Paleocene sub-basaltic sediments on Savoia Halvø, East Greenland

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Field work by the Geological Survey of Denmark and Greenland (GEUS) on Savoia Halvø, central East Greenland in 2001 (see also Larsen *et al.* 2002, this volume) included a study of sediments underlying the Palaeogene basalts on the south coast of Scoresby Sund (Fig. 1). The importance of this small exposure is based on the fact that it provides one of the few opportunities for establishing a marine biostratigraphic date for the sediments below the basalts. Dinoflagellate cysts from the sediments provide a maximum Early Paleocene age for the onset of the volcanism in central East Greenland. Reports from previous field work have mentioned the sediments (Hassan 1953; Birkenmajer 1972), but no precise age assignment was presented due to the absence of diagnostic fossils. The sub-volcanic sediments of Savoia Halvø represent the youngest preserved marine sedimentary deposits of the Upper Palaeozoic – Cenozoic rift-basins onshore East Greenland. The overlying Palaeogene flood basalts occasionally contain very thin sedimentary beds between the lava flows, but these were deposited above sea level. Neogene uplift of the East Greenland margin brought a definitive end to accumulation in the old sedimentary basins (Watt *et al.* 1986; Christiansen *et al.* 1992).

Geology

South of Scoresby Sund (70°N), the Palaeozoic–Cenozoic rift basins of East Greenland are concealed by thick and extensive continental flood basalts of Palaeogene age. The basalts extend uninterrupted for more than 200 km towards the south (*c.* 68°N). North of Scoresby Sund an irregular sub-basaltic peneplain rises above sea level and basalt outliers cap the mountains on Milne Land and areas to the west (Watt *et al.* 1986). A second, less extensive area of Palaeogene basalts occurs further north in North-East Greenland in the Hold with Hope – Clavering Ø region (Fig. 1).

In the Scoresby Sund region the earliest basalts unconformably overlie Caledonian crystalline gneisses and Mesozoic–Palaeogene sedimentary rocks. The earliest flows erupted into palaeovalleys locally developed as hyaloclastic deposits indicative of extrusion into lakes, but pene-contemporaneous marine sediments are only known to crop out at one locality on Savoia Halvø, adjacent to the Kap Brewster settlement (Fig. 1). Elsewhere in East Greenland, contemporaneous sub-basaltic terrestrial sediments are known *c.* 450 km to the north on Clavering Ø and Hold with Hope but have not yet yielded any clear indication of their age. About 250 km towards the south (*c.* 68°N) in the Kangerlussuaq region the earliest volcanics are associated with terrestrial to marginal marine sedimentary deposits.

The Kap Brewster locality

Adjacent to the abandoned Kap Brewster settlement (Fig. 1), the almost vertical basalt cliffs are 200–1000 m high. To the west of the settlement, steep scree-slopes of large basalt blocks at the foot of the cliffs are partly covered by permanent ice and snow. To the east, the valley Bopladsdalen provides easy access to the plateau on southern Savoia Halvø where down-faulted, post-basaltic sediments crop out (Bopladsdalen, Krabbedalen and Kap Brewster Formations; Fig. 1; see Larsen *et al.* 2002, this volume). The Kap Brewster houses are situated on a narrow beach just west of the entrance to Bopladsdalen, and the first *in situ* sediments appear 50 m up the cliff behind the houses. Approximately 40 m of poorly exposed, dark grey, bioturbated mudstone occurs between 50 and 90 m above sea level (Larsen *et al.* 2002, this volume). Except for imprints of spatangid echinoderms (Hassan 1953) no macro-fossils have been reported from the mudstone, but dinoflagellate cysts have been mentioned (Watt & Watt 1983; Larsen & Marcussen 1992). The contact between sediments and the lowest basalt flow, at approximately 91 m, is not exposed; the lowest outcrop of volcanic rocks is a volcanic conglomerate about 50 m to the east.

Thirteen samples from the uppermost 40 m of the mudstone were analysed for dinoflagellates; the highest

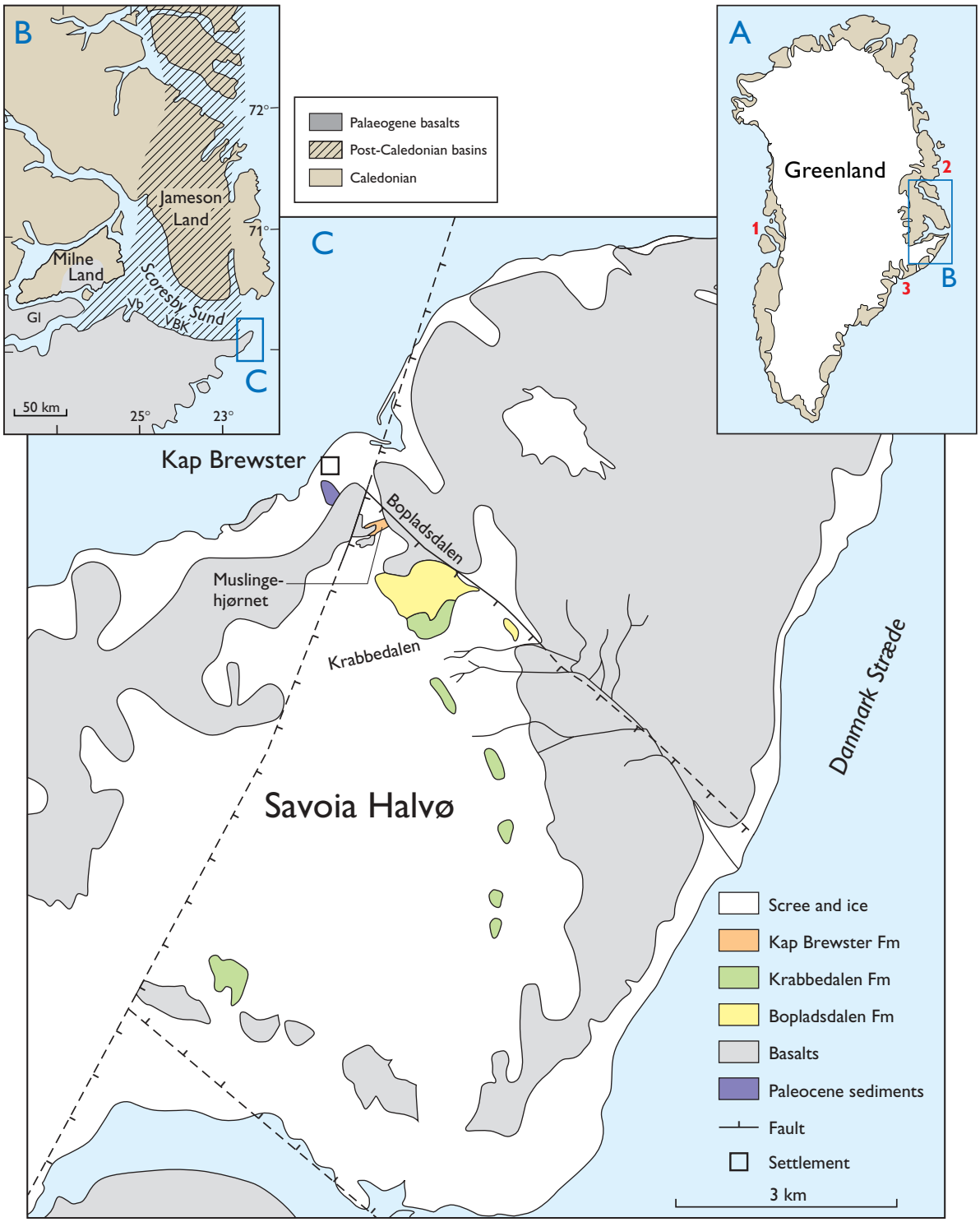

Fig. 1. Map of East Greenland with a simplified geological map of Savoia Halvø based on Birkenmajer (1972, fig. 1). The locality with exposed sub-basaltic sediments is situated adjacent to the Kap Brewster settlement. Inset **A**: Greenland map; **1**: West Greenland, Nuussuaq; **2**: North-East Greenland, Wollaston Forland – Hold with Hope – Clavering Ø region; **3**: East Greenland, Kangerlussuaq region. Inset **B**: **VBK**: Volquart Boon Kyst; **Vb**: Vikingebugt; **Gl**: Gåseland.

sample was taken 1 m below the first basalt flow. The samples were prepared by standard palynological techniques with HCl and HF. The organic residue was oxidised with HNO_3, and the microscopic fossils were separated from the terrestrial debris by swirling or the tube separation method of Hansen & Gudmundsson (1979).

Marine flora

Moderately to well-preserved dinoflagellate cysts are abundant in the mudstone together with an abundance of terrestrial organic material, spores and pollen. All analysed samples contain a rich dinoflagellate flora composed of a mixture of reworked Lower to Upper Cretaceous dinoflagellate cyst assemblages, together with Paleocene marker species.

Cretaceous dinoflagellate cysts

Stratigraphically significant dinoflagellate cysts in the composite assemblage suggest reworking from multiple sources of Cretaceous sediments or perhaps repeated reworking of Cretaceous dinoflagellate assemblages. Cretaceous dinoflagellate assemblages in East Greenland have been described by Nøhr-Hansen (1993), and mid-Cretaceous to Paleocene dinoflagellate assemblages have been described from corresponding latitudes in West Greenland (Nøhr-Hansen 1996; Nøhr-Hansen *et al.* in press).

The presence of *Leptodinium cancelatum* and *Pseudoceratium expolitum* indicates reworking from middle Albian (Lower Cretaceous) strata according to Nøhr-Hansen (1993). *Epelidosphaeridia spinosa*, *Hapsocysta benteae*, *Ovoidinium* sp. 1 Nøhr-Hansen 1993, *Rhombodinium paucispina* and *Subtilisphaera kalaalliti* indicate reworking from Upper Albian to Lower Cenomanian strata (Nøhr-Hansen 1993). *Chatangiella* spp. and *Isabelidinium* spp. suggest reworking from Upper Cenomanian to Upper Maastrichtian (Upper Cretaceous) strata, and the presence of the pollen genus *Aquilapollenites* spp. indicates reworking from Campanian to Upper Maastrichtian strata (Upper Cretaceous) according to Nøhr-Hansen (1996). The possibility that even Paleocene strata could be reworked is indicated by the presence of a few *Spongodinium delitiense* which have a range from Campanian to lower Danian, Paleocene (Hardenbol *et al.* 1998). These reworked Cretaceous assemblages are very similar to the assemblages described from North-East Greenland (Nøhr-Hansen 1993) and West Greenland (Nøhr-Hansen 1996).

Paleocene dinoflagellate cysts

Paleocene dinoflagellate cysts are rare to very rare and are generally poorly preserved, but occur in all studied samples (Fig. 2). Poorly preserved *Alisocysta* spp. (probably *A. margarita*; Fig. 3a–c) occurs together with *Areoligera* spp. (Fig. 3d–e), *Cerodinium striatum* (Fig. 3g–h) and *Palaeoperidinium pyrophorum* throughout the studied section whereas *Phelodinium kozlowskii* (Fig. 3i), *Palaeocystodinium bulliforme* (Fig. 3j–k), *Spiniferites septatus* (Fig. 3f) and *Thalassiphora delicata* (Fig. 3l) are restricted to the upper part.

The presence of probable *Alisocysta margarita* suggests a late Danian (61.58 Ma) to early Thanetian (57.16 Ma) age (Hardenbol *et al.* 1998), but according to the same authors the presence of *Palaeocystodinium bulliforme* and *Palaeoperidinium pyrophorum* excludes

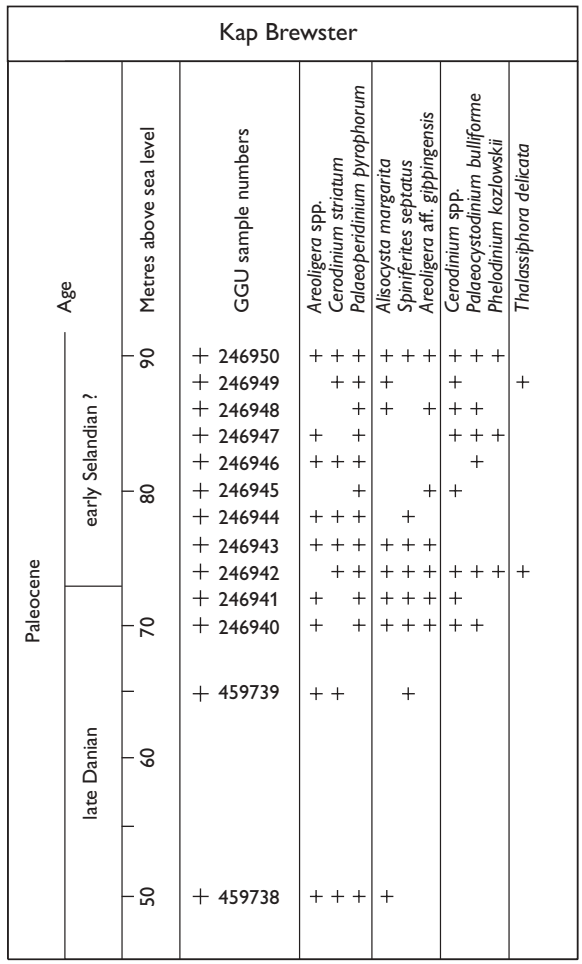

Fig. 2. Stratigraphic occurrence of selected *in situ* Paleocene dinoflagellate cysts in pre-basaltic mudstones at Kap Brewster.

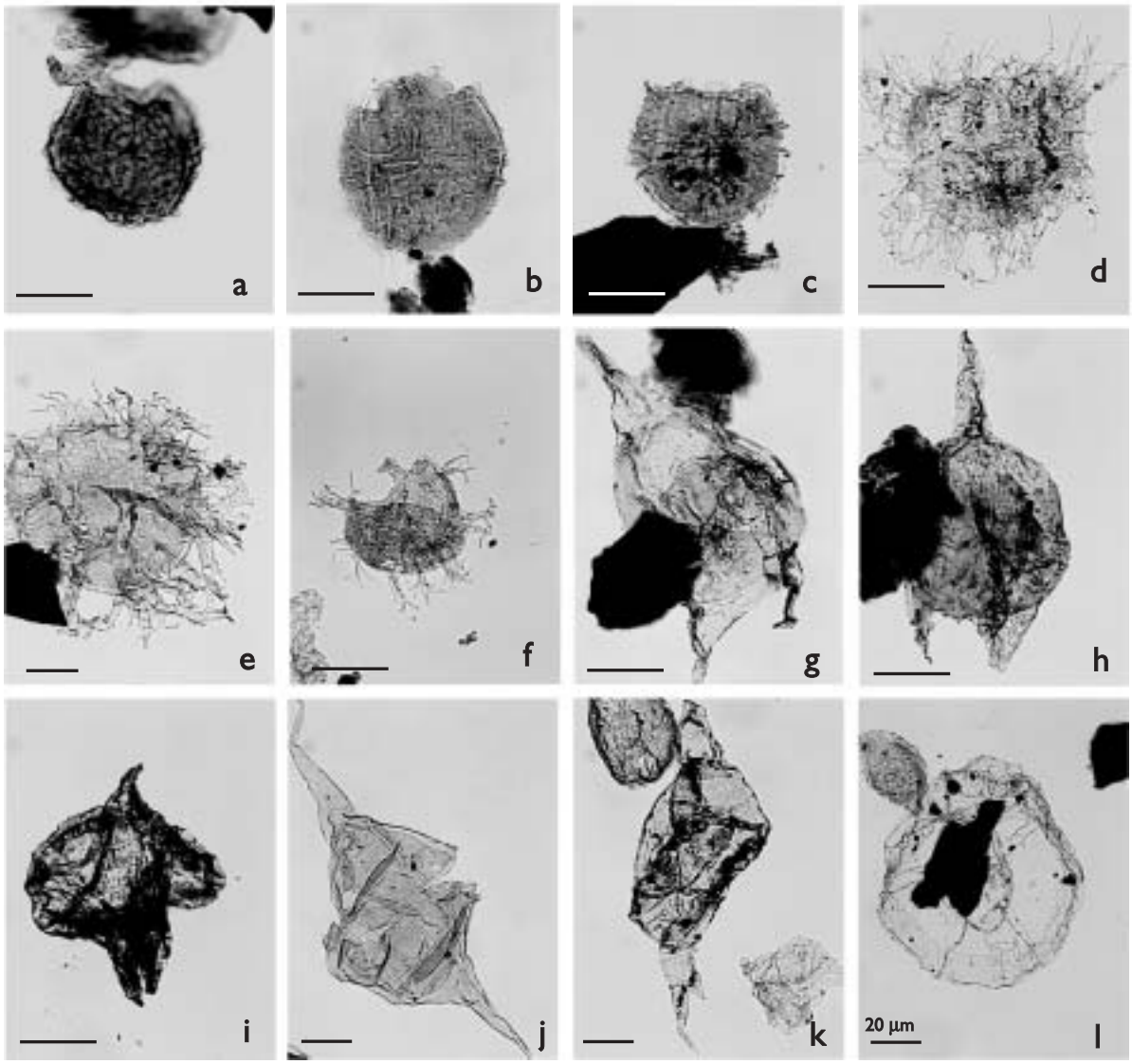

Fig. 3. Stratigraphically important dinoflagellate cysts. The scale bars represent 20 µm. GGU numbers identify the samples, followed by preparation-slide number and the co-ordinates of the microscope table. MI and LVR numbers identify records in the MicroImage database. The illustrated specimens are deposited in the type collection of the Geological Museum, University of Copenhagen and are identified by the MGUH number.

a: *Alisocysta margarita*, GGU 459738-4, 37.0–102.5, MI 11762, LVR 1.23519, MGUH 26.391.
b: *Alisocysta margarita*, GGU 246940-13, 33.2–108.2, MI 11728, LVR 1.23439, MGUH 26.392.
c: *Alisocysta margarita*, GGU 246940-12, 28.5–112.2, MI 11729, LVR 1.23440, MGUH 26.393.
d: *Areoligera* spp., GGU 246940-12, 31.5–103.0, MI 11730, LVR 1.23441, MGUH 26.394.
e: *Areoligera* spp., GGU 246945-7, 43.0–108.6, MI 11735, LVR 1.23451, MGUH 26.395.
f: *Spiniferites septatus*, GGU 246943-4, 33.7–106.4, MI 11733, LVR 1.23447, MGUH 26.396.
g: *Cerodinium speciosum*, GGU 246946-7, 27.0–109.0, MI 11736, LVR 1.23452, MGUH 26.397.
h: *Cerodinium striatum*, GGU 246943-4, 20.3–100.5, MI 11740, LVR 1.23456, MGUH 26.398.
i: *Phelodinium kozlowskii*, GGU 246942-4, 39.6–111.6, MI 11741, LVR 1.23457, MGUH 26.399.
j: *Palaeocystodinium bulliforme*, GGU 246950-4, 38.7–109.3, MI 11739, LVR 1.23455, MGUH 26.400.
k: *Palaeocystodinium bulliforme*, GGU 246947-8, 29.5–95.0, MI 11738, LVR 1.23454, MGUH 26.401.
l: *Thalassiphora delicata*, GGU 246949-7, 36.4–93.9, MI 11737, LVR 1.23453, MGUH 26.402.

Thanetian and suggests an age no younger than late Selandian (58.04 Ma). The first occurrence of *Thalassiphora delicata* in the upper part of the succession suggests an early Selandian or younger age for this part of the section according to Thomsen & Heilmann-Clausen (1985) although Köthe (1990) recorded rare *T. delicata* from the latest Danian in Germany.

Therefore, it can be concluded that the dinoflagellate assemblage indicates a late Danian age for the lower part (50–72 m) and a late Danian – early Selandian? age for the upper part (74–90 m) of the succession, based on correlations with North-West Europe (Köthe 1990; Powell 1992) and West Greenland (Nøhr-Hansen *et al.* in press).

Geological implications

The axis of the Mesozoic Jameson Land basin dips southwards below the fjord of Scoresby Sund. Seismic lines in the fjord reveal sediments intruded by numerous sills and dykes such that stratigraphical correlation with the onshore succession on Jameson Land is difficult; however, sediments younger than the topmost, Lower Cretaceous succession of Jameson Land are known to occur below the basalts (Larsen & Marcussen 1992). Seismic data along Volquart Boon Kyst show that the base of the basalt succession reaches 500 m below sea level in the central part of the basin (Larsen & Marcussen 1992) but gradually approaches sea level towards the basin margins (i.e. at Kap Brewster in the east and Vikingebugt–Gåseland in the west; Fig. 1B). Pre-basaltic erosion planed off basinal areas of sediments between highs of crystalline rocks of the basin margins (Larsen *et al.* 1989). In Gåseland and Milne Land basalts rest on Jurassic sediments and in the central part of the basin on presumed Upper Cretaceous – Paleocene sediments which provide a maximum age for the overlying volcanic rocks.

On Savoia Halvø near the Kap Brewster settlement the base of the basalts comprises the basal Milne Land Formation (Larsen *et al.* 1989; L.M. Larsen, personal communication 2002). Observations at the Kap Brewster locality and seismic data from the central Jameson Land basin (Larsen & Marcussen 1992) suggest that the basalts are conformable with the youngest sedimentary unit. Correlation of the extended Milne Land Formation (includes the earlier Magga Dan Formation; L.M. Larsen, personal communication 2002) with the lowermost Middle Series of the Faeroe Islands basalt succession indicates equivalence to lower Chron 24R, latest Paleocene age, 55 Ma (Larsen *et al.* 1999). However, the onset of volcanism in East Greenland as recorded from boreholes offshore South-East Greenland (Sinton & Duncan 1998) and onshore in the Kangerlussuaq region occurred at maximum 61–62 Ma, corresponding to Chron 27N of latest Danian, Early Paleocene (Hansen *et al.* in press). The latter is contemporaneous with the earliest West Greenland volcanic rocks (60–61 Ma; Storey *et al.* 1998) whereas the proposed correlation of the East Greenland flood basalts (e.g. at Kap Brewster) with a second, younger magmatic phase in West Greenland at approximately 55–52.5 Ma is more speculative.

The dark mudstones below the basalts at Kap Brewster have previously been considered Cretaceous on the basis of screening of dinoflagellate assemblages (Watt & Watt 1983; Larsen & Marcussen 1992), and indeed the sediments are rich in well-preserved but reworked Cretaceous dinoflagellate cysts. However, the new dinoflagellate flora described above clearly indicates a late Danian – early Selandian? (Paleocene) age for these mudstones, i.e. significantly older than the overlying basalts. It can be surmised that a distinct hiatus corresponding to most of the Upper Paleocene separates the mudstone from the overlying basalts. This hiatus may reflect either pre-basaltic erosion of the basin margin (e.g. at Kap Brewster) or a basal unconformity, even though there is an apparent seismic conformity of basalts and the youngest sediments in the central part of the basin.

Conclusions

No sedimentary successions from which the distinctly reworked dinoflagellate Cretaceous assemblages were derived are known in the onshore outcrops of the Jameson Land basin in the Scoresby Sund region, although corresponding strata may be represented in the offshore Lower Cretaceous – Paleocene succession beneath Scoresby Sund.

The *in situ* Paleocene dinoflagellate cyst assemblage can be correlated with Paleocene assemblages from the uppermost pre-volcanic sedimentary successions known onshore Nuussuaq in West Greenland (Nøhr-Hansen *et al.* in press), and corresponds in age to the upper, marine part of the Ryberg Formation in the Kangerlussuaq region (Soper *et al.* 1976).

The latest Danian – early Selandian? (Paleocene) age of the youngest pre-basaltic sediments both in West Greenland and in the Kangerlussuaq region (East Greenland) corresponds to the age of the earliest volcanic rocks in these regions. The biostratigraphic age is also in agreement with the radiometric age of the earliest eruptives

offshore South-East Greenland, onshore at Kangerlussuaq (East Greenland) and in West Greenland. In contrast, a significant hiatus separates the Danian – lowermost Selandian? sediments from the uppermost Paleocene – Lower Eocene volcanics at Kap Brewster.

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