BULLETIN DE L'INSTITUT ROYAL DES SCIENCES NATURELLES DE BELGIQUE SCIENCES DE LA TERRE, 69-SUPP. A: 15-45, 1999
BULLETIN VAN HET KONINKLIJK BELGISCH INSTITUUT VOOR NATUURWETENSCHAPPEN AARDWETENSCHAPPEN, 69-SUPP. A: 15-45, 1999

Maastrichtian and Lower Palaeocene of Northern Saratov Region (Russian Platform, Volga River): Foraminifera and calcareous nannoplankton

by Alexander S. ALEKSEEV, Lyudmila F. KOPAEVICH, Mariya N. OVECHKINA & Alexander G. OLFERIEV

Abstract

From five Maastrichtian outer shelf sections of the high latitude (52°N) North Saratov Region a detailed foraminiferal and calcareous nannoplankton study has been carried out for the first time. The most important taxa are illustrated. The Maastrichtian succession contains several hiatuses, of which the most important encompasses the late early Maastrichtian (zones CC23b and CC24). On top of the Tyoplovka Uplift the uppermost Maastrichtian marls (upper part of CC26) overlie the Upper Albian. The existence of mid-Maastrichtian tectonic movements in this region is shown by detailed stratigraphic correlations. The interval with the Lower Maastrichtian *Belemnella lanceolata gracilis* belongs to Zone CC23A. During the latest Maastrichtian a transgression with invasion of warm-water and deep-water *Globotruncana* taxa was recognized in the Klyuchi 1 section and this transgressive event is an important marker in the White Chalk Sea.

Key-words: Foraminifera - calcareous nannoplankton - biostratigraphy - Maastrichtian - Lower Palaeocene - Russia

Résumé

Dans la partie septentrionale (52°N) de la région de Saratov, une étude détaillée des foraminifères et du nannoplancton calcaire a été effectuée pour la première fois dans cinq sections maastrichtiennes ayant fait partie du shelf externe situé à de hautes latitudes. Les taxa les plus importants sont figurés. La succession maastrichtienne comprend plusieurs hiatus dont le plus important coïncide avec la fin du Maastrichtien inférieur (zones CC23b et CC24). Au sommet du soulèvement de Tyoplovka, les marnes du Maastrichtien le plus supérieur (partie supérieure de CC26) recouvrent l'Albien supérieur. L'existence de mouvements tectoniques au Maastrichtien moyen dans cette région est attestée par des corrélations stratigraphiques détaillées. L'intervalle à *Belemnella lanceolata gracilis* du Maastrichtien inférieur appartient à la Zone CC23A. Au cours du Maastrichtien terminal, une transgression avec arrivée d'eaux chaudes et de taxa de *Globotruncana* d'eau profonde a été mise en évidence dans la section de Klyuchi 1; cet événement transgressif est un marqueur important dans la mer de la Craie blanche.

Mots-clefs: Foraminifères, nannoplancton calcaire, biostratigraphie, Maastrichtien, Paléocène inférieur, Russie.

Резюме

Впервые на севере Саратовской области детально изучены фораминиферы и известковый нанопланктон пяти высокоширотных (52° с.ш.) разрезов Маастрихта, приуроченных к обстановке внешнего шельфа. Наиболее важные таксоны изображены. Разрез Маастрихта в этом районе содержит несколько перерывов, главный из которых приурочен к концу раннего Маастрихта. На вершине Тепловского поднятия мергели верхней части верхнего Маастрихта (верхи зоны CC26) перекрывают верхний альб. Детальная стратиграфическая корреляция показала существование в этом регионе внутри-маастрихтских тектонических движений. Обсуждена тектоническая история Тепловского поднятия. Часть разреза нижнего Маастрихта с *Belemnella lanceolata gracilis* принадлежит зоне CC23A. В конце Маастрихта в разрезе Ключи 1 установлена трансгрессия, сопровождавшаяся проникновением в этот район тепловодных и глубоководных *Globotruncana*. Это трансгрессивное событие является важным маркирующим уровнем для моря «Писчего Мела».

Ключевые слова: Фораминиферы, наннопланктон, биостратиграфия, Маастрихт – нижний Палеоцен, Россия

Introduction

The major part of information on biotic changes across the Maastrichtian/Danian boundary comes from relatively low latitude sections, especially in the tropical and subtropical realms. Only a few sections were studied in high latitudes among which are Stevns Klint and Kjölby Gaard in N Europe (HULTBERG & MALMGREN, 1986, 1987; SCHMITZ *et al.*, 1992) and boreholes in the Antarctic, on Maud Rise and on the Kerguelen Plateau (HUBER, 1990; POSPICHAL & WISE, 1990; THIERSTEIN *et al.*, 1991). Evidence exists that sequences of biotic events and their extent during the Maastrichtian-Danian transition were quite different in tropical and high latitude basins (GARTNER, 1996). Only few data are available from the eastern part of the large, relatively shallow and cold-water marine Russian basin that covered the southern and eastern parts of the Russian Platform between 50-55°N during the Late Cretaceous and Palaeogene. This basin had connections with the Western Siberian Sea through narrow sea straits which crossed the Uralian Uplift Zone and through the wide Turgay Strait east of the Urals. The sediments of this basin contain important information for a better understanding of the terminal Cretaceous events and their appearance in dif-

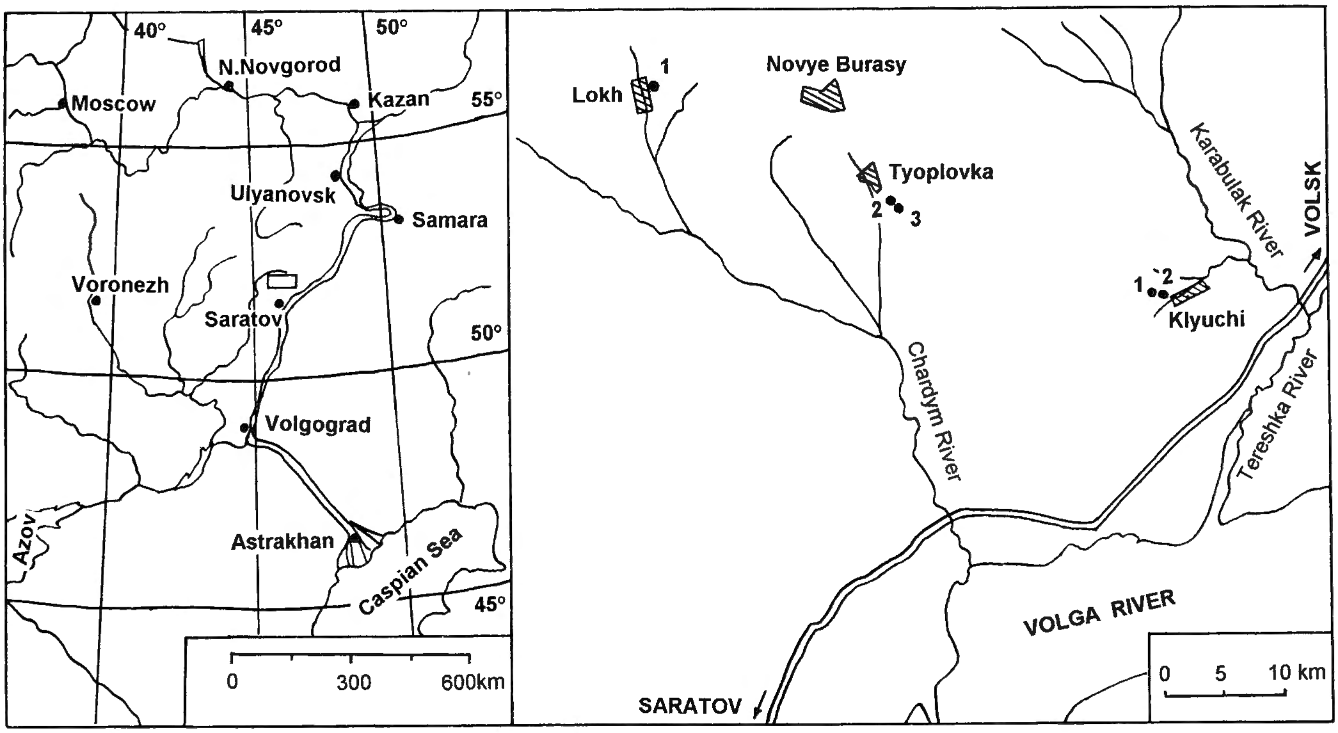


Fig 1. — Location of the area and the sections studied.

ferent climatic belts. Not only latitudinal, but also longitudinal differences exist between stratigraphic ranges of important late Maastrichtian marker species, in W Europe and in E Europe (e.g. belemnitellids), as was shown firstly by NAIDIN (1973).

The Saratov Region is situated in the N. part of the Russian Basin between 50 and 53° N along the Volga River. There is a relatively complete outer shelf Maastrichtian-Danian sequence. This sequence contains rich assemblages of planktonic Foraminifera including true deep water taxa, although never studied in detail (BARYSHNIKOVA, 1966). However, the very first illustrations of foraminiferan shells in transmitted light by EHRENBERG (1854) came from that area (Volsk chalk). Later, ARKHANGELSKY (1912) gave lists of Foraminifera from several rock samples of the *Belemnitella lanceolata* Zone (Maastrichtian) and line drawings of a few species were published by BARYSHNIKOVA *in* KAMYSHEVA-ELPATIEVSKAYA (1967). In one section the lower Upper Maastrichtian calcareous nannofossil assemblage of the *Lithraphidites quadratus* Zone was studied and illustrated (GUTSAKI *et al.*, 1975). The nannofossil *Nephrolithus frequens* Zone was recognized by MUSATOV (1995) in the topmost layers of the Maastrichtian in the Klyuchi area. All these data show the great importance of the Saratov Region for environmental reconstructions of the eastern part of the terminal Cretaceous Chalk Sea. In this paper we present preliminary results of studies of several Maastrichtian and basal Lower Palaeocene (Syzranian) sections in the N Saratov Region.

Geological Setting

The Saratov Region is part of the vast Volga River area (Povolzhie in Russian) of the East European Platform often named the Uliyanovsk-Saratov Syneclise or Depression (NAIDIN 1960, 1969; GERASIMOV *et al.* 1962), situated close to the W and NW margin of the Peri-Caspian Depression. The wide belt of the Russian craton along the Volga River was relatively mobile during Mesozoic times with several tectonic uplifts and swells were recognized (NIKISHIN *et al.*, this volume). In the vicinity of Saratov, to the west and north of the town, numerous small amplitude uplifts occur. These uplifts are known as the Saratov Dislocations and are characterized in their axial parts by Mid-Jurassic sediments overlying with an angular unconformity the Middle Carboniferous (Moscovian) limestones. Different levels of Upper Cretaceous unconformably overlie the Jurassic and Lower Cretaceous formations on the slopes of these uplifts.

The Upper Cretaceous is mainly represented by widely distributed Cenomanian sands (up to 25-30 m), Turonian-Coniacian sandy chalks and chalks (up to 25 m), Santonian and Campanian sandstones, marls and siliceous rocks (40-50 m) and Maastrichtian sands, siliceous "opokas", marls and chalks (up to 60 m). The Maastrichtian sediments are the most widely distributed Upper Cretaceous strata in the Saratov region. They are overlain by siliceous rocks of Palaeocene age known as Syzranian Stage or Syzran Formation. There are three sub-meridional facial belts of Maastrichtian age, which were first

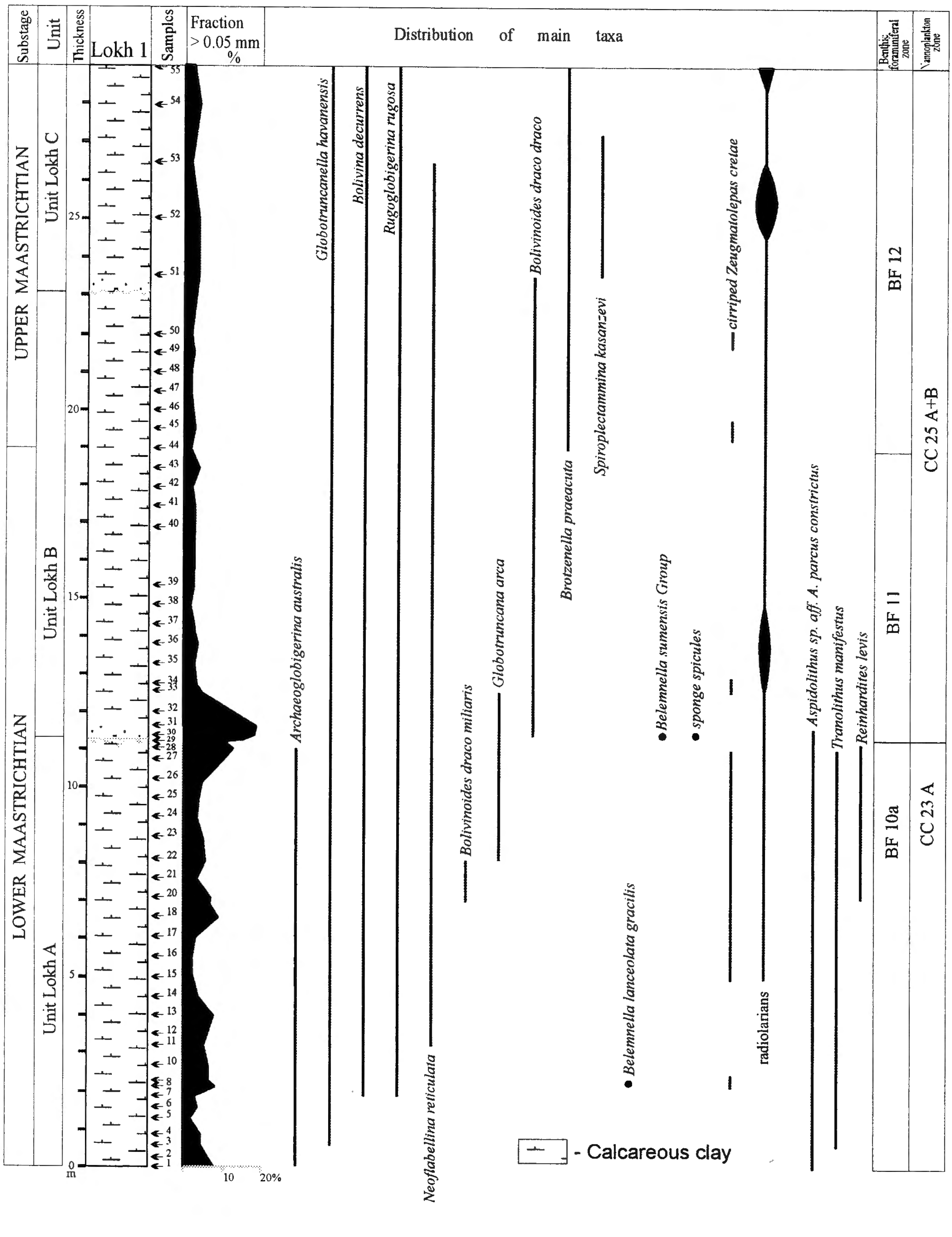


Fig 2. — Section Lokh 1 and stratigraphic distribution of the most important Foraminifera and calcareous nannoplankton taxa. Levels with most abundant radiolarians, sponge spicules, cirripeds and belemnites are also shown.

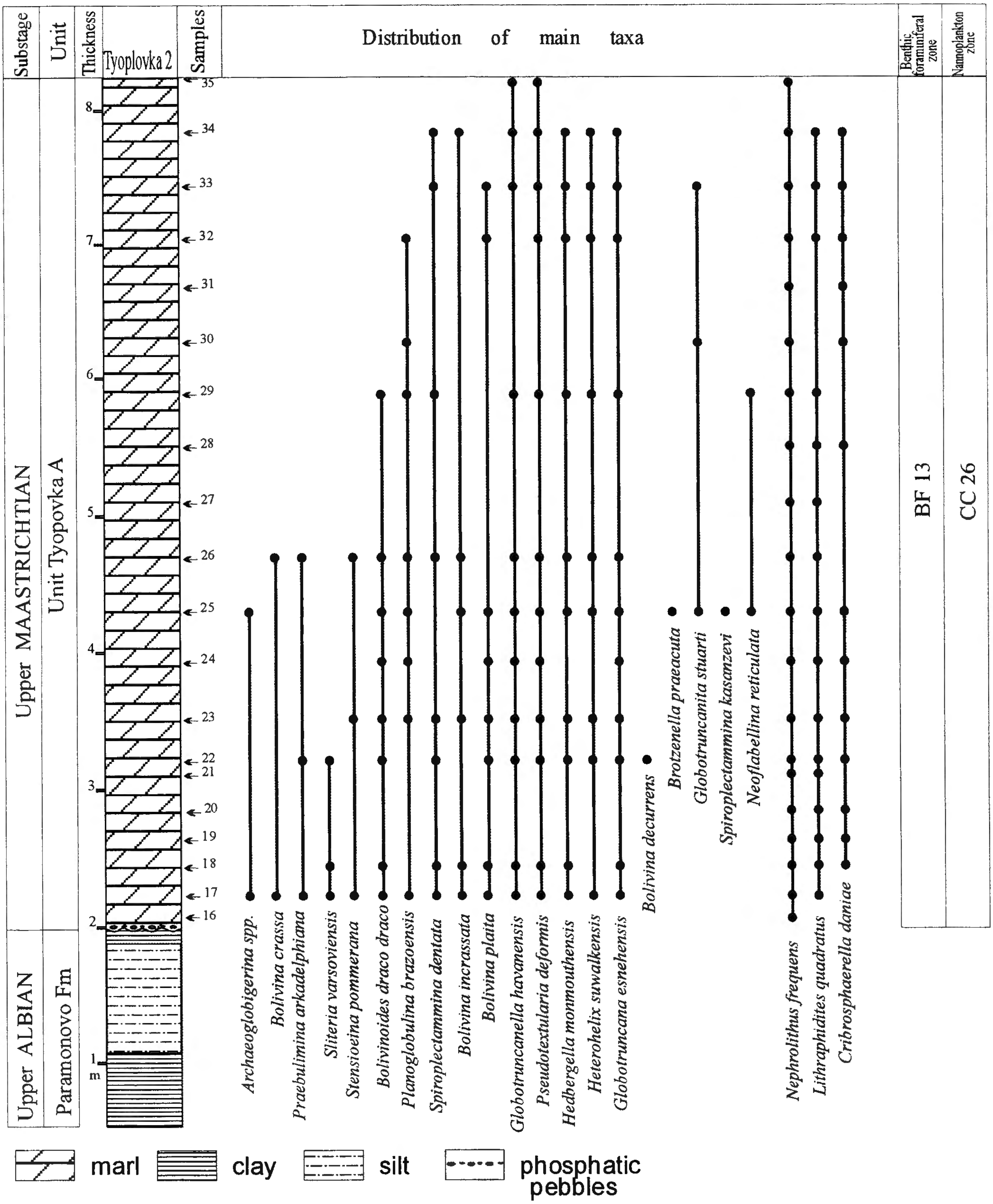


Fig 3. — Section Tyoplovka 2 and stratigraphic distribution of the most important Foraminifera and calcareous nannoplankton taxa.

documented in this region by ARKHANGELSKY (1912) and were more precisely described by FLEROVA & GUROVA (1958) and DERVIZ (1959). The first belt located in the west, consists of calcareous sands. Marls are found in the central part and chalks are present along the Volga River, north of Saratov. No formal lithostratigraphy exists for the Upper Cretaceous of the Saratov Region.

Note: "Opoka": a Polish term for siliceous rocks consisting of a mixture of amorphous silica and clay. In fresh state the opoka has a dark colour, but in weathered state it is whitish. Silica can constitute up to 90 %, but the rock is completely recrystallized under diagenesis and no clear diatom frustula are visible unlike what would have been the case in diatomite. "Opoka" occurs frequently in N. Germany, Poland, on the Russian Platform and in W. Siberia.

Material and methods

Five sections were studied and sampled 60-65 km to the NW, N and NE of Saratov (Figure 1). More than 150 samples were collected at intervals between 0.4 to 1.5 m for foraminiferal and calcareous nannofossil studies. The Foraminifera were extracted from soft marls with standard micropalaeontological techniques by soaking dry samples of 50 g in sodium bicarbonate and washing them through a 0.05 mm screen. Relatively hard Palaeocene "opokas" were disintegrated through melting crushed rock samples with sodium sulfate. For nannofossils normal smear-slides were prepared from each sample. The coccoliths were identified under the light microscope Carl Zeiss Axiolab under magnification x 1500. The SEM photographs of foraminifers and nannofossils were taken by Camscan in the Palaeontological Institute of RAS. The carbonate contents were determined in 37 samples by dissolution of 10 g rock in 20% formic acid on scales, and calculated from carbon dioxide loss with a precision of 1%. As standard in experiments chemically pure $CaCO_3$ was used.

Repository

The collections of macrofossils and Foraminifera are housed in the Paleontological Institute of the Russian Academy of Sciences (PIN) under numbers 4775 and 4776 respectively.

Locality descriptions

1. Section Lokh 1 in the Novye Burasy Area: 52° 08' N, 45° 52' E. A small abandoned quarry on the left bank of a tributary of the Chardym River, 65 km NW of Saratov and 15 km W of Novye Burasy. The quarry is on the slope of a hill covered by hard Palaeocene Syzranian "opokas". The bottom of the quarry is about 20 m above the river. The lower 2 m of the section (Figure 2) were sampled in a trench. The upper part of the section above sample LH1-49 is poorly exposed and mainly covered by grass. Samples were collected at intervals of 1.5 m up to the bottom of deep holes (up to 1 m deep) in the talus.

The base of the Maastrichtian has not been reached, but the presence of abundant clastic material (up to 10%) in the lowermost sample LH1-1 supports the idea that it is close to the lower boundary of unit Lokh 1. According to previous data (BONDARENKO, 1975) the Maastrichtian marls overlie Cenomanian sands in this area. In total 28.5 m of light yellow-grey calcareous clays, siltic in their lower part and clayish marls are seen in section Lokh 1. The sequence can be subdivided into three lithological units.

Unit Lokh A. The lower 11.1 m of the sequence is represented by yellow-grey micaceous calcareous clays with 22-35% $CaCO_3$, sometimes with burrows and fissures filled with gypsum veins, often with iron oxides. The content of the fraction > 0.05 mm is 3-10%.

Unit Lokh B. The top of unit Lokh A is a prominent erosional hardground with numerous up to 60 cm deep burrows. The basal layer that overlies unit Lokh A consists of glauconitic calcareous friable sandstone (0.7 m) with rare, mainly eroded belemnite rostra and moulds of small bivalves. The calcareous sandstone is replaced up section by yellow-grey calcareous clays (28-32% carbonate) with small fragments of bivalve shells. The total thickness of this unit is 11.6 m. The content of the fraction > 0.05 mm is 1-3% only.

Unit Lokh C. In the washed residue of sample LH1-51 quite abundant large grains of glauconite occur, suggesting that this level is very probably near to another hiatus, marked by a basal glauconitic bed. This hiatus is supposed to fall in the interval between samples LH1-50 and LH1-51 that has a thickness of about 1.5 m. Unit Lokh C consists of yellow-grey calcareous clays (5.8 m thick, 23-30% of $CaCO_3$). The top of this unit and the contact with the Palaeocene are not visible in this locality.

2. Section Tyoplovka 2 in the Novye Burasy Area. 52°06' N, 46°04' E. A small ravine on the southwestern slope of a hill on the left bank of a small tributary of the Chardym River known as the Tyoplovka River and located at about 57 km N of Saratov, 10 km SE of Novye Burasy and about 1.5 km SE of Tyoplovka Village.

Below the Syzranian "opokas" which are badly exposed here, 6.3 m of light grey siltic and micaceous thinly laminated marls (41-47% of carbonate) (Figure 3) are visible in a deep and narrow ravine that first cuts the hill slope parallel to it and after that in its crest. Maastrichtian marls overlie Upper Albian black clays of the Paramonovo Formation. The top sample from these clays contains the radiolarian *Crolanium cuneatum* (Smirnova & Kh. Aliev), typical for the Paramonovo Formation, which is widely distributed in Central Russia (ALEKSEEV *et al.*, 1996). A phosphoritic conglomerate lies at the base of the marls. Its thickness is up to 0.1 m. The phosphatic pebbles are generally small (1-2 cm) but occasionally can reach up to 5-7 cm across. The total thickness of the Maastrichtian marls was estimated to be 18 m (BARYSHNIKOVA, 1966). Along this ravine at a distance of 40 m the basal Maastrichtian conglomerate cuts in a westward direction progressively deeper and deeper levels of the Paramonovo Formation. This supports the existence of an angular unconformity between Albian and Maastrichtian strata.

3. Section Tyoplovka 3. A large ravine, 0.5 km south-east of section Tyoplovka 2. This ravine cuts the slope of the Tyoplovka River valley from the Palaeocene "opokas" at its top to Middle Jurassic clastics at its foot. Maastrichtian marls, the same as in section Tyoplovka 2, are situated in the relatively gentle part of the slope and are only poorly exposed. On top of the Paramonovo Formation the basal Maastrichtian phosphori-

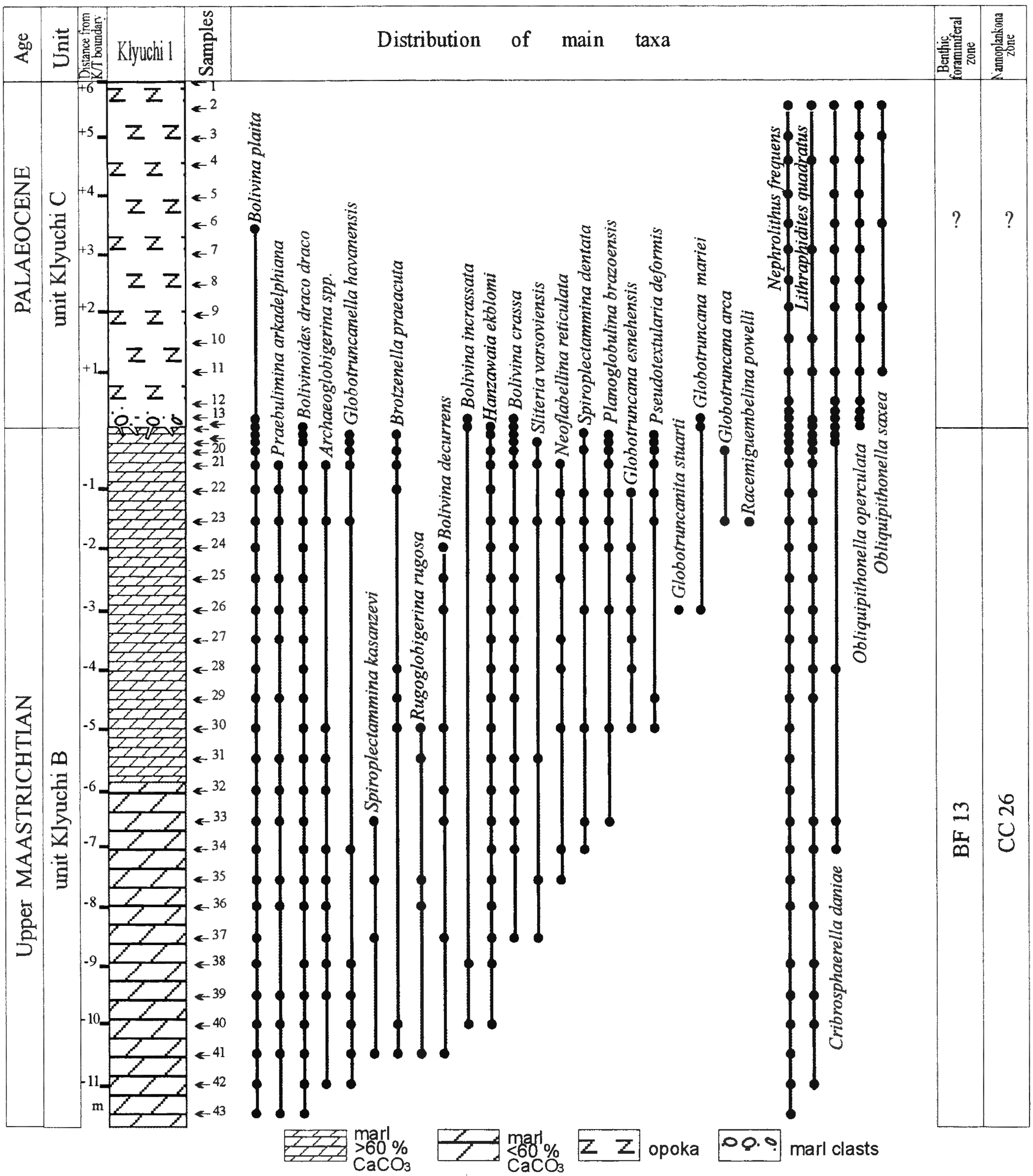


Fig 4. — Section Klyuchi 1 and stratigraphic distribution of the most important Foraminifera and calcareous nannoplankton taxa.

tic conglomerate occurs. The base of the conglomerate dips to the NE under an angle of about 30-40°. Samples TP3-17 and TP3-18 were collected at a distance of 1 m from the base of the Maastrichtian. 40 m upwards, along the ravine, in a small trench, the displaced contact of the Maastrichtian marls and Palaeocene "opoka" can be seen. 75 m upwards along the ravine, on top of a zone without exposures, green-yellow calcareous Syzranian "opoka" crops out (sample TP3-23).

4. *Sections Klyuchi 1 and 2*, in the Bazarny Karabulak Area: 51° 59' N, 46°30' E. Few shallow ravines cross the left gentle slope of the Malyi Klyuch River valley, about 62 km northeastern of the Saratov.

Klyuchi 1 is situated in the ravine furthest from Klyuchi Village, about 1 km beyond the last buildings of the village. The upper part of the section is located 10 m from the field margin (Figure 4). Two units can be recognized.

Unit Klyuchi C. The upper part of the section consists of 5.9 m of Lower Syzranian (Lower Palaeocene) green-grey hard calcareous "opokas" (17-20% of $CaCO_3$) with abundant moulds of small bivalves, gastropods and solitary scleractinian corals (*Trochocyathus calcitrapa* von Koenen) in its lower part (1-2.5 m above the base). The base of the "opokas" consists of a siliceous glauconitic sandstone (0.15 m) with abundant fragments of Maastrichtian marls up to 2-3 cm across. The top of the Maastrichtian is a hardground with burrows which penetrate the underlying marls up to a depth of 0.1-0.2 m. The burrows are filled with green, siliceous sandy glauconitic material which forms the base of the Palaeocene.

Unit Klyuchi B. Below the boundary hardground, a thick succession of white chalky marls (52-65% of carbonate) is seen including levels with abundant *Zoophycos* trace fossils (e.g. at 11.5 m). The lower part of unit Klyuchi B (6 m) contains more carbonate (62-65% $CaCO_3$) but in the topmost 5 m the carbonate content decreases again (55-59%). The base of unit B is covered by soil in this section. On the surface of these marls, in their middle part, a few belemnite rostra were discovered together with iron oxide pseudomorphs on small sponges.

The Klyuchi 2 section is on the same valley slope as Klyuchi 1, but 0.5 km closer to Klyuchi Village. This ravine is the last with good Cretaceous outcrops. The lower part ends in a small temporary marl quarry near the bottom of the valley. Further to the east ravines cut only Upper Pliocene (Akchagylian) or Quaternary clastics. Three unit can be recognized.

Unit Klyuchi A. Lowermost part of the section (Figure 5) consists of yellow-grey siltic calcareous clays which are very similar to the clays of unit Lokh 1, but contain slightly more carbonate (35-36% of $CaCO_3$). The thickness of this unit, although incomplete, is 3.2 m.

Unit Klyuchi Bb. Unit Klyuchi A is overlain by a bed of green-yellow clay (0.8-0.9 m) with rare dispersed glauconite grains. This bed has the lowest carbonate content (only 16-20% $CaCO_3$) of the entire studied Maastrichtian succession. The lower boundary of the clay bed is probably erosional and penetrates into the top of the calcareous clays of unit Klyuchi A, although evidence is very poor. This bed can be very easily traced along the slope as a marker horizon. On the surface of this clay rare belemnite rostra were found.

Unit Klyuchi B. More than 10 m of white chalky marls identical to those of section Klyuchi 1 are visible in this section. A bed 10 cm thick glauconite occurs at the base of the marls, overlying the erosional contact between units Klyuchi Bb and B. The top of these marls should be close to the boundary between units Klyuchi B and C, as shown by micropalaeontological data (see below).

Micropalaeontology

Maastrichtian sediments in the studied sections contain abundant planktonic and benthic Foraminifera (Plates 1 and 2). Moreover, in washed residues of many samples occur diverse, mainly smooth ostracod shells (*Krithe, Cytherella* etc), radiolarian skeletons (especially in section Tyoplovka 2) and capitular plates of the cirriped *Zeugmatolepas cretae* (Steenstrup). Also tiny echinoid spines and inoceramid prisms are constant components of the sediments. Siliceous sponge spicules occur at some levels (for example in the basal bed of unit Lokh B and in the top of the Maastrichtian).

FORAMINIFERA

Foraminiferal assemblages from all studied lithological units, except unit Klyuchi C, are very similar. The main character is the predominance of planktonic Foraminifera. The P/B ratio commonly varies between 75-92% which is typical for an outer shelf environment. Preservation is usually very good, as, quite often, shells are void and clear, and their fine sculptural elements easily visible. The planktonic assemblage has a low taxonomic diversity, resulting from the relatively high latitude position of the studied sections. The total production of planktonic foraminiferids is very high (commonly 3000 - 9000 specimens per gram of rock, and reaching up to 21000 specimens in sample KL1-28). Sedimentation rates appear to have been rather slow.

Among the planktonic Foraminifera, small heterohelicids are most frequent [mainly *Heterohelix globulosa* (Ehrenberg), up to 66-89% of the planktonic assemblage]. Common are *Globigerinelloides* (7-26%) and *Archaeoglobigerina* taxa and transitional forms between *Archaeoglobigerina* and *Rugoglobigerina* (2-15%). *Hedbergella monmouthensis* Olsson, *Rugoglobigerina rugosa* (Plummer), *Globotruncanella petaloidea* (Gandolfi) and *G. havanensis* (Voorwijk) are less frequent, but occur in most samples. The triserial *Guembelitria cretacea* Cushman is very rare. The relative abundance of these groups is characteristic for a shelf environment. The large *Archaeoglobigerina australis* Huber, first described from Antarctica (Huber, 1990), and forms close to it, together with *Rugoglobigerina rugosa* (Plummer), are especially abundant in unit Lokh A. The taxonomy of the high spiral forms intermediate between *Archaeogloberigina* and *Rugogloberigerina* has not been studied in detail. Some authors have established new taxa, such as the genus *Helvetiella* (Longoria & Gamper, 1984), but additional research is necessary to clarify their taxonomy. *Globigerinelloides multispinus* (Lalicker) occurs at some levels, but in the Upper Maastrichtian *G. volutus* (White) is more frequent.

Representatives of more warm-water and deep-water genera such as *Pseudotextularia, Planoglobulina, Globotruncanita* and *Globotruncana* occur sporadically as single specimens and are mainly confined to the late Maastrichtian units Tyoplovka A and Klyuchi B. *Globotruncana arca* (Cushman), *G. mariei* Banner & Blow, *G.*

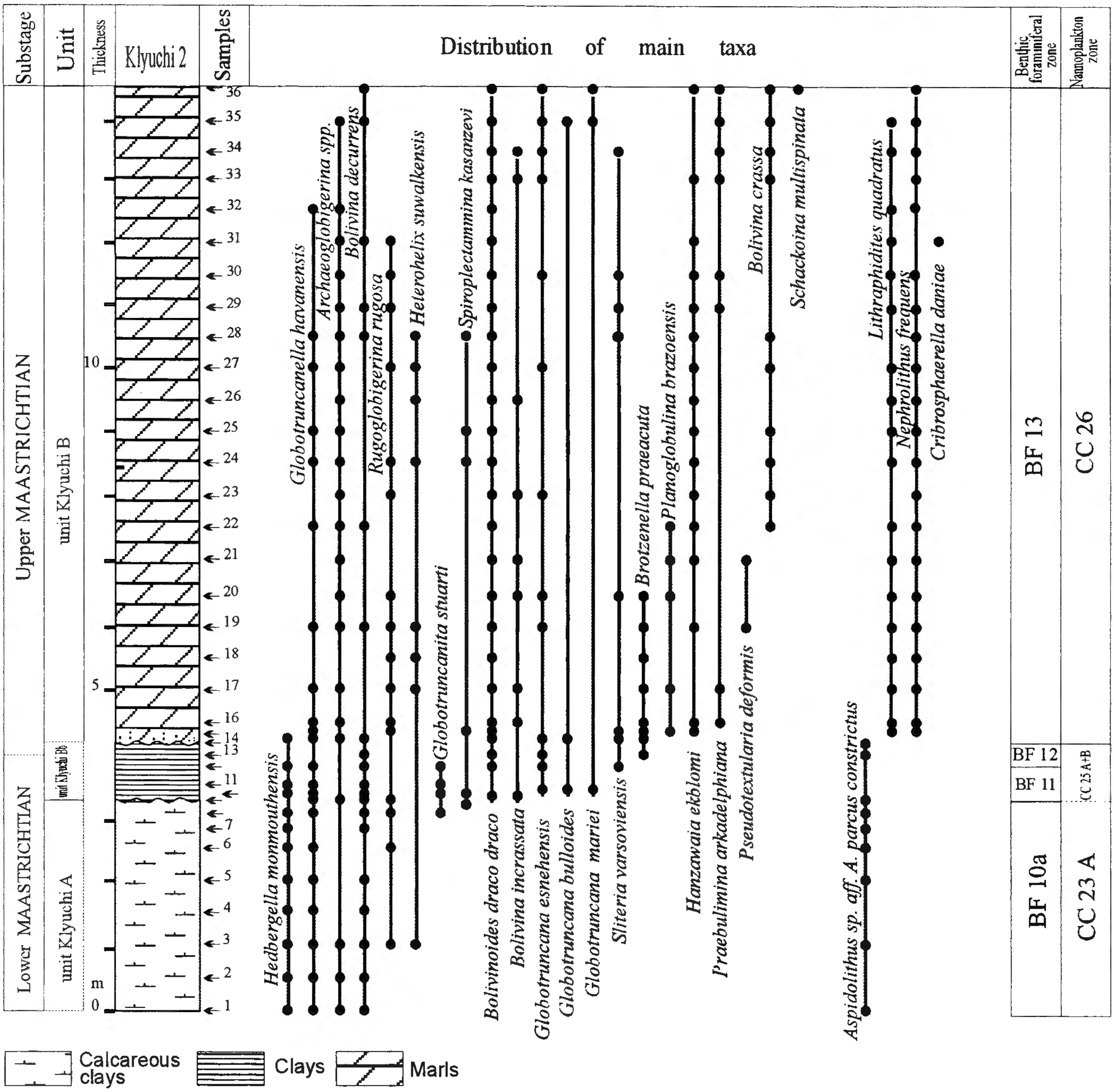


Fig 5. — Section Klyuchi 2 and stratigraphic distribution of the most important Foraminifera and calcareous nannoplankton taxa.

esnehensis Nakkady, *Pseudotextularia deformis* (Kikoine), *Planoglobulina brazoensis* Martin and *Racemiguembelina powelli* Smith & Pessagno occur in the upper 5 m of unit Klyuchi B in section Klyuchi 1.

Pseudotextularia elegans (Rzehak) (= *P. deformis* Kikoine, in this paper) has long been recognised in Europe as an index species of uppermost Maastrichtian at high latitudes (WICHER, 1953; MALMGREN, 1982; HULTBERG & MALMGREN, 1987). The level of first appearance of this species occurs in the upper part of the *Nephrolithus frequens* Zone of northern Europe (Denmark, Sweden) (MALMGREN, 1982).

In this interval (samples KL1-25 and KL2-36) also few specimens of the cosmopolitan but mainly high latitude taxon *Schackoina multispinata* Cushman & Wickenden were found (KRASHENINNIKOV & BASOV, 1985; HUBER, 1990).

Benthic Foraminifera are nicely preserved and relatively abundant (250-1700 specimens per gram of rock). The general taxonomic composition is close to that of the Polish Vistula Basin (GAWOR-BIEDOWA, 1992) and clearly differs from these in the Crimea (ALEKSEEV & KOPAEVICH, 1997). The benthic assemblages are completely dominated by calcareous forms. The agglutinated

Foraminifera (mainly *Spiroplectammina, Bolivinopsis, Arenobulimina, Ataxophragmium* and *Heterostomella*) represent no more than 1-2% of the assemblage. Among the calcareous taxa the most abundant are the infaunal species of *Bolivina, Praebulimina, Bolivinoides, Stilostomella* and *Pseudouvigerina* and some nodosariids. The epifaunal taxa belonging to *Cibicidoides, Gavelinella, Anomalinoides* and *Brotzenella*, as well as *Hanzawaia ekblomi* (Brotzen), *Stensioenia pommerana* Brotzen, *Gyromorphina allomorphinoides* (Reuss) and large *Lenticulina* species constitute a subordinate part of the assemblages.

For age determination we used the benthic foraminiferal zonation of the European palaeobiogeographic province (BENIAMOVSKII & KOPAEVICH, 1998). The oldest Lower Maastrichtian benthic assemblage occurs in units Lokh A and Klyuchi A. It consists mainly of *Bolivina decurrens* (Ehrenberg), *Neoflabellina reticulata* (Reuss), *Spiroplectammina kelleri* Dain, *Bolivina incrassata* Reuss, *Cibicidoides aktulagayensis* (Vasilenko), *C. commatus* (Vasilenko) and *Stensioeina pommerana* Brotzen. In the upper part of unit Lokh A (samples LH1-19 and LH1-22) rare specimens of *Bolivinoides draco miliaris* Hiltermann & Koch occur. These and other forms are characteristic for Subzone BF10a (*Neoflabellina reticulata-Bolivina decurrens* Subzone).

The lower part of Unit Lokh B (7 m, up to sample LH1-43) contains the assemblage of Zone BF11 (*Bolivinoides draco draco* Zone). The marker subspecies *Bolivinoides draco draco* (Marsson) has its first appearance datum in the basal glauconitic sandstone bed of this unit (sample LH1-30). The upper part of unit Lokh B and unit Lokh C belong to Zone BF12 (*Brotzenella praeacuta* Zone) of the lower Upper Maastrichtian. The benthic assemblage of unit Klyuchi Bb is very different from that of the underlying unit and appears to consist of both the BF11 and BF12 zones. *Bolivinoides draco draco* (Marsson) and *Spiroplectammina kasanzevi* Dain have their first appearance at the base of this unit, but *Brotzenella praeacuta* (Vasilenko) was found in sample KL2-13, 0.6 m higher up the section. Unit Klyuchi B belongs to Zone BF13 (*Hanzawaia ekblomi* Zone). This species has its first appearance in sample KL2-15 and 3 m higher up it is joined by the first *Bolivina crassa* Vasilenko.

Unit Tyoplovka A in sections Tyoplovka 2 and Tyoplovka 3 does not contain the marker species of Zone BF13, but the presence of *Bolivinoides draco draco* (Marsson) and sparse *Bolivina crassa* Vasilenko in samples TP2-18 and TP2-26 give a clear indication of their age. Units Klyuchi B and Tyoplovka A are characterized by the presence of a few specimens of *Sliteria varsoviensis* Gawor-Biedowa, although consistently represented. This taxon is considered as an indicator of late Maastrichtian upwelling sites (WIDMARK & SPEIJER, 1997).

CALCAREOUS NANNOPLANKTON

The calcareous nannofossils are abundant in all studied sections and have generally moderate or poor preservation (Plate 3). In some intervals the signatures of dissolution and overgrowth are evident. The dominance in assemblages of resistant species such as *Micula decussata* Vekshina, *Arkhangelskiella cymbiformis* Vekshina, *Prediscosphaera grandis* Perch-Nielsen, *Cribrosphaerella ehrenbergii* (Arkhangelsky) and several others in most assemblages, confirm the influence of dissolution on the taxonomic composition of the nannoflora. The distribution of the identified taxa in the studied sections is shown in Tables 1-4.

In section Lokh 1 the dominant species throughout the succession are *Arkhangelskiella cymbiformis* Vekshina, *Cribrosphaerella ehrenbergii* (Arkhangelsky), *Watznaueria barnesae* (Black *in* Black & Barnes) Perch-Nielsen, *Eiffellithus turriseiffeli* (Deflandre *in* Deflandre & Fert) Reinhardt, *E. parallelus* Perch-Nielsen, *Kamptnerius magnificus* Deflandre, *Prediscosphaera grandis* Perch-Nielsen and *Micula decussata* Vekshina. Also frequent are *Microrhabdulus decoratus* Deflandre, *Lithraphidites carniolensis* Deflandre, *Arkhangelskiella specillata* Vekshina, *Chiastozygus literarius* (Górka) Manivit and *Cretarhabdus conicus* Bramlette & Martini.

The nannofossil assemblage of unit Lokh A is characterized by *Aspidolithus* sp. aff. *Aspidolithus parcus constrictus* (Hattner *et al.*) Perch-Nielsen and *Tranolithus manifestus* Stover which do not cross the boundary between units Lokh A and B. The last specimens of the first species occur in the basal bed of unit Lokh B just above the hiatus, in LH1-31 and LH-32, probably, as a result of reworking. These *Aspidolithus* specimens differ from the typical *A. parcus constrictus* by a wider central field (Plate 3, Figure 13). *Reinhardites levis* Prins & Sissingh *in* Sissingh is rare and was found only in samples LH1-20, LH1-21 and LH1-29 and this is not the real first appearance of this species. The presence of these nannofossil taxa indicates that unit Lokh A belongs to Subzone CC23a.

The nannofossil assemblage of units Lokh B and C indicates subzone CC25a and the lower part of subzone CC25b, because of the absence of *Lithraphidites quadratus* Bramlette & Martini, which according to PERCH-NIELSEN (1985) has its first appearance in the middle of CC25b. In unit Lokh C the nannoplankton assemblage becomes less diverse, but this is due to the disappearance of rare species such as *Braarudosphaera bigelowii* (Gran & Braarud) Deflandre, *Chiastozygus fessus* (Stover) Shafik, *Rhombolithion speetonensis* Rood & Barnard and *Markalius perforatus* Perch-Nielsen.

In the sections Klyuchi 1 and Klyuchi 2 calcareous nannofossils are abundant, but have mainly moderate or poor preservation. The dominant species are the same as in the section Lokh 1. The most ancient assemblage which is identical to the assemblage of unit Lokh A is characteristic for unit Klyuchi A. It contains *Aspidolithus* sp. aff. *A. parcus constrictus* that has its last appearance in sample KL2-14, but no *Reinhardites levis* Prins & Sissingh *in* Sissingh. *R. levis* is probably very rare in the Saratov Region. Unit Klyuchi A belongs to subzone CC23a.

Table 1.
Distribution of calcareous nannofossils in the Maastrichtian of section Lokh1

Species	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Aspidolithus aff. parcus constrictus	F	F	R	F	F	R	F			F			F	R	R	F	F	
Arkhangelskiella cymbiformis	A	A	A	A	A	C	V	A	A	A	C	A	A	C	A	A	C	A
Cribrosphaerella ehrenbergii	A	C	A	C		A	C	A	A	A		A	C	A	C	A	A	A
Calculites obscurus	R	F											F	F				R
Braarudosphaera bigelowii	R										R							
Eiffellithus turriseiffelii	A	C	A	C	C	F	A	F	A	C		C			C	C	A	C
Kamptnerius magnificus	R	F	F		A	F	A	A	C	C	F	C	C	F	F	C	C	C
Micula decussata	A	A	A	A	A	C	F	A	A	A	A	A	A	A	C	A	A	A
Lithraphidites carniolensis	F	F		F	F	F		R	F		F		F	F		C	R	F
Prediscosphaera grandis	R	C	C	C	C	F	F	C	C	C	A	C	A	A	C	A		F
Microrhabdulus decoratus	F		F	F			R	R	C			F	F	F	F	F	F	
Lucianorhabdus cayeuxii	R							R			R	R		R			R	R
Watznaueria barnesae	C		C	C		F	F	F	F		F	C	C		C	F	C	F
Vekshinella angusta	F			F					R		F	F			R	F	F	
Ahmuellerella octoradiata			F		F	F	R	F	F	F						F	F	
Micula concava			F			F							R		F		F	
Tranolithus manifestus			F			R			R			F	F		F			
Zygodiscus spiralis			C				F			F	C				F		F	
Arkhangelskiella specillata				A	A				C	A		A	C	C		C	C	
Chiastozygus litterarius				C	F			A		C	F			F		C		
Rhombolithion speetonensis				R														R
Chiastozygus amphipons					F	F								C			C	
Cretarhabdus conicus					F					F				C	F			R
Prediscosphaera cretacea					F					F				C	F			R
Zygodiscus diplogrammus						R			R						R	R	F	
Prediscosphaera spinosa						F							F	F	F	R		F
Zygodiscus slaughteri						F	R											R
Markalius inversus								R		F	F		R	F				R
Microrhabdulus attenuatus									R									
Chiastozygus platyrhethus												R						
Prediscosphaera buckryi												R						
Stradneria crenulata												F			R			
Cretarhabdus angustiforatus													R					
Markalius perforatus														R				
Chiastozygus fessus																R		
Manivitella pemmatoidea																	R	
Rhagodiscus angustus																		
Obliquipithonella operculata																		
Reinhardites levis																		
Cyclagelosphaera margerelii																		
Prediscosphaera intercisa																		
Obliquipithonella saxea																		
Biscutum constans																		
Eiffellithus parallelus																		
Preservation	G	G	G	M	M	P	M	M	M	M	M	P	P	P	M	M	M	M

Note: Preservation: G - good, M - moderate, P - poor; Abundance: V - very abundant, A - abundant, C - common, F - few, R - rare, P - present

Table 1.
Continued

19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39
F	F					R				R		R	R							
A	C	C	A	A	A	C	A	A	C	A	V	V	A	C	C	V	A	A	A	V
A	C	A	C	C	C	A	C	A	C	A	A	A	A	C	A	V	A	A	A	A
		F	F		F			F		C		F				F			F	
F		R	R		R		R	R	R			R			R	R				
A		C		A		A	A	A	C		C	C	A	C	C	A	C	C	A	A
F	F	R	F	F	F			C		C	A	C	F	F	R		C	R		
A	C	A	C	C	A	A	C	A	A	A	V	V	V	A	A	V	C	A		V
	F	F	F		F	F	F		R		F			C		C		A		A
F	C	A	C	F	C	C	C	C	C	A	V	V	C	A	C	A	A	F		A
		F	F	F	R	F	C	C	F	C	A		A	C		A	A	C	A	C
		R					R	F		R						R			R	
		C	C	F			F	F	C	F	C	C		F	C	F	F	F		C
	C			F						F	A	A					F			F
					F		F	F		F			C			F		F	F	
C		F		R	F	F								F	R					
			R	F		R	F	C												
			F			F	C	C	F	A		A	C	C		A	C	C	F	C
		C				C		A	C		A		A			A	A	C	A	A
A			F	F			A		F	F	C	A		C		C	C		C	F
									R			R	R		R				R	
F			F	F					F						F		C			
R		F			F	F	F		C	F				F		R		R		
R		F			F	F	F		C	F				F		R		R		
F		F	F	R	R	F	F		R		C	C	F	F	R	R				F
	F					R	R				F			F	F	R	R			
				R				F		A		C					R			
			F			R			R				F	C		F		R		F
F		R	R						F											
R		F			R															
			R				F			F	R	F		R			F		R	
F			F								F	F		R		R	F		R	
R					F			C					F		R			F	F	
	F	R								R										
	R																			
						R									R					
													R		R					R
														R	F			F	F	
M	P	M	M	P	M	P	P	M	M	P	P	M	M	P	P	P	P	P	M	M

Table 1.
Continued

Species	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55
Aspidolithus aff. parcus constrictus																
Arkhangelskiella cymbiformis	A	A	C	A	C	A	A	C	A	A	A	A	A	A	C	A
Cribrosphaerella ehrenbergii	A	A	A	A	A	A	A	A	A	A	A	C	C	A	A	A
Calculites obscurus	F										R	F			R	F
Braarudosphaera bigelowii			R	R		R										
Eiffellithus turriseiffelii	C	C	C		C	V	C	A	A	C	F	C	C	C	C	A
Kamptnerius magnificus	F	F	R	R		R			F	F	F		F	R	R	
Micula decussata	C	C	A	A	A	A	V	V	A	A	A	A	A	C	A	C
Lithraphidites carniolensis	C	F		F	A	F		F		F	R	F	F		C	
Prediscosphaera grandis	C	C	A	C	A	A	C	A	A	A	C	C	C	C	A	C
Microrhabdulus decoratus	C	F	C	F			F	F	F		C	F		F	F	A
Lucianorhabdus cayeuxii	R			R			R								R	
Watznaueria barnesae	C	F	C	C		F	A	C	C	F		C	A	C	F	C
Vekshinella angusta	C		C			R			F	F				F		
Ahmuellerella octoradiata			F		F	F		R	C			R	F			F
Micula concava							F	F			F	F	F		F	
Tranolithus manifestus																
Zygodiscus spiralis	C	F	C		R		F	F		C	C	R	C	F	C	C
Arkhangelskiella specillata		A	C	A	C	A	C						A	C		A
Chiastozygus litterarius			A	F	C	C	C		F	C	F	F	F	C	F	V
Rhombolithion speetonensis						R		R								
Chiastozygus amphipons				F			F		C	F		C			F	
Cretarhabdus conicus	F				F	F	F	F			R		R			F
Prediscosphaera cretacea	F				F	F	C	F	F		F	C			F	A
Zygodiscus diplogrammus	F	F		R		F						R		R	R	R
Prediscosphaera spinosa	R			F	R	R	F	R	F	F	R	F			R	F
Zygodiscus slaughteri		C			R	C		R	F		C	R		F	F	
Markalius inversus	F			R		C	F			F	F	F	F			
Microrhabdulus attenuatus		R														
Chiastozygus platyrhethus																
Prediscosphaera buckryi								R				R				
Stradneria crenulata		R														
Cretarhabdus angustiforatus																
Markalius perforatus				F			R	F	F	F						
Chiastozygus fessus				R			R									
Manivitella pemmatoidea													R			
Rhagodiscus angustus	R	F	R				F						F	F		
Obliquipithonella operculata				F									C	F	C	R
Reinhardites levis																
Cyclagelosphaera margerelii																
Prediscosphaera intercisa																
Obliquipithonella saxea		R			R											
Biscutum constans	F			F			F	F	F			F				
Eiffellithus parallelus							R	R							R	R
Preservation	M	P	P	P	P	P	P	M	P	P	P	P	M	M	P	P

Table 2.
Distribution of calcareous nannofossils in the Upper Maastrichtian and Palaeocene of section Klyuchi 1

Species	43	42	41	40	39	38	37	36	35	34	33	32	31	30	29	28	27	26
Arkhangelskiella cymbiformis	A	A	A	A	A	V	C	C	A	A	C	A	A	A	A	C	A	A
Micula decussata	A	A	V	A	V	A	V	C	V	V	A	V	V	A	A	A	V	C
Prediscosphaera cretacea	F		F	F			F	C	F	C	C	F		F			C	
Watznaueria barnesae	C		C		F		C	C	A	C	C	C	A	C	A	A	C	C
Eiffellithus turriseiffeli	C	V	C	A	A			A	A	C	C	A	A	C	A	C	A	A
Lithraphidites carniolensis	F	F	F	F		C	F	C	F	F	F	F	F	F	C	F	F	F
Nephrolithus frequens	C	C	C	C	A	A	C	A	C	C	C	A	F	A	A	F	C	A
Zygodiscus spiralis	F	F	F	C	F		F		F	F		F	F	F	F	F	F	F
Prediscosphaera intercisa	R				R	R		R					R					R
Cribrosphaerella ehrenbergii	A	A	C	A	C	C	C	A	C	C	C	A		C	C	C	C	A
Arkhangelskiella specilata	A				A	A	C		A			F			C			A
Prediscosphaera grandis	A	C	C	C	A	C	C	C	C	C	C		F	C	C	C	A	C
Pr. stoveri	R										R			R		R	R	
Cretarhabdus conicus	F							F	F	F						F	F	
Ahmuerella octoradiata	F	F		R			R						F					
Calculites obscurus	F			F		F	F	R	F	F				F				
Chiastozygus litterarius	C				C		F	F	F		F	F			F			
Ch. amphipons	F			C	C		F	C			F	F			F	F		
Microrhabdulus decoratus	F	F	F		C			C			C		F	C	C			F
Lithraphidites praequadratus	R										R							
Lucianorhabdus cayeuxii	F					R	R					R					F	
Prediscosphaera spinosa		F	F	R				F	F			F	R	F	F	F	C	
Eiffellithus parralelus		R									R	R	R					
Microrhabdulus attenuatus		R	R	R				R	R		R					R	R	
Kamptnerius magnificus		F											F					
Chiastozygus fessus		R																
Micula concava		F	F	R	R	F										R		
Glaukolithus diplogrammus		F		F	F		F	R		F	F				F			
Lithraphidites quadratus		R	R		F	F	R	F		F	F		F	C	F	F	F	F
Vekschinella angusta		F	F	R				F							F			
Zygodiscus diplogrammus			R	F				F		R		R	F	R			F	F
Cretarhabdus crenulatus			F															
Stradneria crenulata			R	F		F					R			F	F			
Ceratolithus aculeus			R															
Braarudosphaera bigelowii					R													
Corollithion signum						R												
Rhagodiscus angustus						R			F	F								
Chiastozygus platyrhethus						R								R				
Aculeus scotus						R												
Cylindrolithus oweinae						R												
Z. slaugtheri						R	R					R						
Watznaueria biporta									R					R		R		R
Broinsonia enormis									R									
Markalius perforatus										F								R
Cribrosphaerella daniae										F	F					R		
Biscutum constrictum										F								
Zygodiscus acanthus										R								
Rhombolithion speetonensis											R							
Manivitella pemmatoidea													R					
Lithraphidites grossopectinatus																		
Vekshinella crux																		
Obliquipithonella operculata																		
O. saxea																		
Preservation	P	P	P	P	M	P	P	M	M	M	M	M	M	M	M	M	M	M

Table 2.
Continued

25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1
A	A	A	A	A	A	A	C	C	C	C	C	C	F		F	F	F	C	C	A	A	A	C	C
A	V	V	V	A	V	A	A	A	A	A	A	C	C	F	C	C	A	A	C	V	A	A	A	A
F	C	F	C	F	F	C	F	F	F	F	R				R				R		F	F	F	F
F	A	C	C	C		C	C	C	C	C	C	F	F		C	F	C	C	C	A	C	C	C	C
C	A	C	C	C	A	C	A	C	C	C	F	F				F	C	C	F	C	C		F	F
F	F	F	F	F	F		F	F	F	F	F		F			F	F				F			F
C	C	C	A	C	C	C	A	F	C	C	C	F	R	F	F	F	F	C	C	C	C	C	F	R
F	F	C	F	F			F	F	F	F			R	R	F	F	F		F	F	F	F	F	C
			R			R											R							
C	A	A	A	C		C	A	C			C	C	F	F		F	F	A	F	A	A		C	A
A		C					C	C			C	C					F				C			
F	C	C	A	C	A	A	C	F	C	C	C			F	F			C	C	C	C	C	F	C
	R																							
R	F	F	F			F	F		F	F				R										
															R		F			R			R	
					F						F			F										
	F		F		F	F	R	F	F	C	F	R	F		F	R		F		F		R	F	F
	F		F		F	F		F	C	C	F	R	F			F				F		F		
					F				R			F			F		F	F	F	F	F	F		F
R	R		R								R													
R	F	R					F	R	F	F	F								R		R		R	R
R		R															R							
R		R	R	R		R	R	R										R					R	
		F			R				R	F	R													R
	R	R				R			R		F				F	R	R		R	F	R	R	R	R
R			F		R																			
F	F	F	F	F	F	F	F	F	F		R	R		R	F			F			R			F
F	F			R	F					R	F							F						R
						R								R										
				F																				
				F	R					R														
															R									
										R														
	F							R													R		R	
				R		R																		
				F												R								
	F						R	F	F	F			F	F		F	F	F	F	F	F	F	F	F
			F									R						F						
														R						R				
R																								
R																								
									F	V		C	A	C	C	C	C	C	C	F	C	C	A	A
															R	R			R					R
G	G	M	M	M	G	G	M	M	M	G	G	M	M	M	M	G	M	G	G	G	G	G	G	G

Table 3.
Distribution of calcareous nannofossils in the Maastrichtian of section Klyuchi 2

Species	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Aspidolithus aff. parcus constrictus	R		R		F	R	R	R	R				R	R			
Micula decussata	V	A	A	A	C	A	V	A	A	C	V	A	V	A	A	V	A
Cribrosphaerella ehrenbergii	A	C	C	A	A	C	C	C	C	A	C		A	C		A	A
Arkhangelskiella cymbiformis	C	A	A	C		C	V	V	A	A	C	C		A	V	C	C
Arkhangelskiella specillata	C		A	A	A		V	C		C		F				C	C
Eiffellithus turriseiffelii	A	C	A	A	C	C	A	V	V	V	V	V	A	C	V	V	A
Prediscosphaera intercisa	F	R	R	F		R							F				
Lithraphidites carniolensis	F		C	C	F	F	F	R		F			F	F		F	R
Micula concava	R	R		F			R	R		F	F	R	R	R		R	
Cretarhabdus conicus	R	F	F				F							F			R
Vekshinella angusta	R					F	F							F			
Microrhabdulus decoratus	F	F	C	C	C	C	C	F	F	F	F	C	C	F	F	F	
Microrhabdulus attenuatus	F	F	R						R	F			R				
Chiastozygus platyrhethus	R			F	F												
Markalius circumradiatus	F			R	R	F					R	R					
Prediscosphaera cretacea	R	F	F	F	F				R	R	F						
Zygodiscus spiralis	F	C	A	C	A	C	C		F	A	C	C	C	A	C	C	F
Ahmuellerella octoradiata	F	C	F		C	A	C	F		A					F		
Chiastozygus litterarius		A	A	A	A	A	A	C	C	C	A	A	A				
Prediscosphaera grandis		C	A	A	A	F	A	C	C	A	A	C	A	A	V	A	C
Zygodiscus slaughteri		F		C												C	F
Parhabdolithus embergerii		R															
Rhagodiscus splendens			R														
Prediscosphaera spinosa			F				F										F
Zygodiscus acanthus				R													
Kamptnerius magnificus					R				R			R			R		
Obliquipithonella operculata					R												
Tranolithus manifestus						R											
Chiastozygus fessus							F										F
Lucianorhabdus cayeuxii								R								F	
Obliquipithonella saxea											R		R				
Ceratolithus aculeus													R		R		R
Rhagodiscus angustus														R			
Chiastozygus amphipons														R			
Braarudosphaera bigelowii															R	R	
Parhabdolithus asper															R		
Biscutum constans															F		
Nephrolithus frequens															C	A	C
Lithraphidites quadratus															F	F	F
Calculites obscurus															F		
Cretarhabdus crenulatus																	
Rhombolithion speetonensis																	
Stradneria crenulata																	
Vekshinella crux																	
Lithraphidites praequadratus																	
Cribrosphaerella daniae																	
Cylindralithus dupeii																	
Lithraphidites grossopectinatus																	
Chiastozygus anceps																	
Preservation	M	M	M	M	M	M	G	G	M	M	G	M	M	M	M	M	M

Table 3. Continued

18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36
V	V	V	V	V	V	A	V	A	V	A	A	A	A	A	V	V	A	V
C	R	A			A	A	A	A	C	C	V	A	C	A	C	A	C	A
A	C	A	A	A	A	C	A	A	C	A	C	A	A	V	A	A	F	C
		C		A		C				A	C		C	V	C		F	C
V	V	V	V	C	C	C	C	A	A	V	A	A	C	C	A	F	C	C
				R	R		R								R	F	R	R
				F	C	F	C		F	F	C	F	F	C	C	F	C	
R	R					R		R	F	R						F	F	
F	F	F	R	F	R	R		F	F	F		F	R	F	F			
				F		F											F	
A	F	C	F	F	F	F	F		F		F		F		A			
						R		R		R	R	R			F	R		
R							R									F		
				C	F			F			R	F			F	R	F	
A	C	A	A	C	C		C	F	F	C		C	C	C	A	A		C
								F		F								
				C	C		A	C		C			C	A		A	A	A
V	F	A	V	A		A	V	A	V	V	A	A	V		V	V	V	V
F	F			F			F	F					F		R	F		
				R		R		F			R		F					
																		F
R	R				F			R		R					R		R	
		C					F	R	R	F	F	F	R	F	R	F		
							R		R						R			
	R					R		R							R			
A	C	A	A	C	A	A	A	C	A	A	C	A		A	A	A	A	A
F	F	F	F	C		F		R	F		F	F	F	F		F	C	
F		F				F	F					F	F		F			
	A																	
		R															F	
				F						R								
									R									
														R				
													F					
																	R	
M	M	M	M	M	M	M	M	M	M	M	M	M	M	P	M	M	M	M

Table 4
Distribution of calcareous nannofossils in the Upper Maastrichtian of section Tyoplovka 2

Species	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35
Arkhangelskiella cymbiformis	C	A	A	A	A	C	A	A	A	V	V	A	V	A	A	A	A	A	A	V
Micula decussata	A	V	A		A	C	A	V	A	V		V	A	V	V	V	V	V	A	V
Kamptnerius magnificus	F	F		F			R			R	F						R	R	R	F
Watznaueria barnesae	C	C	C	C	C	C	C	C	C	A	A	A	C	C	A	A	A		C	A
Rhagodiscus angustus	F					R	R		F	F					F	F		R		F
Lithraphidites carniolensis	R	C	F	F	F	F	C	F	C		F	C	F		F	F	F	F	F	F
Nephrolithus frequens	F	C	C	C	C	C	F	F	C	C	C	C	C	C	A	A	A	C	C	A
Zygodiscus spiralis	F	F	C	F	F	F	F			C	C	C		F	C	F	R	F		F
Z. slaugtheri	R		C						F	C	R	C	F	R		R	R	F		F
Eiffellithus turriseiffeli	F		C		C	C	C	C	C		A		C	F	C	V		C	F	
Prediscosphaera cretacea	R	C	C	F	F	F		C	F			F	C	F	C	A	C	C	F	A
Pr. grandis	F	A	F	C	C	C	A	A	A	F	V	A	V	A	V	V	A	A	A	V
Microrhabdulus decoratus	F	F	F		C	C	C		F	F	F	F	F	F	F	C	C	F	F	F
Cribrosphaerella ehrenbergii	F	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	F	F	C	A
Manivitella pemmatoidea		R														R				
Cretarhabdus conicus		F	F				R	F			F	C	R	F		F	F			F
Vekschinella angusta		F		R				F		R			R				F		F	
Lithraphidites quadratus		F	F		F	R	F	F	C	A	R	R	F	F			F	R	F	
Micula concava		R			R				F		F		F			F		R	F	
Chiastozygus litterarius		C	C	F	C	F	C	F			C	C				V	C	A		A
Ch. amphipons		C	C	F		F				C	C	C		C	A	A	C	A		A
Arkhangelskiella specilata		A		A		C		A		V	V		V	A			A	A		A
Prediscosphaera spinosa			F		F			C	F		F	R		C		F				
Eiffellithus parralelus			R											R						
Ahmuerella octoradiata			F	F					R	F			F		F	F	F	R	R	
Zygodiscus diplogrammus			F	F				F	F					R					R	F
Rhombolithion speetonensis			F									R								
Cribrosphaerella daniae			R	F	R		F	F	F	F			R		F	C	F	A	F	F
Glaukolithus diplogrammus				F	F							F								
Markalius perforatus				F	F															
M. inversus				R				F											F	F
Prediscosphaera bukryi				R											R					
Pr. stoveri				R											R				R	
Chiastozygus fessus				R											R					
Prediscosphaera intercisa					R						F									R
Microrhabdulus belgicus							R													
Obliquipithonella saxea							F													
O. operculata							F		F											F
Biscutum constans								F												
Watznaueria biporta									R	R					F					R
Microrhabdulus attenuatus									R									R		
Calculites obscurus													F							F
Cylindrolithus oweinae															R					
Preservation	M	G	M	M	M	M	M	M	M	M	G	M	G	G	G	M	G	M	M	M

Table 5
Quantitative data for terminal Maastrichtian in section Klyuchi 1

Distance from the top of Maastrichtian (m)	Number of sample	$CaCO_3$ content, %	Total counted specimens	Abundance of planktonic Foraminifera (specimens per 1 g)	Abundance of benthic Foraminifera, (specimens per 1 g)	Planktonic Foraminifera, %	Heterochelicidae, %	*Globigerinelloides*, %	*Globotruncana* (specimens per 50 g)	Other planktonic Foraminifera, %
-0.05	KL1-18	–	548	5684	621	90.1	75.7	21.3	24	2.2
-0.15	KL1-19	–	501	4989	990	83.4	76.6	14.6	30	8.4
-0.25	KL1-20	55	377	3793	376	91.0	72.0	25.1	36	2.6
-0.45	KL1-21	–	647	5509	1116	83.2	78.8	19.0	44	2.0
-0.95	KL1-22	58	972	6117	1116	84.6	81.3	17.3	136	1.4
-1.45	KL1-23	57	514	9275	1735	84.2	89.1	6.5	52	3.7
-1.95	KL1-24	57	621	5679	745	88.4	68.8	26.0	–	4.7
-2.45	KL1-25	–	427	8290	763	91.6	81.6	15.1	5	3.3
-2.95	KL1-26	59	449	2098	374	84.9	73.2	25.7	4	1.1
-3.45	KL1-27	–	516	5938	353	87.4	81.6	16.6	4	1.8
-3.95	KL1-28	58	564	21217	1884	91.8	81.7	15.8	1	2.5
-4.45	KL1-29	58	621	2760	420	86.8	75.3	22.5	4	2.0
-4.95	KL1-30	55	721	6482	1130	85.2	76.1	9.8	13	14.2
-5.45	KL1-31	65	1044	2232	440	83.5	82.3	12.8	–	4.8
-5.95	KL1-32	63	750	3348	491	87.2	89.3	8.3	–	2.4

Unit Klyuchi B from the glauconite-rich basal bed (sample KL2-15) contains a nannofossil assemblage with *Lithraphidites quadratus* Bramlette & Martini and *Nephrolithus frequens* Górka and therefore belongs to zone CC26. *Cribrosphaerella daniae* Perch-Nielsen, a characteristic taxon for the upper part of CC26 in high latitudes of the Southern Hemisphere (POSPICHAL & WISE, 1990), has its first appearance in sample KL1-34. The abundance of *Nephrolithus frequens* and the absence of warm-water *Micula mura* (Martini) Bukry and *M. prinsii* Perch-Nielsen are in agreement with the high latitude setting of the Saratov sections.

The nannofossil assemblage of unit Klyuchi Bb contains *Aspidolithus* sp. aff. *A. parcus constrictus* and this interval, as well as the lower unit Klyuchi A, might belong to CC23a. However this taxon could be reworked and the biozonation of this interval based on nannoplankton remains unclear.

Unit Klyuchi B in section Klyuchi 2 belongs to Zone CC26 because of the presence of *N. frequens*. *Cribrosphaerella daniae* Perch-Nielsen has been found in one level, 7.8 m above the base of unit Klyuchi B (sample KL2-31).

Nephrolithus frequens (first appearance in sample TP2-16) and *Cribrosphaerella daniae* (first appearance in sample TP2-18) are consistently represented throughout unit Tyoplovka A in section Tyoplovka 2 indicating the upper part of zone CC26.

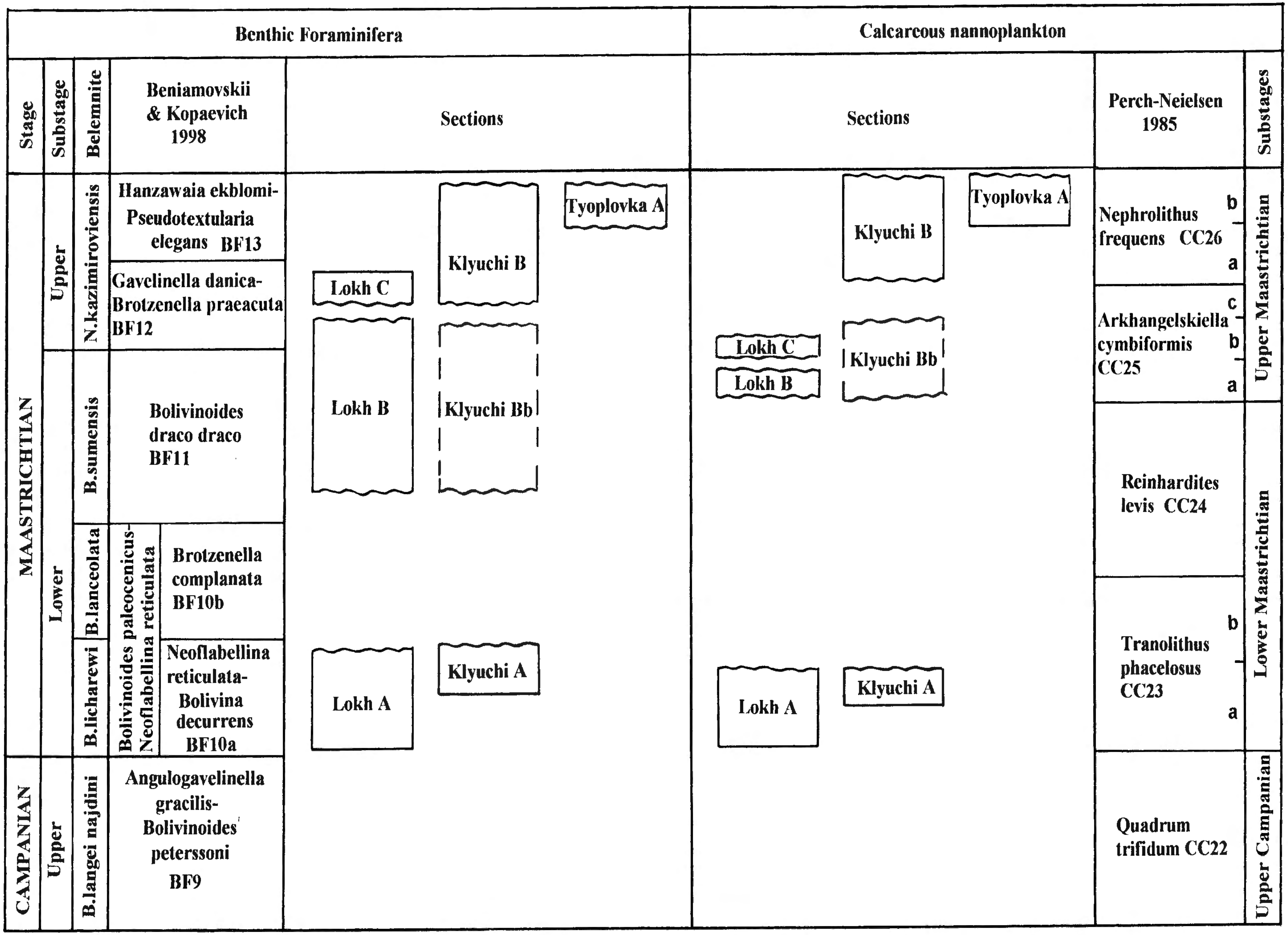
The Lower Palaeocene siliceous rocks in section Klyuchi 1, named Unit Klyuchi C, only contain reworked Cretaceous taxa indicative for CC26. Such Cretaceous species as *Lucianorhabdus cayeuxii* Deflandre, *Cretarhabdus conicus* Bramlette & Martini, *Calculites obscurus* (Deflandre) Prins & Sissingh *in* Sissingh, *Kamptnerius magnificus* Deflandre, *Stradneria crenulata* (Bramlette & Martini) Noël, *Zygodiscus diplogrammus* Deflandre *in* Deflandre & Fert occur only in the lowermost part of Palaeocene Syzran Formation (up to sample KL1-11). However, the relatively abundant *Obliquipithonella operculata* (Bramlette & Martini) and *O. saxea* (Stradner) are characteristic features of the assemblage from unit Klyuchi C and they are the only signature of Palaeocene age for this unit.

MACROFOSSILS

A single rostrum of *Belemnella lanceolata gracilis* Arkhangelsky (Plate 4, Figure 1) was found *in situ*, 1.8 m above base of unit Lokh A, together with moulds of small bivalves. The subspecies is characteristic for the lower Lower Maastrichtian in the southern part of the Russian Platform (NAIDIN, 1974). It was first described by ARKHANGELSKY (1912) from the Lower Maastrichtian of Saratov. The basal sandy bed of unit Lokh B contains rare moulds of *Hoploscaphites* sp. aff. *H. constrictus* (J. Sowerby). This species is characteristic for the Maastrichtian in Europe. Eroded rostra of the *Belemnella sumensis* Group are also common in basal bed of unit Lokh B and occur together with moulds of small unidentifiable bivalves. Belemnite rostra which were collected on clays of unit Klyuchi Bb in section Klyuchi 2 could have been washed out from these clays or from the basal bed of unit Klyuchi B (the latter is more probable). They were identified as *Belemnella sumensis praearkhangelskii* Naidin. Their rostrum surface is smooth and the length of the first visible guard is 27-28 mm (Plate 4, Figures 2 and 3). The juvenile rostra from unit Klyuchi B are more cylindrical in outline, have no recognizable first visible guard and their anterior part is ornamented with weak vascular markings. These rostra belong to *Neobe-*

→

Fig 6. — Correlation of Maastrichtian lithological units based on foraminiferal and calcareous nannoplankton evidence.


Benthic Foraminifera
Calcareous nannoplankton
Stage
Substage
Belemnite
Beniamovskii & Kopaevich 1998
Sections
Sections
Perch-Neielsen 1985
Substages
MAASTRICHTIAN
CAMPANIAN
Upper
Lower
Upper
N.kazimiroviensis
B.sumensis
B.lanceolata
B.licharewi
B.langei najdini
Hanzawaia ekblomi-Pseudotextularia elegans BF13
Gavelinella danica-Brotzenella praeacuta BF12
Bolivinoides draco draco BF11
Bolivinoides paleocenicus-Neoflabellina reticulata
Brotzenella complanata BF10b
Neoflabellina reticulata-Bolivina decurrens BF10a
Angulogavelinella gracilis-Bolivinoides peterssoni BF9
Lokh C
Lokh B
Lokh A
Klyuchi B
Klyuchi Bb
Klyuchi A
Tyoplovka A
Klyuchi B
Tyoplovka A
Lokh C
Lokh B
Klyuchi Bb
Lokh A
Klyuchi A
Nephrolithus frequens CC26
b
a
Arkhangelskiella cymbiformis CC25
c
b
a
Reinhardites levis CC24
Tranolithus phacelosus CC23
b
a
Quadrum trifidum CC22
Upper Maastrichtian
Lower Maastrichtian
Upper Campanian

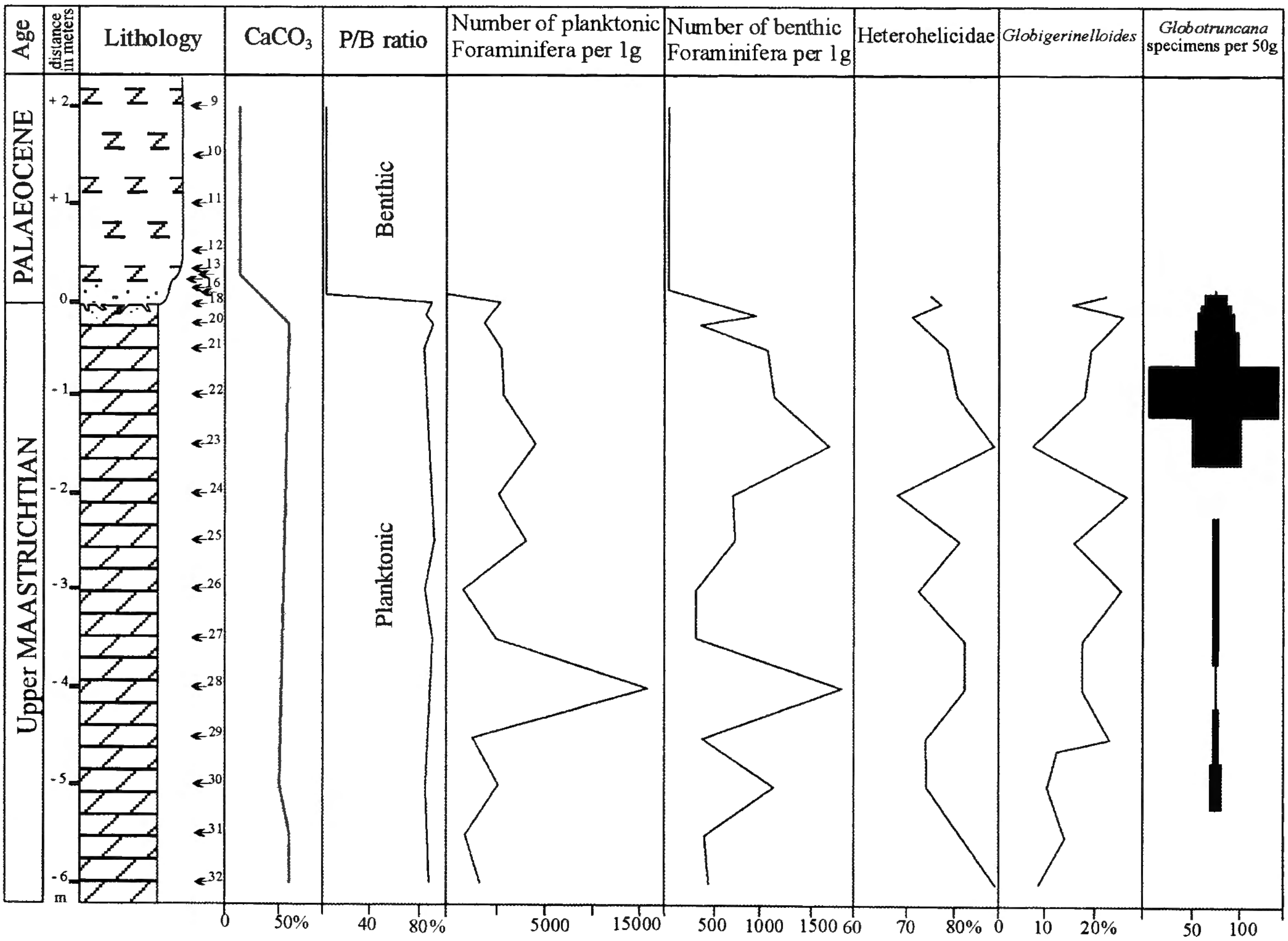


Fig 7. — Evolution of the main lithological parameters and changes in composition of the foraminiferal assemblages in the terminal Maastrichtian of section Klyuchi 1.

lemnella kazimiroviensis (Skolozdrowna). According to KOPAEVICH *et al.* (1987) *Belemnella sumensis praearkhangelskii* Naidin occurs in beds transitional from Lower to Upper Maastrichtian and *Neobelemnella kazimiroviensis* (Skolozdrowna) is distributed in Eastern Europe throughout the entire Upper Maastrichtian. Both taxa were described and figured by NAIDIN (1975) from the Saratov Region.

Thus, the belemnites support the age identifications based on benthic Foraminifera and calcareous nannofossils.

Correlations

The foraminiferal and calcareous nannofossil data certainly confirm an earliest Early Maastrichtian age for units Lokh A and Klyuchi A (Figure 6). The upper Lower Maastrichtian is not represented in the studied sections because of non-deposition or subsequent erosion. However, the correlation of Zone BF10a with the *Belemnella licharevi* Zone is not proven as *Belemnella lanceolata gracilis* Arkhangelsky, the characteristic subspecies for the younger *Belemnella lanceolata* Zone, co-occurs with foraminiferal taxa of the *B. licharevi* Zone.

Units Lokh B and Lokh C belong respectively to the uppermost Lower Maastrichtian and lower Upper Maastrichtian according to benthic foraminiferans, but have to be included in the lowermost Upper Maastrichtian on the base of calcareous nannoplankton. Unit Klyuchi Bb in section Klyuchi 2 may consist of condensed residual sediments of the same age.

Unit Klyuchi B is upper Upper Maastrichtian according to both fossil groups and belongs to CC26. The closely situated sections Klyuchi 1 and Klyuchi 2 can be correlated on the basis of first appearance of *Bolivina crassa* Vasilenko. Thus, the level of sample KL1-37 is the same as that of sample KL2-22. In this case the total thickness of unit Klyuchi B is about 12 m, and on top of section Klyuchi 2 only the uppermost 2 m of the Maastrichtian are not exposed.

According to the nannofossils unit Tyoplovka A from the Tyoplovka area also belongs to the Upper Maastrichtian. It seems to be coeval to the upper part of unit

Klyuchi B. The Maastrichtian succession in the North Saratov Region is very complete towards the top as evidenced by the presence of *Cribrosphaerella daniae* Perch-Nielsen in the upper part of unit Klyuchi B.

The age of unit Klyuchi C (lower part of the Syzranian Formation) in this locality, is uncertain, based on our data. The benthic Foraminifera are mainly represented by Maastrichtian taxa and only very few, for example, *Cibicides succedens* Brotzen, are characteristic for the Palaeocene. Nannofossils are exclusively represented by reworked Upper Cretaceous taxa. Fortunately DIGAS (1976) and KURLAEV *et al.* (1981) reported an abundant foraminiferal assemblage with about 50% of planktonic forms at the base of the Syzranian in this area, but probably from another valley. This assemblage contains according to their identifications *Globoconusa daubjergensis* (Brönnimann), *Subbotina pseudobulloides* (Plummer), *S. triloculinoides* Plummer and *S. varianta* (Subbotina), taxa which are typical for the Danian Zone P1c.

Unit Klyuchi C may be time equivalent of the Belogrodnya Formation - glauconitic clays and siltstones which outcrop about 40 km to the NE of Klyuchi on the right bank of the Volga River (MUSATOV & ERMOKHINA, 1998).

Cretaceous/Tertiary boundary

At section Klyuchi 1 it is possible to study the Cretaceous/Tertiary boundary in the North Saratov Region. The general opinion is that in this region the boundary between the Maastrichtian and the Palaeocene is discontinuous (ARKHANGELSKY & DOBROV, 1913; KAMYSHEVA-ELPATIEVSKAYA, 1951; DERVIZ, 1959).

Three kinds of K/T transitions exist:

(1) As a rule the top of the Maastrichtian is irregular with shallow depressions and with numerous burrows penetrating the underlying marls or chalk to different depths. These burrows are filled with siliceous material of Palaeocene Lower Syzranian "opokas". At the base of the "opoka" a thin (up to 0.5 m) conglomerate occurs with clasts of Cretaceous marls or chalks, sometimes with phosphoritic pebbles and abundant bryozoan fragments.

(2) In other sites, the K/T boundary is marked by a thin (1-5 cm) interbed of green clay with small chalk pebbles overlying the Maastrichtian.

(3) up to 2-3 m deep depressions occur at the top of Maastrichtian carbonate rocks in other localities. These depressions are filled with green-brown clay material containing few mainly agglutinated Foraminifera and Palaeocene "opokas" which often are intensively disrupted and are generally considered as ancient karst signatures.

As in other sites of the Volga River area, in Klyuchi 1 the K/T boundary coincides with a important hiatus and belongs to type (1). The basal bed of unit Klyuchi C, 15-20 cm thick, is heavily silicified and contains small (1-2 cm) clasts of Maastrichtian marls and abundant glauconite. Silification at this boundary interval is more intensive than it is in the upper part of this unit. Zones P0, P1a and P1b are probably missing in this section. However, the sequence of events can be described for the uppermost Maastrichtian in this section (Figure 7).

The planktonic Foraminifera dominate in the assemblage and their number is constant. P/B ratios change in narrow limits 83-91% and do not show a decrease towards the top of the Maastrichtian marls. The number of planktonic Foraminifera appears to increase upwards in the section up to sample KL1-23 (9275 specimens/g) and then decreases to 3700-5600 specimens/g in the interval 1.5 m below the top of Maastrichtian. The abundance of benthic Foraminifera shows a very similar trend, showing a maximum at the same level. The heterohelicids are the most abundant group among planktonic Foraminifera (68-89%), but they decrease in the last 1.5 m from 89 to 75%. The relative abundance of *Globigerinelloides* increases from 10 % at 6 m below the boundary to about 26 % in sample KL1-24, 2 m below the boundary. After a sharp minimum in sample KL1-23 (6.5%) it shows again an obvious tendency to increase. Globotruncanids (Fig. 7), the most explicit deep-water component, are absent in the lowermost part of the section (6-5 m), occur rarely (1-5 specimens per 50 g) in interval 6 - 2 m, but show a sharp increase from sample KL1-23 (52 specimens/50 g) upwards at 1.5 m below the K/T boundary with a maximum in sample KL1-22 (136 specimens/50g). In the terminal 1.5 m of the Maastrichtian the content of globotruncanids is more or less constant (44-24 specimens/50 g).

These data together with the analysis of the taxonomical composition of the planktonic Foraminifera allow to reconstruct the succession of biotic and environmental events at the end of the Maastrichtian.

1. 6-5 m. The relatively abundant large *Archaeoglobigerina* and heterohelicids are dominant components of the planktonic assemblage, reflecting outer shelf environments. The input of clastics was minor. The sediments are mostly carbonate-rich (63-65% $CaCO_3$).

2. 5-1.5 m. The appearance of rare *Globotruncana* and the increase in abundance of *Globigerinelloides* evidence the increase of water depth. This change coincides with a decrease in carbonate content from 65% in sample KL1-31 to 55% in sample KL1-30. The latter can reflect a more humid climate. The carbonate content in the remaining part of the Maastrichtian is 57-59%.

3. 1.5-0 m. The "bloom" of *Globotruncana, Globotruncanita, Planoglobulina, Pseudotextularia deformis* (Kikoine) and even the appearance of *Racemiguembelina powelli* Smith & Pessagno are signs of the terminal Cretaceous transgression, marked by substantial deepening and input of warmer waters in this part of the Russian marine basin.

In the Danish Trough the increase of abundance of *Pseudotextularia elegans-Racemiguembelina fructicosa* complex coincides with the interval 3-6 m below the K/T boundary in section Stevns Klint and 1-4 m in section

Kjølby Gaard (HULTBERG & MALMGREN, 1987). These two events registered in both N and E European sites could have been contemporary. The presence of this transgressive event supports the idea that in this section the youngest Maastrichtian sediments have been preserved.

Hiatuses, transgressions and climatic warming

The Maastrichtian of Saratov Region contains several hiatuses. The first is at the base of the Lower Maastrichtian that unconformably overlies older deposits. The second encompasses upper Lower Maastrichtian (zones CC23b and CC24) and it has the longest duration. The third gap coincides with an interval in the lower Upper Maastrichtian. In the nannofossil zonation the last hiatus covers Zone CC25c and lowermost CC26, but at the top of the Tyoplovka uplift its duration was even longer because the sedimentation there occurred only during the younger half of CC26.

These hiatuses separate three sequences which reflect three transgressive pulses: lower Lower Maastrichtian, lower and upper Upper Maastrichtian. These transgressions are mainly eustatic in origin. The existence of at least two Maastrichtian transgressions was documented in W. Europe by HANCOCK (1989). Two transgressive pulses (early and late Maastrichtian) separated by a short-term regressive event were mentioned for the E. European Platform by NAIDIN (1995). However, the long gap between lower Lower Maastrichtian and lower Upper Maastrichtian as well as the cutting of the Upper Albian at the top of the Tyoplovka Uplift by the uppermost Upper Maastrichtian appear to be related to tectonic activation of the Saratov dislocations in the mid-Maastrichtian.

The terminal Maastrichtian short transgressive warming episode that was registered in section Klyuchi 1 appears to be not only local, but even possibly global. The sharp increase in the abundance of *Pseudotextularia* in uppermost Maastrichtian sediments was recognised not only in N. Europe [where it is well known as "elegans transgression" (WICHER, 1953)], but also in the N. Atlantic (NEDERBRAGT, 1989), even though she attributed this phenomenon to differential dissolution. Recently, in the mid-latitude S. Atlantic the warm episode was shown on isotope data to have occurred during the interval 65.45 - 65.11 Ma, i.e. 100 k.y. before the end of the Cretaceous (LI & KELLER, 1998).

The recognition of a short-term warming in the uppermost Maastrichtian of the North Saratov Region could confirm the global extent of this climatic event, which be registered easily only in relatively high latitudes.

Conclusions

The integrated study of Foraminifera and calcareous nannoplankton together with a few macrofossil records shows that during the Maastrichtian the North Saratov Region was confined to the outer shelf. Correlation between local units described in sections situated 20-25 km apart is quite good. The long gap between lower Lower Maastrichtian and Upper Maastrichtian is typical for most of this area. On the top of the Tyoplovka Uplift the upper Upper Maastrichtian marls (upper part of CC26) overlie the Upper Albian clays with a weak angular unconformity. This intra-Maastrichtian event related to tectonic movements during this time interval gives a good age estimation of the terminal Cretaceous deformations in the eastern part of the Russian Platform.

The Maastrichtian foraminiferal assemblages of the Saratov Region are typical for the northern part of the Russian Basin and are very close to the contemporaneous assemblages of Poland (GAWOR-BIEDOWA, 1992) and even to those from north of the Turgay Strait, east of the Urals. The Turgay assemblages were described by AMON (1990) from the shallow-water Zhuravlevka Formation in Kustanay Region (Kazakhstan) situated at the same latitude (52-53° N) as Saratov. The nannofossil assemblages of the uppermost Maastrichtian contain abundant *Nephrolithus frequens* Górka in the Saratov Region. However, this species occurs only in a very limited interval of the Maastrichtian stratotype area (51° N) and it is absent in the uppermost part of this stage (ROMEIN *et al.*, 1996; MAI, 1999). Probably, the seawater of the Saratov part of the Russian Basin was colder than that in the Maastricht area as supported by foraminiferal and macrofossil data. We did not yet obtain arguments demonstrating that *Nephrolithus frequens* Górka appeared earlier in the Saratov Region than in lower and intermediate latitudes.

The invasion of relatively warm waters and the deepening of the basin during the latest Maastrichtian in the Saratov Region, as evidenced by the appearance of globotruncanids, *Racemiguembelina* and *Pseudotextularia* in Klyuchi 1 section, confirm the widespread terminal Maastrichtian "elegans-transgression" that was an even more obvious event in eastern Europe than in western Europe.

Acknowledgements

We greatly appreciated the technical assistance of Maxim S. Boiko and the help of Vitaly G. Ochev and Dmitry A. Kukhtinov from Saratov University during field work, of Raisa A. Voinova in processing of samples, of Alexey N. Reimers in SEM photography. We are very grateful to Etienne Steurbaut and Hedi Oberhänsli for having reviewed the manuscript and for having offered many useful comments and suggestions. We especially thank Annie Dhondt for editorial assistance. This study was supported by INTAS grant 94-1414 and "Universitety Rossii".

References

ALEKSEEV, A. S., GORBACHIK, T. N., SMIRNOVA, S. B. & BRAGIN, N. Yu., 1996. Age of the Paramonovo Formation (the Albian of the Russian Platform) and global transgressive-regressive cycles of the Cretaceous. *Stratigraphy and Geological Correlation*, **4**: 341-361.

ALEKSEEV, A. S., & KOPAEVICH, L. F., 1997. Foraminiferal biostratigraphy of the uppermost Campanian-Maastrichtian in SW Crimea (Bakhchisaray and Chakhmakhly sections). *Bulletin Institut Royal des Sciences Naturelles de Belgique. Sciences de la Terre*, **67**: 103-118.

AMON, E. O., 1990. Foraminifera and radiolarians. *In* G. N. PAPULOV, V. I. ZHELEZKO & A. P. LEVINA (eds.). Verkhnemelovye otlozheniya Yuzhnogo Zauraliya (raion verkhnego Protoboliya). Sverdlovsk, pp. 9-26. [In Russian].

ARKHANGELSKY, A. D., 1912. Upper Cretaceous of eastern European Russia. *Materialy dlya geologii Rossii*, **25**: 1-631. [in Russian].

ARKHANGELSKY, A. D. & DOBROV, S.A., 1913. Geological sketch of Saratov Governement. *Materialy po izucheniyu estestvennykh uslovii Saratovskoi Gubernii*, **1**: 1-256. [in Russian].

BARYSHNIKOVA, V.I., 1966. Distribution and microfaunal characteristics of the Belemnitella americana Zone in Saratov Povolzhie. *Voprosy Geologii Yuzhnogo Urala i Povolzhiya,* **3**, 2: 274-285. [in Russian].

BENIAMOVSKII, V. N. & KOPAEVICH, L. F., 1998. Benthic foraminiferal zonation in the Late Santonian-Maastrichtian of the European paleobiogeographical area (EPA). *Zentralblatt für Geologie und Paläontologie. Teil I*, **1996**, 11-12: 1149-1161.

BONDARENKO, N. A., 1975. On the oscillating movements of the Earth crust in northern part of Saratov Pravoberezhie during Late Cretaceous. *Voprosy stratigrafii i paleontologii*, **1**: 97-106. [in Russian].

DERVIZ, T. L., 1959. Volga-Ural oil-bearing region. Jurassic and Cretaceous. *Trudy Vsesoyuznogo neftyanogo nauchno-issledovatelskogo geologorazvedochnogo instituta*, **145**: 1-367. [in Russian].

DIGAS, L. A., 1976. New data on the Danian of Srednee Povolzhie territory. *Voprosy Geologii Yuzhnogo Urala i Povolzhiya*, **10**: 56-63. [in Russian].

EHRENBERG, C. G., 1854. Mikrogeologie. Das Erde und Felsen schaffende wirken des unsichtbar kleinen selbstandigen Leben auf der Erde. Vol. 1: 1-374; Vol. 2: 1-88 + atlas, Leipzig.

FLEROVA, O. V. & GUROVA, A. D., 1958. Upper Cretaceous of central region of Russian Platform. O. V. FLEROVA (ed.). Mezozoiskie i tretichnye otlozheniya centralnykh oblastey Russkoi Platformy. Gostoptekhizdat, Moscow, pp. 185-226. [in Russian].

GARTNER, S., 1996. Calcareous nannofossils at the Cretaceous-Tertiary boundary. *In:* N. MACLEOD & G. KELLER (eds.). Cretaceous-Tertiary mass extinctions: Biotic and environmental changes. W. W. Norton & Company, New York-London, pp. 27-47.

GAWOR-BIEDOWA, E., 1992. Campanian and Maastrichtian Foraminifera from the Lublin Upland, Eastern Poland. *Palaeontologia polonica*, **52**: 188 pp.

GERASIMOV, P. A., M , E. E., NAIDIN, D. P. & STERLIN, B. P., 1962. Jurassic and Cretaceous of Russian Platform. *Ocherki regionalnoi geologii SSSR*, **5:** 1-195. [in Russian].

GUTSAKI, V. A., MOROZOV, N. S., SHUMENKO, S. I., 1975. The experiment of multidisciplinary studies of Maastrichtian in upper stream of Sukhaya Kazanla River (Saratov Pravoberezhie). *Voprosy stratigrafii i paleontologii*, **1**: 80-96. [in Russian].

HUBER, B. T., 1990. Maestrichtian planktonic foraminifer biostratigraphy of the Maud Rise (Weddell Sea, Antarctica): ODP Leg 113 holes 689B and 690C. *Proceedings of the Ocean Drilling Program. Scientific Results*, **113**: 489-509.

HULTBERG, S. U. & MALMGREN, B. A., 1986. Dinoflagellate and planktonic foraminiferal paleobathymetrical indices in the Boreal uppermost Cretaceous. *Micropaleontology*, **32**: 316-323.

HULTBERG, S. U. & MALMGREN, B. A., 1987. Quantitative biostratigraphy based on late Maastrichtian dinoflagellates and planktonic Foraminifera from Southern Scandinavia. *Cretaceous Research*, **8**: 211-228.

KAMYSHEVA-ELPATIEVSKAYA, V. G., 1951. On the boundary of Upper Cretaceous and Paleogene in Lower Povolzhie. *Saratovskii Gosudarstvennyi Universitet. Uchenye zapiski. Vypusk geologicheskii*, **28**: 36-44. [in Russian].

KAMYSHEVA-ELPATIEVSKAYA, V. G. (ed.), 1967. Atlas of Mesozoic fauna and spore and pollen assemblages of Lower Povolzhie and adjacent areas. Saratov University Press, 1-257. [in Russian].

KOPAEVICH, L. F., BENIAMOVSKII, V. N. & NAIDIN, D. P., 1987. Lower and Upper Maastrichtian boundary in the European palaeobiogeographic province. *Byulleten Moskovskogo Obshestva Ispytatelei Prirody. Otdel Geologicheskii*, **62**, 5: 43-56. [in Russian].

KRASHENNINIKOV, V. A. & BASOV, I. A., 1985. Cretaceous stratigraphy of Southern Ocean. *Trudy Geologicheskogo Instituta Akademii nauk SSSR*, **394**: 1-174. [in Russian].

KURLAEV, V. I., BONDARENKO, N. A. & AKHLESTINA, E. F., 1981. On the Danian of Saratov Pravoberezhie. *Voprosy Geologii Yuzhnogo Urala i Povolzhiya*, **22**: 94-102. [in Russian].

LI, L. & KELLER, G., 1998. Abrupt deep-sea warming at the end of the Cretaceous. *Geology,* **26:** 995-998.

LONGORIA, J. F. & GAMPER, M. A., 1984. Subfamily Helvetiellinae, a new group of Late Cretaceous (Maastrichtian) planktonic foraminifera. *Micropaleontology*, **30:** 171 - 179.

MAI, H., 1999. Paleocene coccoliths and coccospheres in deposits of the Maastrichtian stage at the ''type locality'' and type area in SE Limburg, The Netherlands. *Marine Micropaleontology*, **36:** 1 - 12.

MALMGREN, B. A., 1982. Biostratigraphy of planktonic Foraminifera from the Maastrichtian white chalk of Sweden. *Geologiske Föreningens i Stockholm Förhandlingar*, **103**: 357-375.

MUSATOV, V. A., 1995. On the Danian Stage of the North Peri-Caspian and results of a study of calcareous nannoplankton. *In*: E. M. BUGROVA (Ed.), Predely tochonosti biostratigraphicheskikh korrelyatsii. *Trudy 36 sessii Vsesoyuznogo Paleontologicheskogo Obshchestva (yanvar 1990, Syktyvkar)*. Moscow, pp. 61-66. [in Russian].

MUSATOV, V. A. & ERMOKHINA, L. I., 1998. Stratotype of the Belogrodnya Beds. *Nedra Povolzhiya i Prikaspiya*, **15:** 35 -42 [in Russian].

NAIDIN, D. P., 1960. The stratigraphy of the Upper Cretaceous of the Russian Platform. *Stockholm Contributions in Geology*, **6**: 39-51.

NAIDIN, D. P., 1969. Biostratigraphie und Paläobiogeographie der Oberen Kreide der Russischen Tafel. *Geologisches Jahrbuch*, **87**: 157-186.

NAIDIN, D. P., 1973. On the relationship of palaeobiogeographic and palaeobiogeographic subdivisions of lowest rank. *Byulleten Moskovskogo Obshestva Ispytatelei Prirody. Otdel Geologicheskii*, **48**, 6: 50-63 [in Russian].

NAIDIN, D. P., 1974. Class Cephalopoda, Superordo Belemnitida. *In:* KRYMGOLZ, G. Ya. (ed.) Atlas of the Upper Cretaceous Donbass fauna. Moscow, "Nedra", pp. 197 - 240 [in Russian].

NAIDIN, D. P., 1975. Late Maastrichtian belemnitellas of Eurasia. *In:* SHIMANSKY, V. N. (ed.). Razvitie i smena organicheskogo mira na rubezhe mezozoya i kainozoya. Novoe o faune. Publishing House "Nauka", Moscow, pp. 91-108 [in Russian].

NAIDIN, D. P., 1995. Eustacy and epicontinental seas of the East European Platform. 2. Upper Cretaceous sequences. *Byulleten Moskovskogo Obshestva Ispytatelei Prirody. Otdel Geologicheskii*, **70**, 5: 49-65 [in Russian].

NEDERBRAGT, A. J., 1989. Maastrichtian *Heterohelicidae* (planktonic Foraminifera) from the North West Atlantic. *Journal of Micropaleontology*, **8**: 183-206.

NIKISHIN, A. M., ZIEGLER, P. A., STEPHENSON, R. A. & USTINOVA, M. A., 1999. Santonian to Palaeocene Tectonics of the East-European Craton and adjacent areas. *Bulletin Institut Royal des Sciences Naturelles de Belgique. Sciences de la Terre*, **69-supplement A**: 147-159.

PERCH-NIELSEN, K., 1985. Mesozoic calcareous nannofossils. H.M. BOLLI, J.B. SAUNDERS & K. PERCH-NIELSEN (ed.). Plankton Stratigraphy. Cambridge University Press, pp. 329-426.

POSPICHAL, J. J. & WISE Jr., S. W., 1990. Calcareous nannofossils across the K/T boundary, ODP Hole 690C, Maud Rise, Weddell Sea. *Proceedings of the Ocean Drilling Program. Scientific Results*, **113**: 515-532.

ROMEIN, A. J. T., WILLEMS, H. & MAI, H., 1996. Calcareous nannoplankton of the Geulhemmerberg K/T boundary section, Maastrichtian type area, the Netherlands. *Geologie en Mijnbouw*, **75**: 231-238.

SCHMITZ, B. & KELLER, O., 1992. Stable isotopic and foraminiferal changes across the Cretaceous-Tertiary boundary at Stevns Klint, Denmark; Arguments for long-term oceanic instability before and after bolide-impact event. *Palaeogeography, Palaeoclimatology, Palaeoecology*, **96**: 233-260.

SCHULZ, M.-G., 1978. Zur Litho-und Biostratigraphie des Obercampan-Untermaastricht von Lägerdorf und Kronsmoor (SW-Holstein). *Newsletters on Stratigraphy*, **7**: 73-89.

THIERSTEIN, H., ASARO , W. U., HUBER, B., MICHEL , H. & SCHMITZ, B., 1991. The Cretaceous/Tertiary boundary at Site 738, southern Kerguelen Plateau. *Proceedings of the Ocean Drilling Program. Scientific Results*, **119**: 849-861.

WICHER, C. A., 1953. Mikropaläontologische Beobachtungen in der höheren borealen Ober-Kreide, besonders im Maastricht. *Geologisches Jahrbuch*, **68**: 1-26.

WIDMARK, R. P., 1997. Benthic foraminiferal ecomarker species of the terminal Cretaceous (late Maastrichtian) deep-sea Tethys. *Marine Micropaleontology*, **31**: 135-155.

Alexander S. ALEKSEEV
Department of Palaeontology, Geological Faculty,
Moscow State University, Vorobiovy Gory,
119899 Moscow GSP, Russia
and
Palaeontological Institute, Russian Academy of Sciences,
Profsoyuznaya 123, 117647 Moscow, Russia
[aaleks@geol.msu.ru]

Lyudmila F. KOPAEVICH
Department of Historical and Regional Geology,
Geological Faculty,
Moscow State University, Vorobiovy Gory,
119899 Moscow GSP, Russia
[lkopaev@geol.msu.ru]

Mariya N. OVECHKINA
Department of Palaeontology, Geological Faculty,
Moscow State University, Vorobiovy Gory,
119899 Moscow GSP, Russia.

Alexander G. OLFERIEV
Geosintez, Varshavskoe Shosse 39a,
113105 Moscow, Russia.

Typescript submitted: 5.1.1999
Revised typescript received: 15.3.1999.

Explanations of Plates

Plate 1

Benthic Foraminifera from the north Saratov Region

Figure 1 — *Arenobulimina vialovi* Woloshyna; section Lokh 1, unit Lokh A, Lower Maastrichtian, sample LH1-7, PIN 4776/1 (X 75).
Figure 2 — *Spiroplectammina kelleri* Dain; section Lokh 1, unit Lokh A, Lower Maastrichtian, sample LH1-6, PIN 4776/2 (X 55).
Figure 3 — *Heterostomella foveolata* (Marsson); section Lokh 1, unit Lokh A, Lower Maastrichtian, sample LH1-19, PIN 4776/3 (X 100).
Figure 4 — *Bolivina decurrens* (Ehrenberg); section Lokh 1, unit Lokh A, Lower Maastrichtian, sample LH1-19, PIN 4776/4, (X 100).
Figure 5 — *Bolivina plaita* Carsey; section Lokh 1, unit Lokh B, Lower Maastrichtian, PIN 4776/5, sample LH1-34 (X 75).
Figure 6 — *Bolivina crassa* Vasilenko *in* Vasilenko & Myatliuk; section Klyuchi 1, unit Klyuchi C, Palaeocene, sample KL1-16a, PIN 4776/6 (X 55).
Figure 7 — *Dentalina basiplanata* Cushman; section Klyuchi 1, unit Klyuchi C, Palaeocene, sample KL1-2, PIN 4776/7 (X 30).
Figure 8 — *Neoflabellina reticulata* (Reuss); section Lokh 1, unit Lokh B, Lower Maastrichtian, sample LH1-34, PIN 4776/8 (X 100).
Figure 9 — *Nonionella communis* (d'Orbigny); section Klyuchi 1, unit Klyuchi C, Palaeocene, sample KL1-10, PIN 4776/9 (X 120).
Figure 10 — *Pullenia jarvisi* Cushman; section Klyuchi 1, unit Klyuchi C, Palaeocene, sample KL1-6, PIN 4776/10 (X 100).
Figure 11 — *Stilostomella* sp. ; section Lokh 1, unit Lokh A, Lower Maastrichtian, sample LH1-7, PIN 4776/11 (X 100).
Figure 12 — *Pseudouvigerina rugosa* (Brotzen); section Lokh 1, unit Lokh A, Lower Maastrichtian, sample LH1-7, PIN 4776/12 (X 150).
Figure 13 — *Bolivinoides draco draco* (Marsson); section Klyuchi 1, unit Klyuchi B, Upper Maastrichtian, sample KL1-20, PIN 4776/13 (X 130).
Figure 14 — *Bolivinoides draco miliaris* Hiltermann & Koch; section Lokh 1, unit Lokh A, Lower Maastrichtian, sample LH1-19, PIN 4776/14 (X 120).
Figure 15 — *Gyromorphina allomorphinoides* (Reuss); section Lokh 1, unit Lokh A, Lower Maastrichtian, sample LH1-6, PIN 4776/15 (X 75).
Figure 16 — *Globulina lacrima* (Reuss); section Lokh 1, unit Lokh A, Lower Maastrichtian, sample LH1-7, PIN 4776/16 (X 100).
Figure 17 — *Guttulina communis* d'Orbigny; section Klyuchi 1, unit Klyuchi C, Palaeocene, sample KL1-6, PIN 4776/17 (X 100).
Figure 18 — *Cribrebella fusiformis* (Gawor-Biedowa); section Lokh 1, unit Lokh A, Lower Maastrichtian, sample LH1-6, PIN 4776/18 (X 100).
Figure 19 — *Gyroidinoides globosus* (von Hagenow); section Lokh 1, unit Lokh A, Lower Maastrichtian, sample LH1-7, PIN 4776/19 (X 130).
Figure 20 — *Cibicides succedens* Brotzen; section Klyuchi 1, unit Klyuchi C, Palaeocene, sample KL1-6, PIN 4776/20 (X 120).
Figure 21 — *Cibicidoides aktulagayensis* Vasilenko; section Lokh 1, unit Lokh A, Lower Maastrichtian, sample LH1-7, PIN 4776/21 (X 100).
Figure 22 — *Cibicidoides commatus* Vasilenko; section Lokh 1, unit Lokh A, Lower Maastrichtian, sample LH1-19, PIN 4776/22 (X 120).
Figure 23 — *Stensioeina pommerana* Brotzen; section Lokh 1, unit Lokh A, Lower Maastrichtian, sample LH1-7, PIN 4776/23 (X 130).
Figure 24 — *Brotzenella taylorensis* (Carsey); section Klyuchi 1, unit Klyuchi B, Upper Maastrichtian, sample KL1-20, PIN 4776/24 (X 100).
Figure 25 — *Hanzawaia ekblomi* (Brotzen); section Klyuchi 1, unit Klyuchi B, Upper Maastrichtian, sample KL1-20, PIN 4776/25 (X 120).

Plate 2

Planktonic Foraminifera from the north Saratov Region

Figure 1 — *Heterohelix globulosa* (Ehrenberg); section Lokh 1, unit Lokh B, Lower Maastrichtian, sample LH1-34, PIN 4776/26 (X 170).
Figure 2 — *Heterohelix globulosa* (Ehrenberg); section Lokh 1, unit Lokh B, Lower Maastrichtian, sample LH1-34, PIN 4776/27 (X 150).

Figure 3 — *Pseudotextularia deformis* (Kikoine); section Klyuchi 1, unit Klyuchi B, Upper Maastrichtian, sample KL1-20, PIN 4776/28 (X 100).
Figure 4 — *Pseudotextularia deformis* (Kikoine); section Klyuchi 1, unit Klyuchi B, Upper Maastrichtian, sample KL1-20, PIN 4776/29 (X 100).
Figure 5 — *Planoglobulina brazoensis* Martin; section Klyuchi 1, unit Klyuchi B, Upper Maastrichtian, sample KL1-20, PIN 4776/30 (X 100).
Figure 6 — *Globigerinelloides volutus* (White); section Lokh 1, unit Lokh A, Lower Maastrichtian, sample LH1-7, PIN 4776/31 (X 200).
Figure 7 — *Globigerinelloides volutus* (White); section Klyuchi 1, unit Klyuchi B, Upper Maastrichtian, sample KL1-20, PIN 4776/32 (X 180).
Figure 8 — *Globigerinelloides volutus* (White); section Klyuchi 1, unit Klyuchi B, Upper Maastrichtian, sample KL1-20, PIN 4776/33 (X 130).
Figure 9 — *Archaeoglobigerina australis* Huber; section Lokh 1, unit Lokh A, Lower Maastrichtian, sample LH1-7, PIN 4776/34, (X 130).
Figure 10 — *Archaeoglobigerina australis* Huber; section Lokh 1, unit Lokh A, Lower Maastrichtian, sample LH1-7, PIN 4776/35, (X 130).
Figure 11 — *Archaeoglobigerina australis* Huber; section Lokh 1, unit Lokh A, Lower Maastrichtian, sample LH1-7, PIN 4776/36, (X 100).
Figure 12 — *Rugoglobigerina rugosa* (Plummer); section Lokh 1, unit Lokh A, Lower Maastrichtian, sample LH1-7, PIN 4776/37, (X 160).
Figure 13 — *Rugoglobigerina rugosa* (Plummer); section Lokh 1, unit Lokh A, Lower Maastrichtian, sample LH1-7, PIN 4776/38 (X 130).
Figure 14 — *Rugoglobigerina rugosa* (Plummer); section Lokh 1, unit Lokh A, Lower Maastrichtian, sample LH1-7, PIN 4776/39 (X 160).
Figure 15 — *Rugoglobigerina rugosa* (Plummer); section Lokh 1, unit Lokh A, Lower Maastrichtian, sample LH1-7, PIN 4776/40 (X 150).
Figure 16 — *Globotruncanella havanensis* (Voorwijk); section Lokh 1, unit Lokh B, Lower Maastrichtian, sample LH1-34, PIN 4776/41 (X 130).
Figure 17 — *Globotruncanella havanensis* (Voorwijk); section Klyuchi 1, unit Klyuchi B, Upper Maastrichtian, sample KL1-20, PIN 4776/42 (X 120).
Figure 18 — *Globotruncanella petaloidea* (Gandolfi); section Lokh 1, unit Lokh A, Lower Maastrichtian, sample LH1-10, PIN 4776/43 (X 130).
Figure 19 — *Globotruncana arca* (Cushman); section Lokh 1, unit Lokh B, Lower Maastrichtian, sample LH1-34, PIN 4776/44 (X 100).
Figure 20 — *Globotruncana arca* (Cushman); section Klyuchi 1, unit Klyuchi B, Upper Maastrichtian, sample KL1-20, PIN 4776/45 (X 120).
Figure 21 — *Globotruncana mariei* Banner & Blow; section Klyuchi 1, unit Klyuchi B, Upper Maastrichtian, sample KL1-20, PIN 4776/46 (X 130).

Plate 3

Calcareous nannofossils from the Maastrichtian of the north Saratov region

Figure 1 — *Cribrosphaerella ehrenbergii* (Arkhangelsky) Deflandre *in* Piveteau; section Tyoplovka 2, unit Tyoplovka A, Upper Maastrichtian, sample TP2-28 (X 5000).
Figure 2 — *Cribrosphaerella daniae* Perch-Nielsen; section Tyoplovka 2, unit Tyoplovka A, Upper Maastrichtian, sample TP2-28 (X 4400).
Figure 3 — *Micula decussata* Vekshina, partially dissolved; section Tyoplovka 2, unit Tyoplovka A, Upper Maastrichtian, sample TP2-28, (X 5000).
Figure 4 — *Arkhangelskiella cymbiformis* Vekshina; section Klyuchi 1, unit Klyuchi B, Upper Maastrichtian, sample KL1-43 (X 6300).
Figure 5 — *Prediscosphaera stoveri* (Perch-Nielsen) Shafik & Stradner; section Tyoplovka 2, unit Tyoplovka A, Upper Maastrichtian, sample TP2-18 (X 7500).
Figure 6 — *Corollithion exiguum* Stradner; section Tyoplovka 2, unit Tyoplovka A, Upper Maastrichtian, sample TP2-28 (X 6300).
Figure 7 — *Kamptnerius magnificus* Deflandre; section Tyoplovka 2, unit Tyoplovka A, Upper Maastrichtian, sample TP2-18 (X 6300).
Figure 8 — *Stradneria crenulata* (Bramlette & Martini) Noël; section Tyoplovka 3, unit Tyoplovka A, Upper Maastrichtian,

sample TP3-18 (X 6300).

Figure 9 — *Micula concava* (Stradner *in* Martini & Stradner) Verbeek, partially dissolved; section Lokh 1, unit Lokh C, Upper Maastrichtian, sample LH1-53 (X 5000).

Figure 10 — *Lithraphidites grossopectinatus* Bukry; section Tyoplovka 3, unit Tyoplovka A, Upper Maastrichtian, sample TP3-18 (X 6300).

Figure 11 — *Nephrolithus frequens* Górka; section Tyoplovka 2, unit Tyoplovka A, Upper Maastrichtian, sample TP2-28 (X 6000).

Figure 12 — *Rhombolithion speetonensis* Rood & Barnard; section Tyoplovka 2, unit Tyoplovka A, Upper Maastrichtian, sample TP2-18 (X 6300).

Figure 13 — *Aspidolithus* sp. aff. *A. parcus constrictus* (Hattner *et al.*) Perch-Nielsen; section Klyuchi 2, unit Klyuchi A, Lower Maastrichtian, sample KL2-3 (X 5400).

Figure 14 — *Vekshinella angusta* (Stover) Verbeek; section Klyuchi 2, unit Klyuchi B, Upper Maastrichtian, sample KL2-16 (X 6300).

Figure 15 — *Lithraphidites quadratus* Bramlette & Martini; section Tyoplovka 3, unit Tyoplovka A, Upper Maastrichtian, sample TP3-18 (X 6300)

Plate 4

Macrofossils from the Maastrichtian of the north Saratov Region

Figure 1 — *Belemnella lanceolata gracilis* (Arkhangelsky); a - ventral side, b - dorsal side; section Lokh 1, unit Lokh A, Lower Maastrichtian, sample LH1-9, PIN 4775/1 (X 1).

Figure 2 — *Belemnella sumensis praearkhangelskii* Naidin; a - ventral side; b - dorsal side; section Klyuchi 2, condensed clay bed of unit Klyuchi Bb, upper Lower and lower Upper Maastrichtian, sample KL 2, PIN 4775/2 (X 1).

Figure 3 — *Belemnella sumensis praearkhangelskii* Naidin; section Klyuchi 2, condensed clay bed of unit Klyuchi Bb, upper Lower and lower Upper Maastrichtian, sample KL 2, view of split guard showing internal characteristics, PIN 4775/3 (X 1).

Figure 4 — *Neobelemnella kazimiroviensis* (Skolozdrowna); a - ventral side; b - dorsal side; section Klyuchi 1, unit Klyuchi 2, Upper Maastrichtian, sample KL 1, PIN 4775/4 (X 1).

Figure 5 — *Neobelemnella kazimiroviensis* (Skolozdrowna); a - ventral side (X 1), b - lateral side (X 1), c - view of split guard showing internal characteristics (X 2); section Klyuchi 1, unit Klyuchi B, Upper Maastrichtian, sample KL 1, PIN 4775/5 (X 1).

Figure 6 — *Neobelemnella kazimiroviensis* (Skolozdrowna); view of split guard showing internal characteristics; section Klyuchi 1, unit Kluychi B, Upper Maastrichtian, sample KL 1, PIN 4775/6 (X 1).

Figure 7 — *Hoploscaphites* aff. *H. constrictus* (J. Sowerby); a - lateral side, b - dorsal side; section Lokh 1, base of unit Lokh B, Lower Maastrichtian, sample LH1-34, PIN 4775/7 (X 1).

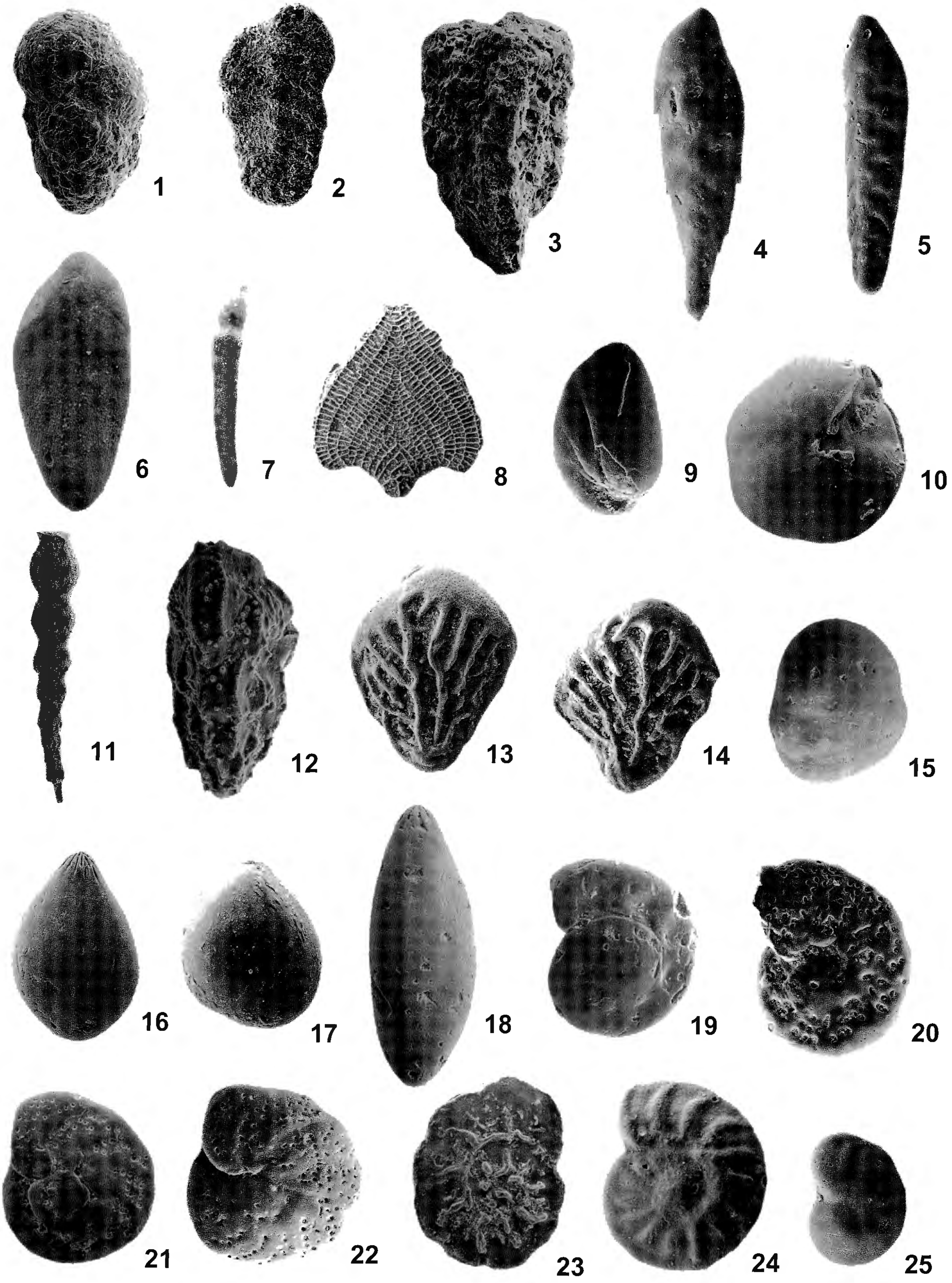


PLATE 1

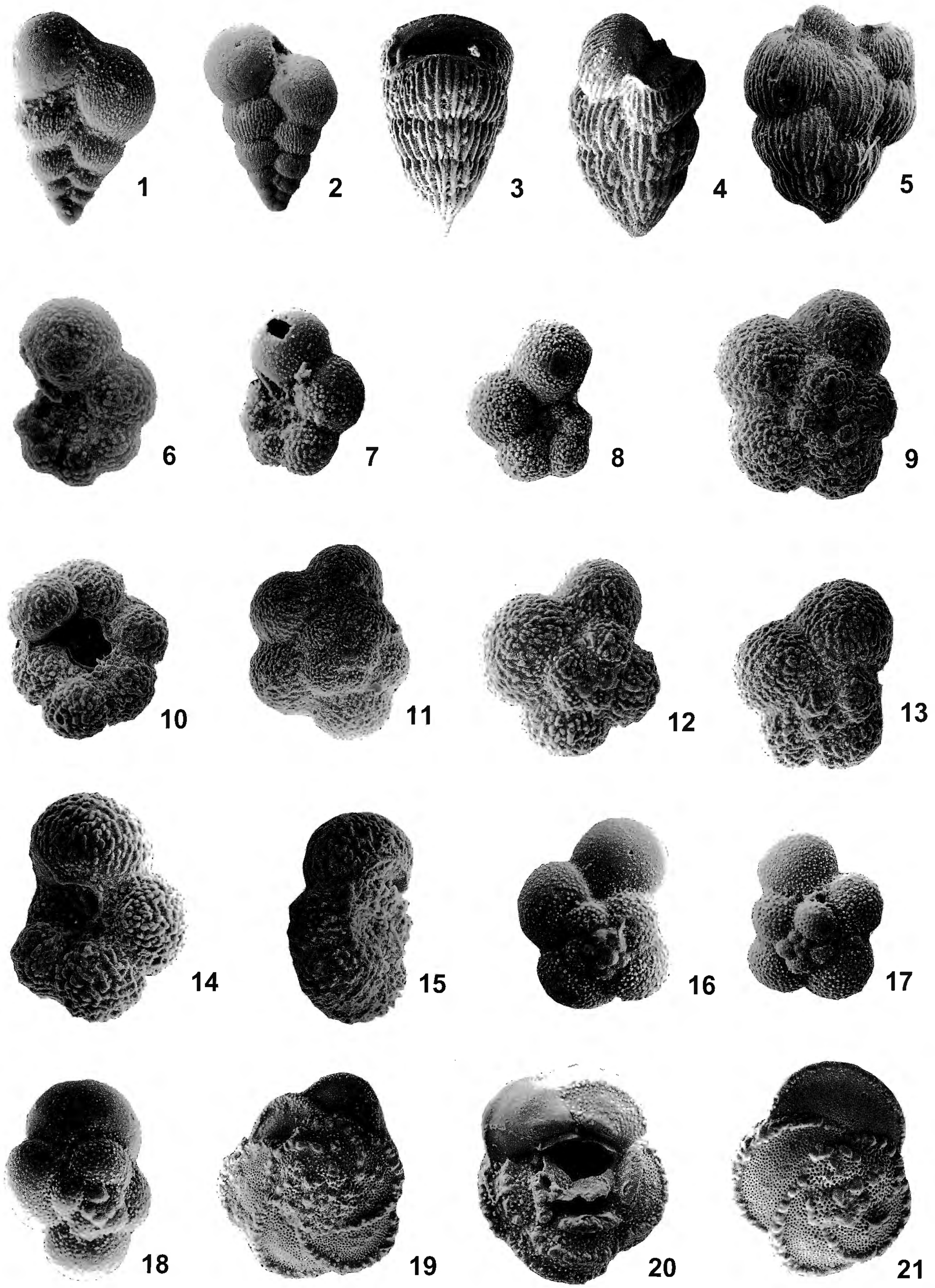


PLATE 2

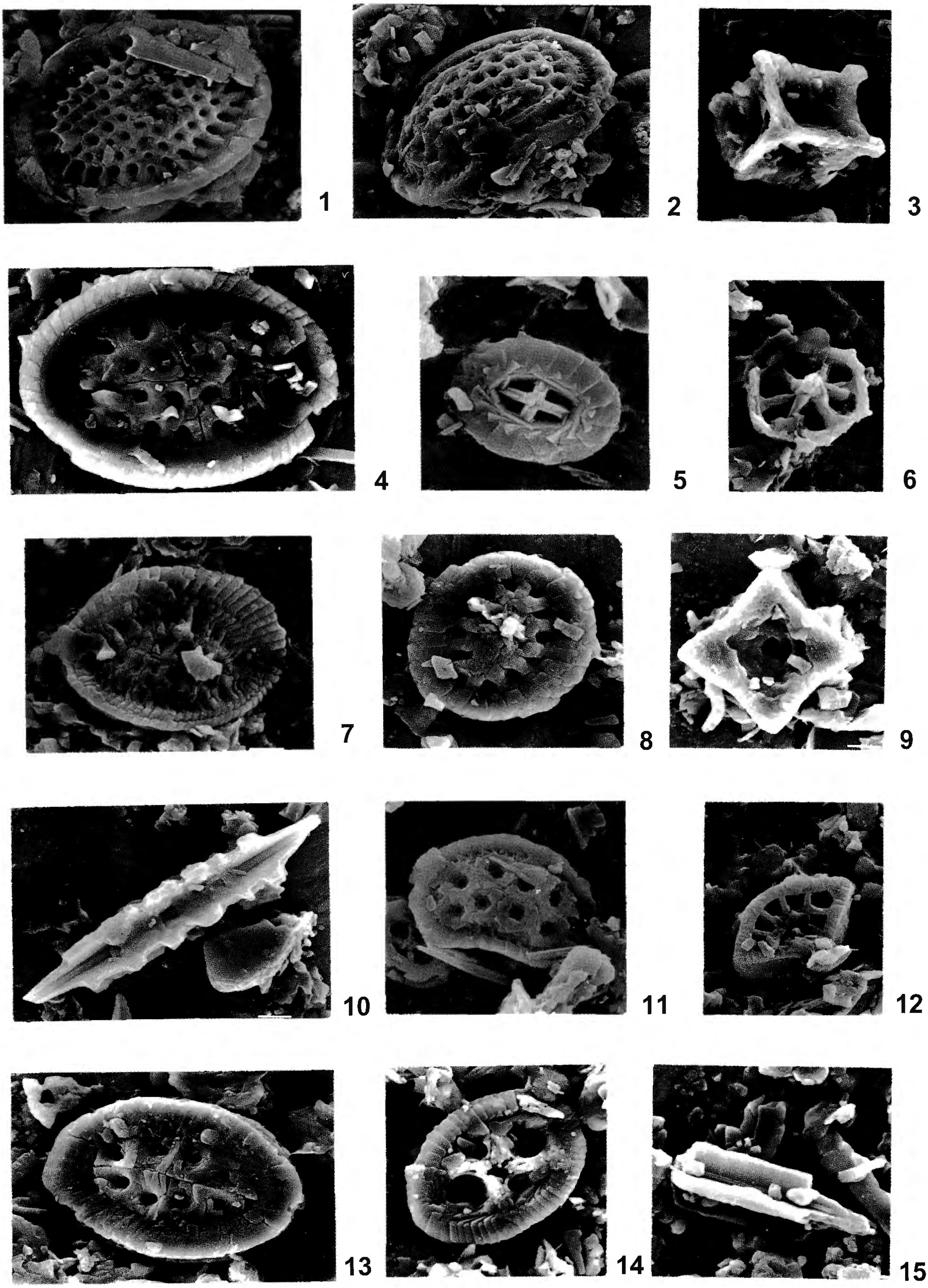


PLATE 3

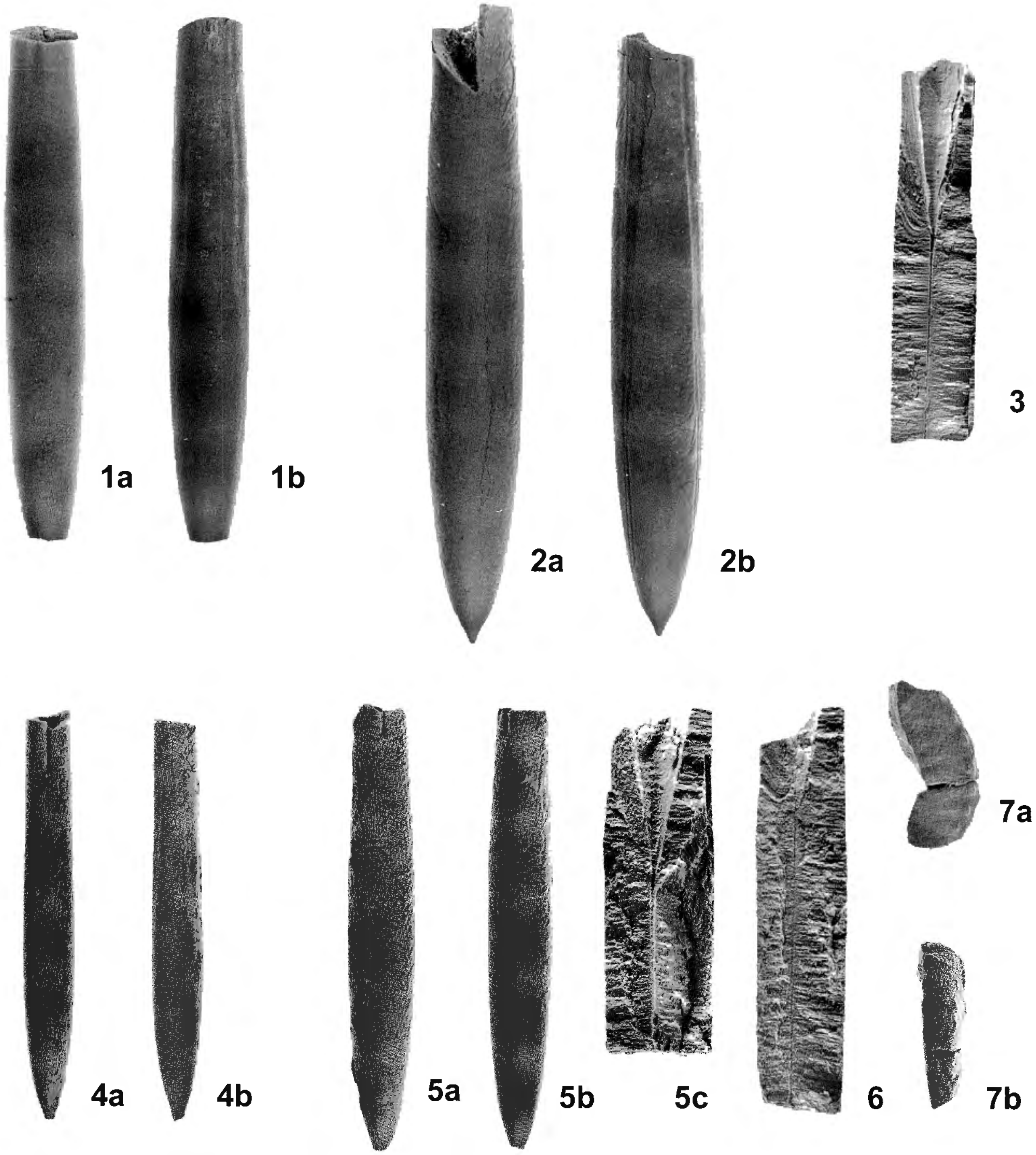


PLATE 4