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GANE-1
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Palynology of the boreholes GANE-1, GANK-1 and GANT-1 Nuussuaq, West Greenland

Nøhr-Hansen, H.

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Contents

Abstract

The dinoflagellate cyst assemblages from 87 samples from the boreholes GANE#1, GANK#1 and GANT#1 on Nuussuaq, West Greenland are described. GANE#1 and GANK#1 are divided into two informal dinoflagellate cyst intervals that can be correlated and dated as Selandian to ?Early Thanetian, Late Paleocene.

GANT#1 is dated as Campanian (Late Cretaceous) to Danian (Early Paleocene) and is divided into four informal dinoflagellate cyst intervals. The Cretaceous/Tertiary boundary has not been precisely located but is supposed to occur just below the base of interval I in GANT#1. Reworked Late Cretaceous species often occur in the Paleocene species assemblages.

The palynological record from GANT#1 has made correlation possible of the Upper Cretaceous deposits from northern Nuussuaq with similar deposits on central Nuussuaq and Svartenhuk Halvø.

Introduction

In the summer of 1995 the first commercial oil exploration drilling for almost 20 years was carried out in Greenland with the Canadian grønArctic energy inc. as operator. In May 1995 grønArctic energy inc. and Platinova A/S were granted an exclusive exploration licence for a 1692 km^2 large area covering western Nuussuaq (Fig. 1). grønArctic began their exploration programme with drilling of three slim-core holes (GANE#1, GANK#1 and GANT#1) to depths between 400 and 900 m.

The Geological Survey of Denmark and Greenland (GEUS) carried out a geological description at the drill sites followed by a major sampling and analytical programme. The results from these studies include detailed sedimentological, organic geochemical and biostratigraphic reports. These reports have been released from 1 April, 1997 whereas all other results obtained by grønArctic energy inc. during their exploration programme are still confidential.

GANE#1 and GANK#1 are situated in the Aaffarsuaq valley, approximately 10 and 15 km, respectively, ESE of GGU's Marraat-1 well (Fig. 1). The main target both places was a Marraat type play, i.e. a Maastrichtian–Lower Paleocene channel or turbidite sandstone reservoir with a deltaic source rock of similar age, within a structural or stratigraphic trap. Both wells are situated some kilometres SE of the area where oil has previously been documented at the surface (Christiansen *et al.*, 1995a, 1996a). Both wells were sited on hyaloclastic breccias, the base of which was penetrated at 497 m in GANE#1 and at 115 m in GANK#1. Oil was identified bleeding from the cores at several levels in the volcanic rocks. In the underlying Maastrichtian?–Tertiary sedimentary succession gas under pressure as well as oil impregnation was encountered (see details in Christiansen *et al.*, 1996c).

GANT#1 is situated in theTunorsuaq valley (Fig. 1) where a Cretaceous–Tertiary succession similar to that known from the north coast of Nuussuaq is exposed. The main target was a structural play, with marine Cretaceous sandstones as the reservoir unit and an inferred mid-Cretaceous oil-prone source rock. The target was clearly inspired by the discovery of wet gas in a mineral exploration drill hole at Serfat (Fig. 1) on the north coast of Nuussuaq in the summer of 1994 (Dam & Nøhr-Hansen, 1995). GANT#1 penetrated a succession of Upper Cretaceous to Lower Paleocene marine sediments. The core documented a number of sandstone layers with gas under pressure (Christiansen *et al.*, 1996c).

Palynology

Previous palynological studies on southern and central Nuussuaq

Croxton (1978a, b) briefly described the palynomorph assemblages from seven localities on central Nuussuaq (C4-C7, C21, M19, M22; Fig. 2). The palynomorphs from Qilakitsoq (C4), Qaatunnat Ilorliit (C5), Ilugisssoq (C6) and Nallurarissat (C7) indicate a Late Cenomanian to Early Campanian age. A possible reworked Maastrichtian assemblage is recorded from the top of section C5, and dinoflagellate cysts from the topmost shale at C6 indicate a possible 'middle' Paleocene age (Croxton. 1978a). Sections C21 and M19 represent the 'Oyster-ammonite conglomerate' from Agatdalen; according to Croxton (1978b) palynomorphs from these sections may indicate reworked Maastrichtian floras. A few dinoflagellate cysts, probably indicating a Late Campanian age, were recorded by Croxton (1978a) from Scaphitesnæsen (M22).

Eight sections from central Nuussuaq (M16-M23; Fig. 2) were sampled by Hansen (1976); data on the palynological content from the two sections M16 and M17 from Tunoqqu have not been published.

Hansen (1980) described the Paleocene dinoflagellate cysts from the Sonja section (M18), Turritellakløft section (M20), Qaarsutjægerdal section (M21) and Ättestupet section (M23). According to Hansen (1980) the Middle Campanian to Early Maastrichtian species *Isabelidinium microarmum* is recorded as reworked specimens in the sections M18-M21.

Piasecki *et al.* (1992) described mid-Paleocene dinoflagellate cyst assemblages from sediments interbedded with the Tertiary volcanic rocks on Disko and Nuussuaq and dated the sediments as NP 4 to NP 8.

Ehman *et al.* (1976) studied the four sections Qilakitsoq (N10), Turritellakløft (N15), Qaarsutjægerdal (N16) and Nassaat (N17) central Nuussuaq (Fig. 2). The ages given by Ehman *et al.* (1976) are Middle Cenomanian and early Danian for N10, Campanian or Maastrichtian to Paleocene for N15, Paleocene for N16 and N17. It should be noted that the ages given in the text by Ehman *et al.* (1976) are not always consistent with the ages given in their logs (see Pulvertaft, 1987, table 1).

Nøhr-Hansen (1994b; 1996) described the palynomorph assemblages from 15 sections and four subsurface sections in the Agatdalen region and dated the marine succession as Late Santonian to Middle Campanian. One sample is dated as Paleocene.

Nøhr-Hansen in Christiansen *et al.* (1995b) described the dinoflagellate cyst assemblages from four samples from the GANW#1 hole on the south coast of Nuussuaq (Fig. 2) and dated the samples as early Thanetian, now Selandian, Early Paleocene.

The upper Cretaceous spore and pollen assemblages from the Ataata Kuua section on south-western Nuussuaq have been studied by D.J. McIntyre, but data have not been published.

Previous palynological studies on northern Nuussuaq

Croxton (1978a, b, 1980) briefly described palynomorph assemblages from three localities on the north coast of Nuussuaq (M25, M27, M28; Fig. 2). The palynomorphs from these three localities in the Kangilia and Annertuneq area indicate a Late Campanian to Maastrichtian age.

Hansen (1980) described the Paleocene dinoflagellate cysts and proposed a zonation for the mudstone deposited above the so-called 'basal Danian conglomerate' in the Kangilia/ Annertuneq section (M25; Fig. 2).

Nøhr-Hansen (1993) described a low diversity dinoflagellate assemblage of Late Maastrichtian? to Early Paleocene age from the uppermost part of the thick turbidite succession exposed on the south-east side of the Itilli valley in Nuussuaq.

Nøhr-Hansen (1994c; 1996) described the palynomorph assemblages from five sections and three subsurface sections on the north coast of Nuussuaq. The sections make up an at least 700 m thick dark mudstone succession. The dinoflagellate cysts and pollen date the majority of the samples as Late Campanian and Maastrichtian. A few samples were dated as Coniacian-Late Santonian and Early Paleocene. The section at Annertuneq includes the Cretaceous/Tertiary boundary and the palynomorph assemblage has been described by Nøhr-Hansen & Dam (1997).

Samples and methods

At the well site, samples were collected and canned at approximately 3 metre intervals (Bate, 1995; Dahl *et al.*, 1995a,b). Cores were wrapped in aluminium foil and packed in core boxes in order to avoid (or at least reduce) contamination. A set of 87 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 samples 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 co-ordinates 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 sample number, slide number, microscope co-ordinates, laser-video-record number (LVR) and data base 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 cyst and acritarch species were recorded from the sieved, oxidised or gravitation-separated slides. Counting of specimens was done on the 73 samples that revealed dinoflagellate cysts (Figs 3, 4, 5), approximately 100 specimens were counted when possible.

The dinoflagellate cyst stratigraphy proposed here for the GANE#1,GANK#1 and GANT#1 holes is based on the first and the last occurrences and the acme of stratigraphically important species.

Palynostratigraphy and thermal maturity of the borehole GANK#1

GANK#1 is situated close to the river Kuussuaq, about 10 km east of the outlet at western end of the Aaffarsuaq valley (Fig. 1). The elevation of GANK#1 is 91 m a.s.l., and the hole was drilled to a total depth of 398.98 m. A side-track hole (GANK#1A) was kicked-off at 218.55 m and terminated at a depth of 332.84 m (Dahl *et al.*, 1995a; Dam, 1996b).

The organic geochemical analyses yielded moderately low Rock Eval T_{max} values between 421 and 440°C throughout the sedimentary succession down to -400 m suggesting a maturity level corresponding to before or in the early part of the oil window (Christiansen *et al.*, 1996b).

The dinoflagellate cyst stratigraphy proposed here for the marine Paleocene section in GANK#1 is based on a study of material from 26 core samples of which one was barren.

Palynological intervals

The species recorded from GANK#1 are listed on the range chart (Enclosure 1).

Only a few morphologically characteristic and stratigraphically important species have been recognised, and based on their first and last occurrences it has been possible to distinguish two dinoflagellate cysts intervals within the Paleocene strata. These intervals are informally described, and a correlation is suggested to the dinoflagellate cyst interval biozones described by Powell (1992) from the North Sea region (Fig. 6).

Interval I, -120.9 to -180.8 m

Age: Selandian (Late Paleocene).

This interval is dominated by terrestrially derived black to brownish woody material, cuticles and few bisacate pollen. Dinoflagellate cysts are common. The diversity is low to moderately high (3 to 24 species). The specimens are generally well preserved. Reworking of Late Cretaceous and Early Paleocene species is common (see Enclosure 1).

The interval of GANK#1 (-130.7 to -180.8 m) may be correlated with the Selandian *Palaeoperidinium pyrophorum* (Ppy) dinoflagellate cyst Interval Biozone (Fig. 6) described from the North Sea region by Powell (1992).

Characteristic species. The interval is characterised by the presence of *Alisocysta margarita* (rare), *Areoligera gippingensis*, *Cerodinium diebelii*, *C. speciosum*, *C. striatum*. *Isabelidinium*

aff. *viborgense*, *Palaeocystodinium bulliforme* and *Palaeoperidinium pyrophorum* (common) (Enclosure 1).

Discussion. The first appearance datum (FAD) and last appearance datum (LAD) of *A. margarita* in the interval suggest a Selandian age correlating with the *P. pyrophorum* (Ppy) or the younger early Thanetian *Alisocysta margarita* (Ama) dinoflagellate cyst Interval Biozones (Fig. 6) of Powell (1992). The common occurrence of *P. pyrophorum* and the presence of *C. speciosum*, *C. striatum*. *P. bulliforme* suggest correlation with the Ppy Interval Biozone since the species all have their LAD at the top of the Ppy Interval Biozone (Powell, 1992).

The FAD of *Areoligera gippingensis* at the base of the interval I suggests correlation with the Ama Interval Biozones according to Powell *et al.* (1996). However, Mudge & Bujak (1996) have recorded *A. gippingensis* (sporadically occurring) together with common *P. pyrophorum* in the Ppy Interval Biozone of Powell (1992). The *A. gippingensis* acme described by Powell *et al.* (1996) from the lower part of the Ama Interval Biozones, has not been recorded in interval I.

The species from Nuussuaq identified as *Isabelidinium* aff. *viborgense* is morphological very similar to the stratigraphically important species *Isabelidinium viborgense* described from Denmark (Heilmann-Clausen, 1985). It differs, however, from the holotype of *I. viborgense* by the presence of a distinct pattern of longitudinal folds on the periphragm. *Isabelidinium viborgense* has its LAD in the lower part of the Ppy Interval Biozone and its FAD in the lower part of the older *Cerodinium speciosum* (Csp) Interval Biozone (Powell,1992). According to Mudge & Bujak (1996) *I. viborgense* has its LAD just before the FAD of sporadic occurrences of *A. gippingensis* in the North Sea. The co-occurrence of few *I.* aff *viborgense* and few *A. gippingensis* in GANK#1 may suggests that *I.* aff *viborgense* have a stratigraphically higher LAD or that *A. gippingensis* have a stratigraphically lower FAD in Arctic areas.

Interval II, -188.9 to - 395.8 m

Age: Selandian (Late Paleocene)

This interval is dominated by terrestrially derived black to brownish woody material, cuticles and few bisacate pollen. Dinoflagellate cysts are common. The diversity is low to moderate (2 to 15 species). The specimens are generally well preserved. Reworking of Late Cretaceous and Early Paleocene species is rare (see Enclosure 1).

The lower part of GANK#1 (-188.9 to -395.8 m) may be correlated with the Selandian *Cerodinium speciosum* (Csp) dinoflagellate cyst Interval Biozone (Fig. 6) described from the North Sea region by Powell (1992).

Characteristic species. The interval is characterised by the presence of *Cerodinium diebelii*, *C. speciosum*, *C. striatum*. *Isabelidinium* aff. *viborgense*, *Palaeocystodinium bulliforme* and *Palaeoperidinium pyrophorum*. *Fibrocysta* cf. *capitata* is common at -379.5 m (Enclosure 1).

Discussion. The presence of *Cerodinium speciosum* throughout this interval suggests Selandian age correlating with the Csp dinoflagellate cyst Interval Biozones in the North Sea region (Powell, 1992).

Isabelidinium viborgense has its FAD in the lower part of the Csp Interval Biozone (Powell, 1992). The presence of *I.* aff. *viborgense* throughout the interval therefore suggests correlation with the middle and upper part of the Csp dinoflagellate cyst Interval Biozone of Powell (1992).

Palynostratigraphy and thermal maturity of the borehole GANE#1

GANE#1 is situated at Eqalulik, about 6 km east of the outlet of the large river Kuussuaq at the western end of the Aaffarsuaq valley (Fig. 1). The elevation of GANE#1 is 114 m a.s.l., and the hole was drilled to a total depth of 641.29 m. A side-track hole (GANE#1A) was kicked-off at 533.4 and terminated at a depth of 707 m (Bate, 1995; Dam, 1996a).

The organic geochemical analyses yielded moderately low Rock Eval T_{max} values between 432 and 443 °C throughout the sedimentary succession from -503.9 to -663.5 m suggesting a maturity level corresponding to the early part of the oil window (Christiansen *et al.*, 1996b).

The dinoflagellate cyst stratigraphy proposed for the marine Paleocene in GANE#1 is based on the study of material from 25 core samples of which 9 were barren.

Palynological intervals

Relatively low species diversity and density are recorded in GANE#1. Only a few morphologically characteristic and stratigraphically important species have been recognised, and based on their first and last occurrences it has been possible to distinguish two dinoflagellate cysts intervals within the Paleocene strata. These intervals are informally described, and a correlation is suggested to the dinoflagellate cyst interval biozones described by Powell (1992) from the North Sea region (Fig. 6).

Interval I, -503.9 to -564.7 m

Age: Selandian (Late Paleocene)

This interval is dominated by terrestrially derived black to brownish woody material, cuticles and a few bisacate pollen. Dinoflagellate cysts are rare to common. The diversity is low to moderate (2 to 17 species). The specimens are generally well preserved. Reworking of Late Cretaceous species occurs throughout (see Enclosure 2).

The interval I of GANE#1 (-503.9 to -564.7 m) may be correlated with the Selandian *Palaeoperidinium pyrophorum* (Ppy) dinoflagellate cyst Interval Biozone described from the North Sea region by Powell (1992).

Characteristic species. The interval is characterised by the presence of *Areoligera gippingensis*, *Cerodinium speciosum*, *Palaeocystodinium bulliforme* and *Palaeoperidinium pyrophorum.* At the base of the interval *Alisocysta margarita* is common. A single specimen of *Isabelidinium* aff. *viborgense* has been recorded from the base (see Enclosure 2).

Discussion. The correlation of interval I with the Selandian Ppy Interval Biozone (Powell, 1992), is, like in GANK#1, based on the FAD and LAD of *A. margarita* at the base of the interval and on the FAD of *A. gippingensis*. However, the dinoflagellate cyst assemblage differs slightly from the assemblages recorded from interval I in GANK#1.

Alisocysta margarita and *I.* aff. *viborgense* only occur at the base of the interval and are characteristically not present at higher levels. *Cerodinium diebelii* is not recorded from the present interval. The species *C. speciosum*, *C. striatum* and *Palaeocystodinium bulliforme* are rare and only occur at the top of the interval.

Interval II, -565.5 to - 663.5 m

Age: Selandian (Late Paleocene)

This interval is dominated by terrestrially derived black to brownish woody material, cuticles and few bisacate pollen. Dinoflagellate cysts are rare to common. The diversity is low (2 to 12 species). The specimens are generally well preserved. Reworking of Late Cretaceous species is relatively common in interval II (see Enclosure 2).

The lower part of GANE#1 (-565.5 to - 663.5 m) may be correlated with the Selandian *Cerodinium speciosum* (Csp) dinoflagellate cyst Interval Biozone described by Powell (1992) from the North Sea region (Fig. 6).

Characteristic species. The interval is characterised by the presence of few *Cerodinium diebelii*, *C. speciosum*, *C. striatum*, *Palaeocystodinium bulliforme* (-635.4 to -663.5 m), *Palaeoperidinium pyrophorum*, Dinocyst sp. 01 HNH 1997 (-635.4 to -649.4 m) and *Isabelidinium* aff. *viborgense* (common at -565.5 m but not recorded below; Enclosure 2).

Discussion. The presence of a few specimens of *Cerodinium speciosum*, *Palaeocystodinium bulliforme* in the interval and common *Isabelidinium* aff. *viborgense* at the top of interval II suggests a Selandian age correlating with the Csp or the older *Spinidinium densispinatum* Sde dinoflagellate cyst Interval Biozones described by Powell (1992) from the North Sea region (Fig. 6).

Palynostratigraphy and thermal maturity of the borehole GANT#1

GANT#1 is situated in the Tunorsuaq valley about 11 km ESE from where the valley converges with the Itilli valley (Fig. 1). The elevation of GANT#1 is 440 m a.s.l., and the hole was drilled to a total depth of 900.68 m (Dahl *et al.*, 1995b; Dam, 1996c). The core recovery was close to 100% in all three wells.

The organic geochemical analyses yielded moderately low Rock Eval T_{max} values between 431 and 444 °C down to -794 m suggesting a maturity level corresponding to the early part of the oil. Below -794 m T_{max} values increase slightly to 448 - 467 °C suggesting peak generation (Christiansen *et al.*, 1996b).

The dinoflagellate cyst stratigraphy proposed here for the marine Lower Paleocene and Upper Cretaceous in GANT#1 is based on the study of material from 36 samples of which 4 were barren.

Palynological intervals

The stratigraphic range of species recorded from GANT#1 are shown on the range charts (Enclosures 3 & 4). Four dinoflagellate intervals are recognised in the Early Campanian to Early Paleocene strata. These intervals are informally described, and when possible correlated to intervals described by Nøhr-Hansen (1996) from the north coast and central Nuussuaq.

Interval I, -58.2 to -133.2 m

Age: Danian (Early Paleocene)

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 moderate (up to 20 species). The specimens are generally well preserved. The Late Cretaceous dinoflagellate cyst species; *Stephodinium coronatum*, *Chatangiella* aff. *tripartita*, the genus *Isabelidinium* and the pollen genus *Aquilapollenites* are considered reworked.

The uppermost part of GANT#1 (-58.2 to -133.2 m) is correlated with the early Danian flora previously described from Annertuneq on the north coast on Nuussuaq (Nøhr-Hansen and Dam,1997).

Characteristic species. The base of the interval is characterised by the FAD of *Senoniasphaera inornata* and by the FAD and abundance of the species *Trithyrodinium fragile*. The interval is also characterised by the occurrence of *Spongodinium delitiense* in the

lowermost part and by the presence of *Alisocysta circumtabulata* in the middle part (see Enclosure 4).

Discussion. The FAD of *Senoniasphaera inornata* and the FAD and abundance of the species *Trithyrodinium fragile* has recently been recorded from sediments just above the uppermost Maastrichtian level at Annertuneq on the north Nuussuaq (Nøhr-Hansen and Dam,1997). The occurrence of *S. inornata* in the lower part of the interval suggests an age not younger than middle Danian (Costa & Davey, 1992) and not older than earliest Danian (Moshkovitz & Habib, 1993). The occurrence of *Spongodinium delitiense* in the lowermost part of the interval suggests an age not younger than early Danian (Williams *et al.*, 1993). This may be supported by the absence of *Cerodinium striatum* which according to Costa & Davey (1992), has a FAD in the late Danian. The species *C. striatum* has been recorded from younger sediment in the area (see above in the description of intervals from GANE#1 and GANK#1). According to Costa & Davey (1992) the presence of *Alisocysta circumtabulata* suggests an early Thanetian age (now Selandian). However, the species has also been reported from the basal Danian nannoplankton Zone N1 (Moshkovitz & Habib, 1993) and from the Late Maastrichtian (Schiøler *et al.*, 1997).

Palynological samples have not been studied from the coarse-grained sediments between -133.2 and -254.7 m (Fig. 5). This coarse-grained interval has been interpreted as representing canyon/major distributary turbidite channel deposits (Dam, 1996c) and is supposed to represent deposits of Maastrichtian and possibly earliest Danian age. The Cretaceous/Tertiary boundary is supposed to occur just below the base of Interval I.

Interval II, -254.7 to -401.1 m

Age: Late Campanian.

The interval is dominated by terrestrially derived black to brownish woody material, cuticles and few bisacate pollen and dinoflagellate cysts are common. The diversity is low (6-9 species), and the specimens are generally poorly preserved.

Interval II is correlated with the Late Campanian *Isabelidinium cooksoniae* interval previously described from the north coast of Nuussuaq (Nøhr-Hansen, 1996). The interval was defined by the abundance of *I. cooksoniae* and *Palaeoperidinium pyrophorum* and its upper limit being immediately below the first occurrence of *Cerodinium diebelii*.

Characteristic species. The lower part of the interval is characterised by the abundance of *I. cooksoniae* and *P. pyrophorum* and the pollen genus *Aquilapollenites* is present throughout the interval.

Interval III, -466.2 to -797.1 m

Age: Early to middle Campanian

The interval is dominated by terrestrially derived black to brownish woody material, cuticles and few bisacate pollen and dinoflagellate cysts are present. The diversity is very low (1-6 species) in the major part of the interval, and the specimens are generally poorly preserved. A questionable *Nyktericysta* species at -519.1 m may be reworked from lower Cretaceous strata.

The interval is correlated with the Late Campanian *Aquilapollenites* interval previously described from central Nuussuaq (Nøhr-Hansen, 1996). The interval was defined from the first occurrence of species of *Aquilapollenites* to the last occurrence of *Isabelidinium microarmum*.

Characteristic species. The lower part of the interval is almost barren with respect to dinoflagellate cysts. However, the upper part contains common dinoflagellate cysts and is characterised by the FAD of *Isabelidinium cooksoniae*, *I.* sp. 1 HNH 1997, *I.* cf. *microarmum* and *I. acuminatum*. The pollen genus *Aquilapollenites* is present throughout the interval.

Discussion. *Isabelidinium acuminatum* and *I.* cf. *microarmum* have previously only been recorded from central Nuussuaq, where they have their FAD within the *Aquilapollenites* interval (Nøhr-Hansen, 1996). This provides the first correlation between strata in northern and central Nuussuaq.

Interval IV, -836.7 to -894.5 m

Age: Early Campanian

The interval is dominated by terrestrially derived black to brownish woody material, cuticles and few bisacate pollen and dinoflagellate cysts are common. The diversity is low (2-9 species) and the specimens are generally poorly preserved.

The interval is correlated with the Late Santonian or Early Campanian *Dinogymnium* sp. cf. *D. sibiricum* interval previously described only from Svartenhuk Halvø north of Nuussuaq (Nøhr-Hansen, 1996). The interval was defined from immediately above the last occurrence of *Heterosphaeridium difficile* up to the last occurrence of *Dinogymnium* sp. cf. *D. sibiricum*.

Characteristic species. The interval is characterised by the FAD, LAD and the abundance of *Isabelidinium* sp. 2 HNH 1997 and by the FAD and LAD of *Dinogymnium* sp. cf. *D. sibiricum*. The stratigraphically important species *Spinidinium echinoideum* and *Trithyrodinium*

suspectum also seem to have their LAD within the interval. The pollen genus *Aquilapollenites* is present in the upper part of the interval.

Discussion. Dinogymnium sp. cf. *D. sibiricum* has previously only been recorded from the *D.* sp. cf. *D. sibiricum* interval on Svartenhuk Halvø (Nøhr-Hansen, 1996). The species *Isabelidinium* sp. 2 HNH 1997 has some morphological similarities with *Isabelidinium* sp. aff. *I. acuminatum* previously only recorded from the *D.* sp. cf. *D. sibiricum* interval (Nøhr-Hansen, 1996). The species *S. echinoideum* and *T. suspectum* have also their LAD in the *D.* sp. cf. *D. sibiricum* interval. The presence of *Aquilapollenites* and the absence of *Heterosphaeridium difficile* suggests an age not older than Early Campanian (Nøhr-Hansen, 1994a, 1996, 1997). The pollen genus *Aquilapollenites* has not been recorded from the *D.* sp. cf. *D. sibiricum* interval on Svartenhuk Halvø (Nøhr-Hansen, 1996) which may suggest that the interval IV is slightly younger, probably Early Campanian.

Conclusion

The drilled sedimentary sections in GANE#1 and GANK#1 have been dated as Selandian to ?early Thanetian. The correlation of the two boreholes is mainly based on the FAD and LAD of the dinoflagellate cyst species *Alisocysta margarita* and the FAD of *Areoligera gippingensis* which define the base of Interval I in both boreholes. Interval I has its base at -180.8 m in GANK#1 and at -564.7 m in GANE#1. It has not been possible to establish a biostratigraphic correlation between GANK#1 and GANE#1 (Selandian to ?early Thanetian) in the south and GANT#1 (Early Campanian to early Danian) in the north.

Acknowledgements

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Figure captions

Fig. 1. Map of Nuussuaq showing the drilling locations.

Fig. 2. Map showing location of previously measured and palynologically analysed sections on Nuussuaq and Svartenhuk Halvø.

Fig. 3. Simplified geological log of GANK#1 with position of samples that revealed dinoflagellate cysts. From Dam (1996b).

Fig. 4. Simplified geological log of GANE#1 with position of samples that revealed dinoflagellate cysts. From Dam (1996a).

Fig. 5. Simplified geological log of GANT#1 with position of samples that revealed dinoflagellate cysts. From Dam (1996c).

Fig. 6. Dinoflagellate cyst interval biozones by Powell (1992) from the North Sea region. The position of the Selandian/Thanetian boundary is according to Powell *et al.* (1996) situated at the base of the *Alisocysta margarita* (Ama) dinoflagellate cyst Interval Biozones (Powell, 1992) from the North Sea region. The Selandian/Thanetian boundary is now correlated with the middle part of NP 6 (Berggren *et al.*, 1995).

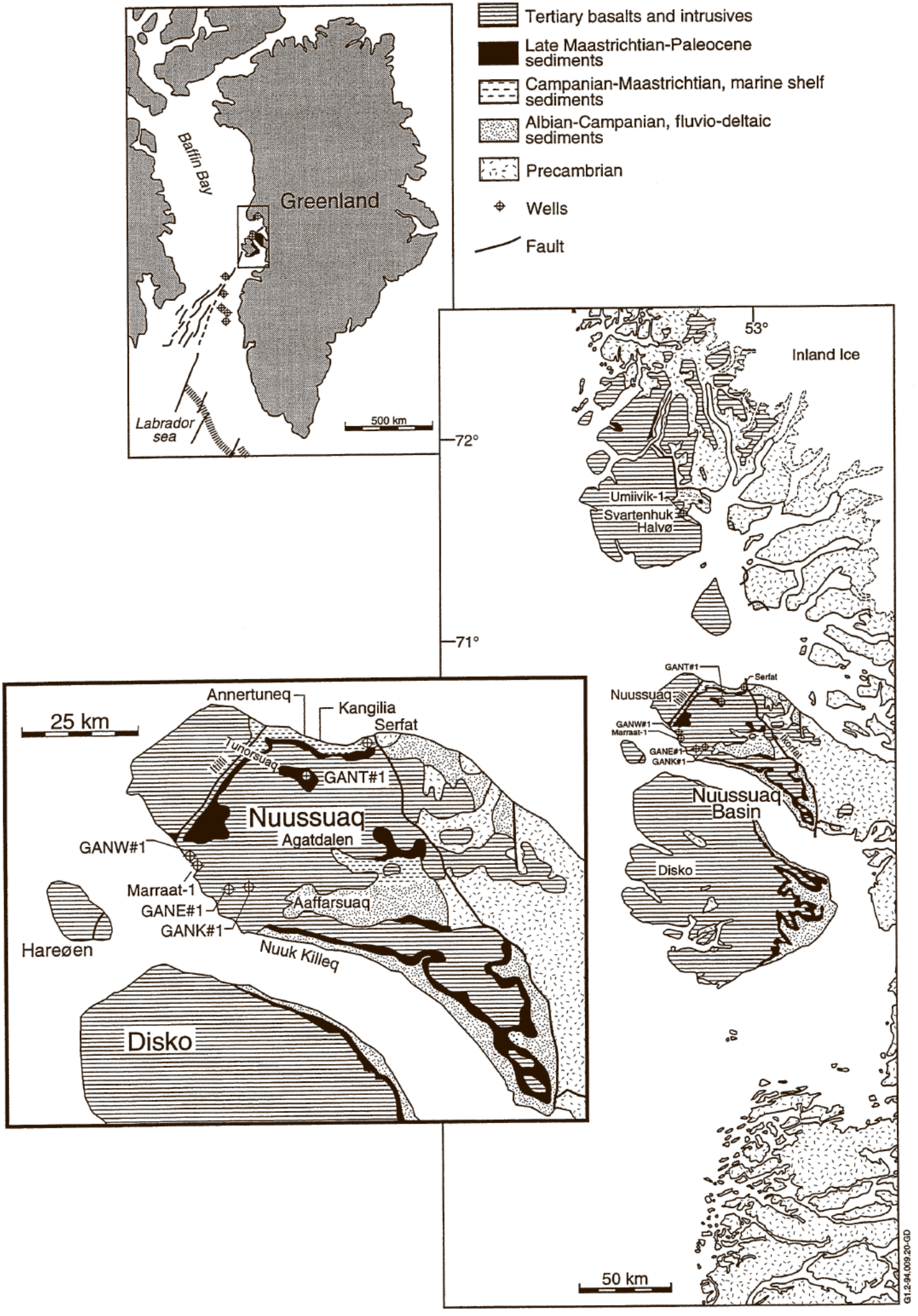

Tertiary basalts and intrusives
Late Maastrichtian-Paleocene sediments
Campanian-Maastrichtian, marine shelf sediments
Albian-Campanian, fluvio-deltaic sediments
Precambrian
Wells
Fault
Baffin Bay
Greenland
Labrador sea
500 km
53°
Inland Ice
72°
Umiivik-1
Svartenhuk Halvø
71°
GANT#1
Serfat
Nuussuaq
GANW#1
Marraat-1
GANE#1
GANK#1
Ikorfat
Nuussuaq Basin
Disko
50 km
25 km
Annertuneq
Kangilia
Serfat
Tunorsuaq
GANT#1
Nuussuaq
Agatdalen
GANW#1
Marraat-1
GANE#1
GANK#1
Aaffarsuaq
Hareøen
Nuuk Killeq
Disko
G1.2-94.009.20-GD

Fig.1

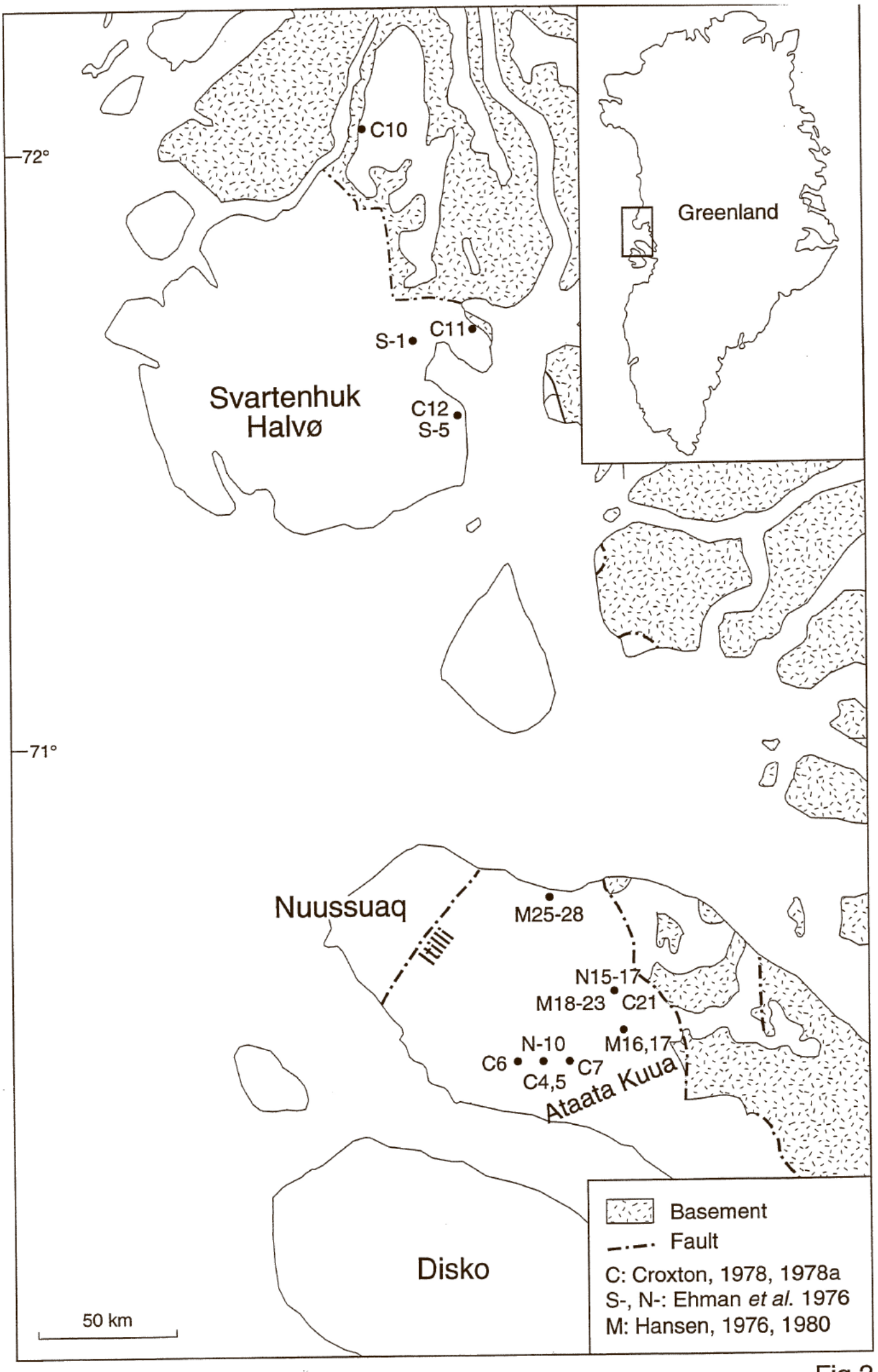
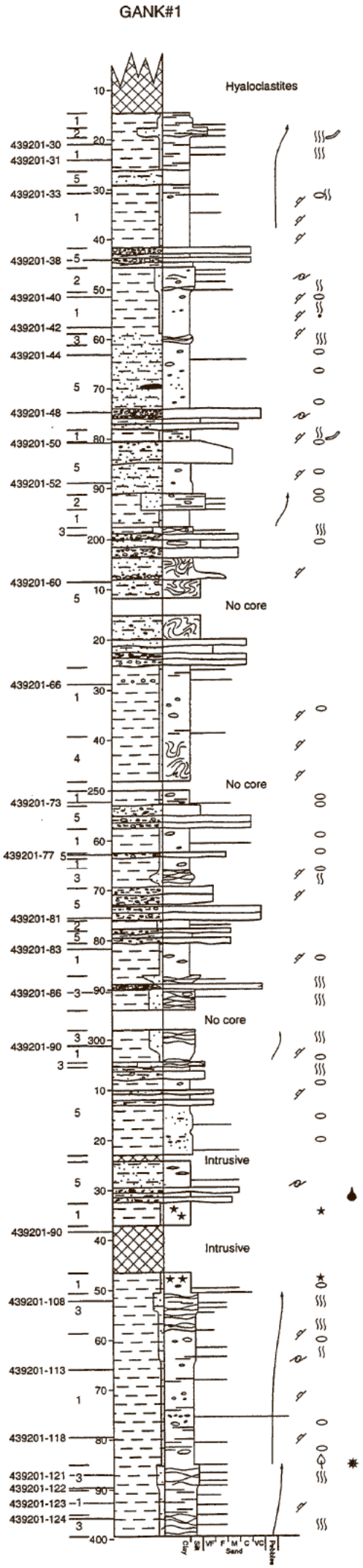

72°
71°
C10
S-1
C11
C12
S-5
Svartenhuk
Halvø
Greenland
Nuussuaq
Itilli
M25-28
N15-17
M18-23
C21
N-10
M16,17
C6
C7
C4,5
Ataata Kuua
Disko
50 km
Basement
Fault
C: Croxton, 1978, 1978a
S-, N-: Ehman et al. 1976
M: Hansen, 1976, 1980

Fig.2



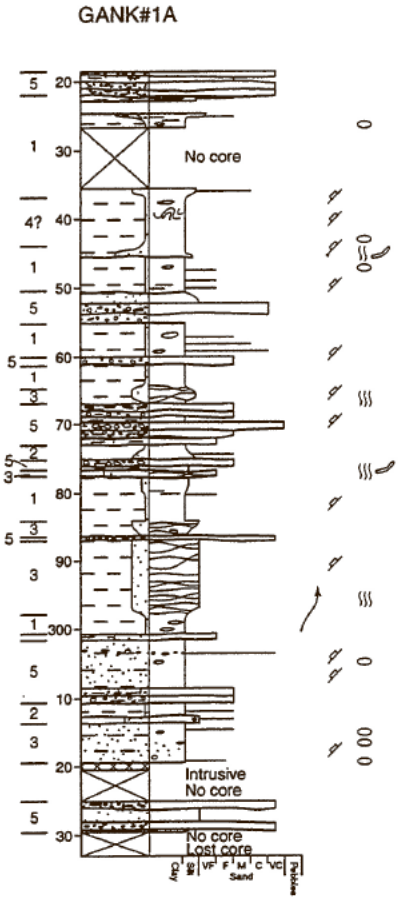


Fig. 3

G6.1-96.023/GD

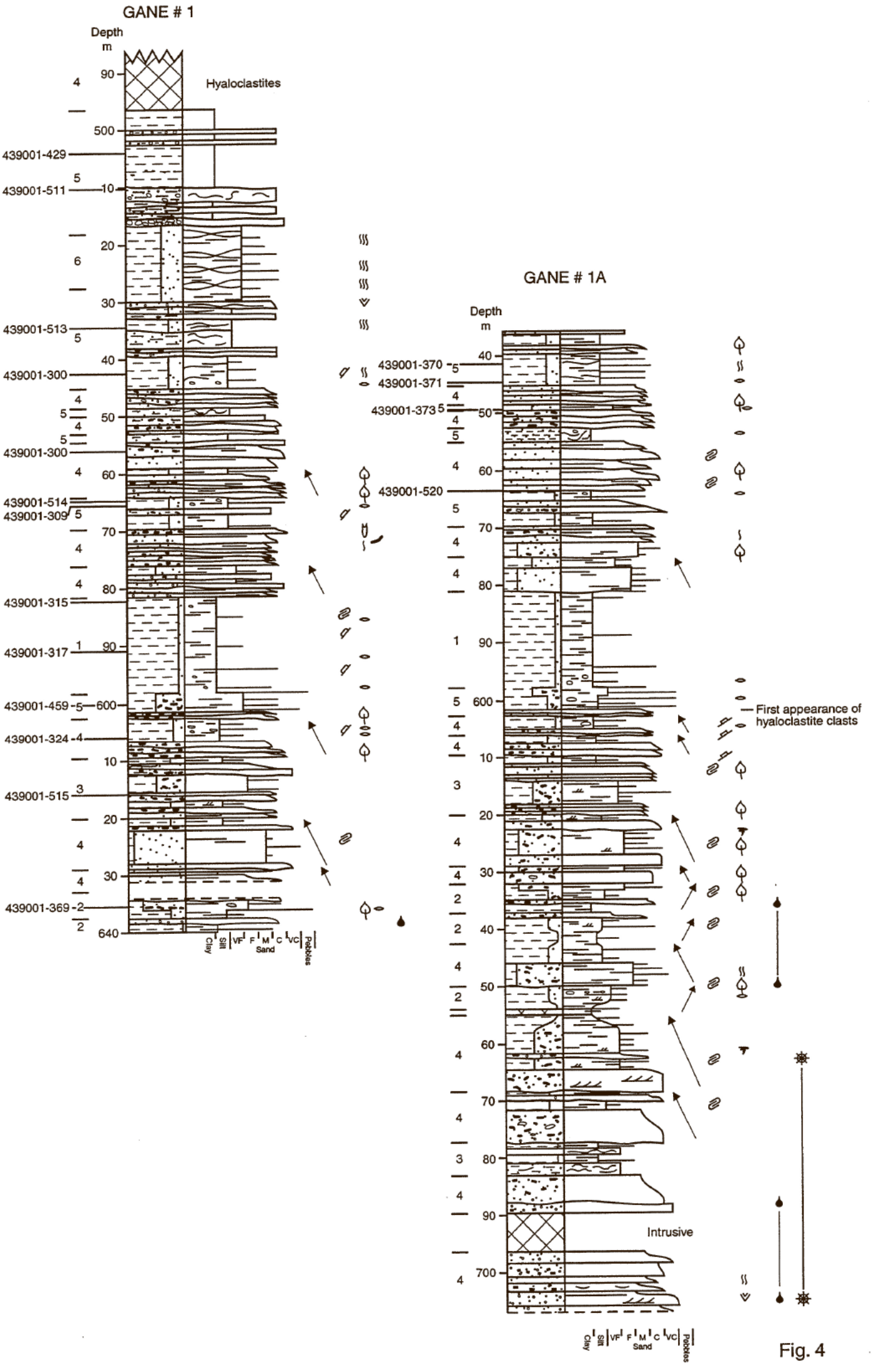

GANE # 1
Depth
m
Hyaloclastites
439001-429
439001-511
439001-513
439001-300
439001-300
439001-514
439001-309
439001-315
439001-317
439001-459
439001-324
439001-515
439001-369
Clay
Silt
VF
F
M
C
VC
Sand
Pebbles
GANE # 1A
Depth
m
439001-370
439001-371
439001-373
439001-520
First appearance of
hyaloclastite clasts
Intrusive
Clay
Silt
VF
F
M
C
VC
Sand
Pebbles

Fig. 4

GANT#1

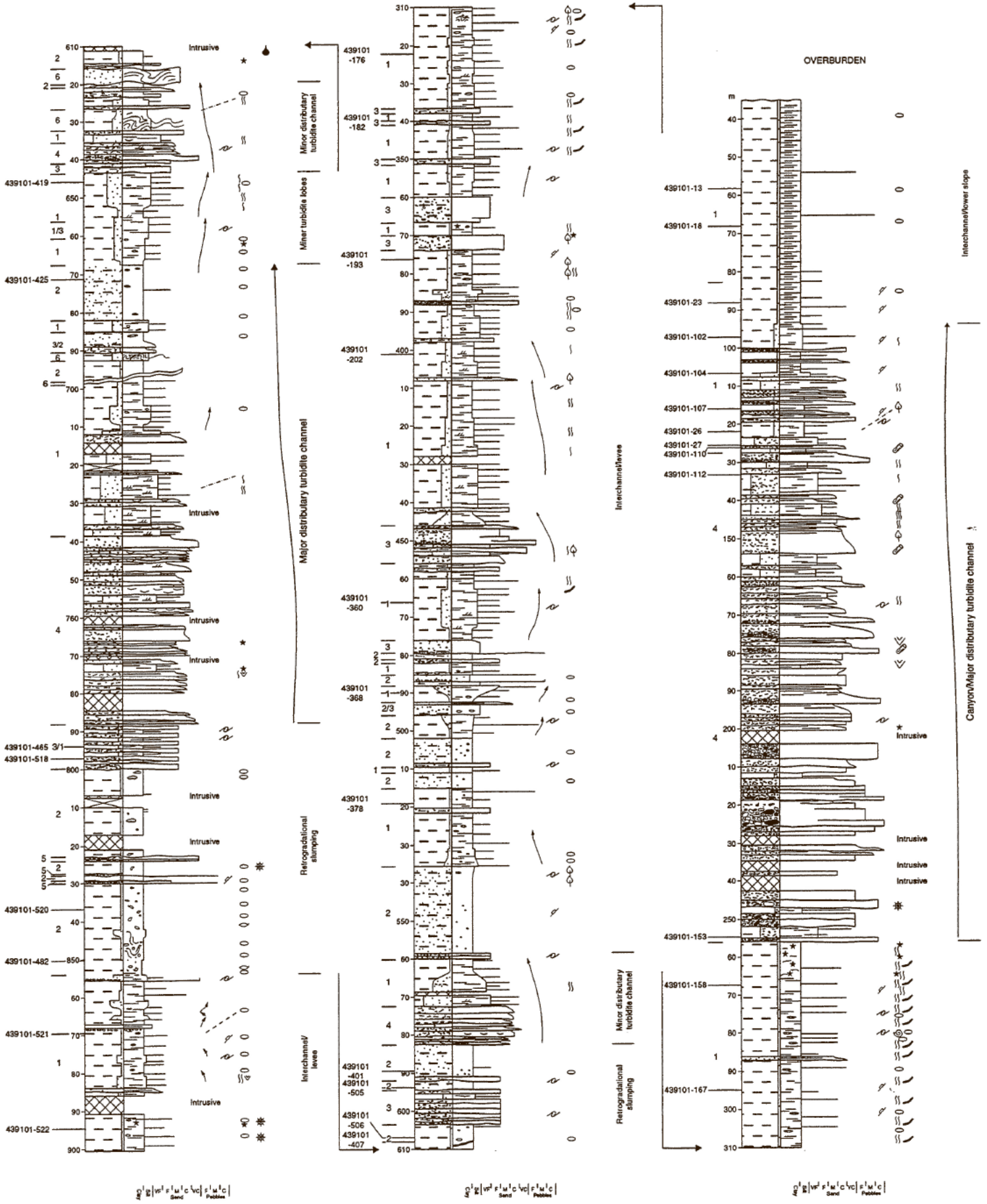

OVERBURDEN
Intrusive
Minor distributary turbidite channel
Miner turbidite lobes
Major distributary turbidite channel
Retrogradational slumping
Interchannel/ levee
Interchannel/levee
Minor distributary turbidite channel
Retrogradational slumping
Interchannel/lower slope
Canyon/Major distributary turbidite channel
439101-419
439101-425
439101-465
439101-518
439101-520
439101-482
439101-521
439101-522
439101-176
439101-182
439101-193
439101-202
439101-360
439101-368
439101-378
439101-401
439101-505
439101-506
439101-407
439101-13
439101-18
439101-23
439101-102
439101-104
439101-107
439101-26
439101-27
439101-110
439101-112
439101-153
439101-158
439101-167

Fig. 5

LEGEND

Facies associations

1 Thinly interbedded sandstone and mudstone

2 Massive sandy mudstone

3 Massive muddy sandstone

4 Amalcamated sandstones and conglomerates

5 Single graded sandstone beds

6 Slumped beds

 Volcanic sills

 Clay and siltstone

 Muddy sandstone/sandy mudstone

 Sandstone

 Sandstone with pebbles and mudstone clasts

 Parallel lamination

 Slumbing

 Disturbed bedding

 Cross-lamination

 Bioturbation

 Concretions

 Ammonite

 Bivalve

 Plant and wood fragments

 Logs

 Weakly bioturbated

 Moderately bioturbated

 Heavily bioturbated

 *Planolites* isp.

 *Helminthopsis horizontalis*

 Escape burrows

 Fractures

 Pyrite

 Oil

 Gas

 CU-succession

 FU-succession

Fig. 5 continued

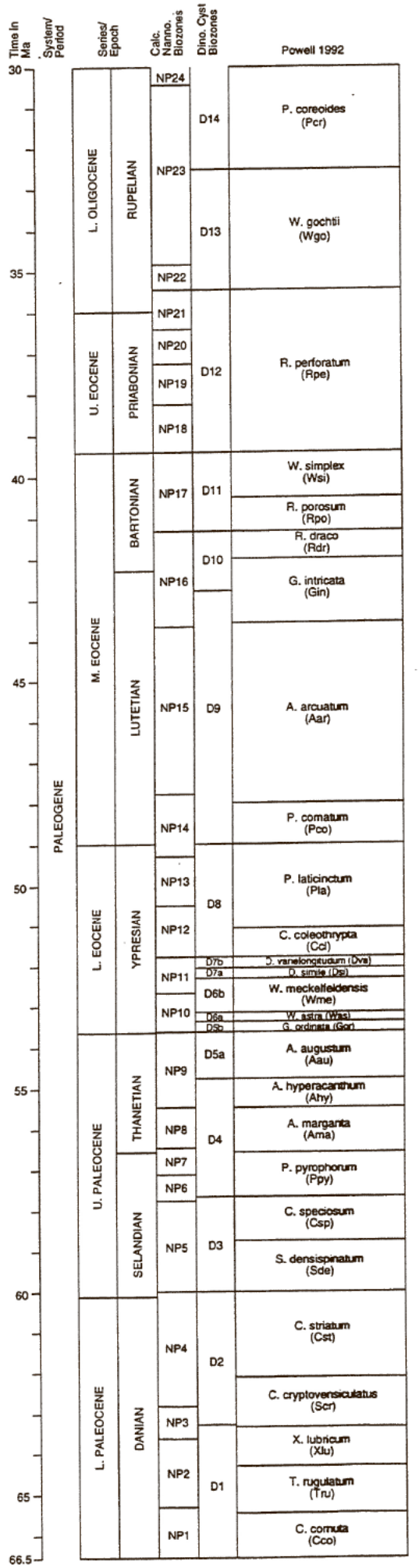

Time in Ma
System/ Period
Series/ Epoch
Calc. Nanno. Biozones
Dino. Cyst Biozones
Powell 1992
30
35
40
45
50
55
60
65
66.5
PALEOGENE
L. OLIGOCENE
RUPELIAN
U. EOCENE
PRIABONIAN
M. EOCENE
BARTONIAN
LUTETIAN
L. EOCENE
YPRESIAN
U. PALEOCENE
THANETIAN
SELANDIAN
L. PALEOCENE
DANIAN
NP24
NP23
NP22
NP21
NP20
NP19
NP18
NP17
NP16
NP15
NP14
NP13
NP12
NP11
NP10
NP9
NP8
NP7
NP6
NP5
NP4
NP3
NP2
NP1
D14
D13
D12
D11
D10
D9
D8
D7b
D7a
D6b
D6a
D5b
D5a
D4
D3
D2
D1
P. coreoides (Pcr)
W. gochtii (Wgo)
R. perforatum (Rpe)
W. simplex (Wsi)
R. porosum (Rpo)
R. draco (Rdr)
G. intricata (Gin)
A. arcuatum (Aar)
P. comatum (Pco)
P. laticinctum (Pla)
C. coleothrypta (Ccl)
D. vanelongistudum (Dva)
D. simile (Dsi)
W. meckelfeldensis (Wme)
W. astra (Was)
G. ordinata (Gor)
A. augustum (Aau)
A. hyperacanthum (Ahy)
A. marganta (Ama)
P. pyrophorum (Ppy)
C. speciosum (Csp)
S. densispinatum (Sde)
C. striatum (Cst)
C. cryptovensiculatus (Scr)
X. lubricum (Xlu)
T. rugulatum (Tru)
C. cornuta (Cco)

Fig. 6.

Enclosures

Enclosure 1. Range chart of the recorded palynomorphs, with division of GANK#1 into two palynological intervals.

Enclosure 2. Range chart of the recorded palynomorphs, with division of GANE#1 into two palynological intervals.

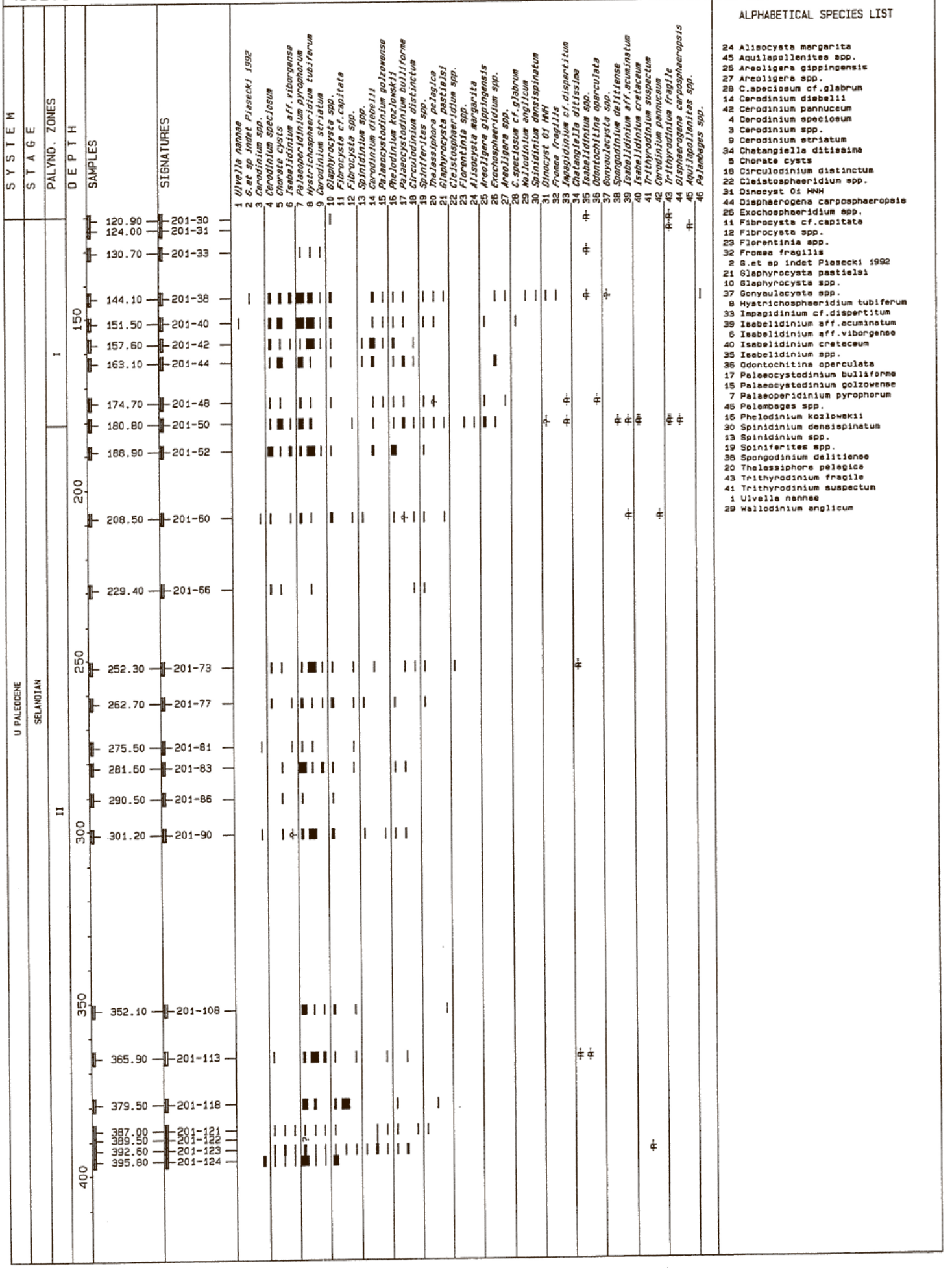
Enclosure 3. Range chart of the recorded palynomorphs, with division of GANT#1 into four palynological intervals.

Enclosure 4. Detailed range chart of the recorded palynomorphs from the upper part of GANT#1.

ENCLOSURE 1 | SHEET: 1 | SCALE: 1: 1000 | Groups: A D S P E | Complete spp. set

GEUS

439201 GANK#1 (120 - 395m)



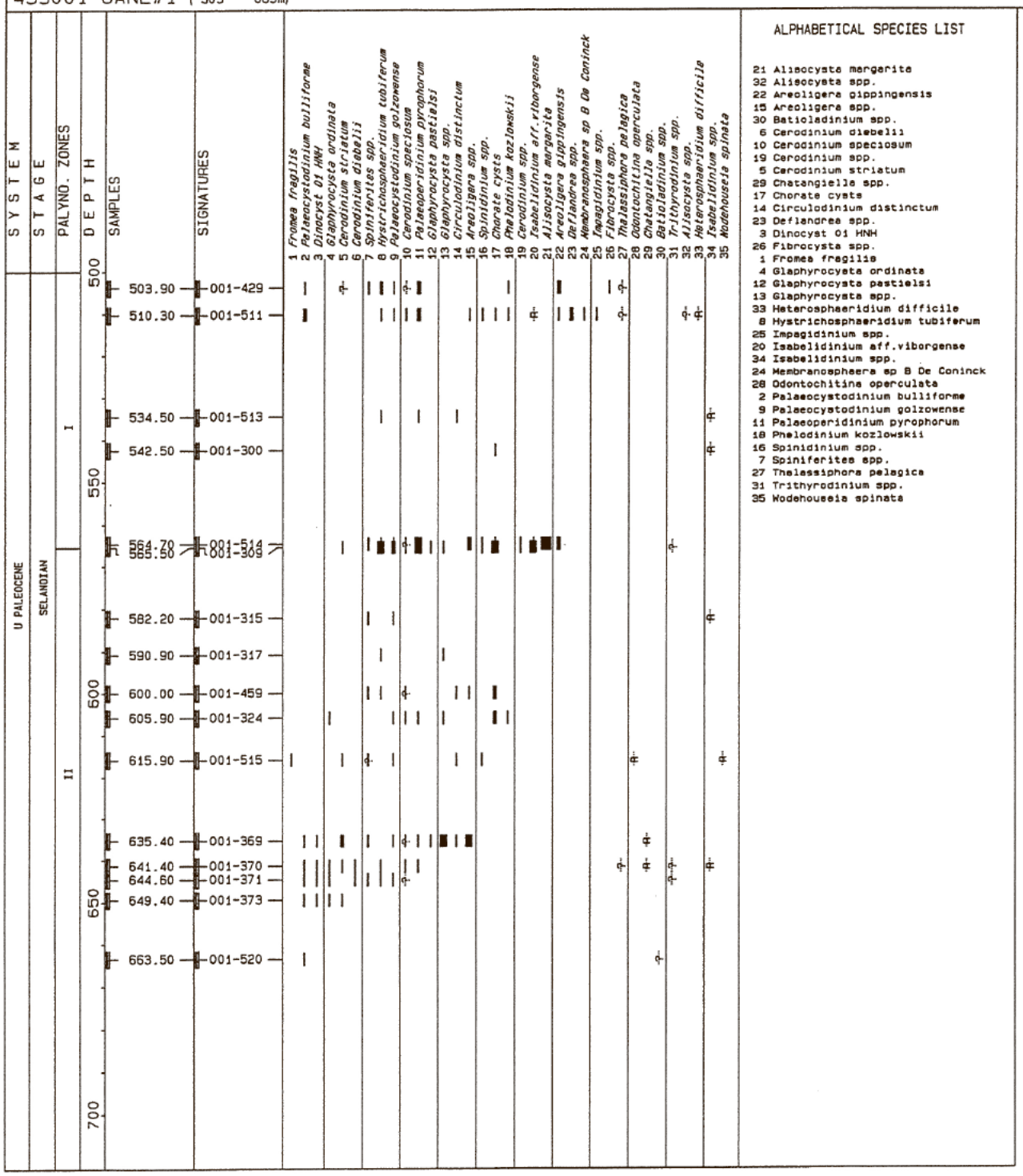
ALPHABETICAL SPECIES LIST

24 Alisocysta margarita
45 Aquilapollenites spp.
25 Areoligera gippingensis
27 Areoligera spp.
28 C.speciosum cf.glabrum
14 Cerodinium diebelii
42 Cerodinium pannuceum
4 Cerodinium speciosum
3 Cerodinium spp.
9 Cerodinium striatum
34 Chatangiella ditissima
5 Chorate cysts
18 Circulodinium distinctum
22 Cleistosphaeridium spp.
31 Dinocyst 01 MNH
44 Disphaerogena carposphaeropsis
26 Exochosphaeridium spp.
11 Fibrocysta cf.capitata
12 Fibrocysta spp.
23 Florentinia spp.
32 Fromea fragilis
2 G.et sp indet Piasecki 1992
21 Glaphyrocysta pastielsi
10 Glaphyrocysta spp.
37 Gonyaulacysta spp.
8 Hystrichosphaeridium tubiferum
33 Impagidinium cf.dispertitum
39 Isabelidinium aff.acuminatum
6 Isabelidinium aff.viborgense
40 Isabelidinium cretaceum
35 Isabelidinium spp.
36 Odontochitina operculata
17 Palaeocystodinium bulliforme
15 Palaeocystodinium golzowense
7 Palaeoperidinium pyrophorum
46 Palambages spp.
16 Phelodinium kozlowskii
30 Spinidinium densispinatum
13 Spinidinium spp.
19 Spiniferites spp.
38 Spongodinium delitiense
20 Thalassiphora pelagica
43 Trithyrodinium fragile
41 Trithyrodinium suspectum
1 Ulvella nannae
29 Wallodinium anglicum

ENCLOSURE 2 | SHEET: 1 | SCALE: 1: 1000 | Groups: A D S P E | Complete spp. set

GEUS

439001 GANE#1 (503 - 683m)



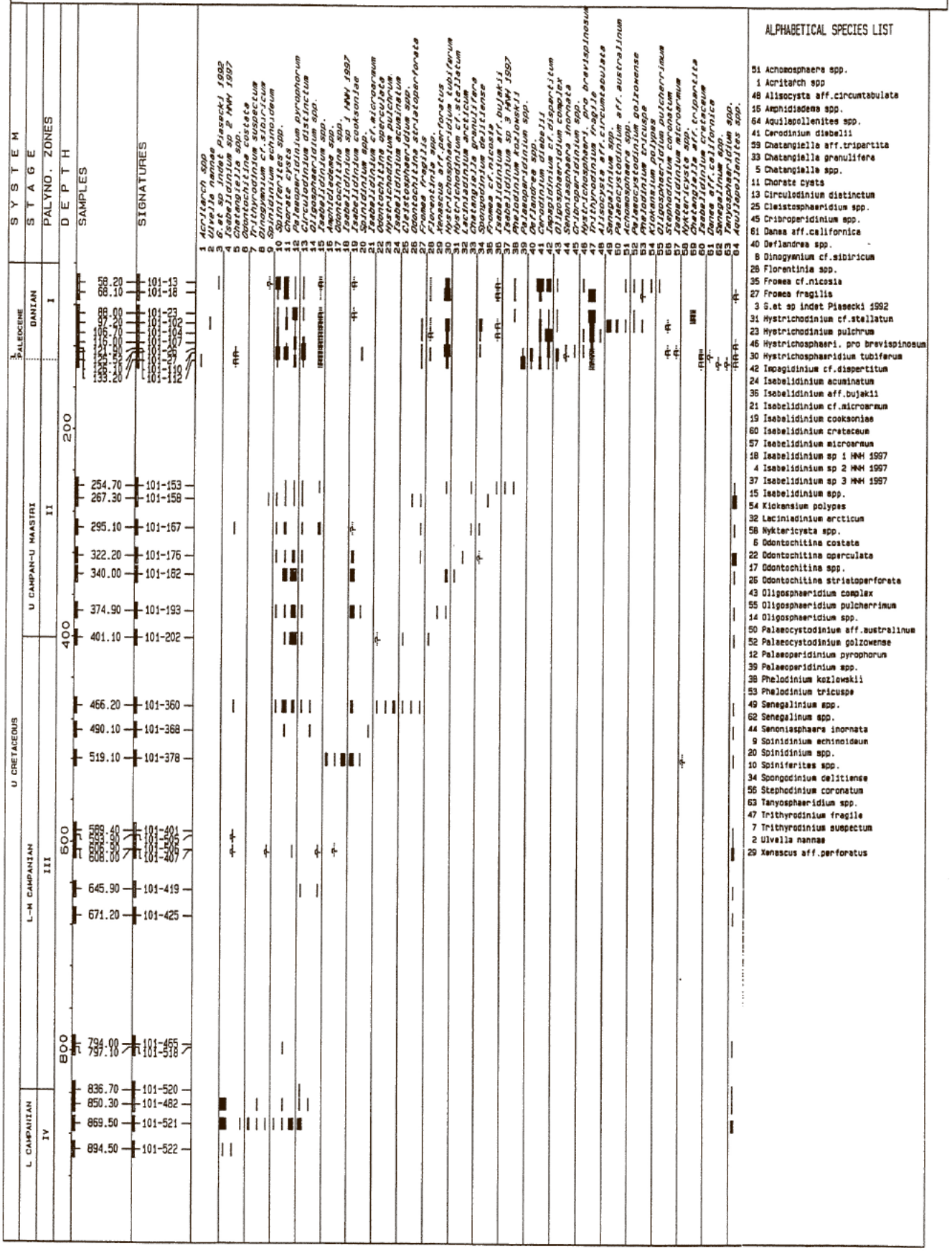
ALPHABETICAL SPECIES LIST

21 Alisocysta margarita
32 Alisocysta spp.
22 Areoligera gippingensis
15 Areoligera spp.
30 Batioladinium spp.
6 Cerodinium diebelii
10 Cerodinium speciosum
19 Cerodinium spp.
5 Cerodinium striatum
29 Chatangiella spp.
17 Chorate cysts
14 Circulodinium distinctum
23 Deflandrea spp.
3 Dinocyst 01 HNH
26 Fibrocysta spp.
1 Fromea fragilis
4 Glaphyrocysta ordinata
12 Glaphyrocysta pastielsi
13 Glaphyrocysta spp.
33 Heterosphaeridium difficile
8 Hystrichosphaeridium tubiferum
25 Impagidinium spp.
20 Isabelidinium aff.vibergense
34 Isabelidinium spp.
24 Membranosphaera sp B De Coninck
28 Odontochitina operculata
2 Palaeocystodinium bulliforme
9 Palaeocystodinium golzowense
11 Palaeoperidinium pyrophorum
18 Phelodinium kozlowskii
16 Spinidinium spp.
7 Spiniferites spp.
27 Thalassiphora pelagica
31 Trithyrodinium spp.
35 Wodehouseia spinata

ENCLOSURE 3 SHEET: 1 Groups: A D S P E
SCALE: 1: 4000 Complete spp. set

GEUS

439101 GANT#1 (58 - 894m)



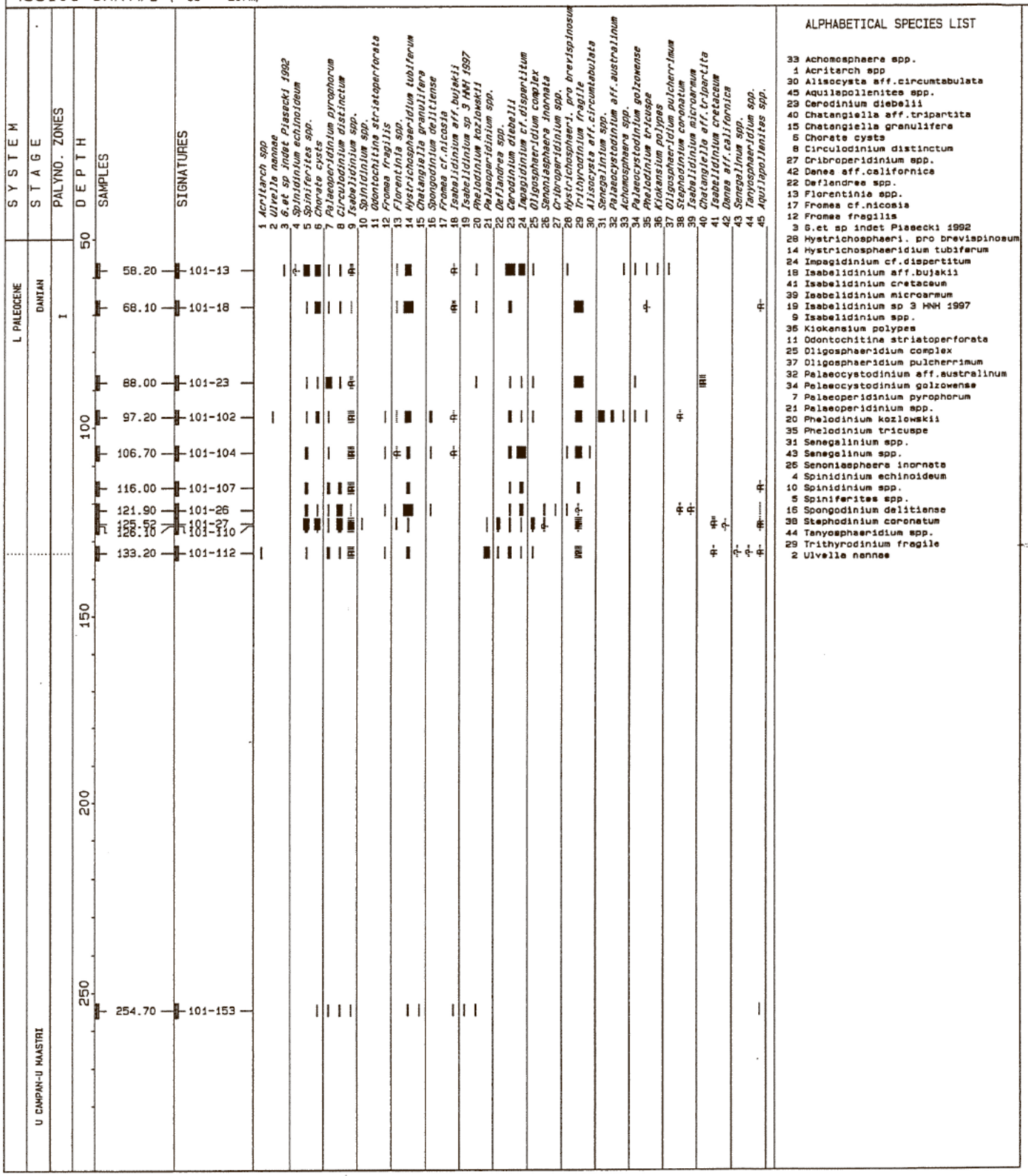
ALPHABETICAL SPECIES LIST

51 Achomosphaera spp.
1 Acritarch spp
48 Alisocysta aff.circumtabulata
15 Amphidiadema spp.
64 Aquilapollenites spp.
41 Cerodinium diebelii
59 Chatangiella aff.tripartita
33 Chatangiella granulifera
5 Chatangiella spp.
11 Chorate cysts
13 Circulodinium distinctum
25 Cleistosphaeridium spp.
45 Cribroperidinium spp.
61 Danea aff.californica
40 Deflandrea spp.
8 Dinogymnium cf.sibiricum
28 Florentinia spp.
35 Fromea cf.nicosia
27 Fromea fragilis
3 G.et sp indet Piasecki 1992
31 Hystrichodinium cf.stellatum
23 Hystrichodinium pulchrum
46 Hystrichosphaeri. pro brevispinosum
30 Hystrichosphaeridium tubiferum
42 Impagidinium cf.dispertitum
24 Isabelidinium acuminatum
36 Isabelidinium aff.bujakii
21 Isabelidinium cf.microarmum
19 Isabelidinium cooksoniae
60 Isabelidinium cretaceum
57 Isabelidinium microarmum
18 Isabelidinium sp 1 HNH 1997
4 Isabelidinium sp 2 HNH 1997
37 Isabelidinium sp 3 HNH 1997
15 Isabelidinium spp.
54 Kiokansium polypes
32 Laciniadinium arcticum
58 Nyktericysta spp.
6 Odontochitina costata
22 Odontochitina operculata
17 Odontochitina spp.
25 Odontochitina striatoperforata
43 Oligosphaeridium complex
55 Oligosphaeridium pulcherrimum
14 Oligosphaeridium spp.
50 Palaeocystodinium aff.australinum
52 Palaeocystodinium golzowense
12 Palaeoperidinium pyrophorum
39 Palaeoperidinium spp.
38 Phelodinium kozlowskii
53 Phelodinium tricuspe
49 Senegalinium spp.
62 Senegalinum spp.
44 Senoniasphaera inornata
9 Spinidinium echinoideum
20 Spinidinium spp.
10 Spiniferites spp.
34 Spongodinium delitiense
56 Stephodinium coronatum
63 Tanyosphaeridium spp.
47 Trithyrodinium fragile
7 Trithyrodinium suspectum
2 Ulvella nannas
29 Xenascus aff.perforatus

ENCLOSURE 4 | SHEET: 1 | SCALE: 1: 1000 | Groups: A D S P E | Complete spp. set

GEUS

439101 GANT#1 (58 - 267m)



ALPHABETICAL SPECIES LIST

33 Achomosphaera spp.
1 Acritarch spp
30 Alisocysta aff.circumtabulata
45 Aquilapollenites spp.
23 Cerodinium diebelii
40 Chatangiella aff.tripartita
15 Chatangiella granulifera
6 Chorate cysts
8 Circulodinium distinctum
27 Cribroperidinium spp.
42 Danea aff.californica
22 Deflandrea spp.
13 Florentinia spp.
17 Fromea cf.nicosia
12 Fromea fragilis
3 6.et sp indet Piasecki 1992
28 Hystrichosphaeri. pro brevispinosum
14 Hystrichosphaeridium tubiferum
24 Impagidinium cf.dispertitum
18 Isabelidinium aff.bujakii
41 Isabelidinium cretaceum
39 Isabelidinium microarmum
19 Isabelidinium sp 3 HNH 1997
9 Isabelidinium spp.
36 Kiokansium polypes
11 Odontochitina striatoperforata
25 Oligosphaeridium complex
37 Oligosphaeridium pulcherrimum
32 Palaeocystodinium aff.australinum
34 Palaeocystodinium golzowense
7 Palaeoperidinium pyrophorum
21 Palaeoperidinium spp.
20 Phelodinium kozlowskii
35 Phelodinium tricuspe
31 Senegalinium spp.
43 Senegalinum spp.
26 Senoniasphaera inornata
4 Spinidinium echinoideum
10 Spinidinium spp.
5 Spiniferites spp.
16 Spongodinium delitiense
38 Stephodinium coronatum
44 Tanyosphaeridium spp.
29 Trithyrodinium fragile
2 Ulvella nannae

Plate 1, GANK#1.

Fig. 1. *Isabelidinium* aff. *viborgense*, GGU 439201-38-4, 24.9–108.0; LVR 1.8863; MI 6396.

Fig. 2. *Isabelidinium* aff. *viborgense*, GGU 439201-38-4, 30.3–94.4; LVR 1.8864; MI 6397.

Fig. 3. *Isabelidinium* aff. *acuminatum*, GGU 439201-50-3, 25.9-100.0; LVR 1.8888; MI 6415.

Fig. 4. *Isabelidinium cretaceum*, GGU 439201-50-7, 42.3–99.5; LVR 1.8890; MI 6416.

Fig. 5. *Isabelidinium cretaceum*, GGU 439201-50-7, 47.3–102.0; LVR 1.8891; MI 6417.

Fig. 6. *Isabelidinium cretaceum*, GGU 439201-50-7, 42.8–112.3; LVR 1.8892; MI 6418.

Fig. 7. *Palaeocystodinium bulliforme*, GGU 439201-37-7, 41.0–97.6; LVR 1.8875; MI 6404.

Fig. 8. *Palaeocystodinium bulliforme*, GGU 439201-48-9, 36.9–111.6; LVR 1.8884; MI 6411.

Fig. 9. *Palaeocystodinium bulliforme*, (lenght: 259 μm) GGU 439201-44.8, 52.8–104.2; LVR 1.8881; MI 6409.

Fig. 10. *Palaeocystodinium golzowense*, GGU 439201-48.8, 33.7–108.0; LVR 1.8886; MI 6413.

Fig. 11. *Cerodinium speciosum*, GGU 439201-40.5, 42.0–103.5; LVR 1.8878; MI 6407.

Fig. 12. *Cerodinium speciosum* supsp. *glabrum*, GGU 439201-40-5, 43.5–111.5 LVR 1.8879; MI 6408.

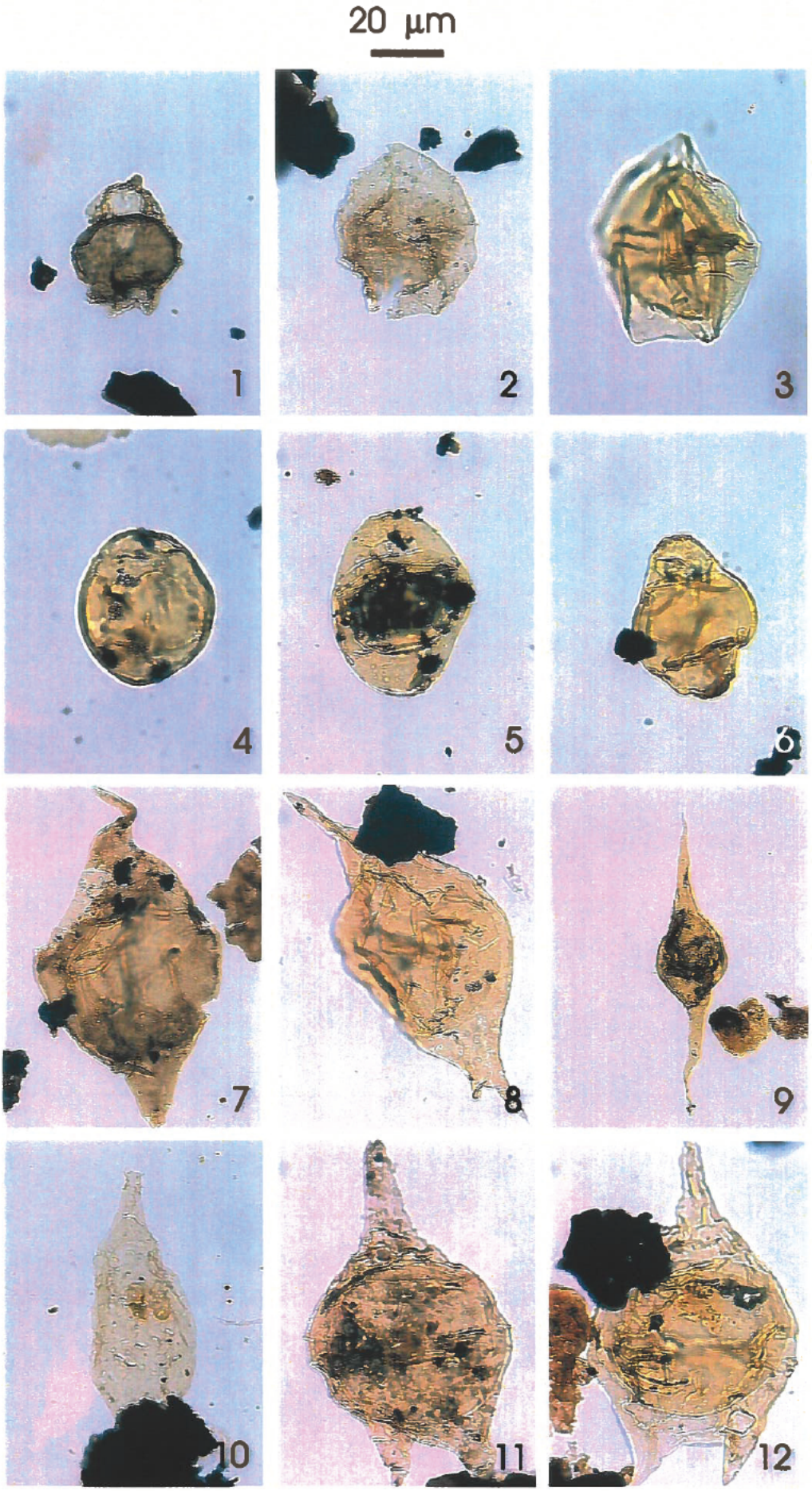

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Plate 2, GANK#1.

Fig. 1. Dinocyst 01 HNH, 1997, GGU 439201-38-4, 21.3–96.8; LVR 1.8867; MI 6399.

Fig. 2. Dinocyst 01 HNH, 1997, GGU 439201-38-4, 21.3–96.8; LVR 1.8868; MI 6399.

Fig. 3. Dinocyst 01 HNH, 1997, GGU 439201-38-4, 21.0-101.1; LVR 1.8870; MI 6400.

Fig. 4. *Gonyaulacysta*? sp., GGU 439201-38-4, 23.3–102.8; LVR 1.8858; MI 6394.

Fig. 5. Gen. et sp. Indet. Piasecki 1992, GGU 439201-38-7, 28.9–104.1; LVR 1.8874; MI 6403.

Fig. 6. *Glaphyrocysta gippingensis*, GGU 439201-40-5, 29.9–111.0; LVR 1.8876; MI 6405.

Fig. 7. *Impagidinium* cf. *dispertitum*, GGU 439201-50-4, 33.2–96.4; LVR 1.8893; MI 6419.

Fig. 8. *Impagidinium* cf. *dispertitum*, GGU 439201-50.-, 33.2–96.4; LVR 1.8894; MI 6419.

Fig. 9. *Fibroysta* cf. *capitata*, GGU 439201-118-4, 28.7-99.0; LVR 1.8898; MI 6422.

Fig. 10. *Fibroysta* cf. *capitata*, GGU 439201-118-4, 26.7-106.7; LVR 1.8896; MI 6421.

Fig. 11. *Fibroysta* cf. *capitata*, GGU 439201-118-4, 26.7-106.7; LVR 1.8897; MI 6421.

Fig. 12. *Fibroysta* cf. *capitata*, GGU 439201-118-4, 31.0-98.3; LVR 1.8899; MI 6423.

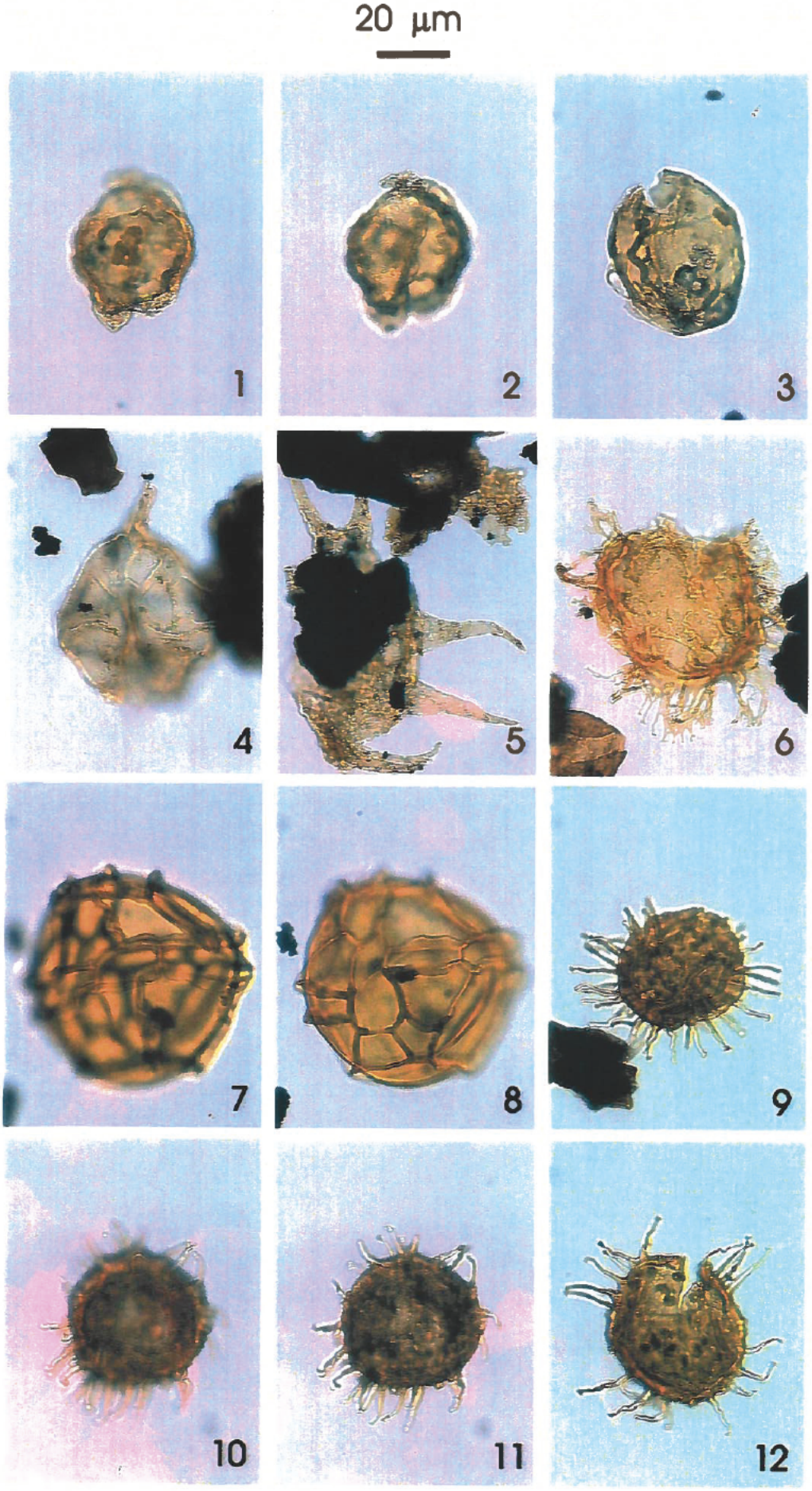
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Plate 3, GANE#1.

Fig. 1. *Alisocysta margarita*, GGU 439001-514-4, 18.8–113.7; LVR 1.8839; MI 6383.

Fig. 2. *Alisocysta margarita*, GGU 439001-514-4, 18.8–113.7; LVR 1.8840; MI 6383.

Fig. 3. *Alisocysta margarita*, GGU 439001-514-6, 47.3–104.9; LVR 1.8841; MI 6384.

Fig. 4. Dinocyst 01 HNH, 1997, GGU 439001-370-4, 23.0–94.3; LVR 1.8847; MI 6388.

Fig. 5. Dinocyst 01 HNH, 1997, GGU 439001-370-4, 26.7–95.2; LVR 1.8849; MI 6389.

Fig. 6. Dinocyst 01 HNH, 1997, GGU 439001-369-4, 23.5–98.3; LVR 1.8844; MI 6387.

Fig. 7. Dinocyst 01 HNH, 1997, GGU 439001-370-4, 25.0–100.5; LVR 1.8854; MI 6392.

Fig. 8. Dinocyst 01 HNH, 1997, GGU 439001-370-4, 36.5–102.8; LVR 1.8851; MI 6390.

Fig. 9. *Trithyrodinium* sp., GGU 439001-370-3, 20.6–108.8; LVR 1.8853; MI 6391

Fig. 10. *Areoligera gippingensis*, GGU 439001-514-4, 24.3-103.6; LVR 1.8842; MI 6385.

Fig. 11. *Cerodinium striatum*, GGU 439001-515-4, 33.6-102.6; LVR 1.8843; MI 6386.

Fig. 12. *Paleocystodinium bulliforme*, GGU 439001-371-4, 50.9-105.2; LVR 1.8856; MI 6393.

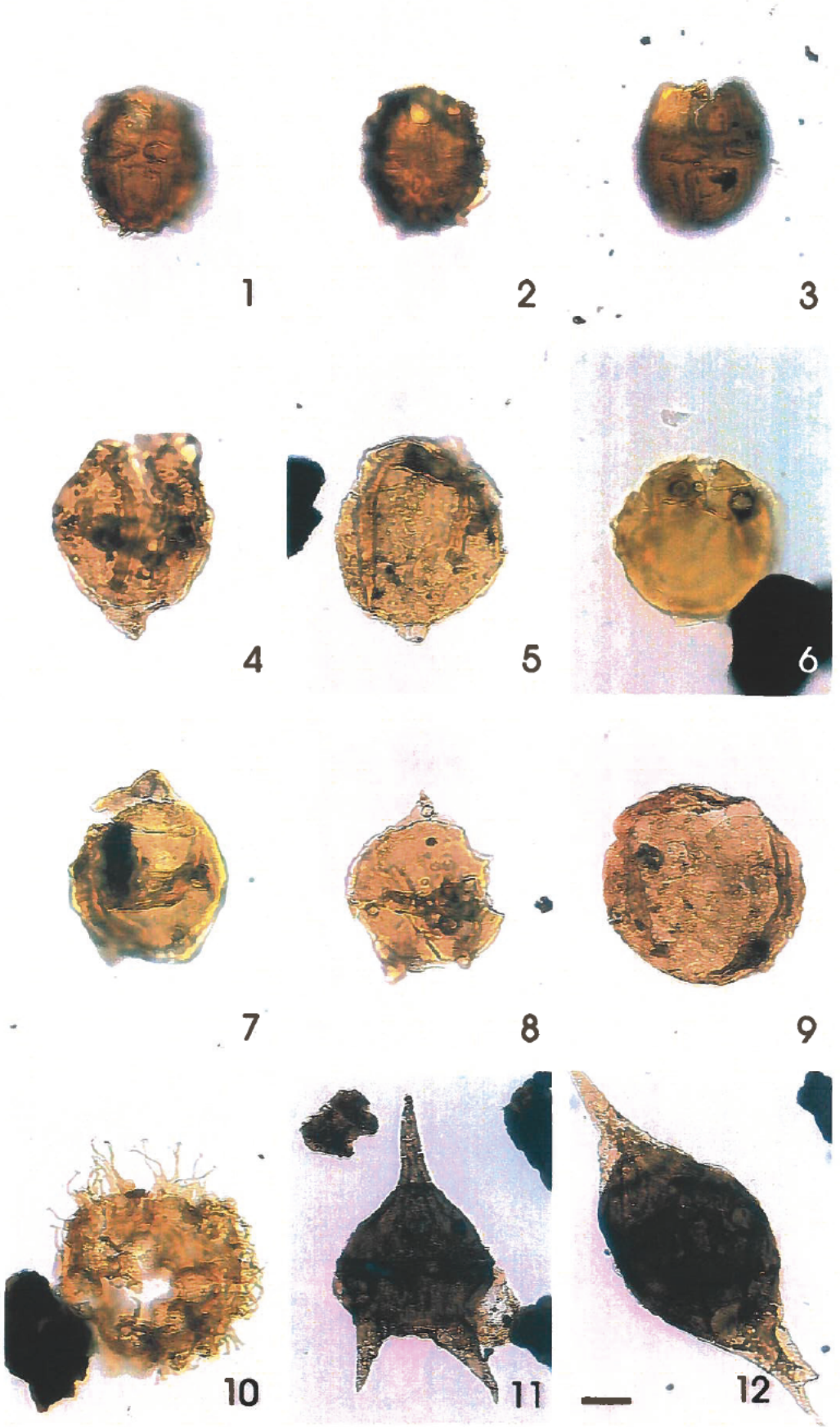
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Plate 4, GANT#1.

Fig. 1 *Trithyrodinium fragile*, GGU 439101-23-2, 46.5–103.9; LVR 1.9123; MI 6578.

Fig. 2. ?*Trithyrodinium fragile*, GGU 439101-112-10, 33.1–111.7; LVR 1.9122; MI 6577.

Fig. 3. *Alisocysta circumtabulata*, GGU 439101-104-9, 53.5–99.4; LVR 1.9125; MI 6579.

Fig. 4. *Senoniasphaera inornatum*, GGU 439101-27-9, 39.8–97.4; LVR 1.9126; MI 6580.

Fig. 5. *Senoniasphaera inornatum*, GGU 439101-27-10, 38.5–107.7; LVR 1.9127; MI 6581.

Fig. 6. *Senoniasphaera inornatum*, GGU 439101-27-10, 38.5–107.7; LVR 1.9128; MI 6581.

Fig. 7. *Deflandrea* sp., GGU 439101-27-9, 47.9–106.4; LVR 1.9129; MI 6582.

Fig. 8. *Deflandrea* sp., GGU 439101-27-9, 54.2–106.1; LVR 1.9130; MI 6583.

Fig. 9. *Paleoperidinium* sp., GGU 439101-112-6, 23.4–109.8; LVR 1.9131; MI 6584.

Fig. 10. *Paleoperidinium* sp., GGU 439101-110-9, 32.3–108.2; LVR 1.9132; MI 6585.

Fig. 11. ?*Danea* aff. *californica,* GGU 439101-110-69, 43.9–112.9; LVR 1.9133 MI 6586.

Fig. 12. ?*Danea* aff. *californica,* GGU 439101-110-69, 43.9–112.9; LVR 1.9134 MI 6586.

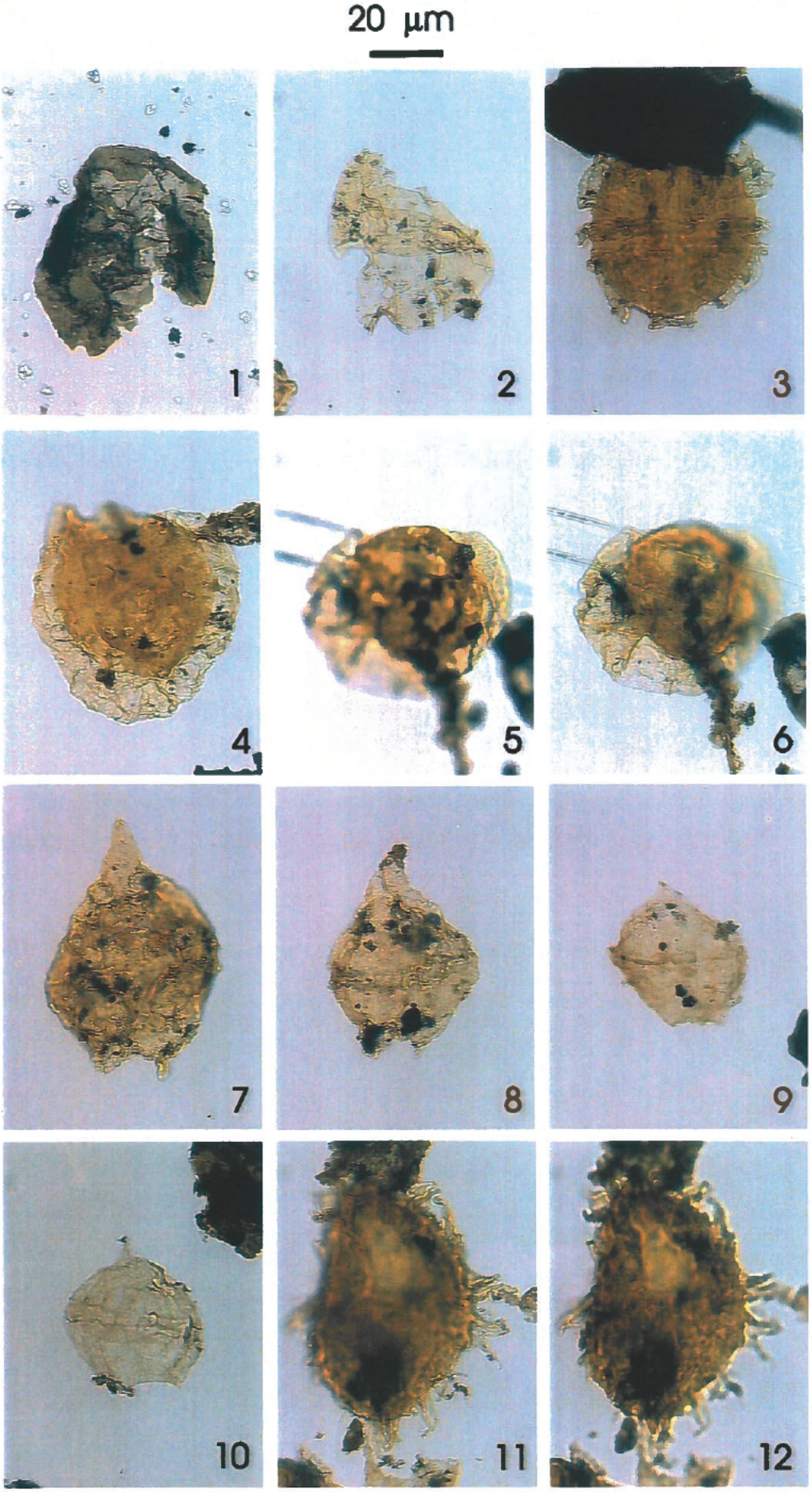
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Plate 5, GANT#1.

Fig. 1. Gen. et sp. Indet. Piasecki 1992, GGU 439101-13-9, 36.9–103.2; LVR 1.8900; MI 6424.

Fig. 2. *Chatangiella* aff. tripartita, GGU 439101-23-4, 48.4–104.0; LVR 1.8901; MI 6425.

Fig. 3. *Chatangiella* aff. tripartita, GGU 439101-23-4, 20.6–104.4; LVR 1.8902; MI 6426.

Fig. 4. *Hystrichosphaeridium tubiferum*, GGU 439101-102-4, 28.3–111.3; LVR 1.8903; MI 6427.

Fig. 5. *Palaeocystodinium* aff. *australinum*, 439101-102-4, 26.8–97.2; LVR 1.8904; MI 6428.

Fig. 6. *Palaeocystodinium* aff. *australinum*, 439101-102-4, 30.1–95.5; LVR 1.8906; MI 6429.

Fig. 7. *Phelodinium tricuspe*, 439101-102-4, 41.5–95.8; LVR 1.8911; MI 6434.

Fig. 8. *Stephodinium coronatum*, 439101-26-4, 42.8–101.2; LVR 1.8916; MI 6437.

Fig. 9. *Dinoymnium* cf. *sibiricum*, 439101-482-3, 41.6–109.6; LVR 1.8932; MI 6450.

Fig. 10. *Trithyrodinium fragile*, GGU 439101-102-4, 36.7–99.1; LVR 1.9112; MI 6436.

Fig. 11. *Trithyrodinium suspectum*, GGU 439101-521-9, 39.6–98.6; LVR 1.9138; MI 6455.

Fig. 12. *Trithyrodinium suspectum*, GGU 439101-521-9, 34.2–108.0; LVR 1.9140; MI 6456.

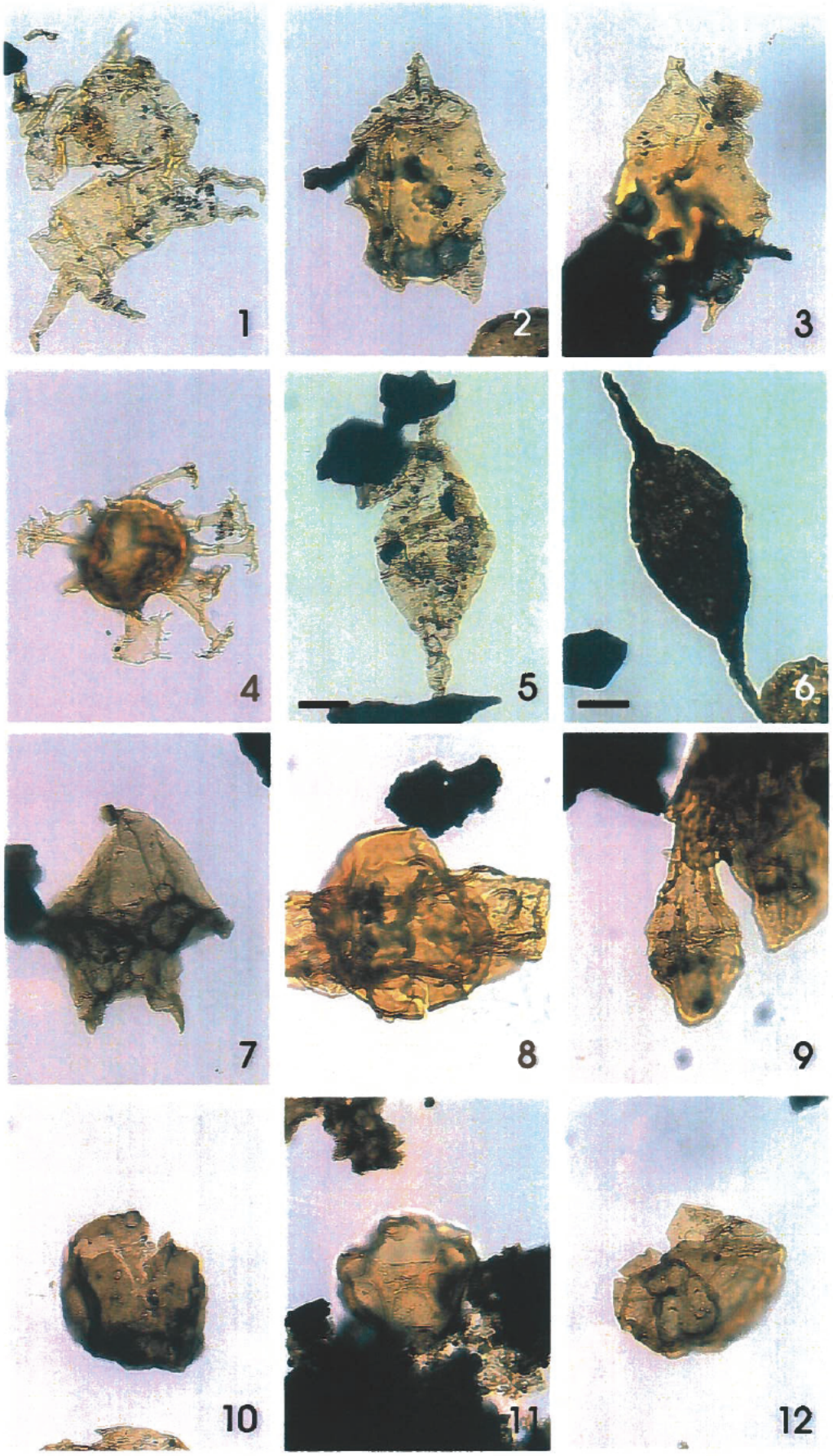
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Plate 6, GANT#1.

Fig. 1. *Isabelidinium* aff. *bujakii*, GGU 439101-102-4, 44.6–109.6; LVR 1.8909; MI 6432

Fig. 2. *Isabelidinium* sp. 3 HNH 1997, GGU 439101-102-4, 40.2–106.9; LVR 1.8917; MI 6438.

Fig. 3. *Isabelidinium* cf. *acuminatum*, GGU 439101-360-3, 16.2–112.9; LVR 1.8920; MI 6440.

Fig. 4. *Isabelidinium* cf. *microarmum*, GGU 439101-368-3, 44.2–102.5; LVR 1.8921; MI 6441.

Fig. 5. *Isabelidinium cooksoniae*, GGU 439101-378-7, 54.0–101.4; LVR 1.8922; MI 6442.

Fig. 6. *Isabelidinium cooksoniae*, GGU 439101-378-4, 38.0–112.5; LVR 1.8925; MI 6444.

Fig. 7. *Isabelidinium* sp. 1 HNH 1997, GGU 439101-378-4, 27.2–104.3; LVR 1.8923; MI 6443.

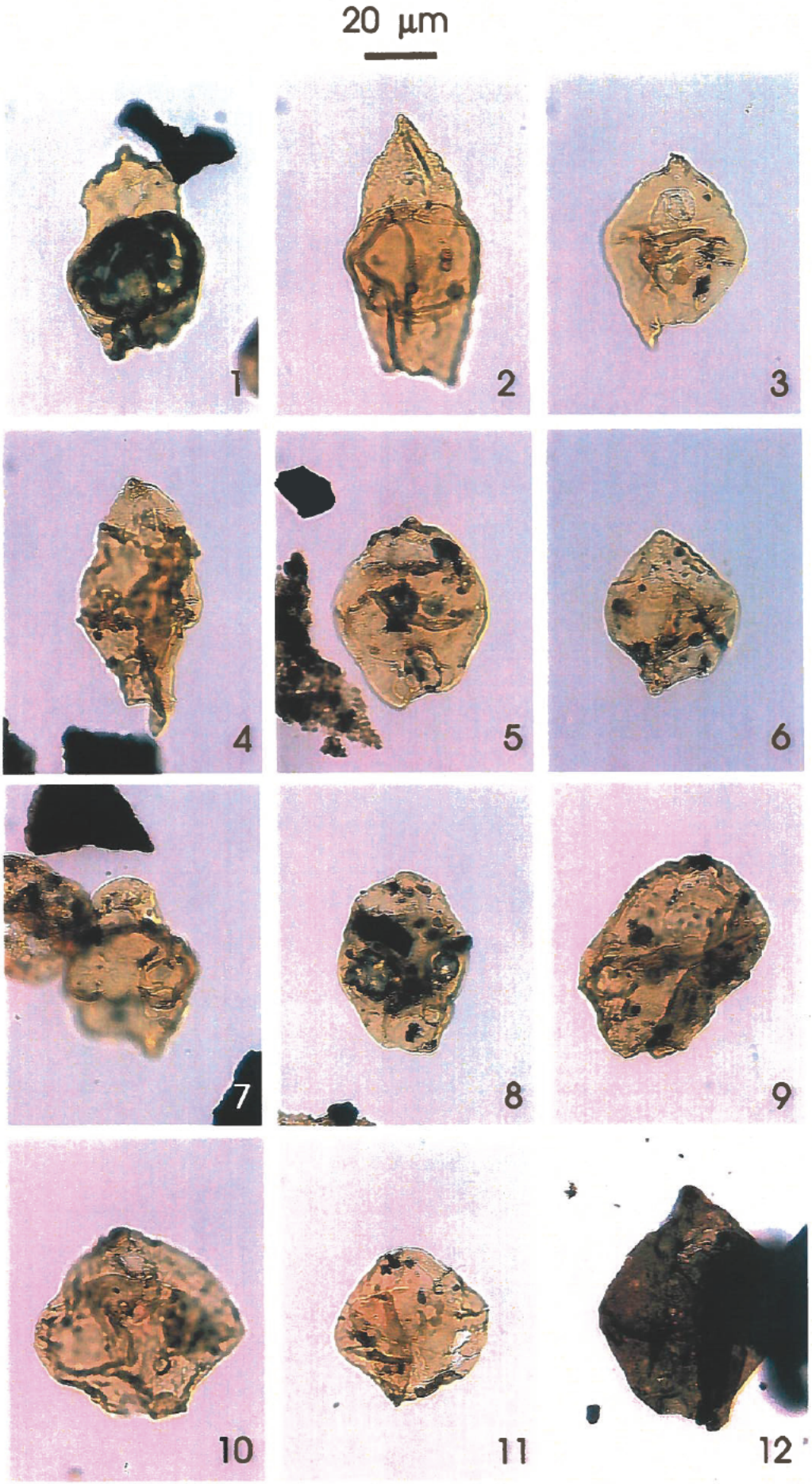
Fig. 8. *Isabelidinium* sp. 1 HNH 1997, GGU 439101-378-8, 33.0–105.6; LVR 1.8926; MI 6445.

Fig. 9. *Isabelidinium* sp. 2 HNH 1997, GGU 439101-482-3, 40.7–100.2; LVR 1.8928; MI 6447.

Fig. 10. *Isabelidinium* sp. 2 HNH 1997, GGU 439101-482-3, 50.5–112.8; LVR 1.8929; MI 6448.

Fig. 11. *Isabelidinium* sp. 2 HNH 1997, GGU 439101-482-4, 38.8–101.8; LVR 1.8931; MI 6449.

Fig. 12. *Isabelidinium* sp. 2 HNH 1997, GGU 439101-522-6, 22.8–111.8; LVR 1.8941; MI 6457.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