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Acta Palaeobotanica 55(1): 19–51, 2015
DOI: 10.1515/acpa-2015-0001

Middle-late Eocene dinoflagellate cysts from NE Ukraine (Borehole No. 230, Dnepr-Donets Depression): stratigraphic and palaeoenvironmental approach

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Received 22 May 2014; accepted for publication 15 December 2014

ABSTRACT. Analysis of the stratigraphic and quantitative distribution of dinoflagellate cysts and other palynomorphs from a shallow marine Eocene section drilled from borehole No. 230 (NE Ukraine) resulted in an updated age-assessment of regional formations and a reconstruction of the major transgressive-regressive trends in the North Ukrainian palaeosedimentological province. Based on dinocyst age-diagnostic events, the Buchak Formation is attributed to the mid-upper Lutetian; the Kiev Formation is assigned to the Bartonian-?lowermost Priabonian; finally, the Obukhov Formation is dated Priabonian. The Buchak Formation accumulation reflects the first major transgressive episode in the North Ukrainian Province; the accumulation of the lower Kiev Formation corresponds to the maximum of regional marine transgression, while the palynological assemblages from the upper Kiev Formation indicate a protracted regression. The beginning of the Obukhov Formation accumulation corresponds to the last marine transgressive cycle.

KEYWORDS: dinoflagellate cysts, palynomorphs, biostratigraphy, Eocene, NE Ukraine

INTRODUCTION

The Palaeogene dinocyst stratigraphy is intensively studied in the Northern Hemisphere, in particular in Northwest Europe (North Sea region) and in the North Atlantic, an area of petroleum exploration. However, the Northern Hemisphere has other regions with large-scale distributions of Palaeogene marine sediments which are essential to a reconstruction of the Palaeogene history of marine basins, and which are still insufficiently investigated stratigraphically and palynologically.

The south of the East European Platform, including the Dnepr-Donets Depression and the Ukrainian crystalline Shield, is one of these important areas. Enveloping the Pripyat'-Dnepr-Donets syncline with adjacent parts of the Ukrainian Shield and Voronezh anticline, this region was a unique marine basin during the Eocene-Oligocene, connected to the West European seas by the Poless and Polish Depressions and to the eastern Peri-Tethys by the North Donets Depression. The deepest part of this marine basin corresponds to the Pripyat' Trough and Dnepr-Donets Depression (Klushnikov 1975). The thickness of Palaeogene deposits varies from a meter to hundreds of meters, increasing toward the axial part of the Dnepr-Donets Depression.

Although Tertiary sediments have been known in Ukraine since the nineteenth century, different groups of fossils remain to be studied irregularly. Indeed, the Dnepr-Donets Depression corresponds to the "northern" type of section (Radionova et al. 1994) which is characterised mainly by non-calcareous sandy clays with rare benthic foraminifers and calcareous nannoplankton, and rich assemblages of radiolaria, diatoms, and silicoflagellates. The most studied groups are molluscs and foraminifers, though they have patchy stratigraphical and geographical distributions. Palaeogene dinocysts have been studied in Ukraine over the last 50 years. The most significant contribution to the stratigraphical application of dinocysts was made by Andreeva-Grigorovich (Grigorovich 1971, 1974, Andreeva-Grigorovich 1984, 1985, 1991, Andreeva-Grigorovich et al. 1975), who established the first Palaeogene dinocyst zonation for the south of the former USSR. During the last two decades, several new studies of dinocysts in Ukraine have been published (Savitskaya 1996, Shevchenko 1995, 2000a, b, 2002, 2003, Ryabokon' & Shevchenko 2001, Zosimovich et al. 2006, Andreeva-Grigorovich et al. 2011). Nevertheless, these studies are still sporadic and do not include all Palaeogene intervals in different Ukrainian regions. The Carpathian region is now the most palynologically investigated area (Andreeva-Grigorovich 1987, Andreeva-Grigorovich & Portnyagina 1985, Andreeva-Grigorovich et al. 1985, 1988), whereas the Ukrainian Shield and Dnepr-Donets Depression had relatively few dinocyst studies.

To extend the Ukrainian dinocyst stratigraphy spatially to the Ukrainian Shield, this paper presents a high-resolution palynostratigraphical analysis of Eocene marine sediments from borehole No. 230 in the northeastern part of the Dnepr-Donets Depression, provides a detailed age-assessment of marine sediments, and interprets the palaeoenvironmental changes in this area during the Eocene.

HISTORICAL NOTES AND REGIONAL LITHOSTRATIGRAPHY OF THE DNEPR-DONETS DEPRESSION AND UKRAINIAN SHIELD

Palaeogene sediments are widely distributed within the Dnepr-Donets Depression. In the nineteenth century, Dubois de Montpereux initially identified fauna in the Kanev Dnestr valley that was similar to those from Tertiary sediments in the Paris Basin. This was the first establishment of lower Tertiary deposits in the 19th century Russian Empire (Gorbunov 1979). The Eocene age of these sediments was confirmed by the work of Koenen (1869) and others. Here the first attempts to establish the stratigraphical scheme of the lower Tertiary sediments in Ukraine were made. Barbot de Marny (1867, 1870) recognised the so-called stage of Spondilov clays and the Kharkiv sediment. Next, Feofilaktov (1873) added to this scheme the stages of so-called Buchak and Traktemirov sandstone, white quartz sands, and parti-colored clays. In 1893, Sokolov prepared the first compilation of stratigraphical studies in the south of the 19th century Russian Empire: the Buchak (middle Eocene), Kiev (upper Eocene), Kharkiv (lower Oligocene), and Poltava (middle-upper Oligocene) were included here. Later, in the first unified stratigraphical scheme of Ukraine (Zosimovich et al. 1963) it was suggested that only the upper part of the Kharkiv stage in terms of 19th century (glauconite sand) corresponds to the Oligocene, whereas its lower part should be attributed to the upper Eocene.

According to the last unified Palaeogene stratigraphical scheme of Ukraine (Makarenko et al. 1987), the Eocene sediments are represented by the Kanev Formation (lower Eocene), Buchak Formation (lower middle Eocene), Kiev Formation (upper middle Eocene), and Obukhov Formation (upper Eocene).

According to Klushnikov (1975), the Buchak Formation is subdivided into two lithological parts: the lower part is represented by green-grey quartz-glauconitic sands, sometimes with small lenses of clay; and the upper part is composed by grey or yellowish sands with a small admixture of glauconite and with blocks of siliceous sandstone. The Buchak Formation deposits reflect a transgressive stage of the marine basin and extend far beyond the limits of the lower Eocene deposition areas. According to the last unified Palaeogene stratigraphical scheme of Ukraine (Makarenko et al. 1987) and Zosimovich et al. (2005), the Buchak Formation is attributed to part of the Lutetian (interval of calcareous nannoplankton NP15 (part) zone of Martini 1971) and is characterised by molluscs *Venericardia elegans*, *Trapezium parissiensis*, *Tellina rostralina*, *Pinna margaritacea*, *Cardium porulosum*, *Rimetta fisurella*, *Terebellum sopitum*, *Ficus tricarinatus*, and *Cassidaria enodis*, and foraminifers *Spiroplectammina* ex.gr. *varianta*, *Bullimina mitgarziana*, *B. arostrata*, *Acarinina interposita*, and *A. rotundimarginata*, and shark *Isistius trituratus* teeth occur within this formation. Palynomorphs Palmae, *Myrica*, Myrtaceae, Ericaceae, *Carya*, and *Castanea* were recognised from the Buchak Formation as well. With regard to dinocysts, the Buchak Formation was not investigated in Ukraine (Zosimovich et al. 2005) but only in adjacent Belarus, where the dinocyst assemblage was characterised by the presence of *Ceratocorys* sp., *Microdinium* sp., *Kisselevia ornata*, and *Deflandrea phosphoritica* (Grigyalis et al. 1988).

According to Klushnikov (1975), the Kiev Formation is widely distributed and is characterised by the deepest (for the Eocene in Ukraine) facies composition. In areas of the most complete development, this formation was subdivided in two subformations: the lower subformation is composed of marls and calcareous clays transitioning to the base to calcareous sands; and the upper subformation is represented by shallow-water micaceous and non-carbonate aleurolite clay transitioning to the top to aleurolite sand. According to Klushnikov (1975), the lower Kiev Formation is characterised by the presence of molluscs *Spondylos tenuispina*, *S. rarispinus*, *S. buchi*, *Ostrea cubitus*, *Chlamys idoneus*, and *Crassatella fuchsi*. It can be noted here that the fauna from the sediments representing shallow-water analogous of the Kiev marls, the so-called Mandrikov fauna near Dnepropetrovsk (Mandrikovka village), was compared by Sokolov (1894, 1905) to that of the Latdorfian in Western Europe. According to the last unified Palaeogene stratigraphical scheme of Ukraine (Makarenko et al. 1987), the lower Kiev subformation is characterised by foraminifers *Textularia carinatiformis*, *Clavulinoides szaboi*, *Acarinina bulbrooki*, *A. rotundimarginata*, *A. pentacamerata*, and *Globigerina turkmenica*, and the calcareous nannoplankton *Discoaster martini*, *D. septemradiatus*, and *D. barbadiensis*. Radiolaria *Amphistylus ensiger* and *Xiphatractus visendus* are also recognised from the Kiev Formation. According to Andreeva-Grigorovich et al. (1975), the lower and middle parts of the Kiev marls in the Kiev Dnepr Valley revealed a calcareous nannoplankton assemblage corresponding to Martini's (1971) NP16 (*Discoaster tani nodifer*) zone, whereas the upper part of the Kiev marls was characterised by nannoplankton from NP17 (*Discoaster saipanensis*). According to Zosimovich et al. (2005), the Kiev Formation stratigraphical interval corresponds to the NP15 (part)-NP17 nannoplankton zones of Martini (1971). The dinoflagellate cyst assemblage from the NP17 nannoplankton zone interval (Andreeva-Grigorovich et al. 1975) was represented by *Charlesdowniea clathrata*, *Microdinium ornatum*, *Rhombodinium* cf. *rhomboideum*, and *Wilsonidium* cf. *lineidentatum*. With the regard to the Upper Kiev subformation (so-called Naglinok), Andreeva-Grigorovich et al. (1975) noted that the dinocyst assemblage was close to that those of the Beloglinka Formation in Crimea and the Northern Caucasus (Priabonian). Glezer (1979) attributed the diatom assemblage with *Paralia oamurensis* from the Upper Kiev Formation to the upper Eocene. According to a study of the central part of the Ukrainian Shield (Rjabokon' & Shevchenko 2001), the Kiev Formation is characterised by a foraminiferal assemblage close to that from the Biarritz in France (P14 zone), and the dinocyst assemblage with *Cordosphaeridium cantharellus*, *Areosphaeridium diktyoplokum*, *Enneadocysta arcuata*, *E. partridgei*, *E. pectiniformis*, *Homotryblium* cf. *floripes*, *Wetzeliella ovalis*, *Charlesdowniea coleothrypta*, *Ch. fasciata*, *Ch. reticulata*, *Rhombodinium porosum*, *Rh. perforatum*, *Heteraulacacysta porosa*, *Thalassiphora fenestrata*, and *Th. reticulata*. Despite the presence of some late Eocene key species (*Rh. perforatum*, *Th. reticulata*), Shevchenko (2002 unpublished) recognised the *Rh. porosum* zone in the upper part of the Kiev Formation and assigned these sediments to the Bartonian (NP17 zone interval). According to the last updated stratigraphic scheme of Ukraine (Zosimovich et al. 2005), the dinocyst assemblage from the Kiev Formation corresponds to part of the *Wilsonidium intermedium-Areosphaeridium diktyoplokus* zone interval.

The Obukhov Formation in the North Ukrainian Province is widely distributed and is composed most often by green-grey non-carbonate sandy-clayey siltstone, sometimes glauconitic sand and sandstone. According to Zosimovich et al. (2005), in different parts of Ukraine the Obukhov Formation is characterised by foraminifers including *Astegerina stelligera*, *Cyclammina pseudocancellata*, *Haplophragmoides stavropolensis*, and *Nummulites concinnus*, the calcareous nannoplankton *Isthmolithus recurvus* and *Sphenolithus pseudoradians* (NP19-20), the molluscs *Leda* *provalis*, *Spondylus septemcostatus*, and *Ostrea callifera*, the brachiopod *Terebratula rotundata*, and the ostracod *Cyterella compressa*. The dinocyst assemblage from the Obukhov Formation is represented by *Charlesdowniea clathrata*, *Ch. clathrata angulosa*, numerous *Deflandrea phosphoritica*, *Microdinium reticulatum*, and *Wetzeliella ovalis* (Krashenninikov & Akhmetiev 1996). According to Zelinskaya et al. (1984), the dinocyst assemblage from the Obukhov Formation is clearly poorer (taxonomically and quantitatively) than those from the carbonate clays and marls of the Kiev Formation.

MATERIAL AND METHODS

GENERAL INFORMATION

Borehole No. 230 (Strelech'e) was drilled by the Belgorod Industrial Geological Department in 1990–1991 on the southeastern slope of the Voronezh anticline near Kharkiv (Fig. 1). A.G. Nazarkov (Centre-Geology Industrial Geological Union) described the section in accordance with the lithostratigraphic scheme of Zosimovich et al. (2005). The Palaeogene deposits of borehole No. 230 overlay, with erosion, chalky limestone of tentatively Maastrichtian age. The Buchak Formation (2 m) is composed by green and greyish green micaceous glauconitic siltstone. The Buchak Formation overlays (probably with erosion surface) the Kiev Formation. The lower part of the Kiev Formation is composed of light sands (ca 3 m) changing to grey and grey-green clay and clayey siltstone with lenses and layers of quartz sand (17 m). The Obukhov Formation is represented by yellow, grey and greenish micaceous-glauconitic, sometimes clayey-silty sands (13.7 m thick). The Obukhov Formation is overlain by Neogene sands of the Poltava Formation.

PREVIOUS MICROPALAEONTOLOGICAL DATA (FIG. 2)

Foraminifera

According to Radionova et al. (1994), two benthic foraminifer assemblages were found in section No. 230. The first one, poorly preserved, with *Globigerina* and *Acarinina* spp., was recognised in the Buchak Formation (87.5–83.8 m depth interval). The upper assemblage, from the Kiev Formation (78.0–78.8 m depth interval), was characterised by a rich and diverse association of ca 70 species, including representatives of *Haplophragmoides*, *Textularia*, *Clavulina*, *Rhabdommina*, *Nodosaria*, *Asterigera*, and *Cibicidoides*. The sediments containing these benthic foraminifers were assigned to the *Hopkinsina bykovae ucrainica* zone established in southern Ukraine by Kraeva & Zernetsky (1969) and to the

Fig. 1. Geographical location of borehole No. 230

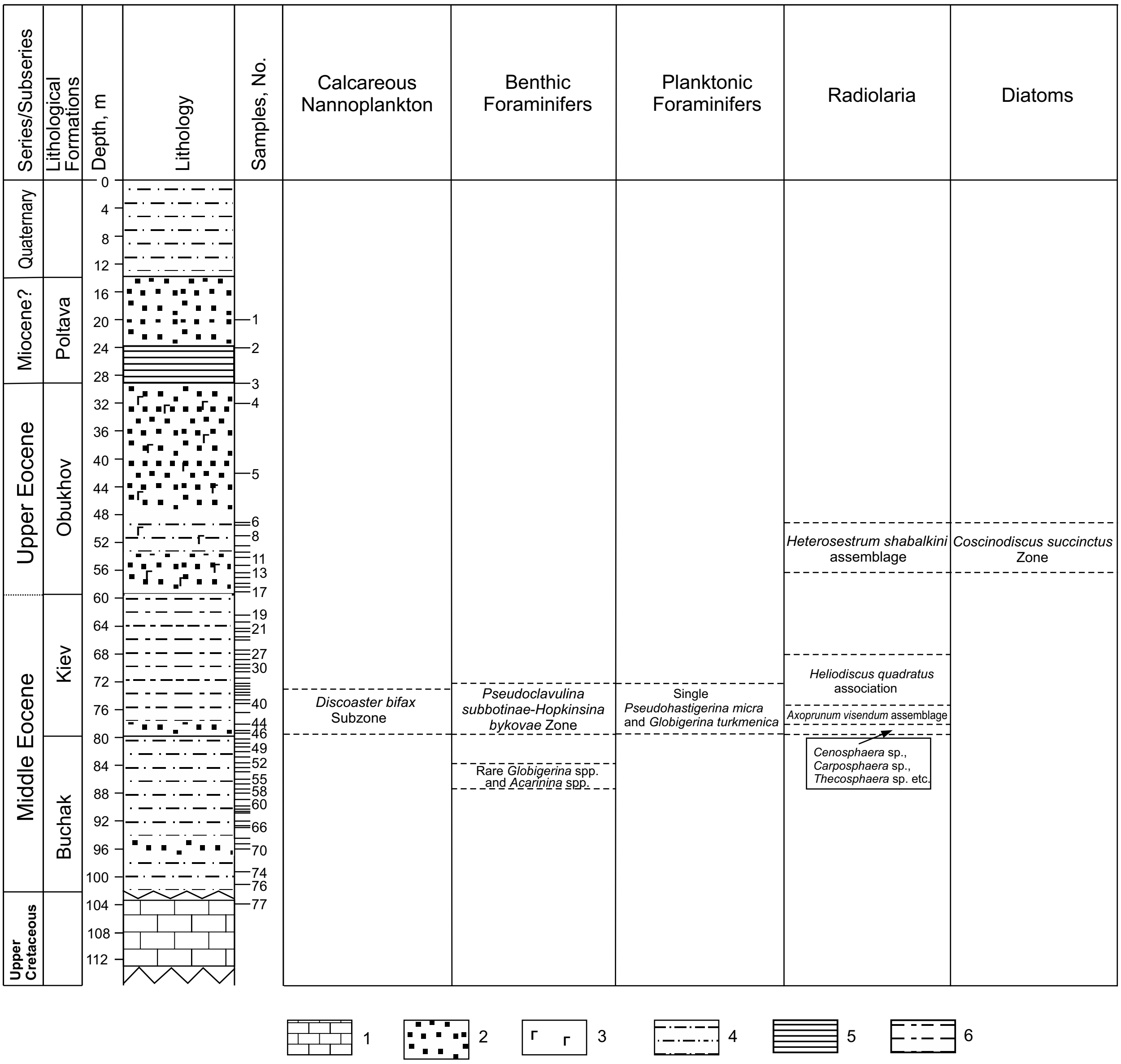

Fig. 2. Lithology and previous micropalaeontological data from borehole No. 230 (from Radionova et al. 1994); **1** – chalk, **2** – sand, **3** – glauconite, **4** – sandy clay, **5** – clay, **6** – siltstone

Pseudoclavulina subbotinae-Bulimina granjuscula zone from the eastern Pre-Caspian region (Benyamovsky et al. 1992). Single planktonic foraminifers *Pseuhastigerina micra* and *Globigerina turkmenica* were recognised within the 78.0–78.8 m interval; *P. micra* is typical for the Lutetian and Bartonian, while *G. turkmenica* is characteristic for the lower Bartonian (*G. turkmenica* zone).

Calcareous nannoplankton

According to N.G. Muzilev (pers. comm. in Radionova et al. 1994), a calcareous nannoplakton assemblage was found in the 79.6–73.0 m depth interval, comprising more than 20 species, including *Coccolithus eopelagicus*, *C. formosus*, *Reticulofenestra umbilica*, *Rhabdoshaera gladius*, *Discoaster strictus*, and *Chiasmolithus solithus*. This association is typical for sediments assigned to the *Discoaster bifax* subzone (CP14a, Okada & Buckry 1980) in the south of the former USSR.

Radiolaria (from Radionova et al. 1994)

A radiolarian assemblage with Liosphaeridae, *Cenosphaera* sp., *Carposphaera* sp., *Tecosphaera* sp., *Prunopyle* sp., *Tristylosphaera* sp., and *Thecotyle* sp. was recognised in the 79.5–78 m depth interval; its stratigraphical age is uncertainly attributed to the Palaeocene-Eocene.

The *Axoprunum visendum* assemblage was recognised in the 76.5–75.4 m depth interval and was characterised by the dominance of *Spongotrochus paciferus*, *Thecosphaera* aff. *obliterata*, *Heliodiscus heliasteriscus*, and *Cromyodruppa tebesensis*. By the presence of *S. paciferus*, *H. heliasteriscus*, *A. visendum*, and *C. tebensis* this interval was tentatively attributed to the terminal Lutetian.

The *Heliodiscus quadratus* assemblage was recognised in the 75.4–67.5 m depth interval. It is characterised by the presence of *Spongotrochus radiatus*, *Cromyodruppa ovatus*, *Axoprunum chabakovi*, *Spongasteriscus gorskii*, and common *Lychnocanium* spp.

This interval was tentatively attributed to the lower Bartonian.

The *Heterosestrum shabalkini* assemblage was recognised in the 56.5–49.0 m depth interval. It is characterised by the presence of *Spongolmelissa callosa*, *Stylosphaera coronata coronata*, *Druppatractus santaennae*, *Heliomma rosula*, and *Plectodiscus circularis*. The stratigraphical age of this interval is tentatively middle-late Eocene.

Diatoms and silicoflagellates (from Radionova et al. 1994, Oreshkina & Iakovleva 2007)

Taxonomically rich diatom and silicoflagellate assemblages were recognised in the 56.9–49.0 m depth interval (Obukhov Formation). The diatom assemblage is characterised by dominance of *Paralia sulcata* var. *crenulata*, *P. ornata*, *P. clavigera*, presence of *Coscinodiscus obscurus* var. *concavus*, *Pseudopodosira westii*, *P. pileiformis*, *Peponia barbadense*, and *Brightwellia coronata*. Rare *Coscinodiscus succinctus*, *C. duplex*, *Peponia barbadense*, *Bipalla oamaruensis*, and *Comiodiscus breviradiatus* occur from 49.6 m depth.

PALYNOLOGICAL METHODS

In the present study, 67 samples were analysed palynologically. All samples were prepared in the Palaeofloristic Laboratory of the Geological Institute, Moscow, with additional sieving of selected samples at Aarhus University (Denmark). Marine and continental palynomorphs were concentrated by the standard palynological techniques used by the Russian Academy of Sciences (Grichuk 1940, Erdtman 1943, Petrova 1986). The samples were processed with 10% hydrochloric acid until the calcium carbonate dissolved, and then processed with 10% Na_2HPO_4H until the soluble organic substances were eliminated. Then the samples were washed several times to eliminate argillaceous compounds. After washing, the samples were centrifuged with a 2.25-density heavy liquid ($K_2[CdJ_4]$), then washed in water and next processed with 10% hydrofluoric acid until the siliceous matter was dissolved. Then samples were boiled in hydrochloric acid to remove fluoro-silicate compounds. Selected samples were finally sieved (20 µm mesh sieve). Residues were mounted on glass slides using glycerine jelly.

Dinocyst taxonomy follows Fensome & Williams (2004).

Quantitative analysis of the palynological samples was done in two steps: 100–300 palynomorphs were counted and grouped in 10 categories (dinocysts in situ, reworked dinocysts, acritarchs, green algae, microforaminifers, bissacate pollen of conifers, angiosperms, spores, fungi, other unknown continental palynomorphs); then, ~180–290 (if possible) dinocysts were counted and the entire slide and two other slides (26×40 mm) for each sample were analysed in order to identify any other dinocyst species. Based on publications dealing with palaeoecological interpretations of dinocyst assemblages (Table 1), morphologically and/or ecologically related dinocyst taxa were assigned to 21 groups: wetzelielloids; deflandroids; *Phthanoperidinium*; *Lingulodinium*-group; *Thalassiphora*; *Areoligera*-group; *Enneadocysta*-group; *Cordosphaeridium*-group; *Operculodinium*; *Cribroperidinium*; *Samlandia chlamydophora*; *Achilleodinium biformoides*; *Spiniferites*-group; *Hystrichokolpoma*; *Microdinium reticulatum*; *Cerebrocysta / Corrudinium*; *Diphyes*; *Nematosphaeropsis*; *Impagidinium*; other small gonyaulacoids; and indeterminate gonyaulacoids. The slides were studied with an Askania microscope at 100 ×, 250 × and 400 ×.

RESULTS

GENERAL ASPECTS

The distribution of dinocyst taxa from borehole No. 230 is shown in Tables 2 and 3. The quantitative distribution of the major palynogroups is presented in Figure 3, and the quantitative distribution of dinocyst eco-groups is given in Figure 4.

In general, most samples from the Buchak, Kiev and lower Obukhov Formations (101.0–49.0 m depth) revealed quantitatively rich assemblages of palynomorphs. The upper part of the Obukhov Formation contains only a few palynomorphs. The lowermost sample from the Poltava Formation (tentatively Neogene from previous studies) revealed numerous Pinaceae and single *Tyttodiscus* sp. and *Palambages* sp., and two other samples were completely barren of palynomorphs.

In total, ca 154 taxa of dinocysts, acritarchs and other algae were recognised in the Eocene part of borehole No. 230. Worth noting is that the ratios between different categories of marine and terrestrial palynomorphs clearly differ across the section within the three lithological formations. The Buchak Formation, which overlies tentatively Maastrichtian chalks, is characterised primarily by the predominance of dinocysts (50–90%), abundant conifers (up to 40%) and a significant amount of reworked dinocysts (up to 15%). The Kiev Formation revealed alternation of dominance by dinocysts (up to 100%), and by acritarchs (up to 55%), with a small share of continental palynomorphs. The dinocyst assemblages are characterised by a significant influx of *Microdinium reticulatum* (up to 65%) in the lower part, followed by dominance of *Deflandrea phosphoritica* (up to 55%) and *Spiniferites* spp. (up to 40%) in the upper part of the Kiev Formation. Finally, the lower Obukhov Formation is again characterised by important changes in palynological associations: dinocysts are

Table 1. Dinocyst eco-groups and their possible palaeoenvironmental interpretation

Dinocyst complex	Taxa included	Palaeoenvironmental interpretation	Bibliographical source
Wetzelielloids	All representatives of Wetzelielloids	Coastal and neritic settings Shallow water with elevated nutrient availability	Stover et al. 1996 Brinkhuis et al. 1992
Deflandrea	*Deflandrea* ssp. and *Alterbidinium*, *Senegalinium*, *Lentinia*, *Lejeunecysta*, *Palaeocystodinium*	Coastal and neritic settings Shallow water with elevated nutrient availability Inshore, possibly brackish eutrophic settings; abundant during high-productivity episodes; Closely tied to an ancient deltaic settings and organic-rich facies; influx of fresh water	Stover et al. 1996 Brinkhuis et al. 1992 Sluijs et al. 2005
Phthanoperidinium	All species of *Phthanoperidinium*	Relatively shallow marine settings; abundant during high-productivity episodes; closely tied to anancient deltaic setting and organic-rich facies; influx of fresh waters	Sluijs et al. 2005
Thalassiphora	All species of *Thalassiphora*	Productivity increase and/or cooling of surface waters	Vonhof t al. 2000
Areoligera	*Areoligera*, *Glaphyrocysta*, *Adnatosphaeridium*, *Membranophoridium*, tentatively *E. ursulae*	Marginal marine, inner neritic settings, often associated with hydrodynamically high-energetic environments	Powell et al. 1996
Enneadocysta	*Enneadocysta*, *Areosphaeridium*	Outer neritic Coastal taxa	Sluijs et al. 2005 Pross & Brinkhuis 2005
Cordosphaeridium	*Cordosphaeridium*, *Fibrocysta*, *Kenleyia*, *Aran. araneosa*	Open marine, neritic settings	Powell et al. 1996
Operculodinium	All species of *Operculodinium*	Open marine, neritic settings	Brinkhuis 1994
Homotryblium	*Homotryblium*, *Dinopterigium*, *Lingulodinium*, *Heteraulacacysta*, *Polysphaeridium*, *Eocladopyxis*	Restricted marine to inner neritic settings with increased or lower salinity Preference for warm water settings	Brinkhuis 1994 Crouch & Brinkhuis 2005
Hystrichosphaeridium	*Hystrichosphaeridium tubiferum*	Inner neritic Possible tolerance to adverse environmental conditions, such as low/high salinity	Powell et al. 1996 Crouch & Brinkhuis 2005
Cribroperidinium	*Cribroperidinium* spp.	? Coastal taxa	Crouch & Brinkhuis 2005
Spiniferites	*Spiniferites*, *Achomosphaera*, *Spiniferella*, *Hafniasphaera*, *Hystrichostrogylon*, *Hystrichosphaeropsis*	Neritic to oceanic settings Stable salinity	Brinkhuis 1994 Lewis et al. 1999
Hystrichokolpoma	*Hystrichokolpoma* spp.	? Offshore taxa	Pross & Brinkhuis 2005
Batiacasphaera	Some *Batiacasphaera*	? Offshore taxa	Pross & Brinkhuis 2005
Corrudinium	*Corrudinium*, *Cerebrocysta*	? Offshore taxa	Pross & Brinkhuis 2005
Impagidinium	All species of *Impagidinium*	Oceanic environments	Brinkhuis 1994
Nematosphaeropsis	*Nematosphaeropsis* spp.	Oceanic environments	Pross & Brinkhuis 2005

common or predominant but acritarchs do not exceed 3%, while green algae, microforaminifers, and continental palynomorphs attain up to 75% of the total assemblage.

Generally, the dinocyst assemblages from borehole No. 230 contain only cosmopolitan species, largely known from different geographical realms of the Northern Hemisphere. In the last 40 years, a number of Eocene dinocyst zonations have been established in different regions of NW Europe (e.g. Châteauneuf & Gruas-Cavagnetto 1978, Costa & Manum 1988, Powell 1992, Bujak & Mudge 1994, Eldrett et al. 2004, Heilmann-Clausen & Van Simaeys 2005, Köthe 2012). Several stratigraphically important dinocyst species known from NW Europe and Ukraine have been recognised across the Eocene section, permitting age-assessment of three major lithological formations. Nevertheless, the dinocyst species record in borehole No. 230 is quite different from the mid-late Eocene records in NW Europe and even in other parts of Ukraine. As

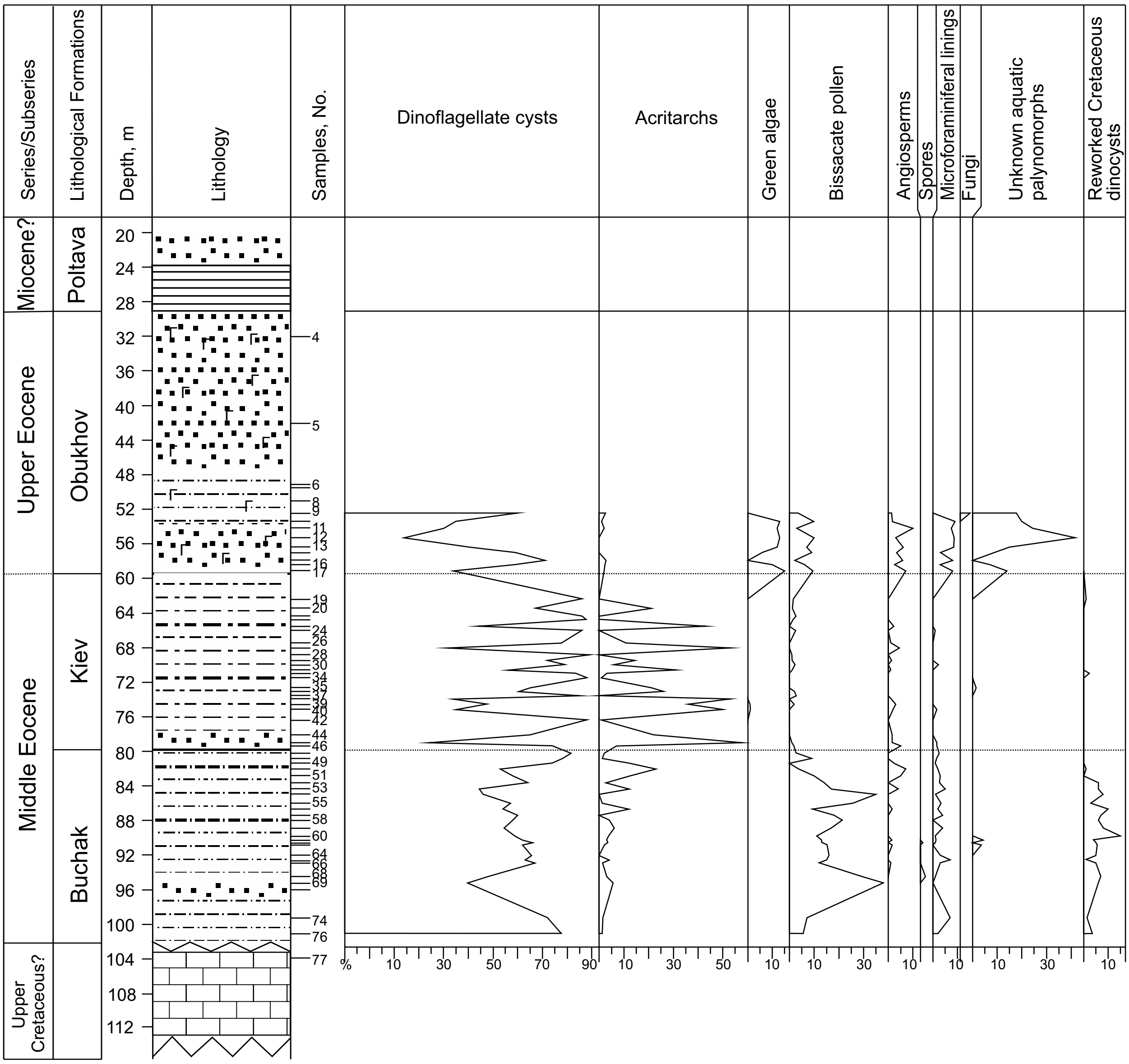

Fig. 3. Quantitative distribution of major palynomorph groups in the Eocene sediments of borehole No. 230

a result, while the dinocyst assemblages from borehole No. 230 are attributed to dinocyst zones of the last updated Ukrainian dinocyst zonation (Zndreeva-Grigorovich et al. 2011), the differences in dinocyst species stratigraphical records are of note and will be discussed below.

STRATIGRAPHICAL AND PALAEOECOLOGICAL RESULTS

The lowermost palynological sample studied in the present section (103.0 m depth), probably mixed with the overlying Buchak Formation, revealed a mixture of Eocene and Cretaceous dinocyst taxa. Among the reworked Cretaceous taxa, *Deflandrea asymmetrica*, *Palaeoperidinium pyrophorum*, *Membranilarnacia* cf. *liradiscoides*, *Leberidocysta chlamydata*, *Fibradinium annetarpense*, *Chatangiella* sp., *Hystrichosphaeridium tubiferum*, and *Spinidinium clavatum* were recognised. Based on the presence of *Membranilarnacia* cf. *liradiscoides* and *Leberidocysta chlamydata*, I tentatively attribute this assemblage to the Maastrichtian.

BUCHAK FORMATION

Based on the occurrence of stratigraphically important dinocyst species as well as major changes in relative abundance fluctuations in palynomorphs, two intervals have been recognised within the Buchak Formation from base to top.

The dinocyst assemblage from the two lowermost samples (101.2–96.0 m depth interval) revealed taxonomically rich assemblages, including the typically Lutetian *Cordosphaeridium*

Series	Stage	Df zones (Andreeva-Grigorovich et al. 2011)	Lithostratigraphy	Samples by depth, m	*Thalassiphora delicata*	*Areosphaeridium diktyoplokum*	*Areosphaeridium ebdonii*	*Cerebrocysta bartonensis*	*Charlesdowniea clathrata*	*Charlesdowniea tenuivirgula*	*Cordosphaeridium cantharellus*	*Costacysta bucina*	*Diphyes ficusoides*	*Diphyes pseudoficusoides*	*Enneadocysta arcuata*	*Melitasphaeridium pseudorecurvatum*	*Microdinium reticulatum*	*Operculodinium nanaconulum*	*Phthanoperidinium geminatum*	*Phthanoperidinium regalis*	*Polysphaeridium zoharyi*	*Wetzeliella ovalis*	*Charlesdowniea coleothrypta* var.1 sensu CHC-LC 1989	*Corrudinium incompositum*	*Oligosphaeridium complex*	*Pyxidinopsis densepunctata*	*Charlesdowniea coleothrypta rotundata* sensu DC 1993	*Glaphyrocysta semitecta*	*Heteraulacacysta porosa*
EOCENE	Priabonian	DP11	Obukhov	49.6		1									2														
				51.2																									
				52.4		4		0							11	0	4		28			1	0	0	1	5	2	1	1
				53.2		11			4		0				4		6		26			2	0	4	3			0	1
				54.4		12	0	2	2		0				4	1	4		16			7		13	0	0		1	2
				55.2		9			2						7	1	4		15			2	0	3		12		0	3
				56.3		9			0		0				11		4		23			8	1	2	1	4		1	1
				57		4	0		1						3	2	3		27			4		1		1		1	1
				57.9		7		5	0		0				10		3	1	27			0	0	1		5		2	2
				58.4	0	6		1	1						4	2	11	0	17			1	1	1		4		1	2
				59.5		7		1	2						6		8	3	18			1		0		12		0	1
		DP10	Kiev	62.5		14	0		0			0			8	1	1					0				3		0	1
	Bartonian			63.3		6		0							10	0	0		4			2	2			2		2	
				64.2		7					0				5							2	9	0		3		1	0
				65	0	8	0		0						14	1	5	2				1	2	0				0	
				65.5		5									2		1					1	0	1		3			
				66.2		9			0						2		2					0	2	3				0	
				67.5		5			2		0				10	2			2				1					0	1
				68		4									10		11						0	1				0	
				68.8		9	1								20	0	1	10				0		1				1	
				69.4		2	0	8				1			22		4	1				0	1	3		5		0	
				70		7	0		1		0	0			24	1	4						3					3	
		DP9		71.4		3			0			0			3	0	41					2		1		1	0	1	
				71.6		8		0	0						10	4	4		5					5		0	0	0	
				72.3		7						2			3		7	1				3	0	1		3			
				72.5	0	6						0		0	9	1	39					3	0	1		1		1	
				73		2						0			6	0	46		3			3	0	3		5			
				73.4		2		2	1						7	1	26	1	2			5	2	1		1			0
				74.1		0									1		45	0	2			0	0	2		0			
				74.5	0				0						3	0	20		4			1	1			0		0	2
				75		3									2	0	16		4			2	0						0
				76.5		2			1						4		29		2				2						
				78		1		1			1				3	1	68		4	1		0						1	
				78.9		1		1							1		57					1				0			0
				79.6		8		1				0		1	18	2	29					2	0	2		5		1	0
	? Lutetian		Buchak	80.3		6		1	0		1		0		9	8	6	1				2	3	1		1			
				81	0	4	0	3	4	0		0	12		0	1	4	0	2	0		4	0	0				2	0
				81.7		4		2	0			0	1	1	9	1	26		0			0	0	1		2	0		0
				82.4		1			1			0	2		8	1	31			3		2	1	3			0	0	
				83		1		1	0		1		3	0	1	1	4			6		1		0			0		
				83.8	2	0			3				2		1		1	0					0	2				0	
				84.6		2		1			2	0	1	1	1		0	0		2			2	1	0				
				85.3	3	1										1		1						4			6		
				86	0	1			7			0			0	1	2		4			1		6				2	
				86.7	1	0			0		0	0	0	0	0	2	3	0	1					2	0				
				87.5	1	0		2	1	1			0			2			2					0					
				88.1	0	2		0	0	0	1	0	1	4	0	1	4	1	6			0	4	1	0		0		
				88.9	0	2		0	0		1	1	1	1	1	2	1		4			0	0	2	1				
		DP8		90	0	2			0			0	0		1	1	3	1	13			2	0	3	2				
				90.2		5		10	3		0	0	0	0	1	2	3		10	1			1	2	3			0	
				91	0	4	1	2	0	3	3	0	1		0	2	2	1	9	1		2			3				
				91.3	0	3		1	0		1	0	0	0	4	1	7		2			0		4	5		1	0	
				92.2	0					1	0	0	0		1	2	1		6				0	2	1			0	
				92.6	1	1		0	1			0	2	1	1	3			0			0		1				0	
				93.3	1	7		2	6	1	0	0	0	2		1	1	1	6		1	0					0	0	
				94.8		2		6	8			0	2	0	1		2	0	3			0						0	
				95.5	1	3		1	1	0		1	3		0		4		5			0	0			1	0	3	0
				96		0		0	0		0						0	0	0					0		0			
		DP7b		99.4		3		0	0	1	3		3	2	0	2	1		2			3	1	3	1				
				101	0	5	0	0	2	0	3	0	6	3	2	3	0	1	2	3	0	1							

Samples by depth, m	*Wetzeliella articulata* subsp. *brevicornuta*	*Phthanoperidinium comatum*	*Araneosphaera araneosa*	*Thalassiphora? spinifera* sensu DC 1986	*Distatodinium ellipticum*	*Hystrichosphaeropsis complanata*	*Charlesdowniea variabilis*	*Membranophoridium aspinatum*	*Hystrichokolpoma?* sp.1 sensu CHC-VS 2005	*Wilsonidium echinosuturatum*	*Operculodinium nanaconulum*-*O. placitum*-group CHC-VS 2005	*Distatodinium* cf. *craterum*	*Dracodinium varielongitudum*	*Homotryblium floripes*	*Rhombodinium draco*	*Distatodinium biffii*	*Thalassiphora fenestrata*	*Areosphaeridium michoudii*	*Deflandrea heteroplycta*	*Lentinia serrata*	*Phthanoperidinium multispinosum*	*Rhombodinium longimanum*	*Pentadinium lophophorum*	*Distatodinium parisiense*	
49.6																									
51.2																									
52.4			0		0			0			1				0		2			2				0	
53.2					1		1	1							1		7					0			
54.4					0		2	1							0		1			1					
55.2						0		0							1		2			2					
56.3					0										1		5								
57			0		0			2							0		3						0		
57.9					0			1							2		1					0			LO *Rh. longimanum*
58.4			0					0							2		5								
59.5															3		2								
62.5										0							0								LO consistent *Th. fenestrata*
63.3	1					0												0							HO *Costacysta bucina*
64.2						0		0		3															
65										4					0		0				3				
65.5							1			0											1				
66.2										0															
67.5		1	1																						
68																									
68.8						0				0										1					LO *Lentinia serrata*
69.4																		0							HO consistent *C. bucina*
70																									
71.4						0																			
71.6																			0						
72.3								cf.																	
72.5						0		cf.									0								
73																									
73.4						0																			
74.1																		0							
74.5																									
75																									
76.5						1																			
78																									HO *Phthanoperidinium regalis*
78.9						0																			
79.6						1		0																	HO consistent *D. pseudoficusoides*
80.3						0																			HO *Diphyes ficusoides*
81	1														0		1								
81.7						2											0								LO consistent *H. porosa*
82.4		0	0							0							0								LO sporadic *Th. fenestrata*
83									0						0										
83.8																									
84.6	1				0	0																			
85.3																									
86	0	0						0																	
86.7																0									
87.5						1																			
88.1	0		0					0	1			0	0	0	0										LO *H. floripes*
88.9	0		0								0														LO *Rh. draco*
90		1							0	0															LO *W. echinosuturatum*
90.2				2																					
91							0	2																	
91.3				0	1	0																			LO *D. ellipticum*
92.2	0		0	2																					
92.6																									
93.3																									
94.8		1																							
95.5	0																								LO sporadic *H. porosa*
96																									
99.4																									
101																									

Table 3. Distribution of stratigraphically important dinoflagellate cyst species in borehole No. 230. Numbers are counted specimens

Subseries	Lithostratigraphy	Samples by depth, m	Achilleodinium biformoides	Adnatosphaeridium multispinosum	Adnatosphaeridium robustum	Areosphaeridium diktyoplokum	Areosphaeridium ebdonii	Cerebrocysta bartonensis	Charlesdowniea clathrata	Charlesdowniea tenuivirgula	Cleistosphaeridium diversispinosum	Cordosphaeridium biarmatum	Cordosphaeridium cantharellus	Cordosphaeridium funiculatum	Cordosphaeridium gracile	Cordosphaeridium inodes	Costacysta bucina	Cribroperidinium giuseppei	Dapsilidinium pseudocolligerum	Diphyes colligerum	Diphyes ficusoides	Diphyes pseudoficusoides	Enneadocysta arcuata	Fibrocysta bipolaris	Fibrocysta vectensis	Glaphyrocysta exuberans	Homotryblium tenuispinosum	Hystrichokolpoma cinctum	Hystrichokolpoma granulatum
Upper Eocene	Obuchov	49.6				1					1												2						
		51.2																											
		52.4	3	0		4		0			5			1	1			4	4	0			11		1		2	1	
		53.2	3			11			4		3		0	2	2	3		16					4		1		3	2	
		54.4	0	0		12	0	2	2		2		0	8	1	1		7					4		0		4	1	
		55.2	1	0		9			2		3			5				10					7	0	1		2	2	
		56.3	2			9			0		7		0	3		7		18					11		1		6	4	
		57	1	0		4	0		1		5			3		5		4	1				3		0		3	2	
		57.9		0		7		5	0		8		0	0	0	5		6	0				10		1		1	1	3
		58.4	1			6		1	1		2			1		2		15	2				4				2	0	1
		59.5	1	0		7		1	2		4			1		7		7					6		0		3	1	0
Middle Eocene	Kiev	62.5	1	0		14	0		0		3			2		2	0	6					8		0		3	2	
		63.3	1	0		6		0			3			1		2		4	1	2			10		1	0	3	3	3
		64.2	2	2		7					3	1	0	1		9		17		0			5		0		3	6	2
		65	3	1		8	0		0		5	0		2	0	2		12	6	4			14		0		6	2	
		65.5	1			5					4			1	0	3		2					2				0	1	0
		66.2	2	0		9			0		3			0				5	2				2		2		5	1	4
		67.5		0		5			2		3		0	3		4		2		3			10		1		2	1	0
		68	0			4					1			0		1		1					10				1	0	
		68.8	1	0		9	1				6			3		6		8					20		1			1	
		69.4	1			2	0	8			2			2		0	1	1					22				0	1	
		70	1	0		7	0		1		0		0	0		4	0	5		2			24		0		2	1	0
		71.4				3			0		1			2	0	1	0	11	0	1			3				1		0
		71.6	3	2		8		0	0		3			1		8		14	8	1			10		1		1	3	2
		72.3	2			7								5	1	9	2	7					3				2	1	
		72.5	1	0		6					4			1	0	5	0	10		0		0	9		2		2	5	0
		73	1			2					0			0		1	0	16		0			6				2	1	
		73.4	3	0		2		2	1					0		1		31		2			7		0		0	2	
		74.1	1			0								1		0		0	0	1			1					1	
		74.5	1						0		0			2		0		4		0			3		0			1	0
		75	1			3								0	0	1		0		1			2					0	1
		76.5	1			2			1					1		3		2		7			4				1	2	2
		78	2			1		1					1	0	2			3		2			3				0	1	
		78.9	0			1		1						0	0			5	0	0			1						
		79.6	1			8		1			2			4	0	5	0	10		2		1	18		0		0	2	1
	Buchak	80.3	1	0		6		1	0		4		1	0				14	1	5	0		9		0		0	1	
		81	5			4	0	3	4	0	2				5	9	0	19		1	12		0		0		2	1	2
		81.7	1	0		4		2	0		2			2	0	2	0	13	0	1	1	1	9		0			0	0
		82.4	6			1			1		3				1	5	0	14		4	2		8				1	0	0
		83	0			1		1	0		3		1		2	5		8	3	4	3	0	1		0		1		0
		83.8	8			0			3		3				0	2			1	1	2		1		1		3	3	1
		84.6	3	0		2		1			10		2		2	4	0	6	1	7	1	1	1		0		2	0	0
		85.3	5			1					4			3	0			6		1				0	2		1	1	
		86	7	0		1			7		8				2	3	0	13	1	2			0		2		1	1	1
		86.7	1		0	0			0		3		0		0	1	0	0	2	1	0	0	0				2	0	0
		87.5	5			0		2	1	1	7				1	4		2		3	0			1			2		
		88.1	4	0	0	2		0	0	0	6		1			5	0	8	0	4	1	4	0		2	0	1	2	
		88.9	2	0		2		0	0		4		1		1		1	5		7	1	1	1		1		1	1	0
		90	4	1		2			0		9				0	6	0	7		2	0		1				1	2	
		90.2	6			5		10	3		9		0			3	0	8		4	0	0	1			0	1	3	
		91	4	1		4	1	2	0	3	3		3			2	0	12		3	1		0			0	1	1	
		91.3	3			3		1	0		6		1			8	0			4	0	0	4				2	2	6
		92.2	4	1						1	13		0			2	0	3		5	0		1		1		4	3	1
		92.6	5			1		0	1		2				1	3	0	0		10	2	1	1		0	2	2	2	0
		93.3	7	4		7		2	6	1	14		0			4	0	2		1	0	2			2	0	4	2	
		94.8	6	0		2		6	8		6					3	0	3			2	0	1				0	1	1
		95.5	8	1		3		1	1	0	3					3	1	6		7	3		0		0	1	5	1	
		96	0			0		0	0		0		0			0		0		0									
		99.4	5	0		3		0	0	1	9		3			8		11		3	3	2	0		0	0	5	1	1
		101	2	1	0	5	0	0	2	0	20	1	3	1	0	8	0	9	2	0	6	3	2	0	0	0	5	3	0

Samples by depth, m	Hystrichokolpoma salacium	Hystrichostrogylon membraniphorum	Kenleyia spp.	Lingulodinium machaerophorum	Melitasphaeridium pseudorecurvatum	Microdinium reticulatum	Operculodinium centrocarpum	Operculodinium microtrianum	Operculodinium nanaoconulum	Palaeocystodinium golzowense	Pentadinium goniferum	Pentadinium laticinctum	Phthanoperidinium crenulatum	Phthanoperidinium geminatum	Phthanoperidinium regalis	Polysphaeridium zoharyi	Pterodinium cingulatum	Rottnestia borussica	Samlandia chlamydophora	Spiniferella cornuta	Spiniferites spp.	Tectatodinium pellitum	Thalassiphora delicata	Thalassiphora pelagica	Turbiosphaera galatea	Wetzeliella articulata	W. aff. articulata-group in Al-CHC 2010
49.6																					3						
51.2																											
52.4	2		0	4	0	4	0	0		1		0		28			1	1	0	0	66	3		2	0	5	1
53.2	2	1	1	4		6				1		1		26					1		27	2		3		7	1
54.4	0			7	1	4	1	1		1		2		16					1	0	24	1		14		8	1
55.2	1			3	1	4		2		0		0		15			1		0	0	28	1		9	1	8	0
56.3				2		4	1			0		0		23				0	4		24	7		6	1	4	
57	5			2	2	3	2	3				0		27			1		0		56	4		9		3	0
57.9	1			2		3	11	1	1					27					2		51	2		10		0	0
58.4	1			2	2	11	1	1	0					17					0		54	0	0	10		3	1
59.5		2		1		8		1	3			0		18				1	4		27	4		1		0	4
62.5			0	1	1	1		2				1						0	1	1	19	1		8		7	6
63.3	0	1	1	2	0	0	2	0				1		4					1	1	32			9			12
64.2			3	4				3				8					2		8	0	44	5		20		12	
65		1	0	5	1	5		6	2			5					2	3	10	1	69	2	0	10		3	4
65.5			1	0		1						1							1	2	17	1		2		3	
66.2			0	1		2		2				3					1	0	5	1	31	0		8		12	
67.5		3		0	2			2						2			1	1	5		62			4		7	5
68		0		1		11						0					0		1	0	9			0			2
68.8			1	1	0	1		1	10			1					2		3	1	25	2		1		4	
69.4			0			4		0	1			0							2	1	18	1		1			0
70		1		5	1	4											3	0	5	0	34			8		3	9
71.4		0		4	0	41	1	1				1					0	0	1	0	29	0		8			2
71.6		1	1	2	4	4	1	0						5					2	1	81	1		3		3	5
72.3				3		7		2	1			0							7	1	52	2		3		2	2
72.5				4	1	39	1	1				0						0		0	62	3	0	0		4	0
73		2		2	0	46						1		3				0	4	0	28	1		3		2	0
73.4				2	1	26			1			5		2				1	5		30	9		15		2	2
74.1				2		45	0		0			0		2					0	1	7	0		0		0	1
74.5				4	0	20	0	5				0		4				0	4		24	0	0	0		2	
75		1		2	0	16	4	2				0		4				0	1		30	0		1		2	
76.5				5		29		6				2		2					6		63	1		4			1
78				1	1	68	1	1				1		4	1			1	1	0	19	1		5		5	
78.9						57		0											0	0	1	2				0	
79.6		2		2	2	29	4	6				2					0	1	2	1	59	3		5		1	0
80.3		1		0	8	6	4	1	1			0						2	3	1	117	2		3		6	
81				6	1	4	0	1	0				1	2	0		1	0	6		53	5	0	6	0	2	
81.7		3	1	1	1	26		2				0		0				2	2	1	46	0		4		0	2
82.4		0		2	1	31		1				0			3			1	6	0	37	6		7		1	
83				3	1	4	5	6				0			6			1	5		62	1		5		8	4
83.8	0			3		1	7	3	0								1	0	6	1	125	5	2	1		8	
84.6		4		0		0	3	3	0			0			2			3	4		52	1		1		4	0
85.3				2	1			6	1								1	2	6	1	37	5	3	3		4	
86		3		1	1	2		0						4			1	2	6		88	4	0	6		2	
86.7		2	1	0	2	3		0	0			0	1	1				0	3	0	62	0	1	0	0	3	
87.5		1		1	2		1	3		1				2					3	1	93	1	1	1		4	
88.1	0	2		0	1	4		4	1	0		0		6			0		4	0	118	3	0	1		4	0
88.9		1		0	2	1		2						4				0	4	2	118	1	0	2		4	
90				1	1	3	1		1			1		13				4	4	2	88	3	0	1		14	
90.2		2		1	2	3	3	2		0		1		10	1				5	1	111	4		1		1	
91		1	0	5	2	2	1		1			0		9	1		0	1	5	0	87	3	0	4	0	12	3
91.3	0	1		3	1	7	1							2			1	1	2	0	102	4	0	0		5	1
92.2		5			2	1	3	2						6				1	1	1	94	1	0	0		3	1
92.6		3		0	3		2	0		0				0				1	3	0	82	1	1	2		1	0
93.3				0	1	1	1	1	1			3		6		1		2	8	2	73	4	1			12	0
94.8		1		1		2		0	0			3		3				2	9	0	35	5		4		22	1
95.5		1		1		4	2			0		0		5				0	4	1	50	2	1	3		7	0
96				0		0		0	0			0		0			0		0		0	0		0		0	
99.4		2			2	1	3							2					3	0	104	2		0		6	
101	1	1	0	4	3	0	2	2	1	1	0	1	11	2	3	0	0	1	7	0	85	5	0	6	0	12	1

Samples by depth, m	Wetzeliella ovalis	Adnatosphaeridium vittatum	Charlesdowniea coleothrypta var.1 in CHC-LC 1989	Corrudinium incompositum	Deflandrea phosphoritica	Elytrocysta brevis	Heteraulacacysta leptalea	Homotryblium abbreviatum	Nematosphaeropsis sp.	Oligosphaeridium complex	Pyxidinopsis densepunctata	Charlesdowniea coleothrypta subsp. rotundata	Dinopterigium cf. cladoides	Fromea fragilis	Glaphyrocysta semitecta	Heteraulacacysta porosa	Thalassiphora gracilis	Wetzeliella articulata subsp. brevicornuta	Impagidinium dispertitum	Operculodinium deconinckii	Areoligera undulata	Hystrichokolpoma spinosum	Areoligera coronata	Glaphyrocysta ordinata	Phthanoperidinium comatum	Operculodinium divergens	Wetzeliella aff. Samlandica
49.6																											
51.2																											
52.4	1		0	0	8	7				1	5	2	2		1	1				4			31			3	
53.2	2		0	4	15		0			3			0		0	1	0						0	1		2	0
54.4	7			13	19	2	4			0	0		0		1	2	0						4	1			
55.2	2		0	3	23	3	1				12		1		0	3	0						1				
56.3	8		1	2	26	7	2			1	4				1	1							1	2		0	
57	4			1	13	4	1	1			1		2		1	1	0						1	1			0
57.9	0		0	1	8	1		1			5		1		2	2							4	1			
58.4	1		1	1	9	2	1				4		4		1	2	1						1	1			
59.5	1			0	21	9	1				12		2		0	1			0	2			0	0			
62.5	0				140	3					3				0	1			1							1	
63.3	2		2		27	9					2		2		2			1								3	
64.2	2		9	0	36	4					3		1		1	0	0		0								
65	1	0	2	0	38	4		1					1		0		0										1
65.5	1		0	1	41	2					3																0
66.2	0		2	3	84	4							0		0					1							0
67.5			1		14	1							3		0	1									1		
68			0	1	25	1							0		0					0							0
68.8	0			1	114										1												1
69.4	0		1	3	83				1		5				0												
70			3		51										3					2							0
71.4	2			1	19	3					1	0	1		1				1								
71.6				5	16	2		0			0	0	2		0					5							0
72.3	3		0	1	67	2					3																1
72.5	3		0	1	17	2					1		1		1					1							0
73	3		0	3	20						5															2	
73.4	5		2	1	57						1		4			0			1	1							1
74.1	0		0	2	24	6					0		2													0	
74.5	1		1		20	5					0		2		0	2											
75	2		0		20	2							2			0											
76.5			2		16				1																		1
78	0				27	6							2		1												
78.9	1				10	6					0					0											
79.6	2		0	2	8	4	0				5		7		1	0	0			1							
80.3	2		3	1	4	2			1		1		4				1		0	1							
81	4		0	0	7	2			1				0		2	0		1	0								
81.7	0		0	1	8	4	0				2	0	4			0	1		0								
82.4	2		1	3	10	2			2			0	4		0				1	0			0	0	0		
83	1			0	6	3			0			0	0						1	2	0						
83.8			0	2	4	4			0				3		0		0		2					0			
84.6			2	1	12	1	0		0	0			1					1		0							
85.3				4	43	2						6					0										
86	1			6	25	1									2		1	0		1					0		
86.7				2	4	1			1	0			0											2		1	0
87.5				0	17	3											1										
88.1	0		4	1	5	5			1	0		0						0		0				0			
88.9	0		0	2	14	1			0	1			1				0	0		1				1			
90	2		0	3	8	1	1		1	2			0				0							0	1		
90.2			1	2	13	2			3	3			1		0								1				
91	2	1			18				0	3										2							
91.3	0	0		4	14			0	2	5		1	2		0				0	1				2			0
92.2			0	2	12				1	1					0			0								2	0
92.6	0	1		1	2				0						0												
93.3	0	0			21		0		0			0	0		0		1						1	0		1	0
94.8	0				33	1	0								0		0				0	0		0	1		
95.5	0	3	0		20	4		0			1	0	2	0	3	0	0	0	0	1							
96				0	0			0			0																
99.4	3	0	1	3	12	1	0	0	1	1																	
101	1																										

Samples by depth, m	Heteraulacacysta sp.	Glaph. cf. semitecta sensu Al-CHC 2010	Araneosa araneosa	Hystrichokolpoma rigaudiae	Thalassiphora? spinifera sensu DC 1986	Distatodinium ellipticum	Fibrocysta axiale	Hystrichosphaeropsis complanata	Charlesdowniea variabilis	Cordosphaeridium exilimurum	Impagidinium velorum	Membranophoridium aspinatum	Senegalinium? Dyleenense	Selenopemphix nephroides	Hystrichokolpoma? sp.1 in CHC-VS 2005	Wilsonidium echinosuturatum	Operculodinium nanaconulum-O. placitum-group	Phthanoperidinium resistente	Wetzeliella lunaris	Distatodinium cf. craterum	Dracodinium varielongitudum	Homotryblium floripes	Impagidinium paradoxum	Impagidinium sp. sensu HB-UB 1993	Pentadinium favatum	Rhombodinium draco	Distatodinium biffii
49.6																											
51.2																											
52.4			0	1		0				0		0					1	1								0	
53.2		0		0		1			1			1													0	1	
54.4				5		0			2			1													0	0	
55.2				2				0				0						1							0	1	
56.3	2			2		0																				1	
57	2		0	4		0				0		2														0	
57.9				2		0						1						0							0	2	
58.4		0	0	6			1					0						2					0			2	
59.5				1																					0	3	
62.5		0		0												0											
63.3	0	0		1				0																			
64.2	1			4				0				0				3									1		
65		0		0												4									1	0	
65.5									1							0											
66.2				1												0											
67.5	3	1	1																						1		
68				0																							
68.8								0								0											
69.4																											
70		1		0																					2		
71.4				2				0																			
71.6																									0		
72.3											cf.														1		
72.5							0	0			cf.														1		
73				1																					1		
73.4								0																			
74.1																											
74.5	1																										
75				0														1									
76.5	1							1																			
78				2																							
78.9								0																			
79.6	1							1				0															
80.3	3							0		0															0		
81	1	0		1						0																0	
81.7				1				2																	1		
82.4		0	0	1												0									2		
83		1		2											0			0								0	
83.8				0																			0				
84.6						0		0						1													
85.3	1																										
86												0		0													
86.7		0																4									0
87.5		1						1																			
88.1			0	2			0			0		0			1					0	0	0	0	1	1	0	
88.9			0														0	1	1								
90		0		0			0								0	0											
90.2					2		1							1													
91		1		0					0	1	1	2	0														
91.3					0	1	1	0																			
92.2	1		0	0	2																						
92.6	0	0																									
93.3																											
94.8																											
95.5																											
96																											
99.4																											
101																											

Samples by depth, m	Impagidinium victorianum	Cordosphaeridium minimum	Hystrichosphaeridium cylindratum	Thalassiphora fenestrata	Impagidinium elegans	Areoligera sentosa	Cerebrocysta cf. Bartonensis	Cordosphaeridium aff. callosum	Enneadocysta? aff. arcuata in CHC-VS 2005	Areosphaeridium michoudii	Deflandrea eocenica	Deflandrea heterophlycta	Wetzeliella sp.2 sensu Al-CHC 2010	Lentinia serrata	Pentadinium sp.1	Phthanoperidinium multispinum	Impagidinium cf. sphaericum in DC 1986	Rhombodinium longimanum	Turbiosphaera magnifica	Pentadinium lophophorum	aff. Membranophoridium sp.	Eisenackia scrobiculata	Lejeunecysta hyalina	Thalassiphora sp.1	DDeflandrea phosphoritica subsp. spinulosa	Distatodinium parisiense
49.6																										
51.2																										
52.4				2					2					2			0		0						1	0
53.2				7														0								
54.4				1										1									0	0		
55.2				2										2			0					0				
56.3				5											0		1		0		0					
57				3																0						
57.9				1														0	0							
58.4				5		0											0									
59.5				2																						
62.5				0																						
63.3								1		0																
64.2																										
65				0		0										3										
65.5	1															1										
66.2																										
67.5							0																			
68							4								0											
68.8							1							1												
69.4										0																
70							0						0													
71.4																										
71.6							1					0														
72.3																										
72.5				0				0			0															
73					1		1																			
73.4																										
74.1								0		0																
74.5																										
75																										
76.5							2																			
78																										
78.9																										
79.6						0	1	0	1																	
80.3			1																							
81				1	0																					
81.7		0		0	2																					
82.4		0	0	0																						
83																										
83.8																										
84.6																										
85.3																										
86																										
86.7	0																									
87.5																										
88.1																										
88.9																										
90																										
90.2																										
91																										
91.3																										
92.2																										
92.6																										
93.3																										
94.8																										
95.5																										
96																										
99.4																										
101																										

Table 2. Distribution of dinoflagellate cyst taxa in borehole No. 230. Numbers are counted specimens

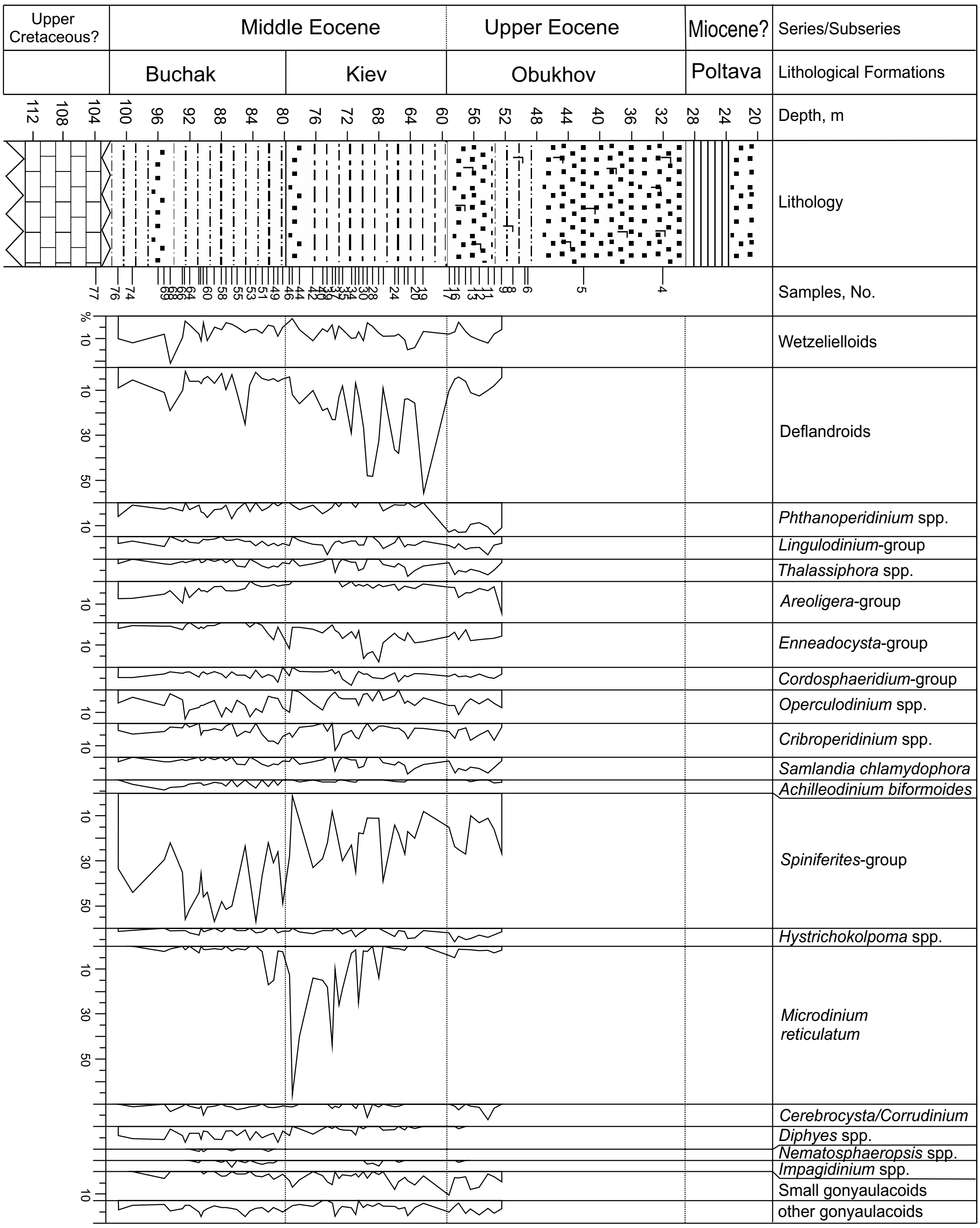

Fig. 4. Quantitative distribution of dinocyst eco-groups in the Eocene sediments of borehole No. 230

cantharellus, *Costacysta bucina*, *Enneadocysta arcuata*, and *Wetzeliella ovalis*. By comparison with the last updated Ukrainian dinocyst zonation (Andreeva-Grigorovich et al. 2011), the lowermost part of the Buchak Formation can be questionably attributed to the DP7b (*E. arcuata*) Ukrainian dinocyst zone interval, middle Lutetian. The palynological associations from these samples are characterised by high dominance of dinocysts in situ, with a slight influx of reworked dinocysts (5%), conifers (10%), and microforaminifers (up to 8%). The dinocyst assemblage is marked by abundant *Spiniferites*-group (35–43%) and common (25–20%) peridinioid cysts (wetzelielloids, deflandroids, *Phthanoperidinium* spp.). Such abundance of the open-marine *Spiniferites*-group combined with the presence of the erosion surface at the base of the formation, overlying Maastrichtian chalk, indicates an important transgressive trend in this part of the marine basin during the middle Lutetian.

The second interval (96.0–79.6 m depth) represents the largest part of the Buchak

Formation and is characterised by the occurrence of a number of stratigraphically important dinocyst species. The lower part of this interval showed the lowest occurrences (LOs) of sporadic *Heteraulacacysta porosa* and *Dapsilidinium ellipticum*; this may suggest attribution of this interval to part of the DP8 Ukrainian dinocyst zone (Andreeva-Grigorovich et al. 2011). The key species *Wilsonidium echinosuturatum*, *Rhombodinium draco*, and *Homotryblium floripes* occur in the middle part of the interval, whereas its upper part is marked by the LO of sporadic *Thalassiphora fenestrata*, LO of consistent *H. porosa*, and the highest occurrences (HOs) of *Diphyes ficusoides* and consistent *D. pseudoficusoides*. The LO of *Rhombodinium draco* permits attribution of this part of the Buchak Formation to the DP9 (*Rh. draco*) Ukrainian dinocyst zone (Andreeva-Grigorovich et al. 2011). Assuming that *Heteraulacacysta porosa* and *Thalassiphora fenestrata* first occur in NW Europe from the *E. arcuata* zone interval (calibrated with Martini's uppermost NP15 zone interval) and that the LO of *Rh. draco* is generally known from the upper *Enneadocysta arcuata* zone interval (calibrated with the upper NP16 zone) (Heilmann-Clausen & Van Simaeys 2005), the whole studied interval of the Buchak Formation may be assigned to the mid-upper Lutetian. Noteworthy is a very early single occurrence of *Distatodinium biffii* at 86.7 m depth; its premature LO is already known from the Danish Basin (Heilmann-Clausen & Van Simaeys 2005) and Pre-Caspian region (Oreshkina et al. in press). Along with the continuing predominance of dinocysts (50–90%), palynological assemblages of this interval are characterised by a significant increase in conifers (up to 40%), the influx of acritarchs (up to 23% in the upper part of the interval) and slight incursions of angiosperms and spores. The dinocyst assemblage is still marked by abundant occurrence of the *Spiniferites*-group (up to 55%), a slight influx of *Impagidinium* spp., and peridinioids varying between 10% and 40%; the uppermost part of this interval is marked by an influx of *Microdinium reticulatum* (18%). The continuing dominance of the open-marine *Spiniferites*-group combined with an influx of acritarchs and conifers (probably originating from land during sea level rise intervals) suggests the prolongation of an important transgressive phase in the marine basin during the late Lutetian.

KIEV FORMATION

Two palynological intervals have been identified within the Kiev Formation from base to top.

Based principally on previous calcareous nannoplankton data, the lower part (79.6–70.0 m depth) of the Kiev Formation is attributed to part of the CP14a nannoplankton zone (Okada & Buckry 1980), the lower Bartonian, and is characterised only by the HO of *Phthanoperidinium regalis*. This interval may still represent a part of the DP9 Ukrainian dinocyst zone. The palynological assemblage of the lower Kiev Formation is marked by significant changes: along with the dominance of dinocysts (40–99%), acritarchs became frequent to superabundant (up to 60%), whereas terrestrial palynomorphs attain no more than 8% of the total assemblage. The dinocyst assemblage is characterised by dominance of *Microdinium reticulatum* (up to 65%), frequent *Spiniferites*-group (up to 35%), and a relative increase in peridinioids (up to 40%). The dominance of dinocysts, combined with several important peaks in acritarchs and a significant drop in continental palynomorphs, indicates a new (or alternatively a continuation of), an important transgressive episode of the marine basin during the early Bartonian.

The interval between 70.0 and 59.5 m depth revealed the HO of consistent *Costacysta bucina* and the LO of *Lentinia serrata* in the lower part, and the HO of *C. bucina* and the LO of consistent *Thalassiphora fenestrata* in the upper part. In terms of Ukrainian dinocyst zonation, despite the absence of the nominative species *Rhombodinium porosum*, this interval may be tentatively assigned to the DP10 (*Rh. porosum*) zone. Based on previous findings of *L. serrata* in different sites of the Northern Hemisphere from the Bartonian (Williams et al. 2004) and the occurrence of consistent *Th. fenestrata* (previously known from the Bartonian and Priabonian in Denmark; Helmann-Clausen & Van Simaeys 2005), the upper Kiev Formation is assigned to the Bartonian-?lowermost Priabonian. The palynological assemblage is still marked by the predominance of dinocysts (45–100%) and significant peaks in acritarchs (up to 55%). At the same time, the dinocyst associations are characterised by an important drop in *Microdinium reticulatum*, a significant increase of peridinioids (especially deflandroids, up to 60%) and a relative increase of the *Areoligera*-group (up to 20%). The dominance of deflandroids, which are presumed to be tolerant of reduced salinity, may reflect an important influx of fresh waters from the land during a new relative rise in sea level.

OBUKHOV FORMATION

The lower Obukhov Formation, with a qualitatively rich dinocyst assemblage (59.5 to 52.4 m depth), showed the lowermost occurrence of *Rhombodinium longimanum*. Based on its previous occurrences in Priabonian sediments in NW Europe (Heilmann-Clausen & Van Simaeys 2005) and Western Siberia (Iakovleva & Heilmann-Clausen 2010), the lower Obukhov Formation is tentatively assigned to the interval of the Ukrainian dinocyst zone DP11 (*Charlesdowniea clathrata angulosa*/*Rh. perforatum*) (Andreeva-Grigorovich et al. 2011) and attributed to the Priabonian. The palynological assemblage from the lower Obukhov Formation is characterised by an important drop in acritarchs, fluctuations in dinocysts between 25% and 85%, and a significant influx of green algae (5–15%), microforaminifers (10%), and especially terrestrial palynomorphs (conifers, angiosperms, fungi, and unknown continental palynomorphs, up to 75%). The dinocyst assemblage, in turn, is marked by abundant gonyaulacoids (primarily *Spiniferites* and *Areoligera*-groups); peridinioids constitute ca 30% of the assemblage. A significant increase of continental elements in the palynological assemblage from the lower Obukhov Formation, followed by a transition to a very impoverished assemblage in the upper Obukhov Formation, indicates a general regressive trend in the history of the marine basin during the Priabonian.

DISCUSSION

The Dnepr-Donets Depression, as well as parts of the Ukrainian Shield and Voronezh anticline, constitute the North Ukrainian palaeosedimentological province. The North Ukrainian Province represents a part of the northern Peri-Tethys. Its Palaeogene seas were connected to the North Atlantic in the west (via marine basins of Belarus, Poland, and the Baltic countries). In the east and southeast, the North Ukrainian Province communicated with marine basins of the Volga region, Caucasus, Pre-Caspian region, and the Black Sea Depression. As already mentioned, the dinoflagellate assemblages recognised in the Buchak, Kiev, and Obukhov Formations are largely cosmopolitan, confirming again the more or less constant connection of the North Ukrainian marine basin to the North Sea Basin and southeastern Peri-Tethys.

As noted above, the Palaeogene sediments of the North Ukrainian Province are represented mostly by non-calcareous sandy-clayey sediments with only fragmentarily distributed palaeontological remnants. The insufficient palaeontological basis limits the ability to make interregional correlations and causes uncertainty about the stratigraphic age of the North Ukrainian lithostratigraphic formations.

According to Zosimovich (2006), a relatively deep basin existed only within the axial part of the Dnepr-Donets Depression, and the peripheral parts of the North Ukrainian Province represented shallow marine zones. In the early and part of the middle Palaeogene, the marine basin extended beyond the Dnepr-Donets Depression only episodically during the maxima of transgressions. Palaeocene sediments (Sumsky Formation) are known in the North Ukrainian Province mostly from deep zones of the Dnepr-Donets Depression and are absent on the western margins of Donbas, on the Ukrainian Shield, and on the pre-crestal parts of the dome-shaped structures of the Dnepr-Donets Depression. Lower Eocene sediments (Kanev Formation) are distributed over more or less the whole North Ukrainian Province but are represented by glauconite sands of low thickness on the slopes of depressions and the Ukrainian Shield. Borehole No. 230, drilled in the northern part of the Dnepr-Donets Depression (southeastern slope of the Voronezh anticline), revealed an abbreviated Palaeogene record: the mid-Eocene deposits of the Buchak Formation directly overlie upper Cretaceous chalk. The absence of Palaeocene-lower Eocene sediments in the borehole No. 230 section may be explained by a feebly marked Palaeocene-early Eocene marine transgression in the northern part of the Ukrainian marine basin. Important erosive processes on the northern slopes of the Dnepr-Donets depression may also play a role in this.

According to Zosimovich (2006), the Buchak Formation is widely distributed over the whole Dnepr-Donets Depression and the slopes of the Ukrainian Shield and consists of marine quartz-glauconitic sands and clayey and terrigenous sandstones. While the generally Lutetian age of the Buchak Formation has been posited since the 1960s, the problem of the temporal identity of the Buchak stratigraphic interval to the Lutetian remains today. According to the present dinoflagellate cyst data (the first dinocyst study of the Buchak sediments in Ukraine), the lower part of the Buchak Formation is attributed to the middle Lutetian, while the lower Lutetian is missing in the present record. In turn, the absence of the lower Lutetian sediments reflects a global regressive cycle starting at the Ypresian-Lutetian transition and well known in the North Sea Basin (Hardenbol et al. 1998), and recently recognised in other parts of Peri-Tethys (King et al. 2013). Based on quantitative palynological data (the general dominance of dinocysts and in particular the abundance of the dinocyst *Spiniferites* group), the accumulation of the lower Buchak Formation corresponds to the beginning of an important transgressive episode in the history of the North Ukrainian Province, reflecting a major transgressive cycle (Lu4) of Hardenbol et al. (1998). According to our data (LOs of *Rhombodinium draco*, *Heteraulacacysta porosa*, *Thalassiphora fenestrata*), the upper Buchak Formation is assigned to the upper Lutetian. Consequently, the stratigraphic age of the whole Buchak Formation revealed in borehole No. 230 is mid-late Lutetian.

According to Zosimovich (2006), sediments of the Kiev Formation have the widest geographical distribution over the North Ukrainian Province, reflecting the most prominent transgressive episode during the Eocene. In the Dnepr-Donets Depression the Kiev Formation is composed generally of marls and calcareous clays with remarkable palaeontological richness (e.g. calcareous nannoplankton, foraminifers, molluscs, radiolarians), while in the Ukrainian Shield and peripheral parts of the Dnepr-Donets Depression and Voronezh anticline, calcareous deposits are replaced by non-calcareous shallower facies. Often (as in the case of borehole No. 230) the lower Kiev Formation is composed of clayey marls and the upper Kiev Formation by non-calcareous sandy clays. According to Zosimovich et al. (2005), the lower boundary of the Kiev Formation is very distinctive and corresponds to the middle or upper Lutetian. In borehole No. 230 the lower Kiev Formation is directly assigned to the CP14a zone of Okada & Buckry (1980). The upper (non-calcareous) Kiev Formation, characterised by the lowermost occurrences of *Lentinia serrata* and consistent *Thalassiphora fenestrata*, seems to correspond to the Bartonian-lowermost Priabonian. Based on palynological data, the dinocyst assemblages from the Kiev Formation show (especially in the upper part) a gradual transition from *Spiniferites*-dominated to *Deflandrea*-dominated assemblages, reflecting an important palaeohydrological change (fresh water and important nutrient input).

According to Zosimovich (2006), the upper Eocene Obukhov Formation is widely distributed over the North Ukrainian Province; this formation is composed mostly of non-calcareous clayey-siliclastic siltstones and sandstones. The basal part of the Obukhov Formation in borehole No. 230 is represented by glauconitic sands, indicating a new transgressive cycle. Based on our dinocyst data (LO of *Rhombodinium longimanum*), the lower part of this formation is assigned to the Priabonian and may possibly reflect global cycle Pr2 of Hardenbol et al. (1998). Nevertheless, the presence of very impoverished dinocyst assemblages in the upper sandy part of the Obukhov Formation as well as the high abundance of continental palynomorphs from ca 55 m depth suggest the beginning of an important long-term regression in the North Ukrainian Province until the end of the Priabonian.

CONCLUSIONS

The present study demonstrated the usefulness of detailed dinocyst analysis for updating the stratigraphic age of the major Eocene lithological (mostly non-calcareous) formations of Northern Ukraine. Based on the lowermost and uppermost occurrences of the age-diagnostic dinocyst taxa, the Buchak Formation is now attributed to the mid-upper Lutetian. Taking into account the calcareous nannoplankton data from the lower part of the Kiev Formation (CP14a zone interval), the whole Kiev Formation may be assigned to the

Bartonian-?lowermost Priabonian. Finally, the terrigenous Obukhov Formation is now attributed to the Priabonian.

ACKNOWLEDGMENTS

I thank Dr. E.P. Radionova and Dr. T.I. Oreshkina (GIN, Moscow) for the material from borehole No. 230, G.N. Aleksandrova (GIN, Moscow) and K. Rosendal (Aarhus University, Denmak) for chemical preparations of palynological material, S.B. Andersen (Aarhus University) for technical preparation of photoplates, Dr. Claus Heilmann-Clausen (Aarhus University) for fruitful discussions and help in determining Cretaceous taxa, and Dr. Angelika Köthe and Dr. Przemysław Gedl for their very constructive reviews.

TAXONOMIC APPENDIX

DINOFLAGELLATE CYSTS

Araneosphaera araneosa Eaton 1976; Plate 1, fig. 1

Areosphaeridum diktyoplokum (Klumpp 1953) Eaton 1971; Plate 1, fig. 6

Areosphaeridium michoudii Bujak 1994; Plate 1, fig. 5

Cerebrocysta bartonensis Bujak in Bujak et al. 1980; Plate 2, fig. 11

Cerebrocysta cf. *bartonensis* Bujak in Bujak et al. 1980; Plate 2, fig. 12

Remarks: Differs from typical *C. bartonensis* by having less prominent ornamentation of crests, giving the cerebral appearance.

Charlesdowniea colethrypta var.1 in Heilmann-Clausen & Costa 1989; Plate 3, fig. 20

Charlesdowniea coleothrypta subsp. *rotundata* (Châteauneuf & Gruas-Cavagnetto 1978) Lentin & Vozzhennikova 1989 sensu De Coninck 1993; Plate 3, fig. 21; Plate 4, fig. 1

Charlesdowniea tenuivirgula (Williams & Downie 1966b) Lentin & Vozzhennikova 1989; Plate 4, figs 2, 3

Cleistosphaeridium diversispinosum Davey et al. 1966; Plate 1, figs 3, 4

Cordosphaeridium cantharellus (Brosious 1963) Gocht 1969; Plate 1, fig. 7

Corrudinium incompositum (Drugg 1970) Stover & Evitt 1978; Plate 2, figs 9, 10

Costacysta bucina Heilmann-Clausen & Van Simaeys 2005; Plate 6, figs 1, 7

Deflandrea phosphoritica Eisenack 1938; Plate 6, fig. 2

Dinopterigium cf. *cladoides* sensu Heilmann-Clausen & Van Simaeys 2005; Plate 6, figs 8, 9

Diphyes ficusoides Islam 1983; Plate 3, fig. 1

Diphyes pseudoficusoides Bujak 1994; Plate 3, figs 2, 3

Distatodinium cf. *craterum* Eaton 1976

Remarks: This specimen resembles *D. craterum* but differs in the number of processes: there are 20, whereas there should be 14 for the type species.

Distatodinium ellipticum (Cookson 1965a) Eaton 1976; Plate 6, figs 11, 12

Elytrocysta brevis Stover & Hardenbol 1994; Plate 2, fig. 13

Enneadocysta arcuata (Eaton 1971) Stover & Williams 1995; Plate 2, figs 1, 2, 4, 5

Enneadocysta? aff. *arcuata* sensu Heilmann-Clausen & Van Simaeys 2005; Plate 2, fig. 3

Glaphyrocysta semitecta (Bujak in Bujak et al. 1980) Lentin & Williams 1981; Plate 2, figs 16, 17

Glaphyrocysta cf. *semitecta* sensu Iakovleva & Heilmann-Clausen 2010; Plate 2, figs 6, 7

Heteraulacacysta porosa Bujak in Bujak et al. 1980; Plate 6, figs 10, 13

Homotryblium floripes (Deflandre & Cookson 1955) Stover 1975; Plate 6, figs 4, 5

Homotryblium tenuispinosum Davey & Williams 1966; Plate 6, fig. 3

aff. *Homotryblium* sp.; Plate 7, figs 1, 2

Remarks: This specimen is characterised by the epicystal archeopyle and 9 processes and shows some resemblance to the genus *Homotryblium*.

Hystrichokolpoma? sp.1 sensu Heilmann-Clausen & Van Simaeys 2005

Hystrichosphaeropsis complanata Eisenack 1965b; Plate 7, figs 7, 8

Impagidinium paradoxum (Wall 1967) Stover & Evitt 1978; Plate 3, figs 5, 6

Impagidinium victorianum Cookson & Eisenack 1965; Plate 3, fig. 4

Impagidinium sp. cf. *I. sphaericum* Wall 1967 – *I. multiplexum* Wall & Dale 1968 sensu De Coninck 1986; Plate 3, fig. 11

Lentinia serrata Bujak in Bujak et al. 1980; Plate 6, fig. 6

Lithosphaeridium? *mamellatum* 1977; Plate 7, figs 4,5

Membranosphaeridium aspinatum Gerlach 1961; Plate 2, fig. 8

Microdinium reticulatum Vozzhennikova 1967; Plate 3, figs 7, 8

Operculodinium nanaconulum Islam 1983; Plate 3, fig. 9

Operculodinium nanaconulum-*Operculodinium placitum*-group sensu Heilmann-Clausen & Van Simaeys 2005

Pentadinium goniferum Edwards 1982; Plate 7, figs 3, 6

Pentadinium laticinctum Gerlach 1961; Plate 7, figs 11, 12

Phthanoperidinium comatum (Morgenroth 1966a) Eisenack & Kjellström 1971

Phthanoperidinium geminatum Bujak in Bujak et al. 1980; Plate 3, figs 12, 13

Phthanoperidinium regalis Bujak 1994; Plate 3, figs 14, 15

Phthanoperidinium resistente (Morgenroth 1966a) Eisenack & Kjellström 1971; Plate 3, fig. 10

Phthanoperidinium sp.; Plate 3, figs 16, 17, 18

Pyxidinopsis densepunctata De Coninck 1985; Plate 2, figs 14, 15

Rhombodinium draco Gocht 1955; Plate 4, fig. 4

Tectatodinium pellitum Wall 1967; Plate 3, fig. 19

Thalassiphora delicata Williams & Downie 1966; Plate 7, fig. 13

Thalassiphora fenestrata Liengjarern et al. 1980; Plate 8, figs 1, 4

Thalassiphora gracilis Heilmann-Clausen & Van Simaeys 2005; Plate 8, fig. 2

Thalassiphora pelagica (Eisenack 1954) Eisenack & Gocht 1960

Thalassiphora sp.1; Plate 8, fig. 3

Remarks: The specimen is similar in shape to *Th. gracilis* but clearly differs by its unusual fenestration of the periphragm. It differs from *Th. reticulata* by its considerably larger size and its sparse openings.

Thalassiphora? *spinifera* sensu De Coninck 1986

Wetzeliella articulata subsp. *brevicornuta* Heilmann-Clausen & Costa 1989; Plate 4, fig. 5

Wetzeliella aff. *articulata*-group sensu Iakovleva & Heilmann-Clausen 2010; Plate 4, fig. 6

Wetzeliella ovalis Eisenack 1954b; Plate 5, figs 1, 3

Wetzeliella aff. *samlandica* Eisenack 1954b; Plate 5, fig. 5

Wilsonidium echinosuturatum (Wilson 1967) Lentin & Williams 1976; Plate 5, fig. 2

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PLATES

Plate 1

1. *Araneosphaera araneosa*; slide 230-52.4m-B2
2. *Cordosphaeridium funiculatum*; slide 230-52.4m-B1

3, 4. *Cleistosphaeridium diversispinosum*; slide 230-52.4m-B1

5. *Areosphaeridium michoudii*; slide 230-58.4m-B1
6. *Areosphaeridium diktyoplokum*; slide 230-58.4m-B1
7. *Cordosphaeridium cantharellus*; slide 230-56.3m-B2


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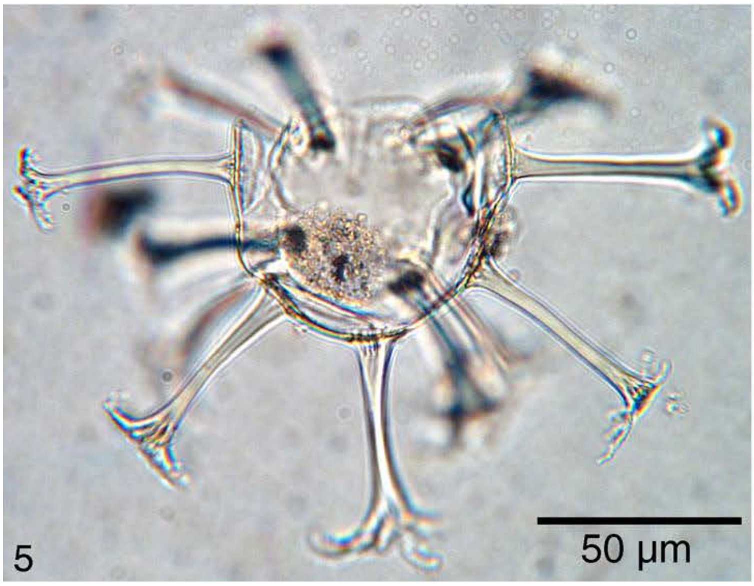

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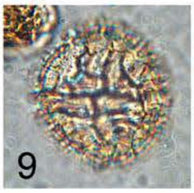
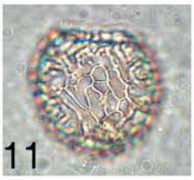
Plate 2

1, 2. *Enneadocysta arcuata*; slide 230-52.4m-B2
3. *Enneadocysta*? aff. *arcuata* sensu Heilmann-Clausen & Van Simaeys 2005
4, 5. *Enneadocysta arcuata*; slide 230-73.0m-1
6, 7. *Glaphyrocysta* cf. *semitecta* sensu Iakovleva & Heilmann-Clausen 2010
8. *Membranophoridium aspinatum*; slide 230-53.2m-B1
9. *Corrudinium incompositum*; slide 230-52.4m-B2
10. *Corrudinium incompositum*; slide 230-54.4m-B1
11. *Cerebrocysta bartonensis*; slide 230-52.4m-B2
12. *Cerebrocysta bartonensis*; slide 230-73.0m-1
13. *Elytrocysta brevis*; slide 230-52.4m-B1
14, 15. *Pyxidinopsis densepunctata*; slide 230-52.4m-B1
16. *Glaphyrocysta semitecta*; slide 230-54.4m-B1
17. *Glaphyrocysta semitecta*; slide 230-82.4m-3





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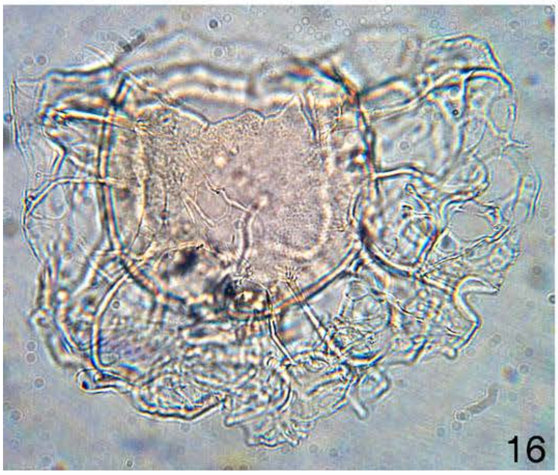

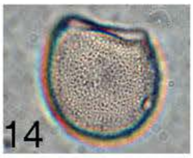

Plate 3

1. *Diphyes ficusoides*; slide 230-101.2m-B1
2. *Diphyes pseudoficusoides*; slide 230-83.0m-2
3. *Diphyes pseudoficusoides*; slide 230-101.2m-B1
4. *Impagidinium victorianum*; slide 230-68.0m-3

5, 6. *Impagidinium paradoxum*; slide 230-72.5m-1

7, 8. *Microdinium reticulatum*; 230-72.5m-1

9. *Operculodinium nanaconulum*; 230-68.8m-B1
10. *Phthanoperidinium resistente*; slide 230-52.4m-B1
11. *Impagidinium* sp. cf. *I. sphaericum* (Wall 1967) – *I. multiplexum* (Wall & Dale 1968) sensu De Coninck 1986

12, 13. *Phthanoperidinium geminatum*; slide 230-96.0m-B1

14, 15. *Phthanoperidinium regalis*; slide 230-81.0m-B1

16, 17, 18. *Phthanoperidinium* sp.; slide 230-81.0m-B1

19. *Tectatodinium pellitum*; slide 230-88.9m-B2
20. *Charlesdowniea coleothrypta* var.1 Heilmann-Clausen & Costa 1989; slide 230-90.0m-B1
21. *Charlesdowniea coleothrypta* subsp. *rotundata* sensu De Coninck 1993; slide 230-52.4m-B2

Plate 3

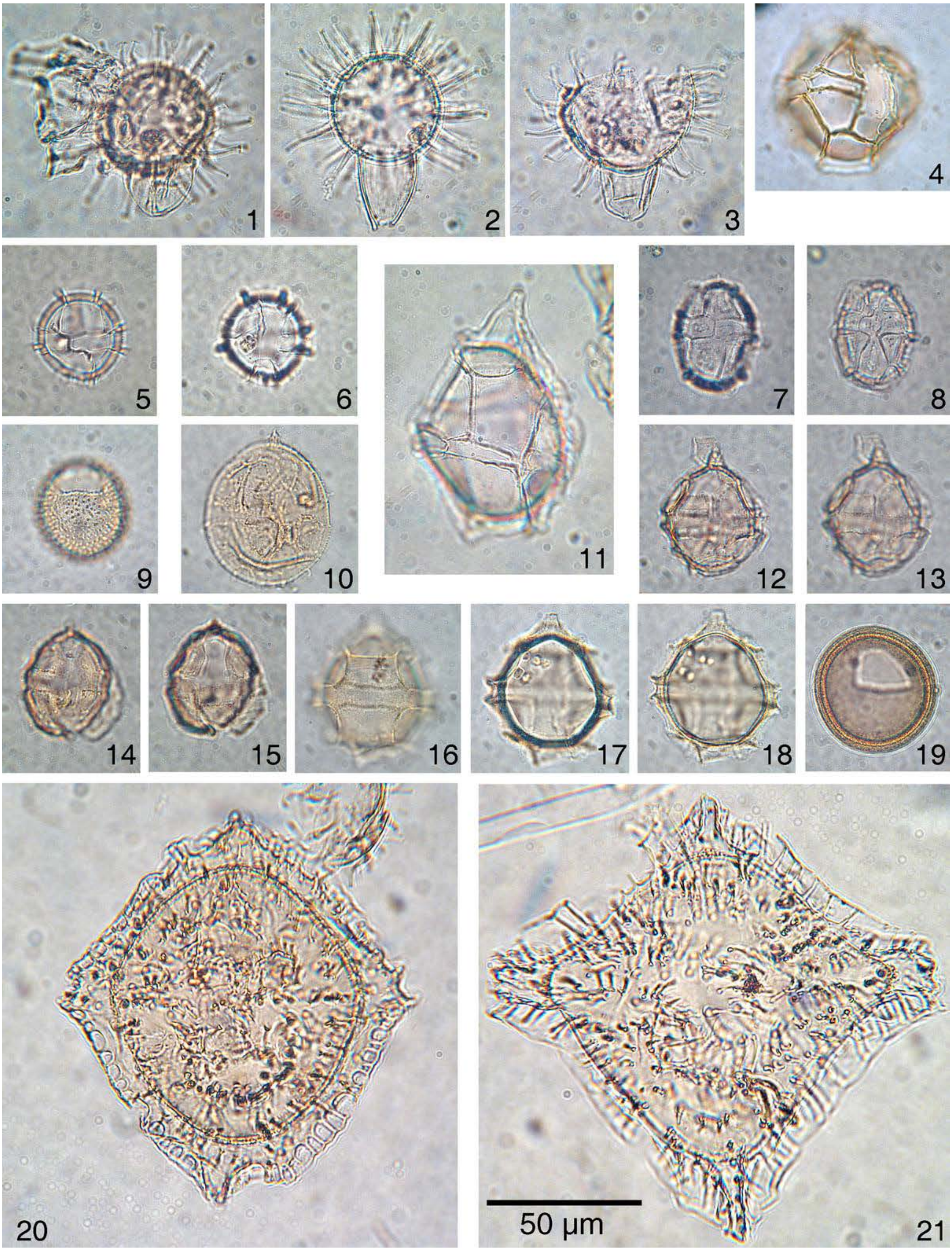

Plate 4

1. *Charlesdowniea coleothrypta* var.1 Heilmann-Clausen & Costa 1989; slide 230-67.5m-3
2. *Charlesdowniea tenuivirgula*; slide 230-101.2m-B3
3. Part of *Charlesdowniea tenuivirgula*, showing details of trabeculate network; slide 230-101.2m-B3
4. *Rhombodinium draco*; slide 230-58.4m-B1
5. *Wetzeliella articulata* subsp. *brevicornuta*; slide 230-95.5m-B3
6. *Wetzeliella* aff. *articulata*-group sensu Iakovleva & Heilmann-Clausen 2010; slide 230-101.2m-B1

Plate 4

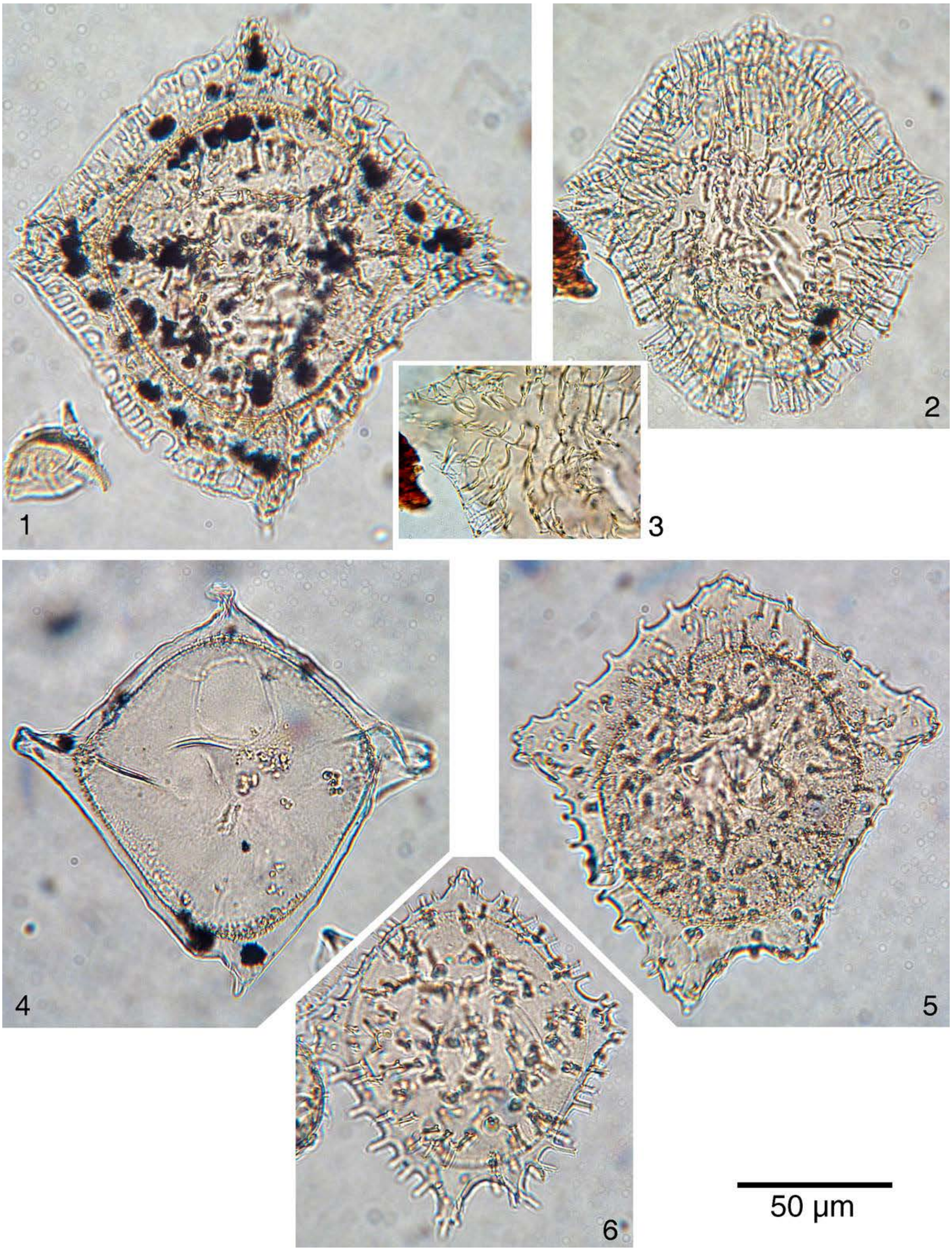

Plate 5

1. *Wetzeliella ovalis*; slide 230-64.2m-B2
2. *Wilsonidium echinosuturatum*; slide 230-62.5m-B2
3. *Wetzeliella ovalis*; slide 230-94.8m-B3
4. *Wetzeliella* cf. *articulata*; slide 230-62.5m-B1
5. *Wetzeliella* aff. *samlandica*; slide 230.65.5m-2

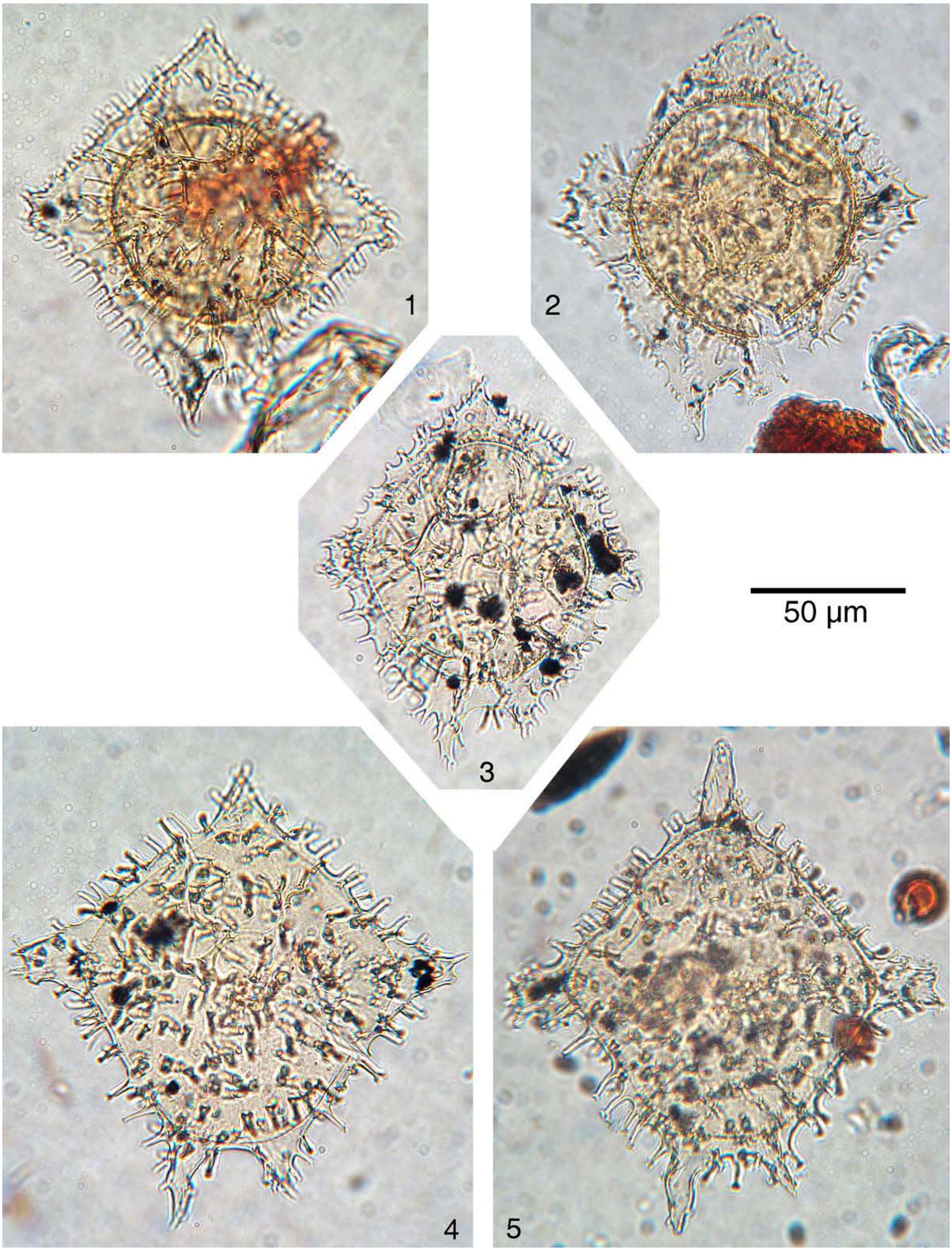
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Plate 6

1. *Costacysta bucina*; slide 230-71.4m-3
2. *Deflandrea phosphoritica*; slide 230-66.2m-B1
3. *Homotryblium tenuispinosum*; slide 230-101.2m-B3

4, 5. *Homotryblium floripes*; slide 230-88.1m-B1

6. *Lentinia serrata*; slide 230-52.4m-B1
7. *Costacysta bucina*; slide 230-90.2m-B2

8, 9. *Dinopterigium* cf. *cladoides* sensu Heilmann-Clausen & Van Simaeys 2005; slide 230-81.0m.B1

10. *Heteraulacysta porosa*; slide 230-52.4m-B1

11, 12. *Distatodinium ellipticum*; slide 230-52.4m-B1

13. *Heteraulacacysta porosa*; slide 230-55.2m-B1


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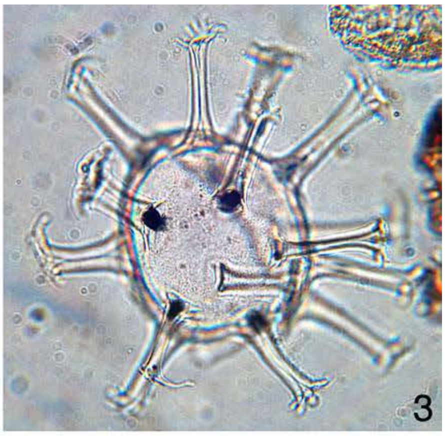
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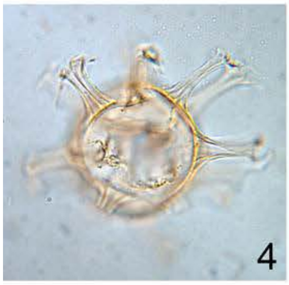
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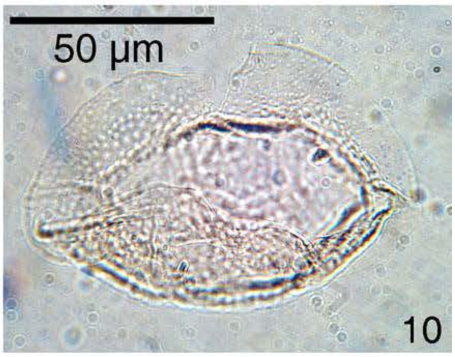

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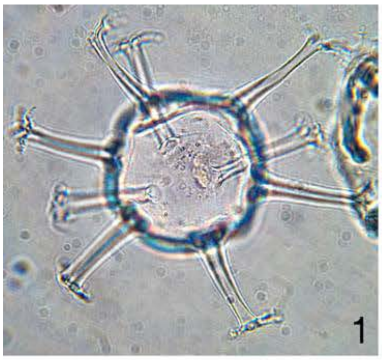
Plate 7

1,2. aff. *Homotryblium* sp.; slide 230-52.4m-B3
3, 6. *Pentadinium goniferum*; slide 230-101.2m-B1
4, 5. *Lithosphaeridium*? *mamellatum*; slide 230-52.4m-B1
7, 8. *Hystrichosphaeropsis complanata*; slide 230-76.5m-B1
9. *Paucilibimorpha triradiata*; slide 230-83.0m-1
10. Continental palynomorph A; slide 230-56.3m-B1
11, 12. *Pentadinium laticinctum*; slide 230-83.0m-1
13. *Thalassiphora delicata*; slide 230-91.3m-B2

Plate 7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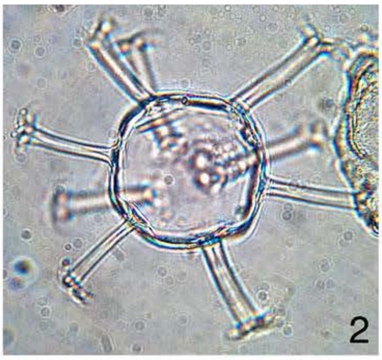
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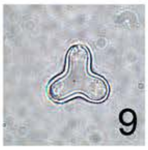
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Plate 8

1. *Thalassiphora fenestrata*; slide 230-52.4m-B2
2. *Thalassiphora gracilis*; slide 230-95.5m-B3
3. *Thalassiphora* sp.1; slide 230-54.4m-B3
4. *Thalassiphora fenestrata*; slide 230-58.4m-B2

50 µm