coincides with the FO of *L. acutus* according to Perch-Nielsen (1985), is recorded in the Potanino 2 and Novouzenskaya boreholes, and in the Nizhnyaya Bannovka section (Figs. 41 and 42). Recent research shows that *M. decoratus* may appear slightly below the FO of *L. acutus* (Ovechkina et al., 2019); however, the levels of FOs of *L. acutus* and *M. decoratus* can be considered very close to each other. The presence of *M. decoratus* is recorded in the Lower Cenomanian Gavelinella cenomanica Zone (Nizhnyaya Bannovka).

Cylindralithus biarcus, the zonal marker of the top of the **UC3** Zone, is recorded only in the Novouzenskaya borehole and found much higher along with the FO of *Micula staurophora* (Fig. 41). So, we cannot use *Cylindralithus biarcus* as a reliable marker. Another startigraphically important species of UC4 (base—FO of *Cylindralithus biarcus*, top—LO of *Lithraphidites acutus*) and UC5 (base—LO of *Lithraphidites acutus*, top—LO of *Helenea chiastia*) have not been found in our material due to the general rarity of nannofossils. Thus, only the undifferenciated interval of the Middle Cenomanian–Lower Turonian **UC3–UC6** zones can be established, which corresponds to the Turonian radiolarian assemblage *Pseudoaulophacus (Spongotripus) aculeatus–Stichocapsa pyramidata* or *Dictyomitra napaensis*. In the upper part of this interval the FO of *Ahmuellerella octoradiata*, which appears in the upper part of the UC5b subzone according to Burnett (1998), is recorded (Nizhnyaya Bannovka section, Middle–Upper Cenomanian Lingulogavellinella globosa Zone) (Fig. 42).

The Lower Turonian **UC7** Zone is traced without any difficulty, since it is established as the interval from the FO of *Quadrum gartneri* to the FO of *Eiffellithus eximius*. Both species are reliable markers; however, it could be difficult to identify *Q. gartneri* the in material with impoverished and poor nannofossil assemblage (Potanino 2 borehole) (Fig. 42). In sections with quite a rich assemblage, finding and identification of *Q. gartneri* poses little problem (Novouzenskaya borehole) (Fig. 41). As noted by Perch-Nielsen (1985), the level of the FO of *Eiffellithus eximius* coincides with the FO of *Lucianorhabdus maleformis*, which is confirmed in the Novouzenskaya borehole. Perch-Nielsen (1985) also suggested to use the FOs of *E. eximius* and L. *maleformis* as interchangeable markers for the base of the CC12 (Perch-Nielsen, 1979, 1985). However, Burnett (1998) recorded the FO of *L. maleformis* in close proximity to the FO of *Q. gartneri* in South England.

The lower part of the UC7 can be correlated with the Lower Turonian benthic assemblage *Gaudryinopsis filiformis–Reussella turonica*, the main upper part—with the Middle Turonian benthic assemblage with *Cibicides polyrraphes*, *Gavelinella vesca* and *Tappanina simplex* (Moscow Basin) and the Middle–Upper Turonian Gavelinella moniliformis Zone and the assemblage with *Reusella kelleri* and *Gavelinella praeinfrasantonica* of the Upper Turonian–Lower Coniacian (Saratov Region, Nizhnyaya Bannovka) (Fig. 42).

The **UC8** Zone can be established on the EEP (Potanino 2 borehole, Nizhnyaya Bannovka section) with some difficulty (Fig. 42). The base of the UC8 Zone is established by the FO of *Eiffellithus eximius* and is traced in the Moscow Basin (Potanino 2) and Saratov Region (Novouzenskaya boreholes and Bolshevik section) (Figs. 41–43). Using the FO of *L. maleformis* as an additional marker for the UC8 base allows to establish this zone in the Nizhnyaya Bannovka section. The UC8 top is defined by the FO of *Lithastrinus septenarius*, which is quite rare in our material, but is recorded in the Moscow Basin (Potanino 2). In the Novouzenskaya borehole, the FOs of *E. eximius* and *L. maleformis* coincide with the FO of *Helicolithus turonicus*, which was recorded by Burnett (1998) slightly higher, in the upper part of the UC8a Subzone.

Burnett (1998) established two subzones, the top of UC8a is marked by the FO of *Lithraphidites quadrifidus*. This species is absent in our material; thus, we cannot further subdivide the UC8 Zone.

The UC8 Zone can be correlated with the Turonian—probably Coniacian benthic foraminifera assemblage *Gavelinella moniliformis–Baggi-*

noides quadrilobus in the Moscow Basin and with the Upper Turonian–Lower Coniacian assemblage with *Reusella kelleri* and *Gavelinella praeinfrasantonica* in the Saratov Region (Nizhnyaya Bannovka) (Fig. 42).

The **UC9** Zone is established with some difficulty. Due to the rarity of *L. septenarius*, its FO is quite difficult to detect; however, the base of the zone has been recorded in the Moscow Basin (Potanino 2) (Fig. 42). The UC9 top is easily distinguished based on the FO of *Micula staurophora* and was recorded in the Saratov Region (Nizhnyaya Bannovka section and Novouzenskaya borehole) (Figs. 41 and 42). In the middle part of this zone, the FOs of *Helicolithus anceps* and *M. furcatus* are recorded. Burnett (1998) noted that the FO of *H. anceps* is recorded much lower, in the middle part of the Lower Cenomanian UC1 Zone. The FO of *M. furcatus* is fixed much lower in the lower part of the UC6b Subzone in North England (Burnett, 1998).

The lower part of the UC9 Zone can be correlated with the Turonian, possibly Coniacian benthic foraminifera assemblage *Gavelinella moniliformis–Bagginoides quadrilobus* in the Moscow Basin (Fig. 42). The FO of *M. staurophora* is recorded in the interval of the Upper Turonian–Lower Coniacian assemblage with *Reusella kelleri* and *Gavelinella praeinfrasantonica* in the Saratov Region (Nizhnyaya Bannovka) (Fig. 42).

The **UC10** Zone is traced with some difficulty and is clearly recognized only in the Novouzenskaya borehole (Saratov Region) (Fig. 41). The base of this zone is easily established by the FO of *Micula staurophora* and its top is fixed by the FO of *Lithastrinus grillii*, which is rare in the sections on the EEP. Perch-Nielsen (1979, 1985) noted that the FOs of *L. grillii*, *Reinhardtites anthophorus* and *Micula concava* coincide; however, Burnett (1998) considered the FO of *R. anthophorus* as an unreliable datum. Nevertheless, our data show that the FO of *R. anthophorus* is an acceptable datum and we suggest to use *R. anthophorus* as an additional marker for the top of UC10. In the Novouzenskaya borehole, the FO of *C. biarcus* coincides with the FO of *M. staurophora*, although Burnett (1998) noted an older occurrence for this species, in the Upper Cenomanian (UC4 Zone).

The UC10 falls within the lower part of the Middle–Upper Coniacian benthic foraminifera Gavelinella thalmanni Zone, or within LC7 Zone.

The **UC11** Zone is established as the interval from the FO of *Lithastrinus grillii* to the LO of *Lithastrinus septenarius*. The zone is traced on the EEP with some difficulty. Due to the rarity of *L. grillii* it is sometimes impossible to separate zones UC10 and UC11, and the undifferentiated interval of these zones is established in the Voronezh Region (Podgornoe 171) and Saratov Region (Pudovkino) (Figs. 42 and 44). The base of UC11 has been recorded only in the Novouzenskaya borehole (Saratov Region), and its top is traced in the Voronezh Region (Podgornoe 171) and Moscow Basin (Potanino 2) (Figs. 42 and 44).

Burnett (1998) recognized three subzones within UC11, which are in fact quite difficult to establish. The UC11a and UC11b subzones cannot be separated in our material, since the datum of the LO of *Quadrum gartneri* is very diachronic. In the Voronezh Region (Podgornoe 171), the LO of *Q. gartneri* is fixed below the level of the FO of *R. anthophorus*, and in the Novouzenskaya borehole the LO of *Q. gartneri* coincides with the FO of *L. grillii*.

The UC11c Subzone can be established in the Saratov Region (Pudovkino, Lysaya Gora) and Voronezh Region (Podgornoe 171), since the FO of *Lucianorhabdus cayeuxii*, which demarcates the base of this subzone, has been recorded there (Figs. 42 and 44).

In the Moscow Basin, the undifferentiated interval of UC9–UC11 correlates with the Coniacian benthic foraminifera assemblage *Gavelinella moniliformis–Bagginoides quadrilobus*. In the Voronezh Region (Podgornoe 171), the undifferentiated interval of UC10–UC11a-b corresponds to the Middle–Upper Coniacian Gavelinella thalmanni Zone (LC7)–lower part of the Upper Santonian Stensioeina pommerana Zone (LC11).

The base of the **UC12** Zone is defined by the LO of *Lithastrinus septenarius* and its top is fixed by the FO of *Arkhangelskiella cymbiformis*. The FO of *A. cymbiformis* is easily traceable in the sections on the EEP. The UC12 has been recorded in the Voronezh Region (Podgornoe 171) and Saratov Region (Pudovkino and Krasny Oktyabr sections, and Novouzenskaya borehole) (Figs. 41–44). Within this zone, the FO of *Calculites obscurus* is recorded in the Belgorod Region (Rovenki 614), Voronezh Region (Podgornoe 171) and Saratov Region (Novouzenskaya borehole) (Figs. 41, 44, and 45). Burnett (1998) records the FO of this species near the Coniacian/Santonian boundary (UC11c).

The FO of *A. cymbiformis* shows a great deal of diachnonizm. In the Voronezh Region (Podgornoe 171), the FO of *A. cymbiformis* is recorded in the Upper Santonian Stensioeina pommerana Zone (Fig. 44). The lowest occurrence of *A. cymbiformis* is recorded in the Lower Santonian Gavelinella infrasantonica Zone (LC8) in the Belgorod Region (Butovo 100 and Rovenki 614) (Fig. 45). The first occurrence of *A. cymbiformis* has not been recorded in these sections, the constant presence of this species is noted from the lowest samples. In the Saratov Region (Pudovkino), the FO of *A. cymbiformis* is recorded within the radiolarian assemblage *Pseudoaulophacus floresensis*, which correlates to the Lower Santonian Gavelinella infrasantonica Zone (upper part of LC8) (Fig. 42).

The **UC13** Zone is fairly well traced on the EEP in the Belgorod Region (boreholes Butovo 100 and Rovenki 614), Voronezh Region (Podgornoe 170 and Podgornoe 171 sections) and Saratov Region (Pudovkino, Krasny Okrybr, Bolshevik sections, and Novouzenskaya borehole) (Figs. 41–45).

The base of the UC13 Zone is established by the FO of *A. cymbiformis*, which has been discussed in detail above. The base of the UC13b subzone is fixed by the FO and consistent presence of *Orastrum campanensis* and is quite confidently distinguished in almost all the studied sections, despite the fact that this species is rare at high latitudes. The consistent presence of *O. campanensis* in sections Podgornoe 170 and Podgornoe 171 is noted in the Upper Santonian Stensioeina pommerana Zone, and in the boreholes Butovo 100 and Rovenki 614 even in the Lower Santonian Gavelinella infrasantonica Zone.

The **UC14** Zone with subzones “a” and “b” is distinguished practically at all latitudes, since the levels of FOs of *Broinsonia parca parca* and *B. parca constricta* are well recorded (Burnett, 1998). The UC14 Zone with these two subzones is traced in practically all studied sections on the EEP: in the Belgorod Region (boreholes Butovo 100, Rovenki 614), Voronezh Region (Podgornoe 170, Podgornoe 171 and Kolbinskoe sections) and Saratov Region (Pudovkino, Lysaya Gora, Krasny Okryabr, Bolshevik sections, and Novouzenskaya borehole) (Figs. 41–45).

The FO of *Br. parca parca* datum shows a certain degree of diachnonizm. In the borehole Rovenki 614, *B. parca parca* is first recorded in the Upper Santonian Gavelinella stelligera Zone; in the section Podgornoe 171, in the Upper Santonian Stensioeina pommerana Zone; in the section Lysaya Gora, Podgornoe 170 and the borehole Butovo 100, in the Lower Campanian Gavelinella clementiana clementiana Zone; in the Bolshevik and Krasny Oktyabr sections, the FO of *B. parca parca* is recorded in the younger Lower Campanian LC13 Zone, which corresponds to the Lower Campanian Cibicidoides temirensis and Cibicidoides aktulagayensis zones (Olferiev et al., 2009b, 2014).

The FO of *B. parca constricta*, which fixes the base of the UC14b is a reliable datum established in many studied sections on the EEP, which, however, also demonstrates diachronism. In the borehole Rovenki 614, it is fixed in the Upper Santonian Stensioeina pommerana Zone (Fig. 45); in the borehole Butovo 100, in the Lower Campanian Gavelinella clementiana clementiana Zone (Fig. 45); in the Podgornoe 170 section, in the Lower Campanian Cibicidoides temirensis Zone (Fig. 44); in the Bolshevik and Krasny Oktyabr sections, in the Lower Campanian LC13 Zone (Fig. 43) (Olferiev et al., 2009a, b, 2014); and in the Lysaya Gora section, the FO of *B. parca constricta* has been fixed at even a higher level at the boundary of the Upper Campanian Brotzenella monterelensis and Globorotalites emdyensis zones (Fig. 42).

The **UC15** Zone can be identified on the EEP; however, it is not always possible to subdivide it into subzones. The base of UC15 is identified by the FO of *Misceomarginatus pleniporus* and this event is recorded in the borehole Butovo 100 in the Upper Campanian Brotzenella monterelensis Zone (Fig. 45). It is impossible to recognize the lower subzones a, b, and c, since the studied sections lack their markers *Cylindralithus biarcus* and *Heteromarginatus bugensis*. At the same time, the FO of *Prediscosphaera stoverii*, which marks the lower boundary of the UC15d subzone, is recorded in the some studied sections. In the borehole Butovo 100, this species appears in the Upper Campanian Brotzenella monterelensis Zone. The top of the UC15d Subzone is marked by the LO of *O. campanensis* and is relatively well traced in the borehole Butovo 100, and in the Belgorod and Rossypnoe sections (Figs. 45 and 46).

In the borehole Butovo 100, the LO of *O. campanensis* is confined to the boundary of the Upper Campanian Brotzenella monterelensis/Globorotalites emdyensis zones; in the section Belgorod, this species disappears in the middle part of the Upper Campanian Angulogavelinella gracilis Zone; and in the Rossypnoe section in the Upper Campanian–Lower Maastrichtian Neoflabellina praereticulata/*N. reticulata* (LC19) (Figs. 45 and 46).

The interval of the UC15e Subzone, which crowns UC15, was determined by Burnett (1998) by the LO of *Eiffellithus eximius*. Perch-Nielsen (1979, 1985) and Burnett (1998) believed that the LO of another important marker, *R. anthophorus*, is also confined to this level. The FOs of both *R. anthophorus* and *E. eximius* are discussed below. In most of the studied sections on the EEP, the FO of *E. eximius* is recorded much earlier than the LO of *R. anthophorus*.

Unfortunately, the UC15 Zone covers a very large stratigraphic interval—the upper part of the lower and practically the entire upper Campanian (except for its uppermost part)—and its use in the present sense gives little for the detailed stratigraphy. As a result, the upper part of the lower and the lower part of the upper Campanian remains undivided.

The Upper Campanian **UC16** Zone is defined as the interval from the LO of *E. eximius* to the LO of *Br. parca constricta* and is quite confidently traced in many sections on the EEP (Rossypnoe, Efremovo-Stepanovka, Lokh, Klyuchi 2, Krasny Oktyabr, Bolshevik and Novouzenskaya) (Figs. 41, 43, 46, and 47); however, some subzones cannot be recognized. The upper boundaries of the UC16a and UC16b subzones cannot be identified, since the zonal species *Heteromarginatus bugensis* and *Tortolithus caistorensis* have not been found. The LO of *Monomarginatus quaternarius* is an unreliable datum, since this species is rare, or even sporadic, in our material.

The diachronism of the UC16 base is noticeable even within the same region. In the Rostov Region, the lower boundary of UC16 is traced in the upper part of the Upper Campanian LC16 (Tarasovskii 1 and Tarasovskii 2); in Rossypnoe, in the lower part of the Lower Maastrichtian LC20 Zone; whereas in the Efremovo-Stepanovka section, in the yonger undivided interval of Lower Maastrichtian LC21 and Upper Maastrichtian LC22 zones (Fig. 46). In the Saratov Region, the base of UC16 is recorded in the transitional Upper Campanian–Lower Maastrichtian LC19 Zone (Bolshevik), or in the lower part of the Lower Maastrichtian LC20a Subzone (Krasny Oktyabr) (Fig. 43).

The **UC17** is fixed quite easily as the interval from the LO of *Br. parca constricta* to the LO of *Tranolithus orionatus* and is established in the Saratov Region. However, in the Lokh section, it was impossible to separate the UC17 and UC18 zones due to the absence of *T. orionatus* (Fig. 47). In the Novouzenskaya borehole and Krasny Oktyabr section, this zone correlates with the upper part of the Lower Maastrichtian Brotzenella complanata Zone (LC20) and the Bolivinoides draco draco Zone (LC21) (Figs. 41 and 43); in the Bolshevik section, the Lower Maastrichtian Brotzenella complanata Zone (LC20) (Fig. 43).

The **UC18** is established as the interval from the LO of *Tr. orionatus* to LO of *R. levis* and can be traced in the Saratov Region (Krasny Oktyabr, Bolshevik sectons, and Novouzenskaya borehole) (Figs. 41 and 43). The UC18 Zone is equivalent to CC24, which description has been discussed above.

The transitional Lower–Upper Maastrichtian **UC19** Zone is recorded as the interval from the LO of *R. levis* to the FO of L. *quadratus* and is established in the Saratov Region (Krasny Oktyabr, Bolshevik sectons, and Novouzenskaya borehole) (Figs. 41 and 43). The UC19 Zone is equivalent to the CC25a Subzone, which description has also been discussed earlier.

The Upper Maastrichtian **UC20** Zone is clearly identifiable at high latitudes; its lower boundary is established by the FO of L. *quadratus*. The proposed by Burnett (1998) detailed subdivision of the upper part of the Maastrichtian does not always work on the EEP.

The lower UC20a Subzone is fixed as the interval from the FO of *L. quadratus* to the FO of *Nephrolithus frequens* and can be establish without any difficulty in some sections of the Saratov Region (Krasny Oktyabr, Bolshevik sectons, and Novouzenskaya borehole) (Figs. 41 and 43). However, the UC20a Subzone has not been identified in the Klyuchi 1 and Klyuchi 2 sections of the Saratov Region (Fig. 47); in these two sections, the FO of *L. quadratus* has been found almost simultaneously with *N. frequens* (Hanzawia ekblomi Zone), which defines the lower boundary of the UC20b Subzone. This is probably indicative of the absence of a corresponding stratigraphic interval in this area.

The subzone UC20c also failed to be identified. Its lower boundary is fixed by the FO of *Arkhangelskiella maastrichtiensis*, which is absent from all studied sections, except for Krasny Oktyabr (Fig. 43). Thus, the FO of *A. maastrichtiensis* is assumed to an unreliable datum on the EEP. The uppermost UC20d Subzone is well established and traceable in all studied sections, since its lower boundary is determined by the FO of *Cribrosphaerella daniae* (Hanzawia ekblomi Zone).

To summarize the above, it is difficult to subdivide the upper part of the Lower and the most of the Upper Campanian on the EEP using the scheme by Sissingh (1977) with additions by Perch-Nielsen (1985), due to the absence or rarity of some zonal index species. Despite the fact that the Boreal scale of Burnett (1998) succeeds in further subdivision of the Campanian and Maastrichtian deposits, it is not particularly instrumental for the detailed division of the stratigraphic interval around the Lower and Upper Campanian boundary.

5.2 Calcareous nannofossils zonal scale for the Upper Cretaceous deposits of the south and east of the East European Platform

The analysis of the applicability of both zonal schemes (Burnett, 1998; Perch-Nielsen, 1985; Sissingh, 1977) for the subdivision of the Upper Cretaceous deposits on the EEP shows that neither one can be used in its entirety. Therefore, it is necessary to identify regional stratigraphic units suitable for the EEP.

The revealed discrepancies in the position of the nannofossil zonal boundaries in different sections compared to benthic foraminifera zones are quite significant and are underlined by the inherent diachronous nature of biozones, based on either nannofossils or foraminifera, the dependence of their stratigraphic ranges on local environmental conditions, and other reasons. Therefore, it seems appropriate to propose an independent scale focused on the peculiarities of the taxonomic composition of nannofossil assemblages of the EEP. In order to achieve this, species with the most stable levels of FOs and LOs have been selected. The revealed sequence of the nannofossil event constitutes the basis for the integrated nannofossil biostratigraphic scale of the Upper Cretaceous on the EEP (Fig. 48).

The proposed version of the zonal scheme below (Fig. 49) broadly follows Burnett (1998). Relationships of the zones with those from the scheme by Sissingh (1977) with additions of Perch-Nielsen (1985) are discussed where necessary, and a number of marker species are replaced. The names of the zones in the newly proposed scheme are given after Burnett (1998), but newly defined zones and subzones are asterisked. The newly proposed zonal scheme must be throroughly tested on other sections in the North-eastern Pery-Tethys for its further refinement.

A zonation based on the benthic foraminifera has been used as an external (independent) scale (Beniamovskii, 2008a, b; Vishnevskaya et al., 2018), since this microfossil group has been traditionally studied in scores of sections on the EEP (Fig. 50).

5.2.1 Nannofossil biozonation

Zones UC0, UC1 (undifferentiated)

Author: Burnett (1998)

Definition: FO of *Eiffellithus turriseiffelii* to FO of *Gartnerago segmentatum.*

Range: Upper Albian to Lower Cenomanian (lower part of Gavelinella cenomanica Zone or LC1a; Turrilites costatus–Schloenbachia varians/Praeactinocamax primus primus–Neohibolites ultimus/Inoceramus crippsii zones).

Remarks: These zones were described by Burnett (1998), but are not included within the scope of this study. Due to the rarity of nannofossils and their poor preservation, the resolution of this interval is poor. However, the FO of *E. turriseiffelii* can be easily established in the boreholes Novouzenskaya (Saratov Region) and Potanino 2 (Moscow Basin). In the middle part of this interval, the FO of *Kamptnerius magnificus*, which appears near the base of UC1c according to Burnett (1998), is recorded.

Distribution: This undifferentiated zonal interval is recognized in the borehole Novouzenskaya.

Zone UC2*

Author: Ovechkina, herein

Definition: FO of *Gartnerago segmentatum* to FO of *Microrhabdulus decoratus*.

Range: Lower Cenomanian (upper but not uppermost part of Gavelinella cenomanica Zone or LC1b except its uppermost part; Turrilites costatus–Schloenbachia varians/Praeactinocamax primus primus–Neohibolites ultimus/Inoceramus crippsii zones).

Remarks: The FO of *M. decoratus* can be easily established in the material of the boreholes Novouzenskaya and Potanino 2.

Distribution: This zone is recognized in the borehole Novouzenskaya.

Zones UC3, UC4, UC5 and UC6 (undifferentiated)

Author: Burnett (1998).

Definition: FO of *Microrhabdulus decoratus* to the FO of *Quadrum gartneri.*

Range: Middle Cenomanian–basal Lower Turonian (uppermost Gavelinella cenomanica to lowermost Gavelinella nana Zone or LC3a Subzone; uppermost Turrilites costatus–Schloenbachia varians/Praeactinocamax primus primus–Neohibolites ultimus/Inoceramus crippsii zones to lowermost Praeactinocamax plenus triangulus Zone).

Remarks: These zones were described by Burnett (1998), but are not included within the scope of this study. Due to the rarity of nannofossils and poor preservation the resolution of this interval is poor. However, the base and the top of this interval can be easily distinguished in our material of the boreholes Novouzenskaya and Potanino 2. In the upper part of this interval the FO of *Ahmuellerella octoradiata*, which appears in the upper part of the UC5b subzone according to Burnett (1998), is recorded.

Distribution: This undifferentiated zonal interval is recognized in the boreholes Potanino 2 and Novouzenskaya.

Zone UC7

Author: Burnett (1998).

Definition: FO of *Quadrum gartneri* to the FO of *Eiffellithus eximius/ Lucianorhabdus maleformis.*

Range: basal Lower Turonian –Middle Turonian (lowermost Gavelinella nana Zone or LC3a Subzone to lower part of Gavelinella moniliformis zones or LC3–LC4a; lowermost Praeactinocamax plenus triangulus Zone to Inoceramus apicalis/Inoceramus lamarcki zones). The zone is equivalent to zone CC11 sensu Perch-Nielsen (1979).

Remarks: Due to the general rarity of nannofossils and their poor preservation the resolution of this interval is inadequate and distinguishing its boundaries may pose some difficulty. As noted by Perch-Nielsen (1985), the level of the FO of *E. eximius* coincides with the level of the FO of L. *maleformis*, which these species can be used as interchangeable markers for the base of CC12 (Perch-Nielsen, 1979, 1985).

Distribution: This zone is recorded in the boreholes Potanino 2 and Novouzenskaya.

Zone UC8

Author: Burnett (1998).

Definition: FO of *Eiffellithus eximius/Lucianorhabdus maleformis* to FO of *Lithastrinus septenarius.*

Range: Middle Turonian (Gavelinella moniliformis Zone or LC4b and lower part of LC5a; Inoceramus apicalis/Inoceramus lamarcki to Mytiloides striatoconcentricus zones).

Remarks: There could be some difficulty with recognition of this zone on the EEP. In the sections with an impoverishment assemblage, *L. septenarius* is quite rare or absent. The FO of *Helicolithus turonicus* is recorded which is coincided with the FOs of *E. eximius* and L. *maleformis.*

Distribution: This zone is recorded in the borehole Potanino 2 and Nizhnyaya Bannovka section.

Zone UC9

Author: Burnett (1998).

Definition: FO of *Lithastrinus septenarius* to FO of *Micula staurophora*.

Range: Upper Turonian to basal Middle Coniacian (upper part of Gavelinella moniliformis Zone to lowermost part of Gavelinella thalmanni Zone; Mytiloides striatoconcentricus Zone to Volviceramus koeneni Zone). The zone is equivalent to subzone CC13b of Perch-Nielsen (1985).

Remarks: Approximately in the middle part of this zone, the FOs of *Marthasterites furcatus* and *Helicolithus anceps* are recorded.

Distribution: This zone is recorded in the borehole Potanino 2 and Nizhnyaya Bannovka section.

Zone UC10*

Author: Ovechkina, herein.

Definition: FO of *Micula staurophora* to FO of *Reinhardtites anthophorus*. Amended by Ovechkina, herein. The zone is equivalent to zone CC14 of Perch-Nielsen (1985) and approximately to zone UC10 sensu Burnett (1998).

Range: Middle Coniacian (lower part of Gavelinella thalmanni Zone or LC7 without its uppermost part; Volviceramus koeneni Zone to Volviceramus involutus Zone).

Remarks: The FO of *M. staurophora* is a reliable datum and can be established with no difficulty. The top of this zone is herein proposed to be fixed by the FO of *R. anthophorus*. Burnett (1998) suggested to mark the top of the UC10 by the FO of L. *grillii*; however, the extreme rarity of this species makes the FO of L. *grillii* an unreliable datum for the use on the EEP. As noted by Perch-Nielsen (1979, 1985), the FOs of L. *grillii*, *R. anthophorus* and *Micula concava* coincide. Burnett (1998) considered the FO of *R. anthophorus* is an unreliable datum; nevertheless, the FO of *R. anthophorus* seems to be acceptable on the EEP. In the borehole Novouzenskaya, the FO of *C. biarcus* coincides with the FO of *M. staurophora*, although Burnett (1998) noted an older occurrence of the former, in the Upper Cenomanian UC4 Zone.

Distribution: This zone is recorded in the Voronezh Region (Podgornoe 171) and Saratov Region (Nizhnyaya Bannovka and Krasny Oktyabr sections, borehole Novouzenskaya).

Zone UC11*

Author: Ovechkina, herein.

Definition: FO of *Reinhardtites anthophorus* to the FO of *Lucianorhabdus cayeuxii.* The zone is equivalent to zone CC15 of Sissingh (1977) and Perch-Nielsen (1985), and is approximately equivalent to subzones UC11a and UC11b of Burnett (1998).

Range: Middle–Upper Coniacian (middle part of Gavelinella thalmanni Zone or uppermost LC7–basalmost LC8; Volviceramus involutus Zone–lowermost Magadiceramus subquadratus Zone).

Remarks: Burnett (1998) established the UC11 Zone as the interval from the FO of L. *grillii* to the LO of L. *septenarius*, but species of *Lithastrinus* are quite rare on the EEP and the base of UC11 is defined by the FO of *R. anthophorus* as discussed above. The top of the UC11 is marked by the FO of *L. cayeuxii* as suggested by Sissingh (1977) and Perch-Nielsen (1985), since the FO of *L. cayeuxii* is a reliable datum on the EEP.

Distribution: Moscow Basin (Potanino 2), Voronezh Region (Podgornoe 171) and Saratov Region (Pudovkino, Lysaya Gora, borehole Novouzenskaya).

Zone UC12*

Author: Ovechkina, herein.

Definition: FO of *Lucianorhabdus cayeuxii* to FO of *Arkhangelskiella cymbiformis.*

Range: Upper Coniacian–lower Lower Santonian (upper part of Gavelinella thalmanni Zone–lower part of Gavelinella infrasantonica Zone or LC8; lowermost Magadiceramus subquadratus Zone to lower part of Belemnitella propinqua propinqua Zone).

Remarks: The zone in the peresent sense is equivalent to the UC11c–UC12 (sub)zones of Burnett (1998) and approximately equivalent to the CC16–lower part of CC17 zones of Sissingh (1977) and Perch-Nielsen (1985). The FO of *L. cayeuxii* is a reliable datum for the definition of the UC12 base on the EEP. The FO of *Arkhangelskiella cymbiformis* is also a good datum and is easily established in our material. Within this subzone (lower part) the LO of *L. septenarius* is recorded and FO of *Calculites obscurus*. The FO of *C. obscurus* has been considered a good marker of the CC16 top; this species is also easily found in our material and it usually occurs before the FO of *A. cymbiformis.* However, in some sections the reverse sequence of events is observed, therefore it is impossible to subdivide this zone further.

Distribution: Saratov Region (Pudovkino, Novouzenskaya borehole) and Voronezh Region (Podgornoe 171).

Zone UC13

Author: Burnett (1998).

Definition: FO of *Arkhangelskiella cymbiformis* to the FO of *Broinsonia parca parca*.

Range: Upper part of Lower–lower part of Upper Santonian (upper part of Gavelinella infrasantonica and Belemnitella propinqua propinqua–lower part of Gavellinella stelligera and Belemnitella praecursor praepraecursor zones, or uppermost LC8–lower part of LC10).

Remarks: Burnett (1998) considered that this zone is globally applicable and established two subzones for the Boreal Province. This zone is approximately equivalent to the upper part of the CC17 Zone of Sissingh (1977) and Perch-Nielsen (1985). The FO of *A. cymbiformis* is a reliable datum on the EEP; however, the FO of *A. cymbiformis* is clearly diachronous: the highest FO is recorded in the Upper Santonian Stensioeina pommerana Zone (Voronezh Region, Podgornoe 171), the lowest FO–in the Lower Santonian Gavelinella infrasantonica Zone (Belgorod Region, Butovo 100 and Rovenki 614 boreholes), and the constant presence of this species has been observed from the lowest samples. The FO of *A. cymbiformis* is fixed in the Saratov Region (Pudovkino) in the radiolarian assemblage *Pseudoaulophacus floresensis*, which correlates with the Lower Santonian Gavelinella infrasantonica Zone. Thus, we conditionally draw the base of the UC13 Zone within the Lower Santonian Gavelinella infrasantonica Zone.

Distribution: Belgorod Region (boreholes Butovo 100, Rovenki 614), Voronezh Region (Podgornoe 171 and 170 sections) and Saratov Region (Pudovkino, Krasny Oktyabr, Bolshevik sections, Novouzenskaya borehole).

Subzone UC13A

Author: Burnett (1998).

Definition: FO of *Arkhangelskiella cymbiformis* to consistent FO of *Orastrum campanensis*.

Range: Upper part of Lower Santonian (upper part of Gavelinella infrasantonica Zone and Belemnitella propinqua propinqua zones or topmost LC8).

Remarks: Burnett (1998) considered that *Orastrum campanensis* is quite rare and sporadic at high latitudes, which is indeed so on the EEP. However, this event can be still used as a reliable zonal marker.

Distribution: Voronezh Region (Podgornoe 170 and 171 sections) and Saratov Region (Pudovkino, Bolshevik sections).

Subzone UC13B

Author: Burnett (1998).

Definition: FO of consistent *Orastrum campanensis* to FO of *Broinsonia parca parca*.

Range: uppermost Lower–lower Upper Santonian (upper part of the Gavelinella infrasantonica and Belemnitella propinqua propinqua–lower part of the Gavellinella stelligera and Belemnitella praecursor praepraecursor Zones, or LC9–lower LC10).

Remarks: The UC13b^{BP} Subzone was discovered in highly condensed oceanic sections (Burnett, 1998). In the Boreal Province to the Western Tethys, it is defined by Burnett (1998) as the interval from the LO of rare *Eprolithus floralis* to the FOs of *Biscutum magnum* and *Hexalithus gardetae*. In southern England, the FO of *Reinhardtites* cf. *R. levis* was recorded in this subzone (Burnett, 1998). On the EEP, the LO of *Eprolithus floralis* and FO of *Biscutum magnum* are recorded slightly higher.

Distribution: Belgorod Region (boreholes Butovo 100, Rovenki 614), Voronezh Region (Podgornoe 170 and Podgornoe 171 sections) and Saratov Region (Pudovkino, Krasny Oktyabr, Bolshevik sections).

Zone UC14

Author: Burnett (1998).

Definition: FO of *Broinsonia parca parca* to FO of *Misceomarginatus pleniporus*.

Range: upper Upper Santonian–lower Upper Campanian (upper part of Gavelinella stelligera–lower part of Brotzenella monterelensis zones or upper part of LC10–lower part of LC14; upper part of Sphenoceramus patootensis/Belemnitella praecursor praepraecursor–Hoplitoplacenticeras coesfeldiense/Belemnitella mucronata mucronata zones).

Remarks: The zone is quite well traced on the EEP. *Misceomarginatus pleniporus* occurs infrequently in the studied sections; however, the levels of its appearance and disappearance are well documented. Burnett (1998) identified her UC14 Zone as corresponding to the lower part of the Lower Campanian, which is equivalent to the CC18 Zone and most of the CC19 Zone of Sissingh (1977). The Boreal zone UC14 of Burnett (1998) is subdivided into two subzones. On the EEP, it is proposed to distinguish three subzones within UC14.

Distribution: The complete zone is established in the Butovo 100 borehole (Belgorod section), and is partly found in other parts of the EEP: Belgorod Region (Rovenki 614 borehole), Voronezh Region (Podgornoe 170, Podgornoe 171 and Kolbinskoe sections), Saratov Region (Pudovkino, Lysaya Gora, Krasny Oktyabr, Bolshevik sections, and Novouzenskaya borehole), Rostov Region (Tarasovskii 1, Tarasovskii 2, Rossypnoe and Efremovka-Stapenovka sections).

Subzone UC14A

Author: Burnett (1998).

Definition: FO of *Broinsonia parca parca* to FO of *Broinsonia parca constricta*.

Range: upper Upper Santonian–uppermost Upper Santonian (upper part of Gavelinella stelligera Zone or upper LC10–LC11; upper part of the Sphenoceramus patootensis/Belemnitella praecursor praepraecursor zones).

Remarks: This subzone is well traced at almost all paleolatitudes except the "Austral" region (Burnett, 1998). On the EEP, the subzone is easily recognizable in all studied sections. Within this subzone the LO of *Eprolithus floralis* and the FO of *Biscutum magnum* are recorded.

Distribution: Saratov Region (Lysaya Gora, Krasny Oktyabr, Bolshevik sections, Novouzenskaya borehole), Belgorod Region (Butovo 100, Rovenki 614 boreholes), Voronezh Region (Podgornoe 170 section).

Subzone UC14B*

Author: Ovechkina, herein.

Definition: FO of *Broinsonia parca constricta* to LO of *Marthasterites furcatus*.

Range: uppermost Upper Santonian–lowest Upper Campanian (uppermost part of Gavelinella stelligera Zone or upper LC11– lowermost part of Brotzenella monterelensis Zone or lowermost LC14; uppermost part of Sphenoceramus patootensis/Belemnitella praecursor praepraecursor–lowermost part of Hoplitoplacenticeras coesfeldiense/Belemnitella mucronata mucronata zones).

Remarks: Burnett (1998) did not use the LO of *M. furcatus* in her scheme; this event was included in the standard scale of Sissingh (1977) with additions of Perch-Nielsen (1985) to establish the top of the CC18 Zone. *Marthasterites furcatus* is rare at high latitudes, but the level of its LO is a fairly good marker.

This subzone is equivalent to the most of Burnett's UC14b or Perch-Nielsen's (1985) CC18b–c. Within this subzone the FO of *Biscutum notaculum* is recorded in its middle part. Rare *Bukryaster hayii* also occur in this subzone. Probably within this subzone *Cylindralithus biarcus* disappears, this species was found only in the Novouzenskaya borehole and it is impossible to accurately correlate the levels of the FO and LO of *C. biarcus*, since foraminifera have not been studied in this section.

Distribution: Saratov Region (Pudovkino, Lysaya Gora sections, Novouzenskaya borehole), Belgorod Region (Butovo 100, Rovenki 614 boreholes) and Voronezh Region (Podgornoe 170, Kolbinskoe section).

Subzone UC14C*

Author: Ovechkina, herein.

Definition: LO of *Marthasterites furcatus* to FO of *Misceomarginatus pleniporus*.

Range: lower Upper Campanian (lower part of Brotzenella monterelensis Zone or LC14 zones; lower part of Hoplitoplacenticeras coesfeldiense/Belemnitella mucronata mucronata zones).

Remarks: This subzone is equivalent to the upper part of the UC14b Subzone of Burnett (1998) or CC19a–b of Perch-Nielsen (1985). The LO of *Lithastrinus grillii* is observed in the middle part of the UC14C* Subzone on the EEP.

Burnett (1998) recorded the FOs of *Staurolithites mielnicesis* and *Markalius inversus* in this interval; however, the FO of *M. inversus* occurs higher on the EEP, in UC15B*.

Distribution: Belgorod Region (Butovo 100 borehole) and Saratov Region (Novouzenskaya borehole).

Zone UC15

Author: Burnett (1998).

Definition: FO of *Misceomarginatus pleniporus* to LO of *Eiffellithus eximius*.

Range: lower Upper Campanian–lower Lower Maastrichtian (Brotzenella monterelensis–Neoflabellina praereticulata/*N. reticulata* zones or middle LC14–LC19; Belemnitella mucronata mucronata–Belemnella lanceolata Zones).

Remarks: Burnett (1998) identified five subzones in her UC15; however, the virtual absence of *Cylindralithus biarcus* (found only in one section of the Caspian syneclise (Novouzenskaya borehole)) and *Heteromarginatus bugensis* on the EEP does not allow us to distinguish the two lower subzones. Therefore, we propose to three subzones. The zonal index *Eiffellithus eximius* was chosen the upper boundary of the zone, it shows a stable level of its LO on the EEP. Burnett (1998) and Perch-Nielsen (1985) noted that the LO of *Reinhardtites anthophorus* is timed to the LO of *E. eximius*, but the LO of *R. anthophorus* is recorded higher in the studied sections on the EEP.

Distribution: The complete zone is established in the Novouzenskaya borehole (Saratov Region), partily so in many other sections on the EEP: Belgorod Region (Butovo 100 borehole, Belgorod section), Rostov Region (Tarasovskii 1, 2, Rossypnoe, Efremovka-Stapenovka sections).

Subzone UC15A*

Author: Ovechkina, herein.

Definition: FO of *Misceomarginatus pleniporus* to FO of *Prediscosphaera stoverii*.

Range: lower Upper Campanian (middle part of Brotzenella monterelensis or LC14 Zones; Belemnitella mucronata mucronata Zone).

Remarks: This subzone corresponds to the UC15a–c subzones in the Boreal scale or the CC19b–CC21 and the lower part of CC22 subzones/zones of the Perch-Nielsen (1985). In the lower part of UC15A* above the level of the FO of *M. pleniporus*, the FO of *Monomarginatus quaternarius* is recorded; however, these species should appear simultaneously according to Burnett (1998). In UC15a–c, Burnett (1998) recorded the LO of *Lithastrinus grillii*, the FO of *Reinhardtites levis* and *Lithraphidites praequadratus* in Northern Germany. The second event was recorded higher on the EEP.

Distribution: Belgorod Region (Butovo 100 borehole) and Saratov Region (Novouzenskaya borehole).

Subzone UC15B*

Author: Ovechkina, herein.

Definition: FO of *Prediscosphaera stoverii* to LO of *Orastrum campanensis*.

Range: Upper Campanian (Brotzenella monterelensis–Angulogavelinella stellaria or (lower part of Angulogavelinella gracilis) zones, or upper part of LC14–LC18; Belemnitella mucronata mucronata–Belemnella licharewi zones). The subzone is equivalent to the UC15d Subzone of Burnett (1998).

Remarks: In the lower part of UC15B*, the FOs of *Reinhardtites levis* and *Markalius inversus*, the LO of *Biscutum magnum* are recorded. In the uppermost part of UC15B*, the LO of *Biscutum coronum* has been recorded within this zone on the EEP.

In UC15d, Burnett (1998) mentioned the LO of *Biscutum dissimilis* (somewhat later in NE England), along with the FO of *Zeugrhabdotus sigmoides*.

Distribution: Saratov Region (Novouzenskaya borehole) and Belgorod Region (Butovo 100 borehole).

Subzone UC15C*

Author: Ovechkina, herein.

Definition: LO of *Orastrum campanensis* to LO of *Eiffellithus eximius*.

Range: upper Upper Campanian–lower Lower Maastrichtian (Neoflabellina praereticulata/*N. reticulata* or upper part of Angulogavelinella gracilis–Neoflabellina reticulata zones, or LC19; Belemnella licharewi–Belemnella lanceolata zones). The subzone is equivalent to the UC15e Subzone of Burnett (1998).

Remarks: This interval is easily established on the EEP. The LOs of *M. pleniporus*, *U. trifidus*, *M. quaternarius* and the FOs of *Eiffellithus parallelus* and *Prediscosphaera bukryii* are recorded within UC15C*. Burnett (1998) recorded the LO of *Zeugrhabdotus biperforatus* in UC15e^{BP} of the Northern Germany, and the LO of *Broinsonia parca parca* in low latitudes.

Distribution: Saratov Region (Krasny Oktyabr section, Novouzenskaya borehole) and Rostov Region (Rossypnoe, Efremovo-Stepanovka sections).

Zone UC16

Author: Burnett (1998).

Definition: LO of *Eiffellithus eximius* to LO of *Broinsonia parca constricta*.

Range: Lower Maastrichtian (Brotzenella complanata Zone or lower part of LC20; upper part of Belemnella lanceolata Zone). This zone is an approximate equivalent of CC23a Subzone of Sissingh (1977).

Remarks: The FO of the *Pachydiscus neubergicus* (von Hauer) ammonite is used to determine the base of the Maastrichtian (Niebuhr, 2003). Nanofossil data of Burnett (1998) indicate that the base of the Belemnella lanceolata Zone, which formerly marked the base of the Maastrichtian in the Boreal region, technically lies within the upper Campanian (Burnett, 1998; Burnett et al., 1992). Subzone CC23a of Sissingh (1977) with additions of Perch-Nielsen (1985) is defined as the interval from the LO of *Reinhardtites anthophorus* to the LO of *Br. parca constricta*, i.e. the latest Campanian to Early Maastrichtian. Our data demonstrate that the highest LO of *E. eximius* is recorded in the Lower Maastrichtian LC20 Zone (Olferiev et al., 2009b).

Burnett (1998) identified four subzones in the interval of UC16, defining their boundaries by the LOs of *Heteromarginatus bugensis*, *Tortolithus caistorensis* and *Monomarginatus quaternarius*. As noted above, the first two species have not been found so far in the sections of the study area; *M. quaternarius* is rather rare, therefore it is proposed to distinguish only two subzones.

Distribution: Rostov Region (Rossypnoe, Efremovo-Stepanovka) and Saratov Region (Lokh, Klyuchi 2, Krasny Oktyabr, Bolshevik sections and Novouzenskaya borehole).

Subzone UC16A*

Author: Ovechkina, herein.

Definition: LO of *Eiffellithus eximius* to LO of *Reinhardtites anthophorus*.

Range: Lower Maastrichtian (Brotzenella complanata Zone or lowest part of LC20; upper part of Belemnella lanceolata Zone).

Remarks: Perch-Nielsen (1985) and Burnett (1998) noted that the LO of *Eiffellithus eximius* coincides with the LO of *R. anthophorus*. Nannofossil data of the Rostov Region (Tarasovskii 1, 2, Rossypnoe, Efremovo-Stepanovka sections) and Saratov Region (Krasny Oktyabr sections, Novouzenskaya borehole) show that *E. eximius* disappears much earlier, which is in a perfect agreement with results obtained by Fritsen (1999).

Distribution: Rostov Region (Efremovo-Stepanovka section) and Saratov Region (Krasny Oktyabr, Bolshevik sections and Novouzenskaya borehole).

Subzone UC16B*

Author: Ovechkina, herein.

Definition: LO of *Reinhardtites anthophorus* to LO of *Broinsonia parca constricta*.

Range: Lower Maastrichtian (Brotzenella complanata Zone or lower part of LC20; upper part of Belemnella lanceolata Zone). The zone is equivalent to CC23a Subzone of Sissingh (1977) or UC20iii Subzone of Gallagher and Hampton (1999).

Remarks: The LO of *Broinsonia parca parca* is recorded within this subzone.

Distribution: Saratov Region (Krasny Oktyabr, Bolshevik sections and Novouzenskaya borehole).

Zone UC17

Author: Burnett (1998).

Definition: LO of *Broinsonia parca constricta* to LO of *Tranolithus orionatus*.

Range: Lower Maastrichtian (Brotzenella complanata–Bolivinoides draco draco zones, or upper LC20– lower LC21; uppermost part of Belemnella lanceolata Zone–Belemnella sumensis Zone). The zone is equivalent to the CC23b Subzone of Sissingh (1977) and NK7 Zone of Mortimer (1987).

Remarks: This zone is easily recognizable on the EEP. In rare cases, *T. orionatus* can be absent, which makes it difficult to trace the top of the zone. Burnett (1998) recorded the LO of *Biscutum dissimilis* in Northern Germany in UC17.

Distribution: Saratov Region (Krasny Oktyabr, Bolshevik sections and Novouzenskaya borehole).

Zone UC18

Author: Burnett (1998).

Definition: LO of *Tranolithus orionatus* to LO of *Reinhardtites levis*.

Range: Upper Lower Maastrichtian (Bolivinoides draco draco Zone or middle part of LC21; Belemnella sumensis Zone). The zone is equivalent to Zone CC24 of Sissingh (1977) and Zone NK6 of Mortimer (1987).

Remarks: This zone is also easily recognizable on the EEP.

Distribution: Saratov Region (Krasny Oktyabr, Bolshevik sections and Novouzenskaya borehole).

Zone UC19

Author: Burnett (1998).

Definition: LO of *Reinhardtites levis* to FO of *Lithraphidites quadratus*.

Range: uppermost Lower Maastrichtian (Bolivinoides draco draco Zone or upper part of LC21; Belemnella sumensis Zone). The zone is equivalent to CC25a Subzone of Perch-Nielsen (1985).

Remarks: The zone is characterized by somewhat impoverished assemblages at all latitudes (Burnett, 1998).

Distribution: Saratov Region (Lokh, Krasny Oktyabr, Bolshevik sectons, and Novouzenskaya borehole).

Zone UC20

Author: Burnett (1998).

Definition: FO of *Lithraphidites quadratus* to LO of unreworked, not survivor taxa.

Range: Upper Maastrichtian (Brotzenella praeacuta/Hanzawai ekblomi Zone or LC22–LC23; Belemnitella junior–Neobelemnella kasimiroviensis Zone).

Remarks: This Zone is well traced on the EEP and its stratigraphic interval corresponds to the CC25b–c and CC26 zones (Perch-Nielsen, 1985).

Čepek and Hay (1969) and Sissingh (1977) proposed to distinguish the Nephrolithus frequens Zone as an interval from the FO to the LO of *N. frequens*. However, with such a definition of the zone, the problem of fixing its upper boundary arises, since *N. frequens* has been also found by us at the base of the Paleocene (unpubl. data), which was also noted by Perch-Nielsen and McKenzie (1982). Therefore, we propose to fix the upper boundary of the zone by the disappearance of unredeposited Late Cretaceous taxa, as was used by Burnett in the Boreal scale (1998).

This zone is well recognized at mid to high latitudes, where *N. frequens* is common, although this cold-water taxon is clearly diachronous (Burnett, 1998; Pospichal and Wise, 1990), and the level of the FO of *N. frequens* can be significantly older when moving northwards. At high latitudes of the Southern Hemisphere, this species appears at the border of the Campanian and Maastrichtian (Pospichal and Wise, 1990).

Burnett (1998) noted that the first appearance of the Paleocene *Neobiscutum* and small (1–2 µm) forms of *Cruciplacolithus primus*, which are found in the Maastrichtian stratotype, may be observed in this zone (Burnett, 1998; Romein et al., 1996). These forms have been recorded in one studied section on the EEP (Novouzenskaya borehole, Saratov Region).

Burnett (1998) recognized four subzones in the UC20 Zone, but not all subzonal markers can be traced on the EEP. For example, *Arkhangelskiella maastrichtiensis* is quite rare and has been found only in the Krasny Oktyabr section (Saratov Region). Therefore, we propose to establish three subzones in UC20.

Distribution: Saratov Region (Krasny Oktyabr, Bolshevik sections, and Novouzenskaya borehole).

Subzone UC20A

Author: Burnett (1998).

Definition: FO of *Lithraphidites quadratus* to FO of *Nephrolithus frequens*.

Range: Upper Maastrichtian (Brotzenella praeacuta Zone or lowest parts of LC22; Belemnitella junior–Neobelemnella kasimiroviensis Zone). The subzone is equivalent to the Lithraphidites quadratus Zone of Doeven (1983) or UC20a^{BP} Subzone of Burnett (1998).

Remarks: This subzone is established easily in several sections; however, the FO of L. *quadratus* coincides with the FO of *N. frequens* in some instances, which is most likely due to hiatuses in the corresponding sections.

Distribution: Saratov Region (Krasny Oktyabr, Bolshevik sectons, and Novouzenskaya borehole).

Subzone UC20B*

Author: Ovechkina, herein.

Definition: FO of *Nephrolithus frequens* to FO of *Cribrosphaerella daniae.*

Range: Upper Maastrichtian (Brotzenella praeacuta Zone or LC22; lower part of Belemnitella junior–Neobelemnella kasimiroviensis Zone). The subzone is equivalent to NK2 Zone of Mortimer (1987), UC20i of Gallagher and Hampton (1999) or UC20b–c^{BP} subzones of Burnett (1998).

Remarks: This subzone is characterized by large morphotypes of *A. cymbiformis.*

Distribution: Saratov Region (Klyuchi 1, Klyuchi 2, Krasny Oktyabr, Bolshevik sections, and Novouzenskaya borehole).

Subzone UC20C*

Author: Ovechkina, herein.

Definition: FO of *Cribrosphaerella daniae* to LO of unreworked, non survivor, Cretaceous taxa.

Range: Upper Maastrichtian (upper part of Brotzenella praeacuta/ Hanzawai ekblomi Zone or uppermost part of LC22–LC23; upper part of Belemnitella junior–Neobelemnella kasimiroviensis Zone). The subzone is equivalent to UC20d of Burnett (1998).

Remarks: This subzone is easily recognizable in many sections.

Distribution: Saratov Region (Klyuchi 1, Klyuchi 2, Teplovka 2, Teplovka 3, Krasny Oktyabr, Bolshevik sections, and Novouzenskaya borehole).

The proposed version of the nannofossil zonal scheme is compiled based on the appearance and disappearance of index species identified on the EEP. All existing Upper Cretaceous nannofossil schemes are not global, but assist with interprovincial correlation.

The comparison of the proposed scheme with the Boreal scale of Burnett (1998), reveals the following features (Fig. 49).

The undifferentiated interval of the UC0, UC1 Zones belongs to the Upper Albian–Lower Cenomanian on the EEP and in the Boreal scale.

The UC2 Zone corresponds to the Lower Cenomanian–basal Middle Cenomanian on the EEP and in the Boreal scale.

The undifferentiated interval of the UC3–UC6 zones corresponds to the basal Middle Cenomanian–basal Lower Turonian on the EEP and in the Boreal scale.

The UC7 Zone belongs to the Lower–Middle Turonian on the EEP, while in the Burnett's scale UC7 corresponds to the Lower Turonian.

The UC8 Zone refers to the Middle Turonian–basal Upper Turonian on the EEP, while in the Boreal scale of Burnett (1998) it belongs to the Lower–Middle Turonian.

The UC9 Zone belongs to the basal Upper Turonian–basal Middle Coniacian on the EEP, but in the Burnett's scale UC9 corresponds to the Middle Turonian–Lower or Middle Coniacian.

The UC10 Zone corresponds to the Middle Coniacian, while in the Burnett's scale UC10 falls into the Middle?–Upper Coniacian.

The UC11 Zone belongs to the Middle to Upper Coniacian on the EEP, and Burnett referred it to the Upper Coniacian to Lower? Santonian.

The UC12 Zone belongs to the Upper Coniacian–lower Lower Santonian on the EEP, while in the Burnett's scale UC12 corresponds to the Lower Santonian to lower Lower Campanian.

The UC13 Zone corresponds to the upper Lower–lower Upper Santonian on the EEP, while Burnett places UC13 into the lower part of the Lower Campanian.

The UC14 belongs to the upper Upper Santonian–lower Upper Campanian on the EEP, whereas Burnett correlates UC14 to the lower Lower to upper Lower Campanian.

The UC15 Zone correlates to the lower Upper Campanian–lower Lower Maastrichtian on the EEP, but according to Burnett UC15 belongs to the upper Lower to upper Upper Campanian.

The UC16 Zone corresponds to the Lower Maastrichtian on the EEP, while in the Burnett's scale UC16 belongs to the upper Upper Campanian.

The UC17 belongs to the Lower Maastrichtian on the EEP, whereas Burnett places UC17 into the upper Upper Campanian to upper Lower Maastrichtian.

The UC18 corresponds to the upper Lower Maastrichtian both on the EEP and in the Boreal scheme.

The UC19 Zone belongs to the uppermost Lower Maastrichtian on the EEP, while Burnett puts UC19 into the Upper Lower to lower Upper Maastrichtian.

The UC20 Zone belongs to Upper Maastrichtian up to the Cretaceous/ Tertiary boundary both on the EEP and in the Boreal scale.

Acknowledgments

The first author expresses her special gratitude to A.S. Alekseev and A.G. Olferiev for their comprehensive assistance during the initial stages of studying nannofossils, providing samples, literature and most valuable advice.

Fig. 31 Light microscope photographs of selected nannofossil species from the Belgorod and Saratov regions. (A) *Ahmuellerella octoradiata* (crossed nicols; Klyuchi 2 section, Nikolaevka Fm., Upper Maastrichtian, sample KL2/16); (B) *Chiastozygus platyrhetus* (crossed nicols; Klyuchi 1 section, Nikolaevka Fm., Upper Maastrichtian, sample KL1/38); (C) *Staurolithites angustus* (crossed nicols; Klyuchi 1 section, Nikolaevka Fm., Upper Maastrichtian, sample KL1/25); (D) *Staurolithites crux* (crossed nicols; Klyuchi 1 section, Nikolaevka Fm., Upper Maastrichtian, sample KL1/25); (E) *Zeugrhabdotus diplogrammus* (crossed nicols; Klyuchi 1 section, Nikolaevka Fm., Upper Maastrichtian, sample KL1/34); (F) *Rhagodiscus angustus* (crossed nicols; Klyuchi 1 section, Nikolaevka Fm., Upper Maastrichtian, sample KL1/38); (G) *Eiffellithus parallelus* (crossed nicols; Klyuchi 1 section, Nikolaevka Fm., Upper Maastrichtian, sample KL1/41); (H) *Eiffellithus eximius* (crossed nicols; Pudovkino section, Pudovkino Fm., Lower Campanian, sample 21); (I) *Reinhardtites anthophorus* (crossed nicols; Pudovkino section, Pudovkino Fm., Lower Campanian, sample 21); (J) *Tranolithus orionatus* (crossed nicols; Lysaya Gora section, Pudovkino Fm., Lower Campanian, sample 5); (K) *Cribrosphaerella ehrenbergii* (normal light; Klyuchi 1 section, Nikolaevka Fm., Upper Maastrichtian, sample KL1/38); (L) *Cribrosphaerella daniae* (normal light; Klyuchi 1 section, Nikolaevka Fm., Upper Maastrichtian, sample KL1/35); (M) *Cribrosphaerella daniae* (crossed nicols; Klyuchi 1 section, Nikolaevka Fm., Upper Maastrichtian, sample KL1/35); (N) *Nephrolithus frequens* (normal light; Klyuchi 1 section, Nikolaevka Fm., Upper Maastrichtian, sample KL1/35); (O) *Nephrolithus frequens* (crossed nicols; Klyuchi 1 section, Nikolaevka Fm., Upper Maastrichtian, sample KL1/35); (P) *Prediscosphaera bukryii* (crossed nicols; Lokh section, Nikolaevka Fm., Lower Maastrichtian, sample L/41); (Q) *Eprolithus floralis* (crossed nicols; Pudovkino section, Mezino-Lapshinovka Fm., Upper Santonian, sample 14); (R) *Arkhangelskiella cymbiformis* (crossed nicols; Klyuchi 1 section, Nikolaevka Fm., Upper Maastrichtian, sample KL1/41); (S) *Broinsonia parca parca* (crossed nicols; Lysaya Gora section, Pudovkino Fm., Lower Campanian, sample 5); (T) *Broinsonia parca constricta* (crossed nicols; Lysaya Gora section, Ardym Fm., Upper Campanian, sample 7); (U) *Lithraphidites grossopectinatus* (crossed nicols; Klyuchi 1 section, Nikolaevka Fm., Upper Maastrichtian, sample KL1/25); (V) *Lithraphidites quadratus* (crossed nicols; Klyuchi 1 section, Nikolaevka Fm., Upper Maastrichtian, sample KL1/27); (W) *Lithraphidites praequadratus* (crossed nicols; Klyuchi 1 section, Nikolaevka Fm., Upper Maastrichtian, sample KL1/42); (X) *Calculites obscurus* (crossed nicols; Lysaya Gora section, Mezino-Lapshinovka Fm., Upper Campanian, sample 3); (Y) *Marthasterites furcatus* (normal light; Lysaya Gora section, Pudovkino Fm., Lower Campanian, sample 5); (Z) *Acutturis scotus* (crossed nicols; Klyuchi 1 section, Nikolaevka Fm., Upper Maastrichtian, sample KL1/38); (Aa) *Lucianorhabdus* *cayeuxii* (crossed nicols; Pudovkino section, Mezino-Lapshinovka Fm., Upper Santonian, sample 11). Scale bars 5 μm.

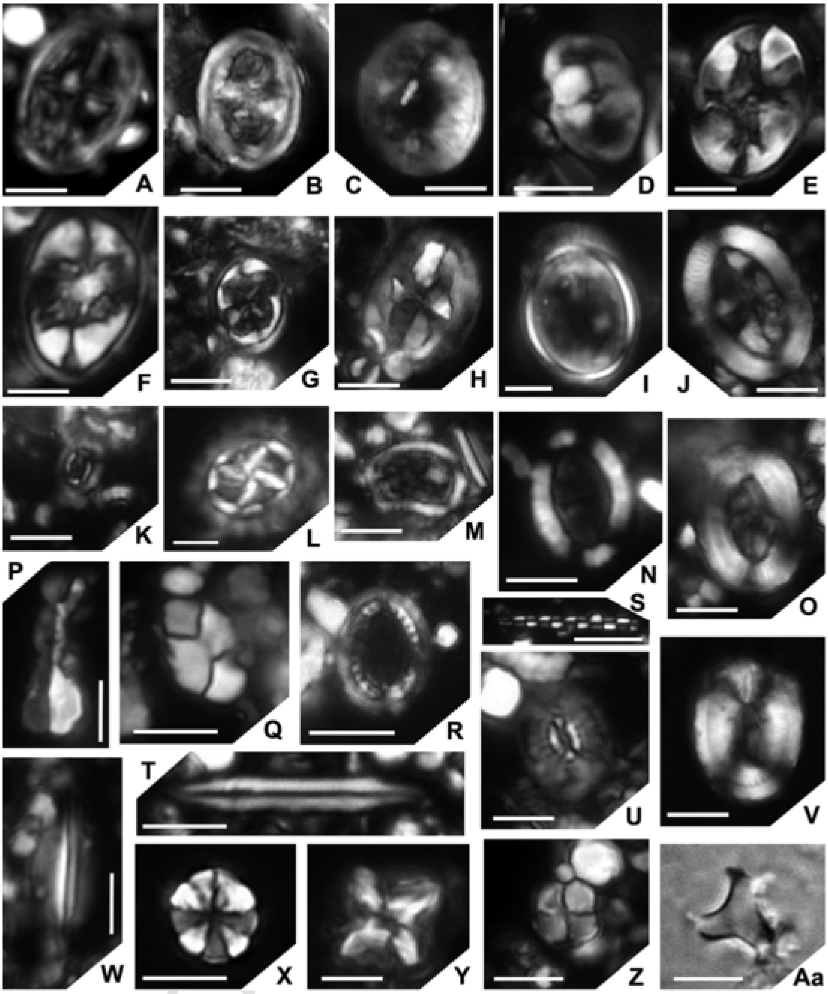

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Fig. 32 Light microscope photographs of selected nannofossil species from the Bolshevik section, Saratov Region. (A) *Misceomarginatus pleniporus* (Sengileev Fm., Lower Campanian, sample 90); (B) *Reinhardtites anthophorus* (Sengileev Fm., Lower Campanian, sample 16); (C) *Reinhardtites levis* (Karsun Fm., Lower Maastrichtian, sample 37); (D) *Tranolithus orionatus* (Karsun Fm., Lower Maastrichtian, sample 28); (E) *Eiffellithus eximius* (Sengileev Fm., Lower Campanian, sample 18); (F) *Eiffellithus parallelus* (Karsun Fm., Lower Maastrichtian, sample 43); (G) *Helicolithus trabeculatus* (Bannovka Fm., Middle–Upper Turonian, sample 7); (H) *Gartnerago segmentatum* (Sengileev Fm., Lower Campanian, sample 16); (I) *Kamptnerius magnificus* (Karsun Fm., Lower Maastrichtian, sample 21); (J) *Arkhangelskiella cymbiformis* (Karsun Fm., Lower Maastrichtian, sample 43); (K) *Prediscosphaera stoverii* (Karsun Fm., Lower Maastrichtian, sample 20); (L) *Prediscosphaera grandis* (Karsun Fm., Lower Maastrichtian, sample 20); (M) *Nephrolithus frequens* (Radischevo Fm., Upper Maastrichtian, sample 64); (N) *Broinsonia parca expansa* (Sengileev Fm., Lower Campanian, sample 16); (O) *Broinsonia parca parca* (Sengileev Fm., Lower Campanian, sample 83); (P) *Lucianorhabdus cayeuxii* (Sengileev Fm., Lower Campanian, sample 11); (Q) *Calculites obscurus* (Volsk Fm., Middle–Upper Coniacian, sample 10); (R) *Cribrosphaerella ehrenbergii* (Karsun Fm., Lower Maastrichtian, sample 43); (S) *Microrhabdulus decoratus* (Sengileev Fm., Lower Campanian, sample 84); (T) *Lithraphidites praequadratus* (Karsun Fm., Lower Maastrichtian, sample 51); (U) *Biscutum ellipticum* (Sengileev Fm., Lower Campanian, sample 16); (V) *Broinsonia parca constricta* (Karsun Fm., Lower Maastrichtian, sample 20); (W) *Lithraphidites quadratus* (Radischevo Fm., Upper Maastrichtian, sample 61); (X) *Radiolithus planus* (Bannovka Fm., Middle–Upper Turonian, sample 8); (Y) *Micula staurophora* (Karsun Fm., Lower Maastrichtian, sample 36); (Z) *Quadrum gartnerii* (Bannovka Fm., Middle–Upper Turonian, sample 7); (Aa) *Marthasterites furcatus* (normal light; Sengileev Fm., Lower Campanian, sample 15). All, except for (Aa), in crossed nicols. Scale bars 5 µm.

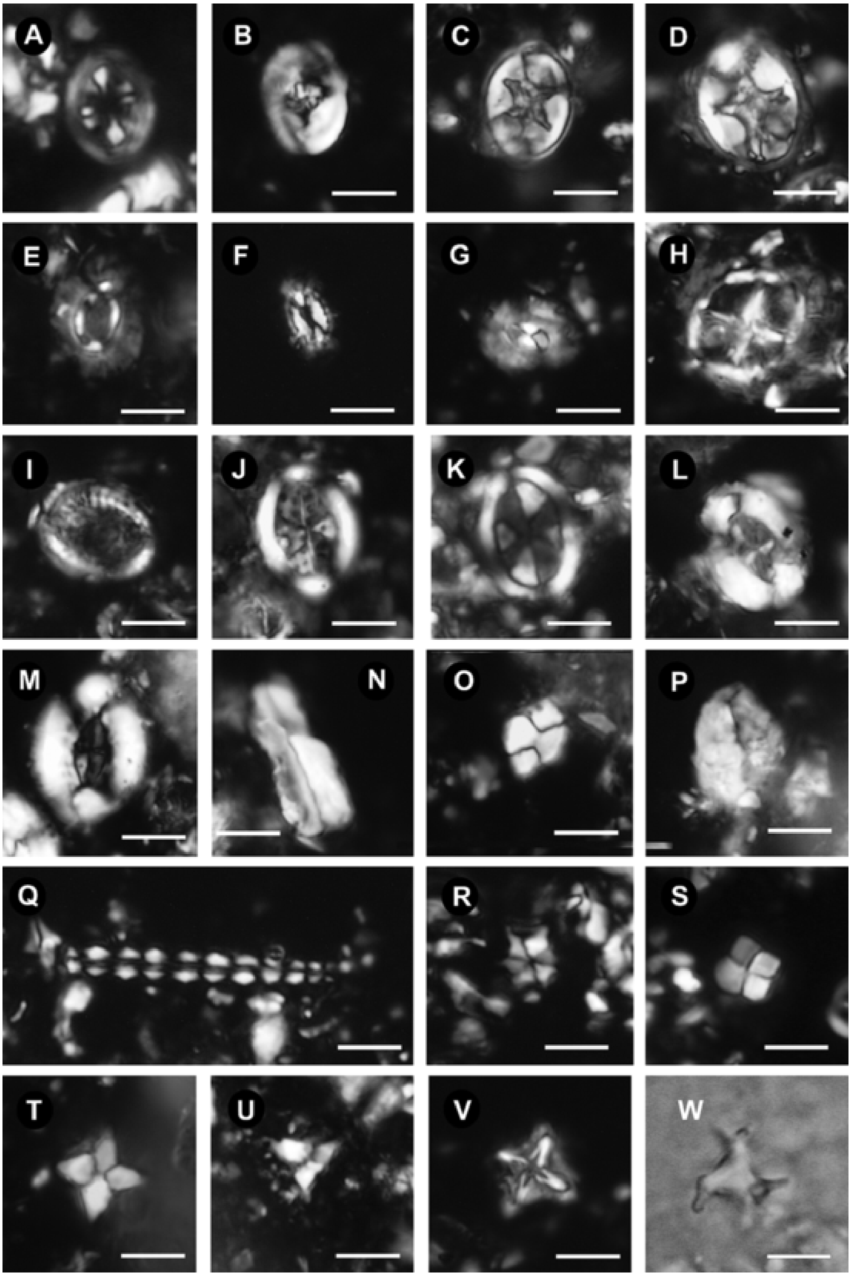
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Fig. 33 Light microscope photographs of selected nannofossil species from the Novouzenskaya borehole, Saratov Region. (A) *Ahmuellerella octoradiata* (sample 47, Upper Santonian); (B) *Reinhardtites levis* (sample 24, Upper Campanian); (C) *Eiffeltithus turriseiffelii* (sample 47, Upper Santonian); (D) *Eiffellithus eximius* (sample 43, Lower Santonian); (E) *Biscutum magnum* (sample 14, Lower Maastrichtian); (F) *Biscutum notaculum* (sample 18, Upper Campanian); (G) *Biscutum melaniae* (sample 25, Upper Campanian); (H) *Prediscosphaera grandis* (sample 37, Upper Santonian); (I) *Cribrosphaerella ehrenbergii* (sample 36, Upper Santonian); (J) *Arkhangelskiella specillata* (sample 20, Upper Campanian); (K) *Arkhangelskiella cymbiformis* (sample 28, Lower Campanian); (L) *Broinsonia parca parca* (sample 22, Upper Campanian); (M) *Broinsonia parca constricta* (sample 23, Upper Campanian); (N) *Lucianorhabdus cayeuxii* (sample 14, Lower Maastrichtian); (O) *Calculites obscurus* (sample 32, Lower Campanian); (P) *Orastrum campanensis* (sample 32, Lower Campanian); (Q) *Microrhabdulus undosus* (sample 27, Lower Campanian); (R) *Lithastrinus grillii* (sample 37, Upper Santonian); (S) *Quadrum gartnerii* (sample 47, Upper Coniacian); (T) *Uniplanarius gothicus* (sample 25, Upper Campanian); (U) *Uniplanarius trifidus* (sample 21, Upper Campanian); (V) *Micula staurophora* (sample 33, Lower Campanian); (W) *Marthasterites furcatus* (normal light; sample 41, Lower Santonian). All, except for (W), in crossed nicols. Scale bars 5 μm.

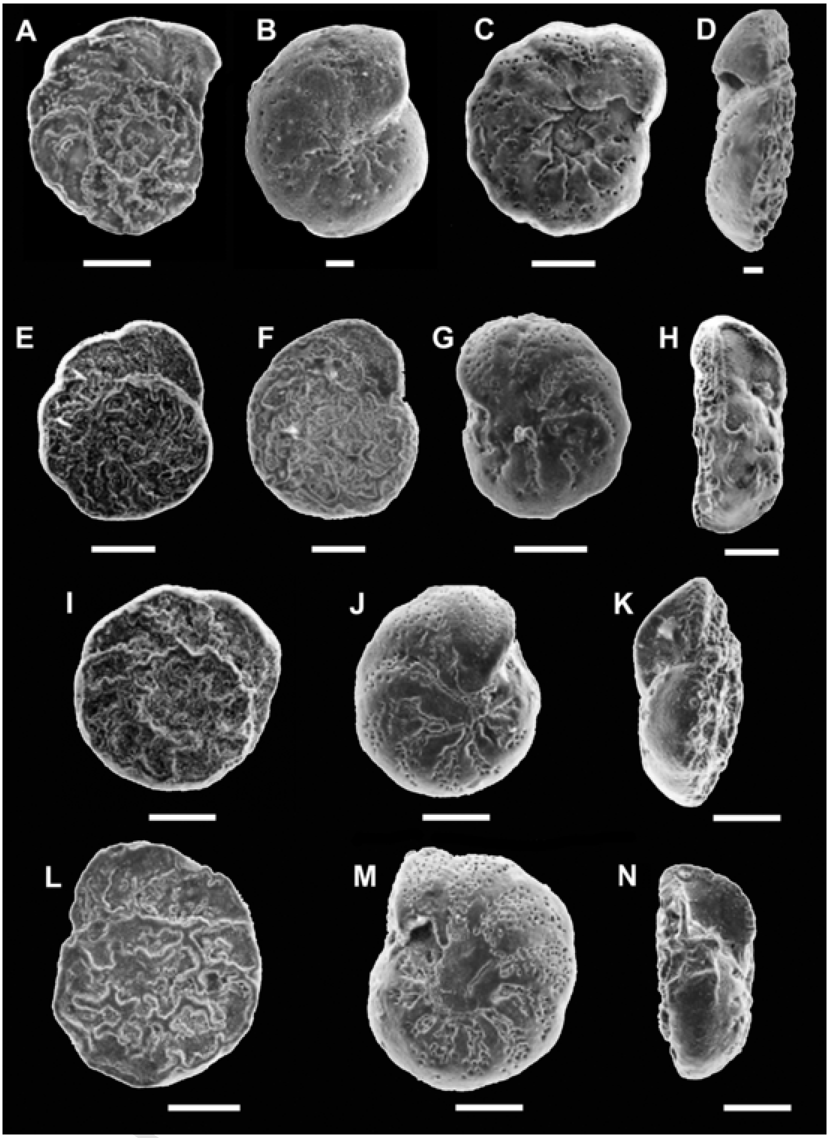
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Fig. 34 SEM photographs of important benthic foraminifera *Stensioeina* species from the Upper Cretaceous of the EEP (Voronezh Region, Podgornoe section). (A–D) *Protostensioeina emscherica* (Baryschnikova): (A, B) spiral, (C) umbilical, (D) axial views (sample 36, Lower–Middle Coniacian); (E–H) *Stensioeina exsculpta exsculpta* (Reuss): (E) spiral, (F, G) umbilical, (H) axial views (sample 34, Upper Coniacian–Lower Santonian); (I–K) *Stensioeina incondita* Koch: (I) spiral, (J) umbilical, (K) axial views (sample 30, Lower Santonian); (L–N) *Stensioeina pommerana* Brotzen: (L) spiral, (M) umbilical, (N) axial views (sample 21, Upper Santonian). Scale bars 100 μm.

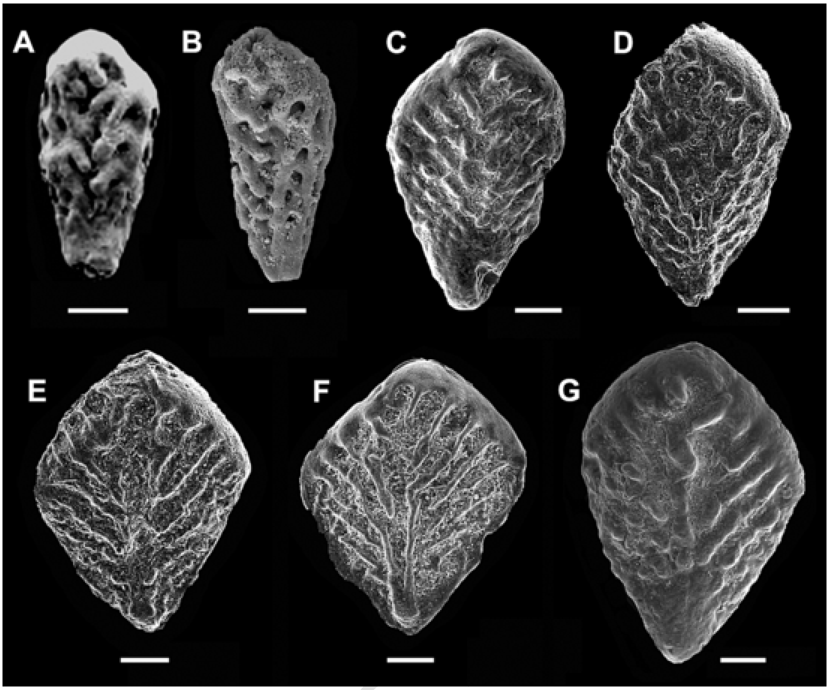

Fig. 35 SEM photographs of important benthic foraminifera *Bolivinoides* species from the Upper Cretaceous of the EEP (Voronezh and Saratov regions). (A) *Bolivinoides strigallatus* (Chapman) (Voronezh High, Podgornoe, Boguchar Fm., Pseudovalvulineria stelligera/Bolivinoides strigllatus Zone, Upper Santonian); (B) *B. culverensis* Barr (Voronezh High, Podgornoe, Boguchar Fm., Stensioeina pommerana Zone, Upper Santonian); (C, D) *Bolivinoides decoratus* (Jones) (Saratov, Vishnevoe village, Rybushkinskaya Fm., Cibicidoides involutus Zone, Lower Campanian); (E) *Bolivinoides draco miliaris* Hiltermann and Koch (Peri-Caspian depression, Uil River, borehole 68, Globorotalires emdyensis Zone, Bolivinoides draco miliaris Subzone, Upper Campanian); (F) *Bolivinoides draco draco* (Marsson) (Peri-Caspian depression, Uil River, borehole 68, Brotzenella complanata Zone, Bolivinoides draco draco Subzone, Lower Maastrichtian); (G) *Bolivinoides giganteus* Hiltermann and Koch (Peri-Caspian depression, Uil River, borehole 68, Brotzenella praeacuta/Hanzawaia ekblomi Zone, Upper Maastrichtian). Scale bars 100 μm.

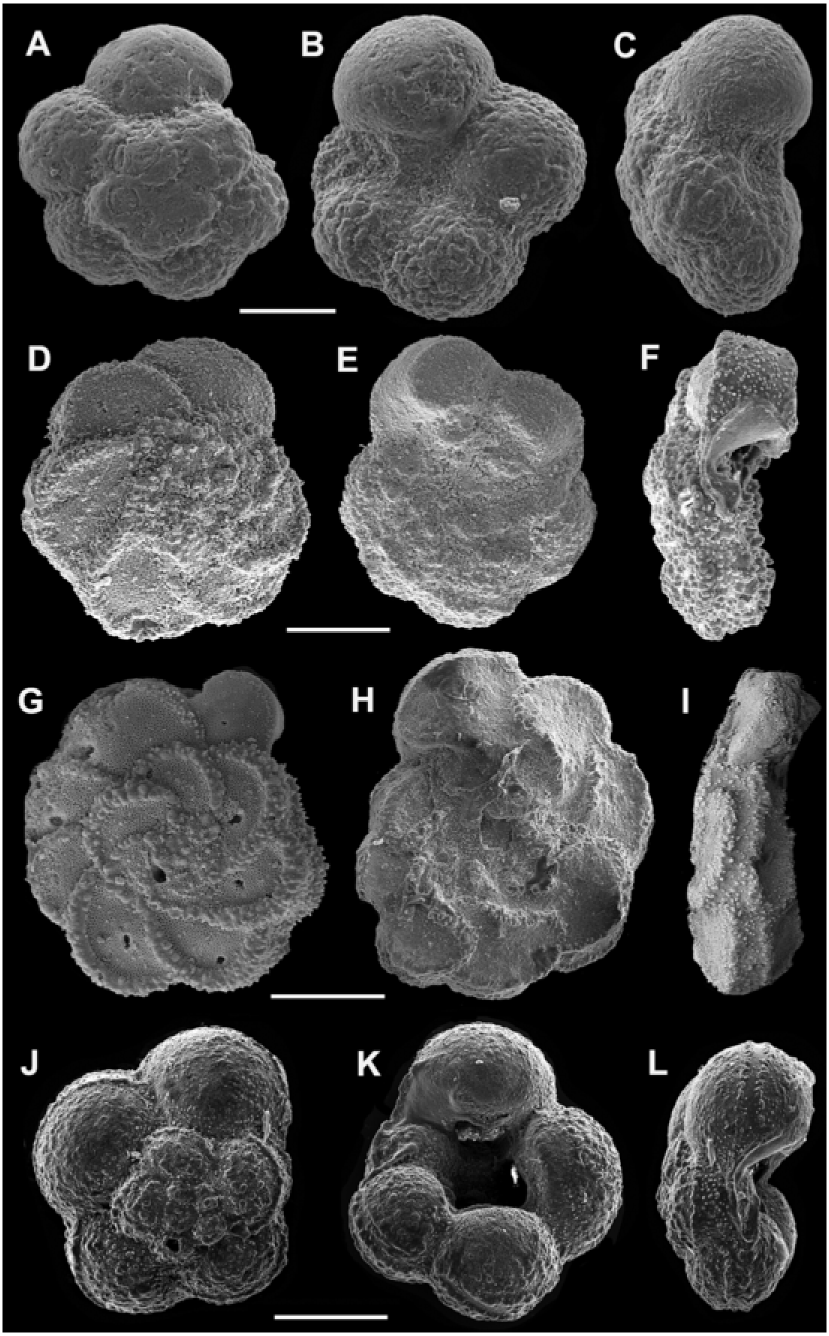
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Fig. 36 SEM photographs of important planktonic foraminifera species from the Upper Cretaceous of the EEP. (A–C) *Whiteinella archaeocretacea* Pessagno: (A) spiral, (B) umbilical, (C) axial views (Voronezh High, Fokino section, Tuskarskaya Fm., beds with Hedbergella holzli/Witheinella archeocretacea, Lower Turonian); (D–F) *Marginotruncana pseudolinneiana* Pessagno: (D) spiral, (E) umbilical, (F) axial views (Voronezh High, Fokino, Tuskarskaya Fm. (upper part), beds with Marginotruncana psedolinneiana, Middle Turonian); (G–I) *Marginotruncana coronata* (Bolli): (G) spiral, (H) umbilical, (I) axial views (Voronezh High, Fokino, Chernevo Fm., beds with Marginotruncana coronata/M. renzi, Upper Turonian–Lower Coniacian); (J–L) *Archaeoglobigerina cretacea* (d'Orbigny): (J) spiral, (K) umbilical, (L) axial views (Donetsk Basin, Zakotnoe section, beds with Archaeoglobigerina cretacea, Upper Coniacian–Lower Santonian). Scale bars 100 μm.

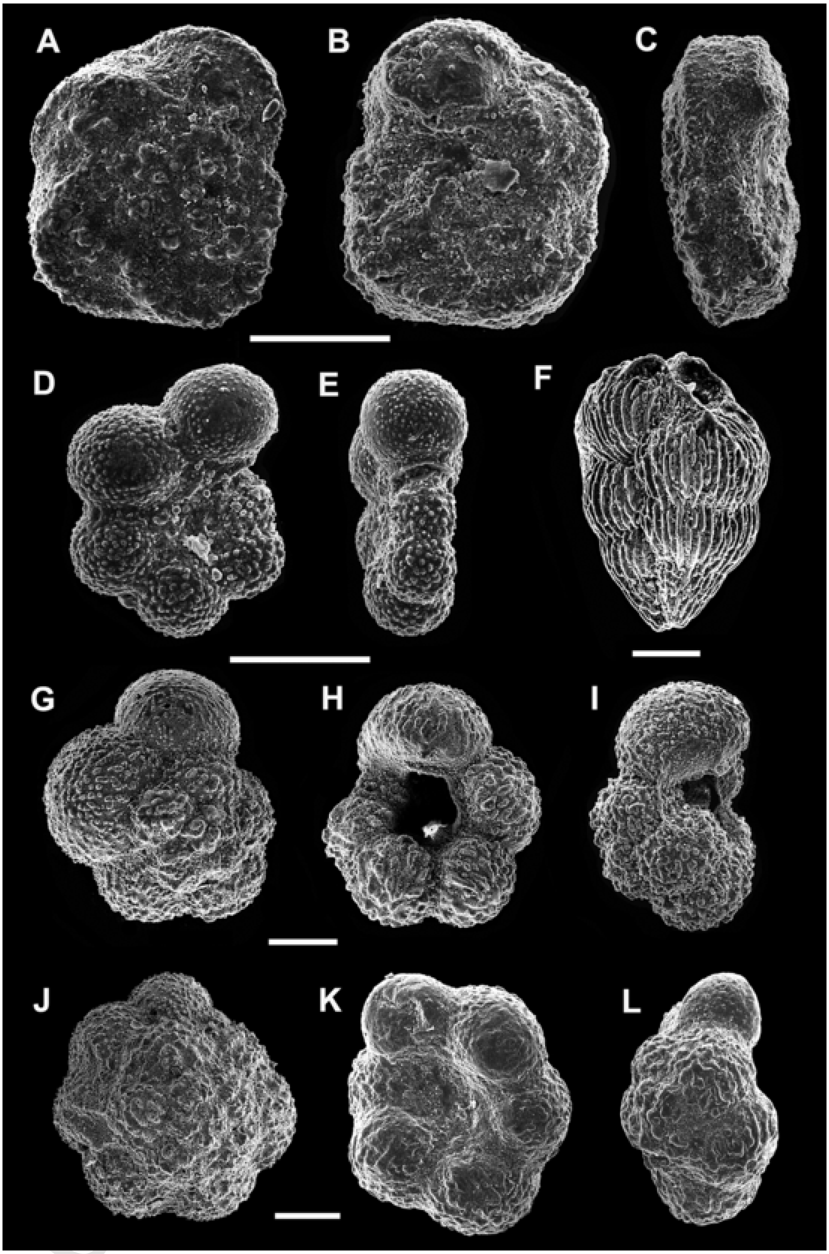
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Fig. 37 SEM photographs of important planktonic foraminifera species from the Upper Cretaceous of the EEP. (A–C) *Globotruncana bulloides* Vogler: (A) spiral, (B) umbilical, (C) axial views (Saratov Region, Vishnevoe, Mezino-Lapshinovka Fm., beds with Globotruncana bulloides, Upper Santonian); (D, E) *Globigerinelloides asper* (Ehrenberg): (D) spiral, (E) axial views (Podgornoe, Tulucheevka Fm., beds with Globigerinelloides asper, sample 31, Lower Santonian); (F) *Pseudotextularia elegans* (Rzehak) (Saratov Region, Klyuchi 1, beds with Pseudotextularia elegans, Upper Maastrichtian); (G–I) *Rugoglobigerina rugosa* Plummer: (G) spiral, (H) umbilical, (I) axial views (Saratov Region, Lokh 1, beds with Rugoglobigerina, Lower Maastrichtian); (J–L) *Rugoglobigerina hexacamerata* Brönnimann: (J) spiral, (K) umbilical, (L) axial views (Volsk, Bolshevik quarry, beds with Rugoglobigerina, Lower Maastrichtian). Scale bars 100 µm.

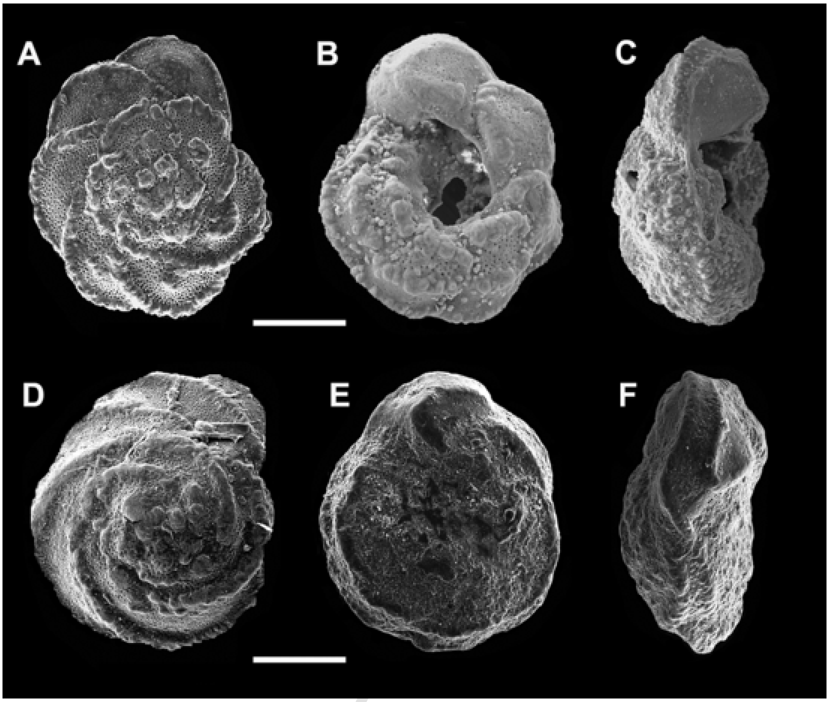

Fig. 38 SEM photographs of important planktonic foraminifera species from the Upper Cretaceous of the EEP. (A–C) *Globotruncana arca* (Cushman): (A) spiral, (B) umbilical, (C) axial views (Peri-Caspian depression, Uil River, borehole 68, beds with Globotruncana arca, lower Campanian); (D–F) *Contusotruncana morozovae* Vassilenko: (D) spiral, (E) umbilical, (F) axial views (Peri-Caspian depression, Uil River, borehole 68, beds with Contusotruncana morozovae, upper Campanian). Scale bars 100 μm.

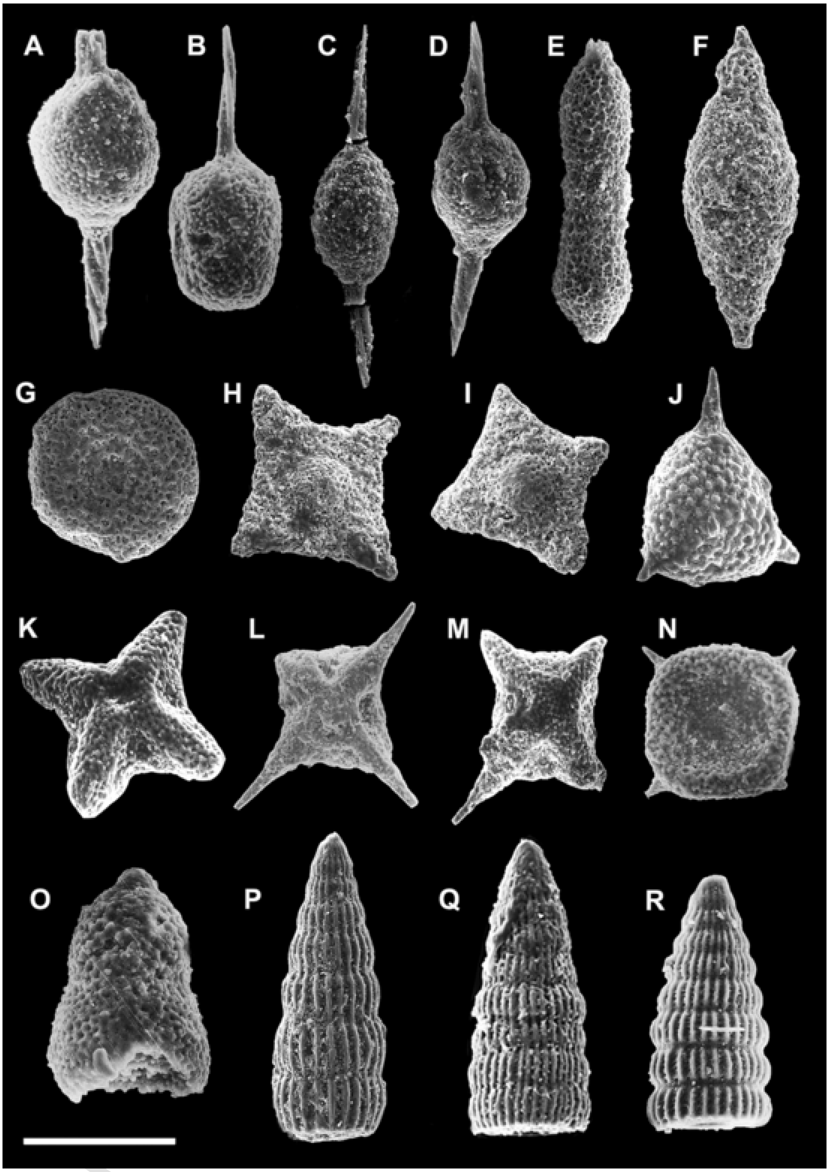
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Fig. 39 Important Radiolaria species from the Upper Cretaceous of the EEP. (A) *Archaeospongoprunum salumi* Pessagno (borehole Potanino 2, sample 1, Lower Campanian); (B, C) *A. hueyi* Pessagno: (B) borehole Potanino 2, sample 1, Lower Campanian, (C) Nizhnyaya Bannovka, sample 3011/14, Upper Campanian; (D) *Archaeospongoprunum stocktonensis* Pessagno (Nizhnyaya Bannovka, sample 3011/14, Upper Campanian); (E) *Prunobrachium mucronatum* (Lipman) (Nizhnyaya Bannovka, sample 3011/13, Upper Campanian); (F) *Prunobrachium articulatum* (Lipman) (Lysaya Gora, sample 6, Lower Campanian); (G) *Orbiculiforma renillaeformis* (Campbell and Clark) (Efremovo-Stepanovka, sample 20, Upper Campanian); (H, I) *Rhombastrum russiense* Vishnevskaya (Efremovo-Stepanovka, sample 22, Upper Campanian–Lower Maastrichtian); (J) *Alievium praegallowayi* Pessagno (Borehole Chernevo 102, sample 4, Santonian); (K–M) *Crucella espartoensis* Pessagno: (K) Borehole Chernevo 102, sample 3, Lower Campanian; (L) Borehole Potanino 2, sample 1, Lower Campanian; (M) Borehole Chernevo 102, sample 2, Lower Campanian; (N) *Orbiculiforma quadrata* Pessagno (Borehole Potanino 2, sample 1, Lower Campanian); (O) *Stichomitra manifesta* Foreman (Borehole Potanino 2, sample 1, Lower Campanian); (P) *Dictyomitra andersoni* (Campbell and Clark) (Efremovo-Stepanovka, sample 8, Upper Campanian); (Q, R) *Dictyomitra densicostata* Pessagno: (Q) Pudovkino, sample 13, Upper Santonian; (R) Borehole Potanino 2, sample 2, Upper Santonian. Scale bars 100 μm.

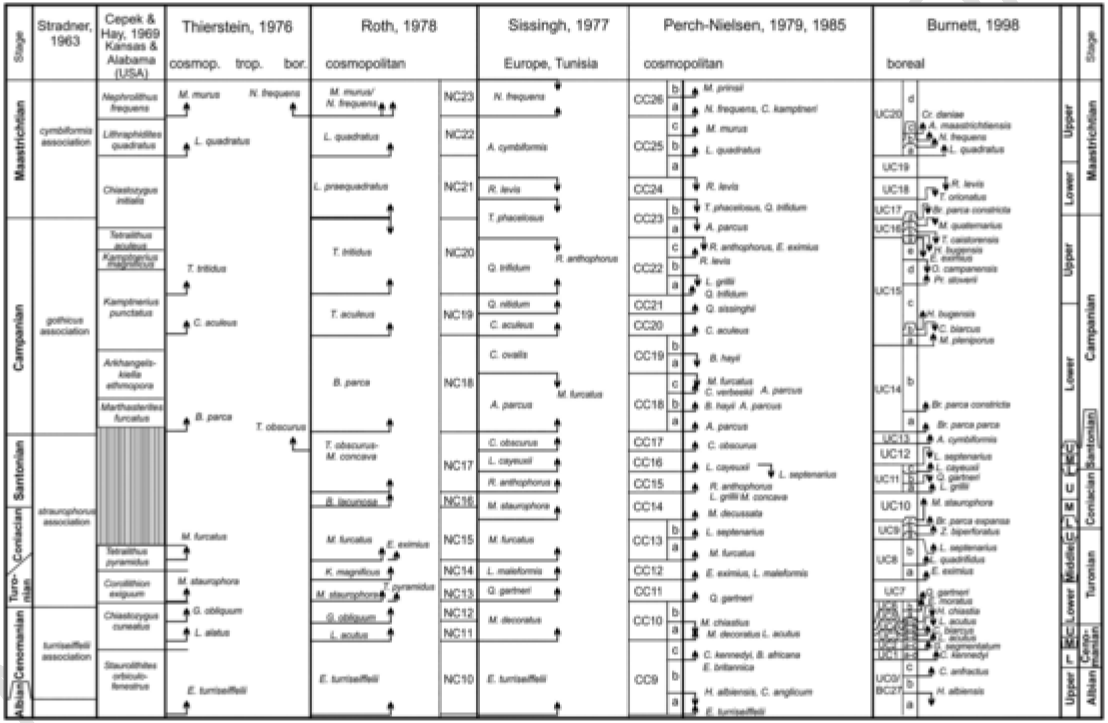

Fig. 40 Comparison of selected calcareous nannofossil zonal schemes for the Upper Cretaceous.

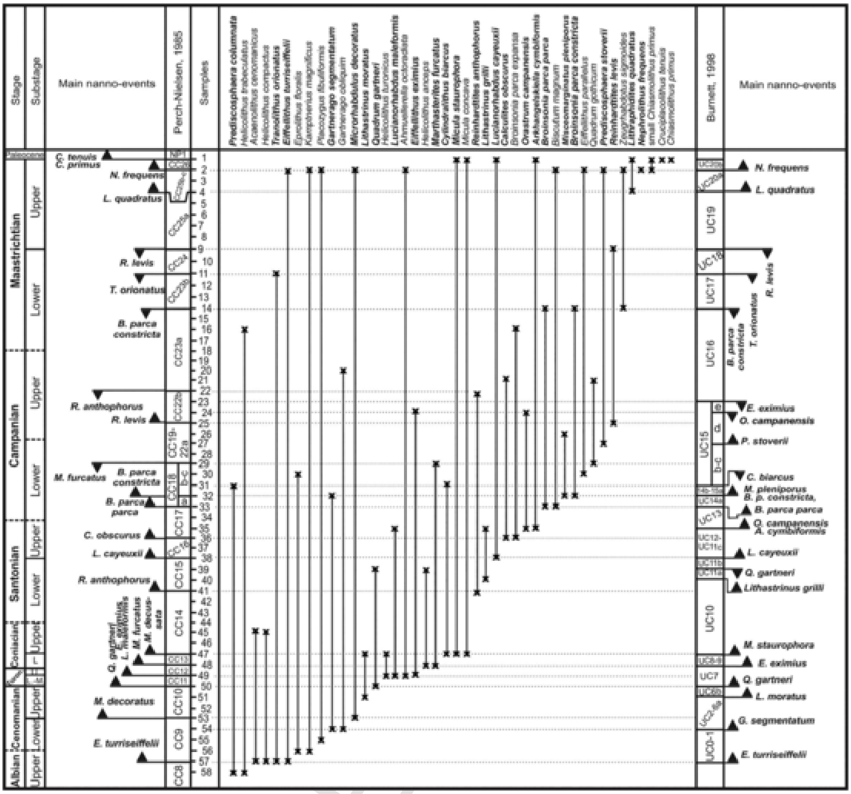

Fig. 41 Stratigraphic distribution of nannofossil species in Novouzenskaya borehole (Saratov Region).

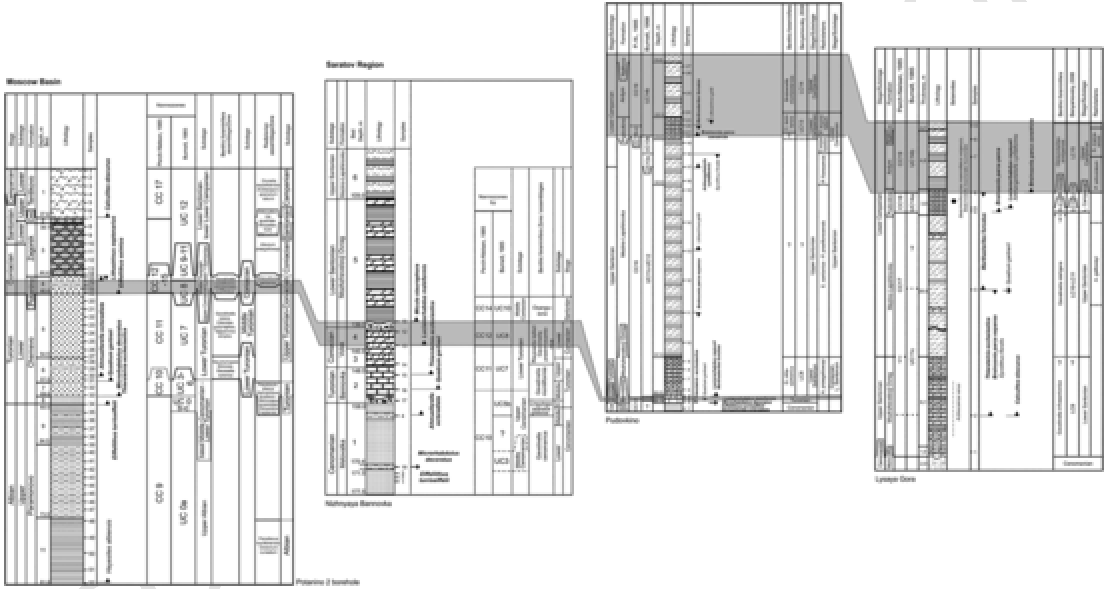

Fig. 42 Correlation of sections of the Moscow Basin (Potanino 2 borehole) and Saratov Region (Nizhnayaya Bannovka, Pudovkino and Lysaya Gora sections). The Potanino 2 borehole vs Nizhnayaya Bannovka section correlates by the base of the Chernevo and Bannovka Fms. as a facial analogue. The Nizhnayaya Bannovka vs Pudovkino correlates by the boundary between Melovatka and Bannovka Fms., Pudovkino vs Lysaya Gora correlates by the boundary between Mozhzhvelovij Ovrag and Mezino-Lapshinovka Fms. Dark gray—UC8 Zone and UC14b Subzone.

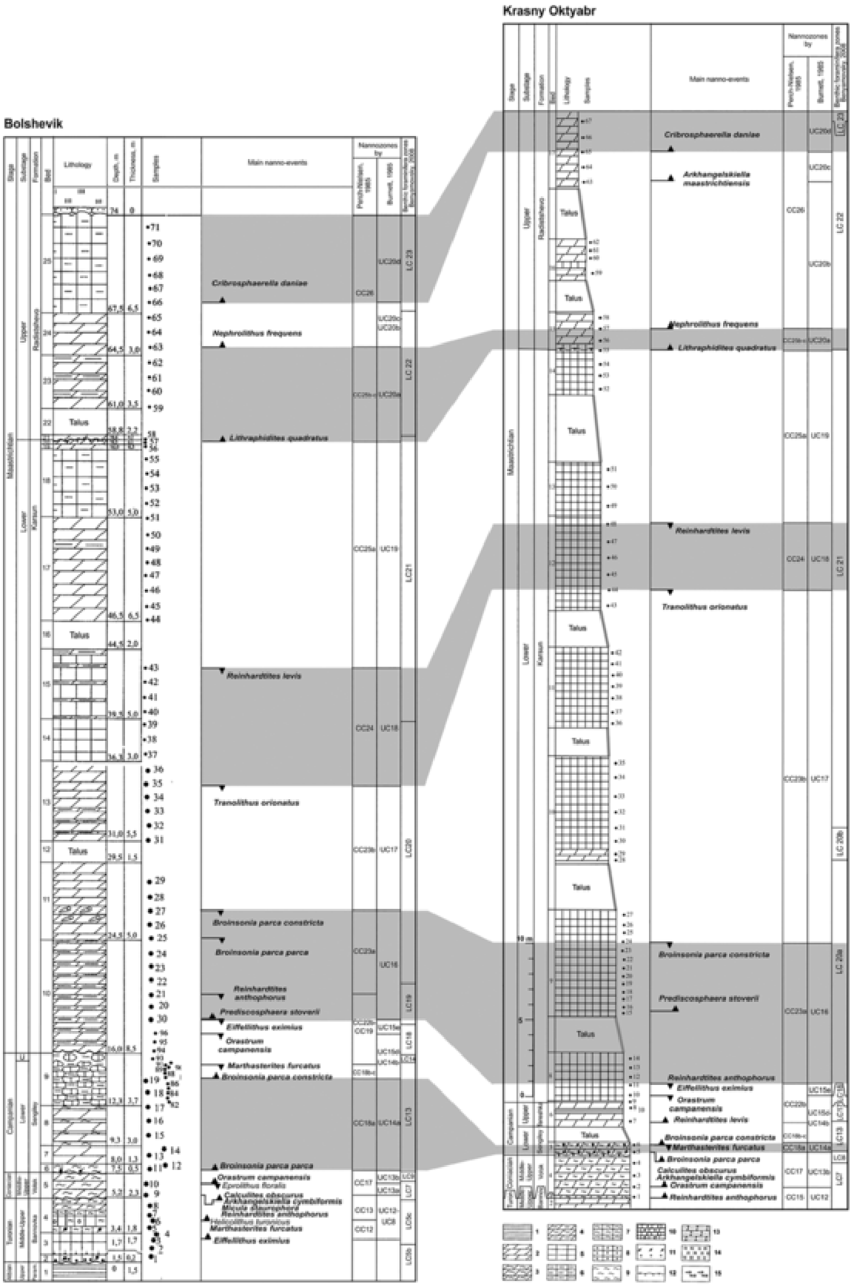
Bolshevik
Krasny Oktyabr
Stage
Substage
Formation
Bed
Lithology
Depth, m
Thickness, m
Samples
Main nanno-events
Nannozones by
Perch-Nielsen, 1985
Burnett, 1998
Maastrichtian
Campanian
Upper
Lower
Radishevo
Karsun
Talus
Cribrosphaerella daniae
Arkhangelskiella maastrichtiensis
Nephrolithus frequens
Lithraphidites quadratus
Reinhardtites levis
Tranolithus orionatus
Broinsonia parca constricta
Broinsonia parca parca
Reinhardtites anthophorus
Prediscosphaera stoverii
Eiffellithus eximius
Orastrum campanensis
Marthasterites furcatus
Calculites obscurus
Arkhangelskiella cymbiformis
Eprolithus floralis
Micula staurophora
Helicolithus turonicus
CC26
CC25a
CC24
CC23b
CC23a
CC19
CC18a
CC17
CC13
CC12
CC15
UC20d
UC20c
UC20b
UC20a
UC19
UC18
UC17
UC16
UC15e
UC14a
UC13b
UC13a
UC12
LC 23
LC 22
LC21
LC20
LC19
LC18
LC13
LC7
Talus

Fig. 43 Correlation of the Krasny Oktyabr and Bolshevik sections of the Saratov Region. Krasny Oktyabr vs Bolshevik correlates by the boundary between Bannovka and Volsk Fms. Dark gray–UC14a Subzone, UC16 Zone, UC18, UC20a and UC20d Subzones. Legend: (1) clay; (2) marl; (3) silty marl; (4) clay marl; (5) chalk; (6) clay chalk; (7) silty chalk; (8) chalk with limestone katuns; (9) siltstone; (10) limestone; (11) gravel and phosphatic pebbles; (12) hardground; (13) sandstone; (14) opoka; (15) belemnites.

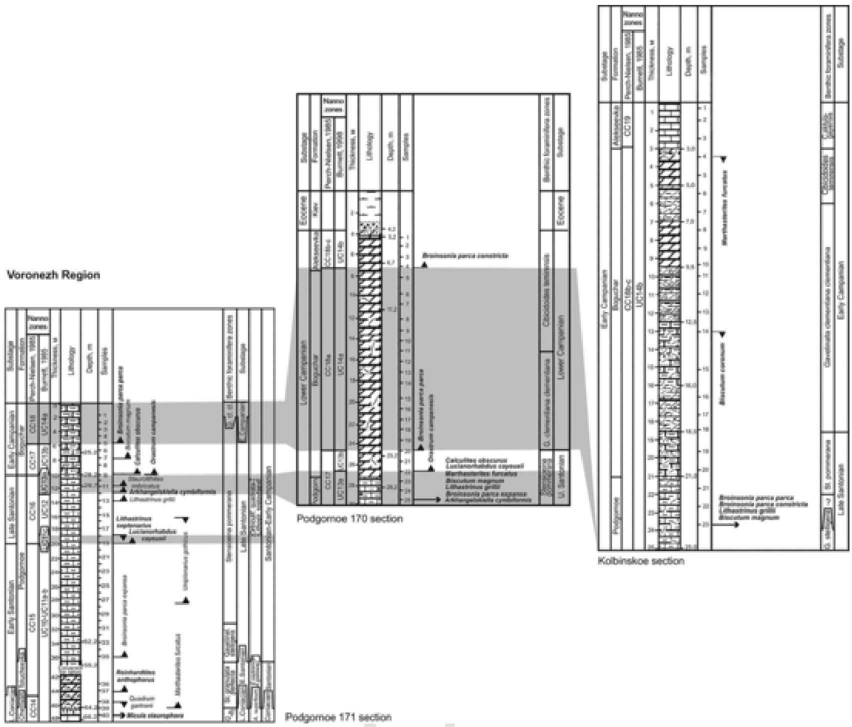

Fig. 44 Correlation of sections in the Voronezh Region (Podgornoe 170, Podgornoe 171 and Kolbinskoe sections). Podgornoe 170, Podgornoe 171 and Kolbinskoe sections correlate by the boundary between Podgornoe and Boguchar Fms. Dark gray—UC11c, UC13a, UC14a Subzones.

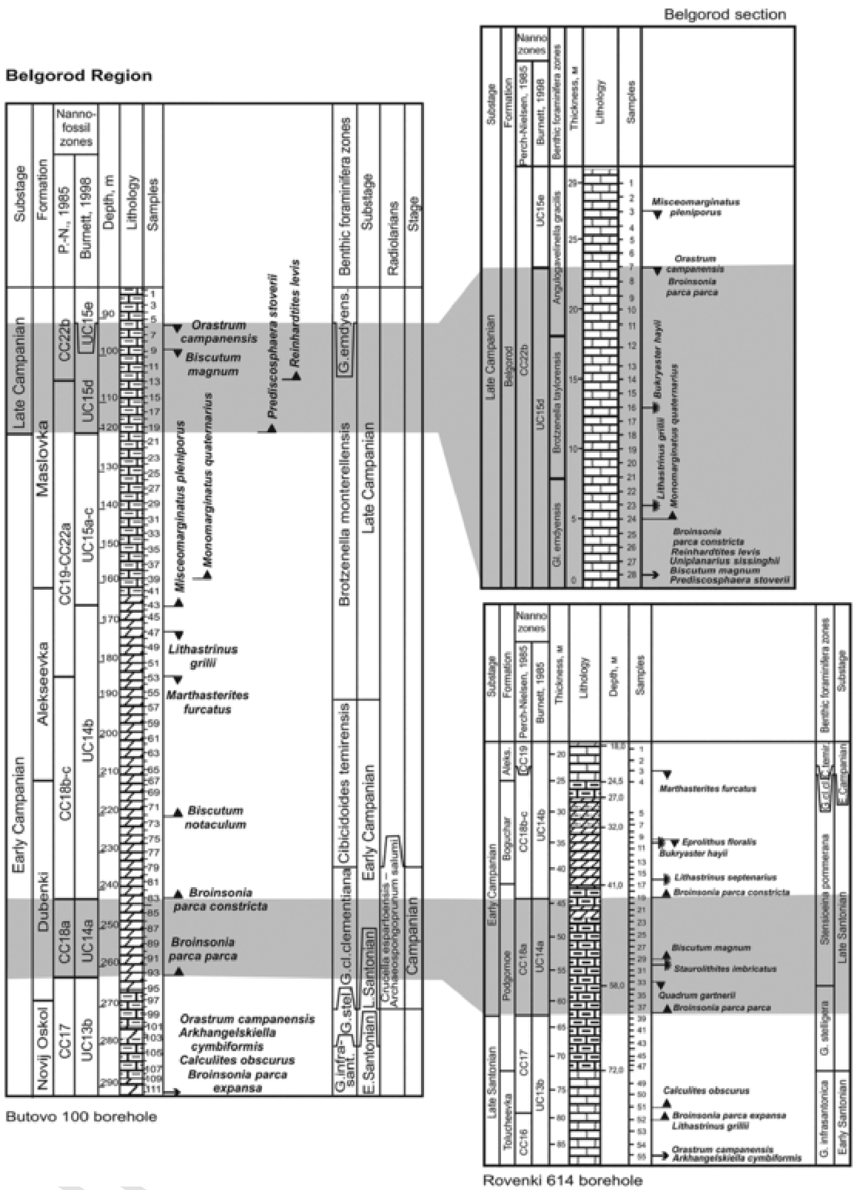
Belgorod Region
Butovo 100 borehole
Orastrum campanensis
Biscutum magnum
Lithastrinus grillii
Marthasterites furcatus
Biscutum notaculum
Broinsonia parca constricta
Broinsonia parca parca
Orastrum campanensis
Arkhangelskiella cymbiformis
Calculites obscurus
Broinsonia parca expansa
Belgorod section
Misceomarginatus pleniporus
Orastrum campanensis
Broinsonia parca parca
Broinsonia parca constricta
Reinhardtites levis
Uniplanarius sissinghii
Biscutum magnum
Prediscosphaera stoverii
Rovenki 614 borehole
Marthasterites furcatus
Eprolithus floralis
Bukryaster hayii
Lithastrinus septenarius
Broinsonia parca constricta
Biscutum magnum
Staurolithites imbricatus
Quadrum gartneri
Broinsonia parca parca
Calculites obscurus
Broinsonia parca expansa
Lithastrinus grillii
Orastrum campanensis
Arkhangelskiella cymbiformis

Fig. 45 Correlation of sections in the Belgorod Region (Butovo 100 and Rovenki 614 boreholes, Belgorod sections). Butovo 100 borehole vs Rovenki 614 borehole correlates by the base of the Alekseevka Fm., Butovo 100 borehole vs Belgorod section correlates by the base of the Maslovka and the Belgorod Fm. as a facial analogue. Dark gray—UC14a and UC15d Subzones.

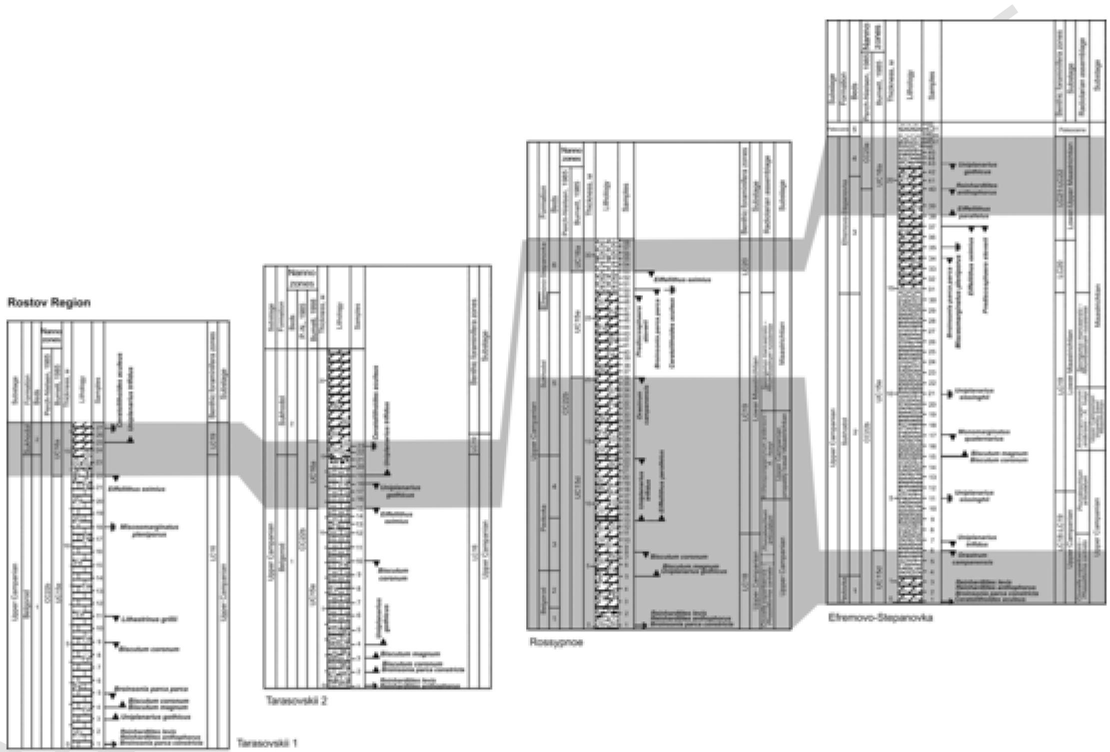

Fig. 46 Correlation of sections in the Rostov Region (Tarasovskii 1, Tarasovskii 2, Rossypnoe and Efremovo-Stepanovka sections). Tarasovskii 1 vs Tarasovskii 2 correlates by the boundary between Belgorod and Sukhodol Fms., Tarasovskii 2 vs Rossypnoe section correlates by the top of the Belgorod Fm., Rossypnoe section vs Efremovo-Stepanovka section correlates by the boundary between Sukhodol and Efremovo-Stepanovka Fms. Dark gray—UC15d and UC16a Subzones.

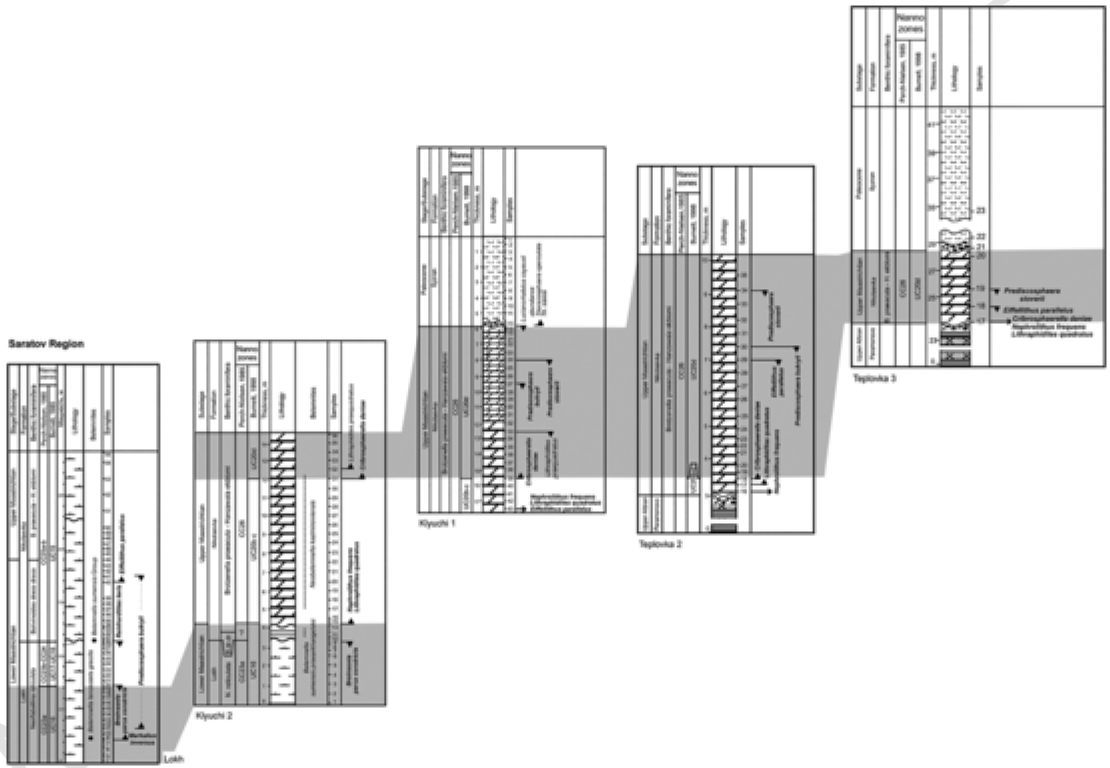

Fig. 47 Correlation of sections in the Saratov Region (Lokh, Klyuchi 1, Klyuchi 2, Teplovka 2 and Teplovka 3 sections). Lokh vs Klyuchi 2 correlates by the boundary between Lokh and Nikolaevka Fms., Klyuchi 2 vs Klyuchi 1 and Teplovka 2 correlates by the FO of *Cribrospaerella daniae*, Teplovka 3 vs Teplovka 3 correlates by the LO of *Prediscosphaera stoverii*. Dark gray—UC16 Zone and UC20d Subzone.

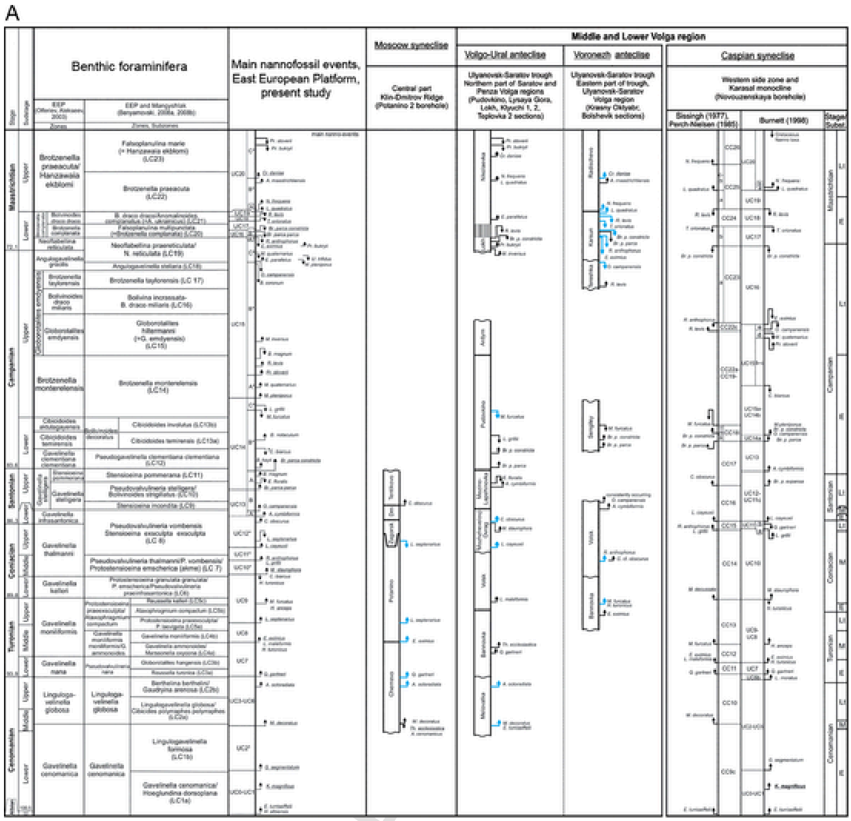

Fig. 48 Calcareous nannofossil distribution in the Upper Cretaceous sections on the EEP. Black arrows—the levels of FOs and LOs of nannofossil species in the sections; blue arrows—used levels of FOs and LOs of nannofossil species for the local zonation; red arrows—unused levels of FOs and LOs of nannofossil species.

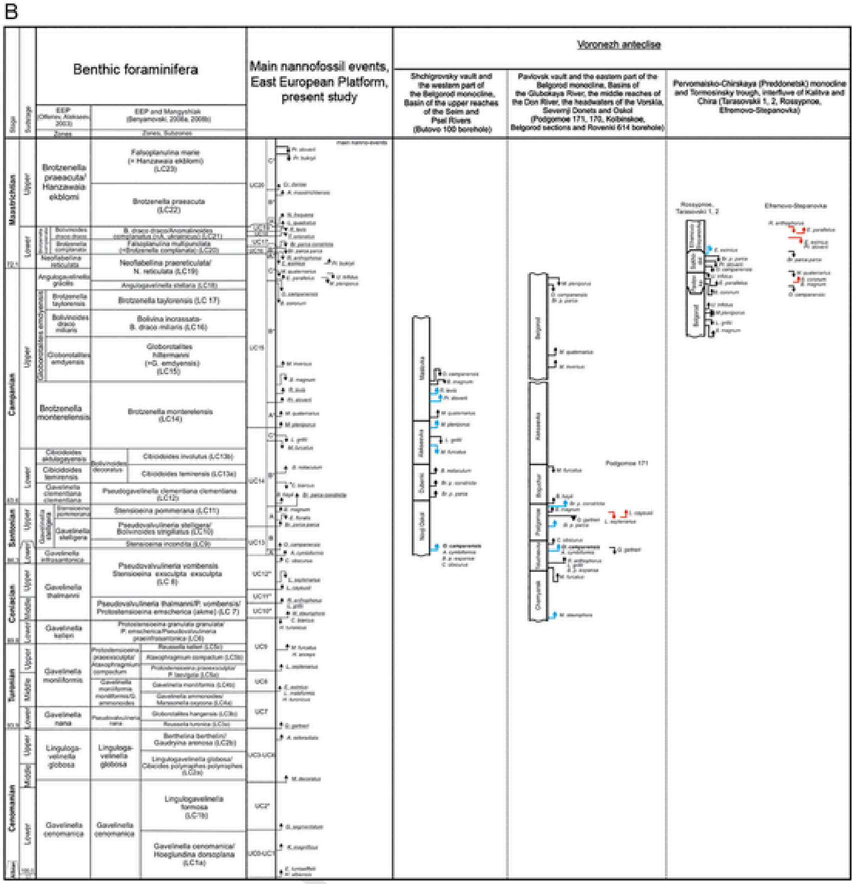

Fig. 48 (*Continued*)

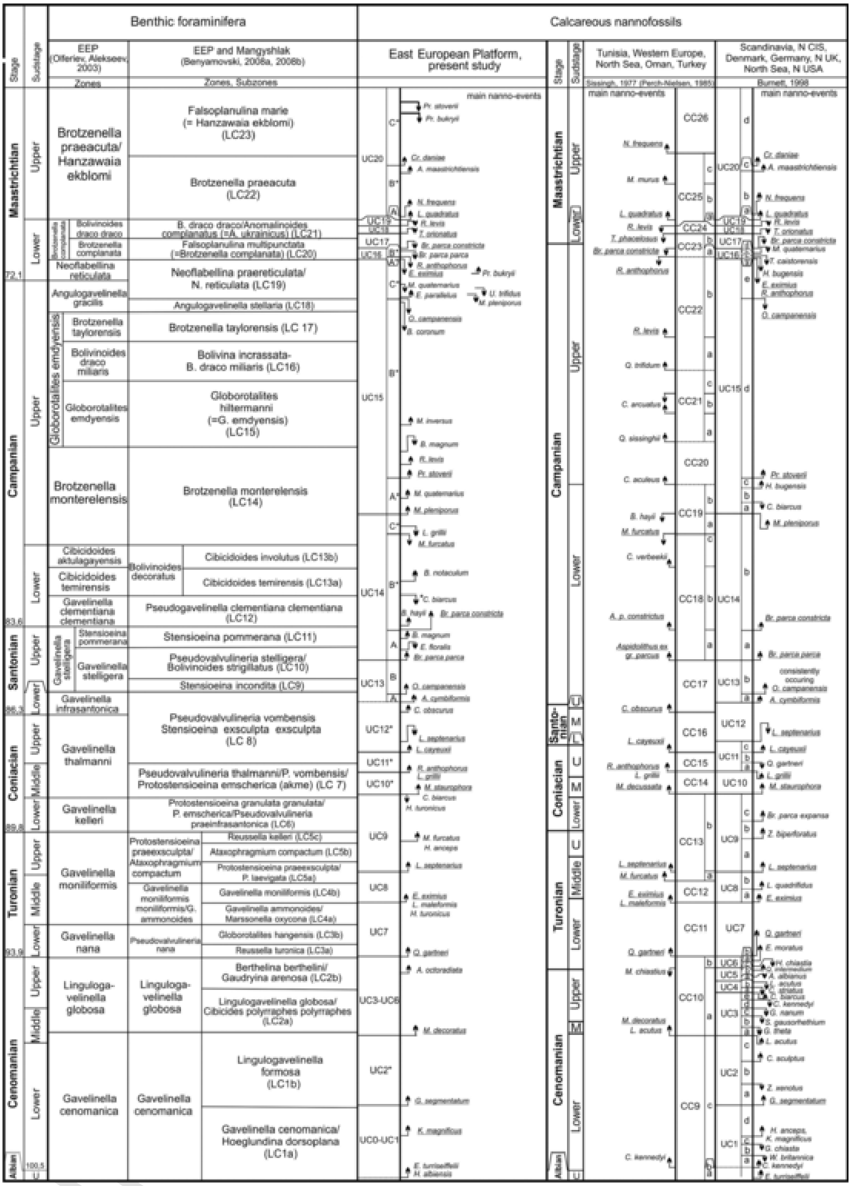

Fig. 49 Comparison of the proposed regional calcareous nannofossil zonation of the Upper Cretaceous deposits of the EEP and the Boreal scheme (Burnett, 1998).

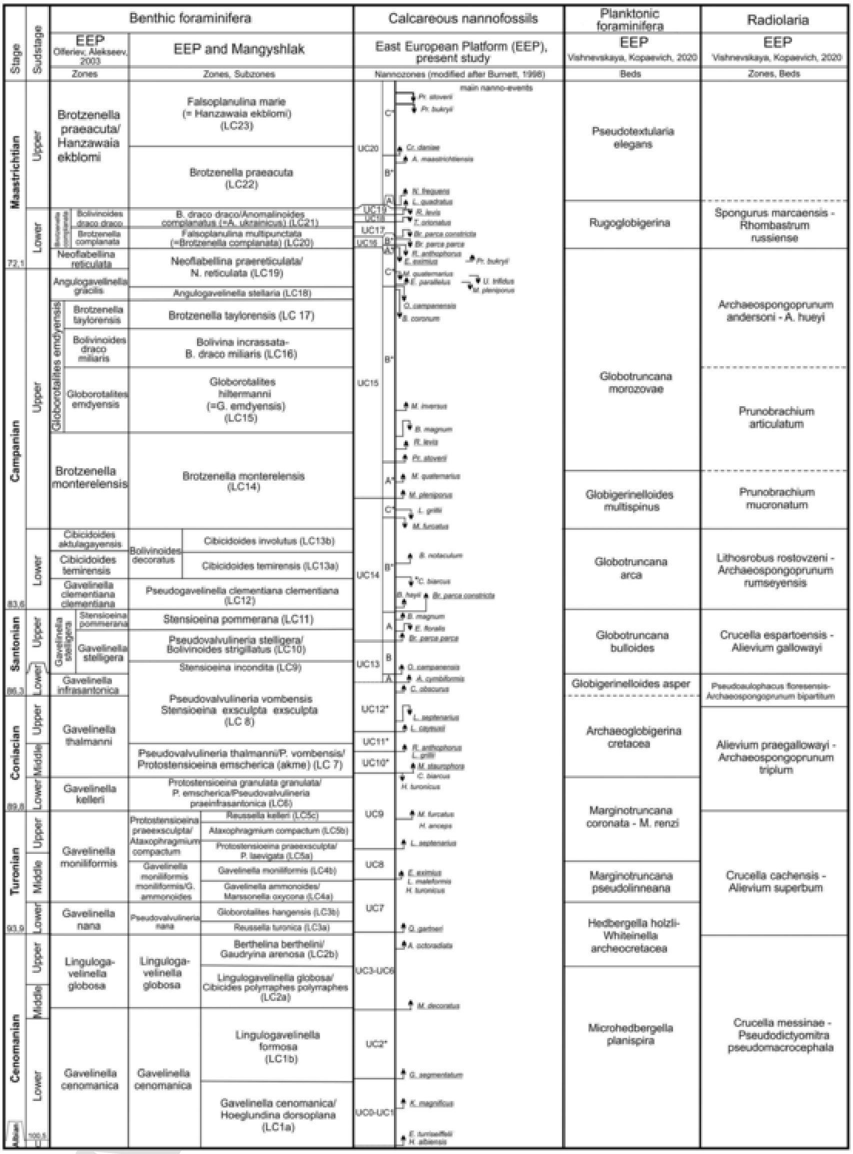

Fig. 50 Calcareous nannofossil biozonation for the Upper Cretaceous and correlation with the scheme based on benthic and planktonic foraminifera and Radiolaria (Vishnevskaya et al., 2018).

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