# The post-basaltic Palaeogene and Neogene sediments at Kap Dalton and Savoia Halvø, East Greenland

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The Palaeogene flood basalts in East Greenland are part of the North Atlantic Igneous Province (NAIP) formed during continental rifting and opening of the northern North Atlantic (Saunders *et al.* 1997). Along the Blosseville Kyst in southern and central East Greenland the basalts are exposed onshore from Kangerlussuaq in the south to Scoresby Sund in the north (Larsen *et al.* 1989). The base of the volcanic succession is exposed at Kangerlussuaq and at Savoia Halvø whereas post-basaltic sediments are found at two isolated localities, Kap Dalton and Savoia Halvø (Fig. 2). These three outcrop areas are thus key sources for biostratigraphic data to constrain the onset and duration of the Palaeogene volcanism in East Greenland, and are widely used in reconstructions of the North Atlantic region during continental break-up (e.g. Clift *et al.* 1998; Dam *et al.* 1999). In August 2001 the Geological Survey of Denmark and Greenland (GEUS) carried out field work in the sedimentary successions at Kap Dalton and Savoia Halvø. This was the first visit by geologists to Kap Dalton since 1975, and it is expected that the new data will provide important new biostratigraphic information and help to refine models for the Palaeogene of the North Atlantic. This report, and the palynological study of the sediments immediately below the basalts at Savoia Halvø presented by Nøhr-Hansen & Piasecki (2002, this volume), present the preliminary results of the field work.

## Previous work

The presence of sediments at Kap Dalton was first recognised by O. Nordenskjöld and N.E.K. Hartz in 1900 during the Amdrup–Hartz Expedition to East Greenland (Fig. 1; Hartz 1902). A collection of sedimentary rocks and fossils brought back by the expedition was examined by Ravn (1904) and formed the basis for dividing the succession into the sandy '*Cyrena* Beds' and the shaly '*Coeloma* Beds'. Both units were interpreted to be of Eocene age by comparison with West European marine faunas, although the close resemblance between the Greenlandic crustacean *Coeloma bicarinatum* in the '*Coeloma* Beds' and European Middle Oligocene species was noted (Ravn 1904).

New studies of the sedimentary succession at Kap Dalton were undertaken by L.R. Wager during the Scoresby Sound Committee's 2nd East Greenland Expedition in 1932 (Wager 1935). Wager recognised a

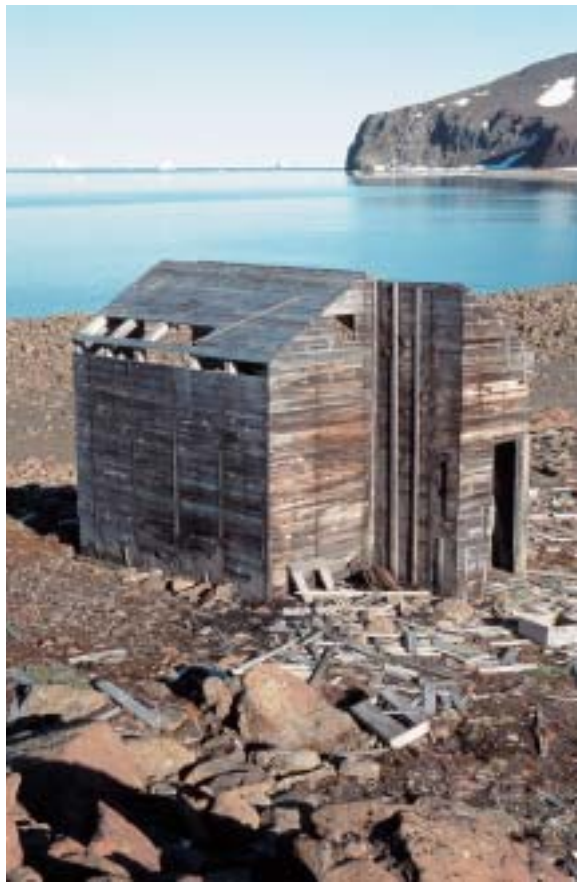

Fig. 1. The Amdrup–Hartz depot hut in the bay north-west of the basaltic headland Kap Dalton.

  

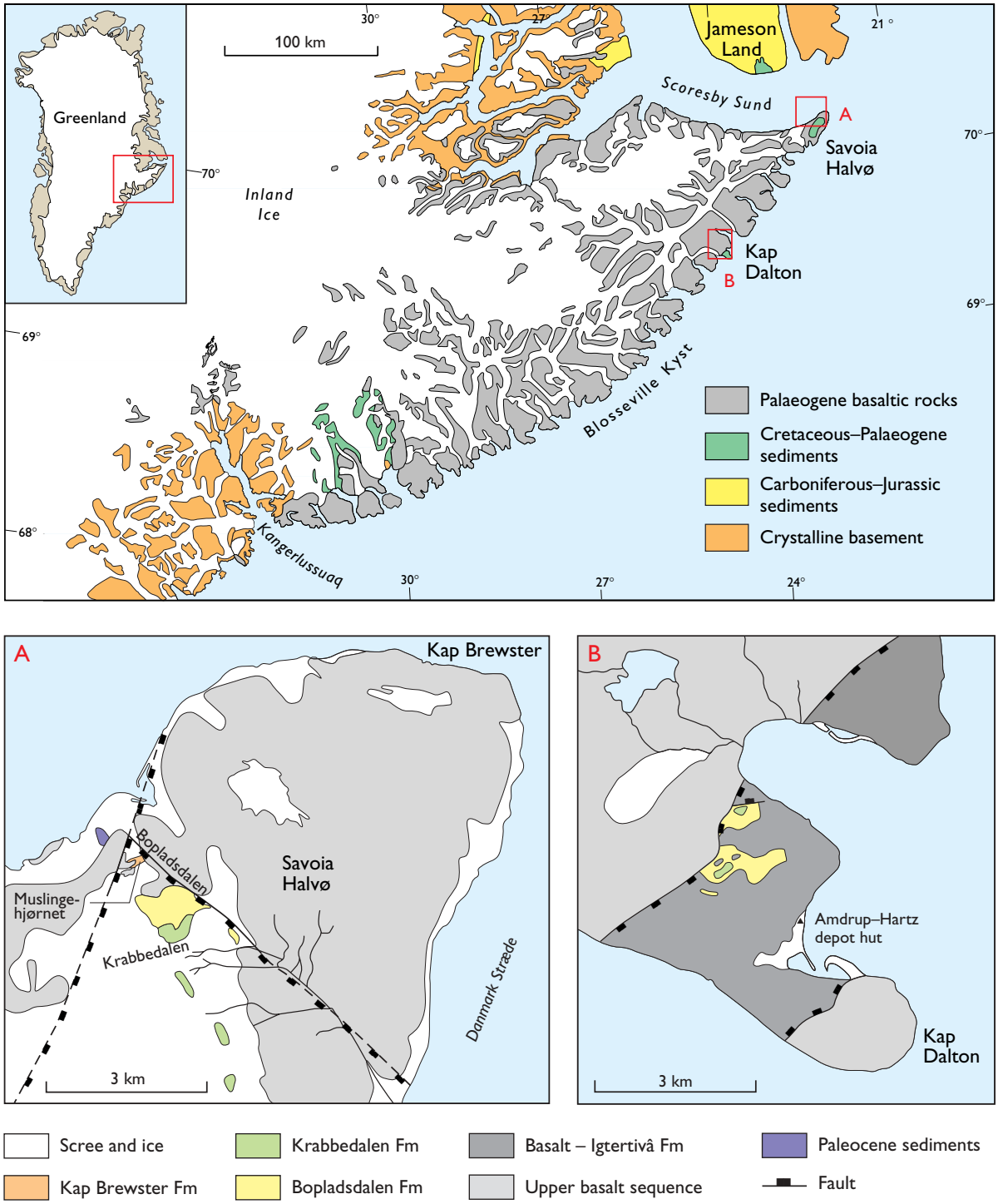


Fig. 2. Map of central and southern East Greenland showing distribution of the Carboniferous–Palaeogene sediments and Palaeogene flood basalts. **A**: Savoia Halvø; **B**: Kap Dalton (modified from, respectively, Nøhr-Hansen & Piasecki 2002, this volume and Birkenmajer 1972).

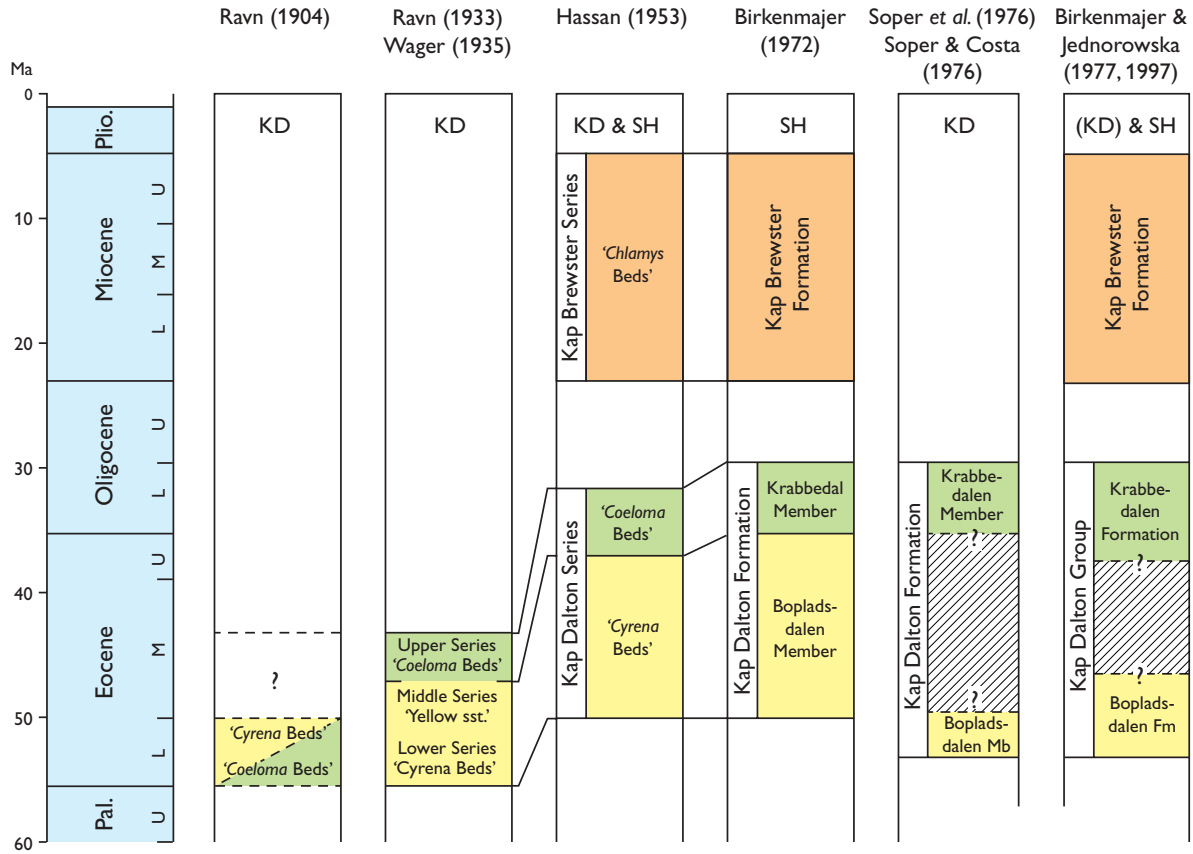


Fig. 3. Stratigraphic scheme showing different interpretations of the Palaeogene sediments at Kap Dalton (**KD**) and Savoia Halvø (**SH**).

small graben structure in which the top of the basalts and the overlying sedimentary succession are preserved. He referred the sediments to the Lower, Middle and Upper Series of the Kap Dalton Series and established the correct stratigraphic succession: the '*Cyrena* Beds' being the oldest and the '*Coeloma* Beds' the youngest (Fig. 3). The main part of his paper, however, was devoted to the petrology of the underlying basalt succession and alkaline basalt pebbles in a conglomerate found at the base of the sedimentary succession.

The sedimentary successions at Savoia Halvø (Kap Brewster) were discovered by D. Mackney and F.W. Sherrell during the Danish Expedition to East Greenland in 1951 (Hassan 1953). The sediments are preserved in a series of small grabens and were divided by Hassan (1953) into an Infra-Basalt unit below the lavas and the Kap Dalton and Kap Brewster Series above (Fig. 3). The Kap Dalton Series was further subdivided into the '*Cyrena* Beds' and '*Coeloma* Beds' following the established stratigraphy at the type locality. Based on macrofossils, Hassan (1953) assigned the Kap Brewster Series ('*Chlamys* Beds') to the Miocene.

Kap Dalton and Savoia Halvø were revisited by geologists in the 1960s and 1970s as part of a mapping campaign by the former Geological Survey of Greenland (GGU), and a formal lithostratigraphy was established. Based on field work at Savoia Halvø, Birkenmajer (1972) renamed the '*Cyrena* Beds' and '*Coeloma* Beds' originally defined at Kap Dalton as the Bopladsdalen and Krabbedalen Formations using geographical names from Savoia Halvø (Fig. 3). More importantly, however, new biostratigraphic data based on studies of dinoflagellate cysts and foraminifera considerably improved age constraints on the units (Birkenmajer 1972; Soper & Costa 1976; Soper *et al.* 1976; Birkenmajer & Jednorowska 1977, 1997).

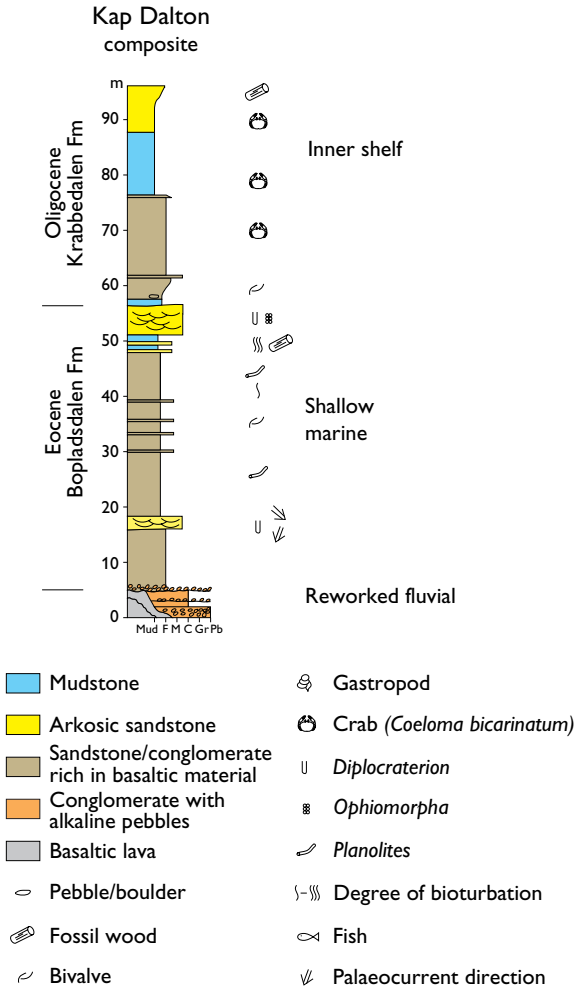


Fig. 4. Composite sedimentological profile of the Eocene–Oligocene succession at Kap Dalton.

Fig. 5. Concretions with perfectly preserved imprints of the crab *Coeloma bicarinatum* from the Oligocene Krabbedalen Formation at Kap Dalton. Concretion is 6 cm across.

## Kap Dalton

### Stratigraphy

The post-basaltic sedimentary succession at Kap Dalton consists of the lower, sandstone-dominated Bopladsdalen Formation and the upper, siltstone-dominated Krabbedalen Formation (Birkenmajer 1972; Birkenmajer & Jednorowska 1997). In the initial descriptions of the sediments at Kap Dalton the field relationships between the two formations were poorly constrained and both formations were believed to be of Early to Middle Eocene age based on macrofossils (Ravn 1904, 1933; Wager 1935). Later studies of dinoflagellate cyst assemblages confirmed an Early Eocene age of the Bopladsdalen Formation whereas the age of the Krabbedalen Formation was revised to the Oligocene (probably Early Oligocene) suggesting the presence of a hiatus at the formation boundary (Soper & Costa 1976; Soper *et al.* 1976).

### Sedimentology

The sedimentary succession is generally poorly exposed and correlation is further hampered by later faulting. However, based on correlation of seven detailed sedimentary sections measured in 2001 it is possible to construct a composite profile, approximately 95 m thick, comprising the entire post-basaltic stratigraphy (Fig. 4).

The sediments rest unconformably on a weathered surface of subaerially extruded basalt flows of the Igtertivâ Formation (Larsen *et al.* 1989). The basal unit consists of a conglomerate, 2–3 m thick, with well-rounded basalt pebbles. The petrology of the pebbles was carefully examined by Wager (1935) who concluded that the assemblage contained an exotic suite of alkaline basalts not present anywhere else along the coast. The basal conglomerate is overlain by approximately 50 m of fine- to coarse-grained sandstones forming the bulk of the Bopladsdalen Formation. The succession consists mainly of poorly indurated brown and black sandstones rich in reworked basaltic material forming the '*Cyrena* Beds' (*sensu* Ravn 1904). However, yellowish, arkosic sandstones form distinct marker units at two stratigraphic levels. The yellow sandstones are slightly better cemented than the brown sandstones and show well-preserved sedimentary structures, mostly planar and trough cross-bedding indicating palaeocurrent directions towards the south and southeast. Locally, U-shaped vertical burrows of *Diplocraterion* and *Ophiomorpha* types are abundant. The bivalve *Cyrena* occurs in 10–30 cm thick beds of well-cemented,

medium- to coarse-grained brown sandstone packed with disarticulated shells of *Cyrena* and scattered gastropods in the middle part of the succession.

The boundary between the Bopladsdalen and Krabbedalen Formations is marked by a change from coarse-grained, arkosic sandstones below to poorly consolidated, grey-brown, fine-grained sandstones above. The latter form the lower 20 m of the Krabbedalen Formation and are overlain by approximately 20 m of laminated, fine-grained sandstones and siltstones, carrying numerous concretions (the '*Coeloma* Beds' *sensu* Ravn 1904). With few exceptions the concretions contain perfectly preserved imprints of the crab *Coeloma bicarinatum* (Fig. 5).

### Interpretation

The weathered surface of the basalts suggests a period of subaerial exposure prior to the onset of sedimentary deposition. The clast-supported conglomerate carrying well-rounded, exotic clasts is accordingly interpreted as laid down by a fluvial system transporting coarse erosional products from the volcanic hinterland. The fluvial channels were apparently restricted to topographic lows in the lava surface and the conglomerate is only very locally developed. During Early Eocene times the area was transgressed and the fluvial deposits and the adjacent basaltic surface were reworked. A thick shallow marine succession punctuated by at least two progradational events was deposited during the remaining part of Bopladsdalen Formation time. The top of the Bopladsdalen Formation is a distinct flooding surface reflecting a change towards deeper marine conditions. The frequent occurrence of small crabs and the general fine-grained lithology of the overlying Krabbedalen Formation suggest deposition in a low energy, possibly oxygen deficient environment. The interpretation of the entire post-basaltic succession as deposited during an overall transgression does not support the existence of a major hiatus at the boundary between the two formations as suggested by Soper & Costa (1976).

## Savoia Halvø

### Stratigraphy

The pre-basaltic sediments exposed on the north coast of Savoia Halvø adjacent to the former Kap Brewster settlement are described by Nøhr-Hansen & Piasecki (2002, this volume), and focus in this study is on the post-basaltic sediments of the Palaeogene Kap Dalton and the Neogene Kap Brewster Formations (Hassan 1953; Birkenmajer 1972). The Palaeogene sediments were divided by Hassan (1953) into the '*Cyrena* Beds' and '*Coeloma* Beds' following the stratigraphic scheme from Kap Dalton. Based on macrofossils the '*Cyrena* Beds' were interpreted to be of Late Eocene age, thus differing from the age assigned to the succession at Kap Dalton (Fig. 4; Ravn 1904, 1933). The overlying '*Coeloma* Beds' were suggested to be of Early Oligocene age at Savoia Halvø, thus following conformably upon the '*Cyrena* Beds'. An Early Oligocene age was supported by the foraminifer assemblage described by Birkenmajer (1972) and Birkenmajer & Jednorowska (1977, 1997). In their publications Birkenmajer & Jednorowska presented a revised stratigraphic scheme changing the age of the Bopladsdalen Formation to Early Eocene (Fig. 4), but this new interpretation was not discussed nor supported by new data.

The Neogene Kap Brewster Formation ('*Chlamys* Beds' *sensu* Hassan 1953) was thought to be of Miocene age based on the macrofossils, although Hassan (1953) stressed that this age was to be regarded as tentative until supported or revised by further evidence. Unfortunately, no such evidence has yet come to light and the presumed Miocene age of the Kap Brewster Formation has still to be confirmed.

### Sedimentology

The sediments on Savoia Halvø are exposed along the river flowing east and north through the valleys Krabbedalen and Bopladsdalen (Fig. 6). The sandstone-dominated Bopladsdalen Formation, 90 m thick, and the lower part of the mudstone-dominated Krabbedalen Formation, 40 m thick, are exposed in a continuous outcrop (Fig. 7A). The approximately 110 m thick conglomeratic Kap Brewster Formation is limited to an isolated outcrop at Muslingehjørnet some 1–2 km further to the north, and cannot be correlated with the other post-basaltic units on field criteria.

The sediments of the Bopladsdalen Formation unconformably overlie a weathered surface of basalts with pillow structures. The lowermost unit is 1–2 m thick and consists of a matrix-supported conglomerate carrying well-rounded basaltic boulders. The conglomerate is overlain by a thick sandstone-dominated succession showing a general fining-upward trend (Fig. 7A). In the lower part numerous incursions of coarse-grained material of angular basalt pebbles are concentrated in erosional layers and elongate lenses showing normal

grading. Bivalve shell material is locally present on bedding surfaces. Higher in the succession silicified tree trunks, up to 5 m long, are interbedded within fine- to medium-grained sandstones. Associated with the silicified trees are large isolated boulders of well-rounded basalt. Bioturbation is present throughout the succession although diagenetic alteration of the sandstone locally hinders recognition of sedimentary and biogenetic structures. The boundary with the overlying Krabbedalen Formation is placed at the first distinctive mudstone bed (Fig. 7A). The latter formation consists of alternating beds of laminated siltstone and massive fine-grained sandstones. Large calcareous concretions are present throughout the succession and like the similar concretions in the formation at Kap Dalton contain imprints of the crab *Coeloma bicarinatum* in two discrete horizons in the middle part. The concretions also contain fragments of bivalves, gastropods, silicified wood and in one case part of a fish spine.

The conglomerates of the Kap Brewster Formation are preserved in the hanging-wall block immediately south of a major NE–SW-trending normal fault. Neither the base nor top of the formation is exposed, and the relationships to the basalts and the other post-basaltic sediments are not known. The succession can be divided into three distinct units with a middle sandstone unit separating a lower and an upper conglomeratic unit (Fig. 7B). The lower unit is approximately 40 m thick, and consists of stacked, matrix-supported conglomerate beds, up to 5 m thick, carrying well-rounded basaltic boulders up to 1.5 m in diameter. The matrix varies in grain-size from poorly sorted, gravelly mudstones to pebbly sandstones. Most of the beds show a crude fining-upward trend in clast size. The stacked conglomerates are overlain by poorly exposed basaltic sandstones forming the middle unit, up to 45 m thick (Fig. 7B). Locally, exposures allow recognition of ripple cross-laminated, pebbly sandstone beds, up to 20 cm thick. These beds are rich in fragmented oysters and other bivalves. The sandstones are overlain by matrix-supported boulder conglomerates of the upper unit reaching up to 25 m in thickness.

Fig. 6. Eocene sandstones of the Bopladsdalen Formation exposed at Savoia Halvø. The river bank is approximately 35 m high.

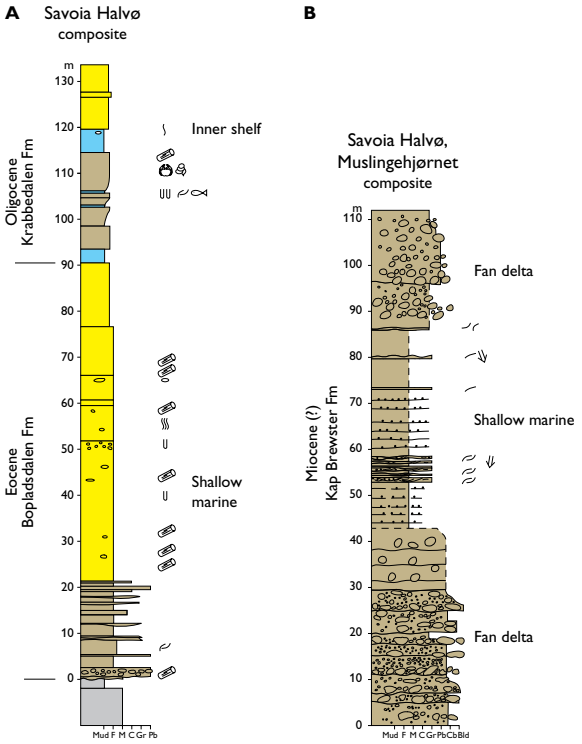


Fig. 7. Composite sedimentological profiles of the Palaeogene and ?Neogene successions at Savoia Halvø. **A**: Bopladsdalen and Krabbedalen Formations measured along the river flowing through Krabbedalen. **B**: Kap Brewster Formation measured at Muslingehjørnet (see Fig. 1A for locations and Fig. 4 for legend).

### Interpretation

The pillow structures present in the basalts immediately below the Bopladsdalen Formation suggest that the uppermost preserved lavas were extruded below water. However, the weathered zone forming the transition to the sediments indicates a period of uplift and subaerial exposure prior to the start of deposition. The rounded boulders in the basal conglomerate of the Bopladsdalen Formation were probably locally derived, and may have been rounded either during current or wave action. The few diagnostic structures in the overlying overall fining-upward succession suggest that deposition took place in a shallow marine environment. The frequent scour-and-fill and the graded beds present in the lower part suggest deposition close to storm-wave base, possibly close to the mouth of a major river system in view of the abundant tree trunks. A continued rise in the relative sea level is indicated by a decrease in the amount of coarse-grained material and wood, and deposition of fine-grained sand and mud of the Krabbedalen Formation in Early Oligocene time.

The matrix-supported conglomerates of the Kap Brewster Formation were probably deposited by gravity flow processes in a marine fan-delta. The tripartite upbuilding suggests at least two progradational pulses leading to gradual fining-upward successions. Although the stratigraphical data are sparse and the field relationships with the other post-basaltic sediments are unknown, the lithological resemblance between the fine-grained parts of the Kap Brewster Formation and the lower part of the Bopladsdalen Formation is striking, and the two formations may represent different parts of the same depositional basin rather than two distinct depositional events.

## Future work

The 2001 season concluded the geological field work in the pre- and early post-basaltic sedimentary successions along the Blosseville Kyst initiated in 1995 with field work in Kangerlussuaq in the southern part (Larsen *et al.* 1996, 2001). Future work will focus on the litho-, bio- and sequence-stratigraphy. Based on the accumulated knowledge, the basin evolution and uplift history of the northern North Atlantic during Palaeogene time will be evaluated.

Following the 2001 field work the sample database at GEUS comprises more than 600 samples covering all lithologies and formations from the Cretaceous–Palaeogene successions of southern and central East Greenland. Mudstones and fine-grained sandstones sampled for palynological work will be analysed at the Geological Institute, University of Aarhus and at GEUS. Based on field observations, two units at Kap Dalton having a distinct arkosic composition will be examined petrographically and geochemically in order to define their provenance areas. The results of this work will be reported elsewhere. A revised lithostratigraphy will be proposed based on the new lithological, sedimentological and palynological data.

## Conclusions

1. The post-basaltic successions rest on a deeply weathered basaltic surface that at Kap Dalton dips southeastwards.

2. At Kap Dalton the basal conglomerates consist of alkaline basaltic pebbles most likely transported in fluvial channels from a westerly source, whereas the remaining part of the post-basaltic succession was deposited in a shallow marine environment.

3. Material from at least three different source areas is present in the successions: (1) alkaline pebbles, (2) siliciclastic sand, (3) sand rich in reworked basaltic material. Of these, only the latter was locally derived. The source area of the alkaline pebbles is unknown, whereas the siliciclastic sand was probably derived from exhumed basement areas to the north-east.

4. Sedimentological data from Savoia Halvø suggest that the Kap Dalton and Kap Brewster Formations may form proximal–distal correlatives of the same depositional system in this area. Biostratigraphic data are, however, needed in order to confirm this interpretation.

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