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Contents

Abstract

From the borehole Umiivik-1 dinoflagellate cyst assemblages from 32 samples are described. The stratigraphical range of 72 recorded marine palynomorph species is given. Based on stratigraphical important species the upper 658 m of the well has been dated as Late Turonian to Early Coniacian, and divided into five informal dinoflagellate cyst intervals. Organic material below -658 m is thermally post mature and reveals no palynological data for stratigraphical age determination.

Species diversity variation of marine palynomorphs suggests a maximum flooding surface at -160 m.

Introduction

Although several types of crude oil have been found in seeps and slim-hole cores in recent years in West Greenland (e.g. Bojesen-Koefoed *et al.*, 1997a; Christiansen *et al.*, 1996a,b) there is only limited knowledge on the actual source rocks and their ages.

The exploration models that were developed and promoted in the early 1990's for both on- and offshore exploration in West Greenland are therefore rather conceptional as regards the source rock question. Main emphasis has been put on a mid-Cretaceous marine source rock (Cenomanian – Turonian) that was first suggested by Chalmers *et al.* (1993) and later supported by direct data from Ellesmere Island in Arctic Canada (Núñez-Betelu, 1993, 1994, Bojesen-Koefoed *et al.*, 1997b). Furthermore there is very strong evidence of a latest Cretaceous – Paleocene deltaic source rock based on a very distinct biomarker composition of the 'Marraat-type' oil (Christiansen *et al.*, 1996a). However, dating by dinoflagellate cysts has not revealed fully marine sediments from the area older than Coniacian/? Late Turonian (Nøhr-Hansen, 1994, 1996).

Background

The background for the drilling programme of the borehole Umiivik-1 has been presented by Bate & Christiansen (1996), a paper that gives a short introduction to the geological setting, previous work in the area and the reasoning behind the well location.

The marine Cretaceous mudstones outcropping in the Svartenhuk Halvø area are the oldest known fully marine deposits from West Greenland (Nøhr-Hansen, 1996). These mudstones have been studied recently during field work in 1991 and 1992, a programme which also included 5 shallow bore holes to depths between 66 and 86 m (Christiansen *et al.*, 1994). Based on analytical work from these cores and samples from nearby outcrops, thermally immature mudstones of Coniacian to Early Santonian age have been documented (see Nøhr-Hansen, 1994, 1996), thereby giving some hope that immature or early mature sediments of Cenomanian – Turonian age could be reached by drilling to relatively shallow depths along the southern shoreline of Umiivik (Fig. 1).

Consequently a seismic programme involving the acquisition of a single refraction and reflection line was carried out in the summer of 1994 (Christiansen *et al.*, 1995). The Umiivik-1 well site was positioned on this line in an area with possibilities for a maximum thickness of what was predicted as Cenomanian/Turonian – Santonian mudstones in a broad syncline (see Bate, 1996 for further details including the seismic data).

The Umiivik-1 borehole was drilled in the period from 21 August to 13 September 1995 and terminated at a planned depth of 1200 m.

Technical details from Umiivik-1 are given in the well completion report by Bate (1996) including a preliminary geological log, description of penetrated lithologies, sample lists and information on hydrocarbon shows.

Penetrated interval

A total of 1200 m of core was drilled in Umiivik-1 (close to 100% recovery) with a core diameter of 63.5 mm in the uppermost 148 m and 47.6 mm in the remaining part.

Almost the entire core consists of Upper Cretaceous marine mudstones and Paleocene dolerite intrusions. The mudstones are dark grey with abundant silty interbeds. Only few sandstone intervals were found (Fig. 2). A total of nineteen dolerite intrusions with a cumulative thickness of 238.25 m were intersected throughout the well. Especially the thick intrusions from -548 to -598 m, from -849 to -890 m, and from -952 to -1027 m have severely altered the marine mudstones, and have thereby limited the possibilities for both detailed palynological and organic geochemical studies in the deeper part of the well.

Palynology

Previous palynological studies on Svartenhuk Halvø

Croxton (1978) briefly described the palynomorph content from three localities at Svartenhuk Halvø and Itsaku (C10, C11, C12; Nøhr-Hansen, 1996, fig. 2). Pollen from the C10 locality was determined as Paleocene, while pollen and dinoflagellate cysts suggested a Coniacian to Campanian age for C12. Croxton (1978, p. 65) mentioned that the thermally altered palynomorphs from the Itsaku section C11 caused problems; however, she dated the lower part of the section as Late Albian–Early Cenomanian, and noted that pollen from the top of the section may indicate a Paleocene age.

Pulvertaft (1987, table 1) noted that the Cenomanian age for localities S5 and S1 in the Umiivik area given by Ehman *et al.* (1976) are not consistent between text and logs.

Hansen (1980, p. 92) recorded Early Paleocene dinoflagellate cysts from an unspecified locality in the Svartenhuk Halvø.

Nøhr-Hansen (1994, 1996) described the palynomorph content from nine surface sections and five slimhole cores on Svartenhuk Halvø and dated the marine succession as Coniacian/Early Santonian to ?Early Campanian. The oldest dinoflagellate cyst assemblage was recorded from the lower part of the core 400709 (Nøhr-Hansen, 1996) and described as the *Chatangiella* sp. cf. *C. madura* interval, the dinoflagellate cyst assemblage from the upper part of 400709 was described as the *Spinidinium echinoideum* interval. A slightly younger dinoflagellate cyst assemblage was described from the lower part of the core 400712 as the *Arvalidinium scheii* Interval (Nøhr-Hansen, 1996).

Samples and methods

At the well site samples were taken out and canned at approximately every 3 metres (Bate, 1996). Cores were wrapped in alumina foil and packed in core boxes in order to avoid (or at least reduce) contamination. A set of 36 samples were processed for palynological studies.

Preparation

Palynological preparation and studies were carried out at GEUS. Palynomorphs were extracted from 20 g of sample by modified standard preparation techniques. 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 a 20 micron nylon mesh. A third slide was made after oxidation (3 to 10 minutes) with fuming nitric acid, followed by washing with a weak potassium hydroxide solution. The oxidation was carried out in order to clean the sample of minor amorphous kerogen particles and pyrite. Finally, palynomorphs were separated from coal particles and woody material in most samples using the separation method described by Hansen & Gudmundsson (1978) or by swirling.

After each of the steps mentioned above the organic residues were mounted in a permanent medium (Eukitt R; produced by O. Kindler, Germany).

Recording of material and analyses

The palynological slides were studied with transmitted light using a Leitz Dialux 22 microscope (512 742/057691). All the coordinates in the plate captions refer to this microscope. England finder index corners: Z 75 4 = 74.6–92.3; Z 1 3 = 1.9–92.2; A 1 1 = 1.9–116.7; A 65 2 = 64.6–116.6, centre: O 38 = 38.1–103.3.

The illustrated dinoflagellate cysts are marked with a GGU sample number, slide number, microscope coordinates, laser-video-record number (LVR) and database number (MicroImage; MI) for later identification. The illustrated dinoflagellate cysts are housed at the Geological Survey of Denmark and Greenland (Copenhagen) where they are accessible for examination.

Dinoflagellate cysts and acritarchs species were recorded from the sieved, oxidised or gravitation-separated slides. Counting of specimens was done on the 32 samples that revealed dinoflagellate cysts, approximately 100 specimens were counted when possible.

A single specimen of *Nyktericysta* spp. recorded from -283.3 m may be reworked from lower Cretaceous deposits; however, reworking seems to be rare.

Composition of the organic material and maturation

The organic material is dominated by terrestrially derived black to brownish woody material and cuticles, whereas amorphous organic material, dinoflagellate cysts, spores and pollen constitute only a minor part. A total of 72 species of dinoflagellate cysts, acritarchs and other algae were recorded.

A TAI (Thermal Alteration Index) evaluation was carried out on the unoxidised sieved slide. The study revealed TAI values between -2 and 4, which indicate that the organic material is thermally immature to post mature with respect to oil generation. The TAI values agree with the organic geochemical analyses which yielded Rock Eval T_{max} values between 427 and 580 °C (Christiansen *et al.*, 1997). The preservation of the dinoflagellate cysts is good in samples from the upper 170 m of the core where T_{max} values are between 427 and 431 °C, while it is moderate to poor in samples from the interval between -170 and -404 m where T_{max} values are between 432 and 463 °C. The preservation of the few recorded dinoflagellate cysts from samples below -404 m is very poor where T_{max} values are above 482 °C.

Diversity

The species diversity of the marine palynomorph assemblages mainly composing dinoflagellate cysts is generally high in samples from the upper 169.5 m of the Umiivik-1 core (Fig. 3). The diversity curve form this interval may suggest a transgressional phase from -169.5 to -153.6 m with a possible maximum flooding surface at -160.2 (diversity 41) followed by a regressional phase up to -120.3 m (diversity 16–24) and terminated by an upper transgression from -110.5 to -60.1 m (diversity 27–32). The diversity below 170 m range from 2 to 21, but it is difficult to interpret whether the diversity curve from the lower part of the well reflects transgressional/regressional phases or if it reflects the influence of increasing downhole thermal maturity caused by the thick dolerite intrusions.

Palynostratigraphy of the borehole Umiivik-1

The dinoflagellate cyst stratigraphy here proposed for the marine Upper Cretaceous in the Umiivik-1 well on Svartenhuk Halvø is based on a study of material from 36 core samples of which the lowermost 4 were barren of dinoflagellate cysts.

The stratigraphical correlation and dating is based on the first and the last occurrences and acme of stratigraphically important dinoflagellate cysts.

Age: ?Middle, Late Turonian to Early Coniacian

Previous biostratigraphic study of dinoflagellate cysts from the Umiivik area dated the oldest deposits as Coniacian to Early Santonian ages (Nøhr-Hansen, 1996); however, it was mentioned that a Late Turonian age could not be excluded. The dating was based on data from the two cores 400709 and 400712 (Nøhr-Hansen, 1996).

The dinoflagellate cyst assemblages from Umiivik-1 are characterised by a large number of specimens of *Chatangiella* and *Isabelidinium*. According to the literature the genus *Chatangiella* ranges from the Late Cenomanian to the Late Maastrichtian (e.g. Costa & Davey, 1992). The genus *Chatangiella* is abundant and often dominant in Late Cretaceous assemblages in the western interior of the USA, western Canada, Arctic Canada and the northern North Sea area. *Chatangiella* is also very abundant in the southern hemisphere (especially in Australia and Antarctica), but it is less common in north-western Europe and in the Tethyan realm (Lentin & Williams, 1980; Costa & Davey, 1992).

The presence of *Heterosphaeridium difficile* down to -540.3 m in Umiivik-1 indicates an Early Turonian to Early Santonian age according to Costa & Davey (1992) and Williams *et al.* (1993), whereas Bell & Selnes (in press) suggest a first appearance datum (FAD) for *H. difficile* close to Early to Middle Cenomanian boundary based on data from the Norwegian shelf. The possible presence of *Raphidodinium fucatum* down to - 540.3 m dates the core as post mid Middle Turonian according to Costa & Davey (1992) or post early Late Turonian according to Foucher (1979). The presence of *Pervosphaeridium truncatum* in the uppermost part of the core suggests an age no younger than Early Coniacian.

The lowermost recorded dinoflagellate cyst from -658.7 m has been identified as a *Chatangiella* spp. suggesting a post Middle Cenomanian age (e.g. Costa & Davey, 1992).

The core from -1191.4 to -687.7 m does not contain preserved dinoflagellate cysts.
Thus, the succession between -60.1 and -540.3 m represent a Late Turonian to Early Coniacian age.

Palynological intervals

The species list on the range chart for Umiivik-1 (Fig. 4) shows that the assemblages in general only change little with time. However, based on the first and last occurrences of a few morphologically characteristic and stratigraphically important species, it has been possible to distinguish five dinoflagellate intervals within the Late Turonian to Early Coniacian strata. These intervals are only informally described, as they are based exclusively on material from Umiivik-1. The stratigraphical range of the species and the interval boundaries described below may therefore very likely change in the future if better and less thermally mature material will be sampled.

Interval I, Umiivik-1, -60.1 to -110.5 m

Age: Early Coniacian

This interval is dominated by terrestrially derived black to brownish woody material, cuticles and few bisacate pollen. Dinoflagellate cysts are common and the diversity is high (27–32). The specimens are generally very well preserved.

The uppermost part of Umiivik-1 (-60.1 to -110.5 m) is correlated with the Early Coniacian *Arvalidinium scheii* interval previously described from the core GGU 400712 (-21.5 to -78.75 m) at Umiivik (Nøhr-Hansen, 1996). The interval was defined by the first occurrence of *Arvalidinium scheii* to immediately below the first occurrence of *Laciniadinium arcticum*.

Characteristic species. The base of the interval is characterised by the first appearence datum (FAD) of the species *Arvalidinium scheii*, *Isabelidinium svartenhukense*, *Chatangiella mcintyrei*, *C. verrucosa*, *Xenascus* sp. aff. *X. perforatus*.The interval is also characterised by the common occurrence of: *Isabelidinium*, *Chatangiella* and *Trithyrodinium* specimens. The following characteristic species are present in the interval *Chatangiella granulifera*, *C.* sp. cf. *C. madura* (a single specimen), *Dorocysta litotes, Florentinia* spp., *Heterosphaeridium difficile*, *Isabelidinium* sp. 7 Nøhr-Hansen (1996), *Odontochitina striatoperforata*, *Palaeohystrichophora infusorioides*, *Pervosphaeridium truncatum, Raphidodinium fucatum*, *Senoniasphaera rotunda, Subtilisphaera pontis-mariae, Spinidinium echinoideum* and *Trithyrodinium suspectum*.

Discussion. The presence of *Pervosphaeridium truncatum* (at -60.1 to -110.5 m) together with the presence of *Senoniasphaera rotunda* at -90.3 m is of great stratigraphic value as it dates interval I as Early Coniacian (Costa & Davey, 1992).

After re-examination of *Exocosphaeridium* sp. 1 Nøhr-Hansen, 1996, from GGU 400712 sample 17 at -30 m (illustrated by Nøhr-Hansen, 1996; pl. 8 fig. 3) the specimen has been identified as *Pervosphaeridium truncatum*, which has a last appearance datum (LAD) at the top of Early Coniacian (Costa and Davey, 1992). The presence of *P. truncatum* in both GGU 400712 and in Umiivik-1 confirms the Early Coniacian age given by *in situ* ammonites by Birkelund (1965) from 'The Ammonite locality', situated at the locality for GGU 400712.

The FAD of *C. verrucosa* at the base of the interval dates the interval as post Turonian according to Williams *et al.* (1993). However, McIntyre (personal communication, 1994) has recorded *C. verrucosa* from Turonian deposits in the Mackenzie Delta area, Canada. The presence of *Raphidodinium fucatum* indicate a post mid Middle Turonian age (Costa & Davey, 1992).

The presence of *Arvalidinium scheii* in the interval is important and may be used for correlation to the Late Cenomanian to Early Campanian Kanguk Formation at Graham Island Arctic Canada (Nøhr-Hansen, 1996). The co-occurrence of *Arvalidinium scheii*, *Isabelidinium svartenhukense* and *Chatangiella mcintyrei* was described by Nøhr-Hansen (1996). However, the LAD of *Isabelidinium* sp. 7 Nøhr-Hansen, 1996, in the lower part of the *A. scheii* interval is a new important stratigraphic observation. *Isabelidinium* sp. 7 Nøhr-Hansen, 1996, has previous only been recorded from the older *Chatangiella* sp. cf. *C. madura* interval described from GGU 400709 (Nøhr-Hansen, 1996). A single specimen of *Chatangiella* sp. cf. *C. madura* at -99.8 m may suggest that *C.* sp. cf. *C. madura* ranges into the *A. scheii* interval, if the specimen not is reworked. In the present study *Laciniadinium arcticum* is recorded sporadic in low numbers down to -403.6 m.

Interval II, Umiivik-1, -120.3 to -169.5 m

Age: Early Coniacian.

This interval is dominated by terrestrially derived black to brownish woody material, cuticles and few bisacate pollen and dinoflagellate cysts are common. The diversity is moderate to high (16–39), and the specimens are generally very well preserved.

The lower boundary of the interval is marked by the incoming of *Arvalidinium* spp. *Chatangiella* sp. aff. *C. spectabilis, Spongodinium delitiense* and a marked increase in abundance of *Isabelidinium* sp. 7 Nøhr-Hansen, 1996. *Spinidinium echinoideum* seems to have an acme occurrence at -160.2 to -153.6 m and *Chatangiella* sp. cf. *C. ditissima* is common in the interval.

The FAD of several species at -160.5 m may not represent real stratigraphical first occurrences but may reflect a maximum flooding surface as suggested above, based on the species diversity peak in the sample. From the same interval several possibly new *Chatangiella* and *Isabelidinium* species have been recorded. These are, however, not included in the rangechart.

The presence of *Isabelidinium* sp. 7 Nøhr-Hansen, 1996, *Spinidinium echinoideum* and *Chatangiella* sp. aff. *C. spectabilis* suggest correlation with the *Chatangiella* sp. cf. *C. madura* or the *Spinidinium echinoideum* interval described from GGU 400709 on Svartenhuk Halvø (Nøhr-Hansen, 1996). However, the species *Chatangiella* sp. cf. *C. madura* has not been recorded from interval II at Umiivik-1.

Characteristic species. The following stratigraphically important species have been recorded from interval II: *Chatangiella* sp. cf *C. ditissima, C. granulifera, C.* sp. aff. *C. spectabilis*, *Desmocysta plekta*, *Florentinia* sp., *Heterosphaeridium difficile*, *Isabelidinium* sp. 7 Nøhr-Hansen, 1996, *I.* sp cf. *I. magnum, Raphidodinium fucatum*, *Odontochitina striatoperforata*, *Palaeotetradinium silicorum, Pervosphaeridium truncatum, Spinidinium echinoideum, Spongodinium delitiense, Subtilisphaera pontis-mariae, Trigonopyxidia ginella* and *Trithyrodinium suspectum*.

Discussion. According to the observations from the North Sea region (Costa & Davey, 1992) the presence of *Heterosphaeridium difficile, Pervosphaeridium truncatum* and *Raphidodinium fucatum* indicates a mid Middle Turonian to Early Coniacian age. Williams & Bujak (1985) reported an Early Coniacian to Late Campanian age for the range of *Trigonopyxidia ginella*. The age of the interval is most likely Early Coniacian but a latest Turonian age cannot be excluded.

Interval III, Umiivik-1, -187.9 to -319.2 m

Age: Latest Turonian to ?Early Coniacian.

The interval is dominated by terrestrially derived black to brownish woody material, cuticles and few bisacate pollen, but dinoflagellate cysts do occur. The specimens are thermally altered and in a moderate state of preservation.

The lower boundary of the interval is placed by the incoming of *Spinidinium echinoideum.* The species *Heterosphaeridium difficile* and *Circulodinium distinctum* are common in the upper part of the interval. *Spinidinium echinoideum* has an acme at -271.4 m and *Raphidodinium fucatum* has an acme at -187.9 m. The interval is older than the *Chatangiella* sp. cf. *C. madura* or the *Spinidinium echinoideum* intervals described from GGU 400709 on Svartenhuk Halvø (Nøhr-Hansen, 1996), which was dated as most likely Coniacian ?Late Turonian. This indicates that *Spinidinium echinoideum* has a stratigraphic earlier first occurrence in Umiivik-1 than previously recorded from the area (Nøhr-Hansen, 1996).

Characteristic species. The folowing stratigraphically important species have been recorded: *Chatangiella* sp. cf. *C. ditissima, C. granulifera, Desmocysta plekta*, *Florentinia* sp., *Heterosphaeridium difficile*, *Isabelidinium* sp. nov., *Palaeoperidinium pyrophorum* (a single specimen at -283.3 m), *Raphidodinium fucatum*, *Odontochitina striatoperforata*, *Spinidinium echinoideum*, *Subtilisphaera pontis-mariae, Surculosphaeridium longifurcatum* and *Trithyrodinium suspectum*.

Discussion. According to observations from the Paris Basin, France (Foucher, 1979) the presence of *Raphidodinium fucatum* and *Spinidinium echinoideum* suggests an age not older than latest Turonian. The interval thus incompasses deposits of latests Turonian to questionably Early Coniacian ages.

Interval IV, Umiivik-1, -331.9 to -403.6 m

Age: Late Turonian.

The interval is dominated by terrestrially derived black to brownish woody material, cuticles and few bisacate pollen, but dinoflagellate cysts do occur. The specimens are thermally altered and in a moderate state of preservation. The lower boundary of the interval is placed by the incoming of *Subtilisphaera pontis-mariae* and *Isabelidinium* sp. nov. The species *Heterosphaeridium difficile*, and *Isabelidinium* sp. nov. are common in the interval.

Characteristic species. The following stratigraphically important species have been recorded: *Chatangiella* sp. cf. *C. ditissima, C. granulifera, Ctenidodinium* sp. aff. *C. elegantulum* (only at -383.8 m), *Florentinia* sp., *Heterosphaeridium difficile*, *Isabelidinium* sp. nov., *Raphidodinium fucatum*, *Odontochitina striatoperforata*, *Subtilisphaera pontis-mariae, Surculosphaeridium longifurcatum, Tanyosphaeridium* sp. cf. *T. variecalamus* and *Trithyrodinium suspectum*.

Discussion. According to observations from the Paris Basin, France (Foucher, 1979) the presence of *Raphidodinium fucatum* and *Subtilisphaera pontis-mariae* suggests an age not older than Late Turonian. Foucher (1979) recorded the FAD of *Raphidodinium fucatum* and *Spinidinium echinoideum* from the latest Turonian and the FAD of *Subtilisphaera pontis-mariae* from then base of Late Turonian in the Paris Basin. The presence of *Tanyosphaeridium* sp. cf. *T. variecalamus* at -383.8 m and *Raphidodinium fucatum* throughout the interval may suggests an age not older than Middle Turonian (Costa & Davey, 1992).

The occurrence of *Ctenidodinium* sp. aff. *C. elegantulum* may be important for stratigraphic correlation within the area in the future, in Umiivik-1 the species has only been recorded from -383.8 m, but the author has also recorded it from a sample containing the belemnite *Actinocamax* sp. cf. *A. primus* recorded by Birkelund (1956) from a locality on north west Svartenhuk Halvø. The previously reported range of *C. elegantulum* is within Lower Cretaceous (Costa & Davey, 1992) so the occurrence of the present *C.* sp. aff. *C. elegantulum* may represent a new species or less likely a reworked.

Interval V, Umiivik-1, -540.3 to -658.7 m

Age: Turonian, upper part of the interval possibly Late Turonian.

This interval is dominated by terrestrially derived black to brownish woody material, cuticles and few bisacate pollen and dinoflagellate cysts are rare. The specimens are all strongly thermally altered and in a poor state of preservation. It has been possible to identify black specimens of *Chatangiella* spp. from -658.7 m, and *Chatangiella* spp. and possible *Heterosphaeridium difficile* and *Trithyrodinium suspectum* specimens from -540.3 m, which according to Costa & Davey (1992) date the interval not older than latest Cenomanian/Early Turonian. A questionable occurrence of *Raphidodinium fucatum* at -540.3 m may suggest an age not older than mid Middle Turonian according to Costa & Davey (1992) and not older than latest Turonian according to Foucher (1979). However, the very sparse content of dinoflagellate cysts precludes a more precise dating of the interval.

Interval VI, Umiivik-1, -687.7 to -1177.9 m

This interval is barren regarding dinoflagellate cysts. The dark brown to black palynomorhps are dominated by terrestrially derived black to brownish woody material, cuticles and few bisacate pollen. The preservation of the organic material is strongly affected by the presence of thick intrusions (Bate, 1996).

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Figure captions

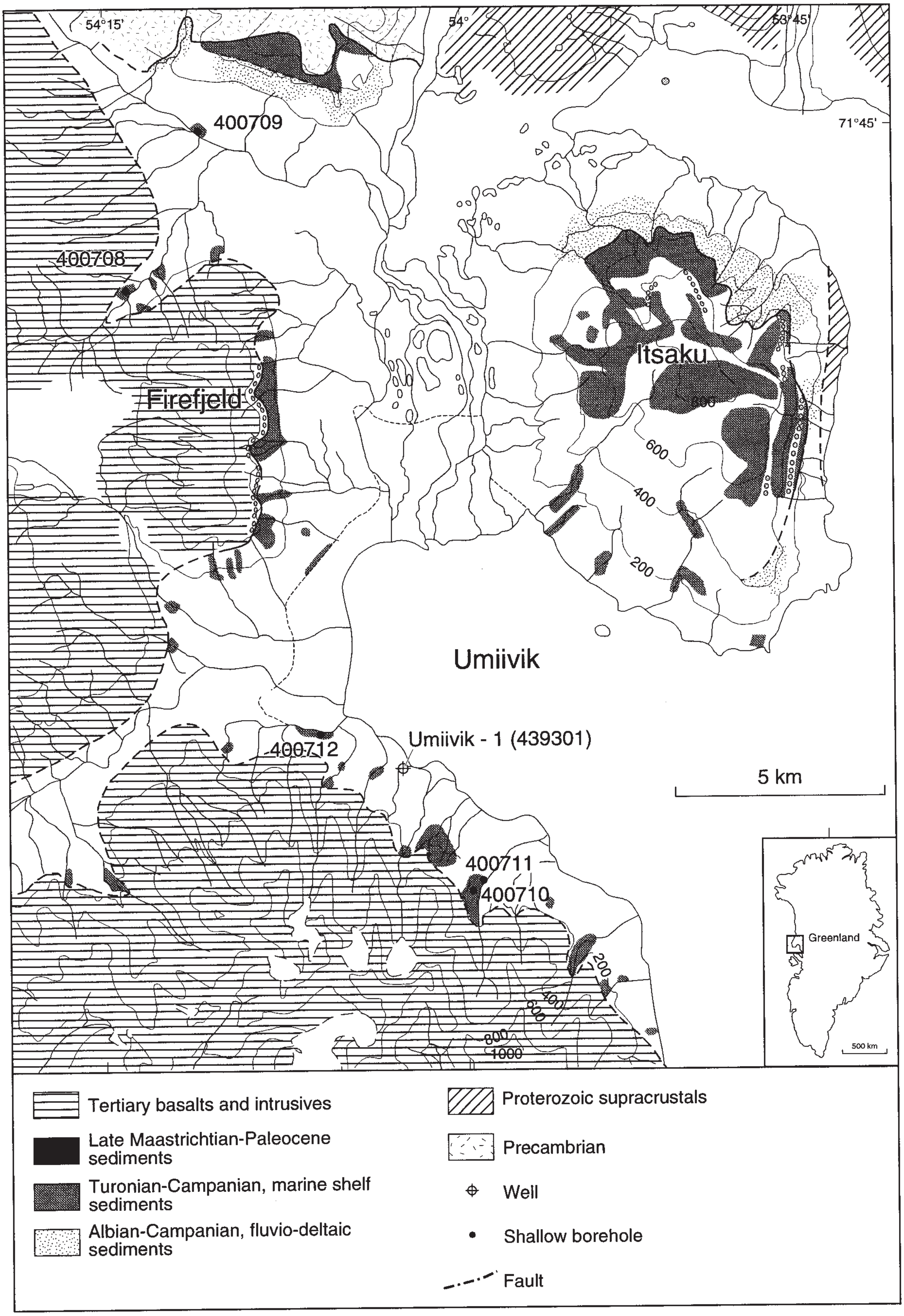
Fig. 1. Map of the Umiivik area showing the location of the wellsite, shallow boreholes. Taken from Bate (1996).

Fig. 2. Simplified geological log of Umiivik-1. Taken from Bate & Christiansen (1996).

Fig. 3. Diversity variation of the marine palynomorphs through the Umiivik-1 well.

Fig. 4. Rangechart of the recorded palynomorphs, with division of the Umiivik-1 well into five palynological intervals.

Fig. 1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Greenland
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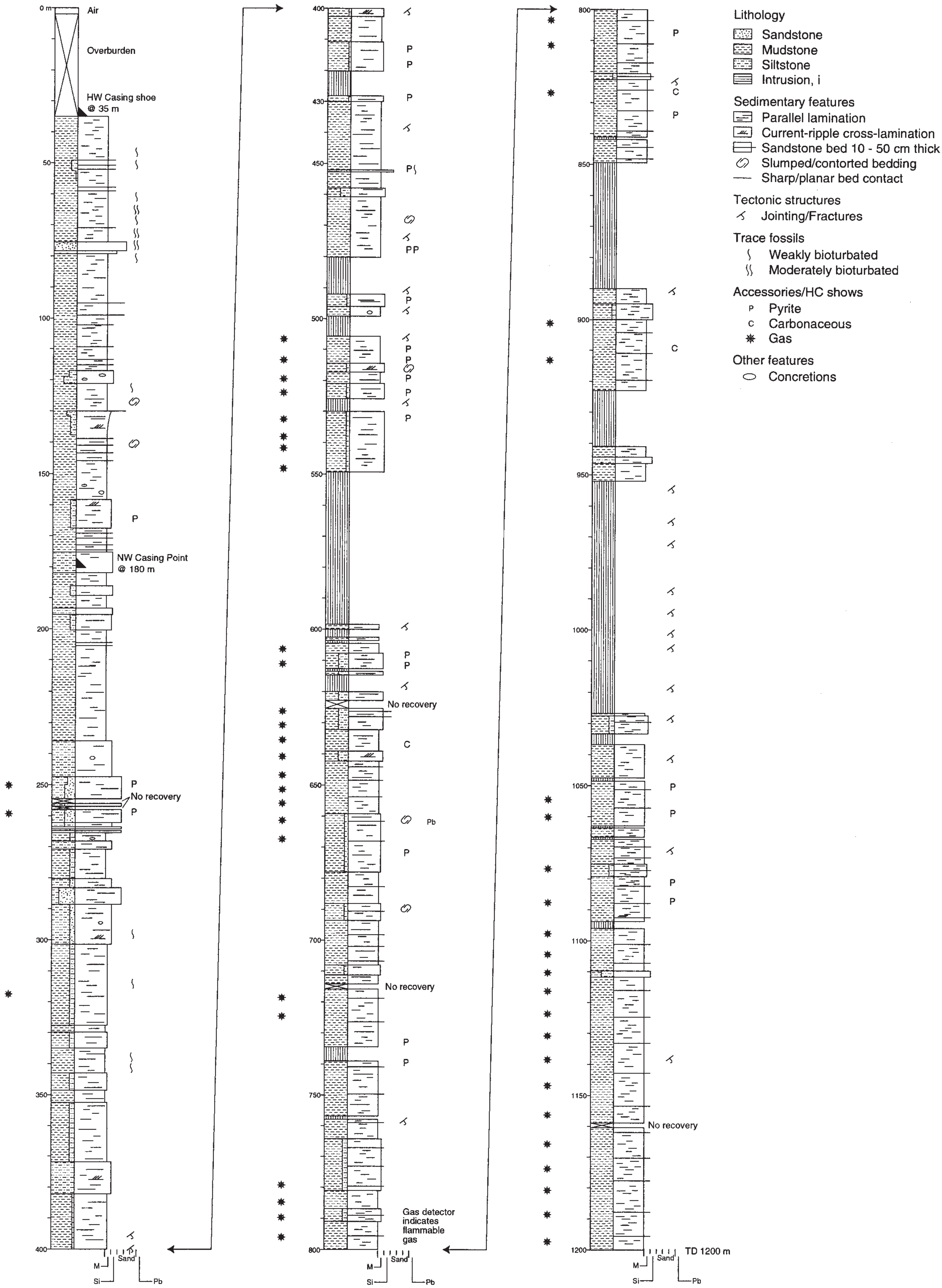
Late Maastrichtian-Paleocene sediments
Turonian-Campanian, marine shelf sediments
Albian-Campanian, fluvio-deltaic sediments
Proterozoic supracrustals
Precambrian
Well
Shallow borehole
Fault

Fig. 2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Mudstone
Siltstone
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Current-ripple cross-lamination
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Sharp/planar bed contact
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Pyrite
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Other features
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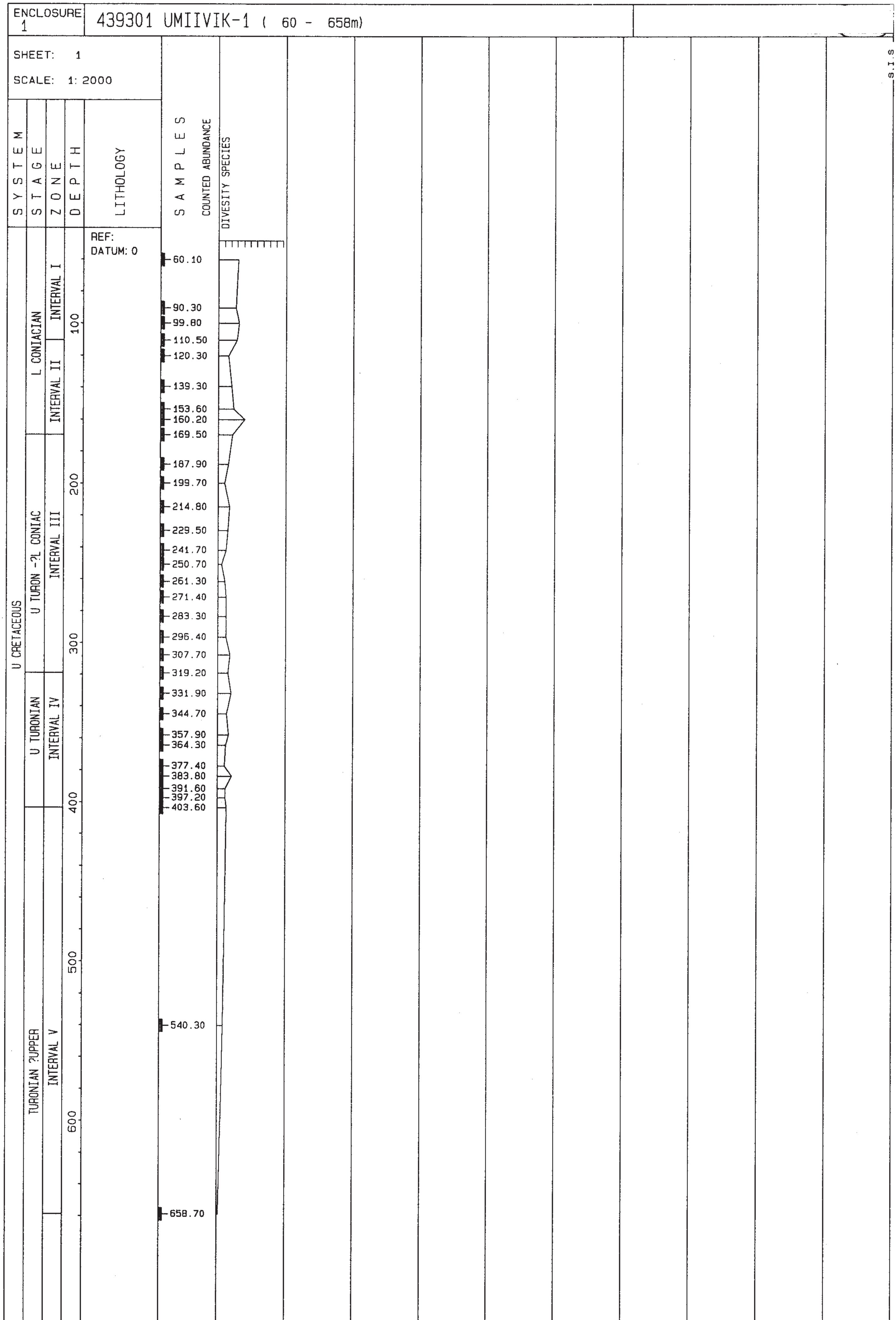
Fig. 3


ENCLOSURE 1
439301 UMIIVIK-1 (60 - 658m)
SHEET: 1
SCALE: 1: 2000
SYSTEM
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U CRETACEOUS
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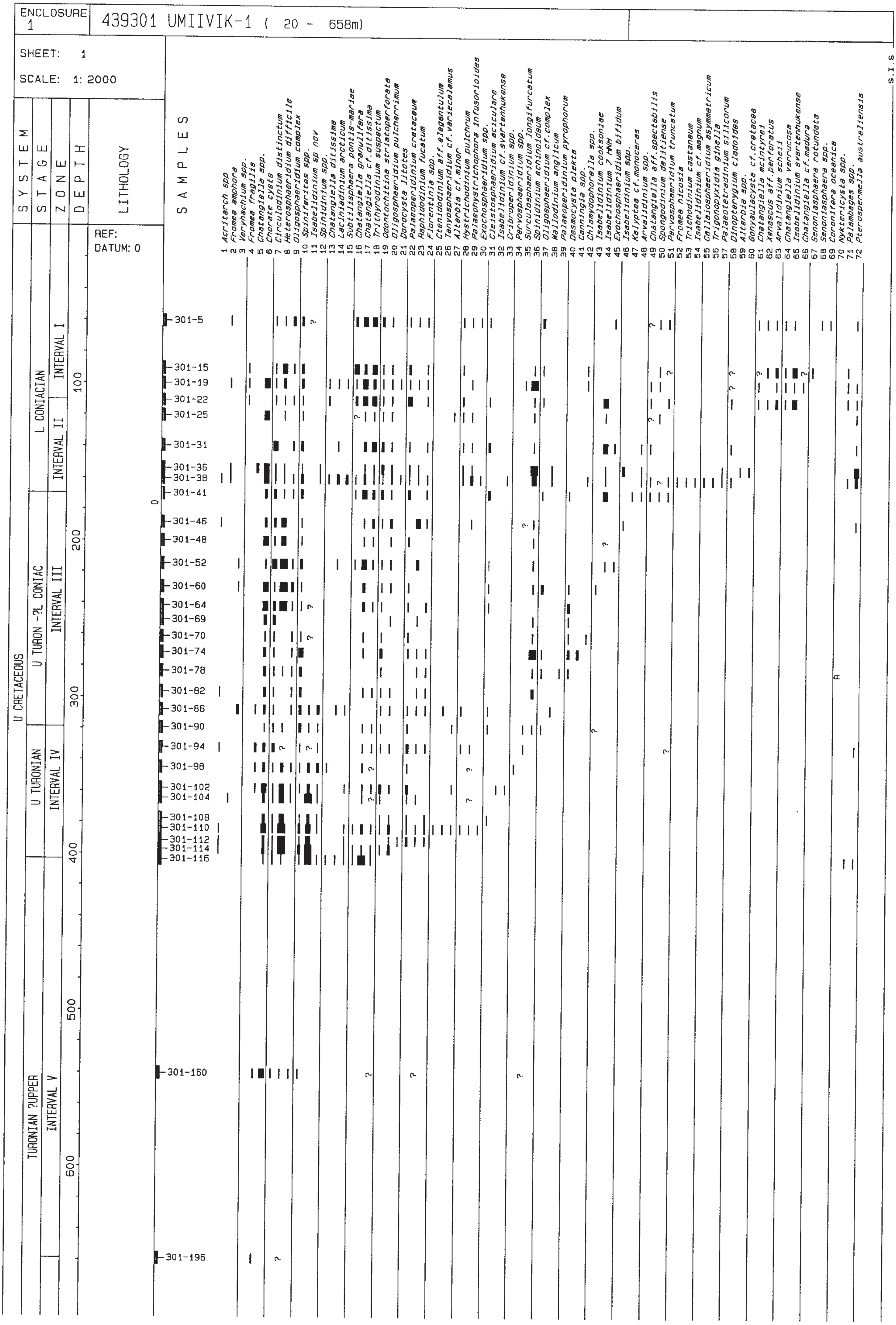
Fig. 4



ENCLOSURE 1
439301 UMIIVIK-1 (20 - 658m)
SHEET: 1
SCALE: 1: 2000
SYSTEM
STAGE
ZONE
DEPTH
LITHOLOGY
SAMPLES
REF:
DATUM: 0
S.I.S
1 Acritarch spp
2 Fromea amphora
3 Veryhachium spp.
4 Fromea fragilis
5 Chatangiella spp.
6 Chorate cysts
7 Circulodinium distinctum
8 Heterosphaeridium difficile
9 Oligosphaeridium complex
10 Spiniferites spp.
11 Isabelidinium sp nov
12 Spinidinium spp.
13 Chatangiella ditissima
14 Laciniadinium arcticum
15 Subtilisphaera pontis-mariae
16 Chatangiella granulifera
17 Chatangiella cf.ditissima
18 Trithyrodinium suspectum
19 Odontochitina striatoperforata
20 Oligosphaeridium pulcherrimum
21 Dorocysta litotes
22 Palaeoperidinium cretaceum
23 Raphidodinium fucatum
24 Florentinia spp.
25 Ctenidodinium aff.elegantulum
26 Tanyosphaeridium cf.variecalamus
27 Alterbia cf.minor
28 Hystrichodinium pulchrum
29 Palaeohystrichophora infusorioides
30 Exochosphaeridium spp.
31 Cleistosphaeridium aciculare
32 Isabelidinium cf.svartenhukense
33 Cribroperidinium spp.
34 Pervosphaeridium spp.
35 Surculosphaeridium longifurcatum
36 Spinidinium echinoideum
37 Oligosphaeridium cf.complex
38 Wallodinium anglicum
39 Palaeoperidinium pyrophorum
40 Desmocysta plekta
41 Canningia spp.
42 Chlamydophorella spp.
43 Isabelidinium cooksoniae
44 Isabelidinium 7 HNH
45 Exochosphaeridium bifidum
46 Isabelidinium spp.
47 Kalyptea cf.monoceras
48 Arvalidinium spp.
49 Chatangiella aff.spectabilis
50 Spongodinium delitiense
51 Pervosphaeridium truncatum
52 Fromea nicosia
53 Trichodinium castaneum
54 Isabelidinium cf.magnum
55 Callaiosphaeridium asymmetricum
56 Trigonopyxidia ginella
57 Palaeotetradinium silicorum
58 Dinopterygium cladoides
59 Alterbia spp.
60 Gonyaulacysta cf.cretacea
61 Chatangiella mcintyrei
62 Xenascus aff.perforatus
63 Arvalidinium scheii
64 Chatangiella verrucosa
65 Isabelidinium svartenhukense
66 Chatangiella cf.madura
67 Senoniasphaera rotundata
68 Senoniasphaera spp.
69 Coronifera oceanica
70 Nyktericysta spp.
71 Palambages spp.
72 Pterospermella australiensis
U CRETACEOUS
L CONIACIAN
U TURON -?L CONIAC
U TURONIAN
TURONIAN ?UPPER
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301-112
301-114
301-116
301-160
301-196

Fig. 4 continued

Species list: 439301 UMIIVIK-1 Encl.: 1

1 Acritarch spp
27 Alterbia cf.minor
59 Alterbia spp.
63 Arvalidinium scheii
48 Arvalidinium spp.
55 Callaiosphaeridium asymmetricum
41 Canningia spp.
49 Chatangiella aff.spectabilis
17 Chatangiella cf.ditissima
66 Chatangiella cf.madura
13 Chatangiella ditissima
16 Chatangiella granulifera
61 Chatangiella mcintyrei
5 Chatangiella spp.
64 Chatangiella verrucosa
42 Chlamydophorella spp.
6 Chorate cysts
7 Circulodinium distinctum
31 Cleistosphaeridium aciculare
69 Coronifera oceanica
33 Cribroperidinium spp.
25 Ctenidodinium aff.elegantulum
40 Desmocysta plekta
58 Dinopterygium cladoides
21 Dorocysta litotes
45 Exochosphaeridium bifidum
30 Exochosphaeridium spp.
24 Florentinia spp.
2 Fromea amphora
4 Fromea fragilis
52 Fromea nicosia
60 Gonyaulacysta cf.cretacea
8 Heterosphaeridium difficile
28 Hystrichodinium pulchrum
44 Isabelidinium 7 HNH
54 Isabelidinium cf.magnum
32 Isabelidinium cf.svartenhukense
43 Isabelidinium cooksoniae
11 Isabelidinium sp nov
46 Isabelidinium spp.
65 Isabelidinium svartenhukense
47 Kalyptea cf.monoceras
14 Laciniadinium arcticum
70 Nyktericysta spp.
19 Odontochitina striatoperforata
37 Oligosphaeridium cf.complex
9 Oligosphaeridium complex
20 Oligosphaeridium pulcherrimum
29 Palaeohystrichophora infusorioides
22 Palaeoperidinium cretaceum
39 Palaeoperidinium pyrophorum
57 Palaeotetradinium silicorum
71 Palambages spp.
34 Pervosphaeridium spp.
51 Pervosphaeridium truncatum
72 Pterospermella australiensis
23 Raphidodinium fucatum
67 Senoniasphaera rotundata
68 Senoniasphaera spp.
36 Spinidinium echinoideum
12 Spinidinium spp.
10 Spiniferites spp.
50 Spongodinium delitiense
15 Subtilisphaera pontis-mariae
35 Surculosphaeridium longifurcatum
26 Tanyosphaeridium cf.variecalamus
53 Trichodinium castaneum
56 Trigonopyxidia ginella
18 Trithyrodinium suspectum
3 Veryhachium spp.
38 Wallodinium anglicum
62 Xenascus aff.perforatus

Plate 1.

Fig. 1. *Arvalidinium scheii*, GGU 439301-22-3, 45.0–109.3; LVR 1.8354; MI 6071.
Fig. 2. *Arvalidinium* spp, GGU 439301-38-3, 41.5–106.5; LVR 1.8336; MI 6054.
Fig. 3. *Arvalidinium* spp, GGU 439301-38-3, 16.0–102.5; LVR 1.8335; MI 6053.
Fig. 4. *Chatangiella* sp. cf. *C. spectabilis*, GGU 439301-41-3, 40.4–97.7; LVR 1.8305; MI 6026.
Fig. 5. *Chatangiella ditissima*, GGU 439301-38-2, 41.1–111.8; LVR 1.8331; MI 6049.
Fig. 6. *Chatangiella* sp. cf. *C. ditissima*, GGU 439301-22-3, 19.9–104.8; LVR 1.8355; MI 6072.
Fig. 7. *Chatangiella* sp. cf. *C. ditissima*, GGU 439301-41-4, 26.4–106.3; LVR 1.8300; MI 6021.
Fig. 8. *Chatangiella* sp. cf. *C. ditissima*, GGU 439301-160-3, 41.7–103.7; LVR 1.8260; MI 5983.
Fig. 9. *Chatangiella* sp. cf. *C. ditissima*, GGU 439301-160-3, 23.7–100.0; LVR 1.8261; MI 5984.
Fig. 10. *Chatangiella* sp. cf. *C. madura*, GGU 439301-19-3, 47.0–95.0; LVR 1.8363; MI 6080.
Fig. 11. *Chatangiella* spp., GGU 439301-196-3, 37.3–100.0; LVR 1.8249; MI 5972.
Fig. 12. *Chatangiella* spp., GGU 439301-160-3, 30.9–113.2; LVR 1.8254; MI 5976.

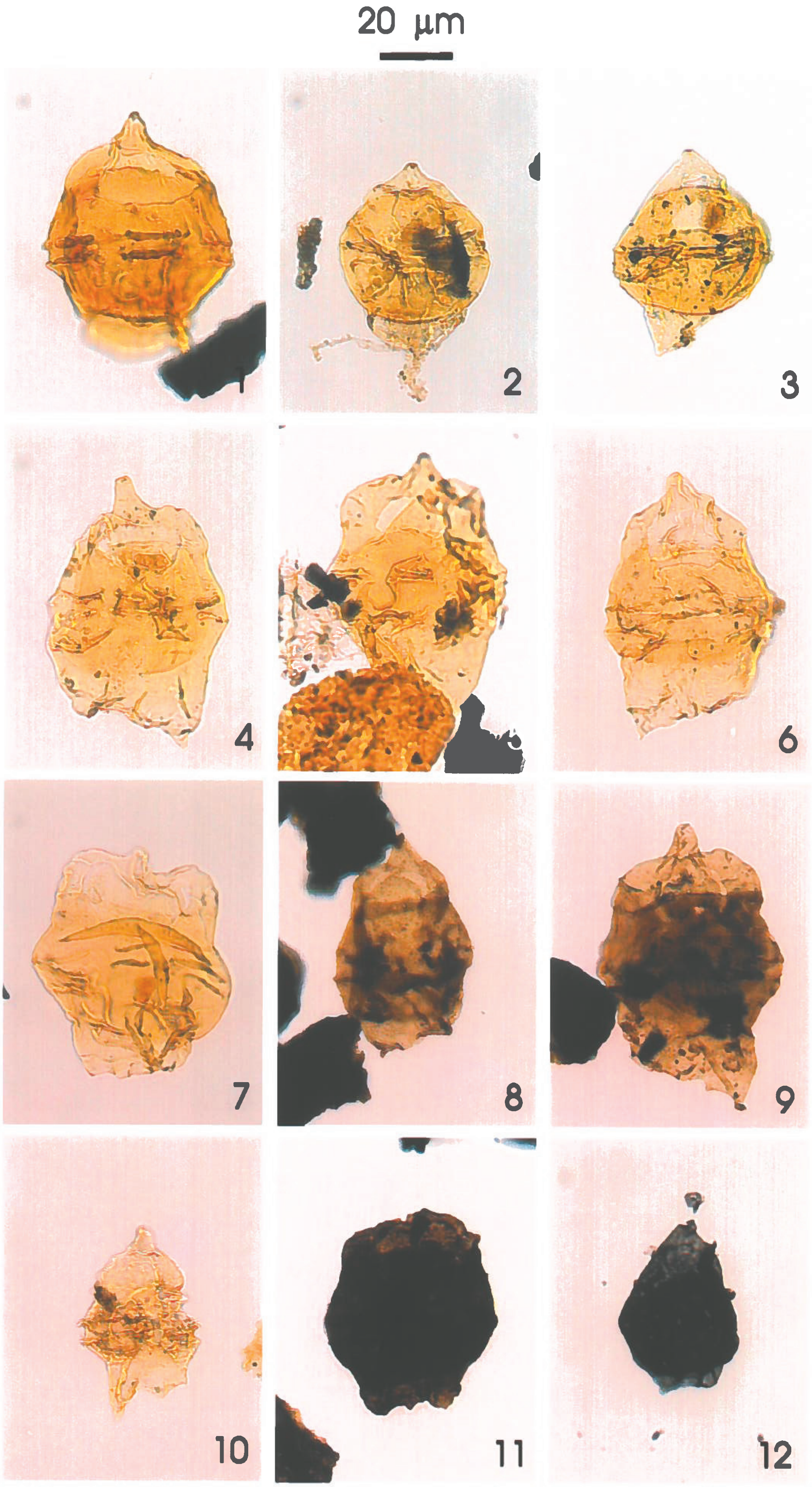
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Plate 2.

Fig. 1. *Isabelidinium* sp. 7 Nøhr-Hansen, 1996, GGU 439301-22-4, 19.1–104.5; LVR 1.8160; MI 5889.
Fig. 2. ?*Isabelidinium* sp. 7 Nøhr-Hansen, 1996, GGU 439301-22-4, 35.3–111.0; LVR 1.8161; MI 5890.
Fig. 3. *Isabelidinium* sp. 7 Nøhr-Hansen, 1996, GGU 439301-22-4, 42.8–99.1; LVR 1.8162; MI 5891.
Fig. 4. *Isabelidinium* sp. cf. *magnum*, GGU 439301-38-2, 22.5–110.1; LVR 1.8321; MI 6040.
Fig. 5. *Isabelidinium svartenhukense*, GGU 439301-15-4, 51.9–103.0; LVR 1.8364; MI 6081.
Fig. 6. *Isabelidinium* spp., GGU 439301-38-2, 41.1–111.8; LVR 1.8330; MI 6048.
Fig. 7. *Isabelidinium* spp., GGU 439301-38-2, 43.7–108.2; LVR 1.8332; MI 6050.
Fig. 8. *Isabelidinium* spp., GGU 439301-38-2, 32.6–110.4; LVR 1.8328; MI 6046.
Fig. 9. *Isabelidinium* spp., GGU 439301-38-2, 30.4–106.6; LVR 1.8325; MI 6044.
Fig. 10. *Isabelidinium* spp., GGU 439301-38-2, 21.1–96.7; LVR 1.8324; MI 6043.
Fig. 11. *Isabelidinium* spp., GGU 439301-38-2, 31.4–102.2; LVR 1.8329; MI 6047.
Fig. 12. *Isabelidinium* spp., GGU 439301-25-2, 30.2–97.8 LVR 1.8351; MI 6068.Plate 2.

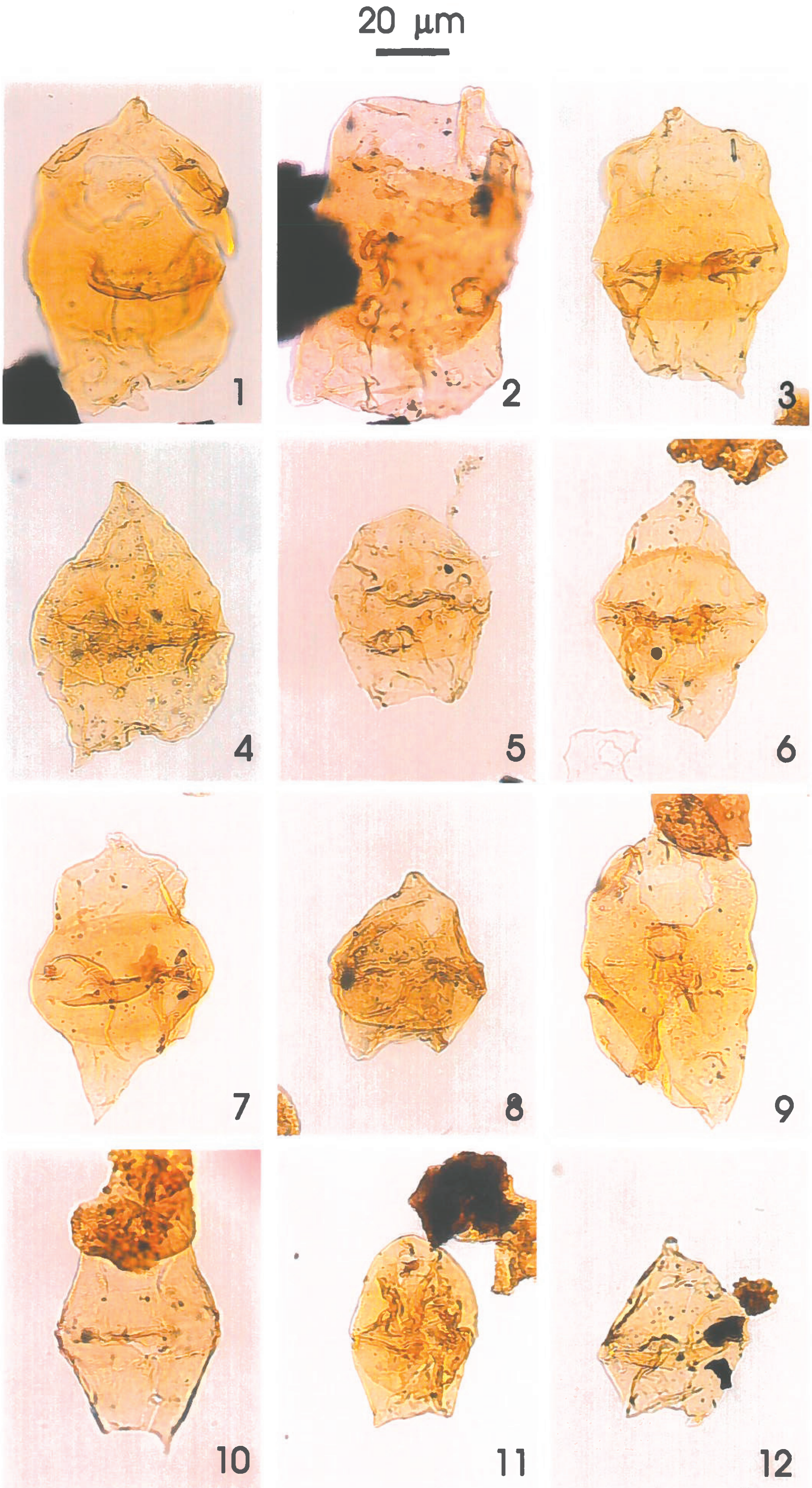
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Plate 3.

Fig. 1. *Isabelidinium* sp. nov., GGU 439301-116-8, 27.3–98.4; LVR 1.8255; MI 5978.
Fig. 2. *Isabelidinium* sp. nov., GGU 439301-116-8, 41.0–102.5; LVR 1.8256; MI 5979.
Fig. 3. *Isabelidinium* sp. nov., GGU 439301-116-8, 38.0–110.3; LVR 1.8257; MI 5980.
Fig. 4. *Isabelidinium* sp. nov., GGU 439301-108-7, 50.1–106.6; LVR 1.8267; MI 5990.
Fig. 5. *Isabelidinium* sp. nov., GGU 439301-86-5, 26.4–96.6; LVR 1.8163; MI 5892.
Fig. 6. *Isabelidinium* sp. nov., GGU 439301-90-8, 38.0–101.4; LVR 1.8164; MI 5893.
Fig. 7. *Isabelidinium* sp. nov., GGU 439301-98-5, 35.4–110.0; LVR 1.8165; MI 5894.
Fig. 8. *Isabelidinium* sp. nov., GGU 439301-104-8, 20.6–111.2; LVR 1.8270; MI 5992.
Fig. 9. *Isabelidinium* sp. ?nov., GGU 439301-102-8, 46.3–104.7; LVR 1.8273; MI 5995.
Fig. 10. *Isabelidinium* sp. nov., GGU 439301-102-8, 48.8–104.5; LVR 1.8276; MI 5998.
Fig. 11. *Isabelidinium* sp. nov., GGU 439301-110-4, 51.5–103.7; LVR 1.8283; MI 6004.
Fig. 12. *Isabelidinium* sp. ?nov., GGU 439301-5-4, 53.3–111.4; LVR 1.8159; MI 5888.

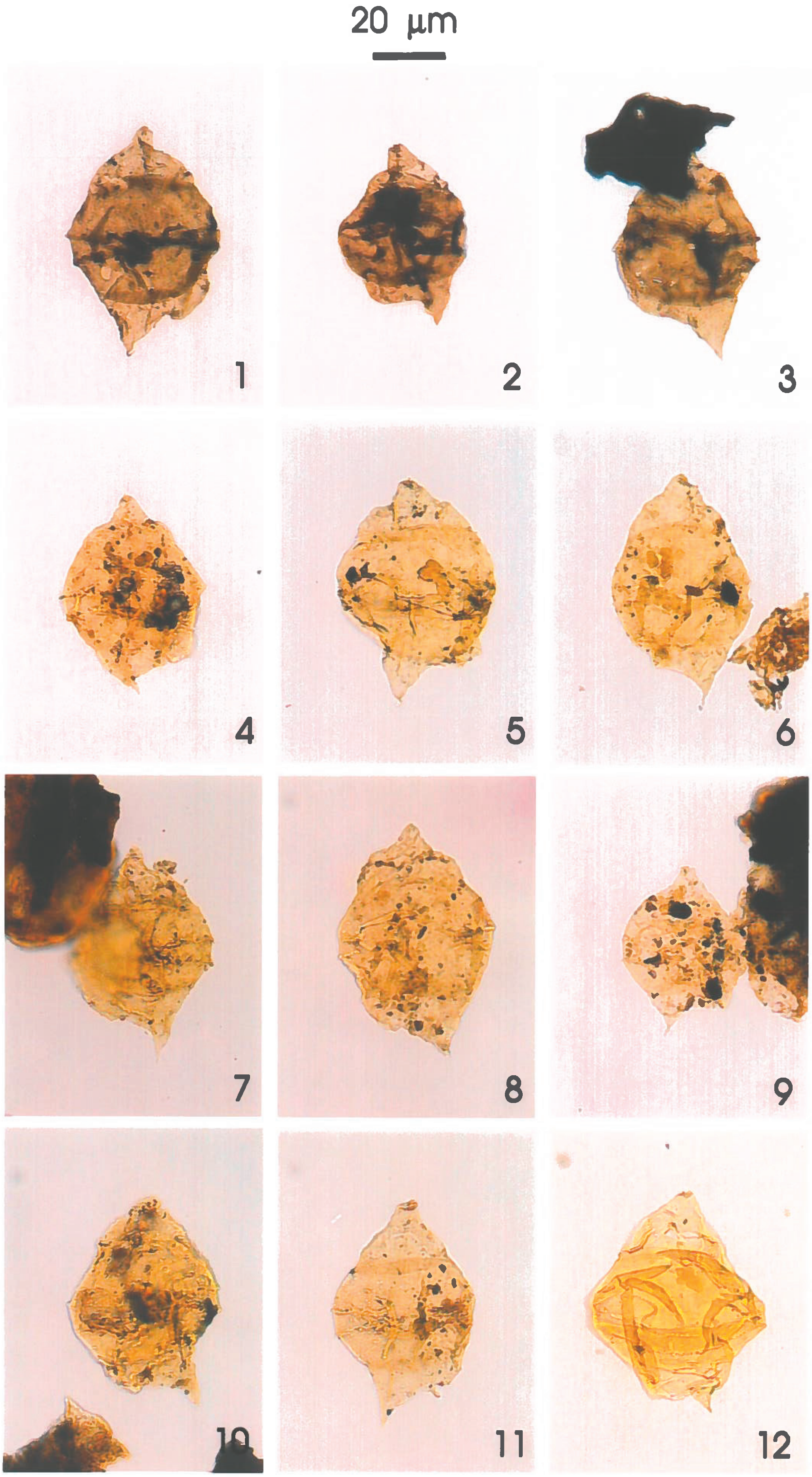

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Plate 4.

Fig. 1. ?*Raphidodinium fucatum,* GGU 439301-160-3, 24.1–99.1; LVR 1.8250; MI 5973.
Fig. 2. *Raphidodinium fucatum,* GGU 439301-112-8, 40.5–98.0; LVR 1.8265; MI 5988.
Fig. 3. *Raphidodinium fucatum,* GGU 439301-46-2, 34.0–93.2; LVR 1.8297; MI 6018.
Fig. 4. *Trigonopyxidia ginella*, GGU 439301-38-4, 51.0–110.2; LVR 1.8344; MI 6061.
Fig. 5. *Palaeotetradinium silicorum*, GGU 439301-38-4, 54.1–112.3 LVR 1.8345; MI 6062.
Fig. 6. *Palaeohystrichophora infusorioides*, GGU 439301-38.3, 24.4–104.3; LVR 1.8337; MI 6055.
Fig. 7. *Heterosphaeridium difficile,* GGU 439301-160-3, 29.7–109.0; LVR 1.8251; MI 5974.
Fig. 8. *Heterosphaeridium difficile,* GGU 439301-112-8, 24.8–96.4; LVR 1.8263; MI 5986.
Fig. 9. *Tanyosphaeridium* sp. cf. *T. variecalamus,* GGU 439301-110-2, 50.0–110.5; LVR 1.8282; MI 6003.
Fig. 10. *Surculosphaeridium longifurcatum*, GGU 439301-94-9, 45.3–103.6; LVR 1.8290; MI 6011.
Fig. 11. *Dorocysta litotes*, GGU 439301-38-2, 31.6–108.5; LVR 1.8322; MI 6041.
Fig. 12. Dinoflagellate cyst spp., GGU 439301-38.2, 19.6–96.0; LVR 1.8320; MI 6039.
Fig. 12. Dinoflagellate cyst spp., GGU 439301-36.2, 36.5–114.5; LVR 1.8311; MI 6030.

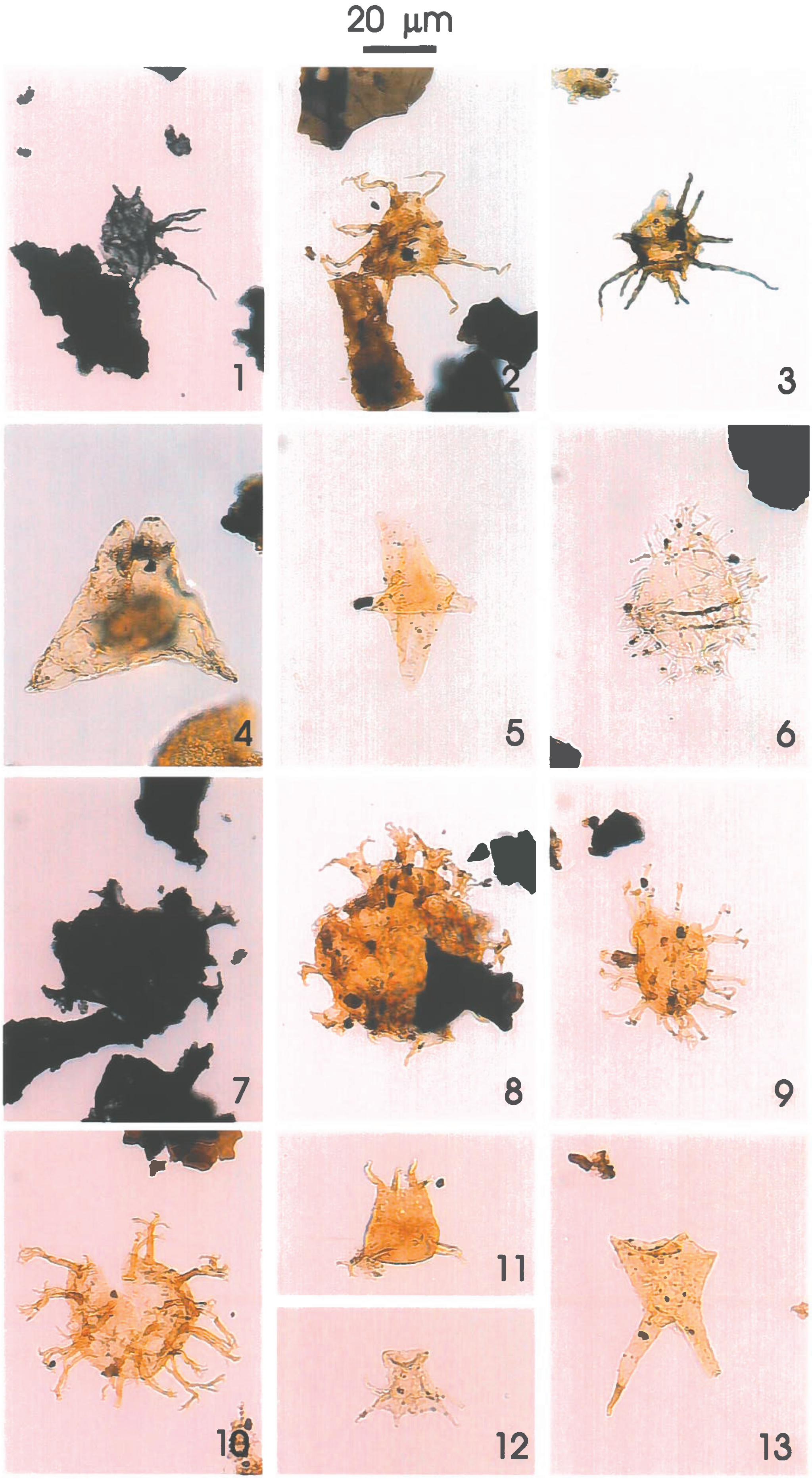
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Plate 5.

Fig. 1. *Trithyrodinium suspectum,* GGU 439301-160-3, 46.0–98.7; LVR 1.8252; MI 5975.
Fig. 2. *Trithyrodinium suspectum*, GGU 439301-38-4, 48.9–96.7; LVR 1.8342; MI 6059.
Fig. 3. *Trithyrodinium suspectum*, GGU 439301-41-4, 18.6–105.4 LVR 1.8299; MI 6020.
Fig. 4. *Alterbia* sp. cf. *A. minor*, GGU 439301-38.2, 19.4–105.5; LVR 1.8323; MI 6042.
Fig. 5. *Subtilisphaera pontis-mariae* GGU 439301-38-4, 46.8–108.7; LVR 1.8339; MI 6057.
Fig. 6. *Subtilisphaera pontis-mariae* GGU 439301-38-2, 16.4–94.4; LVR 1.8319; MI 6038.
Fig. 7. *Pervosphaeridium truncatum*, GGU 439301-41-4, 40.3–95.6; LVR 1.8302; MI 6023.
Fig. 8. *Pervosphaeridium truncatum*, GGU 439301-15-2, 32.0–100.5; LVR 1.8365; MI 6082.
Fig. 9. *Pervosphaeridium truncatum*, GGU 439301-5-4, 22.3–102.4; LVR 1.8377; MI 6093.
Fig. 10. *Exochosphaeridium bifidum*, GGU 439301-31-4, 17.4–97.8; LVR 1.8347; MI 6064.
Fig. 11. *Trichodinium castaneum*, GGU 439301-38.4, 18.9–93.1; LVR 1.8327; MI 6045.
Fig. 12. *Canningia* spp., GGU 439301-74-5, 26.4–101.0; LVR 1.8293; MI 6014.

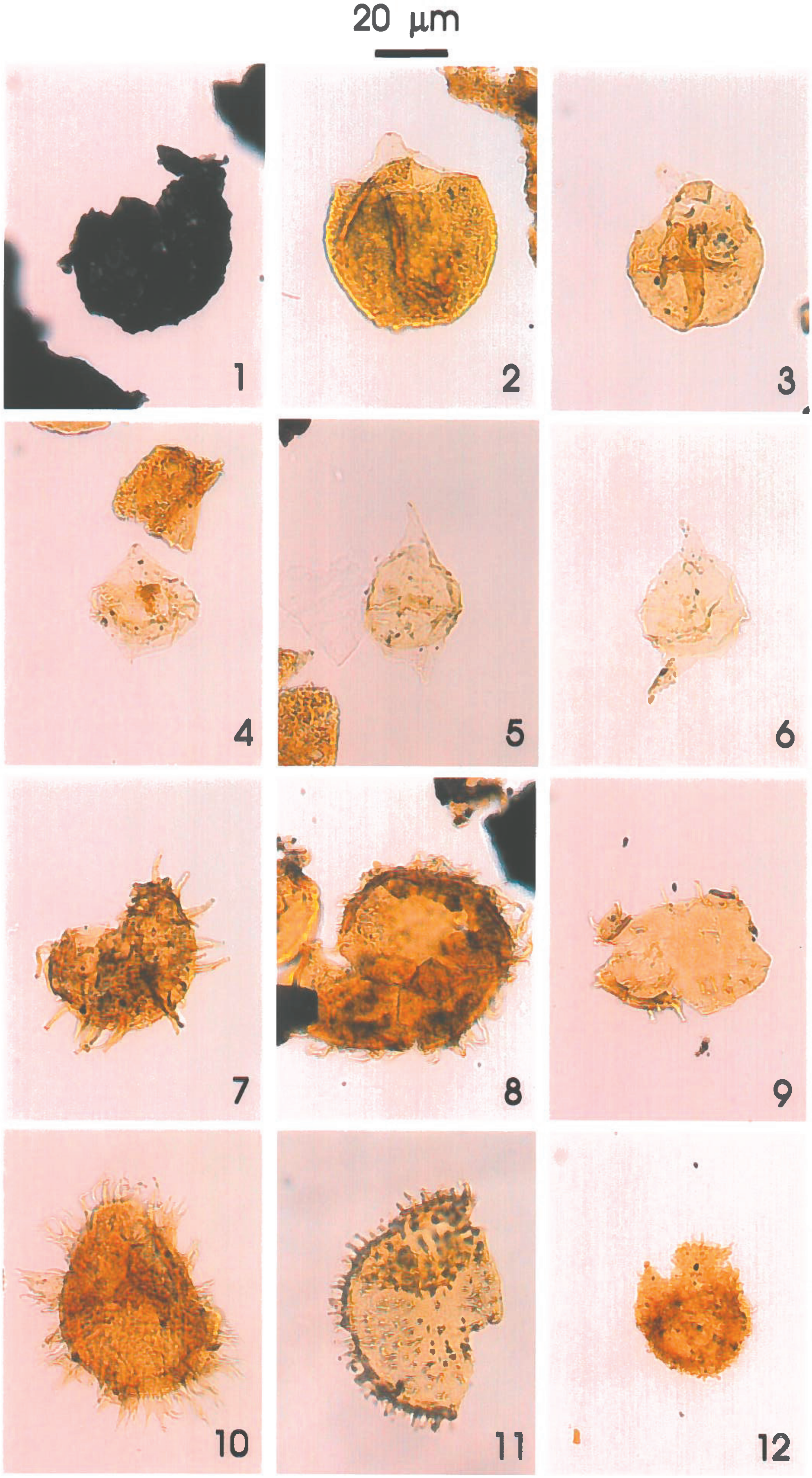
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Plate 6.

Fig. 1. *Spinidinium echinoideum,* GGU 439301-36-2, 20.0–102.6; LVR 1.8308; MI 6027.
Fig. 2. *Spinidinium echinoideum,* GGU 439301-36-2, 15.5–103.2; LVR 1.8309; MI 6028.
Fig. 3. *Laciniadinium arcticum*, GGU 439301-38-2, 19.2–111.5 LVR 1.8318; MI 6037.
Fig. 4. *Ctenidodinium* sp. aff. *C. elegantulum* GGU 439301- 110-3, 26.0–98.6; LVR 1.8277; MI 6000.
Fig. 5. *Ctenidodinium* sp. aff. *C. elegantulum* GGU 439301- 110-4, 45.9–97.4; LVR 1.8280; MI 6001.
Fig. 6. *Ctenidodinium* sp. aff. *C. elegantulum* GGU 439301- 110-2, 18.6–104.8; LVR 1.8281; MI 6002.
Fig. 7. *Senoniasphaera rotundata* GGU 439301-15-3, 19.6–94.1; LVR 1.8368; MI 6085.
Fig. 8. *Senoniasphaera* spp., GGU 439301-5-3, 42.3–112.8; LVR 1.8369; MI 6086.
Fig. 9. *Dinopterygium cladoides* GGU 439301-15.3, 34.6–109.5; LVR 1.8366; MI 6083.
Fig. 10. *Spongodinium delitiense*, GGU 439301-5-4, 43.5–102.2; LVR 1.8375; MI 6092.
Fig. 11. *Xenascus* sp. aff. *X perforatus*, GGU 439301-15-3, 35.5–110.0; LVR 1.8378; MI 6094.
Fig. 12. *Odontochitina striatoperforata*, GGU 439301-104-8, 54.3–102.4; LVR 1.8268; MI 5991.

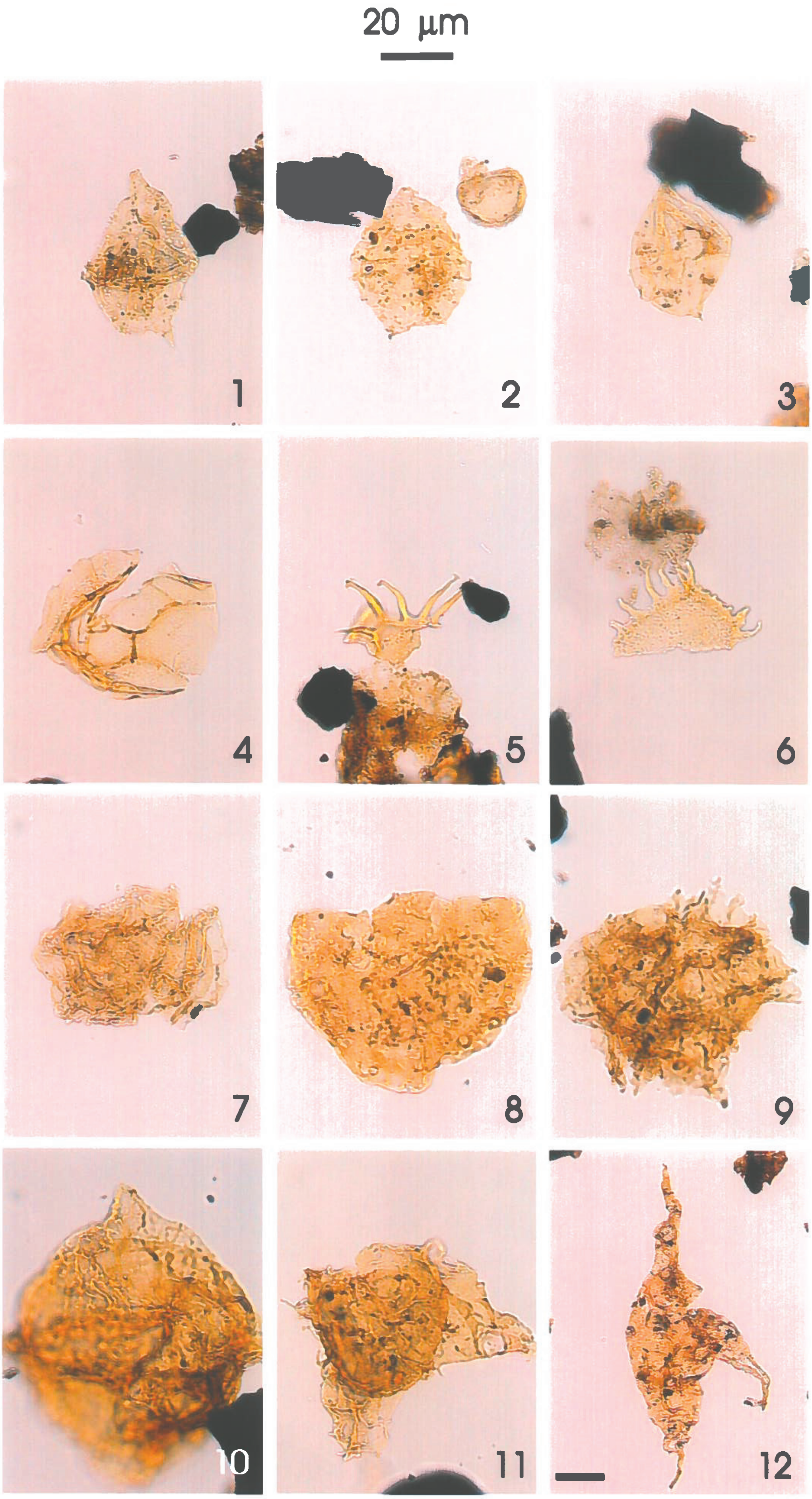
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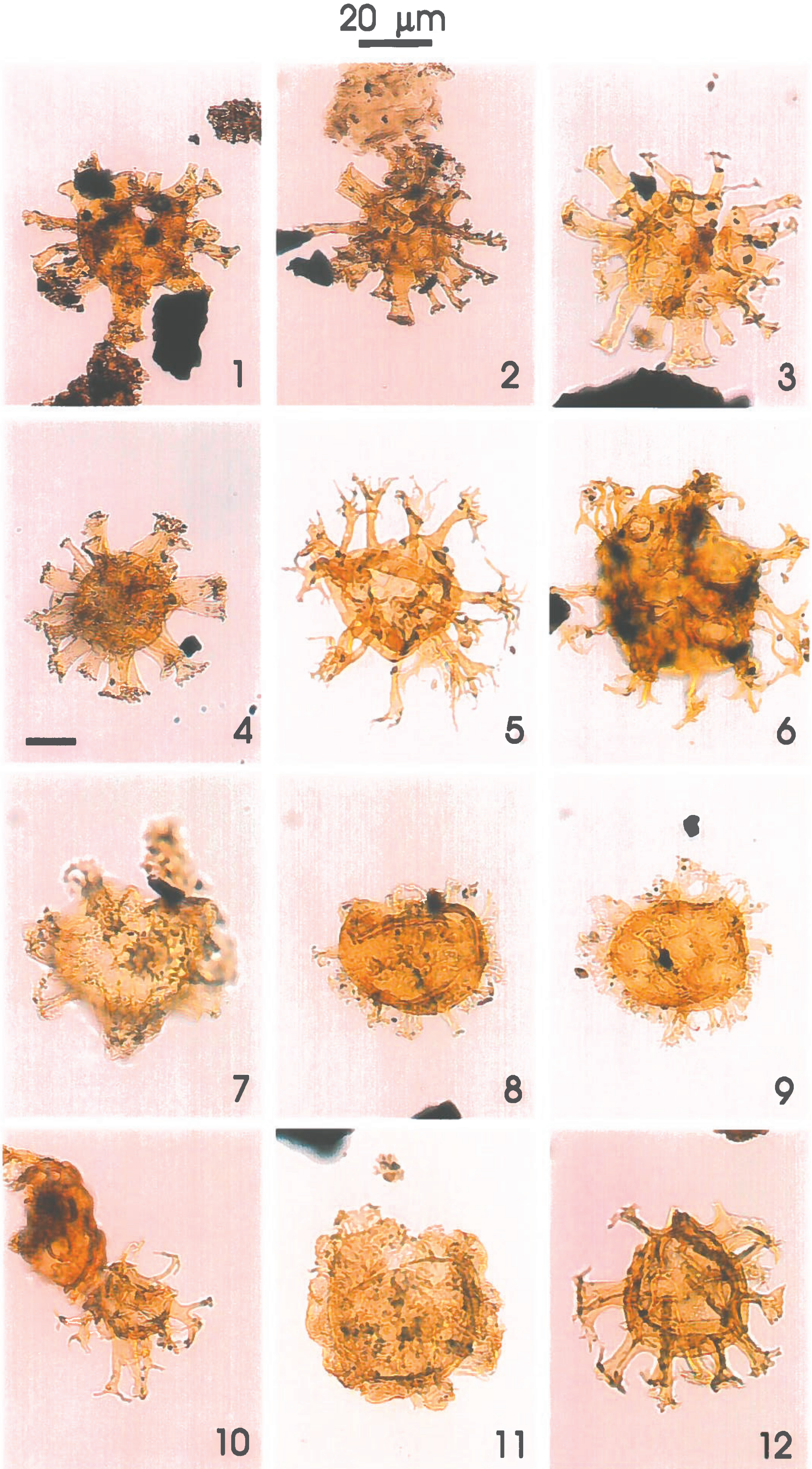
Plate 7.

Fig. 1. *Florentinia* spp., GGU 439301-108-8, 29.9–101,6; LVR 1.8269; MI 5990.
Fig. 2. *Florentinia* spp., GGU 439301-110-3, 36.6–112.7; LVR 1.8284; MI 6005.
Fig. 3. *Florentinia* spp., GGU 439301-22-3, 45.6–99.7; LVR 1.8353; MI 6070.
Fig. 4. *Florentinia* spp., GGU 439301-5-4, 16.9–99.4; LVR 1.8372; MI 6089.
Fig. 5. *Oligosphaeridium* sp. cf. *O. complex*, GGU 439301-41-3, 53.3–97.1; LVR 1.8303; MI 6024.
Fig. 6. Chorate cyst, GGU 439301-60-5, 25.0–101.8; LVR 1.8296; MI 6017.
Fig. 7. Chorate cyst, GGU 439301-38-4, 32.0–101.2; LVR 1.8340; MI 6058.
Fig. 8. Chorate cyst, GGU 439301-5-4, 32.0–111.7; LVR 1.8373; MI 6090.
Fig. 9. Chorate cyst, GGU 439301-31-1, 49.3–106.0; LVR 1.8348; MI 6065.
Fig. 10. Chorate cyst, GGU 439301-19.2, 18.5–95.0; LVR 1.8362; MI 6079.
Fig. 11. Chorate cyst, GGU 439301-5-3, 25.0–107.7; LVR 1.8370; MI 6087.
Fig. 12. Chorate cyst, GGU 439301-5-3, 35.0–110.5; LVR 1.8371; MI 6088.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