# Dinoflagellate cyst stratigraphy of the North Leif I-05 well, Hopedale Basin, Labrador Shelf, offshore eastern Canada

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GEOLOGICAL SURVEY OF DENMARK AND GREENLAND MINISTRY OF THE ENVIRONMENT

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## Contents

Introduction	4
Summary	5
Technical data	6
North Leif I-05, dinoflagellate cysts stratigraphy	7
Samples and methods	7
Palynological preparation	7
Material and analyses	7
Previous palynological studies	7
Stratigraphical results	10
Lower Oligocene/? – Lower Miocene	
Upper Eocene	10
Middle Eocene	10
Upper Paleocene	14
Lower Paleocene	15
Upper Maastrichtian	15
Lower Maastrichtian	
Cenomanian – Upper Albian	
Upper Albian	
Middle Albian	17
Lower Albian – ?Aptian	17
Concluding remarks	18
References	19
Plates 1–48: Illustrations of palynomorphs from North Leif I-05	21

## Introduction

The present report describes the Cretaceous and Palaeogene dinoflagellate cyst stratigraphy of the North Leif I-05 well based on a palynological study of 104 ditch cutting samples provided by the Canada Nova Scotia Offshore Petroleum Board (CNSOPB).

The palynostratigraphy is described and represented in two enclosed range charts (Enclosure 1 illustrate the pesence/absence of species and Enclosure 2 illustrate the absolute numbers of species).

A summary of the dating and stratigraphically important events is presented in Figure 4, and dinoflagellate cyst species are illustrated on 48 plates.

The study is the third part of the project: Regional correlation of Mesozoic–Palaeogene sequences across the Greenland–Canada boundary. In the first part of the project Sønderholm *et al.* (2003) described the regional correlation based on data from the eastern Canadian wells: Ogmund E-72, Skolp E-07, Hekja O-71, Gjoa G-37 and the West Greenland wells: Qulleq-1, Kangâmiut-1, Ikermiut-1, GRO#3 and Umiivik-1 (Fig. 1). The second part described the biostratigraphy of the eastern Canadian Ralegh N-18 well (Nøhr-Hansen 2004).

# Summary

- 1) Lower Oligocene/?Lower Miocene sediments are recorded from DCS 420 m to DCS 510 m.
- 2) Lower Eocene sediments are recorded from DCS 540 m to DCS 660 m.
- 3) Middle Eocene sediments are recorded from DCS 690 m to DCS 1950 m.
- 4) Lower Eocene sediments are recorded from DCS 1980 m to DCS 2190 m.
- 5) Upper Paleocene sediments are recorded from DCS 2220 m to DCS 2340 m.
- 6) Lower Paleocene sediments are recorded from DCS 2370 m to DCS 2490 m.
- 7) Upper Maastrichtian sediments are recorded from DCS 2520 m to DCS 2640 m.
- 8) Lower Maastrichtian sediments are recorded from DCS 2670 m to DCS 2700 m.
- 9) Cenomanian to Upper Albian sediments are recorded from DCS 2730 m to DCS 2760 m
- 10) Upper Albian sediments are recorded from DCS 2790 m to DCS 3090 m.
- 11) Middle Albian sediments are recorded from DCS 3120 m to DCS 3330 m.
- 12) Lower Albian to ?Aptian sediments are recorded from DCS 3360 m to DSC 3500 m (TD).

# **Technical data**

The North Leif I-05 well was drilled in 1980 by a group headed by Petro Canada on the position 54° 24' 38.95" N and 55° 15' 10.57" W in the Hopedale Basin, Labrador Shelf offshore eastern Canada (Fig. 1).

The well was drilled at a water depth of 144.0 m, the rotary table was 12.0 m above sea level, and the total depth was 3513 m below rotary table. The well terminated in Lower Cretaceous? shales/basalt. All sample depths are measured from rotary table datum.



Fig. 1. Exploration wells drilled on the Labrador and South-East Baffin Island shelves offshore eastern Canada.

## North Leif I-05, dinoflagellate cysts stratigraphy

## Samples and methods

## **Palynological preparation**

Palynological preparation of the studied 104 ditch cutting samples (DCS) was carried out by Yvonne Desezar (GEUS). Palynomorphs were extracted from approximately 20 g of sample using modified standard preparation techniques. Only the 1 to 4 mm fraction of the DCS was used in order to reduce the effect of caving. The bulk of the minerals were dissolved by hydrochloric and hydrofluoric acids. A first slide was made after this treatment. A second slide was made of the organic residue after sieving using an 11-micron nylon mesh. A third slide was made after oxidation (3 to 20 minutes) with concentrated nitric acid and sieving with a 20-micron mesh. Oxidation was carried out in order to clean the samples for minor amorphous kerogen particles and pyrite. Finally, palynomorphs were separated from coal particles and woody material in most samples by swirling. After each of the steps mentioned above, the organic residues were mounted in glycerine gel.

One to six palynological slides have been produced for each sample. A set of slides is stored at GEUS, Copenhagen, Denmark, another set is stored at the Geological Survey of Canada (Atlantic), Dartmouth, Nova Scotia, Canada.

## Material and analyses

The palynological slides were studied in transmitted light using a Leitz Dialux 22 microscope (512 742/057691) and a Leitz DM RB (RS232C) microscope.

Dinoflagellate cysts, acritarchs and selected spores and pollen species were recorded from slides of the sieved, oxidised and swirled organic residue. Most of the studied 104 samples revealed dinoflagellate cysts. From each sample 100 specimens were counted where possible, after which the remaining part of the palynological slide was logged for rare taxa.

The sample depths and relative abundance of species referred to in the biostratigraphic section (see below) is illustrated on the rangecharts (Enclosures 1, 2). The illustrations of dinoflagellate cysts from North Leif I-05 (Plates 1–48) are marked with sample number, slide number and laser-video-record number (LVR) for later identification.

## Previous palynological studies

Palynostratigraphic correlations of the Palaeogene and Cretaceous deposits in West Greenland have previously been presented by Nøhr-Hansen *et al.* (2000, 2002). The Early Paleocene to the Late Eocene has been divided into twenty-one palynological intervals (Fig. 2; Nøhr-Hansen 2003) and the Aptian to Late Maastrichtian has been divided into twenty intervals (Fig. 3; Sønderholm *et al.* 2003). These intervals were used by Sønderholm *et al.* (2003) in a regional correlation of the eastern Canadian wells with the West Greenland wells. There is no formal palynological zonation

for the Palaeogene and Cretaceous of the Labrador Shelf, but available data have been summarised by Williams *et al.* (1990).

Series	Stage	Dinocyst zonation*	Palynological intervals present study	Last appearance events	Acmes					
Upper Eocene	Pria. bonian	E8	A. diktyoplokum (H)	A. diktyoplokum	← C. cf. guiseppei ● (H)					
Middle Eocene	Bartonian	E7b	G. texta (H)	G. texta, E. fenestrata, R. longimanum, Phthanoperidinium spp.	← G. texta ■ (H) ← L machaerophorum ● (H) ← L cf. insolitum ■ (H)					
		E7a	G. semitecta (I, K)	C. bartonensis, G. semitecta, H. porosa						
		E6	Late Lutetian (H. I, K)	← P. cf. distinctum ← G. cf. spineta, E. pectiniformis ← A. cf. bicellulum	← Deflandrea sp.1 ■ (I)					
	   Lutetian	E5a	P. regalis (H)	<ul> <li>P. regalis, T. magnifica, D. denticulata</li> <li>C. tenuivirgula</li> </ul>						
				C. magna						
		E4c	C. magna (K)	← H. costae, H. tubiferum, W. cf. lineidentatum						
		E3d- E3c	E. ursulae (K, N2)		← H. tenuispinosum 🔳 (K)					
		ЕЗЬ	C. columna (K, N1, N2, Q)	C. columna, D. brevispinum, W. endocyst, D. aff. pseudocolligerum						
		E3a	E. furensis (H, K, N1, Q)	E. furensis, A. medusettiformis	← H. tenuispinosum ■, Fungal spp. ■ (N1) ← A. cf. bicellulum ■ (H)					
ne				← A. medusettiformis ●	← A. medusettiformis ● (H, I, K)					
Eoce	esian	E2c	A. medusettiformis (I, K, N1, N2?)							
Lower	λbr	E2b	D. condylos (H, K, N1, N2, Q)	D. condylos, D. politum, D. oebisfeldensis, Rhombodinium sp. 1	$\begin{array}{l} \longleftarrow & W.  unaris \blacksquare (N2) \\ \longleftarrow & Spinidnium spp. \blacksquare (N2) \\ \longleftarrow & S. aff. pseudofurcatus \blacksquare (H) \\ \longleftarrow & A. homomorphum \blacksquare (H) \end{array}$					
		E2a	F. bipolaris (H, I, K, N1, N2)	F. bipolaris, Carpatella sp. 1	$\leftarrow F. Dipolaris = (H, N1)$					
		E1	W. astra (K) Spores & D. oebisfeldensis (I, K) pollen	C. dartmoorium (N2), C. crassiramossa (K)	<ul> <li>✓ D. oebisfeldensis ● S. aff. sagittula ● (I), Glaphyrocysta spp. ■ (K)</li> </ul>					
									(H) C. dartmoorium (N2)	≺ ¬ Apectodinium spp.●
ine	Thanetian	P6	dentata Apectodinium acme acme (I, K, N2) (N1)	A. augustum						
Upper Paleocer		P5	A. giþþingensis (H, I, K, N1, N2. Q)	A. margarita	← A. giþþingensis ■ (I, K, Q) ← O. cf. israelianum ■ (I)					
		P4	P. pyrophorum (H, I, K, N2)	P. þyroþhorum consistent P. bulliforme	<ul> <li>Areoligera spp. ■ (H, I, K)</li> <li>P. pyrophorum ■ (I)</li> </ul>					
, e	P2/ P3a? C. kangiliense (N2)			- C kangiliense						
Lower Paleocer			C. kangiliense (N2)	S. cf. iterlaaense						
• Co	mmon	>25	Last occurrence Hiati		H Helllefisk-1 K Kangâmiut-1 N2 Nukik-2					
Abi	undant	>50	← Occurrence		l Ikermiut-1 N1 Nukik-1 Q Qulleq-1					

Fig. 2. Palaeogene palynological intervals and bioevents offshore West Greenland correlated with the dinocyst zonations of Bujak & Mudge (1994) and Mudge & Bujak (1996). From Nøhr-Hansen (2003).

Paleocene	T. evittii (N)			I: Ikermiut-1		
	Palynodinium grallator (S, N, GRO#3)	•	P. grallator, W. spinata   I. majae	O: Ogmund E 72 Q: Qulleq-1 S: Skolp E 07		
U. Maastrichtian	Chatangiella biapatura (S, N)		C. Diapatura T. quinqueangulare	N: North Leif I-05		
	Isabelidinium cooksoniae (S, O, N, GRO#3)	•	l. cooksoniae, H. perforata L. arcticum			
L. Maastrichtian	Alterbidinium acutulum (S, N)	* *	A. acutulum   H. quasicribrata   C. aceras			
	Odontochitina operculata (S, GRO#3)	S. rotunda, T. castanea O. operculata, H. heteracanthum, E. pterococcoides X. wetzellii C. madura R. fucatum T. suspectum A. df. haromanee C. grosse				
U. Campanian	Callaiosphaeridium asymmetricum (S)	* * * * * * *	A. ct. haromense, C. grossa C. asymmetricum C. cf. nyei, C. whitei S. obscurum O. costata, W. lunum B. jaegeri P. infusorioides A. varium C. decorosa			
?	Fromea nicosia (S & Q ?)	*	D. longicornis F. nicosia O. porosa X. ceratioides Fromea sp. 1 C. bondarenkoi			
L. Campanian	Dinocyst sp. E. Ioannides 1986 (S, Q & I)	•	I. microarmum			
U. Santonian ?	Dinogymnium sibiricum (Svartenhuk Halvø, Q ?)		D. cf. sibiricum			
L. Santonian	Heterosphaeridium difficile (Svartenhuk Halvø, Q ?)		H. difficile			
	Arvalidinium scheii (Svartenhuk Halvø, Umiivik-1)	* * *	A. scheil, C. mcintyrei S. longifurcatum J. scheil, I. svartenhukense			
Coniacian	Chatangiella cf. madua (Svartenhuk Halvø, Umiivik-1)	ŧ	I. magnum C. aff. spectabilis			
	Spinidinium echinoideum (Umiivik-1)	•	S. echinoideum ■ S. echinoideum			
U.	Chatangiella cf. ditissima (Umiivik-1)	•	- C. cf. elegantulum I C. cf. ditissima, S. pontis-marie			
Turoman	Raphidodinium fucatum (Umiivik-1)		R. fucatum, T. suspectum			
Cenomanian– Albian	Rugubivesiculites spp. (O, N)	• • •	R reductus Afropollis? R rugosus			
	Quantouendinium dictyophorum/ Odontochitina ancala (O, N)		Q. dictyophorum, O. ancala			
Albian– Aptian	Nyktericysta davisii (O, N, Nuussuaq)		N. davisii			
	Vesperopsis spp. (O,)		Vesperopsis spp., V. longicornis			
	Vesperopsis cf. nebulosa (O)		V. cf. nebulosa Balmula spp.			

Fig. 3. Cretaceous palynological intervals offshore eastern Canada and West Greenland. From Sønderholm *et al.* (2003).

## **Stratigraphical results**

The present stratigraphical results for North Leif I-05 are based on correlation of ranges and events of stratigraphical important marker species with species events known from the Davis Strait area and from the North Sea region. The results are shown in Figure 4 and in Enclosures 1 and 2.

## Lower Oligocene/? – Lower Miocene

## DCS 420 m to DCS 510 m

Age: The LO (last occurrence) of *Systematophora ancyrea* at 420 m indicates an age not younger than Middle Miocene. The LO of *Chiropteridium galea* and *Deflandrea phosphoritica* at 480 m indicates an age not younger than Early Miocene (middle Aquitanian) and not older than earliest Oligocene (Williams *et al.* 2004). The absence of other Miocene markers and the co-occurrence with *Enneadocysta multiconuta* (at 480 m) suggest an earliest Oligocene age.

Reworking: Dinoflagellate cysts as *Chatangiella* spp., *Laciniadinium arcticum, Nyktericysta* spp., *Odontochitina* spp., *Ovoidinium verrucosum* and *Senoniasphaera* spp. from the mid to Upper Cretaceous and *Hystrichosphaeridium tubiferum* and from the Upper Cretaceous to Lower Paleogene have been recorded from the interval.

## **Upper Eocene**

## DCS 540 m to DCS 660 m

Age: The LO of *Areosphaeridium* cf. *michoudii* at 540 m indicates the top of the lower Priabonian *Areosphaeridium michoudii* Subzone (E8a; Figs 2, 4) of Bujak & Mudge (1994). This is supported by the LO of *Enneadocysta* spp. and *Deflandrea* sp. 1 Nøhr-Hansen 2003 at 570 m.

*Deflandrea* sp. 1 was original described from the upper Luthetian (Subzone E7b) in the Ikermiut-1 well, offshore West Greenland by Nøhr-Hansen (2003). However, the occurrence of the species in the present interval and in the E8a Subzone in the Ralegh N-18 well (Nøhr-Hansen, 2004) expands the range of the informal species or indicates reworking.

The LO of *Araneosphaera araneosa* at 630 m also indicates Priabonian (Upper Eocene) according to Williams & Bujak (1985). Nøhr-Hansen (2004) recorded the LO of *Araneosphaera araneosa* above the LO of *Areosphaeridium michoudii* from an interval questionably correlated to E8b in the Ralegh N-18 well.

Reworking: Dinoflagellate cysts as *Chatangiella* spp., *Heterosphaeridium difficile*, *Laciniadinium arcticum*, *Odontochitina* spp. from the mid to Upper Cretaceous and *Palaeoperidinium pyrophorum* from the Upper Cretaceous to Lower Paleogene have been recorded from the Upper Eocene interval.

## **Middle Eocene**

The Middle Eocene has been divided into four intervals.

## Interval 1, DCS 690 m to DCS 1440 m

Age: The LO of *Phthanoperidinium geminatum* at 690 m indicates a late Middle Eocene age (top Bartonian), according to Williams & Bujak (1985) which corresponds to the *Heteraulacacysta porosa* Subzone (E7b; Figs 2, 4) of Bujak & Mudge (1994). This is supported by the LO of *Glaphyrocysta semitecta* at 840 m which Bujak *et al.* 1980 described from the Bartonian Barton Beds Zones Bar-1 to Bar-5.

The single record of *Hystrichostrogylon membraniphorum* subsp. *granulatum* at 750 m indicates an Early to Middle Eocene age (Heilmann-Clausen & Costa 1989).

The LO of *Thalassiphora delicata* at 900 m also indicates that the upper part of the Bartonian Subzone E7b is present. Bujak *et al.* 1980 recorded the LO of the species from the middle part of the Barton Bed Zone Bar-4.

The LO of *Rhombodinium draco* at 1260 m also indicates a Bartonian age. Bujak *et al.* (1980) recorded the range of the species from the Barton Beds Zones Bar-1 to Bar-5.

The LO of *Glaphyrocysta* cf. *spineta* at 1080 m and its occurrence at 1380 m indicates a late Lutetian age. Bujak *et al.* (1980) recorded the LO of *Glaphyrocysta spineta* from the lower part of the Bracklesham Beds Zone B-5, correlating with Subzones E6c–E6b.

#### Interval 2, DCS 1470 m to DCS 1530 m

The LO of *Hystrichokolpoma* cf. *salacia* at 1470 m indicates an Early to Middle Eocene age. Bujak *et al.* (1980) recorded *Hystrichokolpoma salacia* from the Bracklesham Beds Zones B-2 to B-5. This age is supported by the LO of *Glaphyrocysta exuberans* at 1500 m. Bujak *et al.* (1980) described the LO of this species from lower part of the Bracklesham Bed Zone B-5, correlating with the upper Lutetian Subzones E6c–E6b.

#### Interval 3, DCS 1560 m to DCS 1770 m

The LO of *Charlesdowniea tenuivirgula* at 1560 m indicates a mid Lutetian age. Bujak *et al.* (1980) recorded the LO of the species from the middle part of the Bracklesham Bed Zone B-4, correlating with Subzones E6a–E5. However, Costa & Downie (1979) have previously reported the last appearance of the species from the upper Priabonian.

## Interval 4, DCS 1800 m to DCS 1950 m

The LO of *Tetraporina* sp. 1 HNH 2002 at 1800 m indicates a middle Lutetian age. The LO of *Tetraporina* sp. 1 has been recorded from the middle Eocene in the Gjoa G-37 well by Sønderholm *et al.* (2003). In the Gjoa well the LO of *Tetraporina* sp. 1 occurs below the LO of *Cerodinium depressum* and above the LO of *Eatonicysta furiensis* indicating the *Diphyes ficusoides* Biozone (E4; Figs 2, 4) of Bujak & Mudge (1994). In the Ralegh N-18 well the LO of *Tetraporina* sp. 1 HNH 2002 was also recorded from an interval correlating with E4 by Nøhr-Hansen (2004).

The LO of *Cerodinium depressum* at 1920 m also indicates the presence of E4 according to Bujak & Mudge (1994) and Eldrett *et al.* (2004).

Reworking: Dinoflagellate cysts as *Chatangiella* spp., *Chichaouadinium vestitum*, *Fromea fragilis*, *Heterosphaeridium difficile*, *Isabelidinium* spp., *Laciniadinium arcticum*, *Nyktericysta* spp., *Odontochitina* spp., *Ovoidinium verrrucosum*, *Pseudoceratium eisenackii*, *Surculosphaeridium longifurcatum* and the pollen genus *Aquilapollenites* from the mid to Upper Cretaceous and *Areoligera gippingensis*, *Hystrichosphaeridium tubiferum* and *Palaeoperidinium pyrophorum* from the Upper Cretaceous to Lower Paleogene have been recorded from the Middle Eocene intervals.

NORTH LEIF I-05						
Chronostratigraphy			North Leif			
Period/Epoch	Age	Depth	Zone		Events	
		400m		- 420m		
Early Oligocene	Rupelian	450m 500m		-480m -510m	Top of Systematophora ancyrea Top of Enneadocysta multicornuta, Top of Chiropteridium galea, Top of Svalbardella spp. Top of Palaeocystodinium sp 3 Manum 1989, Top of Microdinium reticulatum	
Late Eocene	Priabonian	550m 600m 650m	E8	- 570m - 600m - 630m	Top of Enneadocysta cf. michoudii, Top of Lentinia serrata, Top of Tetraporina spp Top of Deflandrea? sp 1 HNH, Top of Enneadocysta spp. Top of Deflandrea cf.denticulata Top of Glaphyrocysta cf.texta, Top of Araneosphaera araneosa	
680	eac	700m	690	-690m	Top of Phthanoperidinium geminatum	
	Bartonian	750m 800m 850m 900m 950m	50m 50m 50m 50m	- 750m - 780m - 810m - 840m - 900m	Top of Phthanoperidinium aff.distinctum, Top of Hystrichostrogylon memb. granulatum Top of Glaphyrocysta divaricata Top of Hystrichostrogylon membraniphorum Top of Glaphyrocysta semitecta Top of Thalassiphora delicata	
		1000m 1050m 1100m 1150m	E7	— 990m — 1080m — 1110m — 1140m	Top of Phthanoperidinium alectrolophum Top of Glaphyrocysta cf.spineta Top of Azolla spp. Top of G.et sp indet Piasecki 1992	
Middle Eocene		1250m 1250m 1300m 1350m 1400m		— 1260m — 1290m — 1380m	Top of Rhombodinium draco, Top of Rhombodinium porosum Top of Spiniferites pseudofurcatus	
		1450m 1500m 1550m	1670 E6b-E6c	— 1470m — 1500m — 1530m — 1560m	Top of Hystrichokolpoma cf.salacium Top of Glaphyrocysta exuberans Top of Paucilobimorpha triradiata Top of Charlesdowniea tenuivirgula	
	Lutetian	1650m 1650m 1700m 1750m	E5-E6a	— 1650m	Top of Apectodinium quinquelatum, Top of Wetzeliella endocyst	

ŢΤ		l		1		
ig.			1800m	1800	- 1800m	Top of Tetraporina sp 1 HNH 2002
4 7			1850m			
			1900m	E4	1000-	
Sumn			1950m		- 1920m - 1950m	Top of Cerodinium depressum
	950	1980	2000m	1980	- 1980m	Top of Deflandrea cf.spinulosa, Top of Charlesdowniea columna, Top of Diphyes ficusoides, Top of Diphyes
าล ∋if			200011	E3b	-2010m	Colligerum Top of Dracodinium cf.varielongitudum, Top of Diphyes brevispinum
ΞŻ			2050m	2040	2040m	Top of Achilleodinium biformoides, Top of Hystrichokolpoma sp 1 Heilmann-Clausen, Top of Dapsilidinium pseudocolligerum
5 of	Early Eocene	Ypresian	2100m	E3a	-2100m	Top of Eatonicysta furensis Top of Dracodinium politum, Top of Glaphyrocysta texta
ve th			2150m	2130	-2130m	Top of Komewuia sp Ogmund, Top of Dracodinium condylos, Top of Evittosphaerula spp.
e p			2200m	E2b	210011	Top of Svalbardella cf.hampdenensis, Top of Apectodinium paniculatum
a	2220	2220		P6	-2220m	Top of Apectodinium augustum
yn			2250m	2250	-2250m	Top of Cerodinium dartmoorium, Top of Muratodinium fimbriatum, Top of Cerodinium speciosum glabrum, Top of Palaeocystodinium australinum. Top of Areolinera cincingeneis
so	Late Paleocene	Thanetian	2300m	P5	-2310m	Ton of Alicopysta margarita
tra			2350m			Top of Allooyou margana
ıtiç	2370	2370	2400m	2370	-2370m	Top of Trithyrodinium evittii, Top of Spongodinium delitiense, Top of Hystrichosphaeridium tubiferum, Top of Cerodinium diebelii
Jra	Early Paleocene	Danian	2450m	Trithyrodiojum evittij	-2430m	Too of Glaphyrocysta pastielsi
Чd	Lany Faloconio	Buindin	2450111	in a groun han o rita	-2460m	Top of Caligodinium aceras
lic	2620	2520	2500m		2490m 2520m	Top of Alisocysta circumtabulata
datir	Late Cretaceous	2020	2550m	2550 Palynodinium grailator	2550m	Top of Trithyrodinium ci.majae, top of Particulinium granator, top of Senoniasphaera inornata
		Late Maastrichtian	2600m	Chatangiella biapatura	-2610m	
,			2650m	Isabelidinium cooksoniae	-2640m	Top of Isabelidinium belfastense, Top of Hystrichosphaeropsis perforata
<u> </u>		Early Maastrichtian	0700	2670	-2670m	Top of Fibradinium annetorpense, Top of Chatangiella cf.bondarenkoi, Top of Heterosphaeridium heteracanthum,
ter		2700	2/00m	Aiterbidinium acutulum	-2700m -2730m	Top of Xenascus ceratioides
Va		?Cenomanian-Albian	2750m	Rugubivesiculites spp.	-2760m	Top of Heterosphaeridium difficile, Top of Surculosphaeridium longifurcatum, Top of Odontochitina costata, Top of Rugubivesciulites rugosus. Top of Surculosphaeridium longifurcatum, Top of Odontochitina costata, Top of
S	2700 ?	2780 ?	2800m	2790	2790m	Top of Circulodinium cf.attadalicum, Top of Oligosphaeridium albertense, Top of Odontochitina ancala, Top of Palaeoperidinium cf.attadalicum, Top of Oligosphaeridium albertense, Top of Odontochitina ancala, Top of Palaeoperidinium cf.attadalicum, Top of Oligosphaeridium distoration of Historicosphaeridium
an			2850m		202011	aff.arborispinum. Top of Canningia reticulata
d			2900m		-2880m	Top of Oligosphaeridium detacemi, Top of Senonasphaera microrectata, Top of Hapsocysta beneae
stra			2950m	Quantauandinium		
ati		Late Albian		dictyophorum/Odontochitina ancala		
gra			3000m			
ldt			3050m			
nic			3100m			
all	Early Cretaceous	3120	3150m	3120	-3120m	Top of Nyktericysta davisii
y i		3150	515011			
mp			3200m			
ŏ		Middle Albian 3250	3250m	Nyktericysta davisii		
rta			3300m			
nt			3350m			
ev		3380	2400	3390	-3360m	Top of Vesperopsis longicornis
en		Early Albian-?Late Aptian	3400m	Vesperopsis Iongicornis		
Its			3450m		-3450m	Top of Callaiosphaeridium asymmetricum, Top of Xiphophoridium alatum
	3600	3500	3500m	3500	-	

GEUS

<del>1</del>3

## Lower Eocene

The Lower Eocene has been divided into three intervals.

#### Interval 1, DCS 1980 m to DCS 2010 m

Age: The LO of *Charlesdowniea columna* at 1980 m indicates the presence of the *Charles-downiea columna* Subzone (E3b; Figs 2, 4) of Bujak & Mudge (1994) of late Early Eocene age. This is supported by the LO of *Diphyes brevispinum* at 2010 m.

## Interval 2, DCS 2040 m to DCS 2100 m

Age: The common occurrence of *Homotryblium tenuispinosum* at 2040 m and the LO of *Eatonicysta furiensis* at 2070 m indicates the presence of the *Membranilarnacia compressa* Subzone (E3a; Figs 2, 4) of Bujak & Mudge (1994) of late Early Eocene age. The presence of *Apectodinium* spp. together with *Azolla* sp. and *Areoligera* cf. *medusettiformis* within the interval supports a late Early Eocene age. Abundant *Azolla* sp. occur in intervals in the wells Gjoa G-37, and Ralegh N-18 that Sønderholm *et al.* (2003) and Nøhr-Hansen (2004) referred to the *Membranilarnacia compressa* Subzone (E3a).

## Interval 3, DCS 2130 m to DCS 2190 m

Age: The LO of *Dracodinium condylos* together with the LO *Komewuia* sp. Ogmund at 2130 m indicates the presence of the *Dracodinium politum* Subzone (E2b; Figs 2, 4) of Bujak & Mudge (1994) of Early Eocene age. Common *Komewuia* sp. Ogmund occur in intervals in the wells Ogmund E-72 and Ralegh N-18, which Sønderholm *et al.* (2003) and Nøhr-Hansen (2004) referred to the *Dracodinium politum* Subzone (E2b). The LO of an *Evittosphaerula* sp. at 2130 m may be of stratigraphical importance.

Reworking: Dinoflagellate *Isabelidinium* spp. from the mid to Upper Cretaceous has been recorded from the Lower Eocene intervals.

A hiatus representing the lower Ypresian possibly occurs between 2190 m and 2220 m.

## **Upper Paleocene**

The Upper Paleocene has been divided into two intervals.

## Interval 1, DCS 2220

Age: The LO of *Apectodinium augustum* and abundant *Apectodinium* spp. at 2220 m indicates the presence of the *Apectodinium augustum* Biozone (P6; Figs 2, 4) of Bujak & Mudge (1994) and Mudge & Bujak (1996) of latest Paleocene age.

## Interval 2, DCS 2250 m to DCS 2340 m

Age: The LO of *Areoligera gippingensis* at 2250 m and the LO of *Alisocysta margarita* at 2310 m indicate the presence of the *Areoligera gippingensis* Biozone (P5; Figs 2, 4) of Mudge & Bujak (1996) of Late Paleocene age.

Reworking: Dinoflagellate *Isabelidinium* spp. from the mid to Upper Cretaceous has been recorded from the Upper Paleocene intervals.

## Lower Paleocene

## DCS 2370 m to DCS 2490 m

Age: The LO of *Trithyrodinium evittii* and *Alisocysta circumtabulata* at 2370 m indicates the presence of the *Trithyrodinium evittii* Zone of Nøhr-Hansen *et al.* (2002; Figs 3, 4) of Danian, Early Paleocene age. The LO of *Spongodinium delitiense* at the same sample (2370 m) may, however, indicate the middle Danian *Spongodinium delitiense* Subzone of Nøhr-Hansen *et al.* (2002).

## **Upper Maastrichtian**

The Upper Maastrichtian has been divided into three intervals.

## Interval 1, DCS 2520 m

Age: The LO of *Palynodinium grallator* and *Isabelidinium majae* indicates the presence of the *Palynodinium grallator* interval of Sønderholm *et al.* (2003; Figs 3, 4) of Late Maastrichtian age. From the Danish North Sea, Schiøler & Wilson (1993) also recognised the range of *Palynodinium grallator* in the uppermost Maastrichtian *Palynodinium grallator* Zone of Hansen (1977) whereas they only recorded *Isabelidinium majae* from the *Tanyosphaeridium magdalinium* Subzone (lower part of the *Palynodinium grallator* Zone) of Hansen (1977).

## Interval 2, DCS 2550 m to DCS 2580 m

Age: The LO of *Trithyrodinium quinqueangulare* indicates the presence of the Upper Maastrichtian *Chatangiella biapatura* interval of Sønderholm *et al.* (2003; Figs 3, 4), who defined the top of the *Chatangiella biapatura* interval by the LO of *Chatangiella biapatura* and *Trithyrodinium quinqueangulare*. *Chatangiella biapatura* was originally described by McIntyre (1975) from the Upper Maastrichtian from the district of Mackenzie N.W.T., Canada.

## Interval 3, DCS 2610 m to DCS 2640 m

Age: The LO of *Hystrichosphaeropsis perforata* at 2610 m indicates the presence of the *Isabelidinium cooksoniae* interval of Sønderholm *et al.* (2003; Figs 3, 4) of Late Maastrichtian age. Schiøler & Wilson (1993) also recognised the LO of *Hystrichosphaeropsis perforata* in their *Isabelidinium cooksoniae* Interval Zone from the North Sea.

Reworking: Dinoflagellate cysts as *Florentinia* spp., *Odontochitina* spp., *Ovoidinium verrucosum, Pseudoceratium eisenackii, Pseudoceratium polymorphum* and *Stephodinium coronatum* from the mid Cretaceous have been recorded from the Upper Maastrichtian intervals.

## Lower Maastrichtian

## DCS 2670 m to DCS 2700 m

Age: The LO of *Alterbidinium acutulum* at 2670 m indicate the presence of the *Alterbidinium acutulum* interval of Sønderholm *et al.* (2003; Figs 3, 4) of Early Maastrichtian age. Schiøler & Wilson (1993) also recognised the LO of *Alterbidinium acutulum* in their Lower Maastrichtian *Alterbidinium acutulum* Interval Zone from the North Sea.

## Cenomanian – Upper Albian

#### DCS 2730 m to DSC 2760 m

Age: The last consistent occurrence of the pollen *Rugubivesiculites rugusus* at 2730 m indicates the upper part of the Cenomanian to Upper Albian *Rugubivesiculites* spp. interval of Sønderholm *et al.* (2003; Figs 3, 4).

Williams (1975) proposed an Upper Albian *Rugubivesiculites rugosus* Assemblage Subzone from wells on the Scotian Shelf and the Grand Banks offshore eastern Canada. The Subzone was characterised by the presence of *Rugubivesiculites rugosus* and tricolpate pollen. Singh (1971) reported the top of *Rugubivesiculites rugusus* from the Cenomanian and Late Albian in Alberta, Canada.

The LO of the dinocysts *Heterosphaeridium difficile, Palaeohystrichophora infusorioides* and *Surculosphaeridium longifurcatum* also at 2730 m, may suggest a slightly younger age based on the general knowledge of the first occurrence of *Heterosphaeridium difficile* (in the early Turonian; Costa & Davey, 1992). However, Bell & Selnes (1997) later documented the first occurrence of *Heterosphaeridium difficile* from the lower to mid Cenomanian.

## **Upper Albian**

## DCS 2790 m to DSC 3090 m

Age: The LO of *Quantouendinium dictyophorum* at 2790 m indicates the Albian *Quantouendinium dictyophorum* interval of Sønderholm *et al.* (2003; Figs 3, 4). The LO of *Odontochitina ancala* and *Fromea* aff. *expolita* at 2790 m together with the LO of *Circulodinium* sp. 1 HNH 1993 at 2880 m indicate the *Odontochitina ancala* (V2) Subzone of Nøhr-Hansen (1993) of Late Albian age.

The *Quantouendinium dictyophorum* interval was described as an Albian to Aptian brackishwater interval from the Ogmund E-72 well, where it also underlies the non-marine *Rugubivesiculites* spp. interval of Sønderholm *et al.* (2003) of Cenomanian to Late Albian age. Mao *et al.* (1999) described *Quantouendinium dictyophorum* from Aptian to Albian brackish-water deposits in China. However, the diverse dinocyst assemblages in the present interval in the North Leif I-05 well indicate a more marine influenced palaeoenvironment.

Nøhr-Hansen (1993) also recorded *Vesperopsis* aff. *fragilis* from his *Odontochitina ancala* (V2) Subzone of Late Albian age; this record may be important since *Vesperopsis* aff. *fragilis* is probably the same species as *Quantouendinium dictyophorum*.

The present Upper Albian interval is also characterised by the LO of Canningia reticulata, Circulodinium cf. attadalicum, Circulodinium cf. brevispinosum, (all present at 2790 m), LO of Circulodinium spp. (common at 2790 m), LO of Hystrichosphaeridium aff. arborispinum (present at 2970), LO of Oligosphaeridium albertense (common at 2970 m), LO of Palaeoperidinium cf. cretaceum (abundant at 2970 m), LO of Hapsocysta benteae (present at 2820 m) and the LO of Oligosphaeridium asterigerum (present at 2880 m).

The LO of *Oligosphaeridium albertense* suggests an age not younger than Early Cenomanian according to Costa & Davey (1992).

The LO of *Canningia reticulata*, *Circulodinium* cf. *attadalicum* and *Circulodinium* cf. *brevispinosum* at (2790 m) together with the LO of specimens questionably referred to as *Senonias-phaera microreticulata* (at 2820 m) and *Oligosphaeridium asterigerum* (at 2880 m) may suggest reworking or a Late Aptian to Middle Albian age.

## **Middle Albian**

## DCS 3120 m to DSC 3330 m

Age: The LO of *Nyktericysta davisii* at 3120 m and the LO of *Vesperpsis mayi* at 3210 m indicate the Albian to? Aptian *Nyktericysta davisii* interval of Sønderholm *et al.* (2003; Figs 3, 4). *Nyktericysta davisii* has been recorded from upper Middle to lower Upper Albian brackish-water deposits in the Western Interior, USA by Bint (1986) and from the Middle Albian of Arctic Canada by Nøhr-Hansen & McIntyre (1998).

## Lower Albian – ?Aptian

## DCS 3360 m to DSC 3500 m (TD)

Age: The LO of *Vesperopsis longicornis* at 3360 m indicates the presence of the *Vesperopsis* spp. interval of Sønderholm *et al.* (2003; Figs 3, 4) of ?Aptian to Early Albian age and the *Circulodinium brevispinosum* (III) Zone of Nøhr-Hansen (1993) of Early Aptian to Early Albian age.

## **Concluding remarks**

There are no major differences between the overall division into stages based on the present palynological dating and earlier studies of the well by the Bujak Davies Group (1987).

However, the present dating and zonation has been refined based on comparison with and correlation to the new zonations from the North Sea (Bujak & Mudge, 1994; Mudge & Bujak 1996) and West Greenland (Nøhr-Hansen 2003; Sønderholm *et al.* 2003). The re-study of the six Canadian wells, North Leif I-05, Ogmund E-72, Skolp E-07, Hekja O-71, Gjoa G-37 and Ralegh N-18, has contributed with new detailed data that are very useful for establishing a general Cretaceous to Paleogene stratigraphy for the Davis Strait area and for seismic correlation in the region.

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# Plates 1–48: Illustrations of palynomorphs from North Leif I-05

Figs. 1 & 2 Chorat cyst sp. 1 HNH North Leif 32.5-20.0, 420m-3, LVR 27832, 36 Fig. 3 Dinocyst sp. 1 HNH North Leif 32.3-24.7, 450m-2, LVR 27843 Figs 4–6 *Systematophora ancyrea* 44.3-6.3, 450m-3, LVR 27837–39 Figs 7–9 Chorat cyst sp. 2 HNH North Leif 41.7-11.9, 450m-23, LVR 27840–42 Figs. 10–12 *Chiropteridium galea* 18.9-9.8, 480m-3, LVR 27844–46





North Leif I-05 Plate 1 1-2 420 m 3-9 450 m 10-12 480 m

Figs. 1–3 *Chiropteridium galea* 43.7-10.9, 480m-3, LVR 27848–50 Figs 4–6 *Systematophora ancyrea* 43.5-24.2, 480m-3, LVR 27853–55 Fig. 7 *Dinopterygium* sp. 1 HNH North Leif 54.4-15.9, 480m-3, LVR 27856 Figs 8–9 *Hystrichokolpoma* sp. 1 HNH North Leif 47.2-5.7, 480m-3, LVR 27861–62 Figs. 10–11 *Enneadocysta multicornuta* 46.3-7.7, 480m-3, LVR 27857–58





North Leif I-05 Plate 2 1-12 480 m



Figs. 1–2 *Senoniasphaera* sp. 1 HNH North Leif *4*2.6-6.4, 480m-2, LVR 27865–66 Fig. 3 *Svalbardella* sp. 1 HNH North Leif 33.7-19.6, 480m-2, LVR 27868

Figs 4–5 Dinocyst sp. 2 HNH North Leif 53.9-14.0, 480m-3, LVR 27863–64

Fig. 6 Microdinium reticulatum 33.8-15.1, 510m-2, LVR 27869

Fig. 7 Palaeocystodinium sp. 3 Manum et. al 1989 24.4-16.4, 510m-3, LVR 27870

Fig. 8 *Tetraporina* sp. 1 HNH North Leif 37.0-11.3, 540m-3, LVR 27874

Fig. 9 Deflandrea sp. 1 HNH 2003 24.9-17.8, 570m-2, LVR 27875

Figs. 10–12 Areosphaeridium michoudii 28.1-6.0, 540m-2, LVR 27871–73



North Leif I-05 Plate 3 1-5 480 m 6-7 510 m 8, 10-12 540 m 9 570 m

Fig. 1 *Achomosphaera* sp. 1 HNH North Leif 20.4-17.3, 570m-3, LVR 27879 Figs. 2–3 *Cribroperidinium* sp. 1 HNH North Leif 35.6-13.9, 570m-3, LVR 27880–81 Fig. 4 *Dinopterrigyum* sp. 1 HNH North Leif 17.5-10.3, 600m-2, LVR 27882 Figs 5–6 *Systematophora placacantha* 22.7-9.8, 600m-2, LVR 27883–84 Fig. 7 Chorat cyst sp. 2 HNH North Leif 40.7-5.8, 600m-2, LVR 27885 Figs 8–9 *Svalbardella* sp. 1 HNH North Leif 25.4-9.4, 600m-3, LVR 27886–87 Figs 10–11 *Glaphyrocysta* sp. 1 HNH North Leif 30.8-11.7, 600m-3, LVR 27888–89 Fig. 12 *Deflandrea denticulata* 29.7-16.1, 600m-3, LVR 27890



North Leif I-05 Plate 4 1-3 570 m 4-12 600 m

Figs 1–2 *Glaphyrocysta* cf. *texta* 18.4-7.5, 630m-2, LVR 27891–92

Fig. 3 Svalbardella sp. 1 HNH North Leif 33.7-5.6, 630m-4, LVR 27894

Fig. 4 Wetzeliella articulata 38.8-9.5, 660m-2, LVR 27895

Figs 5 Alterbidinium sp. 1HNH North Leif 41.1-15.7, 660m-4, LVR 27898

Figs 6–7 Alterbidinium sp. 1HNH North Leif 38.3-15.8, 660m-4, LVR 27896–97

Figs 8–9 *Spinidinium* sp. 1HNH North Leif 34.8-9.4, 660m-4, LVR 27899–900

Figs 10–11 *Phthanoperidinium comatum* 31.9-10.9, 690m-4, LVR 27901–902



North Leif I-05 Plate 5 1-3 630 m 6-9 660 m 10-11 690 m

- Figs 1–2 *Phthanoperidinium* sp. 1HNH North Leif 49.4-21.9, 690m-4, LVR 27904–905
- Fig. 3 Phthanoperidinium geminatum 43.4-11.1, 690m-4, LVR 27903
- Figs 4-5 Chorat cyst sp. 3 HNH North Leif 52.3-23.0, 690m-4, LVR 27906-907
- Fig. 6 Phthanoperidinium echinatum 34.8-18.5, 720m-2, LVR 27908
- Figs 7–8 Phthanoperidinium comatum 46.7-11.2, 720m-2, LVR 27909–910
- Figs 9–10 *Microdinium reticulatum* 44.3-9.8, 720m-2, LVR 27911–912
- Fig. 11 *Deflandrea* sp. 1 HNH 2003 53.0-11.7, 720m-3, LVR 27913
- Fig. 12 Thrithyrodinium sp. 1 HNH North Leif 49.9-8.4, 720m-4, LVR 27914



## North Leif I-05 Plate 6 1-5 690 m 6-12 720 m

- Figs 1–3 *Phthanoperidinium* aff. *distinctum* 35.3-17.7, 750m-2, LVR 27916–918
- Figs 4–5 Hystrichostrogylon membraniphorum granulatum 44.1-20.8, 750m-2, LVR 27919–20
- Figs 6–7 *Glaphyrocysta divaricata* 30.8-14.1, 780m-3, LVR 27921–922
- Figs 8–9 *Hystrichostrogylon membraniphorum* 810m-2, LVR 27925–926
- Figs 10–11 Chorat cyst sp. 4 HNH North Leif 39.8-22.0, 780m-3, LVR 27923–924





**North Leif I-05 Plate 7** 1-5 750 m 6-7, 10-11 780 m 8-9 810 m



- Figs 1–2 Glaphyrocysta sp. 2 HNH North Leif 41.5-12.4, 840m-3, LVR 27928–929
- Fig. 3 Glaphyrocysta semitecta 44.8-6.7, 840m-3, LVR 27930
- Figs 4–5 Implectosphaeridium sp. 1 HNH North Leif 43.7-9.7, 870m-2, LVR 27931–932
- Figs 6–7 Implectosphaeridium sp. 1 HNH North Leif 29.6-14.6, 870m-2, LVR 27933–934
- Fig. 8–9 *Glaphyrocysta semitecta* 34.4-13.5, 900m-2, LVR 27935–936
- Fig. 10 Thalassiphora delicata 45.5-11.0, 900m-3, LVR 27938
- Fig. 11 Glaphyrocysta sp. 3 HNH North Leif 41.8-20.0, 930m-2, LVR 27939
- Fig. 12 Glaphyrocysta semitecta 39.9-20.4, 900m-3, LVR 27937


**North Leif I-05 Plate 8** 1-3 840 m 4-7 870 m 8-10, 12 900 m 11 930 m

Fig. 1 Cavat sp. 1 HNH North Leif 37.6-11.5, 960m-2, LVR 27941 Figs 2–3 *Phthanoperidinium alectrolophum* 43.1-21.7, 990m-2, LVR 27942–943 Figs 4–5 *Glaphyrocysta* sp. 4 HNH North Leif 27.7-16.6, 1080m-2, LVR 27944–945 Fig. 6 *Cyclonephelium* sp. 1 HNH North Leif 36.0-12.2, 1080m-2, LVR 27951 Figs 7–9 *Glaphyrocysta* cf. *spineta* 38.7-17.3, 1080m-2, LVR 27946–948 Fig. 10 *Cyclonephelium* sp. 2 HNH North Leif 30.6-20.7, 1080m-3, LVR 27952 Figs 11–12 *Heteraulacacysta leptalea* 36.5-17.7, 1110m-3, LVR 27953–954



North Leif I-05 Plate 9 1 960 m 2-3 990 m 4-10 1080 m 11-12 1110 m

Figs 1–2 Gen et sp. indet HNH/SP North Leif 44.2-14.5, 1140m-3, LVR 27955–956

- Fig. 3 Gen et sp. indet HNH/SP North Leif 42.1-4.3, 1140m-3, LVR 27957
- Fig. 4 Phthanoperidinium alectrolophum 27.7-22.7, 1170m-2, LVR 27958

Figs 5–6 *Enneadocysta* cf. *fenestrata* 31.9-22.7, 1170m-2, LVR 27959–960

Fig. 6 Lentinia serrata 53.0-5.9, 1230m-2, LVR 27961

Fig. 7 Lentinia serrata 24.5-16.9, 1230m-2, LVR 27962

Fig. 8 Phthanoperidinium alectrolophum 52.8-15.0, 1230m-2, LVR 27964

Figs 10–11 Glaphyrocysta sp. 5 HNH North Leif 50.5-12.5, 1230m-3, LVR 27966–967





North Leif I-05 Plate 10 1-3 1140 m 4-6 1170 m 7-11 1230



Fig. 1 Lentinia serrata 19.3-16.9, 1260m-2, LVR 27969

Figs 2–3 Lentinia serrata 38.3-10.1, 1260m-2, LVR 27970–71

Figs 4–5 Rhombodinium draco 19.7-5.2, 1260m-2, LVR 27972–73

Fig. 6 Alterbidinium sp. 1 HNH North Leif 30.3-25.1, 1380m-2, LVR 27980

Figs 7-8 Rhombodinium draco 27.5-18.6, 1260m-2, LVR 27978-79

Fig. 9 Paralecaniella indentata 34.4-5.3, 1410m-3, LVR 27983

Figs 10–11 *Glaphyrocysta spineta* 36.3-20.6, 1380m-2, LVR 27981–982

Fig. 12 Rhombodinium porosum 25.1-11.9, 1260m-2, LVR 27976



North Leif I-05 Plate 11 1-5, 7-8, 12 1260 m 6, 10-11 1380 m 9 1410 m

Figs 1–3 *Hystrichokolpoma* sp. 1 HNH North Leif (? *H* cf. *salacium*) 28.2-19.0, 1470m-3, LVR 27984–986

Figs 4–5 *Hystrichokolpoma* sp. 1 HNH North Leif (? *H.* cf. *salacium*) 34.7-17.9, 1470m-2, LVR 27987–988

Fig. 6 Cavat sp. 1 HNH North Leif 27.8-10.2, 1530-2, LVR 27991

Figs 7–8 Hystrichostrogylon membraniphorum 1530m-2, LVR 27992–993

Fig. 9 Glaphyrocysta semitecta 38.8-23.5, 1530m-2, LVR 27994

Figs 10–11 Glaphyrocysta exuberans 42.4-5.0, 1500m-2, LVR 27989–990





North Leif I-05 Plate 12 1-5 1470 m 6-9 1530 m 10-11 1500 m



- Figs 1–2 Charlesdowniea tenuivirgula 49.0-14.2, 1560m-2, LVR 27995–996
- Fig. 3 Dracodinium sp. 1 HNH North Leif 30.3-16.7, 1620m-3, LVR 28000
- Fig. 4 Wetzeliella articulata 41.3-14.5, 1620-2, LVR 28001
- Fig. 5 Wetzeliella endocyst HNH 32.7-22.2, 1650-2, LVR 28002
- Fig. 6 Wetzeliella articulata 39.1-16.7, 1650-2, LVR 28003
- Figs 7-8 Wetzeliella articulata 40.1-9.6, 1650-2, LVR 28004-005
- Figs 9–10 Apectodinium hyperacanthum ? 43.3-8.8, 1650-2, LVR 28006–007
- Fig. 11 Azolla sp. 43.3-15.8, 1650-2, LVR 28008
- Fig. 12 Apectodinium hyperacanthum ? 23.6-18.4, 1650-3, LVR 28009



North Leif I-05 Plate 13 1-2 1560 m 3-4 1620 m 5-12 1650 m

Fig. 1 Wetzeliella articulata 31.9-14.9, 1650-3, LVR 28010

Figs 2–3 Wetzeliella articulata 44.6-16.7, 1650-3, LVR 28011–012

Figs 4–5 Dracodinium sp. 1 HNH North Leif 25.4-8.9, 1650m-3, LVR 28013–14

Fig. 6 Glaphyrocysta sp. 6 HNH North Leif 34.9-11.9, 1680m-2, LVR 28015

Fig. 7 Aranosphaera araneosa 31.9-22.9, 1800m-2, LVR 28016

Fig. 8 Tetraporina sp. 1 HNH 2002 27,5-12.1, 1800m-3, LVR 28017

Fig. 9 Alterbidinium sp. 1 HNH North Leif 31.1-20.7, 1800m-3, LVR 28019

Fig. 10 Alterbidinium sp. 1 HNH North Leif 31.3-25.2, 1800m-3, LVR 28020

Figs 11–12 Senoniasphaera sp. 1 HNH North Leif 39.7-20.3, 1860m-3, LVR 28021–22



North Leif I-05 Plate 14 1-5 1650 m 6 1680 m 7-10 1800 m 11-12 1860 m

Figs 1–3 Senoniasphaera sp. 1 HNH North Leif 40.8-15.2, 1830m-3, LVR 28024–26 Fig. 4 Heterosphaeridium cf. heteracanthum 27.1-4.2, 1890m-2, LVR 28027 Fig. 5 Deflandrea sp. 1 HNH North Leif 22.3-10.9, 1890m-2, LVR 28029 Figs 6–7 Deflandrea sp. 2 HNH North Leif 54.6-9.4, 1890m-2, LVR 28030–31 Figs 8–9 Senoniasphaera sp. 1 HNH North Leif 25.4-16.5, 1890m-2, LVR 28032–33 Fig. 10 Hystrichokolpoma sp. 3 HNH North Leif 52.3-15.4, 1950m-2, LVR 28034 Figs 11–12 Apectodinium homomorphum 19.3-9.1, 1950m-2, LVR 28035–36



North Leif I-05 Plate 15 1-3 1830 m 4-9 1890 m 10-12 1950 m

- Fig. 1 Cordosphaeridium gracile 46.6-9.4, 1950m-2, LVR 28037
- Fig. 2 Trinovantedinium sp. 1 HNH North Leif 22.7-4.7, 1950m-3, LVR 28038
- Fig. 3 Hystrichokolpoma sp. 4 HNH North Leif 43.8-20.1, 1950m-3, LVR 28039
- Fig. 4 Hystrichokolpoma rigaudiae 52.1-14.4, 1950m-2, LVR 28040
- Fig. 5 Trinovantedinium sp. 1 HNH North Leif 32.3-14.4, 1980m-2, LVR 28041
- Fig. 6 Deflandrea denticulata 36.2-10.8, 1980m-2, LVR 28042
- Fig. 7 Charlesdowniea columna 19.6-11.1, 1980m-2, LVR 28043
- Fig. 8 Diphyes ficusoides 24.5-23.6, 1980m-2, LVR 28044
- Fig. 9 *Eatonicysta furiensis*? 19.7-15.2, 1980m-3, LVR 28045
- Fig. 10 Deflandrea spinulosa 24.4-11.4, 1980m-3, LVR 28047
- Figs 11-12 Deflandrea spinulosa 36.1-16.2, 1980m-3, LVR 28048-49



# North Leif I-05 Plate 16 1-4 1950 m 5-12 1980 m

Figs 1-2 Wetzeliella ovalis 30.1-18.1, 1980m-3, LVR 28050-51

Figs 3–4 Homotryblium tenuispinosum 37.3-17.2, 1980m-3, LVR 28052–53

Fig. 5 Cerodinium depressum 38.1-23.3, 1980m-3, LVR 28054

Fig. 6 *Diphyes colligerum* 45.5-22.5, 1980m-3, LVR 28055

Figs 7–8 Wetzeliella ovalis 55.4-12.3, 1980m-4, LVR 28056–57

Figs 9–10 Homotryblium tenuispinosum 21.8-20.7, 2010m-2, LVR 28058–59

Figs 11–12 Trinovantedinium sp. 1 HNH North Leif 22.0-22.6, 2010m-2, LVR 28060–61



North Leif I-05 Plate 17 1-8 1980 m 9-12 2010 m

- Fig. 1 Charlesdowniea columna 21.0-10.6, 2010m-3, LVR 28063
- Fig. 2 Charlesdowniea columna 35.5-15.6, 2010m-3, LVR 28064
- Fig. 3 Spinidinium sp. 2 HNH North Leif 27.6-6.7, 2010m-2, LVR 28065
- Fig. 4 Spinidinium sp. 2 HNH North Leif 33.4-5.6, 2010m-2, LVR 28066
- Fig. 5 Chorat cyst sp. 5 HNH North Leif 24.3-20.3, 2010m-2, LVR 28067
- Fig. 6 Dracodinium cf. varielongitudum 32.7-13.8, 2010m-2, LVR 28070
- Figs 7–8 *Dracodinium* cf. *varielongitudum* 22.6-13.6, 2010m-3, LVR 28071–72
- Fig. 9 Apectodinium homomorphum 43.1-12.8, 2010m-2, LVR 28073
- Figs 10–11 Alterbidinium sp. 1 HNH North Leif 31.6-13.1, 2010m-2, LVR 28071–72
- Fig. 12 Chorat cyst sp. 6 HNH North Leif 48.5-24.6, 2010m-2, LVR 28074



North Leif I-05 Plate 18 1-12 2010 m

- Fig. 1 Cordosphaeridium minimum 53.8-8.5, 2010m-2, LVR 28075
- Fig. 2 Deflandrea denticulata 22.5-19.3, 2010m-3, LVR 28076
- Fig. 3 Deflandrea denticulata 24.9-21.8, 2010m-3, LVR 28077
- Fig. 4 Diphyes brevispinum 18.6-10.3, 2010m-3, LVR 28078
- Fig. 5 Wetziella endocyst HNH 2002 24.2-7.7, 2010m-3, LVR 28080
- Fig.6 Hystrichokolpoma sp. 1 Heilmann- Clausen 1989 26.7-6.3, 2040m-2, LVR 28083
- Figs 7-8 Lejeunecysta sp. 1 HNH North Leif 29.6-15.6, 2010m-3, LVR 28081-82
- Fig. 9 Dapsilidinium cf. pseudocolligerum 28.2-20.0, 2040m-2, LVR 28084
- Fig. 10 Diphyes brevispinum 37.7-6.3, 2040m-3, LVR 28085
- Figs 11–12 Achilleodinium biformoides 34.6-17.7, 2040m-3, LVR 28086–87



North Leif I-05 Plate 19 1-5, 7-8 2010 m 6,9-12 2040 m

- Fig. 1 Senoniasphaera sp. 1 HNH North Leif 35.8-13.5, 2040m-3, LVR 28089
- Fig. 2 Areoligera cf. medusettiformis 30.7-2.9, 2070m-3, LVR 28090
- Fig. 3 Apectodinium sp. 31.7-23.0, 2070m-4, LVR 28091
- Fig. 4 Apectodinium sp. 29.4-17.0, 2070m-4, LVR 28092
- Figs 5–6 Apectodinium sp. 20.3-23.3, 2070m-4, LVR 28093–94
- Fig. 7 Areoligera sp. 1 HNH North Leif 20.1-19.0, 2070m-4, LVR 28096
- Fig. 8 Ovoidinium sp. 1 HNH North Leif 20.9-17.9, 2070m-4, LVR 28097
- Fig. 9 Areoligera sp. 1 HNH North Leif 42.2-13.5, 2070m-4, LVR 28100
- Figs 10-11 Rhombodinium draco 22.3-8.6, 2070m-4, LVR 28098-99
- Fig. 12 Apectodinium sp. 43.2-17.4, 2070m-3, LVR 28095



# North Leif I-05 Plate 20 1 2040 m 2-12 2070 m

Fig. 1 *Diphyes colligerum* 44.6-16.2, 2070m-4, LVR 28101

Figs 2–3 Impagidinium sp. 1 HNH North Leif 42.3-10.8, 2070m-4, LVR 28101–102

Figs 4– 5 Dracodinium sp. 2 HNH North Leif 46.0-19.7, 2070m-4, LVR 28103–104

Figs 6–7 Areosphaeridium michoudii 33.6-13.4, 2070m-2, LVR 28106–107

Figs 8–9 Eatonicysta furiensis 19.3-15.7, 2070m-3, LVR 28108–109

Fig. 10 Apectodinium homomorphum 21.3-16.4, 2070m-3, LVR 28110

Figs 11-12 Cerodinium kangiliense 23.4-19.4 2070m-34, LVR 28111–112



North Leif I-05 Plate 21 1-12 2070 m

- Fig. 1 Apectodinium sp. 22.6-16.8, 2100m-3, LVR 28113
- Fig. 2 Dracodinium politum 27.8-19.7, 2100m-3, LVR 28114
- Fig. 3 Dracodinium politum 36.9-7.5, 2100m-4, LVR 28115
- Fig. 4 *Glaphyrocysta texta* 25.0-16.6, 2100m-4, LVR 28116
- Fig. 5 Deflandrea denticulata? 43.2-17.3, 2100m-4, LVR 28117
- Figs 6–7 Deflandrea denticulata 45.8-15.0, 2100m-4, LVR 28118–119
- Figs 8–9 Dracodinium varielongitudum? 35.1-17.3, 2100m-3, LVR 28120–121
- Fig. 10 Adnatosphaeridium robustum 34.4-17.0, 2130m-2, LVR 28122
- Fig. 11 Adnatosphaeridium robustum 34.1-17.1, 2130m-2, LVR 28123
- Fig. 12 Spiniferites sp. 1 HNH North Leif 52.2-16.3, 2130m-2, LVR 28124



North Leif I-05 Plate 22 1-9 2100 M 10-12 2130 m

Fig. 1 Spiniferites sp. 1 HNH North Leif 36.3-18.1, 2130m-2, LVR 28126

Fig. 2 Adnatosphaeridium robustum 23.3-25.0, 2130m-2, LVR 28127

Fig. 3 Dracodinium condylos 23.0-18.1, 2130m-3, LVR 28128

Figs 4–5 Dinocyst sp. 3 (*Evittosphaerula*) Manum *et al* 1989 23.7-10.0, 2130m-3, LVR 28129–130

Fig. 6 Dinocyst sp. 3 (Evittosphaerula) Manum et al 1989 32.8-20.8, 2130m-3, LVR 28131

Fig. 7 Dinocyst sp. 3 (*Evittosphaerula*) Manum *et al* 1989 34.2-5.7, 2130m-3, LVR 28132

Figs 8–9 Dinocyst sp. 3 (*Evittosphaerula*) Manum *et al* 1989 44.9-15.5, 2130m-3, LVR 28133– 134

Fig. 10 *Glaphyrocysta exuberans* 47.9-4.8, 2130m-3, LVR 28137

Figs 11–12 Hystrichokolpoma sp. 5 HNH North Leif 41.1-12.7, 2130m-3, LVR 28135–136



North Leif I-05 Plate 23 1-12 2130 m

- Fig. 1 Komewuia sp. 1 HNH North Leif 29.4-7.6, 2130m-2, LVR 28138
- Fig. 2 Komewuia sp. 1 HNH North Leif 41.3-13.3, 2130m-2, LVR 28139
- Figs 3-4 Glaphyrocysta sp. 7 HNH North Leif 36.6-16.3, 2160m-2, LVR 28140-141
- Figs 5-6 Lejeunecysta sp. 2 HNH North Leif 26.6-9.0, 2160m-3, LVR 28146-147
- Fig. 7 Svalbardella sp. 1 HNH North Leif 25.1-13.1, 2160m-3, LVR 28145
- Fig. 8 *Eatonicysta furiensis* 50.2-8.6, 2160m-4, LVR 28148
- Fig. 9 *Eatonicysta furiensis* 21.2-20.5, 2160m-4, LVR 28149
- Fig. 10 Areoligera medusettiformis 25.6-19.8, 2160m-2, LVR 28143
- Fig. 11 Areoligera medusettiformis 45.2-25.0, 2160m-2, LVR 28142





North Leif I-05 Plate 24 1-2 2130 m 3-11 2160 m



- Fig.1 Svalbardella cf hampdenensis 27.5-15.6, 2160m-4, LVR 28150
- Fig. 2 Spinidinium sp. 3 HNH North Leif 43.2-4.6, 2190m-2, LVR 28151
- Figs 3-4 Deflandrea sp. 3 HNH North Leif 23.7-21.1, 2190m-2, LVR 28152-153
- Figs 5–6 Apectodinium paniculatum 45.3-18.4, 2190-2, LVR 28154–155
- Fig. 7 Dinocyst sp. 3 (*Evittosphaerula*) Manum *et al* 1989 34.2-5.7, 2190m-3, LVR 28156
- Fig. 8–9 Wilsonidinium sp. 1 HNH North Leif 23.0-22.7, 2190m-4, LVR 28157–158
- Figs 10–11 *Fibrocysta bipolare* 37.2-12.0, 2220m-3, LVR 28164–65
- Fig. 12 Fibrocysta bipolare 21.0-20.3, 2220m-3, LVR 28166



North Leif I-05 Plate 25 1 2160 m 2-9 2190 m 10-12 2220 m

- Fig. 1 Apectodinium augustum/paniculatum 22.3-17.5, 2220m-3, LVR 28167
- Fig. 2 Apectodinium augustum 31.2-12.5, 2220m-3, LVR 28168
- Fig. 3 Apectodinium augustum 41.0-8.7, 2220m-2, LVR 28169
- Fig. 4 Apectodinium augustum 41.3-19.3, 2250m-4, LVR 28171
- Figs 5–6 Apectodinium augustum 43.0-21.6, 2250m-3, LVR 28172–73
- Fig. 7 Cerodinium speciosum glabrum 19.1-11.4, 2250m-3, LVR 28175
- Fig. 8 Cerodinium speciosum glabrum 47.0-18.7, 2250m-3, LVR 28174
- Fig. 9 Apectodinium paniculatum 55.2-18.9, 2250m-3, LVR 28170










North Leif I-05 Plate 26 1-3 2220 M 4-9 2250 m

- Figs 1–2 Hystrichokolpoma sp. 6 HNH North Leif 28.9-6.4, 2250m-3, LVR 28176–177
- Fig. 3 Dracodinium sp. 3 HNH North Leif 26.6-17.6, 2250m-3, LVR 28180
- Figs 4-5 Muratodinium fimbriatum 24.8-5.7, 2250m-3, LVR 28178-79
- Fig. 6 Apectodinium augustum 19.5-13.0, 2280m-3, LVR 28183
- Figs 7–8 Areoligera gippingensis 19.6-15.4 2250m-3, LVR 28181–182
- Figs 9–10 Areoligera gippingensis 16.2-20.2 2280m-3, LVR 28183–184
- Fig. 11 Cerodinium speciosum 31.8-16.2, 2280m-3, LVR 28186
- Fig. 12 Cerodinium striatum 40.9-21.0, 2280m-3, LVR 28187



North Leif I-05 Plate 27 1-5, 7-8 2250 m 6, 9-12 2280 m

- Figs 1–2 Areoligera medusettiformis 42.7-14.3, 2280m-3, LVR 28188–189
- Figs 3-4 Cerodinium speciosum glabrum 28.3-22.1, 2280m-4, LVR 28190-191
- Fig. 5 Alisocysta margarita 28.5-6.9, 2310m-2, LVR 28192
- Fig. 6 Glaphyrocysta sp. 8 HNH North Leif 36.4-8.9, 2340m-3, LVR 28193
- Figs 7-8 Cerodinium striatum 36.8-10.7, 2340m-3, LVR 28194-95
- Fig. 9 Spinidinium aff. sagittula 19.5-15.1, 2340m-3, LVR 28196
- Fig. 10 *Muratodinium fimbriatum* 19.3-6.3, 2340m-2, LVR 28197
- Fig. 11 Palaeoperidinium pyrophorum 27.7-3.6, 2370m-3, LVR 28198



North Leif I-05 Plate 28 1-4 2280 m 5 2310 m 6-10 2340 m 11 2370 m

- Fig. 1 *Phelodinium kozlowski* 22.8-13.1, 2370m-3, LVR 28199
- Fig. 2 Trithyrodinium evittii 24.5-11.0 2370m-3, LVR 28200
- Fig. 3 Palaeoperidinium pyrophorum 35.1-7.1, 2370m-3, LVR 28201
- Figs 4–5 Cordosphaeridiun aff. funiculatum 36.9-19.9, 2370m-3, LVR 28202-203
- Figs 6–7 *Cordosphaeridiun* aff. *funiculatum* 46.4-15.2, 2370m-3, LVR 28205-207
- Fig. 8 Deflandrea denticulata 48.6-17.6, 2370m-3, LVR 28208
- Fig. 9 Spongodinium delitiense 25.2-19.4, 2370m-2, LVR 28209
- Fig. 10 Cerodinium diebelii 25.0-5.5, 2370m-2, LVR 28210
- Fig. 11 Fromea (Bosedinia) laevigata 33.3-9.0, 2370m-2, LVR 28211
- Fig. 12 Cerodinium diebelii 39.6-16.1, 2370m-2, LVR 28212



North Leif I-05 Plate 29 1-12 2370 m

- Fig. 1 Alisocysta circumtabulata 38.9-13.6, 2370m-4, LVR 28213
- Fig. 2 Thalassiphora delicata 35.7-12.9 2370m-4, LVR 28214
- Fig. 3 Hystrichosphaeridium tubiferum 20.3-17.9, 2400m-3, LVR 28215
- Fig. 4 Chorat cyst sp. 7 HNH North Leif 17.0-13.3, 2400m-3, LVR 28216
- Fig. 5 Chorat cyst sp. 7 HNH North Leif 20.2-14.2, 2400m-3, LVR 28217
- Figs 6–7 Dinocyst sp. 2 HNH North Leif 28.0-7.8, 2400m-3, LVR 27218–219
- Figs 8-9 Dinocyst sp. 2 HNH North Leif 41.8-8.3, 2400m-3, LVR 27220-221
- Fig. 10 Deflandrea oebisfeldensis 33.3-10.4, 2400m-2, LVR 28223
- Figs 11-12 Glaphyrocysta sp. 9 HNH North Leif 39.9-3.8, 2430m-3, LVR 28225-226



North Leif I-05 Plate 30 1-2 2370 m 3-10 2400 m 11-12 2430 m

- Figs 1–2 Areoligera sp. 2 HNH North Leif 38.9-3.8, 2430m-3, LVR 28228–229
- Fig. 3 *Cerodinium pannuseum* 19.5-20.9 2430m-4, LVR 28230
- Fig. 4 Spinidinium echinoideum 22.5-3.9, 2430m-3, LVR 28231
- Fig. 5 Tanyosphaeridium sp. 1 HNH North Leif 24.7-14.4, 2430m-3, LVR 28232
- Fig. 6 Cerodinium kangiliense 22.9-23.2 2430m-2, LVR 28236
- Fig. 7 Spiniferites magnificus? 47.7-3.8, 2430m-3, LVR 28237
- Fig. 8 Chorat cyst sp. 7 HNH North Leif 51.2-23.0, 2430m-2, LVR 28238
- Fig. 9 Dinocyst sp. 2 HNH North Leif 33.1-19.4, 2460m-2, LVR 28239
- Fig. 10 Spongodinium delitiense 29.2-18.0, 2460m-3, LVR 28244
- Fig. 11 *Tanyosphaeridium* sp. 1 HNH North Leif 18.9-6.8, 2460m-3, LVR 28245
- Fig. 12 Areoligera sp. 3 HNH North Leif 17.0-24.1, 2460m-3, LVR 28240



North Leif I-05 Plate 31 1-8 2430 m 9-12 2460 m

- Fig. 1 *Caligodinium aceras* 21.5-17.3 2460m-3, LVR 28246
- Figs 2-3 Isabelidinium sp. 1 HNH North Leif 46.6-8.7, 2460m-2, LVR 28248-249
- Fig. 4 Cerodinium sp. 1 HNH North Leif 51.2-19.47, 2460m-2, LVR 28247
- Figs 5-6 Fibrocysta sp. 1 HNH North Leif 27.1-24.9, 2460m-4, LVR 28250-251
- Fig. 7 Glaphyrocysta pastielsii 45.6-17.8, 2460m-4, LVR 28252
- Figs 8–9 Areoligera gippingensis 35.7-18.9 2490-3, LVR 28254–255
- Fig. 10 Areoligera gippingensis 49.3-20.3 2460-4, LVR 28252
- Fig. 11 Senoniasphaera inornata 41.2-8.3 2490m-3, LVR 28256
- Fig. 12 Senoniasphaera inornata 40.2-10.2 2490m-2, LVR 28258



North Leif I-05 Plate 32 1-7, 10 2460 m 9, 11-12 2490 m

- Figs 1–2 Deflandrea sp. 4 HNH North Leif 18.6-7.6, 2520m-3, LVR 28259–260
- Fig. 3 Isabelidinium cf. majae 19.9-22.4, 2520m-3, LVR 28261
- Figs 4–5 *Eatonicysta furiensis*? 27.5-14.9, 2520m-3, LVR 28262–263
- Fig. 6 Cerodinium diebelii 23.8-18.7, 2520m-3, LVR 28264
- Fig. 7 Senoniasphaera inornata 46.0-18.8 2520m-3, LVR 28265
- Fig. 8 Palynodinium grallator 47.7-11.7, 2520m-3, LVR 28266
- Figs 9–10 Palynodinium grallator 44.0-16.5, 2520m-4, LVR 282667–268
- Fig. 11 Apectodinium parvum 44.1-12.9 2520m-4, LVR 28269
- Fig. 12 Stephodinium coronatum 48.8-20.4 2520m-4, LVR 28270



North Leif I-05 Plate 33 1-12 2520 m

- Fig. 1 Isabelidinium cretaceum 17.4-20.3, 2550m-2, LVR 28271
- Fig. 2 Trithyrodinium quinqueangulare 39.1-14.1, 2550m-4, LVR 28272
- Fig. 3 Hystrichosphaeropsis quasicribrata 43.9-15.8, 2550m-4, LVR 28273
- Fig. 4 Palynodinium grallator 31.2-5.3, 2580m-3, LVR 28274
- Fig. 5 Stiphosphaeridium anhtophorum 25.9-11.9, 2580m-3, LVR 28275
- Fig. 6 Hystrichosphaeridium tubiferum/brevispinum 32.0-7.3, 2580m-3, LVR 28276
- Fig. 7 Palaeocystodinium australinum 38.2-13.3, 2580m-3, LVR 28277
- Fig. 8 Trithyrodinium quinqueangulare 37.4-14.1, 2580m-2, LVR 28278
- Fig. 9 Fromea fragilis 16.6-14.3 2610m-3, LVR 28279
- Fig. 10 Cerodinium diebelii (small) 18.1-11.6, 2610m-3, LVR 28280
- Fig. 11 Senegalinium sp. 1 HNH North Leif 18.1-10.0, 2610m-3, LVR 28281
- Fig. 12 Palaeotetradinium silicorum 26.7-5.2 2610m-3, LVR 28282



North Leif I-05 Plate 34 1-3 2550 m 4-8 2580 m 9-12 2610 m

- Fig. 1 Isabelidinium cooksoniae 26.3-12.0, 2610m-3, LVR 28283
- Fig. 2 Dino sp. 3 HNH North Leif 23.4-6.6, 2610m-3, LVR 28284
- Fig. 3 Isabelidinium belfastense 25.9-22.4, 2610m-3, LVR 28285
- Fig. 4-5 Impagidinium sp. 21 HNH North Leif 39.2-5.3, 2610m-3, LVR 28286-287
- Figs 6–7 Hystrichosphaeropsis perforata 40.1-11.6, 2610m-2, LVR 28288–289
- Fig. 8 Isabelidinium cooksoniae 30.5-15.2, 2610m-2, LVR 28290
- Fig. 9 Cyclonephelium sp. 3 HNH North Leif 18.1-17.8, 2640m-3, LVR 28291
- Figs 10-11 Cometodinium whitei 34.4-13.9, 2640m-3, LVR 28292-293
- Fig. 12 Phelodinium trcuspe 36.8-16.6, 2640m-2, LVR 28294



North Leif I-05 Plate 35 1-8 2610 m 9-12 2640 m

- Fig. 1 Hystrichosphaeropsis perforata 25.3-11.9, 2640m-4, LVR 28296
- Fig. 2 Chatangiella spinosa? 36.5-20.1, 2640m-4, LVR 28297
- Fig. 3 Chlamydophorella cf. nyei 18.6-19.5, 2670m-2, LVR 28298
- Fig. 4 Isabelidinium cooksoniae 36.4-19.6, 2670m-2, LVR 28299
- Fig. 5 Spinidinium echinoideum 43.7-25.3, 2670m-2, LVR 28300
- Figs 6–7 Fibradinium annetorpense 24.8-22.3, 2670m-2, LVR 28301–302
- Fig. 8 Chatangiella bondarenkoi 29.1-23.5, 2670m-2, LVR 28303
- Fig. 9 Chatangiella biapatura 33.3-6.8, 2670m-2, LVR 28304
- Fig. 10 Chatangiella sp. 1 HNH North Leif 40.9-18.6, 2670m-2, LVR 28305
- Figs 11–12 Hystrichosphaeropsis sp. 1 HNH North Leif 28.7-10.1, 2670m-3, LVR 28306–7



North Leif I-05 Plate 36 1-2 2640 m 3-12 2670 m

- Figs 1–2 Alterbidinium acutulum 34.3-15.5, 2670m-3, LVR 28309–310
- Fig. 3 Alterbidinium acutulum 45.7-15.3, 2670m-3, LVR 28311
- Figs 4-6 Scriniodinium sp. 1 HNH North Leif 24.5-7.3, 2670m-2, LVR 28313-315
- Fig. 7 Heterosphaeridium heteracanthum 43.0-7.1, 2670m-3, LVR 28312
- Figs 8–9 Chatangiella ditissima 40.3-8.9, 2700m-3, LVR 28317–318
- Fig. 10 Alterbidinium sp. 2 HNH North Leif 35.6-18.3, 2670m-2, LVR 28316
- Fig. 11 Chorat cyst sp. 8 HNH North Leif 31.9-7.6 2700m-2, LVR 28319
- Fig. 12 Chatangiella tripartita 32.8-9.8, 2700m-2, LVR 28320



North Leif I-05 Plate 37 1-7, 10 2670 m 8-9, 11-12 2670 m

- Figs 1–2 Chatangiella tripartita 45.7-13.7, 2700m-1, LVR 28321–322
- Figs 3-4 Xenascus ceratioides 33.3-11.2, 2700m-3, LVR 28323-324
- Fig. 5 Isabelidinium cooksoniae 45.5-8.9, 2700m-3, LVR 28325
- Fig.6 Scriniodinium sp. 1 HNH North Leif 24.7-7.6, 2700m-1, LVR 28326
- Fig. 7 Scriniodinium sp. 1 HNH North Leif /Caligodinium aceras 38.4-17.6, 2700m-3, LVR 28327
- Fig. 8 Historicysta palla 40.3-4.8, 2730m-3, LVR 28328
- Fig. 9 Florentinia stellata 40.2-19.6, 2730m-2, LVR 28329
- Fig. 10 Florentinia stellata 41.7-19.2, 2730m-2, LVR 28330
- Fig. 11 Palaeohystrichophora infusorioides 44.0-22.2, 2730m-2, LVR 28332
- Fig. 12 Xenascus ceratioides 38.7-23.4, 2730m-3, LVR 28333



North Leif I-05 Plate 38 1-7 2700 m 8-12 2730 m

- Fig. 1 Odontochitina operculata 39.1-6.4, 2730m-2, LVR 28334
- Fig. 2 Isabelidinium cooksoniae 36.2-3.0, 2730m-3, LVR 28335
- Fig. 3 Isabelidinium cooksoniae 37.1-7.4, 2730m-3, LVR 28336
- Fig. 4 Rugubivesiculites rugusus 29.3-21.0, 2760m-2, LVR 28337
- Fig. 5 Florentinia cooksoniae 17.8-32.2, 2760m-2, LVR 28339
- Fig. 6 Surculodinium longifurcatum 24.7-7.6, 2760m-2, LVR 28340
- Figs. 7-8 Heterosphaeridium difficile 20.7-21.4, 2760m-2, LVR 28341-342
- Fig. 9 Heterosphaeridium difficile 22.9-19.8, 2760m-2, LVR 28343
- Fig. 10 Dinopterygium cladoides 45.3-12.3, 2760m-2, LVR 28344
- Fig. 11 Odontochitina costata 50.3-20.9, 2760m-2, LVR 28345
- Fig. 12 Circulodinium distinctum 28.2-11.4, 2760m-3, LVR 28346



North Leif I-05 Plate 39 1-3 2730 m 4-12 2760 m

- Figs 1–2 Circulodinium sp. 1 HNH North Leif 31.2-9.3, 2790m-3, LVR 28347–348
- Fig. 3 Oligosphaeridium albertense 19.4-7.5, 2790m-3, LVR 28349
- Fig. 4 Palaeoperidinium cf. cretaceum 17.2-12.7, 2790m-3, LVR 28350
- Fig. 5 Palaeoperidinium cf. cretaceum 21.7-13.9, 2790m-3, LVR 28351
- Figs 6–7 Xenascus ceratioides 19.0-8.0, 2790m-3, LVR 28352–353
- Figs 8–9 Odontochitina ancala 20.1-18.5, 2790m-3, LVR 28354–355
- Fig. 10 *Circulodinium brevispinosum* 20.2-21.3, 2790m-3, LVR 28356
- Figs 11–12 Circulodinium attadalicum 23.1-7.2, 2790m-4, LVR 28358–359



North Leif I-05 Plate 40 1-12 2790 m

- Fig. 1 Canningia reticulata North Leif 20.8-12.3, 2790m-4, LVR 28360
- Fig. 2 Florentinia sp. 1 HNH North Leif 39.9-19.4, 2790m-4, LVR 28361
- Fig. 3 Florentinia sp. 1 HNH North Leif 36.7-15.9, 2790m-5, LVR 28362
- Fig. 4 Odontochitina costata 36.5-20.4, 2790m-5, LVR 28363
- Fig. 5 Florentinia sp. 1 HNH North Leif 35.4-5.7, 2820m-3, LVR 28364
- Fig. 6 Florentinia sp. 1 HNH North Leif 22.6-10.4, 2820m-3, LVR 28365
- Fig. 7 Palaeoperidinium cf. cretaceum 19.3-19.3, 2820m-3, LVR 28366
- Fig. 8 Oligosphaeridium albertense 21.5-19.6, 2820m-3, LVR 28367
- Fig. 9 Hystrichosphaeridium aff. arborispinum 21.5-20.2, 2820m-3, LVR 28368
- Fig. 10 Senoniasphaera microreticulata 41.5-9.2, 2820m-2, LVR 28369
- Fig. 11 Senoniasphaera microreticulata? 49.4-9.2, 2820m-2, LVR 28370
- Fig. 12 Hystrichosphaeridium aff. arborispinum 49.6-10.5, 2820m-3, LVR 28371



North Leif I-05 Plate 41 1-4 2790 m 5-12 2820 m

- Fig. 1 Pseudoceratium cf. interiorense 34.9-15.6, 2820m-3, LVR 28372
- Fig. 2 Coronifera oceanica 45.6-25.6, 2820m-3, LVR 28373
- Fig. 3 Palaeoperidinium cretaceum 22.2-16.2, 2820m-4, LVR 28374
- Fig. 4 Oligosphaeridium poculum 20.4-4.2, 2850m-3, LVR 28375
- Fig. 5 Pareodinia sp. 1 HNH North Leif 45.1-23.1, 2850m-4, LVR 28376
- Fig. 6 Nyktericysta sp. (N. vitrea?) 47.7-17.3, 2850m-4, LVR 28377
- Fig. 7 Nyktericysta sp. (N. vitrea?) 37.7-5.6, 2850m-5, LVR 28378
- Figs 8–9 Quantoendinium dictyophorum 26.2-23.1, 2850m-5, LVR 28379–80
- Fig. 10 Palaeoperidinium cf. cretaceum 20.8-4.6, 2850m-5, LVR 28382
- Fig. 11 Quantoendinium dictyophorum 25.1-24.7, 2850m-4, LVR 28383
- Fig. 12 Nyktericysta sp. (N. vitrea?) 25.1-24.7, 2850m-5, LVR 28384



North Leif I-05 Plate 42 1-3 2820 m 4-12 2850 m

- Fig. 1 Quantoendinium dictyophorum 31.2-15.8, 2880m-3, LVR 28385
- Fig. 2 Rugubivesiculites reductus 20.1-21.6, 2880m-3, LVR 28386
- Fig. 3 Oligosphaeridium asterigerum 21.4-10.0, 2880m-3, LVR 28387
- Fig. 4 Bourkidinium sp. 1 HNH North Leif 25.0-21.9, 2880m-3, LVR 28388
- Fig. 5 Canningia reticulata 33.1-14.3, 2880m-4, LVR 28389
- Fig. 6 Canningia reticulata 29.3-11.2, 2880m-4, LVR 28390
- Fig. 7 Quantoendinium dictyophorum 43.6-15.8, 2880m-3, LVR 28391
- Fig. 8 Cribroperidinium sp. 1 HNH North Leif 40.7-15.1, 2880m-4, LVR 28393
- Figs 9–10 Cyclonephelium membraniphorum 48.8-9.6, 2880m-4, LVR 28394–395
- Figs 11–12 Circulodinium sp. 1 HNH 1993 55.3-9.6, 2880m-5, LVR 28396–397



North Leif I-05 Plate 43 1-12 2880 m

- Fig. 1 Quantoendinium dictyophorum 43.6-3.1, 2910m-3, LVR 28398
- Fig. 2 Circulodinium sp. 1 HNH 1993 22.0-19.2, 2910m-3, LVR 28399
- Fig. 3 Subtilisphaera perlucida 23.4-19.7, 2910m-4, LVR 28400
- Fig. 4 Fromea amphora 47.2-16.3, 2910m-4, LVR 28401
- Fig. 5 Cyclonephelium membraniphorum 29.6-15.9, 2910m-4, LVR 28402
- Fig. 6 Canningia reticulata 18.9-18.8, 2940m-3, LVR 28403
- Fig. 7 Nyktericysta sp. 1 HNH North Leif 24.9-10.4, 2940m-3, LVR 28404
- Fig. 8 Palaeoperidinium cf. cretaceum 30.7-8.7 2970m-3, LVR 28405
- Figs 9–10 Hystrichosphaeridium aff. arborispinum 21.8-7.6, 2970m-3, LVR 28406-407
- Fig. 11 Trichodinium castanea 48.7-12.3, 2970m-3, LVR 28408
- Fig. 12 Trichodinium castanea 39.5-12.5, 2970m-4, LVR 28409


North Leif I-05 Plate 44 1-5 2910m 6-7 2940m 8-12 2970 m

- Fig. 1 Senoniasphaera microreticulata 18.0-13.9, 2970m-4, LVR 28410
- Fig. 2 Kalyptea sp. 1 HNH North Leif 43.7-12.5, 2970m-4, LVR 28411
- Fig. 3 Palaeohystrichophora infusorioides 25.0-20.2, 3000m-3, LVR 28412
- Fig. 4 Xenascus ceratioides 53.0-22.3, 3000m-3, LVR 28413
- Fig. 5 Kalyptea sp. 1 HNH North Leif 19.8-16.2, 3000m-4, LVR 28414
- Figs 6–7 Quantoendinium dictyophorum 32.4-24.6, 3000m-4, LVR 28415–416
- Fig. 8 Palaeoperidinium cf. cretaceum 17.8-21.9 3030m-3, LVR 28417
- Fig. 9 Leaf hair HNH North Leif 42.7-7.3, 3060m-3, LVR 28418
- Fig. 10 Leaf hair HNH North Leif 49.1-17.3, 3090m-3, LVR 28419
- Fig. 11 Rugubivesiculites reductus 24.5-13.6, 3090m-3, LVR 28420
- Fig. 12 Florentinia cooksoniae 47.7-24.5, 3090m-3, LVR 28421



North Leif I-05 Plate 45 1-2 2970m 3-7 3000m 8 3030m 9 3060m, 10-12 3090 m

- Fig. 1 Nyktericysta davisi 42.4-10.8, 3120m-3, LVR 28422
- Fig. 2 Leaf hair HNH North Leif 32.1-21.0, 3150m-3, LVR 28423
- Fig. 3 Pseudoceratium pelliferum 28.7-18.3, 3150m-4, LVR 28424
- Fig. 4 Nyktericysta davisii 37.5-4.7, 3150m-4, LVR 28425
- Figs 5–6 Nyktericysta davisii 37.5-4.7, 3180m-3, LVR 28426–427
- Figs 7-8 Cribroperidinium sp. 3 HNH North Leif 40.7-12.4, 3180m-3, LVR 28429-430
- Figs 9–10 *Cribroperidinium* sp. 4 HNH North Leif 31.3-18.6, 3180m-3, LVR 28431–432
- Fig. 11 Nyktericysta davisii 20.9-12.4, 3180m-4, LVR 28434
- Fig. 12 Nyktericysta cf. davisii 17.6-23.9, 3210m-3, LVR 28435



North Leif I-05 Plate 46 1 3120m 2-4 3150m 5-11 3180m 12 3210 m

- Fig. 1 Hapsocysta benteae 19.6-10.3, 3210m-3, LVR 28436
- Fig. 2 Hapsocysta benteae 50.8-19.9, 3210m-4, LVR 28437
- Fig. 3 Vesperopsis cf. mayi 48.4-6.4, 3210m-4, LVR 28438
- Figs 4-5 Chorat cyst sp. 9 HNH North Leif 49.4-17.4, 3210m-4, LVR 28439-40
- Fig. 6 Nyktericysta davisii 21.4-16.6, 3240m-3, LVR 28441
- Fig. 7 Vesperopsis mayi 29.4-12.2, 3300m-4, LVR 28442
- Fig. 8 Cerodinium sp. 2 HNH North Leif 23.2-18.3, 3360m-4, LVR 28444
- Fig. 9 Cerodinium sp. 2 HNH North Leif 29.5-15.4, 3360m-5, LVR 28445
- Fig. 10 Vesperopsis longicornis 55.6-10.1, 3360m-3, LVR 28446
- Fig. 11 Vesperopsis longicornis 35.2-23.4, 3360m-4, LVR 28447
- Fig. 12 Vesperopsis mayi 44.5-20.5, 3360m-4, LVR 28448



North Leif I-05 Plate 47 1-5 3210m 6 3240m 7 3300m 8-12 3360 m

- Fig. 1 Callaiosphaeridium asymmetricum 21.3-11.9, 3450m-3, LVR 28449
- Fig. 2 Xiphophoridium alatum 36.2-16.7, 3450m-4, LVR 28450
- Fig. 3 Quantoendinium dictyophorum 25.2-22.1, 3450m-4, LVR 28451
- Fig. 4 Batioladinium exiguum? 39.5-20.7, 3450m-5, LVR 28452



North Leif I-05 Plate 48 1-4 3450m

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Well Name Operator : Petro ( Well Code : NORT) Lat/Long : 54°24' Interval : 400m Scale : 1:4000 Chart date: 03 Dec	: NORTH LEIF I-05 Canada Spudded : 08 September 200 HLEIFI-05 Completed : 08 September 200 38.95"N 55°15' 10.57"E 3520m ember 2004	GEUS Report file no. Enclosure 25693 (01/02)	Acttances [YALM													
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cene Late Paleocene Early Eocene	Line 2050m 2000 2050m E3a 2100m E3a 2150m E2b 2200m 2200 P6 2250m 2280 P6 2250m 2280 P5 2370 2400m	2040 2070 2100 2130 2160 2190 2220 2250 2250 2280 2310 2340 2370 2400	I       I													
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GEUS Copenhagen Enclosure 1: Presence/absence of species Project : NORTH LE Chest : north lef Events -----Top of Systematophora ancyrea Top of Enneadocysta multicomuta, Top of Chiropteridium galea, Top of Svalbardella spp., Top of Deflandrea phosphoritica Top of Palaeccystodinium sp 3 Manum 1989, Top of Microdinium reticulatum Top of Lentinia serrata, Top of Tetraporina spp, Top of Areosphaeridium of. michoudil Top of Deflandrea? sp 1 HNH, Top of Enneadocysta spp. Top of Defiandrea cf.denticulata Top of Giaphyrocysta cf.texta, Top of Araneosphaera araneosa Top of Phthanoperidinium geminatum Top of Phthanoperidinium aff.distinctum, Top of Hystrichostrogylon memb. granulatum Top of Glaphyrocysta divaricata Top of Hystrichostrogylon membraniphorum Top of Glaphyrocysta semitecta Top of Thalassiphora delicata Top of Phthanoperidinium alectrolophum Top of Glaphyrocysta cf.spineta Top of Azolla spp. Top of G.et sp Indet Plasecki 1992 Top of Rhombodinium draco, Top of Rhombodinium porosum Top of Spiniferites pseudofurcatus Top of Hystrichokolpoma cf. salacia Top of Glaphyrocysta exuberans Top of Paucilobimorpha triradiata Top of Charlesdowniea tenuivirgula Top of Apectodinium quinquelatum, Top of Wetzeliella endocyst Top of Tetraporina sp 1 HNH 2002 Top of Cerodinium depressum Top of Apectodinium homomorphum Top of Deflandrea cf.spinulosa, Top of Charlesdownlea columna, Top of Diphyes ficusoides, Top of Diphyes colligerum Top of Dracodinium cf.varielongitudum, Top of Diphyes brevispinum Top of Achilleodinium biformoldes, Top of Hystrichokolpoma sp 1 Heilmann-Clausen, Top of Dapsilidinium pseudocolligerum Top of Eatonicysta furensis Top of Dracodinium politum, Top of Glaphyrocysta texta Top of Komewula sp Ogmund, Top of Dracodinium condylos, Top of Evittosphaerula spp. Top of Svalbardella cf.hampdenensis, Top of Apectodinium paniculatum Top of Apectodinium augustum Top of Cerodinium dartmoorium, Top of Muratodinium fimbriatum, Top of Cerodinium speciosum glabrum, Top of Palaeocystodinium australinum, Top of Areoligera glopingensis Top of Allsocysta margarita Top of Trithyrodinium evittil, Top of Spongodinium delitiense, Top of Hystrichosphaeridium tubiferum, Top of Cerodinium diebelli, Top of Alisocysta circumtabulata Top of Glaphyrocysta pastleisi Top of Caligodinium aceras Top of Isabelidinium cf.majae, Top of Palynodinium grallator, Top of Senoniasphaera inomata Top of Trithyrodinium quinqueangulare, Top of Hystrichosphaeropsis quasicribrata Top of Isabelidinium belfastense, Top of Hystrichosphaeropsis perforata Top of Defiandrea galeata, Top of Pseudoceratium cf.expolitum Top of Fibradinium annetorpense, Top of Chatanglella cf.bondarenkol, Top of Heterosphaeridium heteracanthum, Top of Alterbidinium acutuium, Top of Chlamydophorella cf.nyei Top of Xenascus ceratioides Top of Odontochitina operculata, Top of Palaeohystrichophora infusorioides, Top of Rugubivesciculites rugosus Top of Heterosphaeridium difficile, Top of Surculosphaeridium longifurcatum, Top of Odontochitina costata, Top of Rugubivesiculates reductus n Top of Circulodinium cf.attadallcum, Top of Oligosphaeridium albertense, Top of Odontochitina ancala, Top of Palaeoperidinium dictycphorum, Top of Hystrichosphaeridium aff.arborispinum, Top of Canningia reticulata m Top of Palaeoperidinium cretaceum, Top of Senonlasphaera microreticulata, Top of Hapsocysta benteae Top of Oligosphaeridium asterigerum, Top of Circulodinium sp. 1 HNH 1993 Top of Nyktericysta davisli A Top of Vesperopsis longicomis

Top of Callalosphaeridium asymmetricum, Top of Xiphophoridium alatum

Well Name : NORTH LEIF I-05       Spudded : 08 September 2004         Operator : Petro Canada       Spudded : 08 September 2004         Well Code : NORTHLEIFI-05       Completed : 08 September 2004         Lat/Long : 54°24' 38.95"N 55°15' 10.57"E       Beport file no.         Interval : 400m - 3520m       25693 (02/02)         Scale : 1:4000       Chart date: 03 December 2004									NORTH LEIF I-05															95																									
Chronosta	atigraphy Dep	North Leif	r definition Baunbages spo	<ul> <li>Fraucioomorpha unaquata</li> <li>Prerospermella spp.</li> <li>Schrächnis spp.</li> <li>Pediastrum spp.</li> <li>Tetraporina sp 1 HNH 2002</li> </ul>	Aphilieodinium biformoides 103 Achilieodinium biformoides 21 Achomosphaera spp. 106 Adnatosphaera spp. 135 Altisocysta circumtabulata 175 Altenbidinium soutulum 200 Altenbidinium soutulum	119     Apectodinium augustum       84     Apectodinium homomorphum       115     Apectodinium paniculatum       116     Apectodinium paniculatum       133     Apectodinium quinquelatum       85     Apectodinium quinquelatum       87     Apectodinium arandeca	<ul> <li>107 Areoligera cf.medusettiformis</li> <li>122 Areoligera gippingensis</li> <li>68 Areoligera spp.</li> <li>34 Areosphaeridium cf. diktyoplokum</li> <li>15 Areosphaeridium cf. michoudii</li> <li>48 Areosphaeridium michoudii</li> </ul>	<ul> <li>233 Batioladinium aff.exiguum</li> <li>219 Bourkidinium spp.</li> <li>149 Callajosphamerangu</li> <li>213 Callajosphaeridium asymmetricum</li> <li>198 Canningia reticulata</li> <li>229 Canningia spp.</li> </ul>	<ul> <li>123 Cerodinium dartmoonium</li> <li>82 Cerodinium depressum</li> <li>136 Cerodinium diebelii</li> <li>145 Cerodinium pannuceum</li> <li>124 Cerodinium speciosum</li> <li>125 Cerodinium speciosum</li> </ul>	<ul> <li>52 Cerodinium spp.</li> <li>131 Cerodinium striatum</li> <li>53 Charlesdowniea coleothrypta</li> <li>89 Charlesdowniea columna</li> <li>54 Charlesdowniea spp.</li> <li>69 Charlesdowniea tenuivirgula</li> </ul>	<ul> <li>176 Chatangiella cf.bondarenkoi</li> <li>170 Chatangiella cf.spinosa</li> <li>181 Chatangiella sp.</li> <li>182 Chatangiella tripartita</li> <li>70 Chichaouadinium vestitum</li> </ul>	<ol> <li>Contropteriourum galesa</li> <li>Chiropteriotum spp.</li> <li>Chiropteriotum spp.</li> <li>Chiamydophorella cf.nyei</li> <li>Chorate cysts</li> <li>Chorate spp.</li> </ol>	<ul> <li>Circulodinium cf.attadalicum</li> <li>Circulodinium cf.brevispinosum</li> <li>Circulodinium cf.brevispinosum</li> <li>Circulodinium sp. 1</li> <li>Circulodinium spp.</li> <li>Circulodinium spp.</li> <li>Circulodinium huguoniotti</li> </ul>	184 Cometodinium spp. 171 Cometodinium whitei 86 Cordosphaenidium gracile 98 Cordosphaenidium spp. 58 Cordosphaenidium spp. 185 Cordosphaenidium spp.	185 Conconneria oceanica 22 Cribropendinium spp. 221 Ocyclonephelium spp. 172 Ocyclonephelium spp. 104 Deptaidinium pseudocolligerum	<ul> <li>25 Defiandrea d'annuata</li> <li>90 Defiandrea denticulata</li> <li>150 Defiandrea galeata</li> <li>108 Defiandrea kanglilense</li> <li>130 Defiandrea oebisteldensis</li> </ul>	5 Defiandrea prosphortica 11 Defiandrea spp. 23 Dinogramiea? sp 1 HNH 59 Dinogramium spp. 120 Dinopterygium cf.cladoides 6 Dinopterygium spp.	<ul> <li>99 Diphyes brevispinum</li> <li>92 Diphyes colligerum</li> <li>93 Diphyes ficusoides</li> <li>100 Dracodinium cf.varielongitudum</li> <li>112 Dracodinium condylos</li> <li>100</li> </ul>	<ul> <li>109 Draccomum ponuum</li> <li>72 Draccofinium spp.</li> <li>94 Eatonicysta furensis</li> <li>202 Endooseratium cf. dettmanniae</li> <li>49 Enneadocysta cf. fenestrata</li> <li>7 Enneadocysta multicornuta</li> </ul>	<ul> <li>24 Enneadocysta spp.</li> <li>113 Evittosphaenula spp.</li> <li>178 Fibradinium annetorpense</li> <li>121 Fibradinium annetorpense</li> <li>126 Fibrantina tenera</li> <li>203 Florentinia cf.buspina</li> </ul>	<ul> <li>194 Florentinia cooksoniae</li> <li>204 Florentinia spp.</li> <li>205 Fromea aff. expolita</li> <li>225 Fromea amphora</li> <li>162 Fromea fragilis</li> </ul>	<ul> <li>137 Fromea reevgata</li> <li>142 Eromea spp.</li> <li>45 Glaphyrocysta cf.spineta</li> <li>28 Glaphyrocysta cf.texta</li> <li>39 Glaphyrocysta dvaricata</li> </ul>	<ul> <li>31 Glaphyrocysta infricata</li> <li>31 Glaphyrocysta infricata</li> <li>41 Glaphyrocysta semitecta</li> <li>26 Glaphyrocysta spp.</li> <li>110 Glaphyrocysta texta</li> </ul>	<ul> <li>214 Hapsocysta benteae</li> <li>46 Heteraulacacysta leptalea</li> <li>187 Heterosphaenfdium difficile</li> <li>179 Heterosphaenfdium heteracanthum</li> <li>188 Histlocysta palla</li> <li>3 Homotryblium spp.</li> </ul>	<ul> <li>Hornoryprium renurspinosum</li> <li>Hystrichodnium pulchrum</li> <li>Hystrichokolpoma rigaudiae</li> <li>Hystrichokolpoma et. salacia</li> <li>Hystrichokolpoma sp. 1 Heilmann-Clausen</li> <li>Hystrichokolpoma sp.</li> </ul>	<ul> <li>206 hystochosphaerioum au arouvispinum</li> <li>133 Hystrichosphaerioum tubiferum</li> <li>151 Hystrichosphaerious perforata</li> <li>167 Hystrichosphaeropsis perforata</li> <li>158 Hystrichosphaeropsis quasicribrata</li> <li>37 Hystrichostrogylon memb. granulatum</li> </ul>	<ul> <li>1. Inpagricinous spin international approximation</li> <li>1. Impletosphanolum spp.</li> <li>1. Isabelicinium acuminatum</li> <li>1.68 Isabelicinium belfastense</li> <li>1.52 Isabelicinium cr.majae</li> <li>1.63 Isabelicinium cooksoniae</li> </ul>	<ul> <li>159 Isabelidinium cretaceum</li> <li>50 Isabelidinium spp.</li> <li>217 Kiokansium polypes</li> <li>227 Kiokansium polypes</li> <li>207 Kiokansium spp.</li> <li>207 Kiokanuis spp.</li> </ul>	<ul> <li>114 Komewua sp Ogmund</li> <li>78 Laciniadinium arcticum</li> <li>71 Lejeunecysta hyalina</li> <li>101 Lejeunecysta spp.</li> <li>17 Lenthina serrat</li> <li>18 Lingukodinium machaerophorum</li> </ul>	<ol> <li>Microdinium reticulatum</li> <li>Microdinium spp.</li> <li>Muratodinium spp.</li> <li>Muratosphaenopsis labyrinthea</li> <li>Nyttericysta davisi</li> <li>218 Nyttericysta spp.</li> </ol>	<ul> <li>208 Odontochitina ancala</li> <li>195 Odontochitina costata</li> <li>190 Odontochitina operculata</li> <li>196 Odontochitina spp.</li> <li>209 Oligosphaeridium albertense</li> <li>200 Oligosphaeridium asterionum</li> </ul>	<ul> <li>164 Oligosphaendium complex</li> <li>197 Oligosphaendium poculum</li> <li>143 Oligosphaendium pulchenimum</li> <li>128 Oligosphaendium sepp.</li> <li>129 Opercubdinium centrocarpum</li> <li>219 Opercubdinium meantocentur</li> </ul>	<ol> <li>173 Ovoianium verucosum</li> <li>127 Palaeocystodinium australinum</li> <li>151 Palaeocystodinium golzowense</li> <li>14 Palaeocystodinium sp 3 Manum 1989</li> <li>83 Palaeocystodinium sp.</li> <li>191 Palaeohystrichophora infusorioides</li> </ol>	<ul> <li>210 Palaeoperidinium cf.cretaceum</li> <li>215 Palaeoperidinium cretaceum</li> <li>134 Palaeoperidinium pyrophorum</li> <li>147 Palaeoperidinium spr.</li> <li>169 Palaeotetradinium minusculum</li> <li>153 Palynodinium grallator</li> </ul>	<ol> <li>Paralecaniella indentata</li> <li>Paralecaniella indentata</li> <li>Pareodinia s.p.</li> <li>Pelelodinium kozlowskii</li> <li>Phthanopendinium aff.distinctum</li> <li>Phthanopendinium adectrolophum</li> <li>Phthanopendinium comatum</li> </ol>	<ul> <li>35 Phthanoperidinium echinatum</li> <li>33 Phthanoperidinium geminatum</li> <li>36 Phthanoperidinium sop.</li> <li>165 Pseudoceration polymorphum</li> <li>174 Pseudoceratium 61.expolitum</li> <li>15.4 Pseudoceratium eisenaciai</li> </ul>	<ul> <li>228 Pseudoceratium peliferum</li> <li>212 Quantouendinium dictyophorum</li> <li>155 Raphidodinium tucatum</li> <li>192 Rhiptocorys veligera</li> <li>56 Rhombodinium draco</li> <li>57 Rhombodinium porosum</li> </ul>	<ol> <li>Scrinicodinium spp.</li> <li>Senegalinium spp.</li> <li>Senoniasphaera inomata</li> <li>Senoniasphaera microreticulata</li> <li>Senoniasphaera microreticulata</li> <li>Senoniasphaera spp.</li> <li>Senoniasphaera spp.</li> </ol>	102 Spinidinium sop. 103 Spinidinium sop. 148 Spiniferites magnifica" 60 Spiniferites pseudoturcatus 1 Spiniferites spo. 140 Spongodinium delitiense 160 Stephodinium coronatum	<ul> <li>166 Stiphrosphaeridium anthophorum</li> <li>226 Subtilisphaera perlucida</li> <li>79 Subtilisphaera spp.</li> <li>133 Surculosphaeridium longifurcatum</li> <li>117 Svalbardella cf.hampdenensis</li> </ul>	<ul> <li>8 Svalbardella spp.</li> <li>2 Systematophora ancyrea</li> <li>9 Systematophora placacantha</li> <li>144 Tanyosphaendium spp.</li> <li>43 Thalassiphora delicata</li> <li>65 Thalassiphora pelagica</li> </ul>	<ul> <li>Trityrosphaeridium cantharellus</li> <li>Trityrosphaeridium castanea</li> <li>Trityrodinium spp.</li> <li>Trithyrodinium evittii</li> <li>Trithyrodinium quinqueangulare</li> <li>Vescerossis longicomis</li> </ul>	<ul> <li>232 Vesperupos orrenom</li> <li>231 Vesperupos mayo</li> <li>20 Weltodinium tunum</li> <li>30 Wetzeliella articulata</li> <li>75 Wetzeliella articulata</li> <li>74 Wetzeliella endocyst</li> </ul>	97 IWetZeinenia ovanis 66 Wetzeileila spp. 118 Wilsonidium spp. 183 Xenascus ceratioides 235 Xiphophoridium alaturm		Samp	les	1     Fungal hyphae     1       2     Aquilapollenities spp.     1       1     Azolla spp.     1	1 rucula sup. 3 Rugubivesciculities rugosus 4 Rugubivesiculates reductus
Period/Epoch	Age		(Samples in Discipline(s) : Micro, Paty Barren 1 Acritarch spp. Vervhachlium spb.	3     Schizocysta spp.       4     Pterospermella spp.       5     Padrolopinsorpha triradiata       6     Padrolopinsorpha       1     Pediastrum spp.       1     Tetraporina spp.	1 Spiniferites spp. 2 Systematophora ancyrea 3 Homotryblium spp. 4 Chiroptendium galea 5 Drinontendium galea	7         Enneadocysta multicomuta           8         Svalbardella spp.           9         Systematophora placacantha           10         Tityrosphaendium cantharellus           11         Deflandrea spp.           12         Hystrichokolpoma spp.           14         Microdinium reliculatium	1,1 Paracomatic and the second	20         Wallodinium lunum           21         Achomosphaera spp.           22         Cribroperidinium spp.           23         Defilandrea? sp 1           24         Enneadocysta spp.           25         Defilandrea? sp 1	26     Glaphyrocysta spp.       27     Araneosphaera araneosa       28     Glaphyrocysta cf.texta       29     Atterbidinium spp.       30     Wetzeliella articulata       31     Glaphyrocysta intricata	32         Phthanopendinium comatum           33         Phthanopendinium geminatum           34         Areosphaeridium c. diktyoplokum           35         Phthanopendinium echinatum           35         Phthanopendinium echinatum           36         Phthanopendinium echinatum           37         Phthanopendinium spp.	<ul> <li>B Phthanopendinium aff distinctum</li> <li>Glaphyrocysta divaricata</li> <li>Hystrichostrogylon membraniphorum</li> <li>H Glaphyrocysta semiliecta</li> <li>Impletosphaeridium spp.</li> <li>Thalassiphora delicata</li> </ul>	44     Printanoperiorinum aleccolopnum       45     Glaphyrocysta cf.spineta       46     Heteraulacacysta eft.spineta       47     G. et sp. indet Piasacki 1992       48     Areosphaeridium michoudii       49     Enneadocysta cf. fenestrata	50         Isabelidinium spp.           51         Palaeocystodinium golzowense           52         Cercodinium spp.           53         Charlesdowniea coleothrypta           54         Charlesdowniea spp.           55         Charlesdowniea spp.           55         Chiropteridium spp.	56         Rhombodinium draco           57         Rhombodinium porosum           58         Cordosphaeridium spp.           58         Dinogymnium spp.           60         Sprinterites pseudofurcatus           61         Parakezaniella indentata	61     Paratecamplata incentata       62     Microdinium spp.       63     Hystrichokolpoma cf. salacia       64     Glaphyrocysta exuberans       65     Thalassiphora pelagica       66     Wartrailella son	<ul> <li>bit were and syp.</li> <li>bit were a syp.</li> <li>bit Areoligera syp.</li> <li>charles downie a tenuivirgula</li> <li>70 Chichaouadinium vestitum</li> </ul>	71     Leyeunecysta nyalina       72     Dracodinium spp.       73     Apecdodinium quinquelatum       74     Wetzeliella endocyst       75     Metzeliella estra       76     Impagidinium spp.	77         Issabelidinium acuminatum           78         Laciniadinium arcticum           79         Subtilisphaera spp.           80         Senoniasphaera spp.           81         Chorate spp.           150         Caendinium deoressum	82 Cerodinium depressum 83 Palaeocystodinium spp. 84 Apectodinium homomorphum 85 Apectodinium spp.	86         Cordosphaeridium gracile           87         Hystrichokolpoma rigaudiae           88         Trinovantedinium spp.           89         Trinovantedinium spp.           90         Deflandrea dr spinulosa           91         Deflandrea de rigiulaa	92         Diphyes colligerum           93         Diphyes ficusoides           94         Dracodinium variekongitudum           95         Eatonicysta furensis           96         Homobyblium tenuispinosum	97 werzelienia ovalis 98 Cordosphaeridium minimum 190 Diphyss brevispinum 101 Lejeunecysta spp. 102 Spindinium spp.	104 Depsiloritum pseudocoligerum 105 Hystrichokolpoma sp 1 Heilmann-Clausen 106 Adnatosphaeridium robustum 107 Areoligera cf.medusettiformis 108 Deflandrea kangiliense	109     Dracodinium politum       110     Glaphyrocysta texta       111     Senegorinum spp.       112     Dracodinium spp.       113     Evittosphaerula spp.       114     Komewuia sp Ogmund	115         Apecodinium pankuatum           116         Apecdodinium parvuatum           117         Svalbardella cf. hampdenensis           118         Wilsonidium spp.           119         Apecdodinium augustum           119         Apecdodinium augustum           120         Dipopenygium cf.cladoides	121 Trootyse spp. 122 Areologra gippingensis 123 Cerodinium darmoorium 124 Cerodinium speciosum 125 Cerodinium speciosum glabrum 126 Muratodinium fimbriatum	121 Conservencion and an and an and an and an and an and an and and	134         Palaeoperidinium pyrophorum           135         Alisocysta circumtabulata           135         Cerodinium diebelii           137         Fromea laevigata           133         Phabolinium korskowskii	138 Prevolinum kozkowski 139 Spinidinium echinordeum 140 Spongodinium delitiense 141 Trithyrodinium evittii 142 Fromea spp.	144         Tanyosphaeridium spp.           145         Cerodinium pannuceum           146         Glaphyrocysta pastielsi           147         Palaeopendinum spp.           148         Spiniferifes magnifica"           149         Schifferium aceras	150         Deflandrea galeata           151         Hystrichosphaenöluum tubiferum brevispinum           151         Palynodinium of majae           152         Isabelidinium of majae           153         Palynodinium grallafor           154         Pseudoceratum eisenackii           155         Raphidodinium fuzienum kuntum	156         Senoniasphaera inornata           157         Circulodinium distinctum           158         Hystrichosphaeropsis quasicribrata           158         Hystrichosphaeropsis quasicribrata           159         Isabelidinium cretaceum           160         Stephodinium cornatum           214         Trithwordinium cornatum	<ul> <li>161 Intraryrounnun quirqueangulare</li> <li>162 Fromea fragilis</li> <li>163 Isabelidnium cooksoniae</li> <li>164 Oligosphaendium complex</li> <li>165 Pseudoceratiom polymorphum</li> <li>166 Stiphrosphaendium anthophorum</li> </ul>	167         Hystrichosphaeropsis perforata           168         Isabelidinium beffastense           169         Palaeotetradiuum minusculum           170         Chatangiella cf.spinosa           171         Conetodinium whitei           172         Cyclonephelium spp.	173         Ovoidinium verrucosum           174         Pseudoceratium cf.expolitum           175         Atterbidinium acutulum           176         Chantydophorella cf.bondarenkoi           177         Chantydophorella cf.bondarenkoi           177         Fibradophorella cf.bondarenkoi           177         Fibradophorella cf.bondarenkoi	179         Heterosphaendium heteracanthum           180         Scriniodinium spp.           181         Chatangiella difessima           182         Chatangiella tripartita           183         Consocus coratioides           184         Contedodinium sop.	185 Coronifera oceanica 186 Florentina tenera 187 Heterosphaeridium difficile 188 Histiocysta palla 190 Odontoodinium pulchrum 190 Odontoochitina operculata	<ul> <li>191 Palaeohystrichophora infusorioides</li> <li>192 Rhiptocorys veligera</li> <li>193 Surculosphaendium longifurcatum</li> <li>194 Florentinia cooksoniae</li> <li>195 Odontochitina costala</li> <li>195 Odontochitina son</li> </ul>	197         Oligosphaenidium poculum           197         Oligosphaenidium poculum           198         Canningia reticulata           199         Circulodinium ct attacalicum           200         Circulodinium ct brevispinosum           201         Circulodinium spp.	202 Endoceratium ct. dettmanniae 203 Florentinia cf.buspina 204 Florentinia spp. 205 Fromea aff. expolitia 206 Hystrichosphaeridium aff.arborispinum	207 Kiokansium spp. 208 Odontochitina ancala 209 Oligosphaeridium albertense 210 Palaeoperidinium cf.cretaceum	211 Pareodinia spp. 212 Quantouendinium dictyophorum 213 Callaiosphaeridium asymmetricum 214 Hapsocysta benteae 214 Palaeoneridinium cretaceum	215     Preterscrybenium university       216     Senoniasphaera microreticulata       217     Kalyptea spp.       218     Nyttericysta spp.       219     Bounkdinium spp.       2219     Circulodinium spp.       220     Circulodinium spp.	221 Cycloneprenum memurum. 222 Oligosphaeridium asterigerum 223 Trichodinium castanea 224 Chlamydophorella spp. 225 Fromea amphora 226 Subtilisphaera perfucida	227 IXuokansuuri puuyusa 228 Pseudoceratium pelitierum 229 Canningia spp. 230 Nyktericysta davisii 231 Vesperopsis mayri 232 Vesperopsis longicornis	233 Bartioladinium aff.exiguum 233 Cleistosphaeridium huguoniotti 235 Xiphophoridium alatum (samplee in Deceptine(e): Micro.Paty	Barren Diversity: Dinoflagellate Cysts	A 1 Fungal hyphae 1 Azolla spp. 2 Aquitapollenites spp.	12 Inquirations opp. 3 Rugubivesciculates reductus
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A constant of a	34 Bendy Albian-2Late 35 DT 35	50m																					•																				2	9		3420 3450 3480 3500			

GEUS Copenhagen Enclosure 2: Absolute numbers of species Protect: NORTH LEW Cheft : NORTH LEW North Leif Events Ň ------420m Top of Systematophora ancyrea 480m Top of Enneadocysta multicomuta, Top of Chiropteridium galea, Top of Svaibardella spp., Top of Defiandrea -510m Top of Palaeocystodinium sp 3 Manum 1989, Top of Microdinium reticulatum 540m Top of Lentinia serrata, Top of Tetraporina spp, Top of Areosphaeridium cf. michoudli 570m Top of Deflandrea? sp 1 HNH, Top of Enneadocysta spp. -600m Top of Deflandrea cf.denticulata E8 -630m Top of Glaphyrocysta cf.texta, Top of Araneosphaera araneosa 690m Top of Phthanoperidinium geminatum - 750m Top of Phthanoperidinium aff.distinctum, Top of Hystrichostrogylon memb. granulatum -780m - Top of Glaphyrocysta divaricata -810m Top of Hystrichostrogylon membraniphorum -840m - Top of Glaphyrocysta semitecta 900m Top of Thalassiphora delicata 990m Top of Phthanoperidinium alectrolophum - 1080m - Top of Glaphyrocysta cf.spineta E7 -1110m Top of Azolla spp. - 1140m Top of G.et sp Indet Plasecki 1992 1260m Top of Rhombodinium draco, Top of Rhombodinium porosum - 1290m - Top of Spiniferites pseudofurcatus 1470m Top of Hystrichokolpoma cf. salacia - 1500m - Top of Glaphyrocysta exuberans E6b-E6c 1530m Top of Paucilobimorpha triradiata 1560m Top of Charlesdowniea tenuivirgula - 1650m - Top of Apectodinium quinquelatum, Top of Wetzeliella endocyst E5-E6a 1800m Top of Tetraporina sp 1 HNH 2002 E4 1920m Top of Cerodinium depressum - 1950m - Top of Apectodinium homomorphum 1980m Top of Deflandrea cf.spinulosa, Top of Charlesdowniea columna, Top of Diphyes ficusoides, Top of Diphyes colligerum \_\_\_\_\_ E3b 2010m Top of Dracodinium cf.varielongitudum, Top of Diphyes brevispinum 2040m Top of Achilleodinium biformoldes, Top of Hystrichokolpoma sp 1 Heilmann-Clausen, Top of Dapsilidinium pseudocolligerum ------- 2070m Top of Eatonicysta furensis E3a -2100m - Top of Dracodinium politum, Top of Glaphyrocysta texta 2130m Top of Komewula sp Ogmund, Top of Dracodinium condylos, Top of Evittosphaerula spp. \_\_\_\_\_ 2160m Top of Svalbardella cf.hampdenensis, Top of Apectodinium paniculatum E2b P6 2220m Top of Apectodinium augustum 2250m Top of Cerodinium dartmoorium, Top of Muratodinium fimbriatum, Top of Cerodinium speciosum glabrum, Top of Palaeocystodinium australinum, Top of Areoligera gippingensis -2310m - Top of Alisocysta margarita P5 2370m Top of Trithyrodinium evitili, Top of Spongodinium delitiense, Top of Hystrichosphaeridium tubiferum, Top of Cerodinium debelii, Top of Alisocysta circumtabulata - 2430m - Top of Glaphyrocysta pastielsi Trithyrodinium evittli 2460m Top of Caligodinium aceras 2520m Top of Isabelidinium cf.majae, Top of Palynodinium grallator, Top of Senoniasphaera inomata \_\_\_\_\_ Palynodinium grallator 2550m Top of Trithyrodinium quinqueangulare, Top of Hystrichosphaeropsis quasicribrata Chatangiella blapatura 2610m Top of Isabelidinium belfastense, Top of Hystrichosphaeropsis perforata Isabelidinium cooksoniae -2640m - Top of Defiandrea galeata, Top of Pseudoceratium cf.expolitum 2670m Top of Fibradinium annetorpense, Top of Chatanglella cf.bondarenkol, Top of Heterosphaeridium heteracanthum, Top of Alterbidinium acutulum, Top of Chiamydophorella cf.nyel Alterbidinium acutulum -2700m Top of Xenascus ceratioides 2730m Top of Odontochitina operculata, Top of Palaeohystrichophora infusorioides, Top of Rugubivesciculites rugosus Rugubivesiculites spp. -2760m Top of Heterosphaeridium difficile, Top of Surculosphaeridium iongifurcatum, Top of Odontochitina costata, Top of Rugubivesiculates reductus 2790m
 2790m
 2790m
 2790m
 2820m
 2 -2880m - Top of Oligosphaeridium asterigerum, Top of Circulodinium sp. 1 HNH 1993 Quantouendinium tyophorum/Odontochitina ancala 3120m Top of Nyktericysta davisii -----Nyktericysta davisii 3360m Top of Vesperopsis longicomis Vesperopsis longicornis - 3450m Top of Callalosphaeridium asymmetricum, Top of Xiphophoridium alatum