

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

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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 presence/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 Søndersholm *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 Raleigh 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 DCS 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 $54^{\circ} 24' 38.95''$ N and $55^{\circ} 15' 10.57''$ 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.

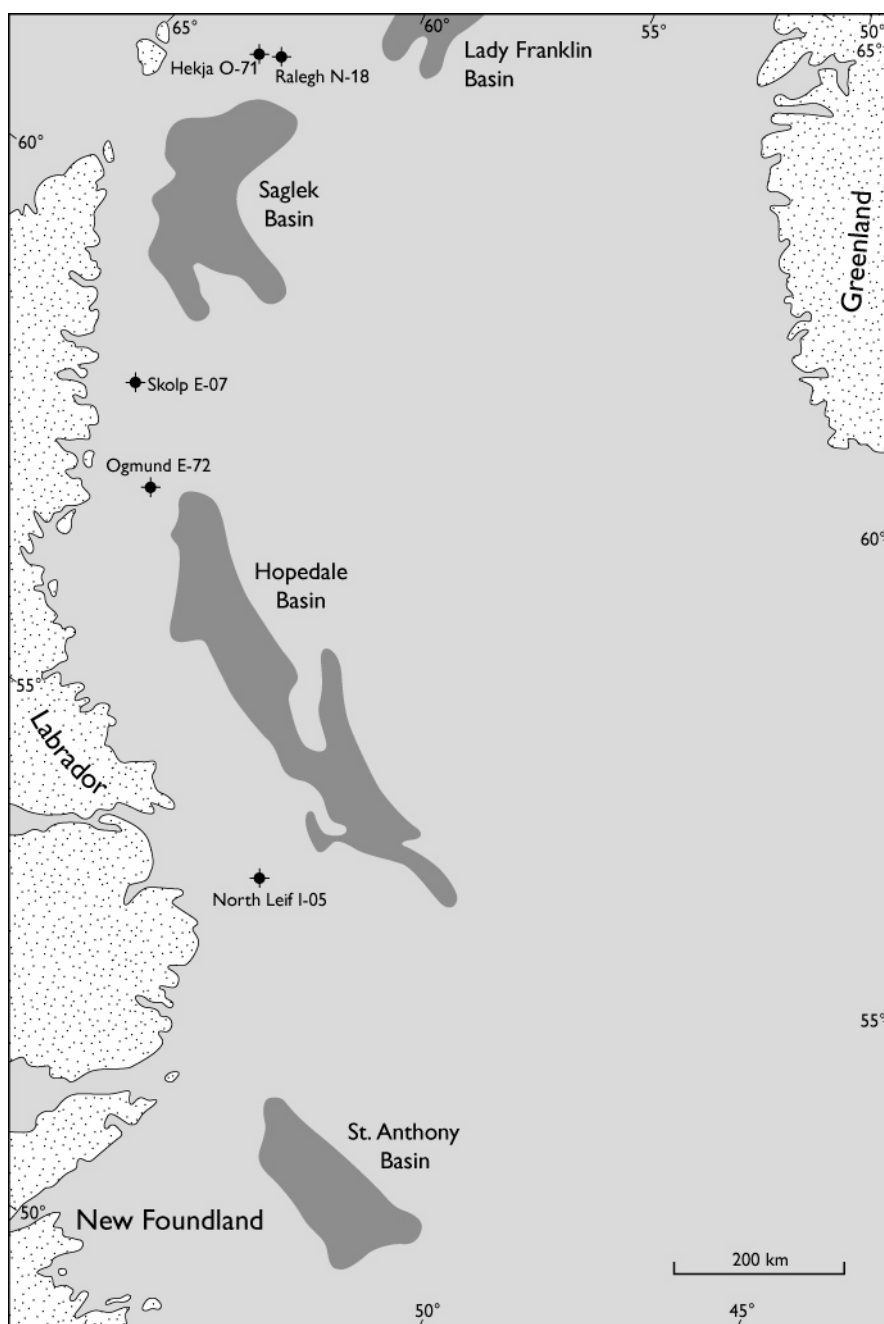


Fig. 1. Exploration wells drilled on the Labrador and South-East Baffin Island shelves offshore eastern Canada.

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).

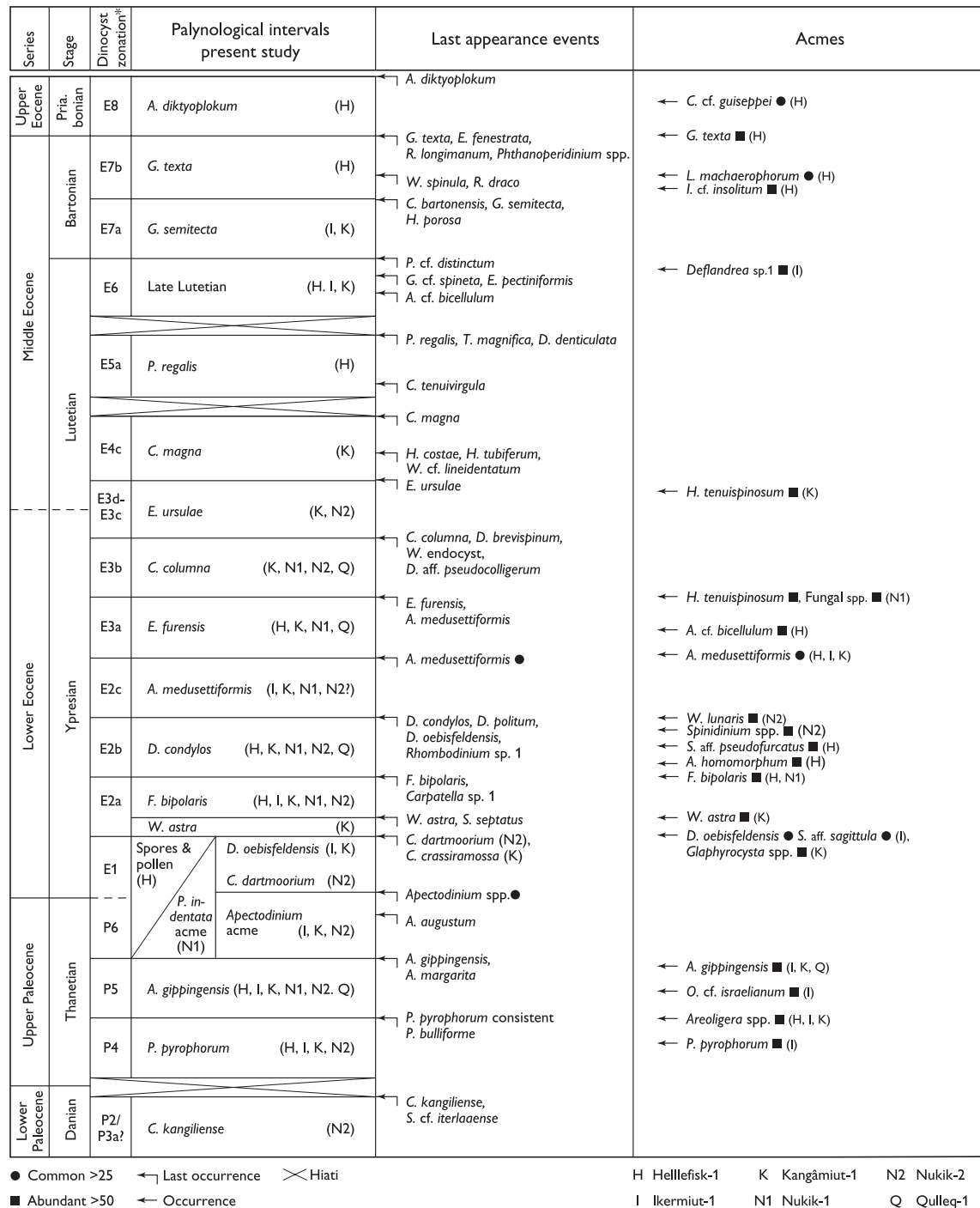


Fig. 2. Palaeogene palynological intervals and bioevents offshore West Greenland correlated with the dinocyst zonations of Bujak & Mudge (1994) and Mudge & Bujak (1996). From Nøhr-Hansen (2003).

Paleocene	<i>T. evittii</i> (N)	
U. Maastrichtian	<i>Palynodinium grallator</i> (S, N, GRO#3)	← <i>P. grallator</i> , <i>W. spinata</i> ← <i>I. majae</i>
	<i>Chatangiella biapertura</i> (S, N)	← <i>C. biapertura</i> ← <i>T. quinqueangulare</i>
	<i>Isabeldinium cooksoniae</i> (S, O, N, GRO#3)	← <i>I. cooksoniae</i> , <i>H. perforata</i> ← <i>L. arcticum</i>
L. Maastrichtian	<i>Alterbidinium acutulum</i> (S, N)	← <i>A. acutulum</i> ← <i>H. quasicribrata</i> ← <i>C. aceras</i>
U. Campanian	<i>Odontochitina operculata</i> (S, GRO#3)	← <i>S. rotunda</i> , <i>T. castanea</i> ← <i>O. operculata</i> , <i>H. heteracanthum</i> , <i>E. pterococcoides</i> ← <i>X. wetzellii</i> ← <i>C. madura</i> , <i>R. fucatum</i> ← <i>T. suspectum</i>
	<i>Callaiosphaeridium asymmetricum</i> (S)	← <i>A. cf. haromense</i> , <i>C. grossa</i> ← <i>C. asymmetricum</i> ← <i>C. cf. nyei</i> , <i>C. whitei</i> ← <i>S. obscurum</i> ← <i>O. costata</i> , <i>W. lunum</i> ← <i>B. jaegeri</i> ← <i>P. infusorioides</i>
	<i>Fromea nicosia</i> (S & Q ?)	← <i>A. varium</i> ← <i>C. decorosa</i> ← <i>D. longicornis</i> ← <i>F. nicosia</i> ← <i>O. porosa</i> ← <i>X. ceratioides</i> ← <i>Fromea</i> sp. 1 ← <i>C. bondarenkoi</i>
--- ? ---		
L. Campanian	<i>Dinocyst</i> sp. E. Ioannides 1986 (S, Q & I)	← <i>Dinocyst</i> sp. E. Ioannides 1986 ← <i>I. microarmum</i>
U. Santonian ?	<i>Dinogymnium sibiricum</i> (Svartenhuk Halvø, Q ?)	← <i>D. cf. sibiricum</i>
L. Santonian	<i>Heterosphaeridium difficile</i> (Svartenhuk Halvø, Q ?)	← <i>H. difficile</i>
Coniacian	<i>Arvaldinium scheii</i> (Svartenhuk Halvø, Umiivik-1)	← <i>A. scheii</i> , <i>C. mcintyreii</i> ← <i>S. longifurcatum</i> ← <i>A. scheii</i> , <i>I. svartenhukense</i> ← <i>C. cf. madura</i>
	<i>Chatangiella cf. madua</i> (Svartenhuk Halvø, Umiivik-1)	← <i>I. magnum</i> ← <i>C. aff. spectabilis</i>
	<i>Spinidinium echinoideum</i> (Umiivik-1)	← <i>S. echinoideum</i> ■ ← <i>S. echinoideum</i>
U. Turonian	<i>Chatangiella cf. ditissima</i> (Umiivik-1)	← <i>C. cf. elegantulum</i> ← <i>C. cf. ditissima</i> , <i>S. pontis-marie</i>
	<i>Raphidodinium fucatum</i> (Umiivik-1)	← <i>R. fucatum</i> , <i>T. suspectum</i>
Cenomanian– Albian	<i>Rugubivesiculites</i> spp. (O, N)	← <i>H. difficile</i> ← <i>R. reductus</i> ← <i>Afropollis?</i> ← <i>R. rugosus</i>
Albian– Aptian	<i>Quantouendinium dictyophorum</i> / <i>Odontochitina ancala</i> (O, N)	← <i>Q. dictyophorum</i> , <i>O. ancala</i>
	<i>Nyktericysta davisii</i> (O, N, Nuussuaq)	← <i>N. davisii</i>
	<i>Vesperopsis</i> spp. (O)	← <i>Vesperopsis</i> spp., <i>V. longicornis</i>
	<i>Vesperopsis cf. nebulosa</i> (O)	← <i>V. cf. nebulosa</i> ← <i>Balmula</i> spp.

I : Ikermiut-1
O : Ogmund E 72
Q : Qulleq-1
S : Skolp E 07
N : North Leif I-05

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 originally described from the upper Lutetian (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 Raleigh 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 Raleigh 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 verrucosum*, *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		Depth	North Leif	Events
Period/Epoch	Age		Zone	
Early Oligocene	Rupelian	400m	E8	420m Top of <i>Systematophora ancyrea</i>
		450m		480m Top of <i>Enneadocysta multicornuta</i> , Top of <i>Chiropteridium galea</i> , Top of <i>Svalbardella</i> spp.
500m	510m Top of <i>Palaeocystodinium</i> sp 3 Manum 1989, Top of <i>Microdinium reticulatum</i>			
540m	540m Top of <i>Enneadocysta cf. michoudii</i> , Top of <i>Lentinia serrata</i> , Top of <i>Tetraporina</i> spp			
Late Eocene	Priabonian	550m		570m Top of <i>Deflandrea?</i> sp 1 HNH, Top of <i>Enneadocysta</i> spp.
		600m		600m Top of <i>Deflandrea cf. denticulata</i>
		630m		630m Top of <i>Glaphyrocysta cf. texta</i> , Top of <i>Araneosphaera araneosa</i>
Middle Eocene	Bartonian	690m		690m Top of <i>Phthanoperidinium geminatum</i>
		750m		750m Top of <i>Phthanoperidinium aff. distinctum</i> , Top of <i>Hystrihostrogylon memb. granulatum</i>
		780m		780m Top of <i>Glaphyrocysta divaricata</i>
		800m	810m Top of <i>Hystrihostrogylon membraniphorum</i>	
		850m	840m Top of <i>Glaphyrocysta semitecta</i>	
		900m	900m Top of <i>Thalassiphora delicata</i>	
		950m		
		1000m	990m Top of <i>Phthanoperidinium alectrolophum</i>	
		1050m		
		E7	1100m	1080m Top of <i>Glaphyrocysta cf. spineta</i>
			1110m	1110m Top of <i>Azolla</i> spp.
			1150m	1140m Top of <i>G. et sp indet</i> Piasecki 1992
		1200m		
		1250m	1260m Top of <i>Rhombodinium draco</i> , Top of <i>Rhombodinium porosum</i>	
		1300m	1290m Top of <i>Spiniferites pseudofurcatus</i>	
1350m				
1400m	1380m Top of <i>Glaphyrocysta spineta</i>			
1450m				
E6b-E6c	1470m	1470m Top of <i>Hystrihostrogylon cf. salacium</i>		
	1500m	1500m Top of <i>Glaphyrocysta exuberans</i>		
	1550m	1530m Top of <i>Paucilobimorpha triradiata</i>		
	1560m	1560m Top of <i>Charlesdowniea tenuivirgula</i>		
1600m				
E5-E6a	1650m	1650m Top of <i>Apectodinium quinquelatum</i> , Top of <i>Wetziella endocyst</i>		
	1700m			
	1750m			
	Lutetian			

Fig. 4. Summary of the palynostratigraphic dating, intervals and stratigraphically important events from North Leif-I-05 well.



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 *Charlesdowniea 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 S nderholm *et al.* (2003) and N hr-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 S nderholm *et al.* (2003) and N hr-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 Søndersholm *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 Søndersholm *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 Søndersholm *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 Søndersholm *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 rugosus* at 2730 m indicates the upper part of the Cenomanian to Upper Albian *Rugubivesiculites* spp. interval of S nderholm *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 rugosus* 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 S nderholm *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 N hr-Hansen (1993) of Late Albian age.

The *Quantouendinium dictyophorum* interval was described as an Albian to Aptian brackish-water interval from the Ogmund E-72 well, where it also underlies the non-marine *Rugubivesiculites* spp. interval of S nderholm *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.

N hr-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 benteeae* (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 *Senoniasphaera 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 *Vesperopsis 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 Raleigh 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

NORTH LEIF – PLATE 1

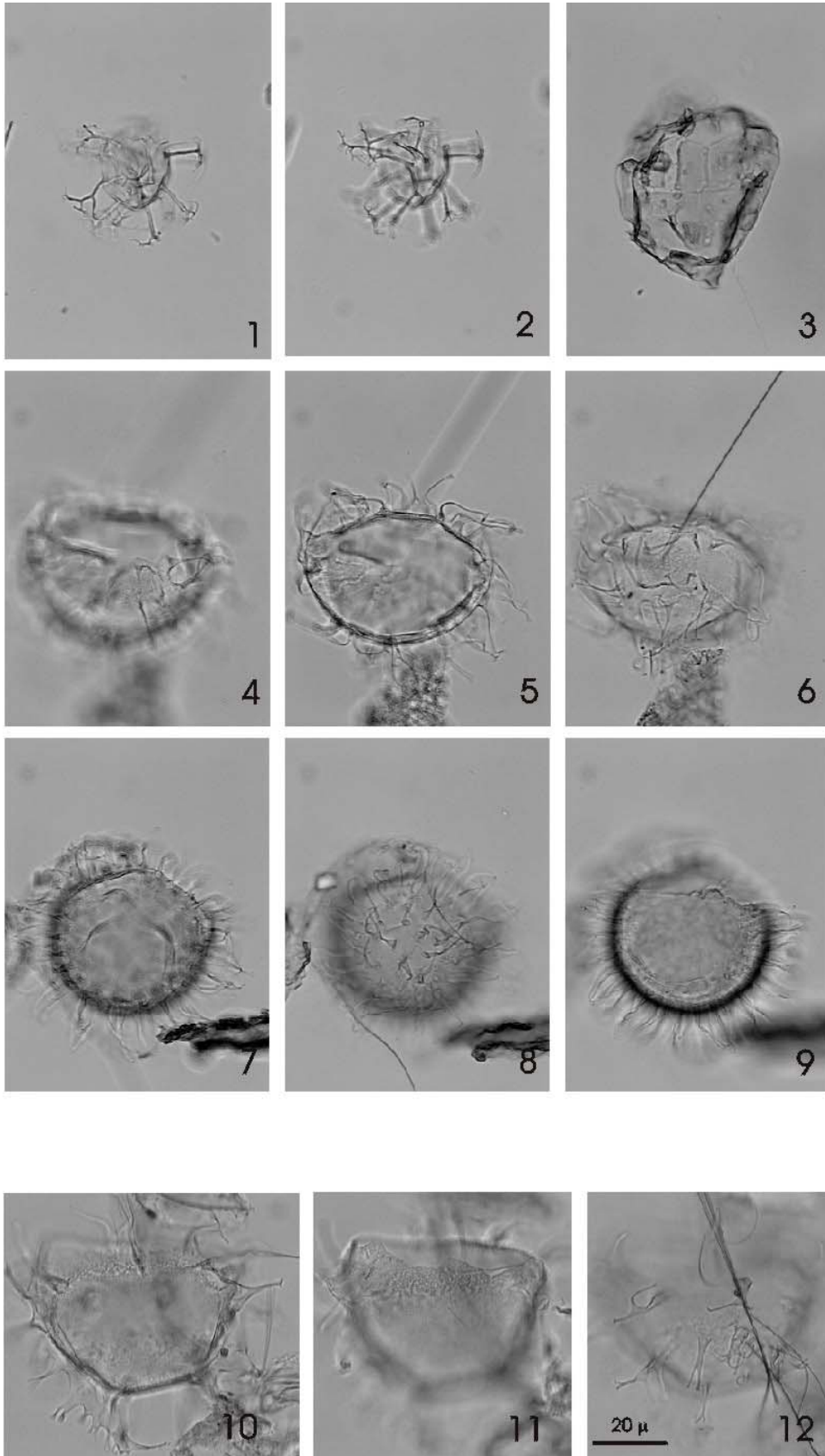
Figs. 1 & 2 Chorot cyst sp. 1 HNH North Leif 32.5-20.0, 420m-3, LVR 27832, 36

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 Chorot 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

NORTH LEIF – PLATE 2

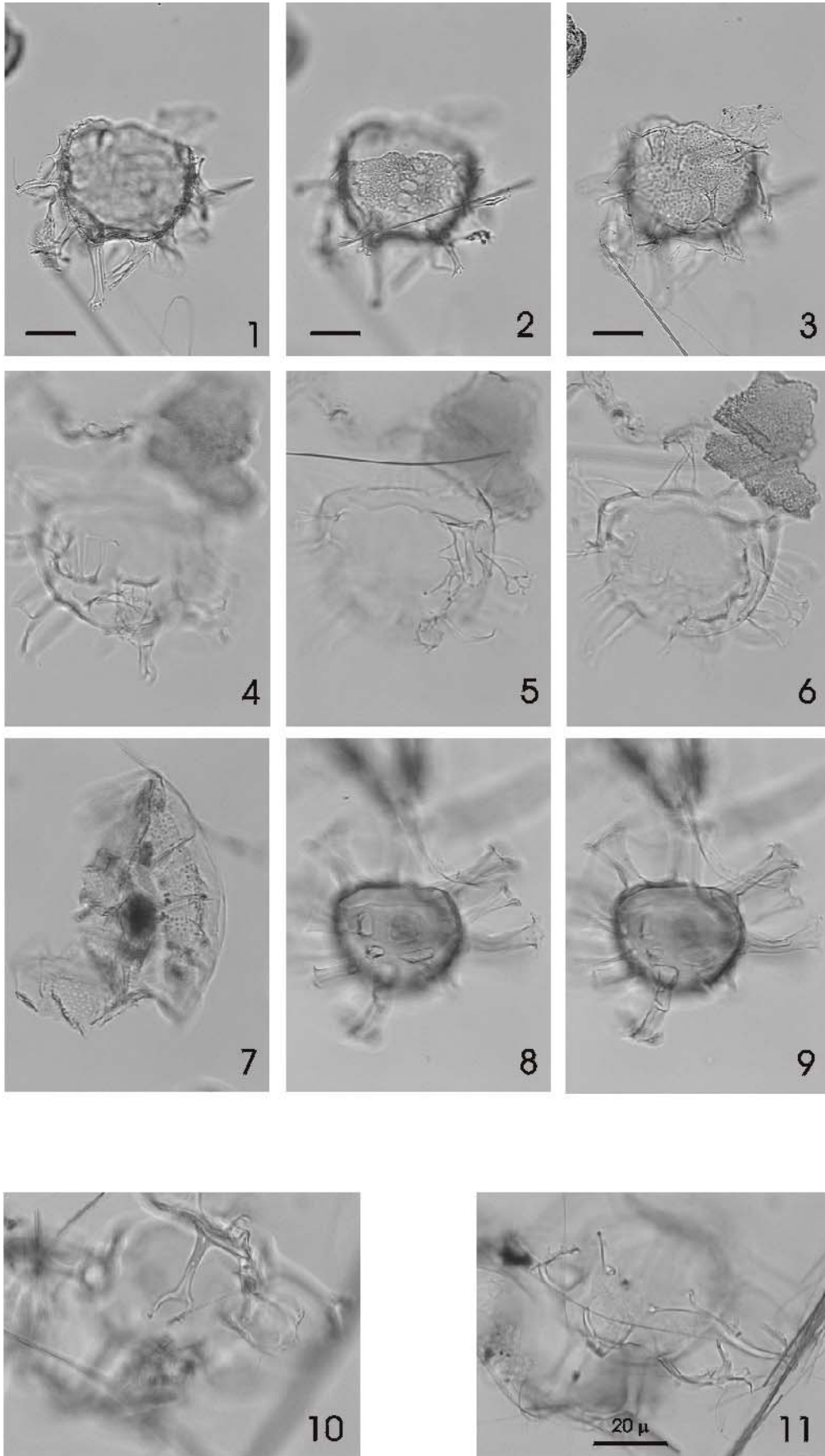
Figs. 1–3 *Chiropteridium galea* 43.7-10.9, 480m-3, LVR 27848–50

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

NORTH LEIF – PLATE 3

Figs. 1–2 *Senoniasphaera* sp. 1 HNH North Leif 42.6-6.4, 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

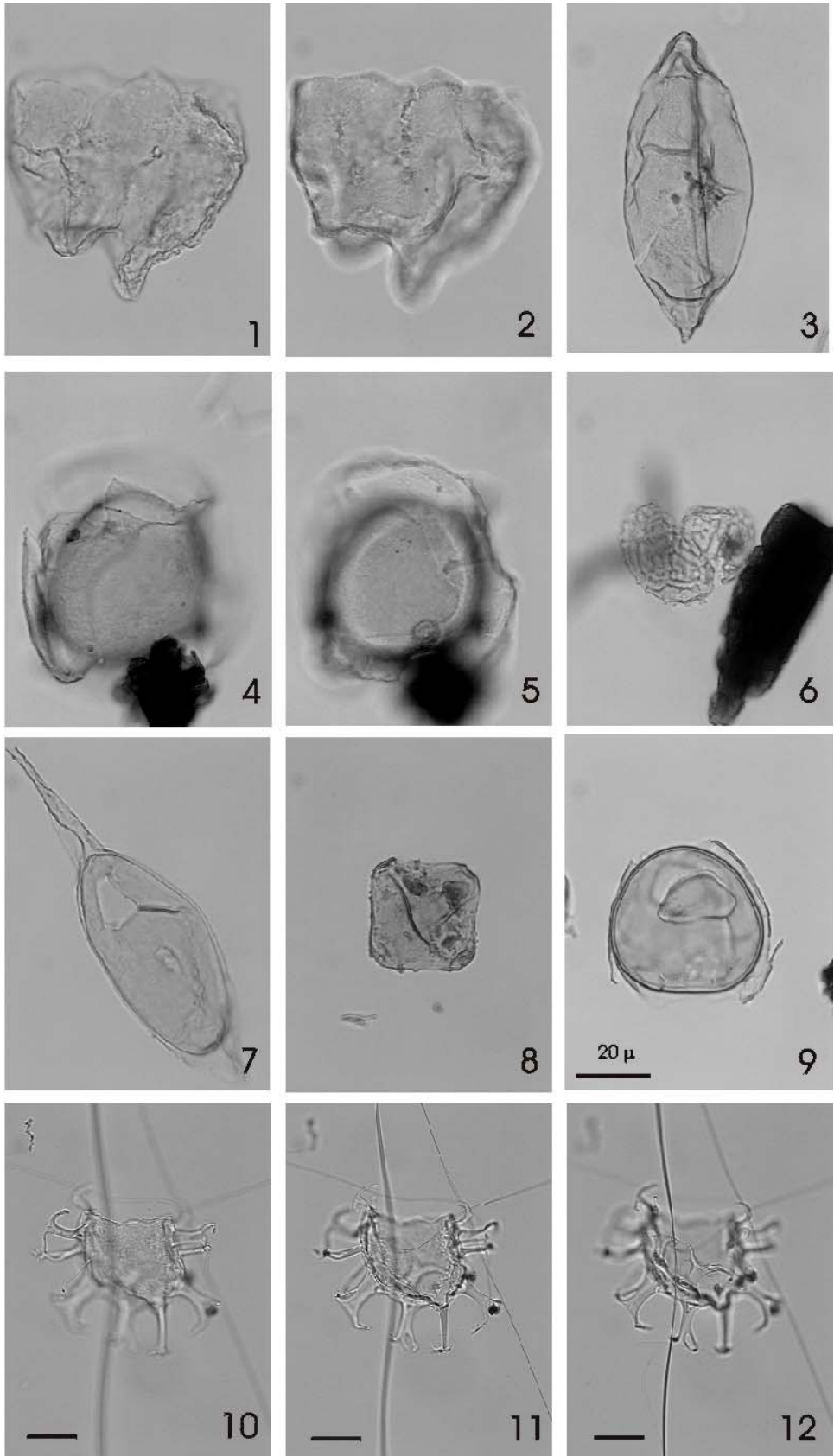
Fig. 6 *Microdinium reticulatum* 33.8-15.1, 510m-2, LVR 27869

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

NORTH LEIF – PLATE 4

Fig. 1 *Achomosphaera* sp. 1 HNH North Leif 20.4-17.3, 570m-3, LVR 27879

Figs. 2–3 *Criboperidinium* 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

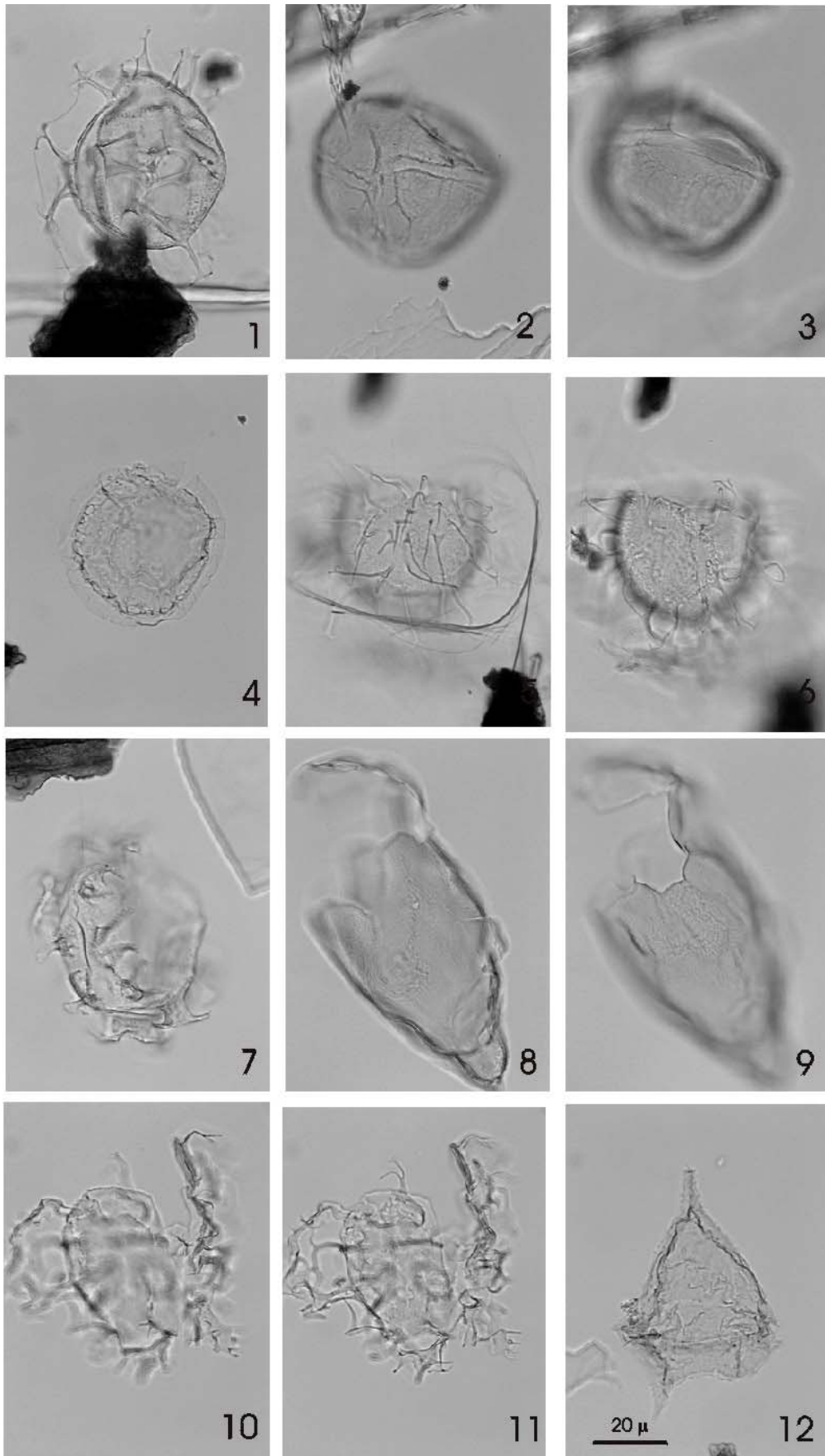
Figs 5–6 *Systematophora placacantha* 22.7-9.8, 600m-2, LVR 27883–84

Fig. 7 Chorot 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

NORTH LEIF – PLATE 5

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

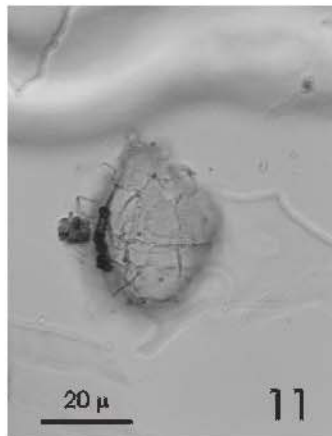
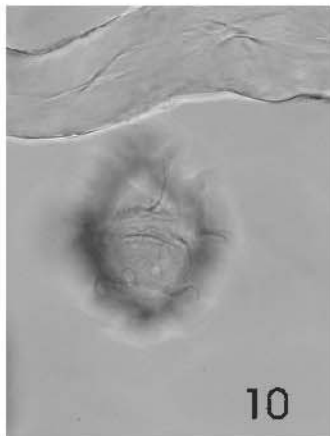
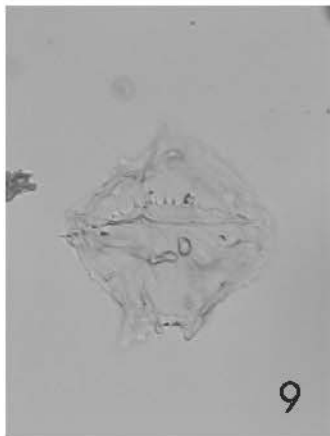
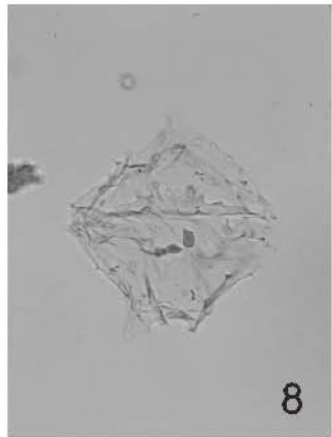
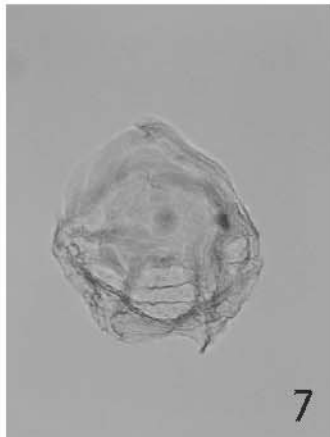
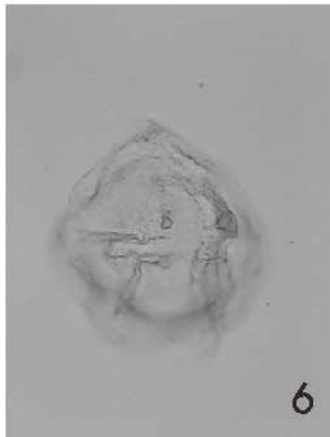
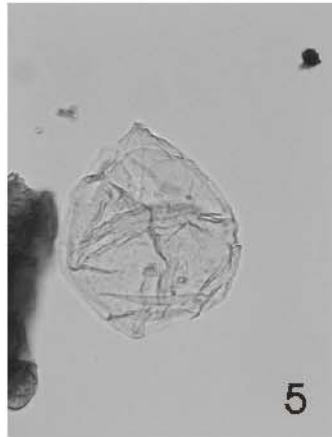
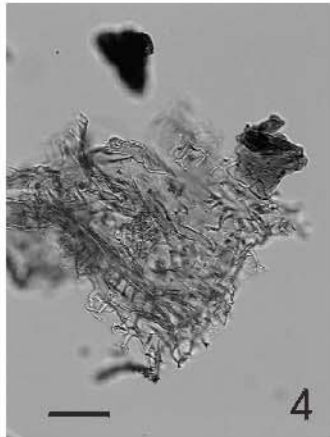
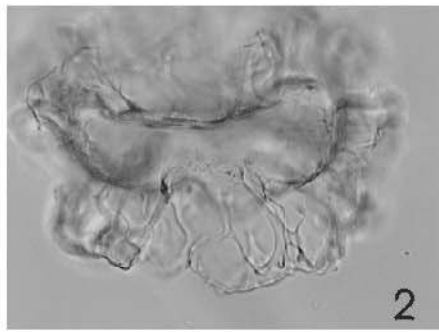
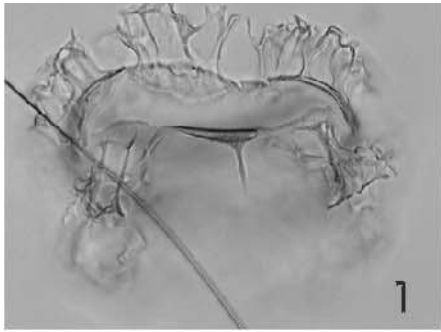
Fig. 4 *Wetziella articulata* 38.8-9.5, 660m-2, LVR 27895

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

NORTH LEIF – PLATE 6

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 Chorot cyst sp. 3 HNH North Leif 52.3-23.0, 690m-4, LVR 27906–907

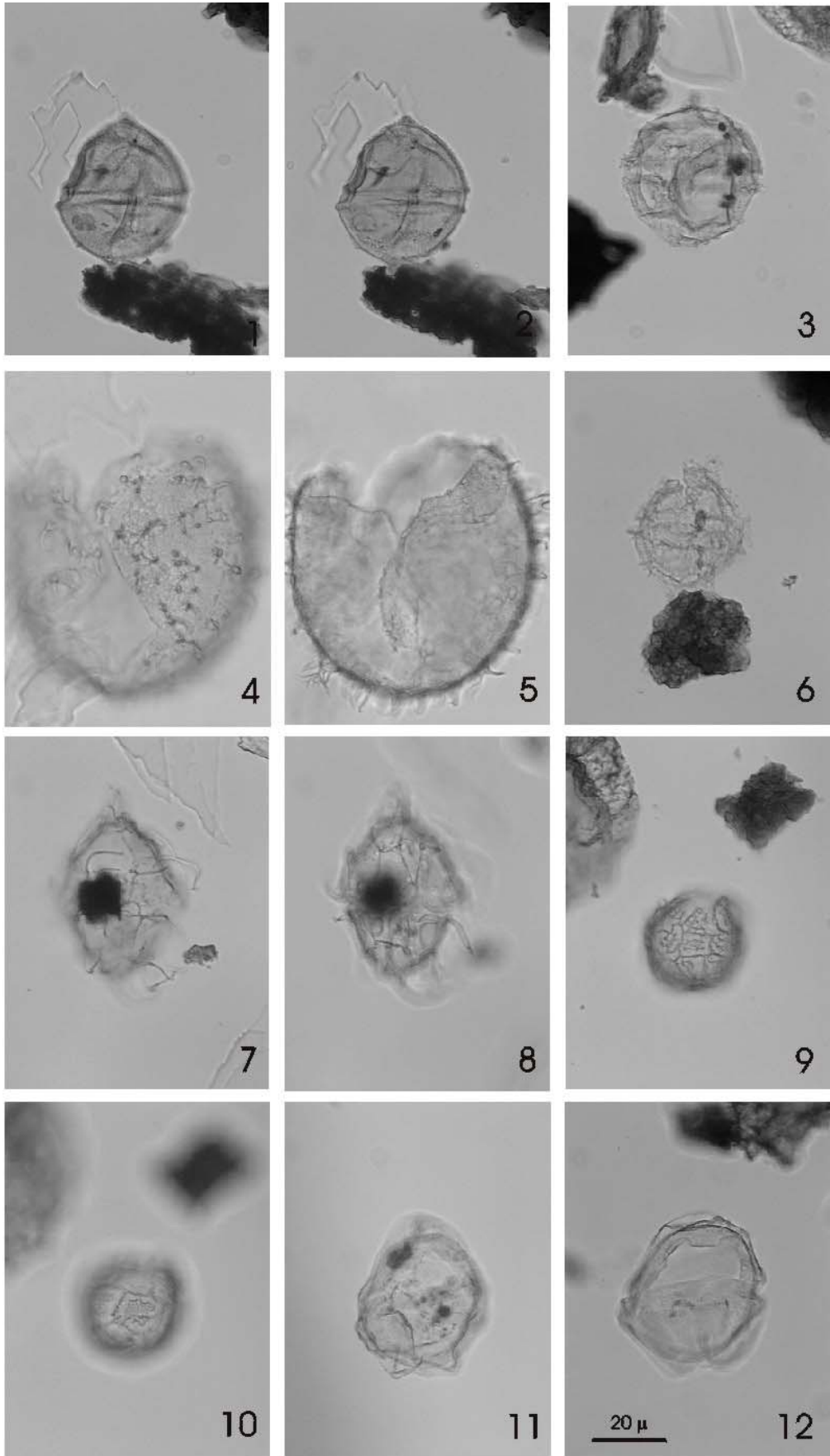
Fig. 6 *Phthanoperidinium echinatum* 34.8-18.5, 720m-2, LVR 27908

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

NORTH LEIF – PLATE 7

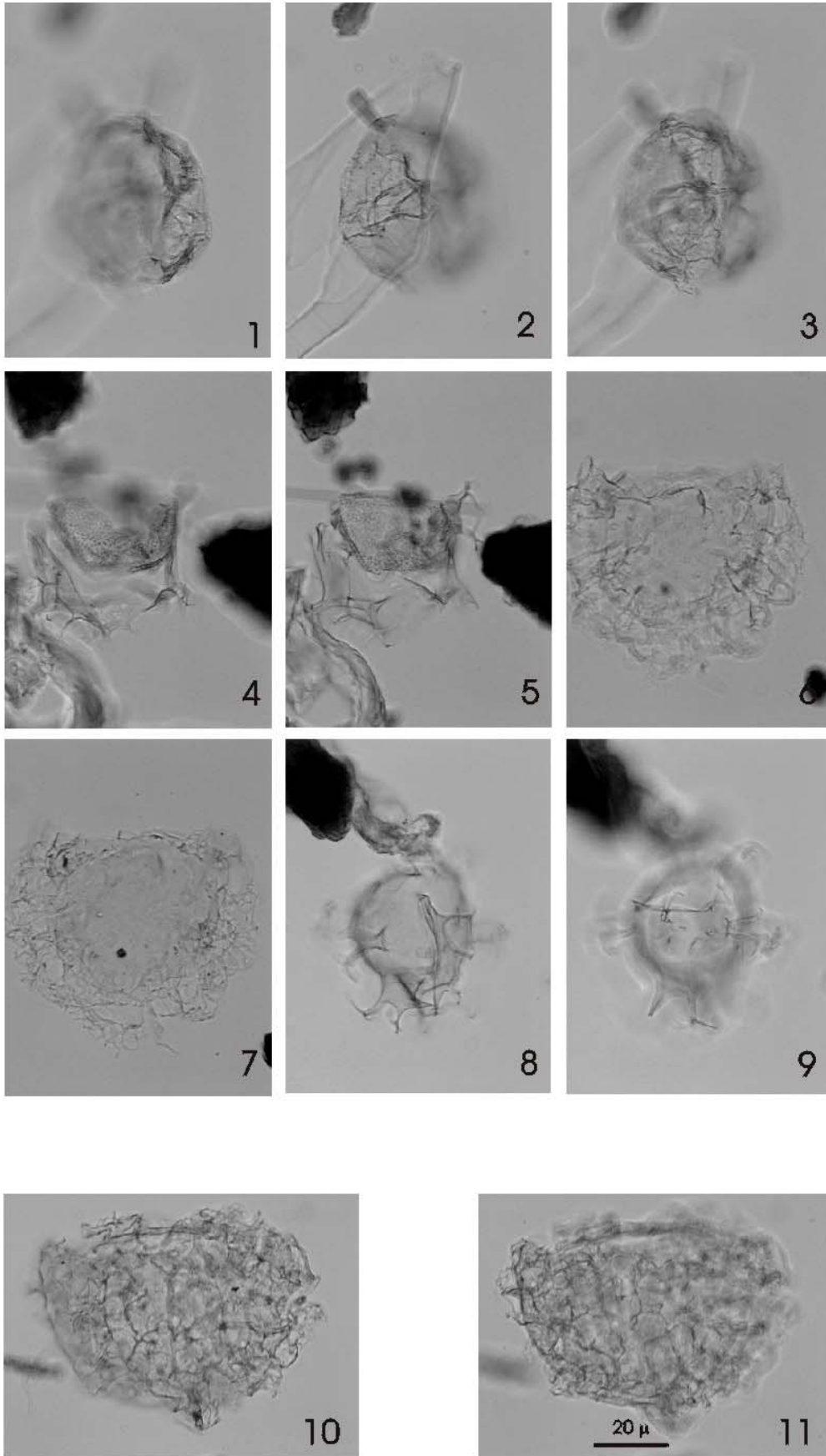
Figs 1–3 *Phthanoperidinium* aff. *distinctum* 35.3-17.7, 750m-2, LVR 27916–918

Figs 4–5 *Hystrihostrogylon 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 *Hystrihostrogylon 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

NORTH LEIF – PLATE 8

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

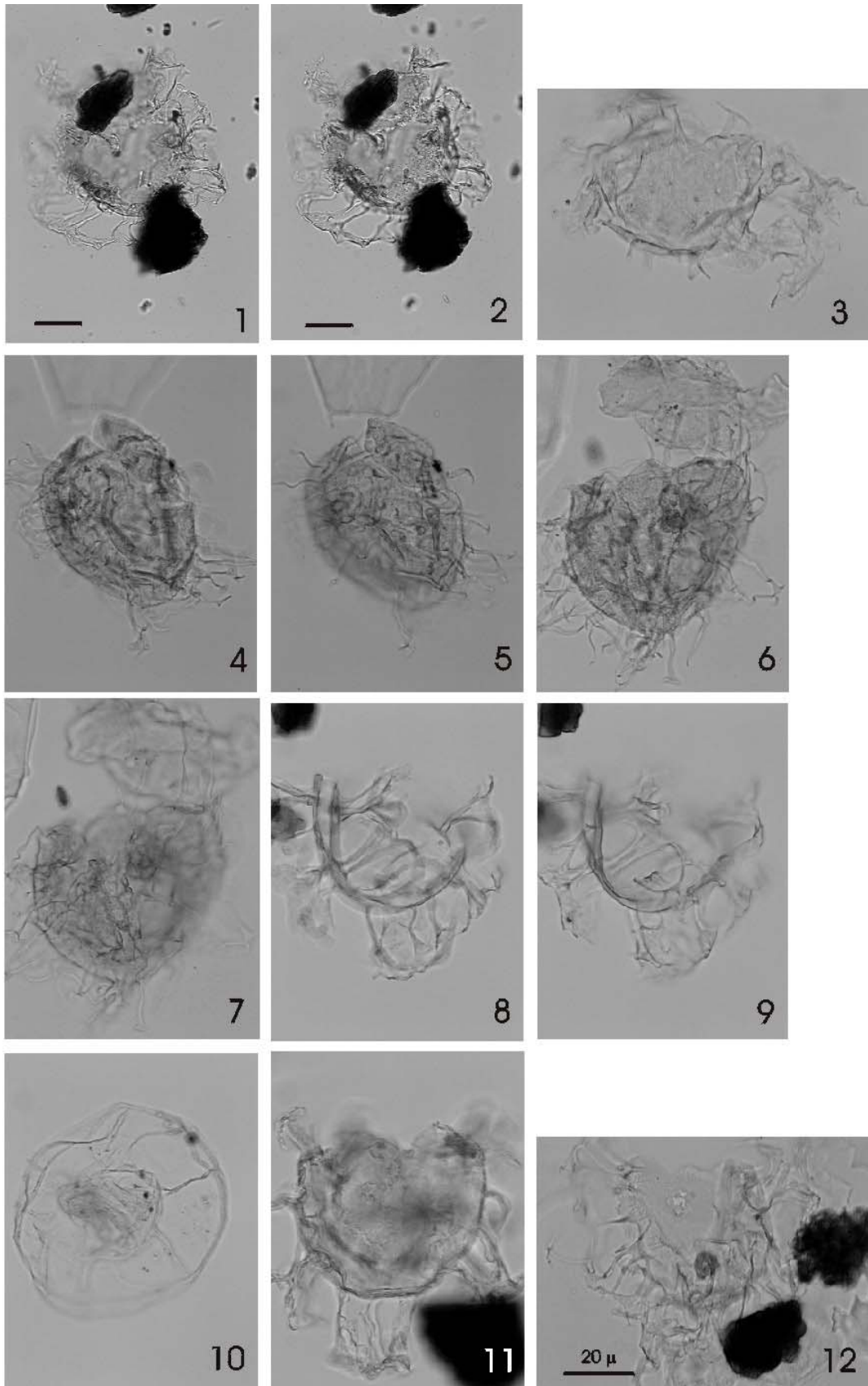
Figs 6–7 *Implectosphaeridium* sp. 1 HNH North Leif 29.6-14.6, 870m-2, LVR 27933–934

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

NORTH LEIF – PLATE 9

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

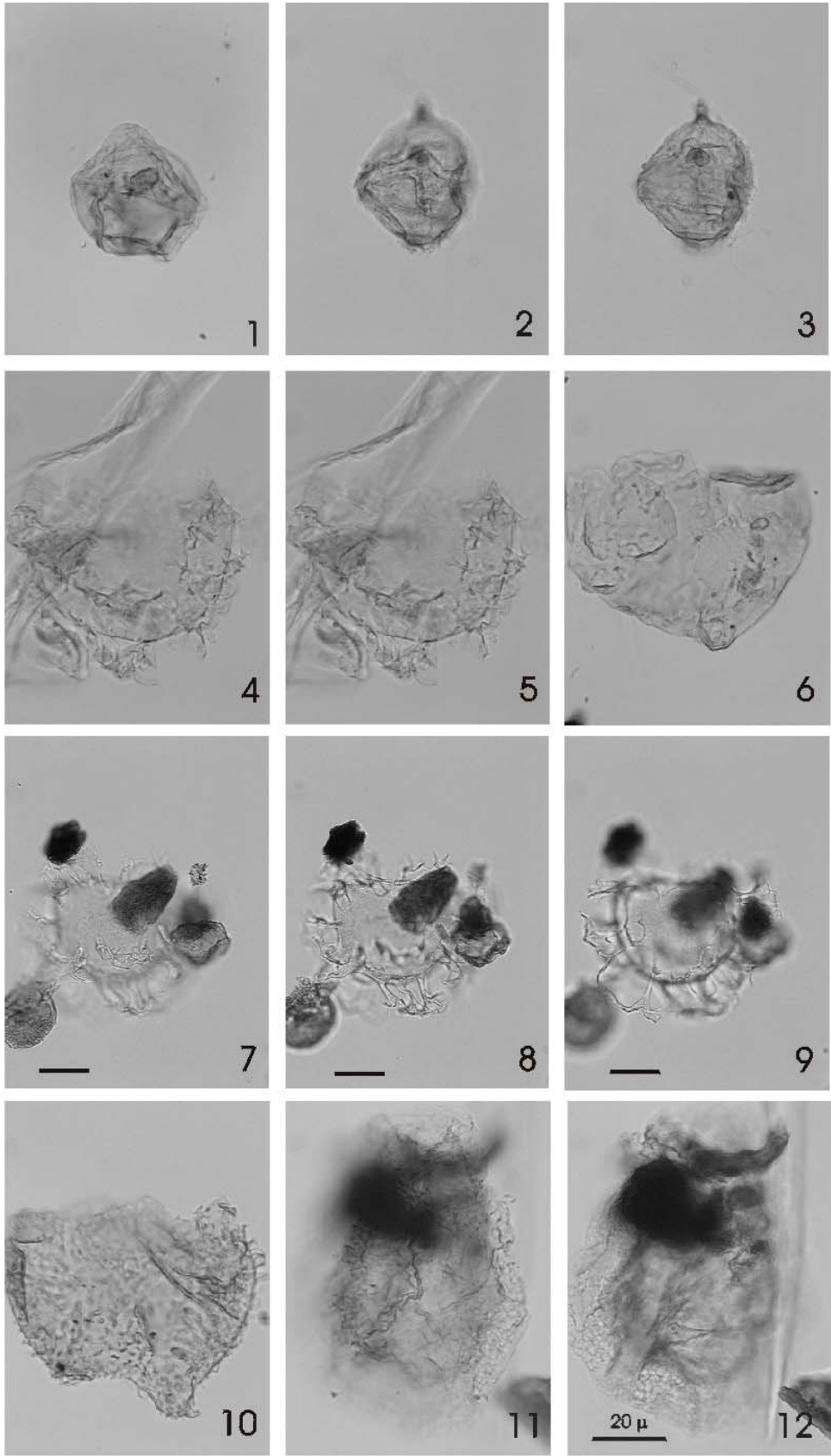
Figs 4–5 *Glaphyrocysta* sp. 4 HNH North Leif 27.7-16.6, 1080m-2, LVR 27944–945

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

NORTH LEIF – PLATE 10

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

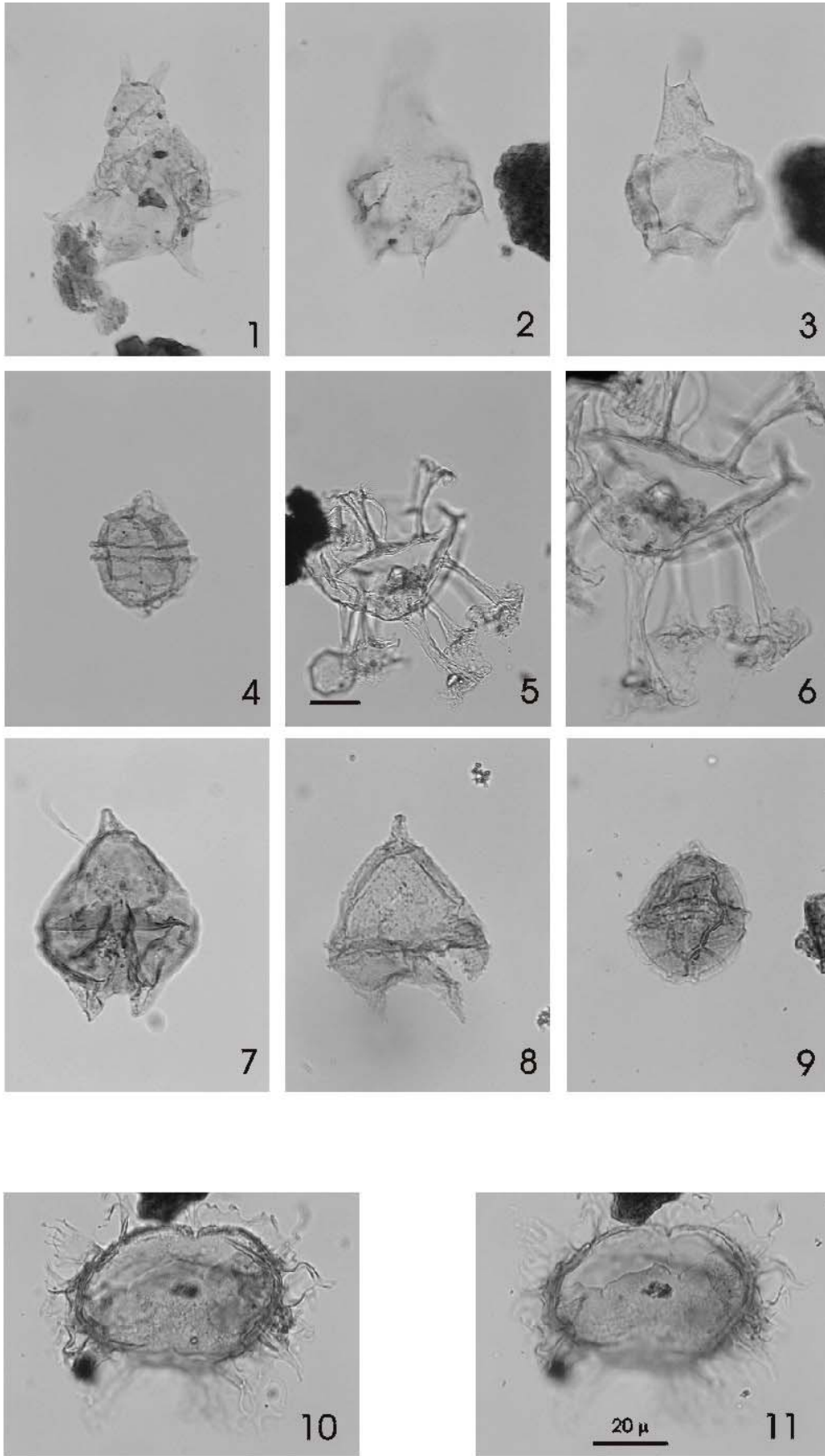
Figs 5–6 *Enneadocysta* cf. *fenestrata* 31.9-22.7, 1170m-2, LVR 27959–960

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

NORTH LEIF – PLATE 11

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

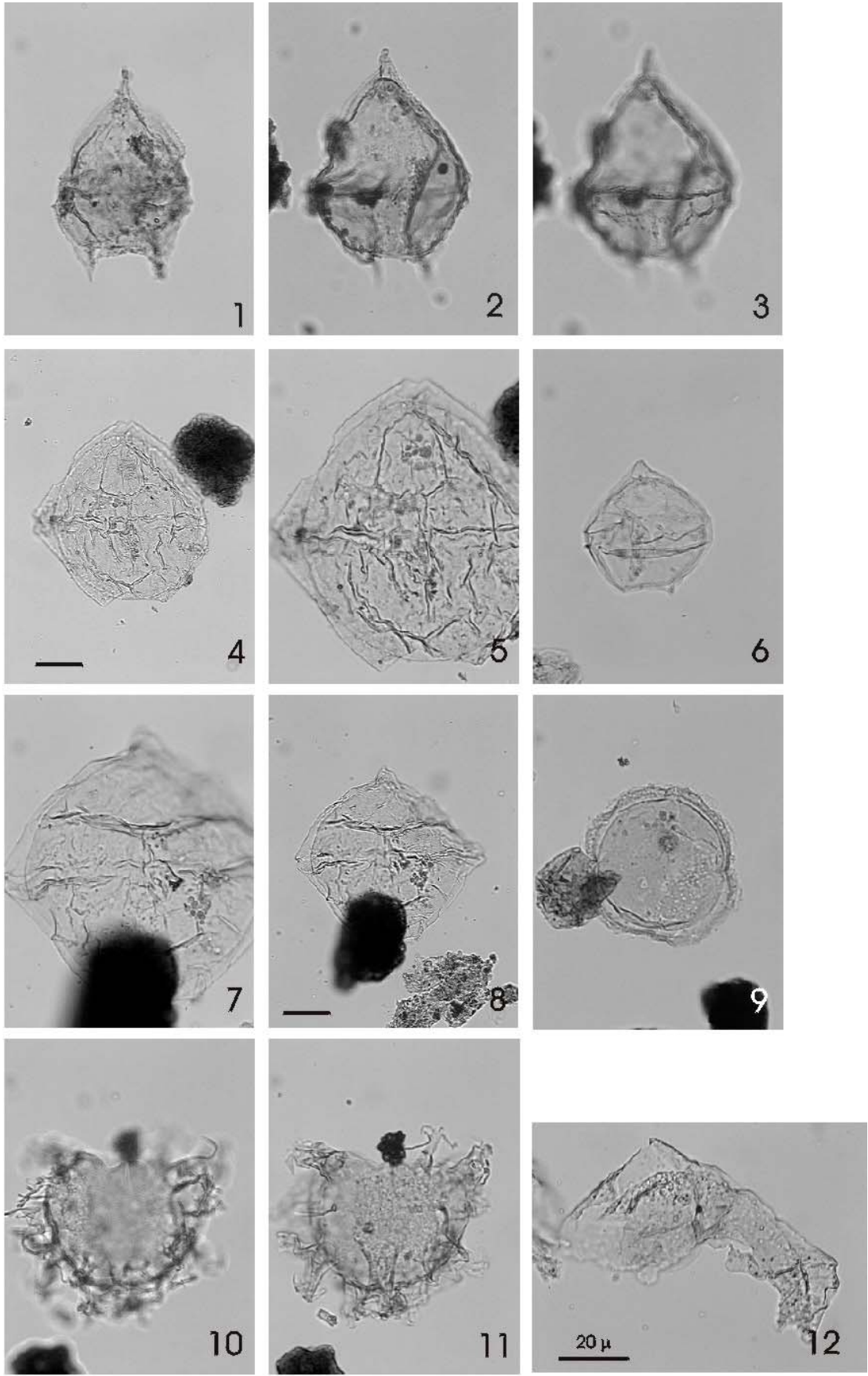
Fig. 6 *Alterbidinium* sp. 1 HNH North Leif 30.3-25.1, 1380m-2, LVR 27980

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

NORTH LEIF – PLATE 12

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

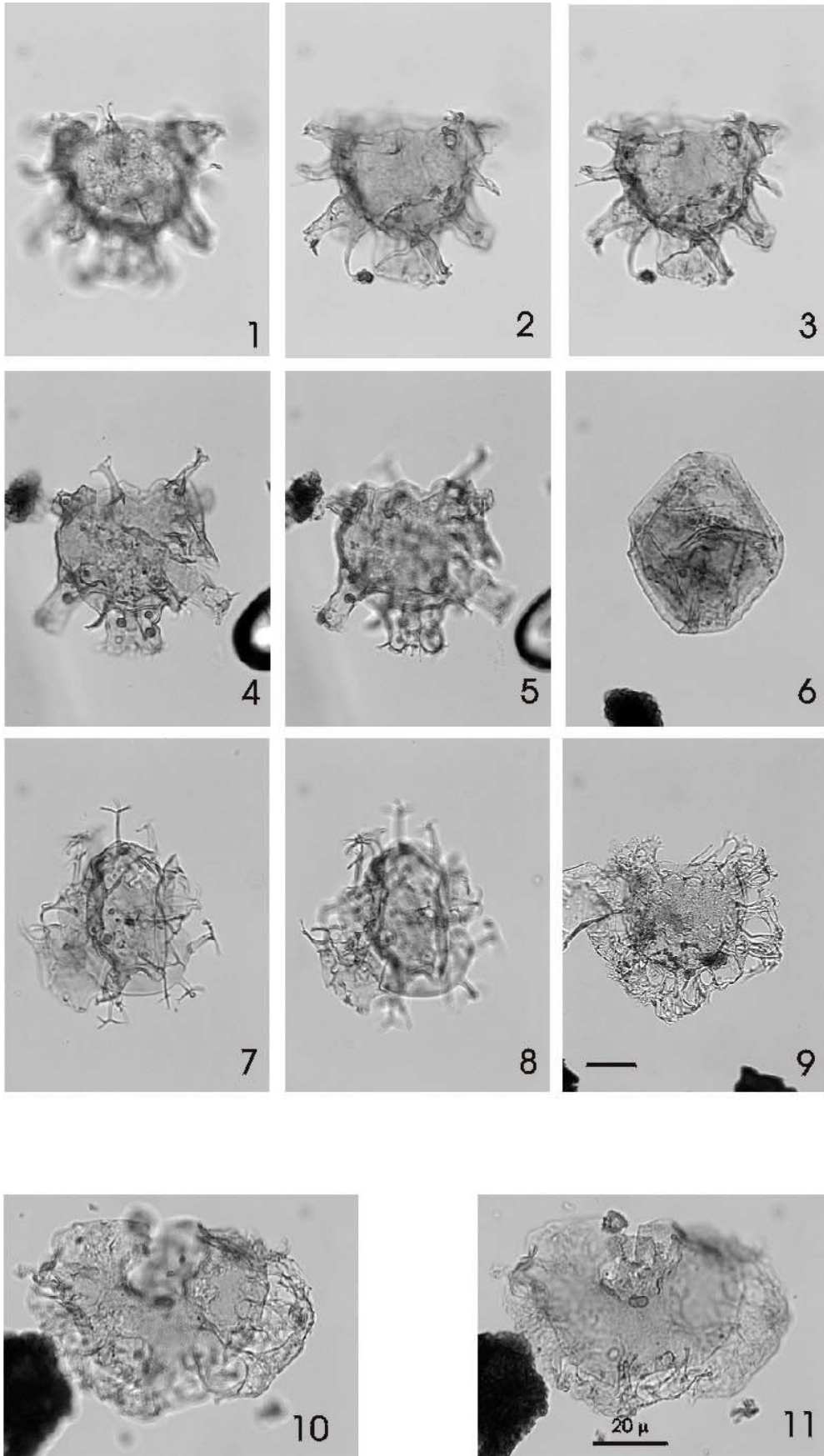
Figs 4–5 *Hystrichokolpoma* sp. 1 HNH North Leif (? *H. cf. salacium*) 34.7-17.9, 1470m-2, LVR 27987–988

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

NORTH LEIF – PLATE 13

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

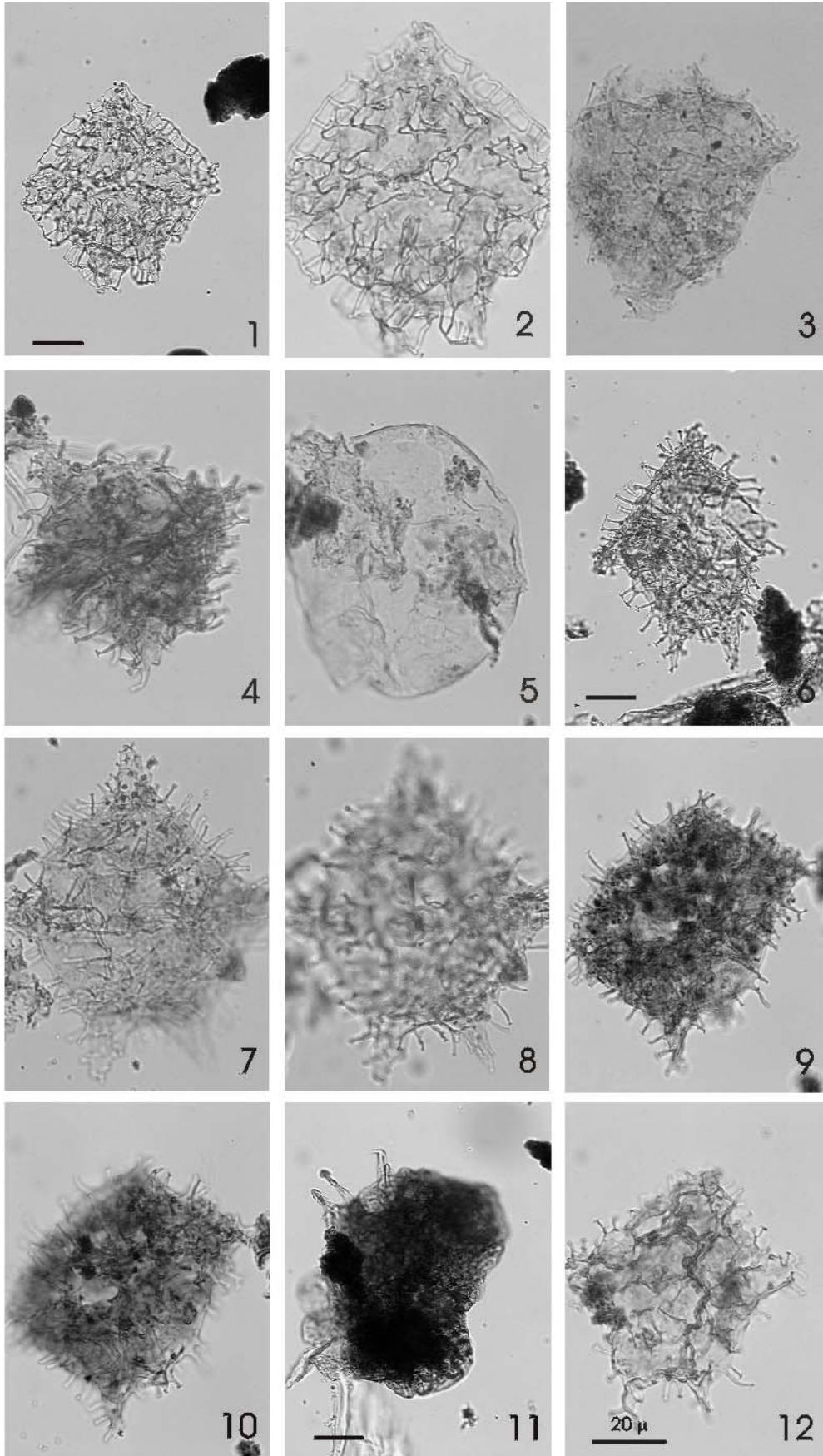
Fig. 6 *Wetzeliella articulata* 39.1-16.7, 1650-2, LVR 28003

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

NORTH LEIF – PLATE 14

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

Figs 2–3 *Wetziella 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

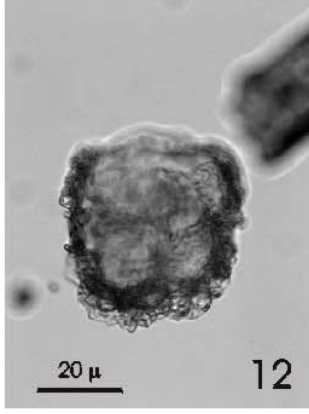
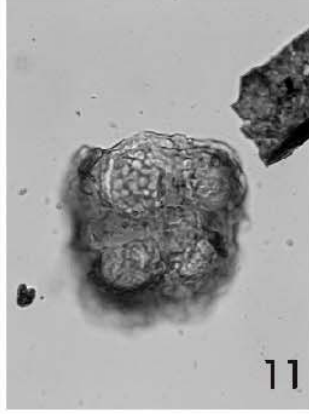
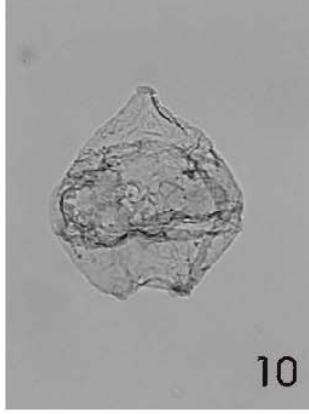
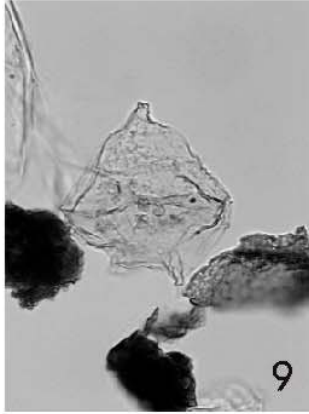
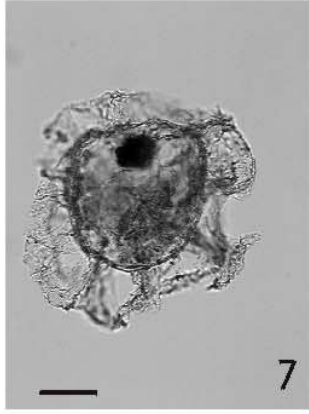
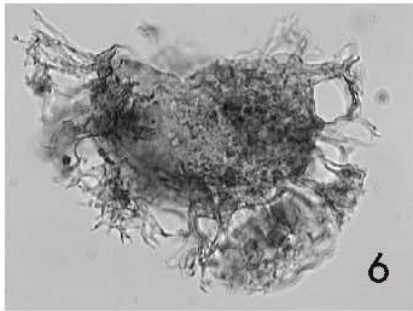
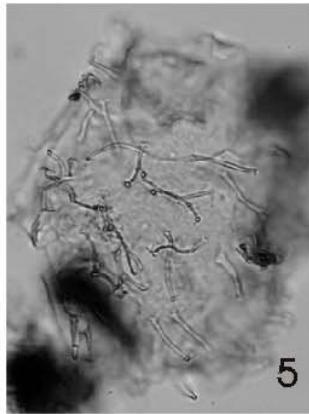
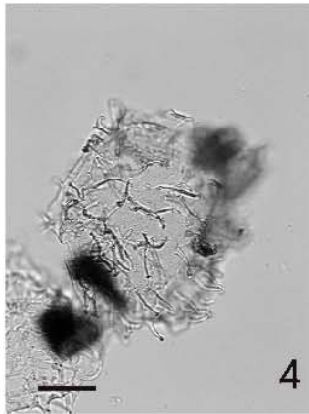
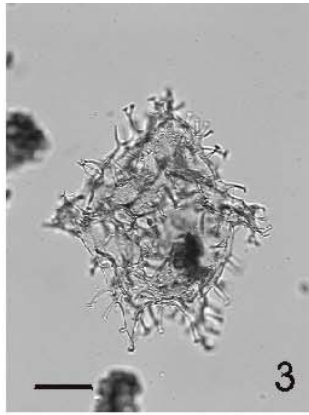
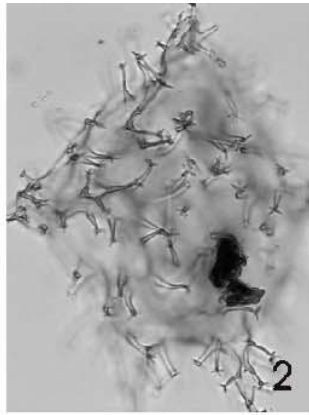
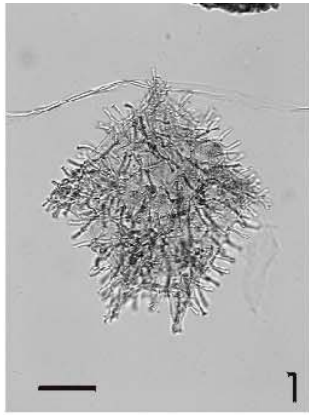
Fig. 7 *Aranosphaera araneosa* 31.9-22.9, 1800m-2, LVR 28016

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

NORTH LEIF – PLATE 15

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

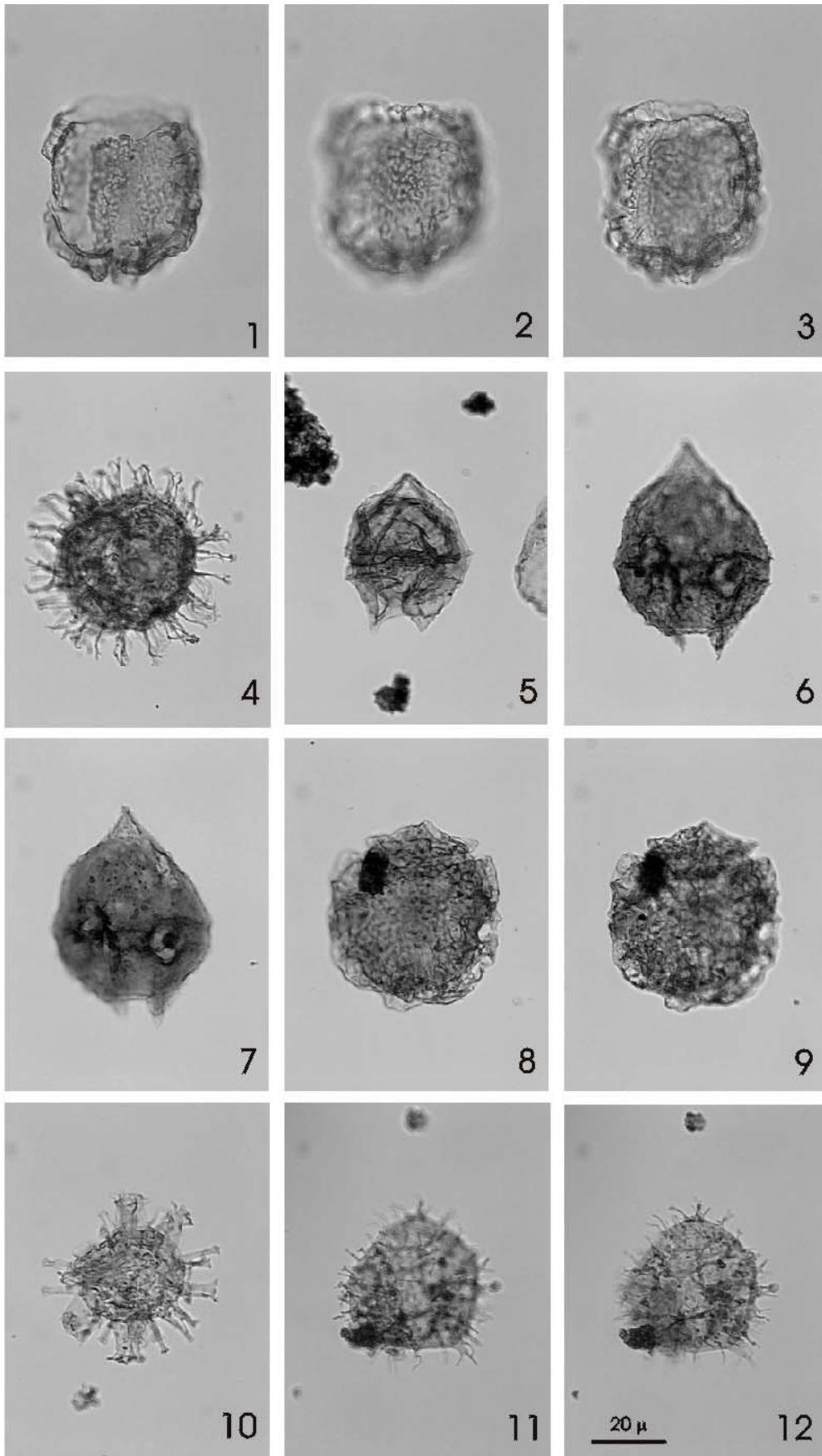
Fig. 5 *Deflandrea* sp. 1 HNH North Leif 22.3-10.9, 1890m-2, LVR 28029

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 *Hystriochokolpoma* 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

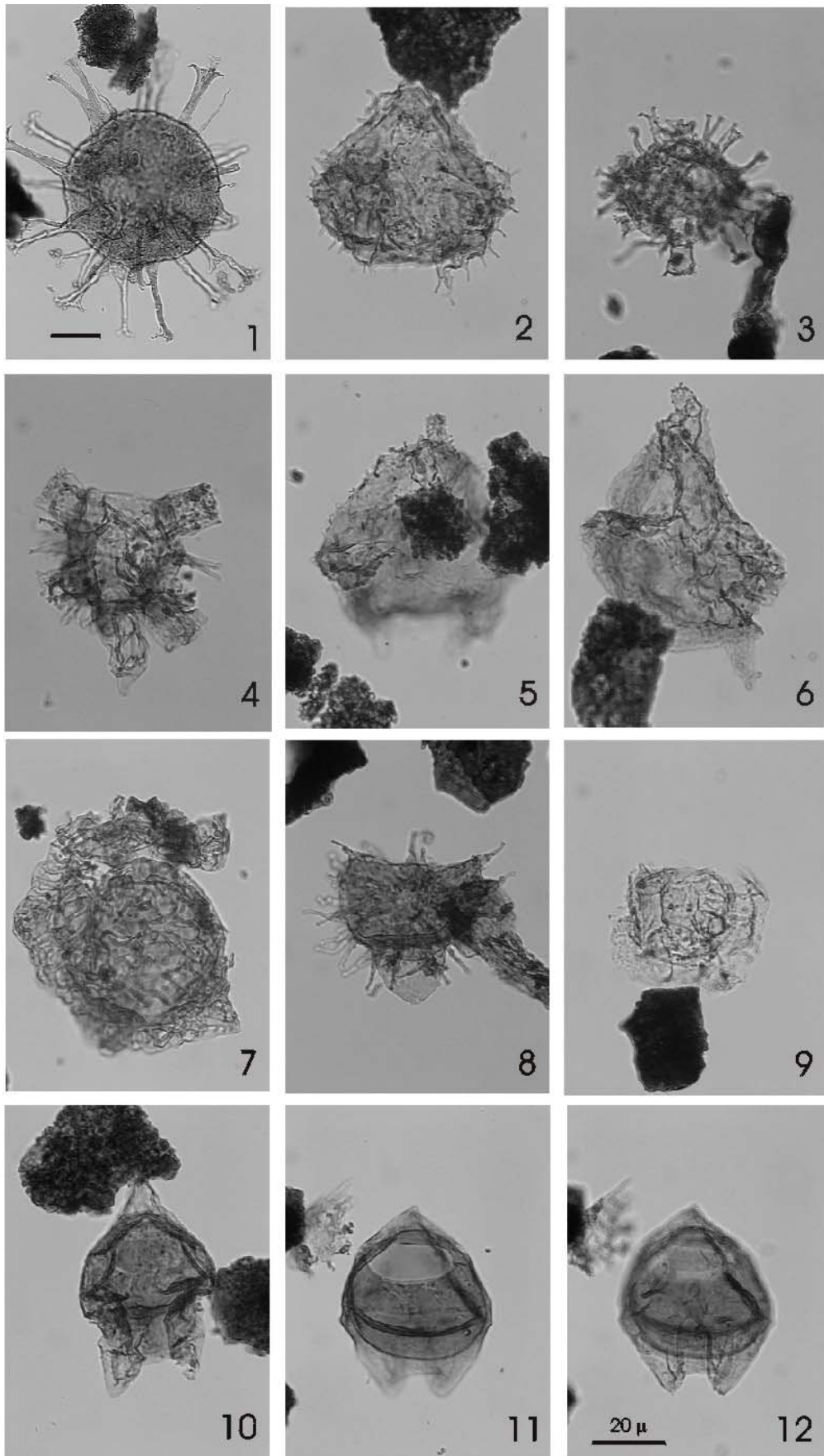
1-3 1830 m

4-9 1890 m

10-12 1950 m

NORTH LEIF – PLATE 16

- 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

NORTH LEIF – PLATE 17

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

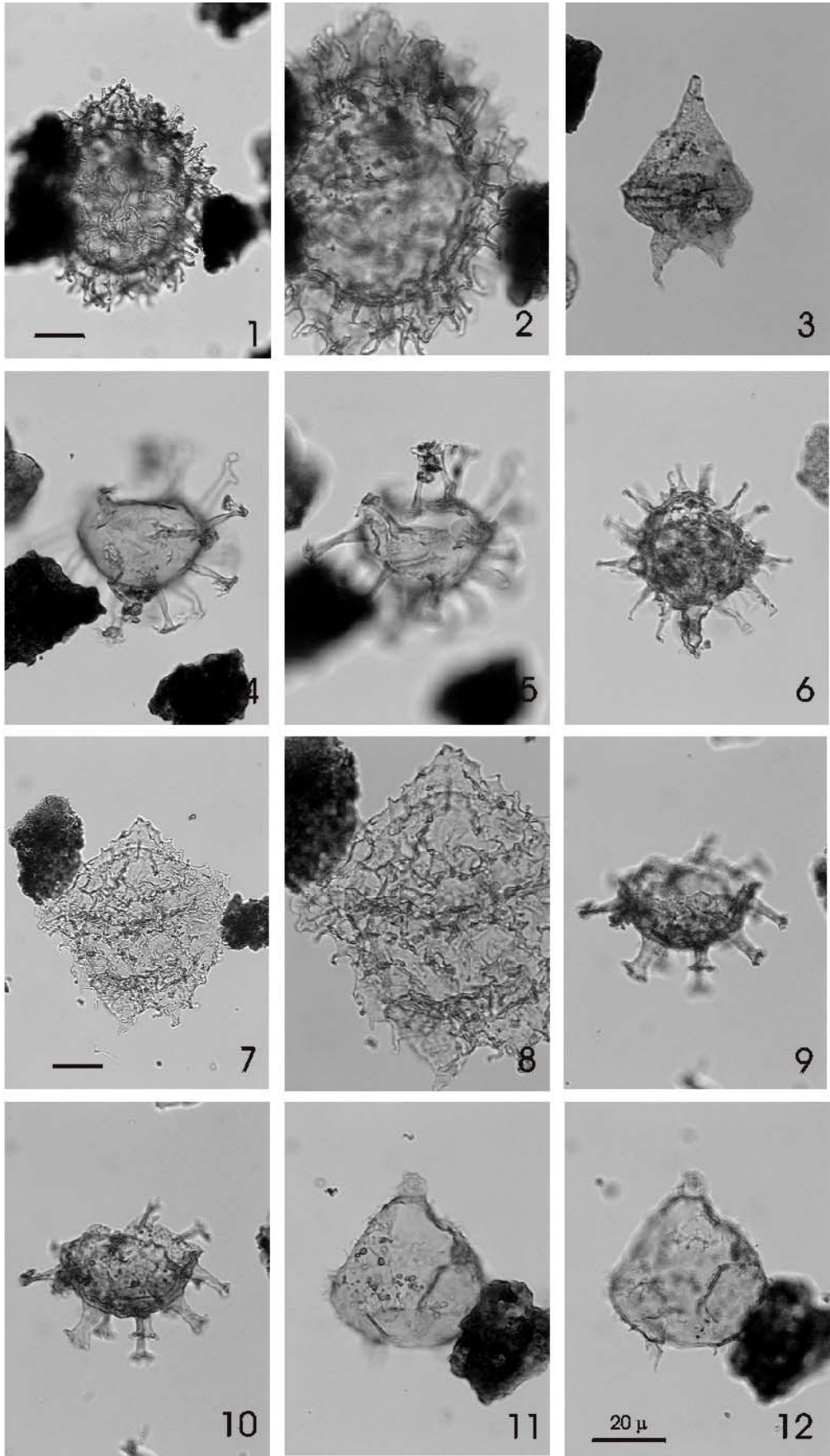
Fig. 5 *Cerodinium depressum* 38.1-23.3, 1980m-3, LVR 28054

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

NORTH LEIF – PLATE 18

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

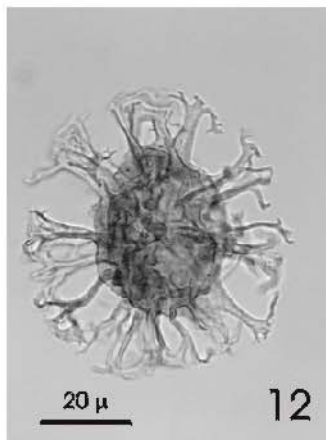
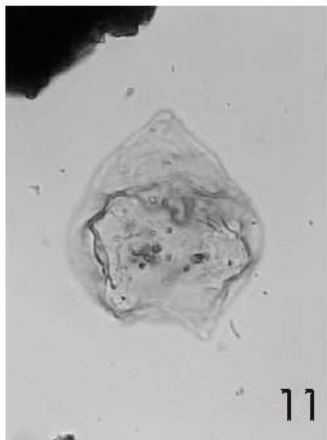
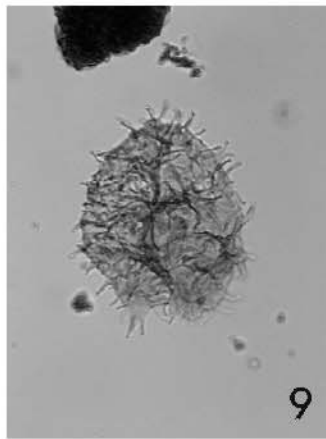
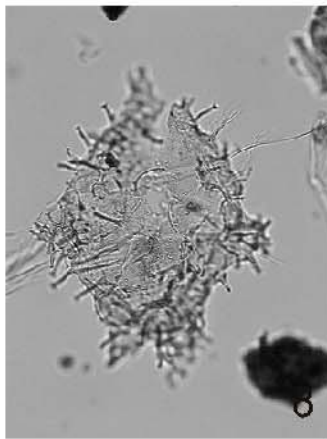
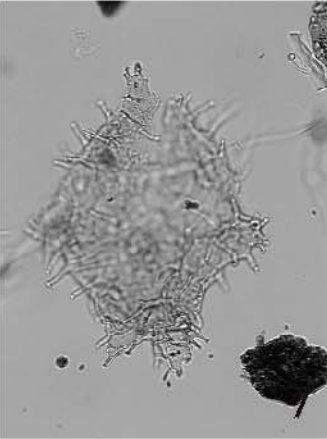
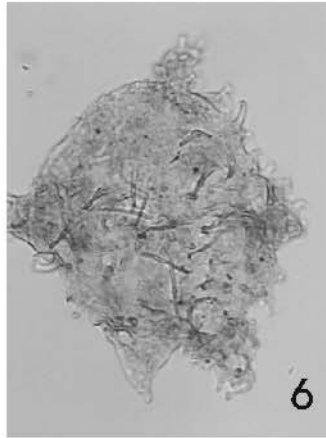
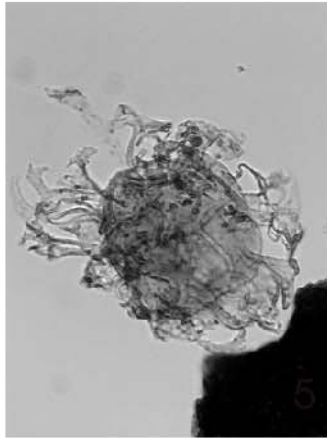
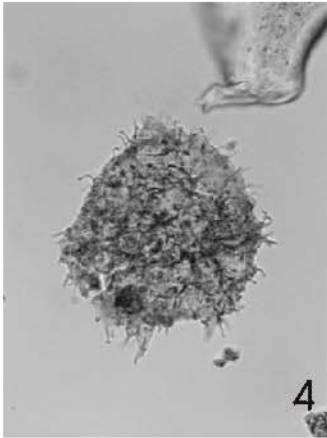
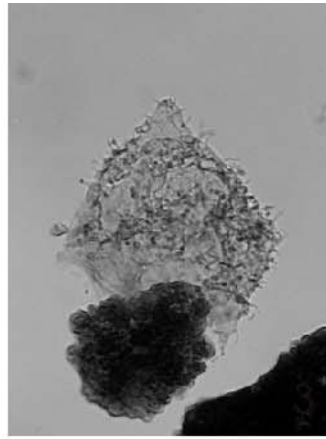
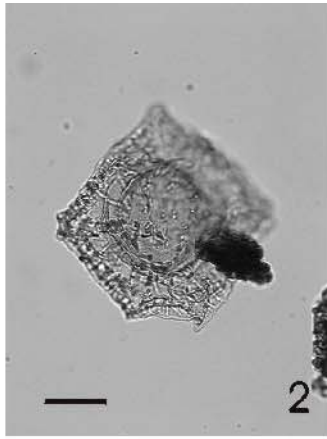
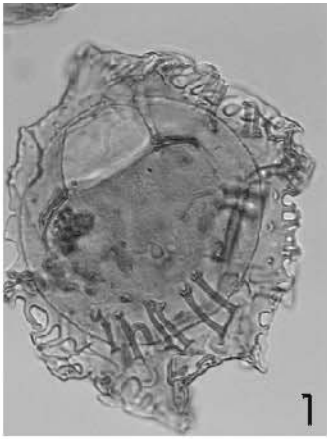
Fig. 6 *Dracodinium* cf. *varielongitudum* 32.7-13.8, 2010m-2, LVR 28070

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

NORTH LEIF – PLATE 19

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

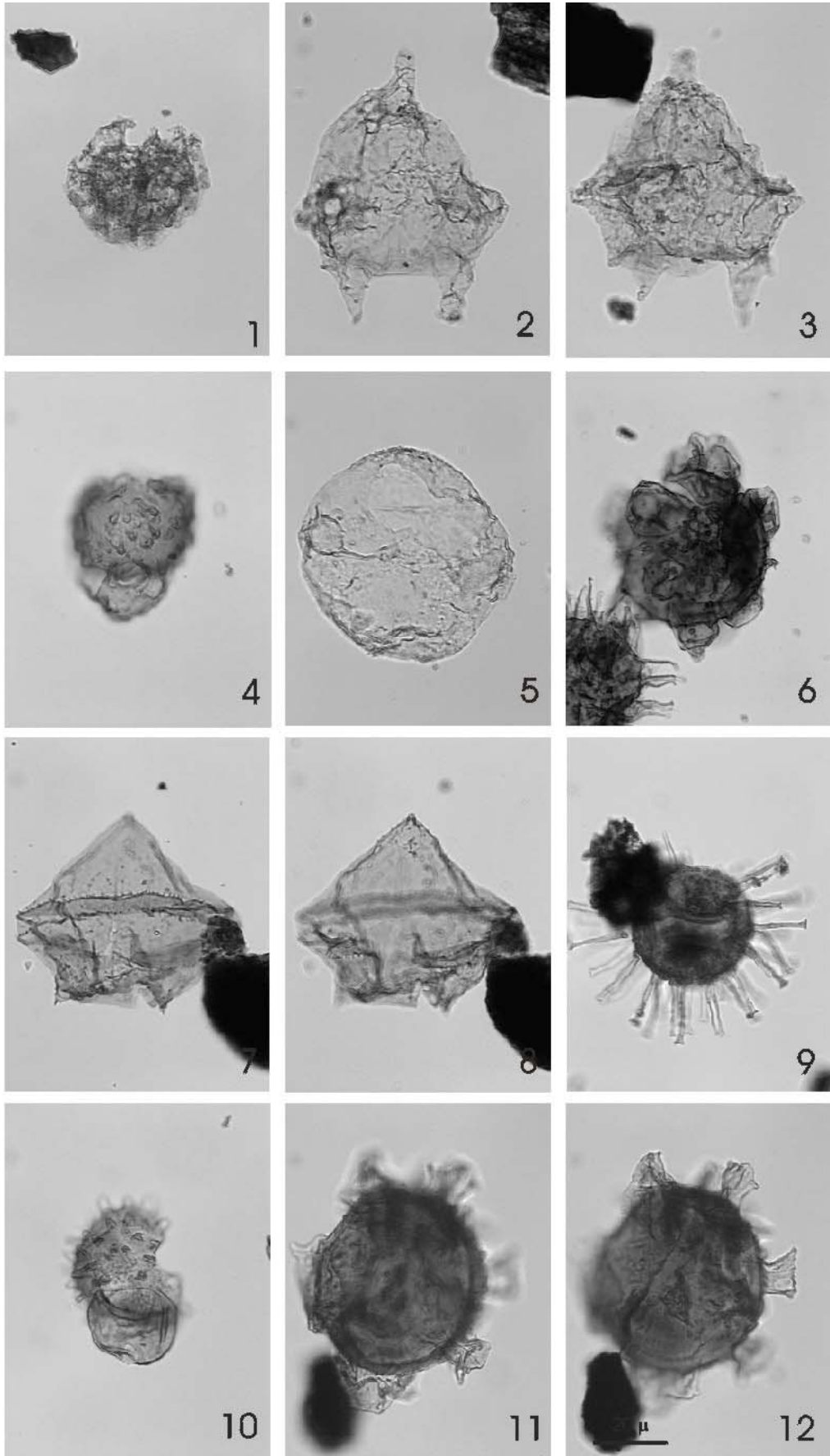
Fig.6 *Hystriocholpoma* sp. 1 Heilmann- Clausen 1989 26.7-6.3, 2040m-2, LVR 28083

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

NORTH LEIF – PLATE 20

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

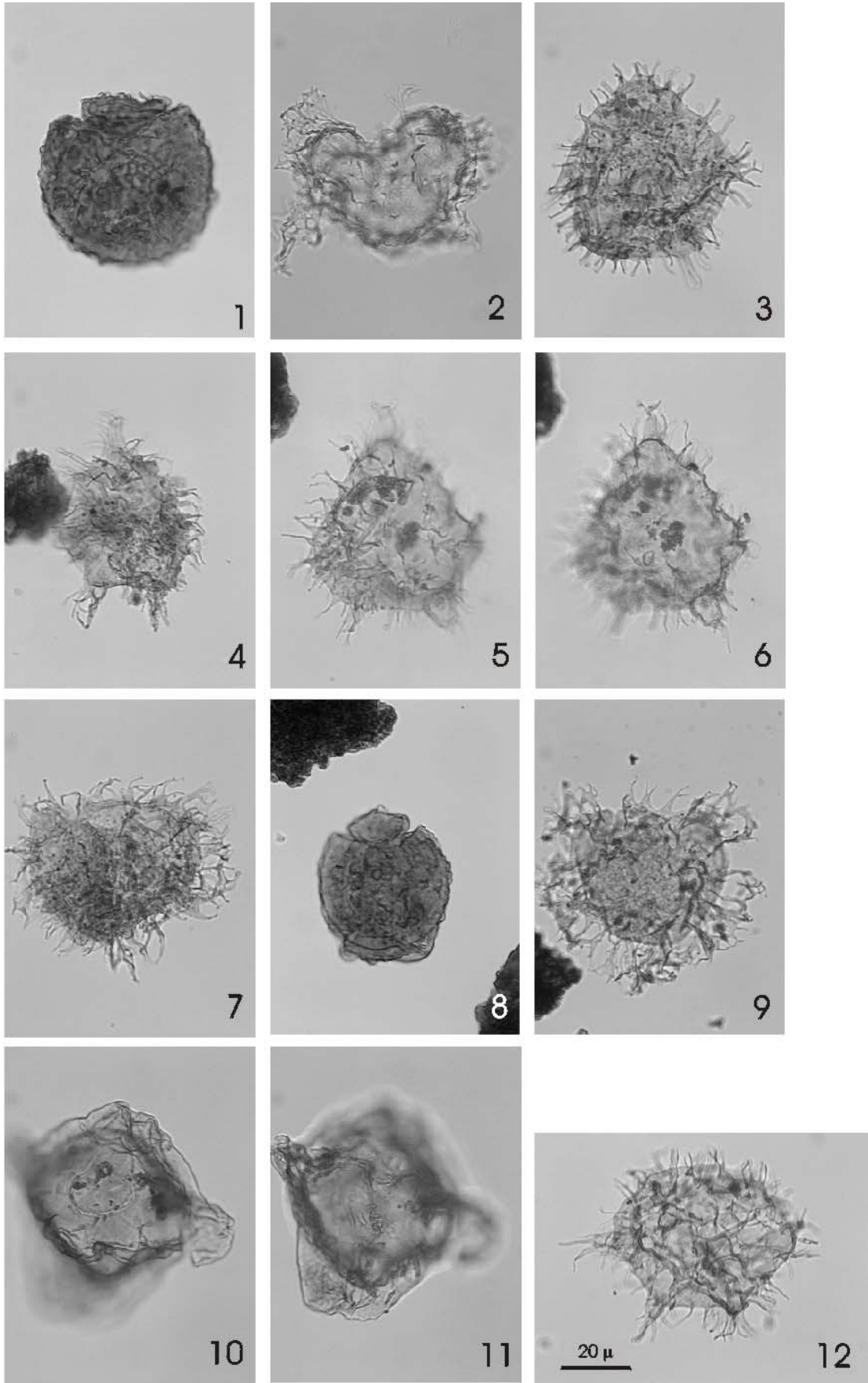
Fig. 7 *Areoligera* sp. 1 HNH North Leif 20.1-19.0, 2070m-4, LVR 28096

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

NORTH LEIF – PLATE 21

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

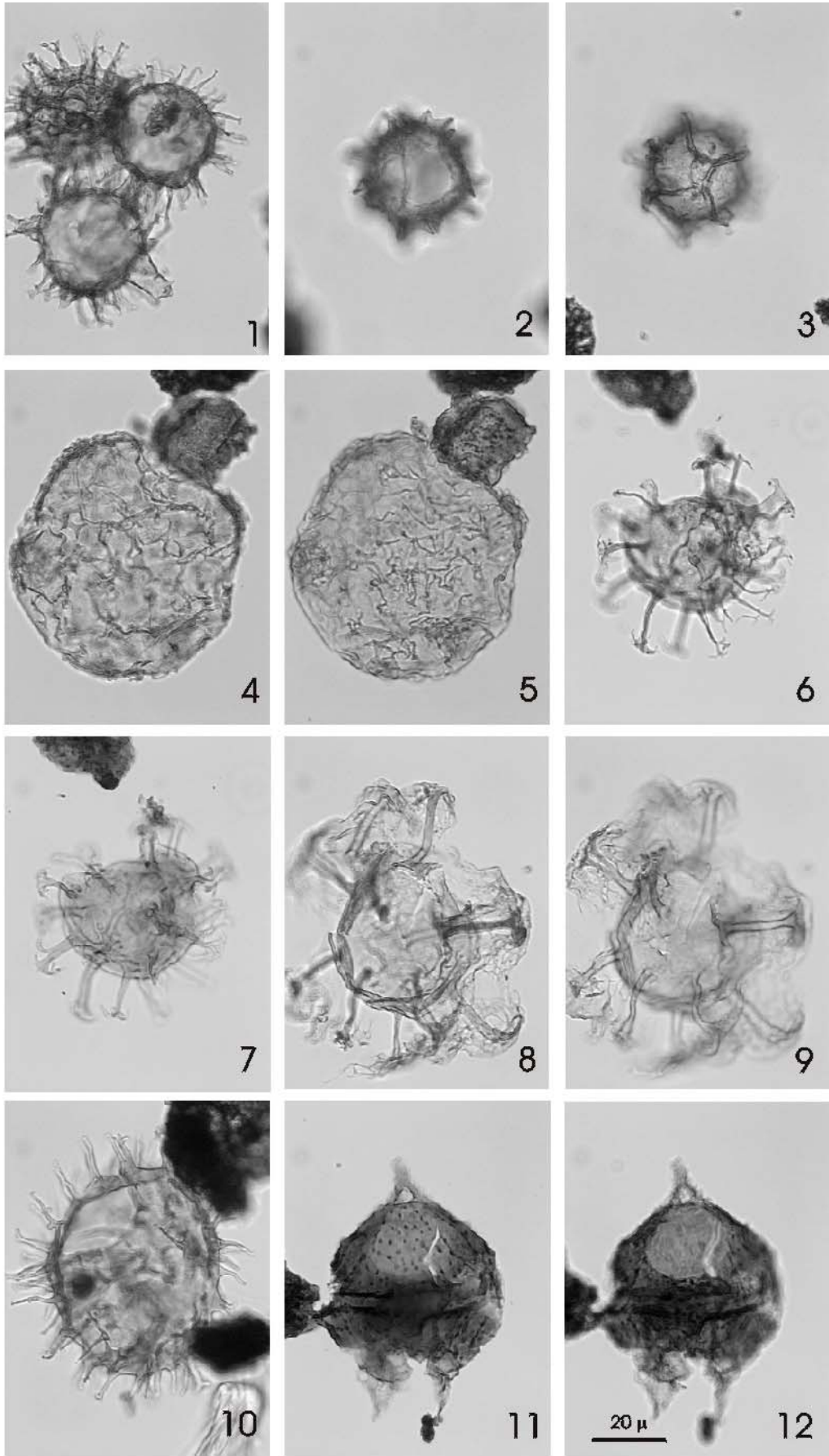
Figs 4– 5 *Dracodinium* sp. 2 HNH North Leif 46.0-19.7, 2070m-4, LVR 28103–104

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

NORTH LEIF – PLATE 22

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

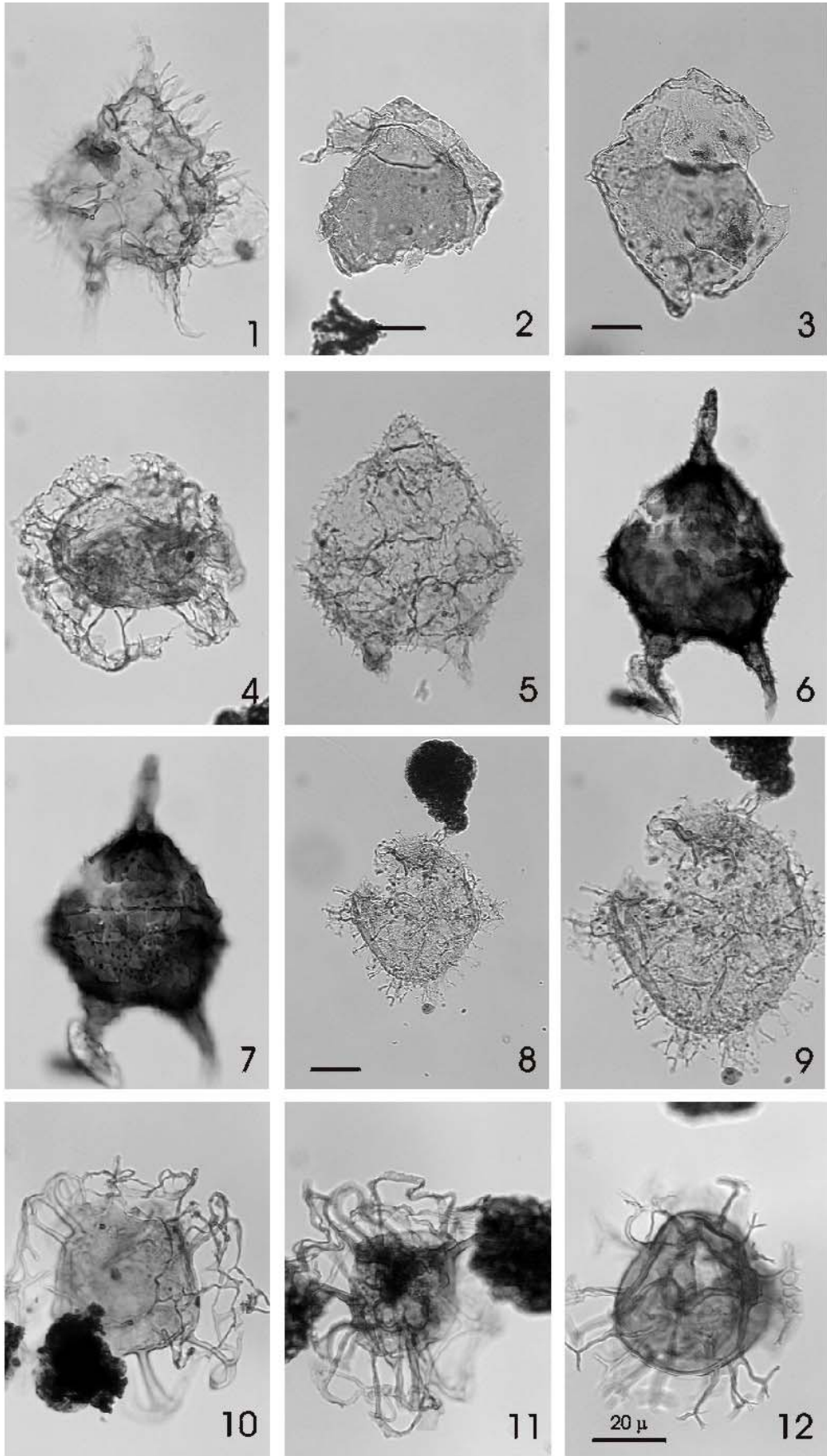
Figs 6–7 *Deflandrea denticulata* 45.8-15.0, 2100m-4, LVR 28118–119

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

NORTH LEIF – PLATE 23

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

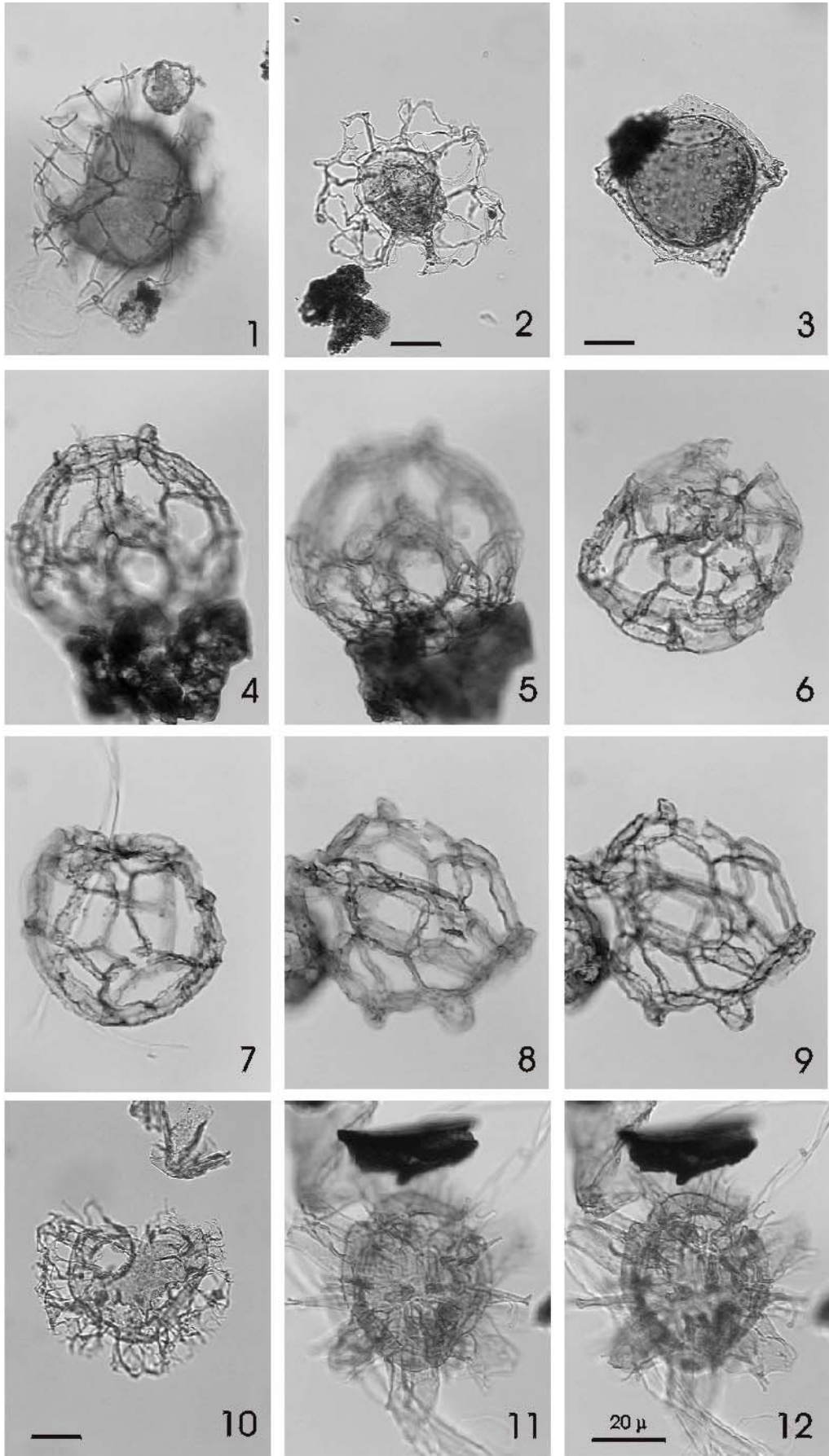
Fig. 6 Dinocyst sp. 3 (*Evittosphaerula*) Manum *et al* 1989 32.8-20.8, 2130m-3, LVR 28131

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

NORTH LEIF – PLATE 24

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

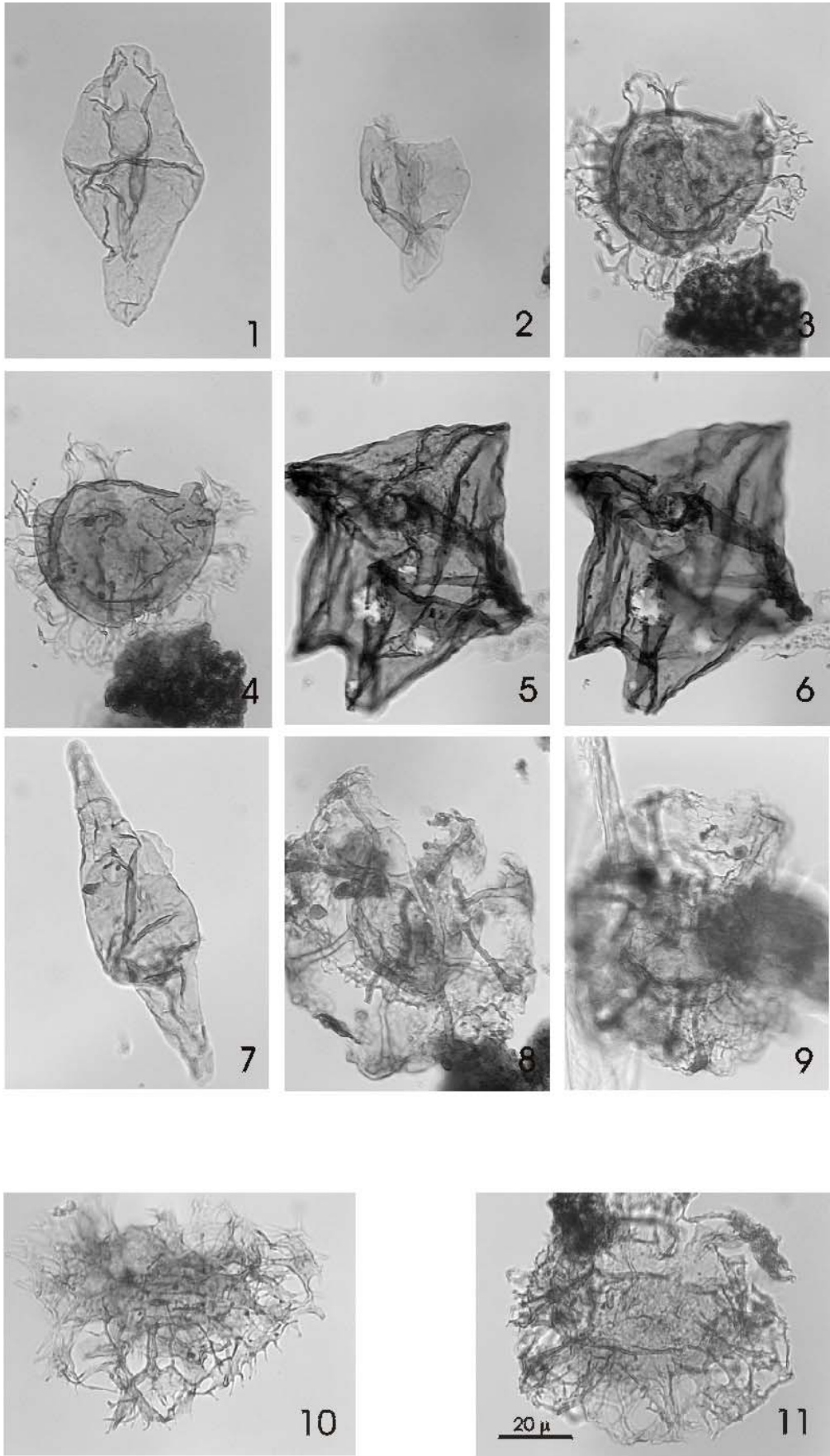
Fig. 7 *Svalbardella* sp. 1 HNH North Leif 25.1-13.1, 2160m-3, LVR 28145

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

NORTH LEIF – PLATE 25

Fig.1 *Svalbardella cf hamptenensis* 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

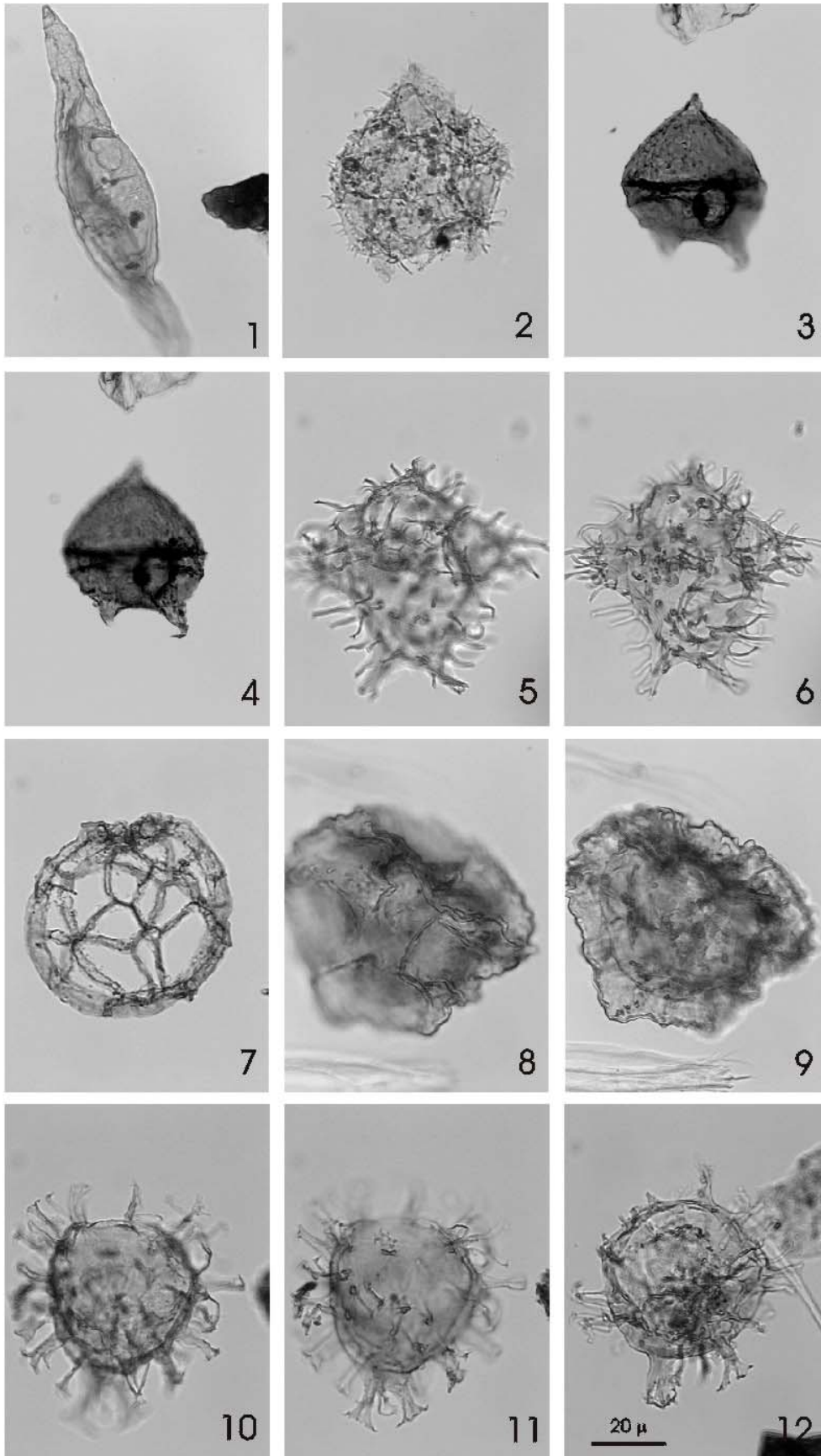
Figs 5–6 *Apectodinium paniculatum* 45.3-18.4, 2190-2, LVR 28154–155

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

NORTH LEIF – PLATE 26

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

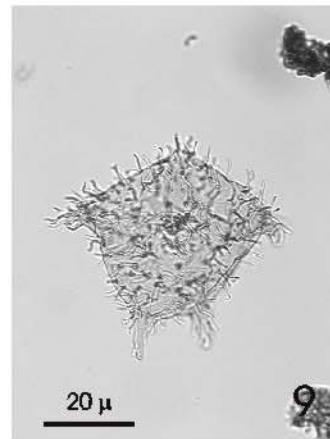
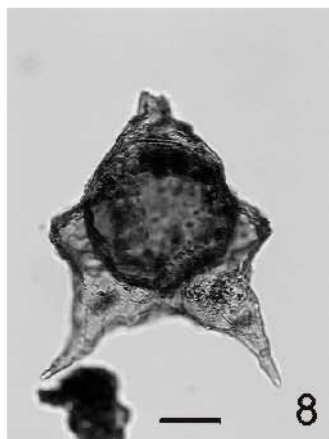
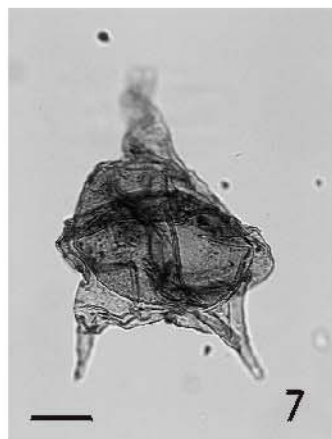
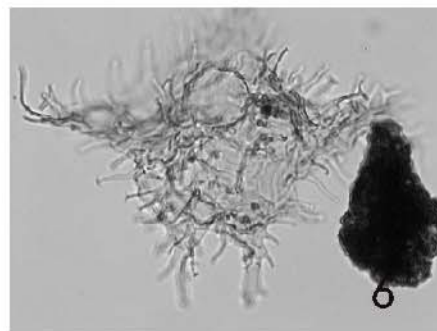
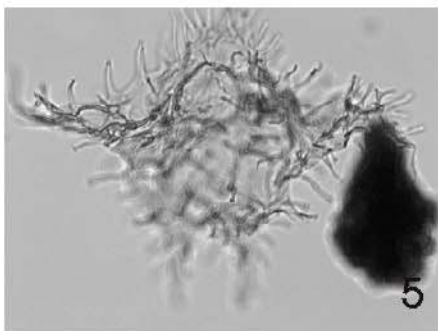
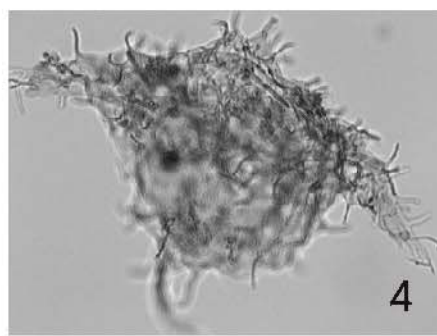
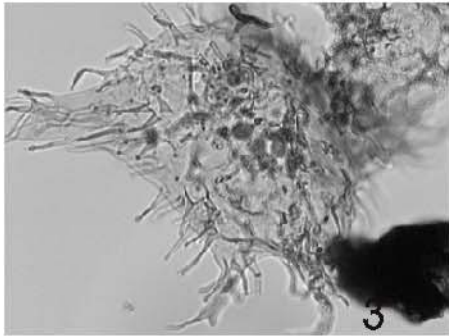
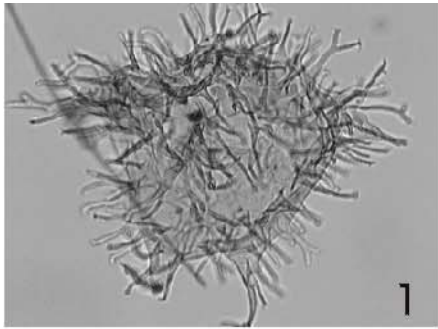
Fig. 4 *Apectodinium augustum* 41.3-19.3, 2250m-4, LVR 28171

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

NORTH LEIF – PLATE 27

Figs 1–2 *Hystriochokolpoma* 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

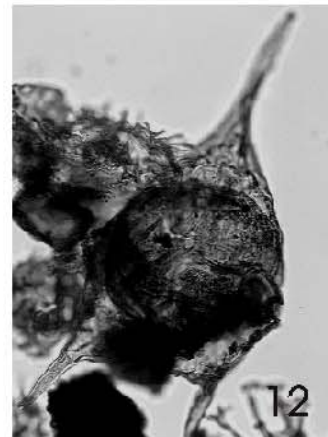
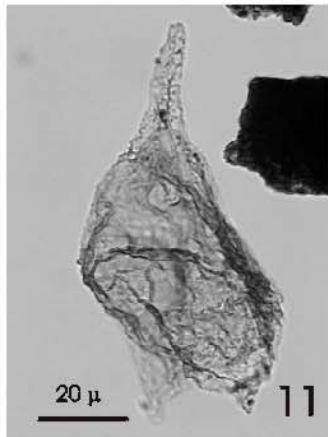
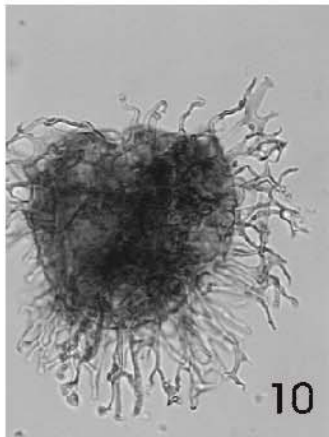
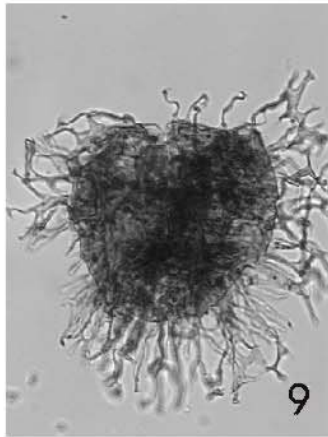
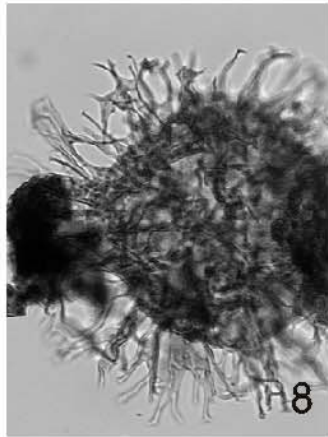
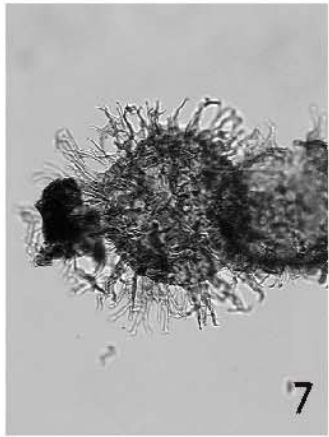
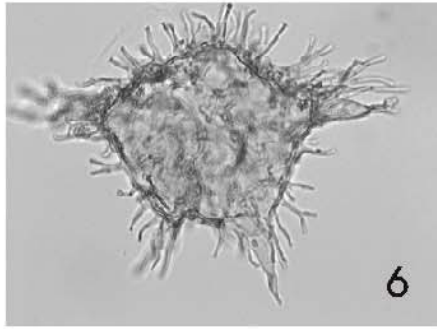
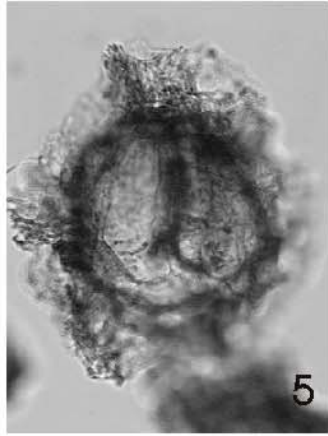
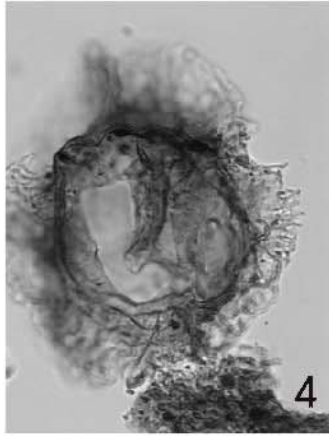
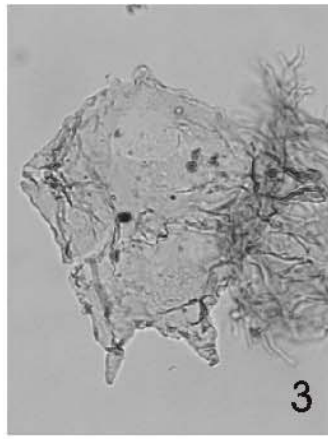
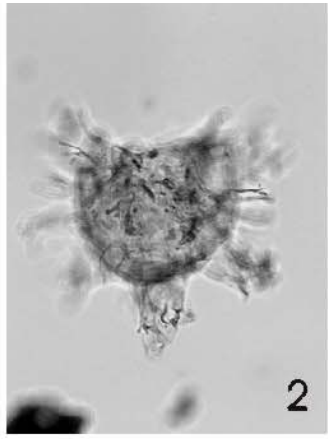
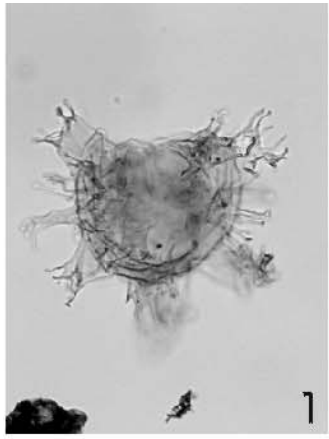
Fig. 6 *Apectodinium augustum* 19.5-13.0, 2280m-3, LVR 28183

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

NORTH LEIF – PLATE 28

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

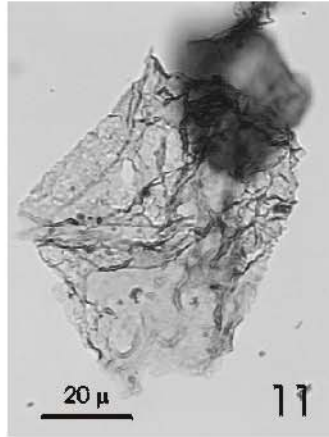
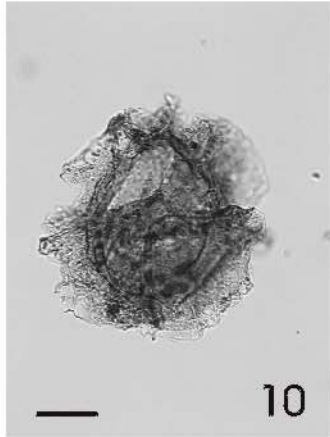
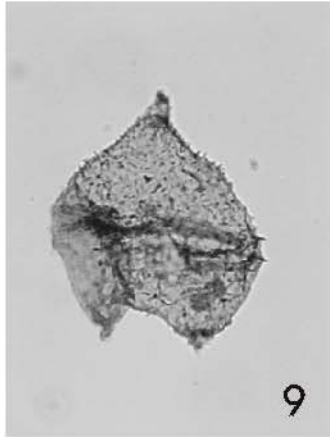
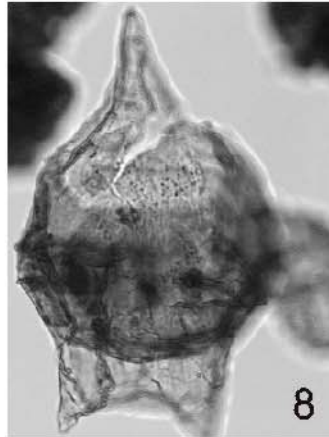
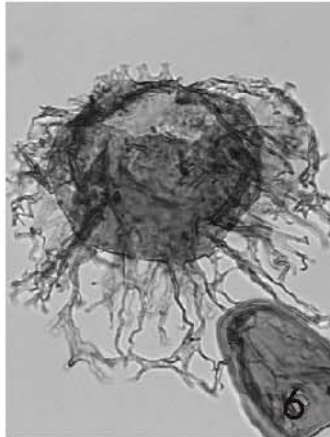
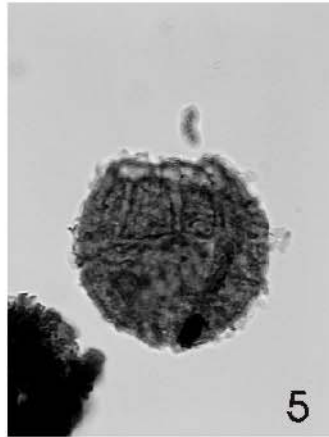
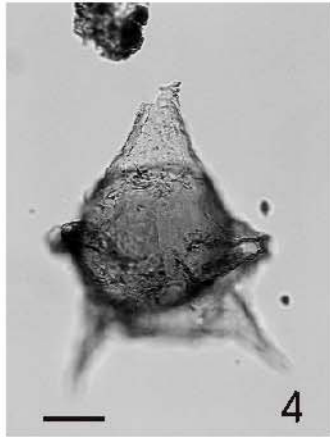
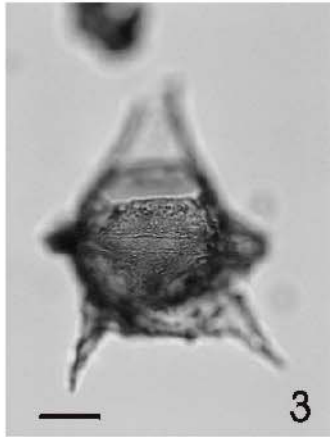
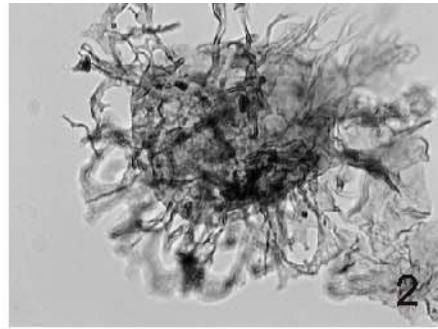
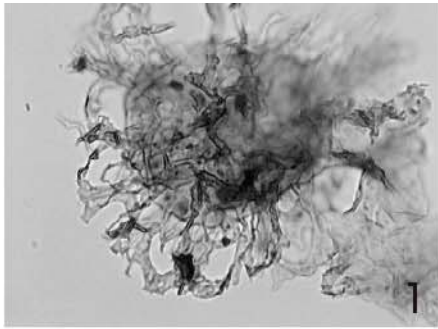
Fig. 6 *Glaphyrocysta* sp. 8 HNH North Leif 36.4-8.9, 2340m-3, LVR 28193

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

NORTH LEIF – PLATE 29

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 *Cordosphaeridium* aff. *funiculatum* 36.9-19.9, 2370m-3, LVR 28202-203

Figs 6–7 *Cordosphaeridium* aff. *funiculatum* 46.4-15.2, 2370m-3, LVR 28205-207

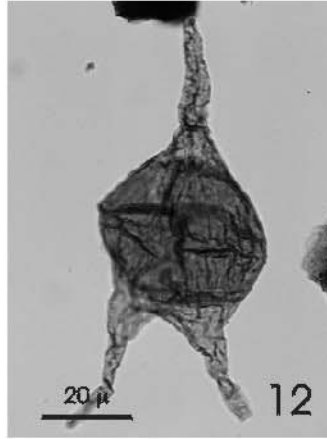
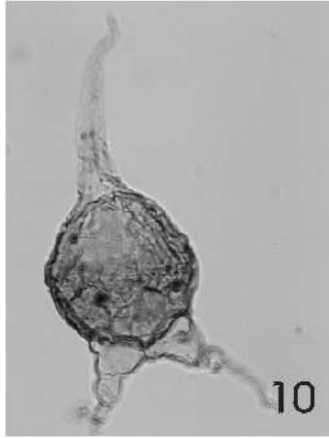
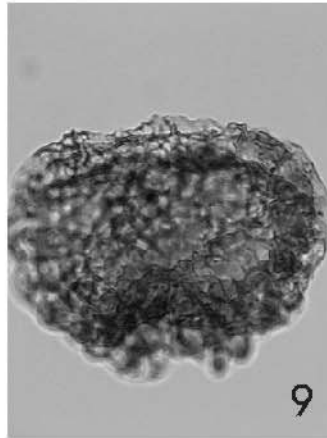
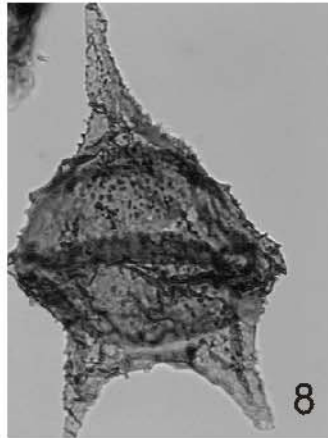
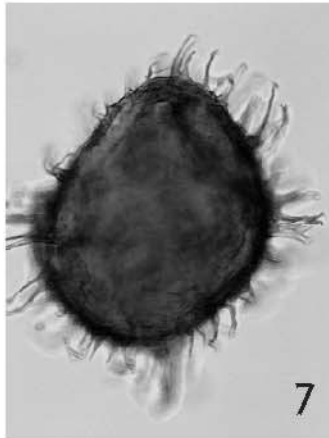
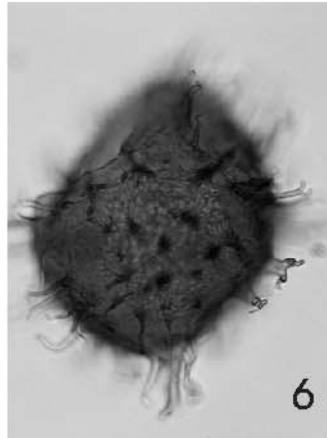
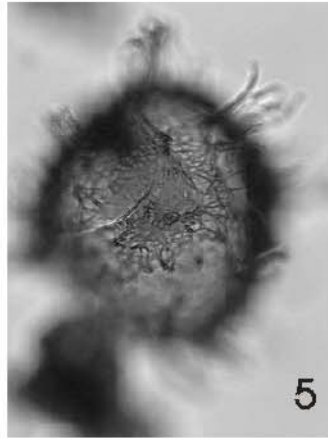
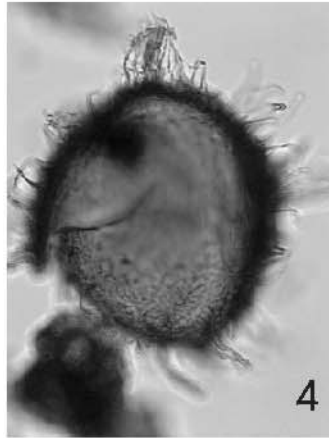
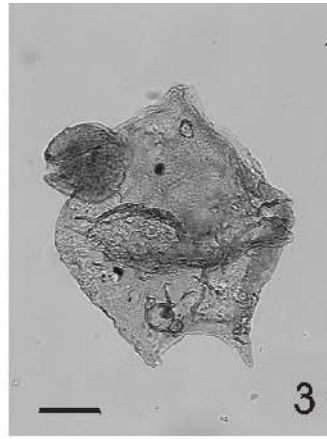
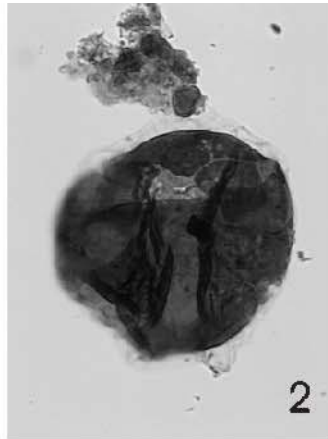
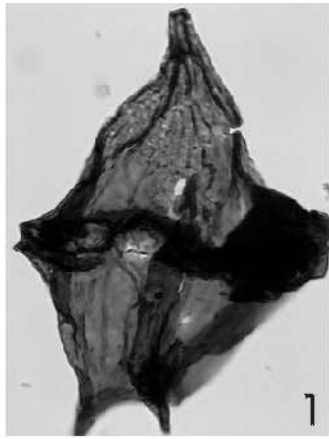
Fig. 8 *Deflandrea denticulata* 48.6-17.6, 2370m-3, LVR 28208

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

NORTH LEIF – PLATE 30

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 Choriat cyst sp. 7 HNH North Leif 17.0-13.3, 2400m-3, LVR 28216

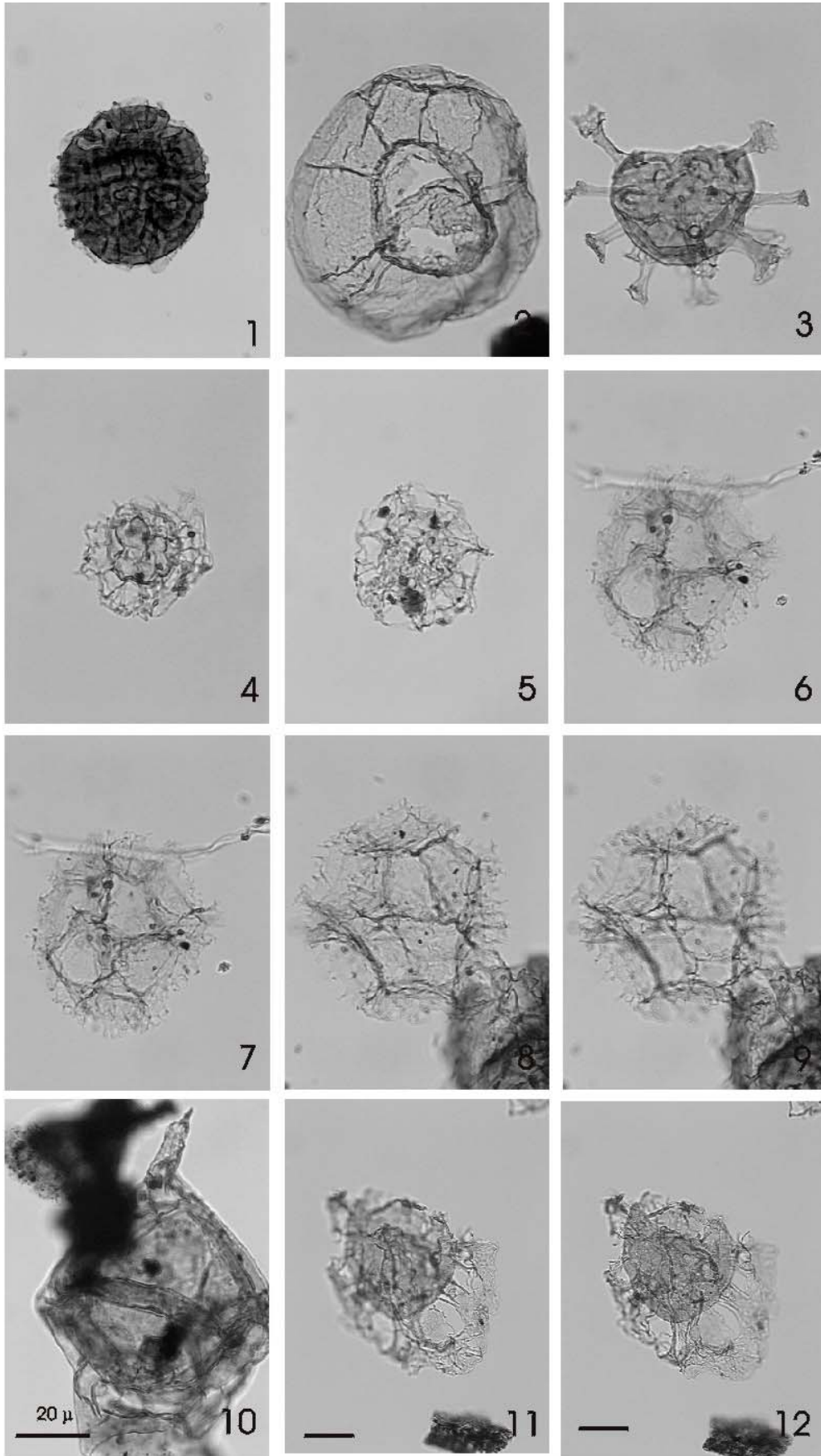
Fig. 5 Choriat cyst sp. 7 HNH North Leif 20.2-14.2, 2400m-3, LVR 28217

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

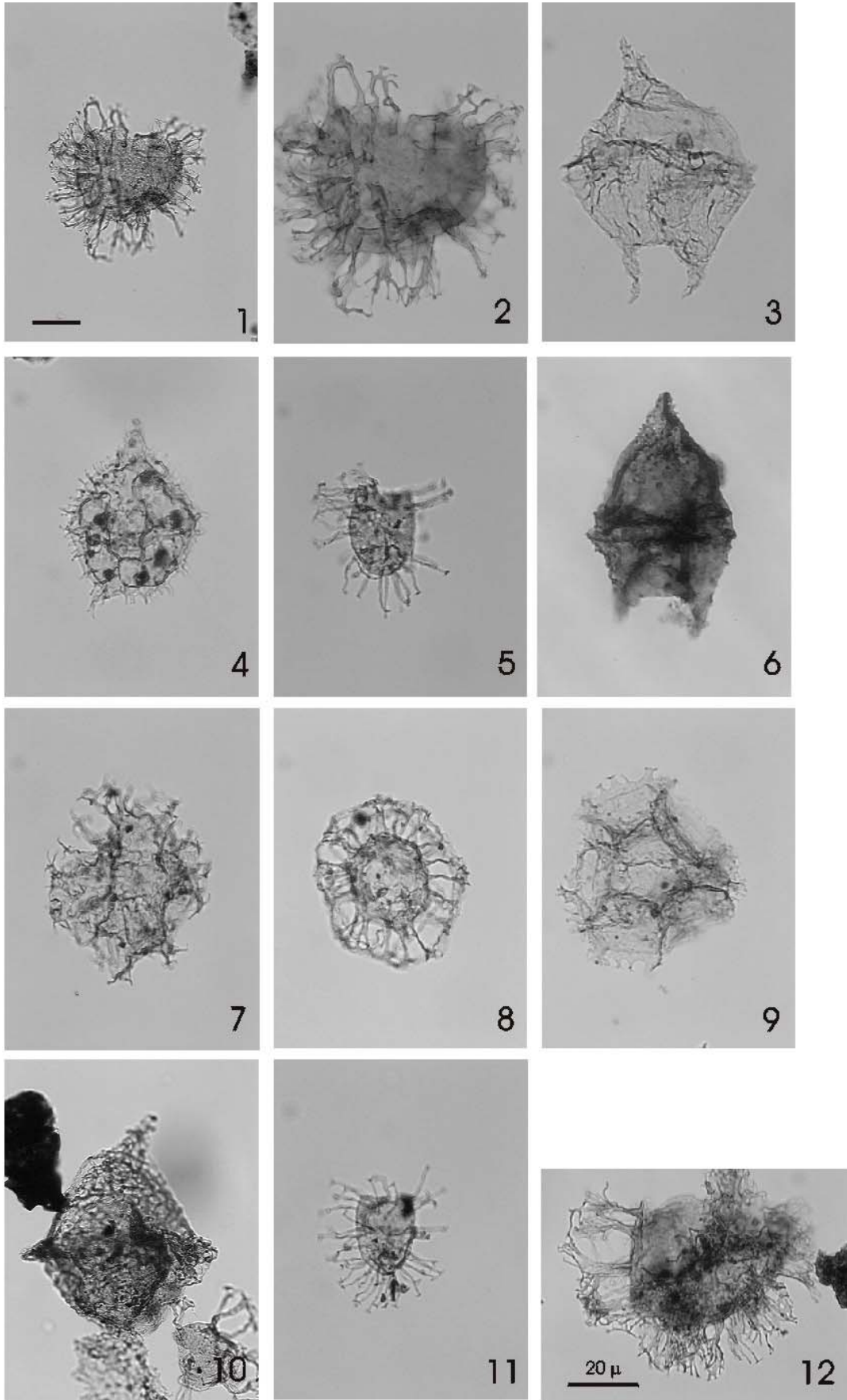
Figs 11–12 *Glaphyrocysta* sp. 9 HNH North Leif 39.9-3.8, 2430m-3, LVR 28225–226



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

NORTH LEIF – PLATE 31

- 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

NORTH LEIF – PLATE 32

Fig. 1 *Caligodinium aceras* 21.5-17.3 2460m-3, LVR 28246

Figs 2–3 *Isabelidium* 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

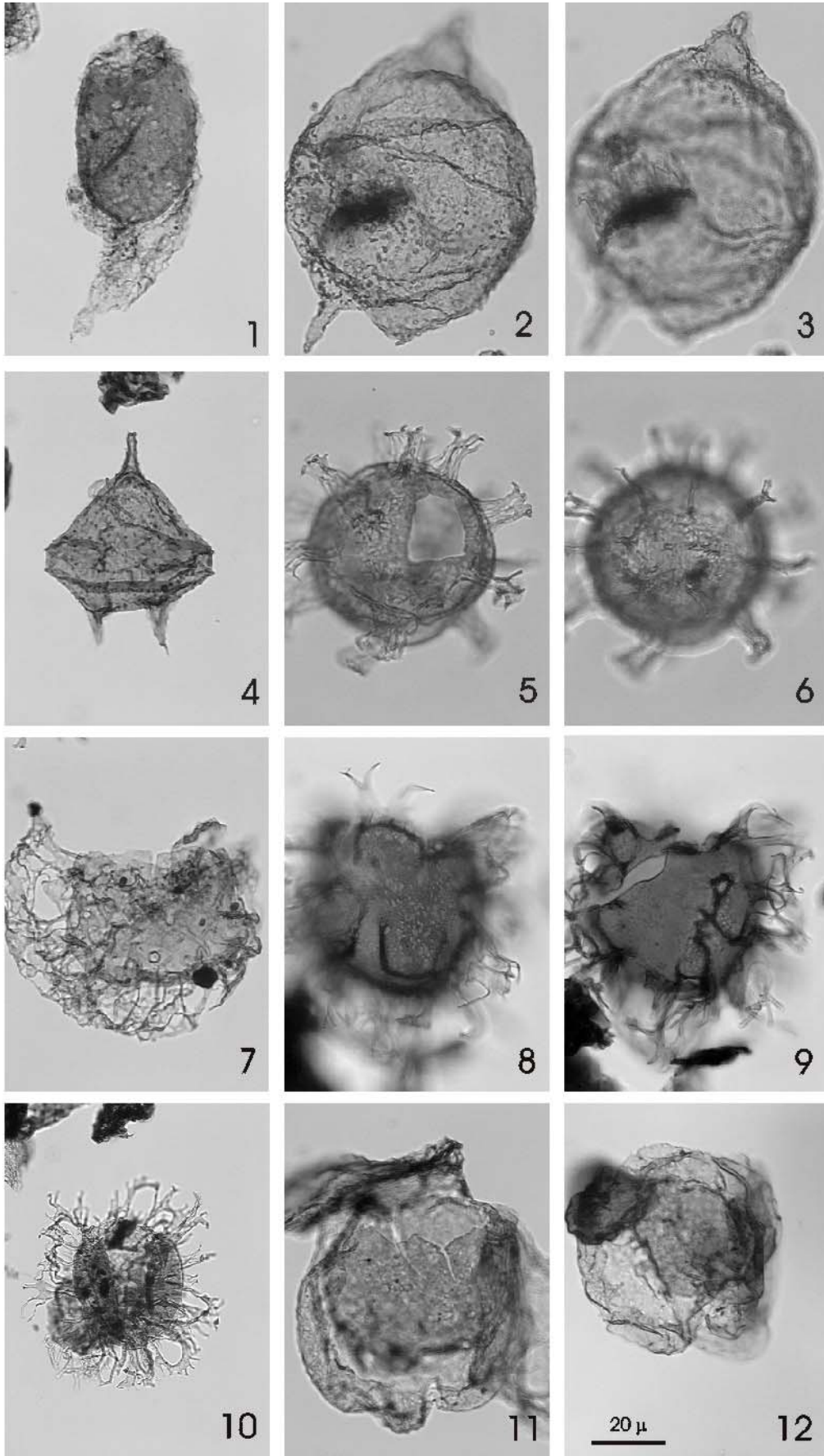
Fig. 7 *Glaphyrocysta pastielsii* 45.6-17.8, 2460m-4, LVR 28252

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

NORTH LEIF – PLATE 33

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

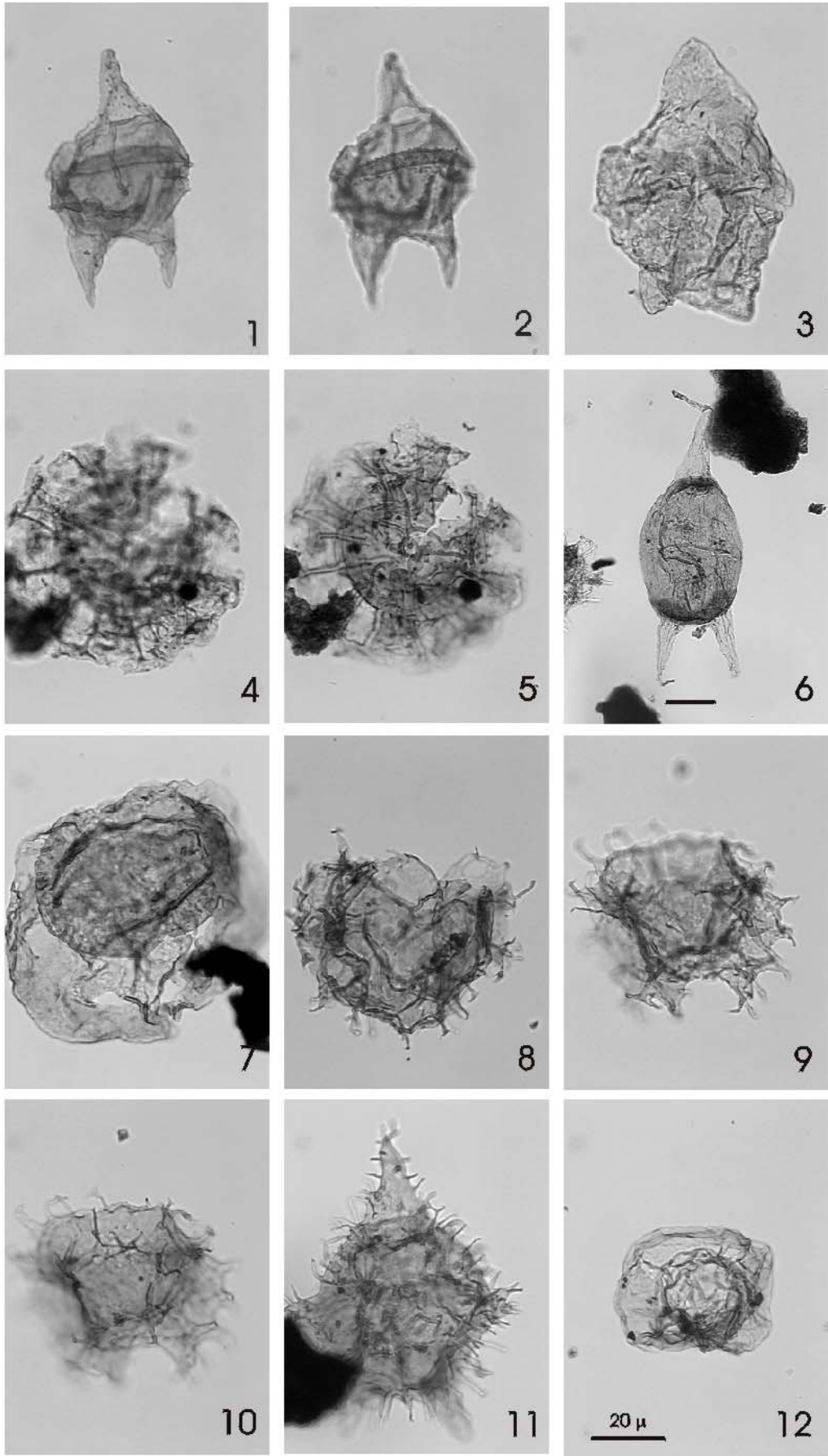
Fig. 7 *Senoniasphaera inornata* 46.0-18.8 2520m-3, LVR 28265

Fig. 8 *Palynodinium grillator* 47.7-11.7, 2520m-3, LVR 28266

Figs 9–10 *Palynodinium grillator* 44.0-16.5, 2520m-4, LVR 282667–268

Fig. 11 *Apectodinium parvum* 44.1-12.9 2520m-4, LVR 28269

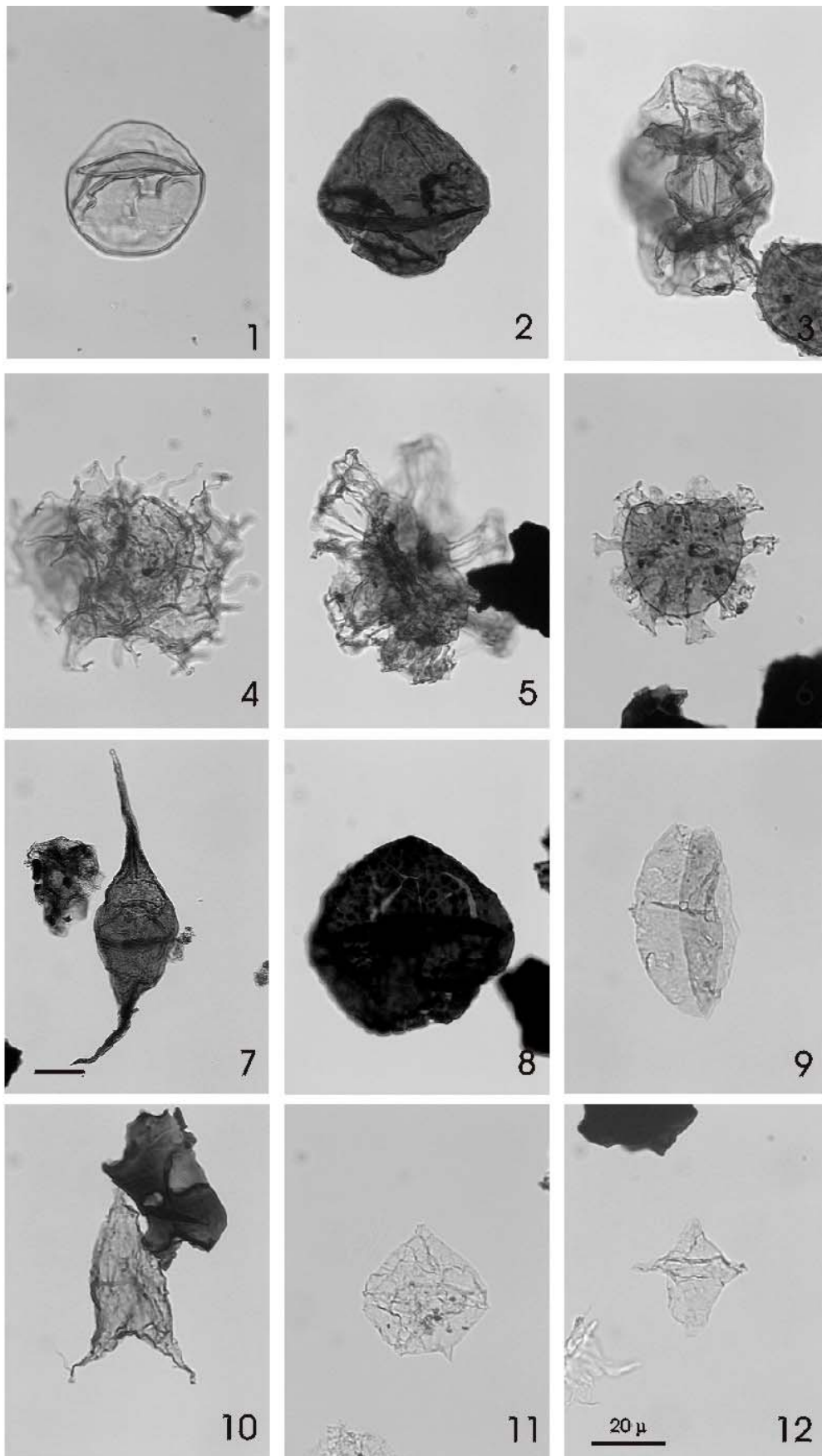
Fig. 12 *Stephodinium coronatum* 48.8-20.4 2520m-4, LVR 28270



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

NORTH LEIF – PLATE 34

- 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 quasicibrata* 43.9-15.8, 2550m-4, LVR 28273
- Fig. 4 *Palynodinium grillator* 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

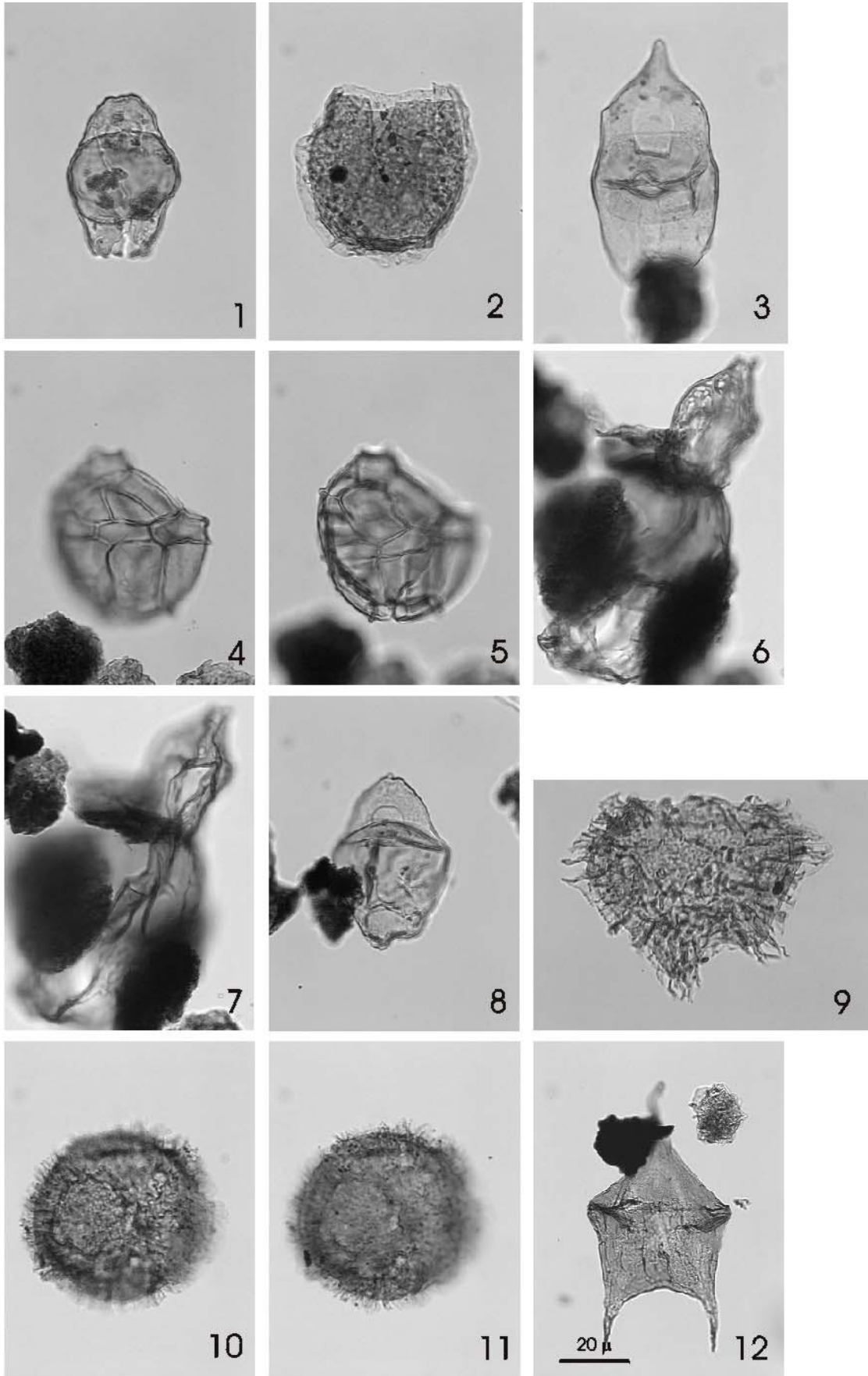
1-3 2550 m

4-8 2580 m

9-12 2610 m

NORTH LEIF – PLATE 35

- 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

NORTH LEIF – PLATE 36

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

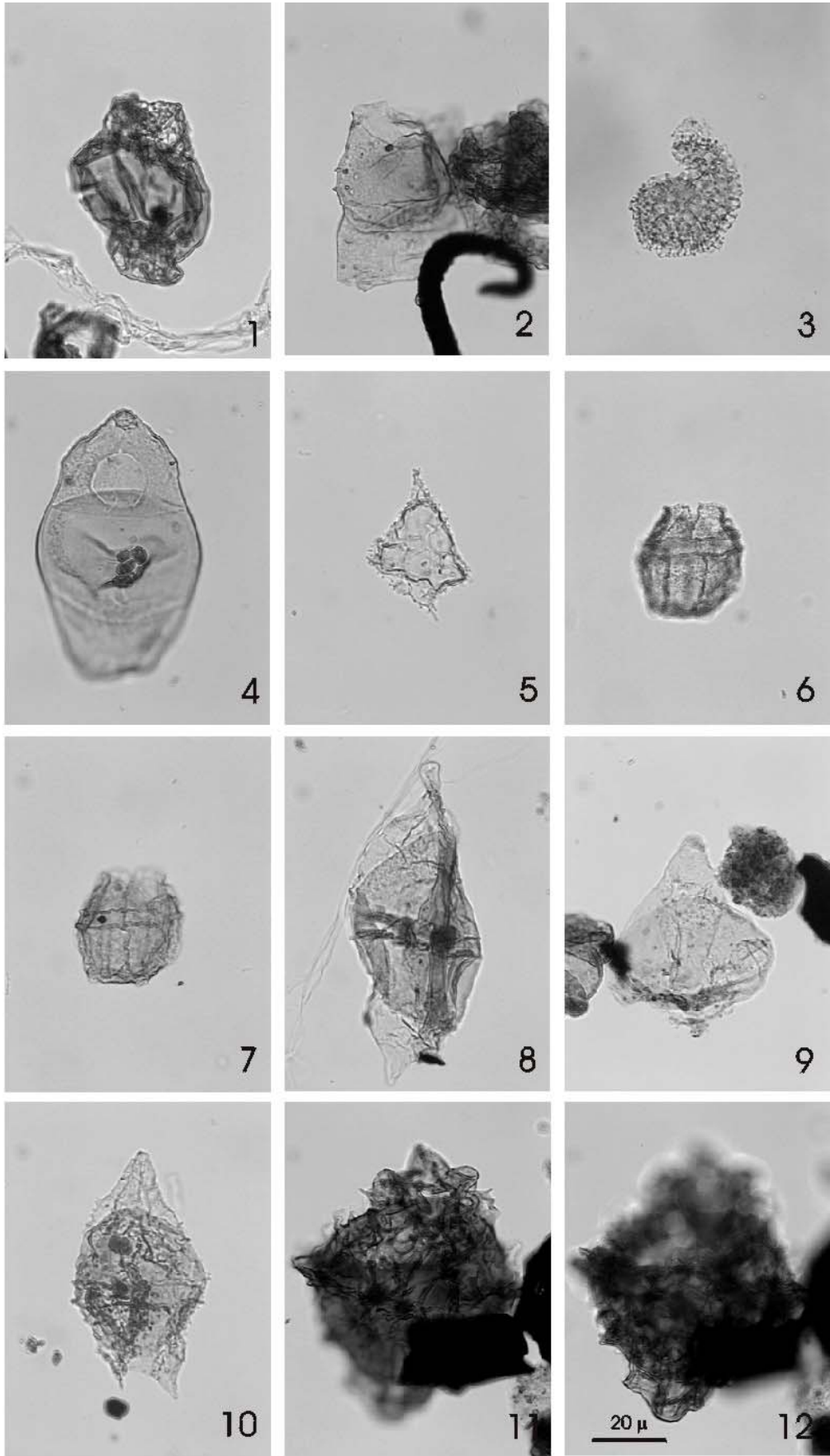
Figs 6–7 *Fibradinium annetorpense* 24.8-22.3, 2670m-2, LVR 28301–302

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

NORTH LEIF – PLATE 37

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

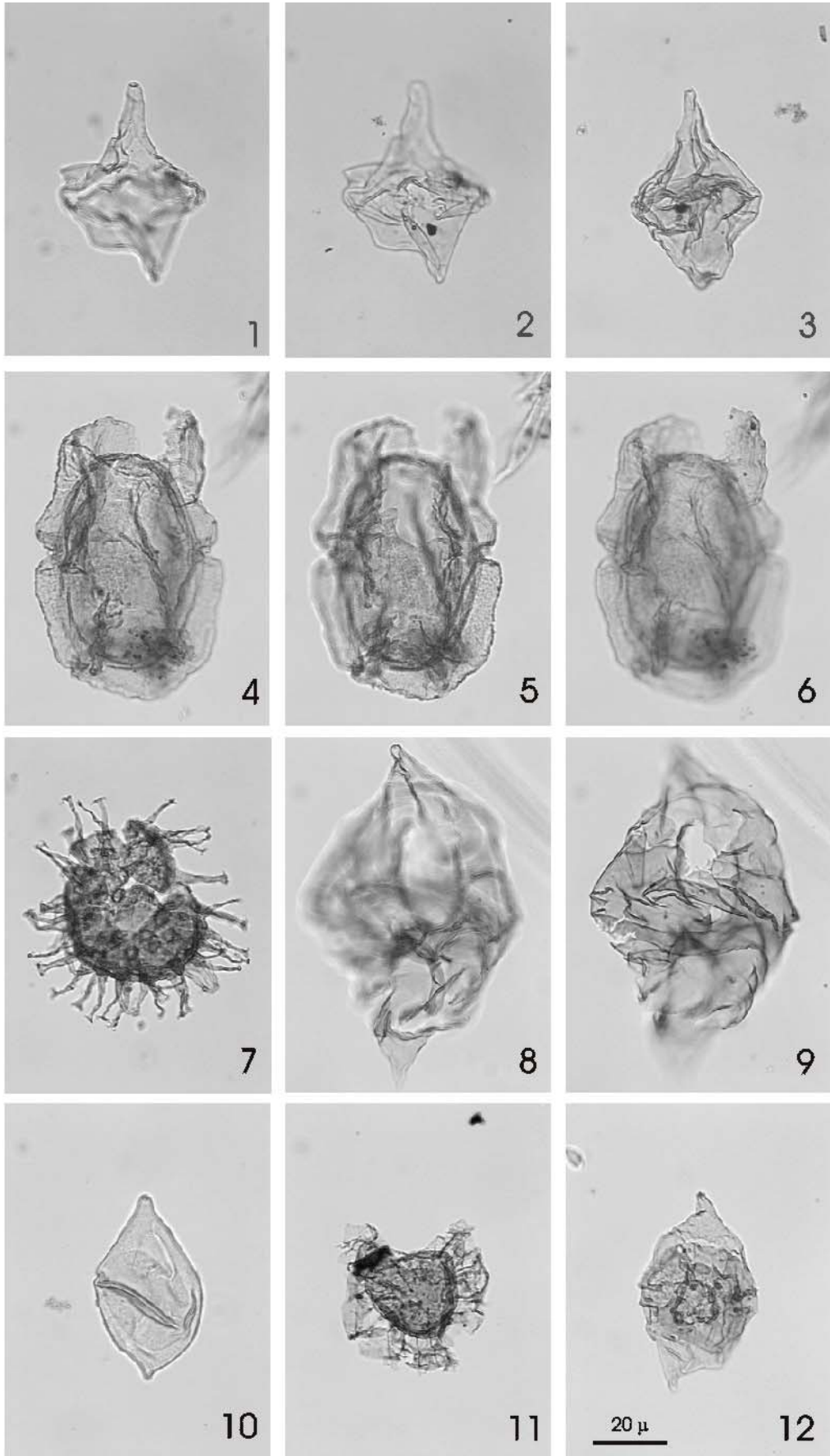
Fig. 7 *Heterosphaeridium heteracanthum* 43.0-7.1, 2670m-3, LVR 28312

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

NORTH LEIF – PLATE 38

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

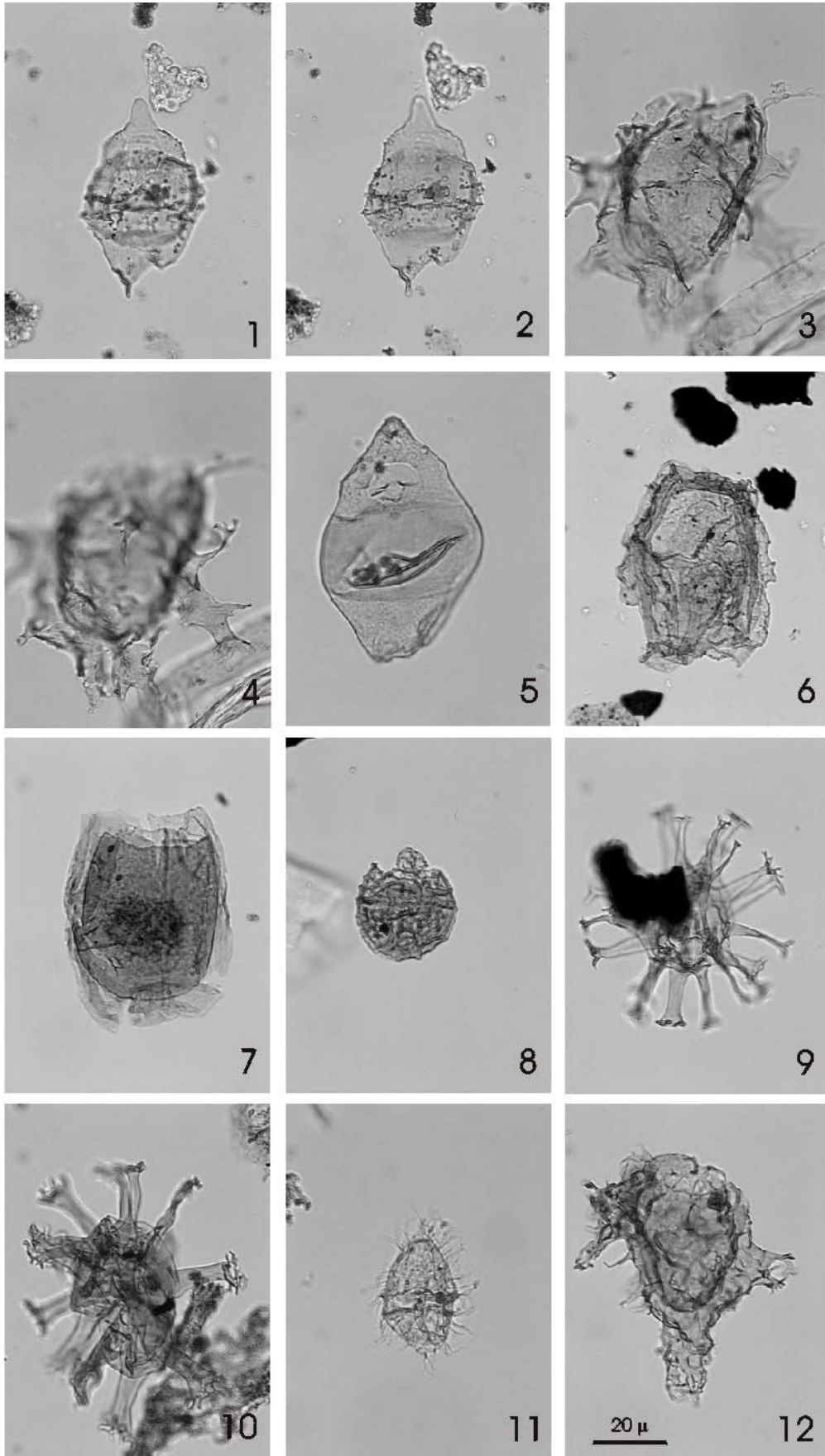
Fig. 8 *Historicysta palla* 40.3-4.8, 2730m-3, LVR 28328

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

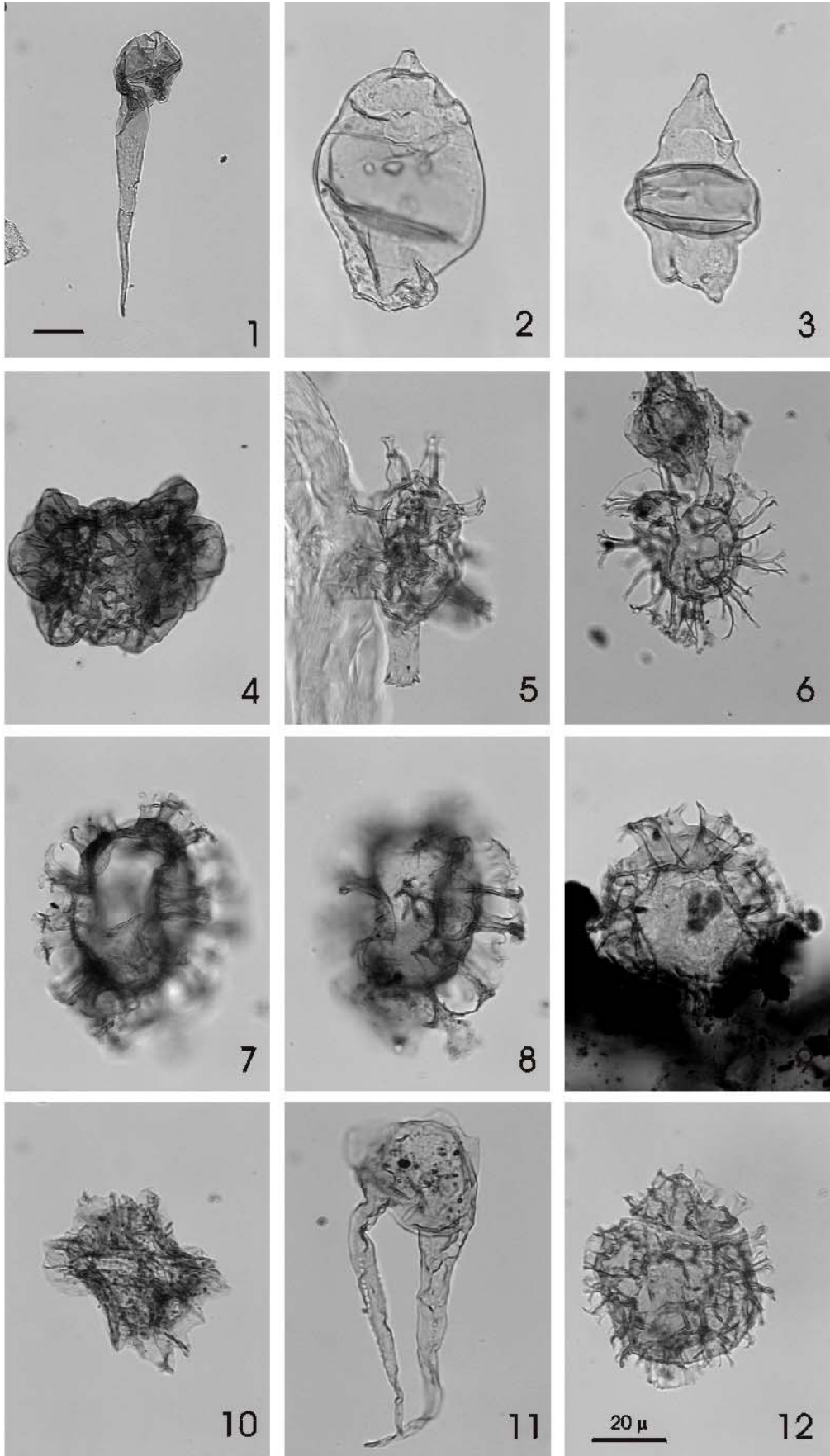
Fig. 12 *Xenascus ceratioides* 38.7-23.4, 2730m-3, LVR 28333



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

NORTH LEIF – PLATE 39

- 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

NORTH LEIF – PLATE 40

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

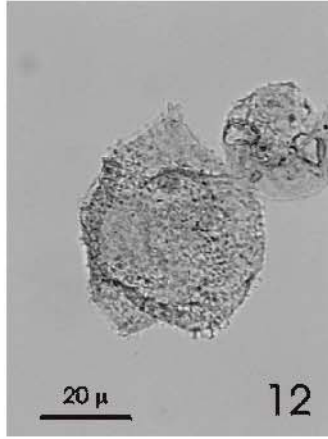
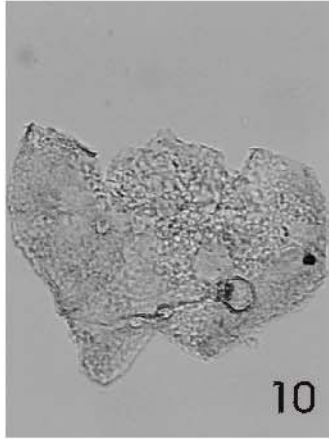
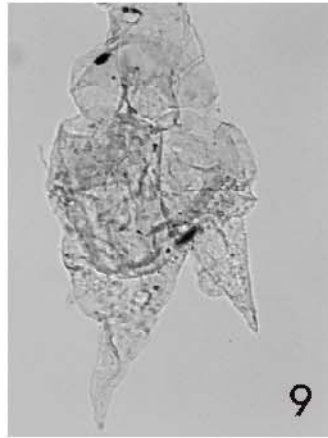
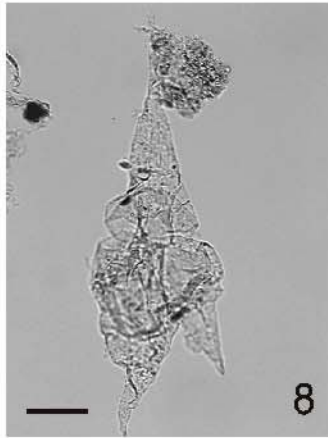
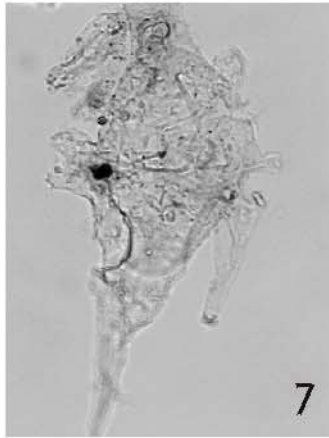
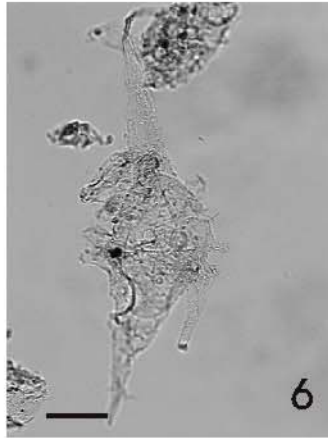
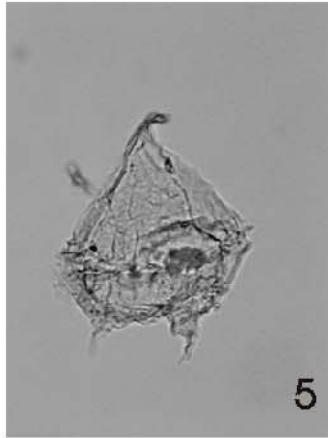
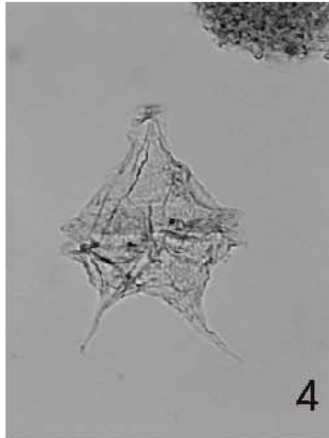
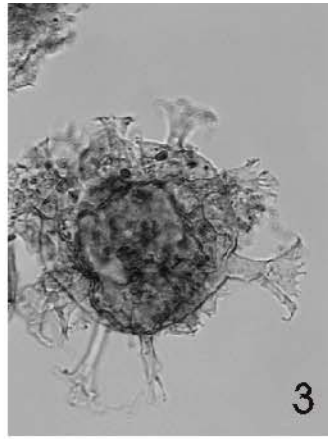
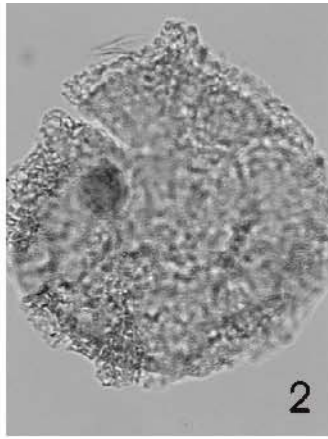
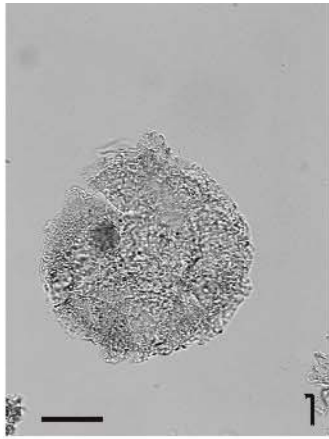
Fig. 5 *Palaeoperidinium* cf. *cretaceum* 21.7-13.9, 2790m-3, LVR 28351

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

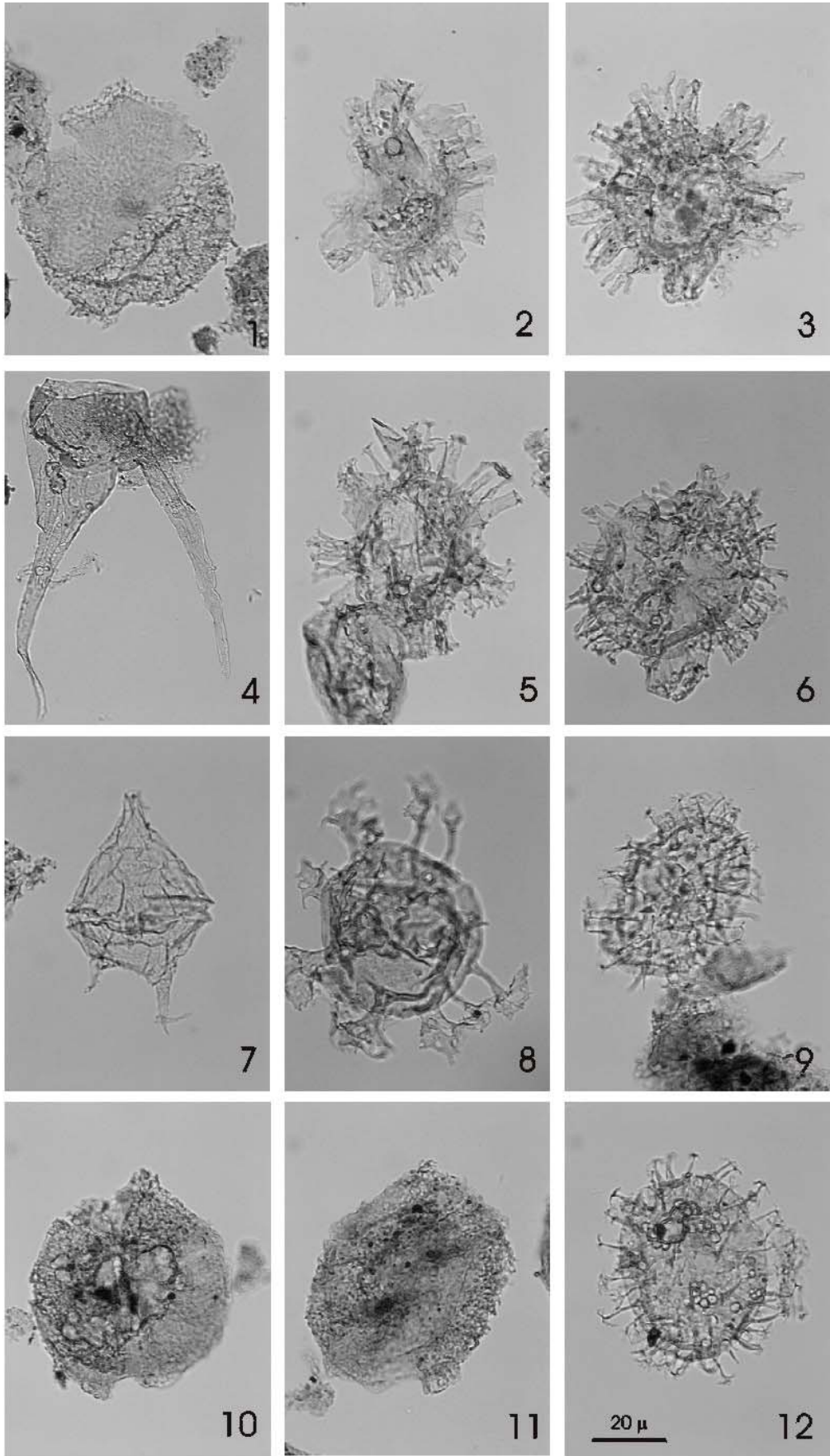
Figs 11–12 *Circulodinium attadalicum* 23.1-7.2, 2790m-4, LVR 28358–359



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

NORTH LEIF – PLATE 41

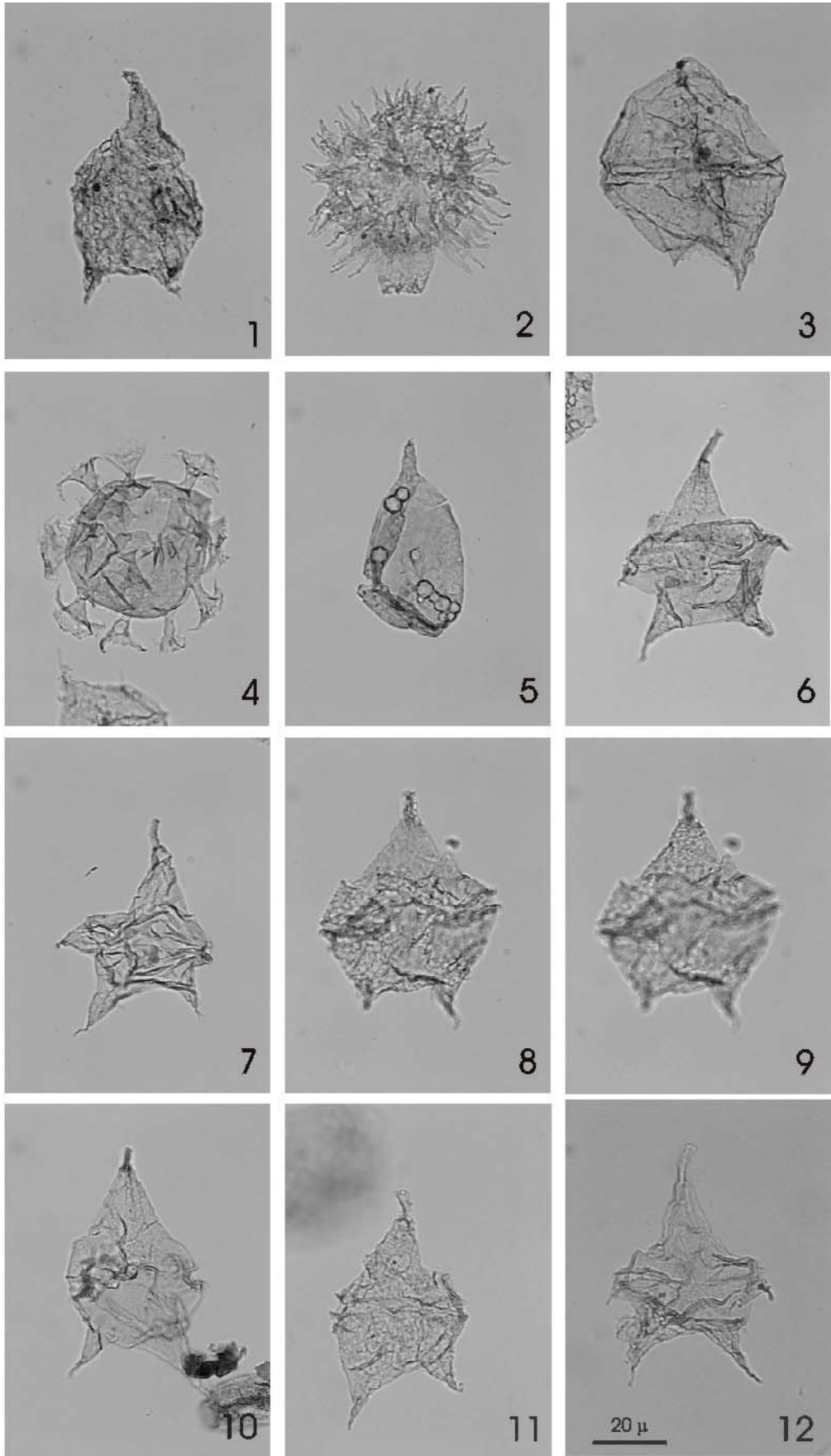
- Fig. 1 *Canningia reticulata* North Leif 20.8-12.3, 2790m-4, LVR 28360
Fig. 2 *Florentinia* sp. 1 HNH North Leif 39.9-19.4, 2790m-4, LVR 28361
Fig. 3 *Florentinia* sp. 1 HNH North Leif 36.7-15.9, 2790m-5, LVR 28362
Fig. 4 *Odontochitina costata* 36.5-20.4, 2790m-5, LVR 28363
Fig. 5 *Florentinia* sp. 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

NORTH LEIF – PLATE 42

- 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

NORTH LEIF – PLATE 43

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

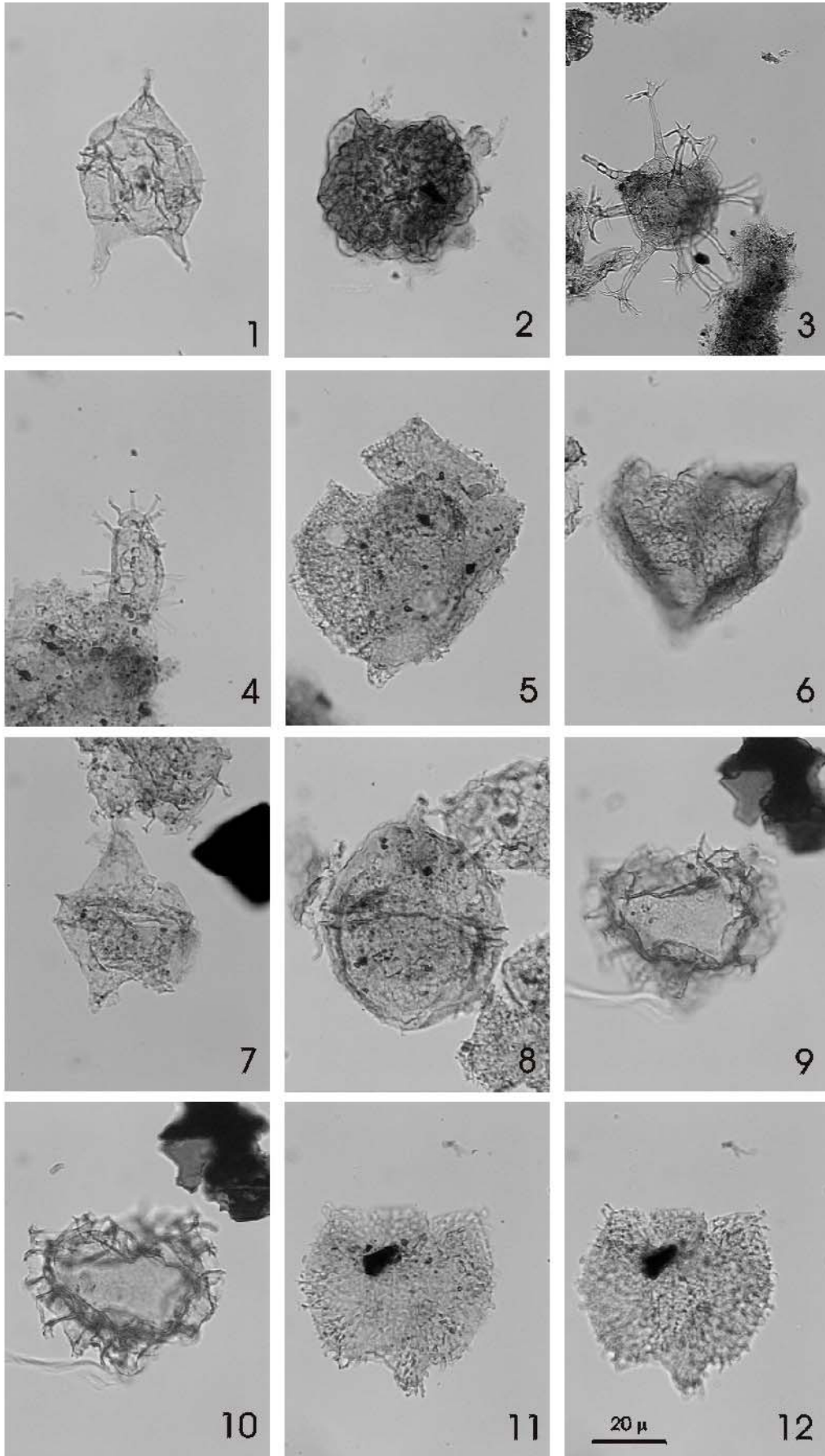
Fig. 6 *Canningia reticulata* 29.3-11.2, 2880m-4, LVR 28390

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

NORTH LEIF – PLATE 44

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

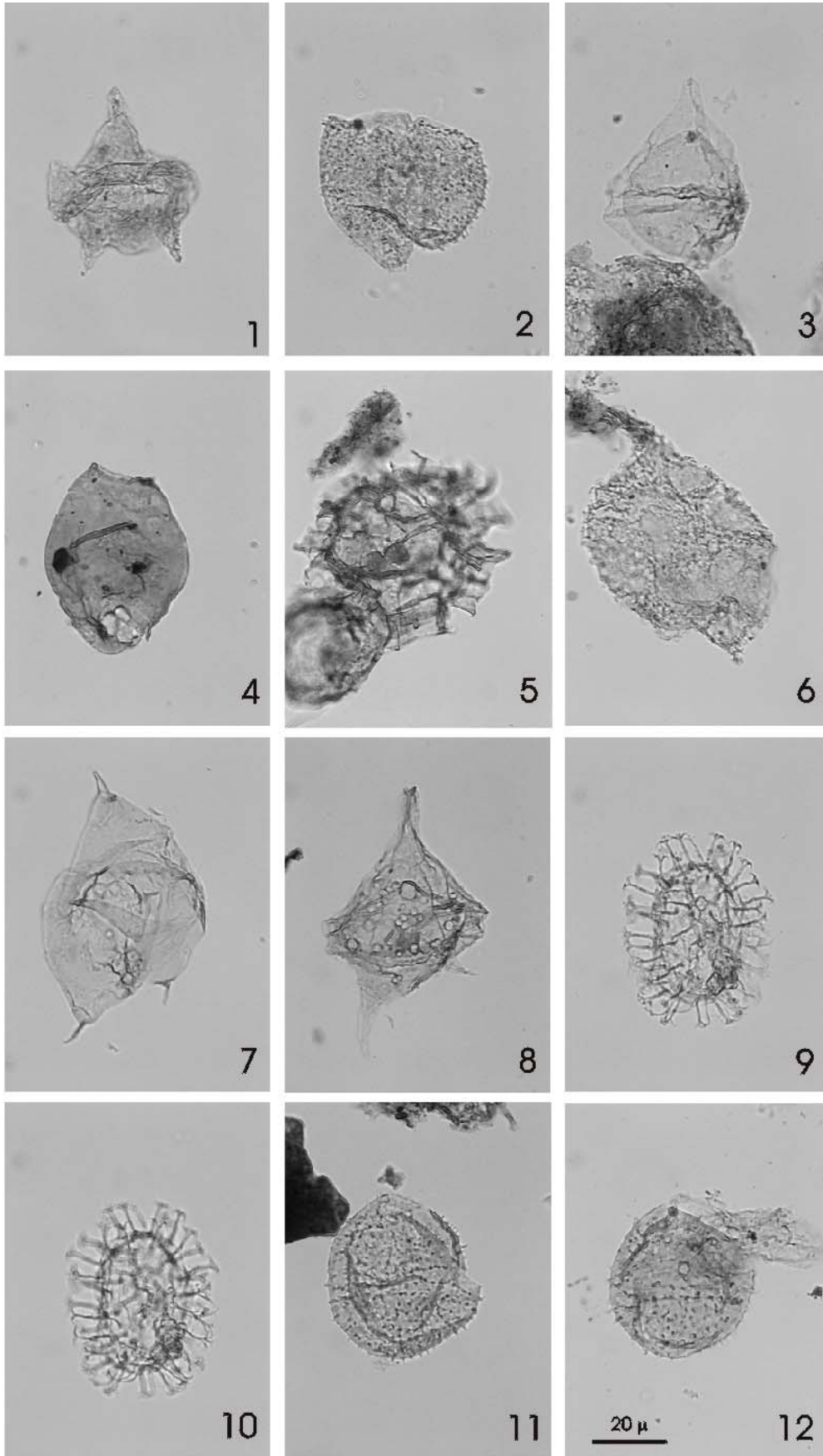
Fig. 7 *Nyktericysta* sp. 1 HNH North Leif 24.9-10.4, 2940m-3, LVR 28404

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

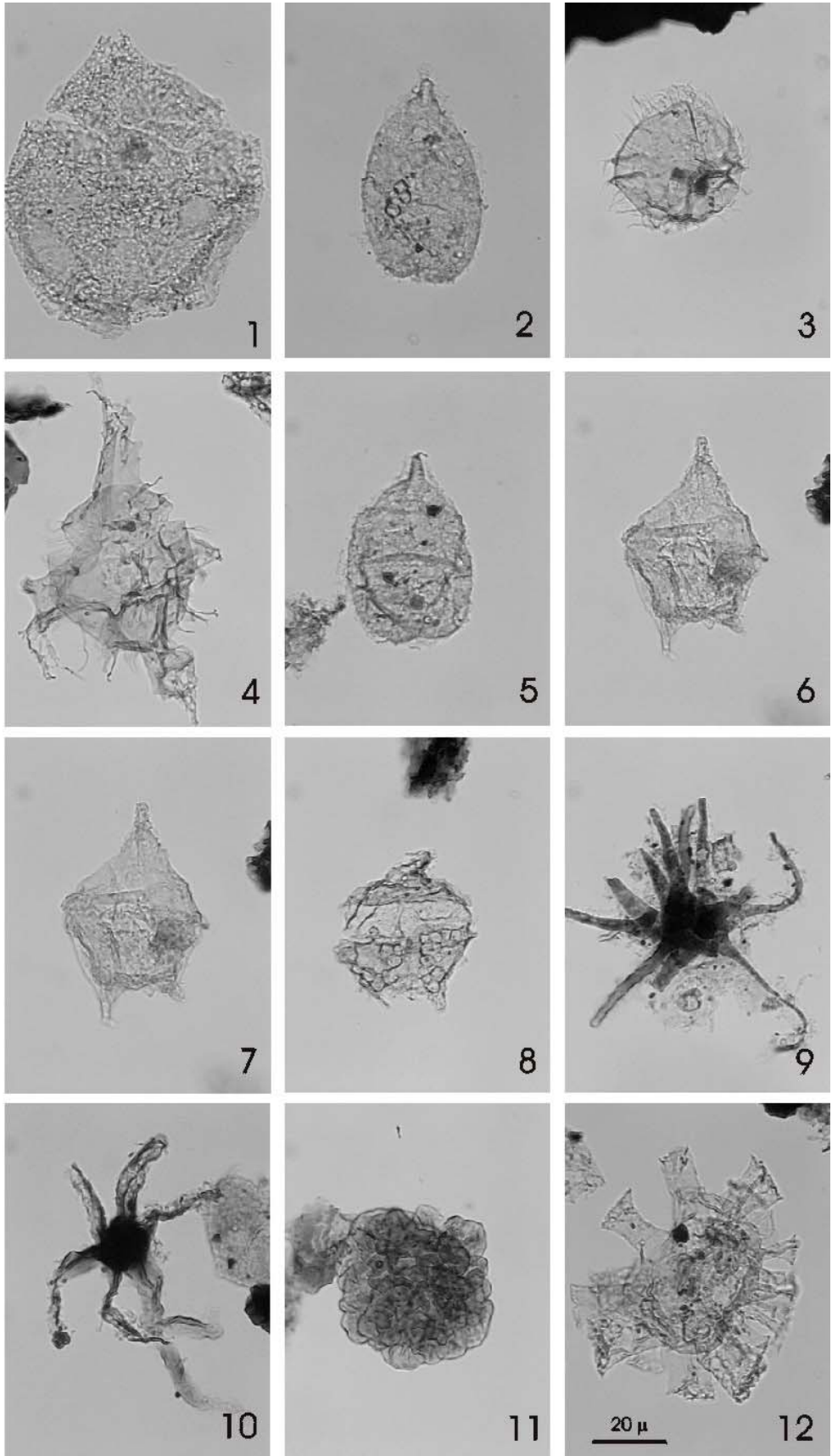


North Leif I-05 Plate 44

1-5 2910m
 6-7 2940m
 8-12 2970 m

NORTH LEIF – PLATE 45

- 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

NORTH LEIF – PLATE 46

Fig. 1 *Nyktericysta davisii* 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

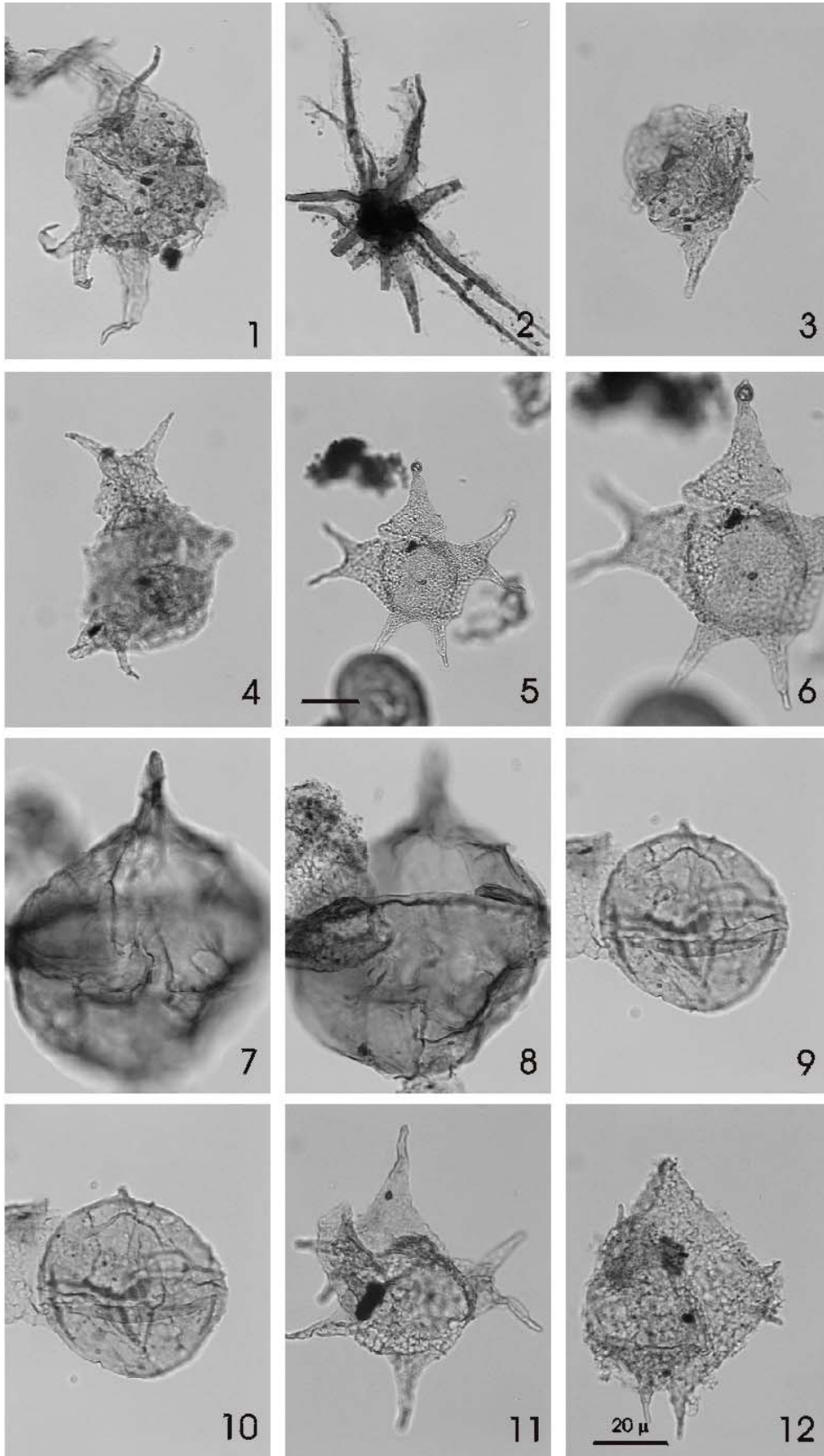
Figs 5–6 *Nyktericysta davisii* 37.5-4.7, 3180m-3, LVR 28426–427

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

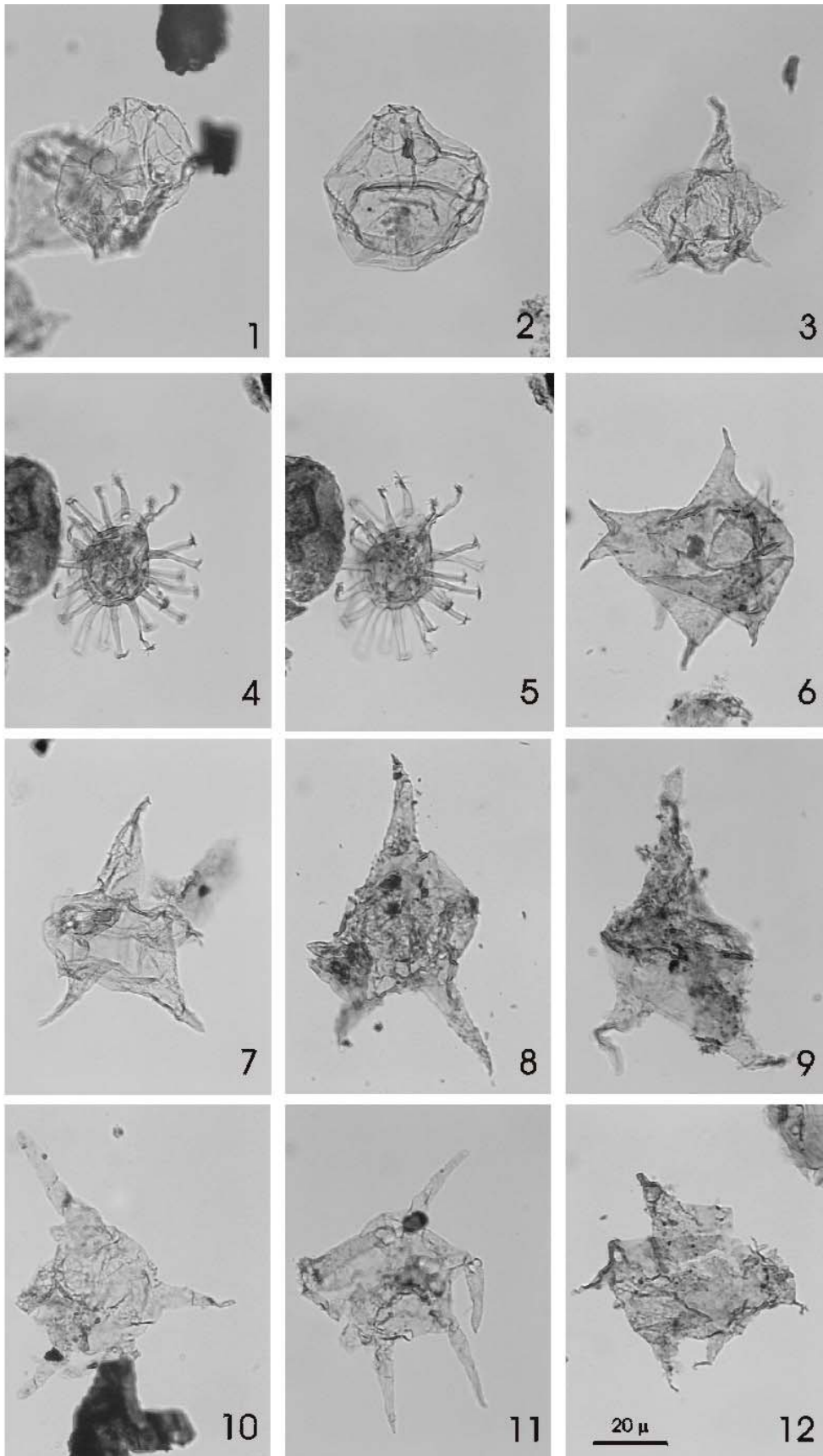


North Leif I-05 Plate 46

1 3120m
 2-4 3150m
 5-11 3180m
 12 3210 m

NORTH LEIF – PLATE 47

- 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 Chorot 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

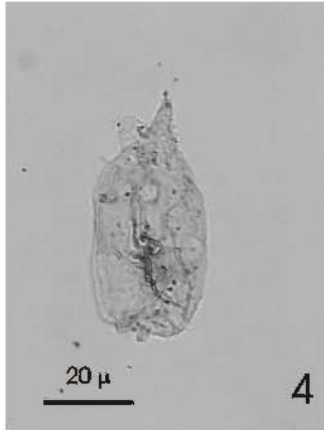
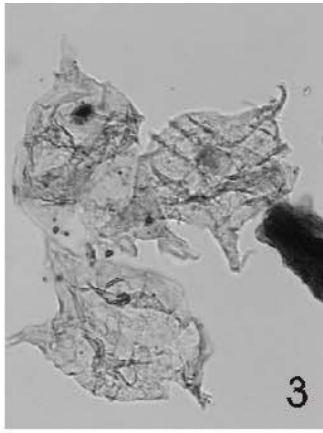
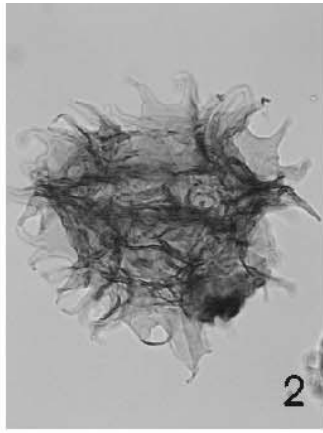
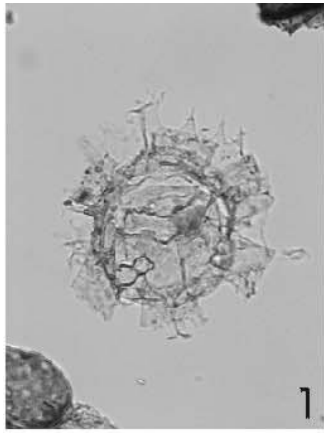
NORTH LEIF – PLATE 48

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

NORTH LEIF I-05

Well Name : NORTH LEIF I-05
Operator : Petro Canada
Well Code : NORTHLEIF05
Lat/Long : 54°47' 38.50"N 16°15' 16.57"E
Interval : 0-3200m
Scale : 1:4000
Chart date: 03 December 2004

Report file no.
Enclosure
25693 (01/02)

Enclosure 1: Presence/absence of species

