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Dinocyst Biostratigraphy of the Lower Cretaceous in North Siberia

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Abstract—The described scheme of the Lower Cretaceous (Berriasian–Barremian) stratigraphic subdivisions is elaborated based on palynological study of sections in the Khatanga depression, Ust-Yenisei region, Pur–Taz interfluve, and around the Ob River latitudinal segment, the North Siberia. Stratigraphic distribution of microphytoplankton studied in detail is used to distinguish 10 biostratigraphic units in the rank of dinocysts zones. Stratigraphic position of the zones is determined with confidence using data on the Lower Cretaceous reference sections in the Khatanga depression, which were principal ones by constructing the Boreal standard zonation. In majority, boundaries of the dinocysts beds are of a high correlation potential and can be regarded as reliable stratigraphic markers, as they are recognizable not only in Siberia, but also in northern Europe and America.

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Key words: Lower Cretaceous, stratigraphy, dinocysts, Siberia, correlation, northern regions of Eurasia and America.

INTRODUCTION

Organic-walled microphytoplankton is widespread in the Lower Cretaceous deposits of western and central Siberia, as experts in palynology noted repeatedly. This group of very diverse microfossils includes dinoflagellate cysts (dinocysts), acritarchs, Chlorophyceae and Zignemataceae remains. A considerable stratigraphic potential of dinocysts well studied in taxonomic aspect is confirmed by a great amount of data on their stratigraphic and lateral distribution in Europe, Asia and America. At present, dinocysts are broadly in use for a high-resolution subdivision of the Lower Cretaceous in West Europe and Canada. In contrast, specialized investigations of dinocysts from the Lower Cretaceous of Siberia with parallel assessment of stratigraphic value of separate taxa are comparatively rare. Hence, new data in this sphere of biostratigraphy are of a great interest.

Presented in this work are the results of palynological study of the Lower Cretaceous sections in the north of western and central Siberia (Fig. 1) and the analysis of stratigraphic distribution of Early Cretaceous dinocysts in northern areas of Eurasia. The results of palynological analysis are used to subdivide in detail the respective North Siberian sections, to establish general succession of the Lower Cretaceous dinocysts zones, and to define correlation levels recognizable far beyond Siberia in northern Europe, Greenland and Canada.

Natural outcrops of the Lower Cretaceous in the Khatanga depression are of special importance for elaboration of the Siberian dinocyst scale. The respective sections bearing diverse paleontological remains facilitated construction of the Boreal standard zonations (Zakharov et al., 1997), and the distinguished palynostratigraphic units have been correlated with zonal subdivisions of macro- and microfauna. In the Berriasian, Valanginian and Hauterivian intervals of sections in the Nordvik Peninsula, the Anabar Bay eastern coast, their stratigraphic position has been controlled by data on ammonites, belemnites, bivalves and foraminifers (*The reference Section…*, 1981; Bogomolov et al., 1983; Zakharov et al., 1983; Bogomolov, 1989; Shenfil’, 1992; Marinov and Zakharov, 2001; Nikitenko et al., 2004). Foraminifers and ammonites have been also identified in borehole section Severo-Vologochanskaya 18 (Nikitenko et al., 2004), while ammonites, foraminifers and bivalves have been detected in the lower Valanginian of borehole section Romanovskaya 140 (Zakharov et al., 1999). In borehole section Gorshkovskaya 1017, age of deposits is defined by palynological data only, as faunal remains have not been found here.

MATERIAL AND INVESTIGATION METHODS

This study is based on palynological analysis of the Lower Cretaceous marine sections extending one another in vertical direction with partial overlap (Fig. 2). In total, the analyzed sections span stratigraphic inter-

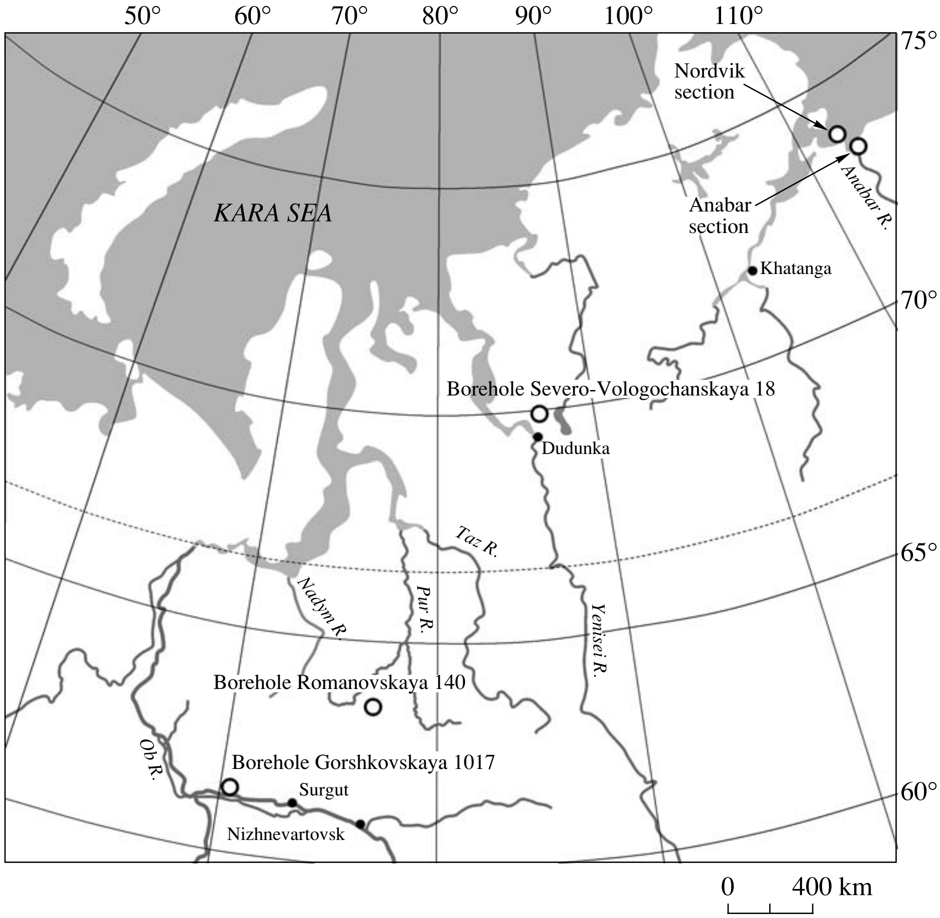


Fig. 1. Geographic localities of the studied sections.

val from the Berriasian up to the lower Barremian inclusive. In the Khatanga depression, the most complete succession has been studied in sections of the Nordvik Peninsula, where the Berriasian and Valanginian deposits are represented by gray clays and aleurites (Fig. 2). Sands prevailing in the Hauterivian Stage are intercalated with subordinate aleurite and clay interlayers of lesser thickness. In section of the Anabar Bay eastern coast, there is exposed only a lower part of the Valanginian. Silty calcareous clays prevailing in this section are intercalated with sandstone interlayers. In the Ust-Yenisei region, the upper Berriasian–lower Hauterivian succession studied in borehole section Severo-Vologochanskaya 18 is composed of gray aleurites with thin clay and sand interlayers (Fig. 3), and there is a general tendency of sandy material increase upward in the section. In the northwestern Siberia, the Lower Cretaceous successions are studied in borehole sections Romanovskaya 140 (Berriasian–Valanginian) and Gorshkovskaya 1017 (Hauterivian–basal Barremian). The first of these sections is composed of dark-colored shales in its lower part and of alternating siltstones and sandstones in the upper one (Fig. 4). The Hauterivian–Barremian deposits of the second section are represented by dark gray shales and sandstones (Fig. 2).

The lit-par-lit palynological analysis is performed for the majority of sections (Fig. 2). Core samples have been selected for analysis with interval of 0.5 to 2 m depending on composition of the rocks: preference was given to clayey and silty sediments usually containing most representative assemblages of palynomorphs. Before palynological analysis, rock samples have been treated in hydrochloric and nitric acids, and in sodium pyrophosphate solution. The cadmium liquid (CdI + KI) with specific gravity 2.25 was used to separate heavy fraction of sediments. Not less than 200 grains were counted in each slide to determine percentage of individual taxa relative to total amount of microphytofossils (spores, gymnosperm pollen, microphytoplankton). Boundaries of palynostratigraphic units are substantiated using the following criteria: first and last occurrences of species and genera, the grown diversity of certain genera and families, and increasing percentage of particular taxa (as additional indication). A special attention was paid to stratigraphic distribution of taxa most important for determination of biostratigraphic boundaries. First or last occurrence of such a taxon at the boundary of biostratigraphic unit corresponds respectively to its oldest or latest datum level not only in North Siberia, but also in other regions. To detect taxa of this kind, distribution of nearly 300 dinocyst species have been analyzed in Lower Cretaceous sections of Siberia (data on the studied sections), northern Europe and America (published data). Species of greatest interest for the Lower Cretaceous stratigraphy of Siberia are listed in Fig. 5 and figured in Plates I and II. Consequently, boundaries of distinguished dinocysts zones are in most cases the important stratigraphic markers of a great correlation potential.

INVESTIGATION HISTORY OF LOWER CRETACEOUS DINOCYSTS IN SIBERIA

Systematic investigations of Lower Cretaceous microphytofossils from Siberia commenced in the terminal 1980s. Il'ina (1988) was first to study microphytoplankton from the Jurassic–Cretaceous boundary deposits in the Nordvik Peninsula, and Fedorova et al. (1993) examined the Berriasian dinocysts of the Boyarka River section. Dinocyst assemblages from particular ammonite zones have been described however without distinguishing independent stratigraphic subdivisions substantiated by dinocysts. Timoshina et al. (1999) described for the first time the freshwater microphytoplankton from the Hauterivian, Barremian and Aptian deposits of the Khatanga depression, while Lebedeva and Nikitenko (1998, 1999) established almost continuous succession of dinocysts zones in the Yatriya River section (Subpolar Urals) beginning from the upper Volgian up to the lower Hauterivian inclusive. In the last works, the distinguished biostratigraphic units have been correlated with the Boreal dinocyst zonations of Europe and Canada, and basic trends of microphytoplankton distribution depending on sedimentary facies have been elucidated. A few works are dedicated to the same approach used for stratigraphic subdivision of the Lower Cretaceous deposits recovered by drilling in unexposed areas of West Siberia (Mchedlishvili, 1971; *Multidisciplinary Study…*, 1978; Lebedeva and Pestchevitskaya, 1998; Kirichkova et al., 1999; Basel et al., 2002).

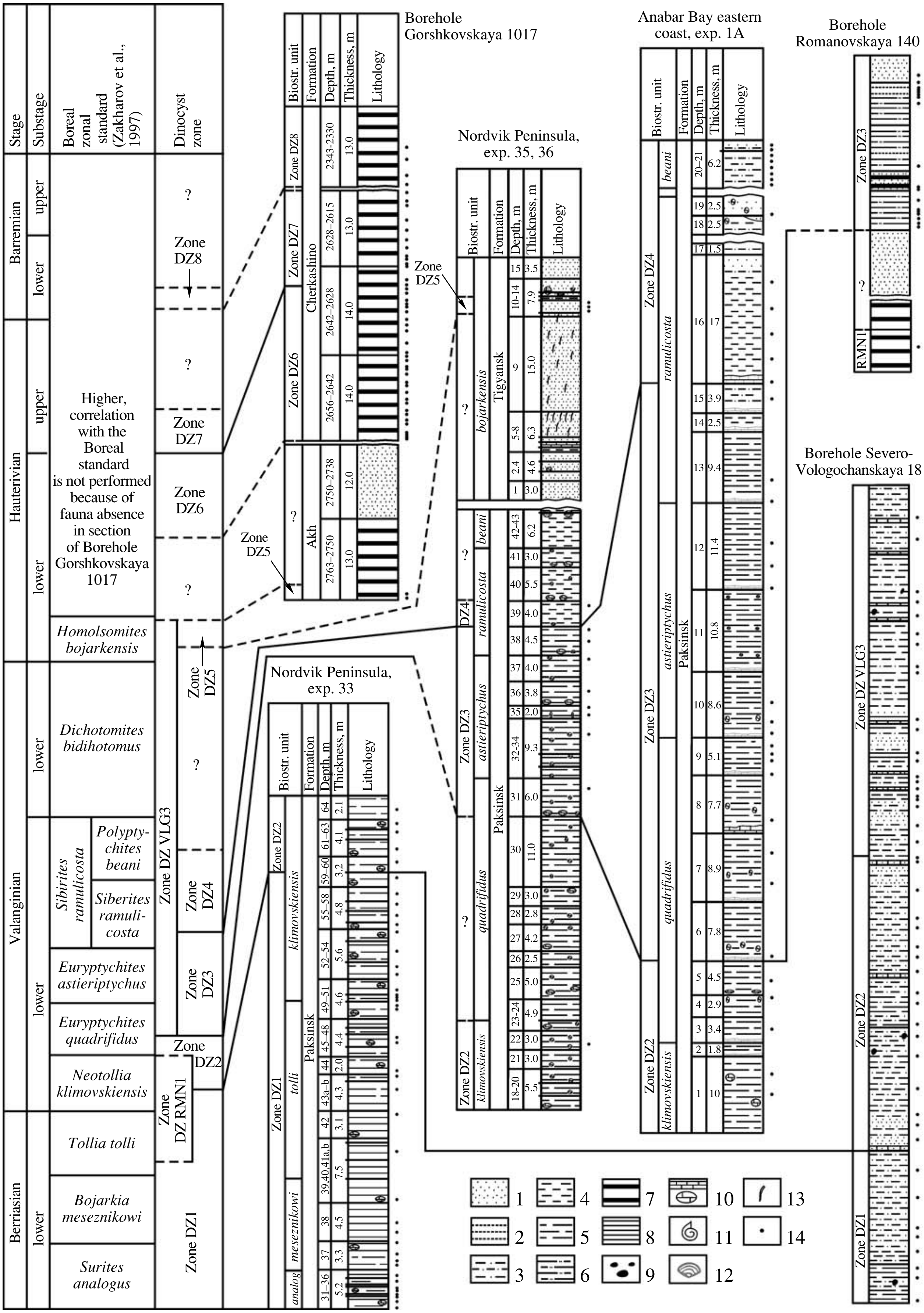
Limited data on dinocysts from the study region have been obtained by N. Aarhus (see in Shul'gina et al., 1994) who studied these fossils in the Jurassic–Cretaceous boundary beds and the lower Berriasian of the Nordvik Peninsula. The upper Berriasian has not been investigated, whereas the Valanginian and Hauterivian intervals have been sampled here at random. My own data characterize palynology of these intervals more exactly (Pestchevitskaya, 2002; Nikitenko et al., 2004). In addition, successions of microphytoplankton assemblages have been established in the Lower Cretaceous sections of the Anabar Bay eastern coast (Pestchevitskaya, 1999, 2000), Ust-Yenisei region (Nikitenko et al., 2004; Pestchevitskaya, 2005b), Pur–Taz interfluve (Lebedeva and Pestchevitskaya, 1998; Zakharov et al., 1999), and around the latitudinal segment of the Ob River (Pestchevitskaya, 2005a).

Comprehensive study of the dinocysts' morphology was used to clarify characterization of certain taxa, to analyze their facies and paleogeographic distribution, and to describe new species (Pestchevitskaya, 2001, 2003, 2006a, 2006b). Stages of dinocysts' development in the Cretaceous seas of Siberia were identified, lateral radiation of microphytoplankton assemblages and diversity dynamics of some taxonomic and morphological groups depending on evolution of environments in the Siberian paleobasin were detected (Lebedeva and Pestchevitskaya, 1997; Pestchevitskaya, 2002, 2003). The succession of the Berriasian–Barremian dinocyst zones has been considered earlier (Pestchevitskaya, 2005a, 2006). Description of these zones is presented below for the first time.

DINOCYST ZONES OF THE LOWER CRETACEOUS IN NORTH SIBERIA

Pareodinioideae–Batioladinium varigranosum–Cassiculasphaeridia reticulata Zone (dinocyst assemblage 1 (DZ1) (Figs. 2, 5)

Characteristic taxa. Dinocysts of simple morphology (*Batiacasphaera norvikii* Burger, *Escharisphaeridia psilata* Kumar, *Sentusidinium* spp.), typical of the beds occur in association with *Sirmiodinium grossii* Alberti, *Jansonia* spp., *Microdinium opacum* Brideaux, *Sirmiodiniopsis orbis* Drugg, *Tubotuberella apatela* (Cookson et Eisenack) Ioannides, *T. rhombiformis* Vozzhennikova, *Chlamydophorella nyei* Cookson et Eisenack, *Ambonosphaera* spp., *Occisucysta wierzbowskii* Poulsen, and *Wrevittia helicoidea* (Eisenack et Cookson) Helenes et Lucas-Clark. Abundance of the first three taxa can be significant. An important feature is persistent diversity of the subfamily Pareodinioideae (*Paragonyaulacysta ?borealis* (Brideaux et Fisher) Stover et Evitt, *Pareodinia ceratophora* Deflandre, *P. minuta* Wiggins, *P. arctica* Wiggins, *Pluriarvalium osmingtonense* Sarjeant, *Evansia evittii* (Pocock) Jansonius and others). Genera *Dingodinium, Fromea, Wallodinium, Cribroperidinium, Tubotuberella*, and *Apteodinium* are diverse as well. Stratigraphically important species are *Cyclonephelium cuculliforme* (Davies) Aarhus, *Stanfordella exanguia* (Duxbury) Helenes et Lucas-Clark, *Cassiculasphaeridia reticulata* Davey, *Achomosphaera neptunii* (Eisenack) Davey et Williams, *Dingodinium ?spinosum* (Duxbury) Davey, *Batioladinium varigranosum* (Duxbury) Davey, *Athigmatocysta* aff. *glabra* Duxbury, and *Spiniferites ramosus* (Ehrenberg) Monteil. Also characteristic of the zone is occurrence of *Horologinella anabarensis* Pestchevitskaya, *Dingodinium minutum* Dodekova, *D. tuberosum* (Gitmez) Fisher et Riley, *D. subtile* Pestchevitskaya, *Cassiculasphaeridia magna* Davey, *Apteodinium granulatum* Eisenack, *A. grande* Cookson et Hughes, *A. maculatum* Eisenack et Cookson, *Circulod-*


Stage
Substage
Boreal zonal standard (Zakharov et al., 1997)
Dinocyst zone
Barremian
Hauterivian
Valanginian
Berriasian
upper
lower
Higher, correlation with the Boreal standard is not performed because of fauna absence in section of Borehole Gorshkovskaya 1017
Homolsomites bojarkensis
Dichotomites bidihotomus
Sibirites ramulicosta
Polyptychites beani
Siberites ramulicosta
Euryptychites astieriptychus
Euryptychites quadrifidus
Neotollia klimovskiensis
Tollia tolli
Bojarkia meseznikowi
Surites analogus
Zone DZ8
Zone DZ7
Zone DZ6
Zone DZ5
Zone DZ4
Zone DZ3
Zone DZ2
Zone DZ VLG3
Zone DZ RMN1
Zone DZ1
Borehole Gorshkovskaya 1017
Biostr. unit
Formation
Depth, m
Thickness, m
Lithology
Cherkashino
Akh
2343–2330
2628–2615
2642–2628
2656–2642
2750–2738
2763–2750
Nordvik Peninsula, exp. 35, 36
Tigyansk
Paksinsk
bojarkensis
beani
ramulicosta
astieriptychus
quadrifidus
klimovskiensis
Nordvik Peninsula, exp. 33
tolli
meseznikowi
analog
Anabar Bay eastern coast, exp. 1A
Borehole Romanovskaya 140
RMN1
Borehole Severo-Vologochanskaya 18
Zone DZ VLG3
1 2 3 4 5 6 7 8 9 10 11 12 13 14

inium spp., *Cleistosphaeridium* spp., *Cribroperidinium tensiftense* Below, *Tanyosphaeridium magneticum* Davies, and *Leberidocysta spinose* Pestchevitskaya.

Lower boundary is defined in the Nordvik Peninsula only (Nikitenko et al. 2004) at the first occurrence level of *Batioladinium varigranosum, Cassiculasphaeridia reticulata*, and *Tanyosphaeridium magneticum.*

Remarks. Basic taxa of the assemblage, representatives of the subfamily Pareodinioideae inclusive, are widespread not only in the Berriasian of North Eurasia, but in the Upper Jurassic as well (Brideaux and Fisher, 1976; Fisher and Riley, 1980; Rawson and Riley, 1982; Davey, 1982; Davies, 1983; Van Helden, 1986; Lebedeva and Nikitenko, 1998; Riding et al., 1999). On the other hand, the assemblage includes stratigraphically important species, first occurrence of which is recorded in the Berriasian of Canada and northern Europe. First occurrence of *Batioladinium varigranosum* in mid-Berriasian strata is known in northwestern Europe (Davey, 1982) and Newfoundland (Van Helden, 1986). Oldest *Cassiculasphaeridia reticulata* forms are found at the base of the *Bojarkia payeri* Zone in the Subpolar Urals (Lebedeva and Nikitenko, 1998). In northern Europe, species *Tanyosphaeridium magneticum* has been observed until present only in the Valanginian, Hauterivian and Barremian dinocyst assemblages (Davies, 1983; Nøhr-Hansen, 1993; Prössl, 1990). An important component of the assemblage is *D. ?spinosum*, the characteristic Berriasian taxon regarded by some researchers as zonal index species (Fisher and Riley, 1980; Rawson and Riley, 1982). Species *Tubotuberella rhombiformis, Paragonyaulacysta ?borealis* and *Cyclonephelium cuculliforme* are reported only from the Subpolar Urals (Lebedeva and Nikitenko, 1998), Khatanga depression (Il'ina 1988; Shulgina et al., 1994; Riding et al., 1999) and Arctic Canada (Brideaux and Fisher, 1976; Davies, 1983) and can be considered as characteristic taxa of subpolar regions in Siberia and Canada. In the studied sections, the persistent occurrence of *Tubotuberella rhombiformis* is limited by the top of zone DZ1. The first occurrence level of *Cyclonephelium cuculliforme* is an important stratigraphic indication, as in Arctic Canada this taxon is one of index species of the respective Berriasian zone (Davies, 1983). *Paragonyaulacysta ?borealis* widespread in the Upper Jurassic and Berriasian deposits is accepted to be the index species of the *Paragonyaulacysta ?borealis–Dingodinium ?spinosum* dinocyst zone (within the extent of *Craspedites okensis*–basal *Neotollia klimovskiensis* ammonite zones), which is recognizable in subpolar regions of Canada and Siberia (Brideaux and Fisher, 1976; Pocock, 1980; Davies, 1983; Il'ina, 1988; Riding et al., 1999; Lebedeva and Nikitenko, 1998, 1999; Nikitenko et al., 2004). Oldest specimens of *Achomosphaera neptunii* have been found at the Berriasian Stage base in Boreal regions of Canada (Williams et al., 1974; Jenkins et al. 1974; Bujak and Williams, 1978) and not far away from Moscow (Iosifova, 1996). In many sections of Greenland and western Europe, this species has been found in the upper Berriasian and Valanginian (Duxbury, 1977; Davey, 1979; Piasecki, 1979; Fisher and Riley, 1980; Duxbury et al., 1999). In the studied sections, persistent occurrence of *Dingodinium subtile* has been observed only in the upper Berriasian, whereas its specimens are extremely rare at higher levels.

In the Pur–Taz interfluve (Borehole Romanovskaya 140), where the zone DZ1 have not been detected, I distinguished zone DZ RMN1 of the wider upper Berriasian–lower Valanginian stratigraphic range.

Type section: the Nordvik Peninsula; Exposure 33, beds 31–59 of argillite-like silty splintery clays bluish to dark gray, with subordinate interlayers of brownish gray flaggy clay of lesser thickness and with thin lenticular intercalations and concretions of limestone (Basov et al., 1970; Zakharov et al., 1983).

Distribution: Khatanga depression (middle part of the Paksa Formation); Ust-Yenisei region (uppermost Nizhnyaya Kheta and basal Sukhaya Dudinka formations).

Stratigraphic position: Upper Berriasian–basal Valanginian interval corresponding to extent of the *Surites analogus* and basal *Neotollia klimovskiensis* ammonite zones; established based on direct correlation with zones of the Boreal standard in section of the Nordvik Peninsula (Basov et al., 1970; Zakharov et al., 1983).

Paragonyaulacysta sp.–Batiacasphaera sp. Zone with DZ RMN1 (Fig. 2)

Characteristic taxa. Dinocysts are of extremely low taxonomic diversity, represented by *Paragonyaulacysta* sp., *Batiacasphaera* sp., and by poorly preserved proximate and chorate forms.

Lower boundary is tentatively defined at the section base.

Fig. 2. Correlation chart of the studied sections based on the established dinocyst zones in the north of Western and central Siberia. The lit-par-lit division of sections is done using the following works: Nordvik Peninsula—Basov et al., 1970; Zakharov et al., 1983; Bogomolov, 1989; Anabar Bay eastern coast—Bogomolov et al., 1983; Bogomolov, 1989; Borehole Severo-Vologochanskaya 18—Nikitenko et al., 2004; Borehole Romanovskaya 140—Zakharov et al., 1999; Borehole Gorshkovskaya 1017—unpublished data of V.A. Kazanenkov and O.O. Savchenkova. Lithology: (1) sands, sandstones; (2) sandy aleurolites; (3) sandy aleurites; (4) aleurites; (5) silty clays; (6) clayey aleurolites; (7) argillites; (8) clays; (9) pebbles; (10) calcareous interlayers and concretions; (11) ammonites; (12) bivalves; (13) fucoids; (14) sampling levels for palynological analysis.

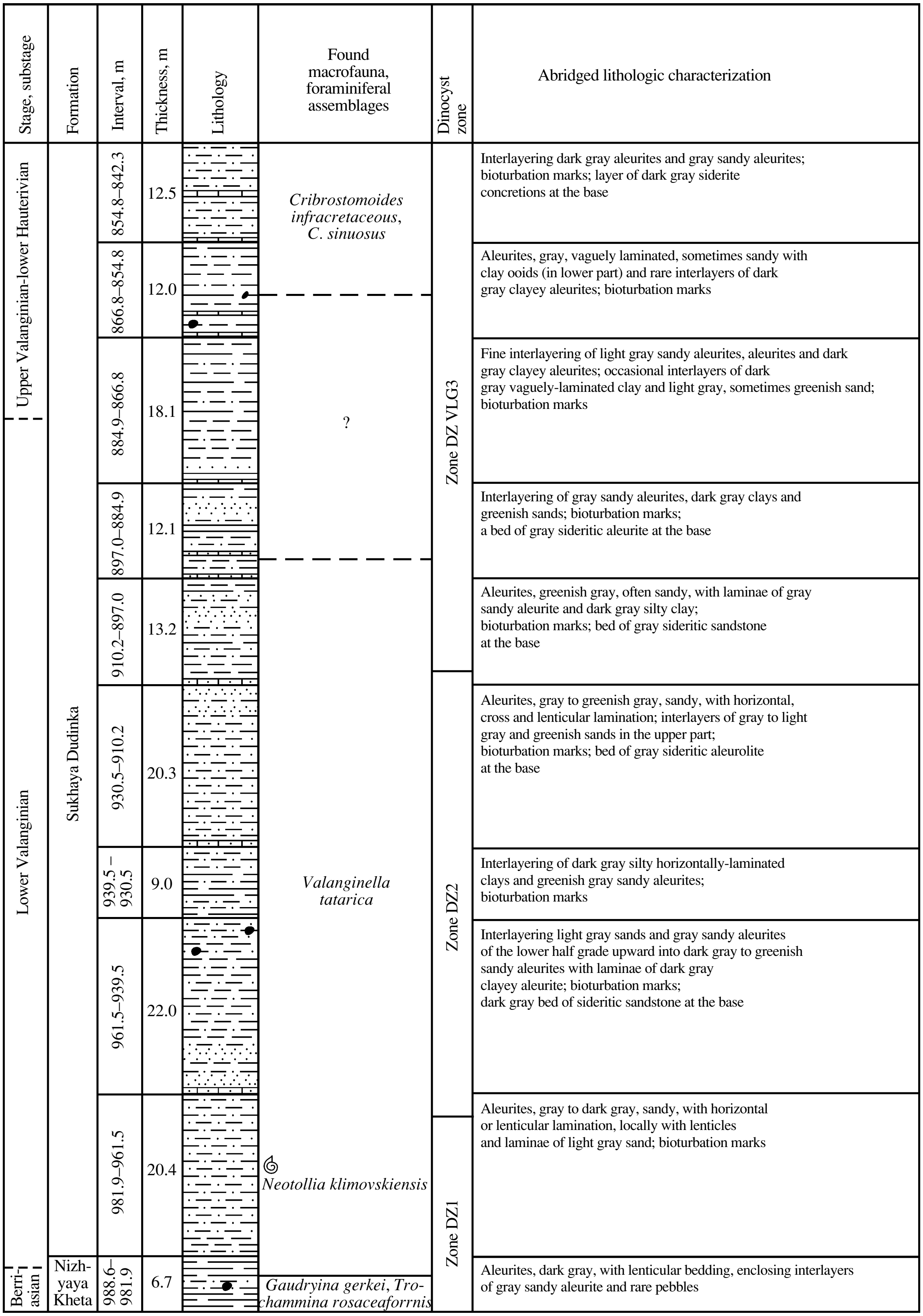


Fig. 3. The Lower Cretaceous section recovered by Borehole Severo-Vologochanskaya 18 (additional data from Nikitenko et al., 2004; symbols as in Fig. 2).

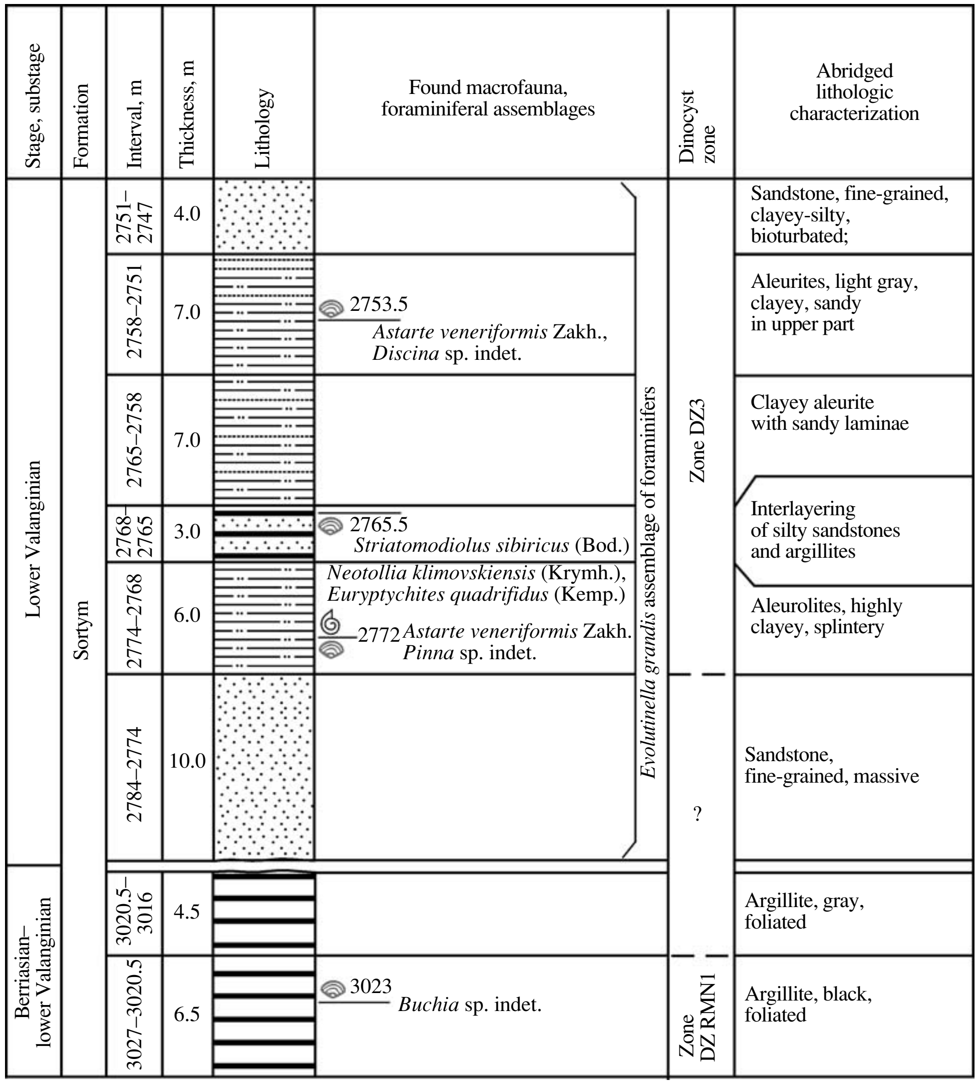


Fig. 4. The Lower Cretaceous section recovered by Romanovskaya 140 (additional data from Zakharov et al., 1999; symbols as in Fig. 2).

Remarks. Because of a very low diversity of dinocysts, it is impossible to define precisely stratigraphic position of the zone. Occurrence of *Paragonyaulacysta* sp. facilitates determination of their upper boundary only. As is established, representatives of this genus do not occur above the *Neotollia klimovskiensis* Zone in sections of the Nordvik Peninsula and the Anabar Bay eastern coast. The upper boundary is tentatively defined in the upper Berriasian.

Type section: Borehole Romanovskaya 140, depth interval 3027–3020.5 m; sediments are represented by black foliated argillites 6.5 m thick.

Distribution: Pur–Taz interfluve (lower part of the Sortym Formation).

Stratigraphic position: upper Berriasian–basal Valanginian.

Escharisphaeridia spp.–Oligosphaeridium spp.–Circulodinium spp. Zone (DZ2, Figs. 2, 5)

Characteristic taxa. Diversity of dinocysts is comparatively low. Main components of the assemblage are forms of simple morphology (*Escharisphaeridia* spp., *Batiacasphaera* spp., *Sentusidinium* spp.) and poorly preserved proximate dinocysts. Persistently occurring species are *Dingodinium* spp., *D. minutum, Oligosphaeridium* spp., *Cleistosphaeridium* spp., sometimes *Chlamydophorella* spp., *Cassiculasphaeridia reticulata* and *Jansonia* spp. Species *Sirmiodinium grossii, Circulodinium* spp., *Tubotuberella apatela, Trichodinium* spp., *Horologinella anabarensis*, *Cribroperidinium exilicristatum* (Davey) Stover et Evitt, *C.* aff. *sarjeantii* (Vozzhennikova) Helenes, some other *Cribroperidinium* forms, *Apteodinium maculatum, A. granulatum, A. ?vescum* Matsuoka, and *A.* cf. *grande* occur frequently. An important feature is the declined diversity

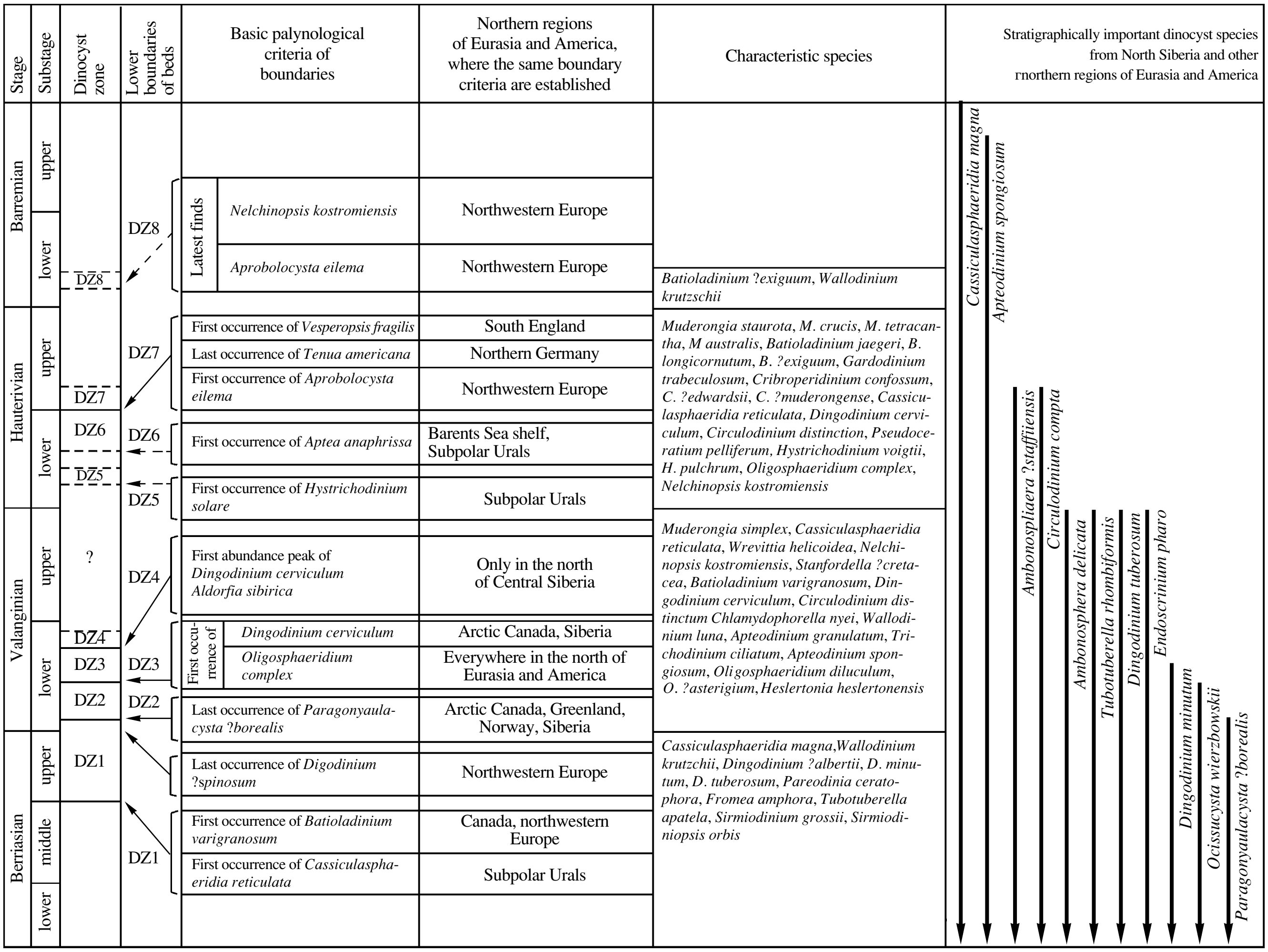


Fig. 5. Palynological substantiation of dinocyst zones, their stratigraphic position and generalized stratigraphic extents of stratigraphically important dinocysts (stratigraphic analysis and palynological comparison of Siberian, European and Canadian biostratigraphic units are performed using original and published data from works cited in the text and Table 4).

of Pareodinioideae represented by *Pluriarvalium* spp., *P. osmingtonense, Pareodinia* spp., *P. arctica*, and *P. ceratophora*, which occur irregularly. New forms occurring are *Nelchinopsis kostromiensis* (Vozzhennikova) Wiggins, *Sentusidinium granulatum* (Courtinat) Stover et Williams, *Circulodinium brevispinosum* (Pocock) Jansonius, *Aprobolocysta sp*., and *Trichodinium ciliatum* (Gocht) Eisenack et Klement.

Lower boundary defined in sections of the Nordvik Peninsula and Borehole Severo-Vologochanskaya 18 marks the last occurrence of *Pagaronyaulacysta* spp. and *P. ?borealis*, the diversity decrease of Pareodinioideae, and persistent presence of *Oligosphaeridium* spp. In the Nordvik Peninsula, *Tubotuberella* spp. and *Dingodinium subtile* occur at random above this level and *T. rhombiformis* disappears from the assemblage. Species *Wallodinium krutzschii* and *Wrevittia helicoidea* do not occur above this level in Borehole Severo-Vologochanskaya 18; *Dingodinium ?spinosum* and *Pareodinia minuta* become extinct somewhat lower.

Remarks. The last occurrence of *Paragonyaulacysta ?borealis* in the Valanginian basal interval is established in Arctic Canada, Greenland, Norway and Siberia, i.e., in the circum-Arctic regions, and the respective level is therefore a reliable stratigraphic marker (Aarhus et al., 1986; Aarhus et al., 1990; Shulgina et al., 1994; Lebedeva and Nikitenko, 1998; Nikitenko et al., 2004). The last occurrence level of *D. ?spinosum*, which is practically coincides with the Berriasian top in northern regions of western Europe (Duxbury 1977; Davey, 1979; Fisher and Riley, 1980; *A Stratigraphic…*, 1992; Duxbury et al., 1999), is the other important marker.

It is likely that the beds are thicker in Exposure 35 (Nordvik Peninsula) and span lower part of the *Euryptychites quadrifidus* Zone (Fig. 2), but having no samples from this part of the section for palynological anal-

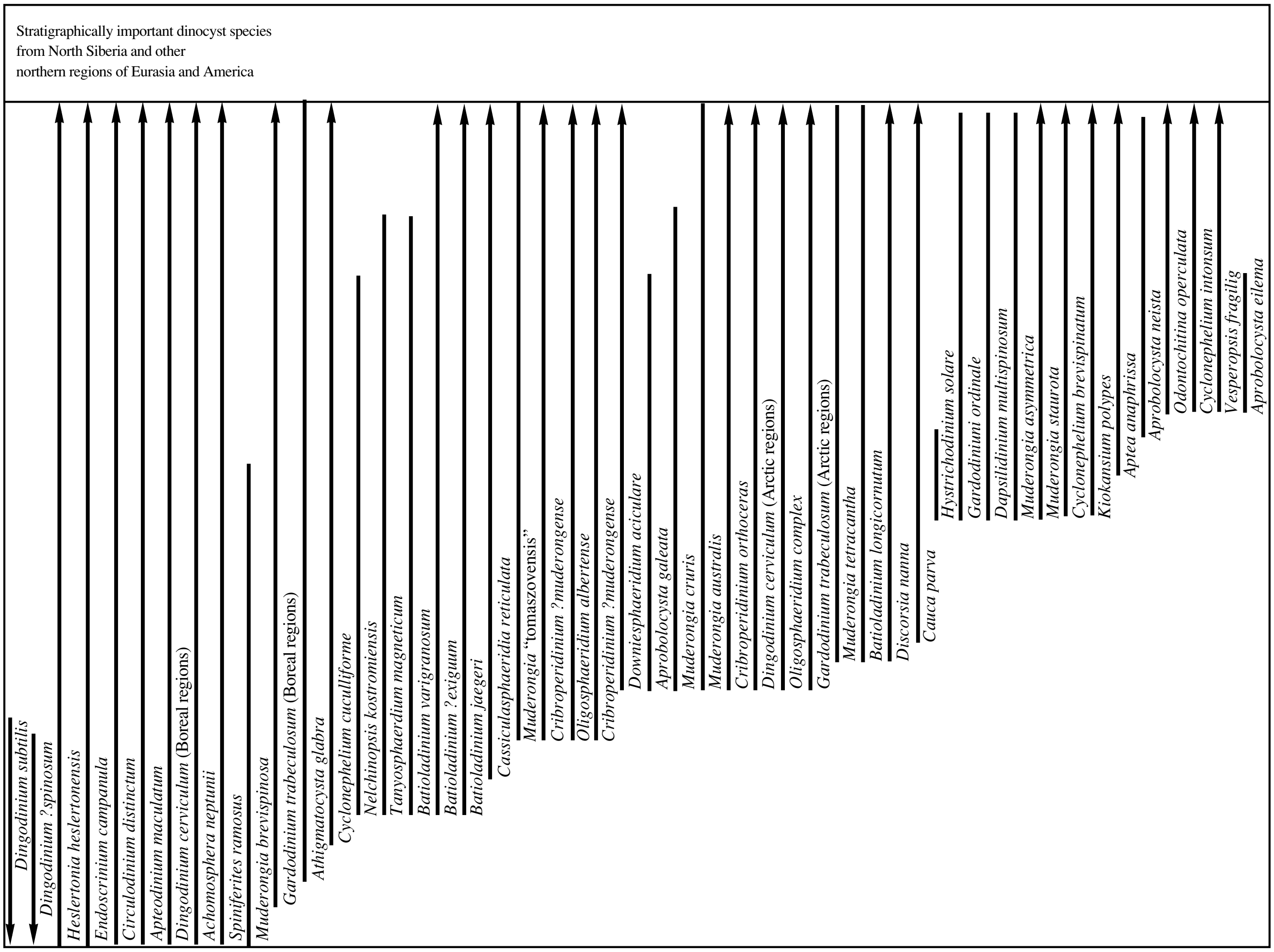


Fig. 5. (Contd.)

ysis I failed to define precisely the upper boundary position here.

Type section: the Nordvik Peninsula; Exposure 33, beds 60–64 of dark gray, argillite-like, silty splintery clays and clayey aleurites with interlayers of limestone concretions; thickness 7.7 m; Exposure 35, beds 18–22 of dark gray silty clay with lens-like limestone concretions; thickness 12.5 m (Basov et al., 1970; Zakharov et al., 1983; Bogomolov, 1989).

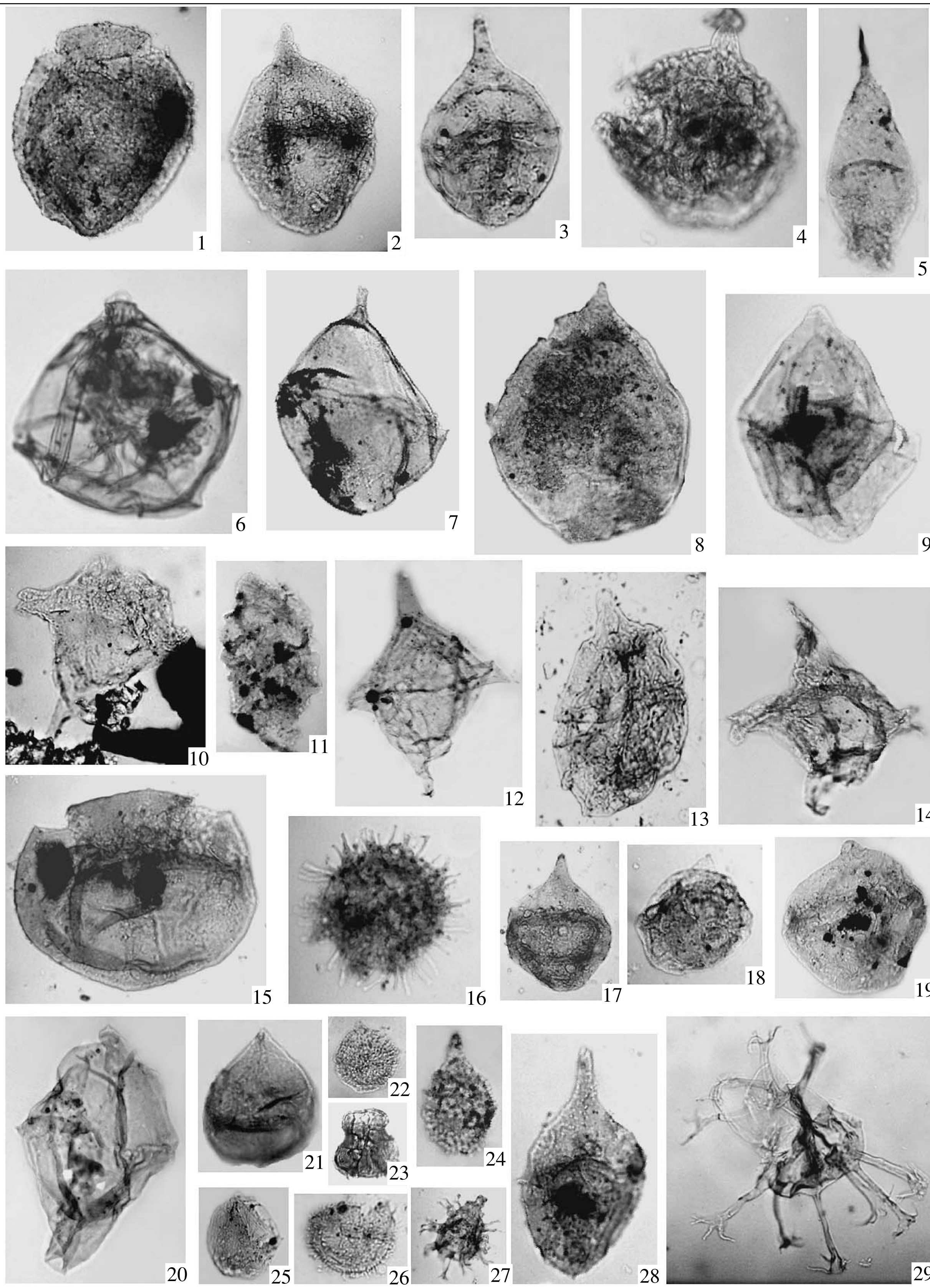
Distribution: Khatanga depression (middle part of the Paksa Formation); Ust-Yenisei region (lower part of the Sukhaya Dudinka Formation without very basal interval).

Stratigraphic position: the basal Valanginian, ammonite zones *Neotollia klimovskiensis* without its lowermost part and *Euryptychites quadrifidus* in its lower part; established based on direct correlation with the Boreal standard zones in sections of the Nordvik Peninsula (Basov et al., 1970; Zakharov et al., 1983; Bogomolov, 1989) and of the Anabar Bay eastern coast (Zakharov et al., 1983; Bogomolov, 1989).

Oligosphaeridium complex–Dingodinium cerviculum Zone (DZ3, Figs. 2,5)

Characteristic taxa. The grown diversity of dinocysts, persistently occurring among which are *Cassiculasphaeridia magna, Sirmiodinium grossii, Chlamydophorella nyei, Oligosphaeridium ?asterigium* (Gocht) Davey et Williams, *Fromea amphora, F. fragilis, Pareodinia ceratophora, Wallodinium luna, Dingodinium minutum, Muderongia simplex* Alberti emend. Riding et al., and representatives of genera *Dingodinium, Oligosphaeridium, Cleistosphaeridium, Escharisphaeridia, Sentusidinium*, and *Circulodinium.* A high diversity of the genus *Oligosphaeridium* is especially remarkable. In West Siberia, diversification of the genus *Muderongia* is established. Of prime importance is appearance of new species *Dingodinium cerviculum* Cookson et Eisenack emend. Khowaja-Ateequzzman et al., *Muderongia cruces* Neale et Sarjeant, *M. australis* Helby, *Gardodinium trabeculosum* (Gocht) Alberti, *Oligosphaeridium complex* (White) Davey et Williams, *O. albertense* (White) Davey et Williams, *O. diluculum*

Plate I



Davey, *Circulodinium distinctum* (Deflandre et Cookson) Jansonius, *Aprobolocysta galeata* Backhouse, *Canningiopsis colliveri* (Cookson et Eisenack) Backhouse, *Cribroperidinium ?muderongense* (Cookson et Eisenack) Davey, *C. orthoceras* (Eisenack) Davey, *Wrevittia cassidata* (Eisenack et Cookson) Helenes et Lucas-Clark, and *Trichodinium speetonense* Davey.

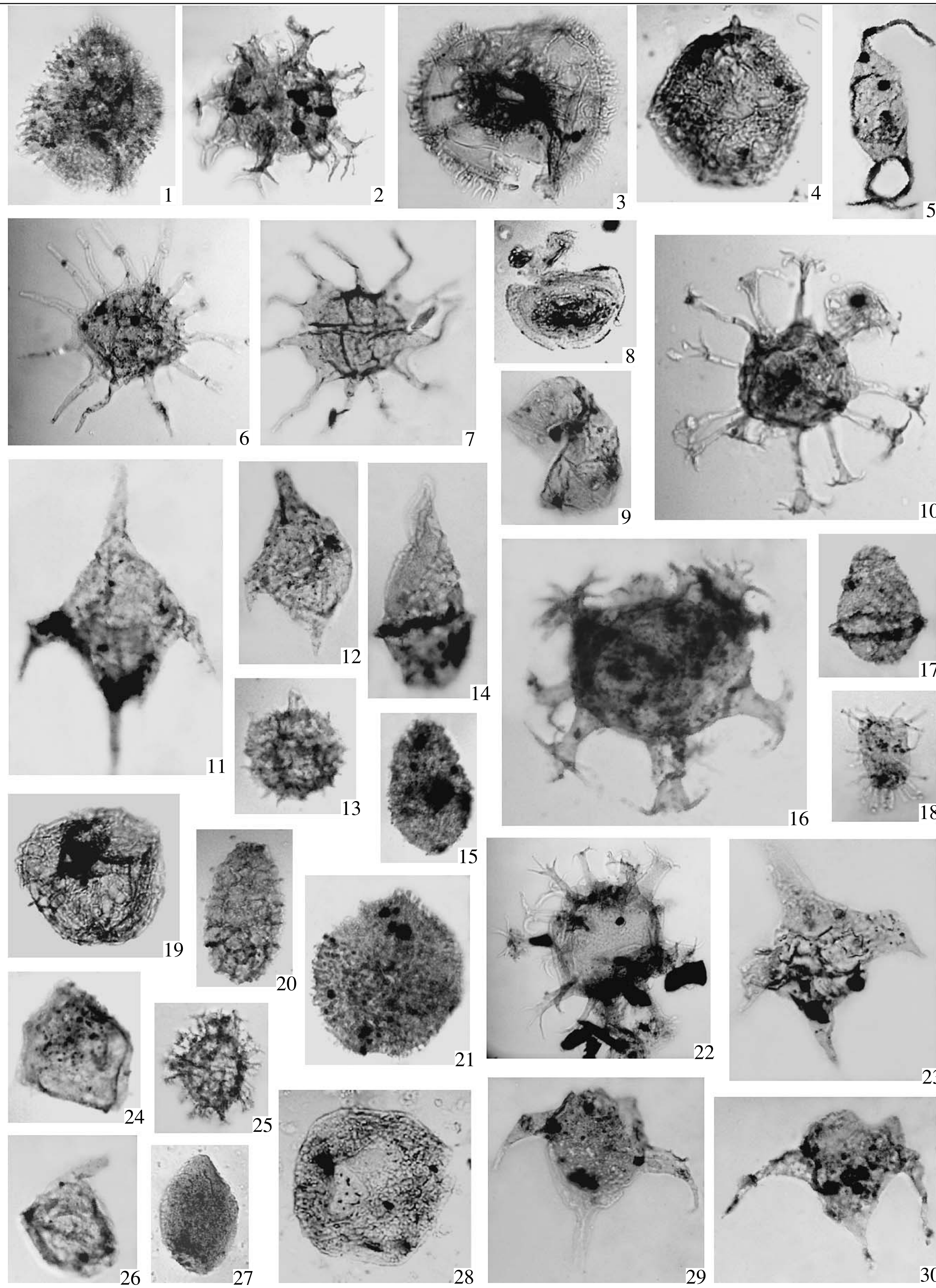
Lower boundary is defined at the first occurrence level of *Oligosphaeridium complex* and *Dingodinium cerviculum* in section of the Anabar Bay eastern coast only.

Remarks. Taxa always present in the assemblage are also widespread in underlying deposits, the Upper Jurassic strata inclusive (see description and remarks to DA1 and DA2). However, newly appeared taxa of DA3 are stratigraphically important being known from the Lower Cretaceous dinocyst assemblage far beyond Siberia in northern Europe and Canada. In western Europe, the first occurrence of *Dingodinium cerviculum* is established at the level of the upper Volgian Substage (Davey, 1979), whereas in northern regions of Canada and Siberia this species occurs beginning from the basal Valanginian (McIntyre and Brideaux, 1980; Davies, 1983; Lebedeva and Nikitenko, 1998). In northern sections of Eurasia and America, the first occurrence level of *Oligosphaeridium complex* is practically isochronous, corresponding approximately to the base of the *Buchia keyserlingi* Zone, thus being a good stratigraphic marker (Duxbury, 1977, 2001; Bujak and Williams, 1978; Piasecki, 1979; Davey, 1979; McIntyre and Brideaux, 1980; Davies, 1983; Aarhus et al., 1986; *A Stratigraphic*…, 1992). First occurrences of *Muderongia crucis* and *Cribroperidinium ?muderongense* are established in the lower Val-

Plate I. Dinocysts of the Lower Cretaceous from northern areas of Siberia. Collection no. 842, is stored at the Central Siberian Geological Museum, Trofimuk Institute of Petroleum geology and Geophysics, Siberian Division, Russian Academy of Sciences, Novosibirsk.

(1) *Barbatacysta brevispinosa* (Courtinat) Courtinat. Nordvik Peninsula, Exposure 33, Bed 31, Sample 31.1, Specimen no. 107.1/11, Paksa Formation, Berriasian, *Surites analogus* Zone, × 420; (2) *Apteodinium granulatum* Eisenack. Nordvik Peninsula, Exposure 33, Bed 31, Sample 31.1, Specimen no. 107.2/36, Paksa Formation, Berriasian, *Surites analogus* Zone, × 450; (3) *Pluriarvalium osmingtonense* Sarjeant. Nordvik Peninsula, Exposure 33, Bed 32, Sample 32.1, Specimen no. 110.1/30, Paksa Formation, Berriasian, *Surites analogus* Zone, ×450; (4) *Aldorfia sibirica* Pestchevitskaya. eastern coast of the Anabar Bay, Exposure 1A, Bed 20, Sample 31, Specimen no. 31.1/13, Paksa Formation, lower Valanginian, *Siberites ramulicosta* Zone, *beani* Subzone, ×450; (5) *Batioladinium jaegeri* (Alberti) Brideaux. West Siberia, Borehole Gorshkovskaya 1017, interval 2628–2642 m, Sample 38, Specimen no. 1403.5/6, Cherkashino Formation, upper Hauterivian, ×420; (6) *Athigmatocysta* aff. *glabra* Duxbury. West Siberia, Borehole Severo-Vologochanskaya 18, depth 988.6 m, Sample 47, Specimen no. 1763.1/20, Nizhnyaya Kheta Formation, Berriasian, ×470; (7) *Cribroperidinium tensiftense* Below. West Siberia, Borehole Severo-Vologochanskaya 18, depth 950.2 m, Sample 80, Specimen no. 1733.1/8, Sukhaya Dudinka Formation, lower Valanginian, ×400; (8) *Apteodinium grande* Cookson et Hughes. Nordvik Peninsula, Exposure 33, Bed 31, Sample 31.1, Specimen no. 107.2/28, Paksa Formation, Berriasian, *Surites analogus* Zone, ×350; (9) *Endoscrinium vellum* Pestchevitskaya. Nordvik Peninsula, Exposure 33, Bed 51, Sample 51.1, Specimen no. 135.1/10.a, Paksa Formation, Valanginian, *Neotollia klimovskiensis* Zone, ×500; (10) *Muderongia brevispinosa* Iosifova. Nordvik Peninsula, Exposure 36, Bed 11, Sample 11.2, Specimen no. 1090.3/8, Paksa Formation, Hauterivian, *Homolsomites bojarkensis* Zone, ×250; (11) *Aprobolocysta neista* Duxbury. West Siberia, Borehole Gorshkovskaya 1017, interval 2628–2642 m, Sample 38, Specimen no. 1403.2/45, Cherkashino Formation, upper Hauterivian, × 320; (12) *Muderongia endovata* Riding et al. West Siberia, Borehole Gorshkovskaya 1017, interval 2628–2642 m, Sample 38, Specimen no. 1403.1/16, Cherkashino Formation, upper Hauterivian, ×270; (13) *Endoscrinium* sp. Nordvik Peninsula, Exposure 35, Bed 35, Sample 35.1, Specimen no. 1075.1/5, Paksa Formation, lower Valanginian, *Euryptychites astieriptychus* Zone, ×480; (14) *Muderongia australis* Helby. eastern coast of the Anabar Bay, Exposure 1A, Bed 20, Sample 30, Specimen no. 30.1/9, Paksa Formation, lower Valanginian, *Siberites ramulicosta* Zone, *Beani* Subzone, ×480; (15) *Batiacasphaera* sp. Nordvik Peninsula, Exposure 33, Bed 32, Sample 32.1, Specimen no. 110.1/19, Paksa Formation, Berriasian, *Surites analogus* Zone, ×400; (16) *Taleisphaera* sp. West Siberia, Borehole Gorshkovskaya 1017, interval 2628–2642 m, Sample 38, Specimen no. 1403.5/20, Cherkashino Formation, upper Hauterivian, ×490; (17) *Evansia evittii* (Pocock) Jansonius. Nordvik Peninsula, Exposure 33, Bed 32, Sample 32.1, preparation 110.1, Specimen 20, Paksa Formation, Berriasian, *Surites analogus* Zone, ×300; (18) *Dingodinium minutum* (Gitmez) Fisher et Riley. Nordvik Peninsula, Exposure 33, Bed 37, Sample 37.1, Specimen no. 115.1/8, Paksa Formation, Berriasian, *Bojarkia meseznikovi* Zone, ×400; (19) *Apteodinium ?vescum* Matsuoka. Nordvik Peninsula, Exposure 33, Bed 46, Sample 46.1, Specimen no. 128.1/11, Paksa Formation, Berriasian, *Tollia tolli* Zone, ×300; (20) *Tubotuberella rhombiformis* Vozzhennikova. Nordvik Peninsula, Exposure 33, Bed 41, Sample 41.1, Specimen no. 123.1/2, Paksa Formation, Berriasian, *Tollia tolli* Zone, ×420; (21) *Pareodinia minuta* Wiggins. West Siberia, Borehole Severo-Vologochanskaya 18, depth 984.3 m, Sample 50, Specimen no. 1760.1/9, Nizhnyaya Kheta Formation, Berriasian, ×450; (22) *Chlamydophorella nyei* Cookson et Eisenack. eastern coast of the Anabar Bay, Exposure 1A, Bed 12, Sample 18, Specimen no. 18.4/8, Paksa Formation, lower Valanginian, *Euryptychites astieriptychus* Zone, ×320; (23) *Hologinella anabarensis* Pestchevitskaya. eastern coast of the Anabar Bay, Exposure 1A, Bed 12, Sample 18, Specimen no. 18.1/26, Paksa Formation, lower Valanginian, *Euryptychites astieriptychus* Zone of ammonites, ×550; (24) *Gardodinium ordinale* Davey. West Siberia, Borehole Gorshkovskaya 1017, interval 2615–2628 m, Sample 58, Specimen no. 1423.1/15, Cherkashino Formation, upper Hauterivian, ×360; (25) *Dingodinium subtile* Pestchevitskaya. Nordvik Peninsula, Exposure 33, Bed 42, Sample 42.1, Specimen no. 124.1/10, Paksa Formation, Berriasian, *Tollia tolli* Zone, ×350; (26) *Cleistosphaeridium* sp. Nordvik Peninsula, Exposure 33, Bed 37, Sample 37.1, Specimen no. 115.1/11, Paksa Formation, Berriasian, *Bojarkia meseznikovi* Zone, ×400; (27) *Spiniferites ramosus* (Ehrenberg) Monteil. West Siberia, Borehole Gorshkovskaya 1017, interval 2628–2642 m, Sample 38, Specimen no. 1403.4/15, Cherkashino Formation, upper Hauterivian, ×290; (28) *Paragonyaulacysta ?borealis* (Brideaux et Fisher) Stover et Evitt. Nordvik Peninsula, Exposure 33, Bed 31, Sample 31.1, Specimen no. 107.1/26, Paksa Formation, Berriasian, *Surites analogus* Zone, ×470; (29) *Oligosphaeridium complex* (White) Davey et Williams. eastern coast of the Anabar Bay, Exposure 1A, Bed 21, Sample 34, Specimen no. 34.1/7, Paksa Formation, lower Valanginian, *Siberites ramulicosta* Zone, *Beani* Subzone, ×390.

Plate II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anginian of northern Europe, Arctic Canada and Subpolar Urals (Davey, 1979; Davies, 1983; Aarhus et al., 1986; Lebedeva and Nikitenko 1998). Species *Muderongia australis, Aprobolocysta galeata* and *Canningiopsis colliveri* constantly occur in the Hauterivian (Iosifova, 1996; Prössl, 1990; Nøhr-Hansen, 1993; Aarhus et al., 1986, 1990). Consequently, dinocysts inherited from the Jurassic communities and taxa characteristic of the Lower Cretaceous are already of equal significance in the assemblage that is its important feature.

Zones DZ3 are probably of a greater thickness in section of the Nordvik Peninsula, but having no opportunity to analyze samples from lower part of the *Euryptychites quadrifidus* Zone I was unable to define with precision the position of lower boundary here (Fig. 2). This subdivision is undetectable in the Ust-Yenisei region, and there is established zone DZ VLG3 spanning upper part of the lower Valanginian, upper Valanginian, and presumably basal Hauterivian.

Type section: eastern coast of the Anabar bay, Exposure 1A, beds 6–15: beds 6–13 are composed of dark gray silty clay with calcareous concretions; beds 14, 15 of gray clayey to sandy-clayey aleurites with calcareous concretions; total thickness 76.1 m (Bogomolov et al., 1983; Bogomolov, 1989).

Plate II. Dinocysts of the Lower Cretaceous from northern areas of Siberia. Collection no. 842, is stored at the Central Siberian Geological Museum, Trofimuk Institute of Petroleum geology and Geophysics, Siberian Division, Russian Academy of Sciences, Novosibirsk.

(1) *Aptea anaphrissa* (Sarjeant) Sarjeant et Stover. West Siberia, Borehole Gorshkovskaya 1017, interval 2628–2642 m, Sample 35, Specimen no. 1400.1/1, Cherkashino Formation, lower Hauterivian, ×300; (2) *Achomosphaera neptuni* (Eisenack) Davey et Williams. West Siberia, Borehole Gorshkovskaya 1017, interval 2628–2642 m, Sample 36, Specimen no. 1401.1/2, Cherkashino Formation, lower Hauterivian, ×420; (3) *Occisucysta wierzbowskii* Poulsen. West Siberia, Borehole Severo-Vologochanskaya 18, depth 984,3 m, Sample 50, Specimen no. 1760.1/12, Nizhnyaya Kheta Formation, Berriasian, ×370; (4) *Cribroperidinium* aff. *janinae* Gyrka. Nordvik Peninsula, Exposure 35, Bed 34, Sample 34.4, Specimen no. 1074.2/26, Paksa Formation, lower Valanginian, *Euryptychites astieriptychus* Zone, ×440; (5) *Batioladinium longicornutum* (Alberti) Brideaux. West Siberia, Borehole Gorshkovskaya 1017, interval 2628–2642 m, Sample 30, Specimen no. 1395.1/11, Cherkashino Formation, lower Hauterivian, ×320; (6) *Hystrichodinium solare* Pestchevitskaya. West Siberia, Borehole Gorshkovskaya 1017, interval 2628–2642 m, Sample 38, Specimen no. 1403.1/40, Cherkashino Formation, upper Hauterivian, ×300; (7) *Hystrichodinium voigtii* (Alberti) Davey. West Siberia, Borehole Gorshkovskaya 1017, interval 2615–2628 m, Sample 58, Specimen no. 1423.2/5, Cherkashino Formation, upper Hauterivian, ×360; (8) *Leberidocysta spinosa* Pestchevitskaya. Nordvik Peninsula, Exposure 35, Bed 39, Sample 39.3, Specimen no. 1081.2/3, Paksa Formation, lower Valanginian, *Siberites* Zone, ×380; (9) *Mendicodinium* sp. West Siberia, Borehole Gorshkovskaya 1017, interval 2615–2628 m, Sample 59, Specimen no. 1424.1/2, Cherkashino Formation, upper Hauterivian, ×340; (10) *Cymososphaeridium "?phoenix"* (Duxbury) Fauconnier. West Siberia, Borehole Gorshkovskaya 1017, interval 2628–2642 m, Sample 36, Specimen no. 1401.1/4, Cherkashino Formation, lower Hauterivian, ×570; (11) *Muderongia mcwhaei* Cookson et Eisenack. West Siberia, Borehole Gorshkovskaya 1017, interval 2628–2642 m, Sample 34, Specimen no. 1399.1/7, Cherkashino Formation, lower Hauterivian, ×420; (12) *Pseudoceratium pelliferum* Gocht. West Siberia, Borehole Gorshkovskaya 1017, interval 2628–2642 m, Sample 38, Specimen no. 1403.6/1, Cherkashino Formation, upper Hauterivian, ×300; (13) *Nelchinopsis kostromiensis* (Vozzhennikova) Wiggins. West Siberia, Borehole Gorshkovskaya 1017, interval 2628–2642 m, Sample 38, Specimen no. 1403.5/3, Cherkashino Formation, upper Hauterivian, ×440; (14) *Aprobolocysta cornuta* Pestchevitskaya. West Siberia, Borehole Gorshkovskaya 1017, interval 2628–2642 m, Sample 38, Specimen no. 1403.6/15, Cherkashino Formation, upper Hauterivian, ×360; (15) *Aprobolocysta galeata* Backhouse. West Siberia, Borehole Gorshkovskaya 1017, interval 2628–2642 m, Sample 40, Specimen no. 1405.1/9, Cherkashino Formation, upper Hauterivian, ×330; (16) *Oligosphaeridium* aff. *totum* Brideaux: West Siberia, Borehole Gorshkovskaya 1017, interval 2628–2642 m, Sample 33, Specimen no. 1398.1/6, Cherkashino Formation, lower Hauterivian, ×450; (17) *Aprobolocysta eilema* Duxbury. West Siberia, Borehole Gorshkovskaya 1017, interval 2628–2642 m, Sample 38, Specimen no. 1403.1/14, Cherkashino Formation, upper Hauterivian, ×360; (18) *Tanyosphaeridium isocalamum* (Deflandre et Cookson) Davey et Williams. West Siberia, Borehole Gorshkovskaya 1017, interval 2628–2642 m, Sample 38, Specimen no. 1403.2/12, Cherkashino Formation, lower Hauterivian, ×430; (19) *Cassiculasphaeridia reticulata* Davey. West Siberia, Borehole Severo-Vologochanskaya 18, depth 950,2 m, Sample 80, Specimen no. 1733.1/8, Sukhaya Dudinka Formation, lower Valanginian, ×490; (20) *Batioladinium reticulatum* Stover et Helby: West Siberia, Borehole Gorshkovskaya 1017, interval 2628–2642 m, Sample 38, Specimen no. 1403.4/4, Cherkashino Formation, upper Hauterivian, ×390; (21) *Cyclonephelium brevispinatum* (Millioud) Below. West Siberia, Borehole Gorshkovskaya 1017, interval 2628–2642 m, Sample 37, Specimen no. 1402.1/18, Cherkashino Formation, upper Hauterivian, ×330; (22) *Florentinia* sp. West Siberia, Borehole Gorshkovskaya 1017, interval 2628–2642 m, Sample 38, Specimen no. 1403.3/16, Cherkashino Formation, upper Hauterivian, ×260; (23) *Vesperopsis mayi* Bint. West Siberia, Borehole Gorshkovskaya 1017, interval 2615–2628 m, Sample 58, Specimen no. 1423.2/6, Cherkashino Formation, upper Hauterivian, ×400; (24) *Pseudoceratium* aff. *expolitum* Brideaux. West Siberia, Borehole Gorshkovskaya 1017, interval 2628–2642 m, Sample 37, preparation 1402.1, Specimen 12, Cherkashino Formation, upper Hauterivian, ×450; (25) *Spiniferites* aff. *hyperacanthus* (Deflandre et Cookson) Cookson et Eisenack. West Siberia, Borehole Gorshkovskaya 1017, interval 2628–2642 m, Sample 32, Specimen no. 1397.1/2, Cherkashino Formation, lower Hauterivian, ×300; (26) *Dingodinium cerviculum* Cookson et Eisenack emend. Khowaja–Ateequzzman et al. West Siberia, Borehole Gorshkovskaya 1017, interval 2628–2642 m, Sample 40, Specimen no. 1405.2/1, Cherkashino Formation, upper Hauterivian, ×350; (27) *Batioladinium varigranosum* (Duxbury) Davey. Nordvik Peninsula, Exposure 35, Bed 35, Sample 35.1, Specimen no. 1075.2/26, Paksa Formation, lower Valanginian, *Euryptychites astieriptychus* Zone, ×300; (28) *Chytroeisphaeridia* sp. Nordvik Peninsula, Exposure 35, Bed 35, Sample 35.1, Specimen no. 1075.1/2, Paksa Formation, lower Valanginian, *Euryptychites astieriptychus* Zone, ×450; (29) *Muderongia cruces* Neale et Sarjeant. West Siberia, Borehole Gorshkovskaya 1017, interval 2615–2628 m, Sample 41, Specimen no. 1406.2/5, Cherkashino Formation, upper Hauterivian, ×300; (30) *Muderongia tetracantha* (Gocht) Alberti. West Siberia, Borehole Gorshkovskaya 1017, interval 2628–2642 m, Sample 32, Specimen no. 1397.1/8, Cherkashino Formation, lower Hauterivian, ×410.

Distribution: Khatanga depression (middle part of the Paksa Formation); Pur–Taz interfluve (middle part of the Sortym Formation.

Stratigraphic position: lower Valanginian; ammonite zones *Euryptychites quadrifidus* (lower part), *Euryptychites astieriptychus*, and lower part of *Siberites ramulicosta* Subzone; established based on direct correlation with the Boreal standard zones in sections of the Nordvik Peninsula (Basov et al., 1970; Zakharov et al., 1983; Bogomolov, 1989) and the Anabar Bay eastern coast (Zakharov et al., 1983; Bogomolov, 1989).

Sentusidinium spp.–Apteodinium spp. Zone (DZ VLG3, Fig. 2)

Characteristic taxa. Most frequently occurring in the assemblage are *Sentusidinium* spp., *Escharisphaeridia* spp., *Apteodinium* spp., and *Cassiculasphaeridia reticulata.* The other characteristic forms are *Sentusidinium granulatum, Dingodinium* spp., *Chlamydophorella* sp., *Sirmiodinium grossii, Fromea fragilis, Lithodinia* sp., *Nelchinopsis kostromiensis, Microdinium ornatum* Cookson et Eisenack, *Jansonia* spp., *Tubotuberella rhombiformis, Circulodinium compta* (Davey) Helby, and *Oligosphaeridium ?asterigium.* The subfamily Pareodinioideae is not diverse, represented only by species of the genus *Pareodinia.*

Lower boundary is defined at the level of a considerable diversity decline (Borehole Severo-Vologochanskaya 18). Disappearing above this level are genera *Cribroperidinium, Wallodinium*, and species *Occisucysta wiersbovskii, Tubotuberella apatela, Sirmiodiniopsis orbis, Pluriarvalium osmingtonense* and some others.

Remarks. Dinocysts of the assemblage represent mostly taxa of wide stratigraphic ranges, and the zone is dated with reference to results of micropaleontological analysis (Nikitenko et al., 2004). Nevertheless, data on dinocysts reliably determine position of the lower boundary (Pestchevitskaya, 2005b), whereas the upper one is tentatively defined at the section top.

Type section: Borehole Severo-Vologochanskaya 18, depth interval 909.6–842.3 m of recovered gray sandy to clayey aleurites with interlayers of clay, sideritic sandstone and aleurolite; thickness 67.3 m.

Distribution: Ust-Yenisei region (upper part of the Sukhaya Dudinka Formation).

Stratigraphic position: upper part of the lower Valanginian, upper Valanginian, and probably basal Hauterivian.

Aldorfia sibirica–Aprobolocysta galeata Zone (DZ4, Figs. 2, 5)

Characteristic taxa. Dominant taxa are *Dingodinium* spp. (up to 5%) and *D. cerviculum* (up to 5.5%) occurring in association with stratigraphically important species *Nelchinopsis kostromiensis, Cassiculasphaeridia reticulata, Oligosphaeridium complex, Dingodinium cerviculum, Sepispinula ?"huguoniotii"* (Cookson et Eisenack) Islam, *Aldorfia sibirica* Pestchevitskaya, *Aprobolocysta galeata, Gardodinium* sp., and *Trichodinium speetonense.* Persistent presence of *Sirmiodinium grossii, Pareodinia* spp., *Circulodinium* spp., *Cleistosphaeridium* spp., and *Oligosphaeridium* spp. is characteristic.

Lower boundary defined in sections of the Nordvik Peninsula and Anabar Bay eastern coast is not very distinct, marked by the grown abundance of *Dingodinium cerviculum* although not persistently. *Aldorfia sibirica* appears at this level in the Anabar section, *Aprobolocysta galeata* in the Nordvik peninsula.

Remarks. In West Siberia (Borehole Romanovskaya 140), *Aprobolocysta galeata* appears lower, in upper part of the *Euryptychites quadrifidus* Zone probably because of southerly position of the section. In the Moscow syneclise and northwestern Europe, this taxon regularly occurring in the Hauterivian is unknown from underlying deposits (Iosifova, 1996; Prössl, 1990). A considerable abundance rate of *D. cerviculum* is characteristic of the upper Valanginian in the Subpolar Urals (Lebedeva and Nikitenko, 1998). It is remarkable that the assemblage consists predominantly of the Cretaceous taxa.

Upper boundary is not established, being tentatively defined at the section top.

Type section: eastern coast of the Anabar Bay, Exposure 1A, beds 16–21; beds 16–18 are composed of gray clayey to sandy-clayey aleurites with calcareous concretions, Bed 19 corresponds to gray clayey sandstone with calcareous concretions, Bed 20 to sandy aleurite with lenticular sand interlayers, Bed 21 to gray cross-bedded sandstone; total thickness 29.7 m (Bogomolov et al., 1983; Bogomolov, 1989).

Distribution: Khatanga depression (upper part of the Paksa Formation).

Stratigraphic position: lower Valanginian, *Siberites ramulicosta* Zone (upper part of the *ramulicosta* Subzone and lower part of the *beani* Subzone); established based on direct correlation with the Boreal standard zones in sections of the Nordvik Peninsula (Basov et al., 1970; Zakharov et al., 1983; Bogomolov, 1989) and the Anabar Bay eastern coast (Zakharov et al., 1983; Bogomolov, 1989).

Hystrichodinium solare–Muderongia spp. Zone (DZ5, Figs. 2, 5)

Characteristic taxa. Persistent components of the assemblage are *Dingodinium* spp., *Oligosphaeridium* spp., *Muderongia* spp., *Sentusidinium* spp., *Escharisphaeridia* spp., *Batioladinium* spp., *Cribroperidinium* spp., *Cleistosphaeridium* spp., *Jansonia* spp., and abundance of the first three species may be significant. The other characteristic forms are *Muderongia* *staurota* Sarjeanti, *M. tetracantha* (Gocht) Alberti, *M. simplex, M. pariata* Duxbury, *M. australis* (up to 9%), *M. "tomaszowensis"* Alberti emend. Riding et al., *M. brevispinosa* Iosifova, *Nelchinopsis kostromiensis, Batioladinium varigranosum, Oligosphaeridium complex, Aprobolocysta* sp., *Tenua ?americana* (Pothe de Baldis et Ramos) Prössl, *Gardodinium trabeculosum*, and *Cassiculasphaeridia reticulata.* Stratigraphically important features are the diversity of the genus *Muderongia* and first occurrence of *Hystrichodinium solare* Pestchevitskaya.

Lower boundary is defined tentatively at the first occurrence level of *Hystrichodinium solare* and the increased diversity and abundance of the genus *Muderongia* (there is a hiatus in exposures of the Nordvik Peninsula and the borehole section Gorshkovskaya 1017 has not been sampled with gaps).

Remarks. The diversity of the genus *Muderongia* and occurrence of *Hystrichodinium solare* are characteristic of the lower Hauterivian dinocyst assemblages from the Subpolar Urals (Lebedeva and Nikitenko, 1998). In Australia (Helby et al., 1987) and northern Europe (Aarhus et al., 1990; Nøhr-Hansen, 1993), persistent occurrence of *Muderongia australis* and its abundance in particular have been observed beginning from the Hauterivian.

The upper boundary of beds with DZ5 is defined conventionally at the section top in the Nordvik Peninsula: in borehole Gorshkovskaya 1017 there is a sampling gap (Fig. 2).

Type section: Nordvik Peninsula, Exposure 36, Bed 11 of gray silty sandstones 4 m thick (Zakharov et al., 1983).

Distribution: Khatanga depression (lower part of the Tigyan Formation) and around latitudinal segment of the Ob River (upper part of the Akh Formation).

Stratigraphic position: lower Hauterivian, middle part of the *Homolsomites bojarkensis* Zone; established based on direct correlation with the Boreal standard zones in section of the Nordvik Peninsula (Zakharov et al., 1983).

Aptea anaphrissa–Oligosphaeridium aff. totum–Batioladinium longicornutum Zone (DZ6, Figs. 2, 5)

Characteristic taxa: Dinocyst diversity increases. In addition to taxa of wide stratigraphic ranges (*Escharisphaeridia* spp., *Leberidocysta* spp., *Cassiculasphaeridia magna, Chlamydophorella* spp., *Jansonia* spp., *Oligosphaeridium* spp., *Circulodinium* spp., *Cleistosphaeridium* spp.), the assemblage constantly includes *Cassiculasphaeridia reticulata, Oligosphaeridium complex, Batioladinium varigranosum*, and *B. longicornutum* (Alberti) Brideaux. Diversity of the genus *Muderongia* spp. increases (*M. tetracantha, M. australis, M. endovata* Riding et al., *M. simplex, M. mcwhaei* Cookson et Eisenack, *M. staurota*). The very characteristic is presence of *Nelchinopsis kostromiensis, Hystrichodinium solare, H. voigtii* (Alberti) Davey, *H. pulchrum* Deflandre, *Oligosphaeridium ?asterigium, O.* cf. *intermedium* Corradini, *Spiniferites ramosus, Achomosphaera neptunii, Aprobolocysta* spp., *Gardodinium trabeculosum*, and *Tenua ?americana.* First occurrences of *Pseudoceratium* sp., *Aptea anaphrissa* (Sarjeant) Sarjeant et Stover, *Batioladinium longicornutum*, and *Oligosphaeridium* aff. *totum* Brideaux are stratigraphically important.

Lower boundary is conventionally defined in borehole section Gorshkovskaya 1017 at the beginning of interval 2656–2642 m (above the missing core interval, Fig. 2). The characteristic dinocyst assemblage gets suddenly the greater diversity at this level, and *Oligosphaeridium* aff. *totum, Aptea anaphrissa, Batioladinium longicornutum*, and single *Pseudoceratium* sp. appear here.

Remarks. In northern areas of western Europe, the oldest occurrence level of *Aptea anaphrissa* is established in upper part of the lower Hauterivian (Aarhus et al., 1990). Morphologically similar dinocysts present as well in the lower Hauterivian assemblages of microphytoplankton in the Subpolar Urals (Lebedeva and Nikitenko, 1998). The diversity of the genus *Pseudoceratium* are characteristic of the upper Hauterivian and Barremian of Canada (Bujak and Williams, 1978) and several northern regions of Europe (Prössl, 1990; Nøhr-Hansen, 1993; Iosifova, 1996; Smelror et al., 1998). Data on their occurrence in Lower Cretaceous of Siberia have not been published, but according to oral communication of A.F. Fradkina, dinocysts of this genus are found in Hauterivian deposits of central West Siberia.

Type section: Borehole Gorshkovskaya 1017, interval 2656–2630.55 m of argillaceous deposits; thickness 25.45 m.

Distribution: region of the Ob River latitudinal segment (lower part of the lower Cherkashino Subformation).

Stratigraphic position: upper part of the lower Hauterivian.

Aprobolocysta eilema–A. neista–Odontochitina spp. Zone (DZ7, Figs. 2, 5)

Characteristic taxa: Dinocyst diversity is increased further. Dominant species are *Escharisphaeridia* spp. and *Muderongia* spp. Common species are *Sentusidinium* spp., *Fromea* spp., *Mendicodinium* spp., *Leberidocysta* spp., *Dingodinium* spp., *D. cerviculum, Cassiculasphaeridia magna, Jansonia* spp., *Apteodinium* spp., *Aptea anaphrissa*, and *Circulodinium* spp. Frequently occurring forms are *Cassiculasphaeridia reticulata, Pareodinia* spp., *Odontochitina* spp., *O. operculata* (O. Wetzel) Deflandre et Cookson, and *Hystrichodinium* spp. (*H. voigtii, H. pulchrum*). Very characteristic is diversity of genera *Aprobolocysta,* *Pseudoceratium, Muderongia*, and *Batioladinium* represented by the following taxa: *Aprobolocysta galeata, A. neista* Duxbury, *A. eilema* Duxbury, *A. cornuta* Pestchevitskaya, *Pseudoceratium* cf. *pelliferum* Gocht, *P. expolitum* Brideaux, *Muderongia tetracantha, M. simplex, M. staurota, M. extensiva* Duxbury, *M. mcwhaei* (up to 2%), *M. "tomaszovensis," M. crucis* (up to 2%), *M. australis, M. asymmetrica* Aarhus, *Batioladinium ?exiguum* (Alberti) Brideaux, *B. varigranosum, B. jaegeri* (Alberti) Brideaux, *B. longicornutum* (Alberti) Brideaux, and *B. reticulatum* Stover et Helby. Important species are *Wrevittia helicoidea, Nelchinopsis kostromiensis, Oligosphaeridium complex, Vesperopsis mayi* Bint, *V. fragilis* (Harding) Harding, *Gardodinium trabeculosum, G. ordinale* Davey, *Gonyaulacysta ?kleithria* Duxbury, *Cyclonephelium intonsum* Duxbury, and *Cymososphaeridium ?phoenix* (Duxbury) Fauconni.

Lower boundary. Taxonomic composition of dinocysts changes to a considerable extent at this boundary that marks the diversity increase in genera *Aprobolocysta, Muderongia*, and *Batioladinium.* The boundary is marked by first occurrences of *Odontochitina* Dux, *O. operculata, Aprobolocysta neista, A. eilema, A. cornuta, Pseudoceratium expolitum, Gonyaulacysta ?kleithria*, and *Cyclonephelium intonsum*; species *Vesperopsis* spp., *V. mayi*, and *V. fragilis* appear somewhat higher. *Dingodinium* spp., *D. cerviculum*, and *Mendicodinium* spp. become commonly occurring, whereas *Hystrichodinium solare, Tenua americana, Oligosphaeridium* aff. *totum, O. ?asterigium, Chlamydophorella* spp. Disappear from the assemblage. Species of the genus *Oligosphaeridium* are of a lesser diversity and do not occur regularly in the assemblage.

Remarks. Single specimens of *Odontochitina operculata* have been found in the upper Valanginian of Arctic Canada (Davies, 1983). This species occurs more frequently in the upper Hauterivian of northwestern Europe and Australia (Helby et al., 1987; Aarhus et al., 1990; Prössl, 1990). Diversity and persistent occurrence of the genus *Odontochitina* is established in the Barremian deposits of Canada and northern Europe, where its species are sometimes fairly abundant (Bujak and Williams 1978; Davey, 1979; Duxbury, 1980, 2001; Aarhus et al., 1986; Nøhr-Hansen, 1993; Iosifova, 1996; Nøhr-Hansen, McIntyre, 1998; Smelror et al., 1998). Constant presence and diversity of *Pseudoceratium* forms is typical of the upper Hauterivian and Barremian dinocyst assembalges (Bujak and Williams, 1978; Prössl, 1990; Nøhr-Hansen, 1993; Iosifova, 1996; Smelror et al., 1998). In northwestern Europe, first occurrence of *Aprobolocysta neista* is detected in middle part of the lower Hauterivian (Davey, 2001), whereas *A. eilema* appears at the base of the upper Hauterivian (*A Stratigraphic…*, 1992; Duxbury, 1977, 2001). In northern areas of Germany, disappearance level of *Tenua ?americana* corresponds to the boundary between substages (Prössl, 1990). Oldest specimens of *Vesperopsis fragilis* have been found at the same level (Harding, 1986). Species *Pseudoceratium expolitum, Gonyaulacysta ?kleithria, Cyclonephelium intonsum, Gardodinium ordinale*, and *Vesperopsis mayi*, which are present in zone DZ7, are widespread and persistently occurring in the Barremian, being abundant sometimes (Nøhr-Hansen, 1993; Iosifova 1996; Smelror et al., 1998).

Upper boundary has not been observed. It was impossible to study compositional changes of dinocysts from transition between DZ7 and overlying subdivision because of sampling gap (Fig. 2).

Type section: Borehole Gorshkovskaya 1017, interval 2630.55–2615 m of argillites; thickness 15.55 m.

Distribution: region of the Ob River latitudinal segment (lower Cherkashino Subformation, upper part).

Stratigraphic position: lower part of the upper Hauterivian.

Canningia spp.–Nelchinopsis kostromiensis Zone (DZ8, Figs. 2,5)

Characteristic taxa. Diversity of dinocysts is sharply decreased. Dominant taxa are *Escharisphaeridia* spp. and *Mendicodinium* spp. Common taxa are *Leberidocysta* spp. and *Canningia* spp. Single specimens of *Wallodinium* sp., *W. krutzschii, Endoscrinium* sp., *Ovoidinium* sp., *Batioladinium* spp., *B. ?exiguum, Aprobolocysta* spp., *A. galeata, A. eilema, A. cornuta, Apteodinium* spp., *Nelchinopsis kostromiensis, Cyclonephelium intonsum*, and *Sentusidinium* spp. are identified as well.

Lower boundary has not been observed because of incomplete core recovery and is defined tentatively based on occurrence of the characteristic dinocyst assemblage that is of sharply declined diversity. All the species of genera *Muderongia, Hystrichodinium, Oligosphaeridium, Vesperopsis, Cassiculasphaeridia, Odontochitina, Pseudoceratium*, and *Gardodinium* disappear from the assemblage along with *Aptea anaphrissa, Cyclonephelium intonsum, Wrevittia helicoidea*, and other forms.

Remarks. Decreasing abundance and diversity of microphytoplankton could be to a consequence of general regression in the West Siberian paleobasin (*Paleolandscapes…*, 1968; Gol'bert, 1987).

Dinocysts are represented mostly by taxa of wide stratigraphic ranges. The highest occurrence of *Aprobolocysta eilema* and *Nelchinopsis kostromiensis* is known in northwestern Europe up to the basal Barremian only, being unknown from higher strata (*A Stratigraphic…*, 1992; Nøhr-Hansen, 1993; Smelror et al., 1998; Aarhus et al., 1990). Upper boundary has not been observed.

Type section: Borehole Gorshkovskaya 1017, interval 2343–2330 m of argillites with insignificant interlayers of silty argillites; thickness 13 m.

Distribution: region of the Ob River latitudinal segment (upper Cherkashino Subformation, lower part).

Stratigraphic position: lower part of the lower Barremian.

COMPARATIVE ANALYSIS OF LOWER CRETACEOUS DINOCYST ASSEMBLAGES FROM SIBERIA, CANADA AND NORTHERN AREAS OF EUROPE

The lower Cretaceous dinocyst zonations are elaborated for the Subpolar Urals, Greenland, and northern regions of Europe and Canada. Successions of dinocyst zones are established for separate regions and generalized scale is suggested for Canada and northwestern Europe (Table 1). In respective works, principal attention is paid to boundaries of biostratigraphic units and to consideration of criteria, which define with confidence stratigraphic positions and ranges of dinocyst zones. In majority of works, these zones are distinguished based on changes in taxonomic composition of dinocyst assemblages, i.e., on first or last occurrences of certain taxa and on their acme in particular sections, which are commonly of local significance. Stratigraphic ranges of the same taxa in other regions are sometimes omitted from considerations, and consequently their stratigraphic significance is improperly evaluated. Accordingly, only some of them can be regarded as appropriate for determination of boundaries between dinocyst zones: the appearance level of such species in the section corresponds to their oldest occurrence or their inceptions can be recognized at the same level in different regions (Table 1). As a result, boundaries of concurrent biostratigraphic units are defined sometimes based on different criteria. In such a case, correlation is possible by means of comparative analysis of general taxonomic composition of microphytoplankton assemblages. This laborious approach is certainly inappropriate for correlation of palynostratigraphic units of a narrow extent, but for a wider stratigraphic interval it is possible to define a group of characteristic species occurring in most regions of North Eurasia and America. The Lower Cretaceous dinocyst assemblages from northern regions of Siberia contain quite a number of respective species (Table 2). In general, they appear in lower stratigraphic intervals and, being widespread Lower Cretaceous, define the “face” of corresponding assemblage.

The general tendency by transition from the Berriasian to Hauterivian consists in growing significance of chorate dinocysts, species of the family Ceratiaceae, and in compositional changes of the family Pareodiniaceae (Table 2). The Berriasian dinocyst assemblages most similar to assemblages of North Siberia are described from the Boyarka River sections (the Yenisei–Khatanga depression; Fedorova et al., 1993), Subpolar Urals (Fedorova et al., 1993; Lebedeva and Nikitenko, 1998), and Moscow basin (Iosifova, 1996). The situation changes in the Valanginian: dinocyst assemblages from nearby (Subpolar Urals, Moscow basin) and remote regions (western Europe, Canada, Greenland) contain many species in common, except for sections of the Barents Sea shelf, where Berriasian and Valanginian assemblages contain each only one taxon occurring in the studied Siberian sections (Table 2). Similarity between North Siberian and Canadian dinocyst assemblages decreases in Hauterivian deposits. The most different are the assemblages from Arctic Canada.

The Barremian assemblages of dinocysts from northern regions of Siberia are of a low taxonomic diversity. In the Barremian Age, area of the West Siberian paleobasin became considerably reduced (*Paleolandscapes…*, 1968; Gol’bert, 1987), and the assemblages likely consisted of taxa, which were able to survive unstable environments in the habitat basin, where depths and salinity often changed. In Europe, the Barremian dinocyst assemblages are known from sections of normal marine facies, and accordingly their dinocysts are extraordinary abundant and diverse (Aarhus et al., 1990; Prössl, 1990; Smelror et al., 1998; Duxbury et al., 1999; Duxbury, 2001).

It is remarkable that concurrent dinocyst assemblages from northern regions of Eurasia and America contain species in common, which are informative in terms of stratigraphy, because their first occurrence is confined to particular level in different regions. The oldest specimens of a certain species are usually known from one region, whereas in the other sections this taxon can be found in higher horizons (Table 3). On the other hand, there is a series of species whose first or last occurrence is recorded practically at the same level in several northern regions of Eurasia and America (Table 3). These species exactly are regarded in this work as palynological criteria determining boundaries of biostratigraphic units in Siberian succession of dinocyst assemblages (Table 4). It is remarkable therewith that the dinocyst zones distinguished in the upper Berriasian, Valanginian and lower Hauterivian of North Siberia are directly correlated with the Boreal standard zonations (Zakharov et al., 1997), being studied in stratotype sections of the Khatanga depression. Consequently, boundaries of the North Siberian dinocyst zones are important stratigraphic markers in most cases owing to this correlation.

As dinocyst zones are defined based on inceptions and extinctions of species at certain stratigraphic levels not only in Siberia, but also in the other northern regions of Eurasia, their boundaries are recognizable over vast territories (Fig. 5, Table 4). In some cases, it is possible therefore to correlate directly the dinocyst biostratigraphic subdivisions of North Siberia with units of dinocyst zonations in Western Europe and Canada.

The Berriasian and two lower Valanginian levels are recognizable in northern regions of Canada, Europe and Siberia (Fig. 5, Table 4). The first occurrence of

Table 1. Correlation of Lower Cretaceous dinocyst zonations established in northern regions of Eurasia and America

Stage	Substage	Southeastern Canada (Bujak et Williams, 1978)	Eastern Canada (Williams et al., 1974)	Arctic Canada (Davies, 1983)	Newfoundland: Van Helden, 1986	Newfoundland: Jenkins et al., 1974	Newfoundland: Arthur et al., 1982	East England LB (Duxbury, 1977)	South England (Harding, 1986): Ammonoid zones	South England (Harding, 1986): Dinocyst zones	
Barremian	upper	*Aptea anaphrissa* Peak Zone LB: first occurrence of *Aptea polymorpha*, *A. anaphrissa* (acme), *Pseudoceratium regium*; last occurrence of *Rhynchodiniopsis serrata*	*Aptea anaphrissa* Peak Zone	?	?	*Aptea anaphrissa* peak Zone	?	Zone (?) *Canningiopsis "tabulata"* appears in upper part	*bidentatum* *rudenckmani* *elegans*	*Odontochitina operculata* Zone	*Palaeoperidinium cretacea* Subzone *Aptea anaphrissa* Subzone
	lower		LB: acme – Aptea anaphirissa, Subtilisphaera perlucida			acme of *Aptea anaphrissa*			*fissicostatum* *rarocinctum* *variabilis*		*Cassiculasphaeridia magna* Subzone
										Subtilisphaera terrula Zone	*Nexosispinium vetusculum* subzone
Hauterivian	upper	*Ctenidodinium elegantum* Assemblage Zone LB: first occurrence of *Circulodinium attadalicum*, *Cyclonephelium vannophorum*, *Cribroperidinium orthoceras*, *Calaiosphaeridium asymmetricum*, *Surculosphaeridium ?longifurcatum*, *Subtilisphaera perlucida*; last occurrence of *B. johnewingi*, *I. kondratjevi*	*Ctenidodinium elegantum–Pseudoceratium pelliferum* Zone			*Ctenidodinium elegantum* Zone		Zone E LB: first occurrence of *Subtilisphaera terrula*	*marginatus* *gottschei*		*Canningia* cf. *reticulata* Subzone
								Zone D LB: first occurrence of *Wrevittia perforobtusa*; *Aprobolocysta eilema* appears in the upper Hauterivian	*speetonensis*	*Discorsia nanna* Zone	*Batioladinium longicornutum* Subzone
	lower			*Valvaeodinium atlanticum* Oppel Zone. LB: first occurrence of *V. atlanticum*; last occurrence of *Apteodinium apiatum*, *Batiacasphaera agglutinata*, *Ellipsoidictyum cinctum*, *Escharisphaeridia rudis*, *S. crystallinum*, *Prolixosphaeridium spissum*, *Leptodinium episomum*, *C. cuculliforme*, *T. rhombiformis*					*inversus* *regale*		
								Zone C LB: first occurrence of *Oligosphaeridium complex*, *Spriniferies ramosus* subsp. *primaevus*; *Discorsia nanna* and *Nematosphaeropsis scala* appear in the middle *Hystrichodinium furcatum* appears at the Hauterivian boundary	*noricum* *amblygonium*		*Kleithriasphaeridium simplicispinum* Subzone
Valanginian	upper	Phoberocysta neocomica Assemblage Zone	*Phoberocysta neocomica* Zone	*Muderongia simplex* Oppel Zone	*Phoberocysta neocomica* Assemblage Zone	*Phoberocysta neocomica* Zone presence of *P. neocomica*, *Pseudoceratium nudum*, *Spriniferites dentatus*, *A. neptunii*, *Systematophora orbifera*	*Phoberocysta neocomica* Zone			?	
	lower			Tanyosphaeridium magneticum Oppel Zone LB: first occurrence of *T. magneticum*, *Apteodinium apiatum*, *Cribroperidinium muderongense*, *Kallosphaeridium ?circulare*, *Batiacasphaera agglutinata*, *L. episomum*, *M. tomaszowensis*, *O. albertense*, *O. complex*, *O. totum*, *O. operculata*	*Endoscrinium campanula* Assemblage Zone			Zone B LB: first occurrence of *K. einoides*; last occurrence of *Papuadinium apiculatum*			
		LB: first occurrence of *Phoberocysta neocomica*, *Biorbifera johnewingi*, *Achomosphaera neptunii*, *Coronifera oceanica*, *Ctenidodinium elegantum*, *Circulodinium distinctum*, *Rhynchodiniopsis serrata*, *Lithosphaeridium siphoniphorum*		?							
Berriasian	upper		LB: first occurrence of *Phoberocysta neocomica*, *Achomosphaera neptunii*, *Systematophora complicata*	*Cyclonephelium culculliforme – Paragonyaulacysta borealis* Oppel Zone LB: first occurrence of *Cyclonephelium cuculiforme*	LB: first occurrence of *Batioladinium varigranosum*, *Nelchinopsis kostromiensis*; last occurrence of *Amphorula metaelliptica*, *A. delicata*, *Cantulodinium arthuriae*, *Sentusidinium rioultii*	*Biorbifora johnewingi* Subzone	*Apteodinium nuciforme* Zone				
	middle			*Trichodinium erinaceoides – Tetrachacysta spinosigiberrosa* Oppel Zone	*Amphorula metaelliptica* Assemblage Zone LB (the Portlandian base), presence of *C. arthuriae*, *Amphorula metaelliptica*, *A. delicata*, *Sentusidinium rioultii*		*Ctenidodinium panneum* Zone	Zone A: first occurrence of *Occisucysta tentorium*, *Wrevittia ?diutina*, *Endoscrinium campanula*, *Circulodinium distinctum*, *Tehamadinium evitii*, *Papuadinium apiculatum*			
	lower										

Notes: (LB) lower boundary; (UB) upper boundary; stratigraphically important taxa listed in the table are printed in bold, if their first or last occurrence is recorded at the given level in different regions, and in regular type, if in the designated section only.

Table 1. (Contd.)

Stage	Substage	Ammonoid zones (England, North Sea; Duxbury, 2001)	Dinocyst zones (England, North Sea; Duxbury, 2001)	Rawson, Riley, 1982 (zone)	Rawson, Riley, 1982 (subzone)	Duxbury et al., 1999	Canada, Northwestern Europe (Fisher et Riley, 1980) (zone)	Canada, Northwestern Europe (Fisher et Riley, 1980) (subzone)	Northwestern Europe (Davey, 1979) (zone)	Northwestern Europe (Davey, 1979) (subzone)	Northeastern Greenland (Nohr-Hansen, 1993) (zone)	Northeastern Greenland (Nohr-Hansen, 1993) (subzone)
Barremian	upper	*bidentatum*	LKP25 Zone; LKP24 Zone; LKP23 Zone; LKP25 Zone; LB: last occurrence of *Cribroperidinium cornutum*, *Scriniodinium barremianum*; UB: *Hystrichodinium ramoides*; LKP22 Zone; LB: last occurrence of *Aprobolocysta neista*	*Sirmiodinium grossii* Zone	*Plaeoperidinium cretacea* Subzone		?		*Odontochitina operculata* Zone	*Palaeoperidinium cretaceum* Subzone. LB: first occurrence of *Carpodinium granulatum*	*Batioladinium longicornutum* Zone	*Pseudoceratium toveae* Subzone; acme of *Pseudoceratium toveae*
	middle	*rudenckmani*	LKP20 Zone, LKP21 Zone		*Aptea anaphrissa* Subzone					*Aptea anaphrissa* Subzone. LB: acme of ***Aptea anaphrissa***; last occurrence of *Nexosispinium vetusculum*		
		elegans	LKP19 Zone; first occurrence of *Achomosphaera ramulifera*, last occurrence of *Ascodinum fissilum*									*Aptea anaphrissa* Subzone. LB: last occurrence of ***N. kostromiensis***; acme of ***A. anaphrissa***
		fissicostatum	LKP18 Zone; acme of *Aptea anaphrissa*									
	lower	*rarocinctum*	LKP17.2 Subzone; LB: last occurrence of ***Nelchinopsis kostromiensis*** (LKP17)		*Kleithriasphaeridium corrugatum* Subzone					*Cassiculasphaeridia magna* Subzone		Nelchinopsis kostromiensis Subzone
		variabilis	LKP17.1 Subzone; LB: last occurrence of *Desmocysta simplex*, *Canningia duxbury*	*Subtilisphaera terrula* Zone	*N. vetusculum*							
Hauterivian	upper	*marginatus*	LKP16.2 Subzone (LKP16 Zone)		*Canningia* cf. *reticulata* Subzone				*Subtilisphaera terrula*	*Nexosispinium vetusculum* Subzone	?	
		gottschei	LKP16.1 Subzone; LB: last occurrence of *Oligosphaeridium junctum*; first occurrence of ***Aprobolocysta eilema***	*Discorsia nanna* Zone	*Gardodinium trabeculosum* Subzone					*Canningia* cf. *reticulata* Subzone (← *Canningia* cf. *reticulata* Subzone. LB: first occurrence of *Subtilisphaera terrula*, *Ophiobolus* sp. A)		*Canningia* cf. *reticulata* Subzone. LB: first occurrence of *Subtilisphaera terrula*, *Ophiobolus* sp. A
		speetonensis	LKP15 Zone; LB: acme of *Oligosphaeridium junctum*						*Discorsia nanna* Zone	*Gardodinium trabeculosum* Subzone. LB: acme of *Gardodinium trabeculosum*		
	lower	*inversus*										
		regale	LKP14 Zone; LB: acme of *Cymososphaeridium validum*									
		noricum	LKP13 Zone; LB: acme of *H. arborispinum*; LKP12 Zone		*Kleithriasphaeridium simplicispinum*					*Kleithriasphaeridum "simplicispinum"* Subzone		
		amblygonium	LKP11 Zone; LKP10 Zone									
Valanginian	upper	unnamed	LKP9 Zone; Zone; LB: last occurrence of *Spiniferites primaevus*	*Phoberocysta neocomica* Zone	*Muderongia extensiva* Subzone		*Phoberocysta neocomica* Zone	*Muderongia extensiva* Subzone. LB: first occurrence of *Muderongia extensiva*	*Spiniferites ramosus* Zone. LB: first occurrence of ***Oligosphaeridium complex***			
		pitrei										
		dichotomites	LKP8 Zone; LB: last occurrence of ***Systematophora palmula***									
	lower	*polyptychites*	7.2 Subzone; LB: last occurrence of *Spiniferites ?spongiosus*, *Systematophora scoriacea* (LKP7 Zone)		*Tubotuberella apatela* Subzone			*Endoscrinium pharo* Subzone. LB: last occurrence of ***Dingodinium ?spinosum***, *Papuadinium apiculatum*, ***Paragonyaulacysta capillosa***, *Ctenidodinium ?schizoblatum*				
		paratollia	7.1 Subzone; last occurrence of *Aprobolocysta extrema*; LKP6 Zone; LB: last occurrence of *Dingodinium ?spinosum*; ***Oligosphaeridium complex*** appears inside zone			?			*Pseudoceratium pelliferum* Zone		*Pseudoceratium pelliferum* Zone. LB: first occurrence of ***Pseudoceratium pelliferum***; last occurrence of ***Dingodinium ?spinosum***, E. pharo	
Berriasian	upper	*albidum*	?	*Dingodinium ?spinosum* Zone	*Egmontodinium toryna* Subzone	LKP5 Zone. UB: last occurrence of ***Dingodinium ?spinosum***, *Dichadogonyaulax culmula*		*Dingodinium ?spinosum* Subzone. LB: last occurrence of *Diacanthum hollisteri*, *Papuadinium apiculatum*, *Biorbifera johnewingi*, *Egmontodinium toryna*, ***Achomosphaera neptunii***, ***Occisucysta tentorium***, ***Endoscrinium campanula***, ***Phoberocysta neocomica***, *Pseudoceratium pelliferum*, *Heslertonia heslertonensis*; last occurrence of *Pareodinia antennata*	*Gochteodinia villosa* Zone. LB at the mid-Portlandian level (*opressus*)	*Endoscrinium pharo* Subzone. LB: last occurrence of *Cannosphaeropsis* sp. A		
		stenomphalus			*Dichadogonyaulax* spp. Subzone	Muderongia simplex (LKP4) Zone. LB: last occurrence of *Batioladinium "pomum"*						
		icenii				LKP3 Zone. LB: last occurrence of *Rotosphaeropsis thule*; acme of *B. radiculatum*, *O. diluculum*				*Cannosphaeropsis* sp. A Subzone. LB: last occurrence of *Egmontodinium* sp. A		
	middle	*kochi*			*Cannosphaeropsis* sp. A Subzone	Rotosphaeropsis thule (LKP2) Zone. LB: first occurrence of *Daveya boresphaera*						
	lower	*runctoni*				Circulodinium compta (LKP1) Zone. LB: acme of *Circulodinium compta*; last occurrence of *C. gigas*, *Leptodinium arquatum*						

Table 1. (Contd.)

Stage	Substage	Denmark (Davey, 1982)	Northwestern Germany (Prössl, 1990)	Subpolar Urals (Lebedeva and Nikitenko, 1998): ammonoid zones	Subpolar Urals (Lebedeva and Nikitenko, 1998): dinocyst zones	North Siberia, lower Berriasian after Nikitenko et al., 004 up to *analogus* and higher from this work: Ammonoid zones (Zakharov et al., 1997)	North Siberia: dinocyst zones	Boxes on the right edge of the chart
Barremian	upper		*Impagidinium alectophorum* Zone LB: first occurrence of *Stephodinium spinulosum*, *Ellipsoidictum reticulatum*, *Protoellipsodinium densispinum*; last occurrence of ***Cassiculasphaeridia magna***, *Pterodinium premnos*				*Canningia* spp., *Nelchinopsis kostromiensis* zones UB: last occurrence of ***Nelchinopsis kostromiensis***, ***Aprobolocysta eilema*** [arrow to the upper boundary of DZ8] ?	
Barremian	lower		*Exiguisphaera plectilis* Zone LB: first occurrence of *Exiguisphaera plectilis*; last occurrence of *Spiniferetis ?magnoserratus*				DZ8 ?	*Aprobolocyta eilema*, *Aprobolocysta neista*, *Odontochitina* spp. zones LB: first occurrence of ***Aprobolocysta eilema***, *Odontochitina operculata* and ***Vesperopsis fragilis*** a bit higher; ast occurrence of **Tenua americana** [arrow to DZ7]
Hauterivian	upper	?	*Coronifera oceanica* Zone. LB: acme of *Coronifera oceanica*, *Caningia pistica*, *Muderongia tetracantha* *Batioladinium longicornutum* Zone LB: first occurrence of *Gonyaulacysta teichos*, *Apteodinium comptum*		LB: first occurrence of ***Hystrichodinium* sp. A (*solare*)** [arrow to the base of the continental deposits] Continental deposits		DZ7	
Hauterivian	lower	*Discorsia nanna* Zone: *Batioladinium longicornutum* Subzone. LB: first occurrence of ***Tanyosphaeridium boletum***, ***Callaiosphaeridium* cf. *asymmetricum***, *Hystrichodinium furcatum*, *Stanfordella ordocavata*	*Cymososphaeridium validum* Zone ?	*versicolor* *bojarkensis*	*Tenua americana*–*Gardodinium trabeculosum* zones *Dingodinium cerviculum* zones	*bojarkensis*	DZ6 ? DZ5	*Aptea anaphrissa* – *Oligosphaeridium* aff. *totum* – *Batioladinium longicornutum* zones LB: first occurrence of ***Aptea anaphrissa*** [arrow to DZ6] *Hystrichodinium solare*, *Muderongia* spp. zones LB: first occurrence of ***Hystrichodinium solare*** [arrow to DZ5]
Valanginian	upper	*Spiniferites ramosus* Zone LB: first occurrence of *Hystrichospaeridium* cf. *arborispinum*		*ramulosus*	LB: first occurrence of ***Tenua americana***	*bidihotomus*	? *Aldorfia sibirica*, *Aprobolocysta galeata* zones LB: first occurrence of *Aldorfia sibirica* [arrow to DZ4]	
Valanginian	lower	*Pseudoceratium pelliferum* Zone LB: first occurrence of ***Pseudoceratium pelliferum***; last occurrence of *Dichadogonyaulax culmula*		*michalskii* *insolutus*	*Muderongia simplex*–*Cribro peridinium muderongense* zones ? *Dingodinium ?albertii*–*Ambonosphaera delicata* zones	*ramulicosta* *astieriptychus* *quadrifidus* *klimovskiensis*	? DZ4 DZ3 DZ2	*Oligosphaeridium complex*, *Dingodinium cerviculum* zones LB: first occurrence of ***Oligosphaeridium complex***, ***Dingodinium cerviculum*** [arrow to DZ3] *Escharisphaeridia* spp., *Oligosphaeridium* spp., *Circulodinium* spp. zones LB: last occurrence of ***Paragonyaulacysta ?borealis***, ***Dingodinium ?spinosum*** [arrow to DZ2]
Berriasian	upper	*Gochteodinia villosa* Zone: *Endoscrinium pharo* Subzone LB: last occurrence of *Rotosphaeropsis thule* *Rotosphaeropsis thule* Subzone		*payeri* *analogus*	LB: first occurrence of ***Nelchinopsis kostromiensis***, *Ambonosphaera delicata* *Paragonyaulacysta ?borealis* zones (LB: upper part of the upper Volgian Substage)	*tolli* *meseznikowi* *analogus*	*Paragonyaulacysta ?borealis*–*Dingodinium ?spinosum* Zone: DZ1: *Pareodinioideae*, *Batioladinium varigranosum*, *Cassiculasphaeridia reticulata* zones LB: first occurrence of ***Batioladinium varigranosum***, ***Cassiculasphaeridia reticulata***, *Tanyosphaeridium magneticum*	
Berriasian	middle	LB: first occurrence of Batioladinium pomum, Aldorfia dictyota		*kochi*		*kochi*	*Paragonyaulacysta cappilosa* – *Sirmiodiniopsis orbis* spp. zones	
Berriasian	lower	*Amphorula expirata* Subzone LB (the upper Portlandian base): acme of *Circulodinium compta*				*sibiricus*		

Table 2. Comparison of the Lower Cretaceous dinocyst assemblages from northern regions of Eurasia and America

Stage, substage	Taxa in common with dinocysts from North Siberian sections		
	Arctic Canada (Williams et al., 1974; Bideaux, Fisher, 1976; Bujak, Williams, 1978; Davies, 1983)	Boreal Canada (McIntyre, Brideaux, 1980; Davies, 1983; Van Helden, 1986; Jenkins et al., 1974)	Greenland (Piasecki, 1979; Nohr-Hansen, 1993, Hakansson et al., 1981)
Lower Barremian	Unstudied	Unstudied	Unstudied
Upper Hauterivian	Pareodinioideae: *Batioladinium jaegeri*; other proximate dinocysts: *Wallodinium luna*, *Dingodinium cerviculum*; chorate: *Oligosphaeridium complex*	Pareodinioideae: *Batioladinium jaegeri*, *B. ?exiguum*; Ceratiaceae: *Pseudoceratium pelliferum*, *Muderongia simplex*; Aeroligeraceae: *Circulodinium distinctum*; other proximate: *Dingodinium cerviculum*; chorate: *Oligosphaeridium complex*	Proximate Gonyaulacoideae: *Cribropereidinium confossum*, *C. ?edvardsii*, *Stanfordella ?cretacea*; Pareodinioideae: *Batioladinium jaegeri*, *B. longicornutum*; Ceratiaceae: *Muderongia simplex*, *Pseudoceratium pelliferum*; Aeroligeraceae: *Circulodinium distinctum*; chorate: *Oligosphaeridium complex*, *Hystrichodinium voigtii*, *H. pulchrum*, *Gardodinium trabeculosum*, *Cassiculasphaeridia magna*
Lower Hauterivian	Proximate dinocysts: *Wallodinium luna*; chorate forms: *Oligosphaeridium complex*	Ceratiaceae: *Muderongia simplex*; Aeroligeraceae: *Circulodinium distinctum*; chorate: *Oligosphaeridium complex*	Pareodinioideae: *Batioladinium jaegeri*, *B. longicornutum*; Ceratiaceae: *Muderongia simplex*; other proximate: *Gardodinium trabeculosum*, *Cassiculasphaeridia magna*; Aeroligeraceae: *Circulodinium distinctum*; chorate: *Oligosphaeridium complex*, *Hystrichodinium voigtii*, *H. pulchrum*
Lower Valanginian	Proximate Gonyaulacoideae: *Tubotuberella rhombiformis*, *Apteodinium granulatum*, *A. spongiosum*, *Wrevittia helicoidea*, *Stanfordella ?cretacea*, *Nelchinopsis kostromiensis*, *Heslertonia heslertonensis*, *Sirmiodinium grossii*, ***Cribroperidinium ?muderongense***; Pareodinioideae: *Pareodinia ceratophora*, <u>*Paragonyaulacysta ?borealis* (at the base)</u>; Ceratiaceae: *Circulodinium distinctum*, *Muderongia simplex*; other proximate dinocysts: *Wallodinium luna*, ***Dingodinium cerviculum***; chorate dinocysts: ***Oligosphaeridium complex*** (from the base of *Buchia keyserlingi* Zone), *O. ?asterigium*, ***O. albertense***	Proximate Gonyaulacoideae: *Nelchinopsis kostromiensis*, *Lithodina stoveri*; pareodinioideae: *Pareodinia ceratophora*, *Batioladinium varigranosum*; Ceratiaceae: *Muderongia simplex*; other proximate: ***Dingodinium cerviculum***; Aeroligeraceae: *Circulodinium distinctum*; chorate: ***Oligosphaeridium complex*** (above the middle), *O. ?asterigium*	Proximate Gonyaulacoideae: *Trichodinium ciliatum*, *Heslertonia heslertonensis*, *Tubotuberella apatela*, *Sirmiodinium grossii*; Pareodinioideae: <u>*Paragonyaulacysta ?borealis*</u> (near the base); Ceratiaceae: *Muderongia simplex*; other proximate: *Dingodinium ?albertii*, *Cassiculasphaeridia magna*; Aeroligeraceae: *Circulodinium distinctum*; chorate: ***Oligosphaeridium complex*** (above the middle), *O. ?asterigium*
Berriasian	Proximate Gonyaulacoideae: *Tubotuberella rhombiformis*, *Microdinium opacum*, *Sirmiodinium grossii*; Pareodinioideae: *Pareodinia ceratophora*, *Paragonyaulacysta ?borealis*; Aeroligeraceae: ***Cyclonephelium cuculliforme***	Pareodinioideae: *Pareodinia ceratophora*, *Batioladinium varigranosum*; Aeroligeraceae: *Senoniasphaera jurassica*; chorate: ***Achomosphaera neptunii***	Proximate Gonyaulacoideae: *Sirmiodinium grossii*, *Tubotuberella apatela*; other proximate: *Dingodinium ?albertii*, *D. ?spinosum*, *Cassiculasphaeridia magna*; chorate: *Achomosphaera neptunii*

Table 2. (Contd.)

Stage, substage	Taxa in common with dinocysts from North Siberian sections		
	England (Duxbury, 1977, 1980; Harding, 1986; Davey, 2001)	North Sea (Duxbury et al., 1999; Duxbury, 201)	Northwestern Europe (Davey, 1979, 1982)
Lower Barremian	Unstudied	Proximate Gonyaulacoideae: <u>*Nelchinopsis kostromiensis* (lower part)</u>	Unstudied
Upper Hauterivian	Proximate Gonyaulacoideae: *Cribroperidinium confossum*, *C. ?edvardsii*, *Nelchinopsis kostromiensis*, *Stanfordella ?cretacea*; Pareodinioideae: *Batioladinium longicornutum*, *Aprobolocysta eilema*, *A. neista*; Ceratiaceae: *Muderongia simplex*, *M. staurota*, *M. crucis*, *M. tetracantha*, *Vesperopsis fragilis*, *Pseudoceratium pelliferum*; other proximate: *Wallodinium luna*, *W. krutzschii*, *Gardodinium trabeculosum*; chorate: *Oligosphaeridium complex*, *Hystrichodinium voigtii*, *H. pulchrum*	Proximate Gonyaulacoideae: *Cribroperidinium confossum*, *Nelchinopsis kostromiensis*; Pareodinioideae: *Batioladinium longicornutum*, ***Aprobolocysta eilema***, ***A. neista***; other proximate: *Cassiculasphaeridia magna*, *Gardodinium trabeculosum*; chorate: *Hystrichodinium voigtii*, *Oligosphaeridium complex*	Proximate Gonyaulacoideae: *Nelchinopsis kostromiensis*, *Cribroperidinium ?edvardsii*; Pareodinioideae: ***Aproblocysta neista***; Ceratiaceae: *Muderongia simplex*, *M. crucis*, *M. extensiva*, *Pseudoceratium pelliferum*; other proximate: *Cassiculasphaeridia magna*, *C. reticulata*; chorate: *Hystrichodinium pulchrum* (abundant), *H. voigtii* (sometimes significant), *Spiniferites ramosus*, *Oligosphaeridium complex* (sometimes abundant)
Lower Hauterivian	Pareodinioideae: *Batioladinium varigranosum*, *B. longicornutum*; Ceratiaceae: *Muderongia simplex*, *M. staurota*, *Pseudoceratium pelliferum*; other proximate: *Wallodinium luna*, *W. krutzschii*, *Gardodinium trabeculosum*; chorate: *Oligosphaeridium complex*, *Hystrichodinium voigtii*, *H. pulchrum*	Proximate Gonyaulacoideae: *Nelchinopsis kostromiensis*; Ceratiaceae: *Muderongia tetracantha*; other proximate: *Cassiculasphaeridia magna*, *Gardodinium trabeculosum*; chorate: *Oligosphaeridium complex*	Pareodinioideae: *Batioladinium varigranosum*, *B. longicornutum*; Ceratiaceae: *Muderongia simplex*, *M. crucis*; other proximate: *Cassiculasphaeridia magna*, *C. reticulata*, *Gardodinium trabeculosum*; chorate: *Hystrichodinium pulchrum* (abundant), *H. voigtii* (sometimes significant), *Oligosphaeridium complex* (sometimes abundant)
Lower Valanginian	Proximate Gonyaulacoideae: *Trichodinium ciliatum*, *Heslertonia heslertonensis*, *Tubotuberella apatela*; Pareodinioideae: *Batioladinium varigranosum*; Ceratiaceae: *Muderongia simplex*, ***M. crucis***; other proximate: *Wallodinium luna*, *W. krutzschii*, *Dingodinium ?albertii*; aeroligeraceae: *Circulodinium distinctum*	Proximate Gonyaulacoideae: *Nelchinopsis kostromiensis*, *Heslertonia heslertonensis*, *Tubotuberella apatela*; other proximate: *Cassiculasphaeridia magna*; chorate: ***Oligosphaeridium complex*** (from the middle of *Paratollia*)	Proximate Gonyaulacoideae: *Wrevittia helicoidea*, *Sirmiodinium grossii*, *Trichodinium ciliatum*, *Tubotuberella apatela*, *Heslertonia heslertonensis*; Ceratiaceae: *Muderongia simplex*, ***M. crucis***; other proximate: *Cassiculasphaeridia magna*, *C. reticulata*, *Dingodinium ?albertii*, *Fromea amphora*; chorate: *Oligosphaeridium diluculum*
Berriasian	Proximate Gonyaulacoideae: *Tubotuberella apatela*; other proximate: *Wallodinium krutzschii*, *Dingodinium ?albertii*, ***D. ?spinosum***; chorate: ***Achomosphaera neptunii***	Proximate: ***Dingodinium ?spinosum***, *Cassiculasphaeridia magna*; chorate: ***Achomosphaera neptunii***	Proximate Gonyaulacoideae: *Sirmiodinium grossii*, *Tubotuberella apatela*, *Aldorfia dictyota*; Pareodinioideae: ***Batioladinium varigranosum***; other proximate: *Dingodinium minutum*, *D. ?albertii*, ***D. ?spinosum***, *Cassiculasphaeridia magna*

Table 2. (Contd.)

Stage, substage	Taxa in common with dinocysts from North Siberian sections	
	Northern Germany (Prössl, 1990)	Norway (Aarhus et al., 1986)
Lower Barremian	Pareodinioideae: <u>*Aprobolocysta eilema*</u>; other proximate: *Wallodinium krutzschii*	Unstudied
Upper Hauterivian	Proximate Gonyaulacoideae: *Cribropereidinium confossum*, *C. ?edvardsii*, *Stanfordella ?cretacea*, *S. exanguia*, *Wrevittia ?diutina*, *Endoscrinium campanula*, *Nelchinopsis kostromiensis*; Pareodinioideae: *Batioladinium longicornutum*, *B. jaegeri*, ***Aprobolocysta neista***, ***A. eilema***; Ceratiaceae: *Pseudoceratium pelliferum*, *Muderongia australis*, *M. simplex*, *M. tetracantha*, *M. staurota*, *Odontochitina operculata*; other proximate: *Chlamydophorella nyei*, *Wallodinium krutzschii*, *W. luna*, *Cassiculasphaeridia magna*, *C. reticulata*, *Dingodinium cerviculum*, *Gardodinium trabeculosum*, *G. ordinale*; Aeroligeraceae: ***Cyclonephelium brevispinatum***, *Circulodinium distinctum*; chorate: *Hystrichodinium pulchrum*, *H. voigtii*, *O. complex*, *Dapsilidinium* "*multispinosum*"	Proximate Gonyaulacoideae: *Cribropereidinuum confossum*, *C. ?edvardsii*; Pareodinioideae: *Batioladinium varigranosum*; Ceratiaceae: *Aptea anaphrissa* (persistent), *Muderongia simplex*, *M. crucis*, *M. staurota*, *Pseudoceratium pelliferum*; other proximate: *Cassiculasphaeridia magna*, *C. reticulata*, *Chlamydophorella nyei*, *Gardodinium trabeculosum*, *Wallodinium krutzschii*; Aeroligeraceae: *Circulodinium distinctum*; chorate: *Cauca parva*, *Dapsilidinium multispinosum*, *Hystrichodinium pulchrum*, *H. voigtii*, *Oligosphaeridium complex*, *Spiniferites ramosus*
Lower Hauterivian	Proximate Gonyaulacoideae: *Cribropereidinium confossum*, *C. ?edvardsii*, *C. ?muderongense*, *Nelchinopsis kostromiensis*; Pareodinioideae: *Batioladinium longicornutum*; Ceratiaceae: *Pseudoceratium pelliferum*, *Muderongia australis*, *M. simplex*, *M. tetracantha*, *M. staurota*; other proximate: *Chlamydophorella nyei*, *Wallodinium krutzschii*, *W. luna*, *Cassiculasphaeridia magna*, *C. reticulata*, *Dingodinium cerviculum*, *Gardodinium trabeculosum*; Aeroligeraceae: ***Cyclonephelium brevispinatum***, *Circulodinium distinctum*; chorate: *Hystrichodinium pulchrum*, *H. voigtii*, *Oligosphaeridium complex*, ***Dapsilidinium "multispinosum"***	Pareodinioideae: *Batioladinium varigranosum*; Ceratiaceae: *Muderongia simplex*, *M. crucis*, *M. staurota*; other proximate: *Cassiculasphaeridia magna*, *C. reticulata*, *Chlamydophorella nyei*, *Gardodinium trabeculosum*, *Wallodinium krutzschii*; Aeroligeraceae: *Circulodinium distinctum*; chorate: *Hystrichodinium pulchrum*, *H. voigtii*, *Oligosphaeridium complex*
Lower Valanginian	Unstudied	Proximate Gonyaulacoideae: *Apteodinium granulatum*, *A. spongiosum*, *Nelchinopsis kostromiensis*, *Wrevittia helicoidea*, *Sirmiodinium grossii*, ***Cribroperidinium ?muderongense***; Pareodinioideae: *Batioladinium varigranosum*, <u>*Paragonyaulacysta ?borealis* (at the very base)</u>; Ceratiaceae: *Muderongia simplex*; other proximate: *Cassiculasphaeridia magna*, *C. reticulata*, *Chlamydophorella nyei*, *Fromea amphora*, *Wallodinium krutzschii*, ***Gardodinium trabeculosum***; Aeroligeraceae: *Circulodinium compta*; chorate: *Oligosphaeridium diluculum*, ***O. complex*** (~from the middle)
Berriasian	Unstudied	Proximate Gonyaulacoideae: *Sirmiodinium grossii*; Pareodinioideae: *Paragonyaulacysta ?borealis*; other proximate: *Cassiculasphaeridia magna*, *Chlamydophorella nyei*, ***Dingodinium ?spinosum***, *Fromea amphora*, *Wallodinium krutzschii*; chorate: ***Spiniferites ramosus***

Table 2. (Contd.)

Stage, substage	Taxa in common with dinocysts from North Siberian sections		
	Barents Sea shelf (Aarhus et al., 1990; Smelror et al. 1998)	Moscow basin (Iosifova, 1996)	Subpolar Urals and Siberia (Il'ina, 1988; Fedorova et al., 1993; Shulgina et al., 1994; Lebedeva and Nikitenko, 1998; Kirichkova et al., 1999; Riding et al., 1999; Beizel' et al., 2002)
Lower Barremian	Pareodinioideae: *Batioladinium ?exiguum*, *Nelchinopsis kostromiensis* (up to the middle)	Unstudied	Unstudied
Upper Hauterivian	Proximate Gonyaulacoideae: *Endoscrinium campanula*, *Stanfordella ?cretacea*, *Cribropereidinium ?edvardsii*; Pareodinioideae: *Batioladinium jaegeri*, *B. longicornutum*; Ceratiaceae: *Pseudoceratium pelliferum*, *Muderongia simplex*, *M. australis*, *M. staurota*, *M. tetracantha*, *M. asymmetrica*; other proximate: *Gardodinium trabeculosum*, *Chlamydophorella nyei*; Aeroligeraceae: *Circulodinium distinctum*, *Aptea anaphrissa*; chorate: *Oligosphaeridium complex*, *Dapsilidinium* "*multispinosum*," *Cymozosphaeridium* "*phoenix*"	Proximate Gonyaulacoideae: *Apteodinium maculatum*, *E. campanula*, *Chytroeisphaeridia chytroides*; Pareodinioideae: *Batioladinium jaegeri*, *B. varigranosum*, ***Aprobolocysta neista***, ***A. eilema***; Ceratiaceae: *Pseudoceratium pelliferum*, *M. simplex*; other proximate: *Wallodinium luna*, *W. krutzschii*, *W. cylindricum*, *Chlamydophorell nyei*, *G. trabeculosum*, *Cassiculasphaeridia reticulata*; Aeroligeraceae: *Circulodinium distinctum*; chorate: *Oligosphaeridium complex*, *Hystrichodinium pulchrum*, *H. voigtii*	Unstudied
Lower Hauterivian	Pareodinioideae: *Batioladinium jaegeri*, *B. longicornutum*; Ceratiaceae: ***Aptea anaphrissa*** (from the upper part), *Muderongia simplex*, *M. australis*, *M. staurota*, *M. tetracantha*; other proximate: *Gardodinium trabeculosum*, *Chlamydophorella nyei*; Aeroligeraceae: *Circulodinium distinctum*; chorate: *Oligosphaeridium complex*, *Cymososphaeridium* "*phoenix*"	Proximate Gonyaulacoideae: *Apteodinium maculatum*, *N. kostromiensis*, *Ambonosphaera ?staffiensis*; Pareodinioideae: *Batioladinium varigranosum*; Ceratiaceae: *Muderongia simplex*; other proximate: *Wallodinium luna*, *W. krutzschii*, *W. cylindricum*, *Chlamydophorell nyei*, *G. trabeculosum*, *Cassiculasphaeridia reticulata*; Aeroligeraceae: *Circulodinium distinctum*; chorate: *Oligosphaeridium complex*, *Hystrichodinium pulchrum*, *H. voigtii*	Proximate Gonyaulacoideae: *Apteodinium maculatum*, *Nelchinopsis kostromiensis*; Pareodinioideae: *B. varigranosum*, *B. longicornutum*; Ceratiaceae: *Muderongia simplex*, *M. crucis*, *M. tetracantha*; other proximate: *Chlamydophorella nyei*, *Dingodinium cerviculum*, *Wallodinium luna*, *W. krutzschii*, *Cassiculasphaeridia reticulata*, *Gardodinium trabeculosum*; Aeroligeraceae: *Circulodinium distinctum*, *Tenua americana*; chorate: *O. complex*, ***Hystrichodinium solare***
Lower Valanginian	Proximate Gonyaulacoideae: *Wrevittia helicoidea*	Proximate Gonyaulacoideae: *Apteodinium maculatum*, *Trichodinium ciliatum*, *T. speetonense*, *Stanfordella fastigiata*, *Tubotuberella apatela*, *Sirmiodinium grossii*; Pareodinioideae: *Pareodinia ceratophora*; Ceratiaceae: *Muderongia simplex*; other proximate: *Wallodinium luna*, *W. krutzschii*, *D. ?albertii*, *Chlamydophorella nyei*, ***Gardodinium trabeculosum***, *Cassiculasphaeridia reticulata*, *Fromea amphora*	Proximate Gonyaulacoideae: *Tubotuberella rhombiformis* (in the lower part), *S. orbis*, *Apteodinium granulatum*, *Nelchinopsis kostromiensis*, ***Cribroperidinium ?muderongense***; Pareodinioideae: *Paragonyaulacysta ?borealis* (at the very base); other proximate: *Chlamydophorella nyei*, ***Dingodinium cerviculum***, *D. ?albertii*, *Wallodinium krutzschii*, *Cassiculasphaeridia reticulata*, *C. magna*; chorate: *Oligosphaeridium diluculum*
Berriasian	Pareodinioideae: *Paragonyaulacysta ?borealis*	Proximate Gonyaulacoideae: *Apteodinium maculatum*, *Tubotuberella apatela*, *Sirmiodinium grossii*; Pareodinioideae: *Pareodinia ceratophora*; other proximate: *W. luna*, *W. krutzschii*, *W. cylindricum*, *D. ?albertii*, *C. nyei*, ***C. reticulata***, *F. amphora*; Aeroligeraceae: *Senoniasphaera jurassica*; chorate: ***A. neptunii***, ***Spiniferites ramosus***	Proximate Gonyaulacoideae: ***Stanfordella exanguia***, *S. orbis*, *T. rhombiformis*, *T. apatela*, *S. grossii*, *Microdinium opacum*; Pareodinioideae: *Paragonyaulacysta ?borealis*, *Imbatodinium kondratjevii*; other proximate: *Wallodinium krutzschii*, *C. nyei*, *Dingodinium ?albertii*, ***Cassiculasphaeridia reticulata***, *C. magna*; Aeroligeraceae: ***Cyclonephelium cuculliforme***

Note: Names of species in common with North Siberian taxa are given in bold or underlined, when they have first or last occurrence in the designated interval.

Table 3. First and last occurrence of the Lower Cretaceous dinocyst species established in different northern regions of Eurasia and America

Age	Epoch	Palynological events: Recognizable in different regions of North Eurasia	Palynological events: Recognizable in Canada only
Barremian	late	┌ ***Cassiculasphaeridia magna*** (G, NE); ┌ acme of ***Aptea anaphrissa*** (everywhere except for Russia); *Gonyaulacysta jurassica* (BS,G)	┘ *Fromea triquetra*, *Pseudoceratium retusum*: (AC)
Barremian	early	┘ acme of ***Aptea anaphrissa*** (every where except for Russia); *Ellipsoidictyum sagena* (G, BS, MB); ┌ ***Nelchinopsis kostromiensis*** (G, NE, BS); ┘ *Protoellipsodinium clavulum* (NE, BS, MB)	┘ *Endoceratium dettmanae* (AC); *Pseudoceratium "regium"* (SC); ┌ *Kallosphaeridium ?circulare*, ***Pilosidinium filiatum***, *Valvaeodinium atlanticum*: (AC); *Ctenidodinium ?scissum*, *Lanterna sportula* *Rhynchodiniopsis serrata*: (SC);
Hauterivian	late		
Hauterivian	early	┘ *Cribroperidinium confossum*, ***Kiokansium polypes***, *Tanyosphaeridium boletus*: (G, NE); ***Cribroperidinium orthoceras*** (SC, BS, G); *Ellipsoidictyum imperfectum* (SR); ┌ *Spiniferites primaevus* (G, NE)	┘ *Circulodinium attadalicum*, *Subtilisphaera ?pirnaensis*, *Surculosphaeridium ?longifurcatum*: (SC); *Cylonephelium vannophorum* (SC, AC); ┌ *Apteodinium apiatum*, *Batiacasphaera agglutinata*, *Leptodinium episomum*, *Prolixosphaeridium "spissum,"* ***Tubotuberella rhombiformis***: (AC); *Biorbifera johneingii*, *Circulodinium hirtellum*: (SC)
Valanginian	late		┌ *Ellipsoidictium cinctum*, *Scriniodinium crystallinum*: (AC); *Imbatodinium kondratjevii* (ЮК); ┘ *Hystrichosphaeridium recurvatum* (SC); ┌ *Trichodinium erinaceoides* (AC)
Valanginian	early	┘ ***Oligosphaeridium complex*** (everywhere except for MB); ┘ ***Cauaca parva*** (SR, S); ┌ ***Paragonyaulacysta capillosa*** (NE, AC, SC); ***Dingodinium ?spinosum*** (NE, SR, S)	┌ *Lithosphaeridium siphoniphorum* (SC); ┘ *Apteodinium apiatum*, *Batiacasphaera agglutinata*, *Caligodinium aceras*, *Cribroperidinium saetigerum*, *Cribroperidinium spinoreticulatum*, *Ctenidodinium ?scissum*, *Fromea senilis*, *Gochteodinia judilentinae*, *Kallosphaeridium ?circulare*, *Leptodinium episomum*, ***Muderongia "tomaszowensis," Odontochitina operculata***, ***Oligosphaeridium albertense***: (AC); ┌ *Systematophora orbifera* (SC); *Leptodinium mamilliferum*, *Moesiodinium raileanui*: (AC);
Berriasian	late		
Berriasian	middle	┘ *Batioladinium ?gochtii* (SC, AC, MB); *Egmontodinium toryna* (G, NE, SR); *Lithodinia pertusa* (G, NE, MB); *Spiniferites alatus* (G, MB); ***Nelchinopsis kostromiensis*** (SC, S); ***Cassiculasphaeridia reticulata*** (MB, S); ┘ *Oligosphaeridium diluculum* (NE, SR, MB); ┌ *Gonyaulacysta eisenackii* (BS, MB)	┘ ***Batioladinium ?exiguum***, ***Batioladinium jaegeri***, ***Batioladinium varigranosum***, *Subtilisphaera perlucida*: (SC); ┌ *Amphorula metaelliptica*, *Cantulodinium arthuriae*, *Sentusidinium* aff. *rioultii*: (SC)
Berriasian	early	┘ *Batioladinium pelliferum* (SR, NE, MB); *Kleithriasphaeridium "simplicispinum"* (SR, MB); *Occisucysta tentorium* (NE, SR, G, S); *Phoberocysta neocomica* (SR, MB); ***Circulodinium distinctum***, ***Endoscrinium campanula***: (SC, G)	┘ *Circulodinium hirtellum*, ***Cribroperidinium sepimentum***, *Ctenidodinium elegantum*, *Biorbifera johnewingii*, *Rhynchodiniopsis serrata*, *Systematophora complicata*: (SC)

Notes. ┘ – first occurrence, ┌ – last occurrence(SC) southern and southeastern Canada, (AC) Arctic Canada, (G) Greenland, West Europe, (NE) South England and northern regions regions of Germany, France and Denmark, (SR) subpolar regions, (BS) Barents Sea shelf, (MB) Moscow basin, (S) Siberia; printed in bold are species found in the studied sections of North Siberia.

Table 3. (Contd.)

Age	Epoch	Palynological events: Recognizable only in northwestern Europe and Barents Sea shelf	Palynological events: Recognizable in Greenland only
Barremian	late	*Fromea quadrugata* (NE, BS); *Carpodinium granulatum* (NE) *Canningiopsis "tabulata," Cribroperidinium boreas, Impagidinium diversum*: (NE); *Kleithriasphaeridium ?sarmentum* (NE, SR); *Muderongia imparilis, Ellipsodinium reticulatum*: (NE) ***Aprobolocysta neista*** (NE, BS); *Cribroperidinium ?cornutum* (NE) *Endoscrinium pharo* (NE, BS) *Batiacasphaera mica* (NE); *Spiniferites fenestratus* (NE	*Kleithriasphaeridium corrugatum* *Batioladinium pelliferum*
	early	*Achomosphaera ramulifera, Gonyaulacysta compta, Impagidinium alectophorum,* *Nyctericysta ?pannosa, Oligosphaeridium fenestratum*: (NE) *Cribroperidinium "comptum"* (BS) *Batiacasphaera mica, Gonyaulacysta dualis* (BS) *Apteodinium reticulatum, Sepispinula ancorifera*: (ΠE); *Muderongia pariata* (BS); *Cerbia tabulata, Exiguisphaera plectilis, Hystrichodinium compactum,* *Pterodinium premnos, Rhynchodiniopsis fimbriata*: (NE) *Nexosispinum vetusculum* (NE, BS); *Ascodinium fissilum, Cribroperidinium colum, Cribroperidinium fragilis, Exiguisphaera phragma, Lagenorhytis delicatula, Pterodinium "?cingulatus," Tanyosphaeridium magneticum, Rhynchodiniopsis cladophora, Tetrachacysta spinosigibberosa*: (NE); *Mendicodinium groenlandicum,* ***Microdinium opacum***, *Muderongia aequicorna, Riguadella aemula, Spiniferites alatus,* ***Wallodinium cylindricum***, *Wrevittia ?diutina*: (BS)	*Batiacasphaera spumosa, Prolixosphaeridium dierense, Sentusidinium verrucosus, Wallodinium elongatum* *Desmocysta plecta*
Hauterivian	late	*Florentinia mantellii* (NE) ***Aprobolocysta eilema*** (NE; BS) *Subtilisphaera terrula* (NE) ***Vesperopsis fragilis***, *Coronifera oceanica,* ***Downiesphaeridium aciculare***, *Florentinia interrupta,* ***Fromea complicata***, *Subtilisphaera terrula, Taleisphaera hydra,* ***Wrevittia cassidata***: (NE); *Aprobolocysta eilema:* (NE, BS) *Australisphaera fragilis, Canningia duxburyi, Canningia grandis, Cymososphaeridium validum, Desmocysta simplex, Systematophora areolata, Kleithriasphaeridium porosispinum*: (NE)	***Cribroperidinium exilicristatum***
	early	*Cribroperidinium "alveolatum," Cribroperidinium ?conutum, Nexosispinum vetusculum,* ***Aprobolocysta neista***, abundance of ***Gardodinium trabeculosum***: (NE); ***Aptea anaphrissa*** (SR) *Stiphrosphaeridium arbustum*: (NE) ***Circulodinium compta***, *Oligosphaeridium junctum* (NE)	
Valanginian	late	***Canningiopsis colliveri***, ***Circulodinium brevispinosum***, *Cometodinium ?comatum, Cribroperidinium "diaphanum," Dapsilidinium laminaspinosum,* ***Downiesphaeridium multispinosum***, ***Gardodinium ordinale***, *Hystrichodinium furcatum, Hystrichodinium ramoides, Rhynchodiniopsis aptiana, Spiniferites speetonensis,* ***Stanfordella ordocavata***, *Tanyosphaeridium salpinx, Subtilisphaera perlucida, Wrevittia ?perforobtusa*: (NE); *Dapsilidinium multispinosum* (NE, SR); *Muderongia aequicora,* ***Muderongia asymmetrica***, *Pseudoceratium nudum, Palaeoperidinium cretaceum,* ***Cymososphaeridium ?phoenix*** (SR) *Systematophora palmula, S. scoiacea*: (NE)	*Batioladinium pelliferum,* ***Cribroperidinium exilicristatum***
	early	*Cribroperidinium ?tenuiceras,* ***Muderongia staurota***: (SR); *Hystrichosphaeridium arborispinum,* ***Muderongia extensiva***: (NE) ***Discorsia nanna***, *Exochosphaeridium phragmites, Nematosphaeropsis vetuscula,* *Nematosphaeropsis scala,* ***Muderongia crucis***, ***M. tetracantha***, *Protoellipsoidinium spinosum*: (NE); *Systematophora silybum* (SR) *Aprobolocysta extrema, Spiniferites ?spongiosus, Tehamadinium daveyi:* (NE)	*Egmontodinium toryna*
Berriasian	late	*Cymososphaeridium validum* (NE) *Exiguisphaera phragma, Lagenorhytis delicatula* (NE) *Ctenidodinium ?schizablata, Dichadogonyaulax culmula, Papuadinium apiculatum, Stiphrosphaeridium dictyophorum*: (CE); *Leptodinium millioudii, Leptodinium subtile, Trichodinium scarburghense*: (BS) *Rotosphaeropsis thule* (NE)	*Endoscrinium granulatum*
	middle	*Gochteodinia villosa* subsp. *multifurcata* (NE, SR); *Gonyaulacysta anglese, Impletosphaeridium tribuliferum:* (SR) *Gochteodinia verrucosa, Sentusidinium separatum* (SR); *Amphorula expirata* (NE, SR); *Egmontodinium polyplacophorum* (NE)	
	early	*Gochteodinia verrucosa, Prolixosphaeridium granulosum*: (SR); *Stiphrosphaeridium arbustum* (NE) *Kalyptea diceras* (SR) *Kleithriasphaeridium fasciatum, K. eoinodes, Diacanthum hollisteri, Tehamadinium evitti*: (NE); *Wrevittia ?diutina* (NE, SR); *Atopodinium polygonale, Systematophora palmula*: (BS)	***Cribroperidinium ?edvardsii***, *Dapsilidinium warrenii,* ***Heslertonia heslertonensis***, *Egmontodinium toryna*; ***Pseudoceratium pelliferum***

Table 3. (Contd.)

Age	Epoch	Palynological events: Recognizable in the Moscow basin only	Recognizable in Siberia only	Recognizable in subpolar regions only	Recognizable in Boreal province only
Barremian	late	*Cyclonephelium hexalobosum*		*Apteodinium reticulatum* (G, NE); ***Batioladinium longicornutum*** (AC, G, SR, NE)	
	early	*Cribroperidinium cooksoniae* *Gardodinium attenuatum*, *Neodiacrodium brevispinosum*, *N. corniculatum*, *N. timofeevii*, *Pseudoceratium aulaeum*		*Nyctericysta ?vitrea*, *Pseudoceratium toveae*, ***Tubotuberella uncinata***: (AC, G)	
Hauterivian	late	*Cribroperidinium cooksoniae*, *Kiokansium prolatum*, *Leptodinium ?hadrum*, *Pseudoceratium iveri*, *Subtilisphaera cheit* ***Ambonosphaera ?staffinensis***, *Apteodinium deflandrei*, *Apteodinium granuliferum*, *Apteodinium gerasimovii*, *Chitroeisphaeridia cerastes*, *Cyclonephelium maugaad*, *Epitricysta vinkensis*, *Hystrichogylon membraniforum*, *Impagidinium orocaviopse*, *Lithodinia arcanitabulata*, *Lithodinia diaphana*, *Microdinium densigranulatum*, ***Senoniasphaera jurassica***, *Trichodinium discus*, ***Tubotuberella apatela***, *Warrenia ?brevispinosa*	***Aprobolocysta galeata***		*Isthmocystis distincta* (NE, MB)
	early	*Gardodinium lowii*, *Gonyaulacysta teichos*	***Vesperopsis mayi***, ***Cyclonephelium intonsum***, ***P. expolitum*** *Druggidium jubatum*, *Oligosphaeridium abaculum* ***Muderongia brevispinosa***, *Ambonosphaera delicata*		***Aprobolocysta neista***, *Gonyaulacysta teichos*, *Hystrichogylon stolidota*: (NE, MB); *Callaiosphaeridium asymmetricum*, *Pseudoceratium* "*gochtii*" (SC, NE)
Valanginian	late	*Apteodinium deflandrei*, *Cyclonephelium maugaad*, *Gardodinium lowii*, *Hystrichogylon membraniforum*, *Impagidinium ordocaviopse*, *Lithodinia diaphana*, *Microdinium densigranulatum*, *Protoellipsodinium mugatae*, *P. touile*, *Rhombodella vesca*, *Trichodinium discus*, *Warrenia ?brevispinosa*	***Tenua americana*** ***Dingodinium tuberosum***, *Cribroperidinium granulatum*	***Cyclonephelium cuculliforme*** (AC, S)	
	early		***Muderongia australis***, ***Aprobolocysta galeata***	***Paragonyaulacysta ?borealis*** (AC, G, S)	
Berriasian	late	*Lithodinia perforata*, *Protobatioladinium rossicum*, *Surculosphaeridium cribrotubiliferum* *Cometodinium whitei*	*Ambonosphaera delicata* *Tanyosphaeridium variecalamus*, ***Escharisphaeridia rudis***	***Cribroperidinium muderongense***, *Trichodinium castanea*: (AC, NE); ***Batioladinium longicornutum*** (NE, S)	
	middle	*Apteodinium granuliferum*, *Apteodinium gerasimovii*, *Cribroperidinium volkovae*, *Epitricysta vinkensis*, *Lithodinia perforata*, *Muderongia brevispinosa*, *Prolixosphaeridium parvispinosum*, *Protobatioladinium rossicum*, *Protoellipsodinium seghire*, *Tehamadinium daveyi* *Prolixosphaeridium conulum*, *Gonyaulacysta dentata*, *Systematophora ovata*	***T. magneticum***, ***Cribroperidinium tensiftense***, ***F. amphora***, ***F. fragilis*** ***Sepispinula ?"huguoniotii"*** *Achomosphaera verdieri*, *Pareodinia hallosa*, *Leptodinium eumorphum*, ***Stanfordella exanguia***, ***Trichodinium speetonense***	***Cyclonephelium cuculliforme*** (AC, S)	*Phoberocysta tabulata* (NE, MB)
	early	***Apteodinium maculatum***, *Canningia grandis*, *Canningia reticulata*, *Cometodinium whitei*, ***Gardodinium trabeculosum***, *Heslertonia pellucida*, ***Stanfordella fastigiata***, *Wallodinium luna*	*Achomosphaera verdieri*, *Pareodinia hallosa* *Cribroperidinium globatum* ***Athigmatocysta glabra***	***Spiniferites ramosus*** (AC, S)	***Achomosphaera neptunii*** (SC, NB); *Spiniferites dentatus* (NE, SC)

Table 4. Palynological substantiation of dinocyst reference level established in North Siberia

Dinocyst levels	Palynological event	Regions, where palynological events are recognized
Lower boundary: *Hystrichodinium solare*, *Muderongia* spp. (DA5); lower Hauterivian, middle *Homolsomites bojarkensis*	**First occurrence of *Hystrichodinium solare***	Subpolar Urals, beginning from the lower Hauterivian (Lebedeva and Nikitenko; 1998)
	First occurrence of *Muderongia staurota*	Barents Sea shelf, beginning from the upper Valanginian (Aarhus et al., 1986) Northwestern Europe, beginning from the upper Hauterivian (Duxbury, 1977; Harding, 1986; *A Stratigraphic*…, 1992)
	First occurrence of *Muderongia tetracantha*	Barents Sea shelf, beginning from the Hauterivian (Aarhus et al., 1990; Smelror et al., 1998); Northwestern Europe, beginning from the upper Hauterivian (Duxbury, 1977; Davey, 1979; Nøhr-Hansen, 1993); *crucis/tetracantha*: in northwestern Europe since the upper part of the lower Valanginian (*Polyptychites*) (*A Stratigraphic*…, 1992); in the Subpolar Urals since the upper Valanginian (Lebedeva and Nikitenko; 1998)
	Diversification of the genus *Muderongia*	Valanginian assemblages commonly include two species *M. simplex* + *M. cruces* and *M. tomaszovensis* or *M. perforata* for the lower substage (Bujak and Williams, 1978; Davey, 1979; Davies, 1983; *A Stratigraphic*…, 1992) and + *M. extensiva* or *M. staurota* for the upper one (Duxbury, 1977; Fisher and Riley, 1980; Aarhus et al., 1986); lower Hauterivian: 4 species *M. tetracantha*, *M. asymmetrica*, *M. aequicorna*, and *M. australis* in the Barents Sea shelf (Aarhus et al., 1990); upper Hauterivian–Barremian: 2–4 species in northwestern Europe and Greenland (Duxbury, 1977, 1980, 2001; *A Stratigraphic*…, 1992; Nøhr-Hansen, 1993)
LB *Aldorfia sibirica*, *Aprobolocysta galeata*, (DA4): middle *ramulicosta*	First abundance peak of *Dingodinium cerviculum*	Persistent abundance is more typical of the upper Valanginian and Hauterivian: Norway (Aarhus, 1986), Subpolar Urals (Lebedeva and Nikitenko, 1998)
Lower boundary *Oligosphaeridium complex*, *Dingodinium cerviculum* (DA3): lower Valanginian, middle *Euryptychites quadrifidus*	**First occurrence of *Muderongia cruces*** (borehole Romanovskaya)	Northern areas of West Europe (Daveey, 1979; *A Stratigraphic*…, 1992)
	First occurrence of *Oligosphaeridium complex*	First occurrence practically isochronous in the lower part of the lower Valanginian: Canada (Bujak and Williams, 1978; Brideaux and McIntyre, 1980; Davies, 1983), Greenland (Piasecki, 1979), northwestern Europe (Duxbury, 1977, 2001; Davey, 1979; Aarhus et al., 1986; *A Stratigraphic*…, 1992)
	First occurrence of *Dingodinium crviculum*	In West Europe first occurrence in the upper Volgian Substage (Davey, 1979); In Arctic Canada and Siberia first occurrence in lower part of the lower Valanginian (Brideaux and McIntyre, 1980; Davies, 1983; Lebedeva and Nikitenko, 1998)
Lower boundary *Escharisphaeridia* spp., *Oligosphaeridium* spp., *Circulodinium* spp. (DA2): lower Valanginian, lower part of *Neotollia klimovskiensis*	**Last occurrence of *Dingodinium ?spinosum* somewhat lower (Severo-Vologochanskaya)**	Practically isochronous last occurrence at the Berriasian top: northern areas of West Europe (Duxbury, 1977; Davey, 1979; Fisher, Riley, 1980; *A stratigraphic*…, 1992; Duxbury et al., 1999)
	Last occurrence of *Pargonyaulacysta ?borealis*	Last occurrence in lower part of the lower Valanginian: Arctic Canada (McIntyre, Brideaux, 1980), Greenland (Hakansson et al., 1981), Norway (Aarhus et al., 1986), Siberia (Lebedeva and Nikitenko, 1998)
	Sharply decreased diversity of Pareodinioideae	–
Loer boundary Pareodinioideae, *Cassiculasphaeridia reticulata*, *Batioladinium varigranosum* (DA1); upper Berriasian, *Surites analogus* base	**First occurrence of *Batioladinium varigranosum***	First occurrence in the mid-Berriasian: Newfoundland (Van Helden, 1986), northwestern Europe (Davey, 1982); last occurrence in the mid-Barremian of the Barents Sea shelf (Smelror et al., 1998); Characteristic component of Valanginian and Hauterivian assemblages in northwestern Europe (Duxbury, 1977; *A Stratigraphic*…, 1992; Davey, 2001) and Moscow basin (Iosifova, 1996)
	First occurrence of *Cassiculasphaeridia reticulata*	First occurrence at the base of the *Bojarkia payeri* Zone in the Subpolar Urals (Lebedeva and Nikitenko, 1998); Characteristic component of Valanginian, Hauterivian and Barremian assemblages in northwestern Europe (Duxbury, 1977; Aarhus et al., 1986; *A Stratigraphic*…, 1992; Davey, 2001) and Moscow basin (Iosifova, 1996)
	First occurrence of *Tanyosphaeridium magneticum*	The lower–middle Valanginian of Arctic Canada (Davies, 1983); the lower upper Valanginian of the Barents Sea shelf (Smelror et al., 1998); The Hauterivian–lower Barremian of northern Germany (Prössl, 1990)

Table 4. (Contd.)

Dinocyst levels	Palynological event	Regions, where palynological events are recognized
Canningia spp.–*Nelchinopsis kostromiensis* Beds (DA8): lower part of the lower Barremian	**Presence of *Nelchinopsis kostromiensis***	The latest specimens are discovered in lower part of the lower Barremian in Greenland and northwestern Europe (Nöhr-Hansen, 1993)
	Presence of *Aprobolocysta eilema*	The latest specimens are discovered in lower part of the lower Barremian in northwestern Europe (Duxbury, 1980, 2001; *A Stratigraphic*…, 1992)
Lower boundary, *Aprobolocysta eilema*–*A. neista*–*Odontochitina* spp. assemblage (DA7): the upper Hauterivian base	**First occurrence of *Aprobolocysta eilema***	First occurrence at the base of the upper Hauterivian (Duxbury, 1977, 2001; *A Stratigraphic*…, 1992)
	First occurrence of *Aprobolocysta neista*	First occurrence in upper part of the lower Hauterivian (Duxbury, 2001)
	First occurrence of *Odontochitina operculata*	First occurrence in the Valanginian of Arctic Canada (Davies, 1983) and since the upper Hauterivian in the Barents Sea shelf and northern Germany (Aarhus et al., 1990; Prössl, 1990
	First occurrence of *Psedoceratium expolitum*, *Gonyaulacysta ?kleithria*, *Cyclonephelium intonsum*	First occurrence of *Psedoceratium expolitum* in the lower Barremian of Moscow syneclise (Iosifova, 1986); *Gonyaulacysta ?kleithria* and *Cyclonephelium intonsum* unknown from the Berriasian–Barremian of North Eurasia and America are described from the Aptian–Albian of South England (Duxbury, 1983)
	First occurrence of *Vesperopsis fragilis*, *V. mayi* somewhat higher	First occurrence of *Vesperopsis fragilis* in the upper Hauterivian of South England (Harding, 1986), *V. mayi* in the upper Barremian of Arctic Canada (Nöhr-Hansen, 1993)
	Last occurrence of *Hystrichodinium solare*	In the Subpolar Urals, forms of similar morphology are established in the lower Hauterivian only (Lebedeva and Nikitenko, 1998)
	Last occurrence of *Oligosphaeridium ?asterigium*	Last occurrence in the Turonian of northern Germany (Prössl, 1990); up to the Aptian in Canada (Bujak and Williams, 1978; McIntyre and Brideaux, 1980) and up to the Barremian in Greenland and Barents Sea shelf (Piasecki, 1979; Aarhus et al., 1990; Nöhr-Hansen, 1993; Smelror et al., 1998)
	Last occurrence of *Tenua Americana*	Last occurrence in the mid-Hauterivian of northern Germany (Prössl, 1990)
	Diversification of the genus *Muderongia*	See DK5 “diversification of *Muderongia*”
	Diversification of the genus *Batioladinium*	In Volgian, Berriasian and Valanginian stages usually 1–2 species; in the Hauterivian and Barremian 1–5 species; a sharp diversity increase is established in the lower Hauterivian of Greenland (Piasecki, 1979) and Barents Sea shelf (Aarhus et al., 1990); in the middle Barremian of the Barents Sea shelf (Smelror et al., 1998
	Diversification of the genus *Aprobolocysta*	Single dinocysts of this genus are known from the Berriasian and Valanginian of northwestern Europe (Davey, 1982; Duxbury, 2001); beginning from the upper Hauterivian, several species (*A. eilema*, *A. neista*, *A. trycheria*, *A. galeata*, and others) persistently occur in England (Duxbury, 2001), Barents Sea shelf (Smelror et al., 1998), and Moscow basin (Iosifova, 1996)
	Diversity decrease in the genus *Oligosphaeridium*	The genus diversity is highly variable in vertical and lateral directions
Lower boundary, *Aptea anaphrissa*–*Oligosphaeridium* aff. *totum*–*Batioladinium longicornutum* assemblage (DA6): the mid-lower Hauterivian	**First occurrence of *Aptea anaphrissa***	First occurrence in the mid-lower Hauterivian of the Barents Sea shelf (Aarhus et al., 1990) and Subpolar Urals (Lebedeva and Nikitenko, 1998); since the upper Hauterivian in Norway (Aarhus et al., 1986); significant since the Barremian in Canada (Williams et al., 1974; Jenkins et al., 1974; Bujak and Williams, 1978), Greenland (Nöhr-Hansen, 1993), and northwestern Europe (Davey, 1979; Duxbury, 1977, 1980, 2001; *A Stratigraphic*…, 1992)
	First occurrence of *Banutioladinium longicortum*	First occurrence in the lower Hauterivian of Norway (Aarhus et al., 1986); in the Subpolar Urals since the upper Valanginian (Lebedeva and Nikitenko, 1998); in Greenland and northwestern Europe since the Hauterivian (Piasecki, 1979; Davey, 1979, 2001; *A Stratigraphic*…, 1992)
	First occurrence of *Pseudoceratium* sp.	In Greenland, *P. pelliferum* since the Berriasian (Piasecki, 1979); in England and North Sea shelf, *P. pelliferum* since the mid-Ryazanian (Davey, 1979; Duxbury et al, 1999; A Stratigraphic…, 1992); in Boreal Canada and Norway, *P. pelliferum* since the Valanginian (Bujak and Williams, 1978); in the Moscow syneclise, *P. pelliferum* since the Hauterivian (Iosifova, 1996); diversity is characteristic of the Barremian in Canada (Bujak and Williams, 1978; Nöhr-Hansen, McIntyre, 1998), Greenland (Nöhr-Hansen, 1993), Barents Sea shelf (Smelror et al., 1998), and Moscow basin (Iosifova, 1996)
	First occurrence of *Oligosphaeridium* aff. *totum*	*Oligosphaeridium totum* since the Valanginian in Arctic Canada (Davies, 1983)

Note: Events observed at the same stratigraphic level in Siberia and different regions of north Europe and America are in bold.

Batioladinium varigranosum in the mid-Berriasian provides opportunity to correlate directly the base of the Pareodinioideae–*Batioladinium varigranosum–Cassiculasphaeridia reticulata* Zone with the lower boundary of the *Endoscrinium campanula* Zone (Van Helden, 1986; Table 1). Owing to occurrence of *Cyclonephelium cuculiform* and *Paragonyaulacysta ?borealis* in the Berriasian assemblage, these zones of Siberia can be correlated with the concurrent *Cyclonephelium cuculliforme–Paragonyaulacysta ?borealis* Zone of Canada (Davies, 1983; Table 1). The base of the *Escharisphaeridia* spp.–*Oligosphaeridium* spp. Zone, corresponding to the upper boundary of the *Paragonyaulacysta ?borealis–Dingodinium ?spinosum* Zone in Siberia (Nikitenko et al., 2004; Table 1) is of a circum-Arctic geographic extent (Fig. 5, Table 4). Disappearance level of *Dingodinium ?spinosum* in Siberian sections does not coincide with that boundary, being recorded somewhat lower at the Berriasian–Valanginian boundary. It is of interest that in northwestern Europe the youngest specimens of this species have been found at the same level. Consequently, disappearance of *Dingodinium ?spinosum* can be regarded as important criterion by defining the Berriasian upper boundary.

The first occurrence of *Oligosphaeridium complex* at the base of the *Oligosphaeridium complex–Dingodinium cerviculum* Zone (Fig. 5) is an important indication as well. In northern regions of Europe and Canada, this event was practically isochronous, being recorded at the base of the *Buchia keyserlingi* bivalve zone (Duxbury, 1977, 2001; Bujak and Williams, 1978; Piasecki, 1979; Davey, 1979; McIntyre and Brideaux, 1980; Davies, 1983; Aarhus et al., 1986; *A Stratigraphic…*, 1992), i.e., at the same level as in Siberia. *Oligosphaeridium complex*, as a zonal index species, is mentioned only for the *Tanyosphaeridium magneticum* Zone in Canada and Zone C in England (Table 1) that provides the direct correlation of their lower boundaries with the base of Siberian zone.

Stratigraphic extent of the *Tanyosphaeridium magneticum* dinocyst zone is defined as corresponding to the lower Valanginian and lower part of the upper Valanginian (?), although the precise position of its lower boundary has not been established (Davies, 1983). The performed stratigraphic analysis and correlation with the corresponding palynostratigraphic subdivision of Siberia, position of which is reliably defined in the Boreal standard (Zakharov et al., 1997), suggest that this boundary is approximately at the base of the *Buchia keyserlingi* Zone, i.e., at a somewhat higher level than the Valanginian base.

The Hauterivian and lower Barremian correlation levels are recognizable in Siberia and Western Europe. Characteristic components of the lower Hauterivian dinocyst assemblages (presence of *Hystrichodinium solare* and increased diversity and abundance of the genus *Muderongia*) are known besides from the Subpolar Urals (Lebedeva and Nikitenko, 1998). Species *Aptea anaphrissa* appearing at the base of the *Aptea anaphrissa–Batioladinium longicornutum–Oligosphaeridium* aff. *totum* Zone marks the same level in the Subpolar Urals and Barents Sea shelf (Fig. 5, Table 4). Of a considerable stratigraphic and correlation potential is the lower boundary of the *Aprobolocysta eilema–A. neista–Odontochitina* sp. Zone (Fig. 5). This level is marked by essential changes in taxonomic composition of dinocysts: it marks at once the first occurrences and extinctions of several species and increased diversity of genera *Muderongia, Aprobolocysta*, and *Batioladinium.* Some of the palynological events are readily recognizable in northwestern Europe as well (Table 4) that is important.

CONCLUSIONS

This study yielded new data on palynological characterization of Lower Cretaceous deposits in northern regions of West and Central Siberia. The results obtained and published data, which have been analyzed, are used to define more precisely stratigraphic ranges of about 130 dinocyst species and to distinguish groups of stratigraphically important taxa, which appear at practically concurrent levels in several northern regions of Eurasia and America (Table 3). Levels of their first or last occurrence can be regarded as important stratigraphic markers. Characteristic species of dinocysts, which become widespread in particular stratigraphic intervals and determine the "face" of respective assemblage, give an important information. Ten biostratigraphic subdivisions ranked as dinocyst zones are distinguished in the Berriasian–Barremian deposits in northern regions of Siberia based on first occurrences of stratigraphically important taxa, higher or lower diversity degree of certain genera and families, and on compositional changes in groups of characteristic dinocyst species. In majority, boundaries of these beds are of a great correlation potential and can be regarded as reliable stratigraphic markers recognizable not only in Siberia, but also in northern regions of Europe and Canada. The dinocyst zones of the upper Berriasian, Valanginian, and lower Hauterivian are confidently correlated with the Boreal standard zones (Zakharov et al., 1997) and can be used, when necessary, for subdivision and dating the deposits in Siberia. The established biostratigraphic succession supplements and specifies the dinocyst zonation substantiated in the Subpolar Urals (Lebedeva and Nikitenko, 1998) and extends upward the succession of dinocyst biozones characterizing the Upper Jurassic–lower Berriasian section of the Nordvik Peninsula (Nikitenko et al., 2004; Table 1). The suggested subdivision scheme of the Lower Cretaceous based on dinocysts is included into the new regional stratigraphic chart for West Siberia (*Regional* …, 2007).

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