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Bulletin No. 123

Stratigraphy, tectonics and palaeogeography of the Jurassic sediments of the areas north of Kong Oscars Fjord, East Greenland

by

Finn Surlyk

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2 illustrations in pocket

1977

Abstract

The lithostratigraphic scheme currently in use for the Jurassic rocks of the Jameson Land area in East Greenland is extended northwards to cover the areas to the north, from Kong Oscars Fjord (72° N) to Store Koldewey (77° N). Most emphasis is laid on the Wollaston Forland area, whereas Traill Ø and Geographical Society Ø are only briefly reviewed. Jurassic sediments are all included in the Jameson Land Group except the latest Jurassic (Middle–Upper Volgian) rocks which are grouped into the Wollaston Forland Group together with Lower Cretaceous rocks of Ryazanian–Valanginian age. Only sediments belonging to the Jameson Land Group are treated here. The group is in the Wollaston Forland area divided into two formations: the Vardekløft Formation below and the Bernbjerg Formation above. The Vardekløft Formation is divided into three members: Pelion Member composed of estuarine sandstones of Bathonian – Late Oxfordian age; Jakobsstigen Member (new) composed of shallow shelf sandstones and mudstones of Early – Late Oxfordian age; and the Muslingebjerg Member (new) composed of barrier–lagoon sandstones and coals of presumed Late Oxfordian age.

The overlying Bernbjerg Formation (new) is composed of dark often sandy mudstones of Late Oxfordian – Kimmeridgian (Early Volgian) age.

The whole succession is at maximum 1 km thick and reflects deposition in progressively deeper water in a shelf area structurally built of slightly westwards tilted roughly N–S orientated fault blocks. Four regional transgressions controlled by basement faulting can be dated to Bathonian, Early Oxfordian, Late Oxfordian, and Early Kimmeridgian. Each transgression was followed by steady subsidence and prograding sedimentation.

Author's address:
Geologisk Museum
Øster Voldgade 5–7
DK–1350 Copenhagen K
Denmark

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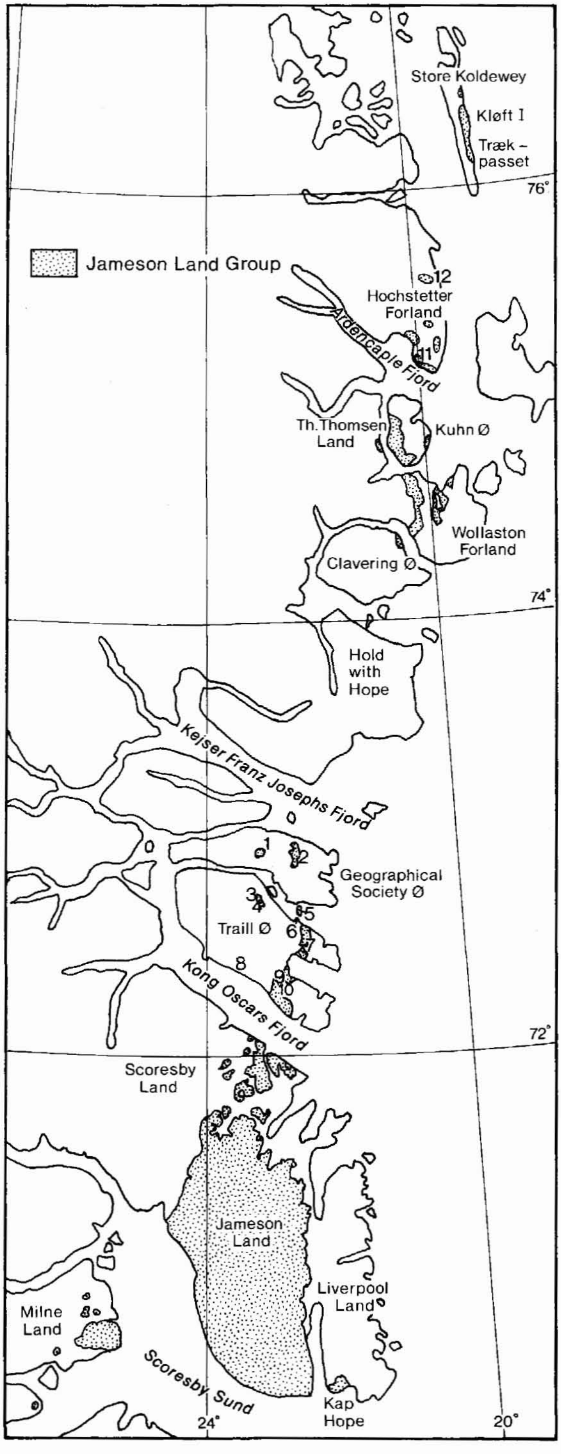


Fig. 1. Distribution of the Jurassic Jameson Land Group in East Greenland. 1: Tværdal; 2: Laplace Bjerg; 3: Rold Bjerge; 4: Månedal; 5: Nordenskiölds Ø; 6: Kap Palander; 7: Mols Bjerge; 8: Svinhufvuds Bjerge; 9: Lycett Bjerg; 10: Bjørnedal; 11: Søndre Muslingebjerg; 12: Kap Oswald Heer.

INTRODUCTION

A new lithostratigraphical scheme (tables 1, 2) is erected for the Jurassic rocks of Traill Ø, Geographical Society Ø, Clavering Ø, Wollaston Forland, Kuhn Ø, Th. Thomsen Land, Hochstetter Forland and Store Koldewey (72°–77° N) (fig. 1).

The stratigraphic scheme established by Surlyk, Callomon, Bromley & Birkelund (1973) for the Jurassic of Jameson Land is where possible extended to the regions north of Kong Oscars Fjord.

Structurally the onshore Jurassic of East Greenland can be divided into two major depositional basins, the Jameson Land basin to the south and the Wollaston Forland basin to the north. The two basins are separated by the Hold with Hope peninsula where Jurassic rocks are absent. Maync (1947) suggested that the absence was primary, Hold with Hope being a land area in the Jurassic, whereas Donovan (1957) was more inclined to believe that the absence was secondary owing to the pre-Aptian erosion of Jurassic rocks. Recent geophysical investigations over the adjacent shelf (Johnson *et al.*, 1975) and detailed study of fault patterns leads the present author to support Maync's interpretation. The thick sedimentary basin demonstrated on the East Greenland shelf is not interrupted east of Hold with Hope (Henderson, 1976) and there is thus strong reason

Table 1. Lithostratigraphic scheme of the Jurassic in northern East Greenland

<table>
<tr><th>Group</th><th>Formation</th><th colspan="3">Member</th></tr>
<tr><td rowspan="3">Jameson Land</td><td>Bernbjerg</td><td colspan="3"></td></tr>
<tr><td rowspan="2">Vardekløft</td><td>Jakobs-stigen</td><td>Muslingebjerg</td><td></td></tr>
<tr><td colspan="3">Pelion</td></tr>
</table>

to believe that the sea covering Wollaston Forland in mid-late Jurassic times extended southwards east of Hold with Hope where it was connected with the sea covering the Jameson Land basin. Theoretically, therefore, there is nothing to hinder the continuity of the more prominent and persistent Jurassic lithostratigraphic units of the two regions, and a common lithostratigraphic scheme consequently seems to be justified (table 2).

The succession of the units is shown on tables 1 and 2 and is now discussed in ascending order.

WOLLASTON FORLAND AREA

Jameson Land Group

General

It is strongly emphasized that the description (except for name and type locality) of the group and its subdivisions is here restricted to cover the Wollaston Forland area (Clavering Ø, Wollaston Forland, Kuhn Ø, Th. Thomsen Land and Hochstetter Forland).

Name

After the peninsula Jameson Land.

Type area

Jameson Land, East Greenland.

Thickness

At maximum 1 km.

Dominant lithology

The group commences with the Vardekløft Formation which comprises tidally influenced estuarine sandstones (Pelion Member) overlain by shallow shelf interlaminated mudstones and sandstones (Jakobsstigen Member) and on Hochstetter Forland by barrier–lagoon sandstones and coal seams (Muslingebjerg Member). Then follows the dark often sandy offshore shelf mudstones of the Bernbjerg Formation.

Boundaries

The group overlies peneplaned Caledonian basement and on Clavering Ø and north-west Wollaston Forland Permian limestones and redbeds. It is overlain with angular or erosional unconformity by the Wollaston Forland Group or by Lower Cretaceous sediments.

Distribution

Eastern Clavering Ø, Wollaston Forland, western and eastern Kuhn Ø, eastern Th. Thomsen Land and Hochstetter Forland.

Geological age

(?)Bathonian – Early Kimmeridgian.

Vardekløft Formation

General

For history, name and type locality see Surlyk *et al.* (1973). In the Wollaston Forland area the formation corresponds to the so-called 'Yellow Series' and in part the 'Grey Series' of Maync (1947).

Thickness

At maximum about 500 m. The true thickness can only be estimated in few areas owing to the nature of the exposure. In northern Wollaston Forland it is *c.* 560 m, whereas on southern Kuhn Ø *c.* 250 m have been indicated (Maync, 1947).

Dominant lithology

Throughout the area the formation is dominated by yellow and whitish or light brownish quartz sandstones (Pelion Member), which in Wollaston Forland are overlain by interlaminated sandstones and mudstones (Jakobsstigen Member) and there is an over-all tendency to a southwards decrease in grain sizes. Scattered thin coals occur, becoming more common northwards and culminating in the thick coal seams on southern Hochstetter Forland described by Clemmensen & Surlyk (1976) as the Muslingebjerg Member.

Boundaries

The formation rests on the Caledonian basement or on Permian limestones and red-beds. It is conformably overlain by dark mudstones of the Bernbjerg For-

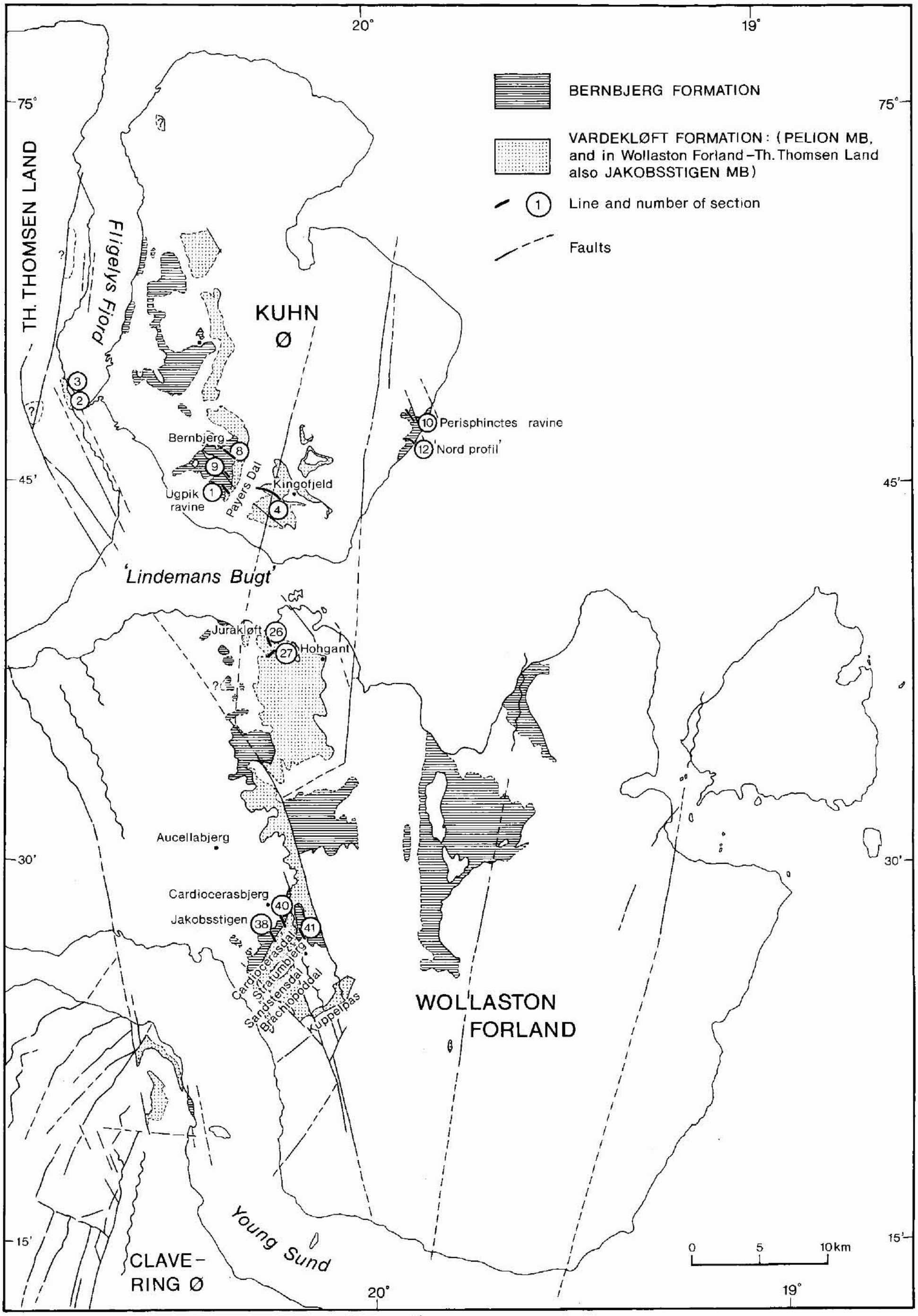


Fig. 2. Distribution of the Jameson Land Group in the Wollaston Forland area. Sources: Koch & Haller (1971), Visher (1943), and the author's observations.

mation or unconformably by sediments belonging to the Wollaston Forland Group, or by Aptian–Albian mudstones and sandstones.

Distribution

Eastern Clavering Ø, Wollaston Forland, Kuhn Ø, eastern Th. Thomsen Land and Hochstetter Forland (fig. 2).

Geological age

Both the lower and upper boundary of the formation are probably diachronous, but precise dating is exceedingly difficult owing to the extreme rarity of ammonites. In south–western Wollaston Forland the basal part of the formation contains a Bathonian fauna (Maync, 1947, p. 84, 96), whereas a Lower Oxfordian fauna has been documented from higher parts (Surlyk & Clemmensen, 1975). In southern Kuhn Ø a bivalve fauna suggestive of a late Bathonian to mid Callovian age has been collected, and the formation is here overlain by the Lower Kimmeridgian Bernbjerg Formation. On Th. Thomsen Land small exposures of the formation are well dated to Upper Oxfordian (Sykes & Surlyk, 1976), whilst on Hochstetter Forland the highest exposed part of the formation is of Late Oxfordian age (Clemmensen & Surlyk, 1976).

Subdivisions

The Vardekløft Formation is subdivided into the Pelion, Jakobsstigen, and Muslingebjerg Members and these will now be considered in turn.

Pelion Member

General

For name and type locality see Surlyk *et al.* (1973). The member is in the present area basically identical to the 'Yellow Series' of Maync (1947) although it is not always clear if Maync used the term as a facies term, or in a lithostratigraphic, or even chronostratigraphic sense. Thus intercalations of more fine-grained sediments in the otherwise sandstone dominated sequence were sometimes referred to by Maync (1947, p. 94, 125) as 'Grey Series' whereas in other connections (Maync, 1947, p. 7–8) the 'Grey Series' denoted a lithostratigraphic rock body overlying the 'Yellow Series'.

Reference sections

Sections in Ugpik ravine (section 1, figs 3, 4, 5), Kingofjeldet (section 4, fig. 6), Jurakløft (section 26, fig. 9), Hohgant (section 27, fig. 10). Cardiocerasdal (fig. 6).

Thickness

Owing to nature of exposure and to faulting the true thickness can only rarely be measured. According to Maync (1947) the member is at least 472 m thick on Clavering Ø, more than 370 m on Aucella Bjerg (central Wollaston Forland), 528 m thick on Hohgant (northern Wollaston Forland), 216 m on Kingofjeldet (southern Kuhn Ø) (fig. 2). The original thickness in southern Wollaston Forland and Clavering Ø was probably of an order of 500–600 m and decreased only slightly northwards to northern Wollaston Forland. The dramatic drop to only 216 m immediately north of Lindemans Bugt is without doubt due to mid –

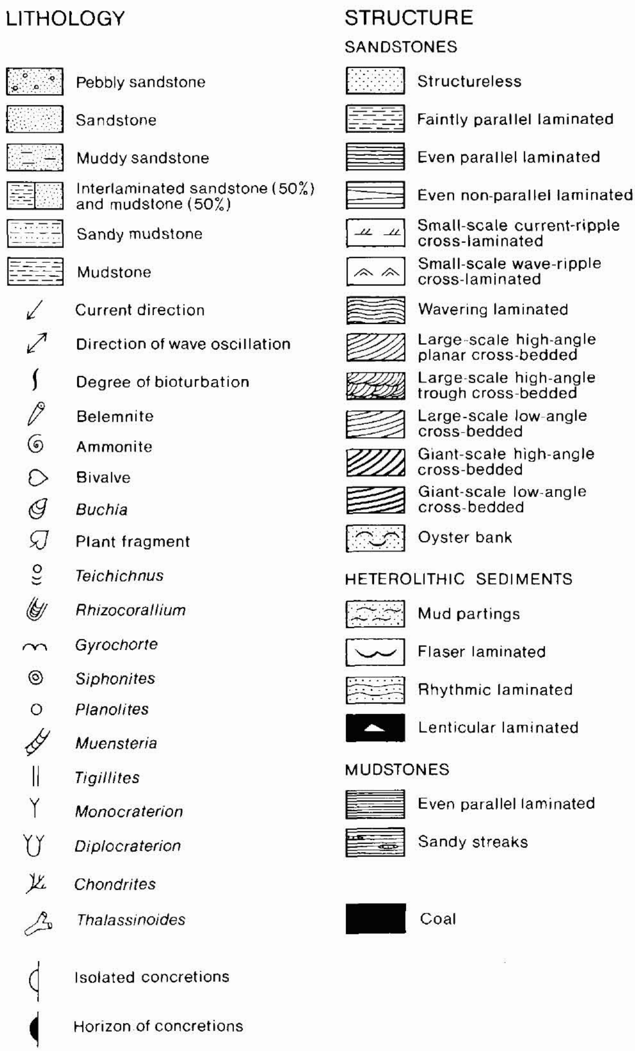


Fig. 3. Legend covering all the figured sections.

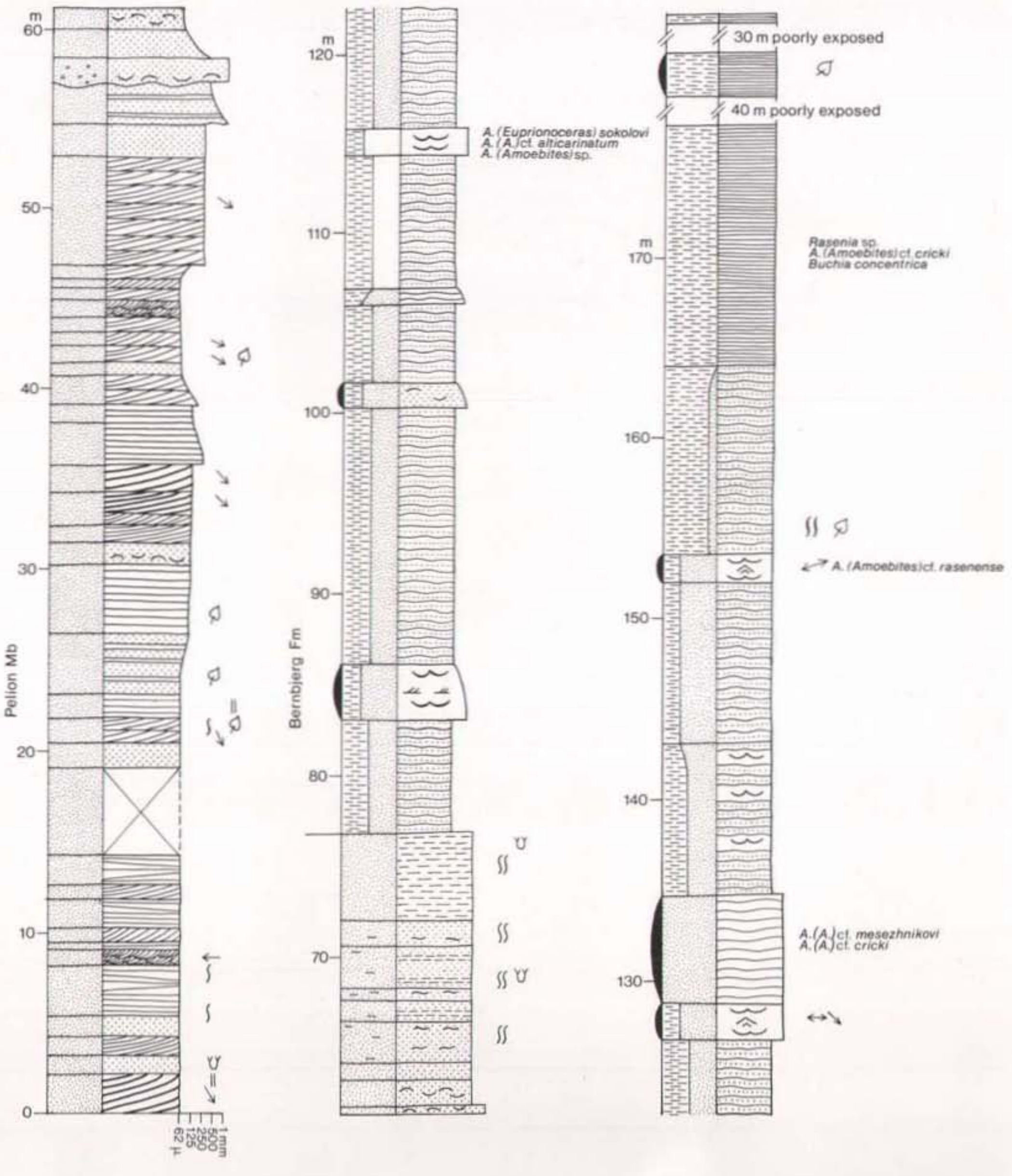


Fig. 4. Section 1 showing top part of Pelion Member overlain by Bernbjerg Formation. West side of Payers Dal, southern Kuhn Ø (fig. 2). Exact position of section indicated by arrow 3 on fig. 5.

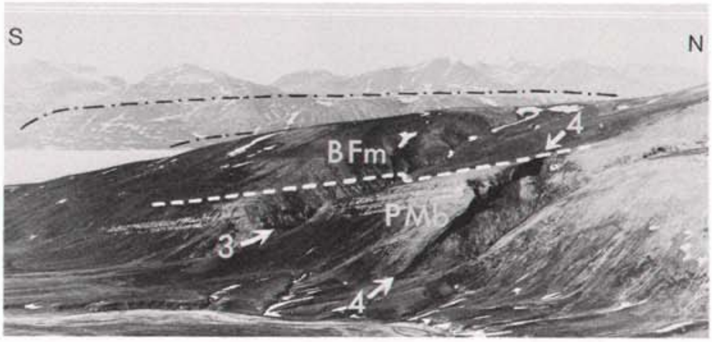


Fig. 5. Western side of Payers Dal, southern Kuhn Ø. In the background Th. Thomsen Land. PMb: Pelion Member; BFm: Bernbjerg Formation. 3 (arrow): position of section 1 (fig. 4). 4 (arrow): dolerite dyke. Stipple-point lines parallel to the coast of Th. Thomsen Land indicate position of two major faults with downthrow to the east.

late Jurassic basin extension by down-faulting of the Kuhn Ø block (Sykes & Surlyk, 1976).

Dominant lithology

The dominant lithologies are fine-, medium-, and coarse-grained sometimes pebbly light coloured often yellowish quartz sandstones. On Kuhn Ø the member commences with conglomerates containing quartzite clasts from the underlying Precambrian Eleonore Bay Group, and on Clavering Ø the basal conglomerate also contains clasts of Permian limestones.

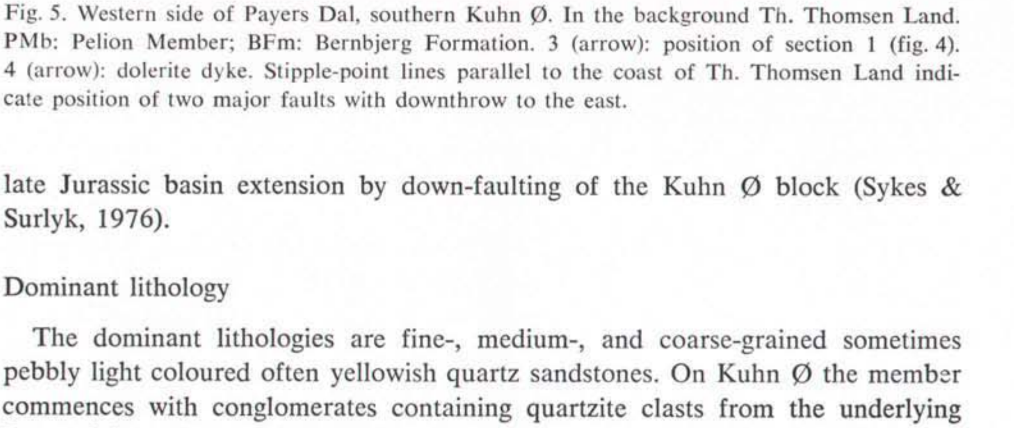


Fig. 6. Pelion Member overlain sharply by Jakobsstigen Member, Cardiocerasdal, south-western Wollaston Forland. Section located to the right of 1 on fig. 15. Measured by Lars B. Clemmensen. The top part of the Pelion Member shows a distinct coarsening-upwards trend.

Thin allochthonous and autochthonous coal seams are found scattered, notably on southern Kuhn Ø.

Giant, and large-scale planar and trough cross-bedding of both low- and high-angle types are characteristic structures and are accompanied by even parallel and non-parallel bedding (figs 6, 8, 11, 23). Some horizons are completely structureless but very close inspection gives the impression that in general the apparent lack of primary sedimentary structures is neither primary nor due to total bioturbation but rather of diagenetic origin.

Bioturbation is generally restricted to vertical burrows of *Tigillites* or *Diplocraterion,* but some sections, especially the cross-bedded parts of the section on Kingofjeldet (fig. 7) are strongly bioturbated and *Planolites, Teichichnus* and *Curvolithus* can be recognized (fig. 12). Macro-invertebrate fossils are invariably poorly preserved, but occur sometimes in great abundances. Thus 5–10 m thick oyster banks can be traced over at least 1 km^2 in several levels in Payers Dal, southern Kuhn Ø. The banks are *in situ* accumulations mainly of oysters. Upwards the banks often show signs of strong reworking and display edgewise coquinas and cross-bedding with forests draped with oyster debris (figs 13, 14). Faunal assemblages are generally of low diversity and very high density possibly suggestive of a high-stress marine environment with fluctuating salinities. The bivalve *Meleagrinella braamburiensis* (Phillips) can dominate thick sequences and are in some cases almost rock forming.

Boundaries

The member overlies peneplaned Caledonian basement and, on south-west Wollaston Forland and Clavering Ø, Permian limestones and red-beds. It is overlain by interlaminated mudstones and fine sandstones of the Jakobsstigen Member with a relatively sharp boundary or by the dark mudstones of the Bernbjerg Formation. Owing to strong block faulting and tilting which took place at the Jurassic–Cretaceous boundary, the member can also be unconformably overlain by the syntectonic sediments of the Wollaston Forland Group (Surlyk, 1975b) or younger sediments.

Distribution

Eastern Clavering Ø, western Wollaston Forland, eastern Th. Thomsen Land, southern and western Kuhn Ø and Hochstetter Forland.

Geological age

The age of the member is only known in broad outline because of a general lack of ammonites. From south-western Wollaston Forland the occurrence of a late Bathonian ammonite fauna is reported in the literature. Maync (1947, p. 84, 96) thus reported *Arctocephalites* sp., *Arcticoceras* sp., *Cadoceras* sp., and *Kepplerites tychonis* (Ravn) in one bed from the basal part of the formation. If the determinations are correct the collection seems, however, to be mixed. Frebold (1932a) recorded *Arcticoceras* aff. *ishmae* (Keyserling) from a comparable situa-

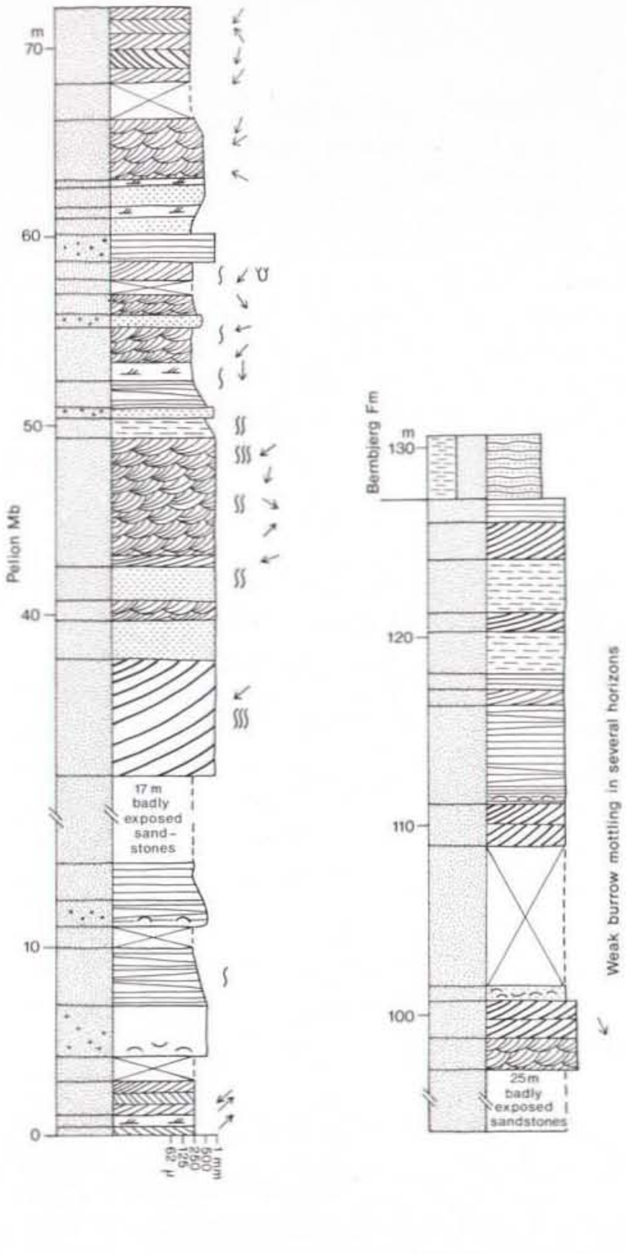


Fig. 7. Section 4 showing Pelion Member overlain by Bernbjerg Formation. West slope of Kingofjeldet, southern Kuhn Ø (fig. 2).

Fig. 8. 'Herring-bone' cross-bedding in Pelion Member sandstones, section 2, Kingofjeldet, southern Kuhn Ø.

tion in Sandstensdal and Brachiopoddal immediately south of Maync's locality. North-east of Kuppelpas, southern Wollaston Forland, Maync (1947, p. 96) found imprints of presumed Bathonian ammonites.

In Cardiocerasdal *Cardioceras* (*Scarburgiceras*) *alphacordatum* Spath of Early Oxfordian age (Mariae Zone, Praecordatum Subzone) (determination by John Callomon, 1975) was found by the author a few metres above the top of the member. This suggests that the age of the Pelion Member in south-western Wollaston Forland is Bathonian – Callovian. The presence of Callovian rocks still has to be proved but since a late Bathonian fauna occurs at the base of the *c*. 500–600 m thick member all of the Callovian is probably represented.

On southern Kuhn Ø a new collection of bivalves is suggestive of a late Bathonian – mid Callovian age (Sykes & Surlyk, 1976) and the member is overlain by the Lower Kimmeridgian strata of the Bernbjerg Formation.

On Hochstetter Forland the top parts of the member contain Upper Oxfordian *Amoeboceras* cf. *nunningtonense* Wright and *Amoeboceras* sp. nov. (Ravn, 1911) indicating a Late Oxfordian *A. glosense* or *A. serratum* zone age (Sykes & Surlyk, 1976).

Consequently both lower and upper boundaries of the member seem to be strongly diachronous and the general tendency is that both boundaries get younger in a northward direction. This younging seems to be stepwise across the fjords between Wollaston Forland and Kuhn Ø and between Kuhn Ø and Hochstetter Forland.

Jakobsstigen Member

General

The member corresponds in part to the so-called 'Grey Series' of Maync (1947), but beds overlying the Pelion Member on Kuhn Ø and referred to the 'Grey

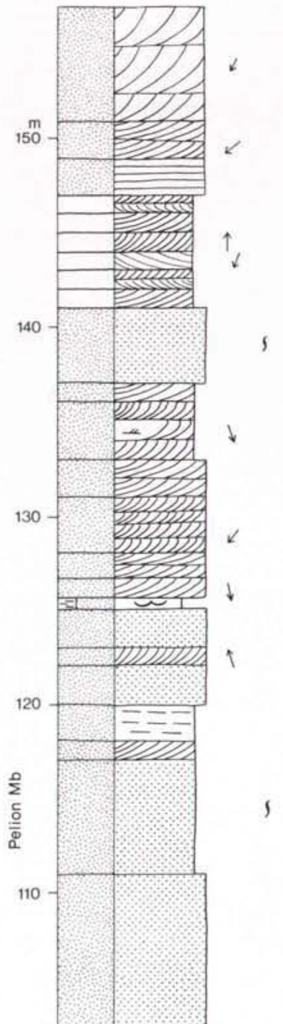


Fig. 9. Section 26 showing Pelion Member sandstones, Jurakløft, north coast of Wollaston Forland (fig. 2). Measured by Lars B. Clemmensen.

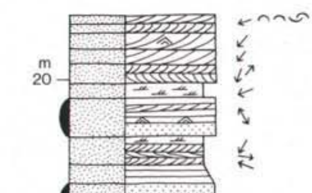


Fig. 10. Section 27 showing Pelion Member sandstones, Hohgant, northern Wollaston Forland (fig. 2). Measured by Lars B. Clemmensen.

Fig. 11. Large-scale trough cross-bedded Pelion Member sandstones. Immediately above top of section 26, Juraklóft, northern Wollaston Forland.

Series' by Maync (1947) are here considered as the basal part of the Bernbjerg Formation (see also Sykes & Surlyk, 1976). Futhermore the thickness of the Jakobsstigen Member in southern Wollaston Forland is much greater than recorded by Maync.

Fig. 12. Foresets of large-scale planar cross-bedded Pelion Member sandstones strongly burrowed by *Planolites*, section 2, Kingofjeldet, southern Kuhn Ø.

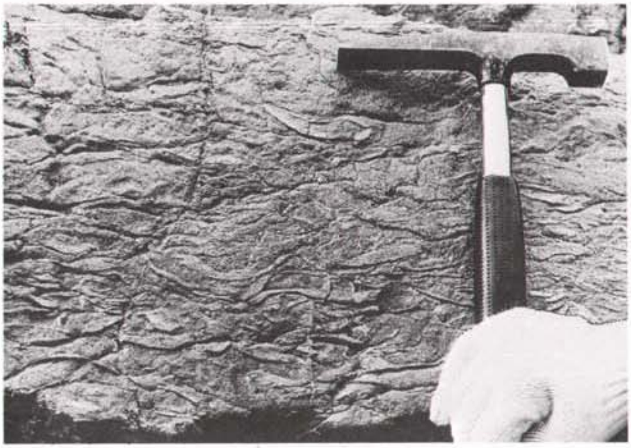


Fig. 13. Oysterbank in Pelion Member sandstones, Payers Dal, southern Kuhn Ø. Note that the oysters are preserved *in situ* with both valves intact.

Name

After the sharp-crested ridge between two streams running from north-west into Cardiocerasdal (arrowed in fig. 15).

Type section

Jakobsstigen, south-western Wollaston Forland (section 38, figs 15, 16).

Fig. 14. Oysterbank (1) overlain by edgewise coquina of oyster shells (2), and planar cross-bedded sandstone with oyster debris along the foresets (3). Pelion Member, Payers Dal, Kuhn Ø.

Fig. 15. North-western side of Cardiocerasdal, south-western Wollaston Forland, view to the north. Pelion Member sandstones (1), overlain by Jakobsstigen Member interlaminated sandstones and mudstones (2), Bernbjerg Formation mudstones (3), and the light grey mudstones of the Valanginian Albrechts Bugt Member (4). The small cone-shaped summit and the snow covered ridge in the background are Tertiary plateau basalt. Arrow shows position of the sharp crested ridge Jakobsstigen, and the location of section 38 (fig. 16).

Reference sections

Coastal section on Th. Thomsen Land (sections 2, 3, figs 18, 19).

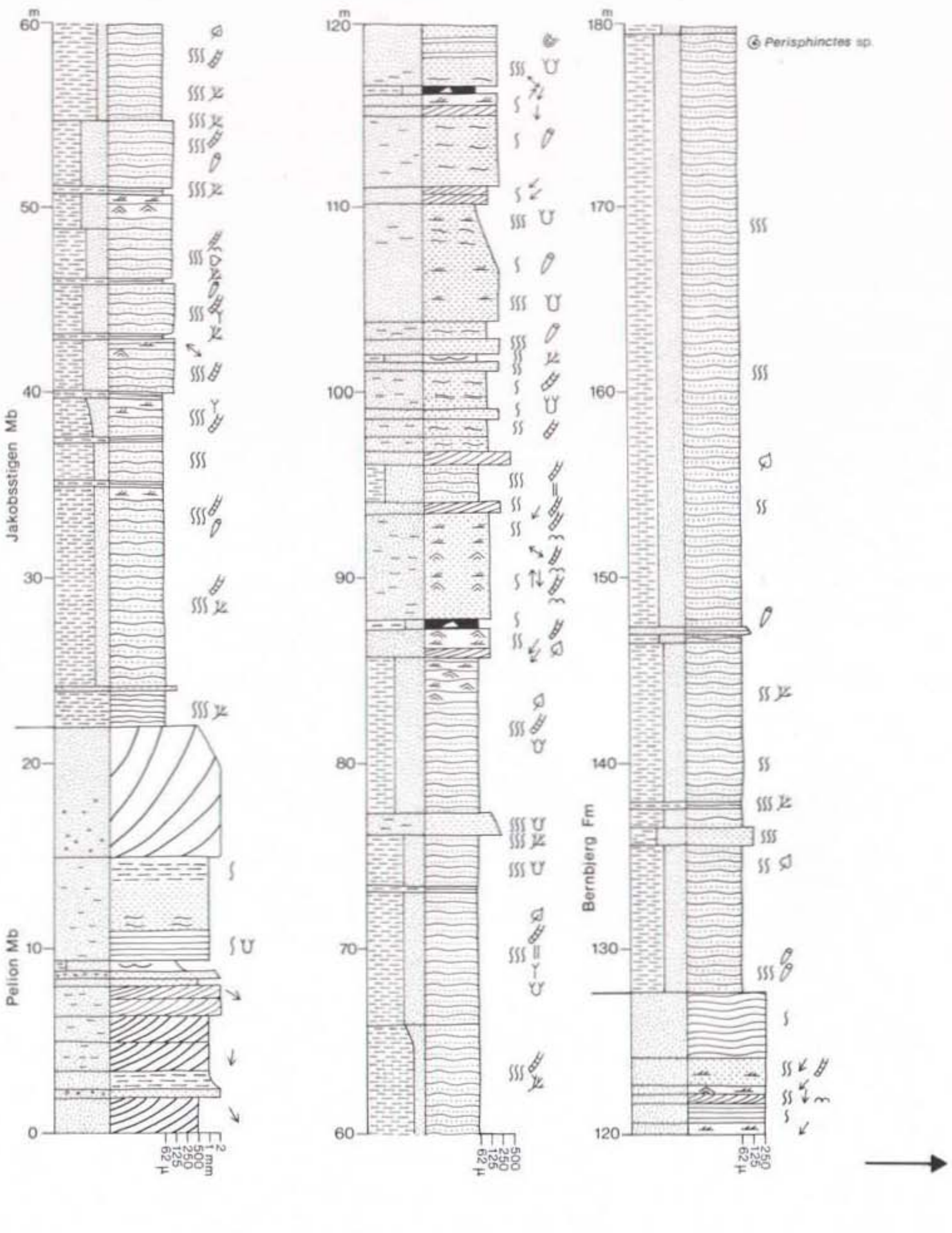
Thickness

The member reaches a maximum recorded thickness of 122 m in Cardiocerasdal (section 38, fig. 16), whereas it is at least 60 m thick on Th. Thomsen Land. The average thickness of 30–40 m recorded by Maync (1947) for the 'Grey Series' cannot be substantiated.

Dominant lithology

Strongly bioturbated rhythmic interlaminated silty mudstones and wave- and current-rippled fine sandstones. Mudflasers occur in all sandstone facies, whereas lenticular bedding is less common. Isolated beds of medium sandstone are either structureless owing to total bioturbation or show large-scale planar cross-bedding (fig. 17).

Small-scale 2–3 m thick coarsening-upwards sequences commencing with a black mudstone overlain by bioturbated rhythmites give some of the profiles a characteristically striped appearance when seen from a distance (fig. 15). The black mudstones contain abundant *Chondrites,* but the burrow fills are identical to the overlying light sandstones (fig. 21). The Th. Thomsen Land section (figs



18, 19, 20) shows a better segregation into muddy and sandy beds than the south-western Wollaston Forland succession.

Well defined trace fossils are not always recognizable owing to the often total burrow mottling of the sediments, but the following ichnogenera occur scattered: *Chondrites* in black mudstones and, less commonly, in rhythmites; *Muensteria*

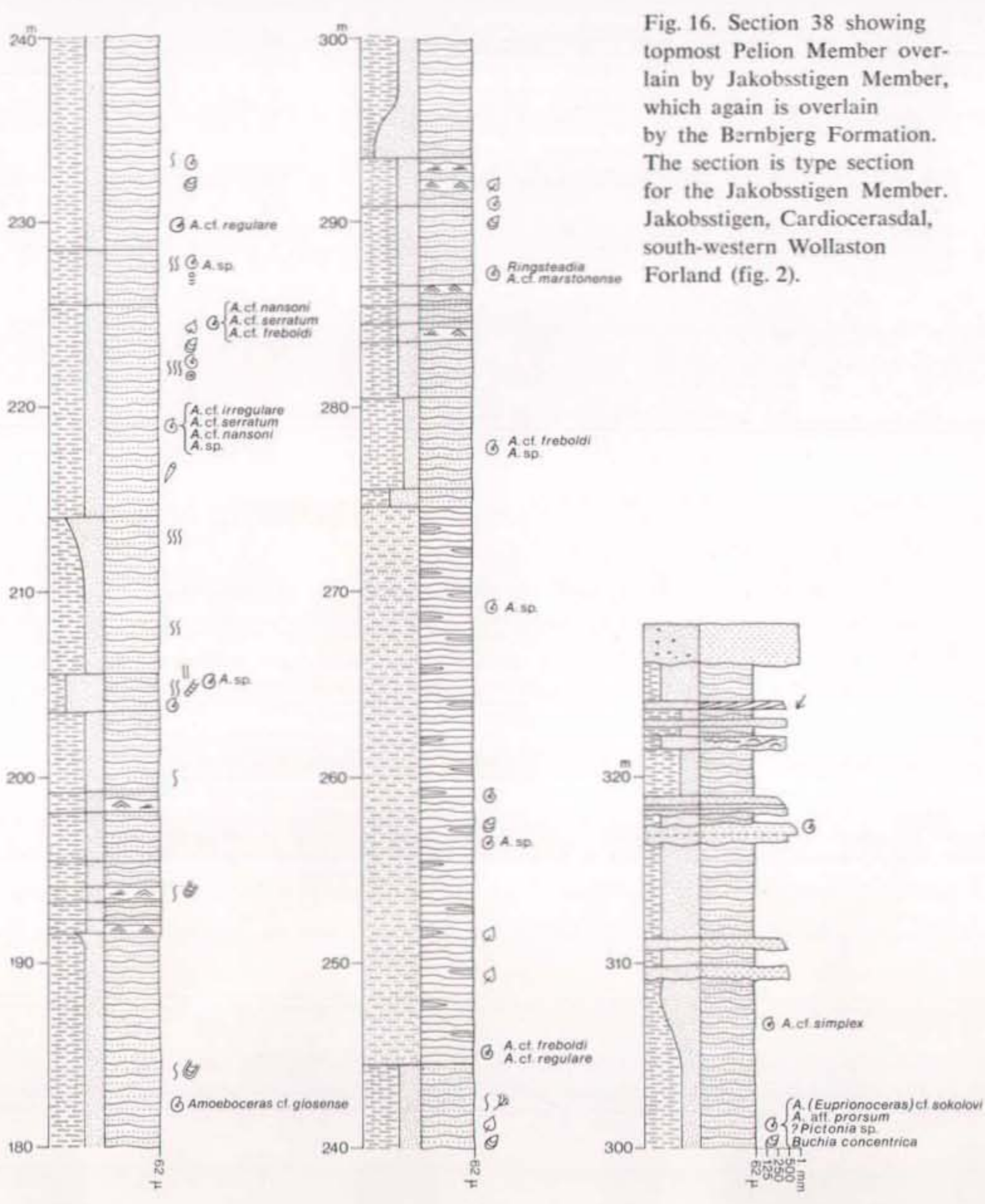


Fig. 16. Section 38 showing topmost Pelion Member overlain by Jakobsstigen Member, which again is overlain by the Bernbjerg Formation. The section is type section for the Jakobsstigen Member. Jakobsstigen, Cardiocerasdal, south-western Wollaston Forland (fig. 2).

very abundantly in rhythmites; *Diplocraterion, Tigillites* and *Monocraterion* mainly in rhythmites; *Siphonites* and *Gyrochorte* only observed in rhythmites; *Rhizocorallium* and *Planolites* occur in most of the finer grained facies whereas *Curvolithus* is only recorded from mud-free, fine-grained sandstones.

Fig. 17. Large-scale low-angle cross-bedded sandstone with current-ripple cross-lamination on the foresets. Top of cross-bedded unit displays wave-ripple lamination and is draped with mudstone. Jakobsstigen Member, section 38 (fig. 16).

Boundaries

The lower boundary is placed at a significant and often abrupt shift from white, yellow and brown coarsely structured sandstones of the Pelion Member to rhythmites and related fine-grained facies of the Jakobsstigen Member. The upper boundary is not always sharp. It is placed where the light coloured rhythmites are overlain by dark-grey to black mudstones and rhythmites with carbonate concretions of the Bernbjerg Formation.

Distribution

The member is exposed in a N-S strip from the south-western coast of Wollaston Forland to the north coast. A few small faulted outcrops occur along the east coast of Th. Thomsen Land.

Geological age

The member can be dated to Early – Late(?) Oxfordian in south-western Wollaston Forland, whereas the presence of Late Oxfordian has been proved on Th. Thomsen Land (Sykes & Surlyk, 1976).

Muslingebjerg Member

General

The name Muschelbjerg Formation was proposed by Donovan (1957, p. 53) for a coal-bearing sandstone sequence exposed on southern Hochstetter Forland. Donovan's description was entirely based on a paper by Frebold (1932b), the results of which were fundamentally revised by Clemmensen & Surlyk (1976).

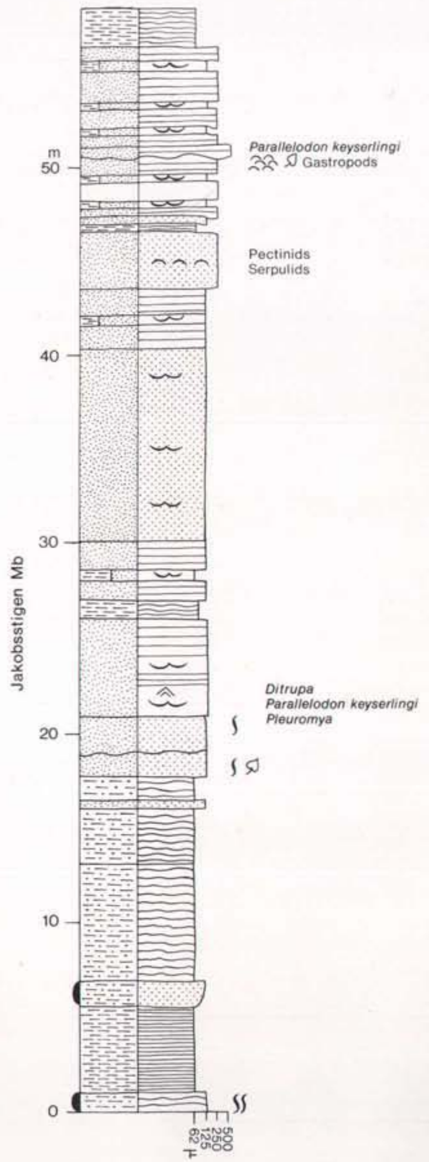


Fig. 18. Section 2 showing Jakobsstigen Member, east coast of Th. Thomsen Land (fig. 2).

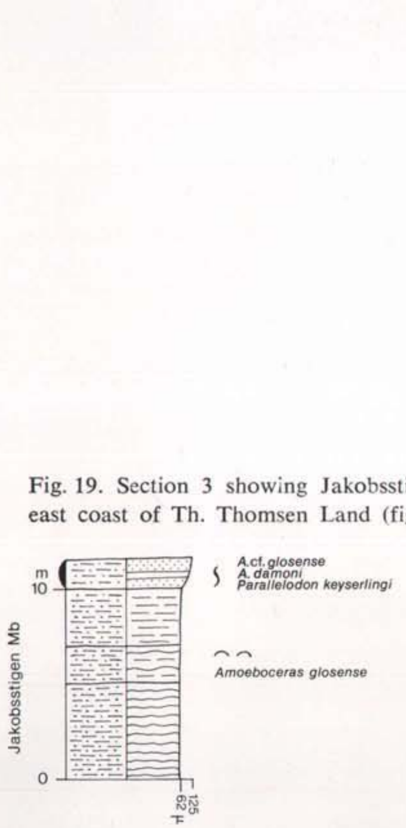


Fig. 19. Section 3 showing Jakobsstigen Member, east coast of Th. Thomsen Land (fig. 2).

Donovan (1957, p. 53) stated: "As the sediments of the Muschelbjerg area cannot be definitely correlated with any of the well-known Jurassic formations, the name 'Muschelbjerg Formation' is here proposed for them, for convenience or reference". No information was given on type section, distribution, or boundaries.

As the sequence can be considered merely a wedge in the Pelion Member containing several thick coal-seams of limited areal extent, the rank of the unit is changed to member status. The new member is here defined as only containing

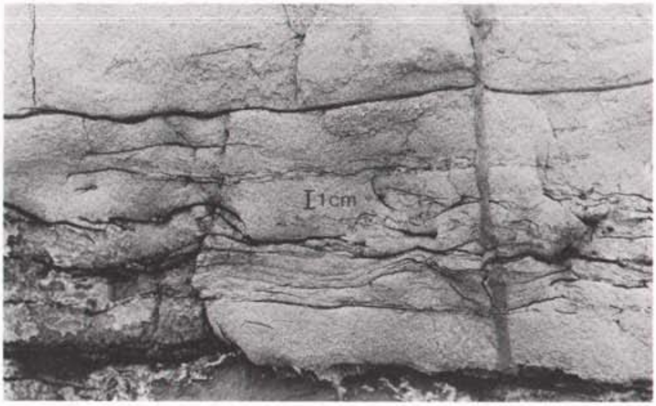


Fig. 20. Jakobsstigen sandstones with coaly and clayey mud-flasers indicating the cross-sectional shape of large bivalves whose shells have been dissolved during diagenesis. East coast of Th. Thomsen Land.

the coal-bearing part of the sequence whereas the sandstones exposed on the south-western slopes of Søndre Muslingebjerg are referred to the Pelion Member. Finally the name Muschelbjerg is a rather odd mixture of German and Danish and is consequently translated into Danish: Muslingebjerg.

Name

From the mountain Søndre Muslingebjerg on southern Hochstetter Forland.

Type section

South-west coast of Hochstetter Forland, immediately south of Kulhus (section 11, fig. 21).

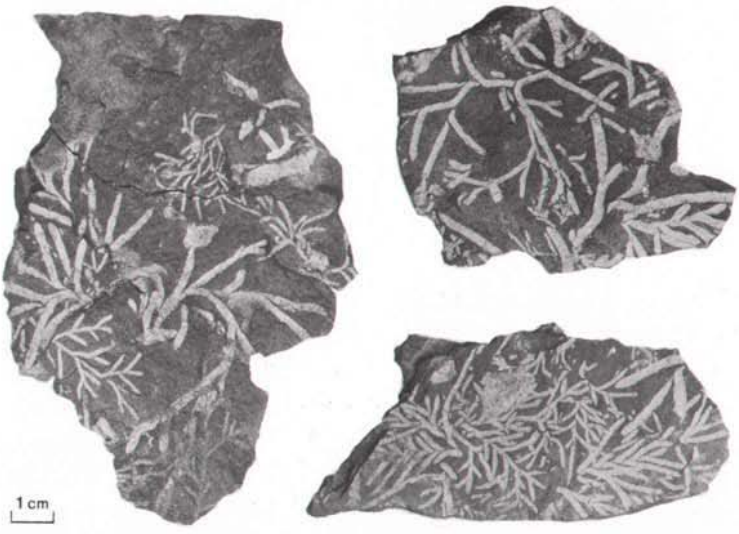


Fig. 21. *Chondrites* burrows in laminated black mudstone at the base of small-scale coarsening-upwards cycle, Jakobsstigen Member, section 38, Cardiocerasdal (fig. 16).

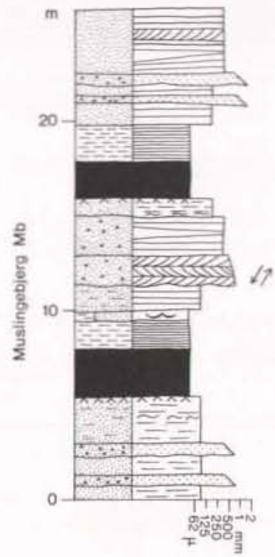


Fig. 22. Section 11 showing Muslingebjerg Member sandstones and coal (type section), south-west coast of Hochstetter Forland (fig. 2).

Thickness

Approximately 30 m.

Dominant lithology

The sequence here named the Muslingebjerg Member was described in detail by Clemmensen & Surlyk (1976). A short summary is given below.

The member comprises eight sedimentary facies: Several autochthonous coal seams varying in thickness between 2 and 3 m; laminated mudstone with coal reaching 2 m in thickness; silty, horizontally laminated sand with coal partings, up to 2 m thick; greyish, fine-grained faintly horizontally laminated sand, about 4 m thick; 3–5 m of light fine- to medium-grained, horizontally laminated sand at the top penetrated by rootlets descending from the overlying coal-seam; pebbly, mainly low-angle cross-bedded sand (2 m); pebbly, structureless sand; and horizontally laminated medium sand dominated by bivalve shells, notably *Ostrea* sp. and *Isognomon groenlandicus*. The eight facies seem to occur in a lower, upwards coarsening sequence followed by an upper, upwards-fining unit topped by a coal seam.

Boundaries

The member occurs in a narrow down-faulted block and is characterized by its content of thick coal seams. The lower and upper boundaries are therefore not well defined. They are, however, placed roughly at the base of the lowest coal seam and at the top of the highest coal seam. The member probably interfingers with the lower parts of the light coloured sandstones of the Pelion Member which occur in the near vicinity on the south-western slope of Søndre Muslingebjerg.

Distribution

The member is known from a very narrow coastal fault block on the south-western coast of Hochstetter Forland. In 1976 Christian Hjort (written communication) found abundant loose blocks of coal-bearing sandstone in northern Hochstetter Forland (NW of Kap Oswald Heer), but the sediments were not found in outcrop.

Geological age

No ammonites have been found in the member as here defined, but the bivalve fauna and ammonite occurrence in the top of the interfingering Pelion Member suggest a Late Oxfordian or slightly older age.

Bernbjerg Formation

General

In its general concept the Bernbjerg Formation is identical to the so-called 'Black Series' of Maync (1947). There are, however, several important differences between the two units. An isolated Upper Kimmeridgian sequence of dark mudstones from eastern Kuhn Ø was named the 'Kuhn Beds' by Maync (1947, p. 38), mainly because they were younger than the Upper Oxfordian – Lower Kimmeridgian 'Black Series'. Furthermore, the 'Kuhn Beds' were described as somewhat more sandy than the 'Black Series'. The first argument is irrelevant in a

Fig. 23. Boundary between even, parallel laminated sandstone of the Pelion Member and dark rhythmites of the Bernbjerg Formation. Section 1, Payers Dal, southern Kuhn Ø (figs 2, 3). Musk-ox calf on junction for scale.

lithostratigraphic connection and the postulated upwards increasing content of sand was not confirmed by the present study, neither does it appear from the section published by Maync (1947, fig. 11).

The 'Kuhn Beds' are consequently grouped into the Bernbjerg Formation together with the 'Black Series'.

Another difference between the Bernbjerg Formation and the 'Black Series' is that on Kuhn Ø the Bernbjerg Formation is defined so as to include the 'Grey Series' of Maync (1947).

Name

From the hill Bernbjerg (620 m) on south-western Kuhn Ø.

Type section

Bernbjerg (section 8, fig. 24).

Reference sections

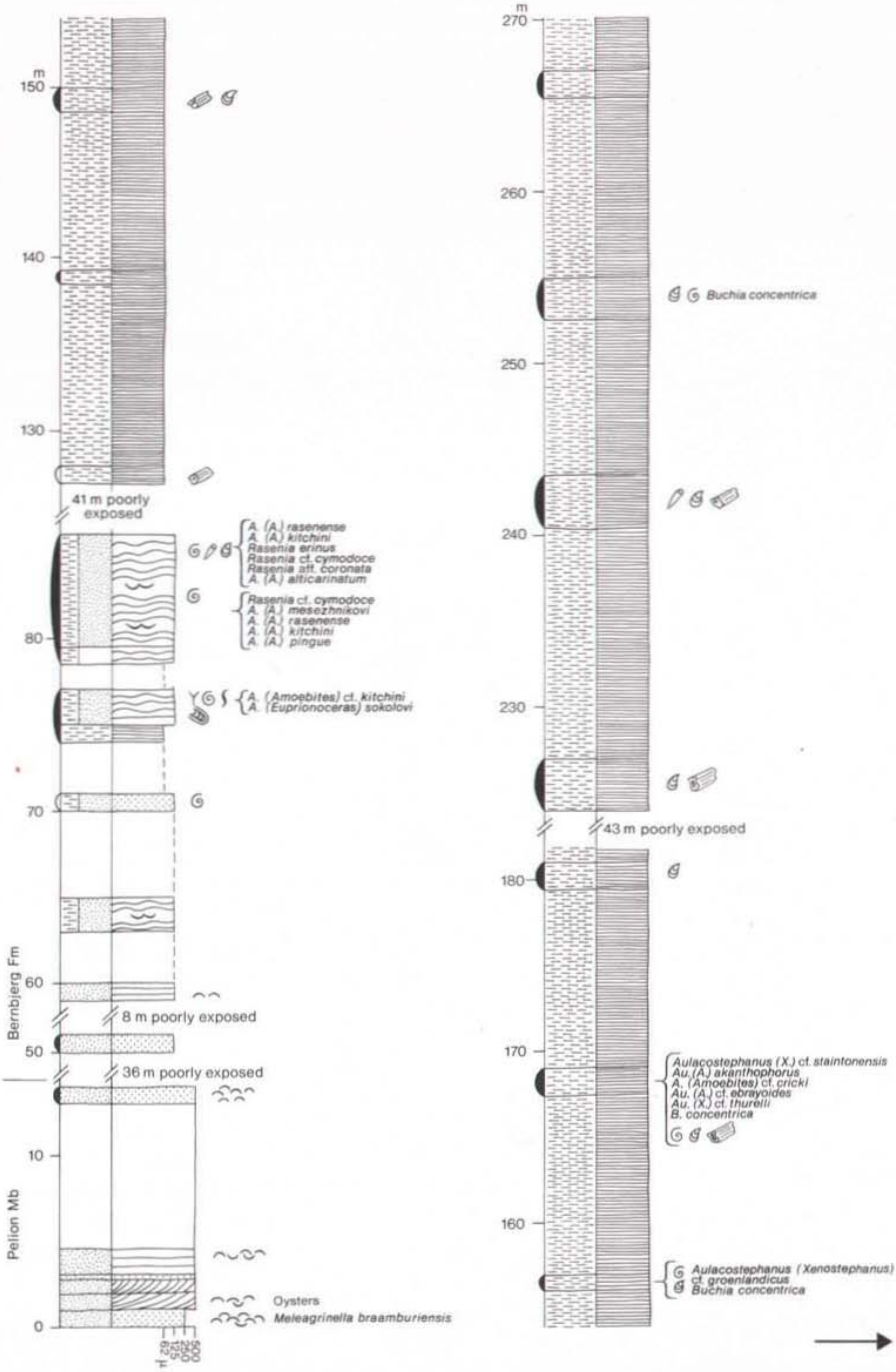
Bernbjerg (section 9, fig. 26), Perisphinctes ravine (section 10, fig. 28), 'Nord Profil' (section 12, fig. 29). Lower boundary: Jakobsstigen, Cardiocerasdal (section 38, fig. 16), Cardiocerasbjerg (section 40, fig. 31), Stratumbjerg (section 41, fig. 32).

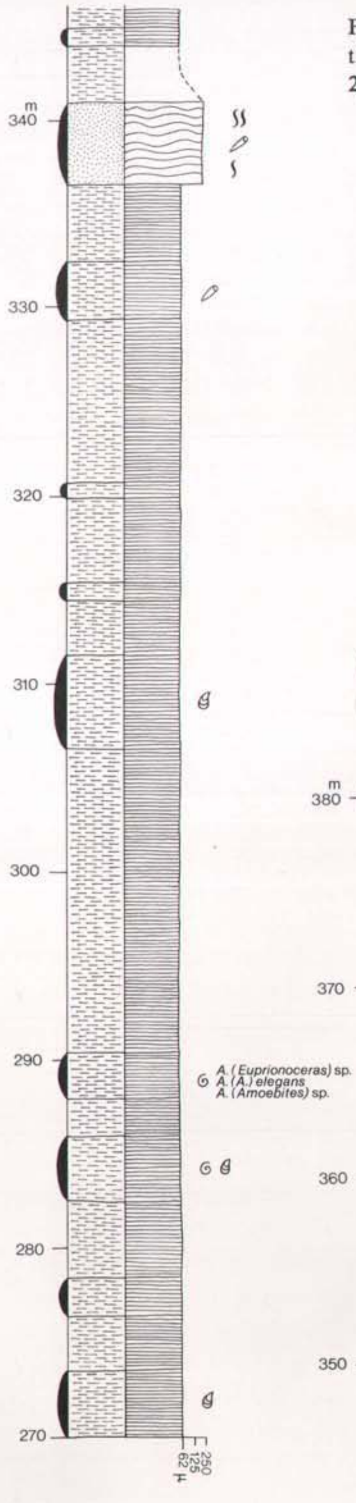
Thickness

The formation is nowhere exposed in its full original thickness, but this is estimated to have been approximately 600 m. According to Maync (1947) the the 'Black Series' and the 'Kuhn Beds' which together make up the Bernbjerg Formation have a total thickness of 600 + 500 = 1100 m. This figure seems to be totally unrealistic and the sections of the 'Kuhn Beds' which were described by Maync as being approximately 500 m thick were remeasured to 113 m and 135 m respectively.

Dominant lithology

The formation is composed of several varieties of dark-grey to black more or less sandy mudstones. In the Cardiocerasdal area the basal 20 m are sand dominated rhythmites which upwards give way to mud dominated rhythmites and mudstones with thin sandy streaks (fig. 33). In southern Kuhn Ø the lowest 75 m are fine sandy rhythmites (figs 25, 27) which upwards pass into parallel laminated mudstones (fig. 30, 33). On eastern Kuhn Ø the sediment mainly comprises mud dominated rhythmites and parallel laminated mudstones.


m
150
140
130
41 m poorly exposed
A. (A.) rasenense
A. (A.) kitchini
Rasenia erinus
Rasenia cf. cymodoce
Rasenia aff. coronata
A. (A.) alticarinatum
Rasenia cf. cymodoce
A. (A.) mesezhnikovi
A. (A.) rasenense
A. (A.) kitchini
A. (A.) pingue
80
A. (Amoebites) cf. kitchini
A. (Euprionoceras) sokolovi
70
60
Bernbjerg Fm
8 m poorly exposed
50
36 m poorly exposed
10
Pelion Mb
Oysters
Meleagrinella braamburiensis
0
62
125
250
500
μ
m
270
260
Buchia concentrica
250
240
230
43 m poorly exposed
180
170
Aulacostephanus (X.) cf. staintonensis
Au. (A.) akanthophorus
A. (Amoebites) cf. cricki
Au. (A.) cf. ebrayoides
Au. (X.) cf. thurelli
B. concentrica
160
Aulacostephanus (Xenostephanus)
cf. groenlandicus
Buchia concentrica



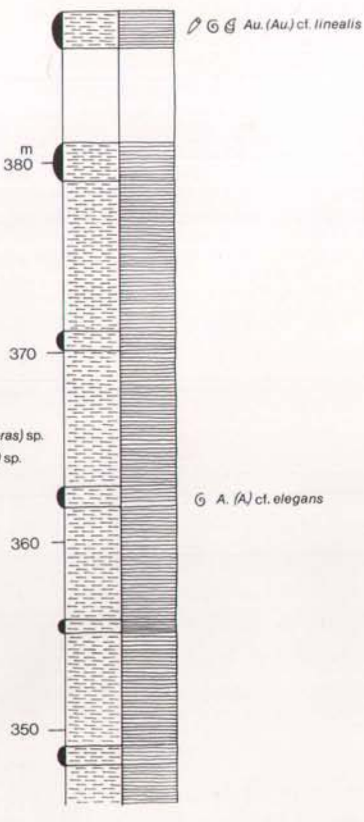


Fig. 24. Section 8 showing Bernbjerg Formation (type section), eastern slope of Bernbjerg, south-western Kuhn Ø (fig. 2).

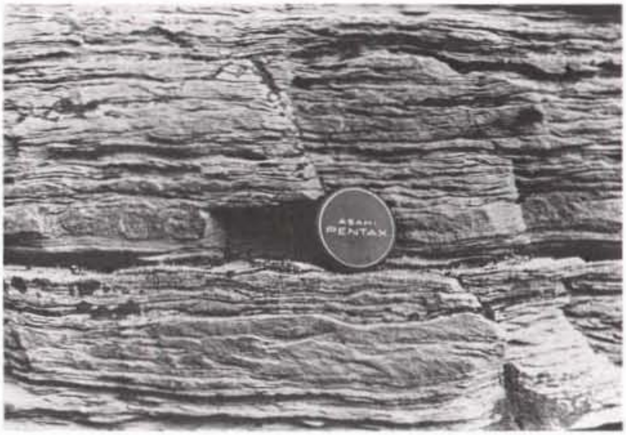


Fig. 25. Current-ripple cross-laminated and wavy bedded sandy part of the basal Bernbjerg Formation. Immediately above top of section 1 (fig. 4).

In all sections the mud dominated sediments are occasionally interrupted by 5–50 cm thick sandstone beds. One type is parallel sided, slightly graded and has a lateral extent of some tens of metres. In a section on eastern Kuhn Ø (section 12, fig. 29) the sandstones show wave-ripple cross-lamination. Another type has a scoop-shaped base, a flat top and a lateral extent of only 1–2 m. In some cases the latter type forms up to 6 m thick units by amalgamation (e.g. section 40, fig. 31).

Calcite cemented concretions occur scattered, or in distinct horizons in all facies types. Ammonites and the bivalve *Buchia* occur in great abundance in most sections, whereas other fossils are very rare. Logs, up to 7 m long and 0.5 m in diameter, occur at many levels and smaller pieces of wood may form the core of the concretions. The sandy rhythmites commonly show strong bioturbation and display *Planolites*, *Muensteria*, and *Rhizocorallium*. The parallel laminated mudstones and the mudstones with sandy streaks are practically unbioturbated and do not contain well-defined trace fossils except for occasional *Chondrites* where they are overlain by sandy layers.

Boundaries

The lower boundary is placed where the dark grey or black rhythmites and mudstones of the formation overlie light coloured sandstones of the Pelion Member or sandy rhythmites and sandstones of the Jakobsstigen Member. The formation is overlain with strong erosional and sometimes angular unconformity by the syntectonic sediments of the Wollaston Forland Group. In a few sections these overlying beds belong to the equally mud dominated Laugeites Ravine or Niesen Members. In these cases the Bernbjerg Formation is consistently finer grained and darker coloured, and its abundant concretions weather in a very characteristic light yellow colour whereas the two other units contain no or few

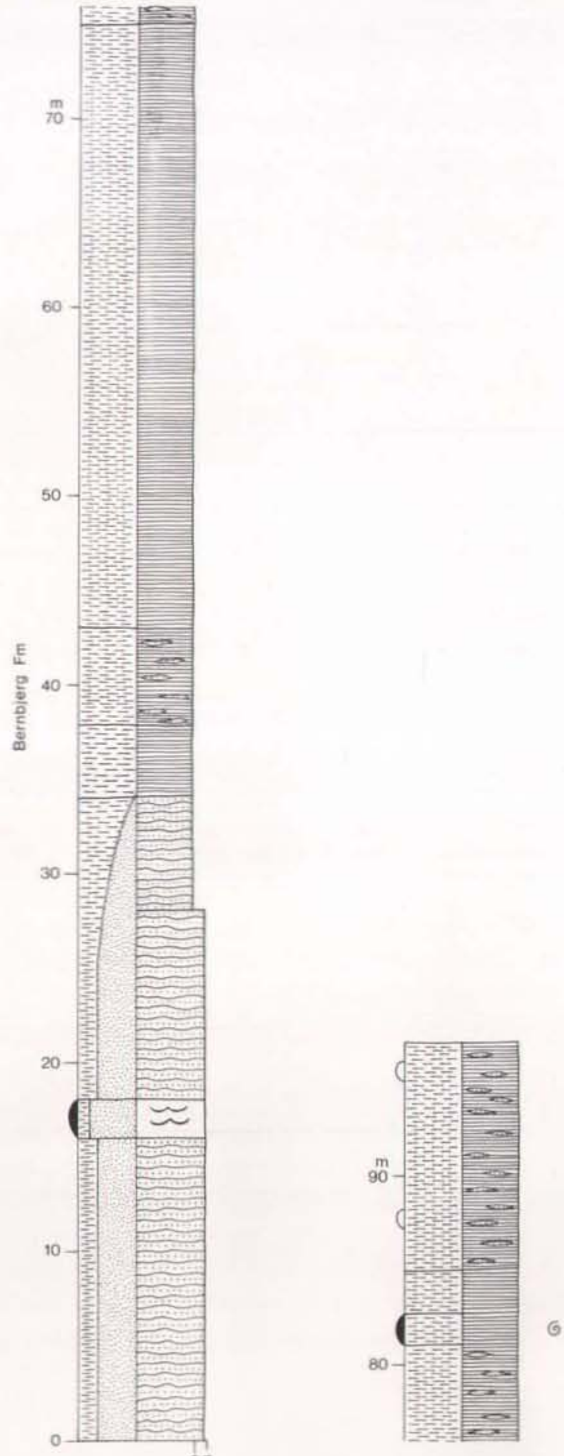


Fig. 26. Section 9 showing Bernbjerg Formation. South-eastern slope of Bernbjerg, Kuhn Ø (fig. 2).

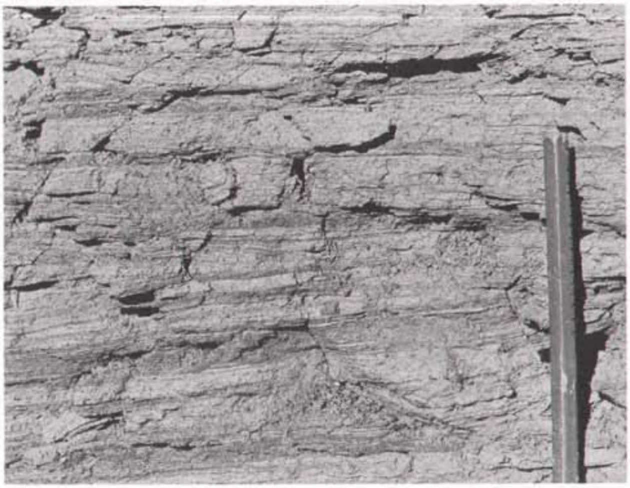


Fig. 27. Interlaminated mudstone and fine-grained sandstone (rhythmic laminated heterolith), Bernbjerg Formation.

concretions, which weather in dark reddish shades. Furthermore, the ammonite faunas of the units are totally different. In the southernmost Mesozoic exposure on the east coast of Kuhn Ø the geological maps of Koch & Haller (1971) indicate the presence of the Bernbjerg Formation. New field work has demonstrated the sediments to be dark Aptian mudstones. Again, fossil evidence and the nature of the concretions are diagnostic for both units. The concretions of the Aptian mudstones are very irregular, often kidney shaped and weather to an orange colour whereas the light yellow Bernbjerg concretions are ellipsoidal.

Distribution

The Bernbjerg Formation occurs from northernmost Hochstetter Forland in the north over Kuhn Ø to Wollaston Forland. A small down-faulted area is found on the east coast of Clavering Ø.

Geological age

The age relations of the Bernbjerg Formation were treated in detail by Sykes & Surlyk (1976). On Wollaston Forland it ranges from the Upper Oxfordian zone of *Amoeboceras glosense* to the Lower Volgian, but the higher parts of the formation have everywhere been removed by pre-Valanginian erosion. On Kuhn Ø the formation begins with the Lower Kimmeridgian zone of *Rasenia cymodoce* and it extends well up into the Lower Volgian, but fossil evidence is too limited to allow any detailed zonation of the higher parts.

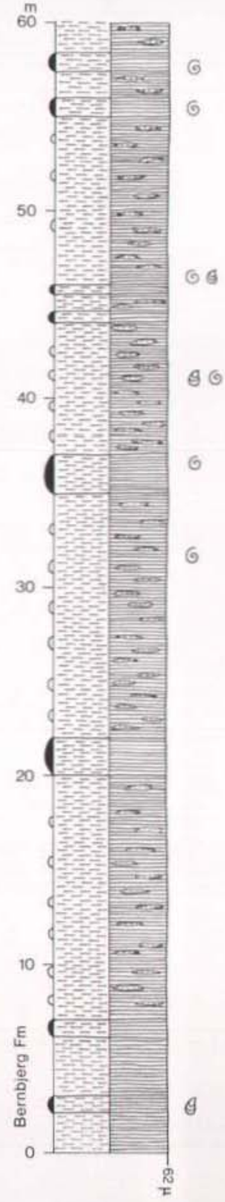


Fig. 28. Section 10 showing Bernbjerg Formation, Perisphinctes ravine, east coast of Kuhn Ø (fig. 2).

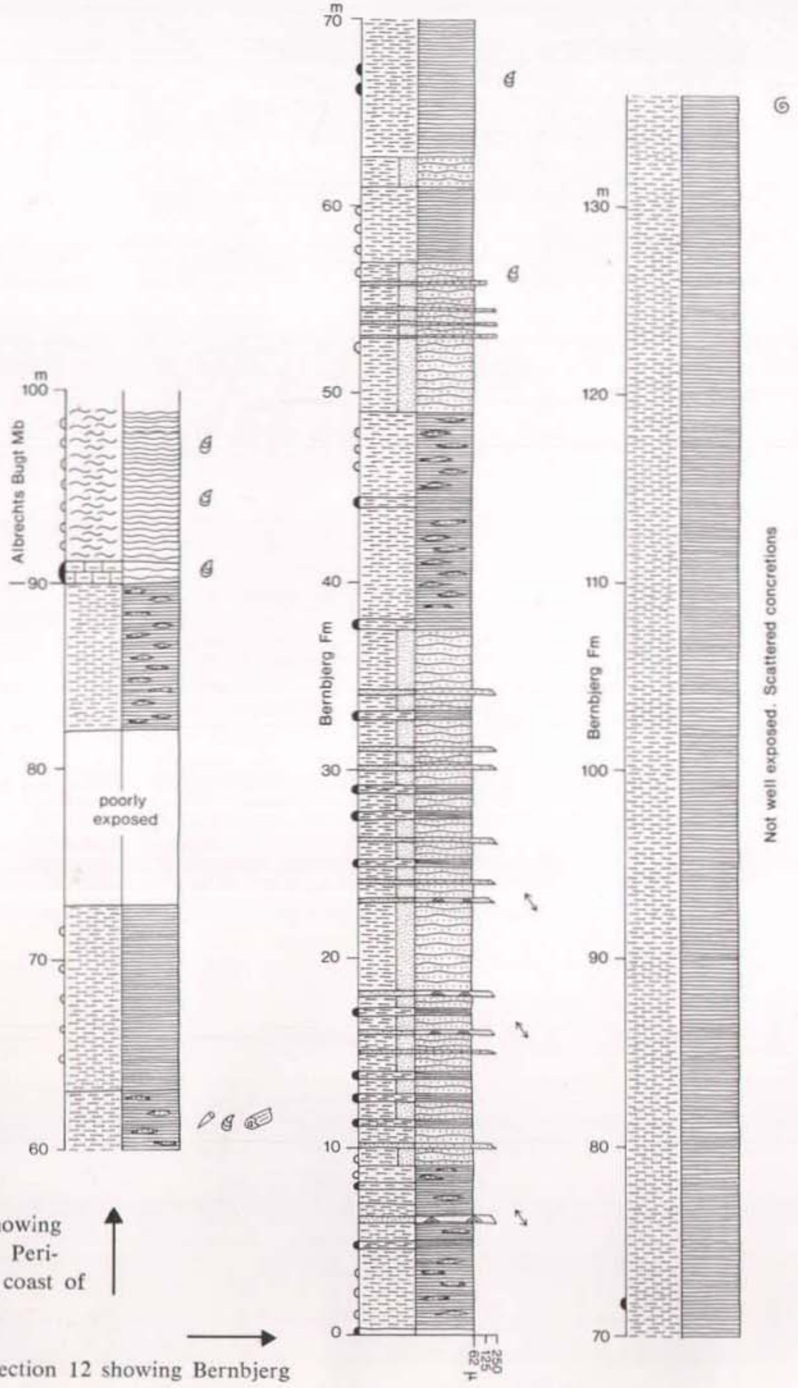


Fig. 29. Section 12 showing Bernbjerg Formation, 'Nord Profil', east coast of Kuhn Ø (fig. 2).

Fig. 30. Even parallel laminated mudstone with sandy streaks. At the centre one of the thicker sandy streaks shows very low-angle current-ripple cross-lamination indicating transport to the right, Bernbjerg Formation.

STORE KOLDEWEY

General

The geology of this island (fig. 1) is only known in outline and the main descriptions are those by Ravn (1911), Koch (1929) and Frebold (1935).

Jameson Land Group

The Jurassic rocks of Store Koldewey are included in the Jameson Land Group as they seem to comprise the same general types as those characteristic of the group elsewhere in East Greenland.

Vardekløft Formation

General

The Jurassic rocks of Store Koldewey are grouped into two lithostratigraphical units the lower of which is referred to this formation.

Pelion Member

General

The Middle Jurassic rocks here included in the Pelion Member have their main occurrence down from Trækpasset, southern Store Koldewey. Faunas collected by 'Danmark Ekspeditionen' were described by Ravn (1911) who also gave a few remarks on the geology. On the basis of Ravn's results and his own observations

Koch (1929) coined the name Trækpas Formation to the succession. Although the sequence is poorly exposed and only little known, it seems to fall naturally within the limits of the Pelion Member, which is well exposed on Hochstetter Forland and Kuhn Ø 50–150 km to the south. The term Trækpas Formation is consequently abandoned here.

Thickness

Not known with certainty, but indicated to be about 50 m.

Lithology

The member is poorly exposed so only its general character is known. It comprises hard, reddish-brown fine-grained, usually non-fossiliferous sandstones.

Boundaries

The boundary relations of the member are poorly known, but the member probably rests on Caledonian basement, and is possibly overlain by the Upper Jurassic Kløft I Formation.

Distribution

The member is restricted to the southern part of the east coast of Store Koldewey. To the west it is limited by the main N–S orientated fault dividing the island into a western basement area and an eastern down-faulted sediment area.

Geological age

The presence of the Late Bathonian zone of *Cadoceras variabile* has been demonstrated (Ravn, 1911; Birkelund & Perch-Nielsen, 1976).

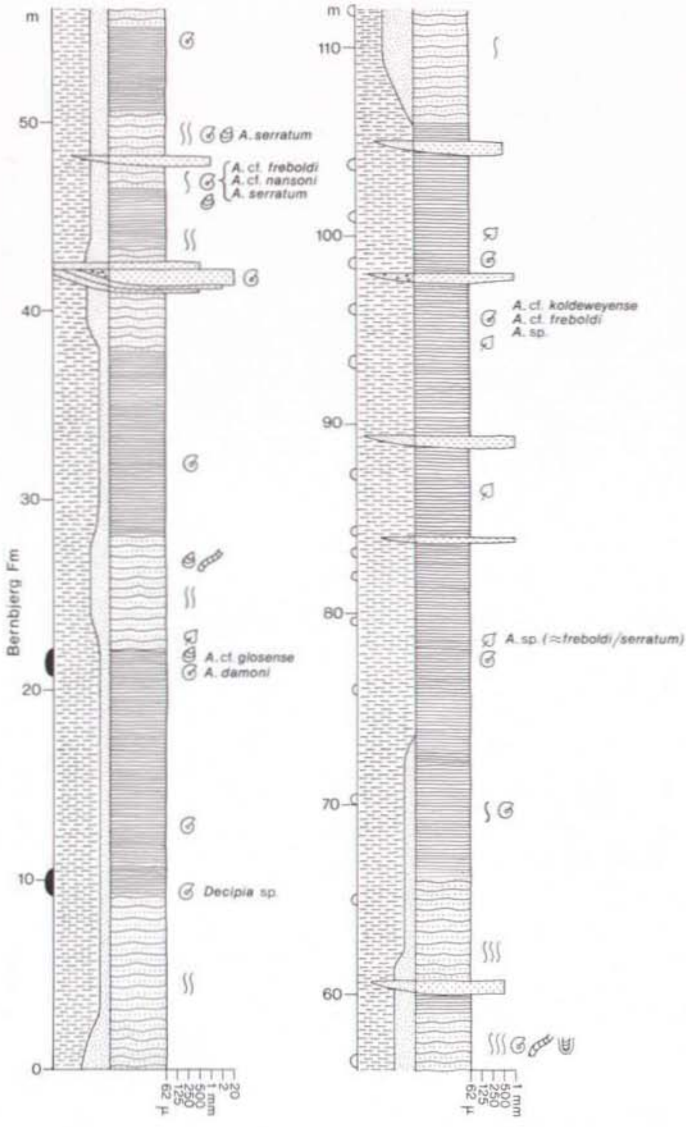
Kløft I Formation

General

Described as Kløft I Formation by Koch (1929) partly on the basis of Ravn's (1911) work.

Name

From Kløft I situated approximately midway along the east coast of Store Koldewey (fig. 1).


m
50
40
30
20
10
0
Bernbjerg Fm
A. serratum
A. cf. freboldi
A. cf. nansoni
A. serratum
A. cf. glosense
A. damoni
Decipia sp.
62 μ
125
250
500
1 mm
2
20
m
110
100
90
80
70
60
A. cf. koldeweyense
A. cf. freboldi
A. sp.
A. sp. (≈ freboldi/serratum)
62 μ
125
250
500
1 mm

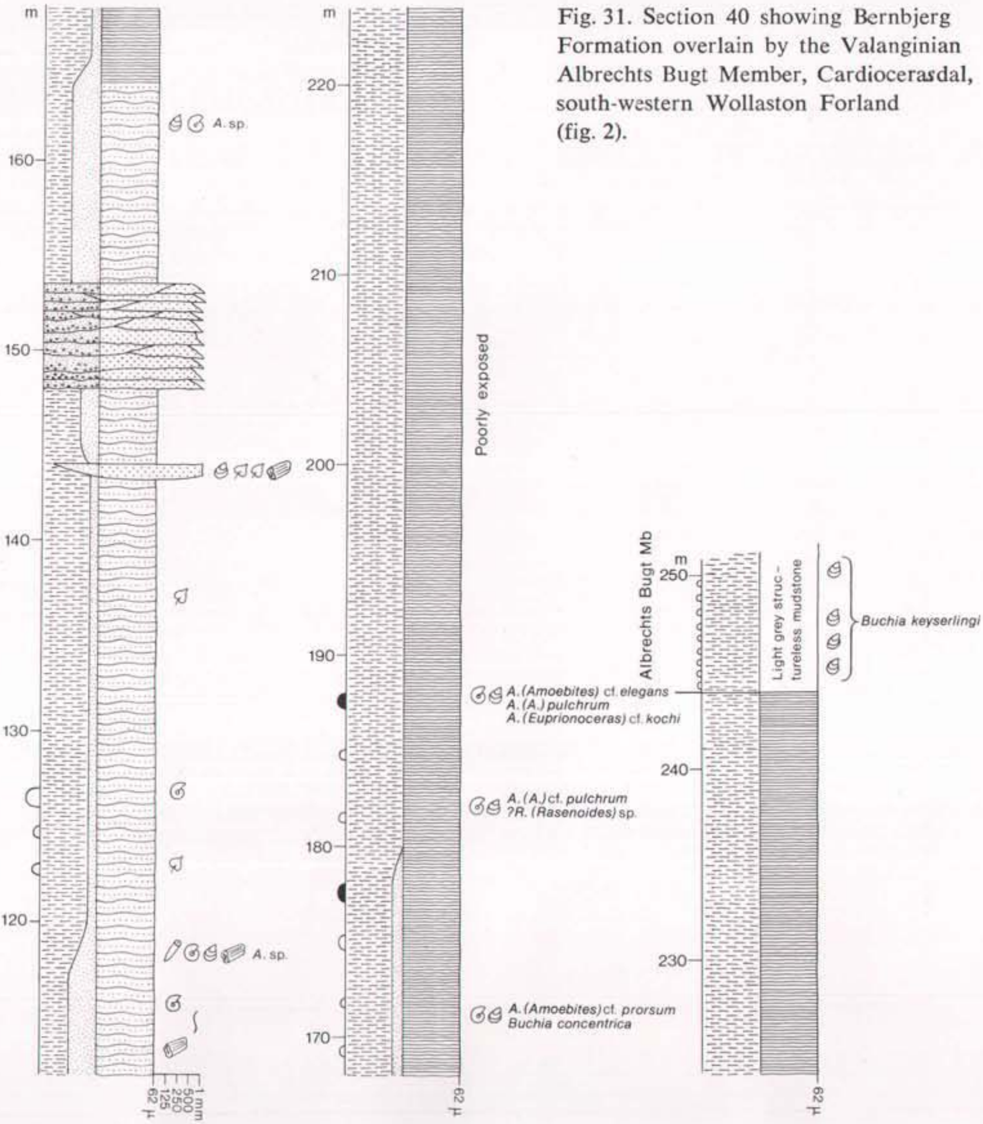


Fig. 31. Section 40 showing Bernbjerg Formation overlain by the Valanginian Albrechts Bugt Member, Cardiocerasdal, south-western Wollaston Forland (fig. 2).

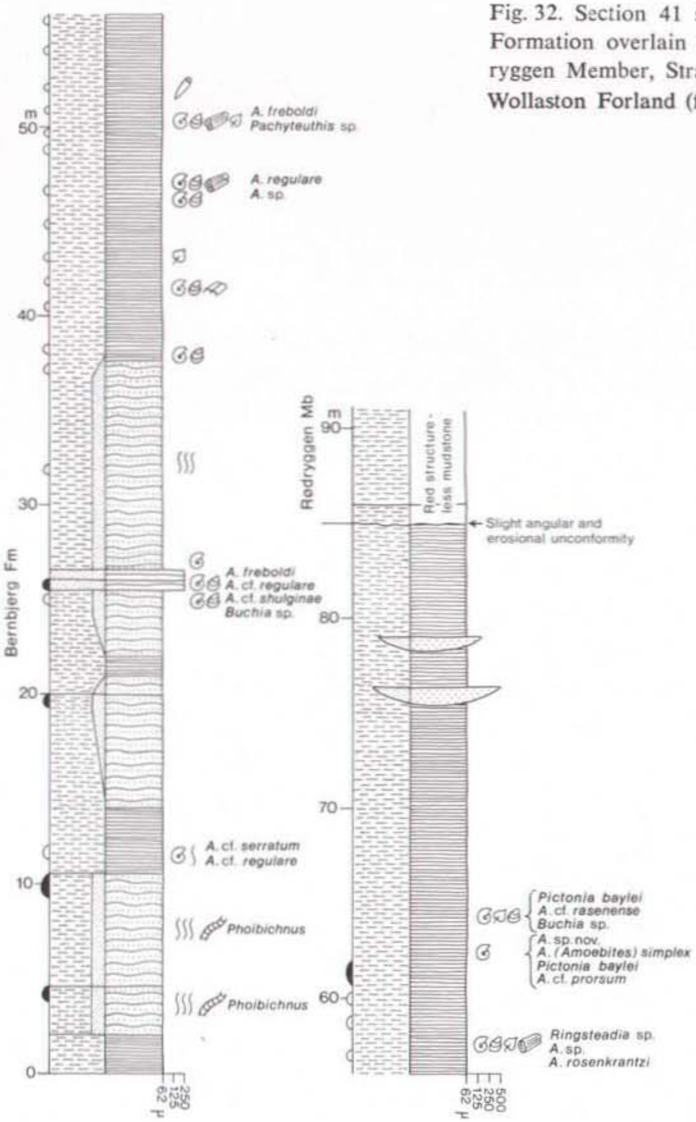


Fig. 32. Section 41 showing Bernbjerg Formation overlain by the Valanginian Rødryggen Member, Stratumbjerg, south-western Wollaston Forland (fig. 2).

Type locality

Kløft I, Store Koldewey.

Thickness

Indicated by Koch (1929) as not exceeding 100 m.

Fig. 33. Even parallel laminated mudstone with very thin sandy streaks, Bernbjerg Formation, section 38, Cardiocerasdal, south-western Wollaston Forland.

Lithology

Well cemented dark, micaceous, very fossiliferous sandstone and shaly sandstone. The very diverse fauna was described by Ravn (1911). It deviates in its richness from that of the Pelion Member and the Bernbjerg Formation, but resembles the contemporaneous fauna of the Jakobsstigen Member in Th. Thomsen Land and the Pecten Sandstone in Milne Land described by Spath (1935).

Boundaries

The member probably overlies the Pelion Member.

Distribution

Central east coast of Store Koldewey.

Geological age

The presence of the Upper Oxfordian zones of *Amoeboceras serratum*, *A. regulare* and *A. rosenkrantzi*, and of the Lower Kimmeridgian zone of *Aulacostephanus mutabilis* have been demonstrated by Sykes & Surlyk (1976).

TRAILL Ø AND GEOGRAPHICAL SOCIETY Ø

General

The areas treated in the preceding section are all situated in or north of the Wollaston Forland Basin, whereas Traill Ø and Geographical Society Ø are situated in the northernmost part of the Jameson Land Basin (fig. 1).

Jameson Land Group

All Jurassic rocks occurring on the two islands are included in this group as they were deposited in the same basin and form a natural northwards continuation of the sequence known from northern Jameson Land and Scoresby Land (Surlyk *et al.*, 1973).

Vardekløft Formation

General

This formation comprises the oldest Jurassic rocks of Traill Ø and Geographical Society Ø as it directly overlies Triassic rocks. There is no trace of the Rhaetic–Hettangian Kap Stewart Formation and Pliensbachian–Toarcian Neill Klinter Formation which both occur immediately south of Kong Oscars Fjord (Donovan, 1957; Lars B. Clemmensen, pers. comm., 1976).

Sortehat Member

General

Donovan (1953, 1957) described a sequence of sandstones and dark shales with abundant plant remains, termed the 'Plant Beds' at the base of the yellow sandstone sequence here referred to the Pelion Member. Near the northern end of Bjørnedal, Traill Ø, at least 100 m of dominantly shaly beds occur below sandstones with *Cranocephalites*. These fine-grained beds are here referred to the Sortehat Member, which in Jameson Land and Scoresby Land forms the basal member of the Vardekløft Formation and everywhere is overlain by the Pelion Member. In eastern Traill Ø the Sortehat Member seems to have wedged out since the Pelion Member rests directly on Triassic rocks (Lars B. Clemmensen, pers. comm., 1976). The age relations of the member are unclear. By analogy with the conditions in Jameson Land it is probably younger than Toarcian and older than Bathonian. The correct age is probably Bajocian.

Pelion Member

General

For name and type locality see Surlyk *et al.* (1973). The rocks here included in the Pelion Member were referred by Donovan (1953, 1955) and Putallaz (1961) to the 'Yellow Series' of Maync (1947).

It is possible that more detailed field work in the area will demonstrate the presence of equivalents of the Fossilbjerget Member and Olympen Formation which overlie the Pelion Member in northern Jameson Land.

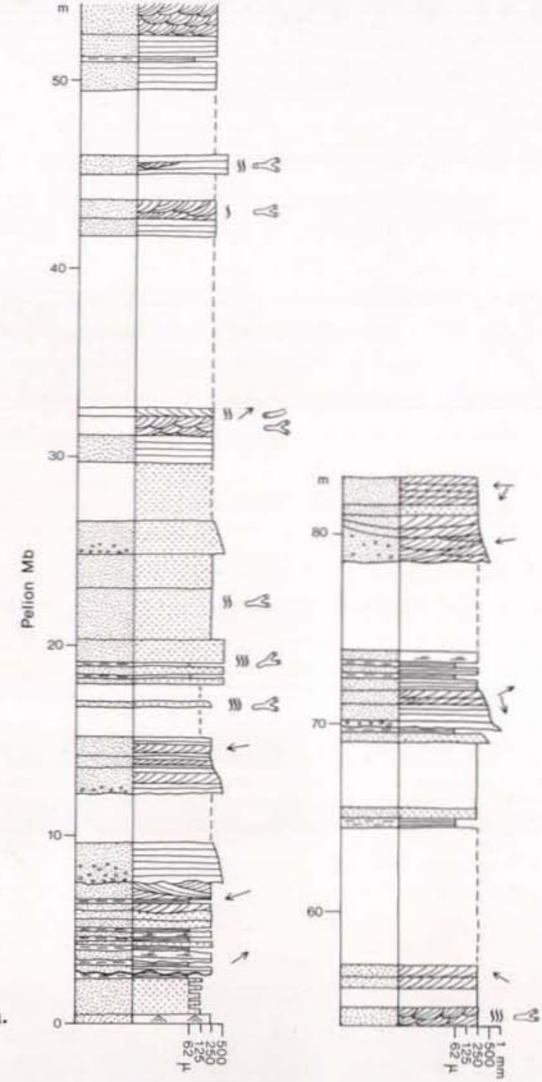


Fig. 34. Section of Pelion Member, Mols Bjerge, northern Traill Ø (fig. 2). Measured 1976 by Lars B. Clemmensen.

Reference section

Section (fig. 34) measured at Mols Bjerge, northern Traill Ø, by Lars B. Clemmensen in 1976.

Thickness

According to Putallaz (1961) the member on the southern slope of Mols Bjerge, Traill Ø, reaches a thickness of 1300 m. Donovan (1957) gives a minimum thickness of 700 m in the Bjørnedal area, Traill Ø, and on Geographical Society Ø it is at least 400 m at Laplace Bjerg and 500 m in Tværdal (Donovan, 1957).

Dominant lithology

The only Pelion section in the area which has been measured in detail is the one shown on fig. 34, measured by L. B. Clemmensen in 1976. The description mainly refers to this section, study of samples deposited in the Geological Museum, Copenhagen, and to scattered remarks in papers by Donovan (1953, 1955, 1957).

The member comprises fine- to medium-grained sandstones showing even, parallel and non-parallel lamination, planar and trough cross-bedding. Some beds are completely structureless. Dark grey sandy and silty mudstones occur as subordinate intercalations in the sandstones. In the Bjørnedal–Lycett Bjerg area, Traill Ø, a predominantly shaly sequence more than 100 m thick occurs in the middle of the succession. Pebbly horizons are very common and there seems to be a general increase in grain size in a northward direction. Extremely well rounded pebbles with a diameter of 5–10 cm thus occur in channel fills at Kap Palander, northernmost Traill Ø (fig. 1). Conglomeratic beds are very common on Geographical Society Ø. Macrofossils are rare and comprise ammonites, bivalves and belemnites. Abundant oysters have, however, been collected by Donovan (1953) in Svinhufvuds Bjerge. Trace fossils are relatively uncommon and are mainly restricted to *Ophiomorpha*, *Thallassinoides*, and *Planolites*.

Boundaries

The member rests directly on reddish and greenish Triassic rocks except for the southern part of Traill Ø where it overlies the Sortehat Member. The upper boundary is placed where yellow sandstones with subordinate shales give way to dark mudstones of the Bernbjerg Formation or where it is overlain unconformably by Lower Cretaceous black mudstones.

Distribution

The Pelion Member is only found as scattered erosional remnants in eastern Traill Ø, a very small down-faulted outlier in Rold Bjerge, northern Traill Ø, on Nordenskiölds Ø, north of Traill Ø, and in the central part of Geographical Society Ø.

Geological age

Donovan (1953, 1955, 1957) described or listed the scattered ammonite finds from the area comprising species of *Cranocephalites*, *Arctocephalites*, *Cadoceras* and *Kepplerites*. They indicate the presence of most of the Bathonian zones of Callomon & Birkelund (in prep.) and possibly the lowest Callovian. On Svinhufvuds Bjerge, Traill Ø, Putallaz (1961) succeeded in finding good specimens of

Cardioceras (*Maltoniceras*) *maltonense* (Young & Bird) and *Cardioceras* (*Maltoniceras*) *vagum* Ilovaisky (both determined by D. T. Donovan) known from the Middle and Upper Oxfordian *tenuiserratum* and *densiplicatum* Zones. The presence of Middle – Upper Callovian and Lower Oxfordian strata has not been proved and it is therefore not known if the Pelion Member in this area covers all stages and substages from the Bathonian to the Middle Oxfordian.

Bernbjerg Formation

General

For name and type locality see earlier. The sediments that are here referred to the Bernbjerg Formation were placed by Donovan (1953, 1957) and Putallaz (1961) in the 'Black Series' of Maync (1947).

Thickness

Donovan (1953) estimated a maximum thickness of 500 m in the Bjørnedal area, Traill Ø. The thickness is almost everywhere strongly reduced by pre-Aptian erosion.

Lithology

Soft, black, parallel laminated mudstones.

Boundaries

The formation overlies the yellow sandstones of the Pelion Member conformably. It is overlain unconformably by Lower Cretaceous mudstones.

Distribution

The formation occurs as scattered erosional remmants in the inner parts of the south-eastern peninsula of Traill Ø. A narrow wedge of black shale along the Månedal Fault, northern Traill Ø has been referred with hesitation to this formation by Donovan (1955). On Nordenskiölds Ø, Pelion Member sandstones are overlain by 30 m of mudstones belonging to the Bernbjerg Formation. The formation seems to be absent on Geographical Society Ø, where it probably was removed by pre-Aptian erosion.

Geological age

A few poorly preserved ammonites were figured by Donovan (1953). They comprise *Cardioceras* sp. indet. and *Amoeboceras* (*Prionodoceras*) sp. indet. of presumed Late Oxfordian age, *Amoeboceras* (*Amoebites*) spp. indet. and *Amoeboceras (Euprionoceras)* sp. indet. of presumed Early Kimmeridgian age.

JURASSIC ENVIRONMENTS IN THE WOLLASTON FORLAND AREA

A general account of the Jurassic environments and tectonics is given below. It is based on the present stratigraphic data and sedimentological studies (Surlyk & Clemmensen, in press).

The Middle – Upper Jurassic Vardekløft and Bernbjerg Formations of northern East Greenland were deposited during a phase of major regional transgressions. The formations attain a total thickness of about 1 km. The transgressions were probably controlled by faulting in the basement, mainly along roughly N–S trending lines, as witnessed by the spatial distribution of facies, the abrupt vertical changes to deeper water facies, and in particular the lateral changes to coarser facies in the vicinity of the faults. The fault induced transgressions were accompanied by a general, probably eustatic transgression that can be traced in many parts of the world in the late Jurassic (Hallam, 1975). The faulting was followed by a slight tilting of the blocks to the west or south-west. The regional palaeoslope was, however, mainly to the SSW as deduced from palaeocurrent data and from lateral facies changes (Surlyk & Clemmensen, in press). The coast was constructed like a recent Ria-coast, the coastline being determined by the main N–S tectonic lines. The more detailed picture was thus one of N–S trending peninsulas, islands or shallow shoals to the east and a stable coastline to the west enclosing shallow marine bays or straits. The peninsulas broadened and were attached to the mainland to the north, and water depth increased in a southward direction with the basin axis running N–S close to the western shoreline.

Bathonian

The initial fault-controlled Jurassic transgression over the Wollaston Forland Block took place in the Bathonian over a peneplaned surface of slightly tilted Caledonian basement (fig. 36). The first depositional cycle corresponding to this submergence lasted from the Bathonian through the Callovian, but the dating is not very good. The rocks of this cycle comprise the Pelion Member. The next block to the north, centred on Kuhn Ø, was probably transgressed somewhat later than the Wollaston Forland area since there is a pronounced stepwise reduction in thickness of the member between northern Wollaston Forland and southern Kuhn Ø. On the Hochstetter Forland block Pelion Member sedimentation seems to have commenced in the Oxfordian and it continued until late Oxfordian times (Clemmensen & Surlyk, 1976; Sykes & Surlyk, 1976).

The Pelion Member reaches a maximum thickness of about 500 m in the Wollaston Forland Basin, but the facies types are relatively uniform shallow water estuarine sandstones throughout, signifying that subsidence and sedimentation kept pace. To the north on Kuhn Ø the individual facies are interbedded without any sequential regularity. The rocks are relatively coarse-grained and poor in stenohaline fossils, whereas oyster banks, and monospecific or at least low diversity assemblages of other bivalves constitute the dominant faunal elements. This probably signifies reduced, brackish-marine salinities (Hudson, 1963), although there is no direct faunal evidence of brackish or fresh water. Scattered thin coal seams on Kuhn Ø may, however, indicate the existence of temporary waterlogged supratidal environments. The Kuhn Ø Pelion sandstones were therefore laid down in the most landward part of a large estuarine delta at the mouth of a river system flowing from the north. The estuary was bordered to the west by the newly rejuvenated mainland which forms the source area of the sediments and to the east by the crestal area of the underlying fault block. The estuary was dominated by the ebb-currents enhanced by outflowing river water.

Further south in the Wollaston Forland Basin there is a gradual facies change. More fine-grained rocks are intercalated between coarse sandstones, and several coarsening-upwards sequences are known from southernmost Wollaston Forland. The fine-grained portions some tens of metres thick, were laid down in environments further offshore than the bulk of the overlying sandstones.

Each coarsening-upwards sequence probably reflects a minor fault episode during which the block was down-faulted resulting in a sudden transgression and followed by progradation. Initial deposition after the transgressive phase was dominated by fine-grained sandstones with mud flaser or layers. The sediment is often intensely bioturbated and it is from here the only ammonites of the Pelion Member of the Wollaston Forland Basin originate (Maync, 1947). The plentiful supply of coarse clastics from the northern estuarine delta system resulted, however, in rapid progradation of the sandstones thus forming a coarsening-upwards sequence ending with large- or giant-scale cross-bedded sandstones.

The Pelion Member in the Wollaston Forland Basin therefore constitutes an estuarine-deltaic, shallow water sequence. The coastlines moved back in a northwards direction in a series of fault induced steps.

Early Oxfordian

In the Early Oxfordian a major fault-episode caused a change of the environmental setting as demonstrated by an abrupt change of facies. The Pelion Member in Wollaston Forland is followed by the offshore normal marine Jakobsstigen Member, which reaches a thickness of about 100 m in the southern Wollaston Forland. The N–S faulting was probably associated with faulting along a subordinate WNW–ESE direction between Wollaston Forland and Kuhn Ø with down-faulting of the southern block. Thus the Jakobsstigen Member is absent on Kuhn Ø and Lower Kimmeridgian Bernbjerg mudstones overlie Pelion sandstones of uncertain age directly (Sykes & Surlyk, 1976). The Jakobsstigen shoreface sediments form a single overall coarsening-upwards unit corresponding to a slow progradation of the coastline following the fault-induced transgression. The sequence ends with facies much like the Pelion estuarine sandstones. Throughout the Jakobsstigen Member small asymmetrical cycles occur, each starting with a black laminated mudstone deposited under euxinic conditions followed by rhythmites or fine-grained sandstones. The change from mudstones to sandstones constitute small-scale coarsening-upwards cycles corresponding to rapid progradations which may be interpreted as resulting from shifting of mouth-bars in the landlocked estuarine delta.

Late Oxfordian

The third major subsidence took place in the Late Oxfordian. This transgression can be followed all along the East Greenland coast (Surlyk *et al.*, 1973; Sykes & Surlyk, 1976) and, as the other parts of the sequence treated in the present paper, might have an overprint of a general North Sea – North Atlantic mid – late Jurassic eustatic rise in sea-level (see Hallam, 1975) .

In a narrow strip along the western margin of the basin in Th. Thomsen Land (fig. 35) Jakobsstigen interlaminated sandstones and mudstones of shoreface origin were still deposited (Sykes & Surlyk, 1976). Down-faulting of the Hochstetter Forland block resulted in deposition of estuarine-deltaic Pelion sandstones and

Fig. 35. East coast of Th. Thomsen Land showing narrow N–S orientated fault-blocks.

Fig. 36. South coast of Kuhn Ø showing the westwards tilted Caledonian peneplane overlain by the Pelion Member and the Bernbjerg Formation. On top horizontal Tertiary plateau basalts.

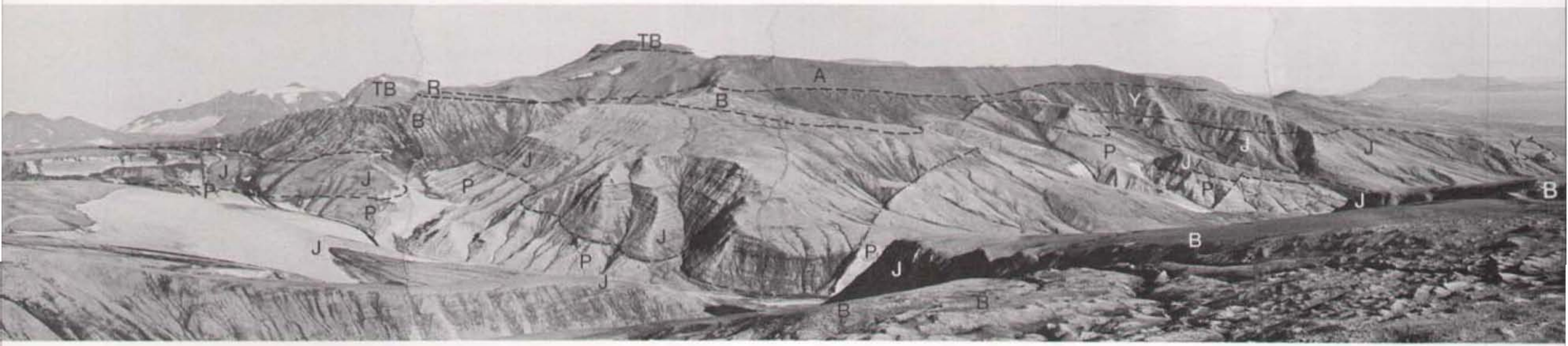


Fig. 37. South-eastern side of Cardiocerasdal, Stratumbjerg, with faulted and westwards tilted sediments of the Jameson Land Group unconformably overlain by Valanginian conglomerates and Aptian–Albian mudstones. P: Pelion Member; J: Jakobsstigen Member; B: Bernbjerg Formation; Y: Young Sund Member; R: Rødryggen Member; A: Aptian–Albian; TB: Tertiary plateau basalt.

coal-bearing barrier beach and lagoonal sediments of the Muslingebjerg Member to at least the Late Oxfordian. Elsewhere in East Greenland the facies shifts abruptly to the black mudstones of the Bernbjerg Formation and its equivalents. Because of this facies change and the rapid change to coarser sediments in the vicinity of the bordering faults the late Oxfordian transgression is also believed to be controlled by basement faulting. The mudstones are well laminated and were laid down under more or less euxinic conditions. Large areas of the surrounding landmasses were now submerged and the remaining land was of low, smooth topography. The substantially reduced topographic energy, erosion and run-off resulted in very limited supplies of coarser detritus, and deposition of mudstones took place not only in the offshore areas but almost to the coastlines.

Deposition of the Bernbjerg mudstones of the Wollaston Forland Basin lasted from Late Oxfordian to Early Kimmeridgian (Sykes & Surlyk, 1976) and the sequence attains a very high total thickness of about 600 m.

Kimmeridgian

The fourth and final transgression took place in the Early Kimmeridgian. In contrast to the previous tectonic-transgressive events this episode cannot be proved everywhere by the facies analysis, but is demonstrated by a detailed biostratigraphic study (Sykes & Surlyk, 1976). In the Wollaston Forland block the Upper Oxfordian mudstone facies continues into the Lower Kimmeridgian without any break or change in sedimentation, whereas on the Kuhn Ø Block Lower Kimmeridgian Bernbjerg mudstones overlie the Pelion sandstones abruptly proving a major down-faulting of this block in early Kimmeridgian times. The reason for the lack of facies response in the Wollaston Forland Block lies in the already very fine-grained nature of the basinal sediment and the extremely subdued surface of the land areas. Coarser clastics are almost only introduced by settling from stormy weather suspensions and as thin grain flow deposits.

The introduction of sandy material was sometimes followed by rapid colonization by a benthonic fauna. This shows that reducing conditions probably were confined to the muddy sediment and did not reach into the lowest part of the water column. The euxinic environment is therefore thought to be a result of fine grain size of the sediment, enormous organic production and only little disturbance by wave action, rather than being of deep-water 'barred' basin origin. Although this fits well with Hallam's (1975) shallow water 'unbarred' model for deposition of black laminated mudstones it must be pointed out that the basins in question actually did possess a barrier, namely the eastern up-tilted crestal areas of the fault blocks. Although the crests were without doubt submerged during the Early Kimmeridgian transgression they probably formed effective oceanographic shoals, thus implying a combination of Hallam's model and the 'barred' basin model. Water depths were probably only of a few tens of metres as witnessed by the occurrence of wave ripples in several horizons. The enormous thickness of very fine-grained sediment laid down within a few ammonite zones also seems to preclude any deep (bathyal) water.

Middle Volgian

The last depositional phase lasted into Early and possibly Middle Volgian times where the entire East Greenland continental margin was broken up by rifting and block tilting (Visher, 1943; Maync, 1947, 1949; Surlyk, 1975a, b). The tilted sequences of the Vardekløft and Bernbjerg Formations were strongly eroded especially along the crestal areas (fig. 37). Deep troughs were formed on the western down-tilted parts of the blocks and within a few ammonite zones a several kilometres thick extremely coarse clastic wedge was deposited comprising breccias, conglomerates, sandstones and to the east mudstones of the Wollaston Forland Group. These beds lie with strong angular and erosional unconformity on the underlying sequence (Visher, 1943; Maync, 1947, 1949; Surlyk, 1975a, b).

JURASSIC PALAEOGEOGRAPHY IN EAST GREENLAND

A series of maps showing palaeogeography and gross facies patterns for the Mesozoic sedimentary basins of the whole East Greenland coast between 70° N and 78° N is shown in figs 38–40. The western coastline is fairly well known in broad outline, whereas the eastern limit of the Jameson Land Basin is strongly speculative. The increasingly landlocked character of the Middle Jurassic sediments when passing from south to north in both the Jameson Land and Wollaston Forland Basin suggests that the eastern crestal areas of the underlying fault blocks were exposed or at least formed prominent oceanographic shoals. Thus the eastern part of Liverpool Land is interpreted as having formed an emerged barrier limiting the Jameson Land Basin to the east. This has been proposed by many earlier authors (see Donovan, 1957). It is corrobated by the thinning of the Vardekløft Formation in the down-faulted Kap Hope Block in southernmost Liverpool Land (Rosenkrantz, 1942), the palaeocurrent pattern recorded by Birkenmajer (1977) and the onlaps of Mesozoic sediments on the westwards tilted Caledonian peneplane. Donovan (1957, fig. 21) put forward the hypothesis of a northwards extension of the ancient Liverpool Land reaching almost to Hold with Hope. This hypothesis is in part followed here although an eastwards opening in the barrier is envisaged approximately at the mouth of Kong Oscars Fjord. A major NW–SE trending fault zone is postulated to follow the fjord (e.g. Surlyk *et al.*, 1973) and Clemmensen (1976) suggested a connection to the sea for the landlocked partly marine Rhaetic – Early Liassic basin of Jameson Land – Scoresby Land. The existence of a more or less continuous barrier to the east is supported by the strongly northwards increasing grain sizes in the Pelion Member and the decrease in diversity and abundance of marine fossils from Jameson Land to Geographical Society Ø. This eastern barrier possibly became submerged during the Late Jurassic transgressions as witnessed by the extreme uniformity of facies. The euxinic nature of the facies strongly suggests, however, that this barrier formed an effective oceanographic shoal to the east (Donovan, 1957).

The palaeogeographic nature of the Hold with Hope area where Jurassic deposits are absent has been much debated. Maync (1947, p. 144) suggested that the area was emerged, but it is not known whether the absence of Jurassic strata is due to non-deposition or to pre-Aptian erosion. Donovan (1957, p. 106) stressed this uncertainty and seemed somehow to favour the last explanation, partly because the Bernbjerg Formation and the higher parts of the Pelion Member have been removed by pre-Aptian erosion on northern Geographical Society Ø immediately south of the postulated landmass. Donovan furthermore claimed that there is no positive evidence such as shoreline facies for the existence of the landmass. This must, however, be rejected since the Pelion Member on northern Traill Ø and Geographical Society Ø constitutes almost nothing but shoreline or very shallow marine facies.

More recent geophysical evidence has demonstrated that a major tectonic structure – the Jan Mayen Fracture Zone – meets the East Greenland coast in Kejser Franz Josephs Fjord between Geographical Society Ø and the Hold with Hope peninsula (Johnson *et al.,* 1975). The time of formation of the fracture zone probably dates from the initial spreading in Palaeocene times but the zone may have a longer history as a tectonic lineament. The position of a major fault zone between Hold with Hope and Geographical Society Ø would probably have important palaeogeographical consequences. It is therefore here taken as supporting Maync's (1947) hypothesis and Hold with Hope is interpreted as forming a Jurassic landmass. The area was, however, subject to the same type of block faulting and slight westwards block tilting as is known from both the Traill Ø – Geographical Society Ø area to the south and the Wollaston Forland area to the north. If parts of the peninsula were submerged in Jurassic times, it would consequently be the western part of the block. The coastline would in this case have been situated roughly along the NNE trending post-Devonian main fault. This possibility is indicated with the stippled line on fig. 40.

North of Hold with Hope in the Wollaston Forland Basin the palaeogeographical evolution during the Jurassic is relatively well known (e.g. Maync, 1947; Clemmensen & Surlyk, 1976; Sykes & Surlyk, 1976). New data collected in 1976 by Christian Hjort and associates (Lund, Sweden) on the previously little known Hochstetter Forland have thrown light on a number of questions. Here also, sedimentation took place on N–S trending slightly tilted fault blocks cut by NW–SE running faults following the fjords and sounds between Wollaston Forland and Kuhn Ø and between Kuhn Ø and Hochstetter Forland. Activation of the

NW-SE system seems to have been consecutively from south to north. Thus the Wollaston Forland Block was transgressed first, then the Kuhn Ø Block and finally the Hochstetter Forland Block. This resulted in a stepwise thinner, younger, and more fragmentary Jurassic record from south to north.

The sedimentation pattern and its underlying fault control has not been realized before as a general plan for the Jurassic sedimentation in East Greenland. Surlyk *et al.* (1973) suggested faulting in Kong Oscars Fjord between Scoresby Land and Traill Ø to explain the absence of the Kap Stewart and Neill Klinter Formations on Traill Ø and Sykes & Surlyk (1976) demonstrated in a comparable way that faulting had taken place in Middle and Late Jurassic times between Wollaston Forland and Kuhn Ø.

In conclusion, a general model for Jurassic sedimentation and tectonics in East Greenland is consequently proposed. The initial basin formed by faulting along mainly N–S trending lines accompanied by slight westwards rotation of the fault blocks. In this way a number of N–S elongated depositional troughs were formed. This pattern already started to develop in the Early Carboniferous and continued throughout the Late Palaeozoic and Mesozoic (Vischer, 1943; Haller, 1971). The trough axes were orientated N–S and were located over the western down-tilted parts of the blocks, whereas the eastern block margins formed mountain ridges, elongated islands or peninsulas, or submarine shoals all depending on the degree of submergence. Subsidence took place mainly by gradual movements along the faults only in some periods interrupted by strong fault activity, for example at the Jurassic–Cretaceous boundary (Vischer, 1943; Maync, 1947, 1949; Surlyk, 1975b).

The general N–S fault pattern was cut by a number of NW–SE trending faults which downthrow to the south. These postulated faults are mainly located in the present fjords: Kong Oscars Fjord, Kejser Franz Josephs Fjord, Lindemans Bugt, and Ardencaple Fjord.

In contrast to the N–S fault system this system seems to have been activated in a series of violent movements reflected by the pronounced stepwise reductions in thickness or disappearance of formations when passing the fault zones from south to north. This new tectonic model is incorporated in the palaeogeographical maps (figs 38–40) and in fig. 41 which shows a strongly generalized N–S section through the Jurassic basins of East Greenland.

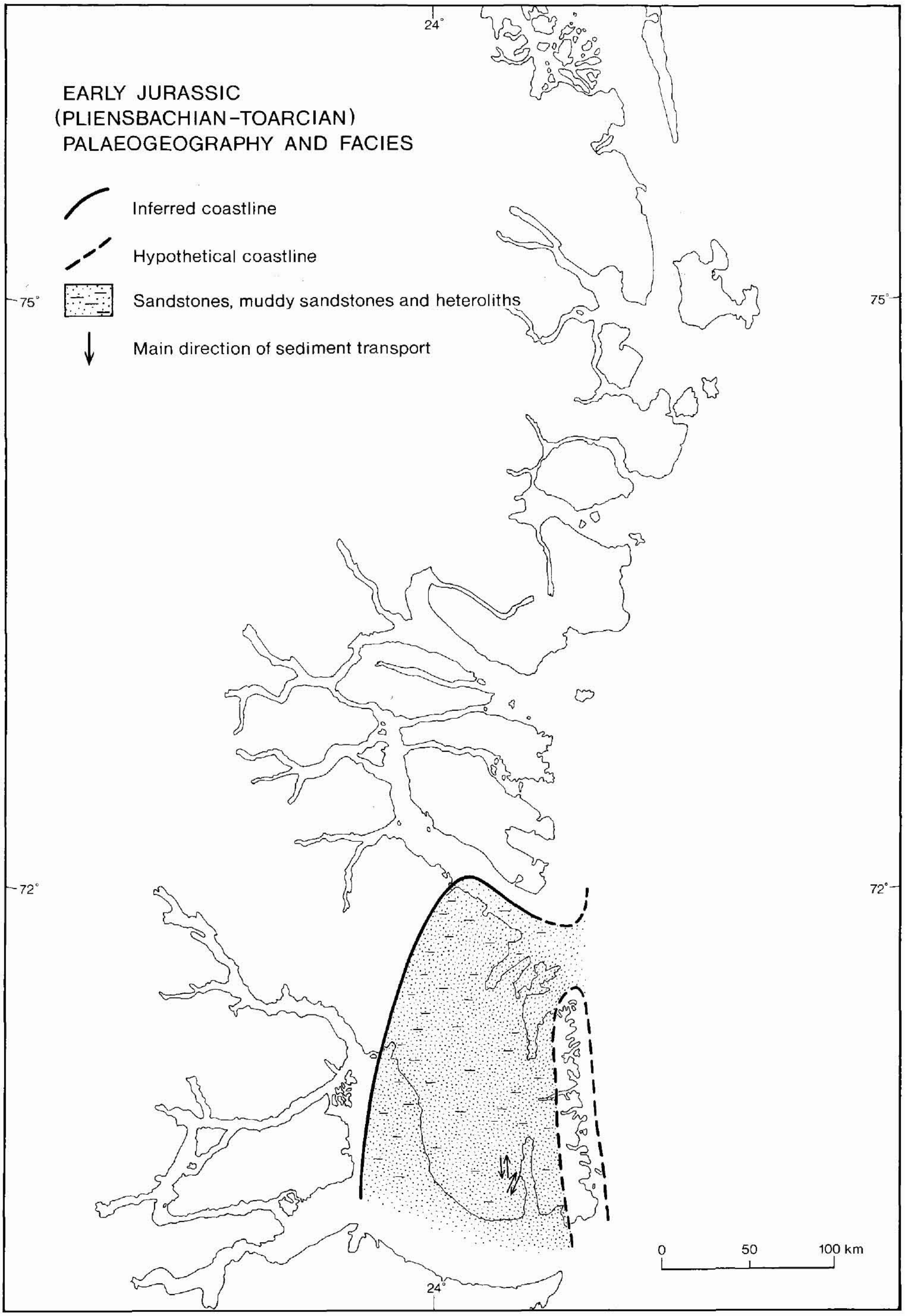


Fig. 38. Early Jurassic palaeogeography and facies, East Greenland. The *inferred* coastlines are based on gross facies and fault patterns and are thought to be fairly reliable, whereas the *hypothetical* coastlines are of a more speculative nature and reflect the general topography of the underlying fault blocks.

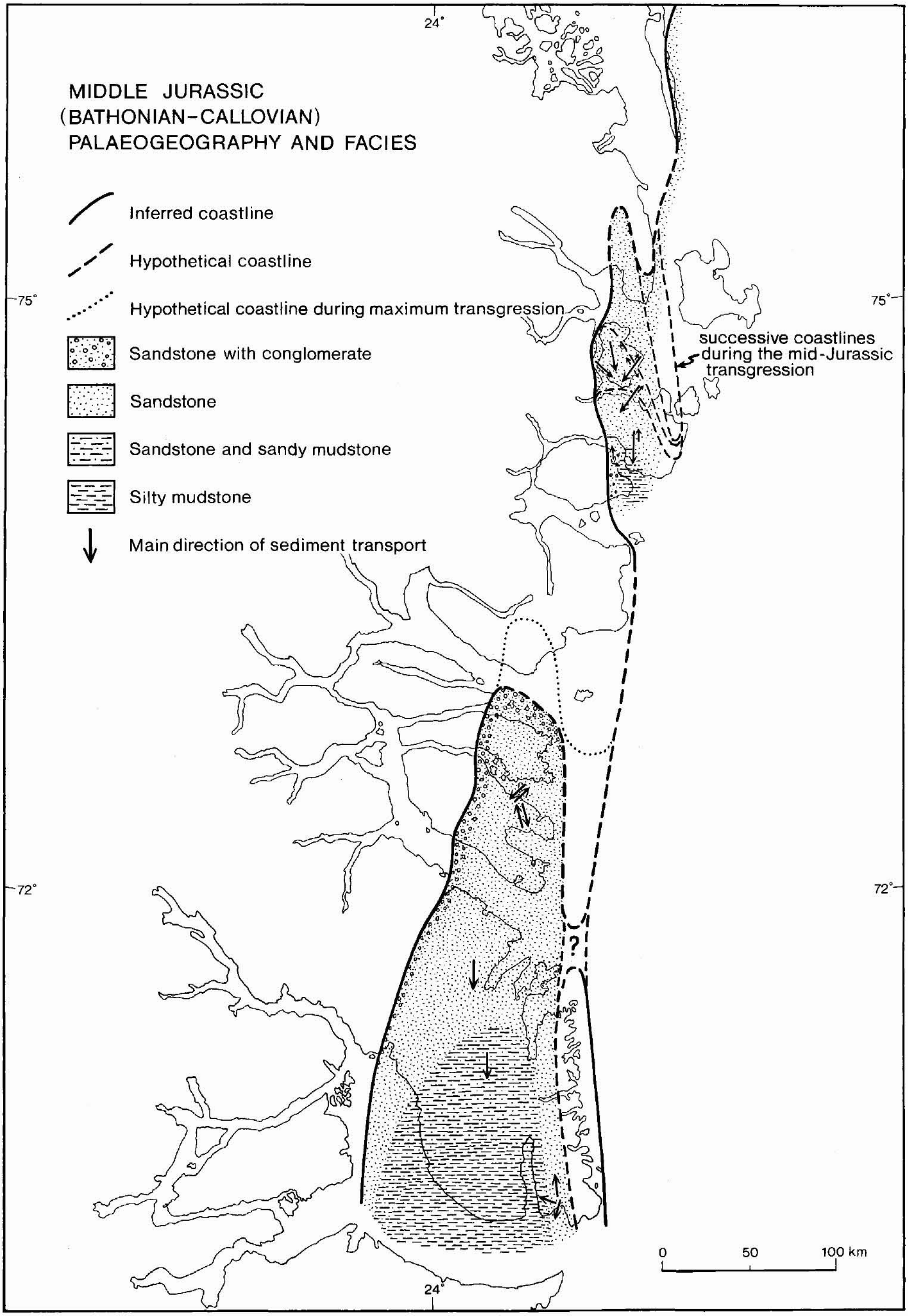


Fig. 39. Middle Jurassic palaeogeography and facies, East Greenland. The Liverpool Land landmass and especially its northwards continuation is highly speculative. See also text to fig. 38.

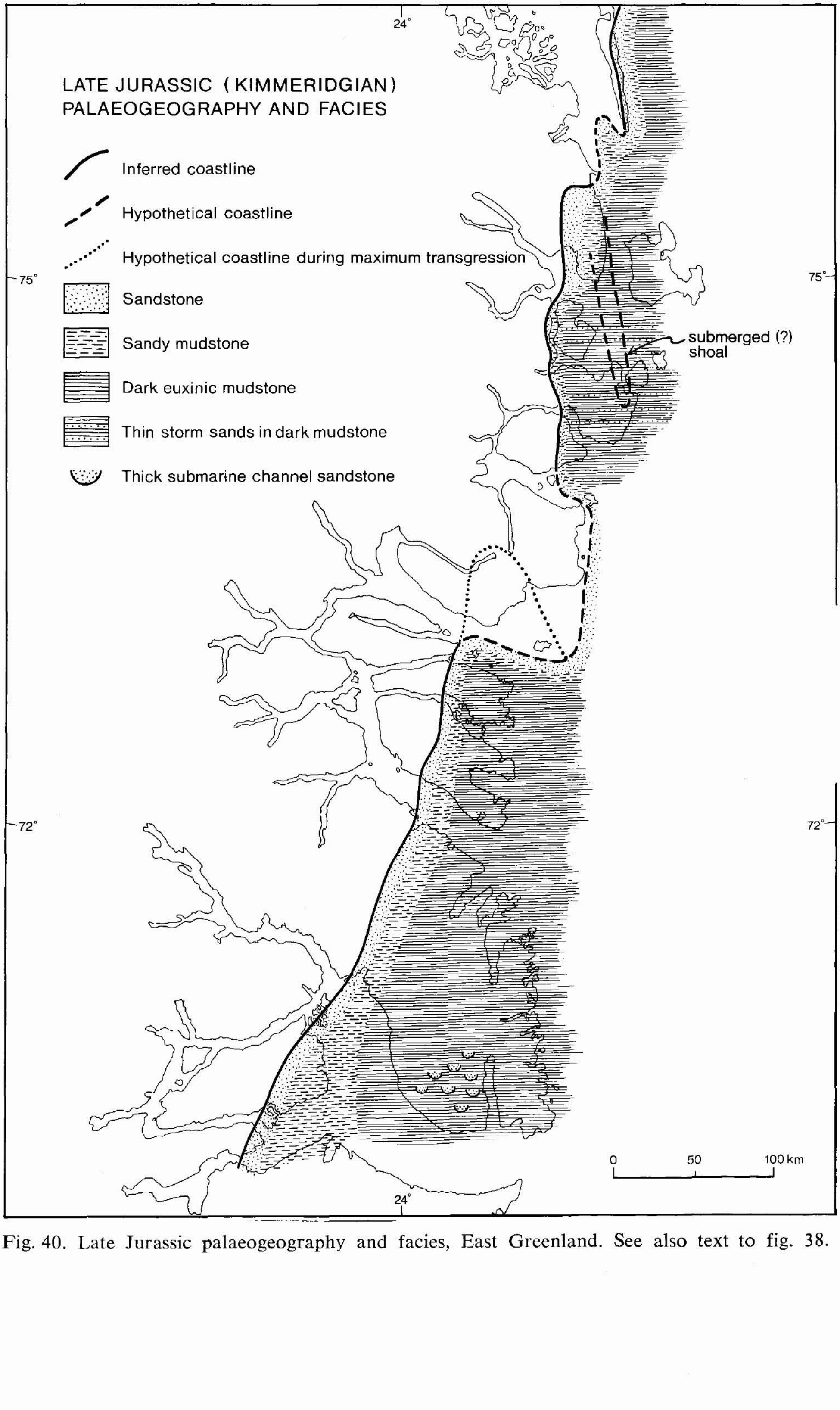


Fig. 40. Late Jurassic palaeogeography and facies, East Greenland. See also text to fig. 38.

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Table 2. Stratigraphic scheme of the Jurassic of East Greenland. Milne Land and Jameson Land is after Surlyk et al. (1973). Other sources: Birkelund & Perch-Nielsen (1976), Birkenmajer (1977), Clemmensen (1976), Donovan (1953, 1955, 1957), Maync (1947), Rosenkrantz (1942), Sykes & Surlyk (1976) and author's observations. New stratigraphic names on Milne Land from the 1:100 000 map sheet Kap Leslie 70 Ø 2 N.

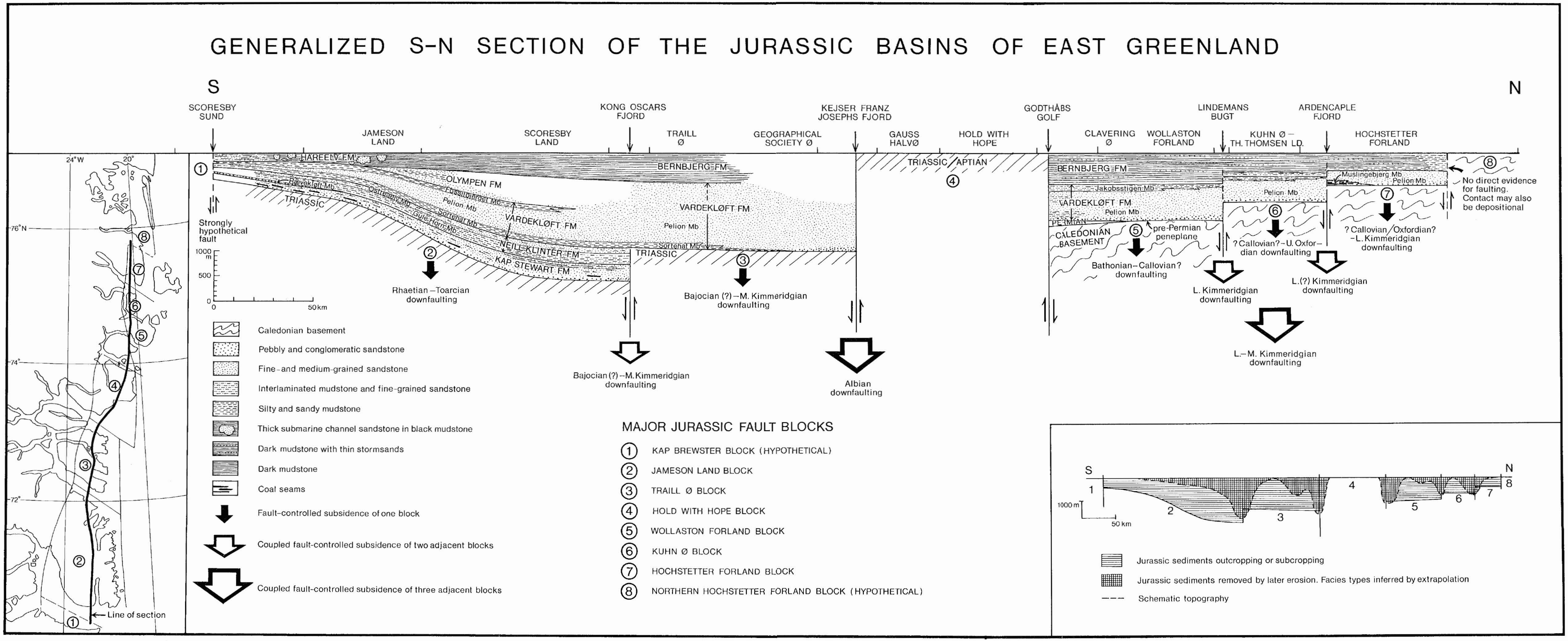

Fig. 41. Strongly schematical south–north section through the Jurassic basins of East Greenland showing the northwards basin extension by down-faulting of the Traill Ø, Wollaston Forland, Kuhn Ø, and Hochstetter Forland blocks.

JURASSIC STRATIGRAPHY OF EAST GREENLAND