GRØNLANDS GEOLOGISKE UNDERSØGELSE
Bulletin No. 148

Upper Ordovician and Silurian carbonate shelf stratigraphy, facies and evolution, eastern North Greenland

by

John M. Hurst

KØBENHAVN 1984

Grønlands Geologiske Undersøgelse
(The Geological Survey of Greenland)
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Upper Ordovician and Silurian carbonate shelf stratigraphy, facies and evolution, eastern North Greenland

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Abstract

A new lithostratigraphic scheme is erected for the uppermost Ordovician and lower Silurian shelf carbonate rocks of Peary Land and Kronprins Christian Land, eastern North Greenland. All carbonate rocks were deposited on a fairly stable shelf which was bordered to the north and east by deep-water basins. The shelf foundered in the latest Llandoverian, terminating carbonate production.

Five formations and two members are defined and extend from the uppermost Ordovician (Cincinnatian) to the uppermost Llandoverian, or possibly lowermost Wenlock in the Silurian. Lithostratigraphic units include: *Turesø Formation* (new) composed of alternating light and dark grey peritidal to shallow subtidal laminated or massive dolomites, cryptalgal laminites and fenestral lime mudstones – uppermost Ordovician (Richmondian, Cincinnatian) to Lower or Middle Llandoverian; *Ymers Gletscher Formation* (new) composed of light grey peritidal lime mudstones, fenestral lime mudstones and cryptalgal laminites – Lower to Middle Llandoverian; *Odins Fjord Formation* (new) composed of shallow to deep subtidal dark lime mudstones, wackestones and commonly floatstone and rudstone biostromes – Middle (possibly Lower) to Upper Llandoverian; *Melville Land Member* (new) composed of light grey peritidal lime mudstones, fenestral lime mudstones and cryptalgal laminites – Middle (possibly Lower) Llandoverian; *Bure Iskappe Member* (new) composed of drowned shelf, dark grey to black laminated lime mudstone with terrigenous mudstone interbeds – Upper Llandoverian; *Samuelsen Høj Formation* (new) composed of light grey to white reef limestones – uppermost Llandoverian; *Harefjeld Formation* (new), a faulted, folded and cleaved black lime and terrigenous mudstone unit in eastern Kronprins Christian Land – Ordovician to Silurian (Llandoverian).

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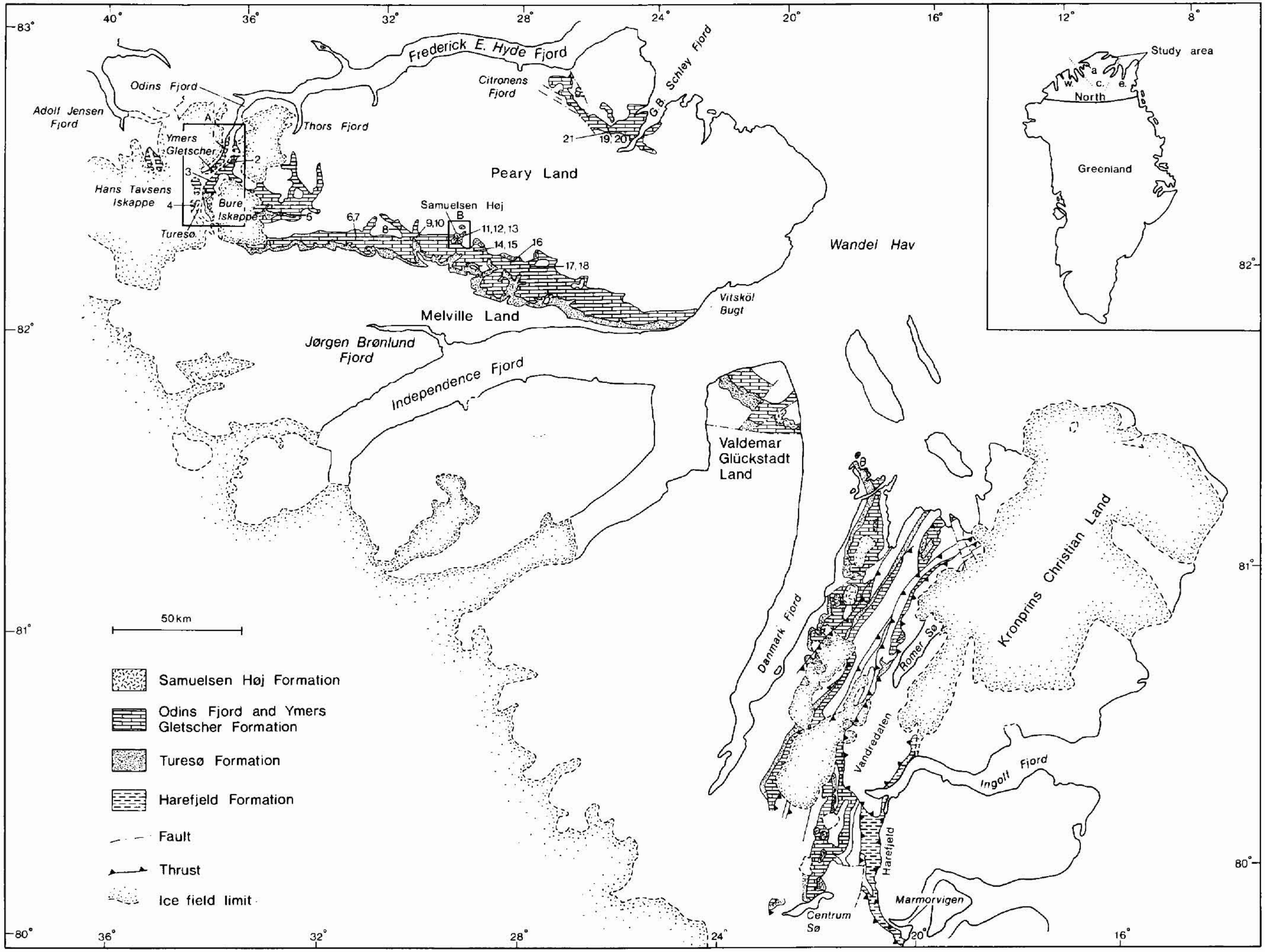

Frederick E. Hyde Fjord
Odins Fjord
Adolf Jensen Fjord
Ymers Gletscher
Thors Fjord
Citronens Fjord
G.B. Schley Fjord
Peary Land
Hans Tavsens Iskappe
Bure Iskappe
Turesø
Samuelsen Høj
Wandel Hav
Vitsköl Bugt
Melville Land
Jørgen Brønlund Fjord
Independence Fjord
Valdemar Glückstadt Land
Kronprins Christian Land
Danmark Fjord
Vandredalen
Romer Sø
Ingolf Fjord
Harefjeld
Marmorvigen
Centrum Sø
Study area
North
Greenland
50 km
Samuelsen Høj Formation
Odins Fjord and Ymers Gletscher Formation
Turesø Formation
Harefjeld Formation
Fault
Thrust
Ice field limit

INTRODUCTION

A new lithostratigraphical scheme is erected for the uppermost Ordovician and lower Silurian carbonate sediments deposited on the carbonate shelf of eastern North Greenland (figs 1, 2). The present-day outcrop of these sediments stretches eastwards from the valley to the south of Adolf Jensen Fjord, through southern Odins Fjord, the remainder of Peary Land, eastwards through northern Valdemar Glückstadt Land and southwards into Kronprins Christian Land (fig. 1).

The carbonate sediments were deposited on the eastern part of an extensive east–west trending carbonate shelf which persisted throughout the Lower Palaeozoic across North Greenland (Dawes, 1971, 1976; Hurst, 1980a; Hurst *et al.*, 1983; Hurst & Surlyk, 1983a, b, 1984; Surlyk & Hurst, 1983, 1984; Surlyk *et al.*, 1980). The shelf was bounded to the north by a deep-water basin in which terrigenous clastics were deposited (Friderichsen *et al.*, 1982; Hurst & Surlyk, 1982; Surlyk & Hurst, 1983, 1984; Surlyk *et al.*, 1980). The location of the northern shelf margin was controlled by a series of faults and lineaments and its position varied throughout the early Palaeozoic (Hurst & Surlyk, 1984; Surlyk & Hurst, 1983, 1984). The deep-water basin throughout North Greenland expanded by several episodes of carbonate shelf margin foundering resulting in the southward shift of the margin to new positions. During the latest Ordovician and early Silurian the shelf margin ran just to the south of and parallel with Frederick E. Hyde Fjord, between northern Odins Fjord and Citronens Fjord (figs 1, 3). A major episode of shelf foundering which occurred during the late Llandoverian to earliest Wenlock resulted in the complete drowning of the early Palaeozoic shelf (Hurst *et al.*, 1983). The foundering of this shelf resulted in an onlapping deep-water turbidite sequence which has obscured much of the immediate shelf margin and facies.

Fieldwork in eastern North Greenland was carried out between 1978 and 1980. In the summer of 1978, sections in the valley south of Adolf Jensen Fjord, Odins

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Fig. 1. Simplified geological map of easternmost North Greenland showing the distribution of the formations described in the text. Letters refer to geological maps in the text, including A (fig. 6) and B (fig. 56). Figures refer to sections in the text; 1 (fig. 32), 2 (fig. 9) 3 (fig. 33), 4 (fig. 8), 5 (fig. 30), 6 (fig. 10), 7 (fig. 11), 8 (fig. 34), 9 (fig. 12), 10 (fig. 13), 11 (fig. 58), 12 (fig. 35) 13 (fig. 59), 14 (fig. 37), 15 (fig. 39), 16 (fig. 37), 17 (fig. 14), 18 (fig. 15), 19 (figs 16, 17), 20 (fig. 40) and 21 (fig. 41). Based on the map in Grønlands Geologiske Undersøgelse Rapport 88 and 106. On inset map, w = western, c = central, and e = eastern North Greenland; a = J. P. Koch Fjord. Note that the Ymers Gletscher Formation does not occur in the G. B. Schley Fjord region of Peary Land or in Kronprins Christian Land. Also Silurian formations of the G. B. Schley Fjord region of Peary Land are undifferentiated.

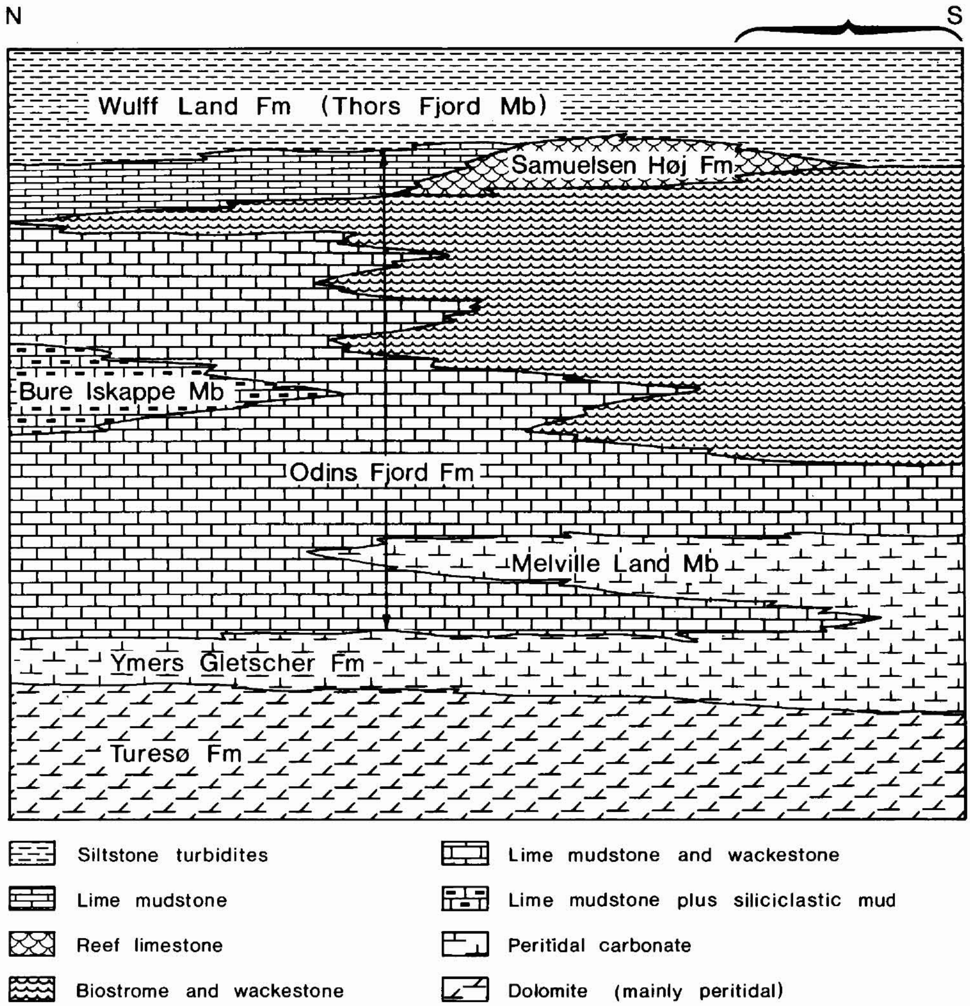


Fig. 2. Schematic diagram showing the main spatial distribution along a north to south transect through the Melville Land region of Peary Land of the main facies associations constituting the formations and members described in the text. Note that the southern part of the diagram is hypothetical (enclosed in brackets). In particular the vertical continuation of the Ymers Gletscher Formation into the Melville Land Member of the Odins Fjord Formation is based on the idea that peritidal environments fringed a southerly situated craton. Shelf margin reefs along the northern shelf margin are not shown as their exact temporal and spatial distribution is not known. Note that biostromal units are concentrated in the southerly part of the shelf. This does not imply that a separate biostromal member unit can be differentiated but simply an area more dominated by biostromal related facies types.

Fjord, Samuelsen Høj and G. B. Schley Fjord regions were examined during a total of approximately 2 months. In the summer of 1980 sections in western Kronprins Christian Land were examined for a total of 3 weeks.

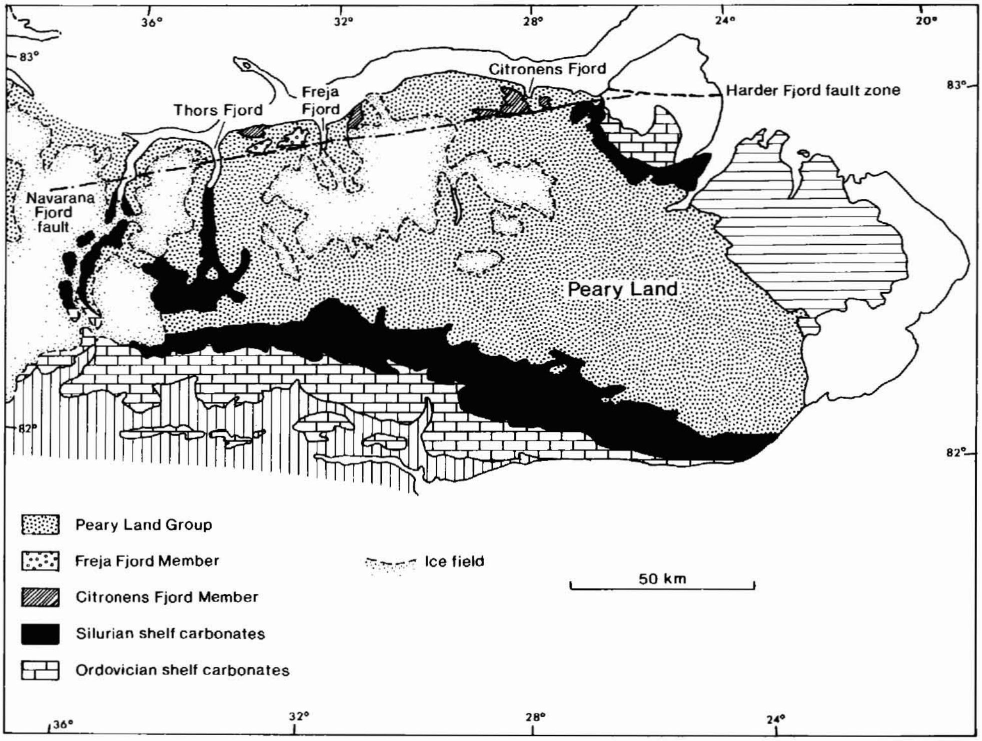


Fig. 3. Simplified geological map of Peary Land showing the surface trace of the deep-seated Navarana Fjord fault which controlled the northern margin of the Ordovician to Silurian carbonate shelf. This fault line was not active after deposition of the Peary Land Group, so that it does not displace these strata. Note the linear nature of the Navarana Fjord fault and the fact that shelf carbonates do not outcrop north of the fault. Base-of-slope conglomerates (Freja Fjord Member and Citronens Fjord Member) are derived from the shelf margin and provide specific information about an area of the shelf which is largely obscured.

Much of this report relies heavily on the measured sections and mapping by other geologists, including H. A. Armstrong (University of Newcastle, U. K.), R. L. Christie (Geological Survey of Canada), J. R. Ineson (University of Keele, U. K., now British Antarctic Survey), P. D. Lane (University of Keele), J. E. Mabillard (Shell, Netherlands), S. A. S. Pedersen (University of Copenhagen), J. S. Peel (Geological Survey of Greenland) and A. T. Thomas (University of Aston, U. K.), who visited central and eastern Peary Land, Valdemar Glückstadt Land and Kronprins Christian Land in the summers of 1978, 1979 and 1980. It should be noted that standard North Greenland geographical terminology, used by the Geological Survey of Greenland, is western, central, and eastern North Greenland (fig. 1). Peary Land and Kronprins Christian Land are part of central and eastern North

Greenland. For the convenience of this report they are referred to as eastern North Greenland (fig. 1).

Following an account of the previous work in the area, the succession of new units is discussed in ascending order. This is followed by a carbonate shelf evolution synthesis, and finally a comparison with contemporaneous sediments in western North Greenland (Hurst, 1980b) is made. This article supersedes all previous accounts of the Silurian stratigraphy of Peary Land and Kronprins Christian Land but, where necessary, the relationship of the old preliminary accounts to the present study is discussed.

PREVIOUS WORK

Following the 2nd Thule Expedition 1916–18, Koch (1918) produced a preliminary geological sketch map of North Greenland on which he located upper Ordovician and Silurian rocks in Peary Land and suggested areas which they may extend to. At this stage it was not known in detail what type of Silurian sediments occurred in Peary Land. Later, as the leader of the Bicentenary Jubilee Expedition 1920–23, Koch (1923a,b, 1924, 1925, 1929, 1935) proposed the first stratigraphic framework which partly encompassed Silurian carbonate sediments of Peary Land (fig. 4). Koch (1923a) recognised a succession of 1) Cryptozoan Limestone, 2) white limestone 100 m thick and devoid of fossils, 3) 400–500 m of greyish blue limestones with badly preserved fossils, 4) about 100 m of grey limestone in which *Maclurea* is common, and 5) 300 m of coral-bearing limestones with *Halysites, Calapaecia, Receptaculites,* and numerous other fossils. He was in no doubt that the latter unit was of Trenton age (late Ordovician). On a map produced in the same publication (Koch, 1923a) it can be inferred that, along the south coast of Peary Land (north coast of Independence Fjord; fig. 1), a unit he referred to as Coral and Graptolite Limestone occurred above the coral-bearing limestones and was thus presumably of Silurian age (fig. 4). In turn this unit was reported to be overlain by sandy shales.

Later Koch (1929) introduced several formation names for Lower Palaeozoic carbonate strata across North Greenland. The actual extent of some of these formations has been in doubt until Dawes & Haller (1979) published Koch's geological maps of North Greenland which had remained unpublished since his field work 50 years previously. Of particular interest is the Cape Calhoun Formation and Cape Tyson Formation (Koch, 1929). The former was equated with the Upper Ordovician (Dawes & Haller, 1979) and thus it can be inferred with the coral-bearing limestones and grey limestones of Koch (1923a; fig. 4). The Cape Tyson Formation is apparently equivalent to the Coral and Graptolite Limestone (Koch, 1923a; Dawes & Haller, 1979; fig. 4).

Subsequently Troelsen (1949) re-examined sections of Lower Palaeozoic carbonates around Jørgen Brønlund Fjord. He named several units, the highest of which, the Ordovician Børglum River Limestone, was equated precisely with the grey limestone of Koch (1923a). Later Troelsen (1956a,b) referred to undifferentiated Silurian sediments on a map of Peary Land (Troelsen, 1956b) and described a Cape Calhoun Formation and a Børglum River Formation (Troelsen, 1956a). It is intriguing that Troelsen (1956a) should describe both a Cape Calhoun Formation and a Børglum River Limestone when he must have been aware that Koch (1929) regarded the Cape Calhoun Formation as including coral-bearing limestone and grey limestone of Koch (1923a). Thus, the equating of the Børglum River Limestone with the grey limestones of Koch (1923a) indicates that the Cape Calhoun Formation and Børglum River Limestone partly overlap.

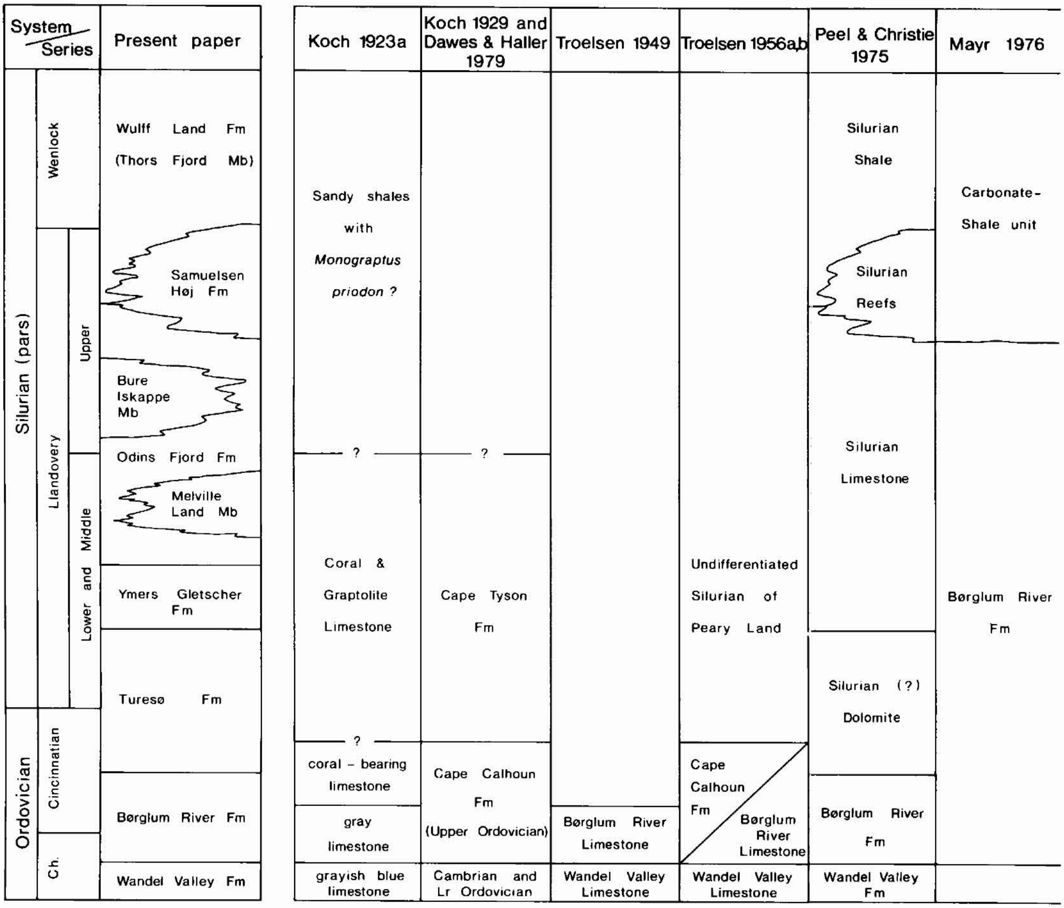
Up to this point the only activity of note concerning Silurian carbonates in Kronprins Christian Land was recorded by Nielsen (1941). As a member of the Danish Northeast Greenland Expedition 1938–39, Nielsen (1941) located 300 to 400 m thick, dark limestones of Gotlandian (Silurian) age, the faunas of which he briefly compared to species known from the Offley Island Formation of western North Greenland (Koch, 1929).

After these brief periods of activity the focus of early exploratory activity moved eastwards to Kronprins Christian Land. Adams & Cowie (1953) erected the Centrum Limestone for a sequence of 2–3 km thick carbonates of Ordovician to Silurian age. Later Fränkl (1955) introduced the term Drømmebjerg Limestone for a sequence of Silurian limestones above the Centrum Limestone. Subsequently, Scrutton (1975) termed these two units the Centrum Formation and Drømmebjerg Formation. Scrutton (1975) attributed the Drømmebjerg Formation to Fränkl (1955) and Cowie (1961). Comparing the maps of Fränkl (1955) and the localities used by Adams & Cowie (1953) it is apparent that the original Centrum Limestone included the Drømmebjerg Limestone.

Thus, until the last decade two entirely different lithostratigraphic nomenclatures were emerging for Lower Palaeozoic carbonate rocks in Peary Land and Kronprins Christian Land. In addition the Silurian carbonate rocks of Peary Land were essentially unknown (fig. 4).

Peel & Christie (1975) were the first to describe in some detail the Silurian sediments from the central part of Peary Land. Above the Ordovician Børglum River Formation they recognised a Silurian(?) dolomite unit (150 m thick), overlain by Silurian limestone (320 m thick) and Silurian reefs. This preliminary stratigraphic report was later substantially enlarged by Christie & Peel (1977; see fig. 4).

Following the exploration work of the Greenarctic Consortium (Canada), Dawes (1976) reported an Unnamed Limestone and Dolomite unit of Silurian age, overlain by shales, siltstones, and reefs in Peary Land. Almost simultaneously, Mayr (1976) produced an account of Silurian sediments, in particular aspects of reef development, from the Samuelsen Høj region of Peary Land (fig. 4). This account was based on field work in 1972 under Greenarctic Consortium exploration ac-



tivities. He extended the Børglum River Formation to include all level-bedded carbonates of Silurian age. Mayr (1976) also recognised an 'Unnamed carbonate–shale unit' which was considered to be of Wenlock to Ludlow age. The carbonates of this unit are in fact reef knolls surrounded by terrigenous mudstones; the latter were termed the Wulff Land Formation (Thors Fjord Member) by Hurst & Surlyk (1982).

The first comprehensive account of the Silurian strata of Peary Land was given by Christie & Peel (1977). They recognised an 'Un-named Silurian(?) dolomite formation' of 150 m thickness above the Ordovician Børglum River Formation (fig. 4). This unit they sub-divided into two members. Above the dolomites they recognised an 'Un-named Silurian limestone formation' which was sub-divided into six members, A to F inclusive, which were considered to be of early Silurian age (early or middle Llandoverian to late Llandoverian). These two units were in-

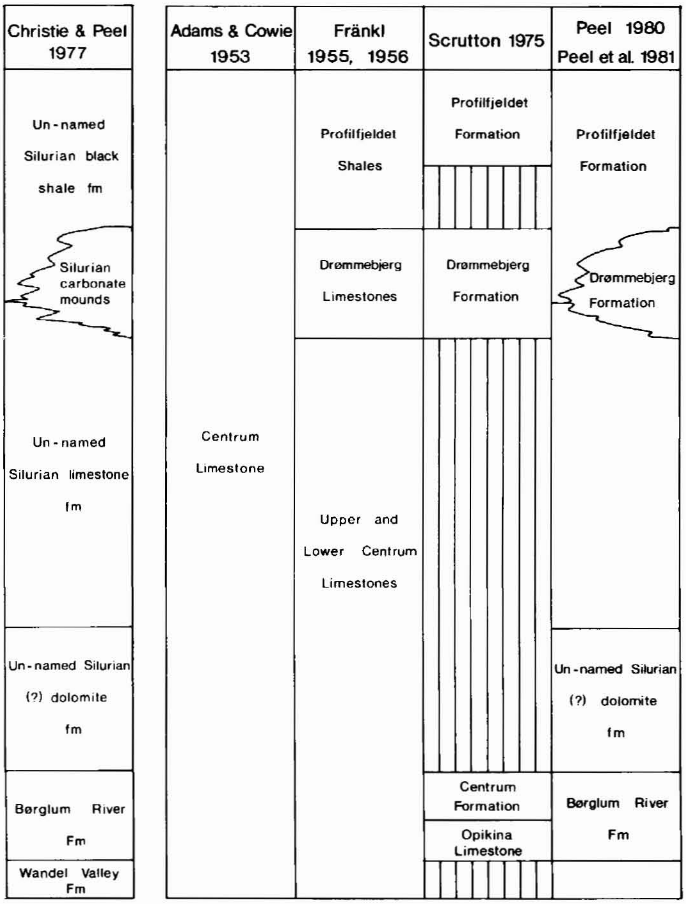


Fig. 4. Previous and present lithostratigraphic schemes erected to cover the carbonate shelf sediments of Peary Land. The middle block of columns relates to Peary Land and the right hand block of columns to Kronprins Christian Land. Ch = Champlainian.

cluded by Mayr (1976) in the Børglum River Formation. The Silurian reefs Christie & Peel (1977) referred to as Silurian carbonate mounds (fig. 4).

The most recent work on the carbonate strata of eastern North Greenland was under the auspices of a three year expedition mounted by the Geological Survey of Greenland during the summers of 1978, 1979 and 1980. As a result of these activities a more detailed picture is emerging concerning the facies, thickness and age variation of the Silurian carbonates of southern Peary Land and Kronprins Christian Land (Aldridge, 1979; Armstrong & Lane, 1981; Boucot & Hurst, 1979; Christie & Ineson, 1979; Hurst, 1979; Hurst & McKerrow, 1981a, b; Lane & Peel, 1980; Lane & Thomas, 1979; Mabillard, 1980; Pedersen, 1979; Peel, 1980; Peel *et al.*, 1981). A recent survey of the status of Lower Palaeozoic stratigraphy of North Greenland, including the Silurian, may be found in Peel (1982, 1984).

A most important point arising from this work is the demonstration by Peel

(1980) that the Lower Palaeozoic carbonate sequences of Peary Land and Kronprins Christian Land are essentially the same (cf. Peel *et al.*, 1981). Further, the so-called Centrum Limestone of Adams & Cowie (1953) was shown to include units which were repeated several times by thrusting, demonstrating that the originally proposed thickness of 2 to 3 km was a large overestimate (Hurst & McKerrow, 1981a, b; Peel, 1980; Peel *et al.*, 1981). Thus, Peel *et al.* (1981) recommended that the term Centrum Limestone be discontinued and the lithostratigraphy of Kronprins Christian Land be described in terms of the Peary Land scheme.

LITHOSTRATIGRAPHY

All sedimentary logs of the type and reference sections in the text are standardised by the author (fig. 5). Description of each lithostratigraphic unit is based on field characteristics together with thin section analysis. In the field detailed bed measurements and characteristics were taken and sediment samples were collected at standardised intervals of between 1 and 10 m. A closer sampling grid was undertaken through obviously highly variable sections. All the sections in Odins Fjord and at Samuelsen Høj were measured by the author. Other sections included in this report were measured by R. L. Christie, J. R. Ineson, J. E. Mabillard, S. A. S. Pedersen and J. S. Peel and were standardised according to the style employed by the author. Facies descriptions of sediments follow the classification of Dunham (1962) as modified by Embry & Klovan (1971).

The biostratigraphic scheme is based primarily on conodonts, brachiopods, corals, gastropods and graptolites. In particular the conodont work on these sections has been largely undertaken by H.A. Armstrong (University of Newcastle, U.K.), as part of a larger study concerned with upper Ordovician and Silurian conodont biostratigraphy of North Greenland (Armstrong, 1983; Armstrong & Aldridge, 1982). It is strongly emphasised that the conodont information included in the biostratigraphic sections of this report is drawn entirely from the work of Armstrong.

In the chronostratigraphic scheme, North American series and stages are used in the Ordovician, whilst the British standard series and stages are used in the Silurian. It is impossible to relate with any degree of certainty strata to the Llandoverian stages, so it is emphasised that Llandoverian stages are only used tentatively.

The individual lithostratigraphic units are described in ascending order. The Harefjeld Formation which is contained on the thrust sheets of Kronprins Christian Land is described last. It is emphasised that, apart from the Harefjeld Formation, the lithologic descriptions of the formations are based on Peary Land which is the least deformed and best known area.

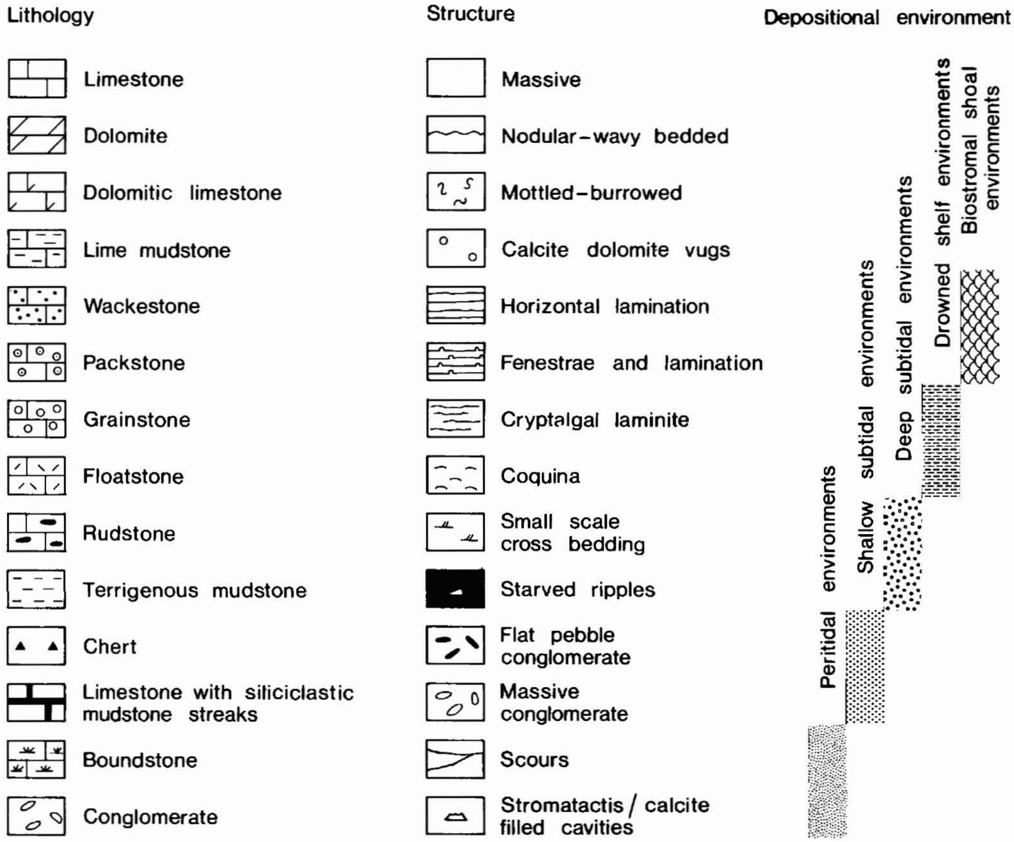


Fig. 5. Legend covering all figured sections in the text. The stepped nature of the right hand line of the sedimentary structure column seen in the sections is not meant to indicate a precise grain size scale as is customary when depicting terrigenous clastic sediments. The stepped nature of this line is a gross characterisation of grain size whilst taking into account the weathering characteristics of the sediments. With the floatstone and rudstone units a split in the lithological column is made, the left hand side of which depicts the interstitial microfacies of the floatstone or rudstone unit. The depositional environments are very broadly defined and as shown on the sections mask a good deal of variation. They are not intended to show all intricate changes but to give a broad idea of the interpretation of the facies. Reef environments (Samuelsen Høj Formation) are excluded because they are highly variable.

Turesø Formation

new formation

History. The formation probably partly corresponds to the Cape Calhoun Formation and Cape Tyson Formation of Koch (1929). In Kronprins Christian Land this unit was included in the embracive Centrum Limestone (Adams & Cowie, 1953). Mayr (1976) included the strata of the Turesø Formation in an expanded Børglum River Formation (fig. 4). It corresponds in part to the Unnamed Limestone and Dolomite unit in Peary Land of Dawes (1976) and to the Silurian(?) dolomite of Peel & Christie

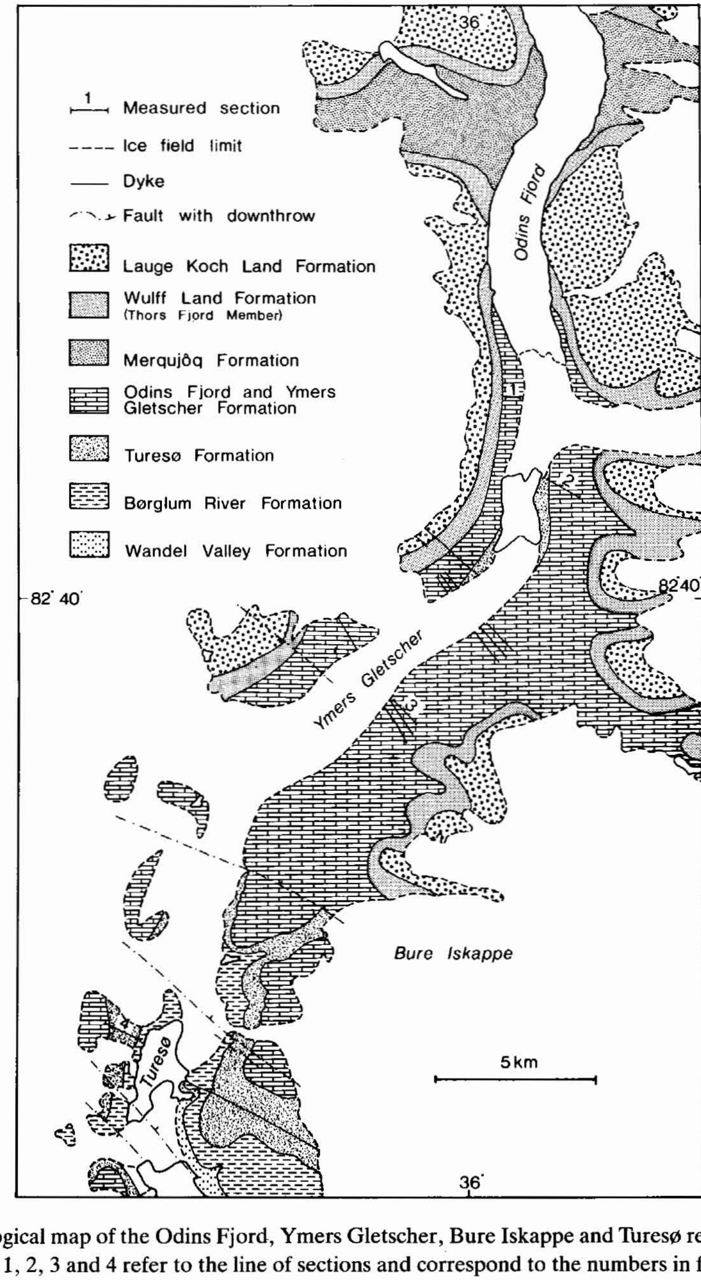


Fig. 6. Geological map of the Odins Fjord, Ymers Gletscher, Bure Iskappe and Turesø region (A on fig. 1). Numbers 1, 2, 3 and 4 refer to the line of sections and correspond to the numbers in fig. 1. Section 1 (fig. 32) is the type section of the Bure Iskappe Member. Section 2 (fig. 9) is the type section of the Ymers Gletscher Formation and Odins Fjord Formation. Section 3 (fig. 33) is a reference section for the Odins Fjord Formation and Bure Iskappe Member. Section 4 (fig. 8) is the type section of the Turesø Formation. The Ymers Gletscher Formation occurs as a thin band at the base of the Odins Fjord Formation. Aerial photographs of these sections are shown in figs 7, 29.

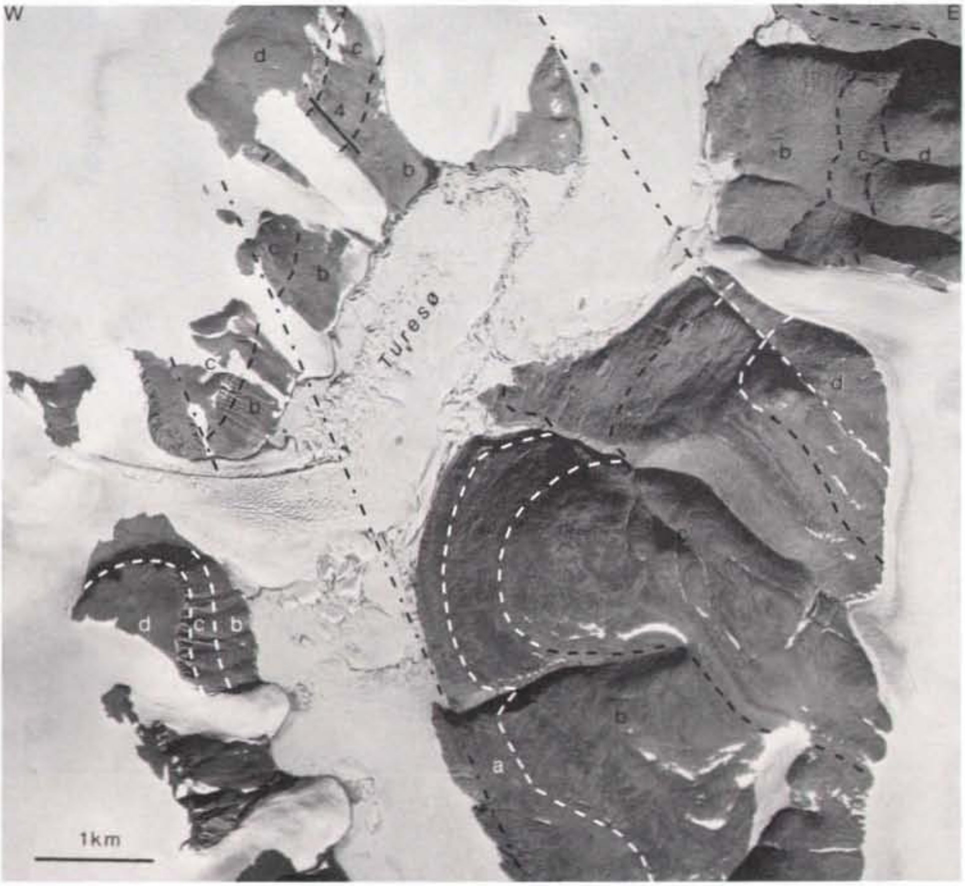


Fig. 7. Vertical aerial photograph, with the geology superimposed, of the area around Turesø (figs 1, 6). Note the location of the type section of the Turesø Formation at 4 (figs 6, 8). Ordovician Wandel Valley Formation (a), Ordovician Børglum River Formation (b), Turesø Formation (c), Ymers Gletscher Formation and Odins Fjord Formation (d). The Ymers Gletscher Formation occurs as a thin band at the base of the Odins Fjord Formation. All geological symbols as in fig. 6. Aerial photograph 256G, No. 692. Copyright Geodætisk Institut, Denmark.

(1975), the 'Un-named Silurian(?) dolomite formation' of Christie & Peel (1977), and the 'Un-named Silurian(?) dolomite formation' of the Odins Fjord region (Hurst, 1979).

Name. From Turesø, an ice-covered lake situated between Bure Iskappe and Hans Tavsens Iskappe, due south of Odins Fjord and Ymers Gletscher (figs 1, 6, 7).

Type and reference sections. The type section is on the western side of the northern end of Turesø (figs 6, 7, 8) and reference sections are located northwards on the eastern side of Ymers Gletscher and throughout Peary Land (figs 8–17).

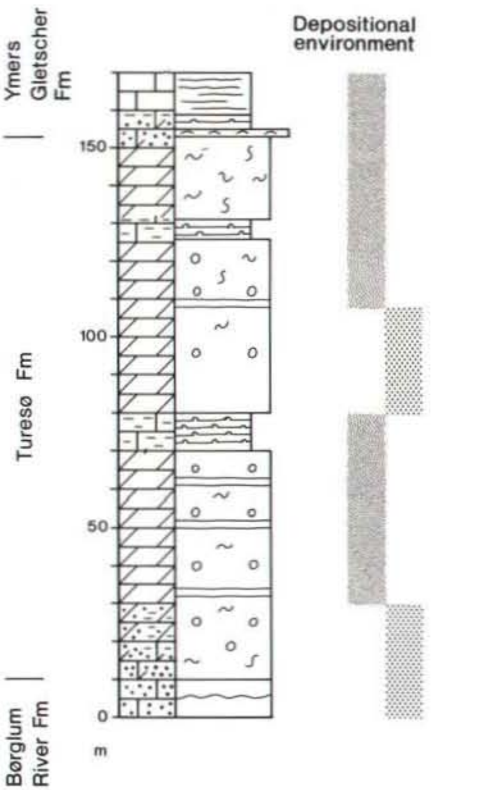
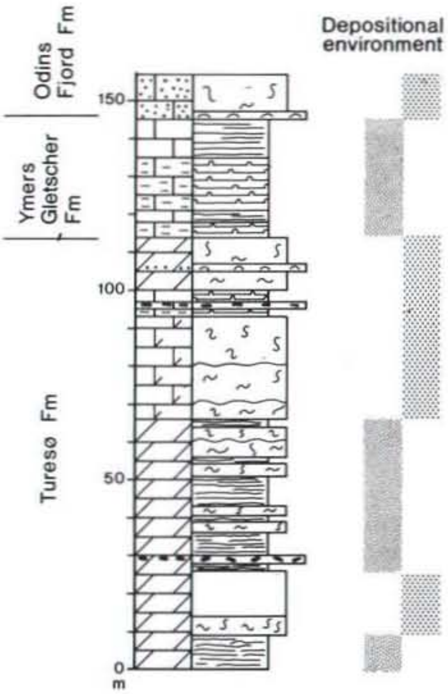


Fig. 8. Sediment log of the Turesø Formation type section. For location of section see figs 1, 6, 7, 20. Symbols shown in fig. 5. Location 4 on figs 1, 6, 7. Co-ordinates WS 33 72 on GGU photomosaic sheet 82 NC.



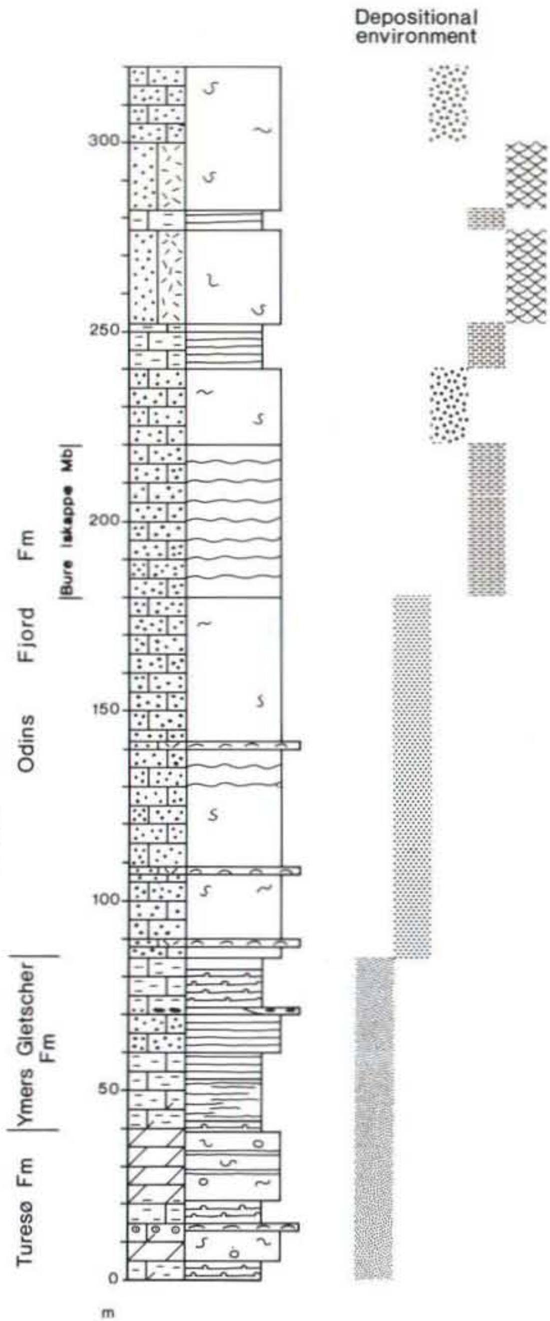


Fig. 9. Sediment log of the type section of the Ymers Gletscher Formation and Odins Fjord Formation. For location of section see figs 1, 6, 18, 29. Symbols shown in fig. 5. Location 2 on figs 1, 6. Co-ordinates WS 43 83 on GGU photomosaic sheet 82 NC.

◄ Fig. 10. Sediment log of the Turesø Formation and Ymers Gletscher Formation in a reference section in Peary Land (location 6 on fig. 1; see also Pedersen, 1982). Symbols shown in fig. 5. Primary section measurement by S. A. S. Pedersen. Co-ordinates XS 005 627 to 004 620 on GGU photomosaic sheet 82 SF.

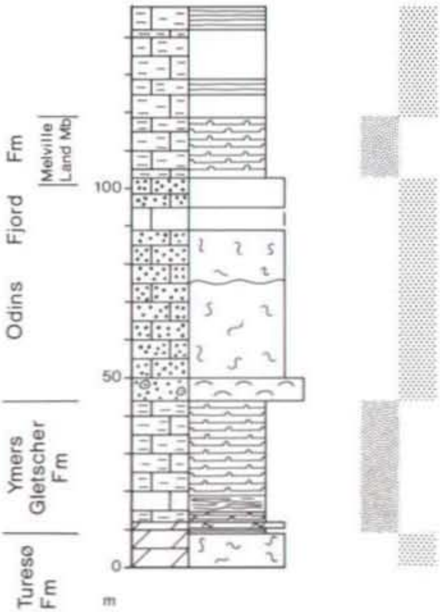
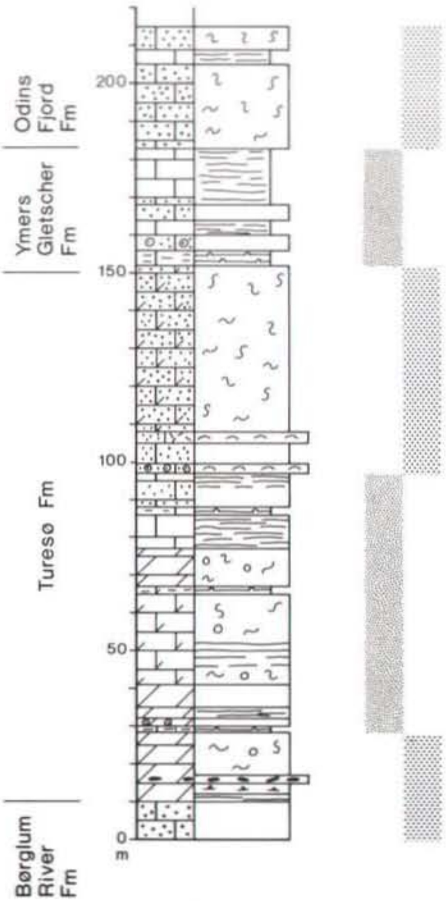


Fig. 11. Sediment log of a reference section of the Ymers Gletscher Formation, Odins Fjord Formation and Melville Land Member (location 7 on fig. 1). Symbols shown in fig. 5. Primary section measurement by S. A. S. Pedersen (1982). Co-ordinates XS 009 625 to XS 017 629 on GGU photomosaic sheet 82 SF.



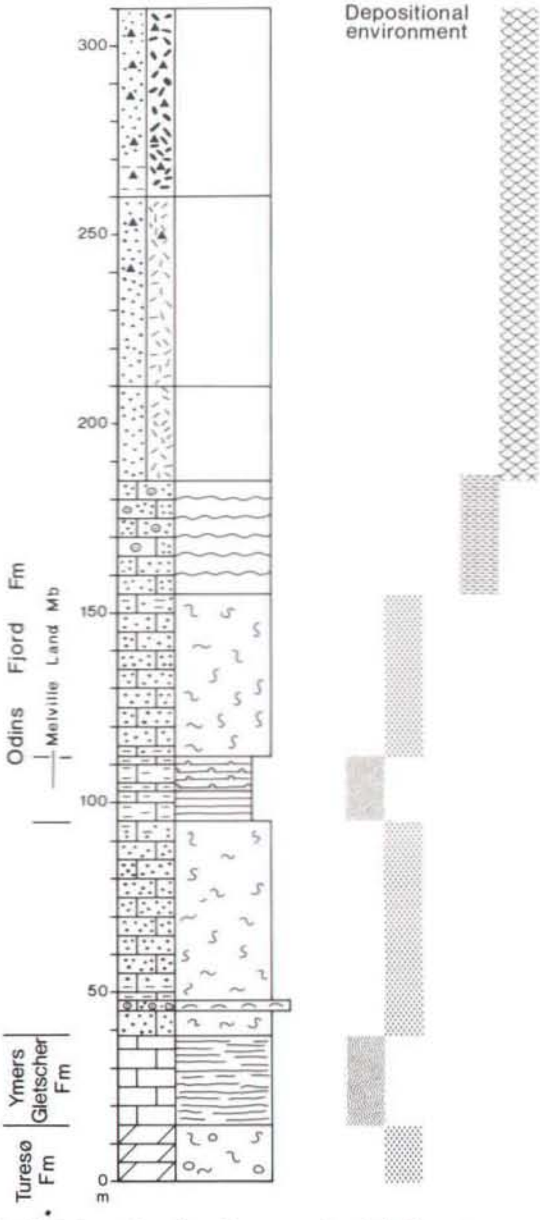


Fig. 13. Sediment log of a reference section of the Turesø Formation, Ymers Gletscher Formation, Odins Fjord Formation, and Melville Land Member in Peary Land near Børglum Elv (location 10 on fig. 1). Symbols shown in fig. 5. Primary section measured by J. E. Mabillard. Co-ordinates UM 20 68 on GGU photomosaic sheet 82 SG.

◄ Fig. 12. Sediment log of a reference section of the Turesø Formation and Ymers Gletscher Formation in Peary Land near Børglum Elv (location 9 on fig. 1; see also Christie & Peel, 1977, section G). Symbols shown in fig. 5. Primary section measured by R. L. Christie and J. S. Peel.

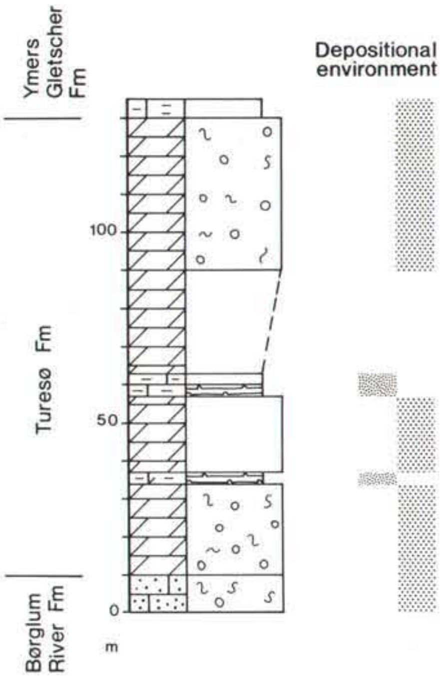


Fig. 14. Sediment log of a reference section of the Turesø Formation in the Melville Land region of Peary Land (location 17 on fig. 1). Symbols shown in fig. 5. Primary section measured by J. E. Mabillard. Co-ordinates UM 93 49 on GGU photomosaic sheet 82 SG.

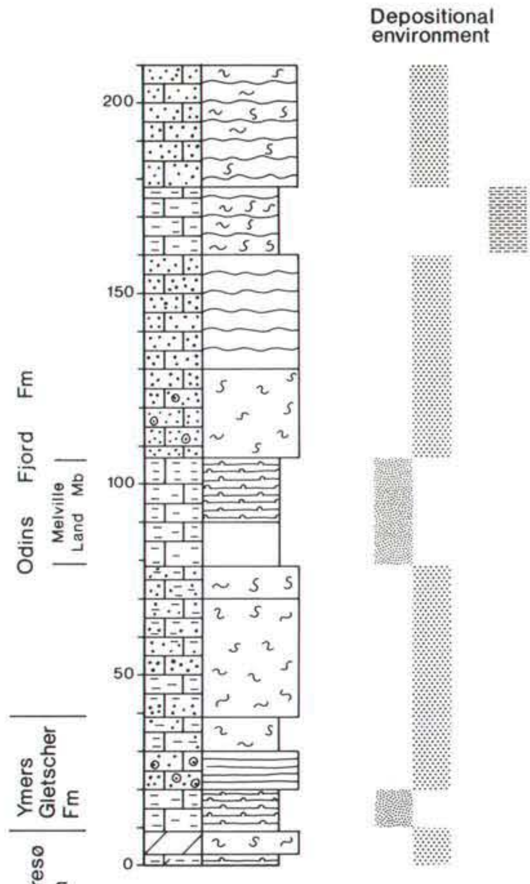


Fig. 15. Sediment log of a reference section of the top of the Turesø Formation, Ymers Gletscher Formation, Odins Fjord Formation and the type section of the Melville Land Member in the Melville Land region of Peary Land (location 18 on fig. 1). Symbols shown in fig. 5. Primary section measured by J. E. Mabillard. Co-ordinates UM 96 54 on GGU photomosaic sheet 82 SG.

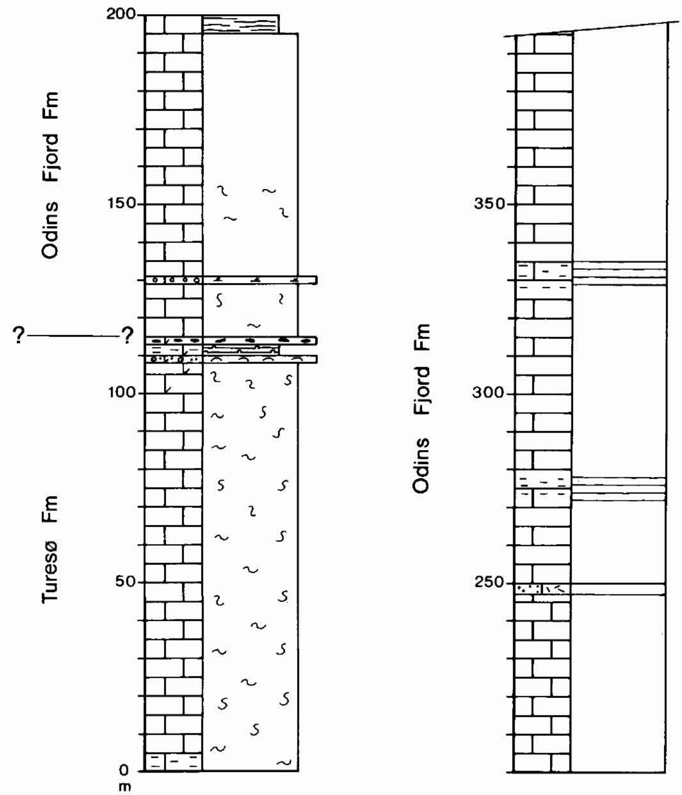


Fig. 16. Sediment log of a reference section of the Turesø Formation and Odins Fjord Formation in the G. B. Schley Fjord region of Peary Land (location 19 on fig. 1). Note sediments are only tentatively assigned to the Turesø Formation and top of the section is faulted. The placement of the top boundary of the Turesø Formation is also questionable. Symbols shown in fig. 5. Primary section measured by R. L. Christie and J. R. Ineson. Co-ordinates VN 373 082 to VN 363 060 on GGU photomosaic sheet 82 NE.

Thickness. Between 115 and 150 m in Peary Land, whereas in Kronprins Christian Land it is at least 200 m thick (Hurst *et al.*, in press; Peel, in press; Peel, 1982, 1984). There does not appear to be any systematic thickness variation of the formation in Peary Land. Armstrong & Lane (1981) report a thickness of only 95 m for the formation in Børglum Elv. This figure is at variance with Christie & Peel (1977), Mabillard (1980) and myself who record a thickness of approximately 150 m.

Lithology. The formation is characterised by medium to thick-bedded (10–100 cm) dolomite and limy dolomite which weather into small cliff-like benches or recessive scree slopes (figs 18, 19). On both fresh and weathered surfaces, the rocks are generally grey and in some horizons a distinctive alternation of light and dark grey

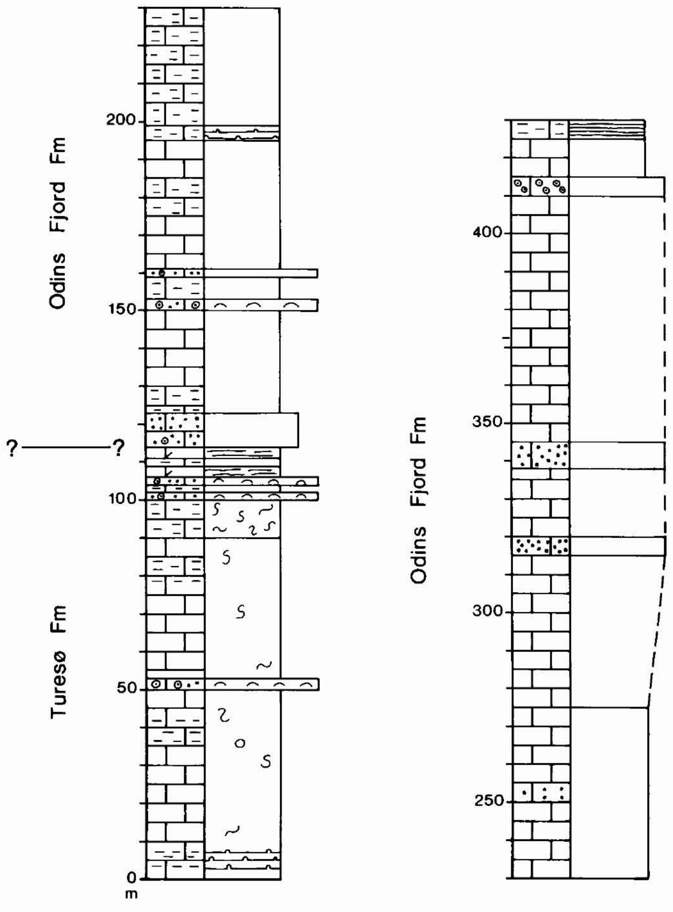


Fig. 17. Sediment log of a reference section of the Turesø Formation and Odins Fjord Formation in the G. B. Schley Fjord region of Peary Land (location 19 on fig. 1). Note that sediments are only tentatively assigned to the Turesø Formation and that the placement of the upper boundary of the formation is questionable. Symbols shown in fig. 5. Primary section measured by R. L. Christie and J. R. Ineson. Co-ordinates VN 373 082 to VN 363 060 on GGU photomosaic sheet 82 NE.

bands (50–100 cm) is apparent (fig. 20). On a large outcrop scale the whole unit is banded dark and light grey, but individual bands cannot be traced over wide distances. In the Melville Land area there is a tendency for the upper half of the formation to be generally slightly darker in colour than the lower part (fig. 19).

Commonly, massive beds consist of crystalline dolomite in which there is little or no trace of the original microfacies (fig. 21). Such beds are often completely bioturbated which is emphasised by strong mottling of sediments (fig. 22). *Chondrites* sp. is the only ichnogenus which has definitely been identified. Rounded to irregular calcite vugs (1 to 5 cm) are commonly developed, sometimes

Fig. 18. Outcrop pattern of the top of the Turesø Formation (a) and the overlying Ymers Gletscher Formation (b). Base of small ledge of Ymers Gletscher Formation (b) is the base of the formation. This is the type section for the Ymers Gletscher Formation and the overlying Odins Fjord Formation (c). Location and measurements in figs 6, 9. Height of cliff in background, beyond gully, approximately 50 m.

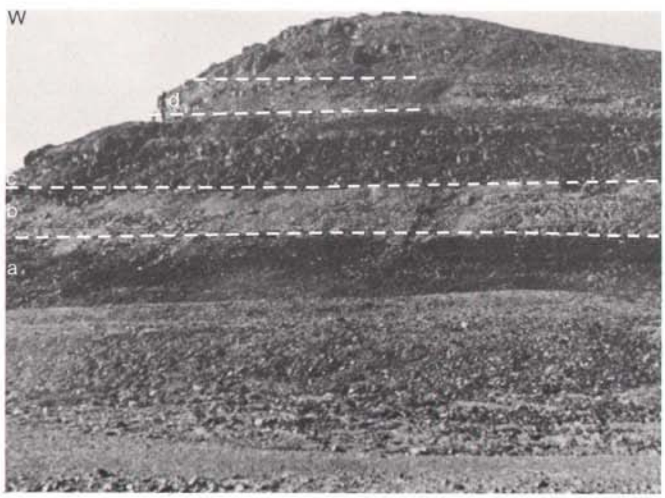


Fig. 19. Outcrop of the top of the Turesø Formation (a), the Ymers Gletscher Formation (b), the lower part of the Odins Fjord Formation (c) and the Melville Land Member (d) in the Melville Land region of Peary Land, near but not at locality 18 (fig. 15; co-ordinates UM 96 54 on GGU photomosaic sheet 82 SG). Cliff height approximately 250 m.

Fig. 20. Type section of the Turesø Formation (figs 6, 7, 8), western Turesø. Børglum River Formation (a), Turesø Formation (b), Ymers Gletscher Formation (c) and Odins Fjord Formation (d). Note black and white striped nature of the Turesø Formation. Cliff height above basal snow patch approximately 200 m.

with fluorite, and traces of irregular laminae, reminiscent of cryptalgal laminate, may be present (fig. 21). More nodular beds are often limy dolomites in which the original microfacies are sometimes preserved. Wackestone, composed of pellets, rare spongy oncolites, crinoid and unidentifiable skeletal debris, all in a clotted mud matrix, is the most common microfacies (fig. 23). Distinct horizons of

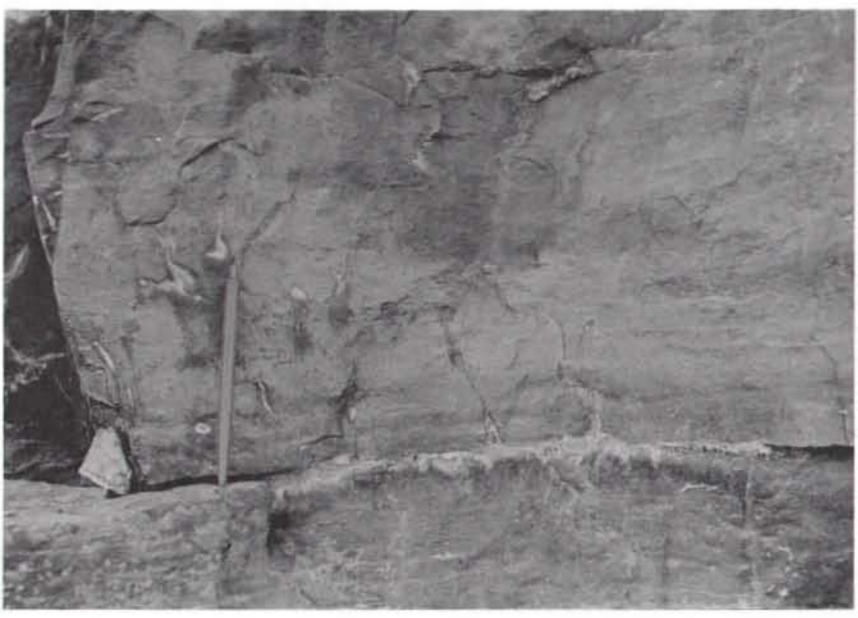


Fig. 21. Crystalline and mottled dolomites of the Turesø Formation. Note incipient lamination in the lowest bed. From section 2 (southern Odins Fjord; fig. 6). Pen 13 cm long.

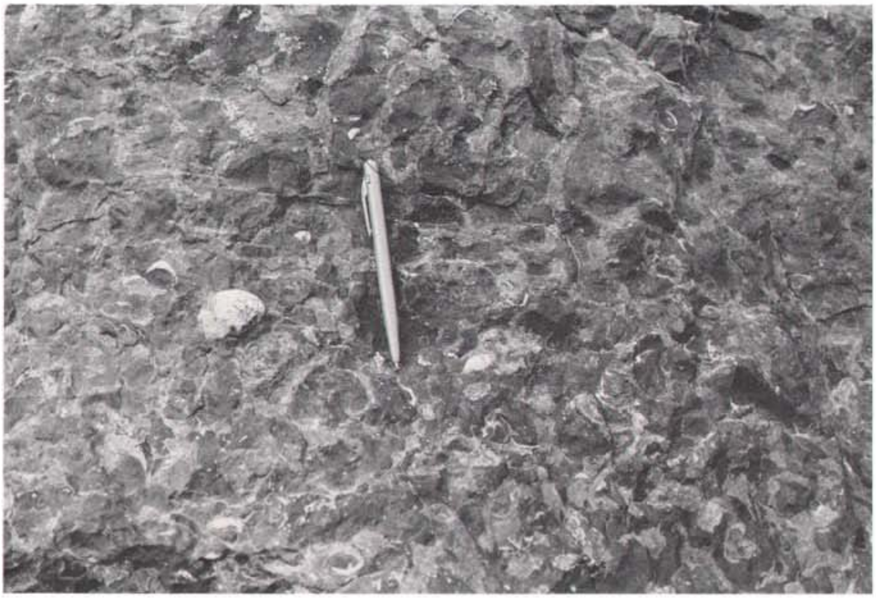


Fig. 22. Burrow (?) mottled dolomites together with scattered shells of virgianid brachiopods from the type locality of the Turesø Formation (figs 6, 7).

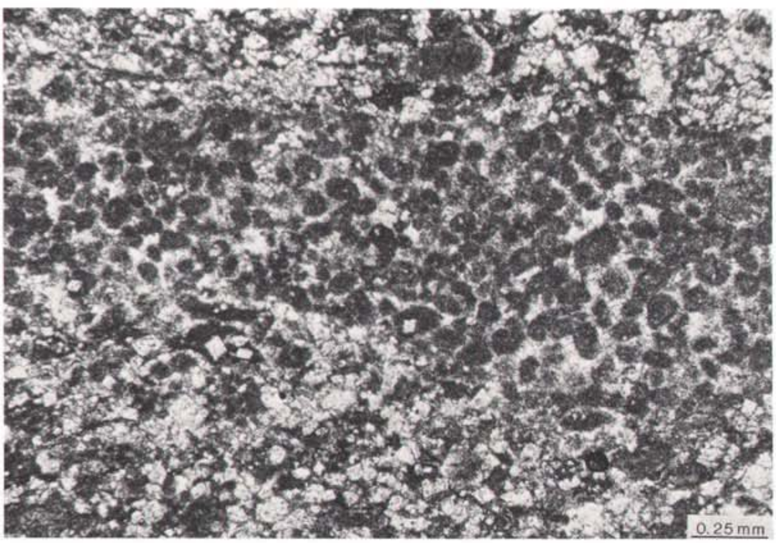


Fig. 23. Thin section photomicrograph showing pelletal lime mudstone with some skeletal fragments pervaded by growth of equant dolomite crystals. Turesø Formation, section 2 (figs 6, 9). Sample GGU 254762.

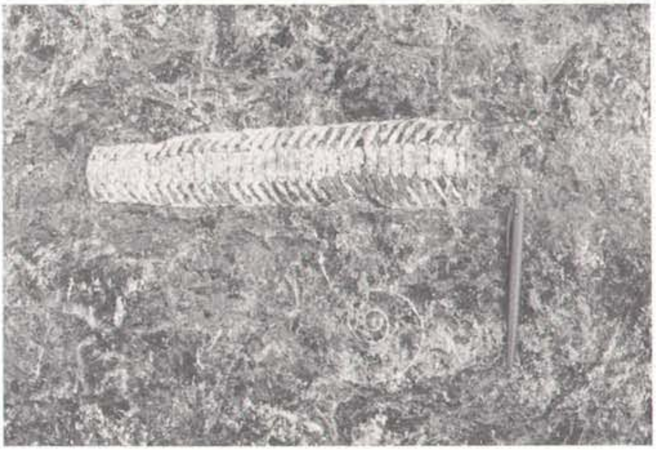


Fig. 24. Actinoceratid cephalopod and macluritid gastropod in mottled dolomites of the lower part of the Turesø Formation in the type section (figs 6, 7, 8). This type of fauna and preservation is diagnostic of the Turesø Formation.

fenestral lime mudstone or cryptalgal laminites (dolomite or limestone) occur up to 10 m thick. These horizons can be traced for considerable distances along strike (up to 500 m). Rare intraformational flat pebble conglomerates are associated with the cryptalgal laminites. Coquinas dominated by virgianid brachiopods (skeletal grainstones) are common in the upper half of the formation (fig. 22). Occasional shrinkage cracks are present (Armstong & Lane, 1981). Actinoceratid cephalopods and macluritid gastropods rarely occur in the lowest part of the formation (fig. 24).

Fig. 25. Boulder limestone conglomerate at the base-of-slope of the shelf margin along the Navarana Fjord fault (fig. 3). Clasts contain information about the immediate shelf margin. From reference section 36 of the Citronens Fjord Member of Hurst & Surlyk (1982).

Fig. 26. Thin section photomicrograph of a boulder of grainstone in the base-of-slope conglomerates derived from the shelf margin and assigned to the Citronens Fjord Member (Hurst & Surlyk, 1982). Sample GGU 254729. Poorly preserved solenoporacean algae (a) and abraded lime mudstone lithoclast (b).

Sediments referable to this formation in the G. B. Schley Fjord region of Peary Land (fig. 1) and Kronprins Christian Land are less dolomitic and consist more of nodular lime wackestone than cryptalgal laminite. There is also a greater percentage of coquinas and greater faunal diversity and density.

The above description pertains to the sediments which are currently exposed in Peary Land and Kronprins Christian Land and which represent the upper Ordovician and lower Silurian shelf facies. However, the rim of the Peary Land carbonate shelf is not exposed, but rock boulders (fig. 25) contained in conglomerates at the base of the shelf slope (Citronens Fjord Member; Hurst & Surlyk, 1982) provide information on the contemporaneous rim facies (fig. 3). Many boulders are identical to the shelf facies, but some exotic clasts are present. Some small dolomite clasts are stained red. A few large boulders (up to 5 m diameter) consist of nodular limestone or limy dolomite with an abundant fauna of virgianid brachiopods, stromatoporoids and gastropods. The microfacies is a distinctive lithoclastic–bioclastic grainstone in which the fragments (1–5 mm) are abraded and sub-rounded, but poorly sorted (fig. 26). Much of the algae is recrystallised, but fragments of solenoporaceans (red algae), dasycladacean (green algae) and very poorly preserved codiacean green algae, the latter resembling *Garwoodia* sp. and *Hedstroemia* sp., occur. Lime mudstone lithoclasts, sometimes pelletal, and pellet wackestones are common and similar in size to the bioclasts.

Facies interpretation. A well developed cyclicity of facies is evident, each cycle varying between 2 and 20 m in thickness and consisting of laminated and cryptalgal laminated carbonate or fenestral lime mudstone interbedded with nodular bioturbated dolomitic wackestone with silt ripples and a rare benthic fauna. These sediments represent deposition in peritidal environments subjected to repeated rapid submergence. The wackestone represents shallow subtidal environments and the cryptalgal laminated carbonate and fenestral lime mudstone indicates intertidal to supratidal environments (cf. Markello & Read, 1981, 1982). They are similar to other lower Palaeozoic subtidal to intertidal couplets (cf. Mayr, 1982; Mazzullo & Friedman, 1975), but the scarcity of intraclast conglomerates and shelly coquinas is suggestive of a very low-energy shelf sequence (James, 1979). Faunal patterns indicate the possibility that there were periodic hypersaline conditions (Fürsich & Hurst, 1980).

The microfacies represented in the boulders at the base-of-slope are indicative of certain shelf rim conditions. The red coloured dolomite clasts indicate thorough oxidation of the dolomite prior to redeposition. Such red zones are often interpreted as representing subaerial exposure surfaces (Dunham & Olson, 1980) and the red dolomite clasts may indicate temporary subaerial exposure of the rimmed shelf margin, parts of which were later redeposited downslope. The grainstone represents the remains of shelf rim debris which was probably deposited as relatively high-energy carbonate sand shoals. The abundance of algae may indicate the presence along the rim of algal reefs (cf. Wray, 1972, 1979).

Boundaries. The lower boundary is taken at the incoming of the first dolomitic or limy dolomitic bed (figs 8, 12, 14). This is generally accompanied by a drastic fall in both faunal diversity and density. The Turesø Formation is lighter coloured (fig. 20) and less nodular than the underlying Ordovician Børglum River Formation and this colour and bedding difference normally coincides with the increase of dolomitisation. Similarly, the upper boundary is taken at the last dolomitic or limy dolomitic bed (figs 8, 9, 10, 11, 12, 13, 14, 15). This boundary is normally sharp as the overlying Ymers Gletscher Formation is light coloured, well laminated and recessive in contrast to the darker and more massive Turesø Formation (figs 19, 20, 27).

In the Melville Land region of Peary Land the boundaries are relatively easy to locate. In contrast, the boundaries are difficult to place in the structurally complex area of the G. B. Schley Fjord region of Peary Land (fig. 1), and the precise extent of the formation is not known (figs 16, 17). Also the placement of the top boundary of the Turesø Formation is complicated by the fact that the formation is not as distinctively dolomitic as elsewhere in Peary Land.

Distribution. The most westerly occurrence of the formation is in southern Odins Fjord and around Turesø (figs 1, 6, 7). Dolomites in the J.P. Koch Fjord area (fig.

Fig. 27. Transition from the Turesø Formation (a) to the Ymers Gletscher Formation (b) in the type section of the Turesø Formation (figs 6, 7). Note the dark, more massive Turesø Formation and the thinner-bedded, laminated and lighter coloured Ymers Gletscher Formation. Slope height approximately 40 m.

1) of Peary Land (Hurst, 1979) are similar to the Turesø Formation and may eventually be assigned to it. This decision awaits further fieldwork. The formation stretches in a west to east belt through Peary Land reaching the eastern coast at Vitsköl Bugt (fig. 1). Isolated outcrops of the formation occur around G. B. Schley Fjord and in northern Valdemar Glückstadt Land. In Kronprins Christian Land the formation is repeated as a series of north to south trending slivers which are bounded by thrusts (fig. 1)

Biostratigraphy. In the type section (fig. 8) conodont fauna attributable to fauna 12 (Sweet *et al.*, 1971) of the Ordovician Richmondian Stage (Cincinnatian Series) occur up to 50 m above the base of the formation (Armstrong, 1983; Armstrong & Aldridge, 1982). There is a gap of approximately 15 to 20 m with no fauna before the first unequivocably Silurian conodont assemblages occur (fig. 28). In the reference section at Børglum Elv fauna 12 occurs up to 50 m above the base of the formation (fig. 12). This is followed by 20 to 30 m of barren strata before lower Silurian faunas appear (Armstrong, 1983; Armstrong & Aldridge, 1982). In the reference section in the Melville Land region of Peary Land approximately the lower 30 m of the formation yields a Richmondian fauna 12 which is followed by a faunal gap (20–30 m approximately) before Silurian conodonts occur (figs 14, 28). In Kronprins Christian Land the age control of the lower part of the formation is

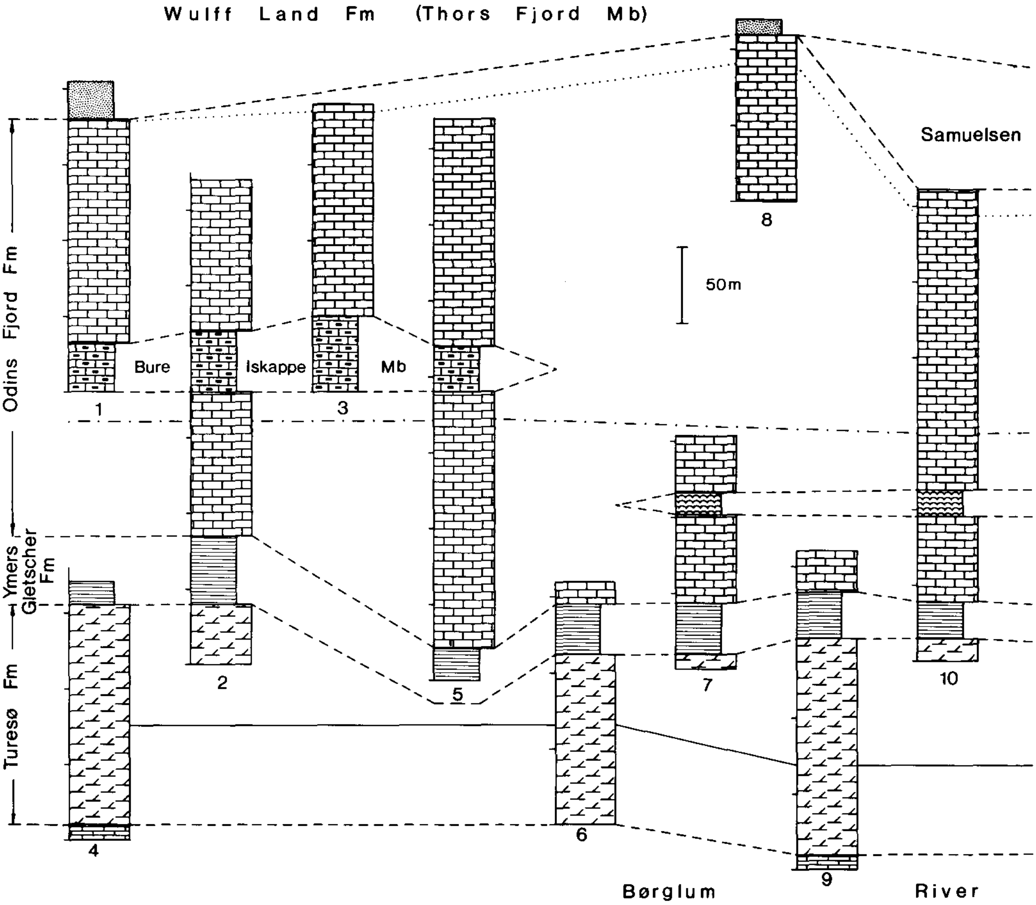
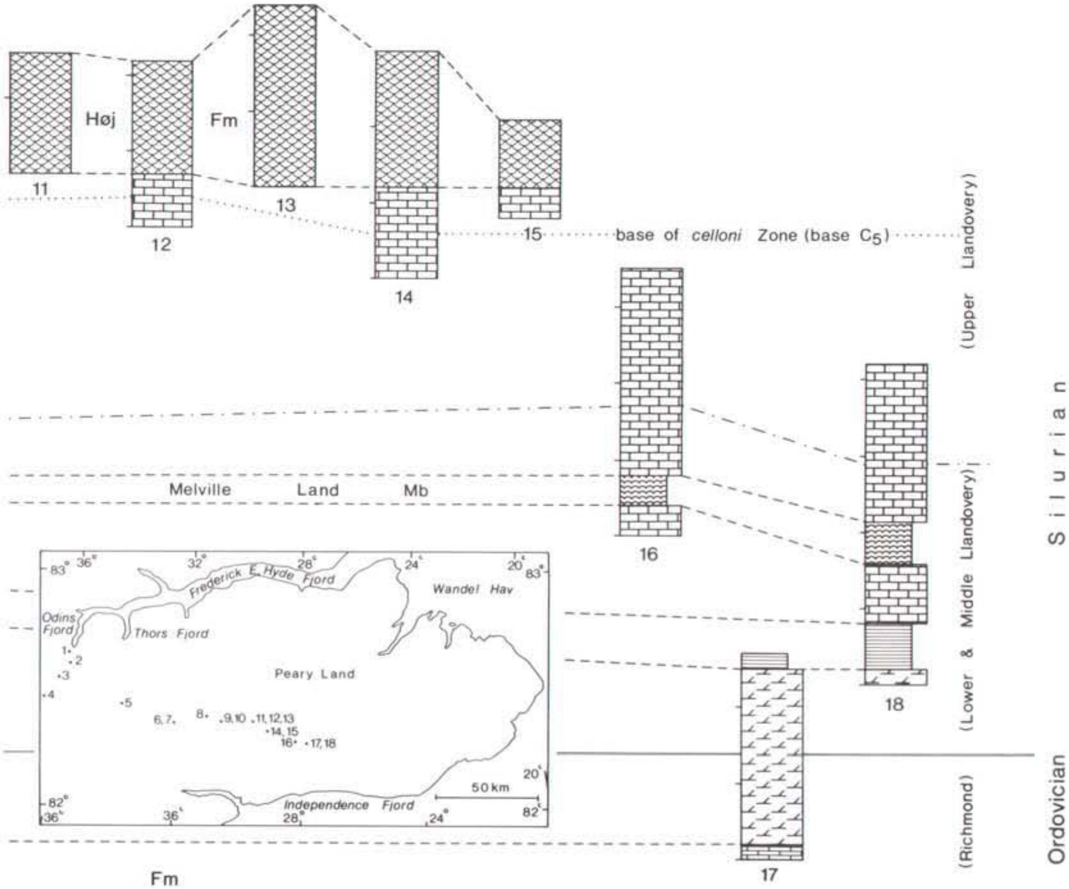


Fig. 28. Simplified stratigraphic scheme showing the thickness variation of the various formations throughout Peary Land and their lateral and vertical extent. Section numbers 1 to 18 correspond to those of fig. 1 and the text. Note that the Ordovician-Silurian boundary and the Middle to Upper Llandovery boundary are accurate in each section to within 10 or 20 m. Note the diachronous top to the

not well documented, in part due to incomplete sections. However, it appears that the first indication of Silurian conodont faunas occurs approximately 65 m above the base of the formation (Armstrong & Aldridge, 1982).

Age diagnostic fauna from the remainder of the formation is sparse. Smooth virgianid brachiopods commonly occur in the upper half of the formation and such forms are normally taken to be indicative of an Early to Middle Llandoverian age (cf. Berry & Boucot, 1970; Boucot *et al.*, 1971). Sparse conodont faunas are in agreement with this assignment (Armstrong & Aldridge, 1982).

To summarise, at least the lower 30 to 50 m of the Turesø Formation contains a Richmond conodont fauna 12 and is therefore of undoubted latest Ordovician age



level-bedded limestones of the Odins Fjord Formation, which is mirrored by the diachronous base of the overlying Thors Fjord Member of the Wulff Land Formation (Hurst & Surlyk, 1982). Conodont data from Armstrong (1983) and Armstrong & Aldridge (1982).

(fig. 28). Subsequently, 15 to 30 m of barren strata occur before undoubted lower Silurian conodont faunas appear. This gap could represent the so-called 'Gamachian' of Anticosti Island. The remainder of the Turesø Formation is of Early to Middle Llandoverian age. There is no precise faunal evidence to indicate the age of the Turesø – Ymers Gletscher Formation boundary, but it is unlikely to be high in the Middle Llandoverian (for reasons see discussion under Odins Fjord Formation; fig. 28).

Geological age. Late Cincinnatian to Early – Middle Llandoverian.

Ymers Gletscher Formation

new formation

History. The formation probably corresponds to the Cape Tyson Formation of Koch (1929). Mayr (1976) included the strata of the Ymers Gletscher Formation in an expanded Børglum River Fomation (fig. 4). It corresponds in part to the 'Unnamed Limestone and Dolomite unit' in Peary Land of Dawes (1976), to part of the Silurian limestone of Peel & Christie (1975), to member 'A' of the 'Un-named Silurian limestone formation' of Christie & Peel (1977), and to member 'A' of the 'Un-named Silurian limestone formation' of the Odins Fjord region (Hurst, 1979).

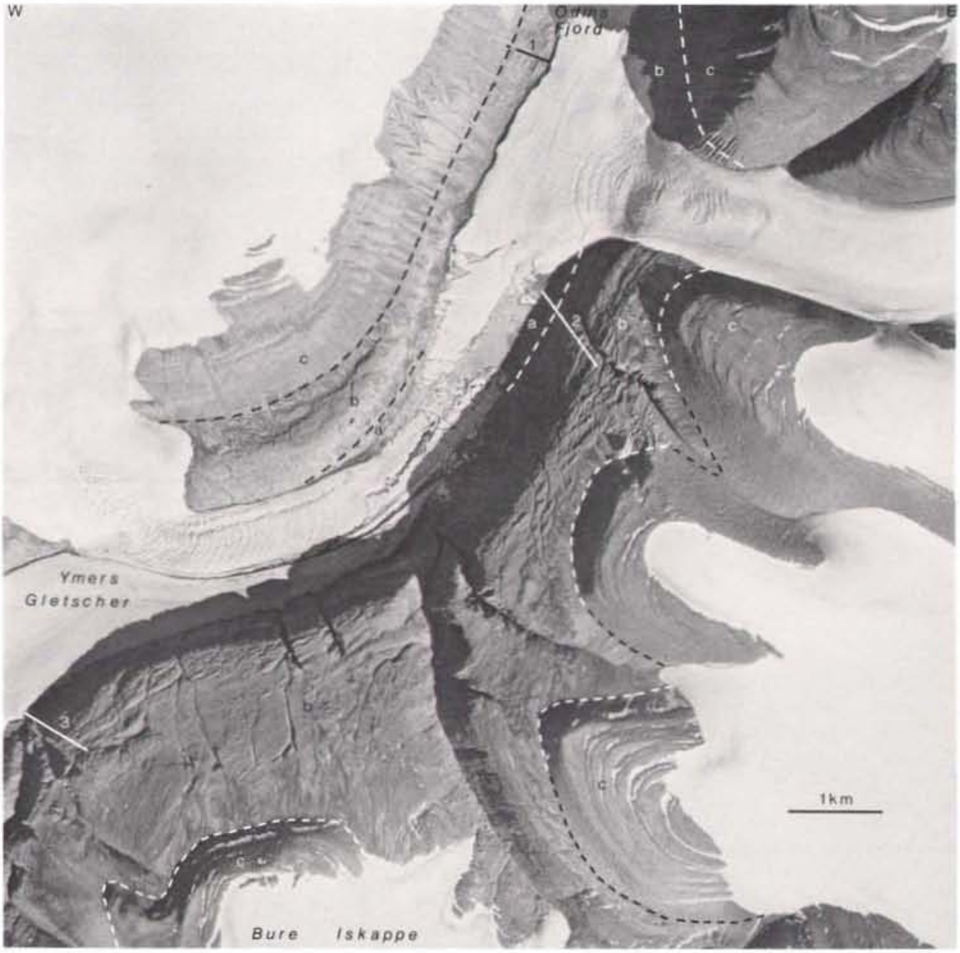


Fig. 29. Vertical aerial photograph, with the geology superimposed, of the southern end of Odins Fjord (figs 1, 6). Section numbers 1, 2, 3 refer to sections shown in figs 32, 9, 33 respectively. Section 1 is the type section of the Bure Iskappe Member and section 2 is the type section of the Ymers Gletscher Formation and Odins Fjord Formation. Turesø Formation (a), Ymers Gletscher and Odins Fjord Formations (b) and the terrigenous clastic sediments of the Peary Land Group (c). All geological symbols as in fig. 6. Aerial photograph 256C, No. 180a. Copyright Geodætisk Institut, Denmark.

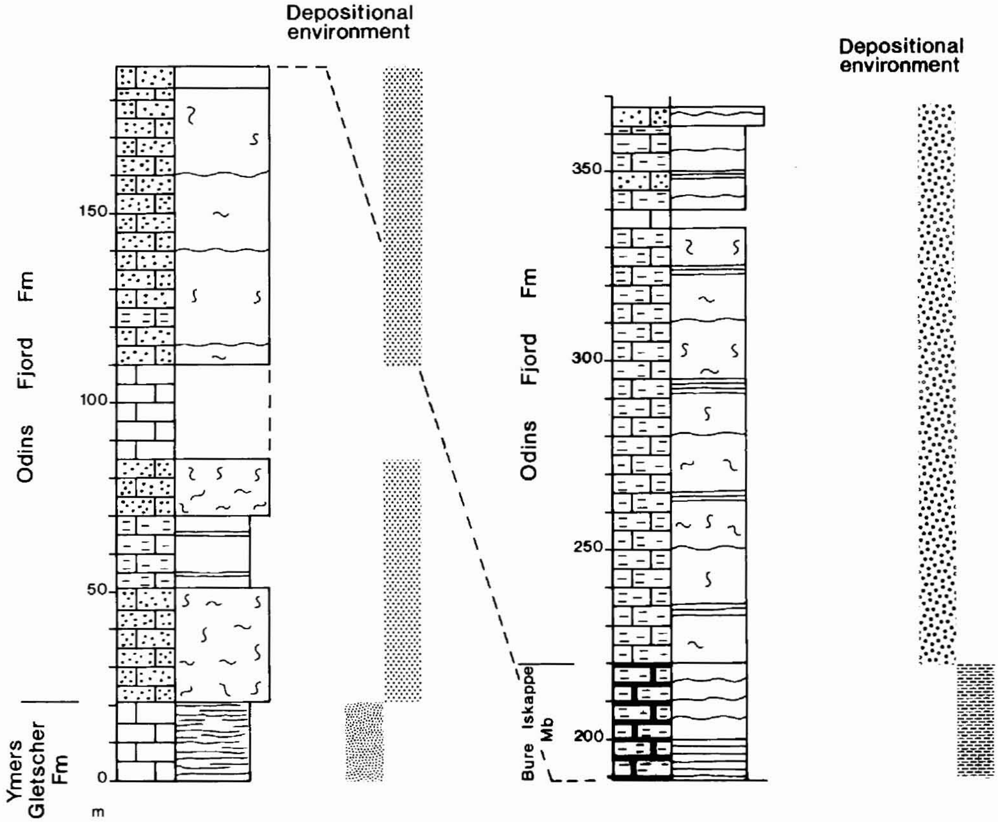


Fig. 30. Sediment log of a reference section of the Ymers Gletscher Formation, Odins Fjord Formation, and Bure Iskappe Member in Peary Land east of Bure Iskappe (location 5 on fig. 1). Symbols shown in fig. 5. Primary section measured by S. A. S. Pedersen. Co-ordinates WS 710 678 to WS 707 685 on GGU photomosaic sheet 82 ND.

Name. After Ymers Gletscher which leads into the southern end of Odins Fjord (fig. 6).

Type and reference sections. The type section is on the eastern side of the northern tip of Ymers Gletscher as it disgorges into southern Odins Fjord (figs 6, 9, 29). Reference sections are located on the western banks of Turesø (the type section of the Turesø Formation) and throughout the Melville Land region of Peary Land (figs 7, 8, 10, 11, 12, 13, 14, 15, 30).

Thickness. Between 25 and 45 m. The formation appears to be thicker in more northerly outcrops, that is nearer the shelf margin (fig. 28).

Lithology. The formation is characterised by thin to medium-bedded limestones

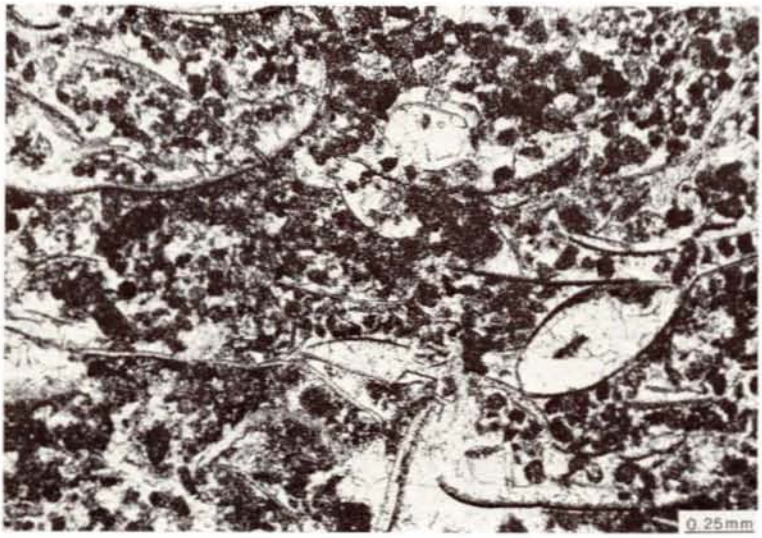


Fig. 31. Thin section photomicrograph of ostracod wackestone from the Ymers Gletscher Formation in the type section (figs 6, 29). Sample GGU 254779.

(10–50 cm) which weather to form recessive slopes (figs 19, 27). The rocks are generally grey and weather to a very light grey colour (fig. 19).

Individual beds are thinly laminated (mm to cm scale) and the laminae are flat and evenly developed (fig. 27). Many of the beds are cryptalgal laminite. In rare cases some of the laminae appear as small domes and resemble stromatolites. These beds appear in thin section as pelletal muds with small indistinct irregular fenestrae. Other lithologies include well-bedded fenestral lime mudstone which may be weakly laminated and laminated lime mudstone. In thin section the former consist of clotted mudstone with small irregular calcite filled fenestrae, whilst the latter are clotted to pelletal. The laminated mudstones are generally of a darker grey and have a sulphurous smell. Rarely ostracod wackestone and packstone lenses and thin beds occur in the laminated lime mudstone (fig. 31). Rare intraformational pebble conglomerates occur and coquinas dominated by virgianid brachiopods (skeletal grainstones) are present.

Facies interpretation. There is no evidence of any facies cyclicity, but there does appear to be a facies gradation between cryptalgal laminites, fenestral lime mudstone and laminated lime mudstone. These sediments represent deposition in peritidal environments. The cryptalgal laminite and fenestral lime mudstone represent intertidal to supratidal environments, whilst the laminated lime mudstone represents low-energy shallow subtidal environments. The monospecific ostracod and virgianid brachiopod beds associated with these sediments may indicate higher than normal salinity conditions (Fürsich & Hurst, 1980). The scarcity of intraclast conglomerates is suggestive of a very low-energy shelf sequence (James, 1979).

Boundaries. The lower boundary is taken at the incoming of the first well laminated limestone beds (figs 8–15). This is accompanied by much lighter coloured sediments in contrast to the underlying darker Turesø Formation (figs 19, 20, 27). Also the sediments of the Ymers Gletscher Formation often form a recessive bench above the Turesø Formation. The upper boundary is taken at the base of the more massively bedded, cliff-forming limestones of the Odins Fjord Formation, which are mottled. These latter sediments are wackestones and have a more diverse and dense fully marine fauna (figs 9, 10, 11, 12, 13, 15). Often the base of the overlying formation is marked by a thick virgianid brachiopod coquina.

Distribution. The most westerly exposure of the formation is in southern Odins Fjord and around Turesø (figs 1, 6, 7). Sediments in the J.P. Koch Fjord (fig. 1) area of Peary Land are similar to the Ymers Gletscher Formation and may eventually be assigned to it. This decision awaits further fieldwork. The formation stretches in a west–east belt through Peary Land reaching the eastern coast at Vitsköl Bugt (fig. 1). It has not been identified in the G.B. Schley Fjord region of Peary Land and every indication is that it has wedged out in this area. It is not known if the formation occurs in Valdemar Glückstadt Land. Examination of two complete Silurian carbonate sections along the north coast of Centrum Sø and to the north-west of Romer Sø (fig. 1) indicates that the formation is not present in Kronprins Christian Land.

Biostratigraphy. The formation conformably follows the underlying Turesø Formation whose upper boundary is of Early to Middle Llandoverian age. Sparse conodont faunas from the type and reference sections (Armstrong, 1983; Armstrong & Aldridge, 1982) only indicate a general early Silurian (Llandoverian) age (fig. 28). Smooth virgianid brachiopods occur throughout the type and reference sections indicating an Early to Middle Llandoverian age. There is no faunal evidence for a Late Llandoverian age anywhere in the formation.

Geological age. Early to Middle Llandoverian. Possibly just Middle Llandoverian.

Odins Fjord Formation

new formation

History. This formation corresponds to the Cape Tyson Formation of Peary Land (Koch, 1929). In Kronprins Christian Land this unit was included in the embracive Centrum Limestone (Adams & Cowie, 1953). In Peary Land this unit was included by Mayr (1976) in a greatly expanded Børglum River Formation (fig. 4). It corresponds to part of the Silurian limestone of Peel & Christie (1975) and

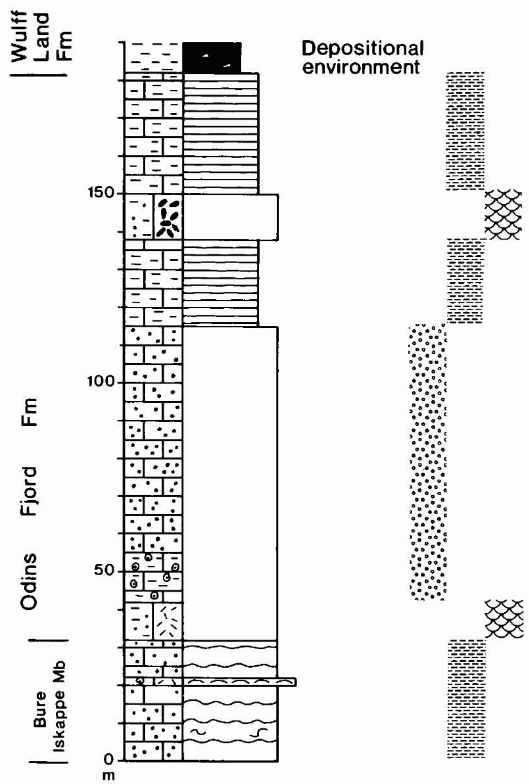


Fig. 32. Sediment log of a reference section of the Odins Fjord Formation and type section of the Bure Iskappe Member, western Odins Fjord. Location 1 on fig. 1 (see also figs 6, 29). Symbols shown in fig. 5. Co-ordinates WS 39 92 on GGU photomosaic sheet 82 NC.

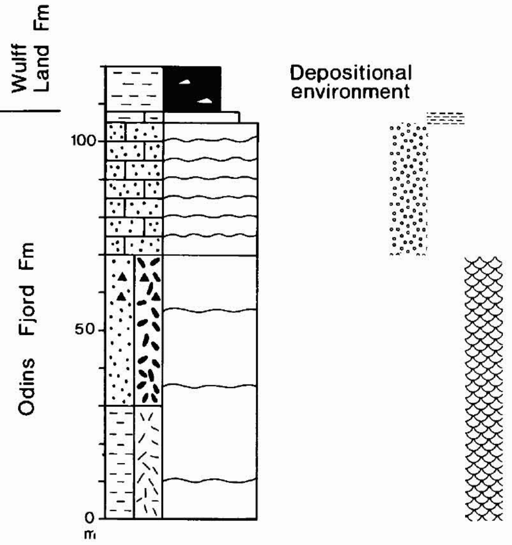


Fig. 34. Sediment log of a reference section of the upper part of the Odins Fjord Formation in Peary Land (location 8 on fig. 1). Symbols shown in fig. 5. Primary section measurement by J. E. Mabillard. Co-ordinates XS 10 72 on GGU photomosaic sheet 82 SG.

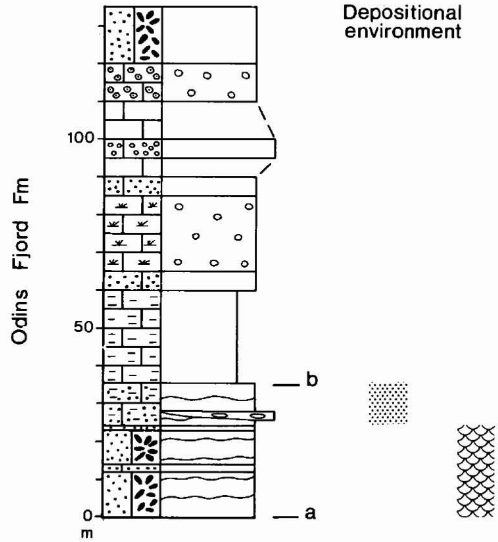
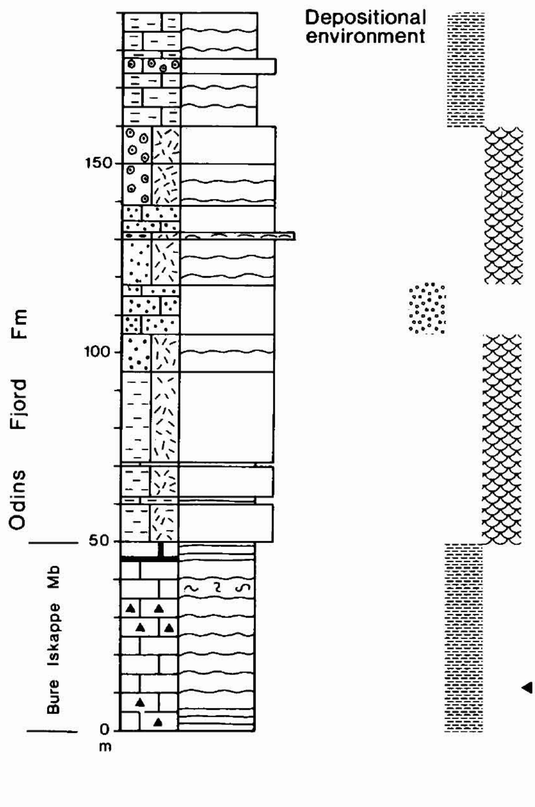


Fig. 35. Sediment log of a reference section of the Odins Fjord Formation and Samuelsen Høj Formation (location 12 on figs 1, 56). Symbols shown in fig. 5. Sequence between points a-b is expanded in fig. 36.



◄ Fig. 33. Sediment log of a reference section of the Bure Iskappe Member and Odins Fjord Formation. Location 3 on fig. 1 (see also figs 6, 29). Symbols shown in fig. 5.

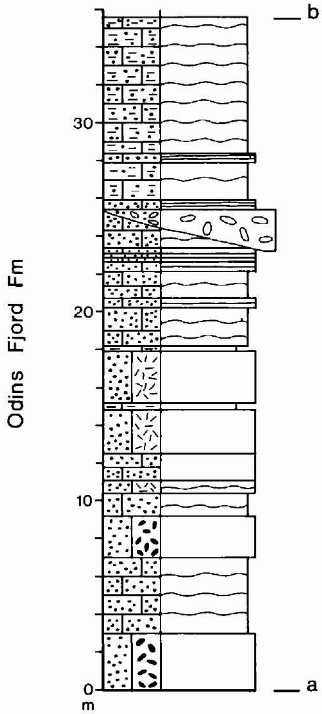


Fig. 36. Expanded sediment log of part of section 12 (fig. 35). Symbols in fig. 5.

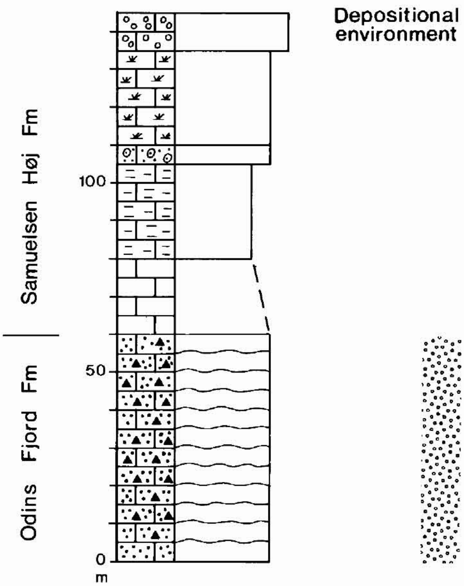


Fig. 38. Sediment log of a reference section of the Odins Fjord Formation and Samuelsen Høj Formation (location 14 on fig. 1). Symbols shown in fig. 5. Primary section measured by J. E. Mabillard. Co-ordinates UM 82 68 on GGU photomosaic sheet 82 SG.

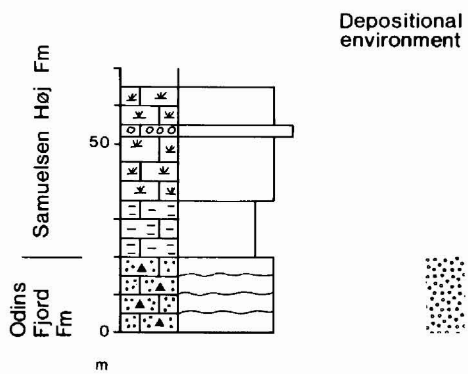
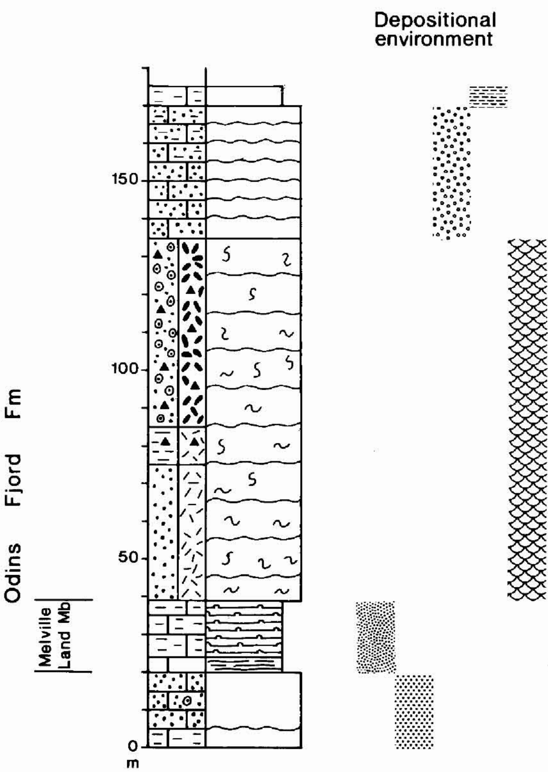


Fig. 39. Sediment log of a reference section through the Samuelsen Høj Formation (location 15 on fig. 1). Symbols in fig. 5. Primary section measured by J. E. Mabillard. Co-ordinates UM 82 68 on GGU photomosaic sheet 82 G.

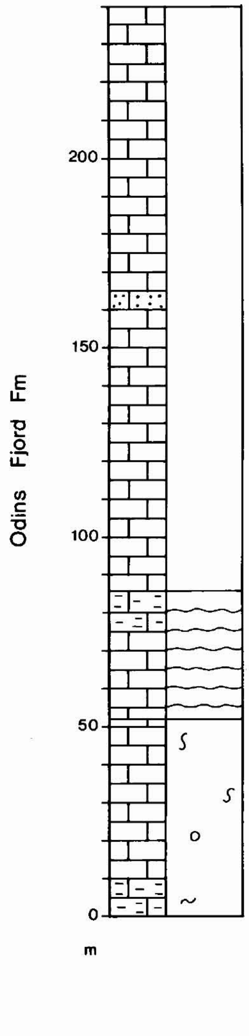


◄ Fig. 37. Sediment log of a reference section of the Melville Land Member and Odins Fjord Formation (location 16 on fig. 1). Symbols shown in fig. 5. Primary section measured by J. E. Mabillard. Co-ordinates UM 85 62 on GGU photomosaic sheet 82 SG.

to members 'B' to 'F' inclusive of the 'Un-named Silurian limestone formation' of Christie & Peel (1977; fig. 4).

Name. After Odins Fjord, the north–south trending fjord at the western end of Frederick E. Hyde Fjord (figs 1, 6, 29).

Type and reference sections. The type section is on the eastern side of the northern tip of Ymers Gletscher as it disgorges into southern Odins Fjord (figs 6, 9, 29). This is also the type section of the Ymers Gletscher Formation. Two reference sections are located in the environs of southern Odins Fjord (figs 6, 29, 32, 33) and a variety of reference sections are located throughout Peary Land (figs 9, 10, 11, 12, 13, 15, 30, 34, 35, 36, 37, 38, 39) and in the G. B. Schley Fjord region of Peary Land (figs 16, 17, 40, 41).



◄ Fig. 40. Sediment log of a reconnaissance reference section of the Odins Fjord Formation in the G. B. Schley Fjord region of Peary Land (location 20 on fig. 1). Symbols in fig. 5. Primary section measured by R. L. Christie and J. R. Ineson. Co-ordinates VN 363 075 on GGU photomosaic sheet 82 NE.

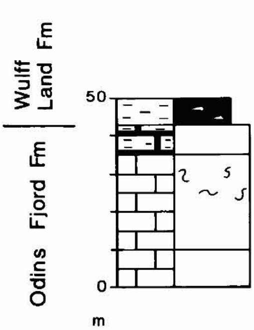


Fig. 41. Sediment log of a reconnaissance reference section of the top of the Odins Fjord Formation in the G. B. Schley Fjord region of Peary Land (location 21 on fig. 1). Symbols in fig. 5. Primary section measured by R. L. Christie and J. R. Ineson. Co-ordinates VN 326 055 on GGU photomosaic sheet 82 NE.

Thickness. Between 200 m and 350 m. In Peary Land there is systematic variation in the thickness. In the more easterly outcrops (eastern Melville Land) furthest south of the northern shelf margin, the formation is only 200 m thick. In the more northerly outcrops approaching the shelf margin the formation is at least 300 m thick (fig. 28). Thus, in Peary Land the formation appears to thicken from south to north approaching the shelf margin. A thick sequence is present in Kronprins Christian Land (Peel, 1982, 1984).

Lithology. The formation is characterised by medium to very thick-bedded (0.5–10 m) limestone which weathers into a variety of cliff-like benches (10 m thick beds) or recessive scree slopes (figs 42, 43). The rocks are dark blue-grey and they form a distinctive monotonous-looking unit above the lighter Ymers Gletscher Formation and striped Turesø Formation.

Throughout Peary Land the lower third to half of the formation is characterised by massive, nodular or wavy-bedded skeletal wackestones (fig. 44). Skeletal grains consist of broken brachiopods, crinoids, corals, stromatoporoids and especially ostracods and elliptical pellets (0.05 – 0.5 mm). Spongy oncolites and blue-green codiacean algae rarely occur. Sorting of grains is poor and they are often contained

Fig. 42. Outcrop pattern of the Odins Fjord Formation (b) in the type section (figs 6, 29). The well-bedded and laminated unit at the base of the cliff is the uppermost part of the Ymers Gletscher Formation (a), also in the type section. Central cliff height approximately 300 m.

Fig. 43. Steep cliff outcrop pattern of the Odins Fjord Formation on the western side of the valley leading south from Odins Fjord. Note the recessive nature of the Bure Iskappe Member (a). Cliff height approximately 500 m.

in a clotted lime mud matrix which may show signs of replacement by spar. The only structures are very occasional impersistent laminae, but mottling, possibly partially representing bioturbation, is common. Thinner-bedded units (up to 20 cm) are weakly horizontally laminated (fig. 45). These units consist of pure lime

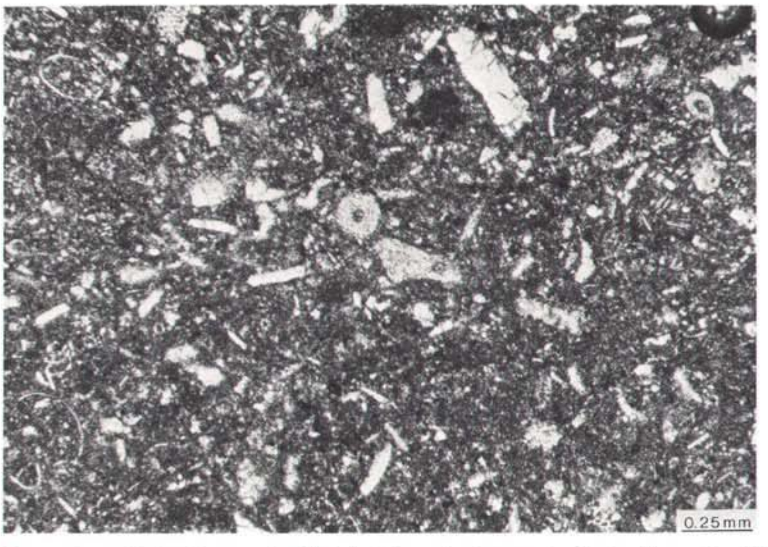


Fig. 44. Thin section photomicrograph of skeletal wackestone microfacies from the Odins Fjord Formation at location 16 on fig. 1. Sample GGU 229070.

Fig. 45. Thin-bedded and laminated lime mudstone in the top of the Odins Fjord Formation in the reference section (location 3 in fig. 1). Sample GGU 198900.

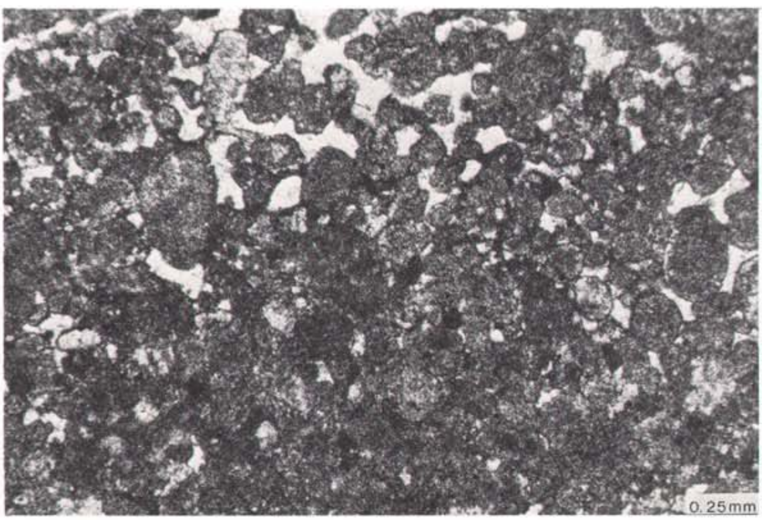


Fig. 46. Thin section photomicrograph of clotted and pelletal lime mudstone in the Odins Fjord Formation in the reference section (location 3 on fig. 1).

mudstone with all gradations through clotted mudstone to compacted pelletal mudstone (fig. 46). Rare beds up to 2 m thick consist of poorly sorted skeletal debris overwhelmingly dominated by virgianid brachiopods. These packstone and grainstone units are laterally persistent.

In the lower half of the formation in the Melville Land region of Peary Land, a distinctive fenestral lime mudstone and laminated lime mudstone unit is present. This is assigned to the Melville Land Member.

In the middle of the formation in the environs of Odins Fjord and Bure Iskappe a distinctive thin-bedded nodular cherty lime mudstone or wackestone unit with siliciclastic mud streaks is present. This is assigned to the Bure Iskappe Member.

Throughout Melville Land the upper part of the formation is characterised by thick-bedded massive or nodular beds up to 10 m thick (fig. 47). Beds are commonly mottled and the sediment is wackestone and lime mudstone as in the lower part of the formation. Colonies of laminar and hemispherical stromatoporoids together with tabulate colonies are often so abundant (50% of rock volume or more) that the sediments are floatstones or rudstones (fig. 48). Fauna is represented by debris of solitary corals, brachiopods, trilobites and echinoderms. The brachiopods often form coquina lenses. Chert nodules are ubiquitous in the

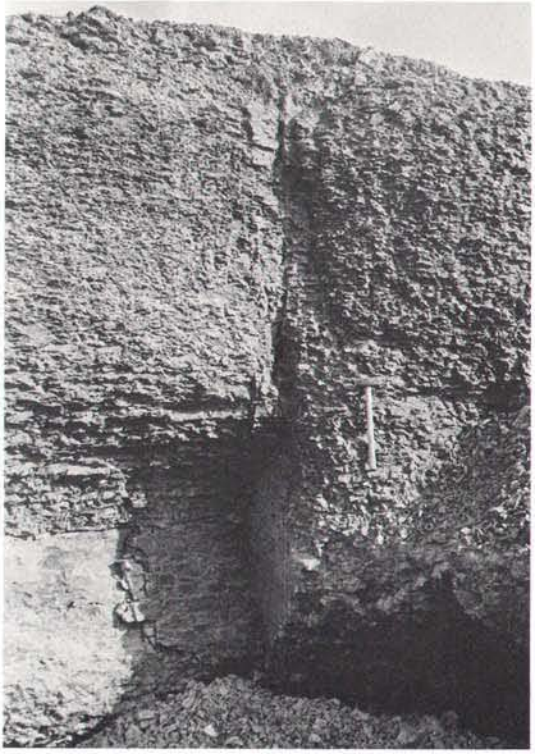


Fig. 47. Typical nodular limestones in the top of the Odins Fjord Formation of east Peary Land in reference section 16 (figs 1, 37).

Fig. 48. Stromatoporoid and tabulate coral rudstone from the Odins Fjord Formation in reference section 1 (figs 1, 32).

Fig. 49. Chaotic channellised limestone conglomerate in the top of the Odins Fjord Formation in section 12 (figs 1, 35).

rudstone units. Individual rudstone and floatstone units can be traced across outcrop (*c.* 500 m), but closely spaced sections cannot be correlated. This suggests that these units are lenticular on a kilometre scale. At one locality, Samuelsen Høj, a small channel fill conglomerate (2 m deep) occurs in the uppermost part of the formation (fig. 49).

The upper half of the formation in the Odins Fjord and Bure Iskappe region of Peary Land has fewer rudstone and floatstone units. Sediments are more commonly wackestone and lime mudstone as in other parts of the formation. In the most northerly outcrop of the formation the upper 50 m are laminated lime mudstone.

The topmost bed of the formation in the northernmost outcrop in Odins Fjord is a 0.5–1 m thick bioclastic and lithoclastic conglomerate with a quartz silt matrix. Lithoclasts are of limestone or quartz siltstone, the latter petrographically identical to the deep-water terrigenous clastics of the Peary Land Group. The bed is disorganised and consists of poorly sorted and angular pebble size clasts. S. A. S. Pedersen (personal communication, 1983) reports a similar unit at the top of the Odins Fjord Formation in areas to the immediate south of Thors Fjord. In all other areas of Peary Land and Kronprins Christian Land the topmost beds of the Odins Fjord Formation consist of a distinctive light pinkish-grey, nodular lime mudstone with no macrofauna. This unit varies in thickness from 1 to 5 m.

Sediments of the Odins Fjord Formation in the G. B. Schley Fjord region and Kronprins Christian Land have not been investigated in the same detail as the rest of Peary Land. However, there is no evidence to suggest major differences in sediment characteristics.

The above description relates to the shelf carbonates currently exposed in Peary

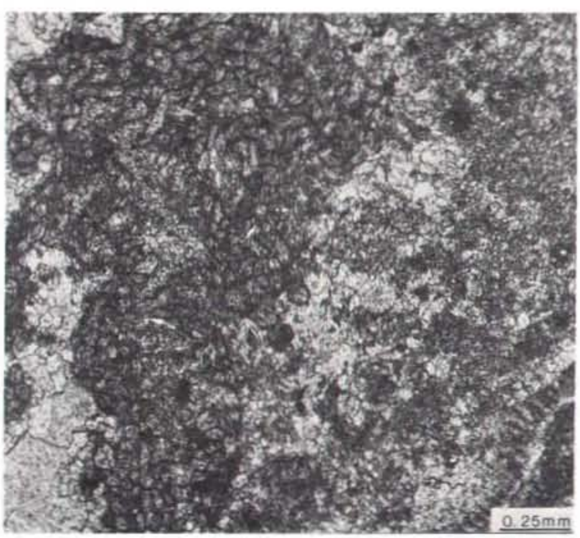


Fig. 50. Thin section photomicrograph of *Girvanella* sp. colony from clasts derived from the shelf margin and constituting the Freja Fjord Member (Hurst & Surlyk, 1982). Sample GGU 270762.

Land and Kronprins Christian Land. The rim of the Peary Land carbonate shelf is not exposed, but boulders contained in conglomerates at the base-of-slope (Freja Fjord Member; fig. 3; Hurst & Surlyk, 1982) provide information on the contemporaneous rim facies. Many clasts are identical to the shelf facies, but some clasts cannot be compared to known shelf lithologies. These clasts are light grey massive limestones up to 10 m in diameter and are composed of grainstone and algal–bryozoan boundstone. The boundstone consists of bryozoan intergrown with the blue-green algae *Sphaerocodium* sp. and very rarely *Girvanella* sp. (fig. 50). *Wetheredella* sp. is a common constituent of the facies and it is often encrusted by *Sphaerocodium* sp. (fig. 51). Red algae, in the form of *Solenopora* sp. is also common (fig. 52). The matrix is lime mud, and anastomosing pods lined with fibrous calcite are common. The grainstones are debris beds composed of limestone lithoclasts and abraded algal bioclasts. Sorting is poor and blue-green and red algae are well represented.

Facies interpretation. The lower part of the formation is indicative of low-energy shallow subtidal environments well within the photic zone. Temporary low-energy peritidal environments recur in central and eastern Peary Land in the form of the Melville Land Member. In these areas the floatstone and rudstone units above the Melville Land Member indicate higher-energy subtidal conditions still within the euphotic zone. The lenticularity of units over many kilometres suggests large-scale shoals with small intervening lower-energy basins.

Fig. 51. Thin section photomicrograph of encrusting sheet-like *Sphaerocodium* sp. (a) on *Wetheredella* sp. (b) in the debris derived from the shelf margin and contained within the Freja Fjord Member (Hurst & Surlyk, 1982). Sample GGU 270760.

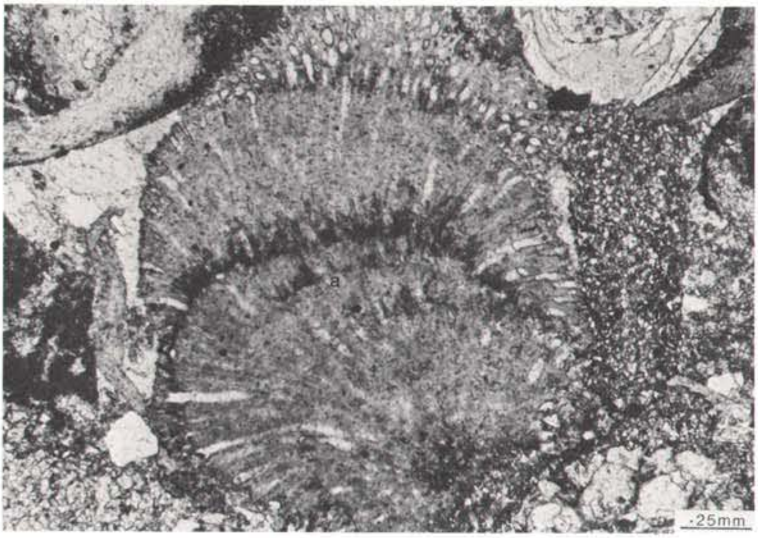


Fig. 52. Thin section photomicrograph of solenoporacean algae (a) in the debris derived from the shelf margin and contained within the Freja Fjord Member (Hurst & Surlyk, 1982). Sample GGU 270756.

The upper half of the formation (including Bure Iskappe Member) in the Odins Fjord – Thors Fjord region is suggestive of low-energy environments, possibly with occasional anoxic bottom conditions. The general lack of algae suggests that deposition was below the euphotic zone in relatively deep environments. The rare floatstone and rudstone units indicate temporary incursion of higher-energy shoals within the euphotic zone. These have possibly prograded northwards from the much more abundant shoals to the south. Similarly, in the G. B. Schley Fjord region of Peary Land the upper half of the formation is indicative of low-energy environments, possibly below the euphotic zone.

The facies represented in the boulders at the base of the northern shelf slope indicate that the shelf was rimmed by a series of high-energy shoals and incipient algal–bryozoan reefs well within the euphotic zone.

Detailed information on the environments in Kronprins Christian Land is lacking, but the sedimentary facies information that is available indicates that shallow subtidal depositional environments prevailed.

Boundaries. The lower boundary is taken at the first incoming of massive, mottled, dark grey skeletal wackestone (figs 9, 10, 11, 12, 13, 15, 30). In many places the boundary is marked by a distinctive virgianid brachiopod shell bed. This boundary is generally accompanied by an increase in faunal diversity and density and the incoming of large stromatoporoids and tabulate corals is noticeable. The colour contrast from the underlying light grey Ymers Gletscher Formation is also well marked (fig. 19).

In most places throughout Peary Land, Valdemar Glückstadt Land, and Kronprins Christian Land, the upper boundary can be precisely placed at the top of a very distinctive light grey unfossiliferous nodular lime mudstone or rarely a thin conglomerate and at the base of the overlying terrigenous black mudstones and turbidites of the Wulff Land Formation (Thors Fjord Member; Hurst & Surlyk, 1982; figs 32, 34, 41). In a few localities in Peary Land, reefs (Samuelsen Høj Formation) overlie the Odins Fjord Formation (fig. 39). In these places the boundary is taken at the top of the level-bedded dark grey nodular carbonates. The overlying reefs are light grey in colour but neither nodular nor level-bedded.

Distribution. The formation does not occur to the west of the valley leading southwards from Adolf Jensen Fjord (fig. 1). The formation occurs in the valley sides of Odins Fjord (fig. 43) and its southern extension, in an anticline south of Thors Fjord and in a west–east belt through Peary Land, reaching the eastern coast at Vitsköl Bugt (fig. 1). Isolated outcrops of the formation occur in the G. B. Schley Fjord region of Peary Land and in northern Valdemar Glückstadt Land. In Kronprins Christian Land the formation strikes north–south and is repeated as a series of slivers by thrusts (fig. 1) striking north–south.

Biostratigraphy. In the type section smooth virgianid brachiopods of the genus *Virgianella* sp. occur approximately 50 m above the base of the formation. They are thought to be indicative of an Early to Middle Llandoverian age (fig. 28). In the same section 10 m above the virgianids the stricklandiid brachiopod *Kulumbella* sp. occurs. This genus occurs throughout the Middle Llandoverian of the Soviet Union, but a single species is known from the Upper Llandoverian. The few specimens from the type section are very similar to the Middle Llandoverian forms and this is the only direct evidence currently available to suggest a Middle Llandoverian age for this part of the formation.

In a reference section (fig. 32) just to the north of the type section large smooth pentamerid brachiopods of the genus *Harpidium* occur 110 m above the base of the formation. Such forms are normally taken as indicative of a mid Late Llandoverian age (late Fronian and Telychian Stages) or younger (Berry & Boucot, 1970; Boucot & Johnson, 1979). Species of *Harpidium* occur throughout the remainder of the Formation.

In Børglum Elv (fig. 13) a collection of corals approximately 110 m above the base of the formation suggests a Middle to Late Llandoverian age (Saied, 1979). This is evidence to suggest the possible maximum extent of the Middle Llandoverian in one reference section.

Conodonts are particularly scarce in the middle and low upper part of the formation and the majority of those that occur are not age diagnostic (Armstrong, 1983; Armstrong & Aldridge, 1982). However, in the type section (fig. 9) the occurrence of the conodont *'O.' fluegeli,* 95 m above the formation base (Bure

Iskappe Member and above) and throughout the remainder of the formation, is indicative of a Late Llandoverian age (Armstrong, 1983; Armstrong & Aldridge, 1982).

Conodonts are particularly abundant in the uppermost part of the formation. In the northernmost reference section in Odins Fjord (fig. 32), conodonts first indicative of the *celloni* Zone occur 2 m below the top of the formation. In sections further to the south the first occurrence of the *celloni* Zone occurs progressively lower in the formation (fig. 28). In the reference section in southern Odins Fjord (fig. 33) it occurs 5 m below the top of the formation; in the Børglum Elv reference section (fig. 13) 15 m below the top; and in the reference section of south-eastern Peary Land 25 m below the top (fig. 37). In the isolated outcrops of north-eastern Peary Land, around G. B. Schley Fjord, the first indication of the *celloni* Zone occurs approximately 1 m below the top of the formation (Armstrong, 1983; Armstrong & Aldridge, 1982). This area is almost directly along strike, with reference to the shelf margin along the Navarana Fjord fault, from the northernmost reference section in Odins Fjord. The base of the *celloni* Zone is correlated with the C_5 unit of the Llandoverian, that is the late Late Llandoverian, Telychian Stage. Thus, the conodont evidence indicates that the top of the Odins Fjord Formation in Peary Land is diachronous, younging southwards away from the shelf margin.

Corroborative graptolite evidence from the base of the overlying Wulff Land Formation (Thors Fjord Member) also indicates diachronism (cf. Hurst & Surlyk, 1982). In Odins Fjord graptolites from no more than 5 m above the Odins Fjord Formation include: *Monograptus vomerina* aff. *M. crenulata, Monograptus priodon* and *Monograptus spiralis spiralis* indicating the *spiralis* Zone of the Upper Llandoverian. In southern Peary Land especially around Samuelsen Høj, scattered collections from the base of the Wulff Land Formation contain rich graptolite faunas, e.g. *Retiolites geinitzianus geinitzianus, Retiolites geinitzianus angustidens, Stomatograptus grandis grandis, Monograptus vomerina vomerina, Monograptus* aff. *M. Priodon, Monograptus spiralis spiralis, Monograptus tullbergi* and *Cyrtograptus sakmaricus* indicating the uppermost Landoverian *sakmaricus–laqueus* Zone (Hurst & Surlyk, 1982). Thus, graptolite evidence indicates that the base of the Wulff Land Formation in Peary Land is diachronous and youngs southwards in the same direction as the diachronism deduced for the top of the Odins Fjord Formation. In northern Odins Fjord and around the G. B. Schley Fjord region, the top of the Odins Fjord Formation is contained within the *celloni* Zone (conodonts) or *spiralis* Zone (graptolites), that is C_5 Late Llandoverian. Further south in Peary Land the top of the Odins Fjord Formation is probably contained within the *sakmaricus–laqueus* Zone (or at least very top of the *spiralis* zone), that is C_6 latest Llandoverian.

Geological age. The Odins Fjord Formation ranges in age from Middle (possibly

Early) to Late Llandoverian age in Peary Land (fig. 28). There is no evidence to suggest that the base of the formation is diachronous. The top of the formation is diachronous, younging southwards through Peary Land and away from the shelf margin, from C_5 to C_6 Late Llandoverian age. The corroborative data for diachronism from both conodonts in the limestones and graptolites in the overlying terrigenous mudstones suggest that there is little or no break in sedimentation at the boundary. The age control of the formation in Valdemar Glückstadt Land and Kronprins Christian Land is not as well documented. There is no available evidence for the age of the base of the formation, but it must fall in the Early to Middle Llandoverian range. Graptolite evidence indicates that the age of the top of the formation is contained within the Late Llandoverian *celloni* Zone. There is some evidence to suggest (based on graptolites in the overlying Profilfjeldet Member) that from eastern Kronprins Christian Land to western Kronprins Christian Land and Valdemar Glückstadt Land the age of the top of the Odins Fjord Formation is diachronous, within the Late Llandoverian, younging westwards (see Hurst & Surlyk, 1982).

Melville Land Member

new member

History. The member corresponds to the uppermost half of the informal member 'C' of the 'Un-named Silurian limestone formation' of Christie & Peel (1977; fig. 4). In the Odins Fjord region Hurst (1979) described a member 'C' of the 'Un-named Silurian limestone formation' and equated it with that of Christie & Peel (1977). The Odins Fjord member 'C' is disbanded and not included in the Melville Land Member as it is of different lithology.

Name. After Melville Land, the area of southern Peary Land to the east of Jørgen Brønlund Fjord (fig. 1).

Type and reference sections. The type section is in eastern Melville Land (figs 15, 19), and reference sections are located throughout Melville Land (figs 11, 13, 37).

Thickness. Between 15 and 30 m in Peary Land. The member thins progressively from east to west (fig. 28). This thinning is also related to a north to south component, and in the Odins Fjord and G. B. Schley Fjord region the member is absent.

Lithology. The member is characterised by thin to medium-bedded limestone (10–50 cm) which weathers into recessive slopes. The rocks are generally grey in colour (fig. 19).

Some of the beds are cryptalgal laminite and only rarely are small low domal stromatolites recognisable (fig. 53). Many of the beds are fenestral lime mudstone which in thin section is pelletal or clotted mudstones with small irregular fenestrae

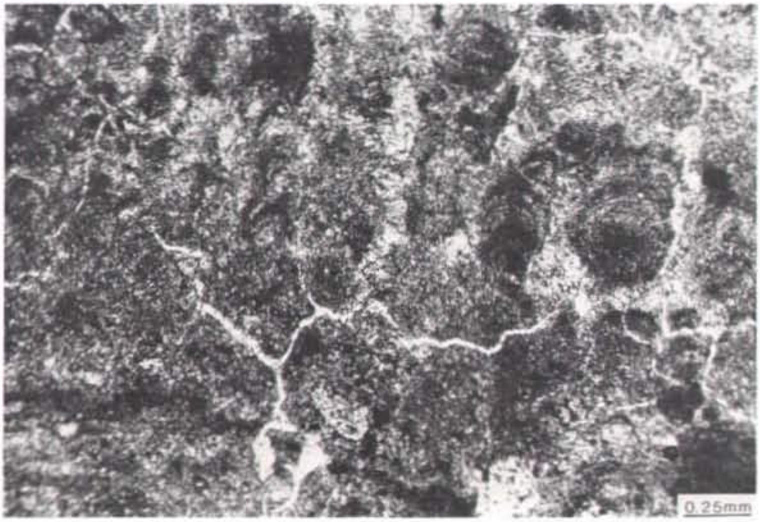


Fig. 53. Thin section photomicrograph of small-scale stromatolites in reference section 16 (figs 1, 37) of the Melville Land Member (figs 1, 15). Sample GGU 229046.

filled with blocky calcite. Other lithologies include laminated lime mudstone, weakly laminated lime mudstone and apparently massive lime mudstone. No sediment cyclicity is evident.

Facies interpretation. These sediments represent deposition in peritidal environments. The cryptalgal laminite and fenestral lime mudstone represents intertidal to supratidal environments, whilst the laminated lime mudstone represents quiet shallow subtidal environments.

Boundaries. The lower boundary is taken at the incoming of the first well laminated limestone beds (figs 11, 13, 15, 37). This is generally accompanied by a slight lightening in the colour of the sediments and a recessive weathering nature of the member (fig. 19). Fauna is very sparse. The upper boundary is taken at the base of the overlying skeletal wackestones which are darker in colour, more massive and generally mottled and nodular (figs 11, 13, 15, 37). This is in direct contrast to the thinly-bedded fenestral lime mudstone which occurs at the top of the member everywhere.

Distribution. The most westerly, and at the same time northerly, exposure of the member is approximately 25 km west of Samuelsen Høj (fig. 1). The member occurs eastwards of this point throughout Melville Land. The member does not occur in the Odins Fjord or Thors Fjord region nor in the G. B. Schley Fjord region of Peary Land. It has not been located in Kronprins Christian Land and considering its regional development it is thought unlikely that it occurs in this region. It is not known if the formation occurs in Valdemar Glückstadt Land.

Biostratigraphy and geological age. No age diagnostic faunas from the member itself have been recovered. However, it occurs above other sediments of the Odins Fjord Formation which are of Early to Middle Llandoverian age (fig. 28). In one reference section in Børglum Elv (fig. 13) the first unequivocable evidence of a Late Llandoverian age occurs at least 40 m above the meber. In conclusion the member is of Early to Middle Llandoverian age and regional stratigraphic considerations would suggest that it is contained completely within the Middle Llandoverian.

Bure Iskappe Member

new member

History. The member corresponds to the informal member 'D' described by Hurst (1979). The preliminary nomenclature used by Hurst (1979) was based on the work of Christie & Peel (1977), but the informal member 'D' of the 'Un-named Silurian limestone formation' of the latter authors is not included within this new member (fig. 4) as the lithologies are different (see distribution).

Name. After Bure Iskappe south of Odins Fjord and to the east of Hans Tavsens Iskappe (figs 1, 6).

Type and reference sections. The type section is in northern Odins Fjord (fig. 32)

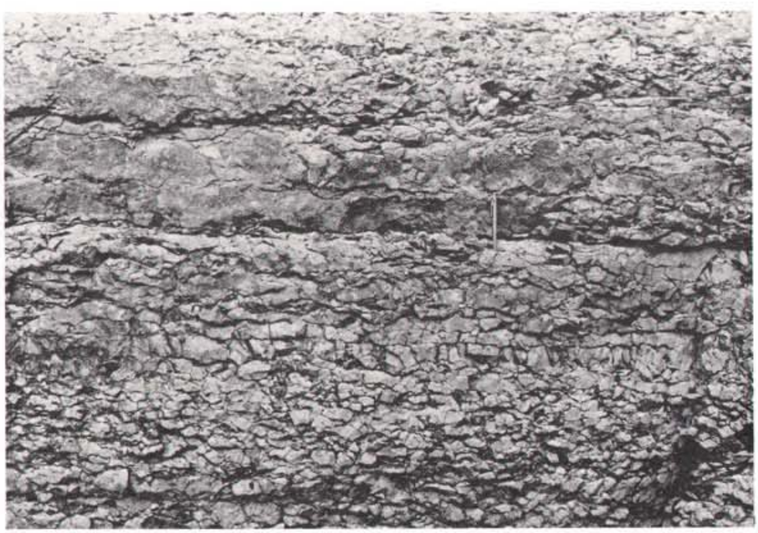


Fig. 54. Nodular limestones typical of the Bure Iskappe Member in type section 1 (figs 1, 6). Pen scale 13 cm.

and reference sections occur throughout the Odins Fjord region and in the anticline to the south of Thors Fjord (figs 9, 30, 33).

Thickness. Between 30 and 50 m. There is no apparent systematic spatial variation in the thickness of the member (fig. 28).

Lithology. The member is characterised by thin to medium-bedded limestone (10–50 cm) which weathers into recessive slopes (fig. 43). A distinctive feature of the unit is the highly nodular and wavy-bedded nature of the sediments (fig. 54) together with the dark grey to black colour. The sediments are rarely mottled, but faunas are commonly silicified.

Sediment is wackestone with a high content of elliptical pellets and broken, poorly sorted fragments of crinoids, corals, brachiopods, ostracods and trilobites. Siliceous sponge spicules are particularly common. Matrix consists of lime mudstone which may be clotted. Rarer facies include laminated lime mudstones, often with siliciclastic mud streaks. Chert nodules and beds are common in some horizons. Terrigenous mud interbeds are also present. In the type section a thick (2–3 m) coquina of disarticulated pentamerid brachiopods (*Harpidium* sp.) can be traced for over 1 km (fig. 55). The coquina is not graded and the interstitial sediments are skeletal wackestone and packstone.

Facies interpretation. The sediments are indicative of very low-energy deep-shelf environments. The total lack of algae strongly suggests that deposition was below

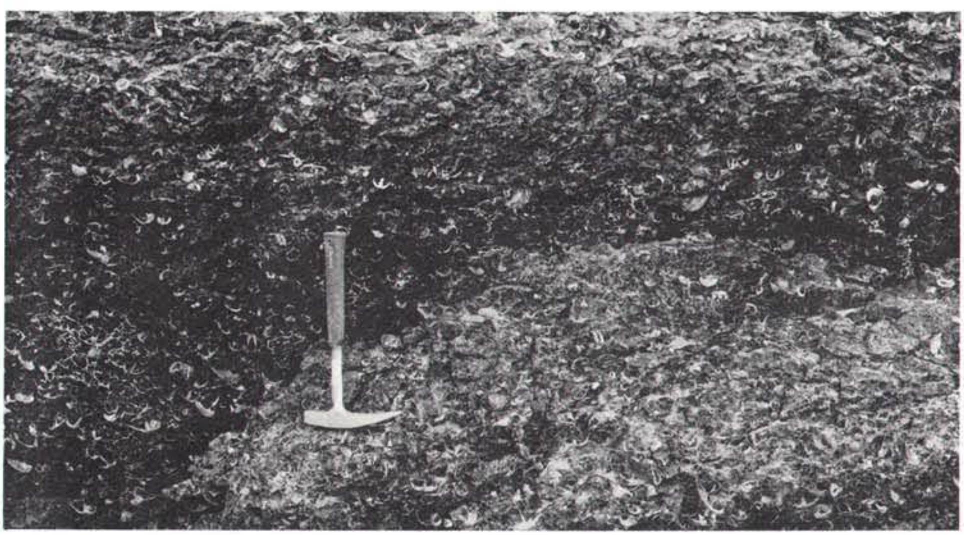


Fig. 55. *Harpidium* sp. pentamerid brachiopod shell bed in the Bure Iskappe Member type section 1 (figs 1, 6).

the euphotic zone. The undisturbed laminae of the lime mudstones suggest anoxic environments. The nodular bedding is similar to nodular carbonates on present-day Bahamian slopes (Mullins *et al.*, 1980) which develop in low-energy deep-water environments.

Boundaries. The lower boundary is taken at the first appearance of thin-bedded, black nodular or wavy-bedded carbonates (figs 9, 30, 32, 33). This change is often associated with chert nodules, siliciclastic mudstone streaks, silicified faunas and a more recessive weathering character. This contrasts sharply to the underlying more massive thicker-bedded units. The top of the member is taken at the base of the first massive thick-bedded unit. This is commonly a floatstone unit and forms a more cliff-like weathering feature (figs 9, 30, 32, 33).

Distribution. The most westerly occurrence of the member is in the environs of Odins Fjord (fig. 1). The member does not occur in the Samuelsen Høj region, its last reported occurrence some 25 km to the west. In the reference section in Børglum Elv (fig. 13) a nodular limestone unit is developed in approximately the same lithostratigraphic position as the Bure Iskappe Member and approximately at the same time. This unit is probably a southerly contemporaneous facies with similarities both to the Bure Iskappe Member and the remainder of the contiguous sediments of the Odins Fjord Formation. However, it is sufficiently different not to be included in the member. Similarly, in the isolated sections in the G. B. Schley Fjord region (fig. 40) a distinctive 35 m nodular unit occurs in the upper part of the Odins Fjord Formation. The unit is very similar to the Bure Iskappe Member, and it occurs in a comparable stratigraphic position. However, due to the isolated nature of the G. B. Schley Fjord region outcrops, this unit cannot yet be assigned with certainty to the Bure Iskappe Member. The member does not occur in Valdemar Glückstadt Land or Kronprins Christian Land.

Biostratigraphy. In the type and reference sections conodonts are indicative of a general Late Llandoverian age (Armstrong, 1983; Armstrong & Aldridge, 1982). The pentamerid brachiopod *Harpidium* sp., which occurs in the middle of the type section (fig. 32), generally indicates C_3 or younger strata (mid Late Llandoverian or younger; Fronian to Telychian Stages). Considering that the first indication of Upper Llandoverian strata occurs some 20 m below the member and the first indication of uppermost Llandoverian strata occurs over 100 m above the member, it appears likely that the Bure Iskappe Member is of early to mid Late Llandoverian age (Fronian to early Telychian Stages; fig. 28).

Geological age. Late Llandoverian.

Samuelsen Høj Formation

new formation

History. This formation is erected to cover the isolated knoll-like reefs of Peary Land, Valdemar Glückstadt Land, and Kronprins Christian Land. Fränkl (1955) referred to a unit, near Centrum Sø in southern Kronprins Christian Land, of reef-like fossil-rich limestones as 'Drømmebjerg Kalk' which he separated from the Centrum Limestone of Adams & Cowie (1953). Information concerning the 'Drømmebjerg Kalk' and its relationship to the Centrum Limestone has always been somewhat ambiguous. Scrutton (1975) referred to the 'Drømmebjerg Kalk' as the Drømmebjerg Formation. Peel (1980) recognised that a series of reef knolls in northern Kronprins Christian Land were identical to the Silurian reefs or Silurian carbonate mounds described in Peary Land by Peel & Christie (1975) and Christie & Peel (1977) respectively. Accordingly, Peel (1980) referred them all to the Drømmebjerg Formation.

After visiting the type area of the 'Drømmebjerg Kalk' in 1980, the author finds it apparent that Peel's (1980) suggestion is correct. However, it is proposed that the Drømmebjerg Formation name is dropped and replaced by the Samuelsen Høj Formation. Reasons for this line of action include:

(1) there is ambiguity surrounding the precise type area of the Drømmebjerg Formation.

(2) the relationship of the Drømmebjerg Formation, at its type locality, to the Centrum Limestone is

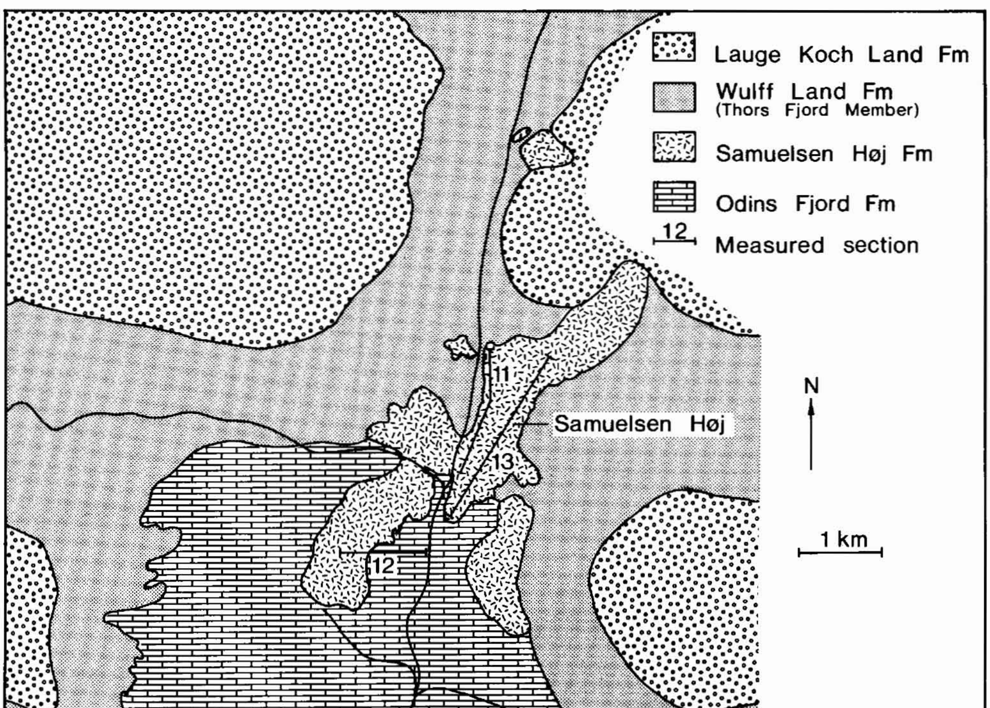


Fig. 56. Geological map of the area around Samuelsen Høj in Peary Land (fig. 1). Section 11 (fig. 58) is the type section for the Samuelsen Høj Formation. Section 13 (fig. 59) is a reference section for the Samuelsen Høj Formation, and section 12 (fig. 35) is a reference section for the Samuelsen Høj Formation and Odins Fjord Formation.

ambiguous. The Drømmebjerg Formation around north-eastern Centrum Sø in the area of the type locality is folded and thrusted. This together with poor exposure means that it is difficult to determine the precise stratigraphic relationship of the unit.

The Samuelsen Høj Formation incorporates the carbonate in the 'carbonate-shale unit' of Mayr (1976), the Silurian reefs of Peel & Christie (1975), and the Silurian carbonate mounds of Christie & Peel (1977; fig. 4).

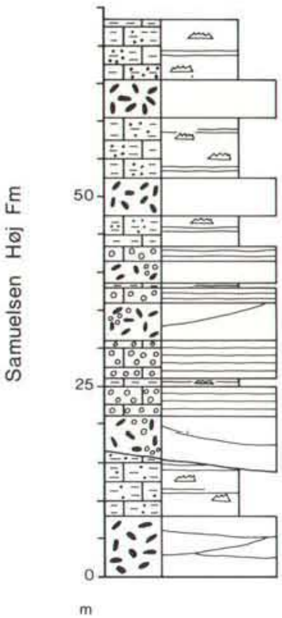
As defined here the Samuelsen Høj Formation is a series of discrete reefs which formed during a brief interval of time when the Lower Palaeozoic carbonate platform of eastern North Greenland foundered in the latest Llandoverian (Hurst *et al.*, 1983; Hurst & Surlyk, 1982). As such they form a distinct entity. This formation apparently does not occur west of Samuelsen Høj and therefore there is no apparent genetic connection between this reef belt and contemporaneous ones over 200 or 300 km to the west (Hurst, 1980a, b; Hurst & Peel, 1979). The Samuelsen Høj Formation also has distinct facies differences from the reefs to the west.

The regional geological and sedimentary evidence (see depositional environments and shelf evolution below) indicates that it is unlikely that the Samuelsen Høj Formation occurs in the subsurface, below the deep-water turbidites of the Lauge Koch Land Formation (see fig. 3). Although true *in situ* reefs have not been recognised at the shelf margin along the Navarana Fjord fault (fig. 3), the evidence from base-of-slope debris beds is that they do occur (Hurst & Surlyk 1983b, 1984). At present the shelf margin reef-like sediments have been described under the supposed contemporaneous shelf sediments of the Turesø and Odins Fjord Formation. If, in the future, it is necessary to stratigraphically recognise this unit of reefs, it is recommended that a separate stratigraphic division is erected and that they are not included in the Samuelsen Høj Formation. The shelf rim reefs have not formed at the same time and under the same dynamic processes as the reefs of the Samuelsen Høj Formation. Further, the facies, and in particular the algal content, is substantially different in the two complexes.

Name. After Samuelsen Høj in Peary Land, 35 km due north of Jørgen Brønlund Fjord (figs 1, 56).

Type and reference sections. The type section together with a series of reference sections are located in the northern part of Samuelsen Høj itself (figs 34, 56, 57, 58, 59). Other reference sections are located in the Melville Land region of Peary Land

Fig. 57. Type section of the Samuelsen Høj Formation (figs 56, 58). Hill height approximately 100 m.



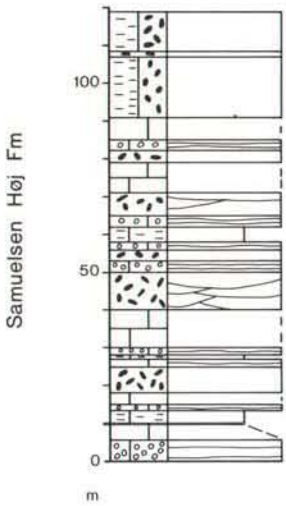


Fig. 59. Sediment log of reference section 13 (fig. 1) of the Samuelsen Høj Formation (figs 56, 57).

Fig. 58. Sediment log of type section 11 (fig. 1) of the Samuelsen Høj Formation (figs 56, 57).

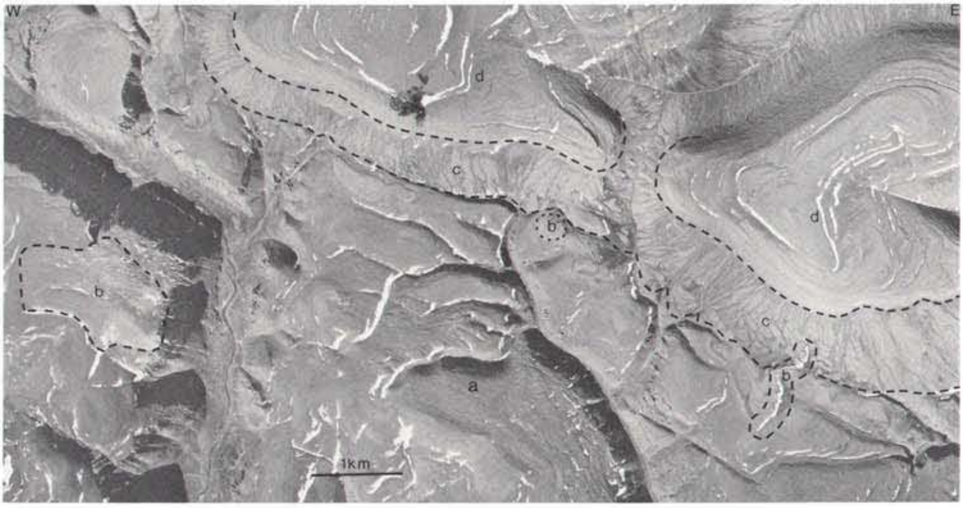


Fig. 60. Vertical aerial photograph, with the geology superimposed, of an area in the Melville Land region of Peary Land around section 16 (fig. 37). Odins Fjord Formation (a), Samuelsen Høj Formation (b), Wulff Land Formation (Thors Fjord Member) (c) and Lauge Koch Land Formation (d) are terrigenous clastic formations (Hurst & Surlyk, 1982). Note the scattered knoll-like nature of the Samuelsen Høj Formation and its relationship to the black mudstones of the Wulff Land Formation. Aerial photograph 256V, No. 493. Copyright Geodætisk Institut, Denmark.

Fig. 61. Samuelsen Høj (fig. 1). Note the domal dips of the beds. Looking towards section 13 (fig. 56) which is up the mound ridge. Height of hill approximately 200 m.

(figs 38, 39, 60). It should be noted that due to the inherently complicated and quick temporal and particularly spatial facies changes in reef-like bodies, the type section is not necessarily representative of all similar bodies assigned to this formation.

Thickness. Due to domal dips (fig. 61) it is difficult to accurately assess thickness of individual reefs, and also thickness varies considerably, within one reef. In Peary Land the smallest reefs are about 50 m thick and the largest 150 m. In Kronprins Christian Land no reefs have been measured in detail, but some in the region of Centrum Sø and Vandredalen may be in the order of at least 300 m thick. Lateral

Fig. 62. Thin section photomicrograph of bryozoan encrusted by unidentifiable algae from the massive facies of the Samuelsen Høj Formation. From section 12 (fig. 56). Sample GGU 254919.

Fig. 63. Thin section photomicrograph of spongiostromes in skeletal wackestone of the Samuelsen Høj Formation. From section 15 (fig. 39). Sample GGU 229026.

dimensions of individual reefs vary from between 50 m wide up to 200 m circumference and 5 km wide and 10 km circumference.

Lithology. The formation is characterised by thick-bedded to massive very light grey to white limestone.

Sediments consist of massive lime mudstone, sometimes with a clotted texture. Occasionally, the lime mudstone displays faint laminations and large irregular and anastomosing cavities (several cm long) filled with several generations of fibrous calcite. Some of the cavities approach a stromatactis form. Incipient boundstones are present and consist of bryozoans (fig. 62) with encrusting blue-green algae in the form of large spongiostrome units (fig. 63). Some of the spongiostrome units interdigitate with sheets of *Sphaerocodium* algae. Abundant sponge spicules are present.

Other facies, especially along the flanks, consist of thick bioclastic floatstone and rudstone in which the interstitial sediment is a skeletal wackestone, packstone or grainstone. Floatstone consists of more than 50% tabular and bulbous stromatoporoids (fig. 64). Rudstones are commonly dominated by crinoids and often occur in graded and laminated beds (allodapic carbonates) of 50 cm to 1 m in thickness.

None of the units can be traced over more than several tens of metres, suggesting lateral lenticularity of facies. Rare conglomerate beds occur in association with the reefs. They are commonly non-graded, chaotic, pebble to cobble grade units up to several metres thick. Clasts are derived entirely from the reefs and are a mixture of

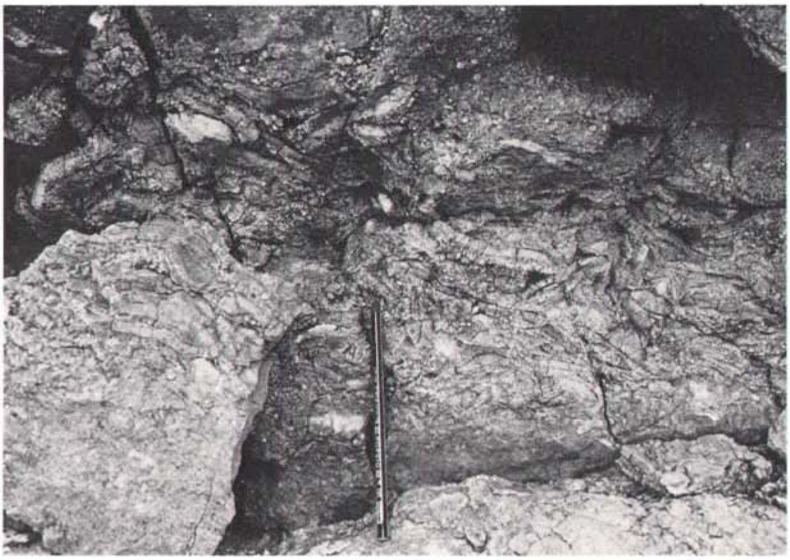


Fig. 64. Tabular stromatoporoids in the Samuelsen Høj Formation floatstone units. From section 12 (fig. 56).

lithoclasts and bioclasts. Matrix content is low. Further details of facies in the Samuelsen Høj Formation may be found in Hurst (1980a) and Mayr (1976).

In a few localities in Kronprins Christian Land thin-bedded black lime mudstone overlies the reefs. They are included in the Samuelsen Høj Formation.

Facies interpretation. Deposition of the facies was in fairly high-energy environments well within the euphotic zone. The abundance of cavities lined with fibrous calcite is suggestive of early submarine lithification. This is also indicated by the penecontemporaneous erosion forming the conglomerates. The height of the reefs is difficult to assess, but the fringe of debris suggests an elevated dome. The thin-bedded black lime mudstones in Kronprins Christian Land possibly represent hemipelagic deposition after reef drowning.

Boundaries. The lower boundary is taken at the first appearance of thick to massive-bedded light grey to white limestone above the contrasting dark grey Odins Fjord Formation (figs 35, 38, 39). The first bed is normally a massive stromatoporoid floatstone or mudstone unit and the dips of these beds are usually slightly discordant to the underlying level-bedded Odins Fjord Formation.

The top of the formation is often the present-day land surface, but in a few places the formation is overlain by terrigenous mudstone and turbidites of the Wulff Land Formation, Thors Fjord Member (Hurst & Surlyk, 1982). In such cases the boundary is taken at the base of the terrigenous mudstone.

It is impossible to precisely define the lateral reef limits when conglomerates derived from the reefs interfinger with contemporaneous sediments. There is no difficulty in qualitatively (visually) assessing the limits of reef units, especially when they are surrounded by terrigenous mudstones.

In Kronprins Christian Land Peel *et al.* (1981) report that reefs, which are here referred to the Samuelsen Høj Formation, occur stratigraphically slightly lower in the succession than in Peary Land. There is lateral interdigitation of the lower part of the reefs with the level-bedded carbonates of the Odins Fjord Formation.

Distribution. The most westerly occurrence of the formation is at Samuelsen Høj itself (fig. 1). Isolated reefs occur in a belt up to 50 km east of Samuelsen Høj in northern Valdemar Glückstadt Land and throughout western Kronprins Christian Land (fig. 1).

Biostratigraphy. Some of the reefs in eastern Peary Land have yielded poor conodont collections, questionably indicating an upper *celloni* Zone, that is a Late Llandoverian age (C_{5-6}). *Celloni* Zone faunas have been obtained from the reefs in Kronprins Christian Land (Armstrong, 1983; Armstrong & Aldridge, 1982). This suggests that the Samuelsen Høj Formation follows conformably on the Odins Fjord Formation of similar age and that there is no hiatus between the two formations (fig. 28).

Graptolites occurring on the flanks of the type locality at Samuelsen Høj indicate the *sakmaricus–laqueus* Zone of latest Llandoverian (C_6) age (Hurst & Surlyk, 1982). In Valdemar Glückstadt Land graptolites from the Profilfjeldet Member, flanking the reefs, indicate the *sakmaricus–laqueus* Zone, and in western Kronprins Christian Land in a similar occurrence graptolites indicate the *spiralis* and possibly *sakmaricus–laqueus* Zones (Hurst & Surlyk, 1982). In eastern Kronprins Christian Land graptolites occurring just above some small reefs indicate the *griestoniensis* Zone which is slightly older than the *spiralis* Zone.

Thus, the Samuelsen Høj Formation appears to start slightly earlier in Kronprins Christian Land than Peary Land (*celloni* as opposed to *upper celloni* Zone). The diachronism of the Samuelsen Høj Formation mirrors the diachronism of the overlying deep-water terrigenous turbidites (Hurst & Surlyk, 1982). This conclusion is also suggested by the fact that Peel *et al.* (1981) report that reefs which are here referred to the Samuelsen Høj Formation start slightly lower in the succession in Kronprins Christian Land as there is some interdigitation between the basal part of the Samuelsen Høj Formation and the top of the level-bedded limestones, here referred to the Odins Fjord Formation.

The age of the top of the reefs is not precisely known, but there is no independent unequivocable evidence suggesting a Wenlockian age. Sparse graptolite evidence (see above) suggests that the Samuelsen Høj Formation in Kronprins Christian Land terminated in the *spiralis* Zone, that is C_6 Late Llandoverian age, whilst in Peary Land it could be slightly later in the latest Llandoverian *sakmaricus–laqueus* Zone. This is supported by the fact that black limestone (included in the Samuelsen Høj Formation) which occurs on top of some reefs in Kronprins Christian Land contains a *celloni* Zone conodont fauna (Armstrong, 1983; Armstrong & Aldridge, 1982). Taking into account regional considerations (Hurst *et al.*, 1983; Hurst & Surlyk, 1982) it is thought likely that the Samuelsen Høj Formation was deposited in a very brief time interval in the Late Llandoverian (C_{5-6}).

It should be noted that Mayr (1976) regarded Peary Land reefs, here referred to the Samuelsen Høj Formation, as of Middle Silurian age, i.e. Wenlockian to early Ludlovian. This determination was based on shelly faunas of corals, brachiopods, trilobites and gastropods. The conodont and graptolite evidence presented above is clearly contrary to the work of Mayr (1976). There is evidence to suggest that North Greenland Silurian shelly macrofaunas occur earlier than in other parts of the world (Boucot & Hurst, 1979; B. Jones, personal communication, 1983). These facts together with evidence from the regional development of the Samuelsen Høj Formation (Hurst *et al.*, 1983) preclude the age assignment suggested by Mayr (1967).

Geological age. Late Llandoverian.

Harefjeld Formation

new formation

History. The formation corresponds to that part of the Centrum Limestone (Fränkl, 1954, 1955, 1956) contained on the nappes on the south-eastern side of Vandredalen.

Name. After Harefjeld, the hill on the eastern side of Vandredalen, Kronprins Christian Land (figs 1, 65).

Type section. No type section is designated because none has been measured, due to a combination of poor exposure and structural complications. The type area for the formation is Harefjeld itself (fig. 65).

Thickness. At least between 200 and 300 m. Fränkl (1955) estimated up to 500 m.

Lithology. The formation is affected by at least two strong cleavages and one set of joints making it difficult to discern original bedding. However, in several areas the sediments appear very thinly bedded, in the order of 10 to 20 cm thick. Sediments are very dark grey to black.

There appears to be an alternation of thinly laminated terrigenous lime mudstone units and purer lime mudstone with occasional wackestone. Lime mudstone also appears to be laminated in places.

Fig. 65. Vertical aerial photograph, with the geology superimposed, of the area around Harefjeld (fig. 1). Harefjeld Formation (a). All geological symbols as in fig. 6, except that the notched line represents a thrust, the notches indicating the overriding thrust sheet. Bar 1 km. Aerial photograph 260K, No. 813. Copyright Geodætisk Institut, Denmark.

Boulders of pentamerid brachiopod coquinas in scree indicate some coarser-grained sediments, but these have not yet been found *in situ*.

Facies interpretation. The sediments apparently represent low-energy fairly deep-water environments which may well have also been anoxic at some time. When compared to contemporaneous shelf facies it is probable that the Harefjeld Formation was deposited in a general slope environment. More detailed interpretations are precluded.

Boundaries. The Harefjeld Formation is contained on a thrust sheet together with other sediments (fig. 65). The lower boundary is taken at the first occurrence of black thin-bedded terrigenous lime mudstone. In practice this boundary, which is easily located as the base of the Harefjeld Formation, rests on a very light grey to white crystalline dolomite unit which is informally known as the 'Danmarks Fjord dolomite', although the relationship of this latter unit with the early Ordovician Danmark Fjord dolomite at the type locality west of Danmark Fjord is unknown (Peel, 1982). The formation forms the top unit of the area in some places, but in others it is in thrust contact and overlain by Proterozoic sandstone assigned to the 'Rivieradal sandstone' unit or the Proterozoic dolomite of the Fyns Sø Formation.

Distribution. On the eastern side of Vandredalen in Kronprins Christian Land, from western Ingolf Fjord, through Harefjeld to Marmorvigen (fig. 1).

Biostratigraphy. Fränkl (1955, pl. 1) showed two fossil localities in carbonates now assigned to the Harefjeld Formation at Harefjeld itself. Apparently, corals were located at one locality which were identified for Fränkl by Cowie as *Cetophyllum* sp. and indicative of the Wenlockian. Other fossils include non-age diagnostic gastropods. None of the fossils collected by Fränkl are diagnostic of the Wenlock and considering the regional stratigraphy it is unlikely that the Harefjeld Formation is of Wenlockian age.

Smooth virgianid brachiopods in boulders (not *in situ*) indicate an Early to Middle Llandoverian age for some part of the formation. Other than that, no further informaton is forthcoming on the age assignment of the formation.

Geological age. Late Ordovician? to Early Silurian?

Discussion. The Harefjeld Formation is described as a separate formation on account of its lithological differences from contemporaneous undisturbed shelf facies, and because it was evidently thrust into its present position some distance from the east (Hurst & McKerrow, 1981a, b, 1984).

As far as can yet be ascertained it is partly contemporaneous with the Turesø Formation and the lower part of the Odins Fjord Formation. There is no evidence to indicate yet that any part of the Harefjeld Formation is equivalent to the older Børglum River Formation.

DEPOSITIONAL ENVIRONMENTS AND SHELF EVOLUTION

The following description and interpretation mainly relates to Peary Land from where the most comprehensive data have been derived. Information concerning the evolution of the shelf in Kronprins Christian Land is not detailed, but nevertheless patterns can be recognised.

The margin of the lower Palaeozoic carbonate shelf of North Greenland was controlled by east–west trending fault zones or flexures (Hurst & Surlyk, 1983b, 1984; Surlyk & Hurst, 1983, 1984; Surlyk *et al.*, 1980). In Peary Land the Silurian carbonate shelf margin was controlled by the Navarana Fjord fault (fig. 3). This shelf margin was a feature inherited from the Ordovician and possibly Cambrian.

It has been recently documented by Hurst & Surlyk (1983a) that the abrupt escarpment slope of the carbonate shelf in Peary Land is not a fault scarp, but represents the topographic expression of the deep-seated Navarana Fjord fault. The shelf to deep-water basin margin was controlled by the deep-seated Navarana Fjord fault. The carbonate shelf and deep-water basin depositional regimes were differentiated by normal down-to-north subsidence along the fault. As a consequence shelf carbonates were unable to prograde northwards across the fault line and thus the carbonate shelf margin accreted through time, building an abrupt escarpment which was also accentuated by subsidence. The shelf margin escarpment was initiated in the Cambro–Ordovician and by the Silurian was a well developed feature in the order of hundreds of metres in height. The shelf slope (that is the escarpment) was also at times an erosional bypass zone in the sense of Schlager & Ginsburg (1981) and Read (1982).

The eastern margin of the carbonate shelf was somewhere to the east of the present outcrops in Kronprins Christian Land, but it is not known in detail. The Silurian carbonates contained on the Sæfaxi Elv Nappe (Hurst & McKerrow, 1981a,b, 1984) are indicative of deep-water environments, possibly in a slope setting. These sediments may reflect a more ramp-like slope (cf. Ahr, 1973; Read, 1982; Wilson, 1974, 1975) to the eastern margin of the carbonate shelf.

During the main part of the upper Ordovician (Børglum River Formation) the carbonate shelf of eastern North Greenland was characterised by deposition of pelletal lime mudstone, skeletal wackestone and occasional packstone, fairly typical of lower Palaeozoic low-energy subtidal sediments (cf. Hurst, 1981; Jones *et al.*, 1979; Sodero & Hobson, 1979).

In latest Ordovician time a major environmental change took place and the established patterns persisted into the early–middle Llandoverian. The carbonate shelf (represented by the Turesø Formation and Ymers Gletscher Formation) shoaled, and low-energy (cf. James, 1979) possibly slightly hypersaline peritidal environments (Fürsich & Hurst, 1979) prevailed (fig. 66). The persistence and thickness of units suggest a monotonous and flat shelf (fig. 67).

In the latest Ordovician, according to Brenchley & Newall (1980, 1982) and McKerrow (1979), there was a world-wide eustatic regression in which sea levels may have dropped by 100 m or more. This may have been a factor in the overall shallowing observed at this time in Peary Land. However, the rock record in Peary Land does not indicate an abrupt shallowing (cf. Armstrong & Lane, 1981), nor is there any evidence of paleokarst on the shelf. Such evidence could suggest that this late Ordovician regression (and subsequent transgression) was not a world-wide

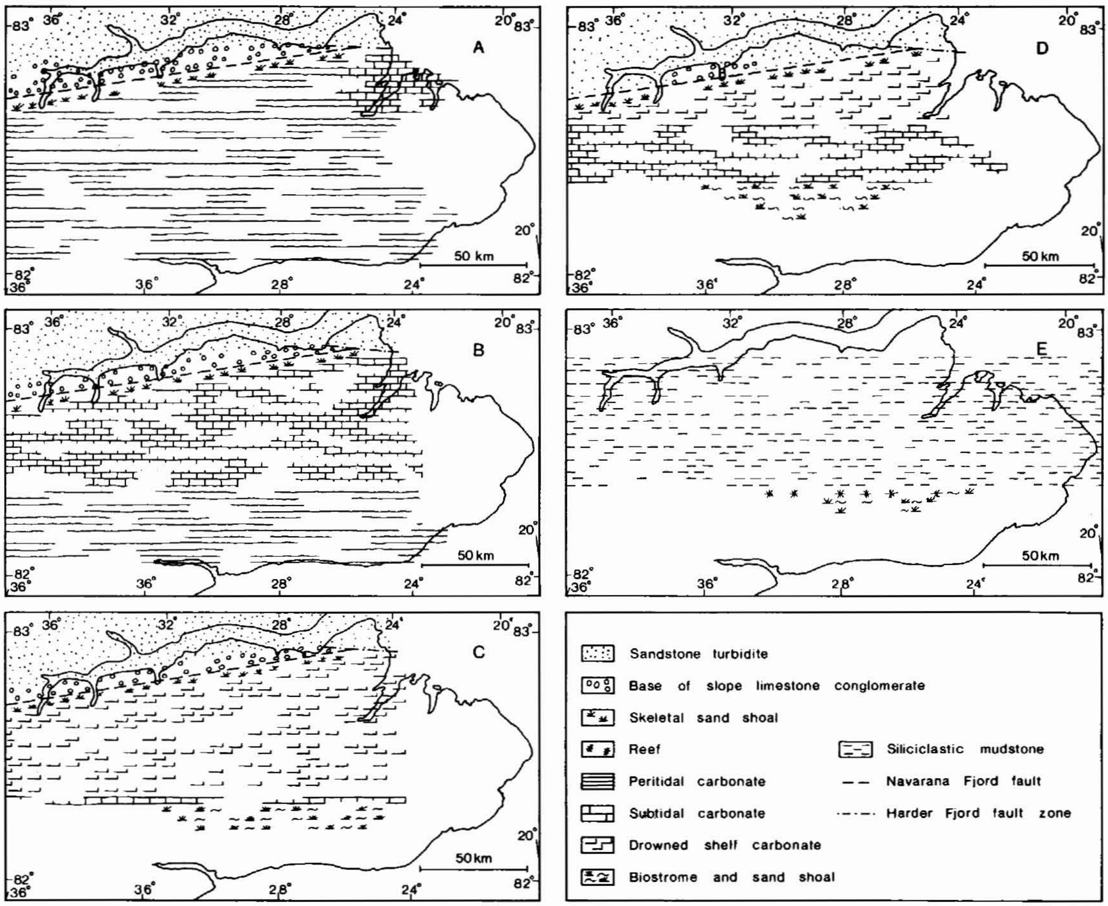


Fig. 66. Evolution of the major facies and environments in Peary Land during the development of the upper Ordovician and Silurian carbonate shelf. A, the Turesø Formation and Ymers Gletscher Formation; B, the lower part of the Odins Fjord Formation up to and including the Melville Land Member; C, the Bure Iskappe Member; D, the uppermost Odins Fjord Formation; E, shelf collapse and the Samuelsen Høj Formation.

phenomenon. Alternatively, shelf subsidence superimposed on a glacio–eustatic regression would tend to nullify the effects of the latter.

The shelf rim during the uppermost Ordovician and lower to middle Llandoverian had isolated high-energy carbonate sand shoals and possibly small reefs dotted along it (Hurst & Surlyk, 1983b; fig. 68). The eroded remains of a former shelf rim subaerial exposure surface (cf. Dunham & Olson, 1980) indicate that the shelf rim was elevated above the shelf and periodically was emergent. Emergence may be directly related to the relative sea level drop which promoted the development of the Turesø and Ymers Gletscher Formations.

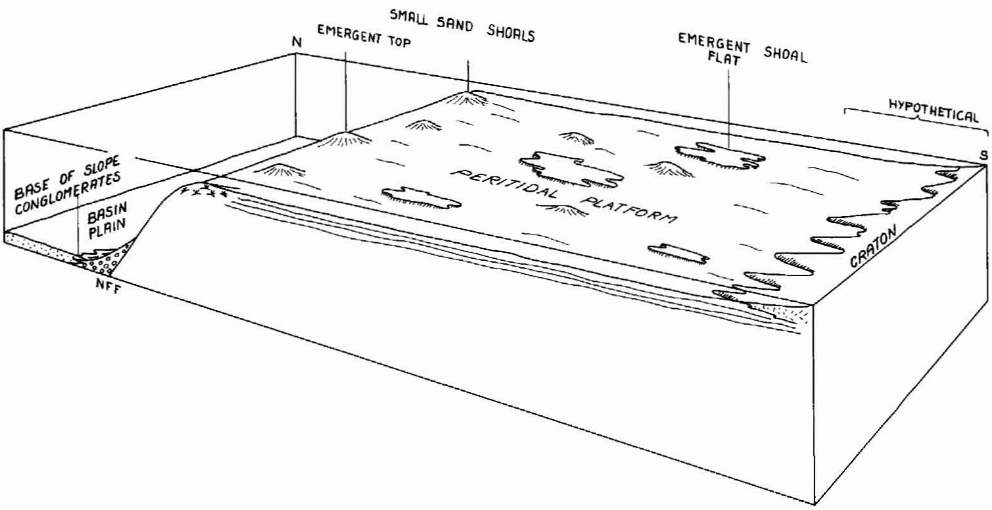


Fig. 67. Block diagram showing reconstruction of the first stage in the evolution of the Silurian carbonate shelf, corresponding to the Turesø and Ymers Gletscher Formations. NFF = Navarana Fjord fault.

In middle Llandoverian time, following the Ymers Gletscher Formation, a major phase of shallow subtidal carbonate deposition (Odins Fjord Formation) was initiated (fig. 66). The process responsible for the relative rise in sea level which flooded the previous peritidal shelf is not known. It may have been entirely glacio–eustatic or have been related to shelf subsidence. A period of sea level still-stand probably resulted shortly after the initial pulse, thus allowing progradation from the southern craton of peritidal environments (Melville Land Member of the Odins Fjord Formation) out over the subtidal sediments (fig. 66). These peritidal deposits are replaced northwards by subtidal carbonates (fig. 69). This facies change may simply reflect the point to which progradation reached. Alternatively, it could indicate that the shelf was tilted down-to-north, thus keeping the northern part of the shelf subtidal, whilst promoting relative uplift of the southerly shelf areas nearer the craton and the development of a northerly prograding wedge of peritidal carbonates (fig. 69).

A further relative rise of sea level took place in the middle to early late Llandoverian time (middle Odins Fjord Formation). Subtidal carbonate sediments were still deposited in the northern shelf areas, whilst the peritidal environments of the southern shelf were replaced by similar shallow subtidal environments (fig. 66).

In the later Llandoverian, continuing relative sea level rise is evidenced by the very low-energy and partially drowned areas of the northern shelf areas immediately adjacent to and south of the shelf margin (Bure Iskappe Member and above; Odins Fjord Formation). Contemporaneous shelf sediments south of an

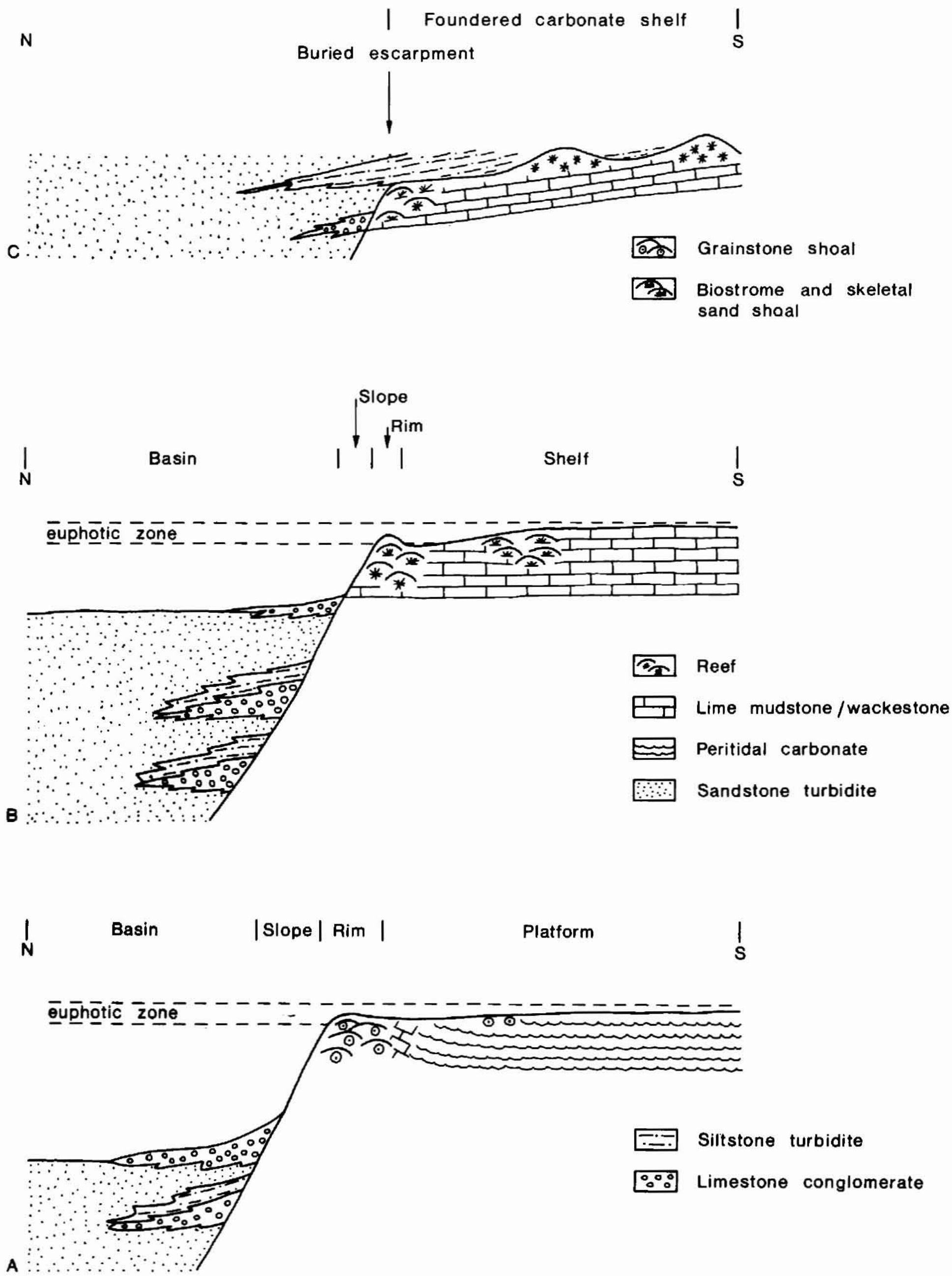


Fig. 68. Schematic representation of the facies, topography and depositional relationships across the carbonate shelf margin during deposition of the Turesø and Ymers Gletscher Formations (a), the upper part of the Odins Fjord Formation (b) and just subsequent to shelf foundering and the development of the Samuelsen Høj Formation (c).

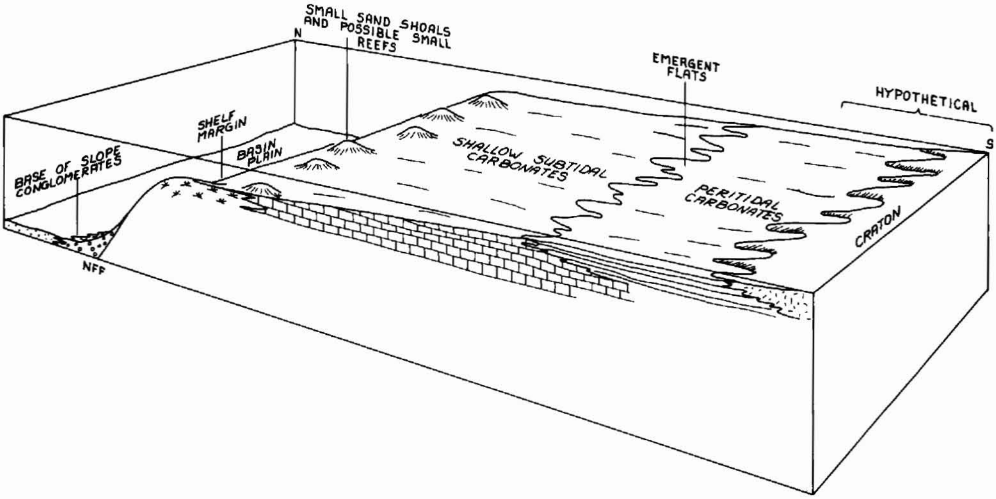


Fig. 69. Block diagram showing reconstruction of a second stage in the evolution of the Silurian carbonate shelf, corresponding to the Melville Land Member of the Odins Fjord Formation.

east–west line running through Samuelsen Høj consist of shallow marine relatively higher-energy large-scale carbonate sand shoals and biostromes (figs 66, 70). In the lee of the shoals lower-energy environments persisted. Occasionally thin tongues of the shoals and biostromes prograded northwards into the deeper partially drowned northern shelf areas, possibly as a result of a temporary stop in relative sea level rise.

It is interesting to note that these large-scale shoals essentially did not prograde northwards of an east–west line running through Samuelsen Høj (figs 66, 70). Similarly, the earlier peritidal environments of the Melville Land Member wedged out at the same point. This suggests that there was some pre-existing shelf topography with an increase in northward dip at this line which essentially prohibited northwards progradation of shallow marine facies.

It is not known if the relative sea level rise was glacio–eustatically induced or related to shelf sinking. Considering that the sea level rise took place during the late Llandoverian (*c.* 5–10 m.y.), it does not appear to have been episodic and that the latest Llandoverian abrupt shelf subsidence was tectonically induced suggests that the relative sea level rise was a result of shelf subsidence. This subsidence could have been a more moderate precursor to the latest Llandoverian shelf foundering (Hurst *et al.*, 1983).

The Upper Llandoverian shelf margin was rimmed by a series of relatively high–energy carbonate sand shoals and small algal–bryozoan reefs (figs 68, 70). This series of shoals and reefs was apparently more extensive and of greater proportions than the earlier phases. The evolution of the shelf rim facies in the late Llan-

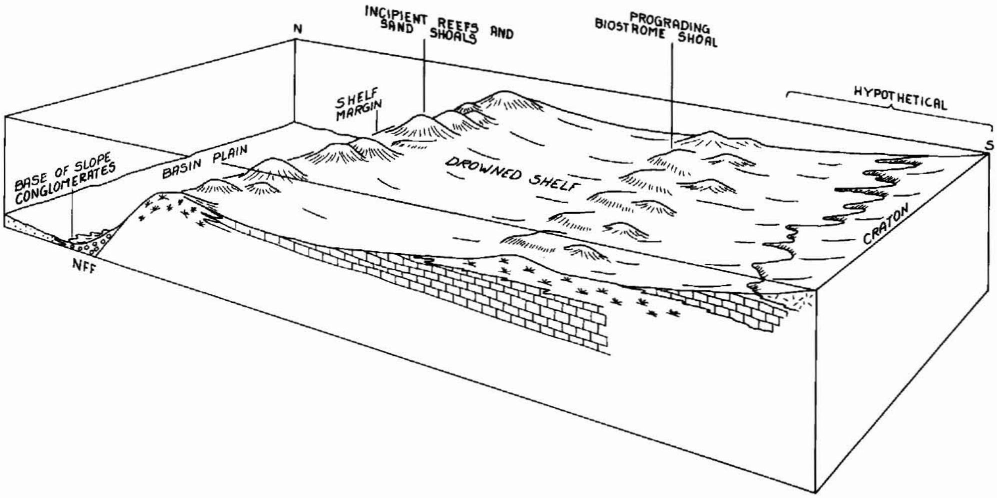


Fig. 70. Block diagram showing reconstruction of a third stage in the evolution of the Silurian carbonate shelf, corresponding to the upper part of the Odins Fjord Formation.

doverian is consistent with a relative sea level rise as reefs often develop during such phases (Hurst, 1980a; Kendall & Schlager, 1981; Schlager, 1981).

The base-of-slope (base of shelf escarpment) conglomerates also provide information concerning the evolution of the shelf margin slope. These conglomerates compare well with debris sheets described from the Exuma Sound of the Bahamas by Crevello & Schlager (1980) and similar Silurian examples from western North Greenland (Hurst & Surlyk, 1983a). The latest Ordovician to Llandoverian age of clasts in a single sheet of the older Citronens Fjord Member (Hurst & Surlyk, 1982) suggests, after taking into account comparable shelf sediment thicknesses of the same age range, that the carbonate shelf margin was elevated hundreds of metres above the base-of-slope and that the slope itself was precipitous (Hurst & Surlyk, 1984; fig. 68). The base-of-slope Citronens Fjord Member conglomerates were subsequently draped by turbidites (Hurst & Surlyk, 1982; Surlyk & Hurst, 1983, 1984). The later Freja Fjord Member conglomerate contains clasts representative of a similar late Llandoverian age. This suggests that during the Silurian subsidence along the Navarana Fjord fault had ceased and that the escarpment to the shelf margin was progressively reduced in height due to basin infill (fig. 68).

In the latest Llandoverian of eastern North Greenland the abrupt change from shallow shelf carbonates to black mudstones and fine siltstone and sandstone turbidites of lower slope and basin plain environments (Hurst *et al.*, 1983; Hurst & Surlyk, 1982, 1984; Surlyk & Hurst, 1983, 1984; Surlyk *et al.*, 1980) is indicative of a major event. Hurst *et al.* (1983) relate this sudden foundering of the carbonate shelf to downwarping due to nappe emplacement on the eastern fringe of the

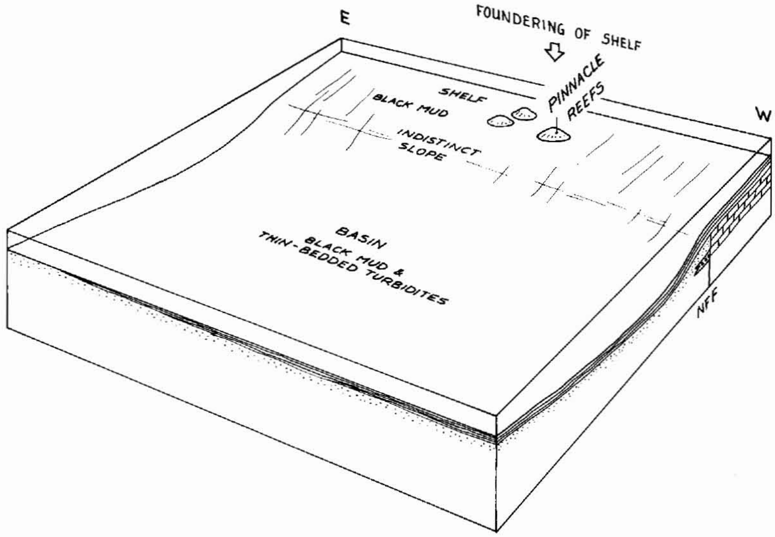


Fig. 71. Block diagram showing reconstruction of the final stage in the evolution of the Silurian carbonate shelf, corresponding to the development of the Samuelsen Høj Formation. From Surlyk & Hurst (1983, 1984).

carbonate shelf. With the initial foundering small isolated pinnacle reefs (Samuelsen Høj Formation) developed on those parts of the carbonate shelf that had not been previously drowned and were later covered by the terrigenous clastic influx (fig. 71). These pinnacle reefs apparently started and stopped growth first in the east (Kronprins Christian Land) reflecting the earlier down-flexing of the carbonate shelf nearer the Caledonian nappes.

COMPARISON WITH WESTERN NORTH GREENLAND

Upper Ordovician and lower Silurian carbonate sediments occur across the whole of North Greenland from Kronprins Christian Land in the east to Washington Land in the west. The succession in Peary Land, Valdemar Glückstadt Land, and Kronprins Christian Land is substantially different from that of western North Greenland. The sediments of the Turesø, Ymers Gletscher and Odins Fjord Formations are at maximum 500 m thick. If the reefs of the Samuelsen Høj Formation are included, the total thickness only approaches 800 m. The contemporaneous sediments of Washington Land approach 2000 m in thickness. The Washington Land sediments were deposited on a homoclinal ramp to rimmed shelf margin and slope (Hurst & Surlyk, 1983a,b) where facies changes occurred rapidly and sediments commonly prograded. Thus, a direct comparison between Peary Land and Washington Land of sediment thicknesses may not be strictly valid as real rock thicknesses (Peary Land) are being compared with stratigraphic thicknesses (Washington Land). Nevertheless, it is important to note that there is an apparent discrepancy of 1200 m of sediment accumulation between easternmost and westernmost North Greenland and this cannot be totally accounted for by differences in real and stratigraphic thickness.

These thickness differences are undoubtedly related to tectonic setting. For instance Hurst & Surlyk (1984) have demonstrated that the carbonate sediments of Washington Land and large areas of westernmost North Greenland reflect deposition on a carbonate ramp which was controlled by deep-seated lineaments. A great deal of subsidence must have occurred to account for the vast thickness of sediments which were mostly deposited as shallow subtidal, reefal or biostromal units, well within the photic zone. In contrast, the contemporaneous sediments in Peary Land, Valdemar Glückstadt Land, and Kronprins Christian Land were for the most part deposited on a featureless and relatively stable carbonate shelf which, along its northern margin in Peary Land, was extremely well differentiated from the deep-water basin along a fault line termed the Navarana Fjord fault (Hurst & Surlyk, 1984; Surlyk *et al.*, 1980; Surlyk & Hurst, 1983, 1984). The lower part of the sequence was deposited under peritidal conditions which are unknown in contemporaneous western sections.

A particularly distinctive feature of sections in the Peary Land – Kronprins Christian Land region is the dark nature of the upper part of the sequence. This may be related to the fact that some of the sequence represents a drowned shelf with anoxic environments. In contrast contemporaneous western sections in western areas are much lighter in colour.

Along the well marked shelf edge in Peary Land (Navarana Fjord fault) there is evidence of a shelf rim facies with algae, in particular red algae. No similar facies arrangement is known from more westerly areas of North Greenland.

There is no unequivocal evidence for the existence of post latest Llandoverian carbonate sediments in eastern North Greenland. The carbonate shelf in this region apparently foundered abruptly in part due to loading by Caledonian nappes (Hurst *et al.*, 1983). In contrast, in western North Greenland there is evidence to suggest that in some areas carbonate deposition continued into the Wenlockian and possibly even the Ludlovian and Pridolian (latest Silurian). In neither area is there evidence of Devonian carbonates (Hurst, 1980b).

Biostratigraphically, there are few differences between the eastern and western part of North Greenland. As far as can be ascertained at present most macrofaunas as well as conodonts, particularly of the *celloni* Zone, appear to be ubiquitous (Armstrong, 1983). Of particular interest is the virgianid (pentamerid) brachiopods in the lower and middle Llandoverian. They are particularly diverse in the Peary Land region (Boucot & Hurst, 1979; Hurst & Sheehan, 1982). This probably reflects preferences for shallow subtidal to peritidal environments (Fürsich & Hurst, 1980).

Acknowledgements

The fieldwork forming the basis of this report was undertaken during the Geological Survey of Greenland's 3-year activity in 1978–1980. All logistical aspects of this fieldwork were organised by N. Henriksen to whom I am especially grateful. I am particularly appreciative and thankful for numerous discussions with many colleagues, in particular F. Surlyk, concerning the evolution and development of the Silurian shelf. I extend my thanks to R. J. Aldridge, R. L. Christie, J. R. Ineson, P. D. Lane, J. E. Mabillard, J. S. Peel, and A. T. Thomas for free access to section data and identification of faunas. Special thanks are directed to H. A. Armstrong for reading the manuscript and for access to conodont biostratigraphic data. J. S. Peel and F. Surlyk critically read the manuscript and provided many useful comments. I am particularly appreciative and thankful for the enormous amount of work L. B. Clemmensen and P. R. Dawes accomplished when critically reviewing the manuscript. I wish to thank W. S. McKerrow, F. Surlyk and P. Venslev for good company in the field. Finally, I thank E. Glendal and B. Thomas for technical assistance.

The aerial photographs and other topographic maps are published with the permission (A. 495/79) of the Geodætisk Institut, Denmark.

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