Dinoflagellate cyst biostratigraphy of the Upper Cretaceous black mudstones in central Nuussuaq, West Greenland

Henrik Nøhr-Hansen

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Abstract

Stratigraphical ranges and geographical distribution of dinoflagellate cysts and selected pollen species are described based on analysis of approximately 100 samples from 15 surface and 4 subsurface sections of Late Cretaceous age in central Nuussuaq, West Greenland. The sections make up an approximately 1100 m thick black mudstone succession, previously dated as Santonian to Maastrichtian on the basis of scattered ammonite occurrences.

The dinoflagellate cysts date the majority of the studied samples to Late Santonian to middle/Late Campanian, whereas one sample is dated as Late Paleocene. It has been possible to divide the studied succession into eight intervals based on eight distinguishable palynomorph assemblages. The diversity of the studied dinoflagellate cysts is relatively low to very low; approximately 55 species were recorded.

The presence of reworked specimen of the Early Cretaceous species *Batioladinium jaegerii* indicates, for the first time that pre-Middle Cenomanian marine deposits may have been deposited in central Nuussuaq.

CONTENTS

INTRODUCTION

The present study is part of the EFP–91 project 'Sequence stratigraphic analysis of the Cretaceous sediments in West Greenland', and aims to set up a palynostratigraphy for sequence stratigraphical analysis for the Disko–Nuussuaq–Svartenhuk Halvø area in West Greenland (Christiansen *et al.*, 1992; Christiansen, 1993).

The Upper Cretaceous–Lower Tertiary black mudstone succession on Disko, Nuussuaq and Svartenhuk Halvø represents the only marine sediments of this age exposed in the entire Labrador Sea–Baffin Bay region and studies of these are therefor essential for a detailed interpretation of the offshore geology.

The stratigraphic correllation of the sediments in the region is problematic due to the presence of interdigitating Cretaceous fluviatile, deltaic and brackish to fully marine deposits (Scheiner, 1975; Pulvertaft, 1979, Pedersen & Pulvertaft, 1992).

Field work on the marine succession in the summers 1990 to 1992 has been concentrated on detailed sedimentological studies, sampling for palynological and organic geochemical studies, and mapping and structural analysis (Christiansen *et al.*, 1992).

PREVIOUS PALYNOLOGICAL STUDIES IN THE SANTONIAN TO CAMPANIAN OF GREENLAND AND ELSEWHERE

West Greenland

Previous studies of Upper Cretaceous dinoflagellate cysts from West Greenland are sparse (Croxton, 1976; 1978; 1978a; 1980; Ehman *et al.*, 1976; Lentin & Williams, 1980). Lentin & Williams mentioned (1980, p. 20) that the Campanian assemblage from West Greenland contains elements of both the offshore eastern Canadian assemblages (also called the Williams suite) and the Mackenzie Delta assemblages from Arctic Canada (the so-called McIntyre suite) described by McIntyre (1974; 1975). The Paleocene dinoflagellate cyst assemblages from West Greenland have been described by Hansen (1980).

Croxton (1978; 1978a) briefly described the palynomorph content from five localities at central Nuussuaq (C4-C7, C21, M19, M22). The palynomorphs from the localities at

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, whereas dinoflagellate cysts from the topmost shale at C6 indicate a possible middle Paleocene age (Croxton, 1978). Section C21 and M19 represent the 'Oyster-ammonite conglomerate' from Agatdalen; according to Croxton (1978a) palynomorphs from this section may indicate a reworked Maastrictian flora. Eight sections from central Nuussuaq (M16-M23) were sampled by Hansen (1976); data on the palynological content from the two sections M16 and M17 from Tunoqqu have not been published. A few dinoflagellate cysts probably indicating a Late Campanian age were recorded by Croxton (1978) from Scaphitesnæsen (M22). Hansen (1980) described the Paleocene dinoflagellate cyst content from the Sonja section (M18), Turritellakløft section (M20), Qaarsutjægerdal section (M21) and Ättestupet section (M23). According to Hansen (1980) and the present study the middle Campanian to earliest Maastrichtian species *Isabelidinium microarmum* has been recorded as reworked specimens in the sections M18-M21.

Ehman *et al.* (1976) studied the four sections Qilakitsoq (N10), Turritellakløft (N15), Qaarsutjægerdal (N16) and Nassaat (N17) in central Nuussuaq. 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 Paleocene for 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 (Pulvertaft, 1987; Table 1).

The above mentioned palynological investigations have been reviewed by Pulvertaft (1987).

Arctic Canada

Santonian to Maastrictian Upper Cretaceous dinoflagellate cysts have been described from Arctic Canada by Manum (1963), Manum & Cookson (1964), Felix & Burbridge (1976), McIntyre (1974, 1975), Doerenkamp *et al.* (1976), Ioannides & McIntyre (1980) and Núnez-Betelu & Hills (1992). Ioannides (1986) studied the dinoflagellate cyst assemblages from the Santonian to Maastrichtian part of the Kanguk Formation and the Lower Paleocene Eureka Sound Formation on Bylot and Devon Islands. The dinoflagellate cyst assemblages described by Ioannides (1986) is very similar to the material from West

Greenland, unfortunately Ionnanides' stratigraphy is not very detailed, due to poor outcrop, and absence of macrofossils.

Western Canada, Western U.S.A.

Upper Cretaceous dinoflagellate cyst assemblages from Western Canada and Western U.S.A. have been described by Wall & Singh (1975), Harland (1973), (Harland, 1977), Sweet & McIntyre (1988), Stone (1973) and Harker *et al.* (1990).

Offshore Eastern Canada, Eastern U.S.A. and the northern hemisphaere

The Upper Cretaceous dinoflagellate cysts from offshore eastern Canada are described by Barss *et al.* (1979), Bujak & Williams (1978), Williams (1975), Williams & Brideaux (1975), Williams & Bujak (1977a, 1977b), Williams *et al.* (1974) and Williams *et al.* (1990).

The stratigraphical distribution of Mesozoic and Cenozoic dinoflagellate cysts has been described by Williams & Bujak (1985) for the world and by Williams *et al.* (1993) for the northern hemisphere.

Upper Cretaceous to Paleocene dinoflagellate cyst assemblages from eastern U.S.A. are described by Benson (1976), May (1980), Tocher (1987), Aurisano & Habib (1977) who established a Campanian to lowermost Tertiary dinoflagellate cyst zonation and by Aurisano (1989) who proposed a Cenomanian to Maastrichtian dinoflagellate cyst zonation for the Atlantic Coastal Plain of New Jersey and Delaware.

Northern North Sea, clastic deposits

According to Costa & Davey (1992, pp. 105–106) dinoflagellate cyst information has not been published from this regions. However, unpublished personal observation by Lucy. I. Costa (reported in Costa & Davey, pp. 105–106) indicates assemblage affinities with the Upper Cretaceous arctic assemblages described by Vozzhennikova (1967) from Siberia, Manum & Cookson (1964) and Doerenkamp *et al.* (1976) from Arctic Canada, and McIntyre (1974) from the District of Mackenzie, Canada.

North-western Europe

The stratigraphical distribution of Upper Cretaceous dinoflagellate cysts in North-West Europe has been compiled by Foucher (1979) and by Costa & Davey (1992). Clarke & Verdier (1967) described the Cenomanian to Campanian on the Isle of Wight and made the first and only attempt to establish a dinoflagellate zonation for the British Upper Cretaceous. Hart *et al.* (1987) listed dinoflagellate cysts together with microfossils from key Upper Cretaceous sections on the Isle of Wight.

Robaszynski *et al.* (1980) described dinoflagellate cyst assemblages of Albian to Santonian age from France. Westin (1992) established a dinoflagellate cyst stratigraphy from the Albian to Santonian in the southern Sweden. The diverse assemblages described from Sweden (Westin, 1992) are dominated by North Sea and North-West European limestone facies species; however the abundance of the northern North Sea genus *Chatangiella*, especially in southern Sweden, is remarkable.

Australia, Antarctica

There are numerous papers describing Cretaceous dinoflagellate cysts from Australia. Helby *et al.* (1987) established a palynological zonation covering the entire Mesozoic of Australia.

Askin (1988) described the Campanian to Eocene palynological succession of Seymour Island and adjacent islands, Antarctica.

Mohr & Gee (1992) and Mao & Mohr (1992) described the Cenomanian to Maastrichtian dinoflagellate cyst assemblages from the ODP leg 120 in the southern Indian Ocean.

The interesting point about the Upper Cretaceous palynomorphs recorded from Australia and around Antarctica is that they are very similar at assemblage level to the material recorded from West Greenland, whereas at species level there are small but distinguishable differences between superficially similar species from the two regions, which makes direct correlation difficult.

SAMPLES AND METHODS

Samples

This study covers samples from central Nuussuaq obtained from fifteen outcrop localities and four slim cores from shallow wells drilled by GGU in 1992 (Figs 1, 2). The sections are 2 to 286 metres thick and represent an approximately 1100 m thick sandy shale succession (Fig. 3).

Preparation

Palynological preparation and studies were carried out at GGU. 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 method described by Hansen & Gudmundsson (1978).

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 text refer to this microscope. England finder index corners: Z 75 4 = 74.6–92.3; Z 1 3 = 1.9–9220; 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 GGU number (sample number), slide number, microscope coordinates, laser-video-record number (LVR) and database number (MicroImage; MI) for later identification. The slides are housed at the Geological Survey of Greenland where they are accessible for examination.

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 a minor part.

The TAI (Thermal Alteration Index) evaluation was carried out on the sieved slide before oxidation. The study revealed TAI values between −2 and +3, which indicate that the organic material is thermally immature to mature with respect to oil generation.

DINOFLAGELLATE CYST STRATIGRAPHY AND ZONATION IN CENTRAL NUUSSUAQ

A dinoflagellate cyst stratigraphy has been established for the Upper Cretaceous sediments on central Nuussuaq (Figs 1 & 2). Marine palynomorphs were recorded from all the 19 studied sections. Due to the very sparse macrofossil content and the monotonous lithology, the stratigraphical correlation of the geographically widely spread 19 sections is based solely on the first and the last occurrences and acme of stratigraphically important dinoflagellate and selected pollen species.

The present study has been very time consuming and the dating and stratigraphical correlation is based on limited observations as the dinoflagellate cyst content in the sections are very low, normally a slide contains one to ten specimens. However, terrestrially dominated samples are not uncommon.

Most of the studied samples with marine palynomorphs contain one or more large specimens of the genus *Chatangiella*. According to the literature the genus *Chatangiella* ranges from the Upper Cenomanian to the Upper Maastrichtian (e.g. Costa & Davey, 1992). The genus *Chatangiella* dominates Upper Cretaceous assemblages in the Western Interior, U.S.A., western Canada, Arctic Canada and the northern North Sea. The genus *Chatangiella* is also very abundant in the southern hemisphere (especially in Australia and Antarctica), whereas it is less distributed in northwestern Europe and in the Tethyan realm (Lentin & Williams, 1980, Costa & Davey, 1992).

The presence of *Heterosphaeridium difficile* and *Chatangiella* together with the absence of the characteristic species *Litosphaeridium siphoniphorum* and *Stephodinium coronatum* (both of which have their last occurrence in the Turonian) suggests according to

Haq *et al.* (1987) and Costa & Davey (1992) a post-Turonian to pre-Campanian age for the three sections GKP 92 1 Nall, GKP 92 V 1 Qilak. & GKP 92 V 2 Qilak. (Encl. 16, Encl. 19 and Encl. 20).

The pollen genus *Aquilapollenites* has been recorded in fourteen of the studied sections. According to Traverse (1988) *Aquilapollenites* has a sporadic occurrence from Late Turonian to Late Santonian, whereas the occurrence becomes consistent in the latest Santonian and occurs throughout to the Early Paleocene. McIntyre (1974) did not record *Aquilapollenites* species in sediments older than middle to Upper Campanian in the District of Mackenzie, Arctic Canada. Croxton (1980, p. 16) concluded "Although only a preliminary assessment has to date been made of the earliest occurrence of *Aquilapollenites* in West Greenland it is not thought to occur in strata older than Campanian in age". The fact that Nøhr-Hansen (1994) did not record *Aquilapollenites* in the Coniacian to Upper Santonian sediments on Svartenhuk Halvø, suggests that the genus has a post-Late Santonian occurrence in West Greenland.

The presence of the species *Isabelidinium* cf. *acuminatum* and *I. microarmum* indicates a Campanian age according to McIntyre (1975) and Costa & Davey (1992).

The species list on the cumulate range chart (Encl. 1) illustrates that the assemblages are of very low diversity. Approximately 55 species were recorded. Based on the first and last occurrences, presence and absence of a few morphologically characteristic and stratigraphically important species, it has been possible to distinguish eight intervals with characteristic dinoflagellate and pollen content from the cumulate section.

Unnamed interval

The very sparse dinoflagellate cyst assemblage recorded from the unnamed interval (Encl. 1, 14, 19, 20) indicates the presence of the oldest recorded marine influenced depositional environment in central Nuussuaq.

Age. The age of the interval is most likely Late Santonian but a latest Turonian or Coniacian age cannot be excluded.

Definition. The interval is defined by containing almost no dinoflagellate cysts, its upper limit being the lowermost occurrence of the species *Heterosphaeridium difficlie.*

Thickness and distribution. The entire section FGC900804/2 Kan. (Encl. 14; 244 m) and the lower part of section GKP 92 V 1 Qilak. (Encl. 19; 120 m) and GKP 92 V 2 Qilak. (Encl. 20; 96 m) are described as the unnamed interval.

Characteristic species. The interval is characterised by the presence of almost no dinoflagellate cysts; onlya few specimens of the genera *Chatangiella* and *Isabelidinium* have been recorded.

Discussion. The presence of the genera *Isabelidinium* and *Chatangiella*, especially the genus *C. granulifera*, indicate an Early Coniacian to Late Campanian range according to Williams & Bujak (1985), whereas Costa & Davey (1992) reported an Early Turonian to Late Campanian range for *C. granulifera.* According to Costa & Davey's (1992) observations from the North Sea region, the absence of *Heterosphaeridium difficile* in the unnamed interval indicates an age not younger than Early Turonian. The absence of *H. difficile* in the unnamed interval may be explained by an Early Turonian age of the sediments. It is however, probably a consequence of the low content dinoflagellate cysts. The unnamed interval might correlate with part of the Late Santonian *H. difficile* Zone on Svatenhuk Halvø, which also is represented by a low diversity assemblage (Nøhr-Hansen, 1994).

***Heterosphaeridium difficile* interval**

Age. Late Santonian.

Definition. The interval is defined from the first occurrence of *Heterophaeridium difficile* to the last occurrence of *Heterosphaeridium difficile.*

Thickness and distribution. The interval is represented by one sample in each of the sections GKP 92 V 2 Qilak. (Encl. 20) and GKP 92 1 Nall. (Encl. 16) The interval constitutes approximately 95 m of the section GKP 92 V 1 Qilak. (Encl. 19).

Characteristic species. The interval is characterised by a relatively diverse dinoflagellate cyst assemblage, whereas the abundance is low. The following species have been recorded: *Heterosphaeridium difficile*, *Laciniadinium arcticum*, *Spinidinium* aff. *echinoideum*, *Odontochitina striatoperforata*, *Chatangiella* aff. *ditissima*, *Surculosphaeridium? longifurcatum*, *Chatangiella granulifera*, *Desmocysta plekta*, *Xenascus* aff. *perforatus* and *Florentinia* spp.

Discussion. The last occurrences of *Heterosphaeridium difficile* within the interval indicates an age no younger than Late Santonian (Costa & Davey, 1992). The *H. difficile* interval correlates with the *H. difficile* Zone proposed for the Late Santonian on Svartenhuk Halvø (Nøhr-Hansen, 1994).

Chatangiella aff. _ditissima_ interval

Age. Late Santonian or ?Early Campanian

Definition. The interval is defined from the last occurrence of *Heterisphaeridium difficile* to immediately below the first occurrence of the genus *Aquilapollenites*.

Thickness and distribution. The interval is represented by one sample in the two sections GKP 92 V 1 Qilak. (Encl. 19), GKP 92 1 Nall. (Encl. 16), 59 m of well GGU 400703 (Encl. 5) and by the lower 65 m in well GGU 400704 (Encl. 6).

Characteristic species. There are no characteristic species in this interval. The species diversity is very low. The species *C.* aff. *ditissima* is almost the only species that has been recorded in more than one sample.

Comments. The *C.* aff. *ditissima* interval may be dated Late Santonian or ?Early Campanian based on the absence of *H. difficile.* The interval has not been recorded in the Late Santonian deposits on Svartenhuk Halvø (Nøhr-Hansen, 1994).

Aquilapollenites 1. interval

Age. Early Campanian

Definition. The interval is defined from the first occurrence of the genus *Aquilapollenites* to immediately below the first occurrence of *Isabelidinium* cf. *acuminatum.*

Thickness and distribution. The interval is represented by 86 m in section GKP 91 4 Tun. (Encl. 8), the lowermost 23 m in section GKP 91 3 Tun. (Encl. 9), the lowermost 40 m of section HNH910816/1 (Encl. 13). and possible by the theee lowermost samples in section HNH910811/1 (Encl. 10).

Characteristic species. The first occurrence of the genus *Aquilapollenites* is the characteristic for the interval. A few specimens of the species *Laciniadinium arcticum* and *C. granulifera* have been recorded from section GKP 91 4 Tun. (Encl. 8). The species *Batioladinium jaegerii* and a ?hair from a leaf seem to be reworked in section GKP 91 4 Tun. (Encl. 8).

Discussion. According to Traverse (1988) the occurrence of *Aquilapollenites* becomes consistent in the latest Santonian and occurs throughout to the Early Paleocene. *Aquilapollenites* species have not been recorded in sediments older than middle to Upper Campanian in the District of Mackenzie, Arctic Canada McIntyre (1974). On Svatenhuk Halvø *Aquilapollenites* has not been recorded in the Coniacian to Upper Santonian succession by Nøhr-Hansen (1994), which suggests that the genus has a post-Late Santonian occurrence in West Greenland.

According to Costa & Davey (1992) *Batioladinium jaegerii* has its last occurrence in the early Middle Cenomanian. The presence of reworked specimens of *B. jaegerii* in the

Campanian section GKP 91 4 Tun (Encl. 8) indicates that Lower Cretaceous marine influenced sediments have been deposited somewhere in central Nuussuaq. The presence of the miscellaneous ?leaf-hair also suggests reworking of Lower Cretaceous sediments. A morphologically similar ?leaf-hair has previously been recorded from Late Barremian to Early Albian in East Greenland and Late Barremian in Arctic Canada (Nøhr-Hansen, 1993).

***Isabelidinium* cf. *acuminatum* interval**

Age. Early Campanian

Definition. The interval is defined from the first occurrence of *Isabelidinium* cf. *acuminatum* to the last occurrence of *Isabelidinium* cf. *acuminatum.*

Thickness and distribution. The Interval is represented by the upper 15 m in section GKP 91 3 Tun. (Encl. 9), by the uppermost sample in section HNH910811/1 Tun. (Encl. 10) and by approximately 45 m in section HNH910816/1 Kan. (Encl 13).

Comments. The *I.* cf. *acuminatum* interval is proposed to be slightly older than the *I. microarmum* interval. The interval may, however, continue up to the *I. microarmum* interval and thereby eliminate the *Aquilapollenites* 2 interval. For further discussion see comments under the *I. microarmum* interval.

Characteristic species. The diversity in this interval is high compared to the underlying *Aquilapollenites* 1 interval. It is characterised by the presence of *Isabelidinium* cf. *acuminatum*, *I.* aff. *?amphiatum* large, *Laciniadinium arcticum*, *Odontochitina striatoperforata*, *Chatangiella* aff. *ditissima*, *C. granulifera*, *Desmocysta plekta* and *Exocosphaeridium* sp.. Only one specimen of the following species has been recorded in the interval: *Surculosphaeridium* aff. *longifurcatum*, *Coronifera oceanica*, *Tanyosphaeridium variacalamus* and *Florentinia* aff. *mantelli.*

Discussion. The species *Isabelidinium acuminatum* has an Early to middle Campanian range in the District of Mackenzie (McIntyre, 1975). Harker *et al.* (1990) recorded *I. acuminatum* from the earliest Campanian in the Western Interior, U.S.A.. According to Costa & Davey (1992) *I. acuminatum* first occurs, or first becomes consistent in the Early Campanian. Large *Isabelidinium* species such as *I. amphiatum* have their first occurrence in the middle Campanian in the District of Mackenzie (McIntyre, 1975), whereas Costa & Davey (1992) report an Early Coniacian to Late Campanian range in and around Great Britain.

The presence of the single specimens of *Tanyosphaeridium variacalamus* and *S.* aff. *longifurcatum* indicate a pre-Campanian age. The single specimen occurrence suggests, however that the species may be reworked or that they have a slightly longer range in West Greenland.

***Aquilapollenites* 2. interval**

Age. Early Campanian

Definition. The interval is defined from immediately above the last occurrence of *Isabelidinium* cf. *acuminatum* to immediately below the first occurrence of *I. microarmum*. For further discussion see under the *I. microarmum* interval.

Thickness and distribution. The interval has been recorded above the *I.* cf. *acuminatum* interval in section HNH910816/1 Kan. (Encl. 13; 150 m) and below the *I. micoarmum* interval in the following sections: well GGU 400702 Agat. (Encl. 4; 40 m), HNH910819/1 Aaff. (Encl. 15; 60 m) and HNH910813/1 Tun. (Encl. 11; 50 m).

Characteristic species. The interval is represented by a low diversity palynomorph assemblage. The most characteristic species is *Aquilapollenites* and the interval is only recognisable by overlying the *I.* cf. *acuminatum* or by underlying the *I. microarmum* interval.

***Isabelidinium microarmum* interval**

Age. Middle or ?Late Campanian

Definition. The interval is defined from the first occurrence of *Isabelidinium microarmum* to the last occurrence of *I. microarmum*.

Thickness and distribution. The interval has been recorded in the following sections: well GGU 400702 (Encl. 4; 20 m), HNH910819/1 Aaff. (Encl. 15; 37 m), HNH910813/1 Tun. (Encl. 11; 60 m), HNH910826/1 Agat. (Encl. 7; 35 m), 400701 Agat. (Encl. 3; 35 m), FGC900731/2 Agat. (Encl. 2; 50 m), GKP 92 4 Qilak. (Encl. 18; one sample), HNH910813/2 Tun. (Encl. 12; 95 m) and GKP 92 3 Qilak. (Encl. 17; one sample).

Characteristic species. The diversity in the present interval is high compared to the underlying *Aquilapollenites* 2 interval. The interval is characterised by the presence of *Isabelidinium microarmum*, *I.* aff. *?amphiatum* large, *Laciniadinium arcticum*, *Odontochitina striatoperforata*, *Chatangiella* aff. *granulifera*, *Desmocysta plekta*, *Exocosphaeridium* aff. *bifidum*, *Exocosphaeridium* aff. *striolatum*, *Hystrichosphaeridium pulchrum* and a single specimen of *Palaeohystrichophora infusorioides*.

Comments. The stratigraphic positions of the *I.* cf. *acuminatum* interval and the *I. microarmum* interval are somewhat problematic as the two species *I.* cf. *acuminatum* and *I. microarmum* have not been recorded in clear stratigraphical succession. They only occur together in one sample (well GGU 400702, Fig. 4, Encl. 4) or in separate sections. In the lower part of section HNH910816/1 Kan. (Fig. 3, Fig. 4, Encl. 13) the species *I.* cf. *acuminatum* occurs, whereas it has not been recorded in the samples from the 150 m thick section above (here named the *Aquilapollenites* 2 interval). The species *I.* cf. *acuminatum* has not been recorded from sediments in clear stratigraphical succession underlying sediments containing *I. microarmum* (Fig. 4).

It is here proposed that the *I.* cf. *acuminatum* interval is older than the *I. microarmum* interval, but whether the *Aquilapollenites* 2 interval should be defined as an interval or included in the upper part of the *I.* cf. *acuminatum* interval is still debatable.

It should be noted that the species *I. microarmum* has been observed reworked in a Paleocene dominated assemblage (Hansen, 1980). However, when reworked there are never more than one to three specimens.

Discussion. The species *Isabelidinium microarmum* has an Early Campanian to middle Maastrichtian range in the District of Mackenzie (McIntyre, 1975).

Ioannides (1986) recorded *I. microarmum* from questionable Maastrichtian strata in Arctic Canada. According to Costa & Davey (1992) *I. microarmum* does not seem to persisted beyond the end of the Campanian in the North Sea region. According to McIntyre (1975) large *Isabelidinium* species as such *I. amphiatum* have their first occurrence in the middle Campanian in the District of Mackenzie, whereas Costa & Davey (1992) report an Early Coniacian to Late Campanian range from the North Sea region.

According to Clarke & Verdier (1967) the species *Odontochitina striatoperforata* is a taxonomic junior synonym of *O. costata*, which has its last occurrence in the earliest Maastrichtian (Costa & Davey, 1992).

The presence of the species *Palaeohystrichophora infusorioides* and *Chatangiella* aff. *granulifera* indicates a pre-Maastrichtian age (Costa & Davey, 1992). A middle Campanian age is proposed for the *I. microarmum* interval on the basis of Costa & Davey's (1992, p. 126) comments that *Isabelidinium* species are common and diverse in the Early Campanian but much less in the Late Campanian.

Cerodinium speciosum **interval**

Age. Late Paleocene

Definition. The interval is defined from the first occurrence of *Cerodinium speciosum* subsp. *?glabrum.*

Thickness and distribution. The interval is only recorded in the uppermost sample of section GKP 92 3 Qilak. (Encl. 17). The lowermost sample in the section represents the

Early or ?middle Campanian *I. miroarmum* interval, and the approximately 200 metres of strata between the two samples is barren of dinoflagellate cysts.

Characteristic species. The interval is characterised by the presence of the species *Cerodinium speciosum* subsp. *?glabrum*, *Phelodinium kozlowskii* and *Glaphyrocysta* sp.. The presence of the pollen species *Wodehousia spinata* indicates reworking.

Discussion. The species *Cerodinium speciosum* dates the sample to a Late Paleocene age. In and around Great Britain the range of the species correlates with NP5 (Powell, 1992). The pollen species *Wodehousia spinata* has a rather restricted stratigraphical range from the latest Maastrichtian to the earliest Paleocene (Nichols & Brown, 1992) which indictes that the species may be reworked in the present sediments.

It is unlikely that the 200 metres of strata between the sample containing *I. microarmum* and the sample with *C. speciosum* represents the entire Upper Campanian to Upper Paleocene stratigraphic column and an unconformity is therefore proposed somewhere in the strata between the two samples.

COMPARISON WITH PREVIOUSLY REPORTED MACROFOSSIL AGES

The presence of ammonites of Santonian, Campanian and Maastrichtian ages in central Nuussuaq (Fig. 4) was recorded by Birkelund (1965; Fig. 2, Table 1) in her monograph on Upper Cretaceous ammonites from West Greenland. The ammonite record was correlated with other macrofossil records by Rosenkrantz & Pulvertaft (1969) in their review of Cretaceous–Tertiary stratigraphy and tectonics in West Greenland.

Birkelund (1965) recorded ammonites indicating the presence of Santonian deposits at the Nordre Baculiteskløft locality in Agatdalen. This locality is very close to the well GGU 400704; in the present study a late Santonian age (the *Chatangiella* aff. *ditissima* interval) is proposed. From the Scaphitesnæsen locality Birkelund (1965) recorded ammonites of Early Campanian age. The section FGC900731/2 Agat. covers the same locality and the dinoflagellate cysts assemblage from Scaphitesnæsen, suggests an Early or ?middle Campanian age.

The ammonites recorded from Ilugissoq and Tunoqqu indicate an Early Santonian age (Birkelund, 1965). The dinoflagellate cyst assemblage from the section GKP 92 V 2 Qilak., which is very close to Birkelunds (1965) Ilugissoq section, suggests a Late Santonian age. The studied sections from Tunoqqu contain dinoflagellate cysts suggesting an Early or ?middle Campanian age.

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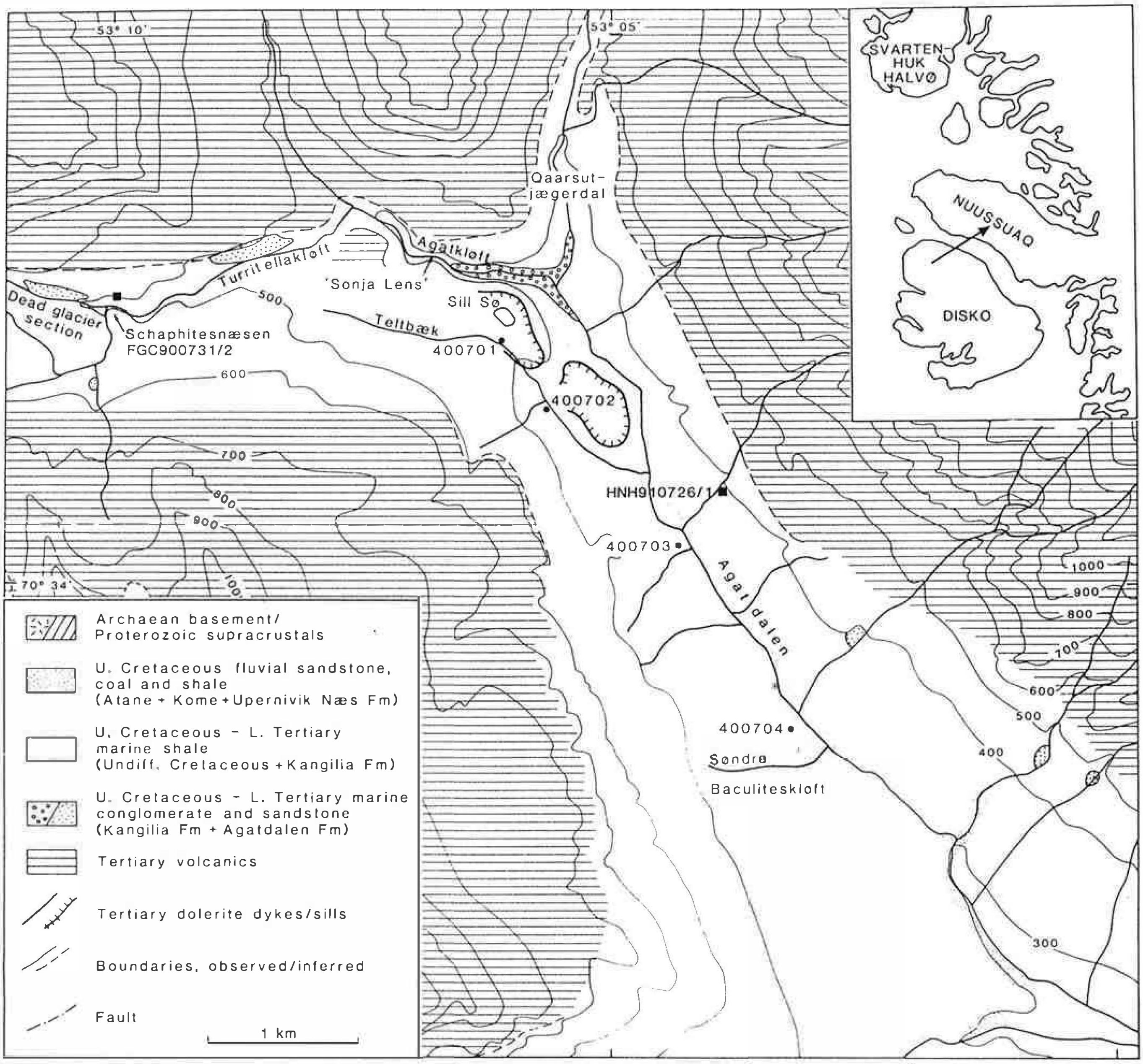


Fig. 1. Location of the examined outcrops and subsurface sections in the Agatdalen area that yielded dinoflagellate cysts.

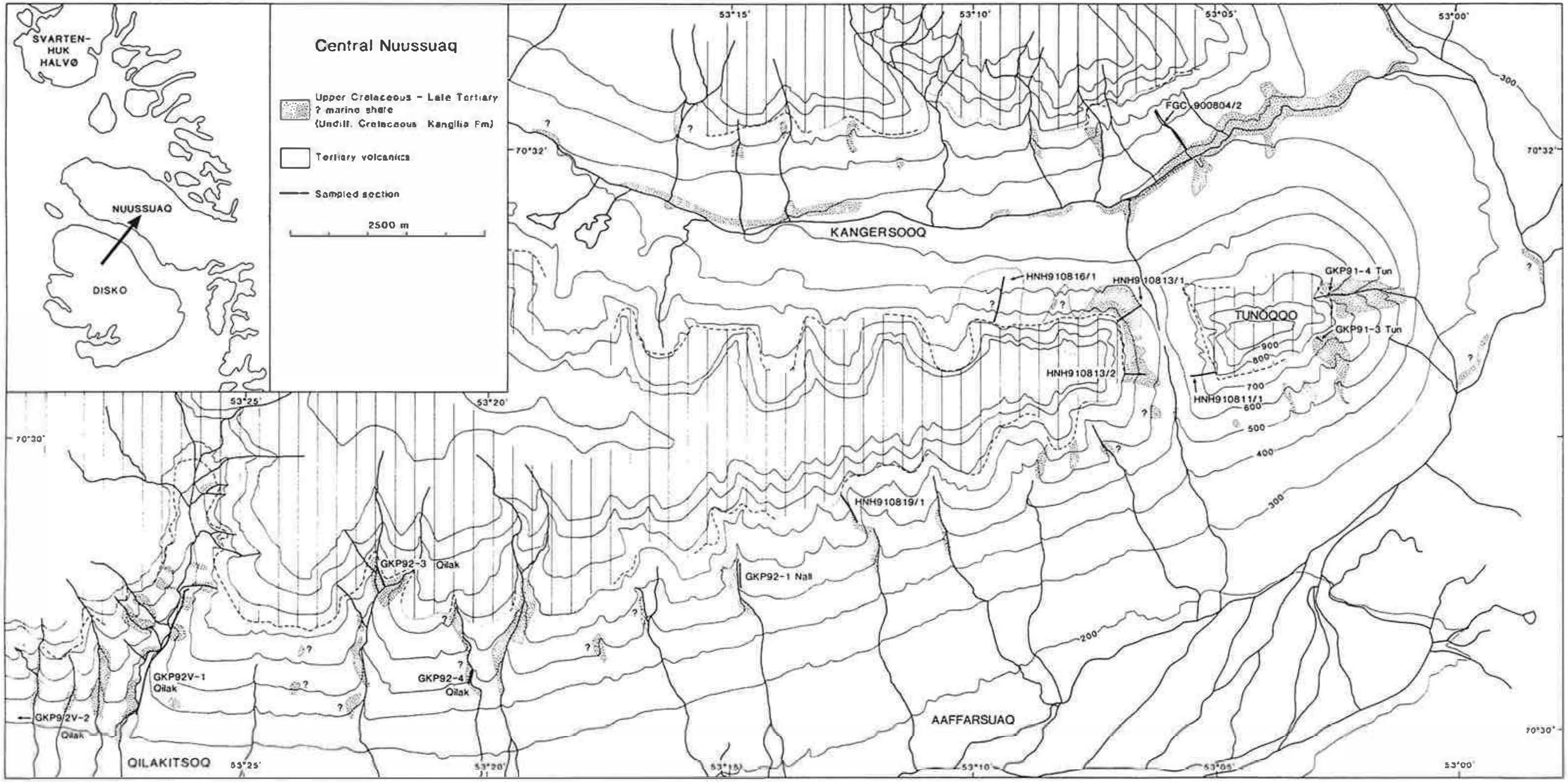


Fig. 2. Location of the examined outcrops and subsurface sections south of the Agatdalen area that yielded dinoflagellate cysts.

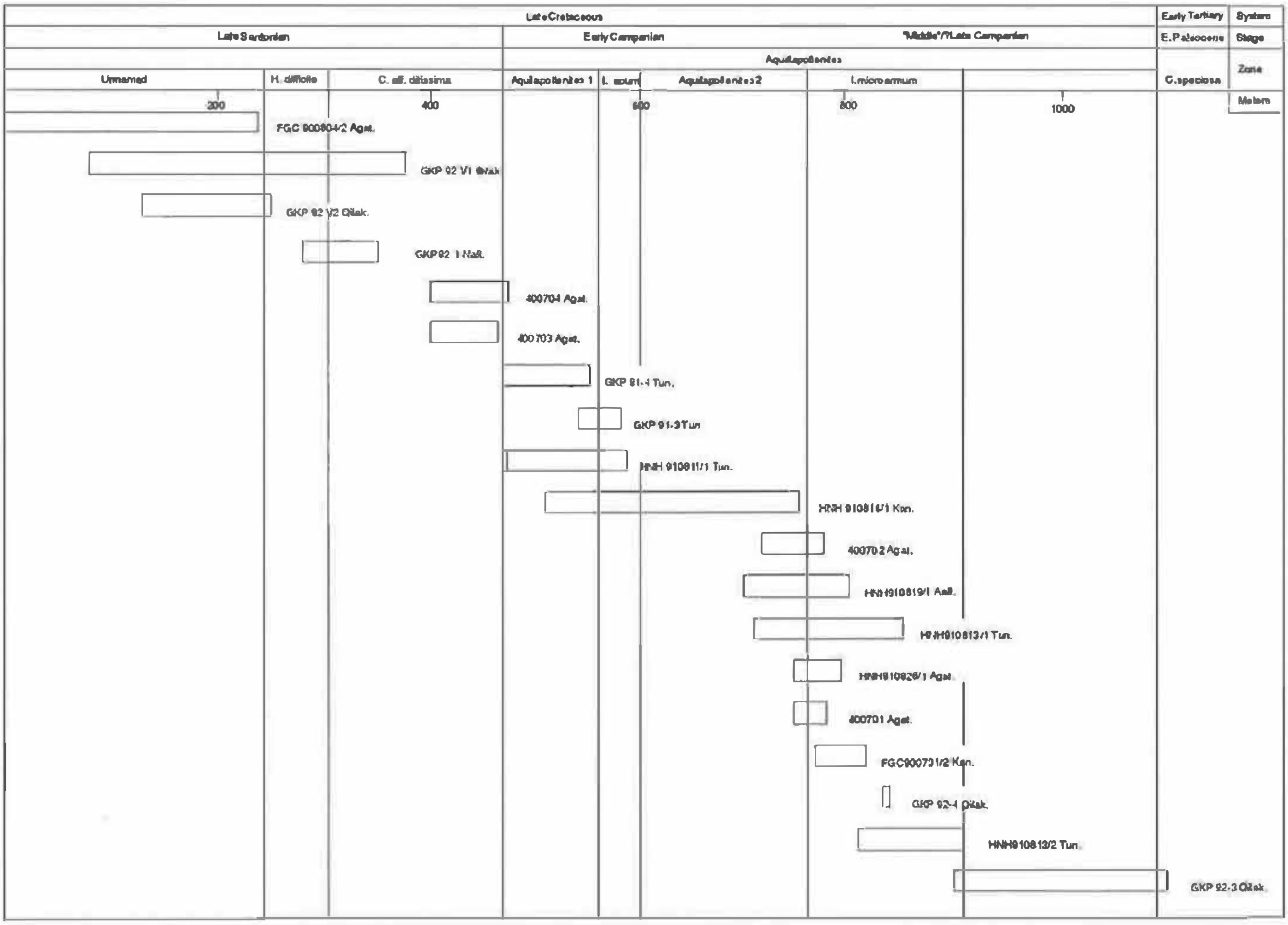


Fig. 3. Stratigraphical correlation of the sections that yielded dinoflagellate cysts . Kan.=Kangersooq, Agat.=Agatdalen, Qilak.=Qilakitsoq, Nall.=Nalluarissat, Tun.=Tunnoqqo, Aaff.=Aaffarsuaq.

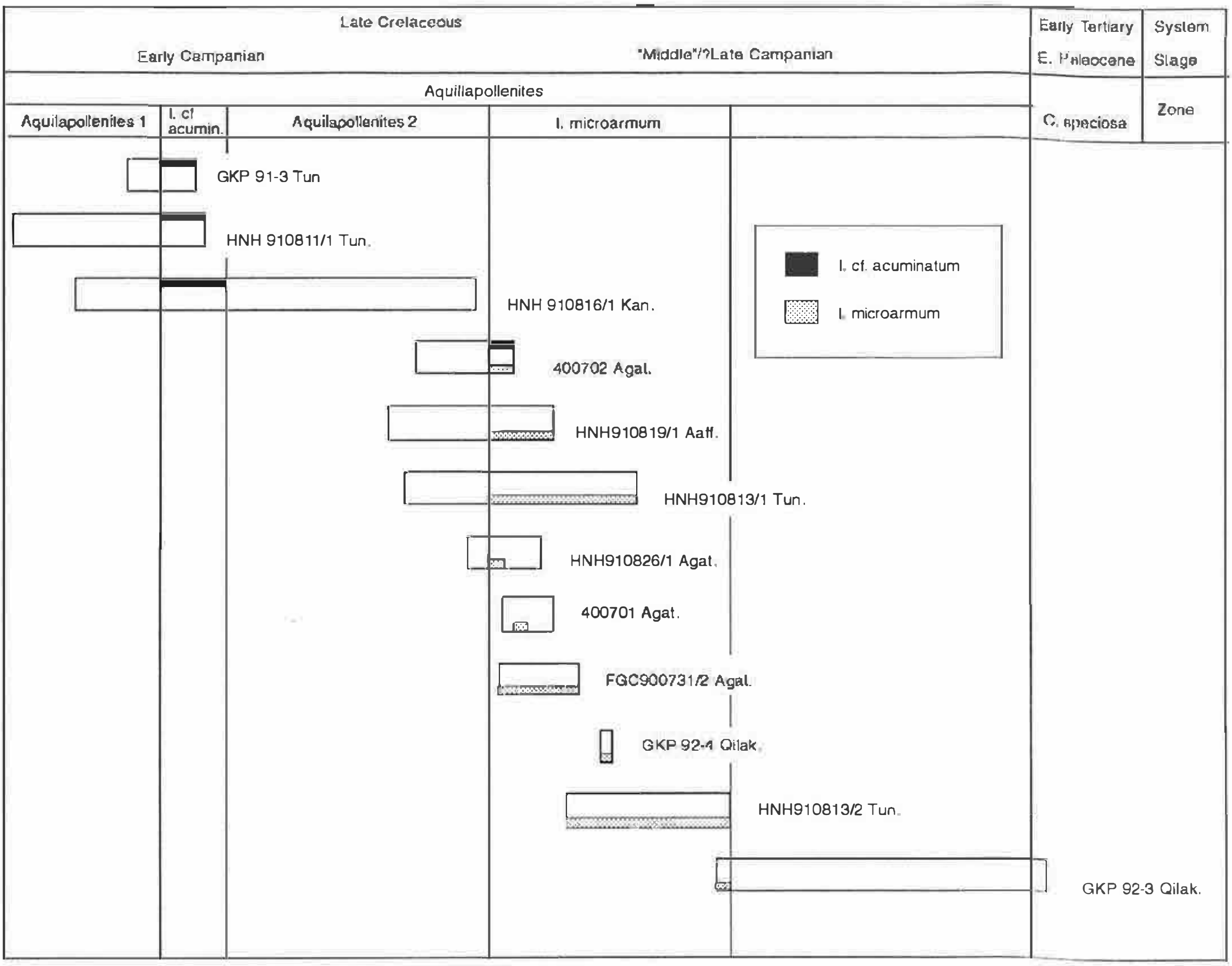


Fig. 4 Stratigraphic occurrence between the species I. cf. acuminatum and I. microarmum.

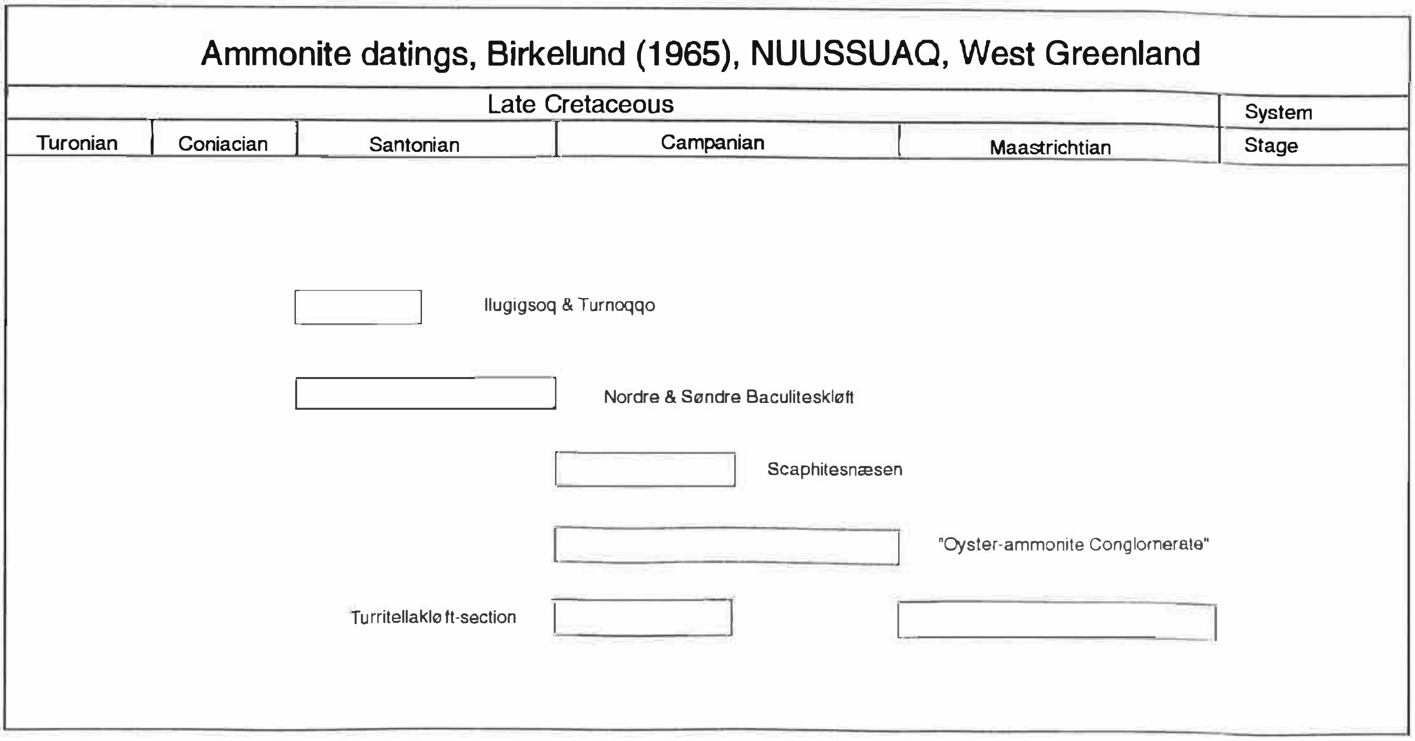
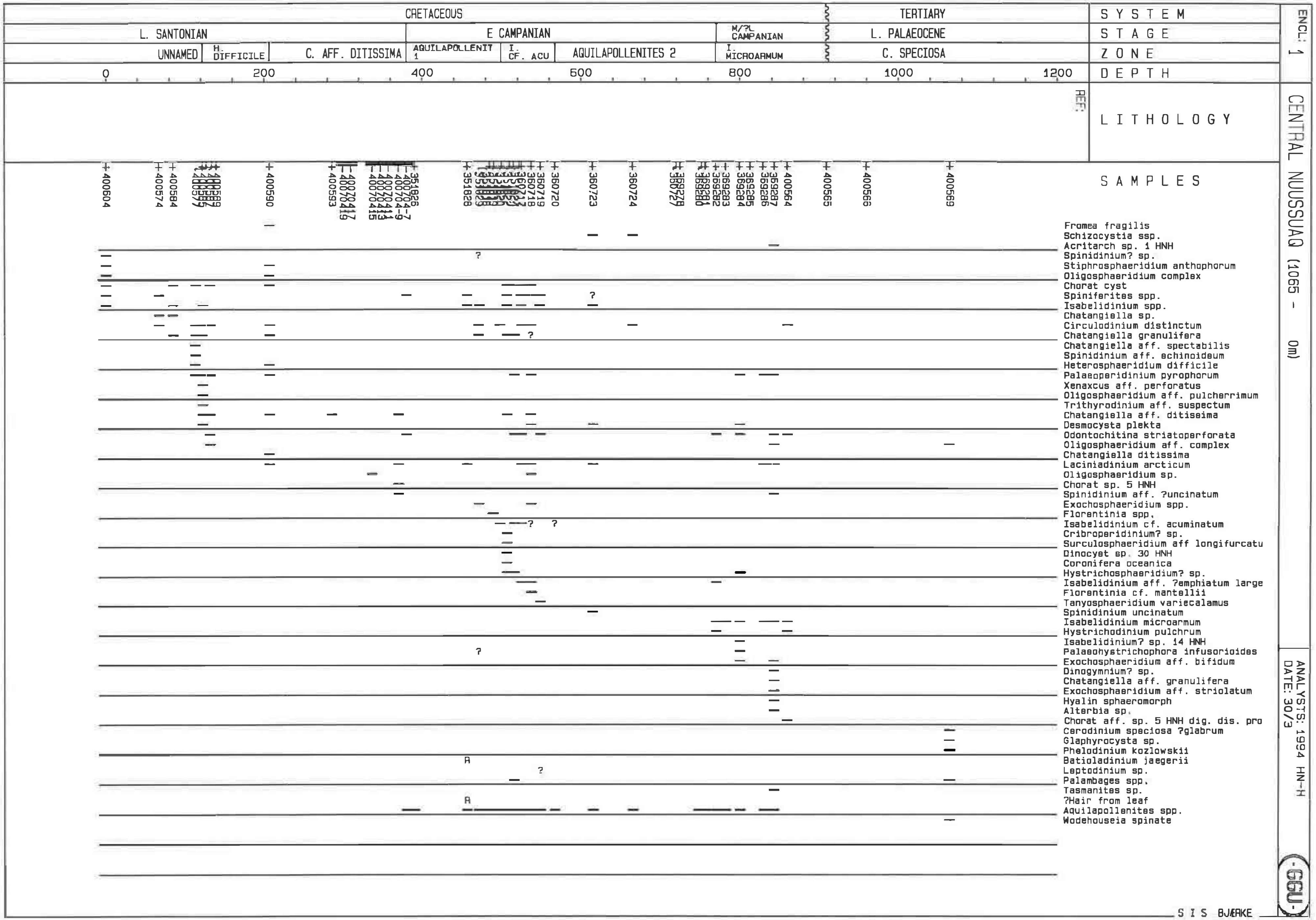


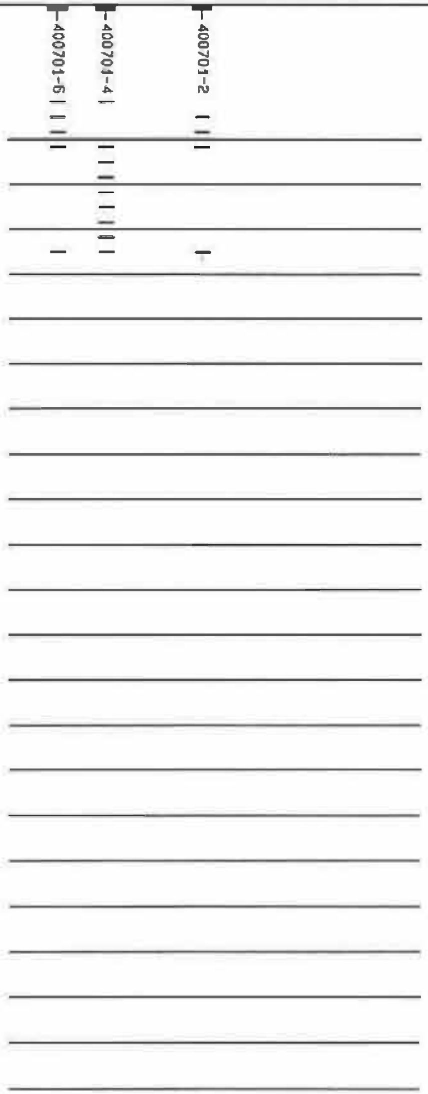
Fig. 5. Previous ammonite datings obtained from Birkelund (1965).



CRETACEOUS
TERTIARY
SYSTEM
L. SANTONIAN
E CAMPANIAN
M/?L CAMPANIAN
L. PALAEOCENE
STAGE
UNNAMED
H. DIFFICILE
C. AFF. DITISSIMA
AQUILAPOLLENIT 1
I. CF. ACU
AQUILAPOLLENITES 2
I. MICROARMUM
C. SPECIOSA
ZONE
0 200 400 600 800 1000 1200
DEPTH
REF:
LITHOLOGY
SAMPLES
400604
400574
400584
400590
400593
351826
351828
360718
360719
360720
360723
360724
369283
369285
369286
369287
400564
400565
400566
400569
Fromea fragilis
Schizocystia ssp.
Acritarch sp. 1 HNH
Spinidinium? sp.
Stiphrosphaeridium anthophorum
Oligosphaeridium complex
Chorat cyst
Spiniferites spp.
Isabelidinium spp.
Chatangiella sp.
Circulodinium distinctum
Chatangiella granulifera
Chatangiella aff. spectabilis
Spinidinium aff. echinoideum
Heterosphaeridium difficile
Palaeoperidinium pyrophorum
Xenaxcus aff. perforatus
Oligosphaeridium aff. pulcherrimum
Trithyrodinium aff. suspectum
Chatangiella aff. ditissima
Desmocysta plekta
Odontochitina striatoperforata
Oligosphaeridium aff. complex
Chatangiella ditissima
Laciniadinium arcticum
Oligosphaeridium sp.
Chorat sp. 5 HNH
Spinidinium aff. ?uncinatum
Exochosphaeridium spp.
Florentinia spp.
Isabelidinium cf. acuminatum
Cribroperidinium? sp.
Surculosphaeridium aff longifurcatu
Dinocyst sp. 30 HNH
Coronifera oceanica
Hystrichosphaeridium? sp.
Isabelidinium aff. ?amphiatum large
Florentinia cf. mantellii
Tanyosphaeridium variecalamus
Spinidinium uncinatum
Isabelidinium microarmum
Hystrichodinium pulchrum
Isabelidinium? sp. 14 HNH
Palaeohystrichophora infusorioides
Exochosphaeridium aff. bifidum
Dinogymnium? sp.
Chatangiella aff. granulifera
Exochosphaeridium aff. striolatum
Hyalin sphaeromorph
Alterbia sp.
Chorat aff. sp. 5 HNH dig. dis. pro
Cerodinium speciosa ?glabrum
Glaphyrocysta sp.
Phelodinium kozlowskii
Batioladinium jaegerii
Leptodinium sp.
Palambages spp.
Tasmanites sp.
?Hair from leaf
Aquilapollenites spp.
Wodehouseia spinate
ENCL: 1
CENTRAL NUUSSUAQ (1065 - 0m)
ANALYSTS: 1994 HN-H
DATE: 30/3
GGU
SIS BJÆRKE

ENCL: 3 — WELL 400701 AGAT (405 - 375m)

CRETACEOUS	SYSTEM
M CAMPANIAN	STAGE
I MICROARMUM	ZONE
400 · 450	DEPTH
REF:	LITHOLOGY
	SAMPLES



Chorat aff. sp. 5 HNH dig. dis. pro
Palaeoperidinium pyrophorum
Chatangiella sp.
Isabelidinium spp.
Chatangiella aff. ditissima
Isabelidinium microarmum
Exochosphaeridium sp.
Circulodinium distinctum
Palaeocystodinium aff. golzowense
Spiniferites spp.
Aquilapollenites spp.

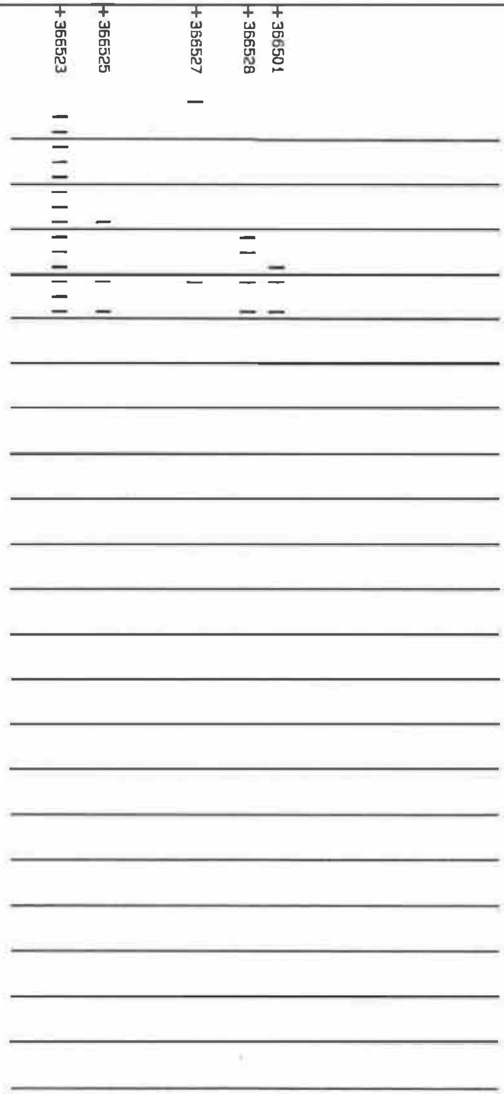
ANALYSTS: 1994 HN-H
DATE: 3/3

GGU

S I S BJÆRKE

ENCL: 2 — FGC 90-7-31/2 AG (554 - 509m)

CRETACEOUS	SYSTEM
M CAMPANIAN	STAGE
I MICROARMUM	ZONE
500 · 550 · 600	DEPTH
REF:	LITHOLOGY
	SAMPLES



Acritarch sp. 1 HNH
Spinidinium aff. ?uncinatum
Spiniferites spp.
Palaeohystrichophora infusorioides
Trithyrodinium aff. suspectum
Isabelidinium aff. ?amphiatum larga
Chatangiella sp. with short spines
Dinocyst sp. 10 HNH
Odontochitina striatoperforata
Palaeoperidinium pyrophorum
Chatangiella aff. granulifera
Circulodinium distinctum
Isabelidinium microarmum
Tasmanites sp.
Aquilapollenites spp.

ANALYSTS: 1994 HN-H
DATE: 2/3

GGU

S I S BJÆRKE

ENCL: 5 — WELL 400703 AGAT (357 - 298m)

CRETACEOUS	SYSTEM
L SANTONIAN	STAGE
C. AFF. DITISSIMA	ZONE
300 · 350 · 400	DEPTH
REF:	LITHOLOGY

SAMPLES

400703181 · 40070314 · 40070312 · 400703-9 · 400703-7

Isabelidinium spp.
Chorat cyst
Chatangiella aff. ditissima
Circulodinium distinctum

ANALYSTS: 1994 HN-H
DATE: 3/3

-GGU-

S I S BJÆRKE

ENCL: 4 — WELL 400702 AGAT (382 - 323m)

CRETACEOUS		SYSTEM
M CAMPANIAN		STAGE
AQUILAPOLLENITES 2	I MICROARMU	ZONE
350 · 400		DEPTH
REF:		LITHOLOGY

SAMPLES

40070222 · 40070220 · 40070216 · 40070214 · 40070212 · 40070210 · 400702-7

Oligosphaeridium aff. complex
Circulodinium distinctum
Chorat aff. sp. 5 HNH dig. dis. pro
Isabelidinium aff. ?amphiatum large
Palaeoperidinium pyrophorum
Circulodinium aff. ?distinctum
Florentinia spp.
Spiniferites spp.
Isabelidinium cf. acuminatum
Exochosphaeridium spp.
Isabelidinium microarmum
Odontochitina striatoperforata
Oligosphaeridium sp.
Palaeohystrichophora infusorioides
Tanyosphaeridium sp.
Chatangiella aff. ditissima
Fromea nicosie
Isabelidinium spp.
Chatangiella sp.
Hyalin sphaeromorph
Spinidinium aff. ?uncinatum
Chatangiella aff. granulifera
Desmocysta plekta
Surculosphaeridium aff longifurcatu
Palambages spp.
Aquilapollenites spp.

ANALYSTS: 1994 HN-H
DATE: 3/3

-GGU-

S I S BJÆRKE

CRETACEOUS	SYSTEM	ENCL: 7
M CAMPANIAN	STAGE	
I MICROARMUM	ZONE	
450 500	DEPTH	
REF:	LITHOLOGY	

SAMPLES

+369209 +369213 +369219

Spiniferites spp.
Isabelidinium microarmum
Palaeoperidinium pyrophorum
Surculosphaeridium aff longifurcatu
Odontochitina striatoperforata
Chorat cyst
Circulodinium distinctum
Aquilapollenites spp.

HNH 91-7-26/1 AG (458 - 415m)

ANALYSTS: 1994 HN-H
DATE: 22/3

-GGU-

S I S BJÆRKE

CRETACEOUS		SYSTEM	ENCL: 6
L SANTONIAN	E CA	STAGE	
C. AFF. DITISSIMA	AQ UI	ZONE	
300 350		DEPTH	
REF:		LITHOLOGY	

SAMPLES

40070419 40070417 40070415 40070413 40070411 400704-9 400704-7

Oligosphaeridium sp.
Chatangiella aff. ditissima
Chorat sp. 5 HNH
Spinidinium aff. ?uncinatum
Laciniadinium aff. arcticum
Odontochitina striatoperforata
Spiniferites spp.
Aquilapollenites spp.

WELL 400704 AGAT (339 - 255m)

ANALYSTS: 1994 HN-H
DATE: 3/3

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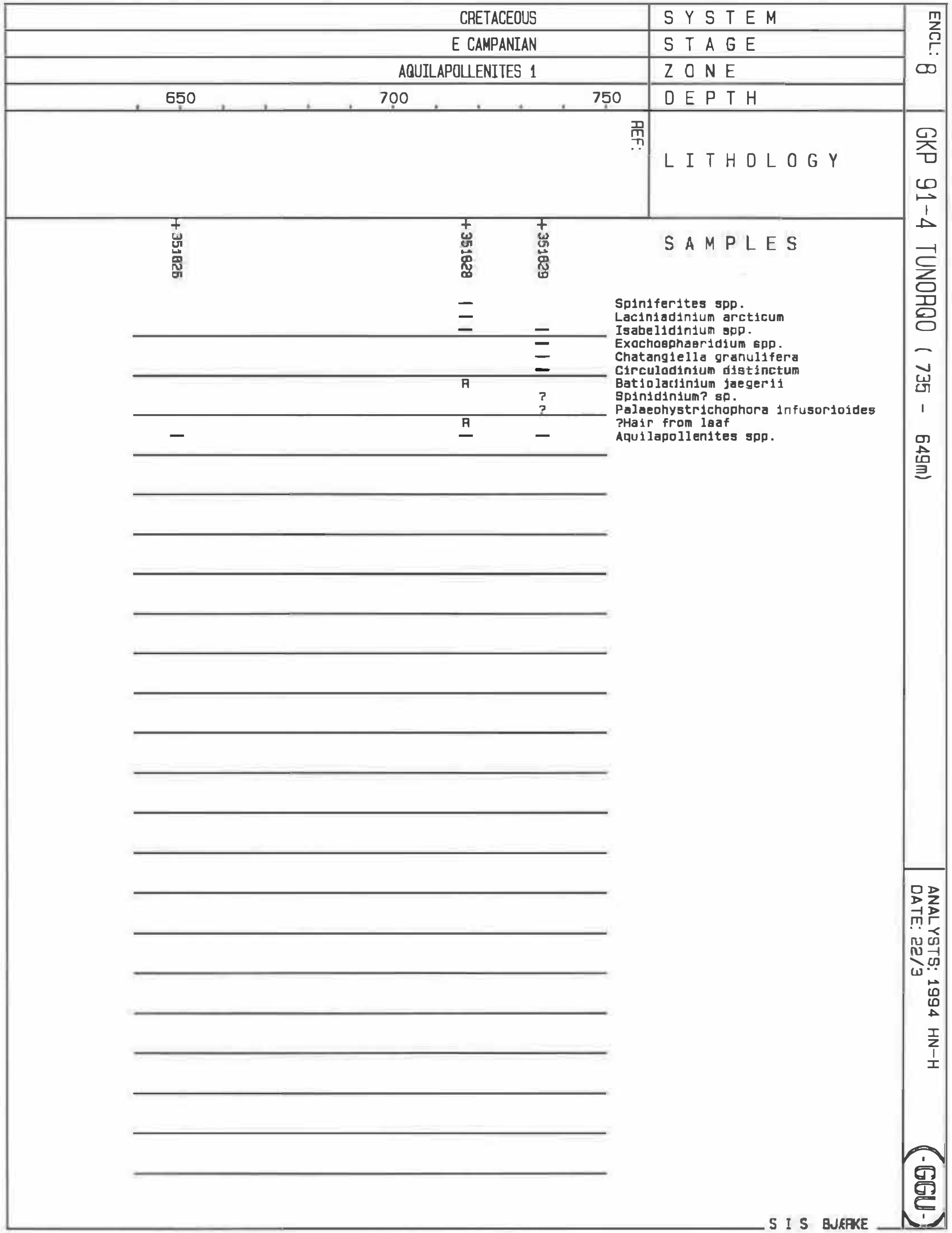
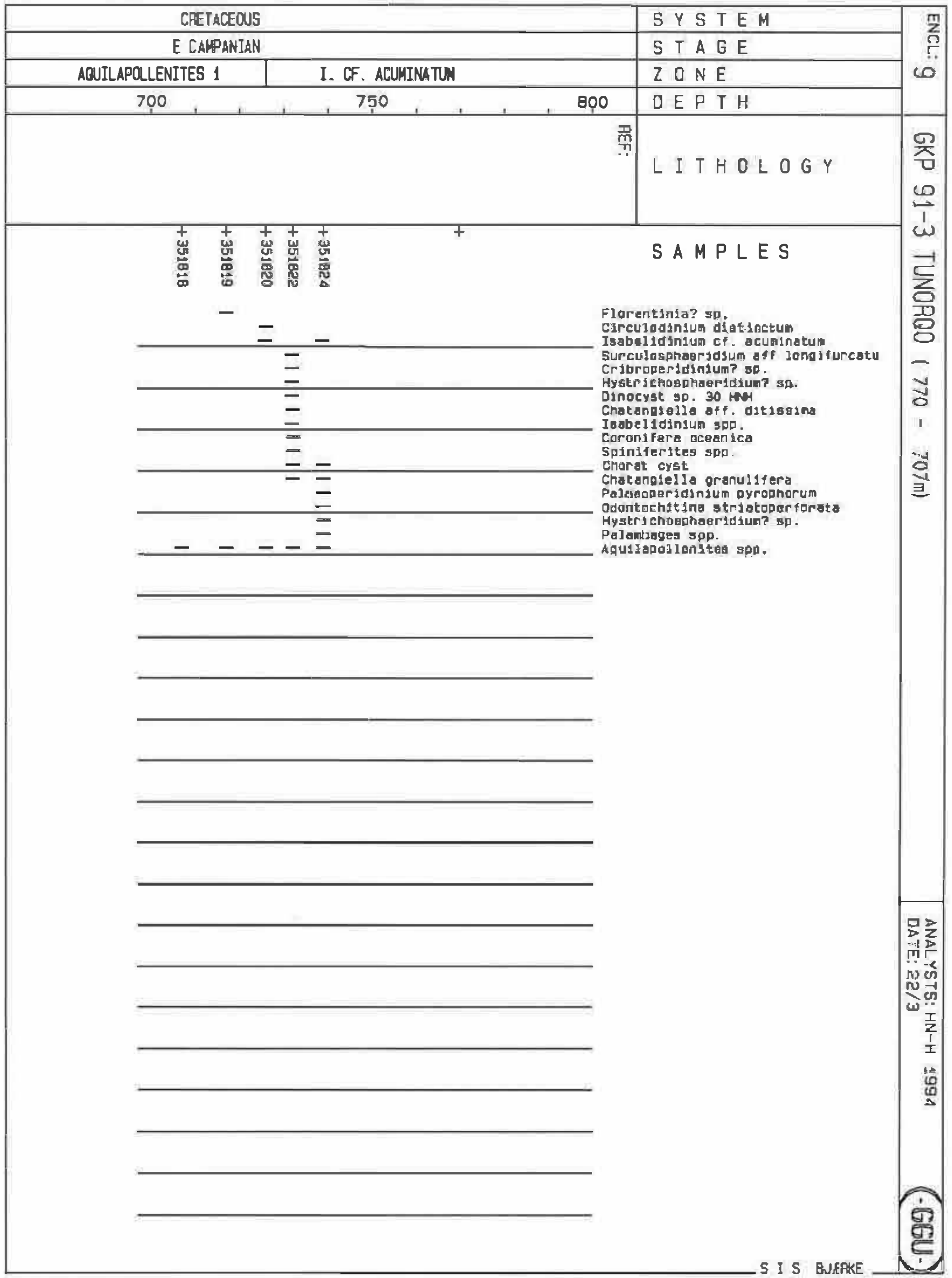
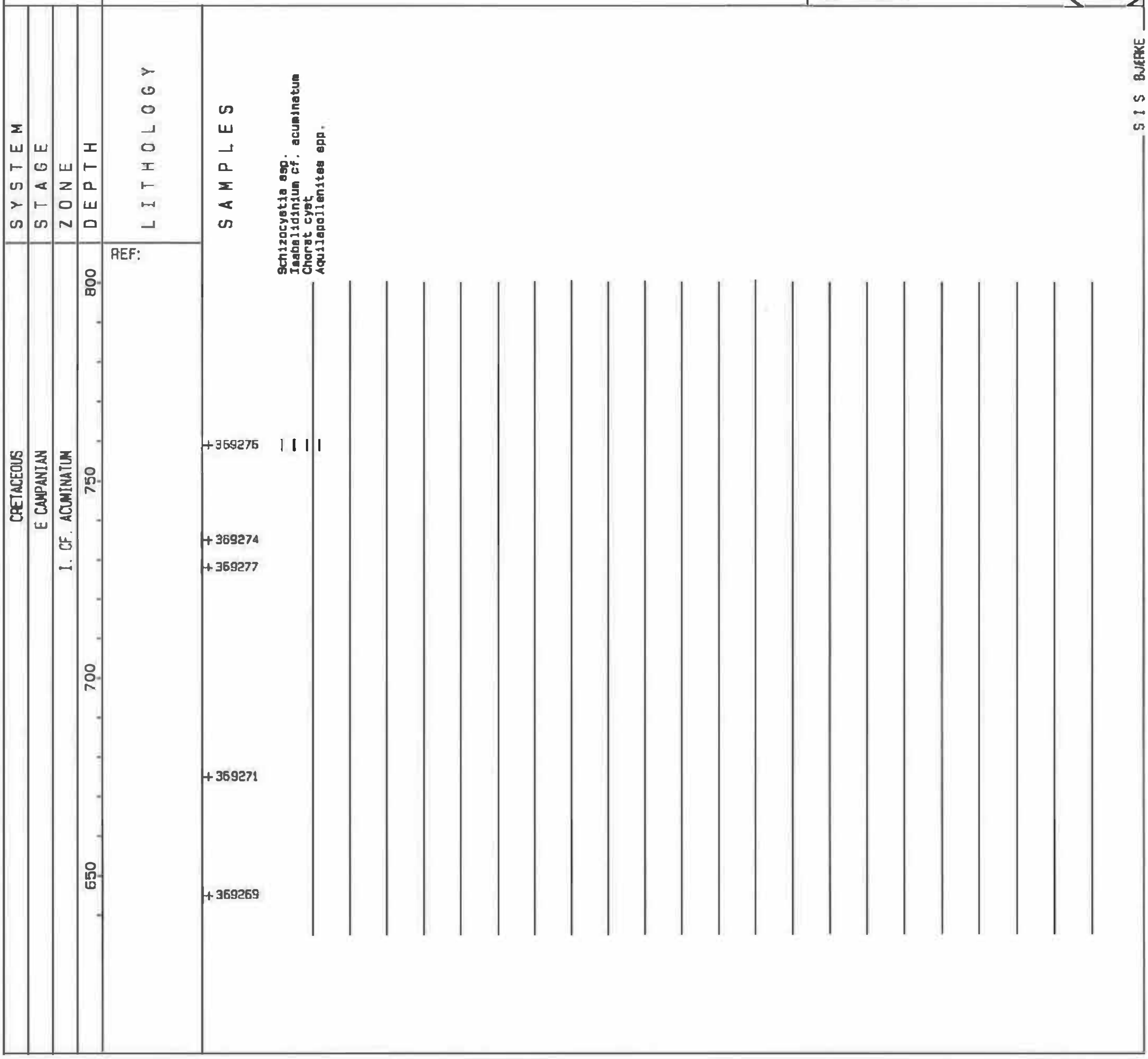
S I S BJÆRKE

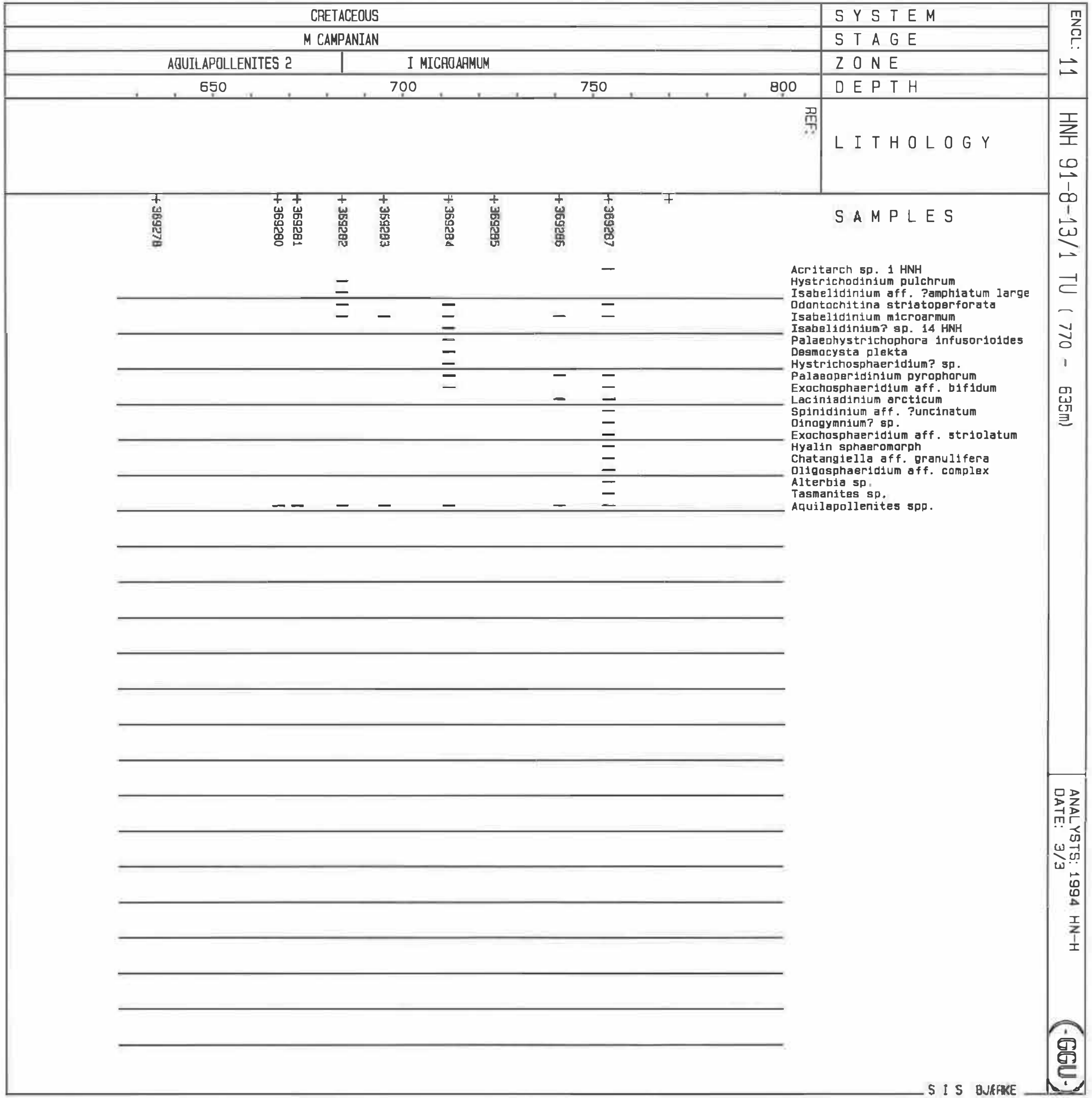


CRETACEOUS
E CAMPANIAN
AQUILAPOLLENITES 1
650
700
750
REF:
SYSTEM
STAGE
ZONE
DEPTH
LITHOLOGY
SAMPLES
351826
351828
351829
Spiniferites spp.
Laciniadinium arcticum
Isabelidinium spp.
Exochosphaeridium spp.
Chatangiella granulifera
Circulodinium distinctum
Batioladinium jaegerii
Spinidinium? sp.
Palaeohystrichophora infusorioides
?Hair from laaf
Aquilapollenites spp.
R
?
ENCL: 8
GKP 91-4 TUNORQO (735 - 649m)
ANALYSIS: 1994 HN-H
DATE: 22/3
-GGU-
S I S BJÆRKE

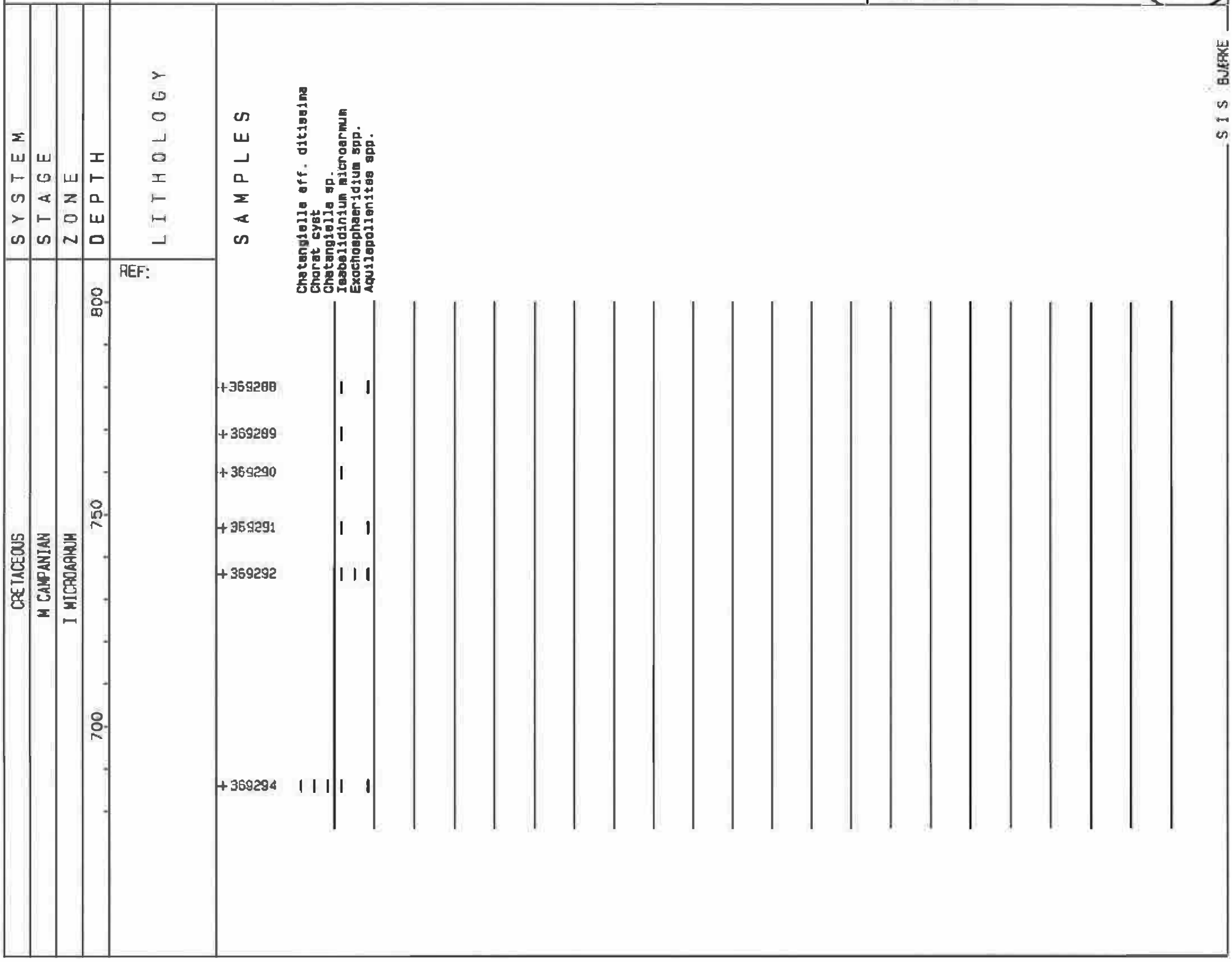

CRETACEOUS
SYSTEM
E CAMPANIAN
STAGE
AQUILAPOLLENITES 1
I. CF. ACUMINATUM
ZONE
700
750
800
DEPTH
REF:
LITHOLOGY
351818
351819
351820
351822
351824
SAMPLES
Florentinia? sp.
Circulodinium distinctum
Isabelidinium cf. acuminatum
Surculosphaeridium aff longifurcatu
Cribroperidinium? sp.
Hystrichosphaeridium? sp.
Dinocyst sp. 30 HNH
Chatangiella aff. ditissima
Isabelidinium spp.
Coronifera oceanica
Spiniferites spp.
Chorat cyst
Chatangiella granulifera
Palaeoperidinium pyrophorum
Odontochitina striatoperforata
Hystrichosphaeridium? sp.
Palambages spp.
Aquilapollenites spp.
ENCL: 9
GKP 91-3 TUNORQO (770 - 707m)
ANALYSTS: HN-H 1994
DATE: 22/3
GGU
S I S BJÆRKE

ENCL: 10 | HNH 91-8-11/1 TU (759 - 645m) | ANALYSTS: 1994 HN-H DATE: 24/3 | -GGU-




CRETACEOUS
M CAMPANIAN
AQUILAPOLLENITES 2
I MICROARMUM
650
700
750
800
SYSTEM
STAGE
ZONE
DEPTH
REF:
LITHOLOGY
SAMPLES
369278
369280
369281
369282
369283
369284
369285
369286
369287
Acritarch sp. 1 HNH
Hystrichodinium pulchrum
Isabelidinium aff. ?amphiatum large
Odontochitina striatoperforata
Isabelidinium microarmum
Isabelidinium? sp. 14 HNH
Palaeohystrichophora infusorioides
Desmocysta plekta
Hystrichosphaeridium? sp.
Palaeoperidinium pyrophorum
Exochosphaeridium aff. bifidum
Laciniadinium arcticum
Spinidinium aff. ?uncinatum
Dinogymnium? sp.
Exochosphaeridium aff. striolatum
Hyalin sphaeromorph
Chatangiella aff. granulifera
Oligosphaeridium aff. complex
Alterbia sp.
Tasmanites sp.
Aquilapollenites spp.
ENCL: 11
HNH 91-8-13/1 TU (770 - 635m)
ANALYSIS: 1994 HN-H
DATE: 3/3
GGU
S I S BJÆRKE

ENCL: 12 | HNH 91-8-13/2 TU (780 - 686m) | ANALYSTS: 1994 HN-H DATE: 24/3 | GGU

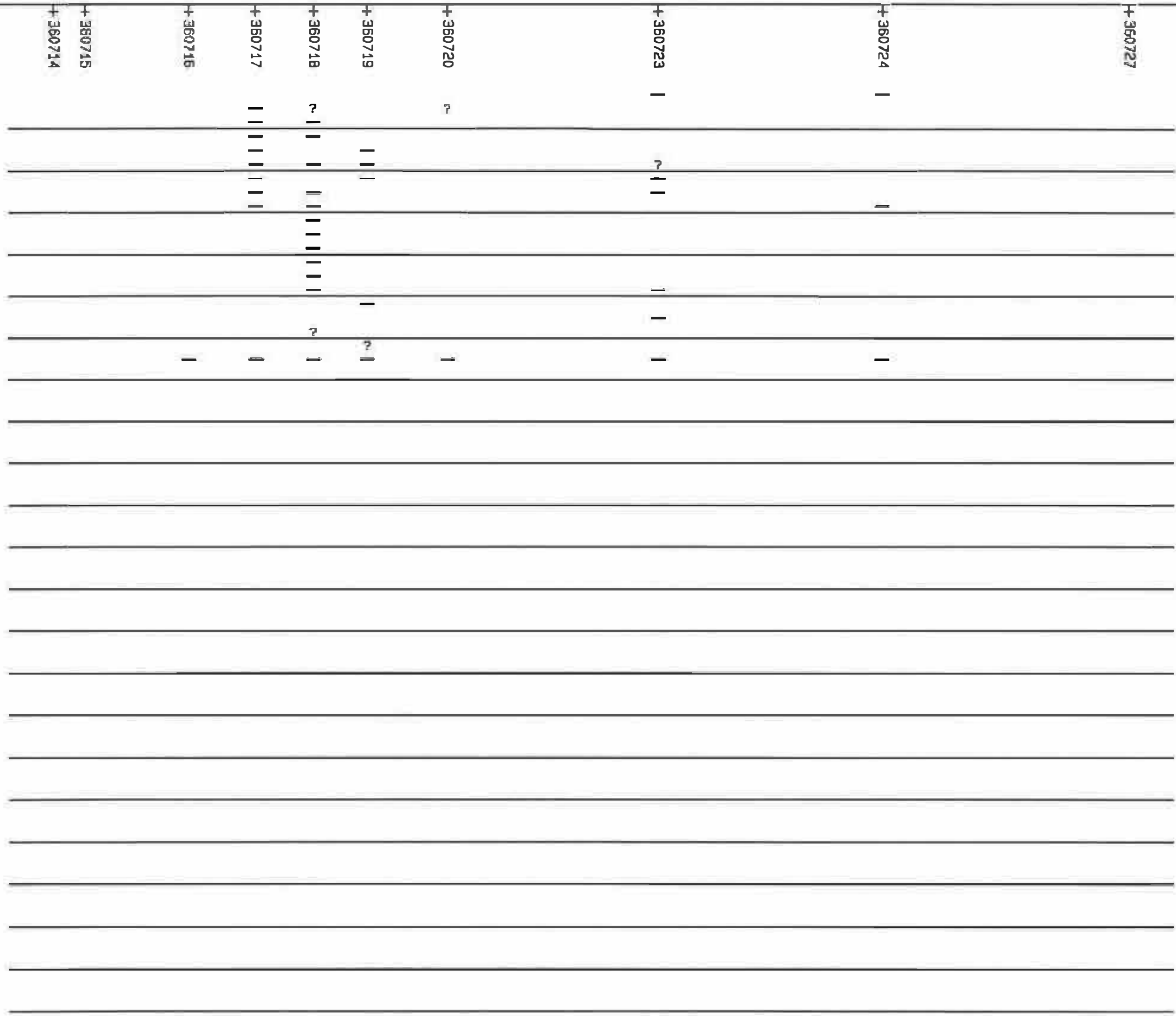


CRETACEOUS	SYSTEM
E CAMPANIAN	STAGE
AQUILAPOLLENITES 1 / I. CF. ACUMINATUM / AQUILAPOLLENITES 2	ZONE
550 · 600 · 650 · 700 · 750 · 800	DEPTH
REF:	LITHOLOGY

ENCL: 13

HNH 91-8-16/1 KA (790 - 550m)

SAMPLES



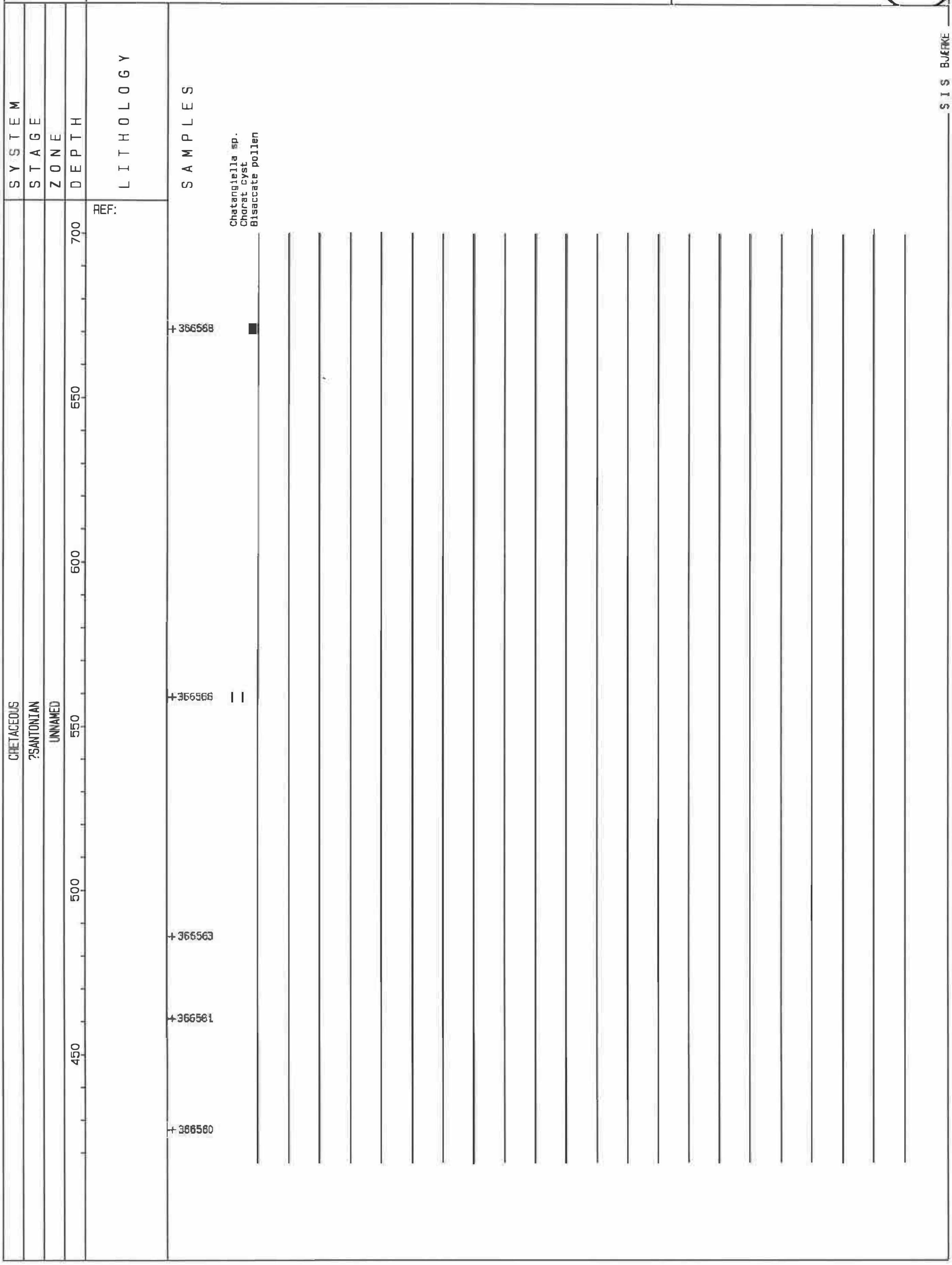
Schizocystia ssp.
Isabelidinium cf. acuminatum
Chorat cyst
Isabelidinium aff. ?amphiatum large
Odontochitina striatoperforata
Spiniferites spp.
Isabelidinium spp.
Laciniadinium arcticum
Circulodinium distinctum
Florentinia cf. mantellii
Chatangiella aff. ditissima
Palaeoperidinium pyrophorum
Oligosphaeridium sp.
Exochosphaeridium spp.
Desmocysta plekta
Tanyosphaeridium variecalamus
Spinidinium uncinatum
Chatangiella granulifera
Leptodinium sp.
Aquilapollenites spp.

ANALYSTS: 1994 HN-H
DATE: 24/3

-GGU-

S I S BJÆRKE

ENCL: 14 | FGC 90-8-04/2 KA (671 - 427m) | ANALYSTS: 1994 HN-H DATE: 9/3 | -GGU-



CRETACEOUS		SYSTEM
M CAMPANIAN		STAGE
AQUILAPOLLENITES 2	I. MICROARMUM	ZONE
750 800 850		DEPTH
REF:		LITHOLOGY

SAMPLES

+360729 +360731 +360732

Odontochitina striatoperforata
Tanyosphaeridium variacalamus
Circulodinium distinctum
Isabelidinium microarmum
Isabelidinium? sp. 14 HNH
Isabelidinium aff. ?amphiatum large
Diconodinium? sp. HNH
Aquilapollenites spp.

ENCL: 15

HNH 91-8-19/1 AA (844 - 744m)

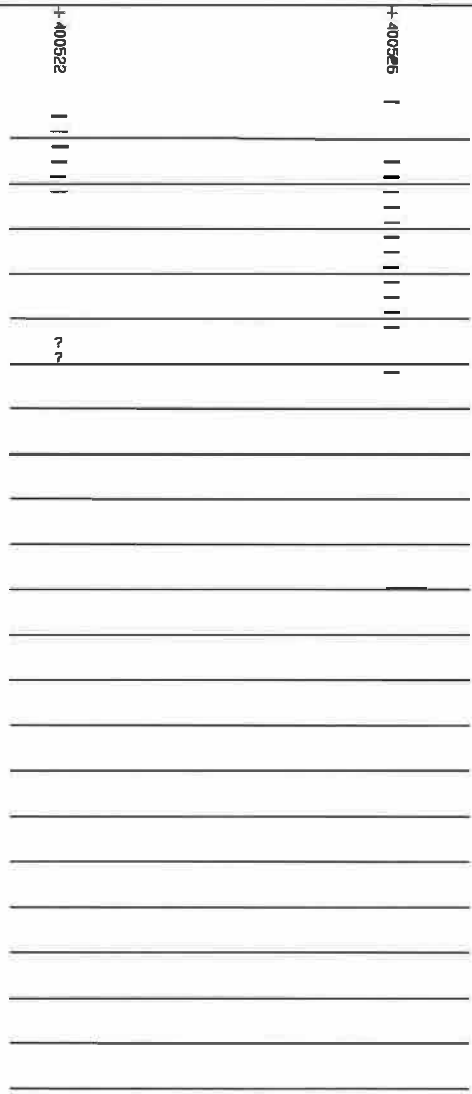
ANALYSTS: 1994 HN-H
DATE: 1/3

SIS BJÆRKE

-GGU-

CRETACEOUS		SYSTEM
L SANTONIAN		STAGE
H. DIFFICILE	C. AFF. DITISSIMA	ZONE
550	600	DEPTH
REF:		LITHOLOGY

SAMPLES



Schizocystia ssp.
Chatangiella ditissima
Surculosphaeridium longifurcatum
Laciniadinium arcticum
Oligosphaeridium pulcherrimum
Chorat sp. 5 HNH
Isabelidinium spp.
Chatangiella granulifera
Chatangiella sp.
Chorat cyst
Exochosphaeridium spp.
Palaeoperidinium pyrophorum
Odontochitina striatoperforata
Florentinia spp.
Spiniferites spp.
Circulodinium distinctum
Fibrocysta? sp.
Heterosphaeridium difficile
Tasmanites sp.

ENCL: 16

GKP 92-1 NALL. (584 - 515m)

ANALYSTS: 1994 HN-H
DATE: 24/3

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S I S BJÆRKE

SYSTEM	CRETACEOUS	E TERTIARY
STAGE	M CAMPANIAN	L PALEOCENE
ZONE	I MICROARMUM	NP 5

DEPTH: 700 750 800 850 900

REF:

LITHOLOGY

SAMPLES: 400564, 400565, 400566, 400569

Species	400564	400565	400566	400569
Circulodinium distinctum	—			
Isabelidinium microarmum	—			
Odontochitina striatoperforata	—			
Hystrichodinium pulchrum	—			
Chorat aff. sp. 5 HNH dig. dis. pro	—			
Oligosphaeridium aff. complex	—			—
Phelodinium kozlowskii				—
Cerodinium speciosa ?glabrum				—
Glaphyrocysta sp.				—
Palambages spp.	—			—
Aquilapollenites spp.	—			
Wodehousaia spinata				—

ENCL: 17

GKP 92-3 QILAKIT (870 - 664m)

ANALYSIS: 1994 HN-H
DATE: 4/3

-GGU-

S I S BJERKE

CRETACEOUS	SYSTEM
M CAMPANIAN	STAGE
I MICROARMUM	ZONE
600	DEPTH
REF:	LITHOLOGY
400562	SAMPLES

Isabelidinium microarmum
Odontochitina striatoperforata
Circulodinium distinctum
Aquilapollenites spp.

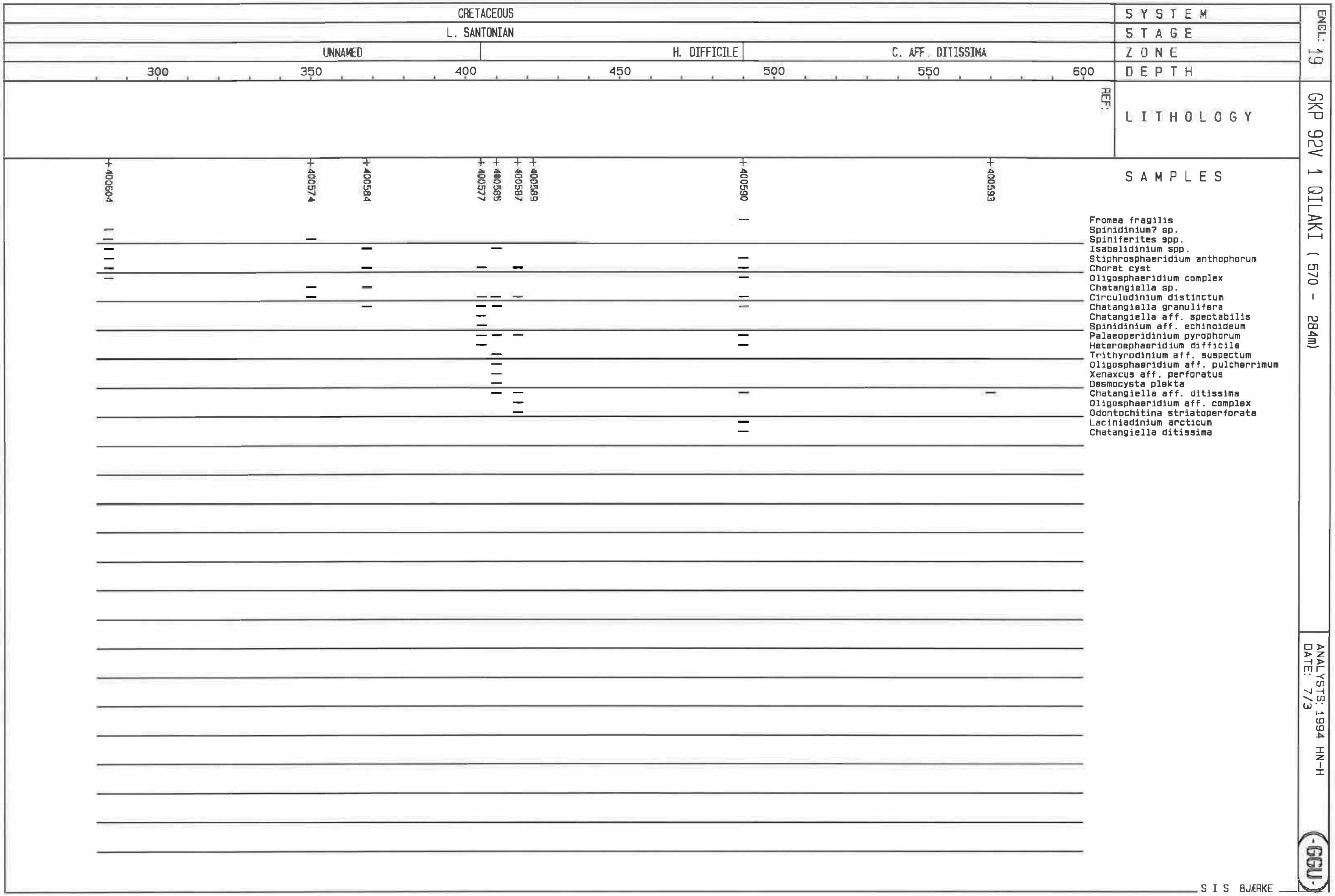
ENCL: 18

GKP 92-4 QILAKIT (580 - 580m)

ANALYSTS: 1994 HN-H
DATE: 4/3

-GGU-

S I S BJÆRKE


CRETACEOUS
L. SANTONIAN
UNNAMED
H. DIFFICILE
C. AFF. DITISSIMA
300
350
400
450
500
550
600
SYSTEM
STAGE
ZONE
DEPTH
REF:
LITHOLOGY
SAMPLES
400604
400574
400584
400577
400585
400587
400589
400590
400593
Fromea fragilis
Spinidinium? sp.
Spiniferites spp.
Isabelidinium spp.
Stiphrosphaeridium anthophorum
Chorat cyst
Oligosphaeridium complex
Chatangiella sp.
Circulodinium distinctum
Chatangiella granulifera
Chatangiella aff. spectabilis
Spinidinium aff. echinoideum
Palaeoperidinium pyrophorum
Heterosphaeridium difficile
Trithyrodinium aff. suspectum
Oligosphaeridium aff. pulcherrimum
Xenaxcus aff. perforatus
Desmocysta plekta
Chatangiella aff. ditissima
Oligosphaeridium aff. complex
Odontochitina striatoperforata
Laciniadinium arcticum
Chatangiella ditissima
ENCL: 19
GKP 92V 1 QILAKI (570 - 284m)
ANALYSTS: 1994 HN-H
DATE: 7/3
GGU
SIS BJÆRKE

CRETACEOUS	SYSTEM
L. SANTONIAN	STAGE
UNNAMED / H. DIFFICILE	ZONE
400 450 500	DEPTH
REF:	LITHOLOGY
+400597 +400601	SAMPLES

Exochosphaeridium aff. bifidum
Trithyrodinium suspectum
Heterosphaeridium difficile
Chatangiella aff. ditissima
Chorat sp. 5 HNH
Chorat cyst

ENCL: 20

GKP 92 V 2 QILAK (484 - 351m)

ANALYSIS: 1994 HN-H
DATE: 22/3

SIS BJÆRKE

GGU

Index of Figured Species

Plate 1 Central Nuussuaq

Fig. 1. *Isabelidinium* aff. *?amphiatum* large, GGU 366523-3, FGC900731/2, 47.5-92.9; LVR 1.1889; MI 1333

Fig. 2. *Isabelidinium* aff. *?amphiatum* large, GGU 366523-3, FGC900731/2, 47.5-92.9; LVR 1.1890; MI 1333

Fig. 3. *Isabelidinium* aff. *?amphiatum* large, GGU 360732-6, HNH910819/1, 33.9-103.3; LVR 1.1970; MI 1400

Fig. 4. *Isabelidinium* aff. *?amphiatum* large, GGU 360718-4, HNH910816/1, 25.0-101.9; LVR 1.3091; MI 2338

Fig. 5. *Isabelidinium* aff. *?amphiatum* large, GGU 360717-5, HNH910816/1, 51.3-113.7; LVR 1.1950; MI 1385

Fig. 6. *Isabelidinium* aff. *?amphiatum* large, GGU 360717-5, HNH910816/1, 22.3-98.8; LVR 1.1944; MI 1379

Fig. 7. *Isabelidinium* aff. *?amphiatum* large, GGU 366523-6, FGC900731/2, 19.4-103.1; LVR 1.1884; MI 1330

Fig. 8. *Isabelidinium* aff. *?amphiatum* large, GGU 360717-9, HNH910816/1, 39.0-99.6; LVR 1.1945; MI 1380

Fig. 9. *Isabelidinium* aff. *?amphiatum* large, GGU 366523-4, FGC900731/2, 51.0-110.5; LVR 1.1892; MI 1334

Fig. 10. *Isabelidinium* aff. *?amphiatum* large, GGU 400702-12-3, 49.7-98.7; LVR 1.3088; MI 2336

Fig. 11. *Isabelidinium* aff. *?amphiatum* large, GGU 400702-12-9, 53.6-106.4; LVR 1.3090; MI 2337

Fig. 12. *Isabelidinium* aff. *?amphiatum* large, GGU 400702-12-3, 51.4-107.7; LVR 1.3087; MI 2335

CENTRAL NUUSSUAQ

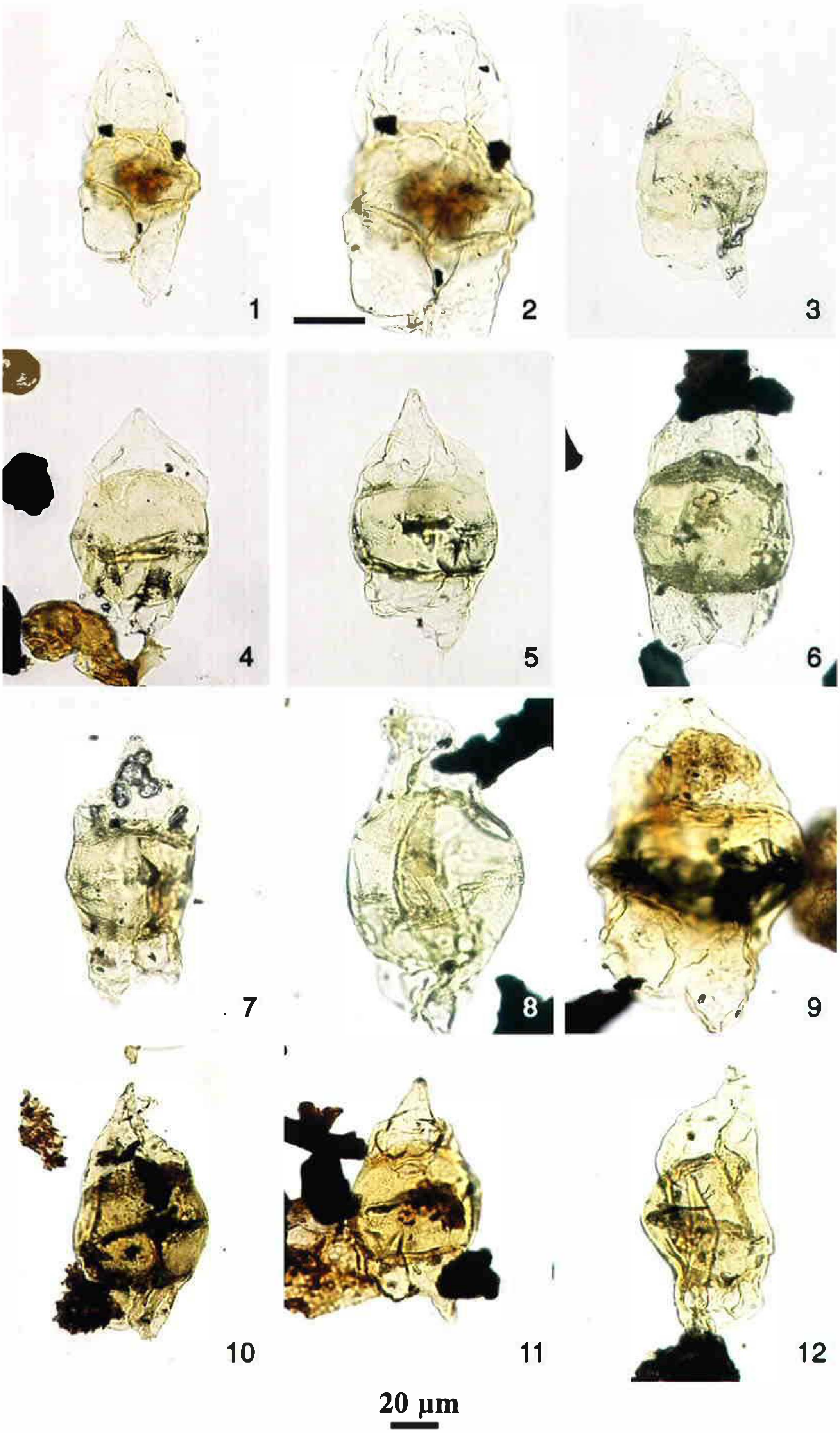


Plate 2 Central Nuussuaq

Fig. 1. *Chatangiella ditissima*, GGU 400585-8, GKP 92-V1 Qilak., 39.9-105.4; LVR 1.1988; MI 1415

Fig. 2. *Chatangiella ditissima*, GGU 360718-8, HNH910816/1, 52.6-105.9; LVR 1.3102; MI 2349

Fig. 3. *Chatangiella ditissima*, GGU 351822-3, GKP 91-3 Tun., 35.1-106.0; LVR 1.3107; MI 2354

Fig. 4. *Chatangiella ditissima*, GGU 351822-3, GKP 91-3 Tun., 38.7-103.6; LVR 1.3108; MI 2355

Fig. 5. *Chatangiella* sp. with short spines, GGU 366523-3, FGC900731/2, 48.2-107.4; LVR 1.1893; MI 1335

Fig. 6. *Diconodinium*? sp. HNH, GGU 360732-4, HNH910819/1, 52.1-109.3; LVR 1.1972; MI 1401

Fig. 7. *Laciniadinium arcticum*, GGU 369287-4, HNH910813/1, 24.9-101.4; LVR 1.1906; MI 1347

Fig. 8. *Laciniadinium arcticum*, GGU 369287-4, HNH910813/1, 26.5-100.5; LVR 1.1907; MI 1348

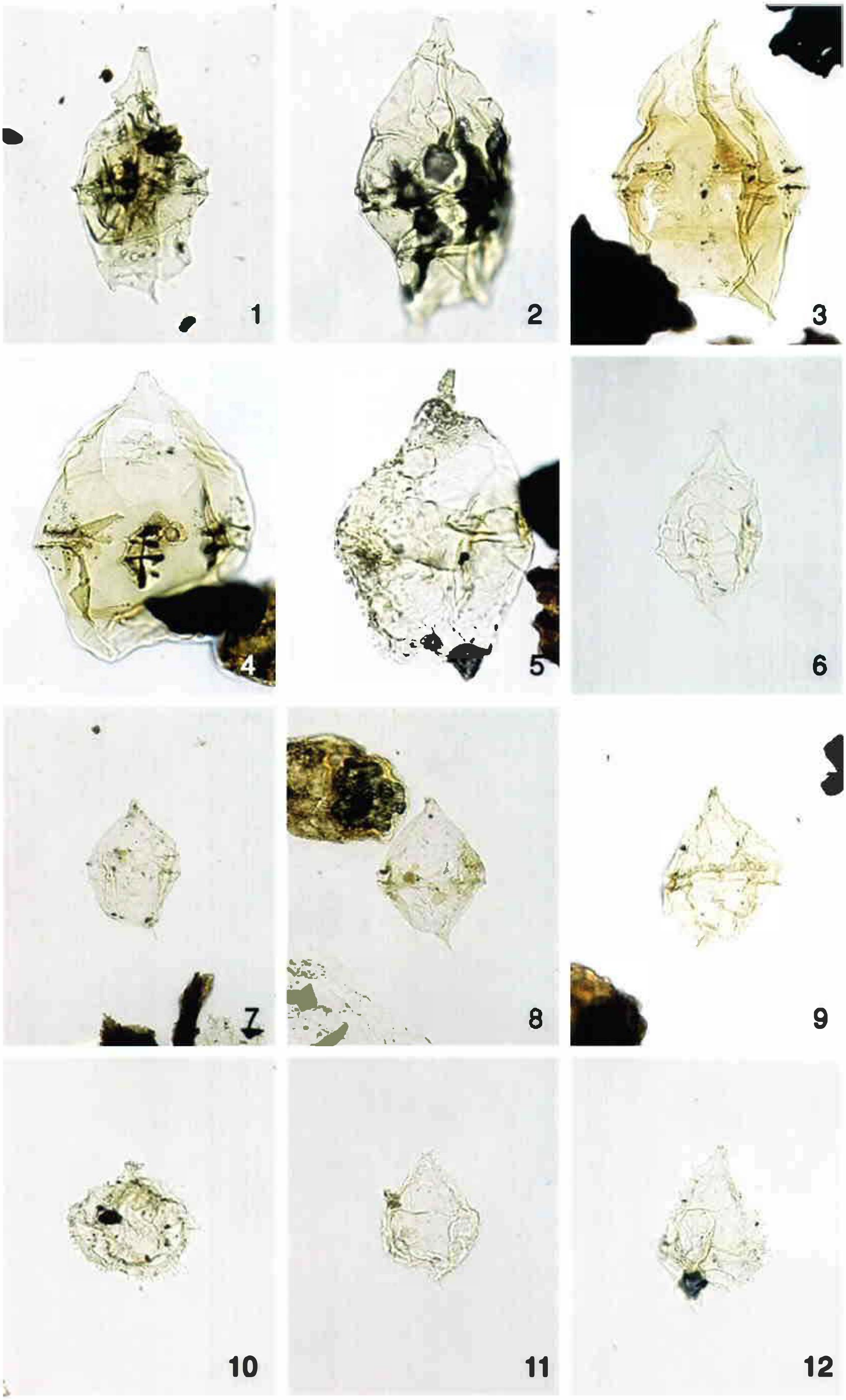
Fig. 9. *Laciniadinium arcticum*, GGU 351828-3, GKP 91-4 Tun., 53.1-107.3; LVR 1.3111; MI 2357

Fig. 10. *Spinidinium echinoideum*, GGU 366523-3, FGC900731/1, 20.1-102.8; LVR 1.1874; MI 1324

Fig. 11. *Spinidinium echinoideum*, GGU 369287-4, HNH910813/1, 37.3-113.2; LVR 1.1914; MI 1354

Fig. 12. *Spinidinium echinoideum*, GGU 369287-4, HNH910813/1, 43.4-113.1; LVR 1.1915; MI 1355

CENTRAL NUUSSUAQ



20 µm

Plate 3 Central Nuussuaq

Fig. 1. *Isabelidinium microarmum*, GGU 360731-10, HNH910819/1, 48.7-107.4; LVR 1.1962; MI 1394

Fig. 2. *Isabelidinium microarmum*, GGU 360732-9, HNH910819/1, 25.5-101.8; LVR 1.1966; MI 1396

Fig. 3. *Isabelidinium microarmum*, GGU 360732-10, HNH910819/1, 29.6-103.2; LVR 1.1968; MI 1398

Fig. 4. *Isabelidinium microarmum*, GGU 360732-6, HNH910819/1, 33.3-114.3; LVR 1.1969; MI 1399

Fig. 5. *Isabelidinium microarmum*, GGU 360717-4, HNH910816/1, 38.6-97.7; LVR 1.3084; MI 2332

Fig. 6. *Albertia* sp., GGU 369287-4, HNH910813/1, 30.7-99.8; LVR 1.1911; MI 1351

Fig. 7. *Isabelidinium*? sp. 14 HNH, GGU 369284-4, HNH910813/1, 21.5-98.2; LVR 1.1899; MI 1340

Fig. 8. *Isabelidinium*? sp. 14 HNH, GGU 369284-4, HNH910813/1, 50.4-113.6; LVR 1.1902; MI 1343

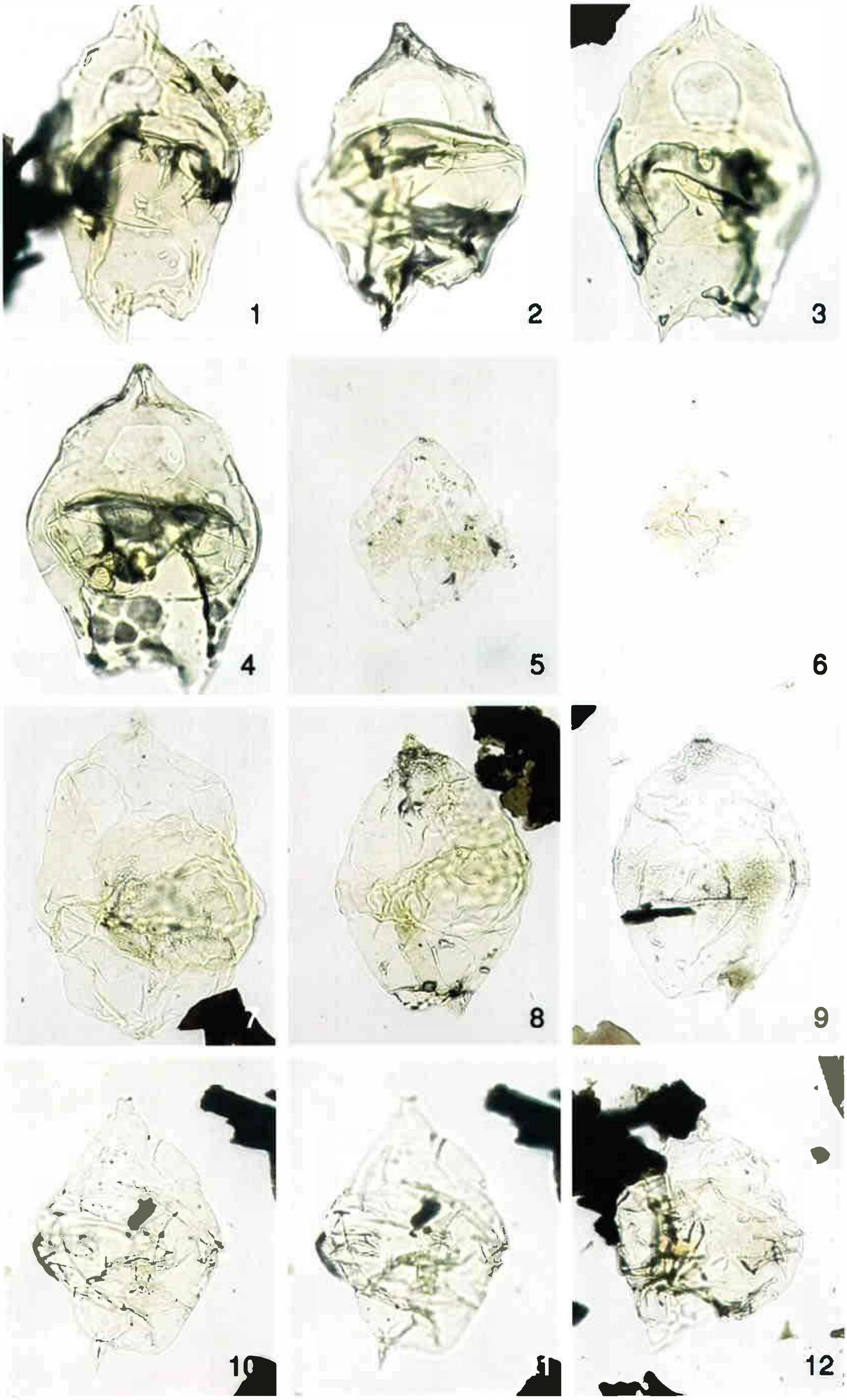
Fig. 9. *Isabelidinium*? sp. 14 HNH, GGU 360731-7, HNH910819/1, 52.7-107.9; LVR 1.1961; MI 1393

Fig. 10. *Chatangiella* aff. *spectabilis*, GGU 400577-4, GKP , 27.6-96.8; LVR 1.1973; MI 1402

Fig. 11. *Chatangiella* aff. *spectabilis*, GGU 400577-4, GKP , 27.6-96.8; LVR 1.1974; MI 1402

Fig. 12. *Chatangiella* aff. *spectabilis*, GGU 400577-4, GKP , 43.4-105.8; LVR 1.1975; MI 1404

CENTRAL NUUSSUAQ



20 µm

Plate 4 Central Nuussuaq

Fig. 1. *Isabelidinium* cf. *acuminatum*, GGU 360717-4, HNH910816/1, 25.5-95.7; LVR 1.1946; MI 1381

Fig. 2. *Isabelidinium* cf. *acuminatum*, GGU 360717-9, HNH910816/1, 44.5-100.3; LVR 1.1947; MI 1382

Fig. 3. *Isabelidinium* cf. *acuminatum*, GGU 360717-9, HNH910816/1, 37.0-96.2; LVR 1.1948; MI 1383

Fig. 4. *Isabelidinium* cf. *acuminatum*, GGU 400702-12-9, 38.9-103.0; LVR 1.3081; MI 2329

Fig. 5. *Isabelidinium* cf. *acuminatum*, GGU 351824-3 GKP 91-3 Tun., 20.1-102.3; LVR 1.3082; MI 2330

Fig. 6. *Isabelidinium* cf. *acuminatum*, GGU 351824-3 GKP 91-3 Tun., 27.8-115.0; LVR 1.3083; MI 2331

Fig. 7. *Isabelidinium* cf. *acuminatum*, GGU 369276-4, HNH910811/1, 53.1-100.3; LVR 1.3085; MI 2333

Fig. 8. *Isabelidinium* cf. *acuminatum*, GGU 400702-10-7, 41.0-103.0; LVR 1.3076; MI 2324

Fig. 9. *Isabelidinium* cf. *acuminatum*, GGU 400702-10-5, 32.7-103.7; LVR 1.3077; MI 2325

Fig. 10. *Isabelidinium* cf. *acuminatum*, GGU 400702-12-9, 24.5-109.3; LVR 1.3079; MI 2327

Fig. 11. *Isabelidinium* cf. *acuminatum*, GGU 400702-12-9, 23.8-108.2; LVR 1.3078; MI 2326

Fig. 12. *Isabelidinium* cf. *acuminatum*, GGU 400702-12-9, 33.0-110.4; LVR 1.3080; MI 2328

CENTRAL NUUSSUAQ

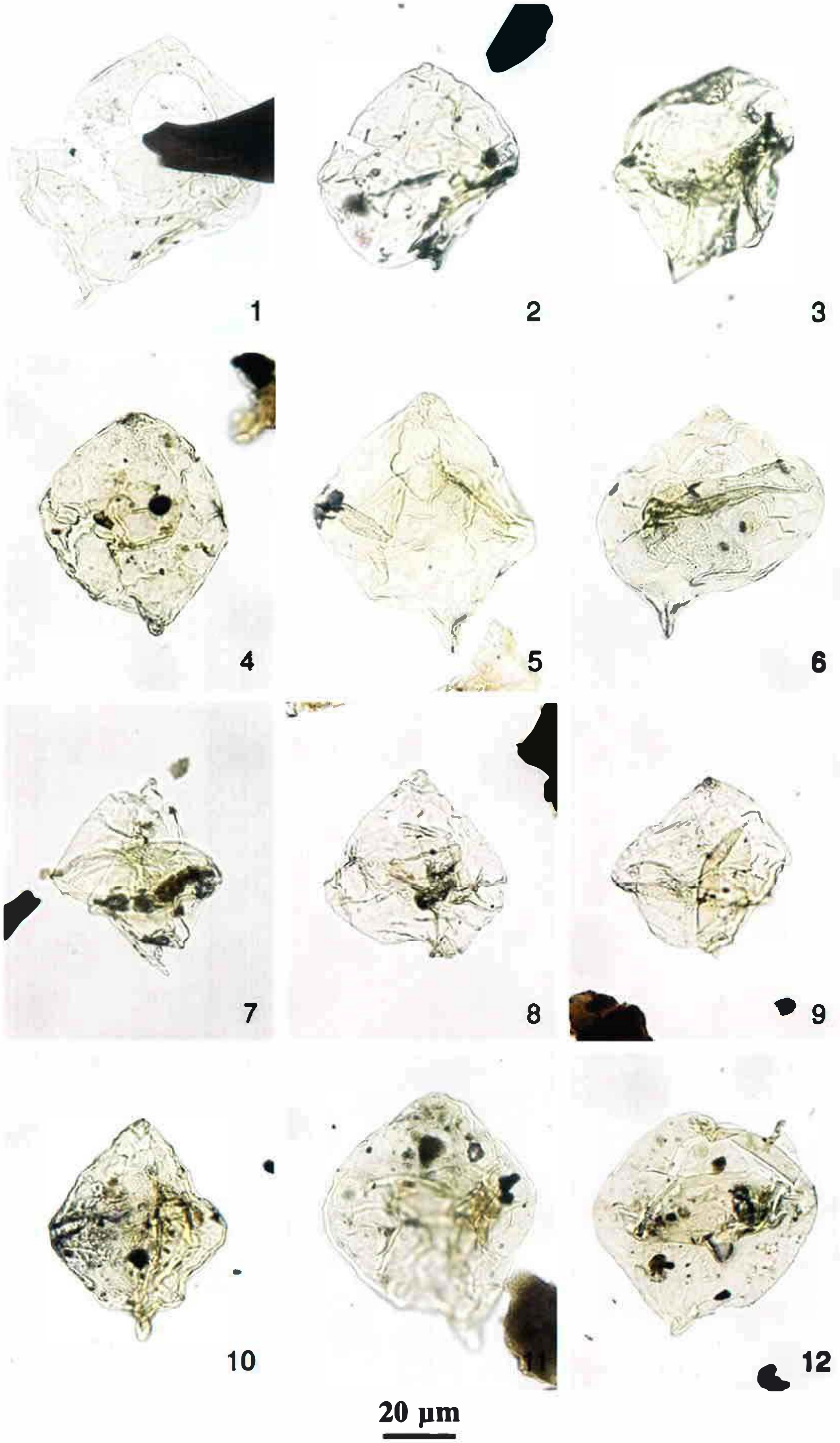


Plate 5 Central Nuussuaq

Fig. 1. *Odontochitina striatoperforata*, GGU 366523-4 FGC900731/2, 48.6-108.0; LVR 1.1885; MI 1331

Fig. 2. *Odontochitina striatoperforata* GGU 369287-4, HNH910813/1, 55.5-101.8; LVR 1.1918; MI 1358

Fig. 3. *Odontochitina striatoperforata* GGU 369287-6, HNH910813/1, 55.1-106.0; LVR 1.1927; MI 1365

Fig. 4. *Odontochitina striatoperforata* GGU 360729-10, HNH910819/1; 25.4-110.2; LVR 1.1954; MI 1389

Fig. 5. *Xenascus* aff. *perforatus* GGU 400585-6, GKP 92 V1 Qilak., 33.2-104.0; LVR 1.1985; MI 1413

Fig. 6. *Xenascus* aff. *perforatus* GGU 400585-4, GKP 92 V1 Qilak., 40.6-107.0; LVR 1.1984; MI 1412

Fig. 7. *Palaeocystodinium* aff. *golzowenze* GGU 400701-4-9, 31.8-93.0; LVR 1.3096; MI 2343

Fig. 8. *Batioladinium jaegerii* GGU 351828-2, GKP 91 4 Tun., 43.6-95.5; LVR 1.3109; MI 2356

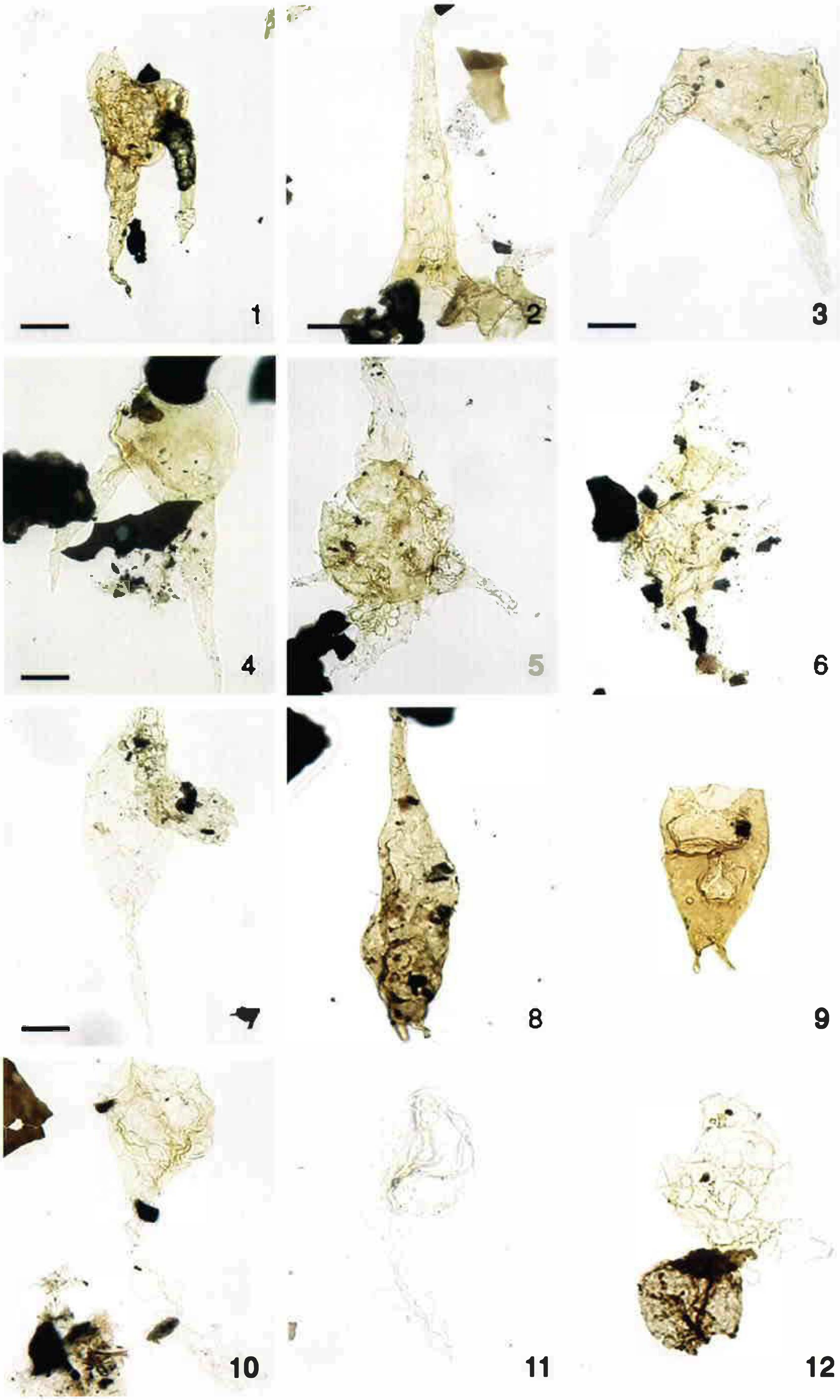
Fig. 9. *Batioladinium jaegerii* GGU 351828-3, GKP 91 4 Tun., 23.8-113.5; LVR 1.3110; MI 2357

Fig. 10. *Desmocysta plekta*, GGU 269284-4, ? 51.0-103.7; LVR 1.1903; MI 1344

Fig. 11. *Desmocsta plekta* GGU 400585-4, GKP 92 V1 Qilak., 32.8-94.0; LVR 1.1980; MI 1408

Fig. 12. *Desmocsta plekta* GGU 360718-8, HNH910816/1, 27.0-111.0; LVR 1.3104; MI 2351

CENTRAL NUUSSUAQ



20 μm

Plate 6 Central Nuussuaq

Fig. 1. *Circulodinium distinctum*, GGU 360717-9, HNH910816/1, 55.3-97.8; LVR 1.1943; MI 1378

Fig. 2. *Circulodinium* cf. *?distinctum*, GGU 400702-12-3, 34.7-104.2; LVR 1.3092; MI 2339

Fig. 3. *Circulodinium* cf. *?distinctum*, GGU 400702-12-7, 34.1-111.2; LVR 1.3093; MI 2340

Fig. 4. *Circulodinium* cf. *?distinctum*, GGU 400702-12-9, 35.0-108.8; LVR 1.3094; MI 2341

Fig. 5. *Circulodinium* cf. *?distinctum*, GGU 400702-12-9, 25.5-105.8; LVR 1.3095; MI 2342

Fig. 6. Hyalin sphaeromorph GGU 369287-4, HNH910813/1, 36.2-103.0; LVR 1.1904; MI 1345

Fig. 7. Hyalin sphaeromorph GGU 369287-4, HNH910813/1, 45.1-109.0; LVR 1.1905; MI 1346

Fig. 8. *Trithyrodinium* aff. *suspectum* GGU 400585-8, GKP 92 V1 Qilak., 35.5-100.2; LVR 1.1989; MI 1416

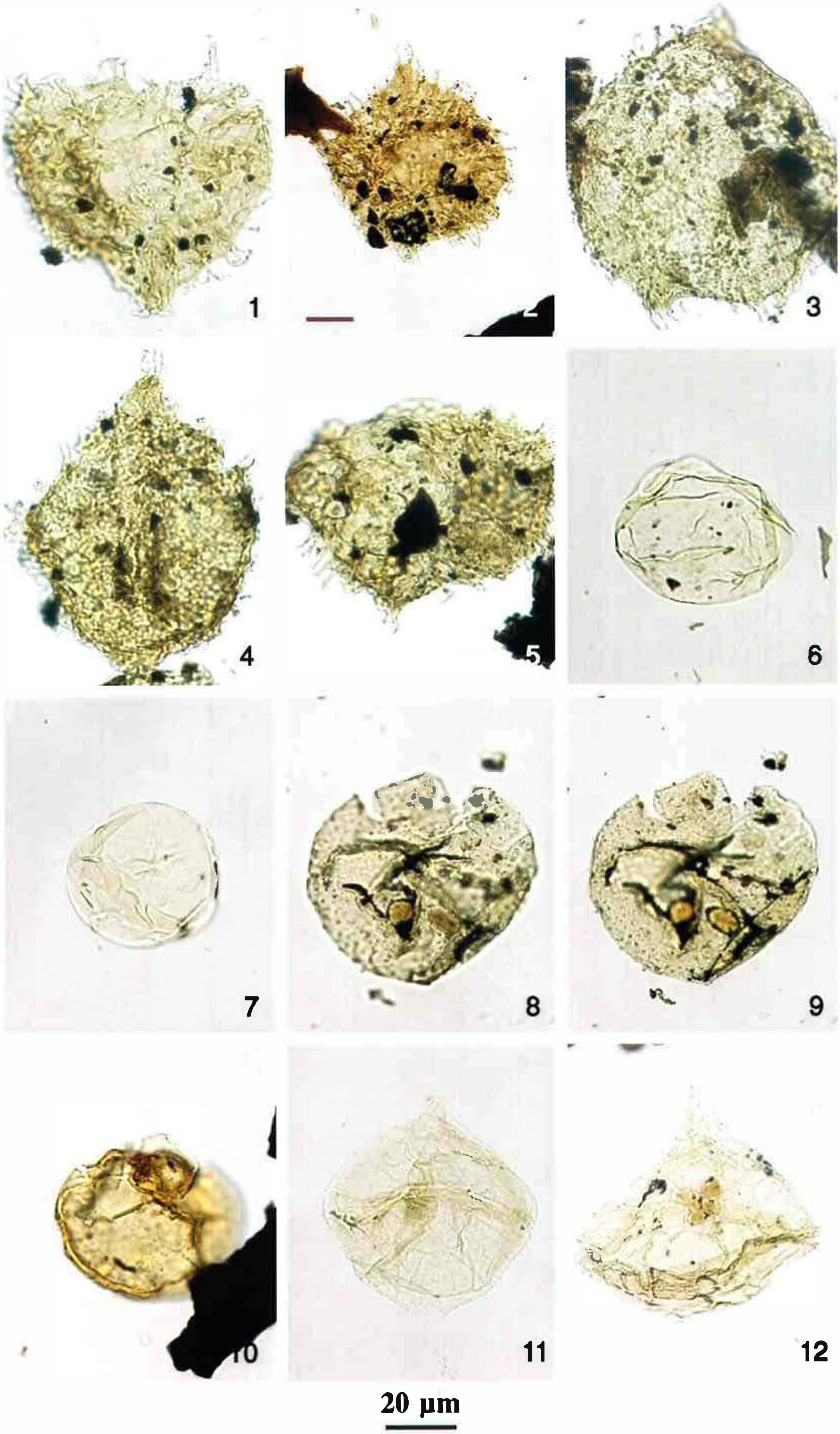
Fig. 9. *Trithyrodinium* aff. *suspectum* GGU 400585-8, GKP 92 V1 Qilak., 35.5-100.2; LVR 1.1990; MI 1416

Fig. 10. *Trithyrodinium* aff. *suspectum*, GGU 366523-3 FGC900731/2, 42.8-102.0; LVR 1.1887; MI 1332

Fig. 11. *Cribroperidinium?* sp., GGU 351822-3 GKP 91-3 Tun., 22.6-94.5; LVR 1.3105; MI 2352

Fig. 12. *Cribroperidinium?* sp., GGU 351822-3 GKP 91-3 Tun., 47.8-96.6; LVR 1.3106; MI 2353

CENTRAL NUUSSUAQ



20 µm

Plate 7 Central Nuussuaq

Fig. 1. Dinocyst sp. 10 HNH, GGU 366523-3 FGC900731/2, 29.2-122.6; LVR 1.1876; MI 1326

Fig. 2. Dinocyst sp. 10 HNH, GGU 366523-3 FGC900731/2, 29.2-122.6; LVR 1.1877; MI 1326

Fig. 3. *Exochosphaeridium* aff. *bifidum*, GGU 369287-4, HNH910813/1, 33.2-105.0; LVR 1.1913; MI 1352

Fig. 4. *Exochosphaeridium* aff. *bifidum*, GGU 369284-4, HNH910813/1, 22.8-106.4; LVR 1.1896; MI 1338

Fig. 5. *Exochosphaeridium* aff. *bifidum*, GGU 369284-6, HNH910813/1, 55.9-100.5; LVR 1.1898; MI 1339

Fig. 6. *Exochosphaeridium* aff. *bifidum*, GGU 369284-4, HNH910813/1, 18.9-108.9; LVR 1.1895; MI 1337

Fig. 7. *Exochosphaeridium* aff. *striolatum*, GGU 369287-6, HNH910813/1, 45.8-96.8; LVR 1.1930; MI 1368

Fig. 8. *Exochosphaeridium* aff. *striolatum*, GGU 369287-9, HNH910813/1, 47.4-96.9; LVR 1.1931; MI 1369

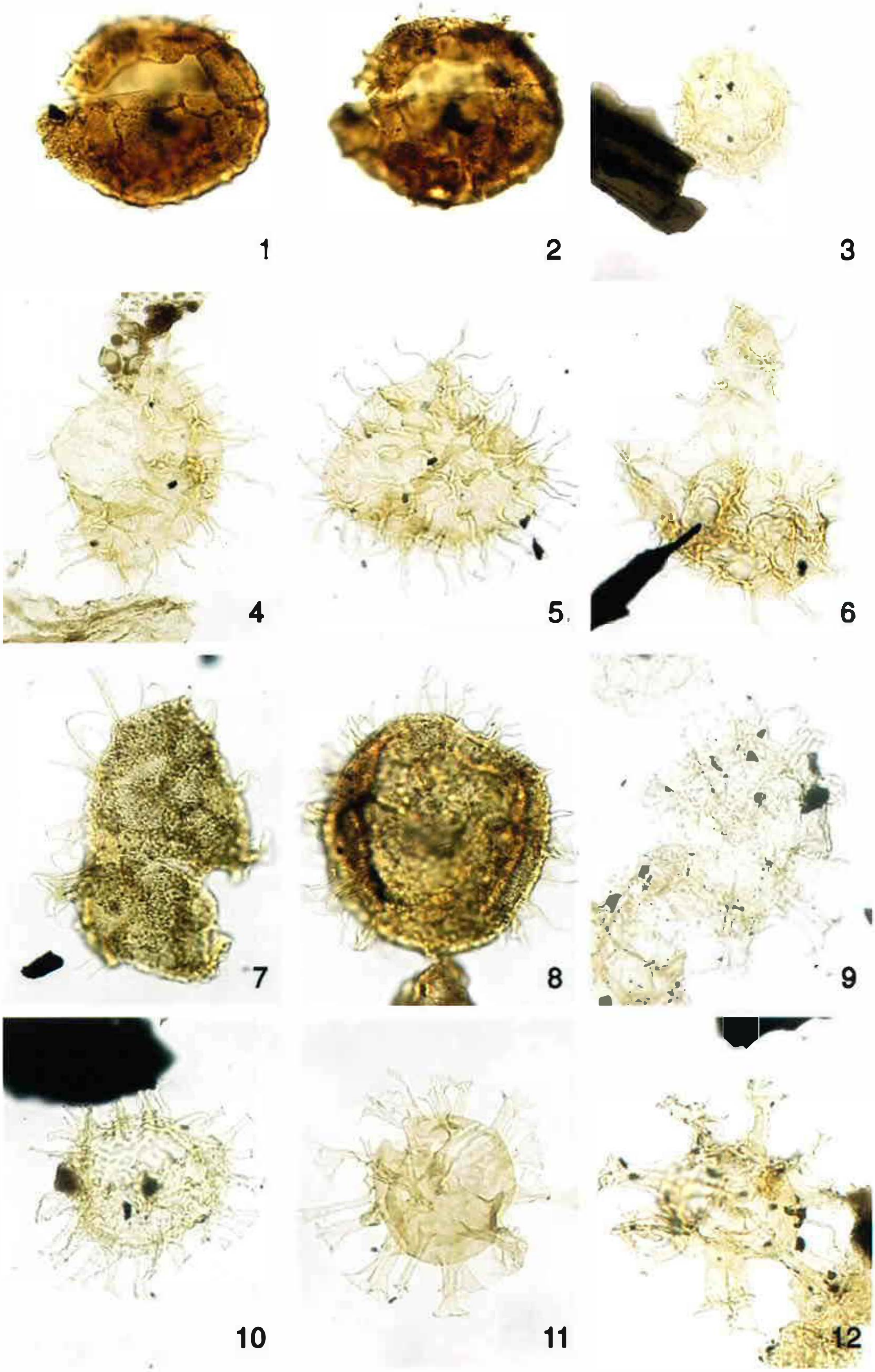
Fig. 9. *Heterosphaeridium difficile* GGU 400577-7, GKP 92 V1 Qilak., 30.0-112.3; LVR 1.1978; MI 1406

Fig. 10. Chorat cyst GGU 400577-9, GKP 92 V1 Qilak., 30.5-104.6; LVR 1.1979; MI 1407

Fig. 11. *Hystrichosphaeridium?* sp., GGU 351824-3 GKP 91-3 Tun., 49.4-103.7; LVR 1.3098; MI 2345

Fig. 12. *Oligosphaeridium* sp., GGU 360718-6, HNH910816/1, 36.4-110.8; LVR 1.3100; MI 2347

CENTRAL NUUSSUAQ



20 µm

Plate 8 Central Nuussuaq

Fig. 1. *Tanyosphaeridium variecalamus*, GGU 360729-4, HNH910819/1, 28.0-100.2; LVR 1.1953; MI 1388

Fig. 2. *Dinogymnium?* sp., GGU 369287-4, HNH910813/1, 45.1-104.9; LVR 1.1916; MI 1356

Fig. 3. *Fromea nicosia*, GGU 400702-10-7, 42.9-99.7; LVR 1.3075; MI 2323

Fig. 4. Tasmanites sp., GGU 366523-6, FGC900731/2, 40.0-106.0; LVR 1.1894; MI 1336

Fig. 5. Acritarch sp. 1 HNH, GGU 369287-4, HNH910813/1, 25.5-107.0; LVR 1.1908; MI 1349

Fig. 6. Schizocystia sp., GGU 369276-4, HNH910811/1, 37.9-113.4; LVR 1.3099; MI 2346

Fig. 7. Monolete spore, GGU 369287-4, HNH910813/1, 55.7-93.6; LVR 1.1920; MI 1360

Fig. 8. *Aquilapollenites* sp., GGU 360717-5, HNH910816/1, 41.3-103.7; LVR 1.1949; MI 1384

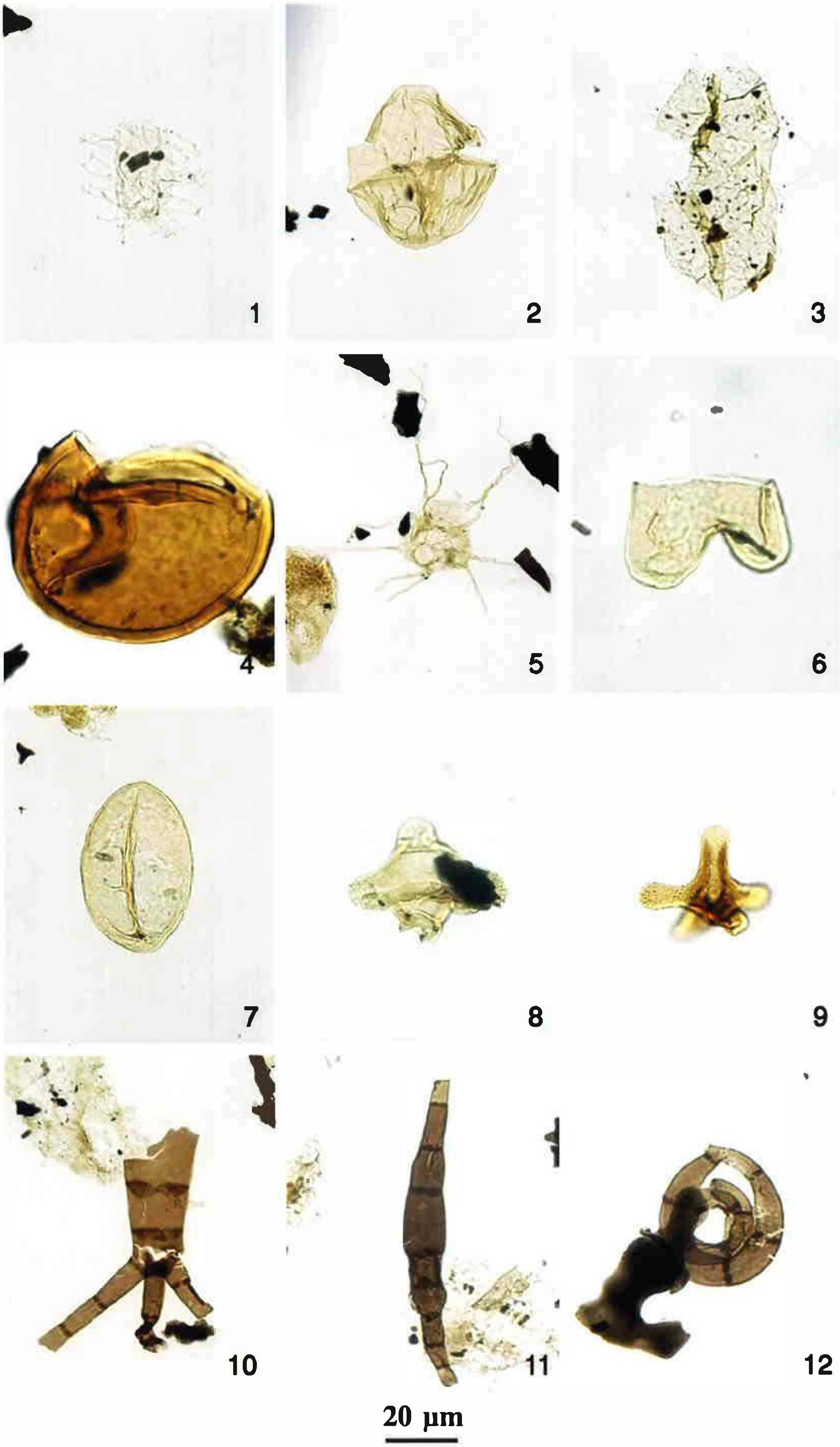
Fig. 9. *Aquilapollenites* sp., GGU 369284-4, HNH910813/1, 28.2-112.8; LVR 1.1900; MI 1341

Fig. 10. Fungal sp. HNH, GGU 369287-4, HNH910813/1, 37.5-103.5; LVR 1.1912; MI 1353

Fig. 11. Fungal sp. HNH, GGU 360717-4, HNH910816/1, 22.0-103.0; LVR 1.1935; MI 1372

Fig. 12. Fungal sp. HNH, GGU 360717-4, HNH910816/1, 38.6-109.5; LVR 1.1936; MI 1373

CENTRAL NUUSSUAQ



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