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Micropalaeontological and palynological analyses across the Jurassic-Cretaceous boundary on Nordvik Peninsula, Northeast Siberia

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with 8 figures and 5 plates

Abstract. Results are presented of a high-resolution study of foraminifers, ostracods and marine palynomorphs from the continuous succession of Middle Volgian – Lower Valanginian (Upper Jurassic to Lower Cretaceous) deposits of the Nordvik section (NE Siberia). Six foraminiferal and six dinoflagellate cyst (dinocyst) zones and subzones have been identified. Volgian foraminiferal assemblages (*Dorothia tortuosa* JF51 zone and *Ammodiscus veteranus*, *Evolutinella emeljanzevi* JF52 zone) may be regarded as correlative markers for Arctic regions as they are also observed in Barents Sea shelf sediments and different regions of Siberia. Marine palynomorph assemblages provide a reliable correlation with northern areas of Western Europe and Canada at three stratigraphic levels: (a) the base of the Upper Volgian, (b) the middle of the Berriasian and (c) the lowermost Valanginian. The stratigraphic position of foraminiferal and dinocyst zones has been analyzed taking into consideration two alternative horizons for the Jurassic-Cretaceous boundary (A – base of the Upper Volgian, B – base of the Boreal Berriasian). Remarkable changes in foraminiferal assemblages and the first occurences of stratigraphically important taxa occur at the base of the *Gaudryina gerkei*, *Ammobaculites gerkei* KF 1 zone, slightly higher than horizon B. The base of the *Ammodiscus veteranus*, *Evolutinella emeljanzevi* JF52 zone (slightly below horizon A) is marked by a significant turnover of the characteristic species and dominant taxa. The strongest changes in dinocyst assemblages occur near the base of the *Paragonyaulacysta* ?*borealis*, *Dingodinium* ?*spinosum* zone (horizon A). The analysis of published macrofauna data and new microfossil information indicates palaeoenvironments ranging from the middle sublittoral to the lower sublittoral.

Résumé. Une étude à haute résolution des foraminifères, des ostracods et du microphytoplancton de la séquence continue du Volgien Moyen – Valanginien Inférieur a été réalisée sur la section typique de la Péninsule Nordvik. Six zones et subzones de cystes de dinoflagellés (dinocystes) et de foraminifères ont été identifiées sur la base de l'analyse stratigraphique détaillée. Suivis sur le shelf de la mer de Barents et dans les différentes régions de la Sibérie, des assemblages volgiens de foraminifères (Zones à *Dorothia tortuosa* et à *Ammodiscus veteranus*, *Evolutinella emeljanzevi*) peuvent être considérées maintenant comme des marqueurs corrélatifs pour les régions Arctiques. Les assemblages du marine palynomorphs permettent d'établir des corrélations fiables avec des régions de

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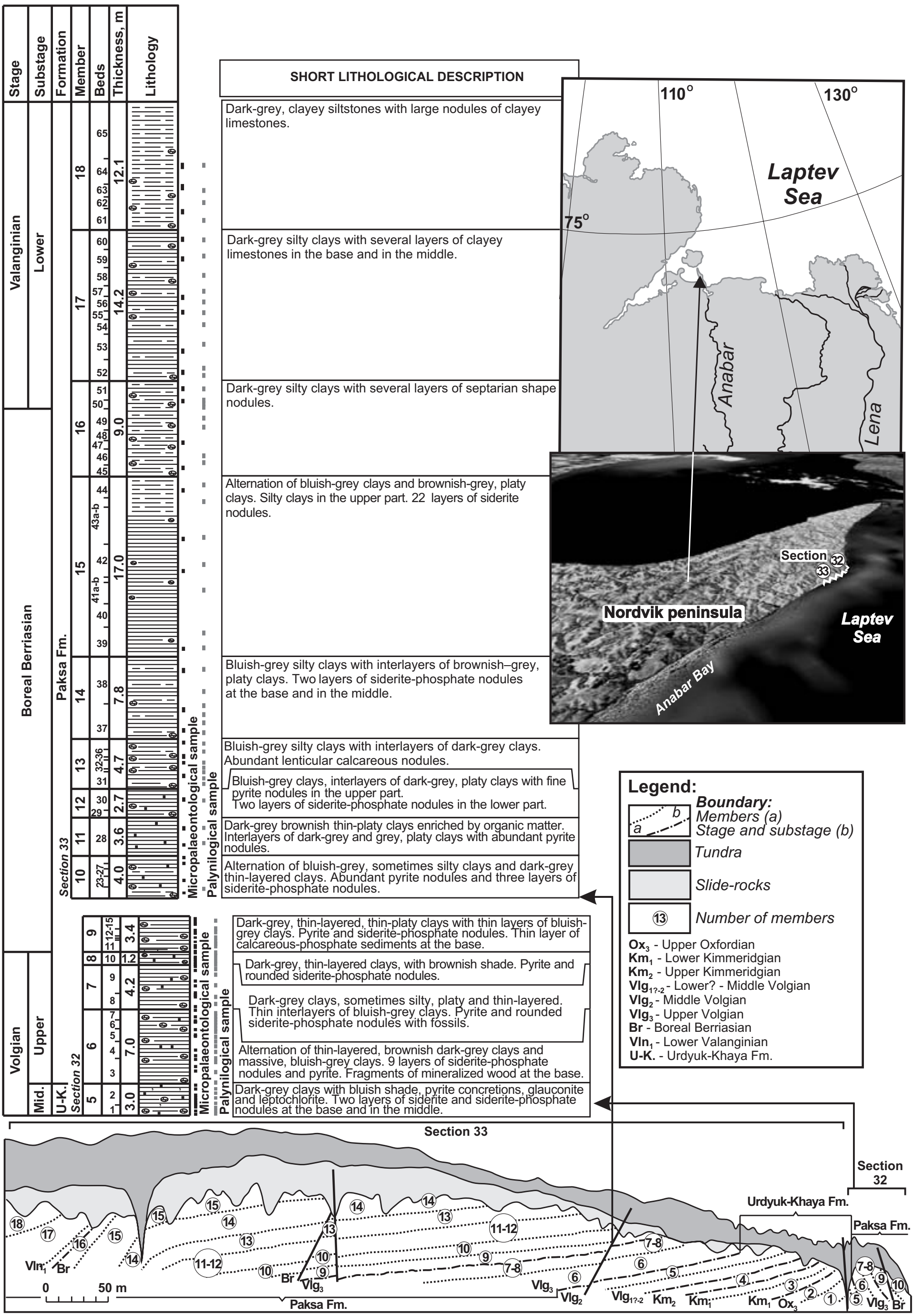

Stage
Substage
Formation
Member
Beds
Thickness, m
Lithology
Valanginian
Lower
Boreal Berriasian
Volgian
Upper
Mid.
Paksa Fm.
U-K.
Section 33
Section 32
Micropalaeontological sample
Palynilogical sample
SHORT LITHOLOGICAL DESCRIPTION
Dark-grey, clayey siltstones with large nodules of clayey limestones.
Dark-grey silty clays with several layers of clayey limestones in the base and in the middle.
Dark-grey silty clays with several layers of septarian shape nodules.
Alternation of bluish-grey clays and brownish-grey, platy clays. Silty clays in the upper part. 22 layers of siderite nodules.
Bluish-grey silty clays with interlayers of brownish–grey, platy clays. Two layers of siderite-phosphate nodules at the base and in the middle.
Bluish-grey silty clays with interlayers of dark-grey clays. Abundant lenticular calcareous nodules.
Bluish-grey clays, interlayers of dark-grey, platy clays with fine pyrite nodules in the upper part.
Two layers of siderite-phosphate nodules in the lower part.
Dark-grey brownish thin-platy clays enriched by organic matter. Interlayers of dark-grey and grey, platy clays with abundant pyrite nodules.
Alternation of bluish-grey, sometimes silty clays and dark-grey thin-layered clays. Abundant pyrite nodules and three layers of siderite-phosphate nodules.
Dark-grey, thin-layered, thin-platy clays with thin layers of bluish-grey clays. Pyrite and siderite-phosphate nodules. Thin layer of calcareous-phosphate sediments at the base.
Dark-grey, thin-layered clays, with brownish shade. Pyrite and rounded siderite-phosphate nodules.
Dark-grey clays, sometimes silty, platy and thin-layered. Thin interlayers of bluish-grey clays. Pyrite and rounded siderite-phosphate nodules with fossils.
Alternation of thin-layered, brownish dark-grey clays and massive, bluish-grey clays. 9 layers of siderite-phosphate nodules and pyrite. Fragments of mineralized wood at the base.
Dark-grey clays with bluish shade, pyrite concretions, glauconite and leptochlorite. Two layers of siderite and siderite-phosphate nodules at the base and in the middle.
110°
130°
75°
Laptev Sea
Anabar
Lena
Section 32 33
Nordvik peninsula
Laptev Sea
Anabar Bay
Legend:
Boundary:
Members (a)
Stage and substage (b)
Tundra
Slide-rocks
Number of members
Ox3 - Upper Oxfordian
Km1 - Lower Kimmeridgian
Km2 - Upper Kimmeridgian
Vlg1?-2 - Lower? - Middle Volgian
Vlg2 - Middle Volgian
Vlg3 - Upper Volgian
Br - Boreal Berriasian
Vln1 - Lower Valanginian
U-K. - Urdyuk-Khaya Fm.
Section 33
Section 32
Urdyuk-Khaya Fm.
Paksa Fm.
0 50 m

l'Europe nord-occidentale et du Canada à trois niveaux stratigraphiques: (a) à la base du Volgien Supérieur; (b) au milieu du Berriasien et, (c) au début du Valanginien Inférieur. La position stratigraphique des zones de foraminifères et de dinocystes a été analysée en tenant compte de deux positions alternatives de la limite Jurassique-Crétacé: A – à la base du Volgien Superieur, B – à la base du Berriasien Boréal. Ainsi, des changements significatifs dans les assemblages de foraminifères et des apparitions de taxons stratigraphiquement importants ont été révélés à la base des Zones à *Gaudryina gerkei*, *Ammobaculites gerkei* légèrement plus haut de la Position B. La base de la Zone à *Ammodiscus veteranus*, *Evolutinella emeljanzevi* (légèrement plus bas de la Position A) a été reconnue par le changement significatif taxinomique des foraminifères. Les changements les plus considérables dans les assemblages de dinocystes ont été observés près de la base de la Zone à *Paragonyaulacysta ?borealis*, *Dingodinium ?spinosum* (Position A). A la base de données publiées sur la macrofaune et nos nouvelles données de l'étude des microfossiles, une analyse des facies a été réalisée, indiquant l'existence des zones sublittorales moyennes à sublittorales inférieures pendant le Volgien Moyen-Valanginien Récent.

Introduction

The outcrops on Nordvik Peninsula (NW Siberia) are included in the Boreal Zonal Standard (Zakharov et al. 1997) as a type section of Jurassic-Cretaceous boundary deposits of Boreal regions (Fig. 1). This is due to comprehensive palaeontological and lithological investigations of the section that allow its reliable biostratigraphic and sedimentological subdivision as well as bivalve-based palaeoenvironmental reconstructions (Saks et al. 1958; Saks et al. 1963; Basov et al. 1970; Saks 1972; Kaplan & Yudovny 1973; Kaplan et al. 1973; Zakharov & Yudovny 1974; Golbert 1981; Zakharov et al. 1983; Bogomolov 1989; Basov 1991). The foraminiferal assemblages were described for a number of stages, substages and ammonite zones (Basov et al. 1970; Basov & Ivanova 1972; Saks 1976; Grigelis 1982). A first biostratigraphic subdivision based on dinocysts was proposed by Ilyina (1985, 1988) for the Upper Jurassic and the lower part of the Berriasian. The necessity of micropalaeontological and palynological evaluations of the Nordvik succession is defined by a) new stratigraphic and palaeoevironmental data based on Siberian foraminifers and dinocysts (Lebedeva & Pestchevitskaya 1996; Zakharov et al. 1996; Lebedeva & Nikitenko 1998, 1999; Riding et al. 1999; Shurygin et al. 2000; Pestchevitskaya 2000, 2005), and b) open issues on the Jurassic-Cretaceous boundary in Boreal regions (Saks 1972; Jeletzky 1984; Remane 1986, 1990; Zeiss 1986; Zakharov 1987, 2003; Hoedemaeker 1990; Rawson 1990; Zakharov et al. 1997; Sey & Kalahceva 1997, 1999).

In the present paper, the two most common views on the position of the Jurassic-Cretaceous boundary are considered (Fig. 2, versions A and B). According to version B, the Jurassic-Cretaceous boundary should be established at the base of the *Chetaites sibiricus* ammonite zone calibrated against the *Riasanites-Garniericeras* ammonite zone of the Russian Platform and the *Berriasella jacobi* ammonite zone of the Standard Stratigraphic

Fig. 1. Location map of the Upper Jurassic – Neocomian reference section on Nordvik Peninsula (Eastern North Siberia); lithostratigraphy based on Basov et al. 1970, geological profile (sections 32 and 33) based on Saks 1972 with modifications.

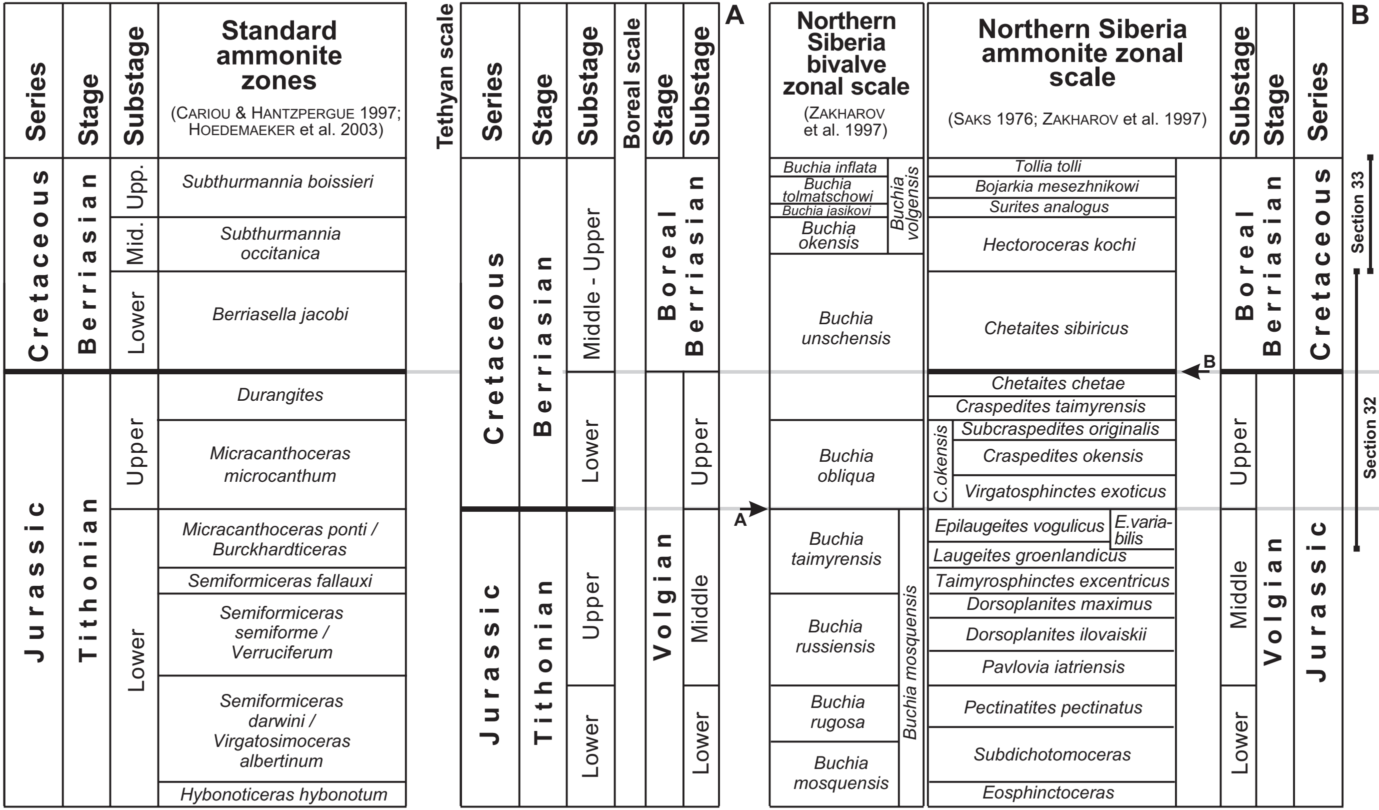


Fig. 2. Stratigraphic position of the Jurassic-Cretaceous boundary in the Boreal regions according to the different authors: location B of J/K boundary (SAKS et al. 1963; KRYMHOLTS 1982; SHULGINA 1984; ZAKHAROV 1987; KRYMHOLTS et al. 1988; ZAKHAROV et al. 1997), location A of J/K boundary (SEY & KALACHEVA 1997, 1999).

Scale (SAKS et al. 1963; KRYMHOLTS 1982; SHULGINA 1984; ZAKHAROV 1987; KRYMHOLTS et al. 1988; ZAKHAROV et al. 1997). It is based on the stratigraphic range of ammonites and *Buchia* in Boreal and Tethyan realms, with special attention being given to taxa that occur in both realms. Version A is based on the simultaneous presence of Boreal *Buchia* (*Buchia okensis* zone) and Tethyan ammonites typical for the Upper Berriasian (*Subthurmannia boissieri* Zone) in the transitional sections situated in the southern Far East of Russia as well as on the patterns of ammonite migrations (SEY & KALAHCEVA 1997, 1999). Therefore the Boreal *Hectoroceras kochi* ammonite zone (stratigraphically corresponding to the *Buchia okensis* zone) is correlated with the lower part of the terminal Berriasian zone (*Subthurmannia boissieri*) of the Standard Stratigraphic Scale. Thus, the Jurassic-Cretaceous boundary is established at the base of the *Craspedites okensis* ammonite zone calibrated against the *Berriasella jacobi* ammonite zone of the Standard Stratigraphic Scale (SEY & KALAHCEVA 1997, 1999).

In the present paper, a joint microfossil study (foraminifers, ostracods and marine palynomorphs) of the Nordvik succession is carried out for the first time. Previous macrofauna investigations provide a reliable correlation of foraminiferal and dinocyst zones against ammonite and *Buchia* zones of the Boreal Zonal Standard (ZAKHAROV et al. 1997).

Material and methods

The studied outcrops are situated on the eastern coast of Nordvik Peninsula (NW Siberia; 73°51′ N, 113°11′ E) near the Urduyk-Khaya Cape (Fig. 1). The Upper Jurassic – Lower Cretaceous sediments are represented by the Paksa Formation, which comprises grey clays and silts deposited in the central part of the palaeobasin. There are no stratigraphic gaps across the Jurassic-Cretaceous boundary. The almost continuous succession of Oxfordian-Valanginian sediments is characterized by diverse macrofauna (ammonites, belemnites and bivalves), foraminifers and palynofloras.

The sediments were analyzed by micropalaeontological and palynological methods. For micropalaeontological analyses, 79 samples of 100–200 g were disintegrated by boiling and then decanted onto a sieve with a 56 μm mesh. If the sample weighted less than 200 g, the counted numbers of foraminifers and ostracods were recalculated on 200 g weight. The relations between young and mature forms as well as between well and poorly preserved specimens were taken into consideration. The abundance of each taxon was defined using a semiquantitative scale: very rare (1–2 specimens), rare (3–5 specimens), often (6–10 specimens), common (11–15 specimens), frequent (first tens of specimens), abundant (some tens of specimens), very abundant (hundreds of specimens) (SAKS 1969). As the basis for a biostratigraphic subdivision, a combined set of foraminiferal zones was used: 1) concurrent-range zones, 2) ecological zones and 3) a set of parallel phylozones. The lower boundaries of foraminiferal zones were defined by the first occurrences of new assemblages and important taxa as well as by acmes of characteristic taxa. For palaeoecological and biofacies reconstructions, the structure of microfauna communities, relative abundance of the taxa on generic and species level and the dynamics of taxonomic diversity were analyzed. Published data on the taphonomy of bivalve communities were also considered (BASOV et al. 1970; ZAKHAROV et al. 1983).

Eighty-four samples were prepared using palynological techniques, including the treatment with nitric acid and natrium pyrophosphate (Wood et al. 1996). Organic and mineral fractions were separated through centrifugation in heavy cadmium liquid (specific gravity: 2.25). All samples yielded rich, well-preserved assemblages of marine palynomorphs, including diverse dinocysts, prasinophytes and acritarchs. At least 200 specimens were counted per sample to establish taxon abundances. The palynological zonation is mostly based on the first and last occurrences of stratigraphically important taxa. The stratigraphic potential of dinocyst taxa for Siberia was previously estimated on the basis of comparative analysis of dinocyst assemblages from Siberia, the Russian Platform, Western Europe, Canada and Greenland (Lebedeva & Nikitenko 1998, 1999; Riding et al. 1999; Pestchevitskaya 2005, 2006).

Dinocyst classification followed Fensome et al. (1993). For the palaeoenvironmental analysis, the relative percentage and diversity of taxonomic and morphological groups were studied using existing concepts on dinoflagellate ecology (Lebedeva & Nikitenko 1998, 1999; Wilpshaar & Leerveld 1994; Pross & Brinkhuis 2005; Sluijs et al. 2005). Taxonomic dinocyst groups include: families – Pareodiniaceae, Gonyaulacaceae, Areoligeraceae, and Peridiniaceae, subfamilies – Broomeoideae, Pareodinioideae, Leptodinioideae, Cribroperidinioideae, Gonyaulacoideae. Morphological dinocyst groups are proximate, proximochorate, chorate, membranate, holocavate, cavate (with well-developed pericoel) dinocysts and forms with simple morphology ("simple" group; *Kallosphaeridium*, *Membranosphaera*, *Escharisphaeridia*, *Chytroeisphaeridia*, *Batiacasphaera*, *Fromea*). Among prasinophytes, the *Leiosphaeridia* group was investigated separately as it apparently has special ecological requirements.

Foraminiferal zonation

Dorothia tortuosa JF51 zone

Characteristic assemblage: Important species: *Dorothia tortuosa* (Pl. 2, figs. 3, 6), *Saracenaria eloguica*, *Saracenaria pravoslavlevi*, *Nodosaria incomes*, *Cribrostomoides* ex gr. *kellogensis*, *Ceratobulimina prudens* (Pl. 2, figs. 1, 11), *Lenticulina rostriformis*, *Grigelis* sp., *Spiroplectammina vicinalis*, *Marginulinopsis embaensis* (Fig. 3). The assemblage is characterized by a high quantity of *Dorothia tortuosa* (up to 41 %), numerous *Cribrostomoides* (14 %), *Recurvoides* (11 %), and diverse *Vaginulinidae* (up to 18 %). Other taxa are common, but less abundant (Fig. 4).
Base: Not recovered.
Type section: Outcrop 32; bed 1, lower part of bed 2, represented by dark grey clays with glauconite and leptochlorite; thickness is 2.14 m.
Stratigraphic position: Lower part of *Epivirgatites variabilis* ammonite zone, Middle Volgian.

Ammodiscus veteranus, *Evolutinella emeljanzevi* JF52 zone Hinweis

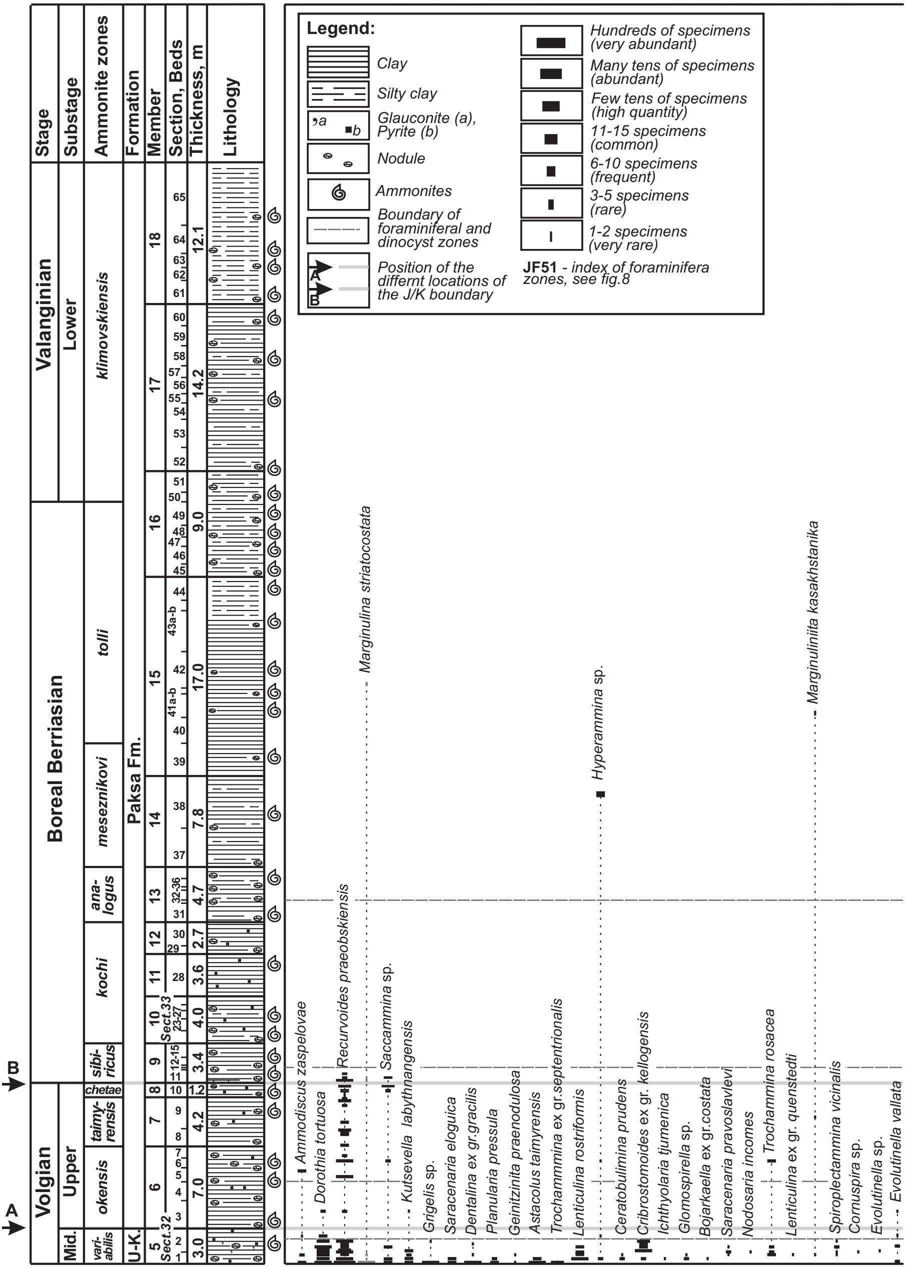
Characteristic assemblage: Important species: *Ammodiscus veteranus* (Pl. 1, fig. 8), *Evolutinella emeljanzevi* (Pl. 1, figs. 4, 5), *Planularia* ex gr. *pressula*, *Trochammina septentrionalis* (Pl. 1, fig. 7), *Trochammina rosaceaformis*, *Marginulina subformosa*, *Saracenaria elegans* (Fig. 3).

Base: Indicated by the first occurrences of *Evolutinella emeljanzevi*, *Ammodiscus veteranus*, *Geinitzinita arctocretacea*, last occurrences of *Grigelis* sp., *Cribrostomoides* ex gr. *kellogensis*, *Spiroplectammina vicinalis*, *Saracenaria pravoslavlevi* (Fig. 3) and a considerable turnover of dominant taxa (Fig. 4).
Type section: Outcrop 32; beds 2–12, represented by blue-grey clays and dark grey clays enriched by organic material, with pyrite dispersion and calcareous nodules; thickness is 14.6 m.
Stratigraphic position: *Epivirgatites variabilis* ammonite zone (upper part) – *Chetaites sibiricus* ammonite zone (lower part), Middle Volgian – lowermost Boreal Berriasian.
Subzones: *Ammodiscus veteranus* subzone, *Evolutinella emeljanzevi* subzone.

***Ammodiscus veteranus* JF55 subzone**
Characteristic assemblage: Important species: *Ammodiscus veteranus*, *Evolutinella emeljanzevi*. The assemblage is characterized by a high dominance of *Ammodiscus veteranus* and *Evolutinella emeljanzevi*. It should be noted that taxa distribution is rather specific. Assemblages from blue clays with low abundances of organic material are rather diverse. They are dominated by *Evolutinella emeljanzevi* (up to 70 %) and *Ammodiscus veteranus* (13 %) (Fig. 4). Assemblages from dark grey clays enriched by organic material are characterized by a strong dominance of *Ammodiscus veteranus* (64 %).
Base: See *Ammodiscus veteranus*, *Evolutinella emeljanzevi* JF52 zone.
Type locality: Outcrop 32; beds 2–4, represented by blue-grey clays and dark grey clays enriched by organic material, with pyrite dispersion and calcareous nodules; thickness is 5 m.
Stratigraphic position: *Epivirgatites variabilis* ammonite zone (upper part) – *Craspedites okensis* ammonite zone (lower part), the upper part of Middle Volgian – the lower part of Upper Volgian.

***Evolutinella emeljanzevi* JF56 subzone**
Characteristic assemblage: Important species: *Ammodiscus veteranus*, *Evolutinella emeljanzevi* (Pl. 1, figs. 4, 5), *Planularia* ex gr. *pressula*, *Trochammina septentrionalis* (Pl. 1, fig. 7), *T. rosaceaformis*, *Marginulina subformosa*, *Saracenaria elegans* (Fig. 3). The assemblage is dominated by *Evolutinella emeljanzevi* (up to 90 %) (Fig. 4). *Lenticulina sossipatrovae*, *Trochammina septentrionalis*, *T. rosaceaformis*, *Gaudryina* ex gr. *gerkei* are sometimes numerous. Other taxa are rather rare.
Base: Indicated by the lowermost occurrences of *Lenticulina sossipatrovae* and *Planularia* ex gr. *pressula* as well as a pronounced dominance of *Evolutinella emeljanzevi* (Fig. 3, 4).
Type section: Outcrop 32; upper part of bed 4 – bed 12, represented by blue-grey clays and dark grey clays enriched by organic material, with pyrite dispersion and calcareous nodules; thickness is 9.6 m.
Stratigraphic position: *Craspedites okensis* ammonite zone (upper part) – *Chetaites sibiricus* ammonite one (lower part), the upper half of Upper Volgian – lowermost Boreal Berriasian.

***Gaudryina gerkei*, *Ammobaculites gerkei* KF1 zone**
Characteristic assemblage: Important species: *Gaudryina gerkei*, *Ammobaculites gerkei*, *Kutsevella praegoodlanlangensis*, *Turritellella cochlea*. The quantity of foraminifers de-


Stage
Substage
Ammonite zones
Formation
Member
Section, Beds
Thickness, m
Lithology
Volgian
Mid.
Upper
Boreal Berriasian
Valanginian
Lower
U-K.
Paksa Fm.
vari-abilis
okensis
taimy-rensis
chetae
sibi-ricus
kochi
ana-logus
meseznikovi
tolli
klimovskiensis
A
B
Sect.32
Sect.33
3.0
7.0
4.2
1.2
3.4
4.0
3.6
2.7
4.7
7.8
17.0
9.0
14.2
12.1
Legend:
Clay
Silty clay
Glauconite (a), Pyrite (b)
Nodule
Ammonites
Boundary of foraminiferal and dinocyst zones
Position of the differnt locations of the J/K boundary
Hundreds of specimens (very abundant)
Many tens of specimens (abundant)
Few tens of specimens (high quantity)
11-15 specimens (common)
6-10 specimens (frequent)
3-5 specimens (rare)
1-2 specimens (very rare)
JF51 - index of foraminifera zones, see fig.8
Ammodiscus zaspelovae
Dorothia tortuosa
Recurvoides praeobskiensis
Marginulina striatocostata
Saccammina sp.
Kutsevella labythnangensis
Grigelis sp.
Saracenaria eloguica
Dentalina ex gr.gracilis
Planularia pressula
Geinitzinita praenodulosa
Astacolus taimyrensis
Trochammina ex gr.septentrionalis
Lenticulina rostriformis
Hyperammina sp.
Ceratobulimina prudens
Cribrostomoides ex gr. kellogensis
Ichthyolaria tjumenica
Glomospirella sp.
Bojarkaella ex gr.costata
Saracenaria pravoslavlevi
Nodosaria incomes
Trochammina rosacea
Lenticulina ex gr. quenstedti
Marginulinita kasakhstanika
Spiroplectammina vicinalis
Cornuspira sp.
Evolutinella sp.
Evolutinella vallata

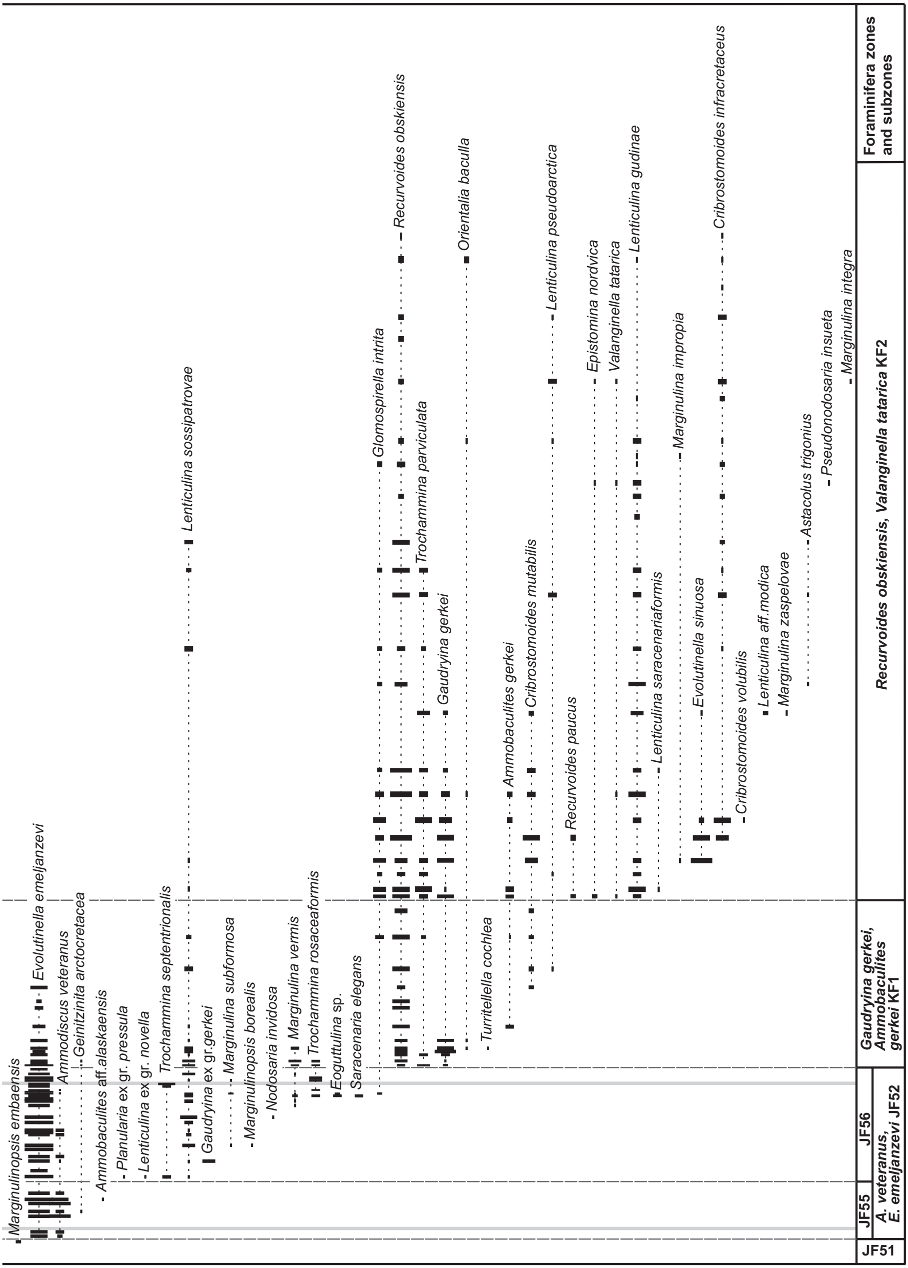


Fig. 3. Stratigraphic distribution of selected foraminiferal taxa in the Middle Volgian – Lower Valanginian of the Nordvik section.

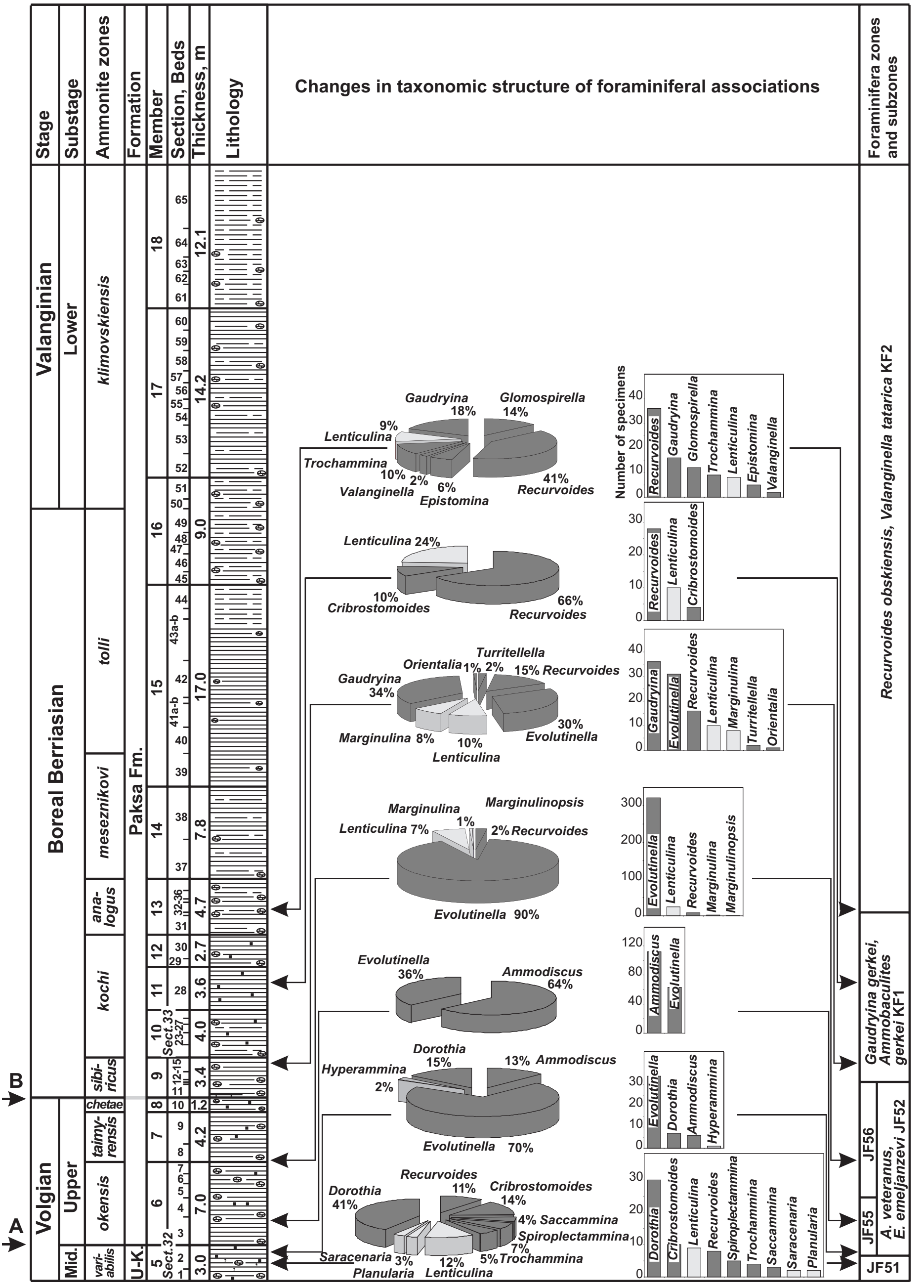


Fig. 4. Fluctuations in the taxonomic composition of foraminifers in the Middle Volgian – Lower Valanginian of the Nordvik section.

creases, while their diversity increases. The assemblage is dominated by *Gaudryina gerkei* (34 %), *Recurvoides obskiensis* (15–66 %), *Lenticulina* spp. (10–24 %) (Fig. 4). In the middle part of the zone, the extinction of *Evolutinella emeljanzevi* is observed. *Trochammina parviculata*, *Recurvoides obskiensis*, *Gaudryina gerkei* and *Turritellella cochea* first occur near the base of this zone.
Base: Indicated by the first occurrences of *Recurvoides obskiensis*, *Trochammina parviculata*, and *Gaudryina gerkei*, as well as the last occurrence of *Recurvoides praeobskiensis* and a considerable turnover of dominant taxa (Fig. 3, 4).
Type section: Outcrop 32; beds 13–15, represented by dark grey clays with pyrite dispersion and calcareous nodules; thickness is 2.6 m. Outcrop 33; beds 23–32, represented by blue-grey clays and dark grey clays enriched by organic material, with pyrite dispersion and calcareous nodules; thickness is 12.2 m.
Stratigraphic position: *Chetaites sibiricus* ammonite zone (upper part) – *Surites analogus* ammonite zone (lower part), Boreal Berriasian.

***Recurvoides obskiensis, Valanginella tatarica* KF2 zone**
Characteristic assemblage: Important species: *Valanginella tatarica*, *Recurvoides obskiensis*, *Epistomina nordvica*, *Lenticulina gudinae*, *Lenticulina saracenariaformis*, *Marginulina impropia*. The assemblage is dominated by *Recurvoides obskiensis* (41–70 %). *Lenticulina* spp. (9–12 %), *Glomospirella intrita* (8–14 %) and *Trochammina* spp. (10–15 %) are rather abundant (Fig. 4).
Base: Indicated by the first occurrences of *Valanginella tatarica*, *Epistomina nordvica*, *Lenticulina gudinae*, and *L. saracenariaformis* (Fig. 3).
Type section: Outcrop 33; beds 33–65, represented by grey clays, silty clays and clayey silts with calcareous nodules; thickness is 62.9 m.
Stratigraphic position: *Surites analogus* ammonite zone (upper part) – *Euryptychites astieriptychus* ammonite zone, the upper part of Boreal Berriasian – lowermost Lower Valanginian.

Dinocyst zonation

***Pareodinia ceratophora*, *Tubotuberella apatela* assemblage zone**
Characteristic assemblage: Dinocysts are dominated by *Pareodinia ceratophora*, *Tubotuberella apatela*, and *Sirmiodinium grossii* (Fig. 5, 6). *Cribroperidinium* spp., *C. ?longicorne*, *Pareodinia* spp., *Gonyaulacysta* spp., *Cassiculosphaeridia magna*, *Chlamydophorella* spp., *Tubotuberella rhombiformis* are rather abundant. Common taxa are *Paragonyaulacysta ?borealis*, *Leptodinium* spp., *Gonyaulacysta dualis*, *Tubotuberella dangeardii*, *Leberidocysta* spp., *Scriniodinium* spp., *Escharisphaeridia* spp., *Kallosphaeridium* spp., and *Sentusidinium* spp. Prasinophytes include rather abundant *Leiosphaeridia* spp. and rare *Cymatiosphaera* spp.
Base: Not recovered.
Type section: Outcrop 32; bed 1, represented by dark grey clays with glauconite, leptochlorite and thin veinlet of pyrite, thickness is 1 m.
Stratigraphic position: Lower part of *Epivirgatites variabilis* ammonite zone, Middle Volgian.

Plate 1. 1–9. Foraminiferal assemblage of the *Ammodiscus veteranus, Evolutinella emeljanzevi* JF52 zone. – **1.** *Marginulina striatacostata* Reuss 1862, specimen N 32911-1, ± 84, outcrop 32, member 9, bed 11, Boreal Berriasian, *Chetaites chetae* ammonite zone. – **2.** *Geinitzinita arctocretacea* (Gerke 1969), specimen N 3263-1, ± 72.5, outcrop 32, member 6, bed 3, Upper Volgian, *Craspedites okensis* ammonite zone. – **3.** *Lenticulina sossipatrovae* Gerke & E. Ivanova 1972, specimen N 3278-1, ± 80, outcrop 32, member 7, bed 8, Upper Volgian, *Craspedites taimyrensis* ammonite zone. – **4, 5.** *Evolutinella emeljanzevi* (Schleifer 1966). – **4.** specimen N 3279-1, ± 46.5, outcrop 32, member 7, bed 9, Upper Volgian, *Craspedites taimyrensis* ammonite zone. – **5.** specimen N 3278-2, ± 50, outcrop 32, member 7, bed 8, Upper Volgian, *Craspedites taimyrensis* ammonite zone. – **6.** *Marginulina vermis* Gerke 1969, specimen N 3279-2, ± 72, outcrop 32, member 7, bed 9, Upper Volgian, *Craspedites taimyrensis* ammonite zone. – **7.** *Trochammina septentrionalis* Scharovskaja 1961, specimen N 32810-1, ± 96, outcrop 32, member 8, bed 10, Upper Volgian, *Chetaites chetae* ammonite zone. – **8.** *Ammodiscus veteranus* Kosyreva 1972, specimen N 3263-2, ± 60, outcrop 32, member 6, bed 3, Upper Volgian, *Craspedites okensis* ammonite zone. – **9.** *Recurvoides praeobskiensis* Dain & Bulynnikova 1986, specimen N 32911-2, ± 60, a – dorsal view; b – ventral view, outcrop 32, member 9, bed 11, Boreal Berriasian, *Chetaites sibiricus* ammonite zone.

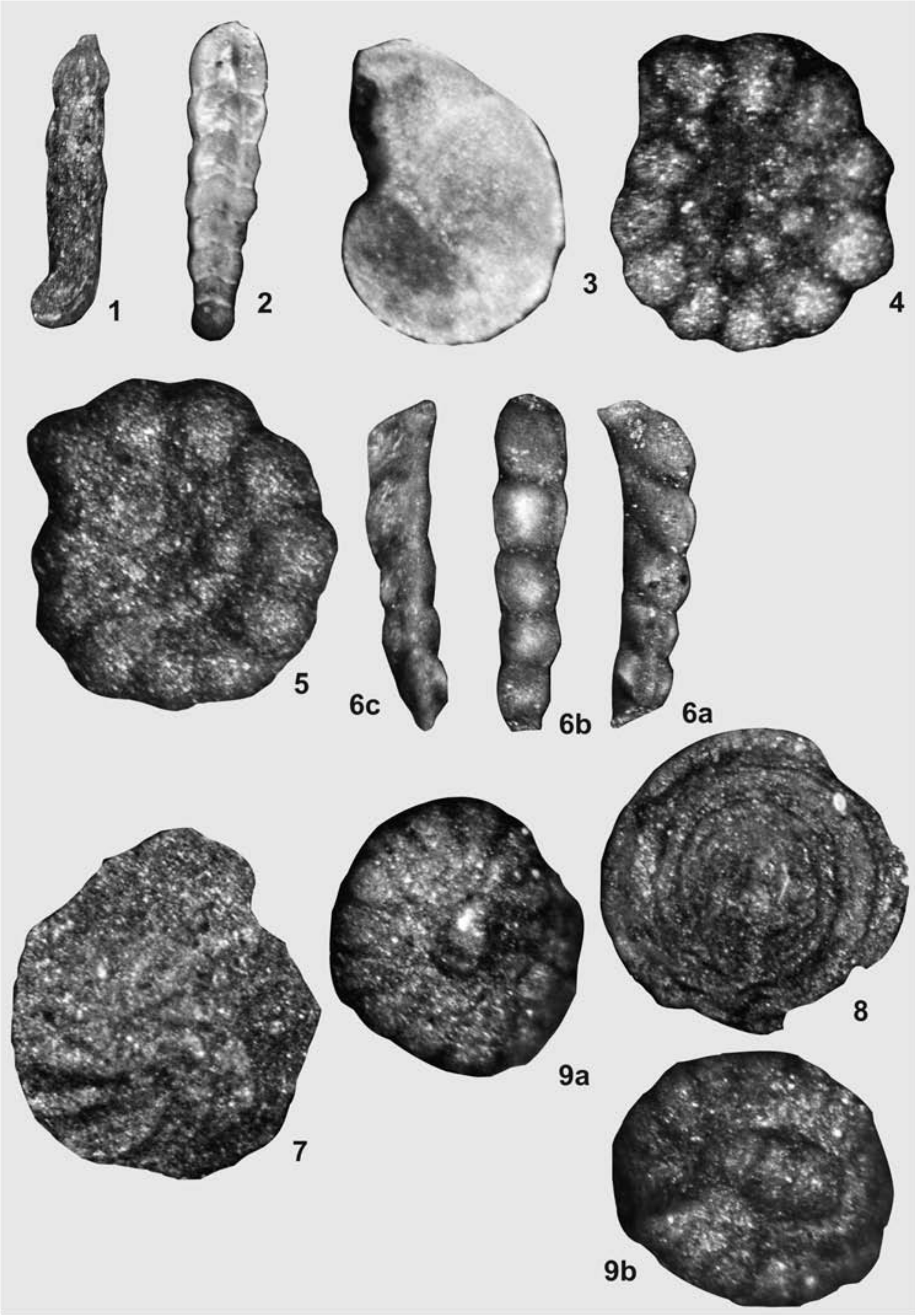

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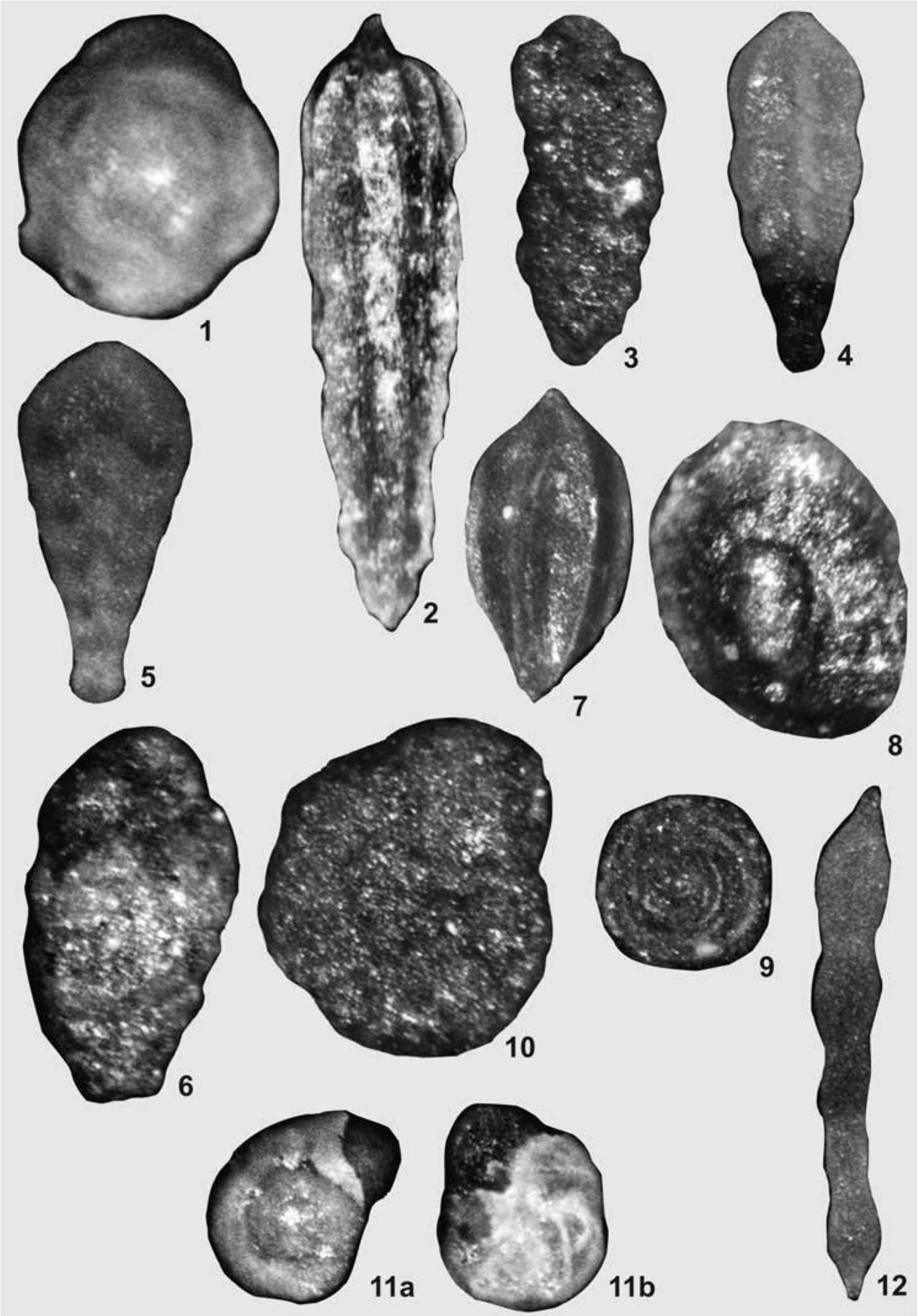
Plate 2. 1–12. Foraminiferal assemblage of the *Dorothia tortuosa* JF51 zone. Notes: all specimens are from the Middle Volgian, *Epivirgatites variabilis* ammonite zone). **1, 11.** *Ceratobulimina prudens* Basov 1969. – **1.** specimen N 3252-1, ± 144, outcrop 32, member 5, bed 2. – **11.** specimen N 3358-1, ± 132, a – dorsal view; b – ventral view, outcrop 33, member 5, bed 8. – **2.** *Marginulinita kasakhstanica* (Kasantzev 1934), specimen N 3252-2, ± 48, outcrop 32, member 5, bed 2. – **3, 6.** *Dorothia tortuosa* Dain & Komissarenko 1972. – **3.** specimen N 3252-3, ± 74, outcrop 32, member 5, bed 2. – **6.** specimen N 3358-2, ± 88, outcrop 33, member 5, bed 8. – **4, 5.** *Geinitzinita praenodulosa* Dain 1972. – **4.** specimen N 3252-4, ± 81, outcrop 32, member 5, bed 2. – **5**. specimen N 3358-3, ± 83, outcrop 33, member 5, bed 8. – **7.** *Ichthyolaria tjumenica* Tylkina 1972, specimen N 3358-4, ± 52, outcrop 33, member 5, bed 8. – **8.** *Recurvoides praeobskiensis* Dain & Bulynnikova 1986, specimen N 3358-5, ± 62, dorsal view, outcrop 33, member 5, bed 8. – **9.** *Ammodiscus zaspelovae* Kosyreva 1972, specimen N 3358-6, ± 114, outcrop 33, member 5, bed 8. – **10.** *Evolutinella vallata* Nagy & Basov 1998, specimen N 3252-5, ± 66, outcrop 32, member 5, bed 2. – **12.** *Dentalina* ex gr. *gracilis* (d'Orbigny 1840), specimen N 3358-7, ± 87, outcrop 33, member 5, bed 8.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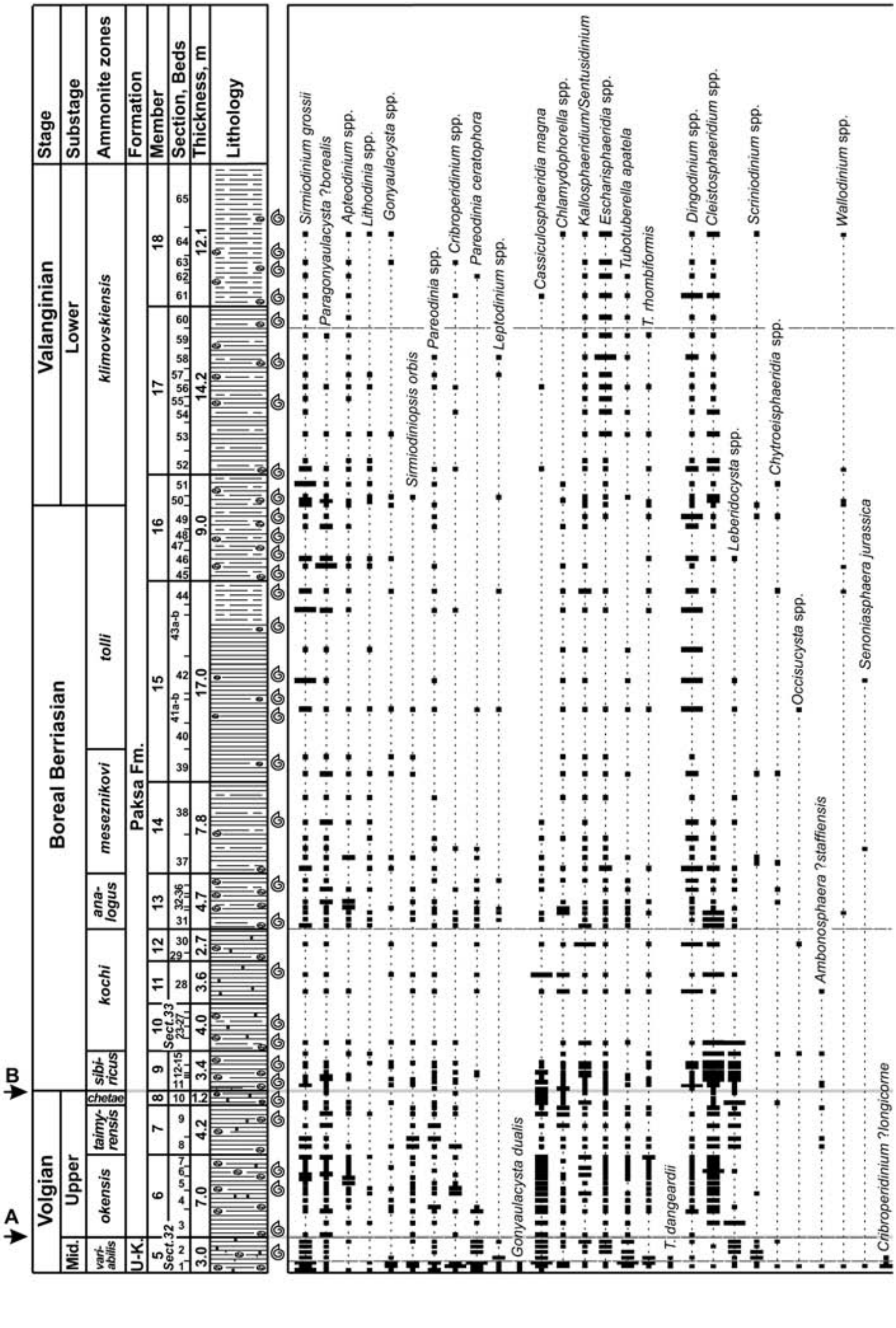

Stage
Substage
Ammonite zones
Formation
Member
Section, Beds
Thickness, m
Lithology
Volgian
Boreal Berriasian
Valanginian
Mid.
Upper
Lower
variabilis
okensis
taimyrensis
chetae
sibiricus
kochi
analogus
mesezhnikovi
tolli
klimovskiensis
U-K.
Paksa Fm.
Sect.32
Sect.33
A
B
Sirmiodinium grossii
Paragonyaulacysta ?borealis
Apteodinium spp.
Lithodinia spp.
Gonyaulacysta spp.
Sirmiodiniopsis orbis
Pareodinia spp.
Cribroperidinium spp.
Pareodinia ceratophora
Leptodinium spp.
Gonyaulacysta dualis
Cassiculosphaeridia magna
Chlamydophorella spp.
Kallosphaeridium/Sentusidinium
Escharisphaeridia spp.
Tubotuberella apatela
T. rhombiformis
T. dangeardii
Dingodinium spp.
Cleistosphaeridium spp.
Leberidocysta spp.
Scriniodinium spp.
Chytroeisphaeridia spp.
Occisucysta spp.
Ambonosphaera ?staffiensis
Wallodinium spp.
Senoniasphaera jurassica
Cribroperidinium ?longicorne

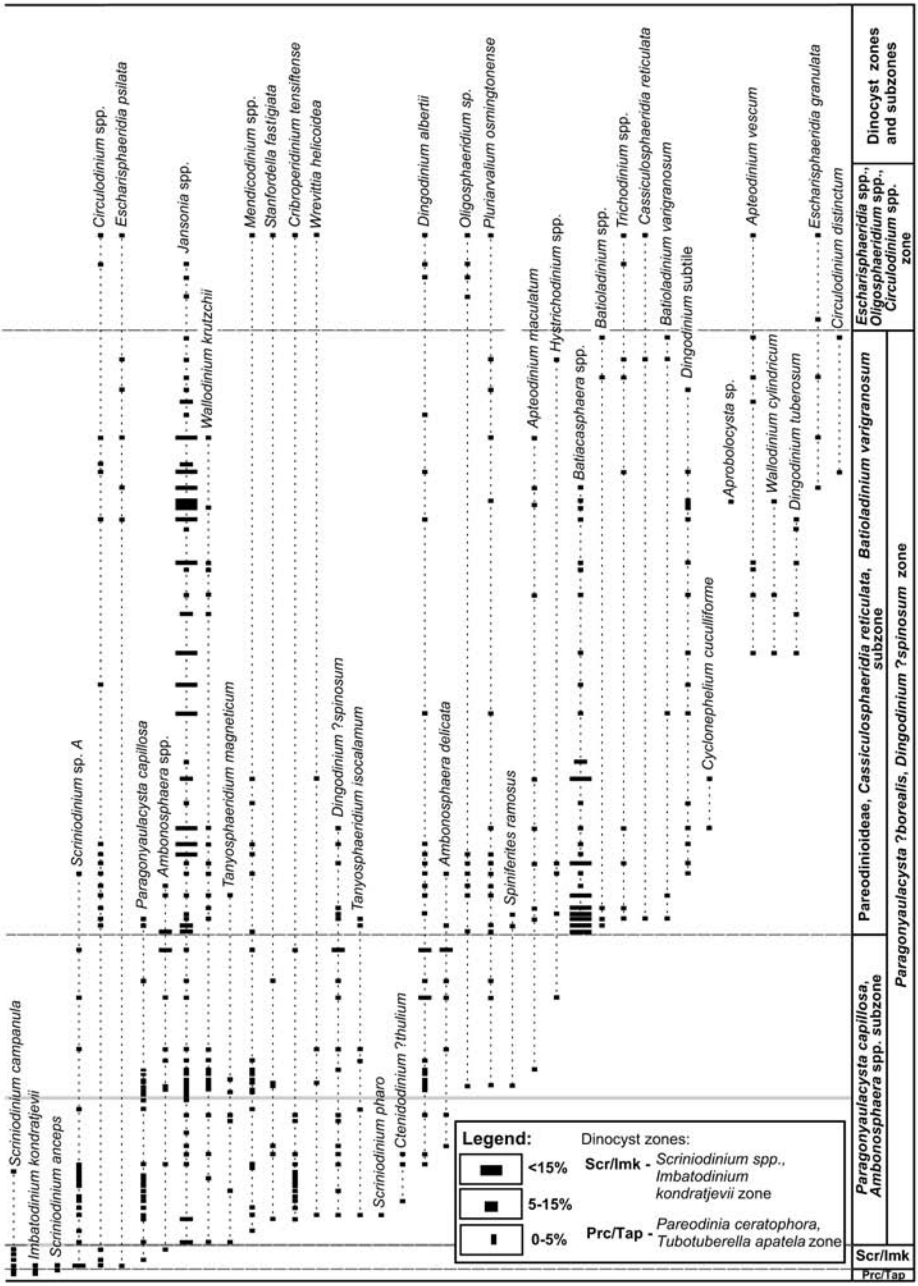


Fig. 5. Stratigraphic distribution of selected dinocyst taxa in the Middle Volgian – Lower Valanginian of the Nordvik section.

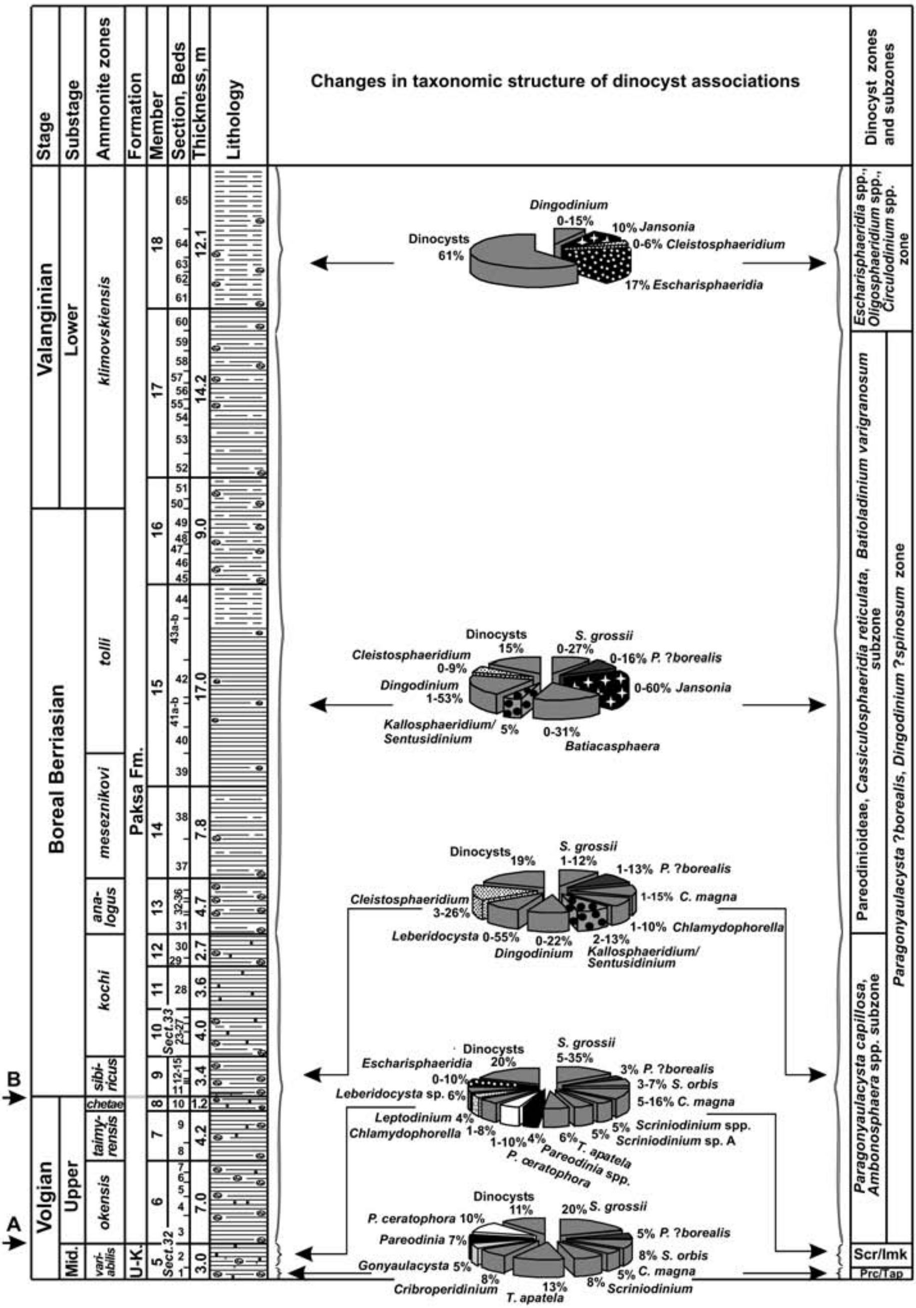


Fig. 6. Fluctuations in the taxonomic composition of dinocysts in the Middle Volgian – Lower Valanginian of the Nordvik section.

***Scriniodinium* spp., *Imbatodinium kondratjevii* assemblage zone**

Characteristic assemblage: *Scriniodinium* spp., *Sirmiodinium grossii*, *Tubotuberella apatela*, *Pareodinia ceratophora*, *Cassiculosphaeridia magna*, *Leberidocysta* spp., and *Escharisphaeridia* spp. are rather abundant (Fig. 5, 6). Common taxa are *Paragonyaulacysta ?borealis*, *Chlamydophorella* spp., *Kallosphaeridium* spp., *Sentusidinium* spp., and *Scriniodinium campanula*. Several species have their first occurences in this zone: *Scriniodinium* sp. A, *Pareodinia capillosa*, and *Escharisphaeridia psilata*. The main characteristic features are the diversity of *Scriniodinium*, decreased percentages of *Cribroperidinium* and *Tubotuberella* and the presence of the following stratigraphically important taxa that do not cross the upper boundary of the zone: *Imbatodinium kondratjevii*, *Tubotuberella dangeardii*, *Gonyaulacysta dualis*, *Cribroperidinium ?longicorne*, and *Scriniodinium anceps*. Prasinophytes include rather abundant *Leiosphaeridia* spp. as well as rare *Pterospermella* spp., *Pterosphaeridia* spp., *Tasmanites* spp., and *Crassosphaera* spp. Acritarchs are represented by very rare *Micrhystridium* spp., *Veryhachium* spp., and *Leiofusa* spp.

Base: Indicated by the first occurrences of *Scriniodinium* sp. A, *Pareodinia capillosa* and an increased diversity of *Scriniodinium*.

Type section: Outcrop 32; bed 2, represented by dark grey clays with glauconite, leptochlorite and thin veinlet of pyrite; thickness is 2 m.

Stratigraphic position: Upper part of *Epivirgatites variabilis* ammonite zone, Middle Volgian.

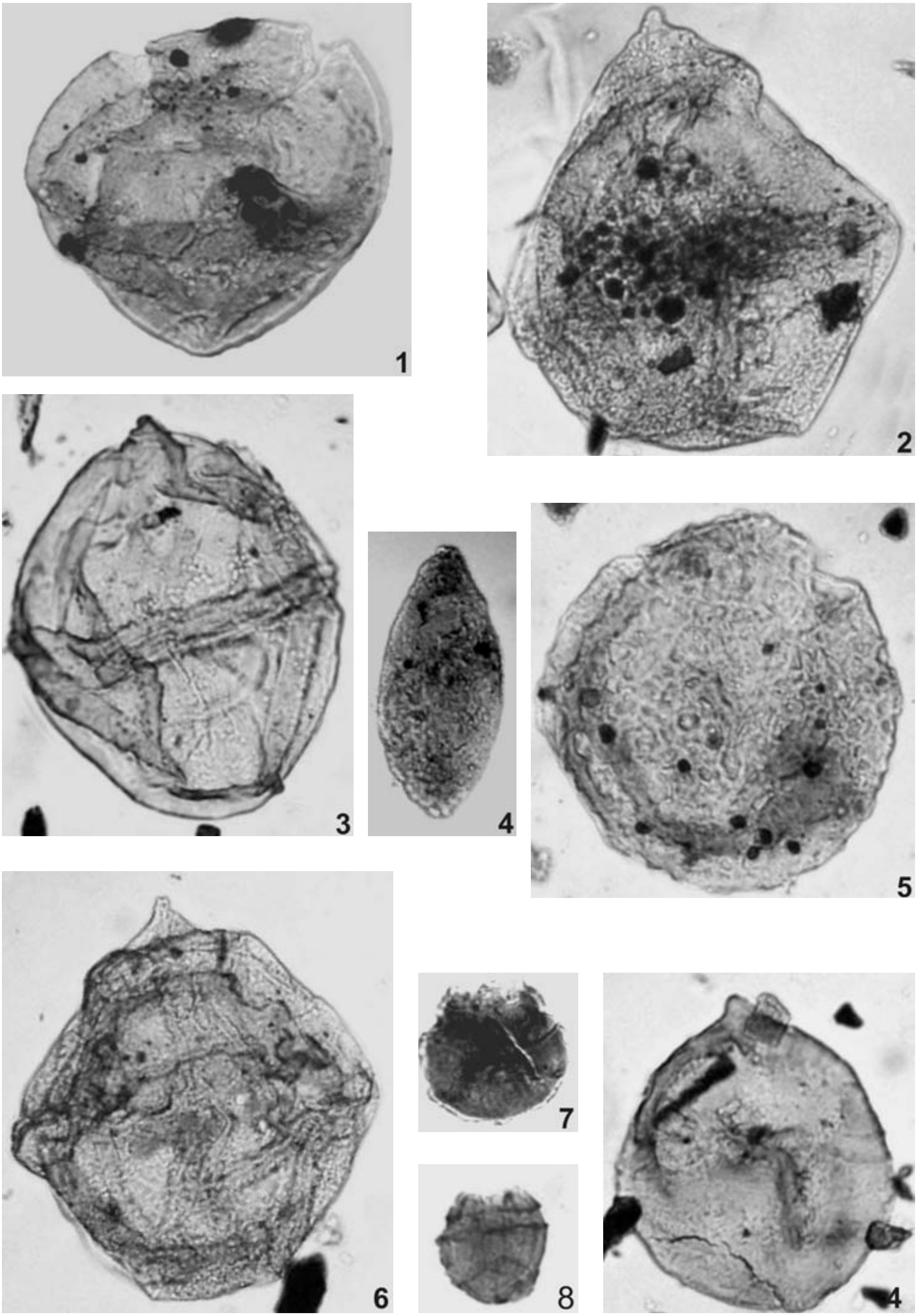
***Paragonyaulacysta ?borealis*, *Dingodinium ?spinosum* assemblage zone**

Characteristic assemblage: *Cassiculosphaeridia magna*, *Sirmiodinium grossii*, *Cleistosphaeridium* spp., *Dingodinium* spp., *Pareodinia ceratophora*, *Leberidocysta* spp., *Membranosphaera* spp., and *Jansonia* spp. sometimes reach high percentages (Fig. 5, 6). Common taxa are *Apteodinium* spp., *Tubotuberella* spp., *Gonyaulacysta* spp., *Chlamydophorella* spp., *Cribroperidinium* spp., *Sirmiodiniopsis orbis*, *Kallosphaeridium* spp., *Sentusidinium* spp., *Chytroeisphaeridia* spp., and *Wallodinium krutzschii*. Characteristic features are the frequent peaks of *Paragonyaulacysta ?borealis*, the occurrences of *Dingodinium ?spinosum*, the abundance and high diversity of *Pareodinia* spp., *Paragonyaulacysta* spp., *Tubotuberella* spp., and *Tanyosphaeridium* spp. Acritarchs are rare to frequent and comprise *Micrhystridium*, *Veryhachium*, *Solisphaeridium*, *Polygonium*, and *Leiofusa*. Prasinophytes are rather abundant, sometimes dominating the assemblage. They are represented by *Leiosphaeridia* spp., *Cymatiosphaera* spp., *Pterospermella* spp., *P. australiensis*, and *Pterosphaeridia* spp.

Base: Indicated by the first occurrences of *Jansonia* spp., *Ambonosphaera* spp., *Wallodinium krutzschii*, *Tanyosphaeridium magneticum*, and an increased abundance of *Paragonyaulacysta ?borealis*. The following species have their first occurences near the base: *Dingodinium ?spinosum*, *Mendicodinium* spp., *Stanfordella fastigiata*, *Cribroperidinium tesiftense*, *Wrevittia helicoidea*, *Tanyosphaeridium isocalamum*, *Scriniodinium pharo*, and *Ctenidodinium ?thulium*. The following taxa have not been observed above the base of this zone: *Gonyaulacysta dualis*, *Tubotuberella dangeardii*, *Cribroperidinium ?longicorne*, *Imbatodinium kondratjevii*, and *Scriniodinium anceps* (Fig. 5).

Type section: Outcrop 32; beds 3–15, represented by dark grey clays with pyrite dispersion and calcareous nodules, thickness is 15.8 m. Outcrop 33, beds 23–59, represented by

Plate 3. All specimens of are from the Upper Jurassic – Lower Cretaceous deposits of the Nordvik type section and are ± 550. – **1.** *Batiacasphaera* sp., outcrop 33, bed 32, sample 32.1, slide 110.1, ammonite zone *Surites analogus*, Boreal Berriasian. – **2.** *Scriniodinium* sp. A, outcrop 32, bed 16, sample 1, slide 35.1, ammonite zone *Hectoroceras kochi*, Boreal Berriasian. – **3.** *Apteodinium grande* Cookson & Hughes 1964, outcrop 32, bed 16, sample 1, slide 35.1, ammonite zone *Hectoroceras kochi*, Boreal Berriasian. – **4.** *Batioladinium varigranosum* (Duxbury 1977) Davey 1982, outcrop 33, bed 31, sample 31.2, slide 108.1, ammonite zone *Surites analogus*, Boreal Berriasian. – **5.** *Cassiculosphaeridia magna* Davey 1974, outcrop 32, bed 11, sample 4, slide 27.1, ammonite zone *Chetaites sibiricus*, Boreal Berriasian. – **6.** *Scriniodinium* sp. A, outcrop 32, bed 16, sample 1, slide 35.1, ammonite zone *Hectoroceras kochi*, Boreal Berriasian. – **7.** *Horologinella anabarensis* Pestchevitskaya 2001, outcrop 33, bed 37, sample 37.2, slide 116.1, ammonite zone *Bojarkia meseznikovi*, Boreal Berriasian. – **8.** *Jansonia* spp., outcrop 32, bed 3, sample 1, slide 1.2, ammonite zone *Epivirgatites variabilis*, Middle Volgian. – **9.** *Apteodinium maculatum* Eisenack & Cookson 1960, outcrop 32, bed 15, sample 2, slide 34.1, ammonite zone *Chetaites sibiricus*, Boreal Berriasian.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blue-grey and dark grey, sometimes silty clays with pyrite dispersion and calcareous nodules. Thickness is 61.5 m.
Stratigraphic position: Ammonite zones: *Craspedites okensis*, *C. taimyrensis*, *Chetaites chetae*, *C. sibiricus*, *Hectoroceras kochi*, *Surites analogus*, *Bojarkia meseznikovi*, *Tollia tolli*, lowermost part of *Neotollia klimovskiensis*; Upper Volgian – lowermost Lower Valanginian.
Subzones: *Pareodinia capillosa – Sirmiodiniopsis orbis* subzone and Pareodinioideae, *Batioladinium varigranosum*, *Cassiculosphaeridia reticulata* subzone.

***Paragonyaulacysta capillosa*, *Ambonosphaera* spp. assemblage subzone**
Characteristic assemblage: The most abundant dinocysts are: *Cassiculosphaeridia magna*, *Leberidocysta* spp., *Cleistosphaeridium* spp., *Sirmiodinium grossii*, and *Paragonyaulacysta ?borealis*, and in the upper part of the subzone, *Dingodinium* spp. (Fig. 5, 6). *Pareodinia* spp., *Sirmiodiniopsis orbis*, *Apteodinium* spp., *Chlamydophorella* spp., *Kallosphaeridium* spp., and *Sentusidinium* spp. are rather abundant. The percentages of *Dingodinium* spp. and *Cleistosphaeridium* spp. increase, while *Pareodinia ceratophora* and *Tubotuberella apatela* become less abundant. The diversity of *Scriniodinium* decreases. A characteristic feature is the permanent presence of *Paragonyaulacysta capillosa*, *Ambonosphaera* spp., *A. delicata*, *A.* cf. *staffiensis*, *Cribroperidinium tesiftense*, *Dingodinium ?spinosum*, and *Dingodinium albertii*. Prasinophytes are represented by rare *Cymatiosphaera* spp. as well as *Leiosphaeridia* spp. and *Pterospermella* spp., sometimes reaching high percentages and dominating the assemblage. Acritarchs include rare *Micrhystridium* spp., *Veryhachium* spp. and *Leiofusa* spp. (Fig. 5).
Base: See *Paragonyaulacysta ?borealis*, *Dingodinium ?spinosum* assemblage zone.
Type section: Outcrop 32; beds 3–15, represented by dark grey clays with pyrite dispersion and calcareous nodules; thickness is 15.8 m. Outcrop 33; beds 23–30, represented by blue-grey clays and dark grey clays enriched by organic material, with pyrite dispersion and calcareous nodules; thickness is 10.3 m.
Stratigraphic position: Ammonite zones: *Craspedites okensis*, *C. taimyrensis*, *Chetaites chetae*, *C. sibiricus*, *Hectoroceras kochi*, Upper Volgian – the lower part of Boreal Berriasian.

Pareodinioideae, *Batioladinium varigranosum*, *Cassiculosphaeridia reticulata* assemblage subzone
Characteristic assemblage: The most abundant dinocysts are: *Dingodinium* spp., *Jansonia* spp., *Sirmiodinium grossii*, *Paragonyaulacysta ?borealis*, and in the upper part of the subzone, *Batiacasphaera* spp. and *Cleistosphaeridium* spp. (Fig. 5, 6). Common taxa are *Sirmiodiniopsis orbis*, *Chlamydophorella* spp., *Pareodinia* spp., *Leberidocysta* spp., *Apteodinium* spp., *Tubotuberella* spp., *Lithodinia* spp., *Gonyaulacysta* spp., *Escharisphaeridia* spp., *Kallosphaeridium* spp., and *Sentusidinium* spp. Characteristic features are the occurrences of *Batioladinium varigranosum*, *Cassiculosphaeridia reticulata* and *Cyclonephelium culliforme*, as well as high diversity of Pareodinioideae (various *Paragonyaulacysta*, *Pareodinia*, *Pluriarvalium*), *Dingodinium* spp. (*D. tuberosum*, *D. ?spinosum*, *D. albertii*, *D. minutum*, *D. subtile*), *Apteodinium* spp. (*A. maculatum*, *A. ?vescum*, *A. granulatum*,

A. grande, *A. bacculiatum*), and *Wallodinium* spp. (*W. krutzschii*, *W. cylindricum*, *W. luna*). Prasinophytes are represented by rare *Pterospermella* spp., *Cymatiosphaera* spp. and *Tasmanites* spp. as well as rather abundant *Leiosphaeridia* spp. Acritarchs are rare and comprise *Micrhystridium*, *Veryhachium*, *Solisphaeridium*, and *Polygonium* (Fig. 5).
Base: Indicated by the first occurrences of *Batioladinium* spp., *B. varigranosum*, *Cassiculosphaeridia reticulata*, *Spiniferites ramosus*, *Achomosphaera* spp., *Apteodinium maculatum*, *Trichodinium* spp., *Batiacasphaera* spp., and a first abundance peak of *Jansonia* spp. The following taxa have their extinctions near the base: *Scriniodinium* sp. A, *Paragonyaulacysta capillosa*, *Ambonosphaera* spp., *A. delicata*, *Tanyosphaeridium magneticum*, and *T. isocalamum* (Fig. 5). The quantity of *Cassiculosphaeridia magna*, *Pareodinia* spp., *Leberidocysta* spp., *Sirmiodiniopsis orbis*, *Chlamydophorella* spp., *Kallosphaeridium* spp. and *Sentusidinium* spp. decreases. *Tubotuberella apatela* and *T. rhombiformis* become less frequent.
Type section: Outcrop 33; beds 31–59, represented by blue-grey and dark grey clays with pyrite dispersion and calcareous nodules; thickness is 51.2 m.
Stratigraphic position: Ammonite zones: *Surites analogus*, *Bojarkia mesezhnikovi*, *Tollia tolli*, lowermost part of *Neotollia klimovskiensis*, the upper part of Boreal Berriasian – lowermost Lower Valanginian.

***Escharisphaeridia* spp., *Oligosphaeridium* spp., *Circulodinium* spp. assemblage zone**
Characteristic assemblage: The diversity of marine palynomorphs decreases. Dinocysts are dominated by proximate dinocysts, *Escharisphaeridia* spp., *Dingodinium* spp., and *Cleistosphaeridium* spp. (Fig. 5, 6). Common taxa are *Sirmiodinium grossii*, *Apteodinium* spp., *Jansonia* spp., *Lithodinia* spp., *Tubotuberella* spp., *Dingodinium albertii*, *Oligosphaeridium* spp., *Kallosphaeridium* spp., and *Sentusidinium* spp. Further characteristic features are the decreased diversity and abundance of Pareodinioideae and the common occurrences of *Oligosphaeridium* spp. Prasinophytes include rare *Tasmanites* spp. and rather abundant *Leiosphaeridia* spp. Acritarchs are very rare and represented by *Micrhystridium* spp. and *Solisphaeridium* spp. (Fig. 5).
Base: Indicated by the last occurrences of *Paragonyaulacysta ?borealis*, *Tubotuberella rhombiformis* and *Dingodinium* sp. A as well as by the derceased diversity and abundance of Pareodinioideae, common occurrences of *Oligosphaeridium* spp. and reduced dinocyst diversity. The abundances of *Sirmiodinium grossii* and *Jansonia* spp. decrease. *Gonyaulacysta* and *Dingodinium* become less diverse, while the diversity of *Cribroperidinium* increases (Fig. 5).
Type section: Outcrop 33; beds 60–65, represented by grey silty clays and clayey silts with calcareous nodules. Thickness is 12.5 m.
Stratigraphic position: *Neotollia klimovskiensis* ammonite zone without lowermost part, Lower Valanginian.

Discussion

Foraminiferal zones established in Siberia by previous workers (Basov et al. 1970; Basov & Ivanova 1972, Golbert 1981; Grigelis 1982) were commonly characterized

Plate 4. All specimens of are from the Upper Jurassic – Lower Cretaceous deposits of the Nordvik type section and are ± 550. – **1.** *Tubotuberella rhombiformis* Vozzhennikova 1967, outcrop 32, bed 11, sample 3, slide 26.4, ammonite zone *Chetaites sibiricus*, Boreal Berriasian. – **2.** *Stanfordella fastigiata* (Duxbury 1977) Helenes & Lukas-Clark 1997, outcrop 32, bed 11, sample 4, slide 27.2, ammonite zone *Chetaites sibiricus*, Boreal Berriasian. – **3.** *Ambonosphaera ?staffiensis* (Gitmez 1970) Poulsen & Riding 1992, outcrop 32, bed 11, sample 3, slide 26.9, ammonite zone *Chetaites sibiricus*, Boreal Berriasian. – **4.** *Tanyosphaeridium isocalamum* (Deflandre & Cookson 1955) Davey & Williams 1969, outcrop 32, bed 15, sample 2, slide 34.1, ammonite zone *Chetaites sibiricus*, Boreal Berriasian. – **5.** *Cleistosphaeridium* sp., outcrop 32, bed 11, sample 3, slide 26.1, ammonite zone *Chetaites sibiricus*, Boreal Berriasian. – **6.** *Evansia* sp. outcrop 32, bed 11, sample 3, slide 26.2, ammonite zone *Chetaites sibiricus*, Boreal Berriasian. – **7.** *Dingodinium ?spinosum* (Duxbury 1977) Davey 1979, outcrop 32, bed 11, sample 3, slide 26.9, ammonite zone *Chetaites sibiricus*, Boreal Berriasian. – **8.** *Pluriarvalium osmingtonense* Sarjeant 1962, outcrop 32, bed 16, sample 1, slide 35.1, ammonite zone *Hectoroceras kochi*, Boreal Berriasian. – **9.** *Dingodinium* subtile *Pestchevitskaya* 2006, outcrop 33, bed 42, sample 42.1, slide 124.1, ammonite zone *Tollia tolli*, Boreal Berriasian. – **10.** *Chlamydophorella nyei* Cookson & Eisenack 1958, outcrop 33, bed 32, sample 32.1, slide 110.1, ammonite zone *Surites analogus*, Boreal Berriasian. – **11.** *Achomosphaera neptuni* (Eisenack 1958) Davey & William 1966, outcrop 33, bed 33, sample 33.1, slide 111.1, ammonite zone *Surites analogus*, Boreal Berriasian. – **12.** *Paragonyaulacysta ?borealis* (Brideaux & Fisher 1976) Stover & Evitt 1978, outcrop 33, bed 33, sample 33.1, slide 111.1, ammonite zone *Surites analogus*, Boreal Berriasian. – **13.** *Ambonosphaera delicata* Lebedeva 1998, outcrop 32, bed 16, sample 1, slide 35.1, ammonite zone *Hectoroceras kochi*, Boreal Berriasian. – **14.** *Pareodinia tamboviensis* (Vozzhennikova 1967) Lentin & Vozzhennikova 1990, outcrop 33, bed 31, sample 31.1, slide 109.1, ammonite zone *Surites analogus*, Boreal Berriasian. – **15.** *Tubotuberella apatela* (Cookson & Eisenack 1960) Ioannides et al. 1977, outcrop 33, bed 31, sample 31.3, slide 109.1, ammonite zone *Surites analogus*, Boreal Berriasian.

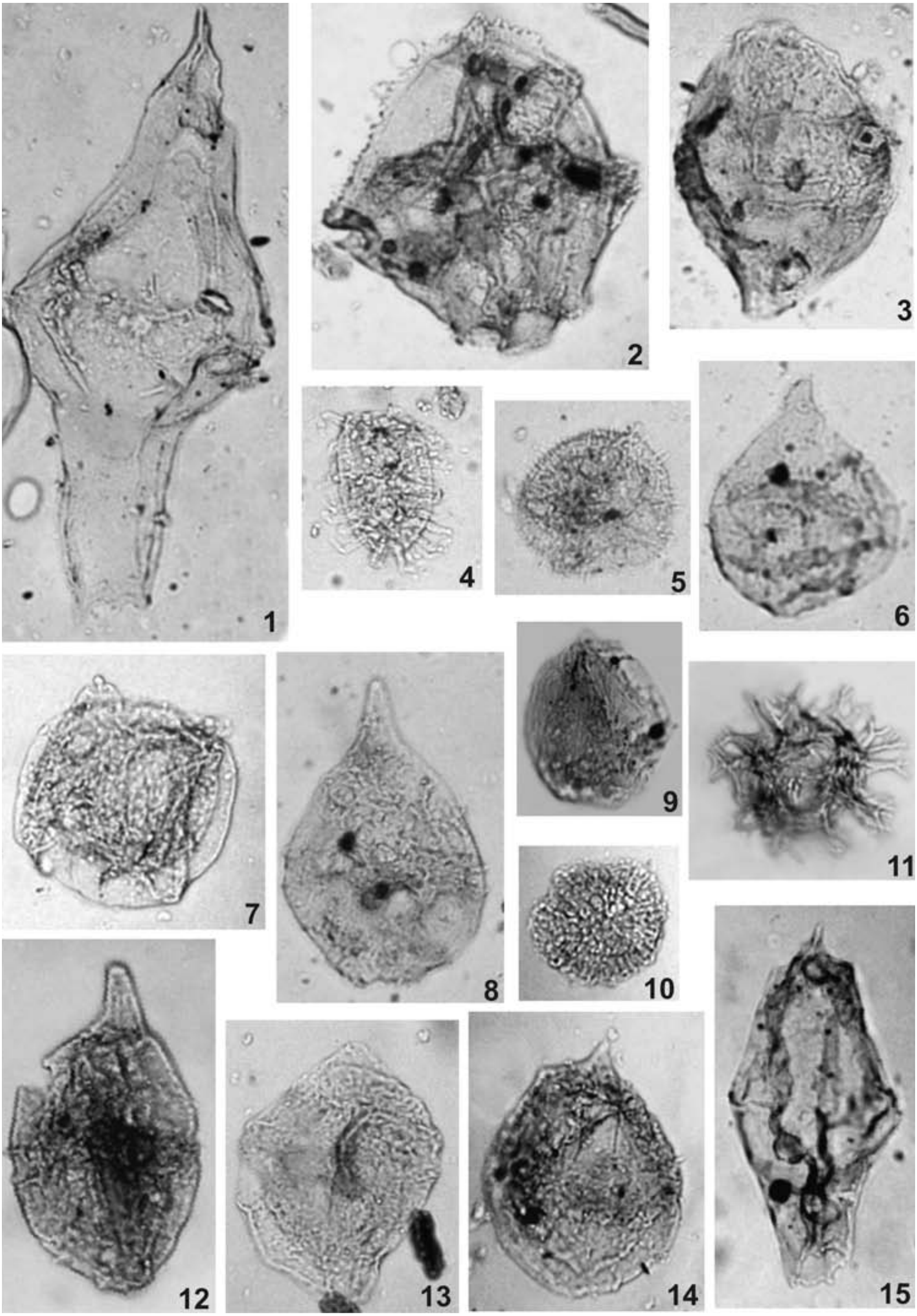
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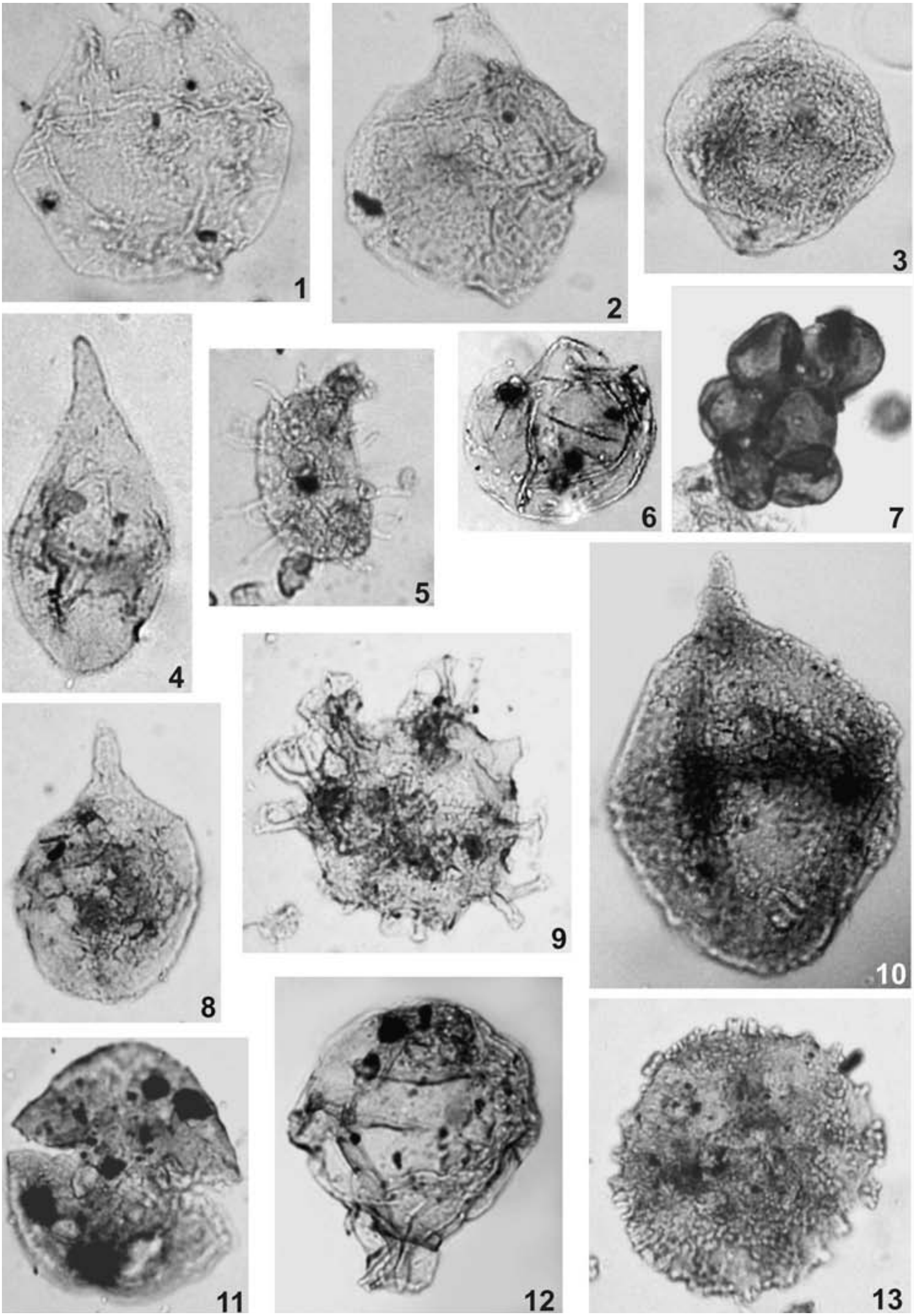
Plate 5. All specimens of are from the Upper Jurassic – Lower Cretaceous deposits of the Nordvik type section and are ± 550. – **1.** *Sirmiodinium grossii* Alberti 1961, outcrop 32, bed 3, sample 1, slide 1.4, ammonite zone *Epivirgatites variabilis*, Middle Volgian. – **2.** *Dingodinium albertii* Sarjeant 1966, outcrop 32, bed 16, sample 1, slide 35.1, ammonite zone *Hectoroceras kochi*, Boreal Berriasian. – **3.** *Dingodinium minutum* Dodekova 1975, outcrop 32, bed 16, sample 1, slide 35.1, ammonite zone *Hectoroceras kochi*, Boreal Berriasian. – **4.** *Paragonyaulacysta capillosa* (Brideaux & Fisher 1976) Stover & Evitt 1978, outcrop 32, bed 3, sample 1, slide 1.1, ammonite zone *Epivirgatites variabilis*, Middle Volgian. – **5.** *Tanyosphaeridium magneticum* Davies 1983, outcrop 32, bed 3, sample 1, slide 1.4, ammonite zone *Epivirgatites variabilis*, Middle Volgian. – **6.** *Leberidocysta* sp., outcrop 33, bed 31, sample 31.2, slide 108.1, ammonite zone *Surites analogus*, Boreal Berriasian. – **7.** *Microevolutinella* sp., outcrop 32, bed 11, sample 3, slide 26.6, ammonite zone *Chetaites sibiricus*, Boreal Berriasian. – **8.** *Pareodinia* sp., outcrop 32, bed 11, sample 4, slide 27.2, ammonite zone *Chetaites sibiricus*, Boreal Berriasian. – **9.** *Spiniferites ramosus* (Ehrenberg 1838) Mantell 1854, outcrop 32, bed 11, sample 4, slide 27.1, ammonite zone *Chetaites sibiricus*, Boreal Berriasian. – **10.** *Apteodinium granulatum* Eisenack 1958, outcrop 33, bed 31, sample 31.2, slide 107.2, ammonite zone *Surites analogus*, Boreal Berriasian. – **11.** *Mendicodinium* sp., outcrop 33, bed 32, sample 32.1, slide 110.1, ammonite zone *Surites analogus*, Boreal Berriasian. – **12.** *Tubotuberella egemeni* (Gitmez 1970) Stover & Evitt 1978, outcrop 33, bed 33, sample 33.1, slide 111.1, ammonite zone *Surites analogus*, Boreal Berriasian. – **13.** *Cyclonephelium cuculliforme* (Davies 1983) Århus 1992, outcrop 32, bed 16, sample 1, slide 35.1, ammonite zone *Hectoroceras kochi*, Boreal Berriasian.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by the boundaries coinciding with those of ammonite zones. Thus, ammonite zones were simply "filled" by microfauna characteristics, which often were the same in the adjacent ammonite zones.

The foraminiferal zonation of the Nordvik succession is based on the analysis of the stratigraphic distribution of microfauna, using the ammonite zones only as a control of the stratigraphic range of foraminiferal zones and the basis for their calibration against the Boreal Zonal Standard. As a result, six foraminiferal zones and subzones were established (Fig. 3). Foraminiferal assemblages of the *Dorothia tortuosa* JF51 zone and *Ammodiscus veteranus*, *Evolutinella emeljanzevi* JF52 zone are characterized by rather wide geographic distributions. Similar assemblages are found in the Barents Sea as well as in Eastern and Western Siberia in the same stratigraphic intervals (Dain 1972; Sharovskaya & Basov 1961; Grigelis 1982; Basov et al. 1989). Other zones and especially subzones are only observed in NE Siberia (Basov et al. 1970).

No considerable changes in the foraminiferal assemblages were observed near the horizons regarded as the Jurassic-Cretaceous boundary (version A and B) (Fig. 3). Most Upper Volgian foraminifer species cross the base of the *Chetaites sibiricus* ammonite zone (version B). Only one species (*Trochammina septentrionalis*) has its extinction there. The inception of new taxa and the shift of dominant taxa have been revealed little upward the section, at the base of *Gaudryina gerkei*, *Ammobaculites gerkei* KF1 zone (Fig. 3). The base of the *Craspedites okensis* ammonite zone (version A) is crossed by some taxa from the Middle Volgian: *Ammodiscus veteranus*, *Evolutinella emeljanzevi*, *Recurvoides praeobskiensis*, *Trochammina rosacea*, *Marginulinopsis borealis*, *Marginulina striatocostata*, *Dorothia tortuosa*, and *Marginulinita kasakhstanica*. Considerable changes of foraminiferal assemblages occur somewhat below this level, at the base of the *Ammodiscus veteranus*, *Evolutinella emeljanzevi* JF52 zone. A number of taxa widespread in the Lower and Middle Volgian have their last occurrences at this boundary: *Geinitzinita praenodulosa*, *Grigelis* sp., *Cribrostomoides* ex gr. *kellogensis*, *Spiroplectammina vicinalis*, *Saracenaria pravoslavlevi*, *Marginulina* sp., *Marginulinopsis embaensis*, and *Dentalina* ex gr. *gracilis*. The following characteristic Upper Volgian and Boreal Berriasian taxa have their first occurences there: *Evolutinella emeljanzevi*, *Geinitzinita arctocretacea*, *Lenticulina* ex gr. *novella*, *L. sossipatrovae*, *Marginulina vermis*, *Trochammina rosaceaformis*, and *Saracenaria bassovi* (Fig. 3).

The strongest changes in the dinocyst assemblages occur at the base of the *Paragonyaulacysta ?borealis*, *Dingodinium ?spinosum* zone (Fig. 5, 6). Near the base of this zone, the extinctions of the following characteristic Upper Jurassic dinocysts are observed: *Tubotuberella dangeardii*, *Scriniodinium anceps*, *Cribroperidinium ?longicorne*, *Imbatodinium kondratjevii*, and *Gonyaulacysta dualis* (Fig. 5), although two latter species (*Imbatodinium kondratjevii* and *Gonyaulacysta dualis*) are reported from the Lower Cretaceous of the Barents Sea (Århus et al. 1990), Canada (Bujak & Williams 1978) and Newfoundland (Van Helden 1986). A number of Tithonian-Berriasian taxa have their first occurences slightly above the base of this zone: *Wallodinium krutzschii*, *Tanyosphaeridium magneticum*, *T. isocalamum*, *Wrevittia helicoidea*, *Dingodinium ?spinosum*, *Scriniodinium pharo*, and *Ctenidodinium ?thulium* (Fig. 5). These species are widely known from Arctic and Boreal regions. They are traditionally used in the Tithonian-

Berriasian dinocyst zonation of Arctic Canada (Davies 1983; Van Helden 1986; Århus et al. 1990), N Europe (Duxbury 1977; Fisher & Riley 1980; Davey 1979, 1982; Riding et al. 1999) and Siberia (Ilyina 1988; Riding et al. 1999; Lebedeva & Nikitenko 1998, 1999; Shurygin et al. 2000). The first occurences of *Dingodinium ?spinosum* and *Scriniodinium pharo* at this level (the lowermost Upper Volgian or the Upper Portland) are also observed in W Europe (Davey 1979, 1982; Fisher & Riley 1980; Rawson & Riley 1982; Powel 1992; Duxbury et al. 1999). Thus, the base of the *Paragonyaulacysta ?borealis*, *Dingodinium ?spinosum* zone may be regarded as a reliable correlative marker.

A characteristic feature of this zone is the abundance of *Paragonyaulacysta ?borealis*, which is observed all over the Arctic Realm: Arctic Canada (Davies 1983; Brideaux & Fisher 1976; Van Helden 1986), Alaska (Wiggins 1969), Barents Sea (Århus et al. 1990), N Siberia (Ilyina 1988; Fedorova et al. 1993; Schulgina et al. 1994; Riding et al. 1999; Lebedeva & Nikitenko 1998, 1999; Shurygin et al. 2000), Spitsbergen, and Greenland (Häkanson et al. 1981). The analysis of the Nordvik succession shows that this species is most abundant in the stratigraphic interval from the *Craspedites okensis* ammonite zone to the lowermost part of the *Neotollia klimovskiensis* ammonite zone. Therefore, the acme of *Paragonyaulacysta ?borealis* is a reliable marker level providing circum-Arctic correlations (Fig. 5).

The assemblage with *Paragonyaulacysta ?borealis* was originally established in Arctic Canada and islands of the Arctic Archipelago (Brideaux & Fisher 1976). Its stratigraphic extent was based on the lowermost and uppermost occurrences of *Paragonyaulacysta ?borealis*, ranging from the Oxfordian to Lower Berriasian. Pocock (1980) considered this species as index taxon for the Tithonian-Lower Berriasian zone in Arctic Canada. Davies (1983) defined a *Cyclonephelium cuculliforme-Paragonyaulacysta ?borealis* zone in the Upper Jurassic and Lower Cretaceous of the Sverdrup Basin (Arctic Canada) dated by ammonites and *Buchia*. Its base is indicated by the first occurences of *Cyclonephelium cuculliforme*, while its top is identified by the last occurrence of *Paragonyaulacysta ?borealis*. Due to the lack of macrofauna in the lower part of this zone, the precise stratigraphic position of its base was not established. It ranges between the Upper Tithonian and Lower Berriasian. The upper boundary is defined at the top of Lower Valanginian *Temnoptychites kemperi* ammonite zone. In the Nordvik section, Ilyina (1988) established the dinocyst zone *Paragonyaulacysta ?borealis -Tubotuberella rhombiformis* based on the abundance peaks of index taxa and dated by ammonites (*Craspedites okensis-Chetaites sibiricus* zones). The upper boundary of this zone was conventionally established at the top of *Chetaites sibiricus* zone as there were no palynological samples available from higher in the section. In the Subarctic Ural, the stratigraphic range of the *Paragonyaulacysta ?borealis* assemblage zone is defined as the uppermost Volgian – Berriasian (ammonite zones *Craspedites taimyrensis – Surites analogus*), although this species is also reported from the lowermost Valanginian (Lebedeva & Nikitenko 1998, 1999). The analysis of the continuous Nordvik succession now allows an accurate determination of the palynological criteria and stratigraphic range of this dinocyst zone.

The reliable correlative marker is the base of the Pareodinioideae, *Batioladinium varigranosum*, *Cassiculosphaeridia reticulata* subzone. Some important Lower Cretaceous species have their first occurences there (Fig. 5). The first occurence of *Cassiculosphaeridia* *reticulata* at this level was also observed in Subarctic Ural (Lebedeva & Nikitenko 1998, 1999). *Batioladinium varigranosum* is reported from the Upper Berriasian of Newfoundland (Van Helden 1986) and NW Europe (Davey 1982). Its inception provides a direct calibration of the lower boundaries of the Pareodinioideae, *Batioladinium varigranosum*, *Cassiculosphaeridia reticulata* subzone and the *Scriniodinium campanula* zone of Newfoundland (Van Helden 1986). The occurrence of *Cyclonephelium cuculliforme* allows the correlation of the Pareodinioideae, *Batioladinium varigranosum*, *Cassiculosphaeridia reticulata* subzone and the *Cyclonephelium cuculliforme-Paragonyaulacysta ?borealis* zone of Arctic Canada (Davies 1983).

At the base of the *Escharisphaeridia* spp., *Oligosphaeridium* spp., *Circulodinium* spp. zone, the last occurrences of *Paragonyaulacysta ?borealis* and *Tubotuberella rhombiformis* have been observed (Fig. 5). *Tubotuberella rhombiformis* may be regarded as a characteristic Berriasian species of Arctic regions as it is only reported from Subarctic Ural (Lebedeva & Nikitenko 1998, 1999), NE Siberia (Ilyina 1988; Shulgina et al. 1994; Riding et al. 1999) and Arctic Canada (Brideaux & Fisher 1976; Davies 1983). The extinction of *Paragonyaulacysta ?borealis* in the lowermost Lower Valanginian is also reported for northern regions of Canada (McIntyre & Brideaux 1980), Norway (Århus et al. 1986) and Subarctic Ural (Lebedeva & Nikitenko 1998, 1999). The diversity decrease of the subfamily Pareodinioideae is also typical for the uppermost Berriasian – lowermost Valanginian dinocyst assemblages of other regions in the north of Siberia: Anabar Bay (Pestchevitskaya 2000) and the Yenisey River mouth (Pestchevitskaya 2005).

Microbenthos and marine palynomorphs associations

The Nordvik section represents a continuous succession evidencing middle and lower sublittoral zones that are sometimes characterized by dysaerobic conditions (Fig. 7). Previous palaeoecological reconstructions were based on detailed investigations of macrofauna communities (Basov et al. 1970; Bogolepov 1983; Zakharov et al. 1983).

The lower sublittoral zone is characterized by an alternation of black clays enriched by organic matter and the blue-grey and dark grey clays, sometimes with glauconite (Fig. 7). Nekton is represented by rare ammonites and belemnites, macrobenthos comprises rare bivalves and gastropods. Among the bivalves, pseudoplanktonical *Aequipecten* and eurybiontic *Buchia* are most abundant (Zakharov et al. 1983). It is interesting to note that bivalve shells are confined to the blue-grey clays, while abundant *Aequipecten* together with fossil fishes are observed in dark grey clays enriched by organic matter. In the middle sublittoral zone, the leptochlorite and silt components increase. Bivalves are dominated by eurybiontic *Buchia*. Characteristic features are the occurrences of gastropods, scaphopods (*Dentalium*) and shot holes of silt-fed infauna (Basov et al. 1970; Zakharov et al. 1983).

The regularities of microbenthos and marine palynomorphs distribution in bionomical zones have been defined on the basis of micropalaeontological and palynological analyses providing more detailed information on the palaeoenvironments (the definition of distal and inner parts of middle and lower sublittoral zones).

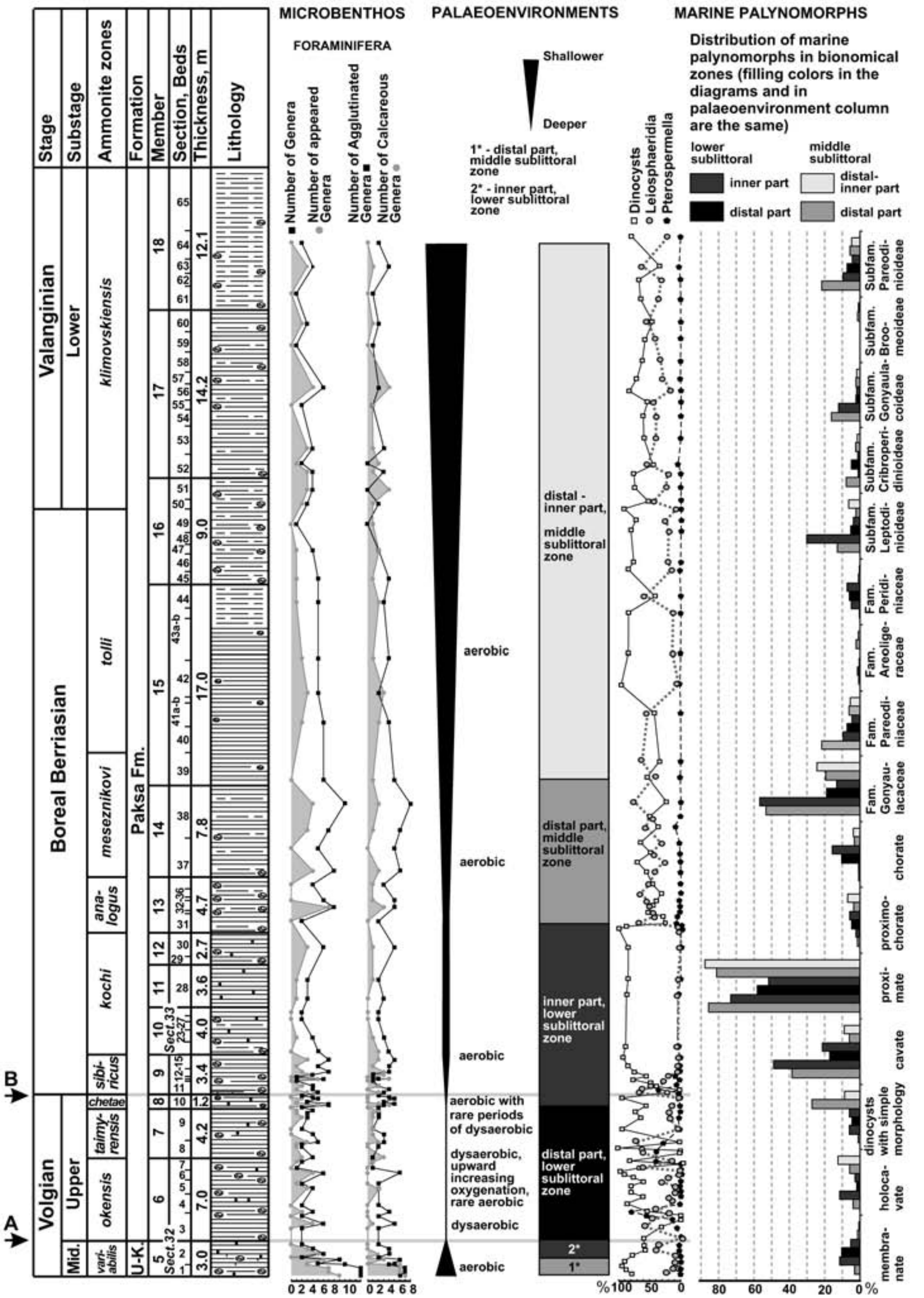

Fig. 7. Diversity of microfossils and abundance of selected taxonomic and morphological groups in the relation to palaeoenvironmental changes.

The most diverse foraminiferal communities have been defined for the aerated palaeoenvironments of middle sublittoral zone. Agglutinating forms are most abundant. The dominant taxa are *Dorothia*, *Recurvoides* and *Cribrostomoides* in the Middle Volgian, and *Recurvoides* and *Gaudryina* in the Boreal Berriasian. Boreal Berriasian assemblages also comprise rather abundant *Glomospirella*, *Lenticulina*, *Trochammina*, *Evolutinella*, and *Cribrostomoides* (Fig. 4). The characteristic feature of these assemblages is the inception of thermophilic *Valanginella* and *Epistomina* (Fig. 3, 4). Calcareous foraminifers are very diverse in the middle sublittoral zone, sometimes reaching high quantity there (*Lenticulina*, *Marginulina*, *Dentalina*, *Astacolus*, *Grigelis*). Nevertheless, their diversity further increases in the inner part of this zone: in the second half of the Berriasian the foraminiferal assemblages occasionally comprise only calcareous forms (*Epistomina*, *Valanginella*, *Lenticulina*, *Pseudonodosaria*).

The diversity of foraminiferal associations is reduced in the lower sublittoral zone. Agglutinated forms are more diverse in the inner part of this zone (4–7 species). In the Middle Volgian, they are dominated by *Evolutinella*, *Dorothia* and *Ammodiscus*. In the Berriasian, agglutinated foraminifers are more diverse. Commonly *Gaudryina* and *Recurvoides* dominate the assemblages (Fig. 4). *Lenticulina*, *Marginulina*, and *Trochammina* are rather abundant, while *Turritellella*, *Cribrostomoides*, *Ammobaculites*, and *Geinitzinita* are more rare. Rare calcareous foraminifers (*Lenticulina*, *Marginulina*) are the permanent members of the assemblages in the inner part of the lower sublittoral zone, while in the distal part they are almost lacking.

The distal part of the lower sublittoral is characterized by low microbenthos diversity (2–4, rarely 6 species). Associations are strongly dominated by eurybiontic and opportunistic species. Dysaerobic palaeoenvironments of the lower sublittoral zone (Late Volgian) are characterized by impoverished associations comprising 1–3 species of the genera *Ammodiscus*, *Evolutinella*, and sometimes *Recurvoides*. The typical feature is a wide distribution of the opportunistic species *Ammodiscus veteranus.* Similar foraminiferal associations are found in deep-water bituminous argillites of the Bazhenovo Formation, in central areas of the Western Siberian palaeobasin (Dain 1972; Grigelis 1982; Shurygin et al. 2000). In the late Late Volgian and Early Berriasian, there is an alternation of dysaerobic and aerobic conditions, which is evidenced by the occurrences of two types of foraminiferal assemblages: 1) very poor (1–2 genera, *Evolutinella* and *Ammodiscus*), and 2) more diverse (*Evolutinella*, *Recurvoides*, sometimes *Trochammina*, *Gaudryina*, *Lenticulina*, *Marginulina* and others) (Figs. 3, 4, 7).

Interestingly, a similar situation has been observed for the marine palynomorphs. The *chetae* and *sibiricus* chrons are characterized by two types of associations. The first one is dominated by dinocysts with numerous Gonyaulacaceae and proximate forms, while acritarchs and prasinophytes are rare. The associations of the second type (confined to black clays enriched with organic matter) are strongly dominated by *Leiosphaeridia* and diverse prasinophytes (Fig. 7). These associations are also typical for dysaerobic conditions of the distal part of the lower sublittoral zone.

In general, dinocyst associations in the lower sublittoral zone are less rich than in middle sublittoral zone, while some groups may reach high percentages there (Fig. 7). Only four groups (Peridiniaceae, proximochorate, chorate, membranate) are more abundant in this zone. The abundance peaks of the two last groups often correlate with high percentage of *Leiosphaeridia* and prasinophytes, suggesting that these dinocysts may be less sensitive to aerobic conditions. In contrast, the quantity of holocavate forms is sharply reduced in dysaerobic palaeoenvironments. The abundance peaks of these dinocysts have been defined for the areas transitional from the lower to middle sublittoral zone.

Marine palynomorph associations of the middle sublittoral zone are rich and abundant. In the Middle Volgian, they are dominated by dinocysts, while the Berriasian is characterized by an alternation of dinocyst and *Leiosphaeridia* dominances that may reflect the changes in the palaeobasin depth (Fig. 7). Among the dinocysts, Gonyaulacaceae, proximate and cavate groups are the most abundant and diverse (Fig. 7). In the Berriasian, the associations from the distal part of this zone also comprise very abundant dinocysts with simple morphology and increased percentages of Areoligeraceae. The inner part of the zone is marked by abundant holocavate forms and an increased quantity of chorate and proximochorate dinocysts. The last may be related with the change to warmer conditions caused by the shallowing of the palaeobasin.

Conclusions

The combined micropalaeontological and palynological analysis of an Upper Jurassic – Lower Cretaceous section from Nordvik Peninsula allows a comprehensive study of foraminifers, ostracods and marine palynomorphs across the Jurassic-Cretaceous boundary. The taxonomic composition of foraminiferal and palynological assemblages as well as the stratigraphic and palaeoenvironmental range of characteristic taxa and their groups have been analysed using original material and published data. New data and good sample recovering provide a more detailed microfossil zonation, than it was proposed earlier, and an accurate determination of the palynological criteria and stratigraphic range of the *Paragonyaulacysta ?borealis*, *Dingodinium ?spinosum* dinocyst zone.

Six foraminiferal and six dinocyst zones and subzones have been established (Fig. 8). Their stratigraphic positions are controlled by published macrofauna data. Two Volgian foraminiferal zones (*Dorothia tortuosa* JF51 zone, *Ammodiscus veteranus*, *Evolutinella emeljanzevi* JF52 zone) have a wide geographic distribution (Barents Sea, Western and Eastern Siberia), and may be regarded as correlative markers for Arctic regions. Other zones and especially subzones are useful for local correlations in NE Siberia. The palynological zonation allows the long-distance correlation on three levels. Due to the occurrences of *Dingodinium ?spinosum* and *Scriniodinium pharo*, the base of the *Paragonyaulacysta ?borealis*, *Dingodinium ?spinosum* zone (base of the Upper Volgian) is well traceable into Western Europe, while the acme of *Paragonyaulacysta ?borealis* is a reliable correlative marker for Arctic regions. The main features of the base of the Pareodinioideae, *Batioladinium varigranosum*, *Cassiculosphaeridia reticulata* subzone (the middle of the Berriasian) are the first occurrences of index species providing correlations with Newfoundland, NW Europe and Subarctic Ural. The extinction of *Paragonyaulacysta ?borealis* (the top of *Paragonyaulacysta ?borealis*, *Dingodinium ?spinosum* zone, the lowermost Valanginian) is followed in Subarctic Ural, Norway and northern Canada.

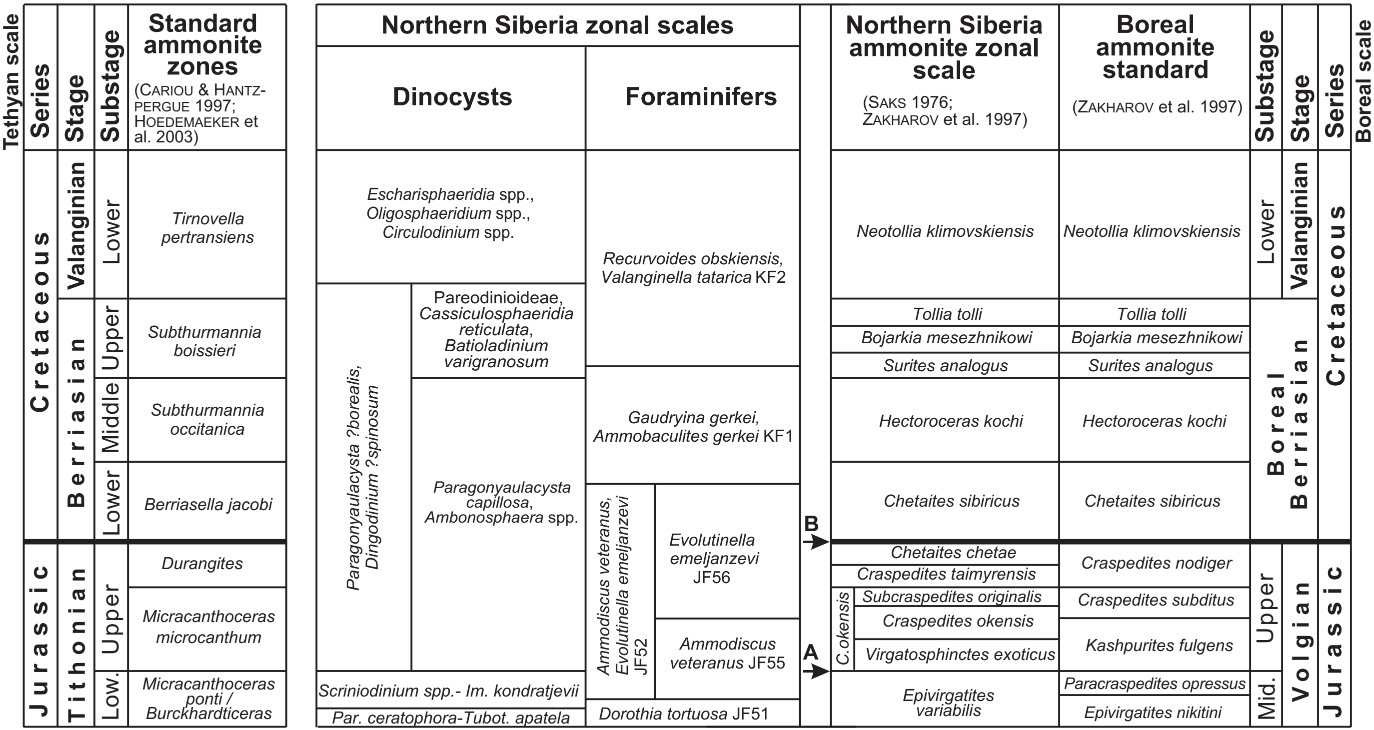

Fig. 8. Middle Volgian – Lower Valanginian zonation of microfossils in the Nordvik section and its calibration against ammonite Boreal Zonal Standard.

The changes in the taxonomic composition of microfossil assemblages and stratigraphic position of foraminiferal and dinocyst zones were analyzed taking into consideration two alternative locations of the Jurassic-Cretaceous boundary (A – base of the Upper Volgian, B – base of the Boreal Berriasian). Remarkable changes of the foraminiferal assemblages and the inceptions of stratigraphically important taxa have been revealed at the base of the *Gaudryina gerkei*, *Ammobaculites gerkei* KF1 zone (slightly higher location B). The base of the *Ammodiscus veteranus*, *Evolutinella emeljanzevi* JF52 zone (slightly lower location A) is marked by a significant turnover of characteristic species and dominant taxa. The most considerable changes in the taxonomic composition of dinocyst assemblages have been observed near the base of the *Paragonyaulacysta ?borealis*, *Dingodinium ?spinosum* zone (location A).

Micropalaeontological and palynological analysis as well as published data on macrofauna also allowed the reconstruction of a bionomical zonation ranging from the middle sublittoral to the lower sublittoral. The basin was well oxygenated except for the Late Volgian and the Earliest Berriasian, which were often characterized by aerobic to dysaerobic conditions.

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Appendix. List of marine palynomorph taxa

List of palynomorph species mentioned in the text and figures with full author citations according to Fensome & Williams (2004). The taxa marked by asterisks are named according to the previous species index of dinoflagellates as their systematic attribution is a matter of a discussion and is differently interpreted by different authors.

Dinocysts

Achomosphaera neptuni (Eisenack 1958) Davey & Williams 1966
Ambonosphaera spp.
Ambonosphaera delicata Lebedeva 1998
Ambonosphaera ?staffiensis (Gitmez 1970) Poulsen & Riding 1992
Aprobolocysta spp.
Apteodinium spp.
Apteodinium bacculiatum Davies 1983
**Apteodinium grande* Cookson & Hughes 1964
Apteodinium granulatum Eisenack 1958
**Apteodinium maculatum* Eisenack & Cookson 1960
Apteodinium ?vescum Matsuoka 1983
Batiacasphaera spp.
Batioladinium spp.

Batioladinium varigranosum (Duxbury 1977) Davey 1982
Cassiculosphaeridia magna Davey 1974
Cassiculosphaeridia reticulata Davey 1969
Chlamydophorella spp.
Chlamydophorella nyei Cookson & Eisenack 1958
Chytroeisphaeridia spp.
Circulodinium spp.
Circulodinium distinctum (Deflandre & Cookson 1955) Jansonius 1986
Cleistosphaeridium spp.
Cribroperidinium spp.
Cribroperidinium ?longicorne (Downie 1957) Lentin & Williams 1985
Cribroperidinium orthoceras (Eisenack 1958) Davey 1969
Cribroperidinium tensiftense Below 1981
Ctenidodinium ?thulium (Davies 1983) Jan du Chêne et al. 1986
**Cyclonephelium cuculliforme* (Davies 1983) Århus 1992
**Dingodinium albertii* Sarjeant 1966
Dingodinium minutum Dodekova 1975
Dingodinium ?spinosum (Duxbury 1977) Davey 1979
Dingodinium subtile Pestchevitskaya 2006
Dingodinium spp.
Dingodinium tuberosum (Gitmez 1970) Fisher & Riley 1980
Escharisphaeridia spp.
Escharisphaeridia granulata (Courtinat 1980) Stover & Williams 1987
Escharisphaeridia psilata Kumar 1986
Evansia sp.
Gochteodinia villosa (Vozzhennikova 1967) Norris 1978
Gonyaulacysta spp.
Gonyaulacysta dualis (Brideaux & Fisher 1976) Stover & Evitt 1978
Hologinella anabarensis Pestchevitskaya 2001
Hystrichodinium spp.
Imbatodinium kondratjevii Vozzhennikova 1967
Jansonia spp.
Kallosphaeridium spp.
Kiokansium spp.
Leberidocysta spp.
Leptodinium spp.
Lithodinia spp.
Mendicodinium spp.
Nelchinopsis kostromiensis (Vozzhennikova 1967) Wiggins 1972
Occisucysta spp.
Oligosphaeridium spp.
Paragonyaulacysta ?borealis (Bideaux & Fisher 1976) Stover & Evitt 1978
Paragonyaulacysta capillosa (Brideaux & Fisher 1976) Stover & Evitt 1978
Pareodinia spp.

Pareodinia ceratophora Deflandre 1947 emend. Gocht 1970
Pareodinia tamboviensis (Vozzhennikova 1967) Lentin & Vozzhennikova 1990
Pluriarvalium osmingtonense Sarjeant 1962
Scriniodinium spp.
Scriniodinium sp. A
Scriniodinium anceps (Raynaud 1978) Jan du Chêne et al. 1986
Scriniodinium campanula Gocht 1959
Scriniodinium pharo (Duxbury 1977) Davey 1982
Senoniasphaera jurassica (Gitmez & Sarjeant 1972) Lentin & Williams 1976 emend. Poulsen & Riding 1992
Sentusidinim spp.
Sirmiodiniopsis orbis Drugg 1978
Sirmiodinium grossii Alberti 1961
Spiniferites ramosus (Ehrenberg 1838) Mantell 1854
Stanfordella fastigiata (Duxbury 1977) Helenes & Lukas-Clark 1997
Tanyosphaeridium isocalamum (Deflandre & Cookson 1955) Davey & Williams 1969
Tanyosphaeridium magneticum Davies 1983
Trichodinium sp.
Trichodinium ciliatum (Gocht 1959) Eisenack & Klement 1964
Tubotuberella egemeni (Gitmez 1970) Stover & Evitt 1978
Tubotuberella apatela (Cookson & Eisenack 1960) Ioannides et al. 1977
Tubotuberella dangeardii (Sarjeant 1968) Stover & Evitt 1978
Tubotuberella rhombiformis Vozzhennikova 1967
Wallodinium spp.
Wallodinium cylindricum (Habib 1970) Duxbury 1983
Wallodinium krutzschii (Alberti 1961) Habib 1972
Wrevittia helicoidea (Eisenack & Cookson 1960) Helenes & Lucas-Clark 1997

Acritarchs

Leiofusa spp.
Micrhystridium spp.
Polygonium spp.
Solisphaeridium spp.
Veryhahium spp.

Prasinophytes

Leiosphaeridia spp.
Cymatiosphaera spp.
Pterospermella spp.
Pterospermella australiensis (Deflandre & Cookson 1955) Eisenack 1963
Pterosphaeridia spp.
Tasmanites spp.

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