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Early Cretaceous Dinocysts of Northern Siberia and Their Stratigraphic Significance

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Abstract—The palynological analysis of the Berriasian–Barremian of northern Siberia has once again demonstrated the great stratigraphic value of dinocysts. A succession of ten dinocyst zones has been established. Most of their boundaries may be considered as important stratigraphic marks, which can be traced, apart from in Siberia, in northern Europe, Greenland, and China. Groups of characteristic species, in common for these territories, are determined for certain intervals. Dinocysts of the suborders Rhaetogonyaulacineae and Cladopixiineae (including two new morphotypes), four species of *Dingodinium* and four species of *Aprobolocysta* are described, among them new species *Dingodinium subtile* and *Aprobolocysta cornuta.* The genus *Horologinella* is revised, and the diagnosis of *Aprobolocysta* is emended.

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Key words: dinocysts, stratigraphy, northern Siberia, Early Cretaceous.

INTRODUCTION

The interest shown by Russian and foreign palynologists in the study of dinocysts during the last few decades is explained by the high stratigraphic and paleogeographic potential of these fossils. The use of dinocysts in detailed subdivision and correlation of Mesozoic sediments of Europe, America, and Australia have repeatedly proved the reliability of dinocyst zonation. Currently, dinocysts are considered among the orthostratigraphic groups of the Jurassic and Cretaceous. However, there is still little published data on Early Cretaceous dinocysts of Siberia; therefore, further study of their taxonomy, morphology, and stratigraphy are very important.

BIOSTRATIGRAPHY

Palynological analysis of the Berriasian–Barremian deposits of northwestern Siberia and the Khatanga Depression (Fig. 1) revealed a succession of ten local zones with characteristic dinocyst assemblages (Pestchevitskaya, 2005), which refines and supplements dinocyst zonations of the Subarctic Ural Mountains and the Nordvik Peninsula (Fig. 2, Pls. 7, 8). The main characteristics of the established dinocyst zones are shown in table. All sections, excluding the Gorshkovskaya Borehole, are stratigraphically controlled by macrofaunal remains and foraminifers. Comparison with the dinocyst assemblages of northern Europe and America revealed groups of characteristic taxa and stratigraphically significant species the appearance of which at certain levels is traced not only in the studied sections, but also in other vast territories (Pestchevitskaya, 2005).

The microphytoplankton assemblages of the Upper Berriasian and Lower Valanginian (DA1) are characterized by the common occurrence of dinocysts of simple morphology (*Escharisphaeridia* spp. and *Batiacasphaera* spp.), inherited Jurassic taxa, and diverse members of the Pareodinioideae and *Dingodinium* (table). *Dingodinium subtile* Pestchevitskaya, sp. nov. and *D. tuberosum* (Gitmez) Riley emend. Poulsen con-

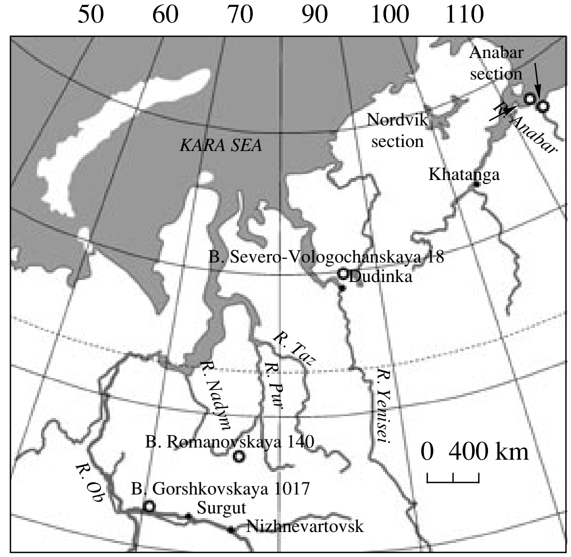


Fig. 1. Schematic map of the sections.

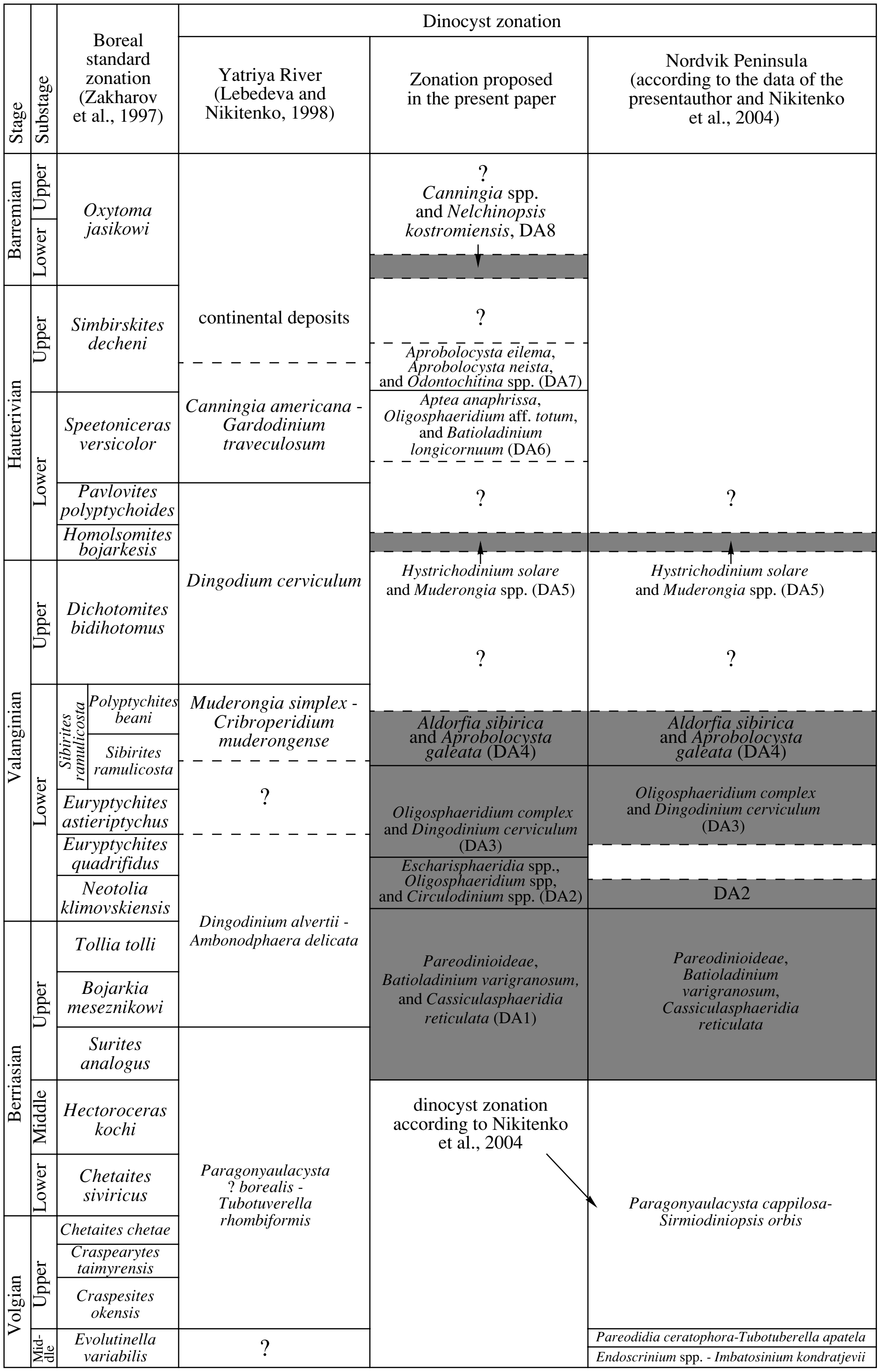


Fig. 2. The comparison between dinocyst zonations of northern Siberia (zones established by the author are in gray).

stantly occur only in the Upper Berriasian of the sections studied and are rare in overlying deposits. Characteristic taxa of northwestern Europe and Canada have been observed. The appearance of *Batioladinium varigranosum* (Duxbury) Davey and *Cassiculasphaeridia reticulata* Davey was recorded in the Middle Berriasian of the Subarctic Ural Mountains (Lebedeva and Nikitenko, 1998), Newfoundland Island (Van Helden, Dinocyst local zones established in northern Siberia and their palynological characteristics

Dinocyst zones	Main characteristics of the lower boundary	Secondary characteristics of the lower boundary	Characteristic assemblages
Aldorfia sibirica, *Aprobolocysta galeata*, (DA4): the middle *ramulicosta* Zone–middle *beani* Zone; Nordvik Peninsula: clayey silts, 18.7 m thick; Anabar Bay: intercalating silts and sandstones, 29.7 m thick	*Aprobolocysta galeata* and *Aldorfia sibirica* appear. The first quantitative pike (up to 5.5%) *Dingodinium cerviculum*; the upper boundary is tentative, at the end of the section		*Dingodinium* spp. and *D. cerviculum* dominate (up to 5.5%); *Sirmiodinium grossii*, *Sirmiodiniopsis orbis*, *Circulodinium* sp., *Cassiculasphaeridia magna*, *C. reticulata*, *C. delicata*, *Sentusidinium* sp., *Batiacasphaera* sp., *Escharisphaeridia* spp., *Aldorfia sibirica*, *Aprobolocysta galeata*, *Gonyaulacysta* sp., *Leptodinium* sp., *Wrevittia helicoidea*, *Nelchinopsis kostromiensis*, *Trichodinium speetonense*, *Cribroperidinium* sp., *Gardodinium* sp., *Cleistosphaeridium* spp., *Oligosphaeridium complex* are present
Oligosphaeridium complex and *Dingodinium cerviculum* (DA3): the middle *quadrifidus* Zone–middle *ramulicosta* Zone; Anabar Bay: silty clays, clayey silts, 76.1 m thick; Borehole Romanovskaya: clayey siltstones with sublayers of sandstones and mudstones, 27 m thick; Nordvik Peninsula: clayey silts, 18.7 m thick	*Oligosphaeridium complex* and *Dingodinium cerviculum* appear	Borehole Romanovskaya 140: *Muderongia crucis*, *M. australis*, *Aprobolocysta galeata*, *Canningiopsis colliveri*, and *Cribroperidinium ?muderongense* appear	*Main taxa* are *Dingodinium* spp., *Oligosphaeridium* spp., *Circulodinium* spp., and *Cleistosphaeridium* spp.; *Oligosphaeridium* (*O. complex*, *O. ?asterigium*, *O. albertense*, and *O. diluculum*) and *Muderongia* (*M. crucis*, *M. simplex*, and *M. australis*) are diverse; *Dingodinium cerviculum*, *D. minutum*, *Gardodinium trabeculosum*, *Pareodinia ceratophora*, *Cassiculasphaeridia reticulata*, *C. magna*, *Circulodinium distinctum*, *Chlamydophorella nyei*, *Gonyaulacysta* spp., *Cribroperidinium ?muderongense*, *Nelchinopsis kostromiensis*, *Wrevittia cassidata*, *Stanfordella cretacea*, *Trichodinium speetonense*, *Sirmiodinium grossii*, *Heslertonia* sp., *Batioladinium varigranosum*, *Hologinella anabarensis*, *Wallodinium luna*, and *Aprobolocysta galeata* are present
Escharisphaeridia spp., *Oligosphaeridium* spp., and *Circulodinium* spp. (DA2): the lower *klimovskiensis* Zone–middle *quadrifidus* Zone; Nordvik Peninsula: outcrop 33, argillic and clayey silts, 11 m thick; outcrop 35, silty clays, 12.5 m thick; Anabar Bay: silty clays, 22.6 m thick; Borehole Severo-Vologochanskaya: interbedding clays, silts, and sands, 55.2 m thick	*Pargonyaulacysta ?borealis* disappears; the diversity of the Pareodinioideae sharply decreases; *Dingodinium ?spinosum* disappears slightly below the boundary (in the roof of the Berriasian)	Nordvik Peninsula: *Tubotuberella rhombiformis* disappears, *Paragonyaulacysta* spp. and *Tubotuberella* spp. are not constant components of the assemblage, *Oligosphaeridium* spp. becomes constant; Borehole Severo-Vologochanskaya 18: *Ocissucysta wierzbowskii* and (slightly below) *Dingodinium ?spinosum* disappear	Main taxa are *Escharisphaeridia* spp. and *Dingodinium* spp.; *Cleistosphaeridium* spp., *Batiacasphaera* spp., *Sirmiodinium grossii*, *Cribroperidinium* spp., *Apteodinium* spp., *Trichodinium* spp., *Jansonia* spp., *Circulodinium* spp., *Tubotuberella apatela*, *Chlamydophorella* sp., and *Dingodinium ?albertii* are common; *Wallodinium* sp., *Fromea* sp., *Hologinella anabarensis*, *Cribroperidinium ?muderongense*, *Nelchinopsis kostromiensis*, *Apteodinium ?vescum*, *Sentusidinium granulatum*, *Cassiculasphaeridia magna*, and *C. reticulata* are present; peridinioid dinocysts are rare (*Pareodinia* spp., *P. arctica*, *Pluriarvalium osmingtonense*, *Paragonyaulacysta capillosa*, and *Gochteodinia* sp.)
Paragonyaulacysta sp. and *Batiacasphaera* sp. (DA RMN1): Upper Berriasian–lower Lower Valanginian, *klimovskiensis*; Borehole Romanovskaya: mudstones, 11 m thick	Conventional upper/lower boundaries based on the beginning/end of core sampling; the stratigraphic position of the zone is controlled by palynological data		*Paragonyaulacysta* sp., *Batiacasphaera* sp., and poorly preserved proximate and chorate dinocysts are present

Table. (Contd.)

Dinocyst zones	Main characteristics of the lower boundary	Secondary characteristics of the lower boundary	Characteristic assemblages
Pareodinioideae, *Cassiculasphaeridia reticulata,* and *Batioladinium varigranosum* (DA1): the base of *analogus*–lower part of *klimovskiensis*; Nordvik Peninsula: mudstonelike clays, 51 m thick; Borehole Severo-Volochanskaya: silts with clay and sand sublayers, 23.8 m thick	*Cassiculasphaeridia reticulata*, *Batioladinium varigranosum*, and *Tanyosphaeridium magneticum* appear		Taxa inherited from the Jurassic are common: *Sirmiodinium grossii*, *Jansonia* spp., *Tubotuberella apatela*, *T. rhombiformis*, *Fromea* spp., and *Ocissucysta wierzbowskii*; some taxa are rare: *Ambonosphaera* spp., *Wrevittia helicoidea*, and *Senoniasphaera jurassica*; peridinioid dinocysts (*Paragonyaulacysta*, *Pareodinia*, *Pluriarvalium*, *Evansia*, *Protobatioladinium* spp., and *P. imbatonense*) and *Dingodinium* (*D. subtile*, *D. minutum*, *D. tuberosum*, and *D. ?spinosum*) are diverse; typical Berriasian species are present: *Batioladinium varigranosum*, *Cyclonephelium cuculliforme*, *Stanfordella exanguia*, *Achomosphaera neptunii*, and *Spiniferites ramosus*
Canningia spp. and *Nelchinopsis kostromiensis*, (DA8): lower Lower Barremian, the lower boundary is conventional; Borehole Gorshkovskaya: mudstones, 13 m thick	Significant decrease of dinocyst diversity; the conventional upper boundary is based on the end of core sampling		The dominants are *Escharisphaeridia* spp. and *Mendicodinium* spp.; *Leberidocysta* spp., and *Canningia* spp. constantly occur; *Wallodinium krutzschii*, *Nelchinopsis kostromiensis*, *Apteodinium* spp., *Endoscrinium* sp., *Ovoidinium* sp., *Batioladinium* spp., *B. ?exiguum*, *Aprobolocysta* spp., *A. galeata*, *A. eilema*, *A. cornuta*, *Cyclonephelium intonsum*, and *Sentusidinium* spp. are present
Aprobolocysta eilema, *A. neista*, and *Odontochitina* spp. (DA7): lower Upper Hauterivian; Borehole Gorshkovskaya: mudstones, 15.55 m thick	*Aprobolocysta eilema*, *A. neista*, and *Odontochitina* spp. appear; *Hystrichodiniumsolare* and *Tenua americana* disappear; *Batioladinium* (*B. ?exiguum*, *B. varigranosum*, *B. jaegeri*, *B. longicornutum*, and *B. reticulatum*) and *Aprobolocysta* (*A. galeata*, *A. neista*, *A. eilema*, and *A. cornuta*) become more diverse; conventional upper boundary is based on the end of core samples	*Psedoceratium expolitum* and *Gonyaulacysta ?kleithria* appear; *Oligosphaeridium ?asterigium* disappears; *Muderongia* (*M. tetracantha*, *M. simplex*, *M. staurota*, *M. extensiva*, *M. mcwhaei*, *M.* "tomaszovensis," *M. crucis*, *M. australis*, and *M. asymmetrica*) become more diverse; *Oligosphaeridium* becomes less diverse; *Cyclonephelium intonsum*, *Odontochitina operculata*, *Vesperopsis fragilis*, and *V. mayi* appear slightly above	The dominants are: *Escharisphaeridia* spp. and *Muderongia* spp.; *Sentusidinium* spp., *Fromea* spp., *Mendicodinium* spp., *Leberidocysta* spp., *Dingodinium* spp., *D. cerviculum*, *Cassiculasphaeridia magna*, *Jansonia* spp., *Apteodinium* spp., *Aptea anaphrissa*, and *Circulodinium* spp. constantly occur; *Cassiculasphaeridia reticulata*, *Gonyaulacysta* spp., *Pseudoceratium* cf. *pelliferum*, *Fromea quadrugata*, *Sirmiodiniopsis orbis*, *Chytroeisphaeridia chytroides*, *Endoscrinium campanula*, *Tubotuberella apatela*, *Gardodinium trabeculosum*, *G. ordinale*, *Horologinella anabarensis*, *Cribroperidinium ?edwardsii*, *C. confossum*, *Leptodinium subtile*, *L.* cf. *?hyalodermopse*, *L. simplex*, *Nelchinopsis kostromiensis*, *Stanfordella cretacea*, *Aldorfia dictyota*, *Microdinium* sp., *Circulodinium compta*, *Oligosphaeridium complex*, *Hystrichodinium voigtii*, *H. pulchrum*, and *Spiniferites ramosus* are present

Table. (Contd.)

Dinocyst zones	Main characteristics of the lower boundary	Secondary characteristics of the lower boundary	Characteristic assemblages
Aptea anaphrissa, *Oligosphaeridium* aff. *totum*, and *Batioladinium longicornutum*, (DA6): upper Lower Hauterivian, the lower boundary is conventional; Borehole Gorshkovskaya: mudstones, 22.45 m thick	*Aptea anaphrissa*, *Batioladinium longicornutum*, *Oligosphaeridium* aff. *totum* appear	*Pseudoceratium* sp. appears slightly above	*Escharisphaeridia* spp., *Leberidocysta* spp., *Cassiculasphaeridia magna*, *C. reticulata, Chlamydophorella* spp., *Jansonia* spp., *Circulodinium* spp., *Cleistosphaeridium* spp., and *Oligosphaeridium complex* constantly occur; *Muderongia* (*M. tetracantha*, *M. australis*, *M. simplex*, *M. mcwhaei*, and *M. staurota*) are diverse; *Batioladinium varigranosum*, *B. longicornutum*, *Oligosphaeridium* spp., *Fromea quadrugata*, *Tenua americana*, *Wallodinium luna*, *W. cylindricum*, *Aprobolocysta* spp., *Chlamydophorella nyei*, *C. ambigua*, *Gardodinium trabeculosum*, *Dingodinium* spp., *Apteodinium maculatum*, *Lithodinia pila*, *Cribroperidinium ?muderongense*, *Gonyaulacysta* spp., *Nelchinopsis kostromiensis*, *H. voigtii*, *H. solare*, *Oligosphaeridium ?asterigium*, *Spiniferites ramosus*, and *Achomosphaera neptunii* are present
Sentusidinium spp. and *Apteodinium* spp. (DA VLG 3): middle *quadrifidus*–Lower Hauterivian (?); borehole Severo-Vologochanskaya: interbedding of sandstones and silts, 67.3 m thick	*Occisucysta wierzbowskii*, *Paragonyaulacysta* spp., and *P. osmingtonense* disappear; sharp decrease in dinocyst diversity		*Cassiculasphaeridia reticulata*, *Sentusidinium* spp., and *Escharisphaeridia* spp. are most common; *Sentusidinium granulatum*, *Dingodinium* spp., *Chlamydophorella* sp., *C. ambigua*, *Sirmiodinium grossii*, *Oligosphaeridium* sp., *Nelchinopsis kostromiensis*, *Lithodinia* sp., *Apteodinium* sp., *Microdinium ornatum*, *Jansonia* spp., *Tubotuberella rhombiformis*, *Circulodinium compta*, *O. ?asterigium*, and *Pareodinia ceratophora* are present
Hystrichodinium solare and *Muderongia* spp. (DA5): middle part of the *Homolsomites bojarkensis*, the lower boundary is conventional; Nordvik Peninsula: silty sandstones, 11.4 m thick; Borehole Gorshkovskaya: mudstones, 1 m thick	*Hystrichodinium solare*, *Muderongia tetracantha*, and *M. staurota* appear; the conventional upper boundary is based on the end of core sampling (borehole Gorshkovskaya)	The diversity and, occasionally, abundance (borehole Gorshkovskaya) of *Muderongia* (*M. simplex*, *M. staurota*, *M. tetracantha, M. brevispinosa*, *M.* "*tomaszovensis*," and *M. australis*)	*Dingodinium* spp., *Circulodinium* spp., and *Oligosphaeridium* spp. constantly occur, *Muderongia* (*M. simplex*, *M. staurota*, *M. tetracantha*, *M. brevispinosa*, *M.* "*tomaszovensis*", and *M. australis*) are diverse; *Sentusidinium* spp., *Escharisphaeridia* spp., *Cleistosphaeridium* spp., *Canningia* sp., *Sirmiodinium grossii*, *Sirmiodiniopsis* sp., *Aprobolocysta* sp., *Gardodinium trabeculosum*, *Tenua americana*, *Lithodinia* spp., *Cribroperidinium* spp., *Batioladinium varigranosum*, *Oligosphaeridium complex*, *Hystrichodinium solare*, *Leptodinium* sp., *Nelchinopsis kostromiensis*, *Spiniferites* sp., and *Trichodinium* sp. are present.

Note: The boundaries are conventional in case of hiatus in the sections or sampling gap.

1986), Moscow Syncline (Iosifova, 1996), and Arctic Canada (Davies, 1983). *Cyclonephelium cuculliforme* (Davies) Aarhus is an index species of the dinocyst zone of the Upper Berriasian in Arctic Canada (Davies, 1983). Local zone DA1 is traced in the Ust'-Yenisei Region and in the Khatanga Depression. Local zone DA RMN1, which has a wider stratigraphic range (Upper Berriasian–Lower Valanginian), is only revealed in the Pur–Taz interfluve (table). The taxonomic composition of the dinocyst assemblage is very poor. The presence of *Paragonyaulacysta* sp. only provides the definition of the upper boundary. In sections of the Nordvik Peninsula and eastern coast of the Anabar Bay, species of this genus do not occur above the *Neotollia klimovskiensis* Zone.

At the base of the lower Lower Valanginian (DA2), the diversity of peridinioid dinocysts decreases. Important events are the extinction of *Pagaronyaulacysta ?borealis* (Brideaux et Fisher) Stover et Evitt at the boundary and *Dingodinium ?spinosum* (Duxbury) Davey in the roof of the Berriasian deposits. The lowermost occurrences of *Dingodinium ?spinosum* in northwestern Europe, where it is considered as a zonal index species (Fisher and Riley, 1980; Rawson and Riley, 1982), are traced nearly isochronously in the uppermost Berriasian; and *Paragonyaulacysta ?borealis* disappears in the lowermost Lower Valanginian in Siberia (Lebedeva and Nikitenko, 1998), Greenland (Häkansson et al., 1981), Norway (Aarhus et al., 1986), and Arctic Canada (McIntyre and Brideaux, 1980). It allows the author to correlate the base of local zone DA2 with the upper boundary of the Canadian zone *Cyclonephelium cuculliforme* and *Paragonyaulacysta ?borealis* (Davies, 1983).

In the middle Lower Valanginian (DA3), the inception of *Oligosphaeridium complex* (White) Davey et Williams and *Dingodinium cerviculum* Cookson et Eisenack emend. Khowaja-Ateequzzman et al. are observed. The lowermost occurrences of *Dingodinium cerviculum* in northern Canada and Siberia were revealed in the lower Lower Valanginian (McIntyre and Brideaux, 1980; Davies, 1983; Lebedeva and Nikitenko, 1998). The appearance of *Oligosphaeridium complex* in northern Europe and Canada is virtually ubiquitous at approximately the base of the *Buchia keyserlingi* bivalve Zone (Duxbury, 1977, 2001; Bujak and Williams, 1978; Davey, 1979; Piasecki, 1979; McIntyre and Brideaux, 1980; Davies, 1983; Aarhus et al., 1986; *A Stratigraphic*…, 1992); therefore, this species is a good stratigraphic marker. Thus, the bases of the Canadian *Tanyosphaeridium magneticum* Zone (Davies, 1983) and the British Zone C (Duxbury, 1977) are possible to correlate with the lower boundary of the Siberian local zone. Local zone DA3 is traced in the Khatanga Depression and the Pur–Taz interfluve. In the Ust'-Yenisei region, starting in the upper Lower Valanginian the dinocyst assemblage mostly includes taxa with a broad stratigraphic range (DA VLG3, table).

The Lower Hauterivian (DA5) is characterized by the inception of *Hystrichodinium solare* Pestchevitskaya and high diversity and abundance of the genus *Muderongia*. The same features are known also for the Lower Hauterivian dinocyst assemblages of the Subarctic Ural Mountains (Lebedeva and Nikitenko, 1998). An important stratigraphic character of the upper Lower Hauterivian (DA6) is the inception of *Aptea anaphrissa* (Sarjeant) Sarjeant et Stover, which was also observed in the Barents Sea shelf (Aarhus et al., 1990). Morphologically similar dinocysts were observed in the Lower Hauterivian microplankton assemblages of the Subarctic Ural Mountains (Lebedeva and Nikitenko, 1998). In the Upper Hauterivian, the genera *Aprobolocysta, Muderongia,* and *Batioladinium* become more diverse, and the taxonomic composition of the dinocyst assemblage changes significantly (table). In northwestern Europe, the inception of *Aprobolocysta eilema* Duxbury and *Vesperopsis fragilis* (Harding) Harding and the extinction of *Tenua americana* (Pothe de Baldis et Ramos) Prössl are observed at the same level as in Siberia (Duxbury, 1977, 2001; Harding, 1986; Prössl, 1990; *A Stratigraphic*…, 1992). *Aprobolocysta neista* Duxbury appears at a slightly lower level (Davey, 2001). In the Lower Barremian (DA8), dinocyst diversity decreases considerably (table). Nevertheless, the presence of *Aprobolocysta eilema* and *Nelchinopsis kostromiensis* (Vozzhennikova) Wiggins testify to the Early Barremian age of the deposits: throughout northwestern Europe they are absent above this level (Aarhus et al., 1990; *A Stratigraphic*…, 1992; Nøhr-Hansen, 1993; Smelror et al., 1998).

The presence of stratigraphically significant species in the Siberian sections predetermines great value of the established dinocyst zones for correlative purposes. Most of their boundaries may be considered as important stratigraphic markers. In this context, lower Valanginian levels (bases of local zones DA2 and DA3) are most interesting, since they are traced in almost all northern regions of Europe and Canada. The middle Berriasian level (base of zone DA1) is observed, apart from Siberia, in Arctic Canada, the Moscow Syneclise, and the Subarctic Urals; the upper Lower Hauterivian level (DA6) is traced in the Subarctic Urals and Barents Sea shelf; and the Upper Hauterivian (DA7) and Lower Barremian (DA8) levels are traceable in northwestern Europe.

As a rule, stratigraphically important species are not numerous. The core of assemblages is formed by characteristic taxa that appear in lower horizons and reach their maximum in the stratigraphic intervals under consideration. For the Berriasian and Valanginian these are *Cassiculasphaeridia magna* Davey, *Wallodinium krutzchii* (Alberti) Habib, *Pareodinia ceratophora* Deflandre, *Fromea amphora* Cookson et Eisenack, *Tubotuberella apatela* (Cookson et Eisenack) Ioannides, and *Sirmiodinium grossii* Alberti; and for the Valanginian, these are *Chlamydophorella nyei* Cookson et Eisenack, *Wallodinium luna* (Cookson et Eisenack) Lentin et Williams, *Apteodinium granulatum* Eisenack, *A. spongiosum* McIntyre et Brideaux, *Batioladinium varigranosum, Trichodinium ciliatum* (Gocht) Eisenack et Klement, *Oligosphaeridium diluculum* Davey, *O. ?asterigium* (Gocht) Davey et Williams, and *Heslertonia heslertonensis* (Neale et Sarjeant) Sarjeant. The Valanginian and Hauterivian are characterized by the presence of *Muderongia simplex* Alberti emend. Riding et al., *Cassiculasphaeridia reticulata, Nelchinopsis kostromiensis, Wrevittia helicoidea* (Eisenack et Cookson) Helenes et Lucas-Clark, *Stanfordella ?cretacea* (Neale et Sarjeant) Helenes et Lucas-Clark, *Dingodinium cerviculum, Circulodinium distinctum* (Deflandre et Cookson) Jansonius, and *Batioladinium varigranosum*; and the Hauterivian is characterized by *Muderongia staurota* Sarjeant, *M. tetracantha* (Gocht) Alberti, *M. crucis* Neale et Sarjeant, *M. australis* Helby, *Batioladinium jaegeri* (Alberti) Brideaux, *B. longicornutum* (Alberti) Brideaux, *B. ?exiguum* (Alberti) Brideaux, *Gardodinium trabeculosum* (Gocht) Alberti, *Pseudoceratium pelliferum* Gocht, *Cribroperidinium confossum* (Duxbury) Helenes, *C. ?edvardsii* (Cookson et Eisenack) Davey, *C. ?muderongense* (Cookson et Eisenack) Davey, *Hystrichodinium voigtii* (Alberti) Davey, *H. pulchrum* (Deflandre), and *Oligosphaeridium complex.* From the Berriasian to the Hauterivian, the contribution of chorate and ceratiacean dinocysts increases, the compositions of the genus *Dingodinium* and the Pareodiniaceae change. In the Hauterivian and Barremian, this family was mostly represented by diverse members of *Batioladinium* and *Aprobolocysta* (subfamily Broomeoideae).

Along with widespread taxa, endemic species and forms with unusual morphology also occur testifying to the specificity of Siberian dinocyst assemblages (Pestchevitskaya, 2001, 2003). Of interest is the presence of dinocysts belonging to the Rhaetogonyaulacineae and Cladopixiineae, which are more typical of the Jurassic.

SYSTEMATIC PALEOBOTANY

DIVISION DINOFLAGELLATA (BUTSCHI) FENSOME ET AL. 1993

SUBDIVISION DINOKARIOTA FENSOME ET AL. 1993

CLASS DINOPHYCEAE PACHER 1914

SUBCLASS PERIDINIPHYCIDAE FENSOME ET AL. 1993

Order Gonyaulacales Taylor 1980

Suborder Rheatogonyaulacineae Norris 1978

Family Shublikodiniaceae Wiggins 1973

Genus *Horologinella* Cookson et Eisenack 1962 emend. Pestchevitskaya

Horologinella: Cookson et Eisenack, 1962, p. 271; Stover and Evitt, 1978, pp. 53, 54; Backhouse, 1988, p. 90.

Type species. *Horologinella lineata* Cookson et Eisenack, 1962, p. 272, pl. 37, figs. 1–3; Lower Barremian, Aptian–Albian; southwestern Australia.

Diagnosis. Cyst small proximate, bilayered, with equatorial constriction, apex and antapex broadly rounded; paratabulation indicated by parasutural features or sculpture; archeopyle apical or combination.

Species composition. *H. lineata* and *H. anabarensis* Pestchevitskaya.

Description. The outlines are from rectangular to trapezoidal, with rounded angles. A small dorsoventral constriction is observed. The apex and antapex are broadly rounded; the cingular area is marked by a constriction. The cyst is bilayered: endophragm and periphragm are closely appressed to each other along the entire cyst surface, except for parasutural areas, where a small pericoel is developed. The bilayered morphology is distinct only in the outer outline. The endophragm is dense, laevigate or scabrous, with rows of short parasutural processes. They bear a thin transparent periphragm, which is either laevigate or weakly granulate. The rows of processes make the paratabulation of precingular and postcingular series more distinct. The paratabulation of apical and antapical areas is expressed in parasutural features or low ridges. The formula is ?>5', 7'', 6-7c, 5s, 6-7''', ?0-2p, 2-3''''. The archeopyle is apical or combination. The paracingulum is accentuated by the equatorial constriction. The parasulcus is broad in the antapical area and becomes significantly narrower toward the apex. The cyst is small.

Comparison. *Horologinella* resembles *Tetrachacysta* Backhouse (Backhouse, 1988) and *Jansonia* Pocock (Pocock, 1972) in the general aspect and small size. The last genus differs in the tabulation (X', 6'', 6c, 6''', 0-1p, 1''''), particularly, in the apical and antapical areas, and one-layered wall (Pocock, 1972; Stover and Evitt, 1978). *Tetrachacysta* also has acavate cyst and is devoid of distinct indications of paratabulation. *Cernicysta* Stover et Helby resembles *Horologinella* in general appearance and bilayered wall (Stover and Helby, 1987). Both genera have wall layers that are closely appressed to each other along the entire cyst surface, except for parasutural areas, where a small pericoel is developed. *Cernicysta* differs in its greater size (49–60 μm long), absence of cingular constriction, and the paratabulation: ?3-4', 6'', Xc, 5''', 1p, 1''''.

Remarks. The assignment of the type species *Horologinella lineata* (Cookson and Eisenack, 1962) to the dinocysts is beyond question. This is demonstrated by the bilayered morphology of the wall as well as the presence of paratabulation and archeopyle. However, most species lack features characteristic of dinocysts, thus casting doubt on their assignment to this algal group and forcing one to treat them as forms of uncertain systematic position (Pestchevitskaya, 2001). Some scientists consider them as acritarchs (Stover and Evitt, 1978; Backhouse, 1988). Based on their emended diagnoses of the genus, they consider the tabulation as an

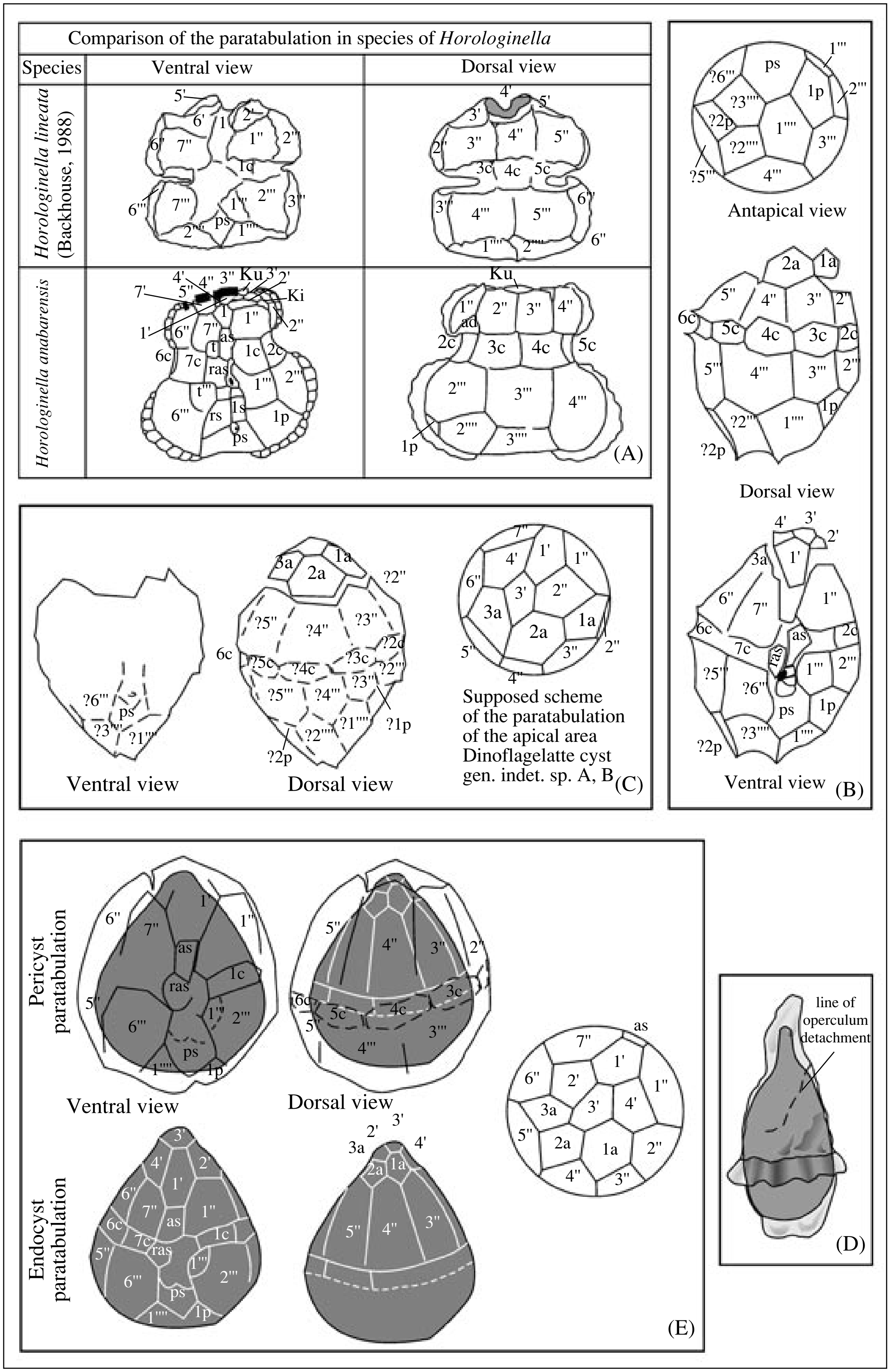


Fig. 3. General morphology and paratabulation of dinocysts: (A) *Horologinella anabarensis* Pestchevitskaya and *H. lineata* Cookson et Eisenack; (B) Dinoflagellate cyst gen. indet. sp. A; (C) Dinoflagellate cyst gen. indet. sp. B; (D) *Aprobolocysta cornuta* sp. nov.; and (E) *Dingodinium subtile* sp. nov.

important taxonomic character and restrict the species composition of the genus to the type species. Backhouse (1988) proposed the following formula of tabulation on the basis of the study of new material: 6', 0a, 7'', ?6c, 7''', 0p, 2'''', Xs. Of interest is the presence of numerous plates in the apical series, since *H. anabarensis* Pestchevitskaya also shows the same trend (Fig. 3A). However, *H. anabarensis* is supposed to have an additional climactic series of paraplates not touching the precingular series. In general, such morphological interpretation does not contradict the material of Backhouse, since his illustrations show the separation of marginal apical plates that may correspond to this series (Backhouse, 1988; text-fig. 26; pl. 48, figs. 2–4). Additional study is necessary for precise determination of the paratabulation. The number and arrangement of the antapical plates have also not been completely understood.

Backhouse describes *H. lineata* as an acavate form. This character is also mentioned in the generic diagnosis. However, a bilayered wall is clearly visible in his photographs (Backhouse, 1988; pl. 30; figs. 1–2). The emended diagnosis contains corrected information about the paratabulation and wall morphology, which is based on detailed study of *H. anabarensis* (Pestchevitskaya, 2001) and the analysis of published material.

Small dinocysts (27–28 μm) with a constriction in the cingular area were described from the Hauterivian of the Ryazan Region as gen. et sp. indet. I (Iosifova, 1996, pl. 6, fig. 2, pl. 7, fig. 1, pl. 13, fig. 1). The main morphological characteristics fit the diagnosis of the genus *Horologinella.* The bilayered morphology of the wall is an important character. The paratabulation is accentuated by relatively high penitabular ridges. The photographs clearly show that the ridges at the margins of the specimens are formed by rows of processes.

Horologinella anabarensis **Pestchevitskaya, 2001**

Plate 7, fig. 1

Horologinella anabarensis: Pestchevitskaya, 2001, pp. 98–100, pl. 1, figs. 1–10, pl. 2, figs. 1–7; Pestchevitskaya, 2003, pl. 1, figs. 1–7, pl. 2, figs. 1, 10.

D e s c r i p t i o n (Fig. 3A). The cyst is suturocavate and has an hourglass outline, a characteristic feature of the genus *Horologinella*. The epicyst is markedly smaller than the hypocyst. The autophragm is dense, dark brown, and laevigate or scabrate. At the margins of the paraplates, it forms short (2–5 μm) bifurcate processes, which bear a thin, transparent periphragm. The processes emphasize the paratabulation of the precingular and postcingular series. The paratabulation of the apical and antapical areas is expressed in parasutural features or small ridges. The paratabulation formula is 13'?, 7'', 7c, 5s, 6''', 1-2p?, 3''''. The paracingulum is slightly laevorotatory; it is emphasized by a strong equatorial constriction. The parasulcus is antapically broad and becomes significantly narrower toward the paracingulum. Sulcal and cingular paraplates are limited by thin parasutural features. A tear-shaped pore complex is visible in many cysts. The operculum is formed by separation of all apical paraplates. The archeopyle is free apical or combination.

M e a s u r e m e n t s (μm): the height is 18–30, the width of the hypocyst is 16–30, the width of the epicyst is 13–21, and the width of paracingulum is 11–16.

L o c a l i t y. *Khatanga Depression*: eastern coast of the Anabar Bay, outcrop 1A, Lower Valanginian, *Euryptychites astieriptychus* Zone, layer 12, Nordvik Peninsula, outcrop 33, Lower Valanginian, *Neotollia klimovskiensis* zone, layers 50–64; *Ust'-Yenisei Region*: borehole Severo-Vologochanskaya 18, Lower Valanginian, 935.0–321.7 m; *Western Siberia*: Gorshkovskaya 1017 borehole, Hauterivian, 2656–2515 m.

M a t e r i a l. More than 40 specimens of good or adequate preservation.

Suborder Cladopixiineae Fensome et al. 1993

Family Cladopixiaceae Stein 1883

Dinoflagelatte cyst gen. indet. sp. A

Plate 7, fig. 19

D e s c r i p t i o n (Fig. 3B). The cyst is proximate acavate, oval, with a narrowly rounded apex and a characteristic notch in the antapical area. The autophragm is dense, dark brown, sculptured with laevigate parasutural ridges 1–2 μm high, which make the paratabulation more distinct. The formula is 4', 3a, 7'', 7c, 5s, ?6''', ?2p, ?3''''. The paracingulum is slightly laevorotatory. The archeopyle is simple combination: AtIt.

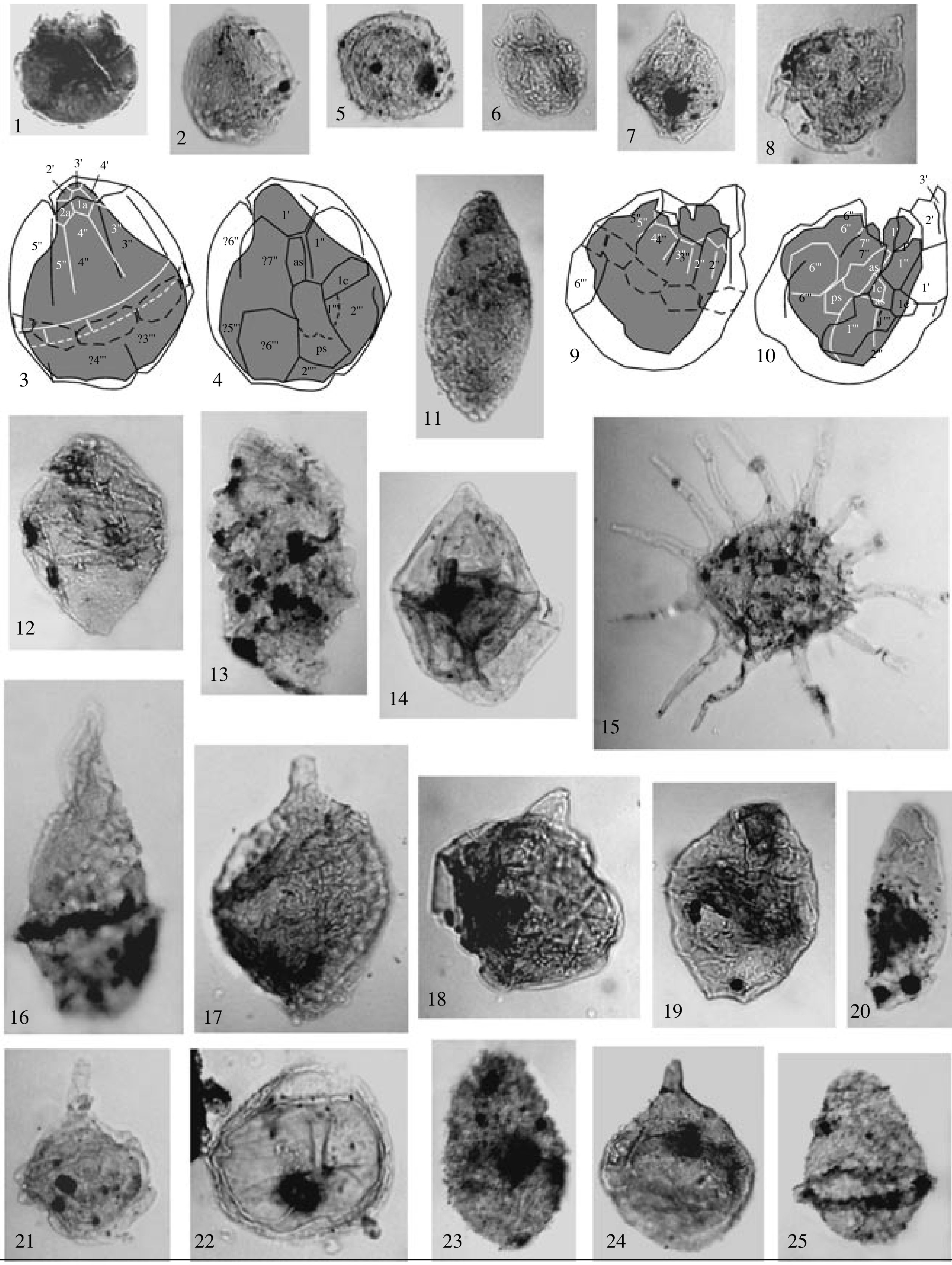
M e a s u r e m e n t s (μm): the length is 63; the length without operculum is 51; the width in the cingular area is 52, in the apical, 11; and in the antapical, 16.

R e m a r k s. The combination of the cyst outline, paratabulation, and archeopyle morphology differentiates the dinocyst type A from all known genera and species. The features of paratabulation are characteristic of the suborder Cladopixiineae and the family Cladopixiaceae (Fensome et al., 1993). In dinocysts of type A the diagnostic features of the suborder and family are revealed (Fig. 3B). The diagnostic features of the suborder are as follows: (1) sulcal plate ps contacts with the first postcingular plate (1'''), and (2) there are no more than five apical paraplates. The diagnostic features of the family are as follows: (1) the sulcal paraplate 1' projects significantly beyond the precingular row and is mostly situated between 4' and 2'; (2) as a rule, there are seven precingular and seven or eight climactal paraplates of the apex; and (3) apical and intercalary paraplates are significantly smaller than precingular paraplates.

L o c a l i t y. Nordvik Peninsula, outcrop 55, layer 22, Lower Valanginian, lower part of the *Neotollia klimovskiensis* Zone.

M a t e r i a l. One specimen of good preservation.

Plate 7



Dinoflagelatte cyst gen. indet. sp. B

Plate 7, fig. 12

Description (Fig. 3C). The cyst is proximate acavate and oval. The apex is rounded; the antapex is narrow, with a characteristic notch. The autophragm is relatively thin, light yellow, laevigate, mostly laterally folded. The paratabulation is expressed by very fine parasutural features and archeopyle. The formula is X', 3a, ?7'', ?7c, ?5s, ?6''', ?2p, ?3''''. The archeopyle is simple combination: AtIt.

Measurements (μm): the length is 72; the length without operculum is 55; the width in the cingular area is 54, in the apical area, 17; and in the antapical, 10.

Remarks. A similar general aspect, paratabulation, and archeopyle type are observed in dinocysts of type A. Type B differs in having a less dense wall without parasutural ridges, more elongate outlines, and a narrow antapex. It is very possible that these types are two species of one genus, but the scarcity of the material prevents the establishment of new taxa.

Locality. Nordvik Peninsula, outcrop 33, layer 33, Berriasian, *Surites analogus* Zone.

Material. One well-preserved specimen.

Family Pareodiniaceae Gocht, 1957

Subfamily Broomeoideae (Eisenack) Fensome et al., 1993

Genus *Aprobolocysta* Duxbury 1977 emend. Pestchevitskaya

Aprobolocysta: Duxbury, 1977, p. 52; Duxbury, 1980, p. 112; Davey, 1982, p. 21; Stover and Williams, 1987, pp. 19, 20.

Type species. *Aprobolocysta eilema* Duxbury 1977; pp. 52, 53, pl. 14, figs. 4–5, text-fig. 19B; Middle Hauterivian–Lower Barremian of England, North Sea shelf and Western Siberia (the middle Ob River); Lower Barremian of the Barents Sea shelf.

Diagnosis. Cyst elongate ovoid, proximate or proximochorate, bilayered; epicyst longer than hypocyst; apex longer and more tapering than antapex; horns and rounded projections may be present in apical and antapical areas; paratabulation not evident or indistinctly indicated by periphragm, structural elements (folds, septa, pustules, and others) and archeopyle margin; archeopyle probably apical or combination.

Species composition. According to Fensome and Williams (2004) with an addition of *Aprobolocysta cornuta* sp. nov.

Description. The cyst is medium-sized, proximate or proximochorate, bilayered, and elongated oval.

Explanation of Plate 7

Fig. 1. *Hologinella anabarensis* Pestchevitskaya, IPGG, no. 116.1/15: layer 37, sample 37.2, Berriasian, ×800.

Fig. 2. *Dingodinium subtile* Pestchevitskaya, sp. nov., holotype, IPGG, no. 124.1/10: layer 42, sample 42.1, Berriasian, ×530.

Fig. 3. Drawing of the morphology shown in Fig. 2, dorsal view, paratabulation.

Fig. 4. Drawing of the morphology shown in Fig. 2, ventral view, paratabulation.

Fig. 5. *Leberidocysta spinosa* Pestchevitskaya, IPGG, no. 125.1/13: layer 43, sample 43.1, Berriasian, ×370.

Fig. 6. *Dingodinium subtile* Pestchevitskaya, sp. nov., IPGG, no. 131.1/1: layer 49, sample 49.2, Berriasian, ×430.

Fig. 7. *Dingodinium tuberosum* (Gitmez) Fisher et Riley, IPGG, no. 116.1/3: layer 37, sample 37.2, Berriasian, ×440.

Fig. 8. *Dingodinium subtile* Pestchevitskaya, sp. nov., paratype, IPGG, no. 131.1/6: layer 49, sample 49.2, Berriasian, ×490.

Fig. 9. Drawing of the morphology shown in Fig. 8, paratabulation, dorsal view.

Fig. 10. Drawing of the morphology shown in Fig. 8, paratabulation, ventral view.

Fig. 11. *Batioladinium varigranosum* (Duxbury) Davey, IPGG, no. 108.1/3: layer 31, sample 31.2, Berriasian, ×630.

Fig. 12. Dinoflagellate cyst gen. indet. sp. B, IPGG, no. 111.1/37: layer 33, sample 33.1, Berriasian, ×490.

Fig. 13. *Aprobolocysta neista* Duxbury, IPGG, no. 1403.1/45: sample 38, ×610.

Fig. 14. *Endoscrinium vellum* Pestchevitskaya, IPGG, no. 135.1/10.a: layer 51, sample 51.1, Valanginian, ×490.

Fig. 15. *Hystrichodinium solare* Pestchevitskaya, IPGG, no. 1403.1/40: sample 38, ×470.

Fig. 16. *Aprobolocysta cornuta* Pestchevitskaya, sp. nov., holotype, IPGG, no. 1403.6/15: sample 38, ×600.

Fig. 17. *Aldorfia sibirica* Pestchevitskaya, IPGG, no. 31.1/8: layer 20, sample 31, ×580.

Fig. 18. *Dingodinium minutum* Dodekova, IPGG, no. 1072.3/17: layer 22, sample 22.1, ×560.

Fig. 19. Dinoflagellate cyst gen. indet. sp. A, IPGG, no. 1072.2/7: layer 22, sample 22.1, ×550.

Fig. 20. *Wallodinium krutzchii* (Alberti) Habib, IPGG, no. 1403.5/8: sample 38, Upper Hauterivian, ×510.

Fig. 21. *Dingodinium cerviculum* Cookson et Eisenack emend. Khowaja-Ateequzzman et al., IPGG, no. 1406.2/5: sample 41, ×550.

Fig. 22. *Leberidocysta spinosa* Pestchevitskaya, IPGG, no. 108.2/3: layer 31, sample 31.2, Berriasian, ×640.

Fig. 23. *Aprobolocysta galeata* Backhouse, IPGG, no. 1405.1/9: sample 40, ×500.

Fig. 24. *Pareodinia* cf. *asperata* Riley in Fisher et Riley, IPGG, no. 109.1/23: layer 31, sample 31.3, Berriasian, ×570.

Fig. 25. *Aprobolocysta eilema* Duxbury, IPGG, no. 1403.1/14: sample 38, ×530.

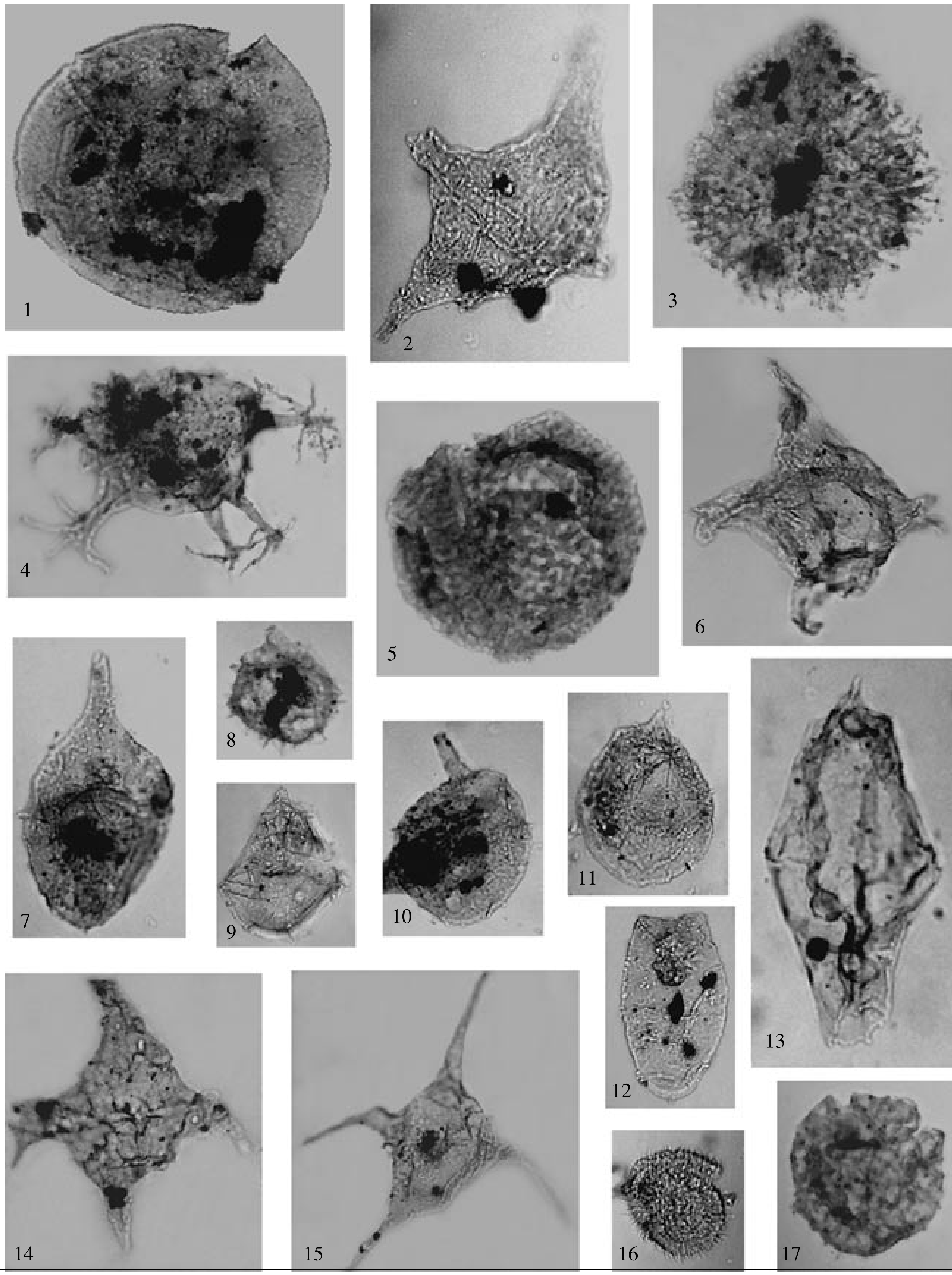
Figs. 1–12, 14, 22, and 24. Khatanga Depression, Nordvik Peninsula, outcrop 33; Paksa Cape Formation, layers with Pareodinioideae, *Batioladinium varigranosum*, and *Cassiculasphaeridia reticulata.*

Figs. 13, 15–16, 20, 21, 23, and 25. Western Siberia, Middle course of the Ob River, Gorshkovskaya borehole 1017; Cherkashinskaya Formation, Upper Hauterivian, local zone with *Aprobolocysta eilema, A. neista*, and *Odontochitina* sp.

Fig. 17. Khatanga Depression, east coast of the Anabar Bay, outcrop 1A; Paksa Cape Formation, Lower Valanginian, local zone with *Aldorfia sibirica* and *Aprobolocysta galeata.*

Figs. 18 and 19. Khatanga Depression, Nordvik Peninsula, outcrop 35; Paksa Cape Formation, Lower Valanginian, local zone with *Escharisphaeridia* spp., *Oligosphaeridium* spp., and *Circulodinium* spp.

Plate 8



The apex and antapex are rounded; rounded prominences or horns are occasionally present (one or two in the antapical area and one in the apical area). The endophragm is relatively dense, laevigate or granulate. The periphragm is usually thinner, transparent, and occasionally weakly perforated or granulate. The periphragm has folds of various height (from 1–2 μm and up to a half of the endocyst), which form various sculptural elements: wrinkles, septa, reticulum, and elevations. The paratabulation is either absent or indicated by the arrangement of structural elements of the periphragm. The supposed formula of paratabulation is ?4', ?2a, ?6'', 0c, 6''', 0p, 1''''. The archeopyle is apical or combination. The operculum is free, and often absent.

C o m p a r i s o n. *Aprobolocysta* resembles *Batioladinium* Brideaux (Brideaux, 1975) in the cyst outline and the morphology of the archeopyle, but differs in the wall structure: the periphragm is clearly separated from the endophragm and forms various structural elements. The wall layers of *Batioladinium* are closely appressed to each other, and therefore rarely discernable. The genus strongly resembles *Riasanodinium* Iosifova in general morphology and wall structure, as was noted by Iosifova (1996). The specific features of *Riasanodinium* are the shape of the archeopyle (without a prominent depression in the sulcal area) and the intratabular arrangement of periphragm processes, which reflect gonyaulacoid formula.

R e m a r k s. The diagnosis is broadened to include dinocysts with apical or antapical horns on the endocyst or epicyst. Originally, the genus *Aprobolocysta* included only proximate dinocysts with a characteristic bilayered wall (Duxbury, 1977). Later, the diagnosis was broadened to include proximochorate cysts (Duxbury, 1980). Davey (1982) restricted the genus: only species with a definite bilayered wall were included, and *A. varigranosa* Duxbury was attributed to the genus *Batioladinium* (Duxbury, 1977). Stover and Williams (1987) refined the archeopyle morphology on the basis of new material and published data. They supposed that it is formed by the separation of apical and intercalary paraplates and, therefore, is of the combination type. However, most scientists believe the archeopyle to be apical (Duxbury, 1977, 1980, 2001; Backhouse, 1987; Smith and Harding, 2004).

Most of the species of *Aprobolocysta* lack paratabulation or show only faint indications, making the determination of the formula impossible. The only species in which the fold arrangement in the precingular and postcingular areas reflects the paratabulation is *A. alata* Backhouse (Backhouse, 1987). These morphological peculiarities allow determination of the formula: ?4',

E x p l a n a t i o n o f P l a t e 8

Fig. 1. *Batiacasphaera* sp., IPGG, no. 108.2/2: layer 31, sample 31.2, ×550.

Fig. 2. *Muderongia brevispinosa* Iosifova, IPGG, no. 1090.3/2: layer 11, sample 11.2, ×420.

Fig. 3. *Aptea anaphrissa* (Sarjeant) Sarjeant et Stover, IPGG, no. 1396.1/3: sample 31, ×550.

Fig. 4. *Oligosphaeridium complex* (White) Davey et Williams, IPGG, no. 1397.1/8: sample 32, ×530.

Fig. 5. *Cassiculasphaeridia sarstedtensis* Below, IPGG, no. 1403.2/41: sample 38, ×690

Fig. 6. *Muderongia australis* Helby, IPGG, no. 30.1/9: layer 20, sample 30, ×750.

Fig. 7. *Paragonyaulacysta ?borealis* (Brideaux et Fisher) Stover et Evitt, IPGG, no. 107.1/26: layer 31, sample 31.1, ×570.

Fig. 8. *Nelchinopsis kostromiensis* (Vozzhennikova) Wiggins, IPGG, no. 1403.6/14: sample 38, ×480.

Fig. 9. *Wrevittia cassidata* (Eisenack et Cookson) Helenes et Lucas-Clark, IPGG, no. 752.1/6: sample 59, ×420.

Fig. 10. *Pareodinia ceratophora* Deflandre, IPGG, no. 107.2/38: layer 31, sample 31.1, ×550.

Fig. 11. *Pareodinia tamboviensis* (Vozzhennikova) Lentin et Vozzhennikova, IPGG, no. 109.1/4: layer 31, sample 31.3, ×480.

Fig. 12. *Fromea* aff. *?laevigata* (Drugg) Stover et Evitt, IPGG, no. 115.1/9: layer 37, sample 37.1, ×740.

Fig. 13. *Tubotuberella apatela* (Cookson et Eisenack) Ioannides, IPGG, no. 109.1/24: layer 31, sample 31.3, ×700.

Fig. 14. *Vesperopsis mayi* Bint, IPGG, no. 1406.1/11: sample 41, ×470.

Fig. 15. *Muderongia tetracantha* (Gocht) Alberti, IPGG, no. 1414.1/12: sample 49, ×300.

Fig. 16. *Cleistosphaeridium* sp., IPGG, no. 1073.1/7: layer 31, sample 35.1, ×520.

Fig. 17. *Cassiculasphaeridia reticulata* Davey, IPGG, no. 1403.1/17: sample 38, ×600.

Figs. 1, 7, and 10–13. Khatanga Depression, Nordvik Peninsula, outcrop 33; Paksa Cape Formation, Berriasian, layers with Pareodinioideae, *Batioladinium varigranosum*, and *Cassiculasphaeridia reticulata.*

Fig. 2. Khatanga Depression, Nordvik Peninsula, outcrop 36; Paksa Cape Formation, Lower Hauterivian, local zone with *Hystrichodinium solare* and *Muderongia* spp.

Figs. 3 and 4. Western Siberia, Middle Course of the Ob River, Gorshkovskaya 1017 borehole; Cherkashinskaya Formation, Lower Hauterivian, local zone with *Aptea anaphrissa, Oligosphaeridium* aff. *totum*, and *Batioladinium longicornutum.*

Figs. 5, 8, 14–15, and 17. Western Siberia, Middle Course of the Ob River, Gorshkovskaya 1017 borehole; Cherkashinskaya Formation, Upper Hauterivian, local zone with *Aprobolocysta eilema, A. neista*, and *Odontochitina* sp.

Fig. 6. Khatanga Depression, eastern coast of the Anabar Bay, outcrop 1A; Paksa Cape Formation, Lower Valanginian, local zone with *Aldorfia sibirica* and *Aprobolocysta galeata.*

Fig. 9. Ust'-Yenisei Region, borehole Severo-Vologochanskaya 18; Sukhaya Dudinka Formation, Lower Valanginian, local zone with Pareodinioideae, *Batioladinium varigranosum*, and *Cassiculasphaeridia reticulate.*

Fig. 16. Khatanga Depression, Nordvik Peninsula, outcrop 35; Paksa Cape Formation, Valanginian, local zone with *Oligosphaeridium complex* and *Dingodinium cerviculum.*

?2a, ?6'', 0c, 6''', 0p, 1''''. Iosifova (1996) supposed that *Riasanodinium* is characterized by a gonyaulacoid formula: 4', ?6'', 6c, 5-6''', 1''''. However, her photographs and drawings do not show this sufficiently clearly, so different interpretation and the presence of intercalary series of paraplates are conceivable. If this is the case, the only difference between *Riasanodinium* and *Aprobolocysta* is the morphology of the detachment line of the operculum, an unsatisfactory character for the establishment of a new genus.

Aprobolocysta cornuta Pestchevitskaya, sp. nov.

Plate 7, fig. 16

E t y m o l o g y. From the Latin *cornus* (horn).

H o l o t y p e. Novosibirsk, IPGG (Trofimuk Institute of Petroleum Geology and Geophysics), no. 1403.6/15, Pl. 7, fig. 16; Western Siberia, middle course of the Ob River, Gorshkovskaya 1017 borehole, 2629.7 m, Upper Hauterivian.

D i a g n o s i s. Cyst elongate oval, proximate, bilayered, with apical horn; apex longer and more tapering than antapex; endophragm thicker, with small granules, periphragm thin and transparent; no paratabulation apparent except for archeopyle margin; archeopyle apical.

D e s c r i p t i o n (Fig. 3D). The cyst is proximate, bilayered, and elongated oval or ovate. The hypocyst is smaller in height, but wider than the epicyst. The apex is rounded. There is a horn of a medium length in the antapical area. It is narrow on the endocyst and wide on the pericyst. The endophragm is relatively dense and finely granulate. The periphragm is thinner, transparent, and folded. The largest fold girdles the cyst in the cingular area like a "skirt." In precingular area, the endophragm and periphragm may be closely appressed to each other or form a small pericoel, which becomes significantly wider toward the apex and antapex. In the apical area, the pericoel is elongate reproducing the outlines of the horn on the endocyst. The paratabulation is visible only in the operculum detachment line. The position of the paracingulum is indicated by a broad fold. The archeopyle is apical.

M e a s u r e m e n t s (μm): the length of the dinocyst is 95–104 (without operculum 75–79); the width is 45–50; the length of the endocyst is 74–79, the width is 35–37; the length of the apical horn on the periphragm is 28–30, the width is 14–16 near the base and 5 at the distal side; the length of the apical horn on the endophragm is 14–15, the width is 4–5 near the base and 2 distally; the width of the pericoel in the antapical area is 10–15.

V a r i a b i l i t y. The sizes of the cyst and pericoel vary slightly.

C o m p a r i s o n. *A. cornuta* differs from the closest species *A. eilema* (Duxbury, 1977) in the presence of an apical horn, and in having a finely granulate endophragm. *A. alata* Backhouse differs in the presence of antapical horns and paratabulation that is expressed not only in the archeopyle, but also in the position of the periphragm folds (Backhouse, 1987).

L o c a l i t y. Western Siberia (middle course of the Ob River), Gorshkovskaya 1017 borehole, 2629.7–2442.6 m, Upper Hauterivian–Lower Barremian.

M a t e r i a l. Four specimens of good or adequate preservation.

Aprobolocysta eilema Duxbury 1977

Plate 7, fig. 25

Aprobolocysta eilema: Duxbury, 1977, pp. 52, 53, pl. 14, figs. 4, 5, 8; Londeix, 1990, pp. 188, 189, pl. IX, fig. 4; Leerveld, 1995, p. 113, pl. XI, fig. o.

D e s c r i p t i o n. The cyst is proximate, bilayered, elongated oval or ovate. The hypocyst is smaller in height but wider than the epicyst. The apex and antapex are rounded. The endophragm is relatively dense and granulated. The periphragm is thinner and transparent; it girdles the cyst in the cingular area like a "skirt." In the precingular area, the endophragm and periphragm may be closely appressed to each other or form a small pericoel that becomes gradually wider toward the apex and antapex. The paratabulation is only expressed by the archeopyle. The position of the paracingulum is indicated by a broad fold. The archeopyle is apical.

M e a s u r e m e n t s (μm): the length is 56–79, and the width is 36–51.

R e m a r k s. The difference between the Siberian specimens and typical cysts is a weakly developed pericoel in the antapical and apical areas (no more than 6 μm). The periphragm has finer folds. The Siberian specimens are usually of the same dimensions as the type material, although smaller cysts occur.

O c c u r r e n c e. Middle Hauterivian–Lower Barremian of England, North Sea shelf, Western Siberia (middle course of the Ob River); Lower Barremian of the Barents Sea shelf.

L o c a l i t y. Gorshkovskaya 1017 borehole, 2629.7–2442.6 m, Upper Hauterivian–Lower Barremian.

M a t e r i a l. Eight specimens of good or adequate preservation.

Aprobolocysta galeata Backhouse 1987

Plate 7, fig. 23

Aprobolocysta galeata: Backhouse, 1987, pp. 212–214, text-figs. 9I–L; Leerveld, 1995, pl. IV, fig. g; Iosifova, 1996, pl. II, figs. 1, 2.

D e s c r i p t i o n. The cyst is proximate, bilayered, and elongated oval. The apex is rounded, the apical horn is absent. The antapex is broadly rounded, occasionally with two small prominences. The endophragm is relatively dense and finely granulate. It is attached at numerous points to a thinner semitransparent and closely appressed periphragm, which forms tight folds and wrinkles. The archeopyle is apical, possibly of the tA type. The operculum is free, often absent. The paratabulation is only expressed by the archeopyle.

M e a s u r e m e n t s (μm): the length is 48–72, and the width is 36–58.

R e m a r k s. Lower Valanginian specimens are usually larger than the Hauterivian specimens. They differ from the type material in their lack of prominent protrusions in the antapical area and larger size (the length of the type material is 47–55 μm, and the width is 25–38 μm).

L o c a l i t y. Nordvik Peninsula, outcrop 35, Lower Valanginian, *ramulicosta* ammonite Subzone, layer 39; borehole Romanovskaya 140, 2765–2758 m, Lower Valanginian, *Euryptychites quadrifidus* ammonite Zone; Gorshkovskaya 1017 borehole, 2629.7–2515 m, level 2442.6 m, Upper Hauterivian–Lower Barremian.

M a t e r i a l. Eight specimens of adequate or good preservation.

Aprobolocysta neista **Duxbury 1980**

Plate 7, fig. 13

Aprobolocysta neistosa: Duxbury, 1980, pp. 112, 113, pl. 2, figs. 8, 9; Davey, 1982, pp. 24, 25, pl. 7, figs. 5–7; Londeix, 1990, pp. 189, 190, pl. IX, fig. 6; pl. XI, fig. 8; Leerveld, 1995, p. 113, pl. XI, fig. o; Iosifova, 1996, pl. VIII, fig. 3.

Aprobolocysta neista: Fensome et Williams, 2004, p. 51.

D e s c r i p t i o n. The cyst is proximate or proximochorate, bilayered, and elongate oval. The apex and antapex are rounded. The endophragm is relatively dense and finely granulate. The periphragm is thin and forms relatively high (up to one-forth of the endocyst width) septa, which are irregularly arranged and form a coarse net. Occasionally, they indistinctly reflect the paratabulation. The archeopyle is apical, supposedly of the tA type. The operculum is free, often absent. The paratabulation is unclear and indicated by the arrangement of the septa and archeopyle.

M e a s u r e m e n t s (μm): the length is 58–96, and the width is 34–82.

O c c u r r e n c e. Lower Hauterivian–lower Upper Barremian of England, North Sea shelf; Upper Hauterivian of Western Siberia (middle course of the Ob River); lower Upper Barremian of the Barents Sea shelf; Hauterivian of the Moscow Basin.

L o c a l i t y. Gorshkovskaya 1017 borehole, 2629.7–2515 m, Upper Hauterivian.

M a t e r i a l. Four specimens of good or adequate preservation.

Suborder uncertain

Family uncertain

Genus *Dingodinium* Cookson et Eisenack 1958 emend. Mehrotra et Sarjeant 1984

Dingodinium cerviculum **Cookson et Eisenack 1958 emend. Khowaja–Ateequzzman et al. 1990**

Plate 7, fig. 21

Dingodinium cerviculum: Cookson and Eisenack, 1958, p. 40, pl. 1, figs. 12–14; Alberti, 1961, p. 17, pl. 3, figs. 14, 15; Mehrotra and Sarjeant, 1984, pp. 296–300; Burger, 1980, p. 72, pl. 22, figs. 5, 6; Prössl, 1990, pl. 9, fig. 5; Fensome and Williams, 2004, p. 190.

D e s c r i p t i o n. The cyst is proximate camocavate. The endocyst is oval or elongate oval, with a fairly dense endophragm, which is sculptured with many small granules or baculae. The pericyst is oval, laevigate, and often variously folded. Apically, a relatively long (up to two-thirds of the total length of the endocyst) horn is developed, which is distally closed and broadly rounded; it is not situated centrally, but significantly shifted toward the ventral face. A relatively wide pericoel is developed in the area of the apical horn and around nearly the entire circumference of the cyst. The pericoel only becomes much narrower dorsally. Occasionally, the layers of the wall are appressed to each other in this area. The paratabulation is not always visible and is expressed by the paracingulum and, occasionally, by the archeopyle. The paracingulum on the pericyst is often indicated by a small fold of the periphragm. The archeopyle is apical or combination.

M e a s u r e m e n t s (μm): the length of the pericyst is 58–65, the length of the endocyst is 32–42, the width of the pericyst is 42–44, the width of the endocyst is 31–36, and the length of the apical horn is 15–19.

O c c u r r e n c e. Upper Volgian–Berriasian of England and the North Sea shelf; Ryazanian–Barremian of the Barents Sea shelf; Lower Cretaceous of New Guinea; Berriasian–Barremian of southeastern Canada; Valanginian (*quadrifidus*)–Lower Hauterivian of northern Siberia; Valanginian (the base of *Buchia keyserlingi* bivalve Zone)–Middle Albian of northern Canada; Neocomian–Albian of Australia; Upper Hauterivian–Turonian of Germany; Barremian of the Island of Newfoundland, and Middle Barremian of the Barents Sea shelf.

L o c a l i t y. Nordvik Peninsula, outcrop 35, layers 22–39, the middle of the *Euryptychites quadrifidus–Sibirites ramulicosta* Zone, *ramulicosta* Subzone, Lower Valanginian; eastern coast of the Anabar Bay, outcrop 1A, layers 9–16, the upper part of the *Euryptychites quadrifidus–Sibirites ramulicosta* ammonite zones, *ramulicosta* Subzone, Lower Valanginian; Gorshkovskaya 1017 borehole, 2630.55–2615 m, Hauterivian.

M a t e r i a l. More than 25 specimens of good or adequate preservation.

Dingodinium minutum **Dodekova 1975 emend. Poulsen 1996**

Plate 7, fig. 18

Dingodinium minutum: Dodekova, 1975, p. 25, pl. 5, figs. 13–15; Poulsen, 1996, pp. 82, 83, pl. 16, figs. 2–7; Fensome and Williams, 2004, p. 190.

D e s c r i p t i o n. The cyst is proximate camocavate. The endocyst is rounded or irregularly oval (the longer axis is along the width of the endocyst). The endophragm is relatively dense, sculptured with relatively numerous granules, and, occasionally, small (about 1 μm) spines with broad bases. The pericyst is laevigate, rounded or irregularly polygonal, with a distally closed short (no longer than one-quarter of the endocyst width) horn having a more or less axial position. The pericyst may be folded. Often, the apical horn and cingular area are sculptured with infrequent small granules. The pericoel is prominent in the area of the apical horn and around the cyst, becoming much narrower on the dorsal face. In this area, the layers of the wall are often appressed to each other. The paratabulation may be indicated by thin parasutural features and the archeopyle both on the endocyst and pericyst. The paracingulum is marked by parasutural features or a small fold of the periphragm. The morphology of the archeopyle is unclear: it is either apical, or combination, or intercalary, possibly type 3I.

M e a s u r e m e n t s (μm): the length of the pericyst is 44–64, the length of the endocyst is 37–49, the width of the pericyst is 40–54, the width of the endocyst is 30–52, and the length of the apical horn is 5–9.

R e m a r k s. The Siberian specimens differ from the type material in the granulate sculpturing of the cingular area of the pericyst and apical horn.

O c c u r r e n c e. Toarcian of Canada (Sverdrup Basin); Upper Bathonian of Bulgaria; Upper Callovian–Middle Volgian of northwestern Europe; upper Upper Oxfordian (with *Tenuiserratum*)–lower Valanginian of Denmark; basal Kimmeridgian–Volgian of Poland; and Berriasian–lower Valanginian of northwestern and north-central Siberia.

L o c a l i t y. Nordvik Peninsula, outcrop 33, layers 37–64, Berriasian–lower Valanginian, *Bojarkia meseznikovi–Neotollia klimovskiensis* zones; eastern coast of the Anabar Bay, outcrop 1A, layers 7–18, Lower Valanginian, upper part of the *Euryptychites quadrifidus–Sibirites ramulicosta* ammonite zones, *ramulicosta* Subzone, borehole Severo-Vologochanskaya 18, 984.3–914.7 m, Upper Berriasian–lower Lower Valanginian.

M a t e r i a l. More than 20 cysts of good or adequate preservation.

Dingodinium tuberosum (Gitmez 1970) Riley 1980 emend. Poulsen 1996

Plate 7, fig. 5

Parvocavatus tuberosus: Gitmez, 1970, pp. 307, 308, pl. 9, fig. 9.

Dingodinium tuberosum: Poulsen, 1996, pp. 83, 84, pl. 16, figs. 8–12; Fensome and Williams, 2004, p. 190.

D e s c r i p t i o n. The cyst is proximate camocavate. The endocyst is rounded or oval (the shorter axis is along the width of the endocyst). The endophragm is relatively dense, sculptured with granules and, occasionally, with small (about 1 μm) broad-based spines. The periphragm is laevigate and transparent. It forms an oval, rounded, or rounded-rhomboidal pericyst with small (no more than one-fourth of the width of the endocyst) and distally rounded apical horn. The horn is conical or cylindrical and is situated more or less axially. A small opening (0.5–1 μm in diameter) is often present at the distal extremity. It is possible that it corresponds to the apical pore plate (pr). The pericyst may form small folds. The pericoel is considerably narrow in the cingular area and becomes wider toward the apex and antapex. Its minimal width is observed on the dorsal side, where the layers of the wall are closely appressed to each other. The paratabulation may be indicated by fine parasutural features and archeopyle both on the endocyst and pericyst. The paracingulum and sulcus are indicated by parasutural features. The morphology of the archeopyle is unclear; apical, combination, or intercalary.

M e a s u r e m e n t s (μm): the length of the pericyst is 51–54, the length of the endocyst is 41–44, the width of the pericyst is 40–43, the width of the endocyst is 37–39, and the length of the apical horn is 8–9.

R e m a r k s. The Siberian specimens differ from the type material in the more elongated outlines of the cyst.

O c c u r r e n c e. Upper Jurassic of France; Upper Oxfordian–Middle Volgian (*Albani* Zone) of England; upper Upper Oxfordian (with *Tenuiserratum*)–middle Volgian (up to the roof of *Albani*) of Denmark; Berriasian–Valanginian of the Khatanga Depression.

L o c a l i t y. Nordvik Peninsula, outcrop 33, layers 37–49, Berriasian, *Bojarkia meseznikovi–Tollia tolli* zones.

M a t e r i a l. More than 20 specimens of good or adequate preservation.

Dingodinium subtile Pestchevitskaya, sp. nov.

Plate 7, figs. 2, 6–8, 10, and 11

E t y m o l o g y. From the Latin *subtile* (thin) characterizing the cyst wall morphology.

H o l o t y p e. Novosibirsk, IPGG, no. 124.1/10; north of Middle Siberia, Paksa Peninsula, outcrop 33, layer 49, Berriasian, *Tollia tolli* Zone; Pl. 7, fig. 2.

P a r a t y p e. Novosibirsk, IPGG, no. 131.1/6, pl. 1, figs. 6, 10, 11; north-central Siberia, Paksa Peninsula, outcrop 33, layer 42, Berriasian, *Tollia tolli* Zone.

D i a g n o s i s. Cyst proximate and camocavate; endocyst ovoid or pear-shaped with rather thin granular endophragm; pericyst smooth and spherical or ellipsoidal, apex and antapex rounded; paratabulation gonyaulacoid, when apparent expressed on endocyst and pericyst by fine paratabulation features and archeopyle; formula 4', ?3a, 7'', 7c, 5s, 6''', 1p, 1''''; archeopyle apical, combination, or intercalary.

D e s c r i p t i o n (Fig. 3E). The cyst is proximate and camocavate. The endocyst is ovate or pear-shaped with a relatively thin endophragm, which is sculptured with numerous small granules. The pericyst is rounded or broadly oval; the apex and antapex are rounded. The periphragm is laevigate, thin, transparent, is folded in thin folds, which occasionally make an impression of indistinct striation. Usually, the pericoel is prominent, except for the dorsal side, where the layers of the wall are often appressed to each other. Occasionally, it becomes narrower near the cingulum. The maximal width is observed in the apical area. The paratabulation is not always visible. It is indicated on the endocyst and pericyst by fine parasutural features and archeopyle. The formula is 4', ?3a, 7'', 7c, 5s, 6''', 1p, 1''''. The paracingulum and sulcus are indicated by more distinct parasutural features. The archeopyle structure is unclear: apical, combination, and intercalary.

M e a s u r e m e n t s (μm): the length of the pericyst is 45–57; the length of the endocyst is 40–46; the width of the pericyst is 39–46; the width of the endocyst is 34–46 in the cingular area and 12–28 in the apical area; and the width of the pericoel is 2–5 in the cingular area (ventral and lateral sides), 7–9 in the antapical area, 8–14 in the apical area, and 0–2 on the dorsal side.

V a r i a b i l i t y. The size of the cyst and the width of the pericoel in different regions are variable as well as the outline of the endocyst (from ovate to pear-shaped).

C o m p a r i s o n. The absence of the apical horn on the pericyst makes *D. subtile* closer to *D. jurassicum* Cookson et Eisenack, which differs in the rounded endocyst sculptured with short spines (Cookson and Eisenack, 1958). By the morphology of the endophragm, *D. subtile* resembles *D. minutum* Dodekova (Dodekova, 1975) and *D. tuberosum* (Gitmez) Fisher et Riley (Gitmez, 1970), but these two species are characterized by a rounded or oval endocyst and the presence of apical horn on the pericyst.

L o c a l i t y. Khatanga Depression, Nordvik Peninsula, outcrop 33, layers 37–56, Berriasian–Lower Valanginian, *Bojarkia meseznikovi* ammonite Zone–lower part of *Neotollia klimovskiensis* ammonite Zone; Ust'-Yenisei Region, borehole Severo-Vologochanskaya 18, 984.3–977.0 m, upper Berriasian–lower Lower Valanginian.

M a t e r i a l. More than 20 specimens of good or adequate preservation.

CONCLUSIONS

The study of the dinocysts from the Lower Cretaceous sedimentary rocks of northern Siberia has once again shown the great stratigraphic potential of this microfossil group. This group is particularly important in western Siberia, where oil-and-gas-related deposits of the Lower Cretaceous often contain poor macrofaunal assemblages. Dinocysts, along with other groups of microfossils, foraminifers, and ostracodes, allow reliable age determination of the productive strata and precise local and interregional correlations.

The comprehensive analysis of the changes in the taxonomic composition of the microphytoplankton of northern Siberia has revealed a dinocyst zonation with ten units. Groups of stratigraphically significant species have been determined by the comparison between Lower Cretaceous assemblages of Siberia, Europe, and Canada. Their lowermost and uppermost occurrences are registered at certain stratigraphic levels, thus providing a palynological basis for the dinocyst zones revealed. Most of them can be considered as important stratigraphic marker levels. In addition to Siberia, they were traced in the Middle Berriasian (base of local zone DA1) of Arctic Canada, Moscow Syneclise, and Subarctic Urals; in the Lower Valanginian (DA2 and DA3) of nearly entire northern Europe and Canada; in the Lower Hauterivian (DA6) in the Subarctic Urals and the Barents Sea shelf; and in the Upper Hauterivian (DA7) and Lower Barremian (DA8) in northwestern Europe.

In addition to the stratigraphically important species, the characteristic taxa have been revealed, widespread in northern Eurasia and America. The presence of new species and forms of unusual morphology shows the singularity of Siberian dinocyst assemblages. The systematic paleobotany includes four species of *Dingodinium* and four species of *Aprobolocysta*, of which two are new taxa: *Dingodinium subtile* and *Aprobolocysta cornuta.* In Siberia, the high diversity of *Dingodinium* is a characteristic feature of the Berriasian, while the diversity of *Aprobolocysta* is typical of the Hauterivian. Dinocysts of the Rhaetogonyaulacineae and Cladopixiineae are also described. The occurrences of members of these suborders are often revealed in the Jurassic and are considered typical of this interval. The genus *Hurologinella* is revised: it is restricted to morphotypes showing clear dinocyst characteristics. The morphology of species of *Aprobolocysta* was analyzed, and the composition of the genus was revised to include forms with apical or antapical horns. The study has shown that Siberian dinocysts are characterized by several morphological features that differentiate them from the type material and typical members of the genera.

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