Zitteliana	20	Hagn/Herm-Festschrift	79–86	München, 31. 12. 1993	ISSN 0373-9627

First Oligocene Silicoflagellates from N. Europe (Silstrup, Denmark)

By

KATHARINA VON SALIS*)

With 3 Text-figures and 2 Tables

ABSTRACT

A Late Oligocene silicoflagellate assemblage from Denmark is described and illustrated for the first time. The silicoflagellates are found in a thin diatomite band overlying the Upper Paleocene/Lower Eocene Fur Formation at the base of the Upper Oligocene Vejle Fjord Formation. The absence of *Naviculopsis lata* and the presence of *Distephanus speculum hemisphaericus* assign this assemblage, which is dominated by *Distephanus crux* s. ampl., to the *D. speculum haliomma* Subzone, which has been correlated to the Late Oligocene *Sphenolithus ciperoensis* Zone (NP 25) and the basal part of the Early Miocene *Triquetrorhabdulus carinatus* Zone (NN 1) of calcareous nannofossils.

The age of the Fur Formation at Silstrup is younger than 54 Ma and the sediments correlatable to the middle part of NP 10.

KURZFASSUNG

Eine spätoligozäne Silicoflagellaten-Vergesellschaftung aus der Vejle Fjord-Formation von Dänemark wird erstmals beschrieben und illustriert. Die Silicoflagellaten finden sich in einem ca. 50 cm mächtigen Diatomit, der die bereits bekannten spätpaläozänen bis früheozänen Diatomite und Aschenlagen der Fur-Formation im nördlichen Jütland überlagert. Die Vergesellschaftung wird dominiert von *Distephanus crux* s. ampl. und enthält *Distephanus speculum hemisphaericus*, aber keine *Naviculopsis lata*. Damit gehört sie in die spätoligozäne *D. speculum haliomma*-Subzone, die mit der spätoligozänen *Sphenolithus ciperoensis*-Zone (NP 25) und dem basalen Teil der frühmiozänen *Triquetrorhabdulus carinatus*-Zone (NN 1) der kalkigen Nannofossilien korreliert werden kann.

Das Alter der Fur-Formation in Silstrup ist jünger als 54 Ma und die Sedimente können zur mittleren NP 10 korreliert werden.

1. INTRODUCTION

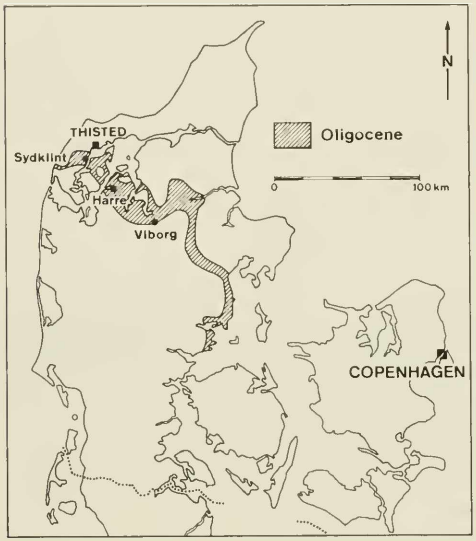
So far, only Late Paleocene and Eocene silicoflagellates were described from the Paleogene of Denmark, Northern Germany, the North Sea area and the Norwegian Sea (MARTINI 1972, 1974, 1981, 1986, PERCH-NIELSEN 1976, MARTINI & MÜLLER 1976 and LOCKER & MARTINI 1986, 1987, 1989). In the present paper, a Late Oligocene assemblage is illustrated and discussed for the first time.

Recently, BERGGREN et al. (1992) reported laser fusion dates from ash layers of the silicoflagellate-bearing Fur Formation. KNOX (1989) showed the correlation of these ash layers to the calcareous nannofossil zonation. These informations allow for a better stratigraphic assignment of the sediments underlying the Late Oligocene layers than previously possible.

*) Prof. Dr. KATHARINA VON SALIS, Geological Institute ETH-Z, CH-8092 Zürich, Switzerland.

I wish to thank Claus Heilmann-Clausen, Århus, for supplying the initial sample from Silstrup that triggerd this investigation and for information about the section at Silstrup. D. Bukry (Menlo Park, USA), C. Heilmann-Clausen (Århus, Denmark), Naja Mikkelsen (Copenhagen, Denmark) and S. Locker (Kiel, Germany) reviewed various versions of the manuscript.

LOCALITY AND MATERIAL



Text-fig. 1: Distribution of Oligocene sediments below the Quaternary in Denmark and localities.

Silstrup Sydklint lies in Thy on the northwestern shore of Limfjorden, Jutland in western Denmark (text-fig. 1; 2 in fig. 1 in Perch-Nielsen 1976, where the legend is missing). A thin diatomite layer of Oligocene age was discovered at this locality by Heilmann-Clausen (1982: 58). The Oligocene layers of the Vejle Fjord Formation, from which the samples were taken, consist mainly of micaceous clays and, at their base, include some 50 cm of diatomites with silicoflagellates (tab. 1). Underlying these diatomites are the diatomites in the Mo Clay of the Fur Formation which spans the Paleocene/Eocene boundary.

The contact between the Lower Eocene Fur Formation and the Upper Oligocene Vejle Fjord Formation is not the result of Quaternary glacial disturbances as suggested by Boggild (1918) and Rosenkrantz (1945). Glauconite-filled burrows penetrate from the Vejle Fjord Formation down into the Fur Formation, showing that the contact, where a hiatus probably spanning over 30 million years is indicated, is not disturbed (Gry 1979).

2. SILICOFLAGELLATE ASSEMBLAGES AND THEIR AGE

m	Lithology	Sample	Silicoflagellates	Fm	Age
7				Vejle Fjord	L. Oligocene
6	d.brown, micaceous clay				
	d.brown clay	5	barren		
5	*brownish clay/diatomite* glauconitic sand, bioturbated	4 A 3	common barren		
4		2	rare	Fur	Early Eocene
3	d.brown, sandy layer; ash + 140? Mo Clay (w. diatomites)				
2	ash + 138				
1		1	common		

Tab. 1: Lithology, samples and silicoflagellate content of the sediments at Silstrup Sydklint. After notes by C. Heilmann-Clausen and the author.

Of the samples studied (Tab. 1), only two, 1 and 4, include rich silicoflagellate assemblages. Besides the common diatoms, also common archaeomonads and rare ebridians and endoskeletal dinoflagellates are present.

2.1 SAMPLE 1

Sample 1 from the Fur Formation (Tab. 1) includes a typical Late Paleocene/Early Eocene silicoflagellate association. Different species of *Corbisema*, *Naviculopsis aspera* and *Dictyocha medusa* are about equally common, while *Dictyocha aspera* is rare. Following Perch-Nielsen (1976), the assemblage belongs to the *N. aspera* Subzone of the *Naviculopsis constricta* Zone which spans the Paleocene/Eocene boundary.

2.2 SILICOFLAGELLATE CORRELATIONS AROUND THE PALEOCENE/EOCENE BOUNDARY

The Paleocene/Eocene diatomites of the Fur Formation in Denmark have been known since the last century. They crop out in western Denmark and contain the ash layers numbered from –39 to +140 by Boggild (1918). While most of the partly laminated Fur Formation is free of $CaCO_3$, occasional layers of „cementstone" are calcareous and often include especially well preserved siliceous assemblages, but no calcareous nannofossils. Recently, Knox (1989) correlated two prominent

AGE	Zone	Subzone	ZONAL MARKERS	locality FUR Fm : No of Ash layers	DENMARK Formations w. Calc. nannos	recognised NP Zones
MIO	*N. lata*		← N.lata*			
OLIGOC.	*N. biapiculata*	*Ds.s. haliomma*	← Ds.s.haliomma*	*Sydklint*	Vejle Fjord	
			← Ds.s.hemisphaericus*			21
	C. apiculata		← C.apiculata+ C.hastata+ N.biapiculata+			19/20
			← D.hexacantha+			18
EOCENE	*D. hexacantha*	*N. punctilia*	← N.punctilia+		Søvind Marl	
		N. vemae	← N.vemae+			17
			← N.vemae*			16
			← D.hexacantha*		Lillebelt Clay	15
	N. foliacea	*D. spinosa*	← D.spinosa*			14
		N. robusta	← N.foliacea*		Røsnæs Clay	12
			← N.aspera+			11
PALEOC.	*N. constricta*	*N. aspera*	← C.naviculoidea+	above + 19		
		C. naviculoidea	← C.naviculoidea*	+ 19 to - 17		
		D. elongata	← D.elongata*	-17 to -19A		
		N. danica	← N.danica*	-30 to -21A		
		N. constricta	← N.constricta*	-33		

Tab. 2: North European Silicoflagellate zonation and the stratigraphic occurrence of silicoflagellate-bearing sediments correlated to the lithologic formations and their calcareous nannofossil zonal assignment. After MIKKELSEN (1975), PERCH-NIELSEN (1971, 1976, 1979) and Thiede et al. (1980). * = First occurrence, + = last occurrence. The ash layers in the Fur Formation are numbered from bottom to top from –34 to +140. Silicoflagellates were only found from -34 to +130.

and chemically distinct ash layers, –17 and +19, with two ash layers in a borehole in N. Germany and with DSDP Site 550. The latter lies some 600 km to the W of the westernmost tip of Great Britain, thus about 1850 km from the Danish occurrences. At Site 550, the two ash layers occur in the lower part of the unusually thick (about 50 m) calcareous nannofossil zone NP 10 of MARTINI (1971) which lies in Polarity Chron 24R.

BERGGREN et al. (1992) reported new laser fusion dates from ashes –17 (54.5 Ma) and +19 (54 Ma) in the Fur Formation of Denmark and the correlation of these ashes to the base of the London Clay Formation (Hales and Harwich Member, respectively). According to KNOX (1984, 1989) the entire series of ashes is contained within NP 10 at Site 550 and the uppermost ashes occur around the middle of NP 10.

No decision as to the exact position of the GSSP (global stratotype section and point) for the Paleocene/Eocene boundary has yet been taken. The current usage, however, puts the boundary within NP 9, at the NP 9/10 boundary, or at the base of the London Clay. All of these positions are below ash layer +19. Thus the layers outcropping at Silstrup Sydklint and containing ash-layers 118 and higher, are younger than 54 Ma and of early Eocene age.

2.3 SAMPLE 4

The silicoflagellate assemblage of sample 4 is totally different from the one in sample 1. It includes the species illustrated on Figures 2 and 3 and discussed below. *Distephanus crux* s. ampl. dominates, while all other species together make up less than 10%. The assemblage can be assigned to the *Naviculopsis biapiculata* Zone of BUKRY (1974, 1978). This zone is defined from the last occurrence of *Corbisema apiculata* or *C. hastata* or the first occurrence of *Naviculopsis biapiculata* to the first occurrence of *N. lata*. The presence of *Distephanus speculum hemisphaericus* assigns the assemblage at Silstrup to the *D. speculum haliomma* Subzone of BUKRY (1981), which is defined from the first occurrence of *D. speculum haliomma* and the first occurrence of *D. speculum hemisphaericus* to the first occurrence of *N. lata*. This subzone has been correlated by BUKRY (1981) to the Late Oligocene calcareous nannofossil zone of *Sphenolithus ciperoensis* and the basal Miocene zone of *Triquetrorhabdulus carinatus* (NP 25 and NN 1, respectively of MARTINI 1971).

Similar assemblages were found by BUKRY (1976b) and MARTINI & MULLER (1976) at DSDP Site 338 on the Voering Plateau in the Norwegian Sea, where they were accompanied by a Late Oligocene calcareous nannofossil assemblage including *Dictyococcites bisectus* and *Cyclicargolithus abisectus* (MULLER 1976). The diatomite samples from Silstrup are non-calcareous and thus barren of calcareous nannofossils. Also, they do not include any reworked silicoflagellates from the underlying diatomites of the Lower Eocene part of the Fur Formation.

No corresponding siliceous interval was found in the Harre boring which was cored only some 30 km to the SSE of Silstrup (Fig. 1; BJØRSLEV NIELSEN et al., in prep.; VON SALIS in prep.) and penetrated Miocene through Danian sediments. In the Oligocene interval of the Viborg boring, cored some 70 km to the SSE of Silstrup (Fig. 1), very rare diatoms but no silicoflagellates have been observed (THIEDE et al. 1980).

BACHMANN (1970) described and illustrated a silicoflagellate assemblage from Austria with a very similar assemblage as the one found at Silstrup. He assigned the austrian assemblage to the Late Oligocene. Since it includes *Naviculopsis lata*, the form marking the base of the zone of that name which presently is correlated to the Lower Miocene calcareous nannofossil zones NN 1 and NN 2 of MARTINI (1971), an Early Miocene age is indicated. The fact that *N. lata* was not found in the assemblage from Silstrup suggests a Late Oligocene to possibly earliest Miocene age for it. BUKRY (1985), who studied the silicoflagellates from Rockall Plateau west of Scotland which is on a similar latitude as Silstrup found *N.* cf. *N. lata* in

DSDP Hole 406. He assigned these samples an ?Early Miocene age. The underlying Late Oligocene assemblage differs from the one treated here by including common specimens of *Naviculopsis biapiculata* and, in its lower part, of the diatom *Rocella gelida*. Both species were not found at Silstrup. The assemblage at Site 406 also includes *Distephanus speculum haliomma*, the presence of which defines the uppermost Oligocene subzone of this name. The presence of this subzone at Silstrup is indicated by the presence of *D. speculum hemisphaericus*.

3. SYSTEMATIC PALAEONTOLOGY

Silicoflagellates are marine, unicellular algae with flagellae. They produce microscopic (30-100 µ), tubular skeletons of opal and thus are mainly preserved in diatomites underlying modern or ancient ocean upwelling areas or in diatomites preserved due to nearby volcanism. The classification follows KRISTIANSEN (1990), the terminology of the silicoflagellates is the one of PERCH-NIELSEN (1985).

Phylum Chrysophyta
Class Dictyochophyceae (silicoflagellates)
Order Dictyochales
Family Dictyochaceae LEMMERMANN, 1901

Bachmannocena apiculata subsp. *glabra* (SCHULZ, 1928) BUKRY, 1987
Text-Fig. 2, fig. 1, 2

1928 *Mesocena polymorpha* var. *triangula* fa. *glabra* SCHULZ: 237, fig. ?3b, 3c.

1978 *Mesocena apiculata glabra* (SCHULZ) BUKRY: 562, pl. 2, fig. 14, 15.

1987 *Bachmannocena apiculata glabra* (SCHULZ) BUKRY: 404.

Remarks: *M. apiculata* has short spines and straight to slightly concave sides.

Corbisema triacantha (EHRENBERG, 1845) HANNA, 1928
Text-Fig. 3, fig. 15, 16

1845 *Dictyocha triacantha* EHRENBERG, 1844: 80.

1931 *Corbisema triacantha* (EHRENBERG) HANNA: 198, pl. D, fig. 1.

1974 *Corbisema triacantha* (EHRENBERG) LOCKER: 634, pl. 1, fig. 10 (= holotype).

Remarks: The holotype of this species is a specimen from the Miocene with short spines and strongly convex sides of the basal ring. The very rare specimens at Silstrup have longer spines and less convex sides than in the holotype.

Dictyocha aspera (LEMMERMANN, 1901) BUKRY & FOSTER, 1973
Text-Fig. 2, fig. 5, 6

1901 *Dictyocha fibula* var. *aspera* LEMMERMANN: 260, pl. 10, fig. 27, 28.

1973 *Dictyocha aspera* (LEMMERMANN) BUKRY & FOSTER: 815-871.

Remarks: The spines are of medium length and the sides of the basal ring only slightly convex and nearly equal in length. A short basal pike is attached about halfway between the strut and the corner of the basal ring in each side. The central bar is less than a third of the length of the diagonal and runs slightly oblique to it. The form is similar to *D. aspera clinata* where, however, the central bar measures about half the length of the diagonal and the basal pikes, where present, are attached at or near the base of the struts.

Dictyocha medusa HAECKEL, 1887
Text-Fig. 2, fig. 3, 4?

1887 *Dictyocha medusa* HAECKEL: 1560, pl. 101, figs. 13, 14.

Remarks: *D. medusa* includes forms with a simple central cross and without basal pikes. The form shown in Text-Fig. 1, fig. 4 seems to be a form between *Dictyocha medusa* and *Distephanus crux darwinii* BUKRY, 1976.

Distephanus boliviensis var. *major* (FRENGUELLI, 1951) CIESIELSKI, 1975
Text-Fig. 3, fig. 22, 23

1940 *Dictyocha boliviensis* var. *major* FRENGUELLI: 44, fig. 4.

1975 *Distephanus boliviensis* var. *major* (FRENGUELLI) CIESIELSKI: 660, pl. 8, figs. 1-5.

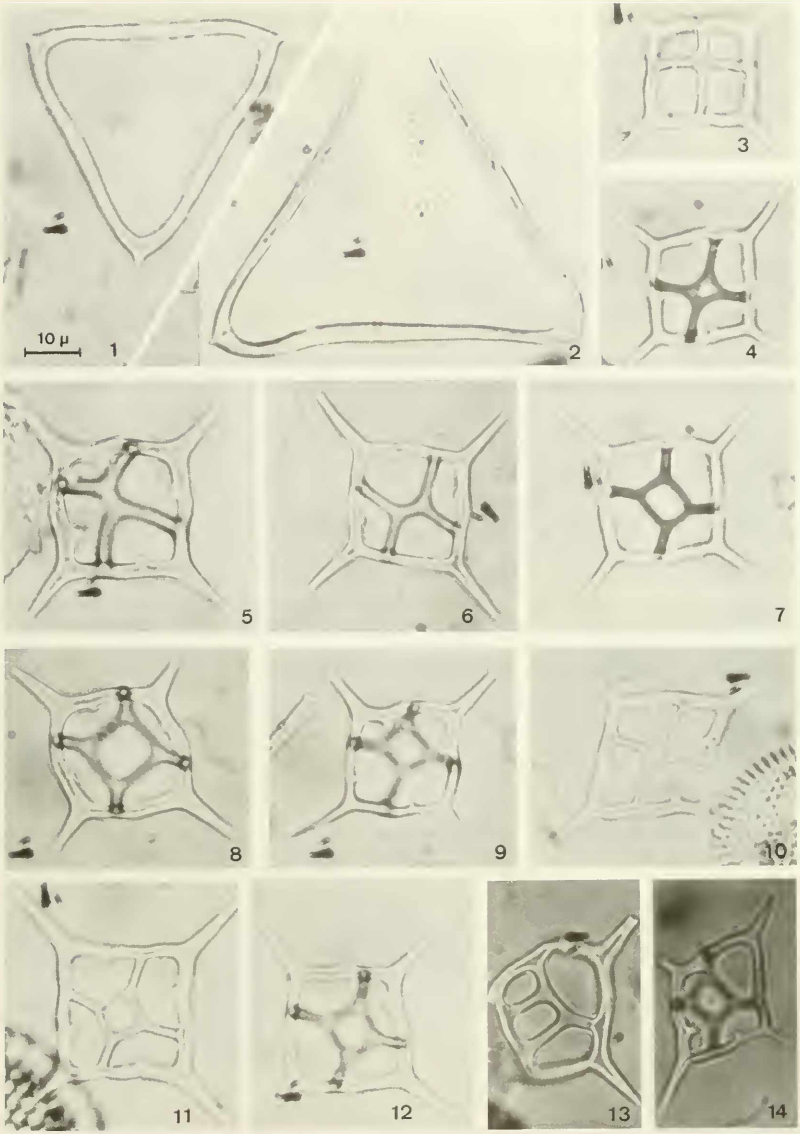
Remarks: As pointed out by MCCARTNEY & WISE (1990), six-sided *Distephanus* exhibit a considerable variability. The forms assigned to *D. boliviensis* differ from those commonly assigned to *D. speculum* by their more massive appearance. But „in many samples the two taxa are distinct and easily separated, but in other samples they appear to intergrade". The variety major is characterised by more than one apical opening. The spines are uneaqual in length.

Distephanus crux (EHRENBERG, 1841) HAECKEL, 1887
Text-Fig. 2, fig. 7-9, 11, 12

1841 *Dictyocha crux* EHRENBERG, Ber. 1840: 207-208.

1887 *Distephanus crux* (EHRENBERG) HAECKEL: 1563.

Remarks: LOCKER (1974) has indicated that a population of *D. crux* may include a variety of sizes of the apical ring. Basal pikes are either missing or relatively short. LOCKER (1974) suggested *Distephanus staurodon* to be a synonym of *D. crux*. The two species are distinguished here on the basis of the form of the basal ring: more or less quadratic in *D. crux* and rhomboedrical in *D. staurodon*.



Text-fig. 2 Light microscope micrographs from sample A, diatomite of the Vejle Fjord Formation, Silstrup. Scale bar = 10 µ.

Fig. 1, 2 *Bachmannocena apiculata* subsp. *glabra* (SCHULZ, 1928) BUKRY, 1987.

Fig. 3 *Dictyocha medusa* HAECKEL, 1887.

Fig. 4 Specimen between *Dictyocha medusa* HAECKEL, 1887 and *Distephanus crux* subsp. *darwinii* (BUKRY, 1976). The latter is often found in the Oligocene *Naviculopsis biapiculata* Zone.

Fig. 5, 6 *Dictyocha aspera* (LEMMERMANN, 1901) BUKRY & FOSTER, 1973.

Fig. 7-9, 11, 12 *Distephanus crux* (EHRENBERG, 1941) HAECKEL, 1887. - Forms without basal pikes, very small basal pikes and well developed basal pikes; forms with small and forms with wide apical opening, which is round, quadratic or rectangular

Fig. 10, 14 *Distephanus staurodon* (EHRENBERG, 1945) BUKRY, 1978.

Fig. 13 Abnormal specimen of *Distephanus crux* s. ampl.

Distephanus speculum (Ehrenberg, 1838) Haeckel, 1887 s. ampl.
Text-Fig. 3, fig. 19

1838 *Dictyocha speculum* Ehrenberg: 132. Nomen nudum.

1840 *Dictyocha speculum* Ehrenberg, 1838: 129, pl. 4, fig. X n.

1887 *Distephanus speculum* (Ehrenberg) Haeckel: 1565.

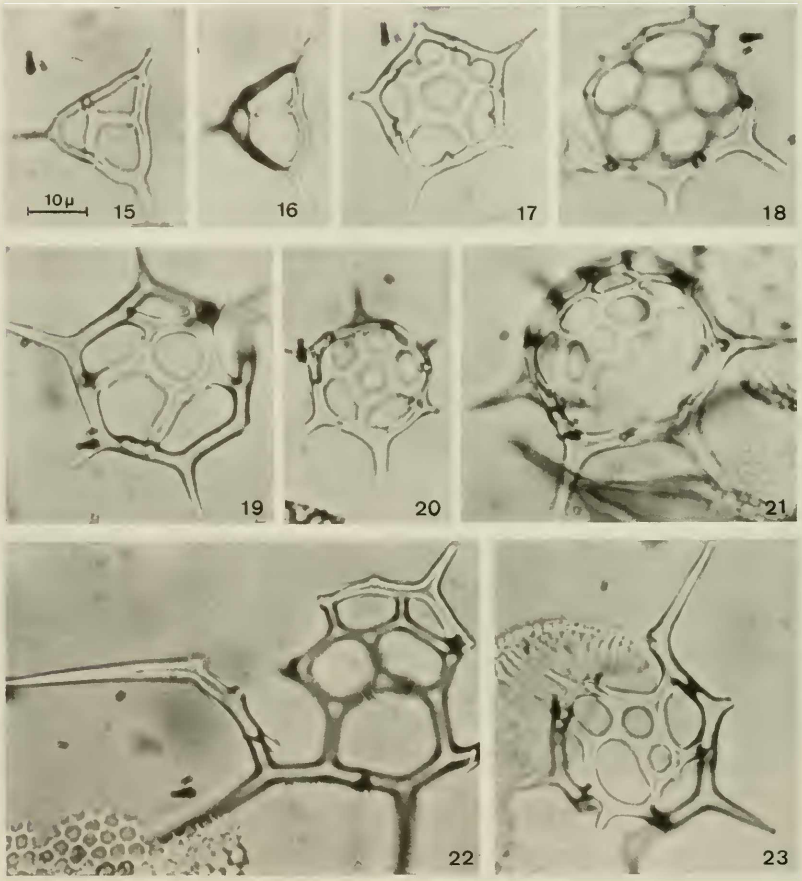
Remarks: *D. speculum* has six sides and spines of equal or unequal length according to Locker (1974) who studied the type material of this species. The specimen illustrated here is abnormal in that its apical ring is supported only by five struts.

Distephanus speculum subsp. *hemisphaericus* (Ehrenberg, 1845) Bukry, 1978
Text-Fig. 3, fig. 18, 21

1845 *Dictyocha hemisphaerica* Ehrenberg, 1844: 266, 267.

1978 *Distephanus speculum hemisphaericus* (Ehrenberg) Bukry: 697.

Remarks: Not following Locker (1974) but rather Bukry (1978), the forms described in the literature as *Distephanus speculum hemisphaericus* and *D. speculum triommata* are not included in *Cannopilus hemisphaericus* but treated as separate subspecies of *Distephanus speculum*.



Text-fig. 3 Light microscope micrographs from sample A, diatomite of the Vejle Fjord Formation, Silstrup. Scale bar = 10µ.

Fig. 15, 16 *Corbisema triacantha* (Ehrenberg, 1845) Hanna, 1931.

Fig. 17 *Distephanus speculum* subsp. *pentagonus* Lemmermann, 1901.

Fig. 18, 21 *Distephanus speculum* subsp. *hemisphaericus* (Ehrenberg, 1845) Bukry, 1978.

Fig. 19 *Distephanus speculum* (Ehrenberg, 1838) Haeckel, 1887 s. ampl.

Fig. 20 *Distephanus speculum* subsp. *triommata* (Ehrenberg, 1846) Bukry, 1976a.

Fig. 22, 23 *Distephanus boliviensis* var. *major* (Frenguelli, 1951) Ciesielski, 1975.

Distephanus speculum subsp. *pentagonus* LEMMERMANN, 1901
Text-Fig. 3, fig. 17

1901 *Distephanus speculum* subsp. *pentagonus* LEMMERMANN: 264, pl. 11, fig. 19.

Remarks: This form is very rare. The spines are of about equal length, the basal pikes are short and the struts nearly radial.

Distephanus speculum subsp. *triommata* (EHRENBERG, 1846) BUKRY, 1976
Text-Fig. 3, fig. 20

1846 *Dictyocha triommata* EHRENBERG, 1845: 76

1974 *Dictyocha triommata* EHRENBERG LOCKER: 643, pl. 4, fig. 5 (holotype figured).

1976a *Distephanus speculum triommata* (EHRENBERG) BUKRY: 896.

Remarks: *D. speculum triommata* is characterised by 3 apical windows. LOCKER pointed out that the population in the sample of the holotype of this subspecies includes forms with 2-5 windows.

Distephanus staurodon (EHRENBERG, 1845) BUKRY, 1978
Text-Fig. 2, fig. 10, 14

1845 *Dictyocha staurodon* EHRENBERG, Ber. 1844: 80.

1978 *Distephanus staurodon* (EHRENBERG) BUKRY: 697.

Remarks: The basal ring of *D. staurodon* is rhomboedric in shape, while the one of *D. crux* is more or less quadratic. The basal pikes are generally better developed in the former than in the latter. The spines are longer along the long axis of the form than along the short one.

REFERENCES

BACHMANN, A. (1970): Silicoflagellaten aus dem oberösterreichischen Egerien (Oberoligozän). - Verh. Geol. B.-A. Wien, **2**: 275-305, 3 figs., 7 tab.; Wien.

BERGGREN, W. A., AUBRY, M.-P. & HARDENBOL, J. (1992): A Late Paleocene Early Eocene new European and North Sea magnetostratigraphic correlation network: a sequence stratigraphic approach. - Abstracts IGCP 308 Meeting, Punta Arenas: 3, 4.

BOGGILD, O. B. (1918): Den vulkanske Aske i Moleret samt en Oversigt over Danmarks ældre Tertiærbjærgarter. - Danm. geol. Unders. Række 2, **33**: 1-159; Copenhagen.

BUKRY, D. (1974): Phytoplankton stratigraphy, offshore East Africa, DSDP Leg 25. - Init. Repts. DSDP, **25**: 635-646, 4 figs, 1 tab.

BUKRY, D. (1976a): Cenozoic silicoflagellate and coccolith stratigraphy, South Atlantic Ocean, Deep Sea Drilling Project Leg 36. - Init. Repts. DSDP, **35**: 885-917, 2 figs, 5 tab., 9 pls.

BUKRY, D. (1976b): Silicoflagellate and coccolith stratigraphy, Norwegian-Greenland Sea, DSDP Leg 38. - Init. Repts. DSDP, **38**: 843-855, 4 tab., 2 pls.

BUKRY, D. (1978): Cenozoic coccolith and silicoflagellate stratigraphy, offshore Northwest Africa, DSDP Leg 41 - Init. Repts. DSDP, **41**: 689-707, 5 figs., 3 pls.

BUKRY, D. (1981): Synthesis of silicoflagellate stratigraphy for Maestrichtian to Quaternary marine sediment. - Spec. Publ. SEPM, **32**: 433-444.

BUKRY, D. (1985): Cenozoic silicoflagellates from Rockall Plateau, Deep Sea Drilling Project Leg 81. - Init. Repts. DSDP, **81**: 547-563, 3 figs., 7 tab., 3 pls.

BUKRY, D. (1987): Eocene siliceous and calcareous phytoplankton, DSDP Leg 95. - Init. Repts. DSDP, **95**: 395-415, 1 fig., 3 tab., 7 pls.

BUKRY, D. & FOSTER, J. H. (1973): Silicoflagellate and diatom-stratigraphy Leg 16, Deep Sea Drilling Project. - Init. Repts. DSDP, **16**: 815-871.

CIESIELSKI, P. F. (1975): Biostratigraphy and paleoecology of Neogene and Oligocene silicoflagellates from cores recovered during Antarctic Leg 28, DSDP. - Init. Repts. DSDP, **28**: 625-691, 9 figs., 9 tab.

EHRENBERG, C. G. (1838): Uber das Massenverhältnis der jetzt lebenden Kiesel-Infusorien und über ein neues Infusorien-Conglomerat als Polirschiefer von Jastraba in Ungarn. - Abh. Akad. Wiss. Berlin **1836**: 109-135; Berlin.

EHRENBERG, C. G. (1840): Über die Bildung der Kreidefelsen und des Kreidemergels durch unsichtbare Organismen. - Abh. Akad. Wiss. Berlin, phys. Abh., **1838**: 59-147; Berlin.

EHRENBERG, C. G. (1845): Uber 2 neue Lager von Gebirgsmassen aus Infusorien als Meeres-Absatz in Nord-Amerika und eine Vergleichung derselben mit den organischen Kreide-Gebilden in Europa und Afrika. - Ber. Akad. Wiss. Berlin, **1844**: 57-97; Berlin.

FRENGUELLI, J. (1940): Consideraciones sobre los Silicoflagelados fosiles. - Rev. Mus. La Plata, Paleont., **2** (7): 37-112, 38 figs., 4 tab.; Buenos Aires.

GRY, H. (1979): Beskrivelse til Geologisk Kort over Danmark. Kortblad Løgstor. - Danm. geol. Unders. Række 1, **26**: 1-58; Copenhagen.

HAECKEL, E. (1887): Report on the radiolaria collected by H. M. S. Challenger during the years 1873-1876. - Rep. Sci. Res. Voyage Challenger, **18** (2): 1803 pp.

HANNA, G. D. (1931): Diatoms and silicoflagellates of the Kreyenhagen Shale. - Mining in California: 197-201.

HEILMANN-CLAUSEN, C. (1982): The Paleocene-Eocene boundary in Denmark. - Newsl. Stratigr., **11** (2): 55-63; Berlin, Stuttgart.

JANECEK, T. R. (1985): Eolian sedimentation in the Northwest Pacific Ocean: a preliminary examination of the data from the Deep Sea Drilling Project Sites 576 and 578. - Init. Repts. DSDP, **86**: 589-603, 8 figs., 2 tab.

KNOX, R. W. O'B. (1984): Nannoplankton zonation and the Paleocene/Eocene boundary beds of NW Europe: an indirect correlation by means of volcanic ash layers. - Quart. J. geol. Soc. London, **141**: 993-999, 5 figs.; London.

KNOX, R. W. O'B. (1989): Mineralogy and Stratigraphy of Volcanic Ash Layers in Lower Palaeogene Beds of the Wursterheide Borehole, Northern Germany. - Geol. Jb., A **111**: 217-231; Hannover.

KRISTIANSEN, J. (1990): Phylum Chrysophyta. - In: MARGULIS, L., CORLISS, J. O., MELKONIAN, M., CHAPMAN, D. J. & MCKHANN, H. I., Handbook of Protoctista, 438-453, 14 figs., 3 tab.

Lemmermann, E. (1901): Silicoflagellatae. - Deutsche Bot. Ges. Ber., **19**: 247-271, 2 pls; Berlin.

Locker, S. (1974): Revision der Silicoflagellaten aus der mikrogeologischen Sammlung von C. G. Ehrenberg. - Eclogae geol. Helv., **67** (3): 631-646, 4 pls.; Basel.

Locker, S. & Martini, E. (1986): Silicoflagellates and some sponge spicules from the SW Pacific, DSDP Leg 90. - Init. Repts. DSDP, **90**: 887-924, 3 figs., 5 tab., 13 pls.

Locker, S. & Martini, E. (1987): Silicoflagellaten aus einigen russischen Paläogen-Vorkommen. - Senckenb. lethaea, **68** (1-4): 21-67, 4 figs., 23 tab., 7 pls.; Frankfurt a. M.

Locker, S. & Martini, E. (1989): Cenozoic silicoflagellates, ebridians and actiniscidians from the Vøring Plateau (ODP Leg 104). - Init. Repts. DSDP, **104**: 543-585, 8 figs., 4 tab., 9 pls.

Martini, E. (1971): Standard Tertiary and Quaternary calcareous nannoplankton zonation. - In: Farinacci, A. (ed.), Plankt. Conf. Second, Rome, 1970. Tecnoscienza, 2: 739-785.

Martini, E. (1972): Silicoflagellate zones in the late Oligocene and Early Miocene of Europe. - Senckenb. lethaea, **53** (1/2): 119-122, 4 figs.; Frankfurt a. M.

Martini, E. (1974): Silicoflagellate zones in the Eocene and early Oligocene. - Senckenb. lethaea, **54** (5/6): 527-532, 1 fig.; Frankfurt a. M.

Martini, E. (1981): Silicoflagellaten im Paläogen von Norddeutschland. - Senckenb. lethaea, **62** (2/6): 277-283, 1 fig., 1 tab., 1 pl.; Frankfurt a. M.

Martini, E. (1986): Silicoflagellates in the Paleogene of Northwest Germany. - Nordwestdeutschland im Tertiär, 1 Beitr. Geol. Erde, **18**: 152-156, 2 figs.; Berlin-Stuttgart (Gebr. Borntäger).

Martini, E. & Muller, C. (1976): Eocene to Pleistocene silicoflagellates from the Norwegian-Greenland Sea (DSDP Leg 38). - Init. Repts. DSDP, **38**: 857-895, 3 figs., 5 tab., 12 pls.

McCartney, K. & Wise, S. W. W. Jr. (1990): Cenozoic silicoflagellates and ebridians from ODP Leg 113: Biostratigraphy and notes on morphologic variability. - Proc. ODP, Sc. Res., **113**: 729-760, 6 figs., 11 tab., 7 pls.

Mikkelsen, N. (1975): Marine Lower Oligocene sediments in Denmark as indicated by coccoliths in the Viborg Formation. - Bull. geol. Soc. Denmark, **24**: 83-86, 1 fig.; Copenhagen.

Muller, C. (1976): Tertiary and Quaternary calcareous nannoplankton in the Norwegian-Greenland Sea, DSDP, Leg 38. - Init. Repts. DSDP, **38**: 823-838, 1 fig., 10 tab., 1 pl.

Perch-Nielsen, K. (1971): Elektronenmikroskopische Untersuchungen an Coccolithen und verwandten Formen aus dem Eozän von Dänemark. - Biol. Skr., **18** (3): 1-76, 2 figs., 1 tab., 61 pls.; Copenhagen.

Perch-Nielsen, K. (1976): New silicoflagellates and a silicoflagellate zonation in North European Paleocene and Eocene diatomites. - Bull. Geol. Soc. Denmark, **25**: 27-40, 35 figs., 3 tab.; Copenhagen.

Perch-Nielsen, K. (1979): Calcareous nannofossil zonation at the Cretaceous/Tertiary boundary in Denmark. - In: Birkelund, T. & Bromley, R. G. (eds.), Cretaceous-Tertiary boundary events, **1**: 115-135, 2 figs., 1 tab., 4 pls.; Copenhagen.

Perch-Nielsen, K. (1985): Silicoflagellates. - In: Bolli, H. M., Saunders, J. B. & Perch-Nielsen, K. (eds.), Plankton Stratigraphy, 713-762, 32 figs.; Cambridge (Cambridge University Press).

Rosenkrantz, A. (1945): Smaabidrag til Danmarks Geologi. 1-8. - Meddr. dansk geol. Foren., **10**: 436-459; Copenhagen.

Schulz, P. (1928): Beiträge zur Kenntnis fossiler und rezenter Silicoflagellaten. - Bot. Archiv, **21**: 225-292; Leipzig.

Thiede, J., Bjorslev Nielsen, O. & Perch-Nielsen, K. (1980): Lithofacies, mineralogy and biostratigraphy of Eocene sediments in Northern Denmark (Deep Test Viborg 1). - N. Jb. Geol. Paläont. Abh., **160** (2): 149-172, 10 figs, 1 tab.; Stuttgart.