University of Nebraska - Lincoln

DigitalCommons@University of Nebraska - Lincoln

Papers in the Earth and Atmospheric Sciences

Earth and Atmospheric Sciences, Department
of

6-2011

Taxonomic Composition, Paleoecology and Biostratigraphy of Late Cretaceous Diatoms from Devon Island, Nunavut, Canadian High Arctic

Jakub Witkowski

University of Warsaw, Poland, jwitkowski@student.uw.edu.pl

David M. Harwood

University of Nebraska-Lincoln, dharwood1@unl.edu

Karen Chin

University of Colorado, Boulder, karen.chin@colorado.edu

Follow this and additional works at: <https://digitalcommons.unl.edu/geosciencefacpub>

Part of the [Geology Commons](#), [Paleontology Commons](#), and the [Stratigraphy Commons](#)

Witkowski, Jakub; Harwood, David M.; and Chin, Karen, "Taxonomic Composition, Paleoecology and Biostratigraphy of Late Cretaceous Diatoms from Devon Island, Nunavut, Canadian High Arctic" (2011). *Papers in the Earth and Atmospheric Sciences*. 280.

<https://digitalcommons.unl.edu/geosciencefacpub/280>

This Article is brought to you for free and open access by the Earth and Atmospheric Sciences, Department of at DigitalCommons@University of Nebraska - Lincoln. It has been accepted for inclusion in Papers in the Earth and Atmospheric Sciences by an authorized administrator of DigitalCommons@University of Nebraska - Lincoln.

Taxonomic composition, paleoecology, and biostratigraphy of Late Cretaceous diatoms from Devon Island, Nunavut, Canadian High Arctic

Jakub Witkowski,¹ David M. Harwood,² and Karen Chin³

1. Department of Historical and Regional Geology, Faculty of Geology, University of Warsaw, ul. Zwirki i Wigury 93, 02-089 Warsaw, Poland; email jwitkowski@student.uw.edu.pl

2. Department of Geosciences, University of Nebraska–Lincoln, P.O. Box 880340, Lincoln, NE 68588-0340, USA; email dkharwood1@unl.edu

3. Department of Geological Sciences/Museum of Natural History, UCB 265, University of Colorado, Boulder, CO 80309, USA; email karen.chin@colorado.edu

Corresponding author – J. Witkowski, tel 48 22 554-0417.

Abstract

Upper Cretaceous sediments of the Kanguk Formation exposed in Eidsbotn and Viks Fiord grabens on Devon Island, Nunavut, Canadian High Arctic, yielded 91 fossil marine diatom species and varieties (including indeterminate taxa), representing 41 genera. Excellent preservation of the assemblages was aided by shallow burial, protection in down-faulted linear grabens, and the presence of abundant volcanic material. Planktonic species and resting spores comprise nearly 70% of the diatom assemblage, and provided abundant food resources for the Late Cretaceous Arctic ecosystem. Deposition of the approximately 225 m-thick stratigraphic sequence was predominantly in a shallow marine neritic setting, with an upward progression to interbedded terrestrial deposits of the Expedition Fiord Formation, reflecting a regression and eventual persistence of terrestrial facies into the Early Cenozoic. The Kanguk Formation is widespread across the Canadian Arctic, and diatom biostratigraphy indicates a Santonian–Campanian age for the sequences reported herein, based on the presence of *Gladius antiquus* in the lowermost strata and occurrence of *Coscopyxis antiqua* throughout the succession. However, *Amblypyrgus* sp. A and *Archeopyrgus* sp. aff. *A. melosiroides*, encountered in the lower part of the succession, are known exclusively from the Lower Cretaceous. This may suggest a slightly older age. New information on shallow shelf diatom assemblages from this study is compared to reports on two other Late Cretaceous Arctic diatom assemblages. These three sites represent an environmental transect from shallow to distal shelf settings and into the oceanic realm.

Keywords: fossil marine diatoms, Late Cretaceous, biostratigraphy, paleoecology, arctic, Devon Island

1. Introduction

1.1. Significance of fossil diatoms

Diatoms are the most diverse group of algae, playing a major role in global carbon and silicon cycles (Kidder and Erwin, 2001; Armbrust, 2009) and inhabiting virtually any environment that provides moisture and sunlight (Mann, 1999). Thus, they offer important information to help reconstruct paleoenvironments and clarify stratigraphic relationships. Their stratigraphic range extends down at least to the Lower Cretaceous (Harwood et al., 2007). Available records list over 20 important Late Cretaceous occurrences of fossil diatoms, including: the Moreno Formation, California (Hanna, 1927, 1934; Nikolaev et al., 2001; Davies, 2006); Gdynia, Poland (Schulz, 1935); Urals and West Siberian Plain (Jousé, 1949, 1951, 1955; Krotov and Schibkova, 1959; Strelnikova, 1966, 1971, 1974, 1975); Alpha Ridge, Arctic Ocean (Barron, 1985; Dell’Agnese and Clark, 1994; Davies, 2006; Davies et al., 2009); Seymour Island, Antarctica (Harwood, 1988); and the islands of the Canadian Arctic (Tapia and Harwood, 2002). These occurrences document a variety of habitats to which diatom taxa were adapted, with

specific environmental preferences, morphological features and assemblage characters that can be used to infer variations in paleoenvironmental setting.

The distribution of these assemblages indicates that diatoms were already abundant, widespread and diverse by the end of the Cretaceous (Harwood et al., 2007). Calculations of various authors estimate the number of Cretaceous diatom genera to be around 80 (Harwood and Nikolaev, 1995), and the number of species to exceed 300 (Strelnikova, 1975, 1990; Sims et al., 2006). From one siliciclastic rich, deltaic shelf sequence in the Antarctic Peninsula Harwood (1988) reported nearly 200 diatom taxa. Nevertheless, Cretaceous diatom fossils are generally sparse, and our limited knowledge is mainly due to the temporal instability of the opal-A (Littke et al., 1991) that forms diatom frustules (Tapia and Harwood, 2002). Fortunately, numerous Cretaceous diatom-bearing deposits are known from polar regions, particularly the Arctic. The often excellent preservation of diatoms in these areas allows to establish a more complete understanding of diatom paleocommunities and biostratigraphic sequences than sites located at lower latitudes, and offers an excellent resource for morphological and taxonomic studies.

Figure 1. Top: Map of the Arctic showing localities discussed or referred to in this paper. 1 – North Pole; 2 – CESAR 6 site (Alpha Ridge); 3 – Slidre Fiord (Ellesmere Island); 4 – Devon Island; 5 – Hoodoo Dome (Ellef Ringnes Island); 6 – Cape Nares (Eglington Island); 7 – Horton River (Northwest Territories). Modified from <http://www.d-maps.com>. Bottom: Map showing fossil localities at Eidsbotn and Viks Fiord grabens on Devon Island, Nunavut, Canadian High Arctic. Modified from Dyke (1999).

1.2. Cretaceous Arctic

Paleoenvironmental conditions in the Arctic during both the Late Cretaceous and the Paleogene differed significantly from those in today's circumpolar areas. Reconstructing Late Cretaceous Arctic paleoenvironments is particularly challenging, however, because there are fewer paleoclimatic proxies than there are for the Cenozoic. Recent successful resolution of seasonal signals from pelagic diatom deposits at the Alpha Ridge in the central Arctic Ocean (Davies, 2006; Davies et al., 2009) demonstrated the potential for diatoms to interpret paleoenvironmental changes. At this site, diatoms occur in interbedded laminae, including vegetative cells and resting spores that reflect seasonal variation. Davies et al. (2009) suggested that a highly stratified water column involving the "fall dump" mechanism (Kemp et al., 2000) caused the continuous high diatom abundance in this region, rather than previously inferred upwelling (Kitchell et al., 1986).

Other successfully applied approaches to interpret Late Cretaceous Arctic paleoenvironments use vertebrate faunas (e.g., Friedman et al., 2003), fossil leaves, and palynology (e.g., Ioannides, 1986; Herman and Spicer, 1996, 1997; Tarduno et al., 1998; Falcon-Lang et al., 2004; Spicer and Herman, 2010). Estimations of terrestrial mean annual temperatures range from below 10 °C to as high as 18–20 °C for different parts of the Late Cretaceous Arctic (Herman and Spicer, 1997; Friedman et al., 2003; Spicer and Herman, 2010; Tomisch et al., in press). While recent reconstructions indicate that winter marine water temperatures in the Late Cretaceous enabled at least temporary ice formation (Davies et al., 2009), mean temperatures as high as 15 °C have also been suggested for the surface waters of the Arctic Ocean (Jenkyns et al., 2004). There is still considerable discussion regarding Cretaceous Arctic temperatures through time, the nature of the meridional temperature gradient, and whether the Cretaceous Arctic ever hosted seasonal or year-round ice (e.g. Hay, 2008; Stein, 2008).

In terms of paleogeography, the Late Cretaceous Arctic Ocean was largely isolated by surrounding land masses, but paleobiogeographic evidence (including distributions of diatoms) indicates the existence of shallow marine connections between lower latitude waters and the otherwise land-locked Arctic Ocean, through the Western Interior Seaway and Turgai Strait (Magavern et al., 1996; Baraboshkin et al., 2003).

1.3. Aim of the present paper

Exploration of Devon Island in 1998 and 2003 revealed a variety of macrofossils in the Kanguk and overlying Expedition Fiord formations, including body fossils from invertebrates and vertebrates, plus abundant coprolites (Chin et al., 2008). Subsequent analyses of sediments from these sequences have identified considerable concentrations of exceptionally well-preserved biosiliceous remains, including the diatoms reported here, as well as silicoflagellates (McCartney et al., in press). Chin et al. (2008) used a multidisciplinary approach including palynology and geochemistry to study the recovered taphocenosis, and considered trophic relationships and community structure (from primary producers through top predators) through the examination of coprolites. The present paper complements the findings of Chin et al. (2008), and (1) describes the fossil diatoms from these deposits, (2) discusses their taxonomic composition, and (3) provides information on their paleoecology and biostratigraphic sequence. This information improves our understanding of the paleoenvironmental and geological history of the Upper Cretaceous Kanguk Formation in this area. We consider new information from this assemblage within the context of diatoms from other deposits of comparable age. These assemblages represent habitats ranging from shallow shelf settings to deeper shelf and oceanic settings in the Cretaceous Arctic Ocean basin (Tapia and Harwood, 2002; Davies, 2006; Davies et al., 2009).

2. Study area and geological setting

Devon Island is a large, uninhabited island in the eastern portion of the Canadian Arctic, located west of central Greenland and south of Ellesmere Island, between 74° and 77°N latitude and 79° and 97°E longitude (Figure 1). Studies of Cretaceous outcrops throughout the Canadian Arctic Archipelago by the Geological Survey of Canada (Fortier et al., 1963; Miall, 1979, 1991; Embry, 1991) have shown that sediments on Devon Island represent deposition at the southern margin of the Sverdrup Basin; these deposits are part of the Arctic Platform, a thick succession of Lower Paleozoic strata that are capped unconformably by ~700 m of Mesozoic and Paleogene non-marine and

marine clastic rocks (Tozer, 1961). The Cretaceous represents a remnant of the transgressive Mesozoic sedimentary cover that was removed by uplift, faulting and erosion during the Paleogene stages of development of the Sverdrup Basin (Thorsteinsson and Mayr, 1987; Ricketts and Stephenson, 1994). This region was further eroded by subsequent glacial excavation during the Late Cenozoic (Dyke, 1999). Mesozoic sediments of the marine Kanguk Formation (Cenomanian–Campanian), which is widespread across the Canadian margin (Embry, 1991; Ricketts and Stephenson, 1994; Núñez-Betelu et al., 1995a, 1995b; Tapia and Harwood, 2002), and the overlying terrestrial Expedition Fiord Formation (Maastrichtian–Lower Paleocene) are preserved locally on Devon Island in fault-bounded troughs within Eidsbotn and Viks Fiord grabens (Mayr et al., 1998) (Figure 2). Paleogeographic reconstructions show that toward the end of the Cretaceous, present-day islands of the Canadian Arctic lay less than 10° south of their present locations (Tarduno et al., 1998), within the Arctic Circle.

Samples for this study were collected from eight measured sections (Figure 2; Figure 3). The approximately 225 m-thick Eidsbotn composite section is a conformable regressive sequence comprising ~140 m of dark, marine biosiliceous mudstones overlain by ~75 m-thick beds of greensand and terrestrial mudstones with coal intercalations. The greensand beds host numerous layers of bentonite, which allow local correlation between the sections (Bloch et al., 2004; Figure 2). Initial age control for the Cretaceous sequences on Devon Island was provided by the occurrence of the palynomorphs *Translucen-tipolis plicatilis* Chlonova and *Wodehouseia edmontoniicola* Wiggins (Chin et al., 2008), which suggest a Campanian age (Lerbekmo and Braman, 2002).

The large-scale formation of glaucony (up to 75 m) at both Devon Island sites (Bloch et al., 2007; Chin et al., 2008) suggests shelfal, low energy conditions coupled with high biological activity (see the study of a Cretaceous glauconitic sequence in ODP Site 748, Bitschene et al., 1992). The process of glaucony formation is observed in modern oceans (Rao et al., 1995) as an outcome of a halmyrolysis process in conditions of low terrigenous input, below 50 m depth (Chafetz, 2007). Glauconite can also form as a result of diagenetic changes, including replacement of biosiliceous remains (Borkowska and Smulikowski, 1973).

Considering the time and low terrigenous input necessary for formation of the thick glaucony complexes on Devon Island, continuous subsidence over an extended period is inferred (J. D. Bloch, personal communication). A fluctuating paleoenvironmental setting is deduced for the Viks Fiord graben locality, where marine mudstones are interbedded with terrestrial sediments containing coal intercalations in facies transitional between the Kanguk and Expedition Fiord formations (Viks Fiord north composite section, Figure 3). Although there are similarities between the Eidsbotn and Viks Fiord successions, Viks Fiord appears to have been located in a shallower setting. In addition, fewer macrofossils were recovered from Viks Fiord graben.

Terrestrial sediments are also present in the uppermost portion of the Eidsbotn graben composite section, as indicated by the presence of coal intercalations, fossil root systems, coalified conifer wood, and terrestrial palynomorphs. Conifer forests have been reported from other Late Cretaceous Arctic localities as well (e.g., Falcon-Lang et al., 2004).

A rich, composite suite of macro- and microfossils from the Devon Island sections was used to reconstruct a Late Cretaceous paleocommunity (Chin et al., 2008), including plesiosaur and bird bones, fish teeth and bones, inoceramid and lingulid shells, crustacean carapaces, sponges, pollen, dinoflagellate cysts, radiolarians, silicoflagellates and the marine diatom flora reported herein. The diatoms were originally identified in thin sections of coprolite samples, presumed to have come from large vertebrates.

3. Materials and methods

Fifty-three sediment samples were collected during the 2003 field season. These samples are from the measured stratigraphic sections and are irregularly spaced (Chin et al., 2008). Samples were collected from below the slumped surface layer associated with freeze-thaw cycles. Stratigraphic positions of samples are indicated in Figures 2 & 3.

Chemical breakdown of the sediment was conducted in new 175 ml beakers (in order to prevent contamination with other material). Samples were broken into small fragments of 2–3 mm diameter, and treated in successive baths of HCl (~10%) and H₂O₂ (~37%), followed by washes in distilled water of not less than 6 h in duration. Diatoms were concentrated by decantation and removal of coarse clastic material. Residues were stored in plastic vials and protected from fungal growth by the addition of a few drops of formaldehyde. Slides were prepared by drying the residues onto 18 × 18 mm coverslips that were then mounted onto glass slides with Naphrax optical adhesive.

Light microscope examination of the slides was performed by means of a Leica DMLB microscope. A sample was considered barren if less than 5 identifiable diatom valves were found in 2 transects (ca. 144 fields of view at magnification ×1000) through the center of a coverglass. Two slides were counted for every diatom-bearing sample. Approximately 400–500 diatom valves were counted on each slide. Valve counting protocol followed the method of Schrader and Gersonde (1978), and numerical results are presented in Table 1.

Light photomicrographs were taken with a Nikon DS-2 digital camera and subsequently processed in Adobe Photoshop. Scanning electron microscope (SEM) examination was conducted with a Hitachi S-4500 microscope at Johann-Wolfgang Goethe University in Frankfurt am Main, Germany.

The following publications provided the principal reference for identifying the Late Cretaceous diatoms recovered from the Devon Island samples: Schmidt et al. (1874–1959), Pantocsek (1886, 1889), Strelnikova (1974), Hajós and Stradner (1975), Barron (1985), Harwood (1988), Dell’Agnese and Clark (1994), Tapia and Harwood (2002), and Davies (2006). Authorship of diatom taxa reported herein is given in Table 1, along with valve counting data. Consult the taxonomic list in Appendix 1 (Supplementary Material) for synonymy of taxa and comments.

4. Results

4.1. General taxonomic composition

Identifiable and sufficiently abundant diatoms are present in 15 of 53 samples examined. Moderate to well-preserved diatom valves (for an overview of preservation states see Figure 4) were identified in 11 samples from Eidsbotn graben (1 sandstone, 4 mudstone and 6 bentonite samples). Specimens are considered well-preserved if they retain delicate structures such as vela (Figure 4A), linking spines, outer and inner openings of processes, and girdle bands. In moderately preserved specimens the valve outline enables identification, but some breakage and/or dissolution of fragile valve structures is observed (Figure 4B). Samples collected at Viks Fiord graben show poorer preservation states; out of four diatom-bearing samples from mudstone beds, only sample VF0102 contains well-preserved diatoms. The remaining samples yielded etched and highly fragmented material (Figure 4C), showing signs of diagenetic change or redeposition, and are regarded as poorly preserved. As a result, many diatoms in these samples can be identified only to the generic level.

A total of 91 diatom taxa belonging to 41 genera were identified. Of these, four taxa were recognized as representing pre-

Figure 2. Stratigraphic columns representing sections measured in Eidsbotn graben. Datum for correlation is the base of the uppermost bentonite layer. Stratigraphic position of samples examined in this study, as well as the distribution of macrofossils, are indicated. Diatom-bearing samples are indicated in bold font. The frame in the lower left corner shows a simplified diagrammatic section of the geological setting of the studied deposit; a rotated, downfaulted block preserves a remnant of Cretaceous sediments within Paleozoic deposits (modified from Mayr et al., 1998, p. 248, following J.D. Bloch, personal communication).

Figure 3. Stratigraphic columns representing sections measured in Viks Fiord graben and the position of samples examined in this study as well as the distribution of macrofossils. Diatom-bearing samples are indicated in bold font. For explanations see Figure 2.

viously unknown genera and species (Figure 13), and will receive appropriate attention in separate publications. Centric diatoms constitute 97% of the identified taxa. Pennate diatoms are represented by only three species belonging to two araphid genera: *Incisoria* and *Sceptroneis*.

The terms “environmental assignment” or “environmental preferences” used below refer to whether a discussed species shows planktonic, tychoplanktonic or benthic characteristics, or whether it is considered a resting spore; these environmental preferences are used to identify ecological groups. Planktonic and probable planktonic diatoms dominate the studied assemblage (38.5% by number of species, 51.5% by abundance). Resting spores also indicate the presence of planktonic taxa and account for nearly 30% of the species (abundance: 33.1%). Probable tychoplanktonic diatoms are the least diverse ecological group in the studied community, comprising 7.7% of the identified taxa (9.8% abundance). Species identified as benthic forms account for 15.4% of the total number of species (1.6% abundance). No environmental assignment is made for the remaining 8.8% percent of taxa (4% by abundance). The majority of taxa encountered in the Upper Cretaceous strata of Devon Island represent extinct genera. Approximately one-third of the genera present in the studied material are extant: *Actinoptychus*, *Aulacodiscus*, *Coscinodiscus*, *Hemiaulus*, *Hyalodiscus*, *Paralia*, *Proboscia*, *Pseudopodosira*, *Rhizosolenia*, *Sceptroneis*, *Sheshukovia*, *Stellarima* and *Stephanopyxis*.

The assignment of environmental preferences to extinct species is difficult. In several cases, judgements are based on morphological features (adaptations for suspension in the water column or the presence of processes for attachment), chain formation, geographical distribution, and associated taxa in other assemblages. If possible, individuals were compared to extant species of the same genus. The groups of diatoms assigned to different environmental preferences are discussed below in order of abundance. Relative abundances of the taxa plotted against their stratigraphic occurrences are summarized in Figure 5.

All samples are dominated by planktonic diatoms and resting spores, although their percentages vary in each sample. Treated together, these two groups constitute as much as 68.1% of the total number of taxa, representing 84.7% of the community in terms of abundance. The lowest abundances of planktonic forms are exhibited by samples EF0402 (20.7%), EF0401 (22.4%), and VF0305 (20.4%). In contrast, planktonic diatoms are the most abundant in samples collected from bentonite beds, particularly EF0303 and EF0304 (74.7% and 67.4%, respectively).

The highest abundance of tychoplanktonic diatoms is observed in sample EF0402 (32.7%), whereas sample EF0304 shows the lowest relative abundance of tychoplanktonic

forms, equal to 0.41%. Benthic diatoms reach the highest abundances in samples collected from the upper part of the studied section (samples EF0106 and EF0107, 3.95% and 3.85% respectively). This is consistent with the general interpretation of the studied section as a regressive sequence. Valves belonging to taxa of unknown environmental preferences are abundant in samples collected from the lowermost strata in the section (sample EF0401, 3.6%), and in samples collected from bentonite beds (specimens of an indeterminate genus reach an abundance of 21.4% in sample EF0304).

Stratigraphic ranges of selected taxa and relative abundances of environmental groups in individual samples are presented in Figure 5. The Eidsbotn graben composite section and Eidsbotn section 3 are plotted separately, because biostratigraphic and lithostratigraphic correlations between the sections are tentative. Viks Fiord north composite section and Viks Fiord section 3 are plotted in stratigraphic order. A few species are present in all studied samples: *Cortinocornus rossicus* (Figure 8A–E, H, R, S; Figure 12A–D), *Costopyxis antiqua* (Figure 7G; Figure 11L), *Costopyxis schulzii* f. *ornata* (Figure 11J), *C. schulzii* (Figure 7E, F, M, N; Figure 11K), *Hemiaulus asymmetricus* (Figure 8K, L) and *Hemiaulus polymorphus* (including *H. polymorphus* var. *frigida*; Figure 9L, M).

4.2. Environmental preferences of the identified taxa

4.2.1. Planktonic and probable planktonic taxa

This most common group of diatoms in the studied material includes 35 taxa (38.5% of total number of taxa, 51.5% by abundance), belonging to 13 genera: *Briggera*, *Cortinocornus*, *Coscinodiscus*, *Gladiopsis*, *Gladius*, *Hemiaulus*, *Proboscia*, *Sphinctoethus*, *Stephanopyxis*, *Thalassiosiropsidella*, *Thalassiosiropsis*, *Trinacria* and *Trochosiropsis*. The most abundant taxa are discussed below.

Hemiaulus is a common Cretaceous and Paleogene taxon and is represented by the largest number of species (14 species and 1 variety) in the studied material. Its most common representatives are: *Hemiaulus antiquus* (31.6% of valves counted in sample EF0304; Figure 8O, P; Figure 12H, I) and *H. asymmetricus* (29% of valves counted in sample EF0307). *Hemiaulus* species are present in all diatom-bearing samples from Devon Island, although their relative abundance varies. The fewest representatives of this genus occur in samples VF0303, VF0305 and VF0104 (three to four species), most likely due to the poor state of preservation. In well-preserved samples the number of *Hemiaulus* species ranges from 4 (sample EF0102) to 12 (sample EF0107).

Cortinocornus is also a common genus in the studied material. *C. rossicus* is the second most abundant taxon, and is represented by two basic morphotypes: the first morphotype

Table 1 (continued). Percentages of taxa occurring in each sample. '+' stands for 'present'.

Sample number	EF0401	EF0402	EF0102	EF0104	EF0103	EF0106	EF0107	EF0309	EF0307	EF0304	EF0303	VF0305	VF0104	VF0102
Lithology	Sandstone	Mudstone	Mudstone	Mudstone	Mudstone	Bentonite	Bentonite	Bentonite	Bentonite	Bentonite	Bentonite	Mudstone	Mudstone	Bentonite
Preservation	Good	Moderate	Good	Good	Good	Good	Good	Good	Good	Good	Moderate	Poor	Poor	Good
Number of valves counted	987	842	984	1023	1142	1012	960	963	1001	984	940	1027	1101	1035
Percentages														
<i>Medinia decusii</i> (Hanna) Nikolaev and Kociolek, 2001				1.27	0.88	0.79	0.94	1.04	0.8	0.1	0.64	0.4	0.09	1.26
<i>Medinia fenestrata</i> (Witt) Sims, 1998					0.18									
<i>Medinia weissei</i> (Grunow in Schmidt et al.) Sims, 1998					0.09									
<i>Odontotropis carinata</i> Grunow, 1884					+									
<i>Odontotropis cristata</i> Grunow, 1884					0.09									
<i>Paralia crenulata</i> (Grunow) Gleser et al., 1992	588	8.31	12.7	5.57	12.4	0.1		0.1	0.3		0.11	3.8	20.4	0.19
<i>Paralia fausta</i> (Schmidt) Sims and Crawford, 2002			0.61		0.18									0.19
<i>Paralia ornata</i> (Grunow) Grunow ex van Heurck, 1882	18.9	24.2	8.84	2.93	1.23	1.48	0.31	1.66	1.3	0.3	0.43	1.01	0.58	1.74
<i>Paralia sulcata</i> (Ehrenberg) Cleve, 1873	0.1	0.12	0.51			0.1					2.73			0.29
<i>Poretzia</i> sp. cf. <i>P. umbonata</i> Gleser, 1962						1.09	1.25	1.77	1		0.11			1.16
<i>Proboscia unicomis</i> Jordan and Ito, 1992						0.2	0.52							0.19
<i>Pseudaulacodiscus</i> sp. A						2.96	2.29	2.91	0.7	1.93	3.83			1.35
<i>Pseudopodocira reticulata</i> Strelnikova, 1974	1.01					2.96	2.4	0.1		0.61	0.32			1.55
<i>Pseudopodocira westii</i> (Smith) Sheshukova-Poretzkaya and Gleser, 1964					0.09									
<i>Pseudopyxilla aculeata</i> Jousé, 1951	0.61													
<i>Pseudopyxilla americana</i> (Ehrenberg) Forti, 1909			0.41		0.61			0.31				0.1		
<i>Pseudopyxilla</i> sp. A	+	+												
<i>Pseudopyxilla</i> sp. B		0.12				0.1			0.3					0.1
<i>Pseudopyxilla</i> spp.	0.71		0.1						0.1					
<i>Pterotheca aculeifera</i> Grunow in Van Heurck, 1880–1885		0.48			0.18	0.2	0.73	0.21	0.5			0.1		0.87
<i>Pterotheca alata</i> Strelnikova, 1971	0.61	1.31			0.09									
<i>Pterotheca clavata</i> Strelnikova, 1974	0.1	1.78				0.4	0.42	0.1		0.1	0.32			0.1
<i>Pterotheca evermanni</i> Hanna, 1927	0.1		0.3	0.68	0.26	0.2	0.42	0.21	0.2					0.19
<i>Pterotheca simplex</i> Strelnikova, 1971														
<i>Pterotheca</i> sp. A	0.61	0.12			0.18	0.89	0.73	0.62	0.2	0.3	0.11			
<i>Pterotheca</i> spp.	0.41	0.83	0.1	0.1		1.58	2.5	1.66		0.51	0.43	0.39	0.09	0.39
' <i>Pterotheca</i> ?' sp. 'Strelnikova, 1974		0.12			0.2	0.2	0.21		0.2	0.1	0.11			0.48
<i>Pyrgodiscus triangulatus</i> Hajós and Stradner, 1975	2.33													
<i>Rhizosolenia dubia</i> (Grunow) Homann, 1991	0.61	0.59			0.18	0.69	1.04	0.1	0.1	0.2	0.11			0.68
<i>Septoneis dimorpha</i> Strelnikova, 1974						0.3	0.42			0.41				
<i>Septoneis</i> sp. cf. <i>S. gracilis</i> Hajós, in Hajós and Stradner 1975		0.12				0.1	0.1			0.71				
<i>Sheshukovia excavata</i> (Heiberg) Nikolaev and Harwood in Nikolaev et al., 2001			0.1		0.18	0.2	0.31	0.42	0.6	0.3	0.11	0.1	0.27	0.68
<i>Sphinctrolethus hemiauloides</i> Sims, 1986						0.4	0.94				0.11			
<i>Stellarima steinyi</i> (Hanna) Hasle and Sims, 1986		1.19			1.19		1.67	2.08	0.6	0.71	0.85		0.27	3
<i>Stephanopyxis barbadensis</i> (Greville) Grunow, 1884							0.31	0.31						
<i>Stephanopyxis dissonus</i> (Schulz) Strelnikova and Nikolaev in Gleser et al., 1988			0.3	0.1	1.14			0.1				0.71	0.09	
<i>Stephanopyxis grunowii</i> Grove and Sturt, in Schmidt et al. 1888														
<i>Stephanopyxis</i> spp.	0.91	0.71	0.61	1.27	2.01	0.1		0.1	1.1	0.41	0.11		0.18	0.58
<i>Thalassiosiropsidella simsi</i> Nikolaev and Harwood, 2007	+	+	1.63	0.98	2.45	1.48	0.83	1.14	1.4	1.12	2.13	0.68	2.45	1.35
<i>Thalassiosiropsidella simsi</i> Nikolaev and Harwood, 2007		0.71										2.82	0.73	0.48
<i>Thalassiosiropsidella wilfiana</i> (Pantocsek) Hasle, in Hasle and Syvertsen 1985	0.71		0.81	0.29	0.35	0.2	0.31	0.42		0.71	0.53			1.06
<i>Trinacria indefinita</i> Jousé, 1951					0.26	1.38	1.67	0.31	0.3	1.22	0.74		0.45	0.19
<i>Trinacria</i> spp.			0.41	0.2	0.26	0.89	2.4	0.42		4.67	1.06	0.1		0.39
<i>Trochosiropsis polychaeta</i> (Strelnikova) Tápia, 2002				+		7.31	13.3	1.56		21.4	7.45			0.1
<i>Truana archangeliskana</i> Pantocsek, 1886		2.26												1.93
Unknown genus and species #1														
Unknown genus and species #2														
Unknown genus and species #3														
Unknown genus and species #4	0.2		0.41	0.29	0.53			0.1

Figure 6. Light Microscope (LM) photomicrographs of diatoms from Devon Island. Magnification $\times 1500$. A and B. *Lepidodiscus elegans* Witt, sample EF0103. Valve view. High and low focus of the same specimen. C and D. *Actinodictyon* sp. aff. *A. antiquorum* Pantocsek, sample EF0103. Valve view. High and low focus of the same specimen. E. *Paralia ornata* (Grunow) Grunow ex van Heurck, sample EF0103. Valve view. F. *Truania archangelskiana* Pantocsek, sample EF0102. Valve view. G. *Paralia fausta* (Schmidt) Sims and Crawford, sample EF0102. Valve view. H. *Paralia sulcata* (Ehrenberg) Cleve, sample VF0102. Valve view. I and J. *Pseudopodosira reticulata* Strelnikova. I and J – sample EF0106, chain of two cells in girdle view. High and low focus of the same specimen. K. *Actinoptychus tenuis* Strelnikova, sample EF0304. Valve view. L and M. *Archepyrigus* sp. aff. *A. melosiroides* Gersonde and Harwood, sample EF0401. Girdle view. High and low focus of the same specimen. N and O. *Amblypyrgus* sp. A, sample EF0402. Girdle view. High and low focus of the same specimen.

Figure 7. LM photomicrographs of diatoms from Devon Island. Magnification $\times 1500$, unless stated otherwise. A and B. *Aulacodiscus* sp. cf. *A. insignis* Hustedt, sample EF0103. Valve view. High and low focus of the same specimen. Magnification $\times 750$. C and D. *Hyalodiscus nobilis* Pantocsek, sample EF0309. Valve view. High and low focus of the same specimen. Magnification $\times 750$. E and F. *Costopyxis schulzii* (Steinecke ex Schulz) Gleser, sample EF0401. Frustule in girdle view. High and low focus of the same specimen. Magnification $\times 750$. G. *Costopyxis antiqua* (Jousé) Gleser, sample EF0402. Frustule in girdle view. High and low focus of the same specimen. Magnification $\times 750$. H and I. *Paralia crenulata* (Grunow) Gleser, sample EF0102. Valve view. High and low focus of the same specimen. Magnification $\times 750$. J and K. *Trochoiroopsis polychaeta* (Strelnikova) Tapia, sample EF0304. Valve view. High and low focus of the same specimen. Magnification $\times 750$. L. *Pyrgodiscus triangulatus* Hajós and Stradner, sample EF0402. Valve view. High and low focus of the same specimen. Magnification $\times 750$. M and N. *Costopyxis schulzii* (Steinecke ex Schulz) Gleser, sample EF0103. Frustule in girdle view. High and low focus of the same specimen. Magnification $\times 750$. O and P. Filament of *Paralia crenulata* terminated with a valve of *Costopyxis schulzii* in girdle view, sample EF0103. High and low focus of the same specimen. Magnification $\times 750$. Q and R. *Gladius antiquus* Forti and Schulz, sample EF0402. Girdle view. High and low focus of the same specimen. Magnification $\times 750$. S. *Gladiopsis speciosa* (Schulz) Gersonde and Harwood f. *porata* Strelnikova, sample VF0102. Girdle view. Magnification $\times 870$.

Figure 8. LM photomicrographs of diatoms from Devon Island. Magnification $\times 1500$. A-E, H, R and S. *Cortinocornus rossicus* (Pantocsek) Gleser. A and B, H, R and S – first morphotype. A and B – sample EF0103. Frustule in girdle view. High and low focus of the same specimen. H – sample EF0103. Valve view. R and S – sample EF0103. Valve view. High and low focus of the same specimen. C-E – second morphotype. C and D – sample EF0304. Frustule in girdle view. High and low focus of the same specimen. E – sample VF0102. Valve view. F, M and N. *Cortinocornus?* sp. A, sample EF0402. F – frustule in girdle view. M and N – valve view. High and low focus of the same specimen. G. *Hemiaulus speciosus* Jousé, sample EF0103. Girdle view. I and J. *Trinacria indefinita* Jousé, sample EF0309. Valve view. High and low focus of the same specimen. K and L. *Hemiaulus asymmetricus* Jousé, sample EF0103. Girdle view. High and low focus of the same specimen. O and P. *Hemiaulus antiquus* Jousé, sample EF0304. Frustule in girdle view. High and low focus of the same specimen. Q. *Hemiaulus echinulatus* Jousé, sample EF0103. Girdle view.

Figure 9. LM photomicrographs of diatoms from Devon Island. Magnification $\times 1500$, unless stated otherwise. A. *Briggera includens* (Grunow) Ross and Sims, sample EF0107. Valve view. Magnification $\times 1250$. B and C. *Hemiaulus sporalis* Strelnikova, sample EF0309. Short chain of two vegetative valves, each bearing a semi-endogenous resting spore. Girdle view. High and low focus of the same specimen. D and E. *Hemiaulus?* sp. A, sample VF0102. Frustule in girdle view. High and low focus of the same specimen. F–H. *Medlinia deciusii* (Hanna) Nikolaev and Kociolek. F – sample EF0103. Teratoid quadripolar form in valve view. G – sample EF0103. Girdle view. H – sample EF0103. Valve view. I. *Medlinia fenestrata* (Witt) Sims, sample EF0103. Valve view. Magnification $\times 900$. J. *Medlinia weissei* (Strelnikova) Sims, sample EF0103. Valve view. Magnification $\times 750$. K. *Hemiaulus?* sp. B, sample EF0103. Girdle view. L and M. *Hemiaulus polymorphus* Grunow, sample EF0103. Frustule in girdle view. High and low focus of the same specimen. N. *Sheshukovia excavata* (Heiberg) Nikolaev and Harwood, sample EF0107. Valve view. Magnification $\times 750$.

Figure 10. LM photomicrographs of diatoms from Devon Island. Magnification $\times 1500$, unless stated otherwise. A and B. *Pterotheca evermanni* Hanna, sample EF0309. Girdle view. High and low focus of the same specimen. C and D. "*Pterotheca?* sp." Strelnikova, sample VF0102. Girdle view. High and low focus of the same specimen. E. *Hemiaulus sporalis* Strelnikova, resting spore, sample EF0309. Valve view. F and G. *Pterotheca aculeifera* Grunow, sample EF0107. Girdle view. High and low focus of the same specimen. H. *Gladiopsis* sp. A, sample EF0103. Girdle view. Magnification $\times 750$. I. *Pseudoaulacodiscus* sp. A, sample EF0106. Valve view. J. *Chasa bicornis* Hanna, sample EF0304. Girdle view. K, Y and Z. *Dasyangea dactylethra* Harwood and Gersonde. K. – EF0102, frustule in girdle view. Y and Z. – sample EF0107, frustule in girdle view. High and low focus of the same specimen. L. *Proboscia unicornis* Jordan and Ito, sample EF0103. Lateral view of the proboscis. M and N. *Sceptroneis* sp. cf. *S. gracilis* Hajós, sample EF0304. Valve view. High and low focus of the same specimen. O–R. *Sceptroneis dimorpha* Strelnikova. O and P. – sample EF0107. Valve view. High and low focus of the same specimen. Q and R. – sample EF0304. Valve view of a broken specimen. High and low focus of the same specimen. S and T. *Incisor lanceolata* Hajós and Stradner, sample EF0106. Valve view. High and low focus of the same specimen. U. *Stellarima steinyi* (Hanna) Hasle and Sims, resting spore, sample EF0307. Valve view. V and W. *Pterotheca* sp. A, sample EF0401. Girdle view. High and low focus of the same specimen. X. *Pterotheca clavata* Strelnikova, sample EF0107. Girdle view.

Figure 11. Scanning Electron Microscope (SEM) photomicrographs of diatoms from Devon Island. Scale bars = 10 μ m. A. *Aulacodiscus* sp. cf. *A. insignis* Hustedt, sample EF0103. Valve view. B. *Thalassiosiropsis wittiana* (Pantocsek) Hasle, sample EF0106. Internal valve view. C. *Gladiopsis speciosa* (Schulz) Gersonde and Harwood f. *porata* Strelnikova, sample VF0102. Valve view. D. *Paralia ornata* (Grunow) Grunow ex van Heurck, sample EF0102. Oblique view. E. *Paralia crenulata* (Grunow) Gleser, sample EF0102. Oblique view. F. *Lepidodiscus elegans* Witt, sample EF0103. Oblique view. G. *Stephanopyxis dissonus* (Schulz) Strelnikova and Nikolaev, sample EF0103. Valve view. H. *Stephanopyxis grunowii* Grove and Sturt, sample EF0102. Oblique view. I. *Truania archangelskiana* Pantocsek, sample EF0103. Oblique view. J. *Costopyxis schulzii* (Steinecke ex Schulz) Gleser f. *ornata* Strelnikova, sample EF0401. Frustule in oblique view. K. *Costopyxis schulzii* (Steinecke ex Schulz) Gleser, sample EF0106. Girdle view. L. *Costopyxis antiqua* (Jousé) Gleser, sample EF0102. Oblique view.

speciosa are present, with low and variable abundance: *f. aculeolata*, *f. porata* and *f. speciosa* (Strelnikova, 1966, 1974). The planktonic nature of this genus is inferred mainly from the cosmopolitan distribution of its representatives (Davies, 2006).

4.2.2. Resting spore taxa

An important paleobiological challenge faced by all studies of fossil diatom floras is discriminating between vegetative cells and resting spores. The criteria of Gersonde and Harwood (1990) are followed in the present study, with vegetative cells considered to have relatively lightly silicified frustules with perforate walls and larger cell volume (see also French and Hargraves, 1980; Kitchell et al., 1986). Resting spores are generally considered to lack girdle elements (Hargraves, 1986).

Taxa regarded as probable diatom resting spores represent the second most numerous and diverse group in this study, comprising 27 taxa (29.7% of total number of taxa, 33.1% of the assemblage by abundance) belonging to 14 genera: *Chasea*, *Cladogramma*, *Costopyxis*, *Dasyangea*, *Goniothecium*, *Hemiaulus*, *Odontotropis*, *Poretzia*, *Pseudoaulacodiscus*, *Pseudopyxilla*, *Pterotheca*, *Pyrgodiscus*, *Rhizosolenia* and *Stellarima*. Resting spores are present in all diatom-bearing samples examined in this study, although their relative abundance varies.

Costopyxis is the most abundant taxon in the studied assemblage, occurring in every diatom-bearing sample. The highest abundance is observed in sample VF0305, where *C. schulzii* constitutes 74% of the assemblage. Other *Costopyxis* species encountered in the studied material occur less frequently. Significant morphological variation is observed within this genus (Figure 7E–G, M–P; Figure 11J–L). *Costopyxis* has previously been regarded as a resting spore (Suto et al., 2009), but it has never been reported in association with chains of *Paralia*. A chain of *Paralia crenulata* valves terminated with a valve of *C. schulzii* (Figure 7O, P) was found in sample EF0103. No similar specimens were found in this study and it cannot be excluded that empty valves of these two genera happened to fit together accidentally. To our knowledge, neither fossil nor extant species of *Paralia* have previously been reported to form resting spores, and *Costopyxis* only occurs together with *Paralia* in the Arctic fossil localities (Strelnikova, 1974; Tapia and Harwood, 2002). We suggest that *Costopyxis* may have been a resting spore of the genus *Paralia*, but further study is required.

Pterotheca and *Pseudopyxilla* are the most diverse resting spore genera in the studied material, represented by seven and four species respectively, although species belonging to these genera rarely exceed a relative abundance of 1%. The most frequently encountered taxa are: *Pterotheca evermanni* (Figure 10A, B), *Pterotheca clavata* (Figure 10X) and *Pterotheca aculeifera* (Figure 10F, G), followed by species of *Pseudopyxilla*.

Hemiaulus sporalis (Figure 9B, C; Figure 10E; Figure 12K) commonly occurs as semi-endogenous resting spores, often associated with a remnant vegetative valve. In the studied material, the resting spores of this taxon are more abundant than vegetative valves (the maximum abundance of resting spores is 10.4% in sample EF0307).

Goniothecium odontellum sensu Strelnikova (name applied following Sims and Mahood, 1998) (Figure 12P) is common in the upper part of the section, with a maximum abundance of 5.2% in sample EF0307, and 4.8% in samples EF0309 and VF0102. Resting spores of *Stellarima steinyi* (Figure 10U) are also encountered frequently toward the top of the section (3% in sample VF0102). *Pyrgodiscus triangulatus* (Figure 7L) is considered a resting spore, following Harwood (1988).

This study documents the presence of *Dasyangea dactylethra* (Figure 10K, Y, Z) in deposits younger than the Lower Cretaceous. Spores conforming to the type species description and illustrations (Harwood and Gersonde, 1990) occur in the middle and higher parts of the studied section.

4.2.3. Tychoplanktonic taxa

It is difficult to attribute a tycho planktonic (from Greek “tycho” – “accidental,” meaning “accidentally suspended”) nature to diatom taxa lacking modern representatives. For this reason, only seven species (within two genera) are included in this group (7.7% of the identified taxa, 9.8% abundance). Tycho planktonic preferences are presumed for species of *Medlinia* (following the suggestion of Davies, 2006) and *Paralia* (following McQuoid and Nordberg, 2003). Although only seven species are considered to be tycho planktonic, in certain samples they are the most abundant group (e.g., EF0402, which has 32.7% tycho planktonic, and 20.7% planktonic diatoms). In such samples, species of *Paralia* can account for more than 20% of the assemblage. The most common members of this genus are *P. crenulata* (Figure 7H, I; Figure 11E) in sample VF0104 and *Paralia ornata* (Figure 6E; Figure 11D) in sample EF0402. *Paralia fausta* (Figure 6G) and *Paralia sulcata* (Figure 6H) are less frequent and occur only in a few samples.

Medlinia is represented by three species (Figure 9F–J; Figure 12G): *Medlinia deciusii* (maximum abundance of 1.3% in sample EF0104), *Medlinia fenestrata* and *Medlinia weissei* (occurring with minor abundances). General environmental preferences for *Medlinia* are unclear. Davies (2006) suggested a neritic environment as the most probable for this genus, based on the considerable silicification of its valves, as well as its limited geographical distribution. In the Kanguk Formation on Devon Island, the relative abundance of valves of *M. deciusii* is constant both in more distal sediments, and in more proximal deposits. For this reason, a tycho planktonic preference is inferred.

4.2.4. Benthic and probable benthic taxa

Benthic diatoms constitute 15.4% of the studied assemblage in terms of number of taxa, comprising 14 species within the following 9 genera: *Actinodictyon*, *Actinoptychus*, *Aulacodiscus*, *Hyalodiscus*, *Lepidodiscus*, *Pseudopodosira*, *Sceptroneis*, *Sheshukovia* and *Truania*. The abundance of benthic diatoms is the lowest among all ecological groups in the Devon Island deposit (1.6%), suggesting that most depositional settings were below the euphotic zone. Environmental assignment of taxa is based mostly on literature conjecture (e.g., Olshtynskaya, 1990; Round et al., 1990; Sims and Crawford, 2007; Tiffany, 2008) and comparisons to extant representatives of the genera. Thus, some of the paleoenvironmental diagnoses remain tentative. Nevertheless, the majority of genera placed in this category are extant; as diatoms of known environmental preference, extant genera do not require a detailed discussion.

Actinodictyon and *Lepidodiscus* (Figure 6A–D) are large diatoms with numerous processes located close to the margins of the valve, and for this reason are regarded as benthic, probably living attached to various substrates. A benthic affinity is also suggested for *Truania* (Figure 6F; Figure 11I), an extinct taxon with a restricted geographic distribution (Sims and Crawford, 2007) combined with remarkably heavy silicification of its cells (to date not reported as chains; see Crawford and Sims, 2008).

Sceptroneis is considered an epiphytic taxon (Round et al., 1990). Based on valve outline, two forms are tentatively distinguished in the studied material (Figure 10M–R). This araphid pennate diatom and the related genus *Incisorina* (Figure 10S, T) of unknown environmental preferences, are observed in only three samples (EF0106, EF0107, EF0304) with good preservation, collected from the upper part of the studied succession. Their individual abundances do not exceed 1% in any sample.

4.3. Stratigraphic succession of diatom assemblages

Three diatom assemblages are identified in the Devon Island samples based on stratigraphic occurrences of the taxa (Figure 14). These assemblages reflect environmental changes and

Figure 12. SEM photomicrographs of diatoms from Devon Island. Scale bars = 10 μm , except for figs. F and H (1 μm). A and B. *Cortinocornus rossicus* (Pantocsek) Gleser, first morphotype, sample EF0103. A. – girdle view. B. – oblique view. Preserved girdle elements visible in both images. C and D. *Cortinocornus rossicus* (Pantocsek) Gleser, second morphotype, sample EF0106. C. – girdle view. D. – valve view. E. *Cortinocornus?* sp. A, sample EF0402. Oblique view. F. *Proboscia unicornis* Jordan and Ito, detail of the proboscis, sample EF0309. G. *Medlinia decusii* (Hanna) Nikolaev and Kocielek, sample EF0103. Valve view. H and I. *Hemiaulus antiquus* Jousé, sample EF0304. H. – detail, showing the exceptional preservation state of cribra occluding the areolae. I. – valve view. J. *Poretzкия* sp. cf. *P. umbonata* Gleser, sample EF0106. Oblique view. K. *Hemiaulus sporalis* Strelnikova, sample EF0309. Paired vegetative cells with a resting spore in girdle view. L. *Pterotheca alata* Strelnikova, sample EF0103. Girdle view. M. “*Pterotheca?* sp.” Strelnikova, sample EF0102. Girdle view. N and O. *Pseudoaulacodiscus* sp. A, sample EF0309. N. – epivalve in valve view. O. – hypovalve in valve view. P. *Goniothecium odontellum* Ehrenberg sensu Strelnikova, sample EF0106. Oblique view.

Figure 13. LM photomicrographs of unknown diatom taxa from Devon Island. Magnification $\times 1500$. A and B. Unknown genus and species #3, sample EF0103. Valve view. High and low focus of the same specimen. C and D. Unknown genus and species #4, sample EF0103. Girdle view. High and low focus of the same specimen. E. Unknown genus and species #2, sample EF0402. F–H. Unknown genus and species #1, sample EF0107. F and G – Valve view, high and low focus of the same specimen. H – Sibling valves, girdle view.

Figure 14. Diatom-based biostratigraphy and correlation of Eidsbotn graben and Viks Fiord graben sections. For lithology explanations see Figure 2.

depositional conditions, and provide important stratigraphic context for the studied succession.

4.3.1. Assemblage 1

Samples EF0401 and EF0402 from the bottom part of the Eidsbotn graben composite section and VF0303 and VF0305 from the Viks Fiord graben section 3 are grouped within assemblage 1. It includes *C. schulzii*, *P. ornata*, *P. crenulata*, *Gladus antiquus* (Figure 7Q, R), *Archepyrgus* sp. aff. *A. melosiroides* (Figure 6L, M) and *Amblypyrgus* sp. A (Figure 6N, O).

Samples VF0303 and VF0305 show poor preservation and in many cases allow identification of diatoms only to the generic level. Diatom valves found in both samples are considerably fragmented, and exceptionally high abundances of strongly silicified taxa (*C. schulzii* accounts for 74% valves found in sample VF0305) suggest selective dissolution. The number of taxa identified in samples EF0401 and EF0402 is similar, and so are relative abundances of ecological groups (Figure 5). The only significant difference between these Eidsbotn samples concerns the relative abundance of tychoplanktonic taxa; there is a higher proportion of *P. crenulata* and *P. ornata* in sample EF0402. Despite the difference in sediment lithology (sandstone versus mudstone), samples EF0401 and EF0402 occur within 5 m from each other (which is reflected in their taxonomic similarity) and show moderate to good preservation of siliceous microfossils.

4.3.2. Assemblage 2

Assemblage 2 is represented by samples EF0102, EF0104, EF0103 (middle part of the Eidsbotn graben composite section) and VF0104 (lower part of the north composite section in Viks Fiord graben). The most important taxa of this assemblage are: *C. rossicus* (first morphotype), *P. crenulata*, *H. polymorphus* var. *frigida*, *C. antiqua*, *C. schulzii*, *C. schulzii* f. *ornata*, *S. dissonus*, *S. grunowii* and *M. deciusii*. The most abundant species are *C. schulzii* (47.5% in sample VF0104), and the first morphotype of *C. rossicus* (37.3% in sample EF0104).

Samples EF0102, EF0104 and EF0103 were collected from mudstones over an interval of ca. 35 m. The relative abundances of each ecological group within these samples are similar (Figure 5), but the number of taxa identified in EF0103 is higher than in the remaining samples. Sample VF0104 was collected from a mudstone bed in a section of uncertain stratigraphic context, with terrestrial facies interfingering with marine facies, and with three major intervals of indeterminate lithology due to surface layer slumping. Preservation of siliceous microfossils in sample VF0104 is poor. High abundance of *C. schulzii* (47.5%) relative to other species in this sample is interpreted as a result of selective dissolution.

4.3.3. Assemblage 3

Samples EF0106 and EF0107 (Eidsbotn graben composite section), EF0309, EF0307, EF0304 and EF0303 (Eidsbotn graben section 3), and VF0102 (Viks Fiord graben north composite section) are included in assemblage 3. The most important species in this assemblage are: *H. antiquus*, *C. rossicus* (second morphotype), *H. asymmetricus*, *Pseudoaulacodiscus* sp. A (Figure 10I; Figure 12N, O), *S. steinyi*, *Trinacria indefinita* (Figure 8I, J), and *D. dactylethra*. Another important taxon present in all of these samples is the unknown genus and species #1 (Figure 13F–H), accounting for more than 21% of the valves counted in sample EF0304. Except for mudstone samples EF0307 and VF0102, all samples in this group were collected from bentonite beds. The number of species ranges from 34 (EF0307) to 55 (EF0106). Percentages of each ecological group are similar in all samples within this assemblage (Figure 5). Samples collected near the top of Eidsbotn section 3 are relatively closely spaced and cover a short stratigraphic inter-

val (about 10 m). Preservation of diatom valves in most of the samples in this assemblage (except for EF0303) is exceptionally good (e.g., Figure 4A; Figure 12H).

5. Discussion

5.1. Biostratigraphy

Diatoms recovered from Kanguk Formation outcrops on Devon Island occur in sufficient numbers to reconstruct their stratigraphical context relative to other diatom-bearing deposits in the Arctic Ocean region. The irregular sample spacing, however, does not allow establishment of an independent biostratigraphic zonation; most diatom-based biostratigraphic frameworks for Cretaceous sediments have been erected based on continuous successions from both continental outcrops (West Siberian Lowlands: Strelnikova, 1974; Canadian Margin: Tapia and Harwood, 2002) and oceanic drilling (DSDP Site 275: Hajós and Stradner, 1975).

Sediments outcropping in the studied grabens are not precisely dated because of the preservational bias against calcareous fossils and because correlation between the sequences exposed in both grabens is unclear. The only stratigraphic markers beside the diatoms reported herein, are the palynomorphs *T. plicatilis*, found in the upper part of the Kanguk Formation exposure at Eidsbotn graben and *W. edmontoniicola*, present in the Expedition Fiord Formation at Viks Fiord graben (Chin et al., 2008). These suggest an equivalence with the Campanian of Alberta and indicate the following time intervals: 73–76 Ma (*T. plicatilis*) and 72–73.5 Ma (*W. edmontoniicola*) (Lerbekmo and Braman, 2002; Chin et al., 2008).

The biostratigraphic zonation proposed for the Canadian Arctic by Tapia and Harwood (2002) is based on stratigraphic sections and samples collected by Geological Survey of Canada geologists during surveys of Ellesmere Island, Ellef Ringnes Island, Eglington Island and the Anderson Plains in Northwest Territories, mainland Canada. Four biostratigraphic units for the Cenomanian through the Campanian of the Canadian Arctic area were described (Tapia and Harwood, 2002): (1) the *G. antiquus* Concurrent Range Zone, defined as the interval between the first occurrence of *Basilicostephanus* sp. 1 and the last occurrence of *G. antiquus*; (2) the *C. antiqua* Partial Range Zone, comprising the interval from the last occurrence of *G. antiquus* up to the last occurrence of the nominative taxon; (3) the *Trinacria indefinita* Interval Zone, comprising the interval between the last occurrence of *C. antiqua* and the first occurrence of *Stephanopyxis simonseni*; and (4) the *S. simonseni* Partial Range Zone, spanning the stratigraphic interval up to the first occurrence of *Azpeitiopsis morenoensis*. Application of the Tapia and Harwood (2002) diatom zonation scheme to the sequences on Devon Island suggests that the studied interval of the Kanguk Formation should be placed within the two lowermost zones, tentatively dated for the Santonian (assemblage 1) and the Campanian (assemblages 2 and 3).

Assemblage 1 is correlative with the *G. antiquus* Concurrent Range Zone, based on the presence of the following taxa: *G. antiquus*, *C. schulzii*, *C. schulzii* f. *ornata*, *G. speciosa*, *P. ornata* (Tapia and Harwood, 2002). Additional taxa known to co-occur with *G. antiquus* in the Lower Cretaceous are also found in the deposit: *Amblypyrgus* sp. A and *Archepyrgus* sp. aff. *A. melosiroides* (both restricted to assemblage 1), plus *D. dactylethra* (found in assemblages 2 and 3). Tapia and Harwood (2002) reported the last occurrence of *G. antiquus* (zonal marker for the top of this biostratigraphic unit) to approximate the Santonian–Campanian boundary. *G. antiquus* is present in all samples included in assemblage 1, but absent from assemblages 2 and 3, suggesting that the Santonian–Campanian boundary occurs in the sediments between samples EF0402 and EF0102. Tapia

Figure 15. Diagram showing an idealized cross-section along a water-depth transect on the Late Cretaceous shelf of the Arctic Ocean. The inferred position and relative paleodepth of the sites discussed in this paper are indicated. For details concerning localities other than Devon Island field sites please refer to Tapia and Harwood (2002) and Davies et al. (2009).

and Harwood (2002) did not report occurrences of the genera *Amblypyrgus* and *Archeopyrgus* from the Santonian of the Canadian Arctic, but Gersonde and Harwood (1990) described both genera from the Aptian–Albian deposits of the Weddell Sea, Antarctica. The diatom assemblages recovered from samples EF0401 and EF0402 differ significantly from all other samples collected in the Eidsbotn graben, however, they do not provide any constraints for the age of the bottom part of the studied succession, which may extend down below the Santonian. Thus, from data in this study, it is only possible to conclude that the sediments comprised in assemblage 1 were deposited between the Albian and the end of the Santonian. The presence of *G. antiquus* in section 3 of Viks Fiord graben provides a means of correlation between sections within this graben, indicating that section 3 underlies the north composite section.

An additional biostratigraphic marker found in samples EF0401 and EF0402, *Thalassiosiropsidella simsii*, allows correlation with the Cretaceous diatom-bearing sequence of ODP Hole 748C (Nikolaev and Harwood, 2007). To date, this rare taxon has only been reported from one core-section in the upper Campanian of the central Kerguelen Plateau (Shipboard Scientific Party, 1989). Its presence in the inferred Santonian interval of the Kanguk Formation on Devon Island clearly indicates its global distribution and a longer stratigraphic range.

Both assemblages 2 and 3 are correlative with the *C. antiqua* Partial Range Zone of Tapia and Harwood (2002), based on the presence of *C. antiqua*, *Basilicostephanus* sp. 1, *C. schulzii*, *C. schulzii* f. *ornata*, *L. elegans*, *P. ornata* and *M. decusii*. In the Devon Island sections, this zone comprises two quite distinct diatom assemblages. Although *T. indefinita*, the nominative taxon for the overlying Interval Zone is a part of assemblage 3, the zonal marker for the top of *C. antiqua* Zone is not observed in this study. This suggests that in the future studies, *C. antiqua* Zone may be subdivided into two or more biostratigraphic units. According to Tapia and Harwood (2002), the *C. antiqua* Zone correlates roughly with the diatom complex “I” of Strelnikova (1974).

5.2. Paleogeographic setting and paleoecology

In the Late Cretaceous, the Arctic Ocean apparently shared only shallow water connections with water bodies to the south (Magavern et al., 1996; Baraboshkin et al., 2003), and the coast was located south of the localities discussed in this pa-

per (Núñez-Betelu et al., 1995a; Falcon-Lang et al., 2004). As suggested by the taxonomic composition of fossil diatom flora (Tapia and Harwood, 2002), the Horton River section in the Northwest Territories is inferred to have been located further out on the shelf at the time of deposition, closer to a connection with the Western Interior Seaway (Magavern et al., 1996; Jenkyns et al., 2004; Davies et al., 2009). Other localities investigated by Tapia and Harwood (2002) were located at inner shelf settings, similar to the sections on Devon Island. The present-day Alpha Ridge sediments (Davies et al., 2009) were deposited in a deeper part of the Arctic Ocean basin, farther north (Figures 1 & 15).

Of the 91 fossil marine diatom taxa encountered in the Kanguk Formation outcrops on Devon Island, 47 are also found in Eurasian high latitude assemblages described by Strelnikova (1974), and 37 are present in Canadian High Arctic assemblages examined by Tapia and Harwood (2002). In addition, taxa reported herein have also been previously identified from oceanic settings, including 28 taxa from the Alpha Ridge in the Arctic Ocean: 16 taxa from the CESAR 6 core (Barron, 1985; Davies, 2006), and 12 taxa from core FI-437 (Dell’Agnese and Clark, 1994). In terms of paleobiogeographic affiliation, the studied community should be placed in the Boreal province, along with similar assemblages from the Ural Mountains, the Arctic Ocean basin, and the Canadian sector of the Arctic (Strelnikova, 1975).

In the Eidsbotn graben composite section, greensands overlay, or are intercalated with dark, biogenic diatomaceous mudstones. Detrital silt content is minor, but intense bioturbation is reported (Chin et al., 2008). Such sediments can be deposited in upwelling zones, where diatoms occur in great numbers (Dell’Agnese and Clark, 1994; Abrantes, 2000). During upwelling, diatoms bloom in reaction to rapid nutrient uptake, followed by resting stage formation after the nutrients are exhausted (Tappan, 1980; Dell’Agnese and Clark, 1994). This pattern is particularly distinct in the fossil record in such localities as the Alpha Ridge in the Arctic Ocean (Barron, 1985; Davies, 2006; Davies et al., 2009). Although high productivity is evident at the Devon Island localities studied herein, the Late Cretaceous paleogeography of the area appears to have precluded the existence of deep water upwelling in the southeastern portion of the Sverdrup Basin. Riverine input is indicated as a more likely source of nutrients (Chin et al., 2008).

The thickness of biosiliceous mudstones in the lower part of the section at the Eidsbotn graben exceeds 140 m. In sam-

ples EF0102 and EF0103, planktonic diatoms dominate the assemblage, with a lower abundance of tychoplanktonic forms (mostly *P. crenulata* and *P. ornata*). Representatives of the genus *Aulacodiscus* are indicative of shallow marine conditions (Round et al., 1990), and are present in low concentrations in these samples. This suggests transport and deposition within a short distance from the coast.

The characteristics of the Devon Island sediments support the interpretation of the lower mudstones as more distal sediments, with the greensands as more proximal beds. Sedimentary structures (ripple marks and hummocky cross-stratifications) preserved in all sections confirm deposition on the continental shelf, but it is impossible to estimate paleodepth for particular assemblages.

Rigby et al. (2007) described sponges preserved in the greensands of Eidsbotn graben and suggested a habitat for these organisms within the photic zone, based on their occurrence high in the regressive section, the bioturbation of the sediment, the presence of wood debris and other terrigenous plant material, and thin intercalations of conglomerate. No diatom remains were found in the greensand samples; however, diatom valves are abundant in coprolites occurring in this glaucony facies. Thin sections of coprolites from benthic feeders reveal that glauconite often formed within radiolarian tests (Chin et al., 2008). Furthermore, aggregates of diatom valves and clastic material overgrown by glauconite are frequent in sample EF0307. The absence of diatoms in the greensands may therefore be caused by secondary changes associated with glauconite formation.

Conversely, diatoms encountered in bentonite samples EF0106, EF0107, EF0304 and EF0309 show excellent preservation (Figure 4A; Figure 12H). Percentages of planktonic diatoms are exceptionally high in these samples. This appears to be inconsistent with the sedimentological context that indicates an obvious regressive sequence; high percentages of planktonic diatoms are normally indicative of more oceanic conditions. Bentonite beds represent episodes of rapid deposition of pyroclastic material (Desmares et al., 2007). Catastrophic events like the 1991 Mt. Pinatubo eruption are known to cause severe mortality in marine populations (Kuhnt et al., 2005), accompanied by rapid formation of thick layers of silica-rich sediment. Such input of siliceous pyroclastic material into marine waters normally undersaturated with respect to silica content, is regarded as a major factor contributing to the exceptionally good preservation of diatom valves in the discussed samples. In contrast, it is estimated that under normal oceanic conditions, more than 50% of biogenic opal produced in the photic zone can be dissolved in the upper 100 m of the water column (Zielinski and Gersonde, 1997). According to Tappan (1980 and references therein) as little as 0.6–6% of the actual planktonic diatom population is preserved in a taphocenosis. For these reasons, the taxonomic composition of diatom assemblages recovered from the bentonite samples in this study is considered more representative of original diatom populations at the time of deposition than assemblages from mudstone samples, which should be regarded as time-averaged. It is also interesting that benthic diatoms are only found in significant abundance in samples EF0106 and EF0107 in Eidsbotn graben, and sample VF0102 in Viks Fiord, but not in the correlative part of Eidsbotn section 3. This discrepancy might have been caused by paleogeographic or paleobathymetric differences.

Observations made during the course of this study allow for comparisons among important Upper Cretaceous diatom-bearing deposits in the Canadian Arctic, through a paleoenvironmental transect (Figure 15). Although the shallow neritic localities studied by Tapia and Harwood (2002), i.e., Cape Nares, Hoodoo Dome and Slidefjord, offer a more continu-

ous succession and a higher number of diatom-bearing samples, the material from the Kanguk Formation has generally better preservation on Devon Island. In addition, more information on the paleoecology of the deposit is available (Chin et al., 2008). These assemblages indicate that highly diverse diatom floras composed mostly of planktonic and resting spore taxa appear to be common features of the shallow neritic fossil localities in the Arctic; prevalent genera in these communities include *Costopyxis*, *Cortinocornus*, *Gladiopsis*, *Hemiaulus* and *Paralia*. Riverine input is regarded the main source of nutrients supporting the rich diatom communities at the Devon Island sites (Chin et al., 2008). No laminated sediment sequences are reported from any of the near-shore localities, hence no inferences with regard to seasonal deposition can be made. The diversity and abundance of *Hemiaulus* in all of the shallow neritic deposits demonstrate that this genus was a particularly important primary producer in Late Cretaceous Arctic communities (for a detailed discussion, see Davies et al., 2009).

The assemblage from the Horton River section (Tapia and Harwood, 2002) is inferred to have been deposited in deeper neritic conditions, as indicated by the prevalence of planktonic diatoms, most notably *T. wittiana* and species of *Stephanopyxis* and *Trinacria*. All of these taxa constitute only a minor fraction of the shallow neritic assemblages. Although no distinct laminations are reported for this section, the data of Tapia and Harwood (2002) show resting spore taxa, like *Costopyxis* spp., to occur in high numbers in some samples. This might be regarded as evidence for a seasonal succession in deposition of resting spores and vegetative valves.

There are significant differences in preservation and diversity between fossil diatoms from the Alpha Ridge and the sites investigated in this study. Davies et al. (2009) reported pristine valves deposited in “grazer-proof” aggregates with negligible fragmentation, whereas some of the diatom communities reported herein suffered from both fragmentation and dissolution. The assemblages reported from the Alpha Ridge are also less diverse (Barron, 1985), reflecting the higher latitude and oceanic setting in which they lived. Quantitative studies, however, revealed that diatom abundances at the Alpha Ridge were comparable to the most productive areas of the modern oceans (Davies et al., 2009). The near-monogeneric laminae dominated by species of *Hemiaulus* (vegetative cells) and resting spores resembling modern taxa of *Chaetoceros*, were interpreted to reflect the annual cycle of nutrient availability (Davies et al., 2009). The taxonomic composition of diatom resting spores differs significantly between the neritic and oceanic settings, with *Costopyxis* flourishing in inner and outer shelf areas, and spores related to the extant *Chaetoceros* taxa prevailing in the open ocean. It is possible, however, that these apparent differences in diatom communities reflect differences in preservation and/or geological age.

6. Conclusions

Upper Cretaceous sediments and fossils on Devon Island offer a truly unique taphonomic window on an ancient polar ecosystem (Chin et al., 2008). Documentation and analyses of the Devon Island diatom flora presented here reveal great diversity and establish a biostratigraphic framework to support a Santonian–Campanian age and placement within the *G. antiquus* Concurrent Range Zone and the overlying *C. antiqua* Partial Range Zone (Figure 14). Preservation of diatoms is excellent in some samples, chiefly those associated with a bentonite matrix; in these deposits structural details of diatom valves are exceptionally well-preserved, including the coverings of cribral pores (Figure 12H). The bentonite beds represent rapid sedimentation episodes, and at the same time offered a buffering effect against dissolution that fostered preservation of bio-

siliceous remains. Thus, the assemblages recovered from bentonites can be considered a close approximation of the actual biocenosis with respect to taxonomic composition.

Diatom assemblages from the Kanguk Formation exposed in Eidsbotn and Viks Fiord grabens are compared to previously published reports, allowing the evaluation of diatom communities along a depth transect from inner neritic settings at Devon Island (this report), Slidre Fjord (Ellesmere Island), Hoodoo Dome (Ellef Ringnes Island) and Cape Nares (Eglington Island) localities (Tapia and Harwood, 2002), through an outer neritic setting at Horton River (Northwest Territories; Tapia and Harwood, 2002), to a deep water oceanic site on the Alpha Ridge in the Central Arctic Ocean (Barron, 1985; Davies et al., 2009) (Figure 15). Analysis of the compositions of these assemblages demonstrates that inner neritic diatom assemblages, dwelling in coastal waters rich in nutrients from riverine discharge, are characterized by high percentages and diversity of planktonic forms and resting spores. High abundances of planktonic diatoms in well-preserved samples from the Horton River section confirm its outer neritic setting inferred from sedimentological premises (Tapia and Harwood, 2002). The open Arctic Ocean setting, as recorded in the Alpha Ridge sediments (Davies et al., 2009), is represented by a sequence of near-monogeneric interbedded laminae of vegetative cells and resting spores different from the community flourishing in the shallow neritic setting.

The fossil record of the Cretaceous Devon Island localities reveals an Arctic marine ecosystem that was shaped and supported by highly diverse and abundant populations of marine diatoms. Many of the diatom species from the Devon Island sites occurred at other places and/or times in the Late Cretaceous Arctic, but this study shows that analyses of the taxa and their sedimentological and paleontological context allow for comparisons of diatom assemblages from inner neritic, outer shelf, and open marine settings. The study also points to different patterns of diatom preservation. These observations shed light on the structure and composition of marine diatom communities in an ancient and more temperate Arctic with no modern counterpart.

Acknowledgments

We are indebted to John Bloch for helpful discussions and providing material for the study. We also thank Jaelyn Eberle and Steve Cumbaa for their work in recovering the samples and Doug Stenton, Julie Ross, and the Government of Nunavut for allowing us to study the material. Patricia Sims and Nina Strel'nikova are thanked for valuable discussions on the taxonomic composition of the studied community. Manfred Ruppel is thanked for SEM examination and photography of the specimens. We also thank Diane Winter, Andrzej Witkowski, Brygida Wawrzyniak-Wydrowska, and Ireneusz Walaszczyk for supporting our work, and two anonymous reviewers for their comments, which greatly improved the manuscript. This paper is a summary of an MSc project accomplished in the Faculty of Geology, University of Warsaw, Poland, advised by Krzysztof Bińka. A portion of this research was funded by NSF Polar Programs Award 0241002. The final draft of this report was completed at the Urbino Summer School in Paleoclimatology in 2009.

References

- Abrantes, 2000 • F. Abrantes, 200 000 yr diatom records from Atlantic upwelling sites reveal maximum productivity during LGM and a shift in phytoplankton community structure at 185 000 yr, *Earth and Planetary Science Letters* **176** (2000), pp. 7–16.
- Armbrust, 2009 • E. V. Armbrust, The life of diatoms in the world's oceans, *Nature* **459** (2009), pp. 185–192.
- Baraboshkin et al., 2003 • E. Yu. Baraboshkin, A. S. Alekseev, and L. F. Kopaevich, Cretaceous palaeogeography of the North-Eastern Peri-Tethys, *Palaeogeography, Palaeoclimatology, Palaeoecology* **196** (2003), pp. 177–208.
- Barron, 1985 • J. A. Barron, Diatom biostratigraphy of the CESAR 6 core, Alpha Ridge. In: H. R. Jackson, P. J. Mudie and S. M. Blasco, eds., *Initial Geological Report on CESAR. The Canadian Expedition to Study Alpha Ridge, Arctic Ocean*, Geological Survey of Canada Paper 84-22 (1985), pp. 137–148.
- Bitschene et al., 1992 • P. R. Bitschene, M. A. Holmes, and J. M. Breza, Composition and origin of Cr-rich glauconitic sediments from the Southern Kerguelen Plateau (Site 748). In: S. W. Wise Jr. and R. Schlich et al., eds., *Proceedings of the Ocean Drilling Program, Scientific Results* vol. 120, Ocean Drilling Program, College Station, TX (1992), pp. 113–134.
- Bloch et al., 2004 • J. D. Bloch, K. Chin, A. R. Sweet, J. J. Eberle, and S. L. Cumbaa, S. L., Terminal Late Cretaceous regression on the southeast margin of the Sverdrup Basin: shale and bentonite petrology of the upper Kanguk Formation, Devon Island, Nunavut, *Geological Society of America, Abstracts with Programs* **36** (2004), p. 461.
- Bloch et al., 2007 • J. D. Bloch, M. Spilde, L. L. Heizler, and N. Dunbar, Glass to glaucony: greensand genesis in the Late Cretaceous Kanguk Formation, Devon Island Nunavut. In: *44th Annual Meeting of the Clay Mineral Society, Santa Fe, New Mexico, USA, June 2–7, 2007*, p. 56.
- Borkowska and Smulikowski, 1973 • M. Borkowska and K. Smulikowski, *Minerały Skalotwórcze*, Wydawnictwa Geologiczne, Warszawa (1973) (in Polish).
- Chafetz, 2007 • H. S. Chafetz, Paragenesis of the Morgan Creek Limestone, Late Cambrian, Central Texas: constraints on the formation of glauconite, *Deep Sea Research Part II* **54** (2007), pp. 1350–1363.
- Chin et al., 2008 • K. Chin, J. D. Bloch, A. R. Sweet, J. S. Tweet, J. J. Eberle, S. L. Cumbaa, J. Witkowski, and D. M. Harwood, Life in a temperate Polar sea: a unique taphonomic window on the structure of a Late Cretaceous Arctic marine ecosystem, *Proceedings of the Royal Society B* **275** (2008), pp. 2675–2685.
- Cleve, 1873 • P. T. Cleve, On diatoms from the Arctic Sea, *Bihang till Kongliga Svenska Vetenskaps-Akademiens Handlingar* **1** (1873), pp. 1–28.
- Crawford and Sims, 2008 • R. M. Crawford and P. A. Sims, Some principles of chain formation as evidenced by the early diatom fossil record, *Monographic Series: Nova Hedwigia Beiheft* **33** (2008), pp. 171–186.
- Davies, 2006 • A. Davies, High resolution palaeoceanography and palaeoclimatology from mid and high latitude Late Cretaceous laminated sediments. Unpublished PhD thesis, University of Southampton, School of Ocean and Earth Science, 2006.
- Davies et al., 2009 • A. Davies, A. E. S. Kemp, and J. Pike, Late Cretaceous seasonal ocean variability from the Arctic, *Nature* **460** (2009), pp. 254–258.
- Dell'Agnese and Clark, 1994 • D. J. Dell'Agnese and D. L. Clark, Siliceous microfossils from the warm late Cretaceous and early Cenozoic Arctic Ocean, *Journal of Paleontology* **68** (1994), pp. 31–47.
- Desmares et al., 2007 • D. Desmares, D. Grosheny, B. Beaudoin, S. Gardin, and F. Gauthier-Lafaye, High-resolution stratigraphic record constrained by volcanic ash beds at the Cenomanian-Turonian boundary in the Western Interior Basin, USA, *Cretaceous Research* **28** (2007), pp. 561–582.
- Dyke, 1999 • A. S. Dyke, Last Glacial Maximum and deglaciation of Devon Island, Arctic Canada: support for an Inuitian ice sheet, *Quaternary Science Reviews* **18** (1999), pp. 393–420.
- Embry, 1991 • A. F. Embry, Mesozoic history of the Arctic Islands. In: H. P. Trettin, ed., *Geology of the Inuitian Orogen and Arctic Platform of Canada and Greenland*, Geological Survey of Canada, *Geology of Canada* vol. 3 (1991), pp. 371–433.
- Falcon-Lang et al., 2004 • H. J. Falcon-Lang, R. A. MacRae, and A. Z. Csank, Palaeoecology of Late Cretaceous polar vegetation preserved in the Hansen Point Volcanics, NW Ellesmere Island, Canada, *Palaeogeography, Palaeoclimatology, Palaeoecology* **212** (2004), pp. 45–64.
- Forti, 1909 • A. Forti, Studi per una monografia del genere Pyxilla (Diatomeae) e dei generi affini, *Nuova Notarisa* **20** (1909), 19–34 (in Italian).
- Forti and Schulz, 1932 • A. Forti and P. Schulz, Erste Mitteilung über Diatomeen aus dem hannoverschen Gault, *Beihefte zum Botanischen Centralblatt* **50** (1932), 241–246 (in German).
- Fortier et al., 1963 • Y. O. Fortier, R. G. Blackadar, B. F. Glenister, H. R. Greiner, D. J. McLaren, N. J. McMillan, A. W. Norris, E. F. Roots, J. G. Souther, R. Thorsteinsson, and E. T. Tozer, Geology of the

- North-Central Part of the Arctic Archipelago, Northwest Territories (Operation Franklin). *Geological Survey of Canada Memoir*, vol. 320 (1963).
- French and Hargraves, 1980** • F. W. French and P. E. Hargraves, Physiological characteristics of plankton diatom resting spores, *Marine Biology Letters* **1** (1980), pp. 185–195.
- Friedman et al., 2003** • M. Friedman, J. A. Tarduno, and D. B. Brinkman, Fossil fishes from the Canadian Arctic: Further palaeobiological evidence for extreme climatic warmth during the Late Cretaceous (Turonian–Coniacian), *Cretaceous Research* **24** (2003), pp. 615–632.
- Gersonde and Harwood, 1990** • R. Gersonde and D. M. Harwood, Lower Cretaceous diatoms from ODP Leg 113 Site 693 (Weddell Sea). Part 1: Vegetative cells. In: P. F. Barker and J. P. Kennett et al., eds., *Proceedings of the Ocean Drilling Program, Scientific Results* vol. 113, Ocean Drilling Program, College Station, TX (1990), pp. 365–402.
- Gleser, 1962** • S. I. Gleser, Species nova generis Poretzkiae Jouse (Bacillariophyta) e depositionibus Palaeoceni declivitatis Orientalis Montium Uralensium, *Botanicheskoye material' y otdela sporov' ykh rastenii* **15** (1962), pp. 32–34.
- Gleser, 1984** • S. I. Gleser, Znachenie issledovaniy po sistematike diatomovykh vodoroslei dl'a biostratigrafii i paleogeografii, *Ezhegodnik Vsesoyuznogo Paleontologicheskogo Obshchestva* **27** (1984), pp. 284–298 (in Russian).
- Gleser et al., 1988** • S. I. Gleser, I. V. Makarova, A. I. Moiseeva, and V. A. Nikolaev, *Diatoms of the USSR: Fossil and Recent* **2** (1988) fasc. 1. Moskva, Nauka (in Russian).
- Gleser et al., 1992** • S. I. Gleser, I. V. Makarova, A. I. Moiseeva, and V. A. Nikolaev, *Diatoms of the USSR: Fossil and Recent* **2** (1992) fasc. 2. Moskva, Nauka (in Russian).
- Gombos, 1976** • A. M. Gombos Jr., Paleogene and Neogene diatoms from the Falkland Plateau and Malvinas Outer Basin: Leg 36, Deep Sea Drilling Project. In: P. F. Barker and I. W. D. Dalziel et al., eds., *Initial Reports of the Deep Sea Drilling Project* vol. 36, U. S. Government Printing Office, Washington (1976), pp. 575–688.
- Grunow, 1879** • A. Grunow, Algen und Diatomeen aus dem Kaspischen Meere, New species and varieties of Diatomaceae from the Caspian Sea, translated with additional notes by F. Kitton, *Journal of the Royal Microscopical Society* **2** (1879), pp. 677–691.
- Grunow, 1884** • A. Grunow, Die Diatomeen von Franz-Josefs Land, *Denkschriften der mathematisch-naturwissenschaftlichen Classe der Kaiserlichen Akademie der Wissenschaften* **48** (1884), pp. 53–112 (in German).
- Hajós and Stradner, 1975** • M. Hajós and H. Stradner, Late Cretaceous archaeomonadaceae, diatomaceae and silicoflagellatae from the South Pacific Ocean, Deep Sea Drilling Project, Leg 29, Site 275. In: J. P. Kennett and R. E. Houtz, eds., *Initial Reports of the Deep Sea Drilling Project*, 29, U. S. Government Printing Office, Washington (1975), pp. 913–1009.
- Hanna, 1927** • G. D. Hanna, Cretaceous diatoms from California, *Occasional Papers of the California Academy of Sciences* **13** (1927), pp. 1–48.
- Hanna, 1934** • G. D. Hanna, Additional notes on diatoms from the Cretaceous of California, *Journal of Paleontology* **8** (1934), pp. 352–355.
- Hargraves, 1986** • P. E. Hargraves, The relationship of some fossil diatom genera to resting spores. In: M. Ricard, ed., *Proceedings of the 8th International Diatom Symposium, Paris, 1984*, Koeltz Scientific Books, Koenigstein (1986), pp. 67–80.
- Harwood, 1988** • D. M. Harwood, Upper Cretaceous and Lower Paleocene diatom and silicoflagellate biostratigraphy of Seymour Island, eastern Antarctic Peninsula. In: R. M. Feldmann and M. O. Woodburne, eds., *Geology and Paleontology of Seymour Island, Antarctic Peninsula*, Geological Society of America Memoir vol. 169 (1988), pp. 55–129.
- Harwood and Gersonde, 1990** • D. M. Harwood and R. Gersonde, Lower Cretaceous diatoms from ODP Leg 113 site 693 (Weddell Sea). Part 2: Resting spores, chrysophycean cysts, and endoskeletal dinoflagellate, and notes on the origin of diatoms. In: P. F. Barker, J. P. Kennett, et al., eds., *Proceedings of the Ocean Drilling Program, Scientific Results* vol. 113, Ocean Drilling Program, College Station, TX (1990), pp. 403–425.
- Harwood and Nikolaev, 1995** • D. M. Harwood and V. A. Nikolaev, Cretaceous diatoms: morphology, taxonomy, biostratigraphy. In: C. D. Blome et al., eds., *Siliceous Microfossils*, Paleontological Society Short Courses vol. 8 (1995), pp. 81–106.
- Harwood et al., 2007** • D. M. Harwood, V. A. Nikolaev and D. M. Winter, Cretaceous records of diatom evolution, radiation, and expansion. In: S. W. Starrat, Editor, *Pond Scum to Carbon Sink. Geological and Environmental Applications of the Diatoms*, The Paleontological Society Papers vol. 13 (2007), pp. 33–60.
- Hasle and Sims, 1986** • G. R. Hasle and P. A. Sims, The diatom genera *Stellarima* and *Symbolophora*, with comments on the genus *Actinoptychus*, *British Phycological Journal* **21** (1986), pp. 97–114.
- Hasle and Syvertsen, 1985** • G. R. Hasle and E. E. Syvertsen, *Thalassiosiropsis*, a new diatom genus from the fossil record, *Micropaleontology* **31** (1985), pp. 82–91.
- Hay, 2008** • W. W. Hay, Evolving ideas about the Cretaceous climate and ocean circulation, *Cretaceous Research* **29** (2008), pp. 725–753.
- Herman and Spicer, 1996** • A. B. Herman and R. A. Spicer, Palaeobotanical evidence for a warm Cretaceous Arctic Ocean, *Nature* **380** (1996), pp. 330–333.
- Herman and Spicer, 1997** • A. B. Herman and R. A. Spicer, New quantitative palaeoclimate data for the Late Cretaceous Arctic: evidence for a warm polar ocean, *Palaeogeography, Palaeoclimatology, Palaeoecology* **128** (1997), pp. 227–251.
- Homann, 1991** • M. Homann, Die Diatomeen der Fur-Formation (Alttertiär) aus dem Limfjord-Gebiet, Nordjütland/Dänemark, *Geologisches Jahrbuch Reihe A, Heft 123*, Schweizerbart, Stuttgart (1991).
- Ioannides, 1986** • N. S. Ioannides, Dinoflagellate cysts from Upper Cretaceous-Lower Tertiary sections, Bylot and Devon Islands, Arctic Archipelago, *Geological Survey of Canada Bulletin* **371** (1986), pp. 1–99.
- Jenkyns et al., 2004** • H. C. Jenkyns, A. Firster, S. Schouten and J. S. Sinninghe Damste, High temperatures in the Late Cretaceous Arctic Ocean, *Nature* **432** (2004), pp. 888–892.
- Jordan and Ito, 2002** • R. W. Jordan and R. Ito, Observations on *Proboscia* species from Late Cretaceous sediments, and their possible evolution from *Kreagra*. In: J. John, ed., *Proceedings of the 15th International Diatom Symposium*. Liechtenstein, A. R. G. Gantner Verlag K. G., Ruggell (2002), pp. 313–329.
- Jousé, 1949** • A. P. Jousé, Algae diatomaceae aetatis supernecretaceae ex arenis argillaceis systematis fluminis Bolschoy Aktay in declivitate Orientali Ural Borealis, *Botanicheskoye material' y otdela sporov' ykh rastenii* **6** (1949), pp. 65–78 (in Russian).
- Jousé, 1951** • A. P. Jousé, Diatomeae et silicoflagellatae aetatis Cretae Superne e montibus Uralensibus Septentrionalibus, *Botanicheskoye material' y otdela sporov' ykh rastenii* **7** (1951), pp. 42–65 (in Russian).
- Jousé, 1955** • A. P. Jousé, Species novae generis *Gladus* Schulz in stratura aetatis Cretaceae superioris, *Botanicheskoye material' y otdela sporov' ykh rastenii* **10** (1955), pp. 72–76 (in Russian).
- Kemp et al., 2000** • A. E. S. Kemp, J. Pike, R. B. Pearce, and C. B. Lange, The 'Fall dump' – a new perspective on the role of a 'shade flora' in the annual cycle of diatom production and export flux, *Deep-Sea Research II* **47** (2000), pp. 2129–2154.
- Kidder and Erwin, 2001** • D. L. Kidder and D. H. Erwin, Secular distribution of biogenic silica through the Phanerozoic: comparison of silica-replaced fossils and bedded cherts at the series level, *Journal of Geology* **109** (2001), pp. 509–522.
- Kitchell et al., 1986** • J. A. Kitchell, D. L. Clark, and A. M. Gombos Jr., Biological selectivity of extinction: a link between background and mass extinction, *Palaios* **1** (1986), pp. 504–511.
- Krotov and Schibkova, 1959** • A. I. Krotov and K. G. Schibkova, Species novae diatomacearum e sedimentis Cretae superioris in montibus Uralensibus, *Botanicheskoye material' y otdela sporov' ykh rastenii* **12** (1959), pp. 112–129 (in Russian).
- Kuhnt et al., 2005** • W. Kuhnt, S. Hess, A. Holbourn, H. Paulsen, and B. Salomon, The impact of the 1991 Mt. Pinatubo eruption on deep-sea foraminiferal communities: A model for the Cretaceous-Tertiary boundary?, *Palaeogeography, Palaeoclimatology, Palaeoecology* **224** (2005), pp. 83–107.
- Lerbekmo and Brame, 2002** • J. F. Lerbekmo and D. R. Brame, Magnetostratigraphic and biostratigraphic correlation of late Campanian and Maastrichtian marine and continental strata from the Red Deer Valley to the Cypress Hills, Alberta, Canada, *Canadian Journal of Earth Sciences* **39** (2002), pp. 539–557.
- Littke et al., 1991** • R. Littke, E. Fourtanier, J. Thurow and E. Taylor, Silica diagenesis and its effect on lithification of Broken Ridge deposits, Central Indian Ocean. In: J. Weissel, J. Peirce, E. Taylor, J. Alt, et al., eds., *Proceedings of the Ocean Drilling Program, Scientific Results* vol. 121, Ocean Drilling Program, College Station, TX

- (1991), pp. 261–272.
- Magavern et al., 1996** • S. Magavern, D. L. Clark and S. L. Clark, $^{87}/^{86}\text{Sr}$, phytoplankton, and the nature of the Late Cretaceous and Early Cenozoic Arctic Ocean, *Marine Geology* **133** (1996), pp. 183–192.
- Mann, 1999** • D. G. Mann, The species concept in diatoms, *Phycologia* **38** (1999), pp. 437–495.
- Mayr et al., 1998** • U. Mayr, de T. Freitas, B. Beauchamp, and G. Eisbacher, eds., *The geology of Devon Island north of 76°, Canadian Arctic Archipelago*, Geological Survey of Canada Bulletin vol. 526 (1998), pp. 1–500.
- McCartney et al., in press** • K. McCartney, J. Witkowski, and D. M. Harwood, Unusual assemblages of Late Cretaceous silicoflagellates from the Canadian Archipelago. *Revue de micropaléontologie*, in press.
- McQuoid and Nordberg, 2003** • M. R. McQuoid and K. Nordberg, The diatom *Paralia sulcata* as an environmental indicator species in coastal sediments, *Estuarine, Coastal and Shelf Science* **56** (2003), pp. 339–354.
- Miall, 1979** • A. D. Miall, Mesozoic and Tertiary geology of Banks Island, Arctic Canada: The history of an unstable craton margin. *Geological Survey of Canada Memoir*, vol. 387 (1979), pp. 1–235.
- Miall, 1991** • A. D. Miall, Late Cretaceous and Tertiary basin development and sedimentation, Arctic Islands. In: H. P. Trettin, ed., *Geology of the Innuittian Orogen and Arctic Platform of Canada and Greenland*. Geological Survey of Canada, Geology of Canada vol. 3 (1991), pp. 437–458.
- Nikolaev and Harwood, 2007** • V. A. Nikolaev and D. M. Harwood, New taxa of extinct diatoms (Bacillariophyta) from Antarctic, *Novosti sistematiki nizshikh rastenii* **41** (2007), pp. 59–69 (in Russian).
- Nikolaev et al., 2001** • V. A. Nikolaev, J. P. Kociolek, E. Fourtanier, J. A. Barron, and D. M. Harwood, Late Cretaceous diatoms (Bacillariophyceae) from the Marca Shale member of the Moreno Formation, California, *Occasional Papers of the California Academy of Sciences* **152** (2001), pp. 1–89.
- Núñez-Betelu et al., 1995a** • L. K. Núñez-Betelu, L. V. Hills, F. F. Krause, and D. J. McIntyre, Upper Cretaceous paleoshorelines of the northeastern Sverdrup Basin, Ellesmere Island, Canadian Arctic Archipelago. In: K. V. Simakov and D. K. Thurston, eds., *Proceedings of the 1994 International Conference on Arctic Margins, Magadan, Russia* (1995), pp. 43–49.
- Núñez-Betelu et al., 1995b** • L. K. Núñez-Betelu, L. V. Hills, and R. A. MacRae, Palynostratigraphy and hydrocarbon potential of the Upper Cretaceous Kanguk Formation: an integrated multidisciplinary analysis of the Northeastern Canadian Arctic Archipelago. In: K. V. Simakov and D. K. Thurston, eds., *Proceedings of the 1994 International Conference on Arctic Margins, Magadan, Russia* (1995), pp. 54–61.
- Olshtynskaya, 1990** • A. Olshtynskaya, Morphology of the diatom genus *Pseudopodosira*. In: H. Simola, Editor, *Proceedings of the Tenth International Diatom Symposium*, Koeltz Scientific Books, Koenigstein (1990), pp. 93–103.
- Pantocsek, 1886** • Pantocsek, J., 1886. *Beiträge zur Kenntnis der Fossilen Bacillarien Ungarns. I. Theil: Marine Bacillarien*. Platzko, J., Nagy-Tapolcsány (in German).
- Pantocsek, 1889** • Pantocsek, J., 1889. *Beiträge zur Kenntnis der Fossilen Bacillarien Ungarns. II Theil: Brackwasser Bacillarien*. Platzko, J., Nagy-Tapolcsány (in German).
- Rao et al., 1995** • V. P. Rao, M. Thamban and M. Lamboy, Verdine and glaucony facies from surficial sediments of the eastern continental margin of India, *Marine Geology* **127** (1995), pp. 105–113.
- Ricketts and Stephenson, 1994** • B. D. Ricketts and R. A. Stephenson, The demise of Sverdrup Basin: Late Cretaceous–Paleogene sequence stratigraphy and forward modeling, *Journal of Sedimentary Research* **B64** (1994), pp. 516–530.
- Rigby et al., 2007** • J. K. Rigby, K. Chin, J. D. Bloch, and J. S. Tweet, A new hexactinellid sponge from the Cretaceous of Devon Island, Canadian High Arctic, *Canadian Journal of Earth Science* **44** (2007), pp. 1235–1242.
- Ross et al., 1977** • R. Ross, P. A. Sims, and G. R. Hasle, Observations on some species of the Hemiauloideae. In: R. Simonsen, Editor, *Fourth Symposium on Recent and Fossil Diatoms, Nova Hedwigia Beiheft* vol. 54 (1977), pp. 179–213.
- Ross and Sims, 1985** • R. Ross and P. A. Sims, Some genera of the Biddulphiaceae (diatoms) with interlocking linking spines, *Bulletin of the British Museum (Natural History)* **13** (1985), pp. 277–381.
- Round et al., 1990** • F. E. Round, R. M. Crawford, and D. G. Mann, *The Diatoms: Biology and Morphology of the Genera*, Cambridge University Press (1990).
- Schmidt et al., 1874–1959** • A. Schmidt, M. Schmidt, F. Fricke, H. Heiden, O. Müller, and F. Hustedt, *Atlas der Diatomaceen-kunde*. Leipzig-Berlin; Reprint 1984, Koeltz Scientific Books, Koenigstein (1874–1959) (in German).
- Schrader and Gersonde, 1978** • H. -J. Schrader and R. Gersonde, Diatoms and silicoflagellates. In: W. J. Zacharias, ed., *Micropaleontological Counting Methods and Techniques: An Exercise of an Eight Metres Section of the Lower Pliocene of Cap Rossello, Sicily*, Utrecht Micropaleontological Bulletin **17** (1978), pp. 129–176.
- Schulz, 1935** • P. Schulz, Diatomeen aus senon Schwammgesteinen der Danziger Bucht. Zugleich ein Beitrag zur Entwicklungsgeschichte der Diatomeen, *Botanisches Archiv* **37** (1935), pp. 383–414 (in German).
- Sheshukova-Poretzkaya and Gleser, 1964** • V. S. Sheshukova-Poretzkaya and S. I. Gleser, Diatomeae marinae novae e Paleogeno Ucrainiae, *Novosti sistematiki nizshikh rastenii* **1** (1964), pp. 78–92 (in Russian).
- Shipboard Scientific Party, 1989** • Shipboard Scientific Party, Site 748. In: R. Schlich, S. W. Wise Jr., et al., eds., *Proceedings of the Ocean Drilling Program, Initial Results* vol. 120, Ocean Drilling Program, College Station, TX (1989), pp. 157–235.
- Sims, 1986** • P. A. Sims, *Sphinctoletthus Hanna*, *Ailuretta* gen. nov., and evolutionary trends within the Hemiauloideae, *Diatom Research* **1** (1986), pp. 241–269.
- Sims, 1998** • P. A. Sims, The early history of the Biddulphiaceae. I. The genus *Medlinia* gen. nov., *Diatom Research* **13** (1998), pp. 337–374.
- Sims and Crawford, 2002** • P. A. Sims and R. M. Crawford, The morphology and taxonomy of the marine centric diatom genus *Paralia*. II. *Paralia crenulata*, *P. fausta* and the new species, *P. hendeyi*, *Diatom Research* **17** (2002), pp. 363–382.
- Sims and Crawford, 2007** • P. A. Sims and R. M. Crawford, The fossil diatom genus *Truania* Pantocsek and its relationship with *Ellerbeckia* Crawford, *Diatom Research* **22** (2007), pp. 195–207.
- Sims and Mahood, 1998** • P. A. Sims and A. D. Mahood, *Vulcanella hanna* Sims and Mahood, gen. et sp. nov., with a discussion of the genera *Tumulopsis* Hendey, *Acanthodiscus* Pantocsek, *Poretzkia* Jousé and *Goniothecium* Ehrenberg, *Diatom Research* **13** (1998), pp. 113–131.
- Sims et al., 2006** • P. A. Sims, D. G. Mann, and L. K. Medlin, Evolution of the diatoms: Insights from fossil, biological and molecular data, *Phycologia* **45** (2006), pp. 361–402.
- Spicer and Herman, 2010** • R. A. Spicer and A. B. Herman, The Late Cretaceous environment of the Arctic: A quantitative reassessment based on plant fossils, *Palaeogeography, Palaeoclimatology, Palaeoecology* **295** (2010), 423–442.
- Stein, 2008** • R. Stein, Mesozoic to Cenozoic paleoenvironmental records of high northern latitudes. In: R. Stein, ed., *Arctic Ocean Sediments: Processes, Proxies, and Paleoenvironments*, Elsevier, Amsterdam (2008), pp. 439–496.
- Strelnikova, 1966** • N. I. Strelnikova, Revisio specierum generum *Gladus* Schulz et *Pyxilla* Grev. (Bacillariophyta) e sedimentis Cretae superioris, *Novosti sistematiki nizshikh rastenii* (1966), pp. 23–36 (in Russian).
- Strelnikova, 1971** • N. I. Strelnikova, Species novae bacillariophytorum e sedimentis Cretae posterioris in declivitate orientali partis polaris ac praepolaris montium Uralensium, *Novosti sistematiki nizshikh rastenii* **8** (1971), pp. 41–50 (in Russian).
- Strelnikova, 1974** • N. I. Strelnikova, *Diatomei pozdnego mela*, *Izdatel'stvo "Nauka"*, Moskva (1974) (in Russian).
- Strelnikova, 1975** • N. I. Strelnikova, Diatoms of the Cretaceous period. In: R. Simonsen, ed., *Third Symposium on Recent and Fossil Diatoms, Nova Hedwigia Beiheft* vol. 53 (1975), pp. 311–321.
- Strelnikova, 1990** • N. I. Strelnikova, Evolution of diatoms during the Cretaceous and Paleogene periods. In: H. Simola, Editor, *Proceedings of the 10th International Diatom Symposium*, Koeltz Scientific Books, Koenigstein (1990), pp. 195–204.
- Suto et al., 2009** • I. Suto, R. W. Jordan, and M. Watanabe, Taxonomy of middle Eocene diatom resting spores and their allied taxa from the central Arctic Basin, *Micropaleontology* **55** (2009), pp. 259–312.
- Tapia and Harwood, 2002** • P. M. Tapia and D. M. Harwood, Upper Cretaceous diatom biostratigraphy of the Arctic archipelago and northern continental margin, Canada, *Micropaleontology* **48** (2002), pp. 303–342.

- Tappan, 1980** • H. N. Tappan, *Paleobiology of Plant Protists*, W. H. Freeman, San Francisco (1980).
- Tarduno et al., 1998** • J. A. Tarduno, D. B. Brinkman, P. R. Renne, R. D. Cottrell, H. Scher and P. Castillo, Evidence for extreme climatic warmth from Late Cretaceous arctic vertebrates, *Science* **282** (1998), pp. 2241–2244.
- Thorsteinsson and Mayr, 1987** • R. Thorsteinsson and U. Mayr, *The sedimentary rocks of Devon Island, Canadian Arctic Archipelago*, Geological Survey of Canada Memoir, vol. 411 (1987).
- Tiffany, 2008** • M. Tiffany, Valve development in *Aulacodiscus*, *Diatom Research* **23** (2008), pp. 185–212.
- Tomsich et al., in press** • C. S. Tomsich, P. J. McCarthy, S. J. Fowell, and D. Sunderlin, Paleofloristic and paleoenvironmental information from a Late Cretaceous (Maastrichtian) flora of the lower Cantwell Formation near Sable Mountain, Denali National Park, Alaska, *Palaeogeography, Palaeoclimatology, Palaeoecology* **295**, 389–408.
- Tozer, 1961** • E. T. Tozer, Summary account of Mesozoic and tertiary stratigraphy, Canadian Arctic Archipelago. In: G. O. Raasch, ed., *Geology of the Arctic*, Alberta Society of Petroleum Geologists, vol. 1 (1961), pp. 381–402.
- Witt, 1886** • O. N. Witt, Ueber den Polierschiefer von Archangelsk-Kurojedowo im Gouv. Simbirsk. *Verhandlungen der Russisch-kaiserlichen mineralogischen Gesellschaft zu St. Petersburg Serie II* **22** (1886), pp. 137–177 (in German).
- Zielinski and Gersonde, 1997** • U. Zielinski and R. Gersonde, Diatom distribution in Southern Ocean surface sediments (Atlantic sector): Implications for paleoenvironmental reconstructions, *Palaeogeography, Palaeoclimatology, Palaeoecology* **129** (1997), pp. 213–250.

Appendix

An alphabetic listing of taxa found in the Devon Island deposit is given below. For synonymy of taxa, and descriptions of the informal taxa used here please refer to the supplementary material.

Alphabetical listing of taxa

- Actinodictyon* sp. aff. *A. antiquorum* Pantocsek, 1889
- Actinoptychus simbirskianus* Schmidt, 1875
- Actinoptychus tenuis* Strelnikova, 1974
- Amblypyrgus* sp. A
- Archeopyrgus* sp. aff. *A. melosiroides* Gersonde and Harwood, 1990
- Aulacodiscus* sp. cf. *A. insignis* Hustedt in Schmidt et al., 1944
- Aulacodiscus septus* Schmidt, 1876
- Basilicostephanus* sp. 1 Tapia and Harwood, 2002
- Briggera includens* (Grunow) Ross and Sims, 1985
- Briggera ornitocephala* (Greville) Ross and Sims, 1985
- Chasea bicornis* Hanna, 1934
- Cladogramma* sp. cf. *C. simplex* Hajós and Stradner, 1975
- Cortinocornus rossicus* (Pantocsek) Gleser, 1984
- Cortinocornus?* sp. A
- Coscinodiscus polymorphus* Strelnikova, 1974
- Costopyxis antiqua* (Jousé) Gleser, 1984
- Costopyxis schulzii* (Steinecke ex Schulz) Gleser, 1984
- Costopyxis schulzii* (Steinecke ex Schulz) Gleser f. *ornata* (Schulz) Strelnikova in Gleser et al., 1988
- Dasyangea dactylethra* Harwood and Gersonde, 1990
- Gladiopsis pacifica* (Hajós and Stradner) Gersonde and Harwood, 1990
- Gladiopsis* sp. A
- Gladiopsis speciosa* (Schulz) Gersonde and Harwood f. *aculeolata* Strelnikova, 1966
- Gladiopsis speciosa* (Schulz) Gersonde and Harwood f. *porata* Strelnikova, 1966
- Gladiopsis speciosa* (Schulz) Gersonde and Harwood f. *speciosa*
- Gladius antiquus* Forti and Schulz, 1932
- Goniothecium odontellum* Ehrenberg 1844 sensu Strelnikova, 1974
- Hemiaulus altus* Hajós in Hajós and Stradner, 1975
- Hemiaulus antiquus* Jousé, 1951
- Hemiaulus asymmetricus* Jousé, 1951
- Hemiaulus curvatulus* Strelnikova, 1971
- Hemiaulus echinulatus* Jousé, 1951
- Hemiaulus elegans* (Heiberg) Grunow, 1884
- Hemiaulus hostilis* Heiberg sensu Harwood, 1988
- Hemiaulus hostilis* Heiberg sensu Strelnikova, 1974
- Hemiaulus polymorphus* Grunow, 1884
- Hemiaulus polymorphus* var. *frigida* Grunow, 1884
- Hemiaulus* sp. cf. *H. inaequilaterus* Gombos, 1976
- Hemiaulus speciosus* Jousé, 1951
- Hemiaulus sporalis* Strelnikova, 1971
- Hemiaulus?* sp. A
- Hemiaulus?* sp. B
- Hyalodiscus nobilis* Pantocsek, 1889
- Hyalodiscus radiatus* (O'Meara) Grunow, 1879
- Incisoria lanceolata* Hajós and Stradner, 1975
- Lepidodiscus elegans* Witt, 1886
- Medlinia deciusii* (Hanna) Nikolaev et al., 2001
- Medlinia fenestrata* (Witt) Sims, 1998
- Medlinia weissei* (Grunow in Schmidt et al.) Sims, 1998
- Odontotropis carinata* Grunow, 1884
- Odontotropis cristata* Grunow, 1884
- Paralia crenulata* (Grunow) Gleser in Gleser et al. 1992
- Paralia fausta* (Schmidt) Sims and Crawford, 2002
- Paralia ornata* (Grunow) Grunow ex van Heurck, 1882
- Paralia sulcata* (Ehrenberg) Cleve, 1873
- Poretzkia* sp. cf. *P. umbonata* Gleser, 1962
- Proboscia unicornis* Jordan and Ito, 1998
- Pseudoaulacodiscus* sp. A
- Pseudopodosira reticulata* Strelnikova, 1974
- Pseudopodosira westii* (Smith) Sheshukova-Poretzkaya and Gleser, 1964
- Pseudopyxilla aculeata* Jousé, 1951
- Pseudopyxilla americana* (Ehrenberg) Forti, 1909
- Pseudopyxilla* sp. A
- Pseudopyxilla* sp. B
- Pterotheca aculeifera* Grunow in Van Heurck, 1880–1885
- Pterotheca alata* Strelnikova, 1971
- Pterotheca clavata* Strelnikova, 1974
- Pterotheca evermanni* Hanna, 1927
- Pterotheca simplex* Strelnikova, 1971
- Pterotheca* sp. A
- “Pterotheca?”* sp. Strelnikova, 1974
- Pyrgodiscus triangulatus* Hajós and Stradner, 1975
- Rhizosolenia dubia* (Grunow) Homann, 1991
- Sceptroneis dimorpha* Strelnikova, 1974
- Sceptroneis* sp. cf. *S. gracilis* Hajós in Hajós and Stradner, 1975
- Sheshukovia excavata* (Heiberg) Nikolaev and Harwood in Nikolaev et al., 2001
- Sphinctoletus hemiauloides* Sims, 1986
- Stellarima steinyi* (Hanna) Hasle and Sims, 1986
- Stephanopyxis barbadensis* (Greville) Grunow, 1884
- Stephanopyxis dissonus* (Schulz) Strelnikova and Nikolaev in Gleser et al., 1988
- Stephanopyxis grunowii* Grove and Sturt in Schmidt et al., 1888
- Thalassiosirapsidella simsii* Nikolaev and Harwood, 2007
- Thalassiosirapsis wittiana* (Pantocsek) Hasle in Hasle and Syvertsen, 1985
- Trinacria indefinita* Jousé, 1951
- Trochosiropsis polychaeta* (Strelnikova) Tapia and Harwood, 2002
- Truania archangelskiana* Pantocsek, 1886
- Unknown genus and species #1
- Unknown genus and species #2
- Unknown genus and species #3
- Unknown genus and species #4

Supplementary data follows

Appendix – Supplementary Material

TAXONOMIC LIST

Genus *Actinodictyon* Pantocsek 1889

Actinodictyon sp. aff. *A. antiquorum* Pantocsek 1889 [Fig. 6C-D]

- 1889 *Actinodictyon antiquorum* Pantocsek; Pantocsek, pl. X, fig. 176
 1974 *Actinodictyon weissflogii* Pantocsek; Strelnikova, pro parte, p. 72, pl. XVIII, figs. 2a,b
 1997 *Actinodictyon antiquorum* Pantocsek; Ross & Sims, p. 327, figs. 10-13

Genus *Actinoptychus* Ehrenberg 1843

A. simbirskianus Schmidt 1875

- 1875 *Actinoptychus simbirskianus* Schmidt; Schmidt et al., pl. 29, fig. 11
 1886 *Actinoptychus simbirskianus* Schmidt; Schmidt et al., pl. 109, figs. 3-8
 1889 *Actinoptychus simbirskianus* Schmidt; Pantocsek, pl. XX, fig. 307
 1974 *Actinoptychus simbirskianus* Schmidt; Strelnikova, p. 68, pl. XV, figs. 1-7b
 1985 *Actinoptychus simbirskianus* Schmidt; Barron, pl. 10.1, fig. 8
 1994 *Actinoptychus simbirskianus* Schmidt; Dell'Agnese and Clark, fig. 3.1
 2002 *Actinoptychus simbirskianus* Schmidt; Tapia and Harwood, p. 318, pl. III, figs. 9-10

A. tenuis Strelnikova 1974 [Fig. 6K]

- 1974 *Actinoptychus tenuis* Strelnikova; Strelnikova, p. 67, pl. XIV, figs. 1-4
- 1994 *Actinoptychus tenuis* Strelnikova; Dell'Agnese and Clark, p. 38, fig. 3.2
- 2002 *Actinoptychus tenuis* Strelnikova; Tapia and Harwood, p. 318, pl. VII, fig. 1

Genus *Amblypyrgus* Gersonde et Harwood 1990

Amblypyrgus sp. A [Fig. 6N-O]

Description: Valves cylindrical, small (less than 10 μm). Valve face convex, with linking spines located in the center. Hyaline margin of the mantle.

Genus *Archepyrgus* Gersonde et Harwood 1990

Archepyrgus sp. aff. *A. melosiroides* Gersonde et Harwood 1990 [Fig. 6L-M]

- 1990 *Archepyrgus melosiroides* Gersonde et Harwood; Gersonde and Harwood, p. 370, pl. 10, figs. 2-6, 14, 15; pl. 13, figs. 13-18
- 2001 *Archepyrgus melosiroides* Gersonde et Harwood; Nikolaev et al., p. 30, pl. XVI, figs. 3-5
- 2006 *Archepyrgus melosiroides* Gersonde et Harwood; Sims et al., fig. 16
- 2008 *Archepyrgus*; Crawford and Sims, pl. 1, fig. 2

Genus *Aulacodiscus* Ehrenberg 1844

Aulacodiscus sp. cf. *A. insignis* Hustedt 1944 [Fig. 7A-B; Fig. 11A]

1944 *Aulacodiscus insignis* Hustedt; Schmidt et al, pl. 458, figs. 4-5

Remarks: Most frequently found only as isolated inflations with tube processes.

A. septus Schmidt 1876

1876 *Aulacodiscus septus* Schmidt; Schmidt et al., pl. 36, figs. 19-21

1974 *Aulacodiscus septus* f. *septus* (Schmidt) Strelnikova; Strelnikova, p. 77, pl. XIX, figs. 1-6a,b

2002 *Aulacodiscus septus* f. *septus* (Schmidt) Strelnikova; Tapia and Harwood, p. 319, pl. VII, fig. 3

2004 *Aulacodiscus septus* Schmidt; Strelnikova et al., p. 288, figs. 9-14, 84, 85

Genus *Basilicostephanus* Gersonde et Harwood 1990

Basilicostephanus sp. 1 Tapia et Harwood 2002

2002 *Basilicostephanus* sp. 1 Tapia et Harwood; Tapia and Harwood, p. 319, pl. I, figs. 7-8, pl. II, figs. 2-4

Genus *Briggera* Ross et Sims 1985

B. includens (Grunow) Ross et Sims 1985 [Fig. 9A]

1974 *Hemiaulus includens* (Ehrenberg) Grunow: Strelnikova, p. 101 pl. XLVIII, figs. 1-6,

1985 *Briggenera includens* (Grunow) Ross et Sims: Ross and Sims, p. 294. pl. 1, figs. 1-9

B. ornitocephala (Greville) Ross et Sims 1985

1865 *Hemiaulus ornitocephalus* Greville; Greville, XV, p. 32, pl. III, fig. 16

1888 *Hemiaulus ornitocephalus* Greville; Schmidt et al., pl. 142, figs. 34, 36, 37

1985 *Briggenera ornitocephala* (Greville) Ross et Sims; Ross and Sims, p. 309, pl. 10-12

Genus *Chasea* Hanna 1934

C. bicornis Hanna 1934 [Fig. 10J]

1934 *Chasea bicornis* Hanna; Hanna, p. 354, pl. 48, figs. 12-16

1975 *Chasea bicornis* Hanna; Hajós and Stradner, p. 928, pl. 5, figs. 1-3

1988 *Chasea bicornis* Hanna; Harwood, p. 80, figs. 10.1-10.2

Genus *Cladogramma* Ehrenberg 1854

Cladogramma sp. cf. *C. simplex* Hajós et Stradner 1975

1975 *Cladogramma simplex* Hajós et Stradner; Hajós and Stradner, p. 928, pl. 4, fig. 7-8

Genus *Cortinocornus* Gleser 1984

C. rossicus (Pantocsek) Gleser 1984

- first morphotype [Fig. 8A-B, H, R-S; Fig. 12A-B]

1884 *Hemiaulus polycystinorum* var. *simbirskianus* Grunow; Grunow, pl. II(B), figs. 44, 45

1886 *Hemiaulus antarcticus* Weisse; Witt, pl. VI, figs. 1-2

1888 *Hemiaulus antarcticus* Weisse; Schmidt et al., pl. 144, figs. 30-35

1974 *Hemiaulus rossicus* Pantocsek; Strelnikova, pl. XLIII, figs. 1-10

1974 *Hemiaulus rossicus* Pantocsek; Gleser et al., pl. XI, fig. 6

1977 *Hemiaulus rossicus* Pantocsek; Ross, Sims and Hasle, p. 195, pl. 8, figs. 48-50

1984 *Cortinocornus rossicus* (Pantocsek) Gleser; Gleser, p. 290

2002 *Cortinocornus rossicus* (Pantocsek) Gleser; Tapia and Harwood, p. 390, pl. III, figs. 5-8

2002 *Hemiaulus* sp. A: Tapia and Harwood, pl. III, figs. 1-2

not 2006 *Hemiaulus rossicus* Pantocsek; Davies, p. 238, pl. 8, fig. 5-6

Remarks: Specimens having relatively high elevations and a rimoportule associated with an external tube were identified as first morphotype. *Cortinocornus* appears to be one of the most common diatoms of the Late Cretaceous. A revision of the genus is necessary because of considerable taxonomic confusion.

- second morphotype [Fig. 8C-E; Fig. 12C-D]

1951 *Hemiaulus polycystinorum* var. *brevicornis* Jousé; Jousé, p. 54, pl. IV, figs. 1a-d

1988 *Hemiaulus rossicus* Pantocsek; Harwood, p. 83, figs. 14.18, 14.21

Remarks: Valves having low, or no discernible elevations, and an external slit associated with the rimoportule were identified as second morphotype.

Cortinocornus? sp. A [Fig. 8F, M-N; Fig. 12E]

Description: Frustules homovalvate. Valves elongate, 15-40 µm long, flat, broader in the center than in the apical parts, with a deep (12 µm) mantle, perpendicular to the valve face. Mantle margin serrated. Ca. 7-9 poroid areolae in 10 µm, arranged in more or less vertical rows on the mantle, perforations of the valve face sparser and smaller. Two internal pseudosepta, dividing the valve into ‘chambers’.

Remarks: No means of sibling valve attachment observed, no processes found. For this reason the generic affiliation is tentative.

Genus *Coscinodiscus* Ehrenberg 1839

C. polymorphus Strelnikova 1974

1974 *Coscinodiscus polymorphus* Strelnikova; Strelnikova, p. 65, pl. III, figs. 8-17

Genus *Costopyxis* Gleser 1984

C. antiqua (Jousé) Gleser 1984 [Fig. 7G; Fig. 11L]

1951 *Stephanopyxis antiquus* Jousé; Jousé, p. 46, pl. I, figs. 3 a,b

- 1951 *Stephanopyxis cancellatus* Jousé; Jousé, p. 46, pl. I, figs. 4 a,b
- 1974 *Stephanopyxis antiqua* Jousé; Strelnikova, p. 56, pl. III, figs. 18-20
- 1985 *Stephanopyxis antiqua* Jousé; Fenner, p. 768, fig. 14.13;
- 1988 *Costopyxis antiqua* (Jousé) Gleser; Gleser et al., pl. 31, figs. 1-3,6
- 2002 *Costopyxis antiqua* (Jousé) Gleser; Tapia and Harwood, 319, pl. II, figs. 10-11, 14-15

C. schulzii (Steinecke ex Schulz) Gleser 1984 [Fig. 7E-F, M-N; Fig. 11K]

- 1949 *Stephanopyxis schulzii* Steinecke ex Schulz; Jousé, p. 65, pl. I, figs. 2-3
- 1974 *Stephanopyxis schulzii* Steinecke ex Schulz f. *schulzii* Strelnikova; Strelnikova, p. 55, pl. IV, figs. 1-3,8
- 1974 *Stephanopyxis schulzii* Steinecke ex Schulz f. *nuda* Strelnikova; Strelnikova, p. 55, pl. IV, figs. 10-12
- 2002 *Costopyxis schulzii* (Steinecke) Gleser; Tapia and Harwood, p. 324, pl. II, figs. 6-7

C. schulzii (Steinecke ex Schulz) Gleser f. *ornata* (Schulz) Strelnikova 1988 [Fig. 11J]

- 1974 *Stephanopyxis ornata* Schulz; Strelnikova, p. 56, pl. IV, figs. 4-7, 9 a,b
- 1985 *Stephanopyxis ornata* Schulz; Fenner, p. 738, fig. 14.7
- 1988 *Costopyxis schulzii* (Steinecke) Gleser f. *ornata* (Schulz) Strelnikova; Gleser et al., pl. 32, figs. 9-16
- 2002 *Costopyxis ornata* (Schulz) Strelnikova; Tapia and Harwood, 319, pl. I, figs. 15-16

Remarks: Tapia and Harwood (2002) list this variety as a separate species.

Genus *Dasyangea* Harwood et Gersonde 1990*D. dactylethra* Harwood et Gersonde 1990 [Fig. 10K, Y-Z]

1990 *Dasyangea dactylethra* Harwood et Gersonde; Harwood and Gersonde, p. 409, pl. 2, figs. 1-7

Remarks: This study is the first record of *D. dactylethra* in the Upper Cretaceous.

Genus *Gladiopsis* Gersonde et Harwood 1990*G. pacifica* (Hajós et Stradner) Gersonde et Harwood 1990

1975 *Gladius pacificus* Hajós et Stradner; Hajós and Stradner, p. 933, pl. 11, fig. 13

1985 *Gladius pacificus* Hajós et Stradner; Barron, p. 141, pl. 10.2, fig. 15

1994 *Gladiopsis pacificus* (Hajós); Dell'Agnese and Clark, fig. 3.7

Gladiopsis sp. A [Fig. 10H]

Description: Valves cylindrical, long, curved. Areolae arranged spirally about the long axis.

Tube process of unknown nature at the apex of the valve.

Remarks: Only broken valves up to ca. 140 µm seen. Possibly a teratoid form of *G. speciosa* (Schulz) Gersonde et Harwood f. *poratus* Strelnikova.

G. speciosa (Schulz) Gersonde et Harwood f. *aculeolata* Strelnikova 1966

1966 *Pyxilla speciosa* (Schulz) Strelnikova f. *aculeolata* Strelnikova; Strelnikova, p. 35, pl. IV, figs. 3,4,11

1974 *Gladius speciosus* Schulz f. *aculeolatus* Strelnikova; Strelnikova, p. 105, pl. LI, figs. 5,6,7-10

2002 *Gladopsis speciosus* f. *aculeolatus* Strelnikova; Tapia and Harwood, p. 324, pl. III, figs. 3,4

G. speciosa (Schulz) Gersonde et Harwood f. *porata* Strelnikova 1966 [Fig. 7S; Fig. 11C]

1966 *Pyxilla speciosa* (Schulz) Strelnikova f. *porata* Strelnikova; Strelnikova, p. 35, pl. IV, figs. 5,6,12

1974 *Gladius speciosus* Schulz f. *poratus* Strelnikova; Strelnikova, p. 106, pl. XLIX, fig. 22, pl. LI, figs 11-12

2002 *Gladiopsis speciosus* f. *poratus* Strelnikova; Tapia and Harwood, p. 324, pl. II, fig.1, pl. V, figs. 1-4

G. speciosa (Schulz) Gersonde et Harwood f. *speciosa*

1935 *Gladius speciosus* Schulz; Schulz, p. 391, pl. II, figs. 6-8

1955 *Gladius speciosus* Schulz; Jousé, p. 76, fig. 4

1966 *Pyxilla speciosa* (Schulz) Strelnikova f. *speciosa*; Strelnikova, pp. 33-34, pl. I, II, pl. III, figs. 5-9, pl. IV, figs. 1-2, 10

- 1974 *Gladius speciosus* Schulz f. *speciosus*; Strelnikova, p. 104, pl. L, figs. 1-19
- 1985 *Gladius speciosus* Schulz f. *speciosus*; Barron, p. 141, pl. 10.2, fig. 14
- 1988 *Gladius speciosus* Schulz f. *speciosus*; Gleser et al., pl. 36, figs. 1-3,6,7,10
- 1990 *Gladiopsis speciosa* (Schulz) Gersonde et Harwood; Gersonde and Harwood, p. 372
- 1994 *Gladiopsis speciosa* (Schulz) Gersonde et Harwood; Sims, figs. 43-48
- 2001 *Gladiopsis speciosa* (Schulz) Gersonde et Harwood; Nikolaev et al., p. 12, pl. 2, fig. 7
- 2002 *Gladiopsis speciosus* f. *speciosus* (Schulz) Strelnikova; Tapia and Harwood, p. 324, pl. II, fig. 1

Remarks: Strelnikova (1966 and 1974) used the names ‘*Pyxilla speciosa* Schulz f. *speciosa*’ and ‘*Gladius speciosus* Schulz f. *speciosus*’ respectively, not mentioning the creator of the discussed form to indicate the variety originally described by Schulz (1935). Gersonde and Harwood (1990) kept the form *speciosa* (feminine) as the specific epithet, instead of the original masculine *speciosus*. Hendey (1993), Sims (1994) and the Catalogue of Diatom Names (Fourtanier and Kociolek 2007) indicated *Gladiopsis speciosa* as the valid name for the species, while Tapia and Harwood (2002) retained the masculine specific epithet.

Genus *Gladius* Forti et Schulz 1932

G. antiquus Forti et Schulz 1932 [Fig. 7Q-R]

- 1932 *Gladius antiquus* Forti et Schulz; Forti and Schulz, p. 242, text-fig. 3, pl. III, fig. 6
- 1990 *Gladius antiquus* Forti et Schulz; Gersonde and Harwood, p. 373, pl. 7, figs. 1-2, pl. 8, figs. 1,2,5,6, pl. 15, figs. 6-7, pl. 17, fig. 12

- 2001 *Gladius antiquus* Forti et Schulz; Nikolaev et al., p. 22, pl. IX, figs. 1-5
- 2002 *Gladius antiquus* Forti et Schulz; Tapia and Harwood, p. 324, pl. I, fig. 2
- 2006 *Gladius antiquus* Forti et Schulz; Sims et al., figs. 11-12
- 2008 *Gladius*; Crawford and Sims, pl. 1, fig. 4

Genus *Goniothecium* Ehrenberg 1843

G.odontellum Ehrenberg 1844 sensu Strelnikova 1974 [Fig. 12P]

- 1951 *Goniothecium odontella* Ehrenberg; Jousé, p. 60, pl. V, figs. 1-7
- 1974 *Goniothecium odontellum* Ehrenberg; Strelnikova, p. 116, pl. LV, fig. 1-3,5-10
- 1975 *Goniothecium odontella* Ehrenberg; Hajós and Stradner, p. 935, pl. 10, figs. 11-12
- 1985 *Goniothecium odontella* Ehrenberg; Barron, pl. 10.2, fig. 13
- 1988 *Goniothecium odontella* Ehrenberg; Harwood, p. 82, figs. 10.21-22
- 1994 *Goniothecium odontella* Ehrenberg; Dell'Agnese and Clark, p. 38, fig. 3.8
- 1998 *Goniothecium odontellum* Ehrenberg sensu Strelnikova; Sims and Mahood, figs. 26-31
- 2006 *Goniothecium odontella* Ehrenberg; Davies, p. 52, pl. 17, fig. 7-8.

Genus *Hemiaulus* Ehrenberg 1844

H. altus Hajós 1975

- 1975 *Hemiaulus altus* Hajós; Hajós and Stradner, p. 931, pl. 5, figs. 17-19
- 1985 *Hemiaulus altus* Hajós; Fenner, p. 137, pl. 4, fig. 3
- 2006 *Hemiaulus altus* Hajós; Davies, p. 238, pl. 5, figs. 5-6

H. antiquus Jousé 1951 [Fig. 8O-P; Fig. 12H-I]

1951 *Hemiaulus antiquus* Jousé; Jousé, p. 52, pl. III, figs. 1 a,b

1974 *Hemiaulus antiquus* Jousé; Strelnikova, p. 101, pl. XLVI, figs. 1-14

1994 *Hemiaulus antiquus* Jousé; Dell'Agnese and Clark, fig. 3.9

Remarks: Davies (2006) illustrated valves and frustules with a prominent rim developed around the mantle margin, not indicated by type illustrations (Jousé 1951) nor by photographs of Strelnikova (1974).

H. asymmetricus Jousé 1951 [Fig. 8K-L]

1951 *Hemiaulus asymmetricus* Jousé; Jousé, p. 52, pl. III, fig. 2

1974 *Hemiaulus asymmetricus* Jousé; Strelnikova, p. 97, pl. XLVII, figs. 1-3

H. curvatulus Strelnikova 1971

1971 *Hemiaulus curvatulus* Strelnikova; Strelnikova, p. 49, pl. I, figs. 12-13

1974 *Hemiaulus curvatulus* Strelnikova; Strelnikova, p. 96, pl. XLVII, figs. 14-16

1975 *Hemiaulus curvatulus* Strelnikova; Hajós and Stradner, p. 931, pl. 6, fig. 8

1988 *Hemiaulus curvatulus* Strelnikova; Harwood, p. 82, fig. 13.12.

H. echinulatus Jousé 1951 [Fig. 8Q]

- 1951 *Hemiaulus echinulatus* Jousé; Jousé, p. 53, pl. III, figs. 3a-c
1974 *Hemiaulus echinulatus* Jousé; Strelnikova, p. 100, pl. XLVI, figs. 18-23
1985 *Hemiaulus echinulatus* Jousé; Fenner, p. 731, fig. 14.10
2002 *Hemiaulus echinulatus* Jousé; Tapia and Harwood, pl. VII, figs. 7-8

H. elegans (Heiberg) Grunow 1884

- 1888 *Corinna elegans* Heiberg; Schmidt et al., pl. 144, figs. 54-55
1974 *Hemiaulus elegans* (Heiberg) Grunow; Strelnikova, p. 98, pl. XLIV, figs. 11,12, 15
1977 *Hemiaulus elegans* (Heiberg) Grunow; Ross, Sims and Hasle, p. 186, pl. 7, figs. 45-47

H. hostilis Heiberg sensu Harwood 1988

- 1988 *Hemiaulus hostilis* Heiberg; Harwood, p. 82, figs. 14.1-14.5

H. hostilis Heiberg sensu Strelnikova 1974

- 1974 *Hemiaulus hostilis* Heiberg; Strelnikova, p. 99, pl. XLVII, figs. 10-13
2006 *Hemiaulus hostilis* Heiberg; Davies, p. 238, pl. 7, figs. 5-6

H. polymorphus Grunow 1884 [Fig. 9L-M]

- 1888 *Hemiaulus polymorphus* Grunow; Schmidt et al., pl. 143, figs. 11-13, 30-34
1977 *Hemiaulus polymorphus* Grunow; Ross, Sims and Hasle, p. 184, pl. II, figs. 10-12
1991 *Hemiaulus polymorphus* Grunow; Homann, pl. 24, figs. 1-19

H. polymorphus var. *frigida* Grunow 1884

- 1888 *Hemiaulus polymorphus* var. *frigida* Grunow; Schmidt et al., pl. 143, figs. 35-36
- 1974 *Hemiaulus polymorphus* var. *frigida* Grunow; Strelnikova, p. 103, pl. XLV, figs. 1-19
- 1988 *Hemiaulus polymorphus* var. *frigida* Grunow; Harwood, p. 83, fig. 14.7
- 2001 *Hemiaulus polymorphus* var. *frigida* Grunow; Nikolaev et al., p. 20, pl. 24, fig. 6, pl. 25, figs. 1-3
- 2002 *Hemiaulus polymorphus* var. *frigida* Grunow; Tapia and Harwood, p. 326, pl. V, fig. 8

Hemiaulus sp. cf. *H. inaequilaterus* Gombos 1976

Description: Typical ‘hemiauloid’ valves with two transverse folds, two polar elevations, each with three massive linking spines, and a marginal ridge. Conspicuous asymmetry of the valve projections.

Remarks: The valve structure is in part similar to *Hemiaulus inaequilaterus* Gombos 1976.

H. inaequilaterus, besides having an asymmetrical valve, exhibits also polar elevations of unequal length. The species reported herein has much more robust cells. Finally, *H. inaequilaterus* is found in sediments of Late Paleocene age (Gombos, 1976), while the discussed species occurs only toward the base of the section (probably Santonian).

H. speciosus Jousé 1951 [Fig. 8G]

- 1951 *Hemiaulus speciosus* Jousé; Jousé, p. 55, pl. III, fig. 5
- 1991 *Hemiaulus speciosus* Jousé; Fenner, p. 138, pl. 8, figs. 1-3

H. sporalis Strelnikova 1971 [Fig. 9B-C; Fig. 12K – vegetative cells with semi-endogenous resting spores; Fig. 10E – resting spore]

1971 *Hemiaulus sporalis* Strelnikova; Strelnikova, p. 48, pl. III, figs. 1-10

1974 *Hemiaulus sporalis* Strelnikova; Strelnikova, p. 95, pl. XLII, figs. 1-11

1988 *Hemiaulus sporalis* Strelnikova; Harwood, p. 84, figs. 15.7-10

2002 *Hemiaulus sporalis* Strelnikova; Tapia and Harwood, p. 326, pl. V, fig. 7

Hemiaulus? sp. A [Fig. 9D-E]

Description: Cells heterovalvar, with one ‘hemiauloid’ valve and one valve resemblant of the genus *Anaulus* Ehrenberg, that is possessing no polar elevations and two prominent pseudosepta. In both valves the pseudosepta reach only to ca. half of the mantle height. Also in both types of valves, the pseudosepta are associated with a shallow transverse fold on the valve face and in the upper part of the valve mantle, resulting in a pronounced ‘chamber’. The ‘hemiauloid’ valve does not have a marginal ridge, which distinguishes it from the genus *Hemiaulus*. The nature of terminations of the elevations is unknown. Only single cells observed.

Hemiaulus? sp. B [Fig. 9K]

Description: Valve ca. 35 µm long, with flat-terminated elevations (ca. 40 µm) at apices. Central part of the valve slightly elevated. Hyaline marginal ridge. Mantle shallow. The

nature of the terminations of horns unknown, linking spines not observed or strongly reduced.

Only valves seen.

Remarks: Because of the inferred lack of linking spines, the placement in the genus

Hemiaulus is tentative.

Genus *Hyalodiscus* Ehrenberg 1845

H. nobilis Pantocsek 1889 [Fig. 7C-D]

1889 *Hyalodiscus nobilis* Pantocsek; Pantocsek, pl. XXVI, fig. 374

1974 *Hyalodiscus nobilis* Pantocsek; Strelnikova, p. 51, pl. II, figs. 3-5

2002 *Hyalodiscus nobilis* Pantocsek; Makarova et al., p. 19, pl. 13, fig. 7

H. radiatus (O'Meara) Grunow 1879

1974 *Hyalodiscus radiatus* (O'Meara) Grunow; Gleser et al., pl. XXII, fig. 6

Genus *Incisoria* Hajós 1975

I. lanceolata Hajós et Stradner 1975 [Fig. 10S-T]

1971 *Incisoria lanceolata* Hajós et Stradner; Hajós and Stradner, p. 937, pl. 13, figs. 22,25,
pl. 36, fig. 6

1988 *Incisoria lanceolata* Hajós et Stradner; Harwood, p. 84, figs. 12.18, 12.19, 17.4

Genus *Lepidodiscus* Witt 1886

L. elegans Witt 1886 [Fig. 6A-B; Fig. 11F]

- 1886 *Lepidodiscus elegans* Witt; Witt, p. 28, pl. VII, fig. 6
1886 *Lepidodiscus elegans* Witt; Schmidt et al., pl. 103, fig. 5
1974 *Lepidodiscus elegans* Witt; Gleser et al., pl. 8, fig. 4
1974 *Lepidodiscus elegans* Witt; Ross and Sims, pl. 4, figs. 25-27
1974 *Lepidodiscus elegans* Witt; Strelnikova, p. 70, pl. XVI, figs. 1-6
1995 *Lepidodiscus elegans* Witt; Strelnikova, p. 439, figs. 37-40
2008 *Lepidodiscus elegans* Witt; Strelnikova and Tsoy, p. 73, pl. 90, figs. 1-7, pl. 91, figs. 1-8

Genus *Medlinia* Sims 1998

M. deciusii (Hanna) Nikolaev et Kociolek 2001 [Fig. 9F-H; Fig. 12G]

- 1927 *Trinacria deciusii* Hanna; Hanna, p. 36, pl. 5, figs. 3-5
1991 *Trinacria deciusii* Hanna; Fenner, p. 141, pl. 9, figs. 11-16
2001 *Medlinia deciusii* (Hanna) Nikolaev et Kociolek; Nikolaev et al., p. 22, pl. 27, figs. 4-6
2002 *Triceratium schulzii* Jousé; Tapia and Harwood, p. 330, pl. II, figs. 5, 12-13
2006 *Medlinia deciusii* (Hanna) Nikolaev et Kociolek; Davies, p. 37, pl. 11, figs. 7-8

Remarks: The species is probably confused in the literature with *T. schulzii* Jousé. Tapia and Harwood (2002) illustrated a form which appears to be a certain life stage of *M. deciusii*, having less internal costae than the form illustrated by Hanna (1927) and in the present paper.

Fenner (1991) distinguishes *T. schulzii* from *M. deciusii*, however the two species need a detailed morphological study to resolve this problem.

M. fenestrata (Witt) Sims 1998 [Fig. 9I]

- 1886 *Triceratium fenestratum* Witt; Witt, p. 33, pl. X, fig. 10
- 1886 *Triceratium fenestratum* Witt; Schmidt et al., pl. 95, fig. 21, pl. 112, figs. 5-6
- 1886 *Triceratium curvato-vittatum* Schmidt; Schmidt et al., pl. 95, figs. 22-26
- 1889 *Triceratium vittatum* Pantocsek; Pantocsek, pl. XXI, fig. 318
- 1935 *Triceratium fenestratum* Witt; Schulz, pl. I, fig. 7
- 1974 *Triceratium fenestratum* Witt; Gleser et al., pl. XV, fig. 1, pl. XVII, fig. 6
- 1974 *Triceratium fenestratum* Witt; Strelnikova, pl. XXIX, figs. 18-19
- 1998 *Medlinia fenestrata* (Witt) Sims; Sims, p. 356, figs. 45-50, 58, 59

M. weissei (Grunow in Schmidt et al.) Sims 1998 [Fig. 9J]

- 1984 *Sheshukovia weissei* (Grunow ex A. Schmidt) Gleser; Gleser, p. 295
- 1998 *Medlinia weissei* (Grunow in A. Schmidt) Sims; Sims, pp. 344-347, figs. 15-20, 34-35, 43-44

Genus *Odontotropis* Grunow 1884

O. carinata Grunow 1884

- 1884 *Odontotropis carinata* Grunow; Grunow, p. 59, pl. V, fig. 58

- 1935 *Odontotropis carinata* Grunow; Schulz, p. 326, pl. II, fig. 10
- 1959 *Odontotropis carinata* Grunow; Krotov and Schibkova, p. 121, pl. 4, figs. 1-2
- 1974 *Odontotropis carinata* Grunow; Strelnikova, p. 94, pl. XL, figs. 3-7

Remarks: Most frequently present only as isolated spines.

O. cristata Grunow 1884

- 1884 *Odontotropis cristata* Grunow; Grunow, p. 59, pl. II, fig. 23
- 1935 *Odontotropis cristata* Grunow; Schulz, p. 393, fig. 4
- 1974 *Odontotropis cristata* Grunow; Strelnikova, p. 94, pl. XL, figs. 1-2
- 1994 *Odontotropis cristata* Grunow; Dell'Agnese and Clark, p. 43, fig. 9.9

Remarks: see *O. carinata*.

Genus *Paralia* Heiberg 1863

P. crenulata (Grunow) Gleser 1992 [Fig. 7H-I, O-P; Fig. 11E]

- 1892 *Melosira sulcata* var. *crenulata* Grunow; Schmidt et al., pl. 177, figs. 23-26,28
- 1927 *Melosira fausta* Schmidt; Hanna, p. 25, pl. 3, fig. 14
- 1955 *Melosira sulcata* var. *crenulata* Grunow; Jousé, p. 83, pl. I, fig. 6
- 1979 *Melosira sulcata* f. *coronata*; Kaczmarska and Kilarski, pl. I, fig. 4
- 2001 *Paralia crenulata* (Grunow) Gleser; Nikolaev et al., p. 15, pl. 8, figs. 1-8
- 2002 *Paralia crenulata* (Grunow) Gleser; Tapia and Harwood, pl. IV, figs. 14-15

P. fausta (Schmidt) Sims et Crawford 2002 [Fig. 6G]

1892 *Melosira fausta* Schmidt; Schmidt et al., pl. 177, figs. 3-10

1974 *Melosira fausta* Schmidt; Gleser et al., pl. XXXI, fig. 4, pl. XLIV, figs. 10-11

2002 *Paralia fausta* (Schmidt) Sims et Crawford; Sims and Crawford, p. 368, figs. 18-37

P. ornata (Grunow) Grunow ex van Heurck 1882 [Fig. 6E; Fig. 11D]

1884 *Melosira ornata* Grunow; Grunow, p. 95, pl. V, figs. 39-40

1892 *Melosira ornata* Grunow; Schmidt et al., pl. 178, figs. 41,43,45,49

1974 *Melosira ornata* Grunow; Strelnikova, p. 47, pl. I, figs. 5,6

1991 *Paralia ornata* Grunow; Homann, pl. 30, figs. 1-6

2002 *Paralia ornata* Grunow; Tapia and Harwood, pl. I, figs. 3,4

P. sulcata (Ehrenberg) Cleve 1873 [Fig. 6H]

1892 *Paralia sulcata* (Ehrenberg) Cleve; Schmidt et al., pl. 176, figs. 24-28, 46

1974 *Melosira sulcata* (Ehrenberg) Kützing var. *sulcata*; Gleser et al., pl. XII, fig. 1, pl. XIII, fig. 1

1974 *Melosira sulcata* (Ehrenberg) Kützing var. *sulcata*; Strelnikova, p. 49, pl. I, figs. 9-14

1979 *Paralia sulcata* (Ehrenberg) Cleve; Crawford, pp. 200-209, figs. 1-17

1988 *Paralia sulcata* (Ehrenberg) Cleve; Harwood, p. 85, figs. 16.8-9

2002 *Paralia sulcata* (Ehrenberg) Cleve; Tapia and Harwood, p. 328, pl. IX, fig. 13

Genus *Poretzkia* Jousé 1949

Poretzkia sp. cf. *P. umbonata* Gleser 1962 [Fig. 12J]

1974 *Poretzkia umbonata* Gleser; Gleser et al., pl. XVII, fig. 10

1998 *Poretzkia umbonata* Gleser; Sims and Mahood, p. 116, figs. 20-25

Genus *Proboscia* Sundström 1986

P. unicornis Jordan et Ito 1998 [Fig. 10L; Fig. 12F]

1998 *Proboscia unicornis* Jordan et Ito; Jordan and Ito, p. 316, figs. 29-40

Genus *Pseudoaulacodiscus* Vekschina 1961

Pseudoaulacodiscus sp. A [Fig. 10I; Fig. 12N-O]

Description: Cells heterovalvar, valves circular, beaked at the poles, epivalve with low polar elevations. Arolae in a central circular patch.

Genus *Pseudopodosira* Jousé 1949

P. reticulata Strelnikova 1974 [Fig. 6I-J, P]

1974 *Pseudopodosira reticulata* Strelnikova; Strelnikova, p. 53, pl. III, figs. 2a,b

P. westii (Smith) Sheshukova-Poretzkaya et Gleser 1964

1990 *Pseudopodosira westii* (Smith) Sheshukova-Poretzkaya et Gleser; Olshtynskaya, p. 96, pl. 3, figs. 13-15

Remarks: Harwood (1988) considered *P. westii* from Seymour Island a resting spore. Species of *Pseudopodosira* are regarded as vegetative cells herein.

Genus *Pseudopyxilla* Forti 1909

P. aculeata Jousé 1951

1951 *Pseudopyxilla aculeata* Jousé; Jousé, p. 60, pl. IV, fig. 7

P. americana (Ehrenberg) Forti 1909

1974 *Pseudopyxilla americana* (Ehrenberg) Forti; Strelnikova, p. 112, pl. LIV, figs. 1-15

Pseudopyxilla sp. A

Description: Cells large, 50-60 µm, with a perforate epivalve completely overlapping hyaline hypovalve. No ornamentation.

Pseudopyxilla sp. B

Description: Cells large, with an ornamented, perforate epivalve completely overlapping and reaching far behind hypovalve. A significant increase in the thickness of the cell wall is observed by mid-height of the cell.

Genus *Pterotheca* Grunow 1909

P. aculeifera Grunow in Van Heurck 1880-1885 [Fig. 10F-G]

1927 *Pterotheca crucifera* Hanna; Hanna, p. 30, pl. 4, fig. 5

1988 *Pterotheca crucifera* Hanna; Harwood, p. 86, fig. 18.5

2001 *Pterotheca crucifera* Hanna; Nikolaev et al., p. 26, pl. 39, figs. 8-9

2006 *Pterotheca crucifera* Hanna; Davies, p. 241, pl. 15, fig. 5

2009 *Pterotheca aculeifera* Grunow; Suto et al., pp. 282-286, pl. 9, figs. 1-47

Remarks: Suto et al. (2009) have evidenced that *P. crucifera* Hanna is a synonym of *P. aculeifera* Grunow.

P. alata Strelnikova 1971 [Fig. 12L]

1971 *Pterotheca alata* Strelnikova; Strelnikova, p. 49, pl. II, figs. 5-7

1974 *Pterotheca alata* Strelnikova; Strelnikova, p. 113, pl. LVI, figs. 16-17

1991 *Pterotheca alata* Strelnikova; Homann, p. 136, pl. 53, figs. 24,25, 30-32

P. clavata Strelnikova 1974 [Fig. 10X]

1974 *Pterotheca clavata* Strelnikova; Strelnikova, p. 115, pl. LVII, fig. 35

P. evermanni Hanna 1927 [Fig. 10A-B]

1927 *Pterotheca evermanni* Hanna; Hanna, p. 31, pl. 4, fig. 6

1974 *Pterotheca evermanni* Hanna; Gleser et al., pl. XII, fig. 4

1974 *Pterotheca evermanni* Hanna; Strelnikova, p. 112, pl. LVI, figs. 12-15

1988 *Pterotheca evermanni* Hanna; Harwood, p. 86, figs. 18.13-14

1991 *Pterotheca evermanni* Hanna; Fenner, p. 139, pl. 2, fig. 13

1991 *Pterotheca evermanni* Hanna; Homann, p. 137, pl. 53, figs. 21-23

P. simplex Strelnikova 1971

1971 *Pterotheca simplex* Strelnikova; Strelnikova, p. 50, pl. I, fig. 17-18

1974 *Pterotheca simplex* Strelnikova; Strelnikova, p. 115, pl. LVII, figs. 31-32

Pterotheca sp. A [Fig. 10V-W]

Description: Only cylindrical, hyaline epivalves to 15 μm seen, with a small rim surrounding the valve face.

‘*Pterotheca?* sp.’ Strelnikova 1974 [Fig. 10C-D; Fig. 12M]

1974 *Pterotheca?* sp. Strelnikova; Strelnikova, p. 116, pl. LVII, figs. 33-34

1985 *Pterotheca?* sp. Strelnikova; Barron, p. 139, pl. 10.2, fig. 11

2006 *Pterotheca?* sp. Strelnikova; Davies, p. 241, pl. 15, fig. 6

Genus *Pyrgodiscus* Kitton 1885

P. triangulatus Hajós et Stradner 1975 [Fig. 7L]

1975 *Pyrgodiscus triangulatus* Hajós et Stradner; Hajós and Stradner, p. 928, figs. 11a,b, pl. 18, figs. 5,6

1988 *Pyrgodiscus triangulatus* Hajós et Stradner; Harwood, p. 87, figs. 19.6-7

Remarks: Sims (1988) listed *P. triangulatus* as a possible synonym of *Sceletonema polychaetum* of Strelnikova (1974), subsequently transferred to the genus *Trochosira* (Sims 1988) and *Trochosiropsis* (Tapia and Harwood 2002). Harwood (1988) considered the discussed species a resting spore. The status of *P. triangulatus* as a distinct species is confirmed herein.

Genus *Rhizosolenia* Brightwell

R. dubia (Grunow) Homann 1991

1991 *Rhizosolenia dubia* (Grunow) Homann; Homann, p. 69, pl. 35, fig. 8

Genus *Sceptroneis* Ehrenberg 1844

S. dimorpha Strelnikova 1974 [Fig. 10O-R]

1974 *Sceptroneis dimorpha* Strelnikova; Strelnikova, p. 110, pl. LIV, figs. 18-30

2006 '*Sceptroneis dimorpha*' Strelnikova; Sims et al., p. 383, figs. 61-65

Sceptroneis sp. cf. *S. gracilis* Hajós 1975 [Fig. 10M-N]

1975 *Sceptroneis gracilis* Hajós; Hajós and Stradner, p. 936, fig. 19

Remarks: No intact valves seen.

Genus *Sheshukovia* Gleser 1984

S. excavata (Heiberg) Nikolaev et Harwood 2001 [Fig. 9N]

1886 *Trinacria excavata* Heiberg; Schmidt et al., pl. 96, figs. 6-8, pl. 97, figs. 6-10

1974 *Triceratium excavatum* (Heiberg) Strelnikova; Strelnikova, p. 82, pl. XXXI, figs. 8-14

1975 *Trinacria excavata* Heiberg; Hajós and Stradner, p. 932, pl. 10, fig. 1

1977 *Trinacria excavata* Heiberg; Ross, Sims and Hasle, p. 195, pl. 8, figs. 53-54

1988 *Trinacria excavata* Heiberg; Harwood, p. 89, figs. 21.15-16

1991 *Trinacria excavata* Heiberg; Homann, p. 119, pl. 46, figs. 1-8, pl. 47, figs. 1-6

2001 *Sheshukovia excavata* (Heiberg) Nikolaev et Harwood; Nikolaev et al., p. 21, pl. 29, figs. 1-5

Genus *Sphinctolethus* Hanna 1927

S. hemiauloides Sims 1986

1986 *Sphinctoletus hemiauloides* Sims; Sims, p. 246, figs. 16-22, 64-65

1991 *Sphinctoletus hemiauloides* Sims; Fenner, p. 140, pl. 4, figs. 2,4

Genus *Stellarima* Hasle et Sims 1986*S. steinyi* (Hanna) Hasle et Sims 1987 [Fig. 10U]

1927 *Coscinodiscus steinyi* Hanna; Hanna, p. 19, pl. 2, fig. 5-6

1974 *Coscinodiscus symbolophorus* Grunow; Strelnikova, p. 63, pl. XII, figs. 1-7

1987 *Stellarima steinyi* (Hanna) Hasle et Sims; Sims and Hasle, p. 230, figs. 8-18, 29-31

1988 *Stellarima steinyi* (Hanna) Hasle et Sims; Harwood, p. 88, figs. 20.3-4

2001 *Stellarima steinyi* (Hanna) Hasle et Sims; Nikolaev et al., p. 18, pl. 20, figs. 1-6

2002 *Stellarima steinyi* (Hanna) Hasle et Sims; Tapia and Harwood, p. 328, pl. VII, fig. 2

2006 *Stellarima steinyi* (Hanna) Hasle et Sims; Davies, p. 26, pl. 4, figs. 7-8

Genus *Stephanopyxis* (Ehrenberg) Ehrenberg 1845*S. barbadensis* (Greville) Grunow 1884

1865 *Crasswelia barbadensis* Greville; Greville, XIV, p. 3, pl. I, fig. 11

1888 *Stephanopyxis barbadensis* (Greville) Grunow; Schmidt et al., pl. 130, figs. 6-10

1974 *Stephanopyxis barbadensis* (Greville) Grunow; Strelnikova, p. 58, pl. VI, figs. 1-8

1994 *Stephanopyxis barbadensis* (Greville) Grunow; Dell'Agnes and Clark, p. 43, figs. 10.7-8

S. dissonus (Schulz) Strelnikova et Nikolaev 1988 [Fig. 11G]

1949 *Coscinodiscus dissonus* Schulz; Jousé, p. 72, pl. II, fig. 1

1974 *Coscinodiscus dissonus* Schulz; Strelnikova, p. 61, pl. VIII, figs. 14-15

1988 *Pyxidicula dissona* (Schulz) Strelnikova et Nikolaev; Gleser et al., p. 41, pl. 22, figs. 1-8

2002 *Stephanopyxis dissonus* (Schulz) Strelnikova et Nikolaev; Tapia and Harwood, p. 328, pl. VI, figs. 1-3

S. grunowii Grove et Sturt 1888 [Fig. 11H]

1888 *Stephanopyxis grunowii* Grove et Sturt; Schmidt et al., pl. 130, figs. 1-5

1927 *Stephanopyxis grunowii* Grove et Sturt; Hanna, pp. 33-34, pl. 4, fig. 12

1955 *Stephanopyxis grunowii* Grove et Sturt; Jousé, p. 85, pl. II, figs. 1-4

2001 *Stephanopyxis grunowii* Grove et Sturt; Nikolaev et al., p. 14, pl. 7, figs. 1-4

2002 *Stephanopyxis grunowii* Grove et Sturt; Tapia and Harwood, p. 328, pl. VII, fig. 5

Genus *Thalassiosiropsidella* Nikolaev et Harwood 2007

T. simsii Nikolaev et Harwood 2007

2007 *Thalassiosiropsidella simsii* Nikolaev et Harwood; Nikolaev and Harwood, pp. 65-67, pl. 3, figs. 1-5

Genus *Thalassiosiropsis* Hasle 1985

T. wittiana (Pantocsek) Hasle 1985 [Fig. 11B]

1985 *Thalassiosiropsis wittiana* (Pantocsek) Hasle; Hasle and Syvertsen, pp. 82-91, figs. 1-41

1988 *Thalassiosiropsis wittiana* (Pantocsek) Hasle; Gleser et al., pl. XXXIII, figs. 1-9

1988 *Thalassiosiropsis wittiana* (Pantocsek) Hasle; Harwood, p. 89, fig. 20.6

1991 *Thalassiosiropsis wittiana* (Pantocsek) Hasle; Homann, pl. 37, figs. 8-10

1994 *Thalassiosiropsis wittiana* (Pantocsek) Hasle; Dell'Agnese and Clark, pl. 10, fig. 9

2001 *Thalassiosiropsis wittiana* (Pantocsek) Hasle; Nikolaev et al., p. 12, pl. I, figs. 1-4

2002 *Thalassiosiropsis wittiana* (Pantocsek) Hasle; Tapia and Harwood, pl. IV, fig. 13

2006 *Thalassiosiropsis wittiana* (Pantocsek) Hasle; Davies, p. 16, pl. 1, figs. 1-2

Genus *Trinacria* Heiberg 1863

T. indefinita Jousé 1951 [Fig. 8I-J]

1951 *Trinacria indefinita* Jousé; Jousé, p. 50, pl. II, figs. 5 a-c

1974 *Triceratium indefinitum* (Jousé) Strelnikova; Gleser et al., pl. XI, fig. 5

1974 *Triceratium indefinitum* (Jousé) Strelnikova; Strelnikova, p. 82, pl. XXX, figs. 1-17

1988 *Trinacria indefinita* Jousé; Sims and Ross, pl. 7, fig. 49

2002 *Trinacria indefinita* Jousé; Tapia and Harwood, p. 330, pl. IV, figs. 1-2,5-6

Genus *Trochosiropsis* Gleser 1984

T. polychaeta (Strelnikova) Tapia 2002 [Fig. 7J-K]

1971 *Skeletonema polychaeta* Strelnikova; Strelnikova, p. 42, pl. I, figs. 3-5

1974 *Skeletonema polychaetum* Strelnikova; Strelnikova, p. 54, pl. III, figs. 3-7

1985 *Skeletonema polychaetum* Strelnikova; Barron, p. 141, pl. 10.1, figs. 2-4

1988 *Skeletonema polychaetum* Strelnikova; Harwood, p. 88, figs. 16.14-15

1988 *Trochosira polychaeta* (Strelnikova) Sims; Sims, p. 251, figs. 15-21, 29-34

1994 *Skeletonema polychaetum* Strelnikova; Dell'Agnes and Clark, p. 38, pl. 4, fig. 7

2002 *Trochosiropsis polychaeta* (Strelnikova) Tapia; Tapia and Harwood, p. 330, pl. VIII, figs. 3-4

2006 *Trochosiropsis polychaeta* (Strelnikova) Tapia; Davies, p. 22, fig. 3.2, pl. 3, figs. 7-8

Remarks: See discussion on *Pyrgodiscus triangulatus* Hajós et Stradner.

Genus *Truania* Pantocsek 1886

T. archangelskiana Pantocsek 1886 [Fig. 6F; Fig. 11I]

1892 *Melosira asiatica* Brun; Schmidt et al., pl. 179, fig. 6

1886 *Truania archangelskiana* Pantocsek; Pantocsek, pl. XX, fig. 178

1892 *Truania archangelskiana* Pantocsek; Schmidt et al., pl. 173, fig. 6

1974 *Truania archangelskiana* Pantocsek; Strelnikova, p. 50, pl. I, figs. 1-2

2007 *Truania archangelskiana* Pantocsek; Sims and Crawford, pp. 197-207, figs. 1-24

2008 *Truania*; Crawford and Sims, pl. 3, fig. 15

Remarks: The present study is the second record of *T. archangelskiana* outside Russia (Sims and Crawford 2007).

Unknown genus and species #1 [Fig. 13F-H]

Description: Frustules connected in ribbon-like chains. Elongate, bipolar lanceolate valves with a low oval to elliptical elevation in the center and two long projections. Valve face undulate. A single rimoportule next to the valve center. 3-7 rings of wedge-shaped bosses on the valve face.

Remarks: A few morphotypes of this species were found, differing with respect to the arrangement of areolae on the valve face.

Unknown genus and species #2 [Fig. 13E]

Description: Valves circular, flat or weakly domed, with a central rimoportule associated with a curved hyaline ray extending from the valve center to near the margin.

Unknown genus and species #3 [Fig. 13A-B]

Description: Valves large, circular, highly domed, with a large central rimoportule. Areolae in radial rows interrupted by numerous solid spines.

Unknown genus and species #4 [Fig. 13C-D]

Description: Valves oval to elliptical, mostly hyaline, with prominent polar elevations terminated in pseudocelli.

References

- Crawford, R.M., 1979. Taxonomy and frustular structure of the marine centric diatom *Paralia sulcata*. *Journal of Phycology* 15, 200-210.
- Davies, A., 2006. High resolution palaeoceanography and palaeoclimatology from mid and high latitude Late Cretaceous laminated sediments. Unpublished PhD thesis, University of Southampton, School of Ocean and Earth Science.
- Dell'Agnese, D.J., Clark, D.L., 1994. Siliceous microfossils from the warm late Cretaceous and early Cenozoic Arctic Ocean. *Journal of Paleontology* 68, 31-47.
- Fenner, J.M., 1985. Late Cretaceous to Oligocene planktic diatoms, in: Bolli, H.M., Saunders, J.B., Perch-Nielsen, K. (Eds.), *Plankton stratigraphy*, vol. 2. Cambridge, pp. 713-762.
- Fenner, J.M., 1991. Taxonomy, stratigraphy, and paleoceanographic implications of Paleocene diatoms, in: Ciesielski, P.F., Kristoffersen, Y. et al. (Eds.), *Proceedings of the Ocean Drilling Program, Scientific Results*, 114. College Station, TX (Ocean Drilling Program), pp. 123-154.
- Forti, A., Schulz, P., 1932. Erste Mitteilung über Diatomeen aus dem hannoverschen Gault. *Beihefte zum Botanischen Centralblatt* 50, 241-246 (in German).
- Fourtanier, E., Kociolek, J.P., 2007-2010. *Catalogue of Diatom Names*. California Academy of Sciences (<http://researcharchive.calacademy.org/research/diatoms/names/> as of June 2010).

- Gersonde, R., Harwood, D.M., 1990. Lower Cretaceous diatoms from ODP Leg 113 Site 693 (Weddell Sea). Part 1: Vegetative cells, in: Barker, P.F., Kennett, J.P. et al. (Eds.), *Proceedings of the Ocean Drilling Program, Scientific Results*, 113. College Station, TX (Ocean Drilling Program), pp. 365-402.
- Gleser, S.I., 1984. Significance of research on the systematics of diatoms for biostratigraphy and paleogeography. In: *Ezhegodnik Vsesoyuznogo Paleontologicheskogo Obshchestva* 27, 284-298 (in Russian).
- Gleser, S.I., Jouse, A.P., Makarova, I.B., Proshkina-Lavrenko, A.I., Sheshukova-Poretzkaya, V.S., 1974. *Diatoms of the USSR: Fossil and Recent*, vol. 1. Nauka, Moskva (in Russian).
- Gleser, S.I., Makarova, I.V., Moiseeva, A.I., Nikolaev, V.A., 1988. *Diatoms of the USSR: Fossil and Recent*, vol. 2, fasc. 1. Nauka, Moskva (in Russian).
- Gombos, A. M., Jr., 1976. Paleogene and Neogene diatoms from the Falkland Plateau and Malvinas Outer Basin: Leg 36, Deep Sea Drilling Project, in: Barker, P.F., Dalziel, I.W.D. et al. (Eds.), *Initial Reports of the Deep Sea Drilling Project*, 36. U.S. Government Printing Office, Washington, pp. 575-688.
- Greville, R.K., 1865. Descriptions of new and rare diatoms. Series XIV. *Transactions of the Microscopic Society of London. New Series* 13, 1-10.
- Greville, R.K. 1865. Descriptions of new and rare diatoms. Series XV. *Transactions of the Microscopic Society of London. New Series* 13, 24-37.
- Grunow, A., 1884. *Die Diatomeen von Franz-Josefs Land*. *Denkschriften der mathematisch-naturwissenschaftlichen Classe der Kaiserlichen Akademie der Wissenschaften*, 48, 53-112 (in German).
- Harwood, D.M., Gersonde, R., 1990. Lower Cretaceous diatoms from ODP Leg 113 site 693 (Weddell Sea). Part 2: Resting spores, chrysophycean cysts, and endoskeletal

- dinoflagellate, and notes on the origin of diatoms, in: Barker, P.F., Kennett, J.P. et al. (Eds.), Proceedings of the Ocean Drilling Program, Scientific Results, 113. College Station, TX (Ocean Drilling Program), pp. 403-425
- Hasle, G.R., Sims, P.A., 1986. The diatom genera *Stellarima* and *Symbolophora*, with comments on the genus *Actinoptychus*. British Phycological Journal 21, 97-114.
- Hasle, G.R., Syvertsen, E.E., 1985. *Thalassiosiropsis*, a new diatom genus from the fossil record. Micropaleontology 31, 82-91.
- Hendey, N.I., 1993. Observations on *Gladiopsis* from the Moreno Shale, California. Nova Hedwigia Beiheft 106, 269-273.
- Homann, M., 1991. Die Diatomeen der Fur-Formation (Alttertiär) aus dem Limfjord-Gebiet, Nordjütland/Dänemark. Geologisches Jahrbuch Reihe A, Heft 123, Schweizerbart, Stuttgart.
- Jordan, R.W., Ito, R., 2002. Observations on *Proboscia* species from Late Cretaceous sediments, and their possible evolution from *Kreagra*, in: John, J. (Ed.), Proceedings of the 15th International Diatom Symposium. A.R.G. Gantner Verlag K.G., Ruggell / Liechtenstein, pp. 313-329.
- Jousé, A.P., 1949. Algae diatomaceae aetatis supernecretaceae ex arenis argillaceis systematis fluminis Bolschoy Aktay in declivitate Orientali Ural Borealis. Botanicheskoye material'ye otdela sporov'ykh rastenii 6, 65-78 (in Russian).
- Jousé, A.P., 1951. Diatomeae et silicoflagellatae aetatis Cretae Superne e montibus Uralensibus Septentrionalibus. Botanicheskoye material'ye otdela sporov'ykh rastenii 7, 42-65 (in Russian).

- Jousé, A.P., 1955. Species novae generis *Gladius* Schulz in stratura aetatis Cretaceae superioris. Botanicheskoye material'nyy otdel sporov'nykh rasteniy 10, 72-76 (in Russian).
- Kaczmarska, I., Kilarski, W., 1979. Budowa pancerzyków *Melosira sulcata* (Ehr.) Kutz. var. *sulcata* z dolnooligocénskich diatomitów z Futomy (Karpaty, Polska). Rocznik Polskiego Towarzystwa Geologicznego 49, 185-194 (in Polish).
- Krotov, A.I., Schibkova K.G., 1959. Species novae diatomacearum e sedimentis Cretae superioris in montibus Uralensibus. Botanicheskoye material'nyy otdel sporov'nykh rasteniy 12, 112-129 (in Russian).
- Makarova, I.V., Strelnikova, N.I., Kozirenko, T.F., 2002. The diatoms of Russia and adjacent countries. Fossil and recent, vol. II, fasc. 3. St. Petersburg University Press, St. Petersburg (in Russian).
- Nikolaev, V.A., Harwood, D.M., 2007. New taxa of extinct diatoms (Bacillariophyta) from Antarctic. Novosti sistematiki nizshikh rasteniy 41, 59-69 (in Russian).
- Nikolaev, V.A., Harwood, D.M., Samsonov, N.I., 2001. Early Cretaceous diatoms. Nauka, St. Petersburg (in Russian).
- Nikolaev, V.A., Kociolek, J.P., Fourtanier, E., Barron, J.A., Harwood, D.M., 2001. Late Cretaceous diatoms (Bacillariophyceae) from the Marca Shale member of the Moreno Formation, California. Occasional Papers of the California Academy of Sciences 152, 1-89.
- Olshtynskaya, A., 1990. Morphology of the diatom genus *Pseudopodosira*, in: Simola, H. (Ed.), Proceedings of the Tenth International Diatom Symposium. Koeltz Scientific Books, Koenigstein, pp. 93-103.
- Pantocsek, J., 1886. Beiträge zur Kenntnis der Fossilen Bacillarien Ungarns. I. Theil: Marine Bacillarien. Platzko, J., Nagy-Tapolcsány (in German).

- Pantocsek, J., 1889. Beiträge zur Kenntnis der Fossilen Bacillarien Ungarns. II Theil:
Brackwasser Bacillarien. Platzko, J., Nagy-Tapolcsány (in German).
- Ross, R., Sims, P.A., 1974. Observations on family and generic limits in the Centrales, in:
Simonsen, R. (Ed.), Second Symposium on Recent and Fossil Diatoms. Nova
Hedwigia Beiheft 45, pp. 97-121.
- Ross, R., Sims, P.A., 1985. Some genera of the Biddulphiaceae (diatoms) with interlocking
linking spines. Bulletin of the British Museum (Natural History), Botany Series
13, 277-381.
- Ross, R., Sims, P.A., Hasle, G.R., 1977. Observations on some species of the Hemiauloideae,
in: Simonsen, R. (Ed.), Fourth Symposium on Recent and Fossil Diatoms.
Nova Hedwigia Beiheft 54, 179-213.
- Schmidt, A., Schmidt, M., Fricke, F., Heiden, H., Müller, O., Hustedt, F., 1874-1959. Atlas
der Diatomaceen-kunde. Leipzig-Berling. Reprint 1984, Koeltz Scientific
Books, Koenigstein (in German).
- Schulz, P., 1935. Diatomeen aus senon Schwammgesteinen der Danziger Bucht. Zugleich
ein Beitrag zur Entwicklungsgeschichte der Diatomeen. Botanisches Archiv
37, 383-414 (in German).
- Sims, P.A., 1986. *Sphinctoletus* Hanna, *Ailuretta* gen. nov., and evolutionary trends within
the Hemiauloideae. Diatom Research 1, 241-269.
- Sims, P.A., 1988. The fossil genus *Trochosira*, its morphology, taxonomy and systematics.
Diatom Research 3, 245-257.
- Sims, P.A., 1994. *Benetorus*, *Gladiopsis* and related genera from the Cretaceous. Diatom
Research 9, 165-187.
- Sims, P.A., 1998. The early history of the Biddulphiales. I. The genus *Medlinia* gen. nov.
Diatom Research 13, 337-374.

- Sims, P.A., Crawford, R.M., 2002. The morphology and taxonomy of the marine centric diatom genus *Paralia*. II. *Paralia crenulata*, *P. fausta* and the new species, *P. hendeyi*. *Diatom Research* 17, 363-382.
- Sims, P.A., Crawford, R.M., 2007. The fossil diatom genus *Truania* Pantocsek and its relationship with *Ellerbeckia* Crawford. *Diatom Research* 22, 195-207.
- Sims, P.A., Hasle, G.R., 1987. Two Cretaceous *Stellarima* species: *S. steinyi* and *S. distincta*; their morphology, palaeogeography and phylogeny. *Diatom Research* 2, 229-240.
- Sims, P.A., Mahood, A.D., 1998. *Vulcanella hanna* Sims and Mahood, gen. et sp. nov., with a discussion of the genera *Tumulopsis* Hendey, *Acanthodiscus* Pantocsek, *Poretzkia* Jousé and *Goniothecium* Ehrenberg. *Diatom Research* 13, 113-131.
- Sims, P.A., Ross, R., 1988. Some Cretaceous and Palaeogene *Trinacria* (diatom) species. *Bulletin of the British Museum (Natural History), Botany series* 18, 275-322.
- Sims, P.A., Mann, D.G., Medlin, L.K., 2006. Evolution of the diatoms: insights from fossil, biological and molecular data. *Phycologia* 45, 361-402.
- Strelnikova, N.I., 1966. Revisio specierum generum *Gladius* Schulz et *Pyxilla* Grev. (Bacillariophyta) e sedimentis Cretae superioris. *Novosti sistematiki nizshikh rastenii*, 23-36 (in Russian).
- Strelnikova, N.I., 1971. Species novae bacillariophytorum e sedimentis Cretae posterioris in declivitate orientali partis polaris ac praepolaris montium Uralensium. *Novosti sistematiki nizshikh rastenii* 8, 41-50 (in Russian).
- Strelnikova, N.I., 1974. *Diatomei pozdnego mela*. Nauka, Moskva (in Russian).
- Strelnikova, N.I., 1995. *Actinoptychus* Ehrenberg and kindred genera in Cretaceous and Paleogene deposits, in: Marino, D., Montresor, M. (Eds.), *Proceedings of the Thirteenth International Diatom Symposium*. Biopress Ltd, Bristol, pp. 431-442.

- Strelnikova, N.I., Fourtanier, E., Kociolek, J.P., 2004. Morphological studies of *Aulacodiscus* species from the "Russian Collection" of the California Academy of Sciences. *Diatom Research* 19, 283-310.
- Strelnikova, N.I., Tsoy, I.B., 2008. The diatoms of Russia and adjacent countries, fossil and recent, vol. II, fasc. 5. St. Petersburg University Press, St. Petersburg (in Russian).
- Suto, I., Jordan, R.W., Watanabe, M., 2009. Taxonomy of middle Eocene diatom resting spores and their allied taxa from the central Arctic Basin. *Micropaleontology* 55, 259-312.
- Tapia, P.M., Harwood, D.M., 2002. Upper Cretaceous diatom biostratigraphy of the Arctic archipelago and northern continental margin, Canada. *Micropaleontology* 48, 303-342.
- Witt, O. N., 1886. Ueber den Polierschiefel von Archangelsk-Kurojedowo im Gouv. Simbirsk. *Verhandlungen der Russisch-kaiserlichen mineralogischen Gesellschaft zu St. Petersburg. Serie II*, 22, 137-177 (in German).