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BULLETIN No. 105

STRATIGRAPHY OF THE JURASSIC–LOWER CRETACEOUS SEDIMENTS OF JAMESON LAND AND SCORESBY LAND, EAST GREENLAND

BY

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WITH 37 FIGURES AND 3 TABLES IN THE TEXT,
AND 11 PLATES

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Abstract

The Jurassic–Lower Cretaceous sediments of Jameson Land and Scoresby Land are divided into seven formations. They comprise from bottom to top: Kap Stewart Formation of Rhaetian–Liassic age; Neill Klinter Formation of Pliensbachian–Toarcian age divided into three members; Vardekløft Formation of ?Bajocian–Middle Callovian age redefined and divided into three members; Olympen Formation of Upper Callovian–Middle Oxfordian age designated as a new formation; Hareelv Formation of Upper Oxfordian–Middle Kimmeridgian age designated as a new formation; Raukelv Formation of Upper Kimmeridgian–Upper Volgian (Lower Ryazanian?) age designated as a new formation and divided into three members; Hesteelv Formation of Ryazanian age designated as a new formation and divided into two members.

The six lower formations together comprise the Jameson Land Group.

The main facies types are described. They comprise black shales, shaly siltstones, horizontally bedded sandstones, ripple-laminated sandstones, massive-bedded sandstones, medium- and large-scale cross-bedded sandstones, black shales with lenticular sand-bodies and coals.

A general interpretation of the changing depositional regimes throughout the Jurassic and Lower Cretaceous of Jameson Land and Scoresby Land is given. The interpretation is based on the spatial distribution of the different facies types, on longitudinal profiles, and on investigations and measurements of cross-bedding, parting-lineation, grain sizes and sand-shale ratios. The exact geographical position of the borderlands and thus of the source areas of the sediments are rarely known but the predominance of very coarse sediments and the large-scale sedimentary structures indicate a position very near the coast.

CONTENTS

INTRODUCTION

The stratigraphical scheme (tables 1 and 2) given in the present paper is a result of four summers' mapping of Jameson Land and Scoresby Land under the auspices of the Geological Survey of Greenland. Before the start of this mapping programme only the geology of the three lowest formations was known. These formations are well exposed along the west coast of Hurry Inlet, whereas the higher formations are only exposed in the inner parts of Jameson Land (plate 10). Earlier investigations in the area have been ably summarized by ROSENKRANTZ (1934) and DONOVAN (1957). Further reference to previous work is made under individual formations.

Table 1. *Lithostratigraphical scheme of Jurassic and Lower Cretaceous deposits of Jameson Land*

	Hesteelv Formation	Muslingeelv Member
		Crinoid Bjerg Member
Jameson Land Group	Raukelv Formation	Fynselv Member
		Salix Dal Member
		Sjællandselv Member
	Hareelv Formation	
	Olympen Formation	
	Vardekløft Formation	Fossilbjerget Member
		Pelion Member
		Sortehat Member
	Neill Klinter Formation	Ostreaelv Member
		Gule Horn Member
		Rævekløft Member
	Kap Stewart Formation	

In addition to ourselves the following have participated in the mapping: M. AELLEN, U. ASGAARD, K. BIRKENMAJER, E. HÅKANSSON, L. MALMROS and K. PERCH-NIELSEN.

One of the topographic names used in the text is new and is at present in course of authorisation by the Greenland Place Name Committee. Several older established names misplaced on the topographic maps (1:250,000 70–71 Ø 1) are placed in their correct place in the present paper. This is the case with the mountain Fossilbjerget and the rivers Hesteelv and Muslingeelv.

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

JAMESON LAND GROUP

new group

Name

After the peninsula Jameson Land.

Type area

Jameson Land, East Greenland.

Thickness

1100–2400 m.

Dominant lithology

The sediments of the group commence with fluviatile arkoses, shales and coals of Rhaetian–Liassic age belonging to the Kap Stewart Formation. These are followed by alternating thick sequences of marine sandstones and shales belonging to the following formations (from below): Neill Klinter Formation, Vardekløft Formation, Olympen Formation and Raukelv Formation.

The sediments of the whole group are composed of terrigenous sand and silt. Clays and carbonates as well as red-beds are practically totally unrepresented.

Boundaries

The group overlies the Triassic Scoresby Land Group, thus excluding the youngest red-beds and dolomites of the area. In southernmost Jameson Land it is overlain with angular unconformity by Lower Cretaceous sediments belonging to the Hesteelv Formation.

Distribution

The group covers the whole of Jameson Land. To the west on Milne Land and northwards to Store Koldewey (76–77° N) sediments of the same age and facies are found.

Geological age

Upper Triassic (Rhaetian)–Upper Jurassic (Volgian). For further details see the discussion under the individual formations.

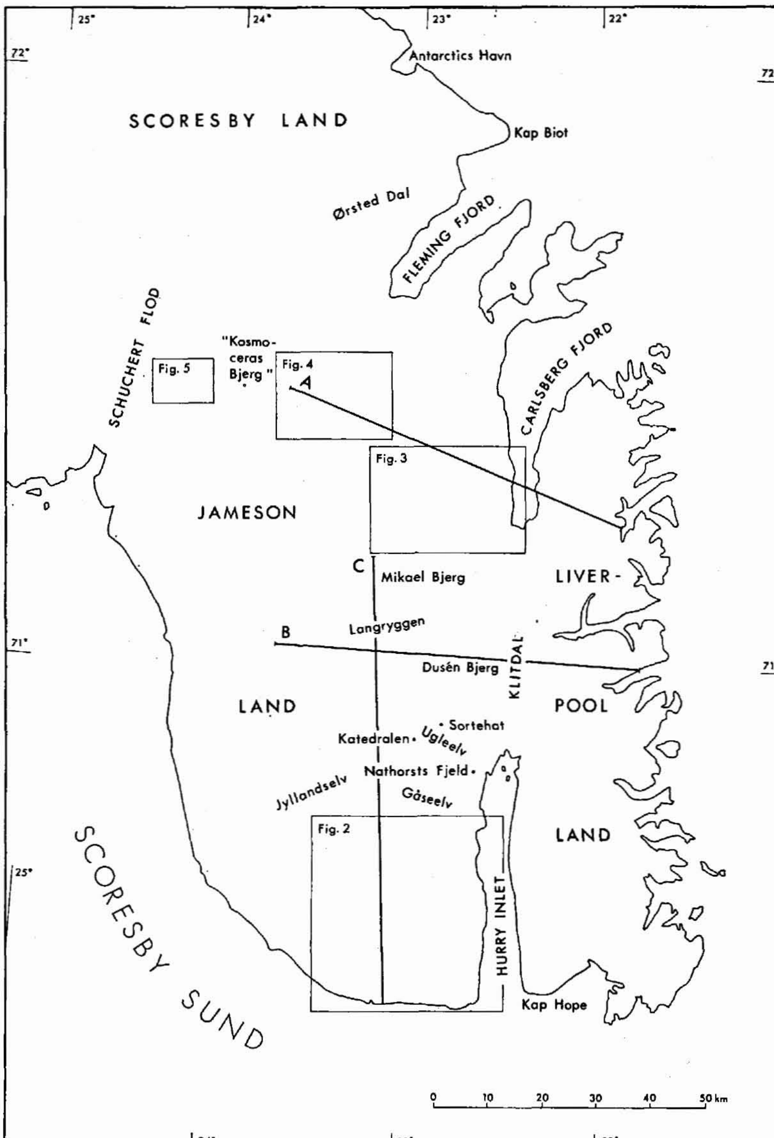


Fig. 1. Map of Jameson Land and Scoresby Land with the positions of the areas shown on figs 2–5 and the sections shown on plate 11 indicated.

Table 2. *Jurassic and Lower Cretaceous deposits of Milne Land, southern and northern Jameson Land in relation to ammonite zonation*

A detailed description of the Boreal ammonite zonation is to be published by CALLOMON & BIRKELUND (*in prep.*). *Ch. Ss.: Charcot Bugt Sandstone. Pc. Ss.: Pecten Sandstone. There is no fossil evidence for the zones in brackets.*

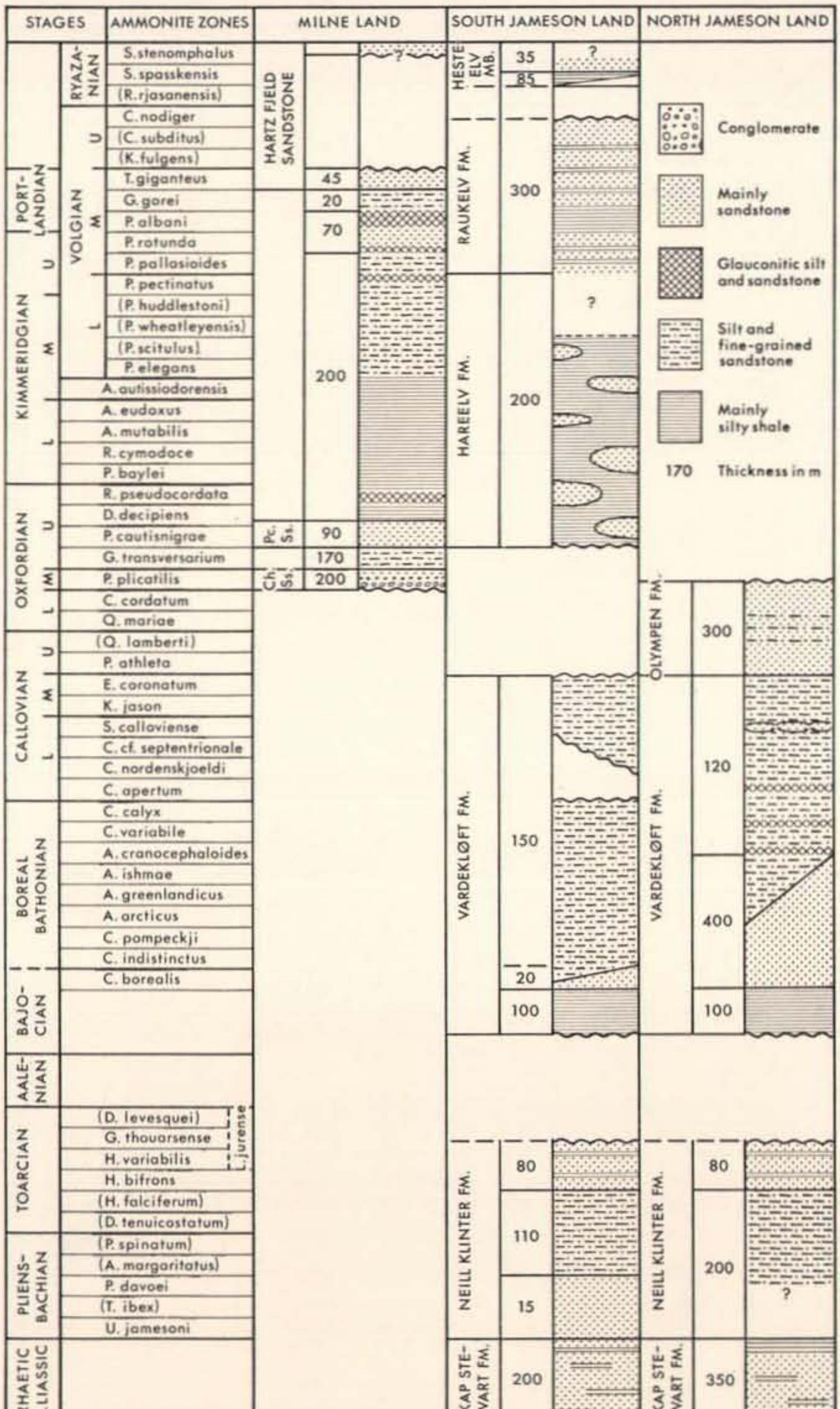

STAGES
AMMONITE ZONES
MILNE LAND
SOUTH JAMESON LAND
NORTH JAMESON LAND
RYAZANIAN
PORTLANDIAN
VOLGIAN
KIMMERIDGIAN
OXFORDIAN
CALLOVIAN
BOREAL BATHONIAN
BAJOCIAN
AALENIAN
TOARCIAN
PLIENSBACHIAN
RHAETIC L.LIASSIC
S.stenomphalus
S. spasskensis
(R.rjasanensis)
C.nodiger
(C. subditus)
(K.fulgens)
T.giganteus
G.gorei
P.albani
P.rotunda
P.pallasioides
P.pectinatus
(P.huddlestoni)
(P.wheatleyensis)
(P.scitulus)
P.elegans
A.autissiodorensis
A.eudoxus
A.mutabilis
R.cymodoce
P.baylei
R.pseudocordata
D.decipiens
P.cautisnigrae
G.transversarium
P.plicatilis
C.cordatum
Q.mariae
(Q. lamberti)
P.athleta
E.coronatum
K.jason
S.calloviense
C.cf. septentrionale
C.nordenskjoeldi
C.apertum
C.calyx
C.variabile
A.cranocephaloides
A.ishmae
A.greenlandicus
A.arcticus
C.pompeckji
C.indistinctus
C.borealis
(D. levesquei)
G.thouarsense
H.variabilis
L.jurense
H.bifrons
(H. falciferum)
(D. tenuicostatum)
(P.spinatum)
(A. margaritatus)
P.davoei
(T. ibex)
U.jamesoni
HARTZ FJELD SANDSTONE
Pc. Ss.
Ch. Ss.
45
20
70
200
90
170
200
HESTE ELV MB.
RAUKELV FM.
HAREELV FM.
VARDEKLØFT FM.
NEILL KLINTER FM.
KAP STEWART FM.
35
85
300
200
150
20
100
80
110
15
200
OLYMPEN FM.
VARDEKLØFT FM.
NEILL KLINTER FM.
KAP STEWART FM.
300
120
400
100
80
200
350
Conglomerate
Mainly sandstone
Glauconitic silt and sandstone
Silt and fine-grained sandstone
Mainly silty shale
170 Thickness in m

Table 2.

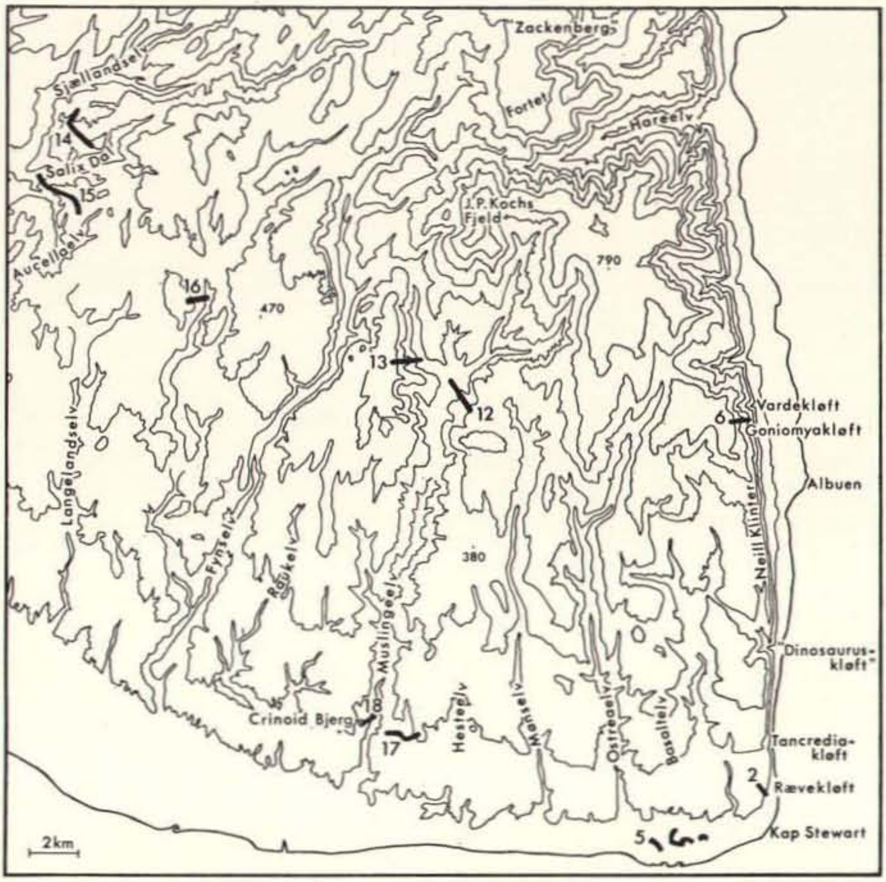


Fig. 2. Map of south-eastern Jameson Land showing the positions of the figured sections (2, 5, 6, 12, 13, 14, 15, 16, 17 & 18). 100 m contours are indicated. For location of the map see fig. 1.

Kap Stewart Formation

History

The formation was originally defined by ROSENKRANTZ (1929, p. 143). On the basis of the flora, HARRIS (1937) subdivided the formation into a "plant-bearing series" above the "barren sandstone" below. However, well-preserved plants have now been reported from the "barren sandstone" by PEDERSEN (in SURLYK *et al.*, 1971). It is thus not necessary to subdivide the formation into members.

A detailed investigation of this formation has not been made, but we include the following general remarks for the sake of completeness.

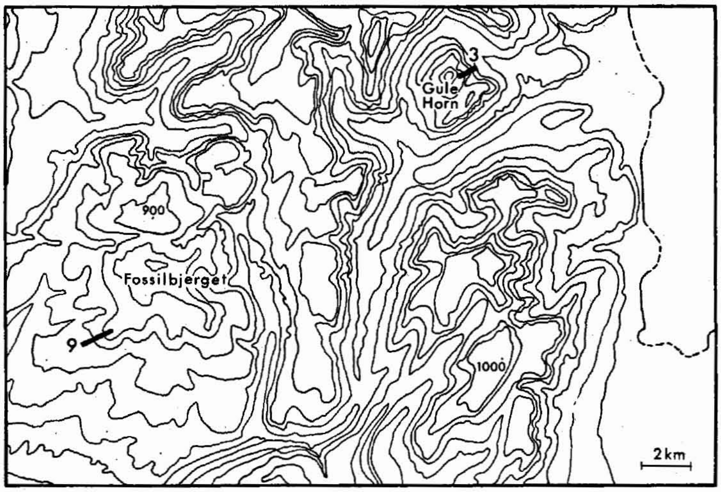


Fig. 3. Map of the Fossilbjerget area, central Jameson Land, showing the positions of the figured sections (3 & 9). 100 m contours are indicated. For location of the map see fig. 1.

Name

From Kap Stewart, south-east Jameson Land.

Type locality

Kap Stewart, south-eastern Jameson Land. The lower boundary of the formation dips below the sea in this region. The upper boundary is well exposed in Rævekløft.

Reference section

Well exposed in a large valley on the east side of and 24 km north of the mouth of Schuchert Flod (fig. 5).

Thickness

About 180 m at Hurry Inlet, over 200 m at Gule Horn and about 350 m at Antarctics Havn.

Lithology

Dominated by usually cross-bedded, coarse-grained, poorly-sorted arkoses and arkosic sandstones with conglomeratic layers, deeply weathered to pale cream, grey or green colours. These arenites are interbedded with dark shales while, especially near the middle of the formation, carbonaceous siltstones and root beds under thin coal seams occur. Plants are well preserved as wood fragments, leaves and fruits in both the arkoses and the shales, especially in south-eastern Jameson Land.

In the northern parts of the area the formation is topped by a relatively thick sequence of black, sterile shales (fig. 6).

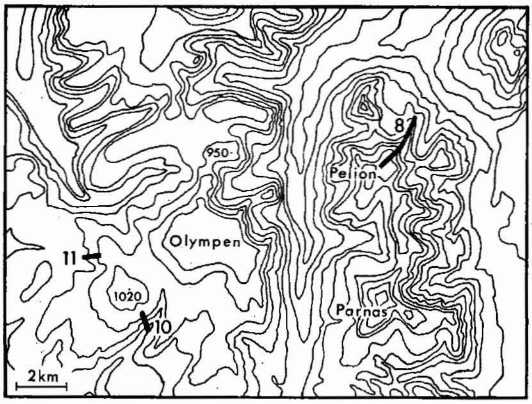


Fig. 4. Map of the Olympen area, central Jameson Land, showing the positions of the figured sections (8, 10 & 11). 100 m contours are indicated. For location of the map see fig. 1.

Boundaries

In north Jameson Land the lower boundary is well defined beneath pale arkose overlying the dolomitic and shaly upper beds of the Fleming Fjord Formation. Further south the lower boundary is equally distinct owing to the red colour of the mudstones which terminate the Fleming Fjord Formation (PERCH-NIELSEN *et al.*, 1972).

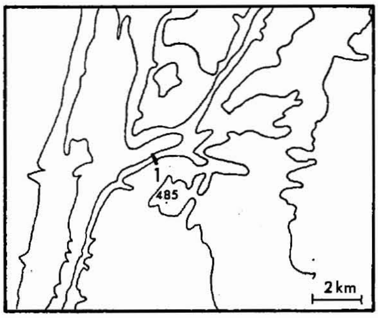


Fig. 5. Map of area east of Schuchert Flod, western Jameson Land, showing the position of section No. 1. 100 m contours are indicated. For location of the map see fig. 1.

The upper boundary is marked in south-east Jameson Land by the appearance of marine faunas in massively cemented sandstone in the Rævekløft Member of the Neill Klinter Formation. Elsewhere, the base of the Neill Klinter Formation (Gule Horn Member) is composed of micaceous, thin-bedded sandstones and shales which contrast with the arkoses at the top of the Kap Stewart Formation.

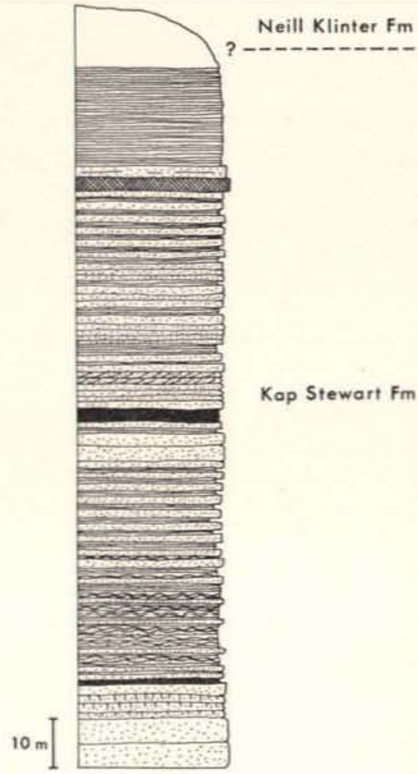
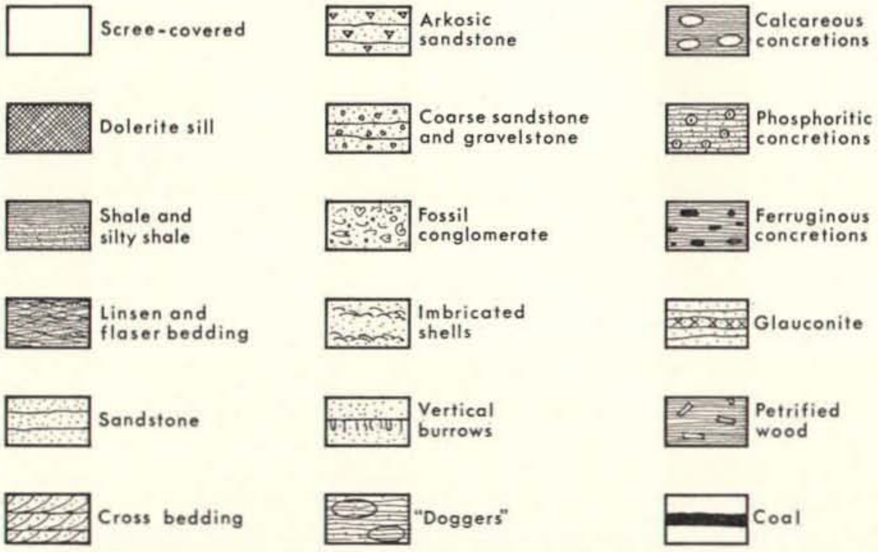


Fig. 6. Section No. 1. Kap Stewart Formation (see p. 10 and fig. 5). The sandstones in the lower half of the section are arkosic. Measured by FS and ECKART HÅKANSSON. The legend (*below*) covers all the figured sections.



Distribution

The Kap Stewart Formation crops out along Neill Klinter at Hurry Inlet but is largely covered with talus. The outcrop continues north along the west of Klitdal and forms valley floors west of Carlsberg Fjord and plateau tops around Ørsted Dal, continuing southwards as a cliff on the east side of Schuchert Flod (plate 10).

Geological age

HARRIS (1937) dated the formation as Rhaetian–Lower Liassic on the basis of the flora.

Neill Klinter Formation

History

The formation was defined by ROSENKRANTZ (1929). A detailed summary of earlier investigations has been given by ROSENKRANTZ (1934) and DONOVAN (1957). The formation falls naturally into three parts, as was demonstrated by ROSENKRANTZ (1934) and these are formally designated here as members.

Name

From Neill Klinter, the cliff-line on the west side of Hurry Inlet.

Type locality

Neill Klinter are composed of sediments of this formation.

Thickness

About 200 m at Neill Klinter and 260 m at Gule Horn.

Lithology

A detailed description of the formation in the type area was given by ROSENKRANTZ (1934). The lithology is dominated by clean, poorly- to well-sorted quartz-mica sandstones with subordinate micaceous shales. However, fossiliferous arkosic sandstones (Rævekløft Member) occur at the base in the type area and thin conglomerates are locally intercalated at all levels. The sediments show a great variety of current-produced structures such as ripple-drift lamination, cross-bedding, flaser structure and parting-lineation.

Boundaries

In the Hurry Inlet area, where the Rævekløft Member is present, the lower boundary of the formation is well marked. Here the Kap Stewart Formation arkoses and shales give way suddenly to coarse,

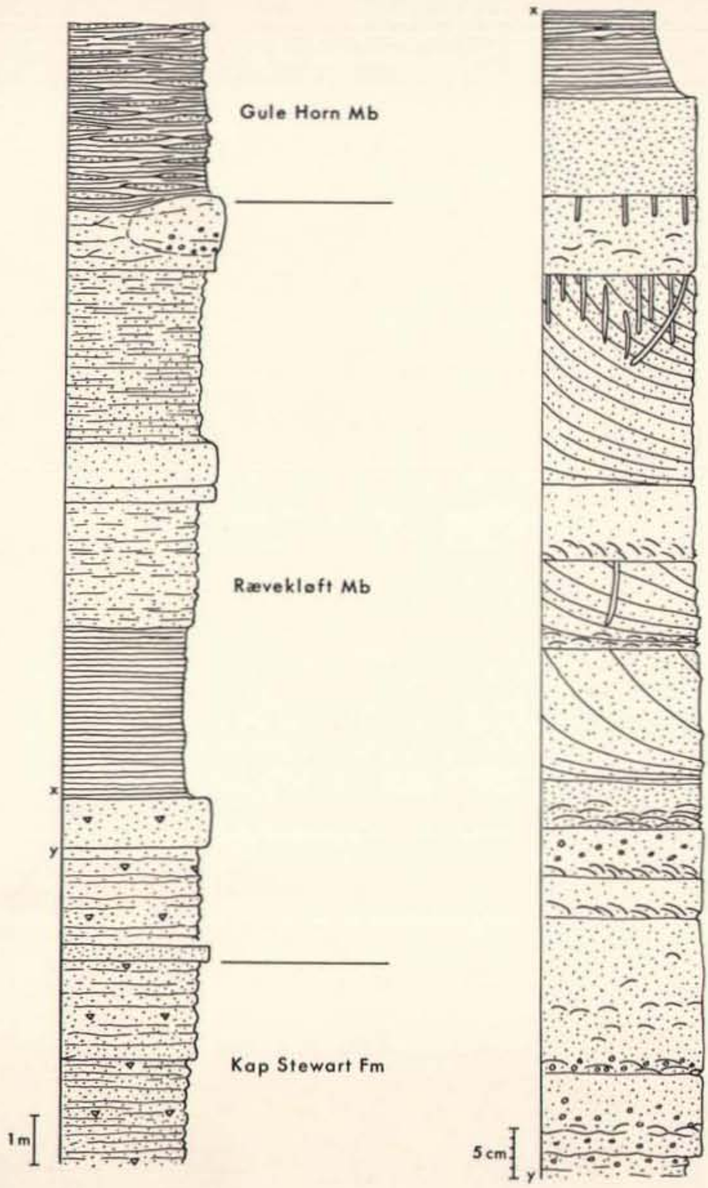


Fig. 7. Section No. 2. Rævekløft Member of the Neill Klinter Formation, type section (see p. 14 and fig. 2). Legend as for fig. 6. A detailed section of the interval x–y is shown to the right. Measured by RGB and Ulla Asgaard (UA).

massively cemented sandstones with a rich marine fauna. Further north and west, where the Gule Horn Member rests directly on the Kap Stewart Formation, the boundary is marked by a change from a heavy dominance of arkoses below to one of quartz-mica sandstone above.

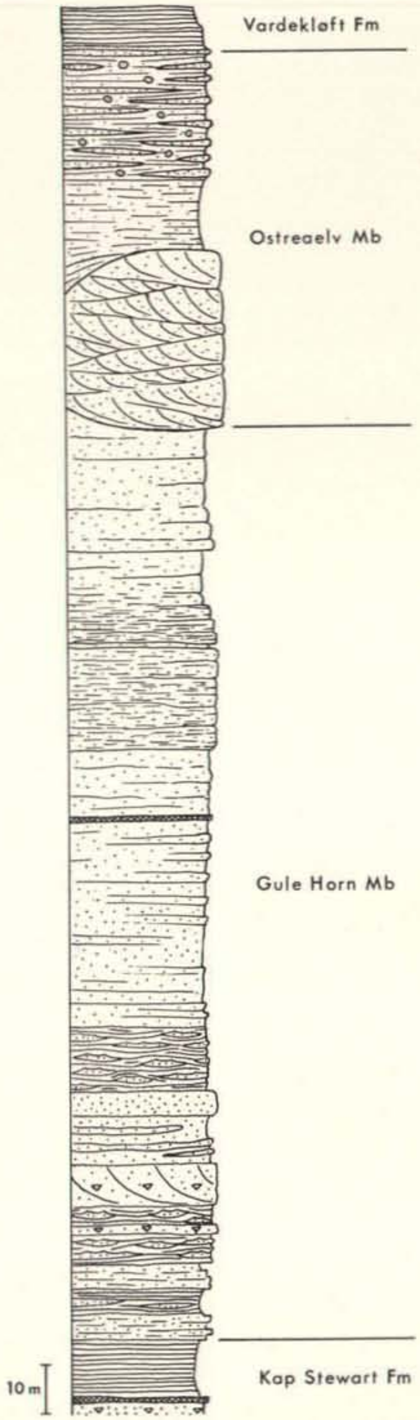


Fig. 8. Section No. 3. Gule Horn Member of the Neill Klinter Formation, type section, Gule Horn (see p. 19 and fig. 3). Legend as for fig. 6. Measured by RGB and UA.

West of Carlsberg Fjord the boundary is emphasized by a dark, pure shale over 10 m thick, representing the top of the Kap Stewart Formation.

The upper boundary is placed where the sandstones of the Ostreaelv Member give way abruptly to the dark shales and silts of the overlying Vardekløft Formation (fig. 13).

Distribution

The formation crops out along the whole length of Neill Klinter and continues north along the west side of Klitdal and Carlsberg Fjord. It forms plateau areas west of the head of Fleming Fjord and is exposed in the valleys east of Schuchert Flod. Further outcrops occur in Scoresby Land west and north-west of Kap Biot (plate 10). It appears to have no equivalents north of Kong Oscars Fjord, where Lias has never been reported.

Geological age

Lower Jurassic. The base of the formation contains a Pliensbachian fauna and the top member yields a fauna of Toarcian age (ROSENKRANTZ, 1934; DONOVAN, 1957).

Subdivisions

The Neill Klinter Formation is here divided into the Rævekløft Member (base), Gule Horn Member and Ostreaelv Member (top), and these will now be considered in turn.

Rævekløft Member

new member

Name

From Rævekløft at Kap Stewart, Jameson Land (fig. 2).

Type locality

The most complete development of the member occurs at Kap Stewart and is well exposed at Rævekløft (fig. 7). This section has been described previously by ROSENKRANTZ (1934, p. 38, pl. 9) but has now been remeasured with the discovery of additional fossiliferous horizons.

Thickness

15 m at the type locality. Further northwards along Neill Klinter the member becomes restricted to a single sandstone bed which is 4.6 m thick at Gåseelv but disappears entirely north of Dusén Bjerg.

Lithology

At the type section (fig. 7) the member is characterized by four prominent horizons of medium- to coarse-grained sandstone hardened by concretionary cement. These sandstones are grey but weather to a reddish-brown colour. Fossils are almost restricted to these four beds, but poorly preserved belemnites and oysters also occur in the top 30 cm of the underlying Kap Stewart Formation.

The second concretionary sandstone from the base (fig. 7, x–y) is rich in feldspar grains and probably represents a reworking of the underlying arkosic sandstones. This bed contains a rich fauna which has been listed by ROSENKRANTZ (1934, p. 40, bed i) and is characterized by pavements of *Entolium* (ROSENKRANTZ, 1934, fig. 2).

Feldspar is largely absent above this bed. The next hard sandstone contains a smaller fauna (ROSENKRANTZ, 1934, p. 38, bed g) which is largely concentrated on a single bedding plane.

The highest fossiliferous sandstone is only locally concretionary and contains conglomeratic pockets.

The second and third sandstones can be traced northwards in Tancrediakløft and probably "Dinosauruskløft". North of this, however, the member is represented by a single bed of sandstone with the lithology and fauna of the second bed at the type locality (fig. 7, x–y). This bed increases in thickness to 4.6 m at Gåseelv but disappears north of Dusén Bjerg.

Boundaries

At the type locality the member is bounded upwards by the upper limit of body fossils in hard, reddish-brown weathered sandstone. The Gule Horn Member above is composed of thinly interbedded micaceous sandstones and shales with no body fossils.

The lower boundary is discussed in the previous section. The coarse-grained arkoses of the underlying Kap Stewart Formation contain, except for the topmost 30 cm, only plant fossils.

Distribution

The member occurs along the length of Neill Klinter and north as far as Dusén Bjerg. To the west, lenses of arkosic sandstone with a lithology similar to that of the x–y sandstone at the type locality (fig. 7), and containing similar fossils, occur locally in the valleys on the east side of Schuchert Flod.

Geological age

Pliensbachian: Zone of *Uptonia jamesoni*. The rich fauna has been listed by ROSENKRANTZ (1934, p. 111). A single specimen of *Aegoceras* aff. *capricornus* and one of *Lytoceras fimbriatum* from the third sandstone (see ROSENKRANTZ, 1934, pl. 5, figs 2, 3) indicate the presence also of the higher Zone of *Prodactylioceras davoei*.

Gule Horn Member

new member

Name

From the mountain Gule Horn west of Carlsberg Fjord, Jameson Land (fig. 3).

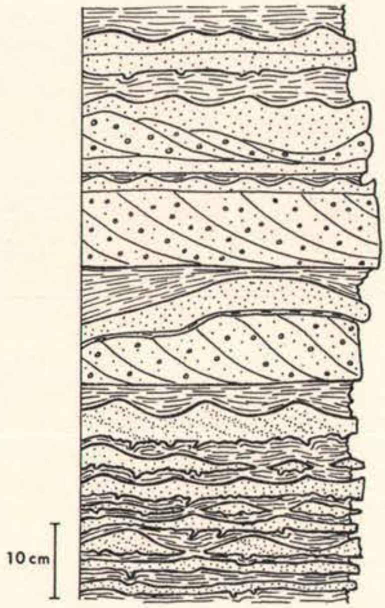


Fig. 9. Section No. 4. Detail of Gule Horn Member 70 m above base of the member, showing small-scale cross-bedding, ripple-marks, and alternation of sandstone and shale. Small gorge 4 km south of the mouth of Hareelv (fig. 2). Measured by RGB and UA.

Type locality

Rosenkrantz (1934, p. 53) measured a complete section of the member at Neill Klinter at Albuen. However, a thicker development of the member is well exposed at Gule Horn and is chosen here as type section.

Thickness

About 100 m at Nathorsts Fjeld, Neill Klinter, 185 m at Gule Horn.

Lithology

The lower part of the member, particularly at Neill Klinter, is dominated by a succession of thin-bedded, alternating quartz sandstones and shales, both richly micaceous. This lithology is highly characteristic of the member, the thin sandstones showing ripple-bedding, the upper surfaces with oscillation or linguoid ripple-marks. Commonly the sandstones are reduced to discrete ridges representing ripple-crests

Fig. 10. Linsen- and flaser-bedding with very little bioturbation. Gule Horn Member of the Neill Klinter Formation, Neill Klinter (fig. 2).

(figs 9, 10). Trace fossils are well preserved in this lithology (SURLYK *et al.*, 1971, p. 28), dominated by *Gyrochorte*, *Muensteria* and *Phycosiphon*.

These alternating thin shales and sandstones are interbedded at intervals with pure shales, flat-bedded sandstones and conglomerates of rounded quartz pebbles or pebbles of limonite mudstone and shale fragments. These lithologies are described and illustrated by ROSENKRANTZ (1934).

Higher in the succession at Neill Klinter and the type locality (fig. 8), shales become less important and quartz sandstones with thin conglomerates predominate, cemented at some levels as large concretions 1–2 m in diameter (ROSENKRANTZ, 1934, fig. 31). Bedding is lenticular throughout the member and consequently there is strong lateral variation.

To the west, near Schuchert Flod, monotonous, dark, poorly-sorted, silty sands characterize the upper part of the member.

Boundaries

The lithological change makes a sharp boundary where the shaly base of the Gule Horn Member rests on the sandstone terminating the Rævekløft Member.

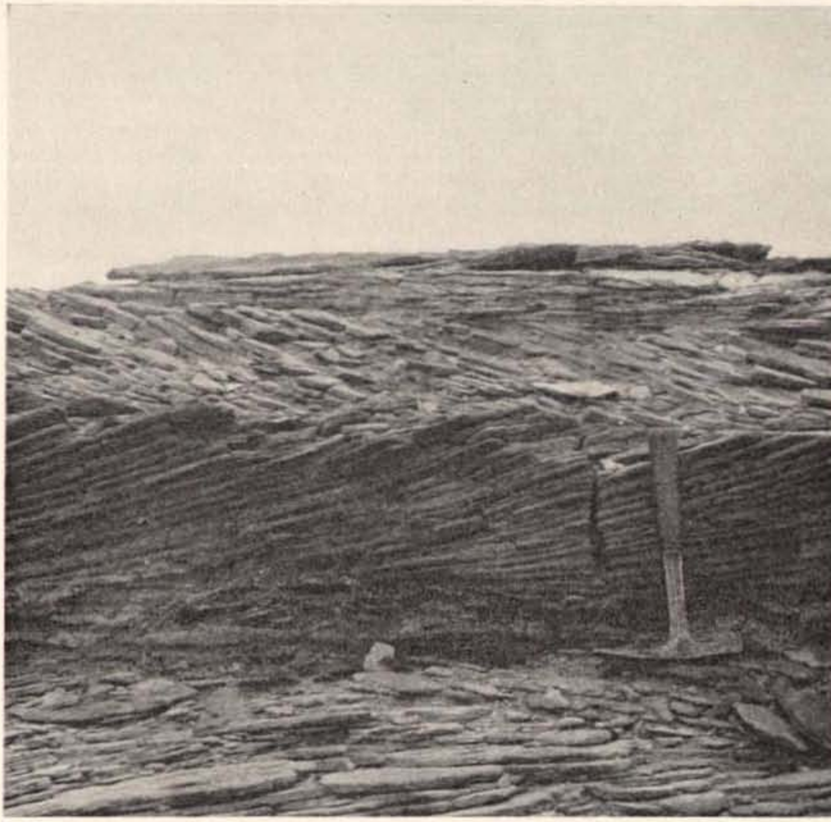


Fig. 11. Cross-bedded sandstone from the Ostreaelv Member, Neill Klinter Formation. Locality north of Ugleelv (fig. 1). The middle sets are tangential with erosive top. The lower set has tangential top and erosive base (not seen on the figure). The current direction of the highest set was from left to right.

Where the Gule Horn Member rests directly upon Kap Stewart Formation, the change at the boundary is striking, with shales and thick, coarse-grained arkoses bearing plant-remains below and shale with quartz-mica sandstones rich in trace fossils above.

The upper boundary is marked by the appearance of thick lenses of sandstone with large-scale cross-bedding and a change in the trace fossil assemblage, representing the base of the Ostreaelv Member.

Distribution

Same as the formation.

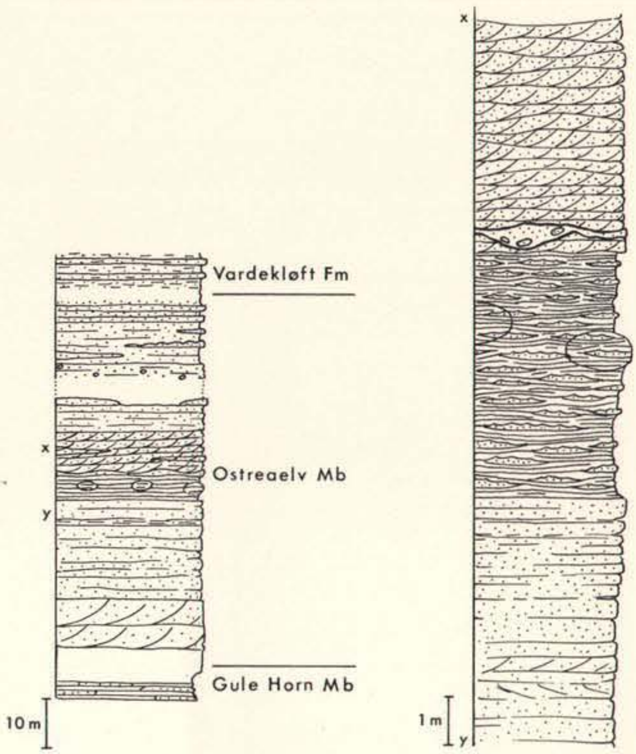


Fig. 12. Section No. 5. Ostreaelv Member of the Neill Klinter Formation, type section, Ostreaelv (see p. 22 and fig. 2). A detailed section of the interval x–y is shown to the right. Legend as for fig. 6. Measured by RGB and UA.

Geological age

Body fossils are almost completely lacking and none diagnostic of age has been found. The member lies between beds of Pliensbachian and Toarcian age.

Ostreaelv Member

new member

Name

From Ostreaelv, south-east Jameson Land.

Type locality

The type section is compounded from two exposures which together make up an almost complete succession (fig. 12). The lower half of the member is based on the exposure in Basaltelv while the upper is exposed in the mouth of the neighbouring river, Ostreaelv (fig. 2).

Reference sections

The section at Gule Horn (fig. 8) shows lithologies which contrast with the type section.

Thickness

This is very constant over Jameson Land. It is not less than 90 m at the type locality, though rather less at several localities along Neill Klinter. It is 80 m at Gule Horn and of the same order of thickness at localities east of Schuchert Flod.

Lithology

At the type section and at Neill Klinter the member consists of medium- to fine-grained quartz sandstones. Many beds are strongly cross-bedded, erosional and laterally variable (fig. 11). Concretionary cement has hardened some beds, either as flat, extensive lenses or as rounded, large concretions. Certain horizons are richly micaceous and trace fossils are well preserved. The trace fossil assemblage is different from that of the Gule Horn Member and is characterized by *Thalassinoides*, *Ophiomorpha*, *Diplocraterion* and *Rhizocorallium*.

Body fossils occur at several horizons, chiefly those hardened by concretionary cement. Small, dark nodules occur in some beds and contain a rich fauna including notably the shrimp *Glyphea rosenkrantzi*. ROSENKRANTZ (1934, p. 116) has listed the fauna.

Further north, at Gule Horn (fig. 3), and west near Schuchert Flod (fig. 1), the member is composed of darker, siltier sediments with less lithological variation than at Neill Klinter. Horizons of dark, phosphatic nodules, however, yield a large fauna, and cross-bedded sandstone lenses occur at the base.

Boundaries

The lower boundary of the member is placed at the base of thick lenses of sandstone with large-scale cross-bedding. In most places these basal sandstones contain characteristic trace fossils in contrast to those of the underlying Gule Horn Member, though at the type locality these have not been detected.

The upper boundary is placed at a sudden change from sandstones with marine body fossils to the overlying largely unfossiliferous dark, silty shales of the Vardekløft Formation. The terminal beds locally incorporate medium to coarse conglomerates of well-rounded pebbles of quartzite.

Distribution

As for the formation. The member tends to produce wide plateaus and is well exposed over much of the area where the formation crops out in Jameson Land.

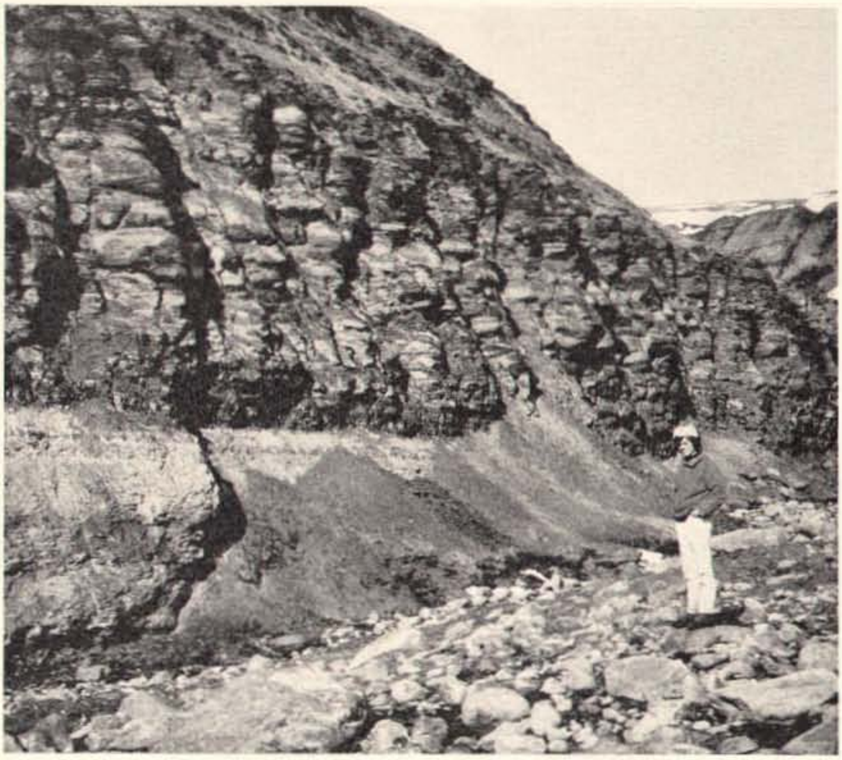


Fig. 13. Boundary between light sandstones of the Neill Klinter Formation and the black shales of the Vardekløft Formation. North of Dusén Bjerg (fig. 1).

Geological age

Lower Toarcian, Zone of *Hildoceras bifrons* and lower part of the Upper Toarcian ("Zone of *Lytoceras jurense*") (ROSENKRANTZ, 1934; DONOVAN, 1957, p. 29).

Vardekløft Formation

History

ROSENKRANTZ (1929, p. 145–146) defined the formation as follows: "The Vardekløft formation is known from Neills Cliff north of Dinosaurus River and from the region north thereof. It covers extensive areas in the northern part of Jameson Land, where the surface of the eastern plateaus is made up of the beds of this formation. The formation, the thickness of which may attain about 225 meters, is largely made up of very micaceous clay shale with occasional sandstone bands, and terminates above with a coarse sandstone layer . . ."

On the basis of exposures on Fossilbjerget, northern Jameson Land, ROSENKRANTZ (1929, p. 146–147) defined a Fossil Mountain Formation as a *c.* 300 m thick series of alternating beds of sandstone and clay shale. ROSENKRANTZ was of the opinion that the Fossil Mountain Formation was younger than the sediments included in the Vardekløft Formation.

SPATH (1932) showed by means of ammonites that the lower fossiliferous part of the Fossil Mountain Formation was in fact a northern equivalent of the Vardekløft Formation at Vardekløft. The overlying barren sandstones comprising the upper part of the Fossil Mountain Formation were ascribed by SPATH to much later (post-Volgian?) beds. These sandstones are here referred to the Oxfordian Olympen Formation (see p. 39).

All the ammonites collected in the shales of the Vardekløft Formation were shown to be of Middle Jurassic age by SPATH (1932). On the strength of a single occurrence of an *Amoeboceras* of presumed Kimmeridgian age in the sandstones overlying the shales, ALDINGER (1935) concluded that there was an important break in sedimentation below the sandstones. ALDINGER's distinction between the Callovian and the Kimmeridgian sediments (both by definition belonging to the Vardekløft Formation) led DONOVAN (1957) to correlate the lower shale sequence with the Vardekløft Formation and the overlying sandstones and shales with the Koch Fjeld Formation (here Hareelv Formation).

The Koch Fjeld Formation was established by ROSENKRANTZ (1929) for the *c.* 100 m of sandstones and shales forming the summit of J. P. Kochs Fjeld although no sections were described and the relations to other formations were left obscure. The succession on J. P. Kochs Fjeld forms, however, a tectonically deformed, dome-like structure incorporating several different formations. The disturbance was probably caused by intrusion of Tertiary basalt. The term Koch Fjeld Formation is therefore abandoned in the present paper.

CALLOMON (1961) pointed out that the Callovian shales are succeeded by black shales of very variable thickness, with thin sandstones, which have yielded Upper Oxfordian amoeboceratids and *Decipia.* These shales and sandstones were referred by him to the Koch Fjeld Formation (here Hareelv Formation), the upper boundary of the Vardekløft Formation being placed as in the present paper.

FREBOLD (1932, p. 21) and MAYNC (1940, p. 21) used the term "Gelbe Sandstein Serie" or "Yellow Series" for the Middle Jurassic sandstone deposits of Clavering Ø, Wollaston Forland and Kuhn Ø. DONOVAN (1957, p. 194) stressed that this yellow weathering sandstone unit can be traced from Store Koldewey (Trækpas Formation) to the head of Carlsberg Fjord (Fossil Mountain Formation) and that it was an advantage to use MAYNC's purely descriptive name "Yellow Series" for the sandy facies wherever developed. Until now this usage has been followed by the present authors (BIRKELUND & PERCH-NIELSEN, 1969; CALLOMON, 1970; BROMLEY *et al.*, 1970; SURLYK *et al.*, 1971; BIRKELUND *et al.*, 1971).

CALLOMON (1961, 1970) introduced a lithological tripartition of the Vardekløft Formation in Jameson Land, allowing it to be subdivided into Lower, Middle and Upper Vardekløft Formations, the Middle comprising in part the "Yellow Series" sandstone facies, sandwiched between a lower and an upper shale unit. These three units are formally designated as members of the Vardekløft Formation in the present paper.

Name

From Vardekløft, a river gorge at Neill Klinter (fig. 2).

Type locality

Vardekløft in Neill Klinter, 3 km north of Albuen on the coast of Hurry Inlet, south-eastern Jameson Land. Both the lower and upper boundaries are present, but rather poorly exposed (ROSENKRANTZ *in* SPATH, 1932, text-fig. 10).

Reference sections

Goniomyakløft, immediately south of Vardekløft, fig. 14.

The northern slope of Pelion, fig. 17. Lower boundary: north of Dusén Bjerg (fig. 13). Upper boundary: Goniomyakløft, fig. 14; Fossilbjerget, fig. 23; Olympen, fig. 24 a.

Thickness

The thickness rapidly increases from south to north, being 225 m in Vardekløft, and *c.* 500 m at Pelion in north central Jameson Land. North of Pelion the middle part of the formation forms the top of the plateaus and the full thickness is therefore not known. In the northernmost exposures in Scoresby Land, at Antarctics Havn, the thickness increases to more than 600 m, although the upper part of the sequence correlates with beds already included in the Olympen Formation of central Jameson Land. In northern Jameson Land, where the formation has a considerable E–W extension, a slight increase in thickness from west to east can be recognized. At the head of Hurry Inlet, along Ugleelv, the reverse is the case.

Lithology

At Hurry Inlet (incl. the type locality Vardekløft) grey or black micaceous non-argillaceous silty shales predominate. Horizons of calcareous, more or less ferruginous and occasionally pyritic concretions occur. A thin sandstone intercalation in the middle part grows gradually thicker to the north. This light sandy member, sandwiched between a lower and an upper shale member becomes dominant from Mikael Bjerg northwards. The lower shale member is described further below as Sortehat Member, the middle sandy member as Pelion Member and the upper shale member as Fossilbjerget Member (plates 5–7).

Boundaries

The lower boundary is put at the sharp change in sedimentation from sandstone, belonging to the Neill Klinter Formation, to dark silty shale. As a reference section for the lower boundary a section north of Dusén Bjerg is selected (fig. 13). Here, the uppermost part of the Neill Klinter Formation consists of fine-grained sandstone with coarse feldspar and quartz grains capped by a horizon containing pyrite concretions. Immediately above the sharp, lower boundary of the Vardekløft Formation the shales contain also coarse feldspar and quartz grains. Half a metre above the boundary concretionary layers of claret-coloured ironstone appear. At other localities the Neill Klinter Formation terminates sharply with a bed of iron-stained quartz pebbles.

The sandstones and shales of Upper Oxfordian age, forming the top of the Vardekløft Formation as originally defined (Rosenkrantz, 1929), are now excluded from the formation. In southern Jameson Land (from Kap Stewart to Langryggen) the upper boundary is formally redefined in accordance with the usage of Donovan (1957) and Callomon (1961) and placed at the sharp junction between the greyish-weathering, silty shales below and the intensely black shales and yellow sandstones of the Hareelv Formation above. Goniomyakløft is chosen as reference section (fig. 14). In northern Jameson Land (from Mikael Bjerg northwards) the upper boundary is placed at the junction of the silty shales of the upper part of the Vardekløft Formation and the light sandstones of the overlying Olympen Formation (reference sections: Fossilbjerget, fig. 23; Olympen, fig. 24 a).

Distribution

The Vardekløft Formation crops out in Neill Klinter at Hurry Inlet and in the Kap Hope area. It covers large areas in central and northern Jameson Land, and in Scoresby Land it crops out in a downfaulted area at Antarctics Havn (plate 10). The formational name has traditionally been used only in the country south of Kong Oscars Fjord, but lateral equivalents occur northwards in Traill Ø and Geographical Society Ø until cut out by the Cretaceous overstep. As mentioned above they then reappear further north as Maync's "Yellow Series" or the "Trækpas Formation".

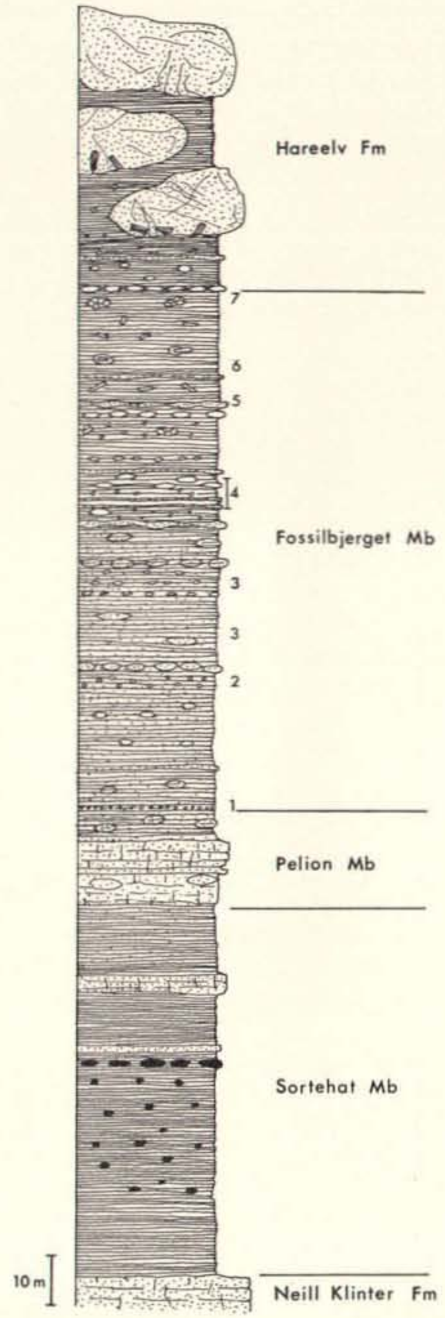


Fig. 14. Section No. 6. Vardekløft Formation, reference section, Goniomyakløft (see p. 26 and fig. 2). Legend as for fig. 6. (See section 1 in CALLOMON & BIRKELUND (in prep.) for further stratigraphical details). 1: *C. borealis* Zone, 2: *A. greenlandicus* and *arcticus* Zones, 3: *A. ishmae* Zone, 4: *A. cranocephaloides* and *C. variabile* Zones, 5: *C. calyx* Zone, 6: *S. calloviense* Zone, 7: *K. jason* or *E. coronatum* Zone. Measured by JHC and FS.

Geological age

Both the lower and the upper boundary of the Vardekløft Formation almost everywhere mark hiati in the sequence. The age of the lower member is uncertain. The middle and upper members range from Upper Bajocian? to Middle Callovian. Fossil evidence shows that the sequence is most complete in northern Jameson Land whereas important non-sequences occur at Hurry Inlet. Numerous horizons with ammonites in the middle and upper part of the sequence have made possible a detailed biozonation which provides a frame of reference for regional lithostratigraphical variations (CALLOMON & BIRKELUND, in prep.).

Subdivisions

The Vardekløft Formation is subdivided into the Sortehat Member (base), Pelion Member and Fossilbjerget Member (top), and these will now be considered in turn.

Sortehat Member

new member

Name

From the mountain Sortehat by Ugleelv at the head of Hurry Inlet (fig. 1).

Type locality

Sortehat by Ugleelv. The lower boundary and most of the sequence is well exposed (fig. 15). The upper boundary is exposed in the riverside of Rævekløft immediately north of the type section.

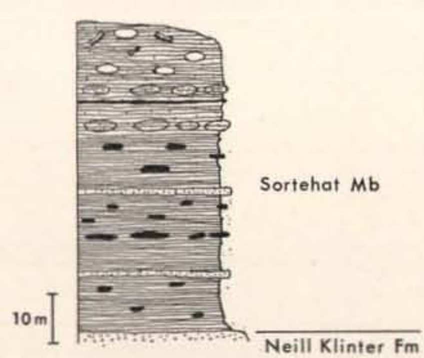


Fig. 15. Section No. 7. Sortehat Member of the Vardekløft Formation, type section, Sortehat (see p. 29 and fig. 1). Legend as for fig. 6. Measured by JHC and TB.

Thickness

The thickness varies between 60 and 120 m. At the type locality it is *c.* 70 m thick.

Fig. 16. Black shales of the Sortehat Member overlain by massive yellow sandstones of the Pelion Member. Both members belong to the Vardekløft Formation. North of Dusén Bjerg (fig. 1).

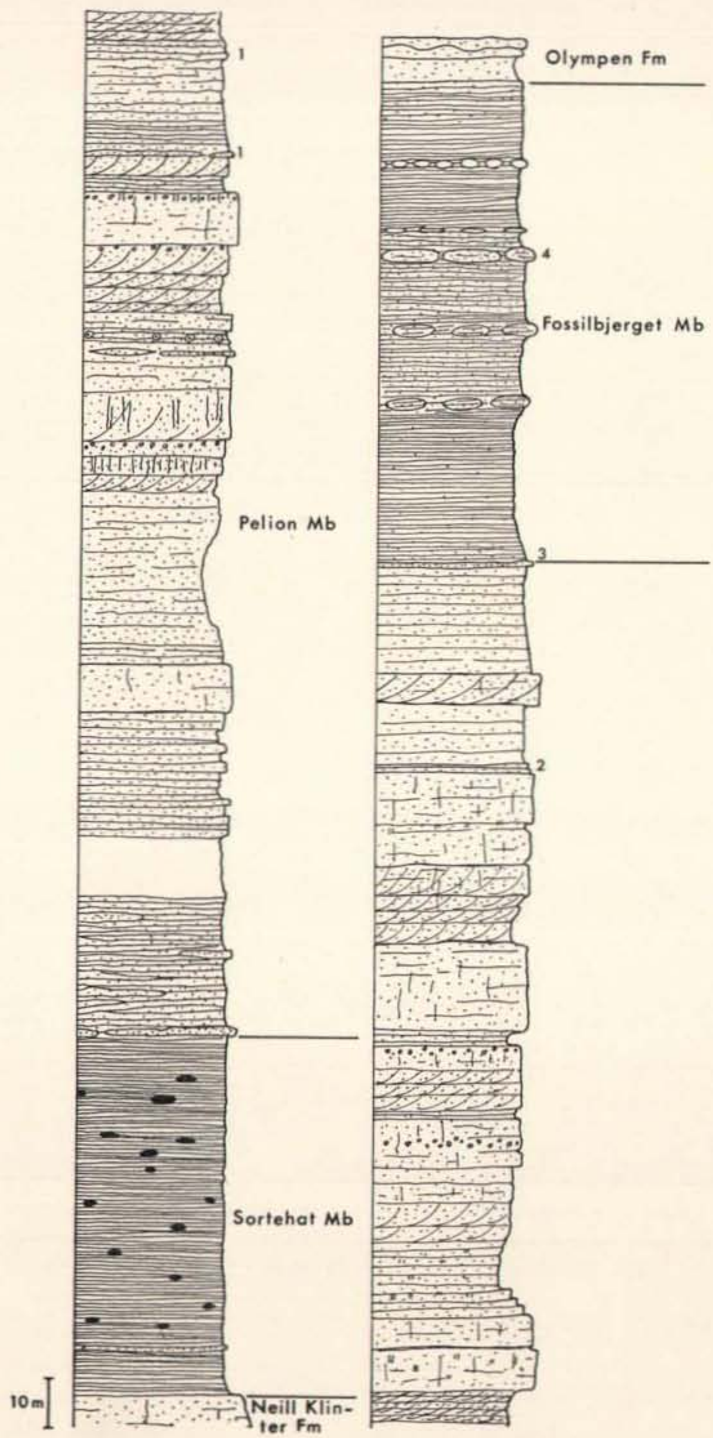


Fig. 17. Section No. 8. Pelion Member of the Vardekløft Formation, type section, Pelion (see p. 33 and fig. 4). Legend as for fig. 6. (See section 58 in CALLOMON & BIRKELUND (in prep.) for further stratigraphical information). 1: *C. pompeckji* Zone, 2: *A. ishmae* Zone, 3: *C. variabile* Zone?, 4: *S. calloviense* Zone. Measured by JHC and TB.

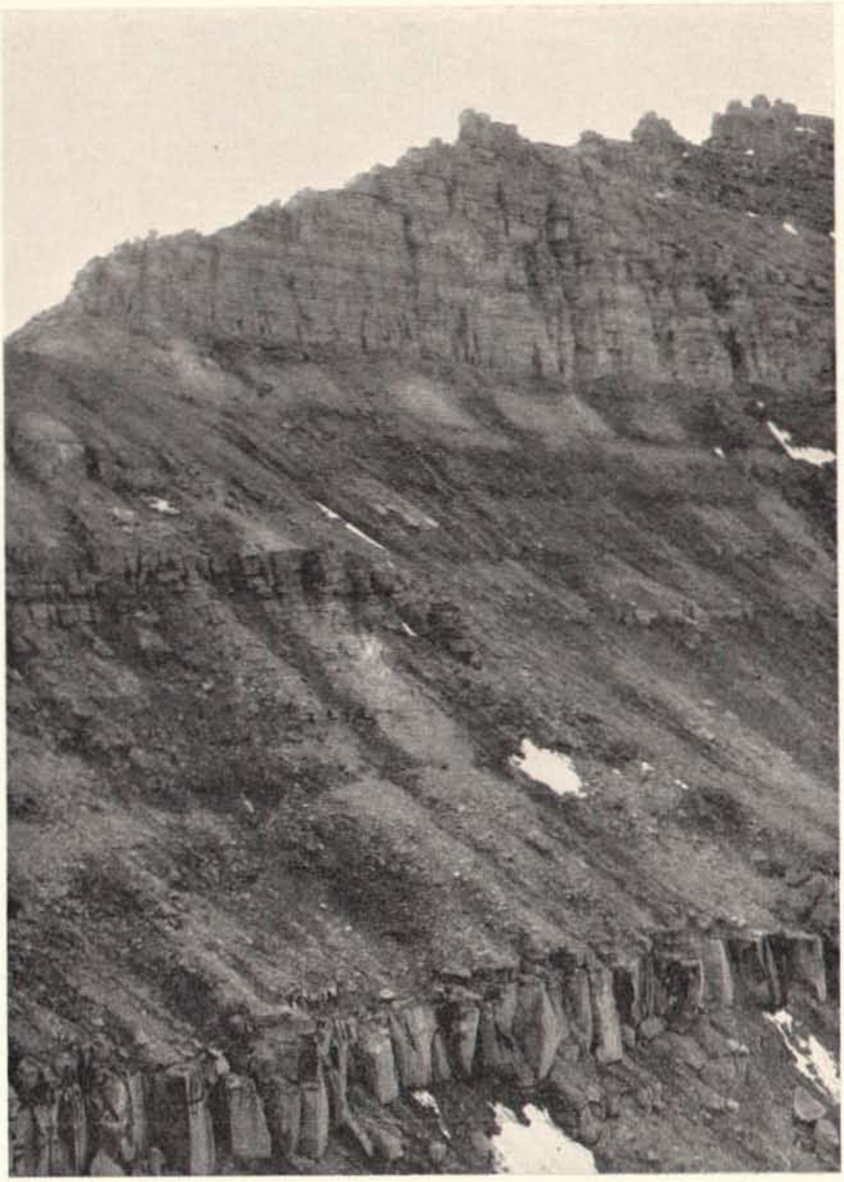


Fig. 18. North slope of the mountain Pelion (fig. 4), showing part of the type section of the Pelion Member, Vardekløft Formation. The massive sandstone is about 10 m thick.

Lithology

The member is very uniform in the whole Jameson Land–Scoresby Land area. The lower part consists of dark-grey to black shale with concretionary layers and nodules of claret-coloured ironstone. In the upper part the shales become more silty, the ironstone decreases or disappears and lenses or layers of fine sand, partly concretionary, appear in the sequence. The upper part may contain layers of calcareous concretions. The only fossils found are bivalves, mostly oyster fragments; belemnites are not uncommon in the top, and profuse plant remains, especially wood, occur. Some of the shales and concretionary fine sands are heavily bioturbated with small endichnial burrows.

Boundaries

The lower boundary is very sharp. It is put at the contact between the sandstone of Neill Klinter Formation below and the dark shales of the Sortehat Member above. The upper boundary may be more gradual. It is put at the first light sandstone bed overlying the sandy-silty upper part of the member.

Distribution

Same extension as the formation in Jameson Land and Scoresby Land. North of Kong Oscars Fjord a similar facies is described from Traill Ø by DONOVAN (1957).

Geological age

As no diagnostic fossils have been found, despite intensive search, the exact age of this member is uncertain. It overlies Toarcian beds and is overlain by ?Upper Bajocian deposits.

Pelion Member
new member

Name

From the mountain Pelion in northern Jameson Land (fig. 4).

Type locality

Pelion in northern Jameson Land. The sequence is very well exposed, including both the lower and the upper boundary (fig. 17).

Reference sections

Sections in Goniomyakløft (fig. 14), "Zackenberg", Katedralen (fig. 19) and Mikael Bjerg (see CALLOMON & BIRKELUND, in prep.) are chosen as reference sections to cover the remarkable variations in thickness and the diachronous upper boundary.

Thickness

The thickness rapidly increases from south to north—from 10 m or less at the southern end of Hurry Inlet to 20 m at "Zackenberg",

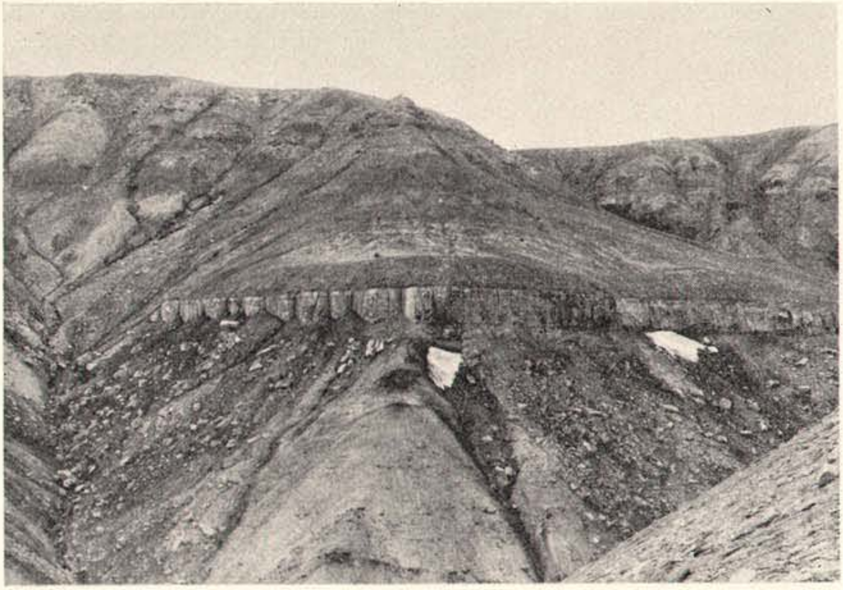


Fig. 19. North slope of the mountain Katedralen (fig. 1), showing the Vardekløft Formation overlain by the Hareelv Formation. The massive sandstone unit in the middle of the section forms the top of the Pelion Member, Vardekløft Formation. The sandstone unit is 15 m thick and forms one cross-bedded set (not clearly visible on the figure except to the right). The Pelion Member is overlain by grey shales of the Fossilbjerget Member, forming a smooth, gentle slope below the steeper sandstones and shales of the Hareelv Formation.

170 m at Katedralen, nearly 300 m at Mikael Bjerg, 310 m at Pelion (the type locality) and more than 550 m at Antarctics Havn.

Lithology

Medium- to coarse-grained, usually micaceous, light-coloured sandstones with subordinate intercalations of fine-grained sandstones and silty shales. Thin conglomeratic horizons containing scattered, well-rounded quartzite pebbles up to 5 cm in diameter may occur. The sandstones are shaly, massive to structureless or cross-bedded, and consolidated to varying degrees (figs 18, 20–22). There is often a tendency to local cyclic alternation between massive sandstones up to 30 m thick and more shaly, fine-grained sandstones. The massive sandstones are usually barren or contain scattered burrows and often terminate by a horizon with vertical U-burrows. The more shaly horizons may be more fossiliferous, being often heavily bioturbated, and isolated beds occur containing bivalves, belemnites and ammonites together with phosphatic

Fig. 20. In the foreground fine-grained sandstone 'doggers' weathered out of the Pelion Member, Vardekløft Formation. North of Sortehat, Ugleelv (fig. 1). In the background, massive sandstones of the Pelion Member are overlain by shales of Fossilbjerget Member. These are overlain in turn by shales and sandstones of the Hareelv Formation, forming a steeper slope.

nodules, sometimes in profusion. Laterally the facies changes from slightly consolidated sandstones in the southern part of the area to often very well consolidated, massive, cliff-forming beds to the north (fig. 18).

Boundaries

The lower boundary is put where light sandstones overlie the dark, silty shales of the Sortehat Member (fig. 16). The upper boundary is put where these sandstones are replaced by light-grey, silty shales of the Fossilbjerget Member. In the south the change is abrupt and complete, but further north it becomes more gradual and the place at which it is drawn in any given section may be somewhat arbitrary. Both boundaries are marked by a distinct change in the dip of the slopes, the shales below and above the member forming terraces clearly visible in the field and on aerial photographs. In the far north, at Antarctics Havn, the arenaceous facies is continuous upwards into the equivalents of what in central Jameson Land is classed as Olympen Formation.

Distribution

Same distribution as the formation in Jameson Land and Scoresby Land. This sandstone facies is widely distributed north of Kong Oscars Fjord (Donovan, 1957).

Fig. 21. Pelion Member. 1 m of cross-bedded sandstone truncated by an erosion surface and overlain by nearly flat bedded sandstone. South-west of Olympen (fig. 4).

Geological age

The earliest ammonite zone represented is the *C. borealis* Zone of ?Upper Bajocian age. The upper boundary is diachronous, rising from the *C. borealis* Zone at Hurry Inlet to the *C. pompeckji* Zone by Ugleelv, and the *A. ishmae* Zone at Mikael Bjerg and further north. The highest beds at Antarctics Havn have yielded Upper Callovian (*P. athleta* Zone) ammonites.

Fossilbjerget Member

new member

Name

From the mountain Fossilbjerget in northern Jameson Land (fig. 3).

Type locality

South-western slope of Fossilbjerget.

Reference sections

Sections in Pelion (fig. 17), Goniomyakløft (fig. 14), Mikael Bjerg, Katedralen and "Zackenberg" (CALLOMON & BIRKELUND, in prep.), are chosen as reference sections.

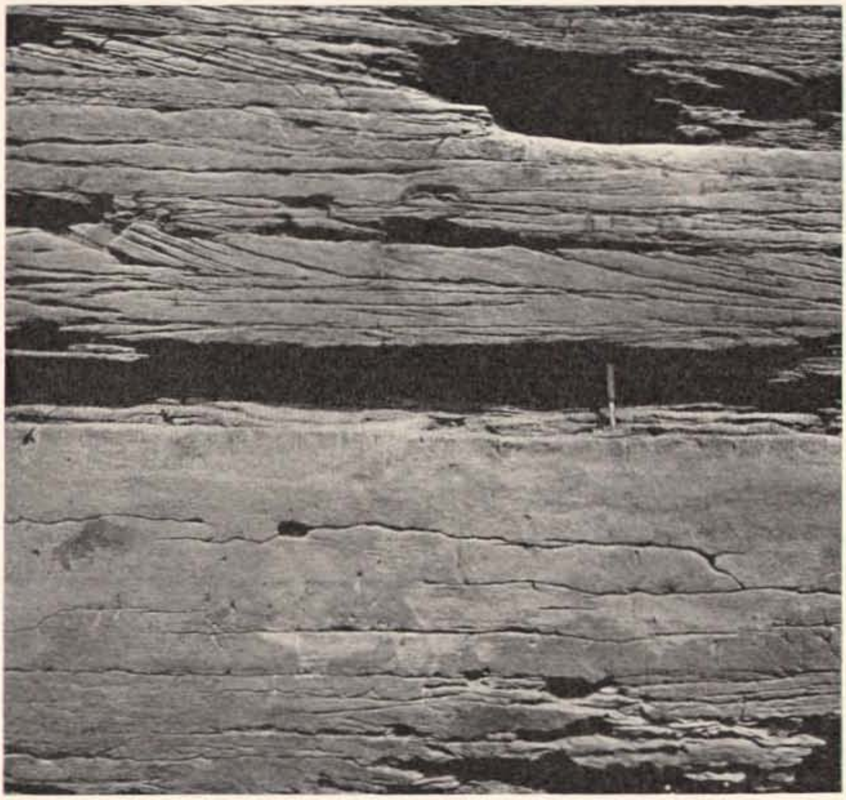


Fig. 22. Pelion Member. A massive sandstone bed with vertical burrows overlain by cross-bedded sandstone. South-west of Olympen (fig. 4).

Thickness

The thickness varies from 80 to 120 m. At the type locality it is 100 m.

Lithology

Silty, micaceous non-argillaceous shales with subordinate fine-grained sandstone horizons. The lower part is more sandy than the upper part and contains glauconitic beds, up to the grade of dark greensands. Numerous horizons with phosphatic nodules, concretionary, indurated silt- or fine-sand bodies ("doggers"), and calcareous concretions occur throughout. Many horizons are extremely fossiliferous, ammonites and belemnites dominating, and a number of trace fossil assemblages occur through the whole sequence. In the upper part fossil wood is widespread, including large petrified tree-trunks. Fossil evidence shows that sedimentation was not continuous. There are marked rythmic sequences: grey barren shales, passing up into indurated shale or dog-

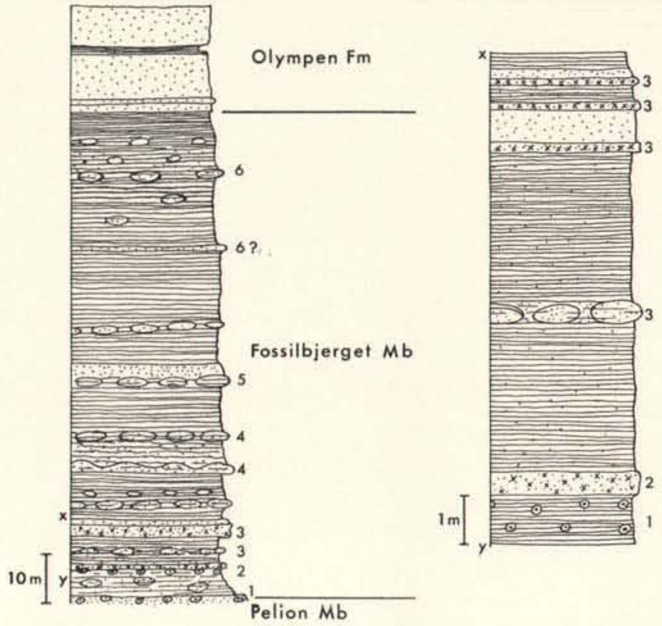


Fig. 23. Section No. 9. Fossilbjerget Member of the Vardekløft Formation, type section, Fossilbjerget (see p. 36 and fig. 3). Legend as for fig. 6. A detailed section of the interval x–y is shown to the right. (See section 43 in CALLOMON & BIRKELUND (in prep.) for further stratigraphical information). 1: *A. cranocephaloides* Zone, 2: *C. variabile* Zone, 3: *C. apertum* Zone, 4: *C. nordenskjoeldi* Zone, 5: *C.* cf. *septentrionale* Zone, 6: *S. calloviense* Zone. Measured by JHC and TB.

gers and terminating with a thin, red-weathering glauconitic concretionary horizon with fossils, often phosphatized, or phosphatic concretions. Each cycle represents typically one ammonite zone and may span 1–20 m of beds. A sudden change in sedimentation to soft, light-grey weathering shales in the upper part of the sequence seems to mark a major hiatus. In the northern part of the area, around Olympen, prominent sandstone horizons, indistinguishable in facies from the sandstones of the Pelion Member, interdigitate. At Antarctics Havn this same sandstone facies rises without interruption from the base of the Pelion Member so that neither Fossilbjerget Member nor Olympen Formation continue to be separately recognisable.

Boundaries

The lower boundary is put where the sedimentation changes from massive, light sandstones to fine, sandy or silty, shaly deposits. The boundary often forms a distinct feature in the landscape, because the shales are less resistant to weathering than the underlying sandstones.

The upper boundary is marked by a sharp change in sedimentation to black shales of the Hareelv Formation (in southern Jameson Land) or light sandstones of the Olympen Formation (in northern Jameson Land) (p. 39).

Distribution

The Fossilbjerget Member crops out in Neill Klinter at Hurry Inlet and in central and northern Jameson Land. The northernmost localities are situated immediately north of Olympen and on Pelion.

Geological age

Bathonian–Middle Callovian. The lower boundary is diachronous, ascending from the *C. indistinctus* Zone in the south to the *A. cranocephaloides* Zone in northern Jameson Land. The uppermost part of the member contains Middle Callovian ammonites both in the southern and in the northern area of distribution. In the southern part of the area two fairly major hiati can be recognized: (1) just above the Pelion Member, and (2) below the Middle Callovian soft, grey shales of the upper part of the sequence. In the northern part of the area the sequence is more complete, but small non-sequences and condensed sedimentation do occur (table 2).

Olympen Formation

new formation

History

The sandstone series overlying the Vardekløft Formation in northern Jameson Land was referred to the Fossilbjerget Formation by Rosenkrantz (1929) on the basis of exposures on Fossilbjerget. This formation included, however, also parts of the fossiliferous Vardekløft Formation (Spath, 1932), and the name is here abandoned.

Callomon (1961, 1970), Birkelund & Perch-Nielsen (1969) and Birkelund *et al.* (1971) referred the sandstone series to the Koch Fjeld Formation, interpreting this name as applying to the whole of the sandstone and shale series overlying the Vardekløft Formation in Jameson Land.

Closer investigations of the top sandstones of Jameson Land have shown that the sandstones of northern Jameson Land (Mikael Bjerg and further north) differ in facies as well as in age from the sandstone and shale series covering the Vardekløft Formation in southern Jameson Land (the Hareelv Formation). The deposits are therefore referred here to a separate formation: the Olympen Formation.

Name

From Olympen, an ice-covered mountain in northern Jameson Land.

Type locality

Upper reaches of Olympelven in a gorge south of Olympen glacier (fig. 4).

Reference section

Point 1000 m, west of Olympen (fig. 24 b).

Thickness

The full thickness is not known, as the formation forms the top of the sequence in northern Jameson Land. The type section (fig. 24 a) measures 180 m, but the thickness in this area may reach 250 m, the upper part being covered by scree and moraine. On Parnas the formation is 300 m thick, on Fossilbjerget 250 m and on Mikael Bjerg 200 m.

Lithology

At the type locality (fig. 24 a) the formation can be divided into three lithological units (from below): (1) Medium-grained, light-coloured, well-sorted sands or massive sandstones, intercalated by subordinate laminated, dark, silty shales or fine laminated sands. The massive sandstones are structureless (fig. 25) or show large-scale cross-bedding. Slump structures may occur. The dark colour of the silty shales and of some of the laminated sands is due to comminuted plant debris and one bed full of macroscopic plant remains has been seen. Except for these, neither trace fossils nor body fossils have been found in this part. (2) Dark silty shales below pass upwards into gradually more sandy shales. The beds are poorly consolidated. Some of the silty shales contain pyrite concretions. The dark colour of the shales as well as of some of the sands is due to coal-partings on the bedding planes. A few beds contain trace fossils (small endichnial burrows) and a single Lower Oxfordian *Quenstedtoceras* cf. *woodhamense* ARKELL (*Q. mariae* Zone) was found. (3) Massive, cliff-forming, medium- to coarse-grained, well-sorted sandstones with subordinate intercalations of silty shales. The sandstones are structureless or show large-scale cross-bedding. Trace fossils occur occasionally. Above the summit of the type section, on the plateau, a Middle Oxfordian *Cardioceras* was found.

In other sections, west and north of Olympen, a similar tripartite division is seen (i. e. the reference section at point 1000 m, fig. 24 b, and on Pelion), but the lower two units are thinner than in the type

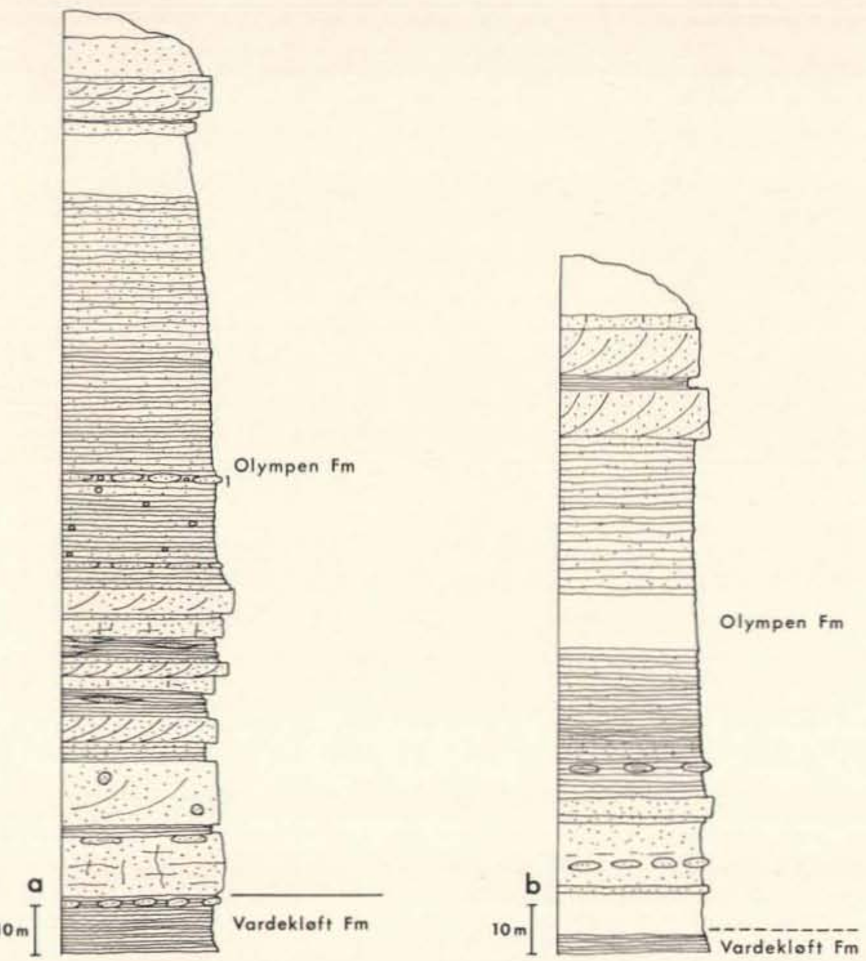


Fig. 24 a. Section No. 10. Olympen Formation, type section, Olympen (see p. 40 and fig. 4). Legend as for fig. 6. 1: *Q. mariae* Zone. Measured by JHC and TB.

b. Section No. 11. Olympen Formation, reference section, Olympen (see p. 40 and fig. 4). Legend as for fig. 6. Measured by JHC and TB.

section and exact correlation has not been proved. In the westernmost outcrop ("Kosmoceras Bjerg") only the lower unit appears to be preserved. It differs from that of the type section in containing a fairly rich trace fossil assemblage and—at the top—a concretionary sandstone yielding an Upper Callovian ammonite fauna. East and south of Olympen, at Parnas, Fossilbjerget and Mikael Bjerg the lithology of the whole sequence resembles the uppermost part (3) of the type section only. This is possibly due to the absence of equivalents of the lower and middle parts (1) and (2) and hence a hiatus in the sequence between the

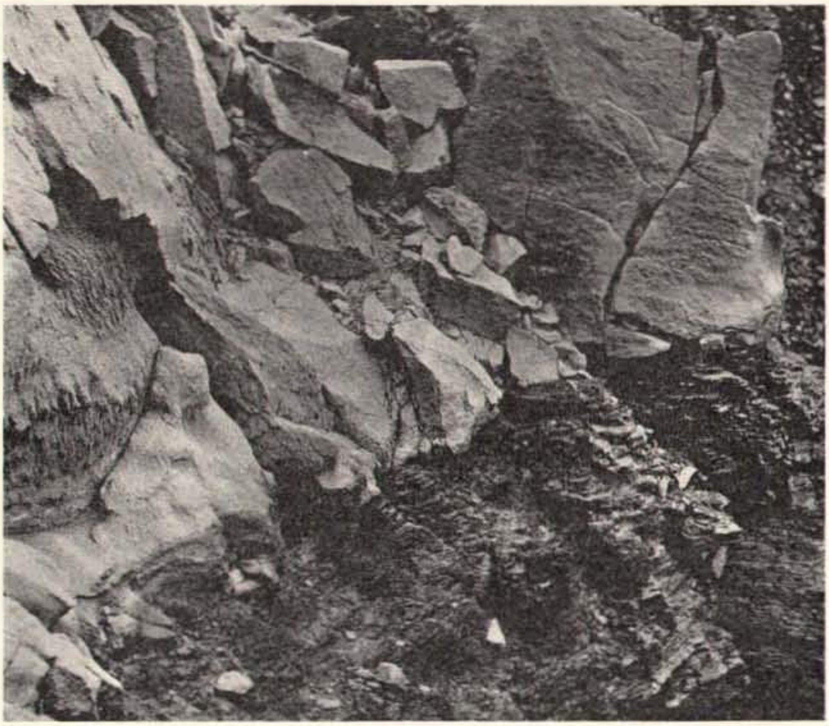


Fig. 25. Lower part of Olympen Formation, type section (fig. 24 a). Dark sandy shale overlain by massive light-coloured sandstone. Note the sharp contact.

Middle Callovian upper part of the Vardekløft Formation and Middle Oxfordian. This hypothesis is, however, only supported by very sparse fossil evidence, viz. a single find of a Middle Oxfordian *Cardioceras* on Parnas 100 m above the base while *Cardioceras* of similar age occur much higher in the section at Olympen (at least 200 m above the base).

Boundaries

The lower boundary is marked by a knife-sharp change in sedimentation from dark shales at the top of the Vardekløft Formation to light sandstones. It is very well exposed in the type section. The upper boundary is unknown, as the formation forms the top of the plateaus everywhere in its area of distribution.

Distribution

The Olympen Formation crops out on the summits in northern Jameson Land from "Kosmoceras Bjerg" in the west, Pelion to the north, Fossilbjerget to the east and Mikael Bjerg to the south (plate

10). South of Mikael Bjerg it seems to be missing, Upper Oxfordian shales and sands of the Hareelv Formation directly overlying the Vardekløft Formation. In southern Jameson Land a loose block has yielded the Middle Oxfordian *Cardioceras* (*Vertebriceras*) *densiplicatum* figured by SPATH (1935, pl. 15, fig. 3), but occurrence *in situ* has not been confirmed. In western Jameson Land, an isolated stream section 5 km ESE of the mouth of Depotelv exposes 10 m of dark shales resembling the middle part ((2) above) which yielded *Cardioceras mirum* ARKELL, of Lower Oxfordian age, *Q. mariae* Zone, *praecordatum* Subzone.

Geological age

Fossils are extremely rare. The lower sandy part of the formation ("Kosmoceras Bjerg") has yielded an Upper Callovian fauna (partly described by BIRKELUND *et al.*, 1971). The middle shaly part has yielded a single Lower Oxfordian *Quenstedtoceras* (in the type section at Olympen), and the upper sandy part has yielded Middle Oxfordian *Cardioceras* (Olympen, Parnas, Mikael Bjerg, described by BIRKELUND *et al.*, 1971).

Hareelv Formation

new formation

Earlier investigations

As shown on p. 25 the basal beds of the Hareelv Formation were originally included in the Vardekløft Formation by definition, but these beds are now excluded following the redefinition of this formation (p. 27).

The type locality of the Koch Fjeld Formation is built up of disturbed sediments (p. 25) belonging to different parts of the Vardekløft Formation, the Hareelv Formation and the Raukelv Formation respectively (SURLYK & BIRKELUND, 1972). The term Koch Fjeld Formation as used in most of the literature is in effect a collective term for all sediments in Jameson Land overlying the Vardekløft Formation, and is therefore best abandoned. It is replaced by the Hareelv and Raukelv Formations here properly defined.

Name

From the river Hareelv, southern Jameson Land.

Type area

Southern slopes of the river Hareelv, where both lower and upper boundaries of the formation are well exposed.

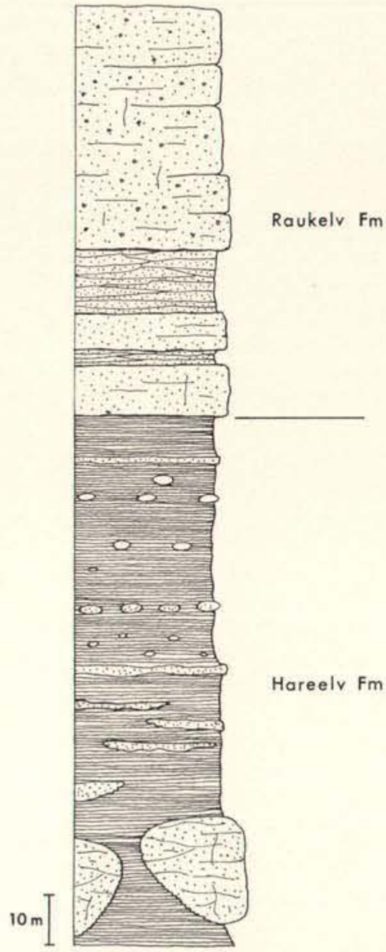


Fig. 26. Section No. 12. Hareelv Formation, reference section for the upper boundary (see p. 44 and fig. 2). Legend as for fig. 6. Measured by FS.

Reference sections

Lower boundary: Goniomyakløft on the west coast of Hurry Inlet (fig. 14). Upper boundary: a section 7 km south of J. P. Kochs Fjeld at the river Muslingeelv (fig. 26).

Thickness

The total thickness of the formation seems to be *c.* 200 m, but is not known precisely as both boundaries are rarely well exposed in the same section.

Lithology

The formation is composed of black and grey shales with large irregular lenses and layers of yellow sandstone (plate 8, fig. 1; fig. 27).

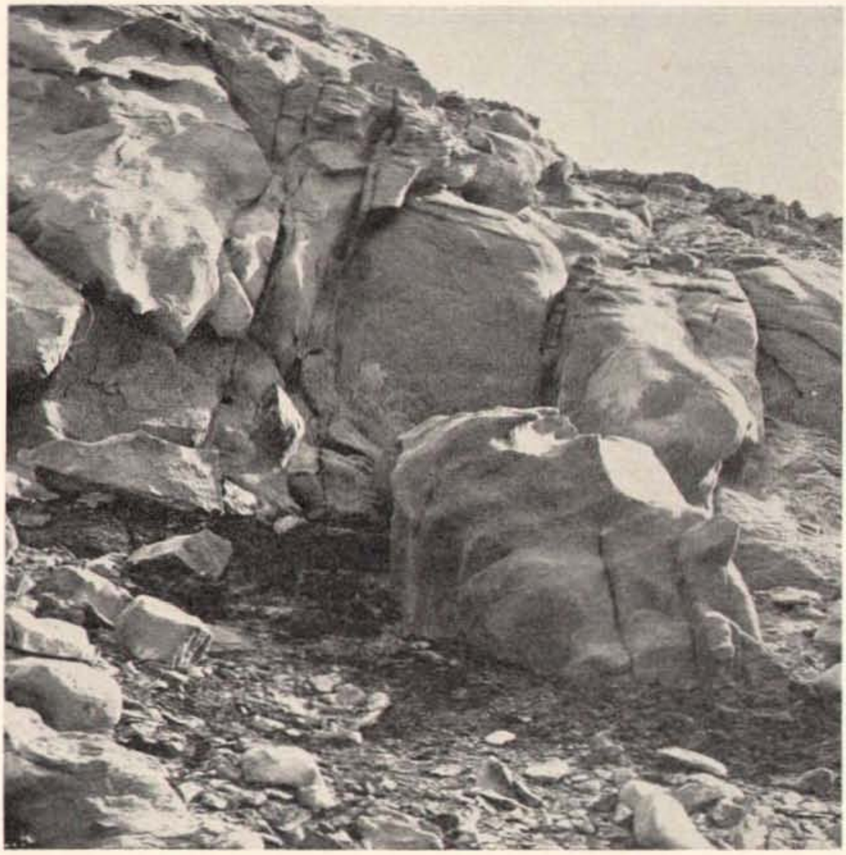


Fig. 27. Hareelv Formation. Detail of one of the sandstone bodies in plate 8, fig. 1. Note the sharp contact between the black shales and the overlying massive light sandstones.

The shales are micaceous and often contain thin beds of loose, light sandstone and occasional calcareous or ferruginous concretions. The shales are normally fine-grained, but at some horizons sandier, lighter grey shales occur. The bedding planes are sometimes covered with a thin layer of mica. The shales are often intensely bioturbated by deposit feeding animals, but well-defined trace fossils are rare except for occasional meandering trails. The shales are marine as they contain ammonites (*Amoeboceras*, *Decipia*), bivalves (*Buchia*) and scattered inarticulate brachiopods throughout.

The boundaries between the shales and the sandstones are always knife-sharp. The sandstone lenses are of a very irregular shape. They may attain a length of several hundred metres and a thickness of 100 metres. The sandstones are well-sorted, medium-grained and rich in mica and sometimes in glauconite. Large angular pieces of black shale

Fig. 28. Detail of the sandstone sill in plate 9, fig. 2, showing branching and sharp contact with shales.

are often incorporated in the basal parts of the sandstones (fig. 30). The lateral contact between the sandstone and the shale is normally curved in cross-section and flame structures are developed on the surface of the sandstone body (see figs 14, 26).

The shales are penetrated by numerous yellow sandstone dykes and sills (plate 9, fig. 2; fig. 28). The sills are often transgressive and may continue into dykes. The thickness of the dykes varies from a few millimetres to about 20 cm. The shales only rarely show disturbance at the contact with the dykes. The density of dykes and sills is largest in the vicinity of the large sandstone lenses.

Inorganic sedimentary structures and trace fossils are very rare in the massive sandstone. An example of load casting is shown on fig. 29. However, the tops of many of these almost structureless sandstone lenses often show trough cross-bedding.

Silicified wood and charcoal are very common in the sandstones and often form the cores of the concretions in the shales. In some of the harder glauconitic sandstone lenses small bivalves (e. g. smooth and costate pectinids) are found, but normally the massive sandstones are completely free of fossils. Rare ammonites are found, however, in thin hard glauconitic sandstones.

The depositional environment of this formation is of a rather unusual kind. The rocks are marine throughout and there is no evidence

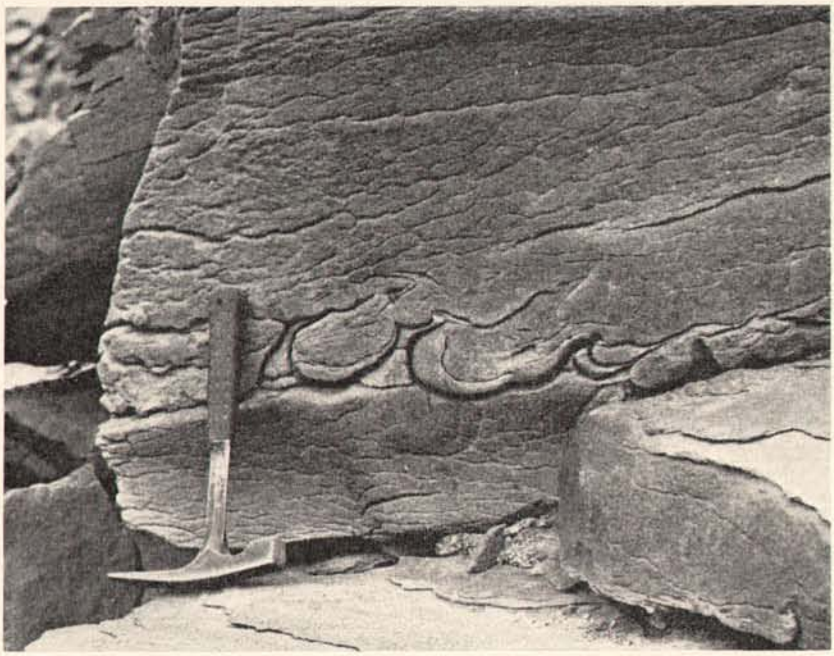


Fig. 29. Load structure in otherwise massive sandstone, Hareelv Formation, Katedralen (fig. 1).

to indicate a place of deposition near the coast. The large sandstone lenses have the same shape as normal channel sands. They are, however, deposited under marine conditions and at a time when the shales were at least relatively hardened—judged from the very regular shape of the shale pieces incorporated basally in many of the "channel sands". These features combined with the existence of numerous sandstone dykes and sills of undoubtedly intrusive nature suggest the following depositional regime. A sequence of clastic sediments were deposited along a coast with coast-near sands gradually passing into black mud far off-shore. Triggered by some unknown mechanism, presumably earthquakes, the sand moved sea-ward as slumping masses and eroded deep channels in the more or less hardened fine-grained deposits.

Deposition of the sand flows was followed by intrusion of sandstone dykes and sills and the sand settled with expulsion of water. By erosion and rotation of the lateral parts of sand bodies the large-scale longitudinal side-ridges were developed and flame structures were formed. The rotational nature of these large ridges can be seen from their shape and their repeated occurrence, one above the other and from the orientation of the mica flakes. The cross-bedding found at the top of the "channel sands" was probably formed by reworking of the exposed part of the sand bodies after the sand had settled in the eroded channels.

Fig. 30. Hareelv Formation. Massive sandstone with pieces of black shale incorporated. The base of the sandstone rests on black shale 30 cm below the lowest visible shale fragment. Katedralen (fig. 1).

Boundaries

Due to the loose character of the shales of both the Hareelv and Vardekløft Formations the lower boundary is rarely well exposed. It is put where the light-grey, silty, very micaceous shales of the Vardekløft Formation are overlain by black, soft shales with thin irregular bands of yellow sandstone (fig. 14). The upper boundary is put where the shales and irregular sandstone lenses of the Hareelv Formation are overlain by regular horizontal layers of sandstone of the Raukelv Formation (fig. 26) or by the shales of the Hesteelv Formation (fig. 36 a).

Distribution

The Hareelv Formation is found in the southern half of Jameson Land where it forms the top bed over large areas (plate 10). Only in the south-western part is it covered by younger deposits. The northernmost occurrence is at Langryggen, 10 km south of Mikael Bjerg (fig. 1).

Geological age

In the basal shales of the formation a rich fauna of Upper Oxfordian ammonites is found (*Decipia* and *Amoeboceras*, plate 1). Higher parts have yielded late amoeboceratids, *Rasenia* (plate 1) and ?*Aulacostephanus*, indicating the presence of the whole of the Lower Kimmeridgian. Sparse finds of ?*Subdichotomoceras* above may indicate a Middle Kimmeridgian age for the upper part of the sequence.

Raukelv Formation

new formation

Earlier investigations

Previously the sediments belonging to the Raukelv Formation were known only indirectly from the descriptions by MADSEN (1904), SPATH (1936) and DONOVAN (1964) of a few fossils of Volgian age found in the lower reaches of the river Aucellaelv at the south-western corner of Jameson Land. ALDINGER (1935) described a sequence of large-scale cross-bedded sandstones from the area around Raukelv (fig. 2) as the top member of the Lower Cretaceous sediments (described p. 57). These sandstones are now known in fact to underlie the Cretaceous, and constitute the top beds of the Raukelv Formation. They are of Upper Jurassic (Upper Volgian) age and dip under the Lower Cretaceous sediments.

Name

From the river Raukelv in southernmost Jameson Land (fig. 2), where ALDINGER (1935) first observed rocks of the formation.

Type section

Between the upper courses of Raukelv and Muslingeelv (fig. 31 a).

Reference sections

Lower boundary: Muslingeelv (fig. 26). Upper boundary: east of Raukelv (plate 9, fig. 1, centrally in the foreground of the figure).

Thickness

The maximum thickness is estimated to be 300 m on the basis of several sections.

Lithology

The formation consists of cyclically alternating, thick, massive or large-scale, cross-bedded sandstone units and shaly siltstones. The sandstone horizons vary in thickness from 10 to 50 m and form conspicuous marker horizons (plate 8, fig. 2). In the central part of the area five distinct sandstone beds named A–E from below can be distinguished. These sandstones characteristically produce a fantastic landscape of extensive plateaus dissected along joints to leave more or less isolated columns separated by deep, narrow clefts (fig. 32).

The sandstones are white or yellow, but weather often to brown or dark-red colours. They are composed almost solely of quartz grains,

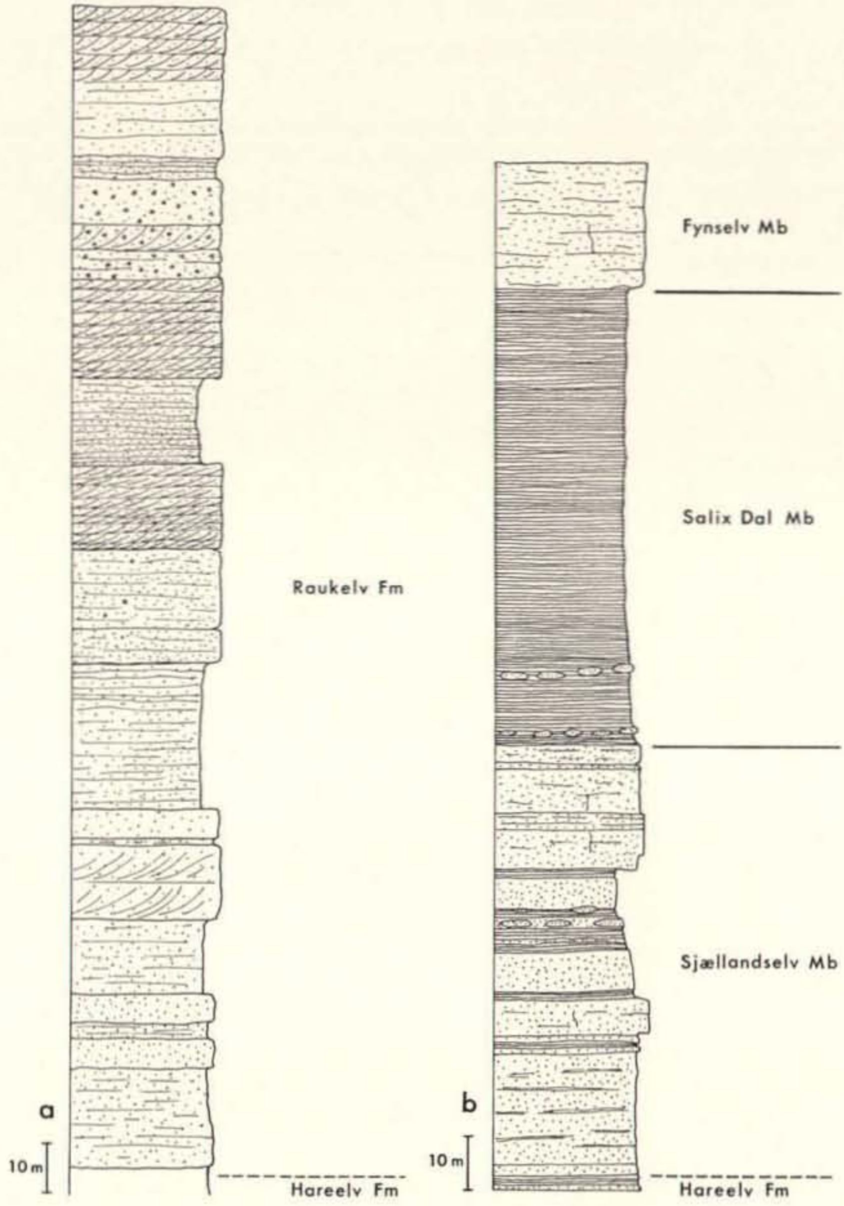


Fig. 31 a. Section No. 13. Raukelv Formation, type section (see p. 49 and fig. 2). Legend as for fig. 6. Measured by FS.

b. Section No. 14. Sjællandselv Member of the Raukelv Formation, type section, Sjællandselv (see p. 55 and fig. 2). The upper half of the Salix Dal Member is rather poorly exposed. Legend as for fig. 6. Measured by TB and FS.

Fig. 32. Characteristic exposure of the sandstones of the Fynselv Member, Raukelv Formation. The thickness of the massive units in the foreground is approx. 20 m. Aerial photograph 8 km west of J. P. Kochs Fjeld (fig. 2).

and in the massive and small-scale cross-bedded layers glauconite often plays an important role. The degree of sorting is very poor, the grain size is mainly in the coarse sand or gravel fraction. Large quartz pebbles are very common. The more fine-grained horizons often contain a large amount of reworked pieces of grey or black shale.

The sandstones are commonly massive or cross-bedded (fig. 33). The massive beds are sometimes divided into large irregular sheets with a thickness of 0.1–0.3 m. These sheets may represent very flat cross-bedding. In the basal part of the formation platy, red-brown sandstone with parting-lineation or small-scale linguoid ripples often occur.

Palaeocurrent directions in the cross-bedded sandstones are very uniform, often varying within only a few degrees in an area of several square kilometres. The main transport direction is towards the south-east. From the air the foresets can be seen to form large concave fans with the concave side in the current direction (fig. 35).

The foresets are sigmoidal or more commonly tangential. They normally show graded bedding with coarse gravel at the base passing within a few centimetres into medium-grained sand. The form sets are tabular, commonly with erosional surfaces and vary in thickness from 0.3–10 m.

Fig. 33. Sandstone of the Fynselv Member, Raukelv Formation, showing large-scale, sigmoidal cross-bedding. The cross-bedded set is 2.5 m thick. Immediately west of Raukelv.

A characteristic cyclicity is often observed. The modal cyclothem commences with one or two large-scale cross-stratified sandstones each 5 to 10 m thick. The top surface is erosional, penetrated by numerous vertical burrows and covered with a thin ferruginous crust. This is followed by a massive 5–10 m thick, poorly-sorted sand- or gravelstone, sometimes with ammonites, bivalves and crinoids, and again with an erosional, burrowed, iron-impregnated top surface. It is overlain by silty or fine-sandy, intensely bioturbated shale with rare ammonites and bivalves.

Numerous variations on this theme are seen, but the main features —cross-bedded sandstone, followed by massive sandstone, followed by shale—play a very important role throughout the formation.

The sandstones often contain brown concretions. These vary in size from 1 cm to 1 m and in shape from perfectly ball-shaped to completely irregular masses.

In the cross-bedded sandstones root horizons are seen at some localities. In the overlying sediments huge petrified tree-trunks with a diameter up to 0.5 m are common. In the massive, coarse sandstones and gravelstones, ammonites, bivalves and crinoids are often found in great numbers. Pavements of large, smooth pectinids with the convex side up or shell conglomerates with no preferred orientation of the fossils are seen at several places. In the cross-bedded sandstones only very few body fossils (e.g. oysters) have been seen, but vertical burrows such as mantled U-tubes and *Monocraterion* are characteristic of the sediment.

Between the sandstones occur thin horizons of brownish, silty or sandy shale. They normally weather out into large concretionary, ellipsoidal bodies. The shales contain rare ammonites and bivalves and occasionally large plant fragments. They are intensely bioturbated and contain a wealth of trace fossils.

In the western part of the area one of the shale horizons thickens considerably and assumes a grey-black colour.

Boundaries

The lower boundary is put where the black shales and irregular sandstone lenses of the Hareelv Formation are overlain by regularly bedded sandstones. The formation is overlain with angular unconformity by sandstones and shales of Lower Cretaceous age belonging to the Hesteelv Formation.

Distribution

The Raukelv Formation is found in the southernmost part of Jameson Land and forms extensive plateaus west and south-west of J. P. Kochs Fjeld. Its northernmost occurrence is in the area around Jyllandselv and at the mountain Fortet. Only in the extreme southernmost part of Jameson Land is the formation covered by the Lower Cretaceous Raukelv Formation (plate 10).

Geological age

In the basal part of the formation perisphinctids of ?Middle Kimmeridgian age are found. Higher beds contain successive faunas of *Pavlovia*, *Dorsoplanites*, *Epipallaciseras* and *Laugeites* of Upper Kimmeridgian–Portlandian (Middle Volgian) age and *Subcraspedites* and *Chetaites* of the Upper Volgian (plates 2, 3).

Subdivisions

The formation is divided into three members, from bottom to top: Sjællandselv Member, Salix Dal Member, Fynselv Member.

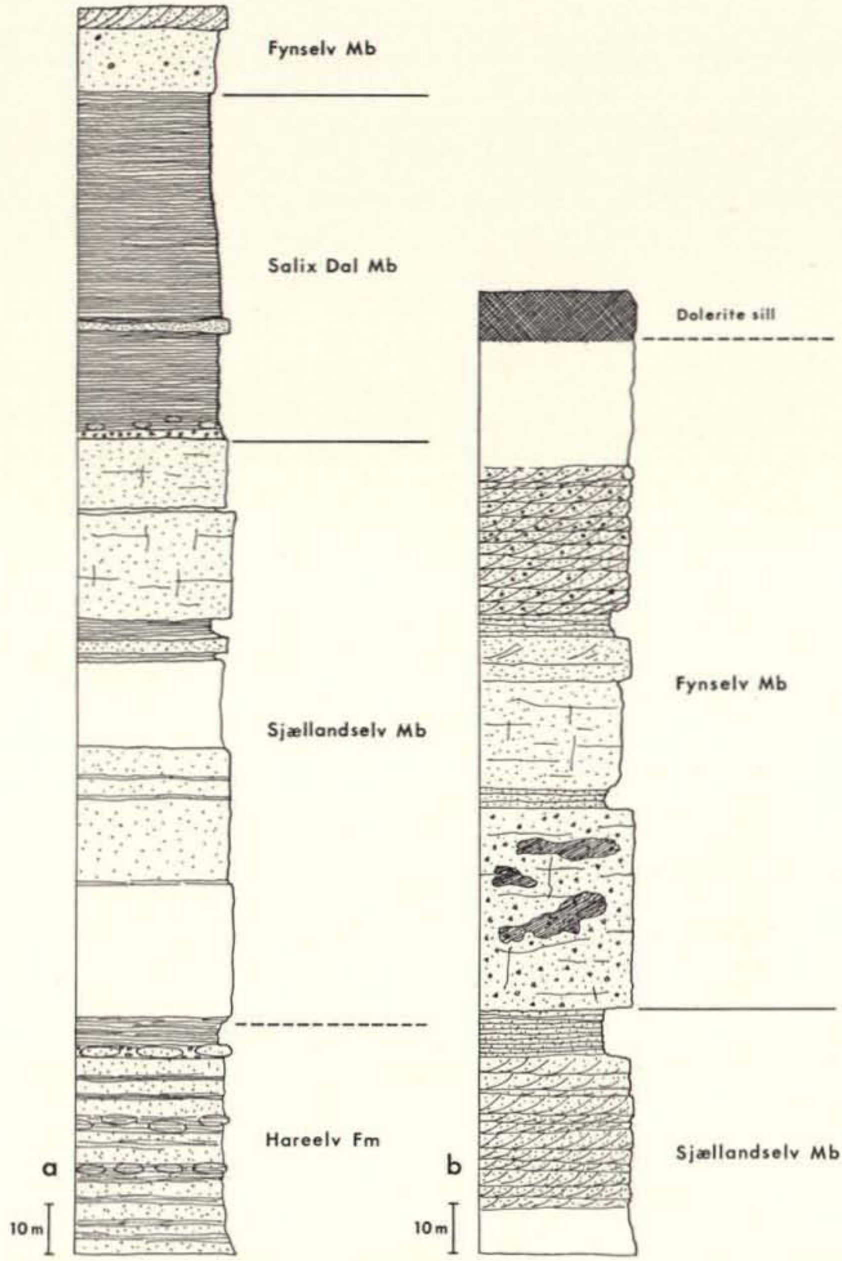


Fig. 34 a. Section No. 15. Salix Dal Member of the Raukelv Formation, type section, Salix Dal (see p. 55 and fig. 2). Legend as for fig. 6. Measured by JHC and TB.

b. Section No. 16. Fynselv Member of the Raukelv Formation, type section, Fynselv (see p. 56 and fig. 2). Legend as for fig. 6. Measured by FS.

Sjællandselv Member

new member

Name

From the river Sjællandselv in southern Jameson Land.

Type section

Sjællandselv (fig. 31 b).

Thickness

100–200 m.

Lithology

Thick, massive and cross-bedded sandstones alternating with silty and sandy shales (figs 31 b, 34 a). Along the margins of the depositional area the cyclicity is only vaguely developed, but in the central part a sequence of three thick sandstone horizons (A-B-C) alternating with shales can be followed over a large area. In the western part, i.e. around the type locality, the sequence is developed in a more shaly facies (fig. 31 b).

Boundaries

The lower boundary coincides with the lower boundary of the formation. Where the member is overlain by the Salix Dal Member, the upper boundary is put at the base of a thick sequence of soft, grey-black micaceous shales. Where the member is overlain by the Fynselv Member the upper boundary is put at the base of the most conspicuous sandstone horizon of the formation (bed D). This bed is a major feature-forming element in the landscape of southern Jameson Land.

Distribution

Same as the formation.

Geological age

Middle?–Upper Kimmeridgian.

Salix Dal Member

new member

Name

From the valley Salix Dal in southern Jameson Land.

Type section

Salix Dal (fig. 34 a).

Thickness

0–70 m.

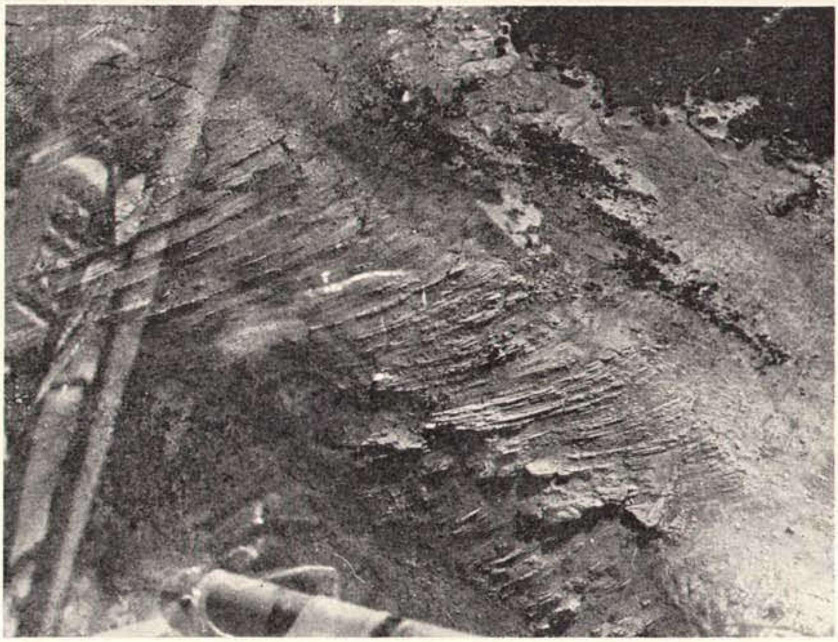


Fig. 35. Vertical aerial photograph of Fynselv Member, showing huge fans of cross-bedded sandstone. The sets are approx. 2 m thick. Transport direction from right to left. Flight height is about 300 m. (The pale marks to the left and at bottom are reflections from the helicopter window).

Lithology

Uniform grey to black micaceous silty shales with occasional calcareous concretions. A few thin layers of yellow sandstone occur. A thick, massive sandstone containing ammonites and bivalves is found half way up in the succession in several localities. In some horizons the shales weather out into irregular, lenticular bodies with a rusty colour. The member rapidly wedges out towards south and east.

Distribution

The member covers a rather large area in the western part of the distributional area of the formation. In the eastern part a few thin shales representing the member are found at the river Mønselv. The member rapidly wedges out towards the central part and has completely disappeared in the area around Fynselv.

Geological age

Upper Kimmeridgian–Portlandian.

Fynselv Member

new member

Name

From the river Fynselv in southern Jameson Land.

Type section

Western branch of Fynselv (fig. 34 b).

Thickness

Approximately 130 m.

Lithology

Thick horizons of massive and cross-bedded sands and sandstones alternating with shaly siltstones and sandstones in a cyclical manner. In the major part of the area two sandstone horizons (beds D-E) form conspicuous marker beds.

Boundaries

The lower boundary is put at the base of bed D (figs 31 b, 34 a–b) and hence coincides with the upper boundary of either the Salix Dal Member or, where this is absent, the Sjællandselv Member.

The boundary to the overlying Hesteelv Formation is discussed on p. 58.

Distribution

The member forms the top plateau of south central Jameson Land. Its northernmost occurrence is in the area between the upper courses of the rivers Fynselv and Sjællandselv. In the western part it overlies the Salix Dal Member and in the rest of the area the Sjællandselv Member. In the southernmost parts it is overlain with angular unconformity by the Lower Cretaceous Hesteelv Formation (plate 10).

Geological age

Upper Kimmeridgian (Middle Volgian)–Upper Volgian.

Hesteelv Formation

new formation

Earlier investigations

ALDINGER (1935) described sediments of Lower Cretaceous age in southern Jameson Land. He collected a rich fauna which was described by SPATH (1947). Furthermore, in the area around the river Raukelv ALDINGER found a succession of massive and cross-bedded sandstone which he took to be the top member of the Lower Cretaceous sediments; but in fact these sandstones are the top beds of the underlying Upper Jurassic Raukelv Formation (bed E). The Lower Cretaceous Hesteelv Formation is deposited in a small synclinal trough, and hence its top sandstone comes to lie directly with angular unconformity on bed E of the Raukelv Formation at the margins of the trough. A detailed description of the formation and its boundary relations is given by SURLYK (in press).

Name

From the river Hesteelv, southern Jameson Land.

Type section

Between the rivers Muslingeelv and Hesteelv (fig. 36 a).

Thickness

10–120 m.

Lithology

The sediments of the Hesteelv Formation fill a small synclinal trough formed in the older rocks in southernmost Jameson Land (plate 9, fig. 1). The axis of the syncline dips gently towards the south. The central parts of the depression are filled with black shales which pass upwards into silty and sandy micaceous, somewhat irregular shales. The shaly sequence is terminated by a sandy shell conglomerate which in the marginal parts of the trough lies directly on the sediments of the Jurassic Raukelv Formation. In the central parts the shell conglomerate is overlain by a thin sequence of shale which again is topped by coarse sandstones.

Boundaries

The lower boundary is easily recognised in the central parts of the synclinal trough at the point at which the coarse sandstones of the Raukelv Formation are overlain with sharp contact by black or grey-brown, shaly siltstones. Along the margins of the trough the top sandstones of the formation rest directly on the sandstones of the Raukelv Formation. The two sandstones are impossible to distinguish lithologically so here the boundary can only be located by tracing the individual beds towards the central parts of the trough. At a few localities (e.g. the type locality) in the southern part of the area, the formation overlies the Hareelv Formation, but here also the boundary between the silty shales of the Hesteelv Formation and the black shales with irregular lenses of yellow sandstones characteristic of the Hareelv Formation is easy to recognise. The upper boundary is unknown, as the Hesteelv Formation comprises the youngest sediments found in Jameson Land.

Distribution

The formation is restricted to a small area in the southernmost Jameson Land along the rivers Hesteelv and Muslingeelv (plate 10).

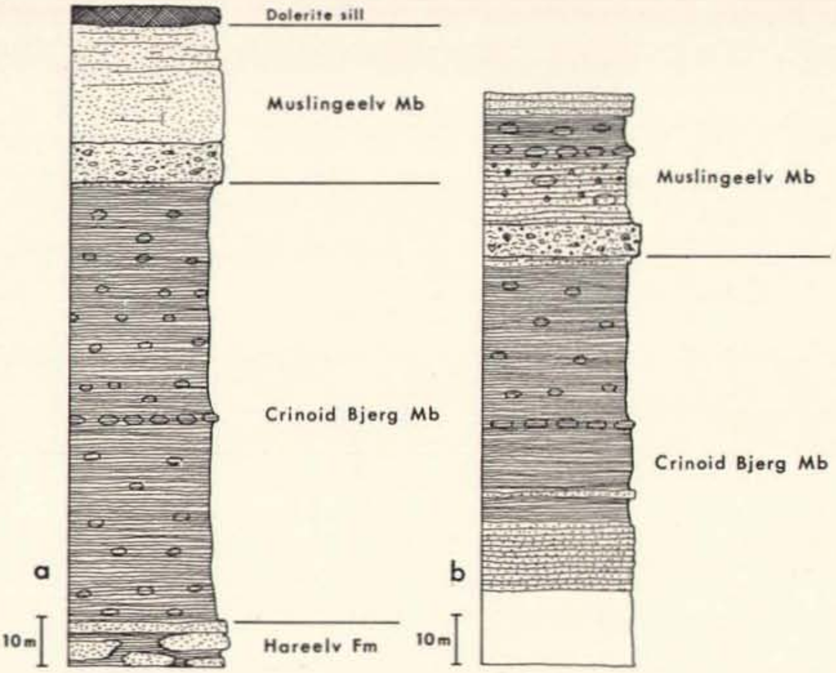


Fig. 36 a. Section No. 17. Hesteelv Formation, type section (see p. 58 and fig. 2). Legend as for fig. 6. Measured by FS.

b. Section No. 18. Crinoid Bjerg Member and Muslingeelv Member, type section, Muslingeelv (see p. 61 and fig. 2). Legend as for fig. 6. Measured by FS.

Geological age

The lower, shaly sequence contains the ammonites *Hectoroceras kochi* Spath and *Praetollia maynci* Spath. In the shell conglomerate *H. kochi* is with rare exceptions the only ammonite found. In the highest sandstone *H. kochi* is found together with a few specimens of *Surites* (plate 4, fig. 4). The whole fauna is thus of Lower Cretaceous, Ryazanian age (table 3). In an isolated occurrence on the summit of the tectonically disturbed J. P. Kochs Fjeld a few ammonites of presumed Valanginian age have been found (plate 4, fig. 5), (see also Surlyk & Birkelund, 1972, fig. 4).

Subdivision

The formation is divided into two members: a lower Crinoid Bjerg Member and an upper Muslingeelv Member.

Table 3. *Correlation of Volgian-Ryazanian deposits in Russia and southern Jameson Land*

SACHS, MESEZHNIKOV & SHULGINA, 1968			BASOV *et al.* 1970	This paper
Stages	North Ural	Basin of Volga River	Bay of Anabar	Southern Jameson Land
Valanginian			*Polyptychites stubendorffi*	Cf. *Polyptychites mokschensis*
			Neotollia klimovskiensis?	
Ryazanian	*Tollia payeri*		*Bojarkia mesazhnikowi*	
	Surites analogus	*Surites spasskensis*	*Surites analogus*	*Surites* aff. *poreckoensis* *Hectoroceras kochi*
	Hectoroceras kochi		*Hectoroceras kochi*	*Hectoroceras kochi* *Hectoroceras kochi* *Praetollia maynci*
	?	*Riasanites rjasanensis*	*Chetaites sibiricus*	
Volgian	?	*Craspedites nodiger*	*Chetaites chetae*	Aff. *Chetaites chetae*
			Craspedites taymyrensis	*Subcraspedites* cf. *plicomphalus*
	Craspedites subditus	*Craspedites subditus*	*Craspedites okensis*	
	Kachpurites fulgens	*Kachpurites fulgens*		
	Laugeites (?) *vogulicus* *Laugeites groenlandicus*	*Epivirgatites nikitini*	*Epivirgatites variabilis*	*Laugeites vogulicus*

Crinoid Bjerg Member

new member

Name

From the mountain Crinoid Bjerg situated immediately west of Muslingeelv (fig. 2), southern Jameson Land.

Type section

North-eastern slope of Crinoid Bjerg (fig. 36 b).

Thickness

0–85 m.

Lithology

In the southern part of the synclinal trough (plate 9, fig. 1; plate 10; plate 11) the member is developed as uniform black shales. Upwards and towards the margins the shales become more sandy and are characteristically developed as light brownish, irregular silty and fine sandy shales. The lower half of the member weathers to a greyish colour, whereas the upper half weathers light yellow-brown. Thin yellow layers of loose sandstone occur. The shales are very micaceous and often contain numerous small pieces of reworked dark grey shale. They weather out into huge ellipsoidal concretionary bodies and contain light brown calcareous concretions sometimes with barytes-filled cracks. The bedding planes are often covered with finely comminuted plant debris. Large pieces of wood are common in many horizons. They are occasionally bored by bivalves. The shales are often intensely bioturbated and well-defined trace fossils are found at many levels. Upwards the shales grade into grey-brown, fine-grained sandstones with parting-lineation or linguoid ripples.

Boundaries

The lower boundary is identical with the lower boundary of the formation except at the margins where the member wedges out. The upper boundary is put between the silty shales and the overlying often very fossiliferous sandstones of the Muslingeelv Member.

Distribution

The member is found in the major part of the distributional area of the formation, but has wedged out at the northern and easternmost localities.

Geological age

Ryazanian (see p. 59).

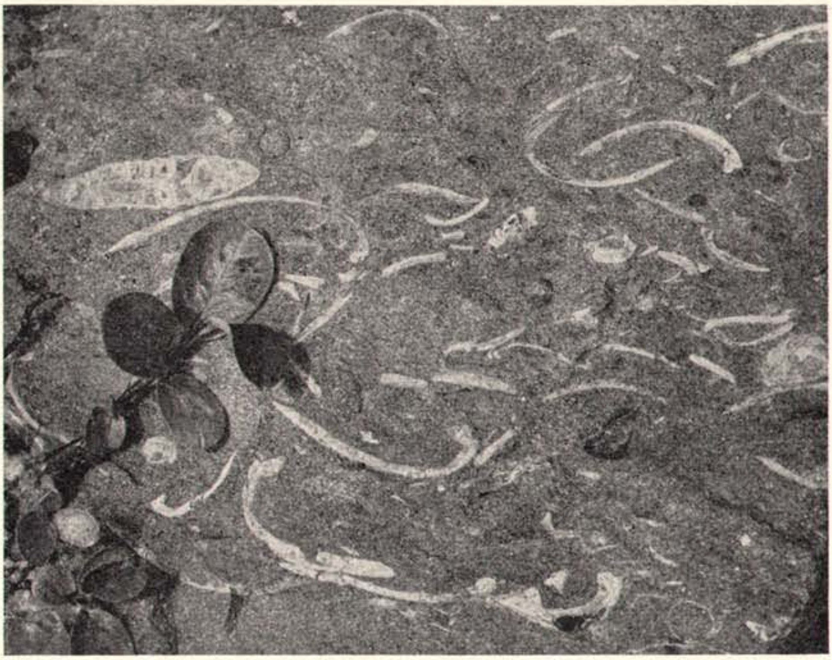


Fig. 37. Detail of Muslingeelv Member, Hesteelv Formation, type section see fig. 24. The rock consists of large bivalves, ammonites and other fossils in a sandstone matrix. Natural size.

Muslingeelv Member

new member

Name

From the river Muslingeelv, southern Jameson Land.

Type section

North-eastern slope of the mountain Crinoid Bjerg situated immediately west of Muslingeelv (fig. 36 b).

Thickness

10–35 m.

Lithology

The member commences with a very characteristic, sandy shell conglomerate (fig. 37), which can be traced as a marker horizon in the central part of the area. The matrix between the shells is a hard, grey sandstone or gravelstone often containing larger quartz pebbles. The fossil assemblage is dominated by large, thick-shelled bivalves with subordinate ammonites and belemnites. The bivalves are in most cases found with the shell preserved. At some localities they are completely randomly orientated. At other localities (e.g. the type locality of the formation) the shells are mainly orientated parallel with the layering. Upwards the number of fossils decreases but this is to some extent merely a matter of preservation, for a clear transition can be seen from a fauna with shells preserved, through layers with fossils preserved as casts, to layers where the fossils are only recognizable as thin curved, white lines. The shell conglomerate is followed by massive or cross-bedded light sandstones and in the central part of the area by a thin sequence of brownish micaceous shale of the same type as the shales characteristic of the Crinoid Bjerg Member. These shales are overlain by massive or large-scale, cross-bedded sandstones with vertical burrows. The surfaces of the sets are erosional, penetrated by burrows, corroded and covered by a thin ferruginous crust. Perfectly spherical concretions varying in size from a few millimetres to 0.5 m are very common at many horizons.

Boundaries

The lower boundary is put where the silty shales of the Crinoid Bjerg Member are overlain by massive or cross-bedded, light sandstones. At the margins the member overlies the sandstones of the Raukelv Formation directly and here the boundary can only be placed by following the individual sandstone beds towards the central parts of the trough. As the member comprises the youngest rocks in Jameson Land, the upper boundary is unknown.

Distribution

Identical to the distribution of the formation.

Geological age

Ryazanian (see p. 59).

DESCRIPTION OF FACIES

Black shales

Description

The facies covers non-argillaceous, non-calcareous shales with a grain size in the fine silt fraction. The shales have characteristically a very large content of mica flakes, and many bedding planes are covered with plant debris. Calcareous and sideritic concretions commonly occur. Glauconite is common in certain beds. Phosphoritic nodules occur at some horizons. Ripples, cross-lamination and parting-lineation are all absent and trace fossils are rare. Fossils are normally restricted to individual concretionary horizons. Ammonites dominate and are followed less commonly by bivalves (oysters, *Buchia*) and belemnites. The facies is characteristic of parts or all of the following units: Kap Stewart Formation, Sortehat Member, Fossilbjerget Member, Olympen Formation, Hareelv Formation, Salix Dal Member and Crinoid Bjerg Member.

Interpretation

Absence of current-produced features suggests that the sediments were deposited from suspension in water. Deposition in marine environment is indicated by occasionally abundant marine fossils. The bottom may have been somewhat oxygen-deficient as the normal benthonic fauna appears to be generally absent.

Irregular shaly siltstones and silty sandstones

Description

The facies covers the range of grain sizes from medium siltstone to fine sandstone. The sediments have a large content of mica. Bedding is irregular owing to bioturbation, diagenesis and on occasion, current activity. Trace fossils are very abundant in a number of different associations. Calcareous and sideritic concretions are sometimes common. Glauconite is a characteristic constituent in some horizons. Fossils are normally abundant, sometimes occurring in large quantities. Ammonites dominate and are followed by bivalves, belemnites and gastropods. The facies is characteristic of parts or all of the following units: Sortehat Member, Fossilbjerget Member, Crinoid Bjerg Member.

Interpretation

Absence of current-produced features suggests that the sediment was deposited from suspension. The abundance of the benthonic fauna shows that the bottom was well oxygenated.

Ripple-laminated sandstone

Description

Silty- to medium-grained sandstone. There is sometimes an alternation between fine to medium sandstone and medium to coarse siltstone. The content of mica is rather large. The sedimentary structures comprise the wavy and lenticular bedding types (Reineck & Wunderlich, 1968; Sellwood, 1972, figs 8–9). Ripples are normally asymmetrical and may be reduced to isolated crests (figs 9, 10). Burrows are very common in several associations. Body fossils are rare. The facies is characteristic of the Gule Horn Member.

Interpretation

Both the flaser structures and the sandy laminae with silty drapes are probably related to intermittent current or wave activity and irregularity in the supply of sediment. The situation resembles sedimentation on Recent tidal flats. A discussion of comparable facies-types is given by Collinson (1969, p. 199–200).

Horizontally-bedded sandstone

Description

Covers a wide range of grain sizes from silty, fine sandstone to coarse and often conglomeratic sandstones. The content of mica is normally large. The grains are chiefly quartz, but in some cases a large content of feldspar is found. Many horizons are rich in glauconite. The beds are normally structureless, although thin-bedded, fine-grained sandstones often show parting-lineation. The degree of sorting is very variable. Pebbles show a preferred horizontal orientation in vertical sections. Thickness of beds varies from a few centimetres to 30–40 cm. Vertical and other burrows as well as other traces are common. Body fossils are normally quite rare and comprise ammonites, belemnites, bivalves and crinoids. The facies is characteristic of parts or all of the following units: Kap Stewart Formation, Gule Horn Member, Ostreaelv Member, Pelion Member, Olympen Formation, Raukelv Formation, Muslingeelv Member.

Interpretation

The occurrences of body fossils and trace fossils suggest deposition in a near-shore, marine environment. Only the arkoses of the Kap Stewart Formation were probably deposited in a fluviatile regime. The coarse layers presumably indicate strong traction currents.

Massive-bedded sandstone

Description

Variable grain size. Some beds are very well sorted whereas others are extremely coarse and pebbly. The grains are almost entirely quartz with occasionally larger quantities of mica. Glauconite is often present. The beds vary from 1 m to more than 30 m in thickness (figs 25, 27) and can often be followed over considerable distances (plate 8, fig. 2). The top surfaces of the massive beds are often erosive, impregnated with a ferruginous crust and penetrated by vertical burrows (fig. 22). Fossils are normally rare but at some horizons they may occur in large quantities. Ammonites dominate and are followed by bivalves and crinoids. The facies is characteristic of parts of the following units: Ostreaelv Member, Pelion Member, Olympen Formation, Hareelv Formation, Raukelv Formation, Muslingeelv Member.

Interpretation

The occurrence of body fossils and trace fossils shows that the depositional environment was marine. The very large grain size of some beds suggests deposition by powerful currents near a coast, but a more precise interpretation is not possible.

Medium-scale cross-bedded sandstone

Description

The grain size ranges from fine to extremely coarse pebbly sandstone, but the most common is rather well-sorted, medium-grained sandstone. The sandstones are normally composed of quartz but in the Kap Stewart Formation they are arkosic. Glauconite is common and the mica content is normally rather high. The sandstone is cross-bedded in sets from a few centimetres to several metres thick. The sets are tabular or trough-shaped and may form cosets up to 50 m in thickness. Foresets may be tangential, angular or asymptotical (figs 7, 11). Body fossils are very rare and almost restricted to ammonites whereas vertical burrows locally occur in abundance. The facies is characteristic of parts of the following units: Kap Stewart Formation, Neill Klinter Formation, Pelion Member, Fossilbjerget Member, Olympen Formation, Raukelv Formation, Muslingeelv Member.

Interpretation

The trace fossil assemblages and the rare ammonites indicate a marine depositional environment. The arkoses of the Kap Stewart Formation were presumably deposited in a fluviatile regime. The tabular sets and the trough sets are interpreted as the products of migration of straight-crested or linguoid bed forms. Local scouring appears to have been of minor importance as indicated by the lateral consistency of most sets.

Large-scale cross-bedded sandstone

Description

The grain size of this facies covers the range from medium to often extremely coarse, pebbly sandstone. The sandstone consists of quartz with a content of glauconite and mica. It is bedded in tabular or large-scale trough sets between 3 and 20 m thick (fig. 21). The lateral extent of the sets is up to 7–8 km in the direction of the foreset dip and often several kilometres perpendicular to this direction (fig. 35). The sets normally occur isolated but may form cosets comprising up to 4 sets. The foresets are planar, tangential or asymptotical (fig. 33). Tangential foresets with an upper horizontal erosion surface are the most common type. Body fossils are very rare and restricted to ammonites and oysters, whereas vertical burrows and other trace fossils are abundant. The facies is characteristic of parts of the following units: Pelion Member, Olympen Formation, Sjællandselv Member, Fynselv Member and Muslingeelv Member.

Interpretation

As mentioned by Jerzykiewicz (1967) the interpretation of large-scale cross-bedding by direct analogy with modern sedimentation is not yet possible for lack of geological publications dealing with such structures from marine basins. Collinson (1968) explains similar large-scale cross-bedding from the Upper Carboniferous of northern England as due to the advance of classical Gilbert-type deltaic sedimentation units into bodies of quiet water. The trace fossils and scarce ammonites and oysters indicate a marine depositional environment.

Black shales with lenticular sand-bodies

This facies type is only found in the Hareelv Formation in which it is characteristic. A description and interpretation is given on p. 45 (figs 27, 30; plate 8, fig. 1).

Coals

These are only of minor importance and are restricted to the Kap Stewart Formation. A description is given on p. 11.

DEPOSITIONAL ENVIRONMENT

We have attempted to give a general interpretation of the changing depositional regimes throughout the Jurassic of Jameson Land and Scoresby Land based on the spatial distribution of the different facies types, on the profiles (plate 11), and on investigations and measurements of heavy minerals (Bromley *et al.*, 1970), cross-bedding, parting-lineation, grain sizes and sand-shale ratios. The term basin is here understood as an area of deposition where relatively uniform tectonic and depositional conditions prevailed for long periods of time. The exact geographical positions of the borderlands and thus of the source areas of the sediments are rarely known, but the predominance of very coarse sediments and the large-scale sedimentary structures indicate a position very near to a coast. Only on Milne Land can direct evidence be seen of an Upper Jurassic transgression; Middle Oxfordian conglomeratic sandstones here overlie the deeply weathered crystalline basement.

In Rhaetic time the red-bed facies characteristic of the Triassic gave way to the light arkoses, shales and thin coal seams of the Kap Stewart Formation, marking a considerable climatic change from arid to humid conditions. Deposits from this period are found all over Jameson Land and Scoresby Land, but north of Antarctics Havn (fig. 1) they appear to be unknown. The subsidence of the depositional basin was greatest towards the north. The sediments were deposited mainly in the non-marine parts of large deltas and rivers. In the channels light arkoses show tabular and trough cross-bedding. In the quieter environment between the channels, silty shales and occasional coal seams were deposited. Both autochthonous and allochthonous coals occur, judging from the presence of root beds under some seams.

The sediments become more fine-grained towards the north-west and trace fossil assemblages and occasional fishes make their appearance, suggesting brackish–marine intercalations.

An important Liassic marine transgression submerged the whole of the Jameson Land–Scoresby Land area but again no deposits of that age have been found north of Antarctics Havn.

In the southern part of the area coarse beach sands and gravels with pavements of bivalves form the basal member of the Neill Klinter

Formation. These layers were deposited in a high-energy environment. They thin northwards and westwards and transport was chiefly in a northerly direction (cross-bedding). The overlying, more fine-grained sediments of the Gule Horn Member were presumably deposited in a shallow sea. The subsidence of the basin was largest towards the north. The deposition took place in a rather low- to medium-energy environment. Characteristic sedimentary structures are parting-lineation, all kinds of ripple-marks and cross-bedding. The sediments show great lateral variation. Channelling, changes from thin beds with parting-lineation to beds with linguoid ripple-marks, and antidune deposits may indicate deposition in an intertidal environment. Rich trace fossil assemblages are found whereas body fossils are practically missing.

These stable conditions changed towards the end of the Lias. Uplift in the source regions yielded large amounts of coarse, clastic sediments which were deposited under marine medium- and high-energy conditions. The cross-bedded, light sandstones of the Ostreaelv Member contain rich marine faunas, notably oysters and characteristic trace fossil assemblages. The direction of transport seems to be from north to south (cross-bedding) with a palaeoslope towards the south. Subsidence of the basin was rather uniform throughout the area.

While strong subsidence of the basin prevailed south of Kong Oscars Fjord during Rhaetic and Liassic time, deposits of this age appear to be lacking north of the fjord (DONOVAN, 1957). On the other hand Middle Jurassic deposits are developed very similarly both north and south of the fjord. This may suggest tectonic disturbance of the Kong Oscars Fjord region in early Jurassic time.

After a break in the sequence the sediments of the Neill Klinter Formation are followed by grey and black, silty shales of presumably Middle Jurassic age (Sortehat Member). The source areas were stable and the subsidence was uniform throughout the basin. The sea covered the whole of Jameson Land–Scoresby Land and northwards at least as far as Traill Ø. The shales were deposited under marine low-energy conditions and contain scattered oysters and belemnites and rich trace fossil assemblages. Directional structures are totally missing.

This period of stable conditions was again changed by strong uplift of the source areas especially towards the north. The uplift was probably followed by faulting activity. The sea now covered a far larger area than before as deposits from this period are found on the whole east coast of East Greenland from Jameson Land to Store Koldewey (76–77°) except for the Hold with Hope area ($73^1/_2$°), where the deposits are missing either due to non-deposition or to pre-Aptian erosion (DONOVAN, 1957). The subsidence of the basin was considerably greater towards the north. Thus, the Pelion Member sediments increase in thickness from only 10 m at the southern point of Jameson Land to about 900 m on Traill Ø ($72^1/_2$° N), although this increase is accounted for to a large degree by an upward diachronous transgression of facies. The grain size increases markedly from south to north, but the dominant sediments are well-sorted, medium sands to gravels.

The palaeoslope was consistently towards the south. Sedimentation here occurred under shallow sublittoral marine conditions and the succession contains many breaks. Towards the north sedimentation is characterized by the very large sediment supply from nearby source areas. Sedimentation took place in a high-energy environment with a cyclic alternation between coarser and finer horizons. Directions of transport seem to have been lateral from north-east and north-west and longitudinal in the central part of the basin (cross-bedding, heavy minerals), where the succession is more complete than in the south. It is perhaps worth stressing that the sedimentary history in this part of the column coincides with those periods of marine "regression" in north-west Europe which were reflected there in widespread deposits of deltaic facies (the "Estuarine Series" of Britain), followed by a return to marine conditions more or less in the Callovian.

The highest member of the Vardekløft Formation, the Fossilbjerget Member, represents a return to quieter conditions. The boundary between the sandy Pelion Member and the shaly Fossilbjerget Member is diachronous and gradual, since the finer-grained sediments were deposited towards the south and gradually encroached northwards with time, interrupted by occasional larger supplies of coarser material.

In Oxfordian time Milne Land to the south-west was transgressed by the sea for the first time, conglomerates and sandstones being deposited directly on the weathered crystalline basement (Charcot Bugt Sandstone). In the central Jameson Land area the sandstones of the Olympen Formation were transported mainly from north-east (sand–shale ratio). In Upper Oxfordian time the Jurassic transgression reached its maximum-known extent. Marine conditions extended from Milne Land over Jameson Land to Store Koldewey with the exception of the Hold with Hope area (see p. 70). The facies of the Hareelv Formation is dominantly one of marine, black and grey shales with minor sandstones. The uplift of the source areas was modest and the subsidence of the basin relatively uniform although somewhat larger towards north-east. The sedimentation of the Hareelv Formation of Upper Oxfordian–Middle Kimmeridgian age is, however, characterized by direct evidence of tectonic activity, which, towards the north, culminated in late Jurassic time with large-scale block-faulting and tilting (Maync, 1949). Throughout the uniform, black, marine shales there occur lenses or channel-fills of yellow sandstones. These sands were initially deposited in near-shore areas. However, they appear to have been subsequently mobilized, possibly by earthquakes, and to have slumped down-slope into the basin where they eroded and filled deep channels in the shales. The shock effect was followed by the intrusion of sandstone dykes and sills in the surrounding shales.

By the expulsion of water the sand settled with the development of flame structures along the sides of the sandstone lenses. Large, regularly shaped bodies of shale were incorporated in the basal part of the sandstones, indicating that the shale was already indurated and rigid when the erosion took place.

Tectonic activity apparently increased in Kimmeridgian/Volgian time. The uplift and faulting of the north-western borderland supplied the enormous amounts of coarse clastic sands and gravels represented by the Raukelv Formation (cross-bedding). Much of these sediments was deposited as huge cross-bedded fans, presumably in the marine part of a delta characterized by great differences in niveau and torrential sediment supply.

The sea still covered large areas on the East Greenland coast at this time but the sediments are everywhere of a very coarse nature.

In Jameson Land these unstable conditions culminated in a gentle folding of southernmost Jameson Land into a shallow syncline. The folding can be dated to later than the Upper Volgian *Subcraspedites* beds and before the Ryazanian *Hectoroceras–Praetollia* beds, corresponding to a period with strong faulting activity in the north-western areas. The break in sedimentation was very short and the synclinal trough was transgressed from the south in Ryazanian time. Deposition of the Hesteelv Formation starts with a thin basal conglomerate followed upwards by marine shales and sandstones. These sediments rest with tectonic overstep on the folded Jurassic rocks (plate 9, fig. 1). In many respects the sediments of the Lower Cretaceous are reminiscent of those of the Jurassic, but as they are separated by an angular unconformity the Hesteelv Formation is not included in the Jameson Land Group.

In conclusion it can be said that the Jurassic sediments of the Jameson Land Group were deposited in a marine basin covering still larger parts of the East Greenland coast. The source areas were situated towards the east and west. The eastern borderland, which produced enormous piedmont fans in Triassic time (PERCH-NIELSEN *et al.*, 1972), remained important during the Jurassic. However, towards the end of the Jurassic, the western borderlands became more important as suppliers of sediment as strong tectonic activity rejuvenated these areas. For most of the time the palaeoslope was towards the south.

The sediments alternate consistently between silty shales deposited in a low-energy marine environment and sandstones, gravels and conglomerates deposited in a near-shore high-energy environment. The basin is characterized by a considerable subsidence in the near-shore, brackish? areas towards the north where the most continuous succession is found. Towards the south thin marine fossiliferous shales, with many breaks, dominate the sequence. The basin is thus of the type known as a "clastic wedge".

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Plate 1

Figs 1, 2. *Decipia* sp. nov. ? aff. *decipiens* (J. SOWERBY)

This microconch species appears to be the same as that found in the Upper Calcareous Grit of Yorkshire, England, from which a specimen was figured by ARKELL, 1947, pl. 78, fig. 7. New Yorkshire material shows it to differ consistently from the true *D. decipiens*, a microconch of which was also illustrated by ARKELL, 1937, pl. F, figs 4 a, b. GGU No. 144129/1, 2, TB & JHC coll. 1971, Hareelv Formation, Falsterselv, north bank, 15 km east inland from Scoresby Sund coast, 88 m above sea level. Also common on the south slope of Astartekløft, Hurry Inlet, 639 m above sea level (bed 26, JHC coll. 1958). Approximately *P. cautisnigrae* Zone, Upper Oxfordian.

Fig. 3. *Amoeboceras* cf. *marstonense* SPATH or sp. aff.

Upper Oxfordian. GGU No. 143021, FS coll. 1971, Hareelv Formation, Katedralen, south bank of Ugleelv, 600 m above sea level.

Figs 4–8. *Amoeboceras* (*Amoebites*) cf. or aff. *rasenense* SPATH

All these forms are well enough preserved to be more closely identifiable when reliably dated reference collections have been worked out, either in Milne Land or in Europe. Figs 4, 5: examples of what seems to be a common and widespread species from the Lower Kimmeridgian, possibly *R. cymodoce* Zone. GGU No. 144179/2, 1, TB coll. 1971, Hareelv Formation, Jyllandselv, northern tributary, 18 km east inland from Scoresby Sund coast, 160 m above sea level. Figs 6, 7: probably slightly younger, *A. mutabilis* Zone? GGU No. 138134/1, 2, FS coll. 1970, Hareelv Formation, Astartekløft, 680 m above sea level. Fig. 8: GGU No. 138136, FS coll. 1970, Hareelv Formation, 500 m east of Ostreaelv, 551 m above sea level.

Fig. 9. *Rasenia* (*Rasenia*) *cymodoce* (D'ORBIGNY) (m)

Compares closely with similar specimens from Milne Land, Dorset (N. MORRIS coll., Oxford) and the lectotype of D'ORBIGNY's species (designated and refigured by LEMOINE, 1904, pl. 55, figs T2, T2a, T2b) which is the nucleus of a macroconch. GGU No. 144132/1, TB & JHC coll. 1971, Hareelv Formation, stream sections, $5^1/_2$ km south-west of Falsterselv at the locality of figs 1, 2. Lower Kimmeridgian, *R. cymodoce* Zone.

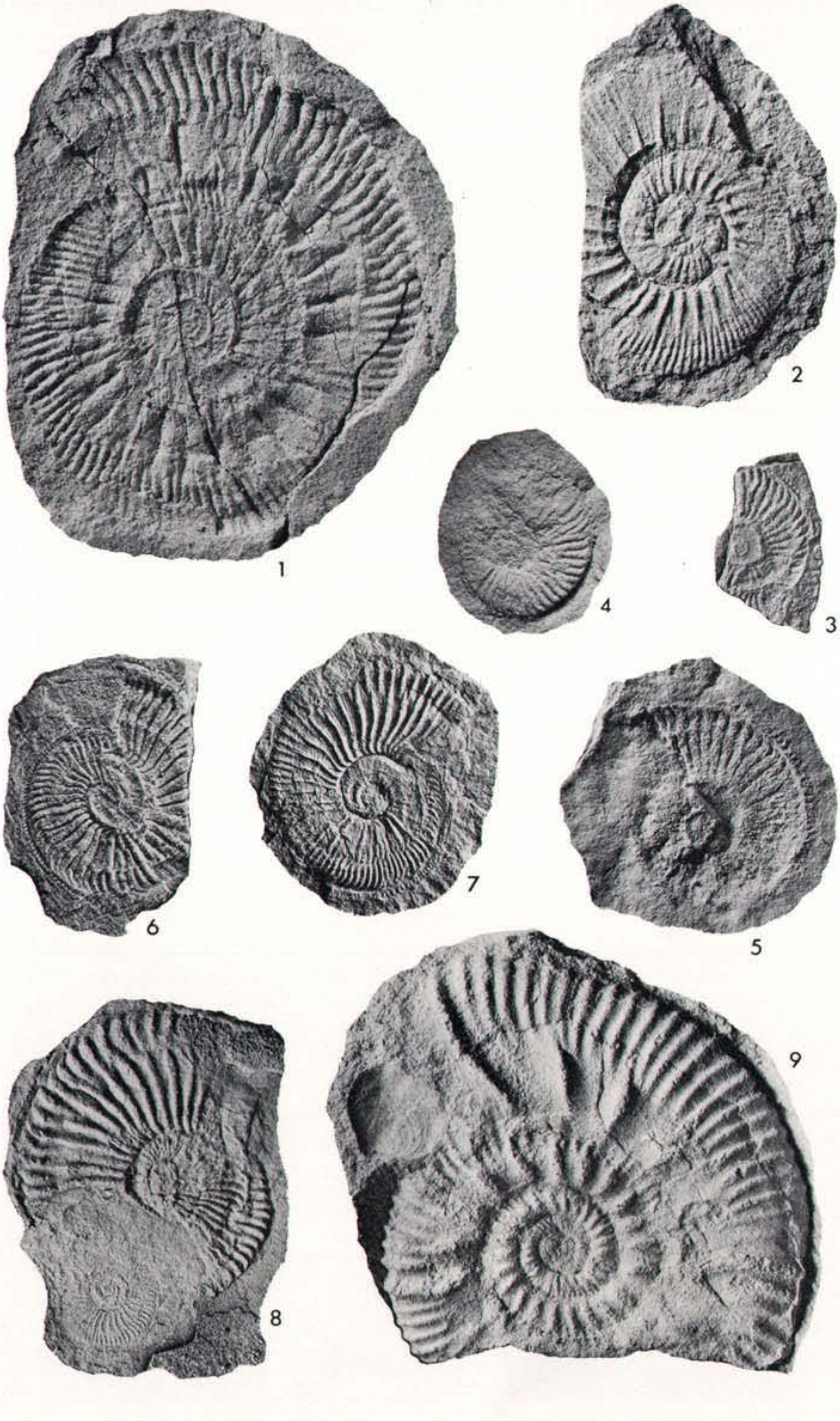


Plate 2

Figs 1 a, b. *Pavlovia (Crendonites)* sp.

Can probably be matched with material from Milne Land 'shales α' (ALDINGER, 1935) at the top of the Glauconitic Series just below the Hartzfjeld Sandstone. GGU No. 144156/1, TB coll. 1971, Salix Dal Member, Aucellaelv, west bank, 20 km east inland from Scoresby Sund coast, 305 m above sea level. Portlandian, *P. albani* or *G. gorei* Zones of the English succession.

Figs 2 a, b. *Pavlovia (Epipallasiceras)* aff. *costata* SPATH

Compares closely with SPATH, 1936, pl. 10, fig. 7; pl. 18, fig. 3; pl. 26, fig. 4, from Milne Land; and *P. (E.) pregorei* SPATH, 1936, pl. 22, fig. 2, and *P. (E.)* aff. *costata*, BUCKMAN, 1926, pl. 693 from the basal Portland Sand of Dorset. GGU No. 144156/2, TB coll. 1971, Salix Dal Member, same locality as fig. 1. Position in Milne Land: a few metres below the *P. (E.) pseudaperta* bed on a ridge south of Krebsedal. (ALDINGER, 1935). In England: Massive Bed, basal Portlandian, *P. albani* Zone. These forms are of the greatest importance for the correlation of the Upper Jurassic of Greenland and Europe.

1a 1b

2a 2b

Plate 3

Fig. 1. *Laugeites* cf. or aff. *vogulicus* (ILOVAISKY, 1917)

The species was published in the text of ILOVAISKY's monograph of 1917 (p. 67) with only a minimal description. It was to be illustrated on pl. xxii which, although printed, was never published (see ILOVAISKY, 1924, p. 338). There were some 20 syntypes: a lectotype was designated and figured by MIKHAILOV, 1966, pl. 19, fig. 2; pl. 20, fig. 2, together with a full description. The Russian material is said to come from the 'Zone of *Laugeites groenlandicus*'. GGU No. 144163, TB coll. 1971, Fynselv Member, Aucellaelv, east bank, 17 km east inland from Scoresby Sund coast, 245 m above sea level.

Fig. 2. *Subcraspedites* cf. *plicomphalus* (J. SOWERBY)

GGU No. 143113, FS coll. 1971, Fynselv Member, 1.5 km west of the western branch of Fynselv, 305 m above sea level. Upper Volgian.

Figs 3, 4. Aff. *Chetaites chetae* SHULGINA, 1962

Compare with SHULGINA in SACHS, ed., 1968, pl. 13, figs 3 a, b, c; pl. 14, fig. 2; pl. 16, figs 2 a, b. GGU No. 143158/1, 2, FS coll. 1971, Fynselv Member, eastern bank of the western branch of Fynselv, 105 m above sea level. Upper Volgian or Lower Ryazanian.

1

3

4

2

Plate 4

Figs 1, 2 a, b. *Hectoroceras kochi* SPATH

GGU No. 138186/2, 1, FS coll. 1970, Muslingeelv Member, eastern bank of Muslingeelv, 60 m above sea level. Two topotypes. Ryazanian.

Fig. 3. *Praetollia maynci* SPATH

GGU No. 138144, FS coll. 1970, Crinoid Bjerg Member, eastern bank of Muslingeelv, 68 m above sea level. In Jameson Land *Praetollia* and *Hectoroceras* are found together in some places, and must therefore have overlapping ranges and very similar ages. Ryazanian.

Fig. 4. *Surites* cf. or aff. *poreckoensis* SAZONOV, 1951

Compare with SAZONOV, 1951, p. 60, pl. 1, fig. 2. GGU No. 143066, FS coll. 1971, Hesteelv Formation, northernmost exposure, 1 km east of Muslingeelv, 300 m above sea level. Ryazanian.

Fig. 5. Cf. *Polyptychites mokschensis* (BOGOSLOVSKY)

Compare with DONOVAN, 1953, pl. 21, figs 3 a, b, from Traill Ø. GGU No. 143050, FS coll. 1971, 100 m west of the summit of J. P. Kochs Fjeld, 875 m above sea level. Valanginian?

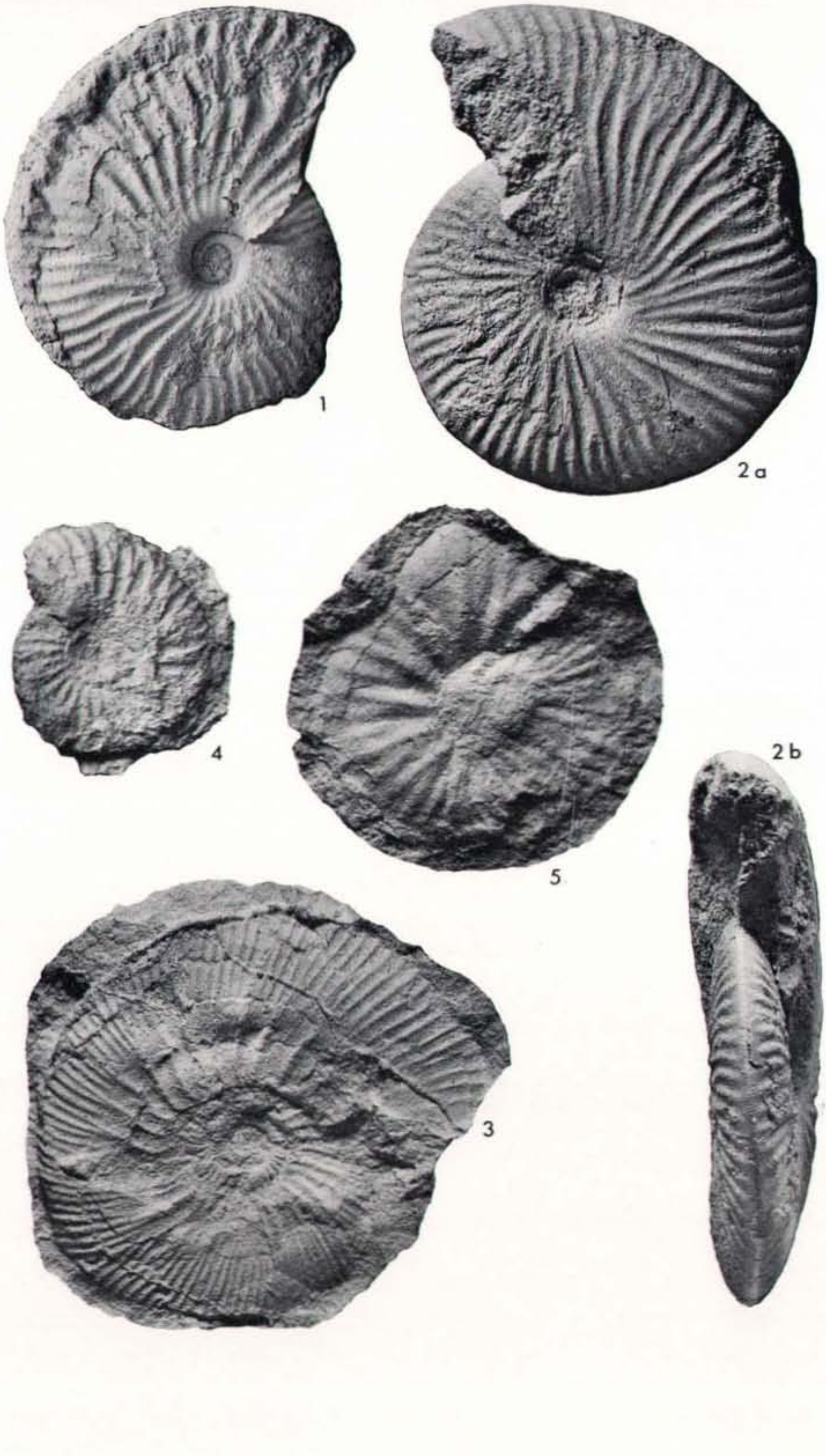

1
2a
4
5
2b
3

Plate 5

Vertical aerial photograph of the Ugleelv valley (fig. 1). 1 = Kap Stewart Formation. 2 = Neill Klinter Formation. 3 a = Sortehat Member of the Vardekløft Formation. 3 b = Pelion Member and Fossilbjerget Member of the Vardekløft Formation. 4 = Hareelv Formation. (Photo and copyright Geodetic Institute, Copenhagen, 284 T, 074, August 18th, 1969).


4
4
4
3b
3a
2
1

Plate 6

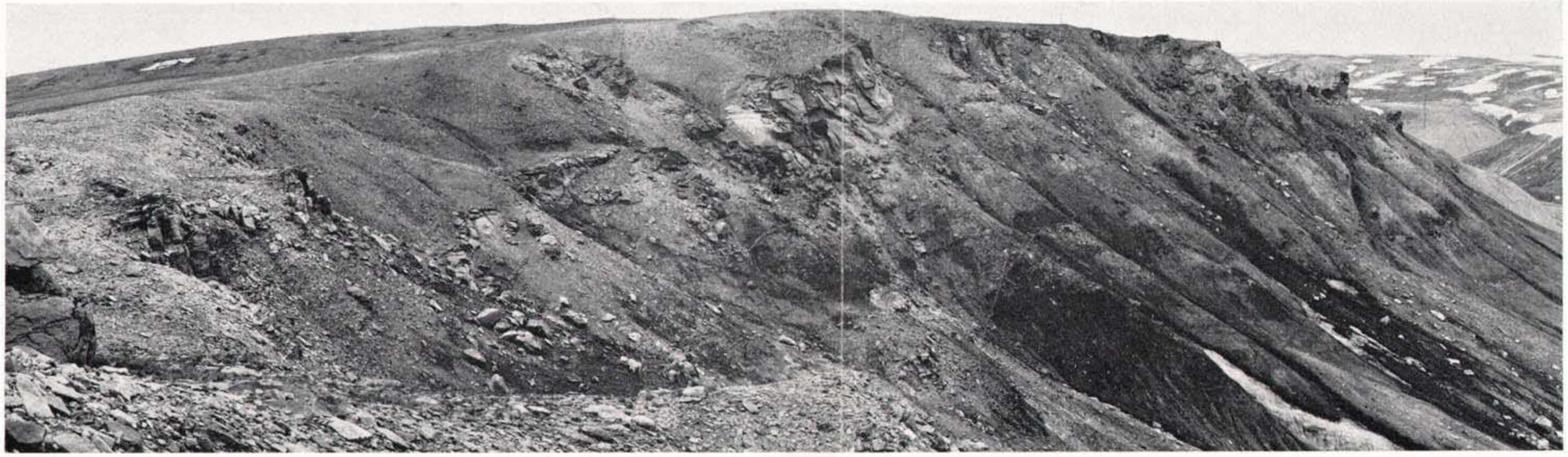
Oblique aerial photograph of the Ugleelv valley (same as plate 5) taken towards south-west. 1 = Kap Stewart Formation. 2 = Neill Klinter Formation. 3 = Vardekløft Formation. 4 = Hareelv Formation. (Photo and copyright Geodetic Institute, Copenhagen, 652 B-V, 11536, August 17th, 1950).


4
3
4
3
2
1
0
3
3
2

Plate 7

Oblique aerial photograph of the area south of Gule Horn (fig. 3). Taken towards west. 1 = Kap Stewart Formation. 2 = Neill Klinter Formation. 3 = Vardekløft Formation. (Photo and copyright Geodetic Institute, Copenhagen, 652 A-V, 12798, August 17th, 1950).


3
2
1
3
3
2

1


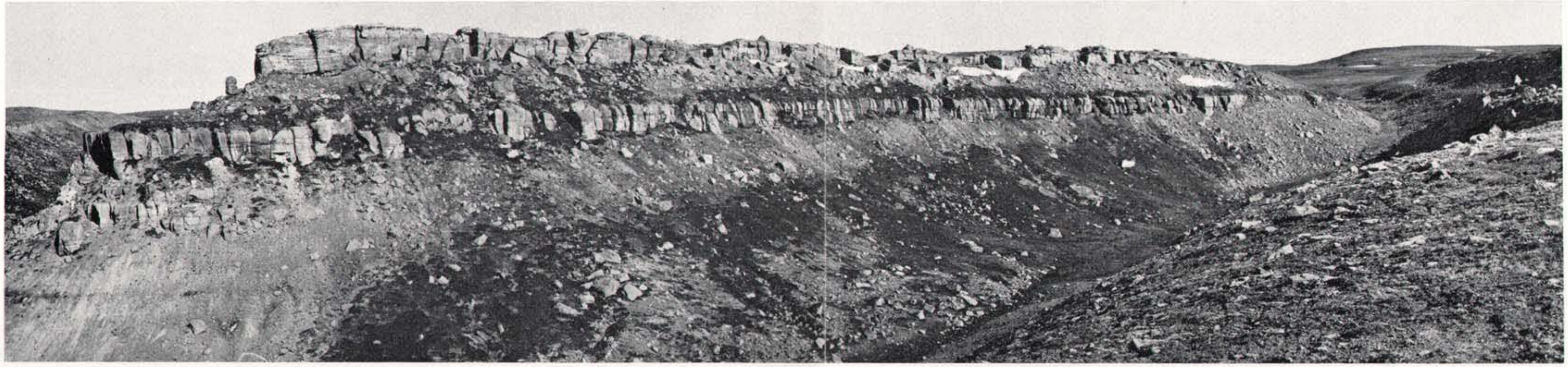
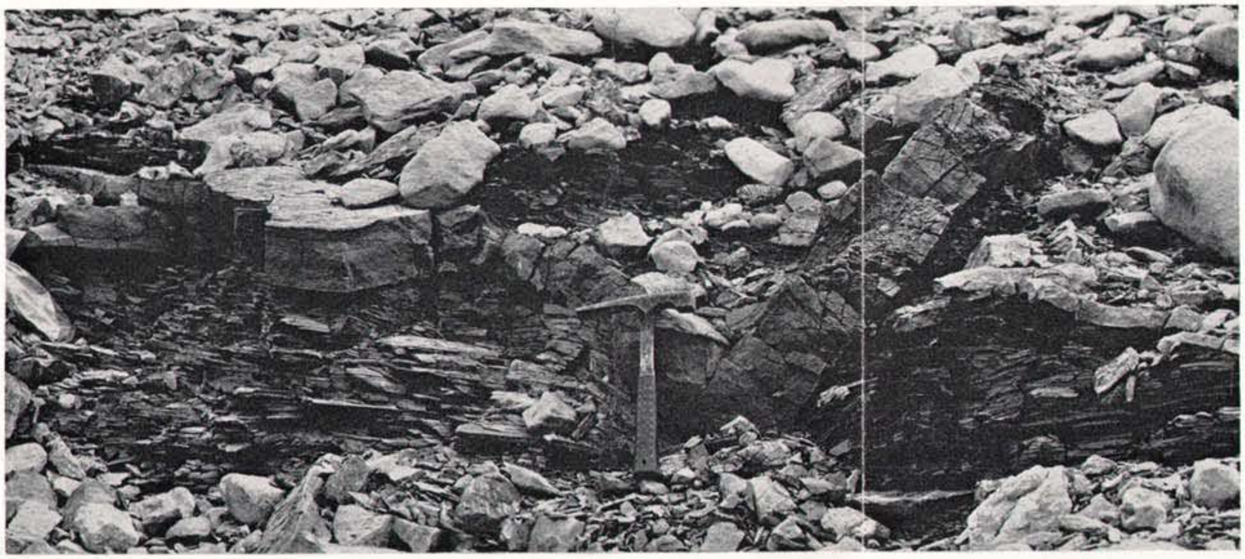
2


Fig. 1. Hareelv Formation, north slope of Katedralen (fig. 1). Massive sandstone bodies in black shales. A more detailed description of the lithology is given on p. 44.

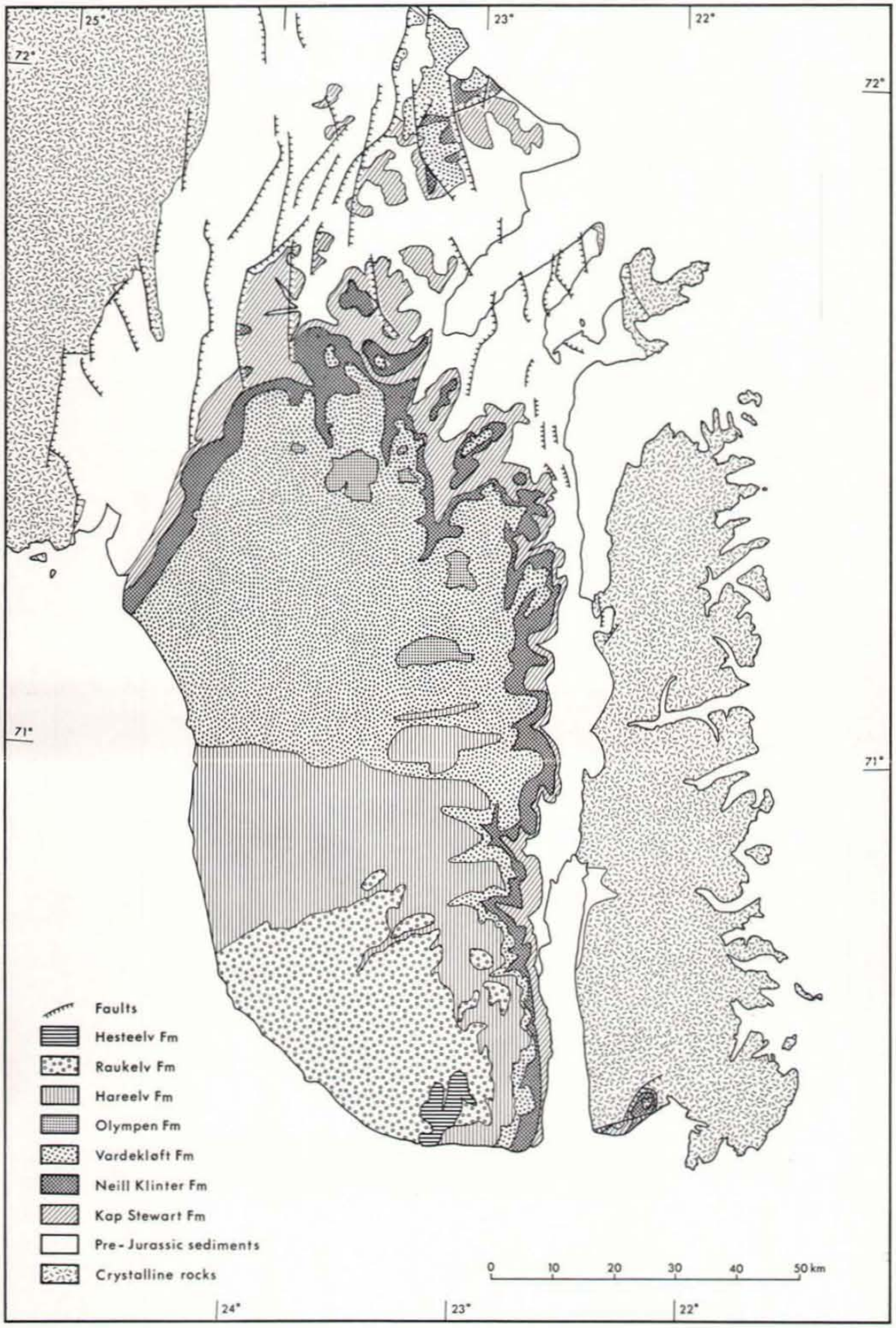
Fig. 2. Lower part of the Fynselv Member, Langelandselv (fig. 2). Note the continuity of the massive sandstone units. Each unit is approx. 10 m thick.



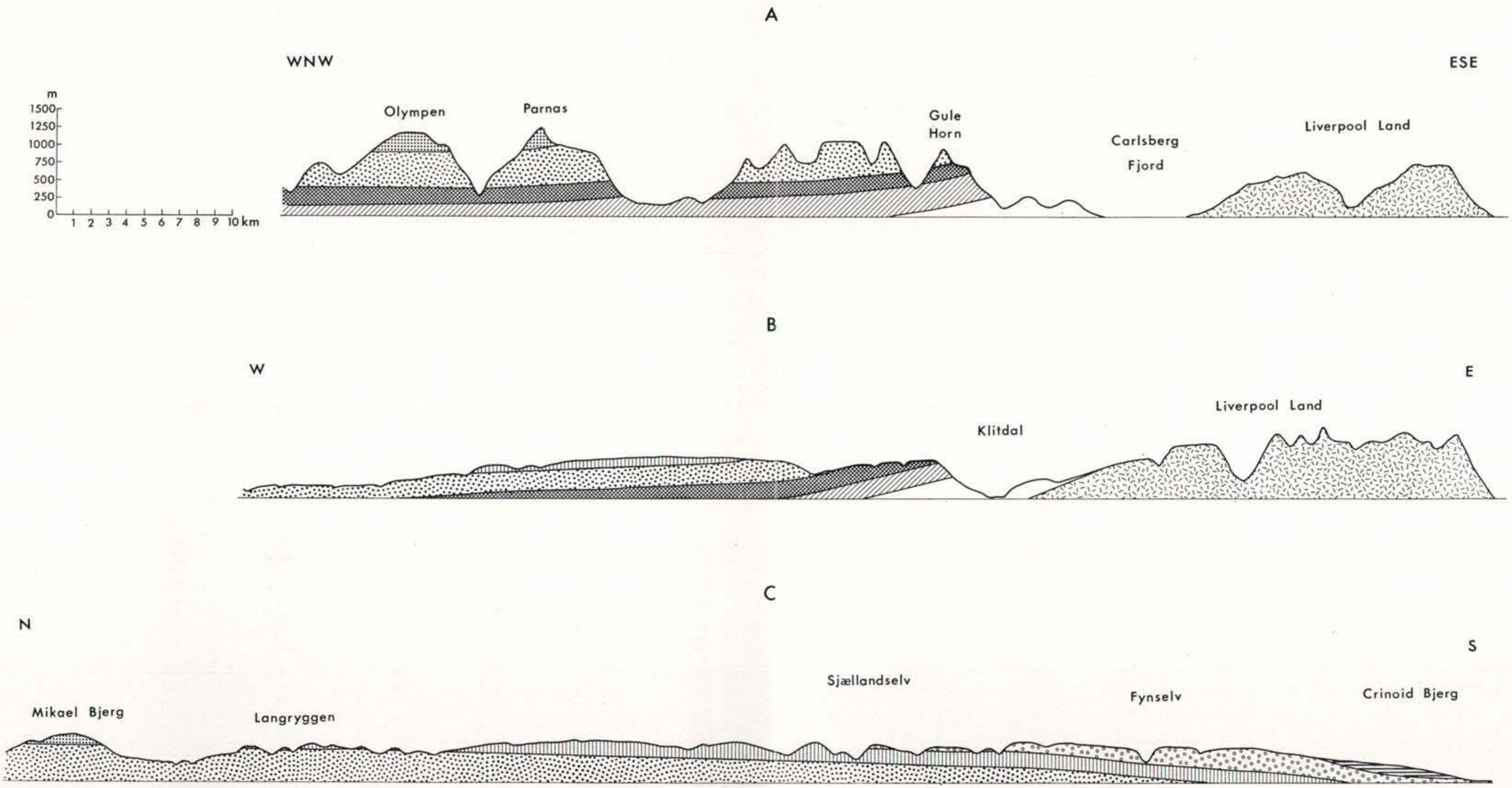
2

Fig. 1. Aerial photograph of southernmost Jameson Land, looking south-east. In the background to the right the plateau basalts south of Scoresby Sund and to the left the crystalline rocks of Liverpool Land. In the foreground the angular unconformity between the Lower Cretaceous Hesteelv Formation and the Jurassic Raukelv Formation is clearly seen. The white lines indicate the boundaries between the individual members. 1: Fynselv Member; 2: Crinoid Bjerg Member; 3: Muslingeelv Member. Note the overstep of the Muslingeelv Member on the Fynselv Member centrally in the figure.

Fig. 2. Hareelv Formation. Sandstone dyke and sill in black shale. Katedralen (fig. 1).



Simplified geological map of the Jurassic–Lower Cretaceous of Jameson Land and Scoresby Land. Small outcrops of Precambrian and Lower Palaeozoic sediments are included under the crystalline rocks. See SURLYK & BIRKELUND (1972) for a more detailed map.



Sections through Jameson Land and Liverpool Land. The positions of the sections are shown in fig. 1. Legend as for plate 10.