



Lower and Middle Ordovician platform carbonate lithostratigraphy of Warming Land, Wulff Land and Nares Land, North Greenland

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Four formations, namely the Johansen Land Formation (new), the Warming Land Formation (new) including the Røhling Land Member (new), the Steensby Gletscher Formation (new) and the Cape Webster Formation, are assigned to the lower part of the Ordovician platform carbonate sequence in the Warming Land/Nares Land region. These are formally described, and a correlation with the sequences in Washington Land and Peary Land is proposed.

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The Lower and Middle Ordovician platform carbonates, i.e., the 'recessive dolomite unit', the 'cliff-forming limestone and dolomite unit' and the Cape Webster Formation of Peel (1980), were logged in detail at 10 localities from Freuchen Land in the east to Washington Land in the west (fig. 1) during the 1984 field season.

Three new formations and one new member are formally established within the 'recessive dolomite unit' and the 'cliff-forming limestone and dolomite unit' of Peel (1980), namely the Johansen Land Formation, the Warming Land Formation, including the Røhling Land Member, and the Steensby Gletscher Formation. It is possible to map these formations in Nares Land, Wulff Land and Warming Land, while the overlying Cape Webster Formation can be traced from Washington Land to Nares Land.

A description of the individual formations and their possible correlation with the stratigraphies of Washington Land and Peary Land (fig. 2) is given below.

Johansen Land Formation

new formation

History. A short description of this unit was given by Peel (1980), who included it in the 'recessive dolomite unit' on top of the 'white marker sandstone.'

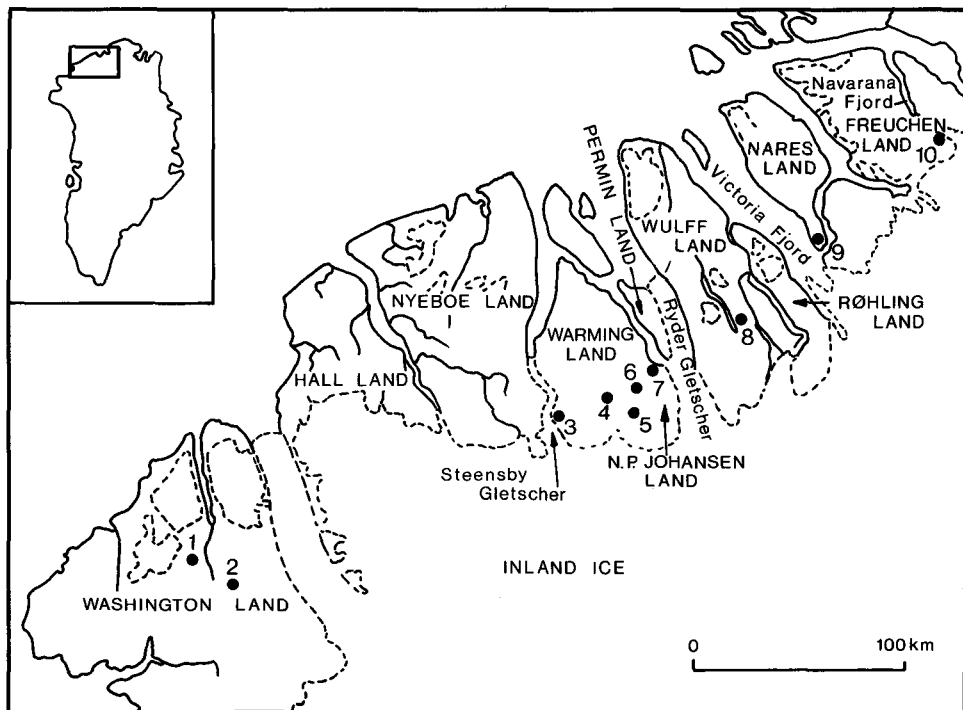


Fig. 1. Location map of the sections measured during the 1984 field season. Washington Land as employed here also includes Dagaard-Jensen Land.

Name. From N. P. Johansen Land in the south-eastern part of Warming Land.

Type locality. Northernmost N. P. Johansen Land, opposite the southern end of Permin Land, map sheet 81 V2 NØ, UTM-coordinates 22 DR 9950 (loc. 7, fig. 3).

Reference localities. Localities 4, 5, 8 and 9 (fig. 1).

Thickness. The thickness varies between 15 and 35 m, and the unit shows a general thinning towards the east.

Lithology. Dark brown to light grey sucrosic dolomites often strongly burrow mottled (fig. 4). Vague traces of large and small-scale cross-lamination occur. The formation contains digitate stromatolites (except at loc. 4). The macro-fauna is generally sparse (indeterminate gastropods), but at locality 8 in Wulff Land some levels were very fossiliferous yielding both indeterminate gastropods and specimens of the brachiopod *Finkelburgia*(?).

	WASHINGTON LAND	WARMING LAND - NARES LAND		PEARY LAND		
		This report	Peel (1980)			
ORDOVICIAN	M	GONIOCERAS BAY	GONIOCERAS BAY	GONIOCERAS BAY	BØRGLUM RIVER	
		CAPE WEBSTER	CAPE WEBSTER	CAPE WEBSTER	WANDEL VALLEY	
		NUNATAMI	STEENSBY GLETSCHER	"cliff forming limestone and dolomite unit"		
		CANYON ELV				
	L	NYGAARD BAY	WARMING LAND	"recessive dolomite unit"	? - - - -	
		POULSEN CLIFF				
		CHRISTIAN ELV				RLM
		CAPE CLAY				JOHANSEN LAND
						KCM
	U. CAMB.	CASS FJORD	RYDER GLETSCHER GROUP			

Fig. 2. Upper Cambrian to Middle Ordovician stratigraphical correlations for Washington Land and Peary Land (from Peel, 1982) with proposed correlations and new nomenclature for the Warming Land – Nares Land area. Kap Coppinger Member (KCM) and Røhling Land Member (RLM).

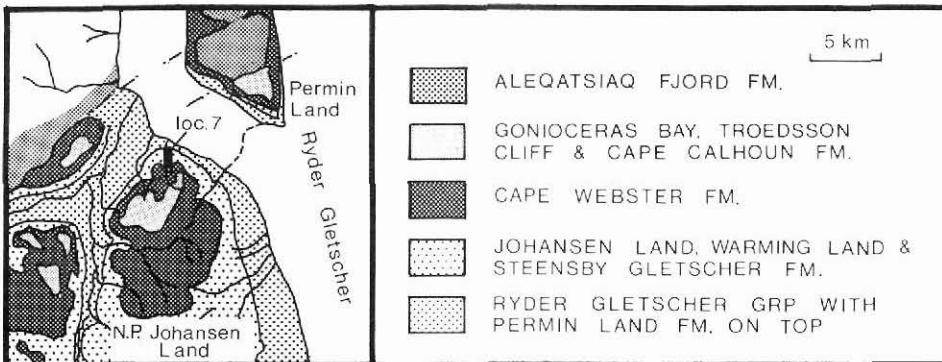
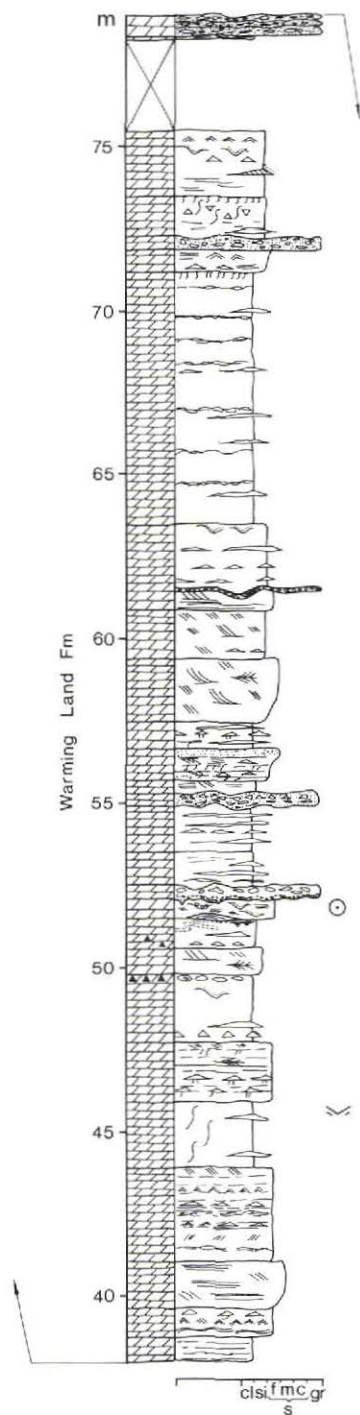
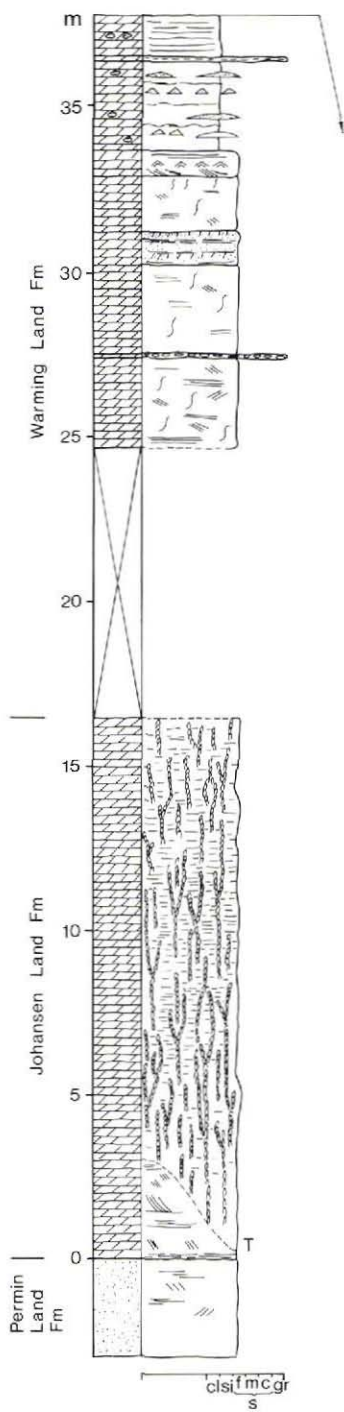


Fig. 3. Geological map showing the location of the type section of the Johansen Land, Warming Land and Steensby Gletscher Formations (loc. 7).



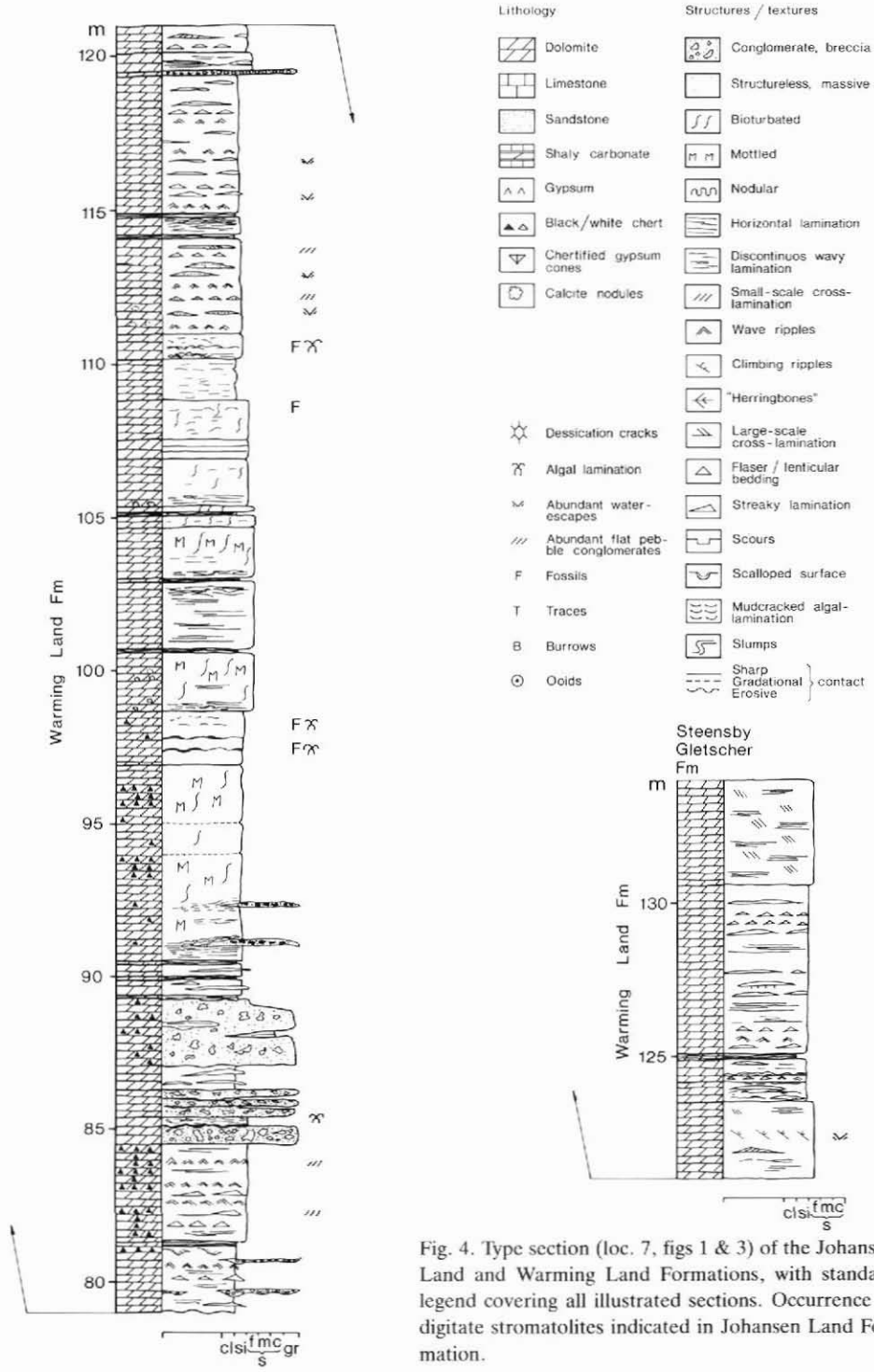


Fig. 4. Type section (loc. 7, figs 1 & 3) of the Johansen Land and Warming Land Formations, with standard legend covering all illustrated sections. Occurrence of digitate stromatolites indicated in Johansen Land Formation.

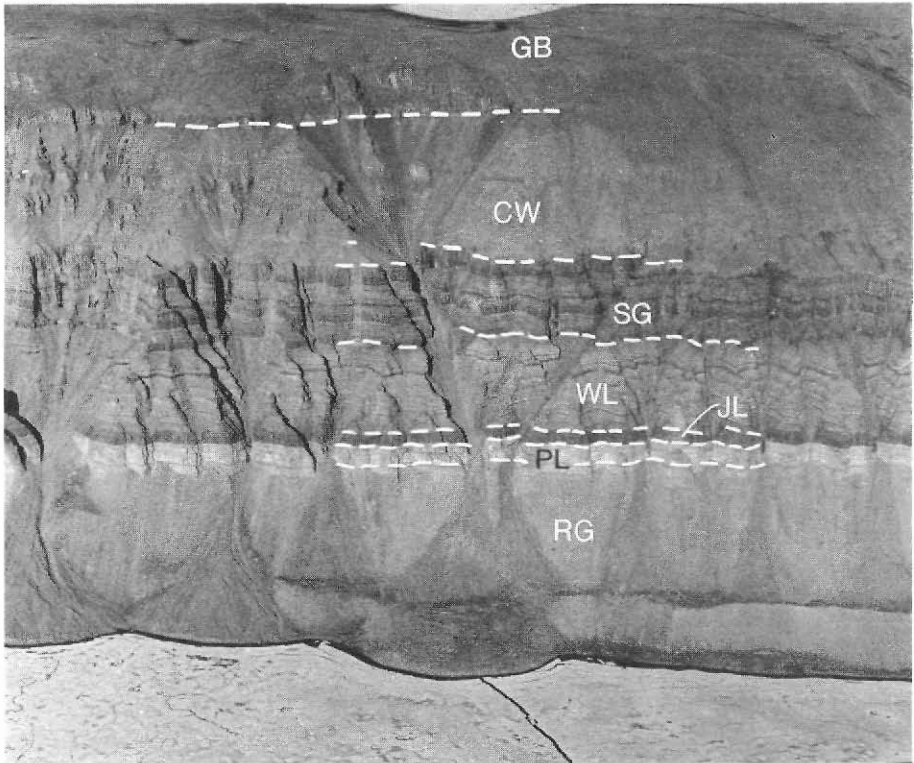


Fig. 5. Outcrop of the Ryder Gletscher Group (RG), Permin Land Formation (PL), Johansen Land Formation (JL), Warming Land Formation (WL), Steensby Gletscher Formation (SG), Cape Webster Formation (CW) and Gonioceras Bay Formation (GB) on the southern cliffs of Permin Land opposite location 7 (see fig. 3). Height of cliff from fjord to base of Gonioceras Bay Formation is 600 m.

Boundaries. The boundary to the underlying Permin Land Formation (formerly 'white marker sandstone', Bryant & Smith, 1985) is transitional over some centimetres due to inter-bedding of dolomites and sandstone. The boundary is placed at the last occurrence of the thin sandstones. The boundary to the overlying Warming Land Formation is described below.

Distribution. The formation is found from Nares Land, at least 10 km east of locality 9, to Warming Land where it can be traced as a brown weathering cliff-forming unit above the white sandstones of the Permin Land Formation (fig. 5).

Age. The presence of the brachiopod *Finkelburgia* suggests an Early Ordovician age; very similar specimens have been described by Poulsen (1927) from the Cape Clay Formation in Washington Land (J. S. Peel, personal communication, 1984).

Warming Land Formation

new formation

History. This formation corresponds to the main part of the 'recessive dolomite unit' of Peel (1980).

Name. From Warming Land.

Type locality. Same as Johansen Land Formation.

Reference localities. Localities 4, 5, 8 and 9 (fig. 1).

Thickness. The formation is 50–150 m thick and shows a thickening from east to west.

Lithology. Alternating beds of dark to light grey dolomite give the formation a characteristically striped appearance (fig. 5).

The dolomites are mainly dolomicrites and dolosiltites, but heterolithic and more coarse-grained beds occur (fig. 4). Chert-nodules are abundant at several levels within the formation.

Beds may be massive or show horizontal lamination (cryptalgal lamination), flaser and wavy bedding, small and large-scale cross-lamination, including wave-formed cross-lamination, and climbing ripple lamination. The structures are often affected by bioturbation and symsedimentary deformation (e.g., loading, fluidization and slumping).

Flat pebble conglomerates sometimes showing rosette structures are abundant in the lower half of the formation in Warming Land.

Dessication cracks, scalloped surfaces and erosion topography are found throughout the formation, indicating frequent subaerial exposure. At the same levels, occasional chert-nodules resembling replaced gypsum cones were seen.

There is a general lack of macro-fossils, but at some levels, mainly in the upper half of the formation, a sparse fauna was found. Various gastropods, including some high spired murchisoniaceans are associated with indeterminate cephalopods.

Boundaries. The boundary to the Johansen Land Formation is seldom exposed due to the recessive character of the Warming Land Formation.

The transition from the Johansen Land to the Warming Land Formation was seen at localities 4 and 5 where it is marked by a change from grey brown mottled sucrosic dolomites to more fine-grained light grey dolomites with very little bioturbation and preserved sedimentary structures.

The upper boundary is to the Steensby Gletscher Formation (see below).

Distribution. The formation is found from Nares Land, at least 10 km east of locality 9, to Warming Land. Here it can be followed as a striped recessive unit of alternating light and dark weathering bands between the cliff-forming Johansen Land Formation and Steensby Gletscher Formation (fig. 5).

Age. The poor fauna indicates an Ordovician age.

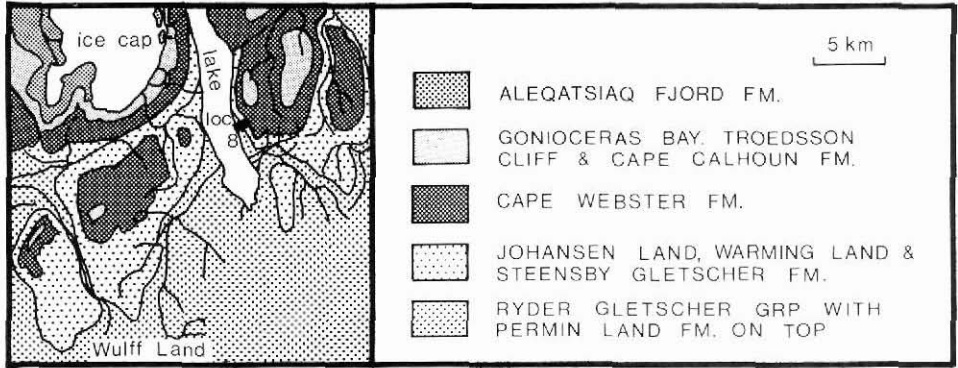


Fig. 6. Geological map showing the location of the type section of the Røhling Land Member (loc. 8).

Subdivision. A sandstone member, the Røhling Land Member, is found from 3 to 18 m above the base of the Warming Land Formation.

Røhling Land Member

new member

History. The member has not been described earlier.

Name. From Røhling Land on the eastern side of Wulff Land.

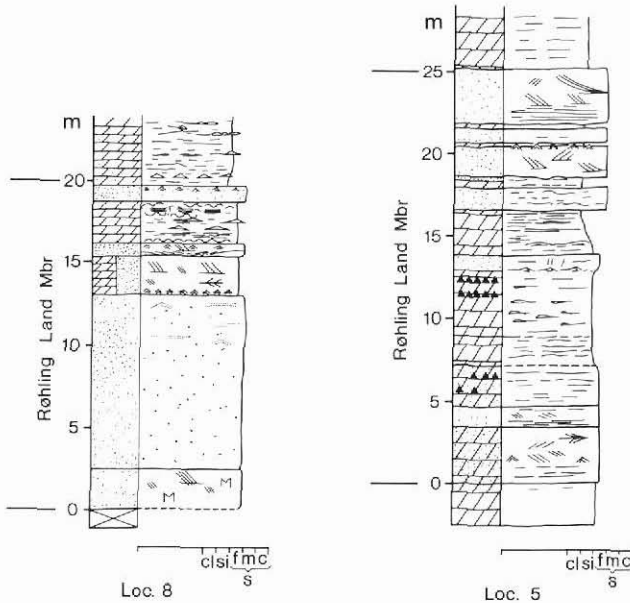


Fig. 7. Type section (loc. 8) of the Røhling Land Member and reference locality 5 (figs 1 & 6).

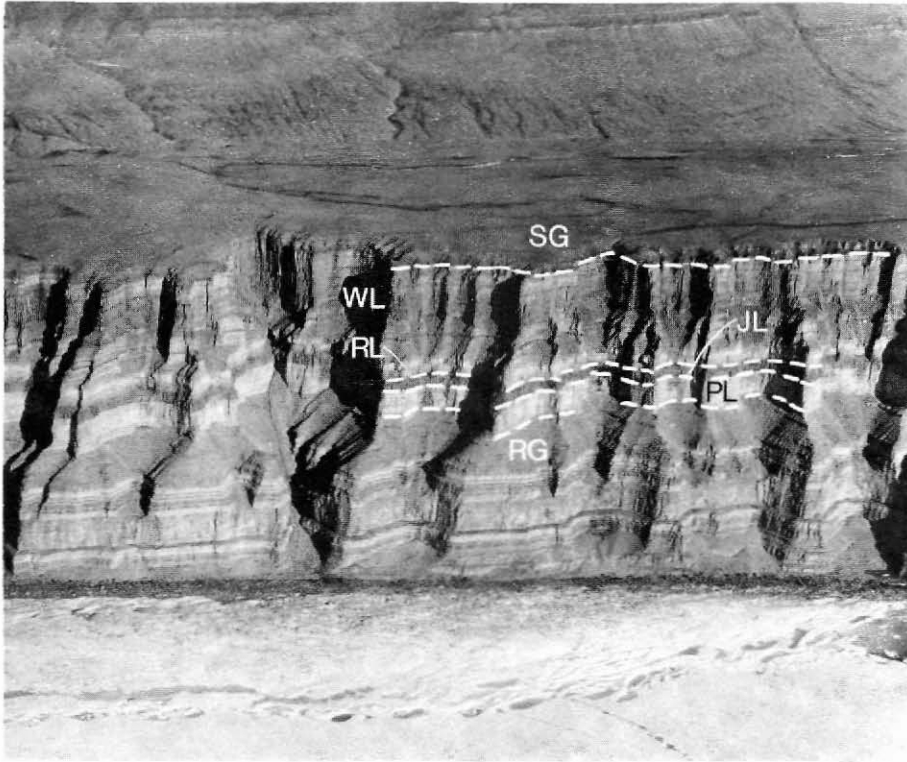


Fig. 8. Outcrop of the Røhling Land Member (RL) as a white weathering band within the Warming Land Formation on the cliffs of Wulff Land at Ryder Gletscher opposite the southern tip of Permin Land. Other abbreviations as in fig. 5. Height of cliff approximately 500 m.

Type locality. On the east coast of the westernmost large lake in Wulff Land (loc. 8, figs 1 & 6), map sheet 81 V3 NV, UTM-coordinates 22 ER 3767.

Reference localities. Localities 9 and 5.

Thickness. 19 m in Wulff Land, 7 m in Nares Land (loc. 9) and 25 m in south-eastern Warming Land (loc. 5).

Lithology. The member consists of very well sorted fine sandstones which may be interbedded with dolomites (fig. 7). It may be massive or show wave-formed and current-formed large and small-scale cross-lamination, including herringbone structures. Palaeocurrent measurements indicate very variable current directions. The dolomites consist of discontinuously laminated dolomicrites and dolosiltites. The member is strongly dominated by sandstones at the type locality (loc. 8) and at locality 9, while dolomites form c. 30% of the member at locality 5 (fig. 7).

Boundaries. The lower and upper boundaries of the member are drawn at the first and last sandstone bed, respectively.

Distribution. The member is found as a white weathering band in the Warming Land Formation (fig. 8) from western Nares Land to south-eastern Warming Land. On Permin Land the member wedges out a few kilometres west of Ryder Gletscher.

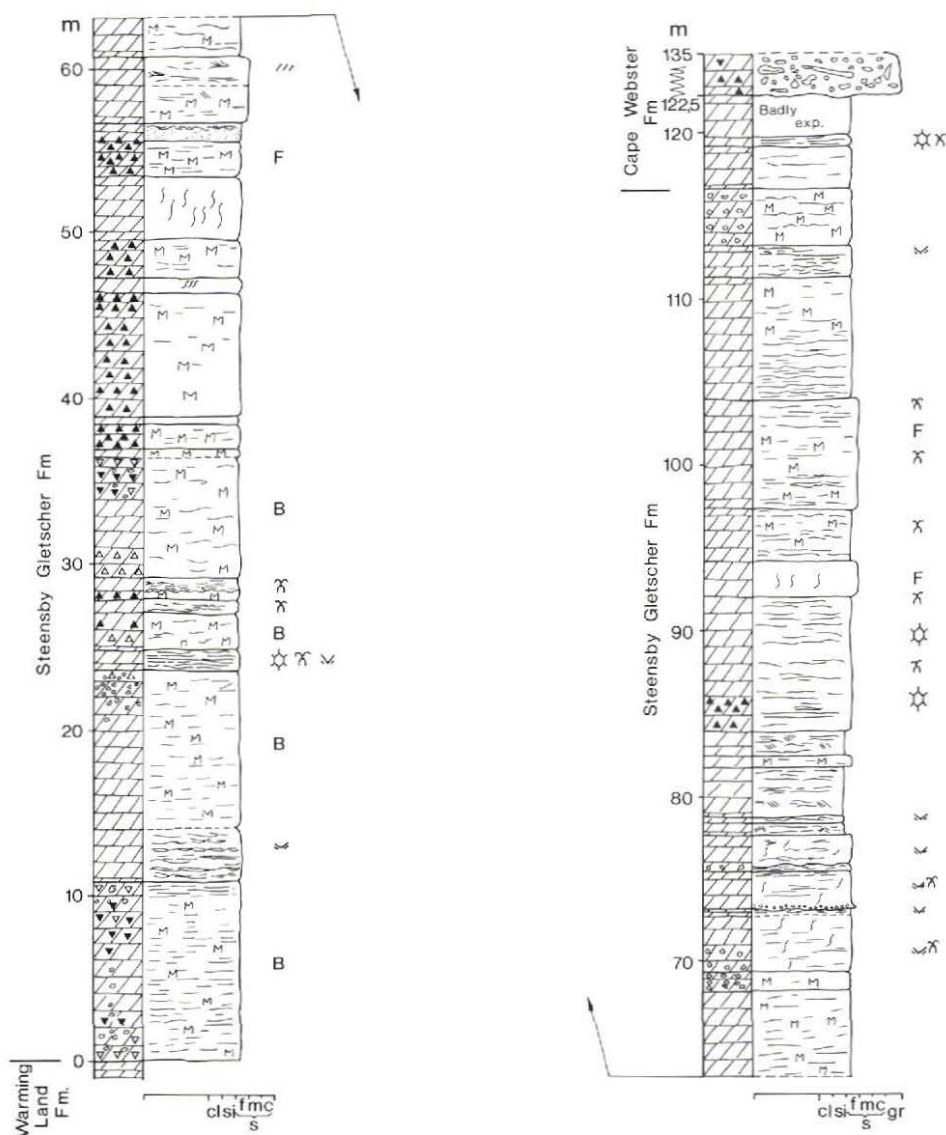


Fig. 9. Type section of the Steensby Gletscher Formation (loc. 7, figs 1 & 3).

Steensby Gletscher Formation

new formation

History. The formation corresponds to the 'cliff-forming limestone and dolomite unit' of Peel (1980).

Name. From Steensby Gletscher between Warming Land and Nyeboe Land.

Type locality. Same as Johansen Land Formation.

Reference localities. Localities 3, 5, 6, 8 and 9 (fig. 1).

Thickness. The thickness was measured to 90–125 m, with the largest thickness in the west.

Lithology. The lower half of the formation is dominated by 5–15 m thick beds of dark brown, strongly mottled sucrosic dolomites with abundant black and white chert nodules. These are interbedded with 0.5–2.5 m thick grey cryptalgal laminated dolomicrites showing both desiccation cracks and water escape structures (fig. 9).

The upper half has a larger content of laminated dolomites which show light colours from grey to brown. They show crinkly lamination, wave and current-formed small-scale cross-lamination and abundant desiccation cracks. The lamination is often disturbed by fluidization and varying degrees of bioturbation. Towards the top the amount of mottled dark, sucrosic dolomites increase.

At some levels in the dark dolomites, macro-fossils are abundant and yield both cephalopods, gastropods (*Ceratopea*, *Helicotoma*, *Ophileta*, and indeterminate murchisoniaceans) and some trilobite fragments.

Boundaries. The boundary to the underlying Warming Land Formation is sharp and is drawn at the first appearance of dark, sucrosic, mottled dolomites. The boundary to the overlying Cape Webster Formation is described below.

Distribution. From at least 10 km east of locality 9 to the western part of Warming Land (loc. 3). It can be followed as a strongly cliff-forming, mainly dark weathered unit (fig. 5).

Age. The presence of *Ceratopea* indicates a late Early Ordovician age.

Cape Webster Formation

Koch (1929)

History. The formation has been described in Washington Land (Koch, 1929) and in the Warming Land – Wulff Land area (Peel, 1980).

Name. From Kap Webster in Washington Land.

Type locality. At Kap Webster in Washington Land.

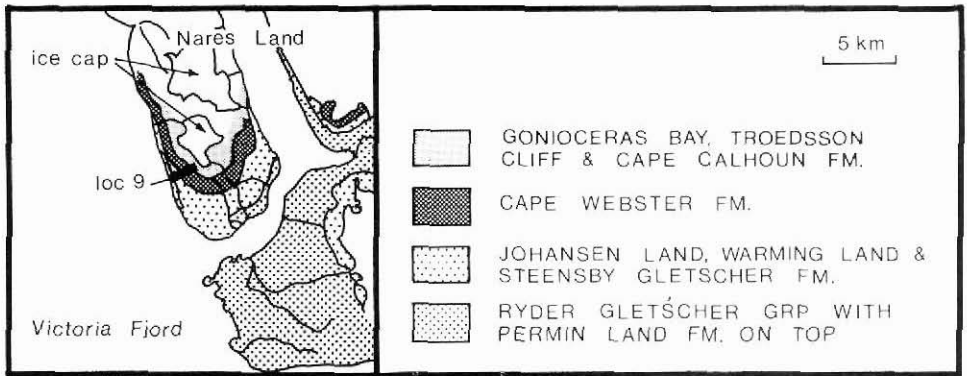


Fig. 10. Geological map showing the primary reference locality (loc. 9) of the Cape Webster Formation in central North Greenland.

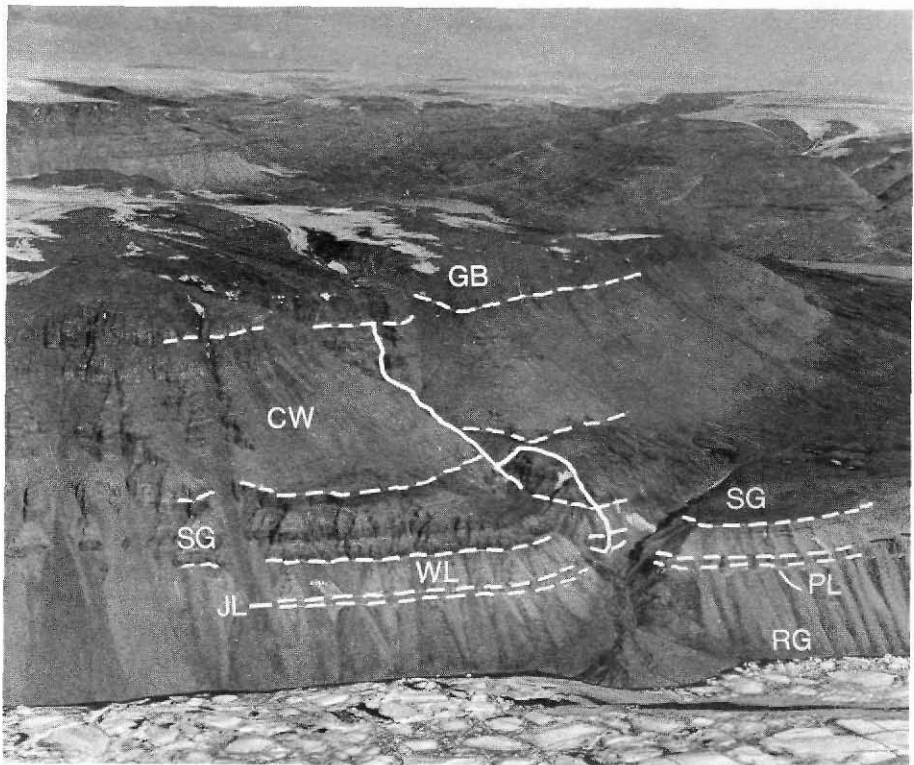


Fig. 11. Outcrop at locality 9 in Nares Land (figs 1 & 10) with measured section shown. Abbreviations as in fig. 5. Height of section from fjord to base of Gonioceras Bay Formation is 450 m.

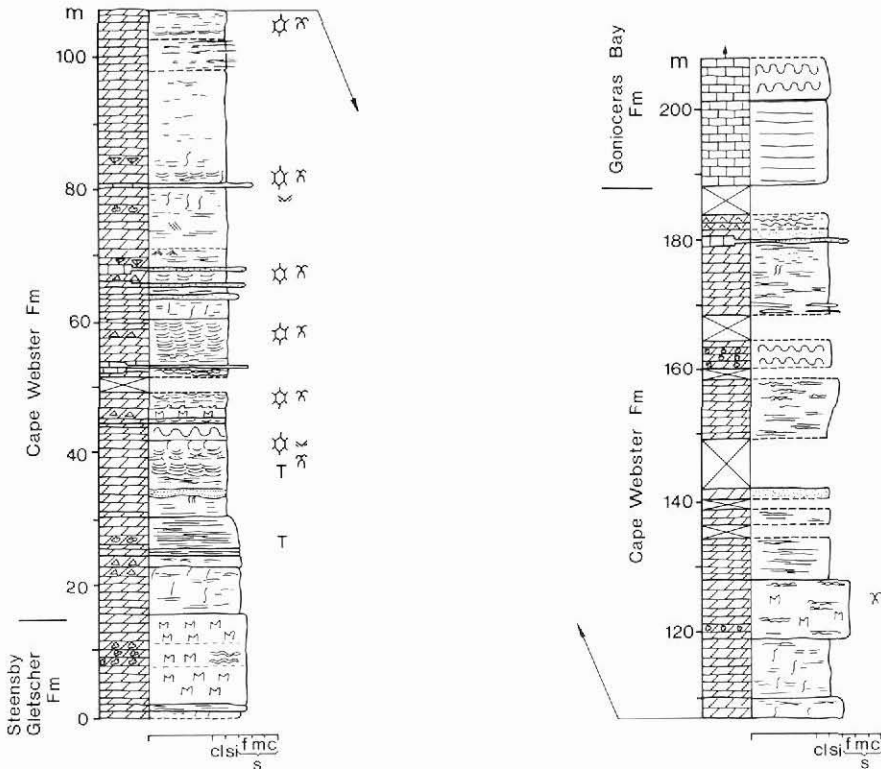


Fig. 12. Section through the Cape Webster Formation (loc. 9, figs 1 & 10).

Reference locality in central North Greenland. At the southern end of Nares Land, map sheet 81 V3 NØ, UTM-coordinates 23 MM 8600 (loc. 9, figs 10 & 11).

Other reference localities. Localities 1, 3 and 6 (fig. 1).

Thickness. The thickness of the Cape Webster Formation was measured to 175–200 m.

Lithology. Grey to dark grey dolomiticrites. Horizontal lamination and cryptalgal lamination dominate and often show desiccation cracks and fluidization features (fig. 12). In Nares Land thin beds of nodular anhydrite/gypsum appear near the top of the formation.

In Warming Land chaotic breccias in beds from less than 0.5 m up to at least 13 m thick are abundant.

Boundaries. The lower boundary is to the Steensby Gletscher Formation which is marked by a gradual decrease in grain size from sand grained to micritic dolomites over approximately 10–15 m. It is drawn at the top of the last bed of dark grey, sucrosic, mottled dolomite.

The boundary between the Cape Webster Formation and the overlying Gonioceras Bay Formation is defined by the change from dolomites to limestones, and it is drawn on the top of the last dolomite bed. At most localities the base of the Gonioceras Bay Formation is developed as a dark, nearly black, bituminous and fossiliferous limestone. At the locality in Nares Land the lower 13 m of the Gonioceras Bay Formation consist, however, of grey thin to medium-bedded limestones.

Distribution. The formation is found from at least 10 km east of locality 9 in Nares Land to Washington Land. It can be followed as a strongly recessive light grey weathering unit between the cliff-forming Steensby Gletscher and Gonioceras Bay Formations (figs 5 & 11).

Age. No fossils were found, but the stratigraphic position indicates a Middle Ordovician age, which is in agreement with Koch (1929).

Lithostratigraphic correlations

In order to link the stratigraphy of the Warming Land – Nares Land region of North Greenland to the pre-existing stratigraphies of Washington Land and Peary Land (fig. 2), two sections were measured in Washington Land (loc. 1 & 2), and one (loc. 10) at Navarana Fjord (figs 1 & 13).

Washington Land

The Permin Land Formation corresponds to the Kap Coppinger Member of the Cass Fjord Formation of Washington Land (Bryant & Smith, 1985). In conjunction with the regionally distributed Cape Webster Formation and the overlying Morris Bugt Group, this horizon permits good correlation from the Warming Land – Nares Land area to Washington Land.

The upper part of the Cass Fjord Formation (30 m), above the Kap Coppinger Member, consists of dark grey micrites and calcarenites, mostly mottled and with thin beds of flat pebble conglomerates. One 1 m thick bed contains digitate stromatolites.

The Cape Clay Formation (50 m) consists of totally mottled, light grey micrites.

The upper parts of the Cass Fjord Formation and the Cape Clay Formation are thought to be equivalent to the Johansen Land Formation. This is suggested by lithological similarities and by the presence of the brachiopod *Finkelburgia* in both the Johansen Land Formation and the Cape Clay Formation (Poulsen, 1927; J. S. Peel, personal communication, 1984).

The Christian Elv Formation (140 m) mainly consists of grey micrites, algal laminated, in places with both wave and current-formed small-scale cross-lamination. Scalloped surfaces are abundant. The Poulsen Cliff Formation (100 m) consists of evaporites and light grey micrites containing both algal lamination and wave-formed cross-lamination.

The overlying Nygaard Bay Formation (40 m) consists of a lower limestone member and an upper evaporite member (Peel, 1982).

The Cape Clay and the Canyon Elv Formations correlate with the upper part of the Johansen Land Formation and the lower part of the Steensby Gletscher Formation, respectively (fig. 2). Consequently the Christian Elv to Nygaard Bay Formations can be correlated with the Warming Land Formation. There are gross similarities between the Christian Elv For-

Warming Land - Nares Land

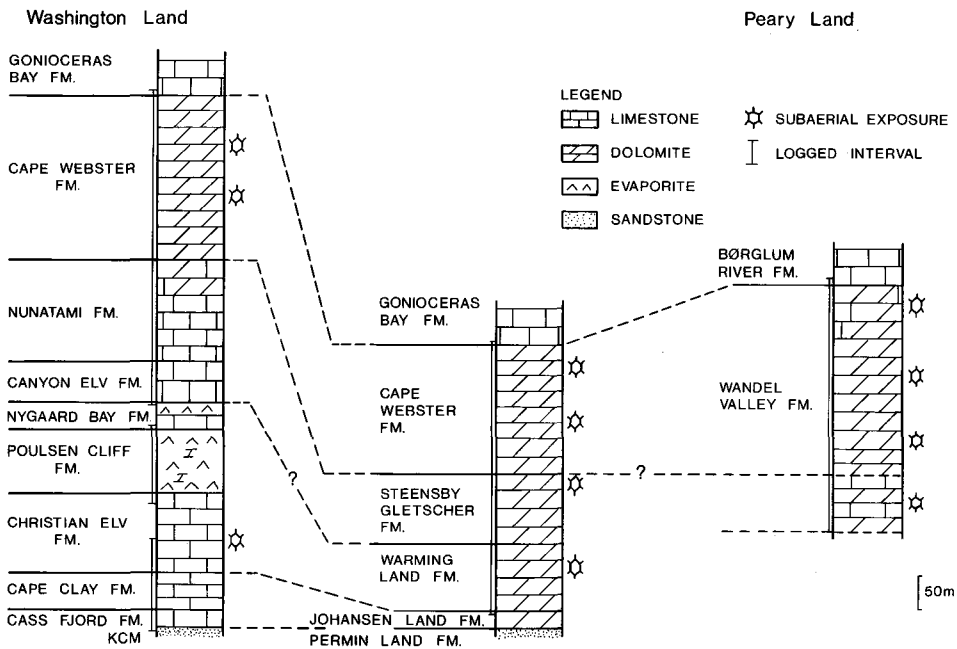


Fig. 13. Scheme showing the proposed correlations between the lithostratigraphical units in the Warming Land - Nares Land region and Washington Land and Peary Land, respectively.

mation and the Warming Land Formation, and it is suggested that the evaporites of the Poulsen Cliff and Nygaard Bay Formations laterally give way to the dolomicrites of the Warming Land Formation.

The Canyon Elv Formation (60 m) consists of greyish black, intensely burrow mottled, fossiliferous micrites. The lower 100 m of the overlying Nunatami Formation (150 m) are much like the Canyon Elv Formation, although the colours are somewhat lighter (dark grey). Bioturbation is also less intense since horizontal lamination is partly present. Black chert nodules are common at some levels. The upper part (50 m) of the Nunatami Formation is less bioturbated, and thin beds of light grey, sucrosic dolomites occur. The beds show algal lamination, wave-formed cross-lamination, dessication cracks and may contain stromatolites.

Due to the close similarities in lithologies, the Canyon Elv and the Nunatami Formations are correlated with the Steensby Gletscher Formation.

The Cape Webster Formation in northern Washington Land (250 m) mainly consists of greyish dolomicrites, mostly burrow mottled or horizontally laminated with abundant beds of dissolution breccias, and is hence similar to the Cape Webster Formation in central North Greenland.

Freuchen Land/Navarana Fjord

A 360 m thick section was measured through the Wandel Valley Formation at Navarana Fjord (loc. 10, fig. 1). The lower boundary of the formation was not exposed, but the upper limit of the section was defined by the boundary between the Wandel Valley and the Børglum River Formations (fig. 2). The lower 80 m of this section consist of interbedded dark grey-brown fossiliferous micrites, more or less mottled, and light grey, sucrosic dolomites, algal laminated with abundant dessication cracks. The upper 280 m of the formation are mainly dolomites, but the topmost 100 m are interbedded with dark grey-brown micrites. Emergence features are abundant (dessication cracks and karstic(?) surfaces).

The correlation of this section with the sequence in Warming Land is rather tenuous, but in accordance with Hurst & Peel (1979) it is suggested that the lower part is equivalent to the Steensby Gletscher Formation, while the upper part correlates with the Cape Webster Formation.

It is hoped that the proposed lithostratigraphical correlations between the sequences in the Warming Land – Nares Land area and Washington Land and Peary Land will be supported by the results of forthcoming conodont studies.

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