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Stratigraphy of the Silurian turbidite sequence of North Greenland

by

John M. Hurst and Finn Surlyk

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Stratigraphy of the Silurian turbidite sequence of North Greenland

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John M. Hurst and Finn Surlyk

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Abstract

A new lithostratigraphic scheme is erected for the Silurian deep-water clastic rocks of North Greenland, from Washington Land in the west to Kronprins Christian Land in the east. All Silurian clastic rocks are included in the Peary Land Group and were deposited in upper to lower slope, submarine fan and basin plain environments. All age determinations are based on graptolites. Ordovician faunas are of North American aspect whilst Silurian faunas are cosmopolitan. Therefore, series and stage definitions in the Ordovician follow American terminology whereas in the Silurian standard international terminology is used.

Eight formations and six members are included in the Peary Land Group, which extends from the latest Ordovician (Cincinnatian) to the latest Silurian (Pridoli). Lithostratigraphic units include: *Sydgletscher Formation* (new) composed of basinal, extremely thick, structureless sandstone beds and black mudstones – Lower Llandovery; *Cape Schuchert Formation* composed of upper slope mudstones, calcarenites and cherts – Middle Llandovery to lower Upper Llandovery; *Lafayette Bugt Formation* composed of upper to lower slope mudstones and resedimented limestone conglomerates – Middle Llandovery to Ludlow; *Merqujôq Formation* (new), a middle to outer fan and basinal sandstone dominated turbidite sequence of 'classical flysch' appearance – uppermost Ordovician (Cincinnatian) to uppermost Llandovery; *Citronens Fjord Member* (new), a base-of-slope resedimented limestone conglomerate, shale and thin-bedded siltstone and mudstone turbidite sequence – ?Middle Llandovery to Upper Llandovery; *Freja Fjord Member* (new), an isolated base-of-slope resedimented limestone conglomerate – Upper Llandovery; *Wulff Land Formation* (new), a lower slope to basin plain black mudstone and thin-bedded fine sandstone and siltstone turbidite sequence – Upper Llandovery to Lower Ludlow; *Repulse Havn Member* (new), a lower slope to basin plain sequence of thin-bedded mudstone and siltstone turbidites – Lower to Middle Ludlow; *Thors Fjord Member* (new), a lower slope to basin plain sequence of black mudstones with fine siltstone and sandstone turbidite units – Upper Llandovery to Middle Wenlock; *Lauge Koch Land Formation* (new), an outer fan and basinal sandstone and siltstone turbidite sequence of 'classical flysch' appearance – Upper Llandovery to Lower Ludlow; *Profilfjeldet Member* (new), a faulted, folded and cleaved sandstone turbidite and mudstone sequence in Kronprins Christian Land – Upper Llandovery to Middle Wenlock; *Nordkronen Formation* (new), a sequence of chert pebble conglomerates, pebbly sandstones and sandstones deposited in a base-of-slope and submarine fan environment – ?Middle Wenlock to ?Lower Ludlow; *Hendrik Ø Member* (new) which represents the western distal wedge of the Nordkronen Formation – ?Lower Ludlow; *Chester Bjerg Formation* (new) composed of basinal laminated mudstones and fine turbiditic sandstones – ?Lower Ludlow to Upper Pridoli.

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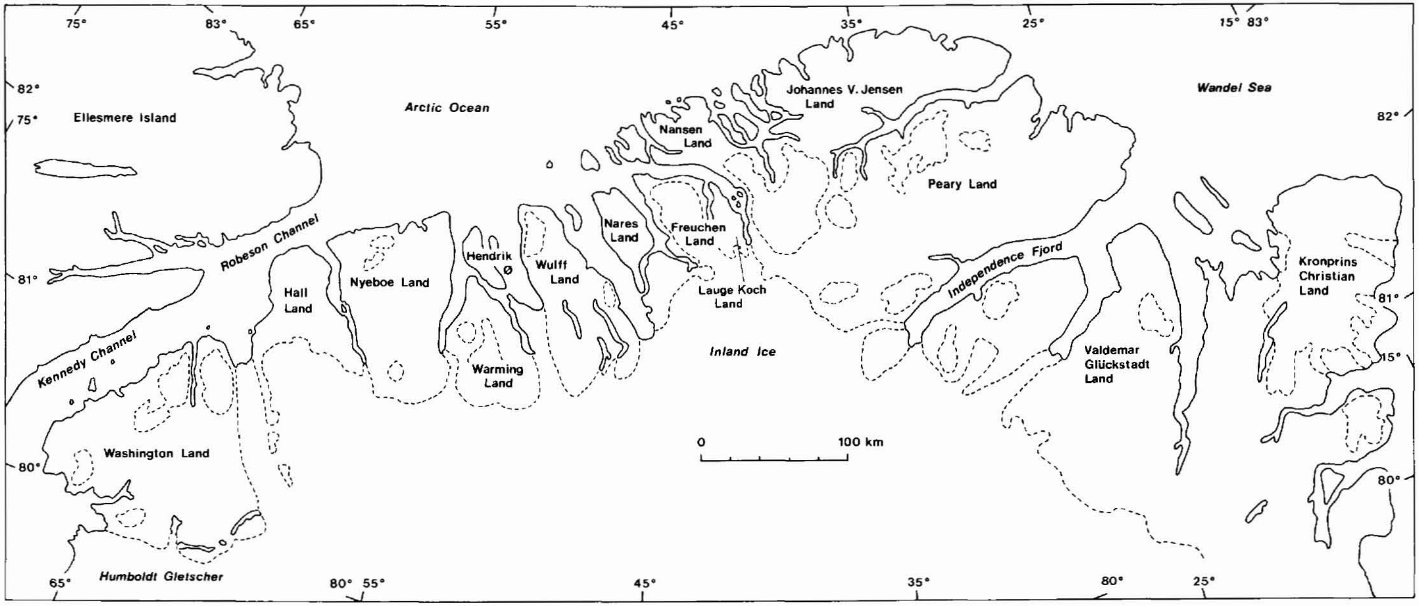


Fig. 1. Locality map of North Greenland showing land areas mentioned in the text.

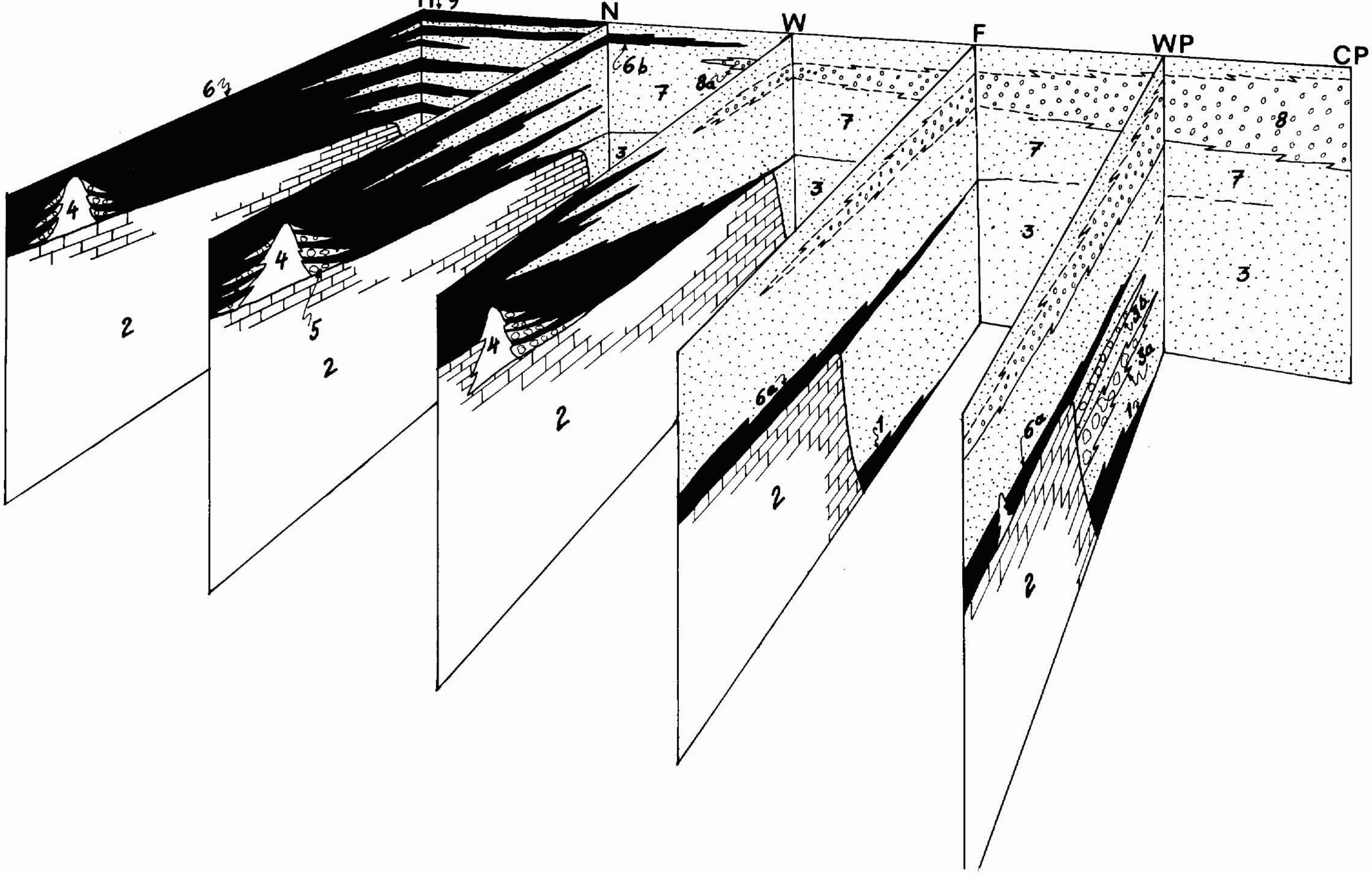
INTRODUCTION

A new lithostratigraphical scheme is erected for the uppermost Ordovician and Silurian clastic sediments, referred here to the Peary Land Group, which occur across the whole of North Greenland, from Washington Land in the west to Kronprins Christian Land in the east (fig. 1).

Sediments of the Peary Land Group were deposited in a deep-water basin (partly equivalent to the Hazen Trough (Trettin, 1971) of Ellesmere Island, Arctic Canada) which bounded the northern edge of the lower Palaeozoic platform on which carbonate deposition predominated (fig. 2). The evolution of the platform-trough system started in the latest Precambrian or earliest Palaeozoic; the southern margin was apparently controlled by major faults and the trough seems to have formed by rifting (Surlyk *et al.,* 1980). The trough expanded by several episodes of platform margin collapse, resulting in a southwards shift of the margin to positions controlled by new fault systems. Thus, the younger the deep-water sequence the more widespread it is (fig. 2). A major episode of platform margin collapse occurred during the late Llandovery to early Wenlock interval (Hurst *et al.,* 1983). The position of the new basin margin is not known, but in most of eastern North Greenland the onlapping turbidite sequence can be followed several hundred kilometres to the south of the previous trough margin.

The transition from the Ordovician to the Silurian is marked by a discrete phase of sedimentation resulting in a several kilometres thick turbidite pile, which was derived longitudinally from the rising Caledonian mountains in the east. Silurian turbidite deposition was periodically punctuated by deposition of conglomerates derived laterally from the upper slope and platform margin (fig. 2).

Field work in North Greenland has been carried out in several episodes in the last 5 years. Hurst spent a total of 3 months in the field in Washington Land and western Hall Land, with helicopter support, during the summers of 1976 and 1977. During the summer of 1978 he spent approximately 1 month of a longer field season, with helicopter support, on a reconnaissance investigation of Silurian clastics of Peary Land, Lauge Koch Land and Wulff Land. For 2 months in the summer of 1979 both authors specifically investigated the Silurian sediments of the whole of Peary Land and Lauge Koch Land. As helicopter and aircraft support was good, the opportunity was taken to spend 3 weeks extending the area of study westward to include Wulff Land, Hendrik Ø, Warming Land, Nyeboe Land and Hall Land. The study in this area forged a link with the earlier studies of JMH in western Hall Land and Washington Land. Finally, during the summer of 1980 JMH had the opportunity to visit the Silurian turbidites, particularly the 'Profilfjeldet Shale' type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section, known from Kronprins Christian Land. Thus, in the past 5 years an overall view of the Silurian deep-water sediments and related rocks of North Greenland has been obtained. The Silurian sediments of eastern North Greenland are known in more detail than in western North Greenland (Freuchen Land to Hall Land) as a greater number of detailed measured sections have been recorded. Also most of the east has been covered by helicopter reconnaissance.

Following an account of the topography and a general review of previous work in the region, the succession of new and redefined units is discussed in ascending order. This is followed by a short basin evolution synthesis and finally a review of the graptolite zonation of the Silurian flysch and related sediments.

Topography

Silurian turbidites and related sedimentary rocks of the Peary Land Group crop out between 16°W and 68°W, and between latitudes 80°N and 83°N, from Washington Land in western North Greenland to Kronprins Christian Land 850 km away in eastern North Greenland (fig. 3). Generally, the Peary Land Group is bounded to the south by Silurian, Ordovician or Cambrian carbonates and to the north by older Palaeozoic clastic rocks.

The Peary Land Group is in the main exposed in a broad strip of flat-lying rocks forming distinct plateau areas in Nyeboe Land, Warming Land, Wulff Land, Nares Land, Freuchen Land, Lauge Koch Land and Peary Land. Hill top exposure is poor, but there are many beautifully exposed valley and coastal sections, though many are precipitous due to the flat-bedded nature of the sediments. In Washington Land and Hall Land rocks belonging to the group are very fine grained and form low-lying areas as they are more prone to erosion. Generally, exposure in Hall Land is very poor, restricted to small isolated stream and cliff sections, but in Washington Land good coastal sections are available.

Along the northern coasts of Hall Land, Nyeboe Land, Hendrik Ø, Wulff Land,

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Fig. 2. Schematic conceptual diagram showing the main spatial distributional patterns of the Silurian formations. H, Hall Land; N, Nyeboe Land; W, Wulff Land; F, Freuchen Land; WP, west Peary Land and CP, central Peary Land. 1, Amundsen Land Group (Ordovician); 2, carbonate platform; 3, Merqujôq Formation; 3a, Citronens Fjord Member; 3b, Freja Fjord Member; 4, Hauge Bjerge Formation; 5, Lafayette Bugt Formation; 6, Wulff Land Formation; 6a, Thors Fjord Member; 6b, Repulse Havn Member; 7, Lauge Koch Land Formation; 8, Nordkronen Formation; 8a, Hendrik Ø Member and 9, Chester Bjerg Formation. The northern edge of the carbonate platform in Freuchen Land and western Peary Land corresponds to the trace of the Navarana Fjord fault. The Sydgletscher Formation occurs to the north of the axis connecting Peary Land and Hall Land between central Peary Land and west Peary Land. For the sake of convenience it is not included on this diagram. Note that in the region between Wulff Land and Hall Land the precise subsidence history of the platform is not yet known. Several possible alternatives present themselves, but at this stage we prefer to express our doubts by leaving the areas of the carbonate platform free of ornament.

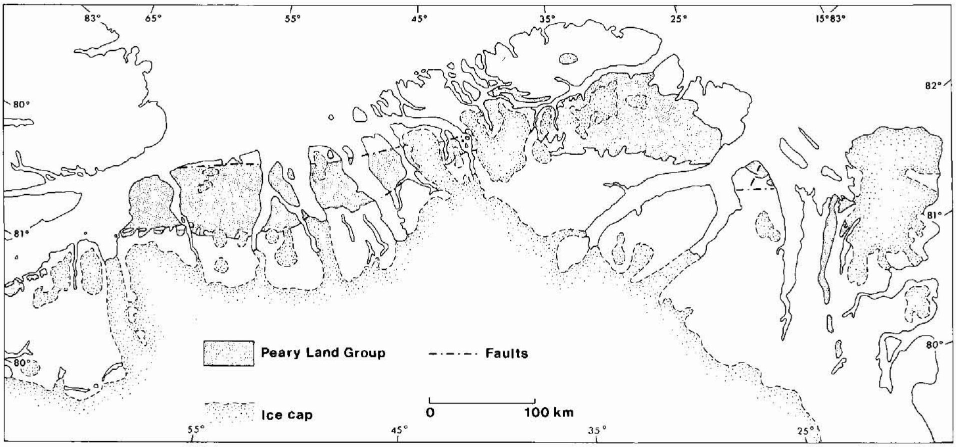


Fig. 3. Simplified geological map indicating the widespread distribution of the Silurian Peary Land Group in North Greenland.

Nares Land, Freuchen Land and Lauge Koch Land, the Peary Land Group has been involved in thrusting and folding, which has produced a more varied and rugged topography quite different from the plateau lands to the south. Exposures are generally good, but long continuous sections are not common due to the faulting.

Similarly in Johannes V. Jensen Land, north Peary Land, intense folding and thrusting together with uplift along the Harder Fjord fault have produced an alpine topography. Exposures of the Peary Land Group are good and complete but often inaccessible due to steep cliffs. Large areas of rock are intensely shattered and thus poorly exposed due to solifluction.

In Kronprins Christian Land the Peary Land Group is involved in intense thrusting and folding. Many small sections exist, but they are often folded or with thrusted contacts.

PREVIOUS WORK

The earliest geological investigations of note, concerned with the clastic sediments of North Greenland, were those by Feilden & De Rance (1878). As a member of the expedition led by G. S. Nares through the Kennedy Channel and Robeson Channel (fig. 1) in 1875–76, Feilden was able to examine the sediments in eastern Ellesmere Island and western North Greenland. Feilden & De Rance (1878) erected the name 'Cape Rawson beds' to cover a variable sedimentary succession of quartzites, grits, slates and impure limestones located between

2ND THULE EXPEDITION 1916–1918				BICENTENARY JUBILEE EXPEDITION 1920 –1922			
KOCH 1918		KOCH 1920, 1923		KOCH 1925		KOCH 1929	
SANDSTONE	SILURIAN	UNFOSSILIFEROUS SANDSTONE	DEVONIAN	SANDSTONE	UPPER and MIDDLE SILURIAN	POLARIS HARBOUR FORMATION	UPPER SILURIAN (LUDLOW)
MONOGRAPTUS SHALES		GRAPTOLITE SHALES (LIMESTONE)	UPPER SILURIAN	MONOGRAPTUS SHALES		CAPE TYSON FORMATION	MIDDLE SILURIAN (TARANNON-WENLOCK)
CORAL LIMESTONE		CORAL LIMESTONE		LIMESTONE, SHALE, CONGLOMERATE, SANDSTONE INCL. PENTAMERUS LIMESTONE			
RASTRITES SHALES		PENTAMERUS LIMESTONE	MIDDLE SILURIAN			OFFLEY ISLAND FORMATION	LOWER SILURIAN (LLANDOVERY)
PENTAMERUS LIMESTONE				ARETHUSINA FORMATION	LOWER SILURIAN	CAPE SCHUCHERT FORMATION	
ORTHOCERATITE LIMESTONE		ORTHOCERATITE LIMESTONE	ORDOVICIAN	ORDOVICIAN		CAPE CALHOUN FORMATION	UPPER ORDOVICIAN
CORAL LIMESTONE						CAMBRIAN and LOWER ORDOVICIAN	
CAMBRIAN or ALGONKIAN		RED SANDSTONE	CAMBRIAN?	CAMBRIAN		THULE FORMATION	ALGONKIAN

Fig. 4. Previous lithostratigraphic schemes, erected by Koch, covering both platform carbonate and deep-water Silurian sediments. From Lane *et al.* (1980, fig. 2).

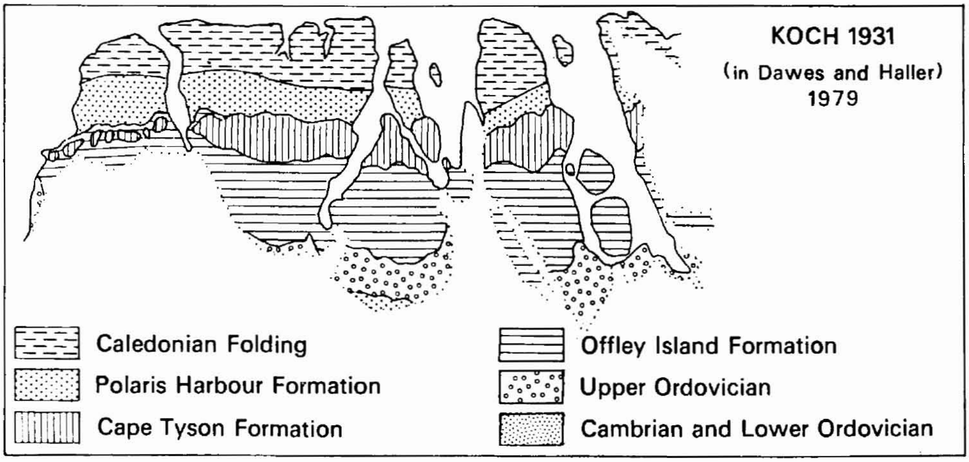


Fig. 5. Geological map of western North Greenland made by Koch in 1931, first published in Dawes & Haller (1979, pl. 3) and Lane *et al.* (1980, fig. 3).

Scoresby Bay and Cape Creswell in eastern Ellesmere Island. Some sandstone and mudstone sediments in northern Hall Land and northern Nyeboe Land were also assigned to the 'Cape Rawson beds'.

Subsequently, work by Schei (1903, 1904) in Ellesmere Island, during the Second Norwegian Polar Expedition led by Sverdrup, influenced later work in Greenland. Schei (1903, 1904) recognised a complex sequence of sediments of which 'Series C', erected to cover coarse unfossiliferous sandstone and regarded as Silurian in age, was central to the later work by Lauge Koch.

In their attempts to survey North Greenland, some expeditions had visited Peary Land and brought back rock samples before the pioneering work of Lauge Koch. Members of 'Danmark-Ekspeditionen til Grønlands Nordøstkyst 1906–1908' visited Depot Bugt, Frederick E. Hyde Fjord, Peary Land (Johan Peter Koch, 1917) and collected samples which Ellitsgaard-Rasmussen (1955) later described. Some of these samples described undoubtedly resemble Silurian turbidites.

The first stratigraphic framework encompassing the Silurian clastic sediments of North Greenland was proposed and refined by Koch (1918, 1920, 1923a, b, 1925, 1929, 1935) after two sledge expeditions through North Greenland in 1916 to 1918 and 1920 to 1922 (figs 4 & 5). Initially, Koch (1918) proposed a simple bipartite division of the Silurian clastic rocks stratigraphically above the Silurian platform carbonates. This included a 'lower *Monograptus* shales' and an 'upper sandstone unit', the latter of which was considered to be Upper Silurian or Devonian. Later Koch (1920) used the term 'Graptolite Slates' ('Graptolite Shales-Limestone' in Koch, 1923) for the previous '*Monograptus* shales', assigned them to the Upper Silurian and elaborated on a number of localities in Hall Land, Nyeboe Land and Warming Land where he had observed the sequence. Koch (1920) also recognised, above the 'Graptolite Slates', a 'Postsilurian unfossiliferous Sandstone' which he considered to be of Devonian age. This unfossiliferous sandstone was correlated with 'Series C' on Ellesmere Island (Schei, 1903, 1904) and indicated as Devonian in age, although Schei (1904) clearly states that 'Series C' was of Silurian age. Further, Koch (1920, p. 62) also considered the 'Cape Rawson beds' to be of Devonian age, although the faunal evidence (e.g. Etheridge, 1878) clearly showed it to be at least partly Silurian in age.

There are many ambiguities and discrepancies within and between Lauge Koch's publications resulting from the 2nd Thule Expedition of 1916 to 1918. Many of these were later overcome with the publications resulting from the Bicentenary Jubilee Expedition of 1920 to 1922. Koch (1929) erected two formations to encompass the previous units. The 'Cape Tyson Formation' was proposed to cover a sequence of limestone breccias and conglomerates, limestones and graptolitic shales which corresponded to the 'Graptolite Slates' and '*Monograptus* shales' of previous publications together with carbonate sediments. The 'Cape Tyson Formation' was considered to be of Tarannon-Wenlock age (Upper Llandovery to Wenlock) and to extend from Washington Land to eastern Peary Land. The younger 'Polaris Harbour Formation' was proposed to cover a sequence of "Coarse, loose, unbanded sandstone, occasionally containing slaty bands and numerous mica laminae of grey or brownish colour" (Koch, 1929, p. 241). This undoubtedly corresponded to the 'informal sandstone unit' and 'Postsilurian unfossiliferous Sandstone', but it was now judged to be of Ludlow (late Silurian) age. Koch (1929) considered the 'Polaris Harbour Formation' to be part of Feilden & De Rance's 'Cape Rawson beds', but felt that comparison with Schei's (1903, 1904) 'Series C' from Ellesmere Island should not be maintained, and that there was no evidence that the formation extended into the Devonian. The 'Polaris Harbour Formation' was indicated as extending from Washington Land to Peary Land.

Later Troelsen (1950), after the 'Danske Thule og Ellesmere Island Ekspedition 1939–1941' clarified some points concerning Lauge Koch's stratigraphy and continued to assign the clastics of northern Hall Land and northern Nyeboe Land to the 'Cape Rawson beds'. Troelsen (1950) also revised the area of outcrop he assigned to the 'Cape Rawson beds'. With hindsight it is obvious that Troelsen's concept of the 'Cape Rawson beds' was very homogeneous and essentially corresponded to the Silurian flysch of Ellesmere Island and western North Greenland.

Prior to 1940 the Silurian clastic rocks of North Greenland had only been studied in western North Greenland, and very little was known about such rocks in Peary Land and nothing at all about them in Kronprins Christian Land. As a member of the 'Dansk Nordøstgrønlands Ekspedition 1938–39', Nielsen (1941) first located shales and conglomerates of Gotlandian (Silurian) age above limestones at Profiljeldet and other areas to the west of Ingolf Fjord, Kronprins Christian Land.

Later Fränkl (1954, 1955a), as a member of 'De Danske Ekspeditioner til Østgrønland 1947–55' under the leadership of Lauge Koch, proposed the term 'Profilfjeldet Shales' to cover these rocks, which he described as "dark marly and sandy shales, weathering light-green or yellow" (Fränkl, 1954, p. 79), about 400 m thick, and of ?late Niagaran (Ludlow) age. Later, Fränkl (1956) considered that the 'Profilfjeldet Shales' were restricted to a Danmark Fjord Basin in the environs of Kronprins Christian Land, and were of Wenlock age (cf. Cowie, 1961). Curiously, Fränkl (1956) introduced the term 'Kjoveslette Sandstones' to cover a sequence of sandy shales of +50 m thickness occurring in southern Peary Land, yet ambiguously attributed the name to Troelsen. Fränkl (1956, p. 20) tantalisingly suggested that "the Kjoveslette Sandstones may correspond to the Profilfjeldet Shales". As commented on by Peel *et al.* (1974), this brief mention in Fränkl (1956) is the only reference to the 'Kjoveslette Sandstones', although both Koch (1923a) and Troelsen (1956) show localities where graptolites were found in the unit at Kjoveslette. It appears probable that the 'Kjoveslette Sandstones' correspond to the Cape Tyson Formation of Koch (see Dawes & Haller, 1979).

Fränkl (1955b) proposed a detailed lithostratigraphy for the clastic sediments of Johannes V. Jensen Land, north Peary Land. The upper two units, termed the 'Upper Nysne Gletscher Graphitic Slates' and the overlying 'Sydgletscher Sandstones', he correlated with the 'Cape Tyson Formation' and 'Polaris Harbour Formation' respectively.

A new phase of activity in North Greenland was initiated as a result of the Geological Survey of Canada's 'Operation Grant Land', 1965–1966. Allaart (1965, 1966) noted in Hall Land a sequence of mudstones, rhythmically bedded sandstones and shales, calcareous sandstones, grey slates and platy limestones some 950 m thick, which were referred to the 'Cape Rawson Group', the 'Cape Rawson beds' having previously been renamed by Blackadar (1954). Dawes (1966) examined the type locality of the 'Polaris Harbour Formation' and found that it consisted mainly of Quaternary deposits with minor sporadic exposures of bedrock. This together with the fact that Koch's concept of the 'Polaris Harbour Formation' had never been clear, prompted Dawes (1966) to suggest that the use of the formation name be discontinued.

Simultaneously with the Greenland work, more evidence was accumulating with regard to the 'Cape Rawson Group' on Ellesmere Island. Christie (1964) regarded the 'Cape Rawson Group' in north-eastern Ellesmere Island as Silurian. Kerr (1967) considered that the group extended into the Devonian both in Ellesmere Island and Greenland. In eastern Ellesmere Island, Kerr (1967, p. 497) states that the group is "as old as Late Ordovician in the north to probably Middle Devonian in the south (south of Canyon Fiord)". He further states (Kerr, 1967, p. 503) that the group "is as young as late Early or Middle Silurian on northern Hall Land, yet on the north coast of Washington Land it rests on the Cape Tyson and can be no older than Middle Silurian, and is probably no older than Early Devonian".

In his first review of the geology of North Greenland Dawes (1971) revised some of the previous stratigraphy of Koch. As a consequence of the renewed interest in using the term 'Cape Rawson Group' for similar sediments in Ellesmere Island and Greenland (e.g. Kerr, 1967) and the fact that some of Koch's earlier stratigraphies were ambiguous, Dawes (1971) was led to advocate the retention of the old 'Cape Rawson Group' in western North Greenland, from Hall Land to Wulff Land (see also Dawes & Soper, 1973). Further, Dawes (1971) abandoned the 'Cape Tyson Formation' and extended the 'Offley Island Formation' to include limestones and associated rocks previously assigned to the 'Cape Tyson Formation'.

Ironically, just after the term 'Cape Rawson Group' was gaining new life, particularly in Greenland, Trettin (1971) proposed that the term be abandoned altogether, mainly for two reasons:

1) because the name 'Cape Rawson beds' or 'Cape Rawson Group' had been used as a reconnaissance map unit and in a stratigraphic sense.
2) because the original 'Cape Rawson Group' included a wide variety of sediment types which cannot justifiably be retained within one group. Trettin (1971) was able to recognise four formations which were previously encompassed by the Cape Rawson Group.

It was not until the investigations of Allaart (1965, 1966), Kerr (1967), Norford (1967, 1972) and Dawes (1971) that it was shown that the Silurian rocks of western North Greenland did not simply represent layercake stratigraphy and that intricate facies changes were common. The complexity of facies changes between carbonates and clastics was demonstrated, but the comparably spectacular facies changes within the clastics still remained to be documented.

Recently Norford (1972) revised the Silurian stratigraphy of Koch (1920, 1929), from western North Greenland. Based on his observations at Kap Tyson, Offley Ø and Kap Schuchert, Norford rejected the term 'Cape Tyson Formation' considering it equivalent to the 'Offley Island Formation'. Further, he imported the name 'Cape Phillips Formation' from Arctic Canada to cover off-reefal graptolitic mudstones.

In the last decade the focus of work in North Greenland has been concentrated on Peary Land. Dawes & Soper (1973) established a section through the fold belt of Johannes V. Jensen Land, north Peary Land (see also Soper & Dawes, 1970). They erected, from below to above, the 'Paradisfjeld', 'Polkorridoren' and 'Sydgletscher Groups' and eleven informal formations which essentially corresponded to the divisions previously erected by Fränkl (1955b). Of particular note was the comparison Dawes & Soper (1973) drew between the 'Polkorridoren Group' and the Silurian 'Cape Rawson Group' of western North Greenland. This was in contrast to the suggestion made previously by Fränkl (1955b) that the 'Sydgletscher Sandstones' (the top unit of Dawes & Soper's 'Sydgletscher Group') was equivalent to the 'Polaris Harbour Formation' which was considered to be part of the 'Cape Rawson Group'.

Later Dawes (1976) elaborated further on correlation of clastic units. The 'Polkorridoren Group' was tentatively correlated with the 'Cape Rawson Group' of Kerr (1967) on Ellesmere Island, and the overlying 'Sydgletscher Group' was indicated as possibly extending into the Devonian. Of particular note was that Dawes (1976) abandoned the use of the term 'Cape Rawson Group' in North Greenland.

Mayr (1976) produced the first account of Silurian sediments from the central part of Peary Land, an area that on most maps prior to Dawes (1971, 1976) was left blank. Mayr noted an 'Unnamed carbonate-shale unit' of Ludlovian-Wenlockian age and an overlying 'Unnamed siltstone unit' of Ludlovian age. The lower 'Unnamed carbonate-shale unit' was shown to consist of interfingering reefs and shales. The 'Unnamed siltstone unit' was compared to the Imina Formation of north-western Ellesmere Island (Christie, 1957; Trettin, 1969) some 700 km to the west.

The first comprehensive account of the Silurian stratigraphy of central Peary Land was given by Christie & Peel (1977). Above a thick sequence of carbonates they recognised an 'Un-named Silurian black shale formation' about 100 m thick which was considered to be of late Wenlock age (see also Peel & Christie, 1975). Overlying this unit they recognised an 'Un-named Silurian flysch formation' approximately 800 m thick and noted it to be of late Wenlock age. The 'Un-named Silurian black shale formation' is equivalent to the 'Unnamed carbonate-shale unit' of Mayr (1976) and the 'Un-named Silurian flysch formation' is the same as the 'Unnamed siltstone unit'. Christie & Peel (1977) noted that the 'Un-named Silurian flysch formation' equated with the 'Kjoveslette Sandstones' (Fränkl, 1956; Peel *et al.,* 1974).

Two palaeontological papers (Lane, 1972; Scrutton, 1975) contain fragments of information concerning the 'Profilfjeldet Shales' of Kronprins Christian Land. The information derives from P. J. Adams and J. W. Cowie, who were members of 'De Danske Expeditioner til Østgrønland 1947–54' under the leadership of Lauge Koch. Both Lane (1972) and Scrutton (1975) report that the base of the 'Profilfjeldet Shales' sporadically contains limestone conglomerates. These are in contrast to the quartzite conglomerates which are now known to occur in places at the base of the 'Profilfjeldet Shales' (Peel, 1980; JMH, personal observations) and reflect resedimented portions of carbonate buildups. The 'Drømmebjerg Limestone' at the type locality, which underlies the 'Profilfjeldet Shales', is now known to be a reef complex (JMH, personal observations). Scrutton (1975) formalised the 'Profilfjeldet Shales' to 'Profilfjeldet Formation'.

Dawes & Soper (1979) proposed a basic stratigraphic framework for the sediments of the North Greenland fold belt, which was the result of their fieldwork a decade previously. South of the Harder Fjord fault in Johannes V. Jensen Land they recognised a basic tripartite clastic stratigraphy informally labelled from below 'formation A, B and C'. 'Formation C' consisted of well-bedded, grey to brown and yellow-weathering sandstone turbidites, interbedded with siltstone and shale together with limestone breccio-conglomerates. 'Formation C' was considered to be at least 250 m thick with a projected composite thickness of at least 600 m, and to pass up into the 'Un-named Silurian flysch formation' further south (Christie & Peel, 1977; Dawes & Soper, 1979). The age of 'formation C' was shown to be within the early Silurian, and basically it was identical to what had been termed the 'Cape Rawson Group' previously by Dawes (1971) and Dawes & Soper (1973). Thus it was still correlated with some reservations with the 'Polkorridoren Group' of the north Peary Land fold belt, and the overlying 'Sydgletscher Group' again questionably extended into the Devonian. Recently, Friderichsen *et al.* (1982) have provided a basic lithostratigraphic framework for the deep-water sediments of North Greenland in which much of the earlier work of Dawes & Soper (1973, 1979) has been revised.

The most recent geological activity in North Greenland was under the auspices of a 3 year expedition mounted by the Geological Survey of Greenland during the summers of 1978, 1979 and 1980. A more detailed picture is emerging concerning the facies, thickness and age variation of the Silurian clastic sequences of southern Peary Land (Christie & Ineson, 1979; Hurst, 1979; Lane & Thomas, 1979; Pedersen, 1979, 1980; Hurst & Surlyk, 1980; Mabillard, 1980; Surlyk *et al.*, 1980). Other important points include the demonstration by Peel (1980) that the 'Un-named Silurian black shale formation' and the 'Un-named Silurian flysch formation' of Peary Land extend southwards through Valdemar Glückstadt Land and into Kronprins Christian Land. It is now known (JMH, personal observations) that the 'Profilfjeldet Shales' represent the 'Un-named Silurian flysch formation' of Peary Land.

The discovery of Lower Llandovery (Silurian) graptolites near the top of the 'Sydgletscher Group' in the north Peary Land fold belt shows that the underlying two groups of this sequence are mostly pre-Silurian (Hurst & Surlyk, 1980; Surlyk *et al.*, 1980). Therefore, the correlation of the underlying 'Polkorridoren Group' with the Silurian 'Cape Rawson Group' (Dawes, 1971; Dawes & Soper, 1973) or 'formation C' (Dawes & Soper, 1979) is not tenable.

In Wulff Land Hurst & Peel (1979) recognised a tripartite sequence of Silurian clastic rocks including a lower 'Silurian shale and breccia formation' (*c.* 240 m), a 'Silurian siltstone formation' (*c.* 300 m) and an upper 'Silurian turbidite formation' (70 m examined). Recognition of this clastic sequence emphasised the basic similarity of the Silurian clastic sequences across North Greenland, from Washington Land to Kronprins Christian Land.

The most recent revision of some aspects of the Silurian clastics of North Greenland was undertaken by Hurst (1980), in Washington Land and western Hall Land. The name 'Cape Phillips Formation' of Arctic Canada was abandoned, and the shale and resedimented carbonates that it represented were incorporated in a new 'Lafayette Bugt Formation'. Hurst (1980) also introduced the 'Peary Land Group' for a sequence of predominantly turbidites, mudstones, cherts and resedimented carbonate conglomerates, which occur across the whole of North Greenland and are mainly Silurian in age. It was emphasised by Hurst (1980) that the description of the Peary Land Group at that time was based only on the two formations assigned to it ('Cape Schuchert Formation' and 'Lafayette Bugt Formation') in Washington Land and western Hall Land and that a fuller description of the group throughout North Greenland would follow. This is done in this account.

An enlightening account of the social, economic and scientific background to Lauge Koch's expeditions is given by Dawes & Haller (1979). This recent publication has clarified many of the ambiguous statements in Koch's publications. In particular the distribution of what Lauge Koch meant by the 'Polaris Harbour Formation' is now established (see also Lane *et al.,* 1980).

To summarise, prior to 1940 geological knowledge of North Greenland was gained primarily as a by-product of expeditions whose aim was to reach the North Pole (e.g. Peary) or general exploration (e.g. Lauge Koch). The vast majority of these early expeditions reached North Greenland via the Nares Strait and therefore most observations concerning the geology derived from western North Greenland. Of the early expeditions it was only those of which Koch was a member or leader that can be said to have gone with the specific aim of tackling geological problems. Again Koch took the well-tried routes to the north via the Nares Strait. Subsequently, expeditions again mounted by Koch to East Greenland opened the way for new geological work in eastern North Greenland (Kronprins Christian Land and Peary Land). Later in the 1960s, the emphasis again shifted to western North Greenland with activities associated with the Geological Survey of Canada's 'Operation Grant Land'. The last phase of geological work during the three year expedition organised by the Geological Survey of Greenland was concentrated in eastern North Greenland (Kronprins Christian Land and Peary Land), but enabled peripheral studies westwards as far as Hall Land. Thus, for the first time a general overview of the Silurian clastics of North Greenland across the whole region, from Washington Land to Kronprins Christian Land, is possible.

LITHOSTRATIGRAPHY

Latest Ordovician and Silurian sedimentation patterns essentially show axial deposition of sandstone turbidites and chert pebble conglomerates derived from the east together with lateral derivation from the south of resedimented carbonate and chert conglomerates (Surlyk *et al.*, 1980). Consequently, facies changes occur both longitudinally in the trough, as well as laterally (fig. 2).

The depositional environments of the individual lithostratigraphic units are being evaluated by the authors. An elongate submarine fan, basin plain and possibly deep-sea channel environment is suggested for the main part of the sequence. Deposition in a mid and outer fan setting can, however, only be inferred for parts of the eastern sections in Peary Land. This is at variance with the fan model interpretation of most ancient turbidite successions. The description of each lithostratigraphic unit includes a section on the inferred depositional environment.

In an east–west axial transect of the basin the proportion of mudstone dominated units increase westwards; the further east the thicker the sandstone units (fig. 2). At the same time a north–south transect reveals that the sandstone beds are more common along the basin axis whilst siltstones and finally mudstones predominate towards the southern margin (fig. 2).

Such complicated and rapid facies changes mean that sections not too far apart can be very different. The uniformity of the turbidite lithologies results, however, in problems of recognising the same stratigraphic unit unless a very tight graptolite zonation can be established. The lithostratigraphic problem can be attacked in two ways. Each individual stratigraphic unit in separate areas can be given different names, which means a very cumbersome lithostratigraphical scheme would exist. The alternative preferred here is to recognise the major sandstone, siltstone and mudstone units corresponding to the main sedimentation episodes and to erect formations to cover them. Within each formation distinctive units, including interdigitating mudstones and conglomerate wedges of limited areal extent, are named as members. The intervening sandstone turbidite units have not been sub-divided into members (fig. 2). As the mudstone, siltstone and sandstone grade sediments form the basis of the formations, then the sections displaying rapid facies changes from mudstone, siltstone and sandstone units will also be the sections in which the formations are seen to interdigitate.

We suggest that, if in one such section a number of interdigitating mudstone and sandstone units occur, they are referred to a mudstone and a sandstone formation respectively. If one or all the sandstone units require a name, then they should be treated as members of the component formations. Such a procedure recognises and preserves the overall continuity of the sedimentary patterns. Otherwise the introduction of large numbers of formational names will only confuse the picture.

Sandstone turbidites, particularly in Peary Land, display a variety of related

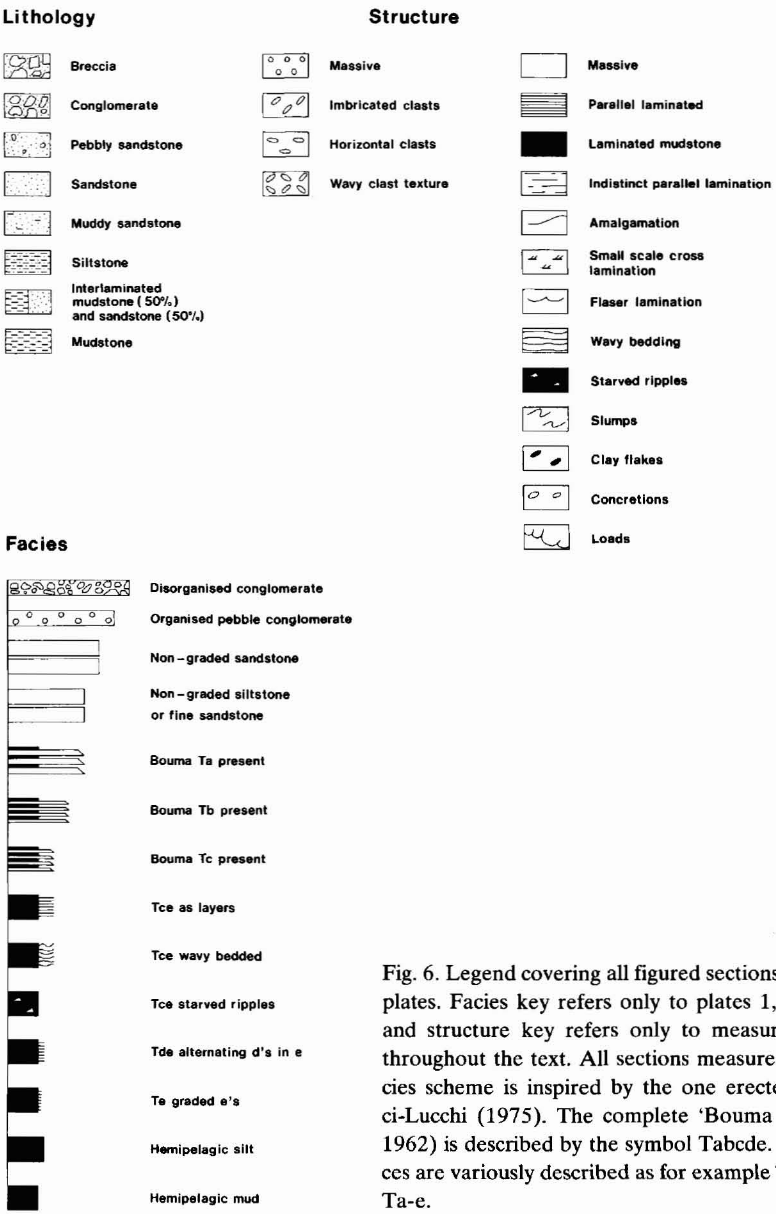


Fig. 6. Legend covering all figured sections both in the text and plates. Facies key refers only to plates 1, 2 and 3. Lithology and structure key refers only to measured sections figured throughout the text. All sections measured in metres. The facies scheme is inspired by the one erected by Mutti & Ricci-Lucchi (1975). The complete 'Bouma sequence' (Bouma, 1962) is described by the symbol Tabcde. Incomplete sequences are variously described as for example Tab, Ta-c, Ta/c-e or Ta-e.

facies. At present many facies types have been lumped into one formation. However, we suggest that if a distinctive facies (e.g. thick amalgamated, non-graded and structureless fine sand beds occurring in units up to 100 m thick) has to be named, it is done so as the member of a formation.

In the chronostratigraphic scheme North American series and stages are used in the Ordovician whilst all internationally standard series and stages are used in the Silurian. Graptolites are the only abundant fossils in the Peary Land Group, and the base of the Silurian is conveniently taken at the base of the *Glyptograptus persculptus* Zone in Europe and at the base of the same zone or the *Diplograptus modestus-Climacograptus* aff. *C. trifilis* Zone in North America, particularly Arctic Canada.

Faunal identification and sedimentary logs

This stratigraphic report relies on the graptolite determinations. All graptolites have been kindly determined by Merete Bjerreskov (Copenhagen) as part of a larger study of North Greenland Silurian graptolites (e.g. Bjerreskov, 1981).

All sedimentary logs of the type and reference sections, both in the text and on plates 1, 2 and 3 are standardised (fig. 6).

Peary Land Group

History. Hurst (1980, p. 73) erected the Peary Land Group "for a sequence of predominantly mudstones, cherts, resedimented carbonates and turbidites which occur across the whole of North Greenland and are mainly Silurian in age". The type area was given as North Greenland. This initial description of the Peary Land Group was not comprehensive, because at the time the group was erected it was premature to discuss it in the context of the whole of North Greenland from Washington Land to Kronprins Christian Land (fig. 3). Also it is important to note that this description of the Peary Land Group sediments in Washington Land and western Hall Land was not central to the basic concept of the group, which is concerned with turbidites. Thus, although the Peary Land Group concept was formulated and understood, Hurst (1980) emphasised that his description of the group was only concerned with Washington Land and western Hall Land.

In North Greenland the group encompasses the 'Cape Rawson beds' of Feilden & De Rance (1878) and the 'Cape Rawson Group' in the sense of Dawes (1966, 1971) and Dawes & Soper (1973) and the 'clastic unit' and 'clastic group' of Dawes (1971, 1976, 1979, 1982). Also included are the 'Un-named Silurian black shale formation' and the 'Un-named Silurian flysch formation' of Christie & Peel (1977), 'formation C' of Dawes & Soper (1979) and the 'Sydgletscher Sandstones' (Fränkl, 1955b) of the 'Sydgletscher Group' (Dawes & Soper, 1973). The 'Profilfjeldet Shale' of Kronprins Christian Land (Nielsen, 1941; Fränkl, 1954, 1955a) and the 'Kjoveslette Sandstones' (Fränkl, 1956) are also included in the group. The recently redefined 'Cape Schuchert Formation' together with the newly erected 'Lafayette Bugt Formation' (Hurst, 1980) are also assigned to the group in Washington Land. The extent of the 'Polaris Harbour Formation' of Koch (1929) is now known (Dawes & Haller, 1979), and it is also included in the Peary Land Group. In western North Greenland Trettin (1979) referred strata now included in this group to the Imina Formation.

Name. After Peary Land where the group forms the top unit in most of the area.

Type area. North Greenland, from Washington Land in the west to Kronprins Christian Land in the east.

Thickness. The group reaches its maximum thickness of about 3 km in Peary Land.

In the western end of the outcrop belt in Washington Land it has decreased to about 500 m.

Dominant lithology. The bulk of the group comprises yellow to brown weathering quartz dominated siltstone and sandstone turbidites of 'classical flysch' appearance. The turbidites have a calcareous matrix and cement and are characterised by a conspicuous content of visible mica flakes. A major black mudstone dominated unit occurs in the middle of the group and the proportion of mudstone increases to the west. In the lower half of the group along the southern margin of Frederick E. Hyde Fjord, Peary Land and in Washington Land, Hall Land, Nyeboe Land and Wulff Land a sequence of redeposited limestone conglomerates occur. In Kronprins Christian Land the group is characterised by quartzite pebble conglomerates interbedded with the sandstone turbidites. The upper part of the group is generally characterised by abundant chert pebble conglomerates.

Depositional environment. The Peary Land Group is an excellent example of classical longitudinal flysch basin deposition. East of Wulff Land the group includes basin plain, outer fan and localised braided midfan environments. In the western part of the basin only basin plain deposits are recognised. Along the southern margin the basinal turbidite sequence interdigitates with lower slope mudstones and base-of-slope conglomerates.

Boundaries. In Johannes V. Jensen Land, Lauge Koch Land, Freuchen Land, Nares Land and Wulff Land the lower boundary is placed where the black cherts and mudstones of the Amundsen Land Group (Friderichsen *et al.,* 1982) are overlain by buff weathering turbidites of the Peary Land Group. Along the southern margin of the outcrop belt in Kronprins Christian Land and Peary Land and to the west in Nyeboe Land and Hall Land the group overlaps Lower Silurian platform carbonates. In Washington Land the group overlaps Upper Ordovician to lowest Silurian platform carbonates referred to the Aleqatsiaq Fjord Formation of the Morris Bugt Group (Hurst, 1980). The group forms the top unit in the western part of the fold belt and most of the eastern part. In the eastern Peary Land region it is locally overlain, with angular unconformity, by Upper Carboniferous conglomerates and sandstones in red bed facies of the Mallemuk Mountain Group (Håkansson, 1979). In Kronprins Christian Land it is occasionally in thrust contact with Precambrian rocks referred to as Rivieradal sandstones (Hurst & McKerrow, 1981).

Distribution. The group is widespread in North Greenland from Kronprins Christian Land in the east to Washington Land in the west (fig. 3).

Geological age. Uppermost Ordovician (late Cincinnatian) to uppermost Silurian and may possibly extend into the lowest Devonian.

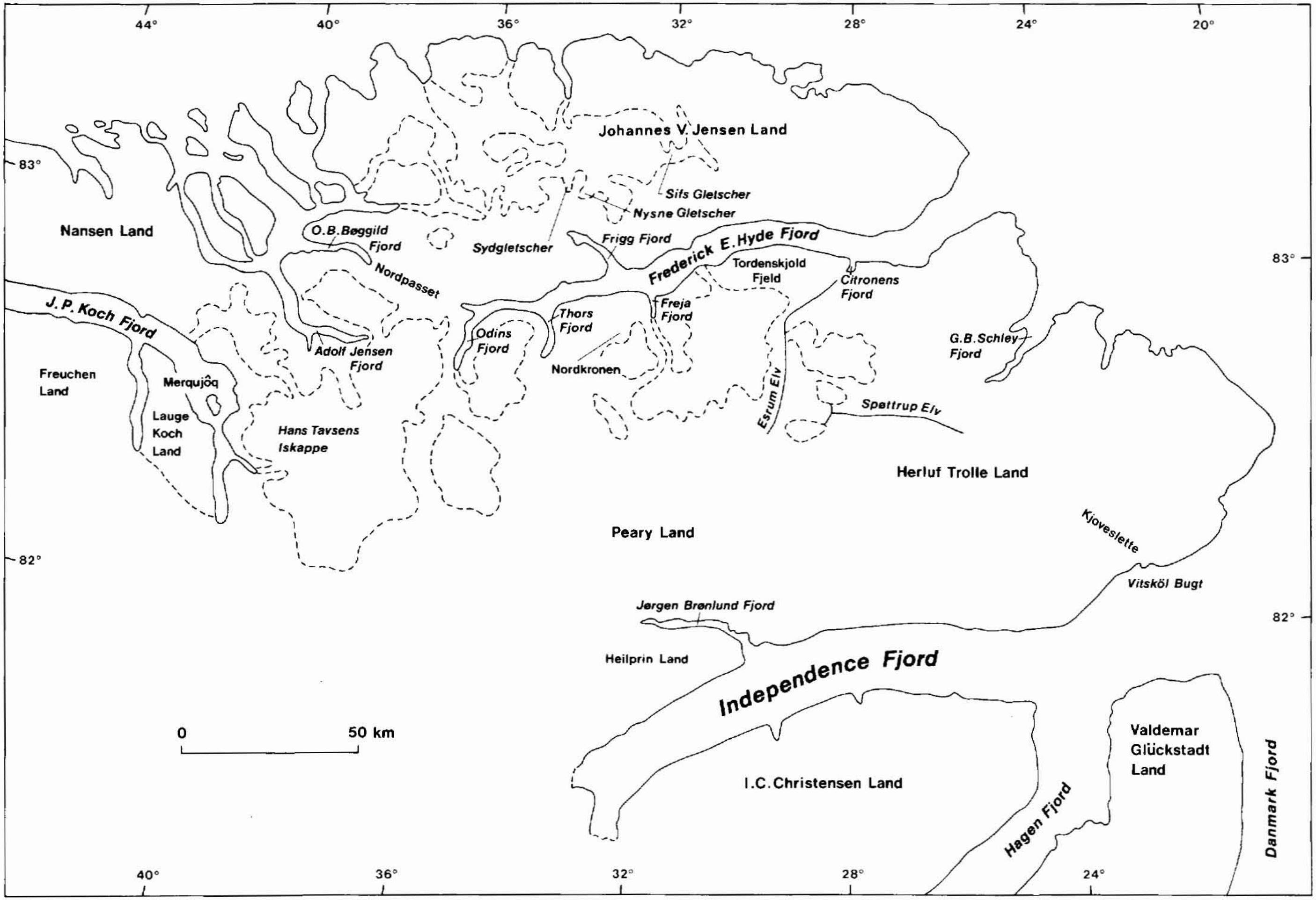


Fig. 7. Detailed locality map of Peary Land showing areas mentioned in the text. Note that Johannes V. Jensen Land is the northernmost part of Peary Land.

Fig. 8. Location of the type section (31) of the Sydgletscher Formation (a) in Johannes V. Jensen Land (plate 1; fig. 7). Aerial photograph 548 F–Ø, no. 1620. Copyright Geodætisk Institut, Denmark. Sydgletscher is approximately 3 km across.

Subdivisions. The group is divided into eight formations and six members. These include the Sydgletscher Formation, the Merqujôq Formation (with the Citronens Fjord and Freja Fjord Members), the Cape Schuchert Formation, the Lafayette Bugt Formation, the Wulff Land Formation (with the Thors Fjord and Repulse Havn Members), the Lauge Koch Land Formation (with the Profilfjeldet Member), the Nordkronen Formation (with the Hendrik Ø Member) and the Chester Bjerg Formation. Several of the formations are lateral equivalents.

The concept of the Peary Land Group is centered on the thick sandstone turbidites of the Merqujôq and Lauge Koch Land Formations. These two units also form the bulk of the strata assigned to the group. Lateral facies changes of these two formations include siltstone turbidites, mudstones and resedimented carbonate conglomerates (assigned to other formations), but which are subordinate in thick-

Fig. 9. Base of the type section (plate 1, section 31) of the Sydgletscher Formation (fig. 8) showing the typical development of thick non-graded sandstone turbidites (b) interbedded with black mudstones (c). Sandstone turbidite (a) marks base of Sydgletscher Formation. Cliff height approximately 100 m.

ness and extent to the sandstone turbidite units of the Merqujôq and Lauge Koch Land Formations. For convenience and order, the descriptions of the formations and members of the Peary Land Group are chronological, starting with the oldest and ending with the youngest.

Sydgletscher Formation

new formation

History. The formation name is adapted from Fränkl's (1955b, p. 41) 'Sydgletscher Sandsteine' later referred to as '3e Calc-sandstone' ('Sydgletscher sandstones') of the 'Sydgletscher Group' by Dawes & Soper (1973, p. 126) (see also Soper *et al.*, 1980; Higgins *et al.*, 1981).

Name. From Sydgletscher, the prominent southerly directed glacier, some 10 km north from Frigg Fjord (fig. 7).

Type section. Central Johannes V. Jensen Land, immediately to the west of Sydgletscher (figs 8, 9; plate 1, section 31).

Thickness. In the type section up to 175 m were recorded (plate 1, section 31). The boundary to the overlying thin to medium-bedded classical turbidites of the Merqujôq Formation has not been observed, so the exact thickness of the formation is not known.

Fig. 10. Thick structureless sandstone turbidites above recessive black mudstone. Base of sandstone marked by dotted line. Sydgletscher Formation type section (figs 8, 9; plate 1, section 31). Cliff height approximately 40 m.

Lithology. Up to 30 m thick, non-graded, buff-yellow coloured, fine-grained beds of well-sorted, angular quartz sandstone with a conspicuous content of visible mica flakes characterise the formation (fig. 10). They are generally structureless, with non-erosive bases, but occasionally shale rip-up clasts are incorporated in the basal sandstone layers. The sandstones are apparently not amalgamated. Some of the thinner sandstone beds (*c.* 2 m thick) are weakly parallel laminated. Interbedded are laminated black mudstones up to 6 m thick. The sandstones constitute approximately 60% of the formation and the mudstones 40% (plate 1, section 31). Only very poorly preserved graptolites occur in the mudstones (Dawes & Soper, 1973). Thus it differs substantially from the sand-rich, thin to medium-bedded classical turbidite sequences of the overlying Merqujôq Formation. Also the interbedded mudstones of the Sydgletscher Formation resemble the black Ordovician muds and not the buff-coloured muds of the Merqujôq Formation.

Depositional environment. The Sydgletscher Formation exhibits a characteristic suite of very thick beds, deposited by enormous catastrophic flows related to high-density turbidity currents. The flows were probably confined to a deep-sea channel in the axial part of the basin. The intervening mudstone sequences are probably of hemipelagic or dilute turbidity current origin. The lack of thin lenticular siltstone and sandstone turbidites makes a levée origin less likely.

Boundaries. The lower boundary is exposed in the type section west of Sydgletscher (fig. 8) where the base is taken at the bottom of the first thick buff-yellow

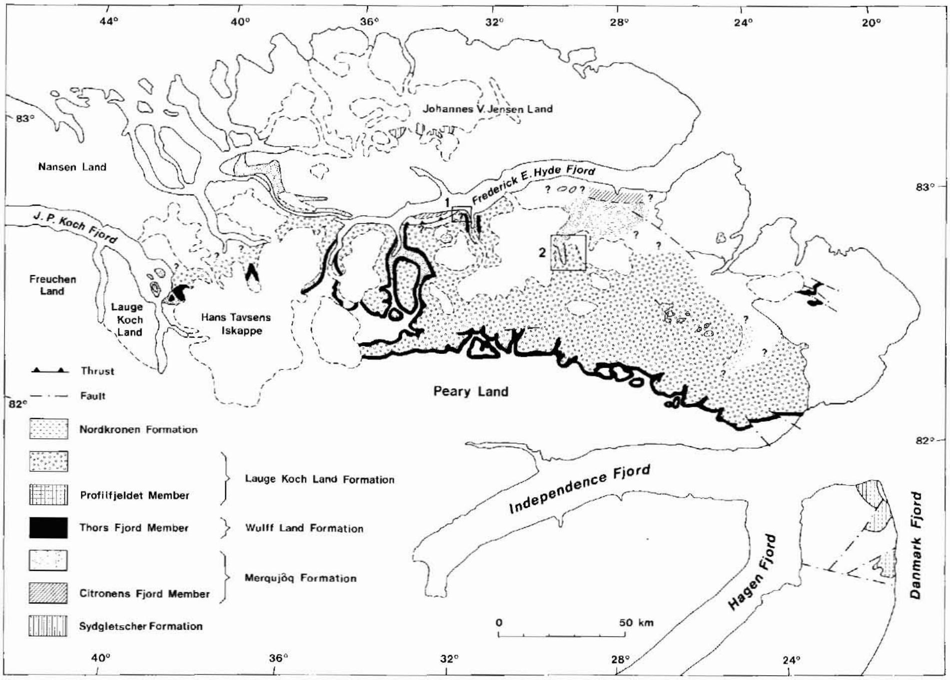


Fig. 11. Partly simplified geological map of Peary Land and Valdemar Glückstadt Land showing the distribution of the component members and formations of the Peary Land Group. Figures refer to geological maps in text, including 1 (fig. 67) and 2 (fig. 103). Based on the map in Grønlands Geologiske Undersøgelse Rapport 88.

coloured fine-grained sandstone turbidite (fig. 9). Here the formation is in contact with an alternation of black mudstones, siltstones and cherts with rare calcarenites and silty turbidites assigned to the Amundsen Land Group (Friderichsen *et al.*, 1982). The upper boundary is defined where the thick-bedded structureless sandstones are overlain by thin to medium-bedded classical turbidites of the Merqujôq Formation.

Distribution. The Sydgletscher Formation outcrop is restricted and is spatially separated from the main outcrop of the other formations assigned to the Peary Land Group (fig. 11). It forms the high ground and nunataks in central Johannes V. Jensen Land between Sydgletscher and Sif Gletscher (figs 7, 11).

Geological age. No age diagnostic faunas have yet been reported from the formation. Surlyk *et al.* (1980) report graptolites, including *Climacograptus rectangularis* and *Atavograptus* aff. *A. Atavus* from 60 m below the base of the Sydgletscher Formation, and conclude that the sample is probably referable to a stratigraphical level around the *atavus-cyphus* Zones in the Lower Llandovery. The bulk of the

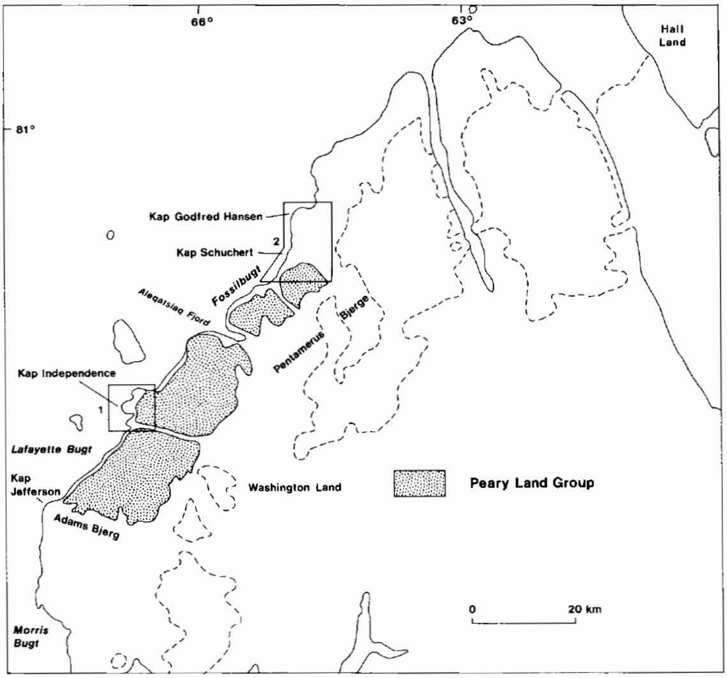


Fig. 12. Simplified geological map of Washington Land showing the distribution of the Peary Land Group and showing localities mentioned in the text. In Washington Land the Peary Land Group consists of two formations, the Cape Schuchert Formation and Lafayette Bugt Formation. The outcrop pattern of the former rims the distribution of the group itself, and the bulk of the outcrop is taken up by the Lafayette Bugt Formation. Figures refer to geological maps in the text, including 1 (fig. 14) and 2 (fig. 15).

Sydgletscher Formation was deposited during very few sedimentation episodes, each episode being responsible for up to 30 m of sediment. The sedimentation rate of the formation is thought to have been very high, and it is thus highly unlikely that the Sydgletscher Formation is much younger, if at all, than Lower Llandovery.

Cape Schuchert Formation

History. This formation erected by Koch (1929) has recently been redefined by Hurst (1980).

Name. After Kap Schuchert, a low-lying gravel delta in Fossilbugt, Washington Land (fig. 12). When Koch originally erected the formation, Kap Schuchert was named Cape Schuchert.

Type and reference sections. The type section is just south of Kap Independence, Washington Land in a narrow gully on the west facing slope of a major north–south valley on the shore of Lafayette Bugt (figs 13, 14). Good reference profiles occur in

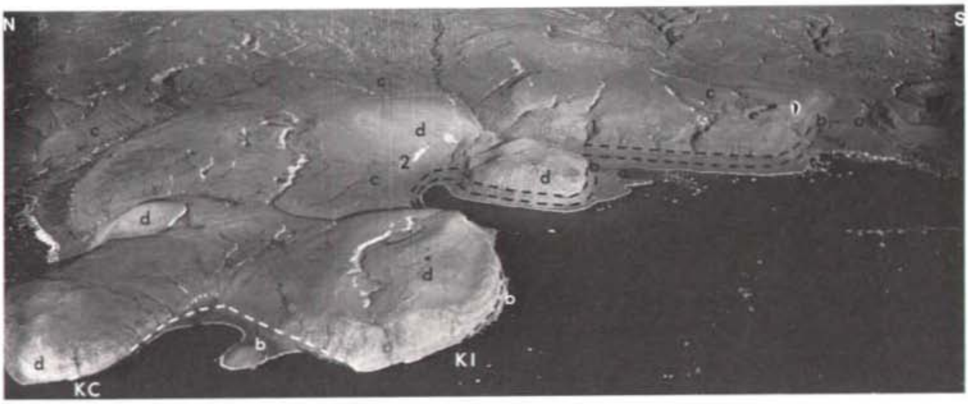


Fig. 13. Coastal areas of Washington Land at Lafayette Bugt. Kap Constitution (KC) and Kap Independence (KI). Aleqatsiaq Fjord Formation (a), Cape Schuchert Formation (b), Lafayette Bugt Formation (c) and Kap Independence Member of the Hauge Bjerge Formation (d). Type locality and section for the Cape Schuchert Formation and Lafayette Bugt Formation indicated by 1 and 2 respectively (see Hurst, 1980). Aerial photograph 545 KI–SØ, no. 2259. Copyright Geodætisk Institut, Denmark. Cliff heights between 400 and 500 m.

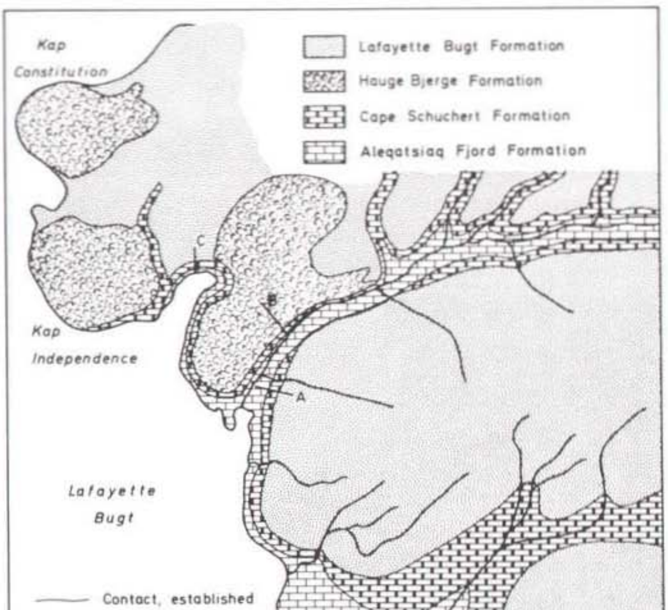


Fig. 14. Geological map of the Kap Independence and Lafayette Bugt region (reference map fig. 12). Type locality for the Cape Schuchert Formation (A), Lafayette Bugt Formation (C) as well as the Kap Independence Member (B) of the Hauge Bjerge Formation (see Hurst, 1980).

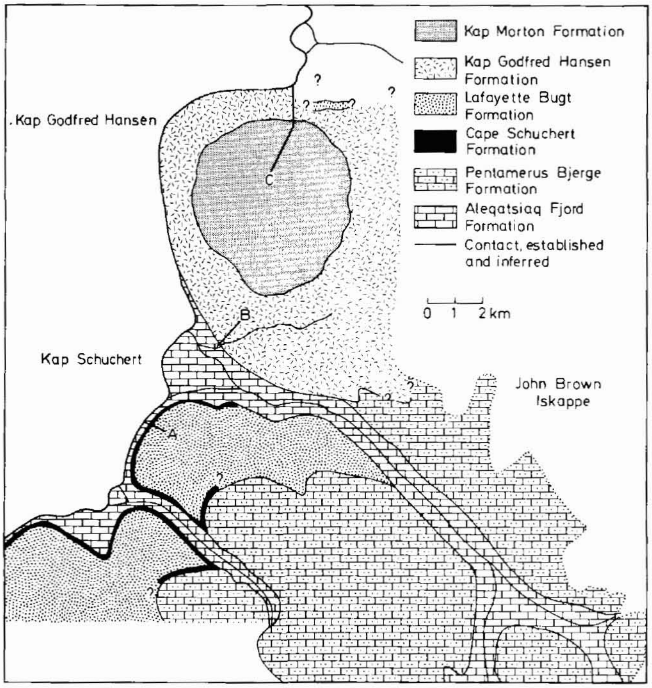


Fig. 15. Geological map of the environs of Kap Godfred Hansen and Kap Schuchert (reference map fig. 2). Section A is a reference section for the Cape Schuchert Formation at a locality just to the south of the cape (Hurst, 1980). This section also corresponds to section N of Norford (1972). Also shown are type and reference sections of the Kap Godfred Hansen Formation, respectively along line of sections B and C.

and around Kap Schuchert and Kap Independence (figs 14, 15; Hurst, 1980, figs 56, 58, 59).

Thickness. 55 to 80 m.

Lithology. The formation is characterised by thin-bedded, black, bituminous, cherty lime mudstones, occasionally faintly laminated (fig. 16). In and around the type section chert bands up to 25 cm thick and abundant chert nodules occur in more massive lime mudstones. Mudstone beds are common and these increase in thickness and abundance everywhere towards the top of the formation. Rarely, thin calcarenitic turbidites also occur. Some thin conglomerate beds and slumped carbonate blocks occur at Kap Jefferson, Washington Land.

Depositional environment. There is no internal organisation to the sediments assigned to the Cape Schuchert Formation. The formation represents an upper slope environment characterised by quiet water deposition of fine-grained sediments (Hurst, 1981). Periodically, calcarenitic turbidites and limestone conglomerate debris flows derived from the carbonate platform and carbonate buildups were emplaced along the slope.

Fig. 16. Interbedded lime mudstones, cherts and calcarenites in the Cape Schuchert Formation in the reference section south of Kap Schuchert (fig. 15).

Boundaries. The lower boundary is exposed all along the western coast of Washington Land, between Kap Schuchert and Kap Jefferson and follows conformably the platform limestone Aleqatsiaq Fjord Formation of the Morris Bugt Group. It interdigitates with carbonates of the Adams Bjerg Formation, Pentamerus Bjerge Formation and the Kap Godfred Hansen Formation. In the type section the base is taken at the beginning of massive, black, bituminous, cherty limestones which are in direct contrast to the underlying light coloured, crinoidal limestones of the Aleqatsiaq Fjord Formation. The upper boundary around the type section is taken at the base of thick black shales of the overlying Lafayette Bugt Formation (figs 13, 14 & 15).

Distribution. The Cape Schuchert Formation only occurs in Washington Land, along the north-west coast between Kap Jefferson and Kap Godfred Hansen. Localised thin-bedded bituminous lime mudstones and mudstones in central Wulff Land, below the Lafayette Bugt Formation, may eventually prove to be an isolated development of this formation.

Geological age. The lower boundary of the formation is apparently contained within the Middle Llandovery, although in and around the type section the lowest beds may be Lower Llandovery. The upper boundary of the formation is diachronous between Middle Llandovery (Idwian) and lower Upper Llandovery (Fronian). For details see Hurst (1980).

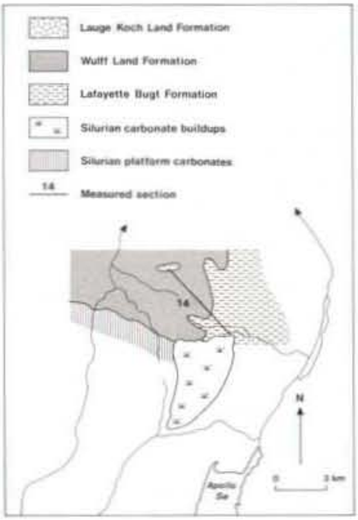


Fig. 17. Geological map of the northern end of Apollo Sø, Wulff Land (4 on plate 4). Section 14 is the type section for the Wulff Land Formation and the easternmost reference section of the Layfayette Bugt Formation (plate 1, section 14).

Lafayette Bugt Formation

History. Hurst (1980) erected the formation for Washington Land and western Hall Land. At that time the formation description was based solely on that area. Here the formation is described within the context of Washington Land, Hall Land, Nyeboe Land, Warming Land and Wulff Land. Included in this description of the Lafayette Bugt Formation is the 'Silurian shale and breccia formation', including 'member A' and 'member B' of Hurst & Peel (1979).

Name. After Lafayette Bugt, the broad bay south of Kap Independence, Washington Land (fig. 12).

Type and reference sections. The type section in Washington Land is in the centre of the small bay to the east of Kap Independence (figs 13, 14). Many reference sections occur on the coast of Washington Land. The most easterly reference section known is in Wulff Land (figs 17, 18; plate 4).

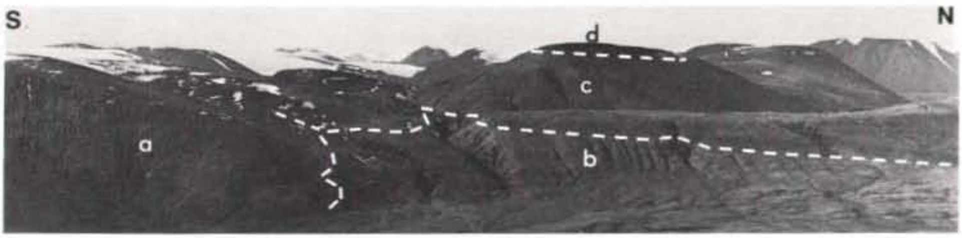


Fig. 18. North end of Apollo Sø, central Wulff Land (fig. 17). Lafayette Bugt Formation (b), interdigitating with carbonate buildups (a) and overlain by the Wulff Land Formation (c) and Lauge Koch Land Formation (d). Main gully in centre of the picture is type section for Wulff Land Formation (plate 1, section 14) and easternmost reference section for the Lafayette Bugt Formation (fig. 17). Hill at the top of the type section approximately 1000 m high.

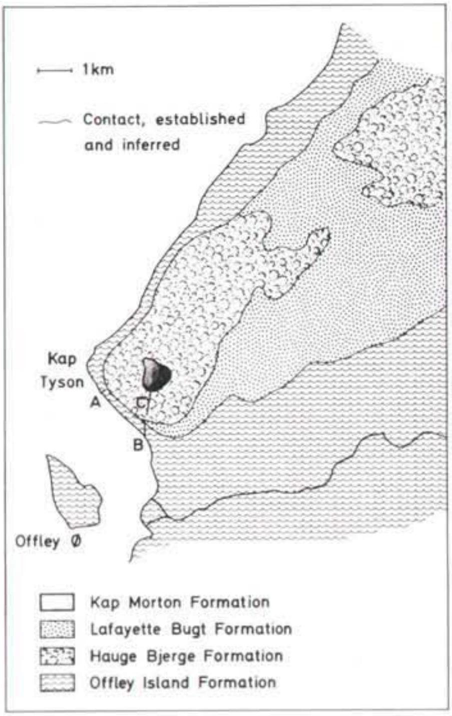


Fig. 19. Geological map of the Kap Tyson – Offley Ø region in Hall Land (1 on plate 4), showing the close association of the Lafayette Bugt Formation with carbonate buildups of the Hauge Bjerge Formation. Letters A, B and C refer to lines of sections through various carbonate formations showing some interdigitation with the Lafayette Bugt Formation (see Hurst, 1980).

Thickness. Up to 300 m in and around the type section. Everywhere in Washington Land and Hall Land (fig. 19) the top of the formation is a present-day erosion surface, so it is impossible to measure a maximum thickness. In Nyeboe Land the formation is at least 100 m thick. Only in Wulff Land is the depositional thickness

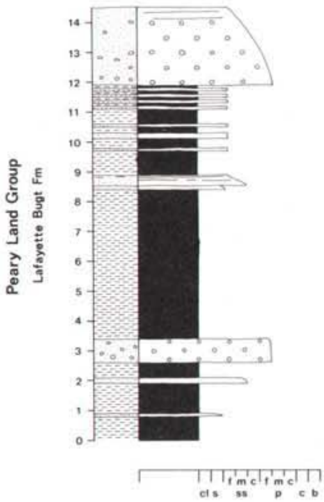


Fig. 20. Detailed sedimentological log illustrating the Lafayette Bugt Formation facies. Part of the reference section of the Lafayette Bugt Formation in the type section for the Cape Schuchert Formation (figs 13,14).

Fig. 21. Interbedded calcarenites and mudstones of the Lafayette Bugt Formation. From the reference section and the type section of the Cape Schuchert Formation (figs 13,14).

Fig. 22. Outcrop pattern of Lafayette Bugt Formation in eastern Nyeboe Land (plate 4) showing recessive weathering nature of the formation producing low lying plains. Hill in far distance composed of Wulff Land Formation. Width of valley approximately 5 km.

Fig. 23. Huge limestone block in black mudstones. Lafayette Bugt Formation, eastern Nyeboe Land.

of the Lafayette Bugt Formation known, *c.* 240 m (plate 1, section 14), but the base of the formation is not exposed.

Lithology. In Washington Land and Hall Land the formation is characterised by thick black mudstone units interbedded with poorly laminated lime mudstones and redeposited limestone conglomerates up to 10 m thick, which are derived from the platform carbonate margin and basin slope carbonate buildups (fig. 20). With increasing distance from the platform carbonates and carbonate buildups the mudstones are interbedded with thin laminated or graded and laminated calcarenitic turbidites (allodapic limestones) and fine carbonate cobble conglomerates. Occasional chert nodules occur and they rarely form bands (fig. 21). Rare continuous chert beds are also present.

Fig. 24. Bedded limestone block in black mudstones. Lafayette Bugt Formation, eastern Nyeboe Land.

In Nyeboe Land parts of the Lafayette Bugt Formation are characterised by large exotic blocks (up to about 50 m in diameter) of limestone derived from the adjacent southerly carbonate platform margin (figs 22, 23, 24). The mudstone around the blocks is squeezed and contorted and contains interbedded calcarenites.

In Wulff Land the Lafayette Bugt Formation shows a mainly fining upwards arrangement of sediments. In the reference section the lower half of the formation is characterised by a large number of redeposited carbonate conglomerates, often in thick beds. The upper half of the formation is characterised by thicker mudstone units, in which the redeposited carbonate conglomerates are less frequent and much thinner (figs 25, 26).

Depositional environment. The Lafayette Bugt Formation is dominated by hemipelagic black mudstones. Resedimented limestone conglomerates and calcarenitic turbidites derived from the carbonate platform and carbonate buildups are common. The formation represents an upper to lower slope environment. Towards the lower slope it interdigitates with the basin margin mudstones of the Wulff Land Formation.

Boundaries. In Washington Land the formation follows conformably upon the Cape Schuchert Formation, but its upper surface is the present-day erosion surface. It probably interdigitates with all post Middle Llandovery platform carbonate and carbonate buildup formations of the Washington Land Group in Washington Land,

Fig. 25. Lower part of section 14 (figs 17, 18; plate 1) showing the Lafayette Bugt Formation (a) overlain by the Wulff Land Formation (b). In the Lafayette Bugt Formation the white bands are resedimented conglomerates and note how they decrease in thickness and frequency upwards.

Fig. 26. Interbedded black mudstones and resedimented conglomerates in the base of section 14 (figs 17, 18; plate 1) of the Lafayette Bugt Formation in Wulff Land. Section height approximately 50 m.

and possibly Hall Land. In the field it has only been seen to interdigitate with the Hauge Bjerge, Pentamerus Bjerge and Kap Godfred Hansen Formations (fig. 19).

The lower boundary in Hall Land is in conformable contact with the top of the Upper Llandovery Offley Island Formation (fig. 19). It also interdigitates and is in conformable contact with the top of the Hauge Bjerge Formation. The lower boundary has not been observed in Nyeboe Land.

At the reference section in Wulff Land the base is not seen. It interdigitates with un-named carbonate buildups and probably platform carbonates of a general late Llandovery age. Towards the deep-water basin it probably interdigitates with the Wulff Land Formation, which in the reference section eventually overlies it.

Distribution. The Lafayette Bugt Formation is known from the western coastal regions of Washington Land between Kap Jefferson and Kap Godfred Hansen, and inland for approximately 5 to 10 km. In Hall Land it occurs in isolated pockets and patches in between and surrounding the carbonate buildup complex of the Hauge Bjerge Formation, trending in a west–east direction from Kap Tyson in western Hall Land to opposite Howgate Ø in Newman Bugt, eastern Hall Land. North of the Hauge Bjerge large tracts of central Hall Land may be underlain by the Lafayette Bugt Formation, but this cannot be determined due to lack of exposure.

The Lafayette Bugt Formation outcrop extends across Newman Bugt into Nyeboe Land where it is more continuous, forming a narrow belt striking west–east. It probably forms the bedrock of most of the low-lying area in the major west–east valley bounded to the south by Korsgaard Bjerg and Dreyer Firn and to the north by I. P. Ravn Højslette (plate 4).

In Warming Land and Permin Land the formation has not been seen, but it undoubtedly forms a narrow strip of low-lying ground immediately to the north of Daniel Bruun Firn in Warming Land, and eastwards to north of Kap Buttress, Permin Land (Koch, 1920). In Wulff Land the formation again occurs in a narrow strip bordering the northern edge of the carbonate platform rocks, from Solitary Cliffs in the west to north of Apollo Sø and on to the east coast (plate 4).

It is not known whether the Lafayette Bugt Formation extends into Nares Land or even western Freuchen Land. The formation does not occur in eastern Freuchen Land, Lauge Koch Land, Peary Land or Kronprins Christian Land. Thus, somewhere between Wulff Land and eastern Freuchen Land the Lafayette Bugt Formation wedges out.

Geological age. In Washington Land the base of the Lafayette Bugt Formation is diachronous between Middle and lower Upper Llandovery, and it extends into the Lower Ludlow (Hurst, 1980). In Hall Land all exposures examined belong to the Upper Llandovery or Lower Wenlock. The age of the formation in Nyeboe Land and Permin Land is unknown, but probably, in the main, Upper Llandovery. According to Koch (1920) graptolites were collected from the northern shore of Sankt George Fjord, but examination of his travels (Koch, 1940) indicates that the graptolites were most likely collected at Lerbugten and Graptolitsletten, on the north-west coast of Warming Land. These graptolites, *Stomatograptus grandis grandis, Monograptus turriculatus, Monograptus spiralis spiralis* and *Cyrtograptus sakmaricus* are from four different collections of undoubted Lafayette Bugt Formation. They indicate an age range for the Lafayette Bugt Formation in Warming Land of at least *turriculatus* Zone to *sakmaricus-laqueus* Zone, that is lower Upper Llandovery (C_{2-3} Fronian) to uppermost Llandovery (C_6 Telychian). This represents the widest age range of the formation outside Washington Land. In the reference section, Wulff Land, the formation ranges from Upper Llandovery to Lower Wenlock (Hurst & Peel, 1979).

Merqujôq Formation

new formation

History. The formation includes 'formation C' of Dawes & Soper (1979).

Name. After the island Merqujôq in the central part of J. P. Koch Fjord (fig. 7).

Type and reference sections. The type section (plate 1, section 1) on the eastern coast of Lauge Koch Land is directly opposite Merqujôq (figs 27, 28). Reference

Fig. 27. Geology of the area in central J. P. Koch Fjord (fig. 7) and around Merqujôq, the most southerly of the four islands. Amundsen Land Group (a), Merqujôq Formation (b), Thors Fjord Member of the Wulff Land Formation (c) and Lauge Koch Land Formation (d). Type section of the Merqujôq Formation (plate 1, section 1) in the cliff immediately west of Merqujôq (see fig. 28). Aerial photograph 874 F, no. 2295. Copyright Geodætisk Institut, Denmark. Cliff heights approximately 1000 m.

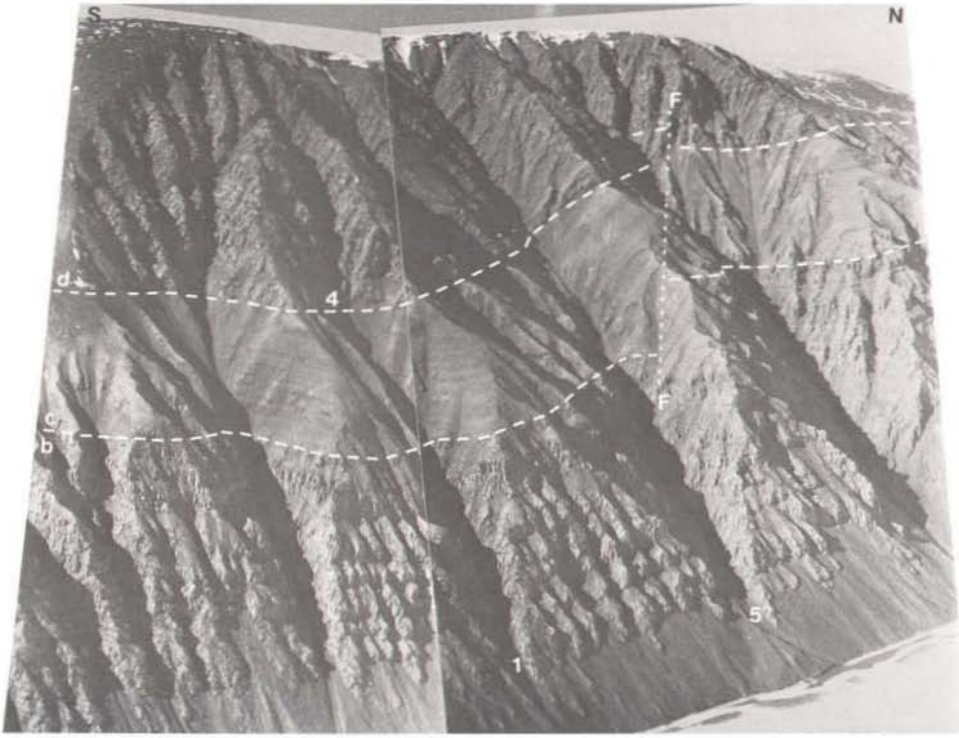


Fig. 28. Cliff immediately to the west of Merqujôq (fig. 27) showing the gully which is the location of the type section (plate 1, section 1) of the Merqujôq Formation (1). Sections 4 (plate 2, type section of the Lauge Koch Land Formation) and 5 (plate 1) are located. Both sections are on plates 1 & 2. Merqujôq Formation (b), Thors Fjord Member of the Wulff Land Formation (c) and Lauge Koch Land Formation (d). Letter keys are same as for fig. 27. F, fault. Cliff height approximately 1000 m. Note faulted southern limb of box fold.

sections are in O. B. Bøggild Fjord (fig. 29), Thors Fjord, Frederick E. Hyde Fjord and Citronens Fjord (plate 1, sections 1, 5, 10, 30, 35 and 37 and plate 3, sections 32 and 36; figs 30, 31, 32, 33, 34, 35, 36, 37).

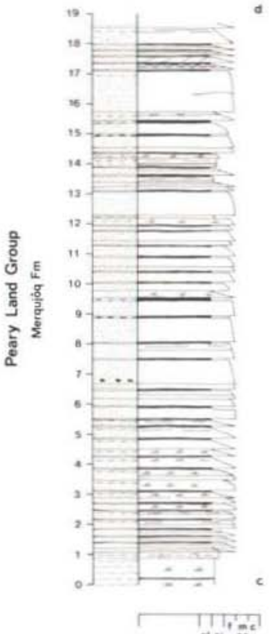
Thickness. There is no complete section through the formation, therefore an accurate estimate of the thickness is difficult (cf. plate 1, sections 1, 5, 10, 30, 35 and 37). Its maximum thickness is between J. P. Koch Fjord and Citronens Fjord where it is judged to be in the order of 500 m to 1 km thick. It is at least 500 m thick in eastern Freuchen Land and a similar thickness is probably present in Nares Land.

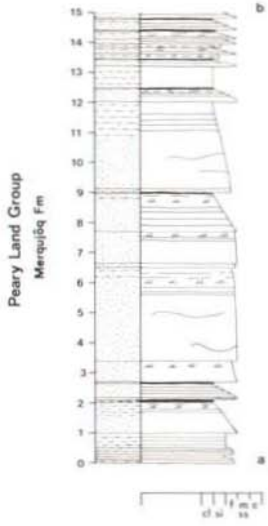
Lithology. The bulk of the formation is characterised by yellow to brown weathering siltstone and well-sorted quartz dominated sandstone turbidites of 'classical flysch' appearance. A high content of fine-grained carbonate matrix or cement is

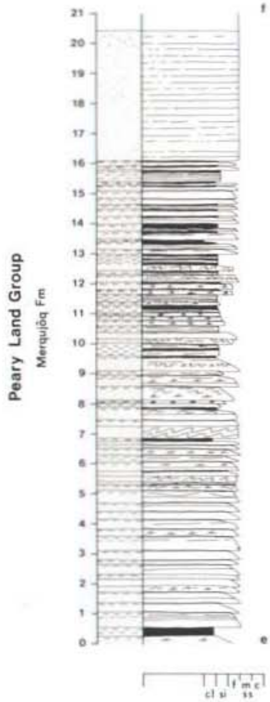
Fig. 29. Geology of the area around O. B. Bøggilds Fjord. Ordovician Amundsen Land Group (a) and the Merqujôq Formation (b). 10 is the location of section 10 through the basal part of the Merqujôq Formation shown on plate 1. Aerial photograph 874 D, no. 2819. Copyright Geodætisk Institut, Denmark. Maximum width of fjord 3 to 4 km.

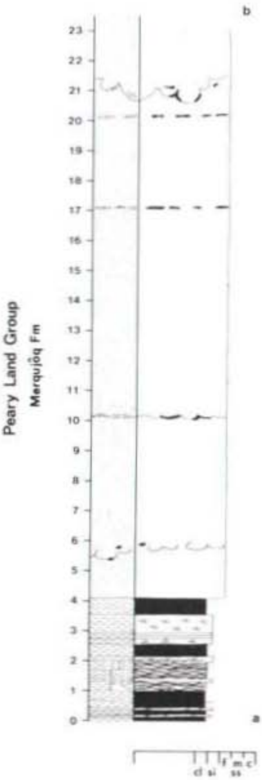
characteristic. The turbidite units occur in beds from a few centimetres to 10 m in thickness (figs 30, 37, 38, 39). Sandstone beds, particularly those over 1 m in thickness, are non-graded, amalgamated and mainly structureless, although scarce mudstone rip-up clasts, load casts and slumps occur (figs 31, 33, 36, 40, 41). Thinner sandstone and siltstone beds (5–100 cm) display a variety of typical 'Bouma sequence' characteristics with loaded and fluted soles together with a variety of other structures including chevron marks, grooves and prods (figs 42, 43, 44). Ta/c, Tbc and Ta-c sequences are most typical, with rarer Ta-e, Ta/e or Tb/e sandstone and siltstone turbidites (fig. 45). Fine siltstone and mudstone interbeds are rare (*c.* 1% of formation) and are normally accounted for by thin Te divisions.

Channels up to 50 m deep and several hundred metres wide occur in J. P. Koch Fjord (figs 46, 47, 48, 49, 50, 51, 52) and Thors Fjord (figs 53, 54, 55). They are typically filled with fine to medium-grained sandstone turbidites with loaded bases and numerous mudstone rip-up clasts (fig. 34). Thin slumped horizons are commonly associated with the channels. Mudstones (Te) are also more frequently associated with channels (fig. 34).









Top left

Fig. 30. Details of sediment log of the Merqujôq Formation from section 1 (plate 1, c–d) the type section (figs 27, 28).

Top middle

Fig. 31. Details of sediment log of the Merqujôq Formation from section 1 (plate 1, a–b) the type section (figs 27, 28).

Top right

Fig. 32. Details of sediment log of the Merqujôq Formation from section 1 (plate 1, e–f) the type section (figs 27, 28).

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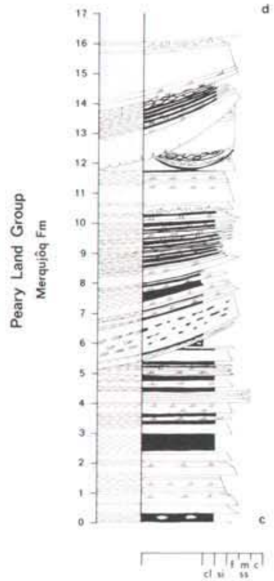
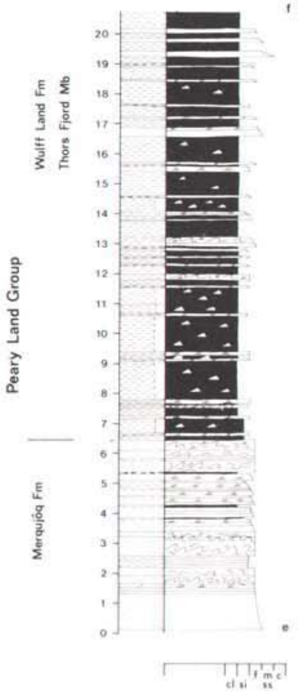
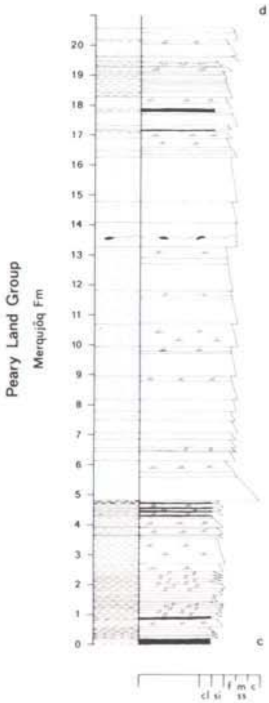
Fig. 33. Details of sediment log of the Merqujôq Formation from the reference section 32 in Thors Fjord (fig. 89; plate 3, a–b). Note thick, structureless and amalgamated fine sandstone turbidite beds.







Top left

Fig. 34. Details of sediment log of the Merqujôq Formation from the reference section 32 in Thors Fjord (fig. 89; plate 3, c–d). Note channelling.

Top middle

Fig. 35. Details of sediment log through the Merqujôq Formation – Thors Fjord Member (Wulff Land Formation) boundary. Section 32 (fig. 89; plate 3, e–f) is the reference section for the Merqujôq Formation and the type section for the Thors Fjord Member.

Top right

Fig. 36. Details of sediment log of the Merqujôq Formation from the reference section 37 in Esrum Elv (fig. 103; plate 1, c–d).

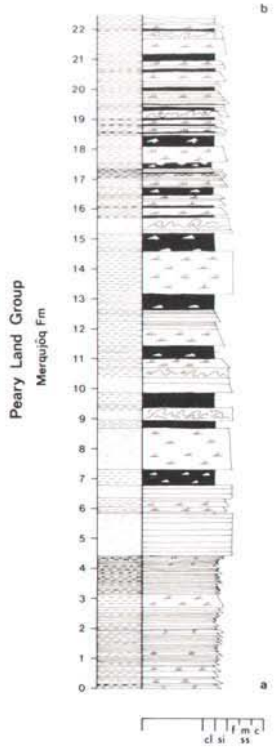


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Fig. 37. Details of sediment log of the Merqujôq Formation from the reference section 37 in Esrum Elv (fig. 103; plate 1, a–b).

Fig. 38. Typical outcrop pattern of thin-bedded turbidites of the Merqujôq Formation in the type section 1 (figs 27, 28, plate 1). The island Merqujôq is in the background.

Fig. 39. Thick amalgamated sandstone turbidites of the Merqujôq Formation in the type section 1 (figs 27, 28, plate 1). The island Merqujôq is in the background.

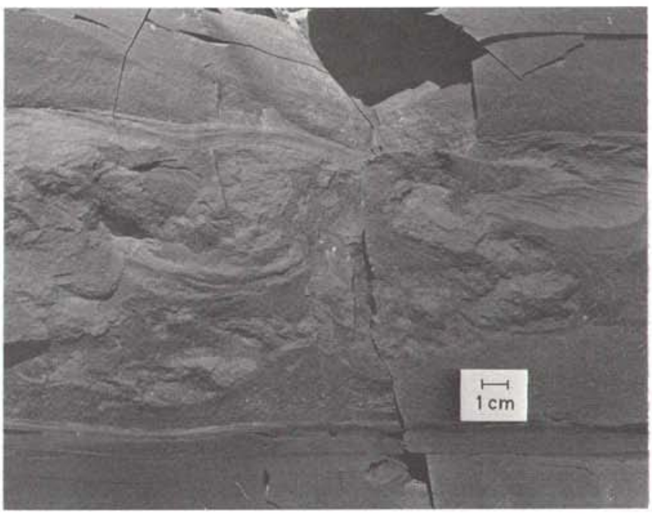


Fig. 40. Typical mudstone rip-up clasts in the Merqujôq Formation in the type section 1 (figs 27, 28, plate 1).

Fig. 41. Enormous, mainly structureless, non-graded, amalgamated fine sandstone turbidites in section 32 at Thors Fjord (fig. 89; plate 3).

In the lower half of the formation between Citronens Fjord and Thors Fjord, on the south coast of Frederick E. Hyde Fjord, the formation is characterised by thick (*c.* 1–15 m) resedimented limestone boulder conglomerates assigned to the Citronens Fjord Member (fig. 11). The conglomerates are often non-graded, structureless and disorganised, but rarely reverse grading occurs and more commonly sub-horizontal or wavy clast orientation. The conglomerates are composed of mat-

Fig. 42. Loaded flutes from the Merqujôq Formation in reference section 5 (figs 27, 28, plate 1).

Fig. 43. Poorly developed L-ridge moulds with superimposed scaly surface and poorly developed loaded flutes from the Merqujôq Formation in the type section 1 (figs 27, 28, plate 1). Scale bar 1 cm.

erial derived from the southerly carbonate platform. Interbedded with the conglomerates are thick (*c.* 1–2 m) mudstone units with abundant starved ripples, thin siltstone Tde turbidites and rare Tc/e division fine-grained sandstone turbidites. The upper half of the Merqujôq Formation contains one unit of resedimented limestone conglomerate assigned to the Freja Fjord Member, which varies from 5 to 10 m in thickness.

Depositional environment. The formation is composed of thick sequences of basin plain turbidites which pass upwards, in a rather irregular way, into fan fringe and outer fan lobe deposits. The top parts of the formation represent a braided midfan environment. Turbidite deposition was punctuated along the southern basin margin by deposition of thick resedimented carbonate conglomerates of the Citronens Fjord Member. The conglomerates formed topographic highs on the basin floor and they are characteristically overlain by thin-bedded, fine-grained mudstone and siltstone turbidite sequences formed by overflow of dilute turbidity currents.

In the lower part of the formation, in the O. B. Bøggild Fjord region, the basinal turbidites show lateral interfingering with silty mudstones of the southern slope.

Boundaries. The Merqujôq Formation rests conformably on Ordovician black mudstones and cherts of the Amundsen Land Group (Friderichsen *et al.*, 1982) north of the O. B. Bøggild Fjord-Nordpasset axis (fig. 29). This is the only place in Peary Land where the lower boundary of the formation is observed on top of the

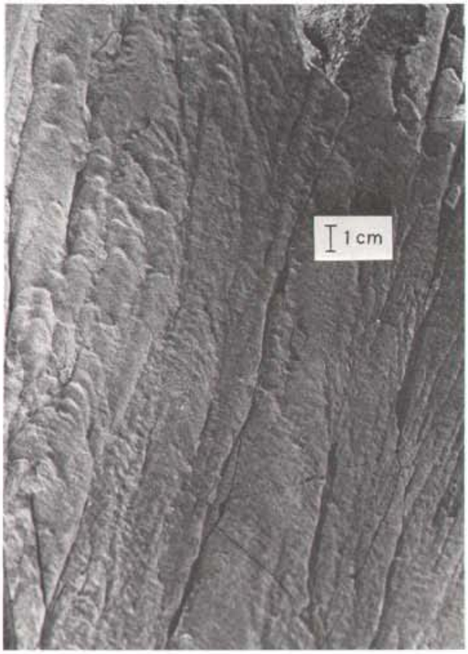


Fig. 44. Rill marks with poorly developed frondescent markings from the Merqujôq Formation in the type section 1 (figs 27, 28, plate 1).

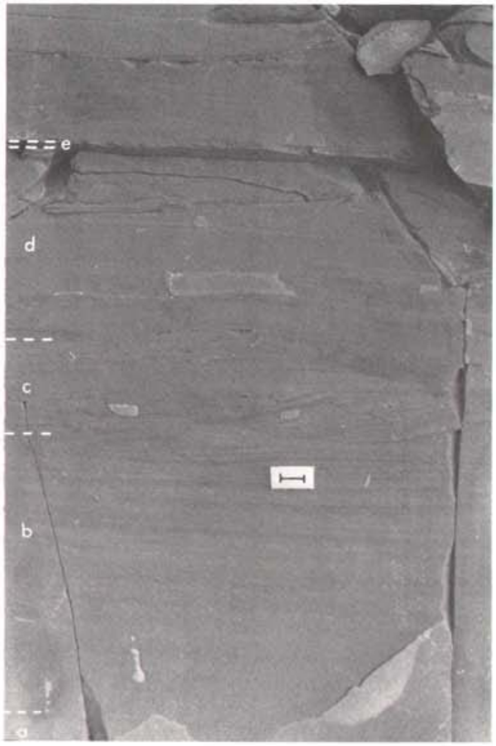


Fig. 45. Ta–e turbidite from the Merqujôq Formation in the type section 1 (figs 27, 28, plate 1).

Amundsen Land Group. In practice the boundary is easy to locate as primarily recessive black mudstones, cherts and resedimented conglomerates of the Amundsen Land Group give way to buff-yellow turbidites, but in detail the boundary is often covered by scree, and the lower part of the Merqujôq Formation often comprises dark silty mudstone interbeds (fig. 56). In such terrain the lack of primary chert beds and chert pebble conglomerates at the appropriate level may be an indicator of the Merqujôq Formation. The lower boundary to the formation can be traced through Lauge Koch Land, Freuchen Land, Nares Land and possibly northernmost Wulff Land. To the south in Freuchen Land a very thin sequence of Merqujôq Formation (*c.* 20 m) possibly overlaps conformably onto lower Palaeozoic platform carbonates (fig. 57). In northernmost Wulff Land the transition from sediments comparable to those of the Amundsen Land Group of Friderichsen *et al.* (1982) to the Merqujôq Formation is abrupt from resedimented conglomerates to thick-bedded structureless fine sandstone turbidites.

The upper boundary is placed where the dominantly buff-yellow sandstone turbidites of the formation are overlain by dominantly black or dark grey mudstone

Fig. 46. Channels in Merqujôq Formation from reference section 5 (figs 27, 28, plate 1). Cliff height approximately 30 m.

sediments of the Thors Fjord Member of the Wulff Land Formation (fig. 35). In the environs of Esrum Elv, south of Citronens Fjord, it is conformably overlain by the Lauge Koch Land Formation (for details see Lauge Koch Land Formation).

Distribution. The formation occurs from Peary Land to possibly northernmost Wulff Land (fig. 11; plate 4). It is not known in Kronprins Christian Land or west of Wulff Land. North of O. B. Bøggild Fjord and Nordpasset in Peary Land it occurs in imbricate thrust sheets (Friderichsen *et al.,* 1982). The formation forms

Fig. 47. Base of channel (dotted) in Merqujôq Formation from reference section 5 (figs 27, 28, plate 1).

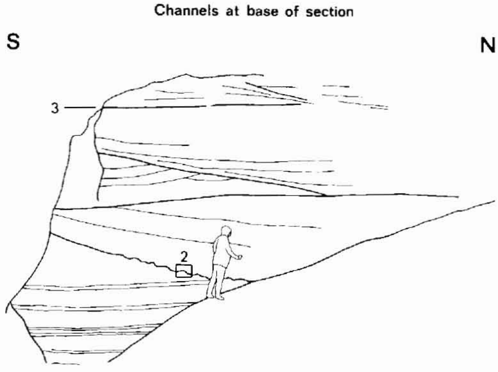


Fig. 48. Field sketch of channelling in base of reference section 5 (figs 27, 28, plate 1) of the Merqujôq Formation. Numbers 2 and 3 refer to figs 49 and 50 respectively.

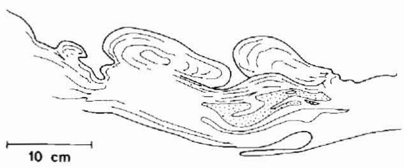


Fig. 49. Details of one of channel bases in fig. 48 (number 2).

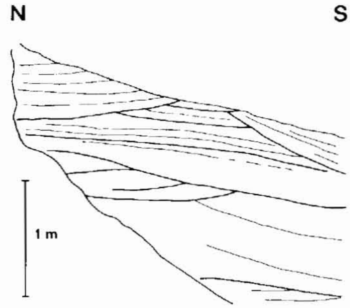


Fig. 50. Details of one of channel tops in fig. 48 (number 3).

the coastal cliff sections on the south side of Frederick E. Hyde Fjord between Citronens Fjord and Odins Fjord, as well as the lower parts of the cliffs in Adolf Jensen Fjord and the central part of J. P. Koch Fjord and Navarana Fjord (fig. 11). Its precise distribution on Nares Land is not known, and the most westerly occurrence of the formation known to date is possibly in northernmost Wulff Land.

Geological age. In the environs of O. B. Bøggild Fjord the graptolites *Climacograptus miserablis* and *Orthograptus* sp. resembling *O. quadrimucronatus,* indicating the Upper Ordovician (Cincinnatian: Eden to Maysville), have been obtained from the top of the Amundsen Land Group some 20 m below the base of the Merqujôq Formation. Thus the base of the Merqujôq Formation in this area is likely to be as old as Cincinnatian (Maysville or Richmond). No other details concerning the base

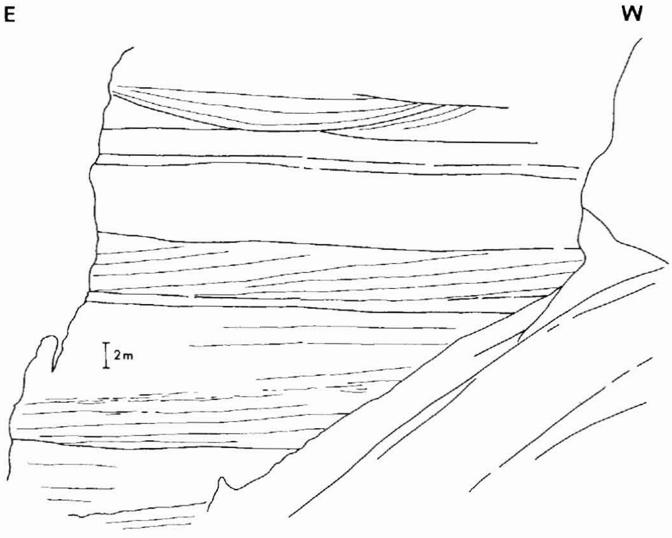


Fig. 51. Sketch of channels in cliff opposite reference section 5 in the Merqujôq Formation (figs 27, 28, plate 1).

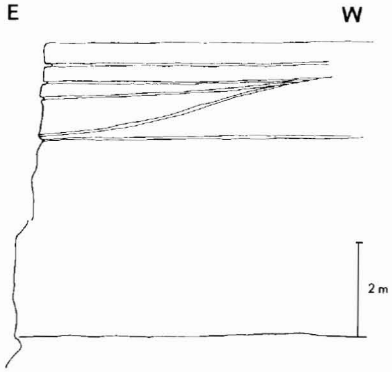


Fig. 52. Small-scale channelling 105 m from the base of reference section 5 in the Merqujôq Formation (figs 27, 28, plate 1).

of the formation are known, but further investigations will probably show the lower boundary to be diachronous, in the Upper Ordovician to Lower Silurian range.

Rare scattered graptolites from near the top of the formation from many localities in Peary Land include *Retiolites geinitzianus angustidens, Stomatograptus grandis grandis* and *Monograptus priodon.* These indicate the Upper Llandovery *spiralis* Zone (Telychian). As the overlying Thors Fjord Member of the Wulff Land Formation falls within the Upper Llandovery to Lower Wenlock interval (see later), then the top of the Merqujôq Formation is apparently not diachronous in the Peary Land area, at least within the resolution of one graptolite zone (*spiralis* Zone). However, as the *spiralis* Zone is greatly expanded in the Arctic regions (cf. Jackson, 1978), it is of restricted use in precisely determining diachronism of formation boundaries.

Fig. 53. Large-scale channelling in the top part of the Merqujôq Formation (reference section 32, plate 3) in Thors Fjord (fig. 89).

The age span of the Merqujôq Formation is thus uppermost Cincinnatian (Maysville-Richmond) to uppermost Llandovery (Telychian).

Subdivisions. Two distinct units of the Merqujôq Formation have been defined as members. The lower Citronens Fjord Member covers a unit dominated by resedimented carbonate conglomerates with interbedded mudstone and siltstone turbidites, and the upper Freja Fjord Member covers a restricted resedimented carbonate conglomerate unit. The enveloping mainly sandstone turbidite sequences have not been recognised as members.

Citronens Fjord Member

new member

History. This new member corresponds to the 'limestone breccio-conglomerates' of 'formation C' (Dawes & Soper, 1979, p. 25) and includes the 'coarse clastic limestone-conglomerate' reported by Pedersen (1980, p. 82) in the region to the north of Nordpasset.

Name. After the small fjord in Peary Land, aligned north–south along the southern coast of Frederick E. Hyde Fjord (fig. 7).

Type and reference section. The type section is at the southern end of Citronens Fjord (figs 58, 59; plate 1, section 33), and reference sections are located on the south coast of Frederick E. Hyde Fjord (figs 60, 61; plate 3, section 36) midway between Thors Fjord and Freja Fjord.

Fig. 54. Oblique view of stacked channels (dotted) in the top part of the Merqujôq Formation (reference section 32, plate 3) in Thors Fjord (fig. 89). Cliff height approximately 50 m.

Thickness. Between 10 and 200 m.

Lithology. Huge conglomerates composed of angular to rounded blocks derived from the Lower Palaeozoic southern carbonate platform sequences characterise

Fig. 55. Close up of lower channel in fig. 54 showing pinching and cutting out of infilling beds.

Fig. 56. Merqujôq Formation (b) overlying black mudstones and resedimented conglomerates (white bands) of the Ordovician Amundsen Land Group. In northern Lauge Koch Land (fig. 1; plate 4). Cliff height approximately 500 m.

the member (fig. 61). The conglomerate beds range in thickness from 50 cm to around 50 m. The thinner units are mainly composed of coarse pebble size clasts (fig. 62), but the thicker beds are of boulder size clasts, and blocks up to 2 m in

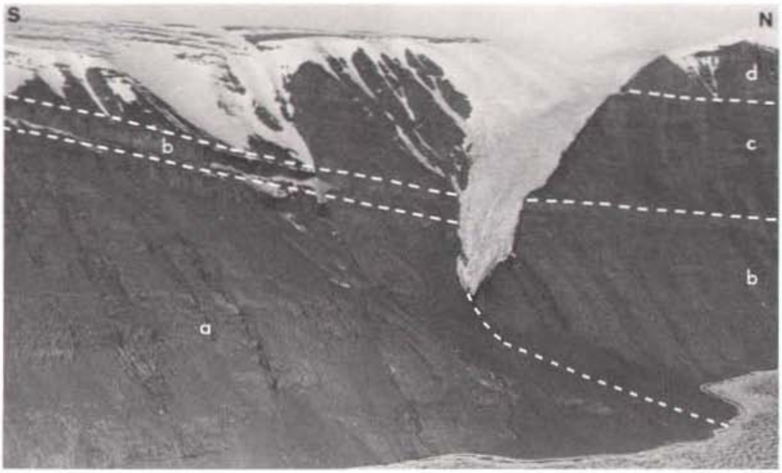


Fig. 57. Probable Ordovician and Silurian platform carbonates (a) possibly overlain by thin Merqujôq Formation (b). These beds have not been inspected on the ground. The thin bed overlying the platform carbonates may be a resedimented conglomerate. Thors Fjord Member of the Wulff Land Formation (c) and Lauge Koch Land Formation (d). West side of Navarana Fjord (plate 4). Cliff height approximately 1000 m.

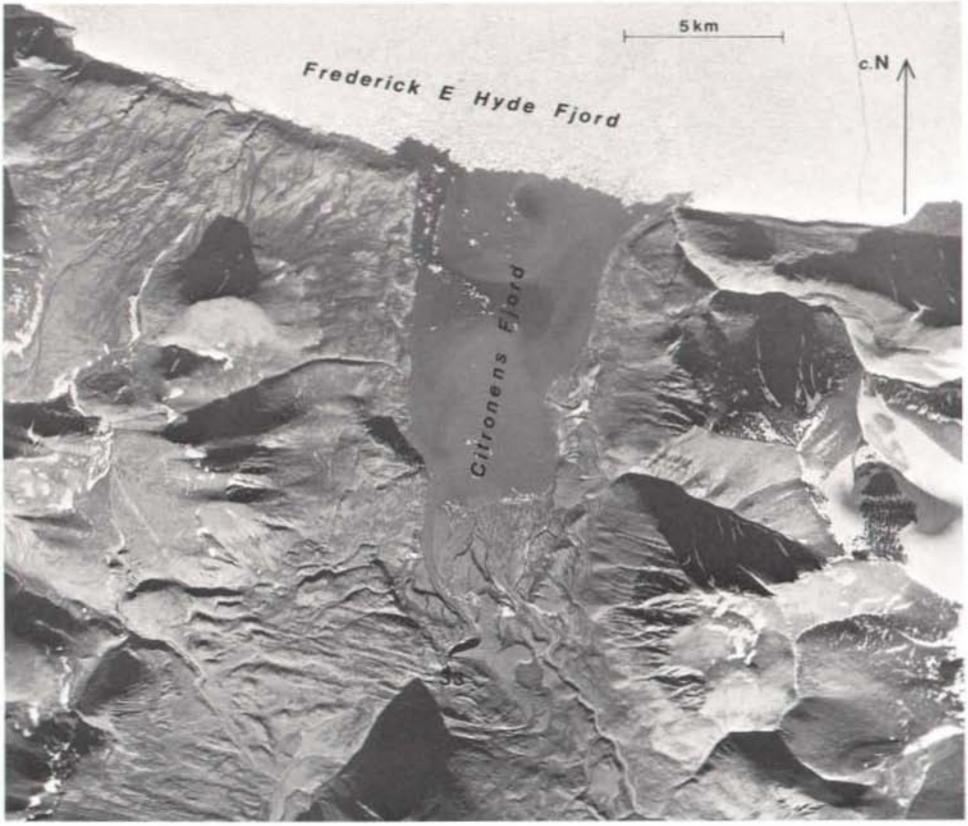


Fig. 58. Geology of the area around Citronens Fjord. The ridges immediately to the south of the fjord are formed by conglomerate beds. 33 is the location of the type section 33 of the Citronens Fjord Member (fig. 59; plate 1). The hills around are of deformed sandstone turbidites of the Merqujôq Formation. Aerial photograph 255 J, no. 732. Copyright Geodætisk Institut, Denmark. Width of fjord mouth 3 to 4 km.

length are common (figs 63, 64). Some of the very thin beds are weakly graded, but the thick conglomerates are typically non-graded and disorganised. Interbedded are thick fine-grained mudstone units (*c.* 1–2 m) with starved ripples and thin (*c.* 5–10 cm) siltstone Tc/e and Tde turbidites (figs 65, 66). Rarely wavy-bedded sequences occur. As defined here the member is a sequence of thick resedimented limestone conglomerate units, interbedded with thin-bedded mudstone and siltstone turbidite units.

Depositional environment. The conglomerates, which are restricted to the southern margin of the basin, represent base-of-slope debris flow deposits derived from the carbonate platform to the south. They compare closely with the debris sheets

Fig. 59. View of the type locality of the Citronens Fjord Member (fig. 58) showing typical outcrop pattern of conglomerate ridges of the type section 33 (plate 1) for the member. Width of river approximately 10 to 25 m.

described by Crevello & Schlager (1980) from the Exuma Sound of the Bahamas. The overlying thin-bedded mudstones and siltstone turbidites were deposited by overflow by dilute turbidity currents draping the topographic highs formed by the thick conglomerate beds.

Boundaries. The lower boundary is taken at the incoming of the first redeposited limestone conglomerate bed. This boundary is thought to be exposed in both the type and reference sections (plate 1, section 33; plate 3, section 36). However, it cannot be ruled out that in both sections lower unexposed conglomerate beds do occur. The upper boundary is taken at the top of the last limestone conglomerate, and this is exposed in the reference section midway between Thors Fjord and Freja Fjord on the south coast of Frederick E. Hyde Fjord (fig. 61). In the type section folding has obscured the upper boundary. The upper and lower boundaries of the single conglomerate bed to the north of Nordpasset also constitute the member boundaries in this area.

Distribution. Along the south coast of Frederick E. Hyde Fjord, between Thors Fjord and Citronens Fjord, the member is well-exposed and contains three main

Fig. 60. Geology of the area around central Frederick E. Hyde Fjord with Thors Fjord in the middle distance (fig. 7). 36 is the location of reference section 36 for the Citronens Fjord Member (plate 3). The ridge topography in the reference section and at 'a' is formed by conglomerate bands of the Citronens Fjord Member. Merqujôq Formation (b). Aerial photograph 548 F–V, no. 10175. Copyright Geodætisk Institut, Denmark. Width of fjord in foreground approximately 5 km.

limestone conglomerate beds. The conglomerates thin quickly northwards away from the carbonate platform. In the area to the north of Nordpasset (fig. 7) Pedersen (1980) reports a single 10 m thick resedimented limestone conglomerate bed approximately 100 m above the base of the Merqujôq Formation. This conglomerate is considered the northerly distal fringe of one of the three main conglomerates to the south and illustrates the rapid northerly wedging of the member. It is likely that the member wedges out completely not far north of Nordpasset.

Geological age. In the reference section (plate 3, section 36), a single graptolite *Monograptus* aff. *M. anguinuus* from 30 m below the top of the member indicates the Upper Llandovery *spiralis* Zone.

We have found no other age diagnostic fossils in the member. However,

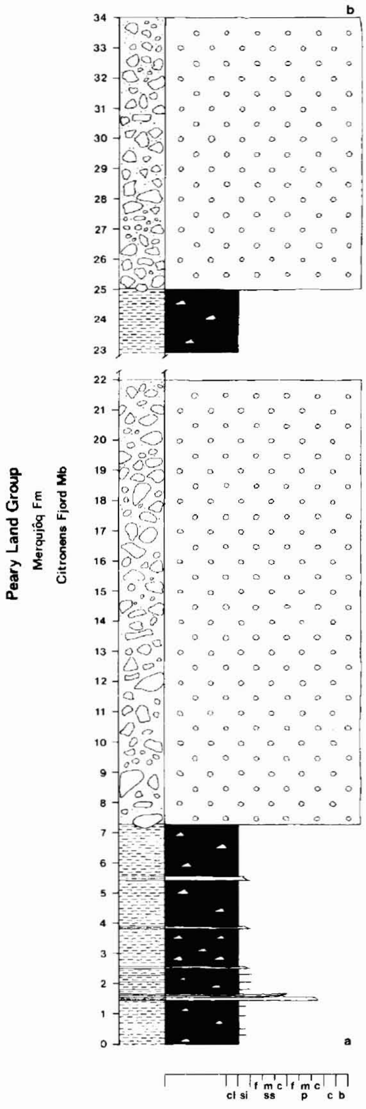


Fig. 61. Detailed sediment log of the reference section 36 (plate 3, a–b) of the Citronens Fjord Member. Location shown in fig. 60. Note a third conglomerate bed occurs above the top of this section and has not been included on the log.

Dawes (1976, p. 275) reports that Greenarctic Consortium found *Monograptus* cf. *M. concinnus, Monograptus convolutus, Monograptus leptotheca, Monograptus* cf. *M. pandus* and *Monograptus sedgwickii* from argillaceous limestones and shales in Peary Land. They indicate the *convolutus* Zone (probably the uppermost part) of the Middle Llandovery. These graptolites are most likely derived from the Citronens Fjord Member, which is the only stratigraphic division which could correspond to the rock description.

Fig. 62. Coarse pebble limestone conglomerate from the type section 33 (plate 1) of the Citronens Fjord Member. Location shown in figs 58, 59.

As the Citronens Fjord Member occurs in the lower part of the Merqujôq Formation (in the Nordpasset area approximately 100 m above the base according to Pedersen, 1980) whose upper part also belongs to the *spiralis* Zone, this suggests that the Citronens Fjord Member occurs in the lower part of the Upper Llandovery *spiralis* Zone and possibly extends down into the Middle Llandovery *convolutus* Zone.

Faunas collected from the limestone clasts in the conglomerates indicate an age span of resedimented material from Upper Ordovician to Lower Silurian (Bjerre-

Fig. 63. Boulder limestone conglomerate from the type section 33 (plate 1) of the Citronens Fjord Member. Location shown in figs 58, 59.

Fig. 64. Boulder limestone conglomerate from reference section 36 of the Citronens Fjord Member (fig. 60; plate 3).

skov & Poulsen, 1973; Hurst, personal observations; Peel, personal communication, 1981).

Freja Fjord Member

new member

History. This member was originally mapped by Pedersen (1979, fig. 20) as 'limestone conglomerate'.

Name. After Freja Fjord in the central part of Frederick E. Hyde Fjord (fig. 7).

Type section. The type section is in the first main river valley to the west of Freja Fjord (figs 67, 68; plate 1, section 35).

Thickness. Mainly between 5 and 10 m (fig. 69).

Lithology. Thick conglomerate bed composed of angular to rounded blocks derived from the Lower Palaeozoic carbonate platform sequences. The blocks occasionally reach a size of 10 m where they comprise the whole bed, but blocks of 50 cm to 1 m are more common (fig. 70). It is non-graded and in many places disorganised, but occasionally a subhorizontal orientation of clasts is approached (fig. 69). Pedersen (1979) mapped two conglomerate beds in one localised area west of Freja Fjord (fig. 70). Each bed is approximately 3 m thick and they are

Fig. 65. Thick mudstone units with starved ripples and thin silty turbidites interbedded with the limestone conglomerates of the Citronens Fjord Member in the type section 33 (figs 58, 59, plate 1).

separated by thin turbiditic calcarenites (*c.* 20 cm thick) and terrigenous clastic turbidites.

Depositional environment. Base-of-slope conglomerates transported as debris flows from the southern carbonate platform.

Boundaries. The lower and upper boundary of the member is taken at the base and

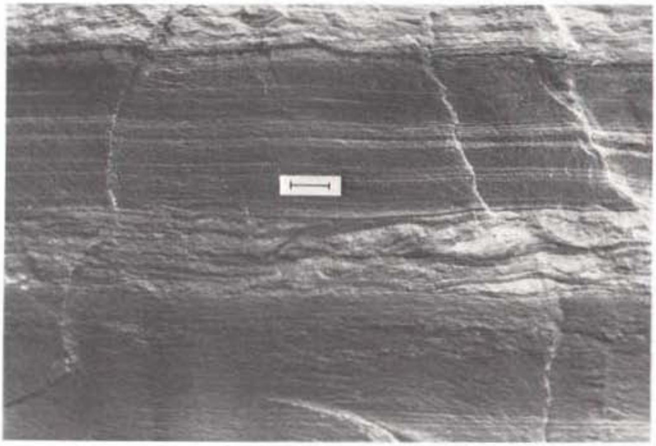


Fig. 66. Close up of starved ripples and silty Td turbidites in the Citronens Fjord Member in the type section 33 (figs 58, 59, plate 1). Scale bar is 1 cm.

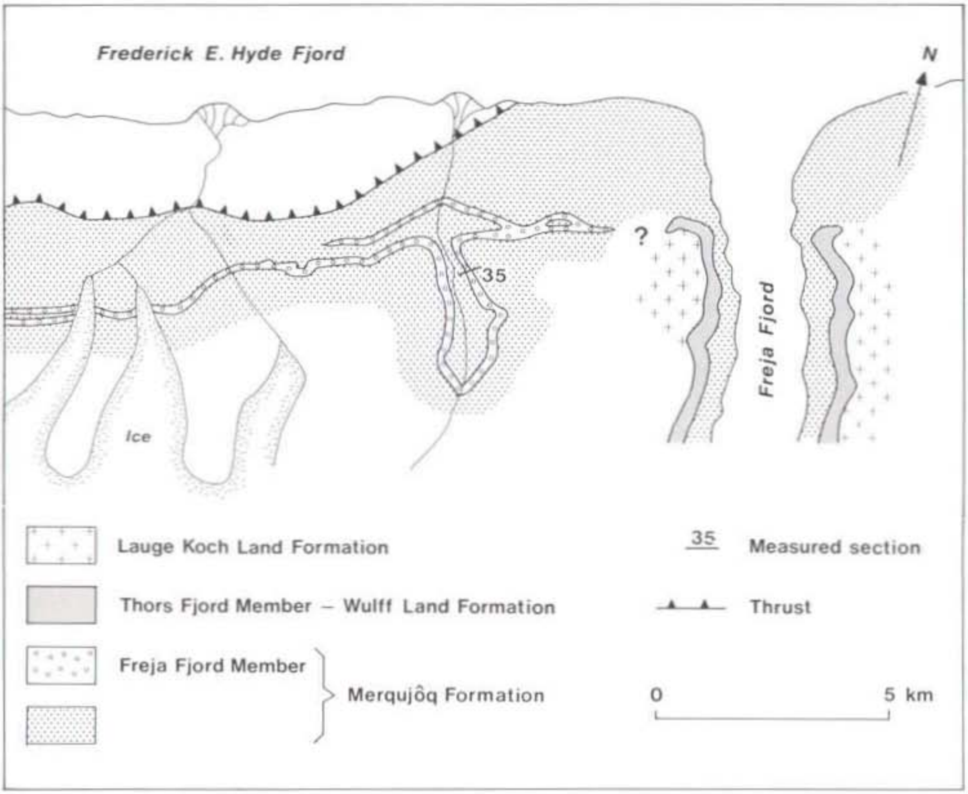


Fig. 67. Geological map of area around Freja Fjord, modified from Pedersen (1979), showing the distribution of the Freja Fjord Member and the position of the type section 35 (plate 1). For location see fig. 11.

top of the conglomerates respectively. Both are exposed in the hills and valleys for up to 10 km west of Freja Fjord.

Fig. 68. Location of the type section of the Freja Fjord Member (plate 1, section 35). Distinct cliff forming ledge is the Freja Fjord Member which is approximately 6 m thick.

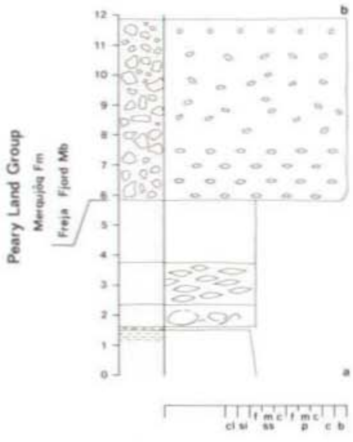


Fig. 69. Detailed sediment log of the Freja Fjord Member in the type section 35 (figs 67, 68; plate 1).

Distribution. Only known from the area around the mouth of Freja Fjord.

Geological age. The member is bracketed by sediments which contain fossils indicative of the Upper Llandovery *spiralis* Zone. Faunas collected from the limestone clasts in the conglomerate indicate that the resedimented material is derived from Llandovery carbonates. Considering the general stratigraphic relationship of the Freja Fjord Member to the Citronens Fjord Member and within the Merqujôq Formation, it is likely that the Freja Fjord Member was deposited in the uppermost part of the Merqujôq Formation and thus in the upper part of the Upper Llandovery *spiralis* Zone.

Comments. The conglomerates assigned to the Freja Fjord Member are very similar to the conglomerates of the Citronens Fjord Member, but the two members are differentiated for the following reasons:

1) Whilst the age range of both members is contained partly or wholly within the Upper Llandovery *spiralis* Zone it cannot be conclusively shown that the two members are contemporaneous, as the *spiralis* Zone is of long duration and it is not yet possible to subdivide it. Indeed regional stratigraphic relations suggest that the Freja Fjord Member is slightly younger than the Citronens Fjord Member. According to Pedersen (1980) the Citronens Fjord Member starts approximately 100 m above the base of the Merqujôq Formation in the Nordpasset area, whereas the Freja Fjord Member occurs many hundreds of metres above the base of the formation.
2) The Freja Fjord Member outcrops to the south of the Citronens Fjord Member and thus nearer the base-of-slope of the carbonate platform. In such a direction, if the Freja Fjord Member was a lateral equivalent of one of the three thick

Fig. 70. Boulder limestone conglomerate, typical of the Freja Fjord Member in the type section 35 (figs 67, 68; plate 1, a–b).

conglomerate beds of the Citronens Fjord Member, it should be thicker and contain coarser clasts. This is not the case as the Freja Fjord Member conglomerates are thinner and generally contain finer clasts. They also have an organised fabric in many places as opposed to the totally disorganised nature of the Citronens Fjord Member conglomerates.

3) The Freja Fjord Member consists of one or two isolated conglomerates apparently not associated with other thinner conglomerates as in the Citronens Fjord Member.
4) The turbidites associated with the Freja Fjord Member are 'classical flysch' sandstone turbidites. In contrast the turbidites enveloping the conglomerates in the Citronens Fjord Member are of fine-grained siltstone and mudstone grade.

All available evidence suggests that the Freja Fjord Member is an isolated conglomerate separate from the conglomerates of the Citronens Fjord Member. If later work indicates the contemporaneity of the two members, we suggest the Freja Fjord Member is abandoned and the type section made a reference section of the Citronens Fjord Member.

Wulff Land Formation

new formation

History. The formation includes the 'Silurian siltstone formation' (including members A, B and C) of Hurst & Peel (1979) and the 'Un-named Silurian black shale formation' of Christie & Peel (1977). In part it corresponds to the 'Polaris Harbour Formation' of Koch (1929).

Name. After Wulff Land, the large land area in central North Greenland (fig. 1).

Type and reference sections. The type section is in central Wulff Land at the northern end of Apollo Sø (figs 17, 71; plate 1, section 14; plate 4). Reference sections

Fig. 71. Location of section 14 (measured 1978; fig. 17), the type section for the Wulff Land Formation (plate 1). Lafayette Bugt Formation (a), Wulff Land Formation (b). Cliff height to left approximately 1000 m above the valley bottom.

occur in western Nyeboe Land (type section for the Repulse Havn Member, plate 2, section 22) and Thors Fjord, Peary Land (type section for the Thors Fjord Member, plate 2, sections 19 and 22; plate 3, sections 23 and 32).

Thickness. Between 12 and 300 m measured (plate 1, section 14; plate 2, sections 19 and 22; plate 3, sections 23 and 32), but possibly as great as 500 m in central Nyeboe Land.

Lithology (for details see member descriptions). The formation is dominated by black mudstones and includes subordinate fine black or green siltstones and rare thin beds of fine-grained sandstones (fig. 72). The black mudstone units (1 to 5 m) are often laminated and contain numerous starved ripples. Thin concretion horizons (*c.* 10–30 cm) and thin slumped beds are common. The siltstone units are up to 20 m thick and consist of thin-bedded siltstone turbidites (*c.* 1–5 cm thick) of Tc/e and more commonly Tde divisions against a background of bioturbated and laminated silty mud (fig. 73). The thin sandstone turbidite beds (*c.* 5–100 cm thick) occur sporadically or in packets and consist of graded or non-graded well-sorted fine-grained sand, either structureless or with well-developed 'Bouma sequences', normally Tab/e, Tbc/e or Ta-c/e. Convoluted and slumped horizons are common.

Depositional environment. The Wulff Land Formation includes mudstones of the lower slope and southern basin plain margin. In the distal western part of the basin

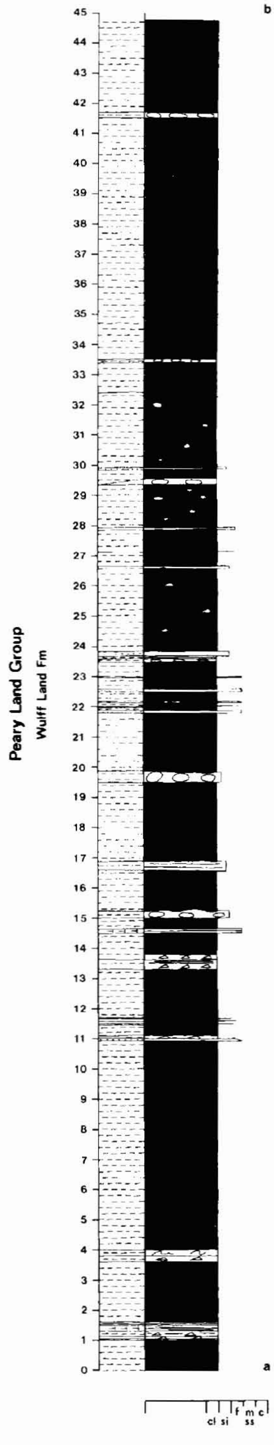


Fig. 72. Detailed sediment log illustrating the typical characteristics of the Wulff Land Formation in the reference section 23 (plate 3, a–b) in eastern Nyeboe Land (fig. 77).

Fig. 73. Typical outcrop pattern of the mudstones and siltstones assigned to the Wulff Land Formation. Section 23 (plate 3; fig. 77).

the two environments merge imperceptibly into each other, and thicker mudstone sequences with common thin fine-grained siltstone and rarer sandstone turbidites represent the confluence of the lower slope and distal basin plain environment. Stratigraphically, the start of the formation reflects an episode of platform collapse, and it accordingly reaches much further to the south than the underlying Merqujôq Formation and directly overlies platform carbonates. It thus represents a transgressive period when the main sand sources in deltas and other coastal areas were drowned, resulting in basin starvation (fig. 2).

Boundaries (fig. 11; plate 4). The lower boundary of the Wulff Land Formation in Wulff Land, Nyeboe Land and Warming Land is placed where the black mudstones and resedimented carbonate conglomerates of the Lafayette Bugt Formation are succeeded by siltstones and mudstones of a more turbiditic aspect lacking resedimented carbonate conglomerates (plate 1, section 14). The colour difference between the Wulff Land Formation and the Lafayette Bugt Formation is slight, but the absence of light-coloured limestone conglomerates in the former is notable. In Freuchen Land, Lauge Koch Land and Peary Land between Thors Fjord and Freja Fjord the lower boundary of the formation is placed at the base of the first thick packet of black mudstone with starved ripples which overlies the buff-yellow fine sandstone turbidites of the Merqujôq Formation (fig. 35). In Peary Land, south of Frederick E. Hyde Fjord and east of Odins Fjord as well as in the G. B. Schley Fjord region, the Wulff Land Formation rests conformably on black limestone of

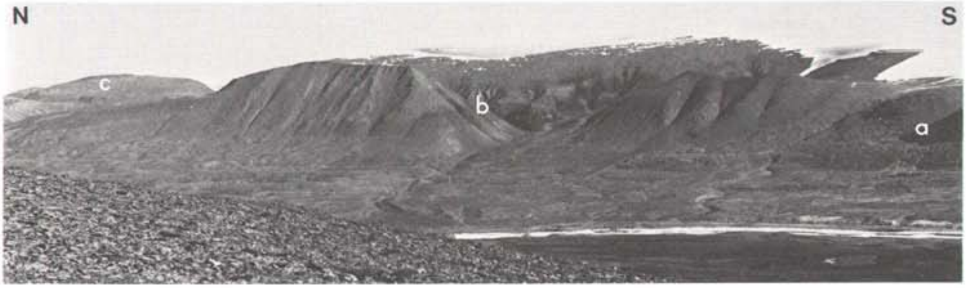


Fig. 74. Central Wulff Land opposite the type section for the Wulff Land Formation (plate 1, section 14), showing large expanse of Wulff Land Formation (b) north of platform carbonates and carbonate buildups (a) and overlain by Lauge Koch Land Formation (c). Cliff height approximately 1200 m.

the 'Un-named Silurian limestone formation' and rests on, as well as interdigitates with, Silurian carbonate mounds.

From Nyeboe Land to Peary Land the upper boundary of the Wulff Land Formation is placed at the top of the last black mudstone or siltstone turbidite packet which is overlain by buff-yellow fine sandstone turbidites of the Lauge Koch Land Formation.

Distribution. The formation is one of the most widespread in North Greenland, occurring from Peary Land to Hall Land (fig. 11; plate 4). In Peary Land it underlies and fringes the main turbidite outcrop of the Lauge Koch Land Formation. West of J. P. Koch Fjord into Nyeboe Land, where the formation increases substantially in thickness, and the outcrop width also increases, it underlies and forms a broad southern fringe to the Lauge Koch Land Formation (figs 74, 75, 76, 77). In northern Nyeboe Land and Hall Land, the Wulff Land Formation interdigitates with the Lauge Koch Land Formation (fig. 78).

Fig. 75. Western coast of Wulff Land showing thick pile of Wulff Land Formation covering platform carbonates which can be seen in the base of the gullies. Cliff height approximately 500 m.

Fig. 76. Outcrop pattern of Wulff Land Formation in eastern Nyeboe Land. Reference section 23 (fig. 72, plate 3) measured in gully area to west. Height of cliffs approximately 500 m.

Geological age. In the type section the base of the Wulff Land Formation is Lower Wenlock (Hurst & Peel, 1979). Some 130 m from the top of the formation graptolites indicate a Lower Ludlow horizon. Clearly, the top half of the formation post-dates the Lower Ludlow, but its precise age is not known (Hurst & Peel, 1979).

From Lauge Koch Land through to eastern Peary Land numerous graptolite collections derive from the base of the Wulff Land Formation. They indicate (for details see section on Thors Fjord Member) that the whole of the formation in north Peary Land is in the *spiralis* or *sakmaricus-laqueus* Zones of the uppermost Llandovery. In the south the base of the formation is in the very top of the *spiralis* Zone or *sakmaricus-laqueus* Zone and the formation extends into the Middle Wenlock *flexilis* or *linnarssoni* Zone.

In northern Hendrik Ø and northern Nyeboe Land an interdigitative wedge of the Wulff Land Formation (for details see section on Repulse Havn Member) contains *bohemicus* Zone graptolites of the Lower Ludlow. In northern Hall Land interdigitating wedges of the Wulff Land Formation contain few graptolites (*Monoclimacis vomerina, Pristiograptus* aff. *P. dubius, Monograptus priodon*) indicating an Upper Llandovery to Lower Wenlock interval for some of the lower wedges (fig. 2).

To summarise, the base of the Wulff Land Formation between Wulff Land and Peary Land is diachronous from Upper Llandovery in the east to Lower Wenlock in the west. All evidence indicates that the base of the formation is synchronous from west to east between Lauge Koch Land and Freja Fjord in Peary Land, but weakly diachronous north to south, younging to the south. Similarly, the top

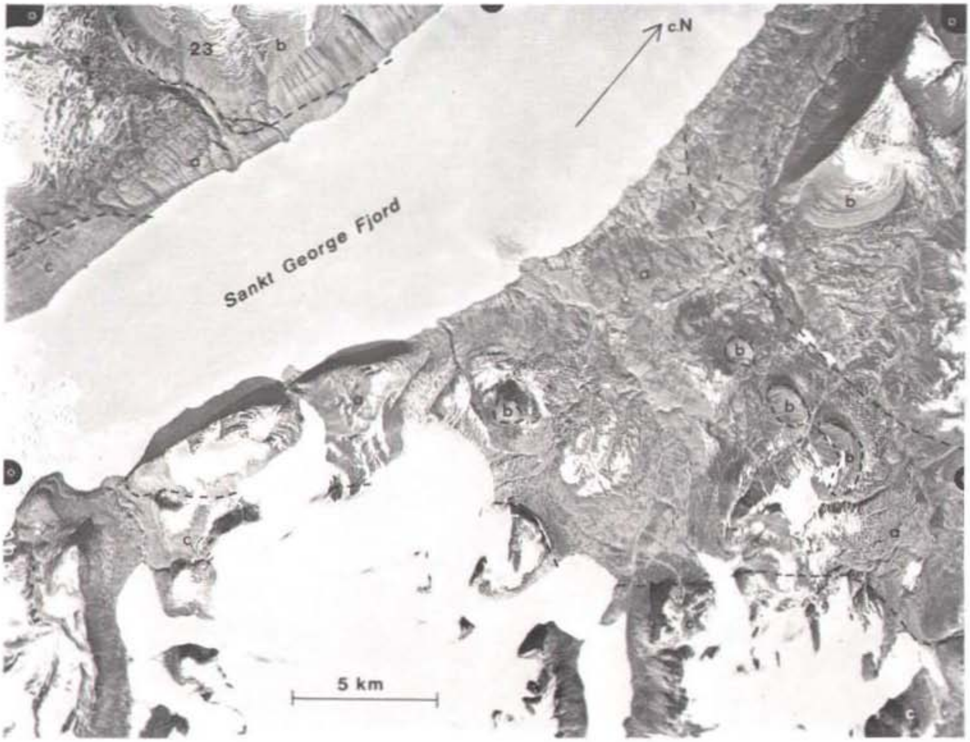


Fig. 77. Annotated aerial photograph showing the geology of eastern Nyeboe Land and western Warming Land (fig. 1). Carbonates (c), Lafayette Bugt Formation (a) and Wulff Land Formation (b). Reference section 23 (fig. 72, plate 3) located in gully at 23. Aerial photograph 874 E, no. 99. Copyright Geodætisk Institut, Denmark. Maximum width of fjord 8 km.

boundary of the formation is diachronous between Wulff Land and Peary Land, being younger than the Lower Ludlow in the west and Upper Llandovery to Middle Wenlock in Peary Land. Interdigitations in northern Hendrik Ø and Nyeboe Land indicate a Lower Ludlow horizon.

Subdivisions. Two members, the Thors Fjord and Repulse Havn Members, are recognised. The Repulse Havn Member occurs as a thin turbiditic mudstone wedge in the Lauge Koch Land Formation, and has the same age as the top of the Wulff Land Formation in the type section. It is placed as a member of the Wulff Land Formation as it is considered a northerly prograding wedge of the formation possibly resulting from a switch in the fan lobes responsible for the deposition of the turbidites of the Lauge Koch Land Formation. Further work may show it as an isolated separate unit, and thus at such a stage it may be necessary to raise the Repulse Havn Member to formational status.

Fig. 78. Interdigitating Lauge Koch Land Formation (a) and Wulff Land Formation (b) in northern Hall Land (fig. 1). This is also part of section 19 (plate 2) located on fig. 82. Cliff height approximately 300 m.

Repulse Havn Member

new member

Name. After Repulse Havn in north-west Nyeboe Land (fig. 79).

Type and reference sections. Type section in the gully 5 km due south of Repulse Havn (figs 79, 80; plate 2, section 22). The reference sections occur in the western bank of the northerly flowing river on the north–west side of Hendrik Ø, near Dragon Point (fig. 81; plate 3, section 17; plate 4), and in northern Hall Land, immediately south of Kap Ammen (fig. 82; plate 2, section 19).

Thickness. Approximately 200 m in Nyeboe Land, possibly the same in Hendrik Ø, and approximately 120 m in Hall Land.

Lithology. The member is characterised by thick units (1 to 10 m thick) of thin-bedded mudstone and siltstone turbidites (Tc/e and Tde) set against a background of silty mudstone (fig. 83). The silty mudstones are light grey to green, often heavily bioturbated, and with rare starved ripples, limestone concretion horizons and minor slumped horizons up to 50 cm thick (figs 84, 85). The thin-bedded siltstone turbidite units are separated by thin units (50 cm to 5 m) of thicker-bedded (10 to 50 cm) silty sandstone and fine sandstone turbidites, commonly Tc/e and more rarely Ta/e and Tb/e. The characteristic feature of the member, which differentiates it from all other mudstone dominated wedges, is the heavy bioturbation of the sediments (fig. 85).

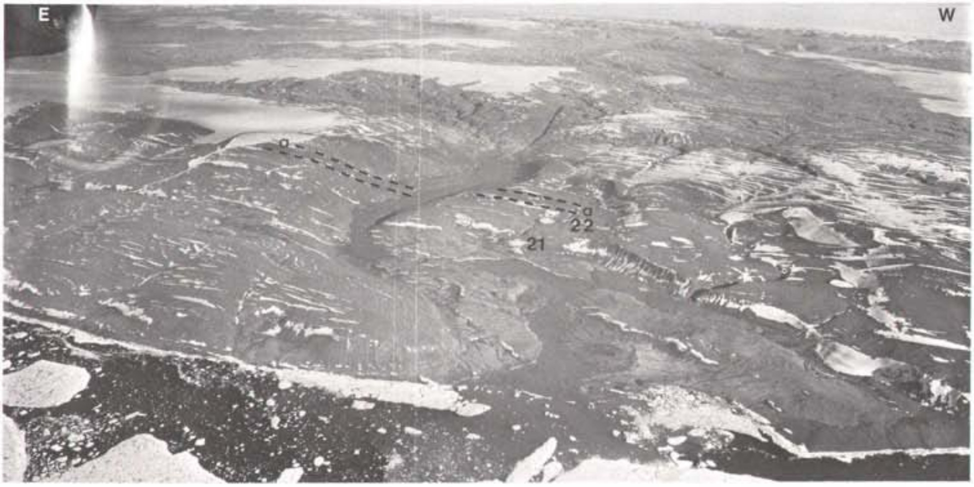
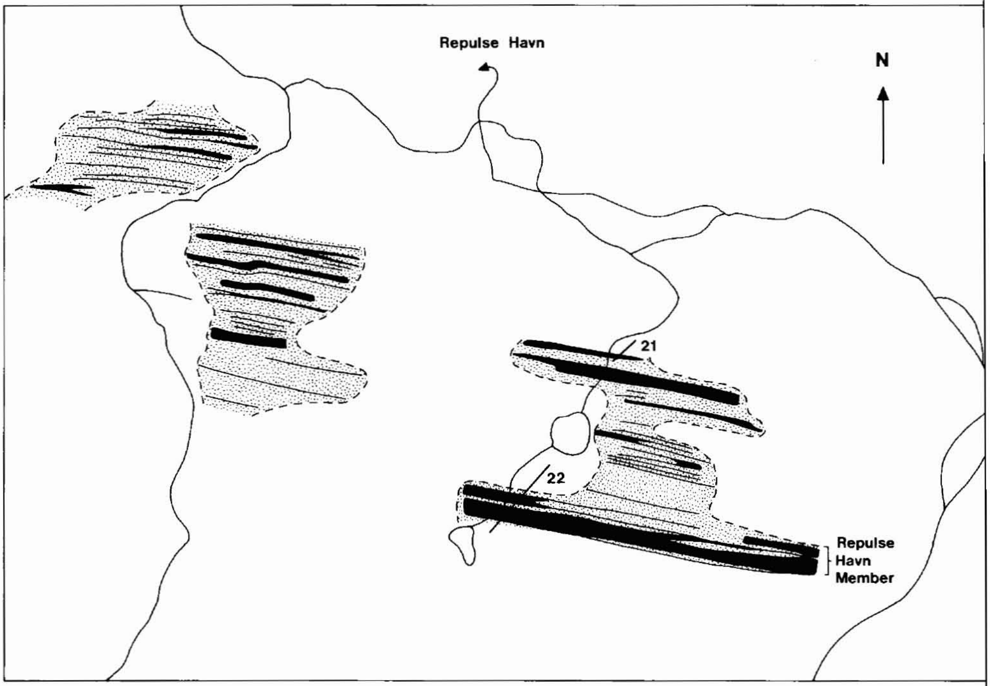


Fig. 79. Repulse Havn (foreground) showing the distribution of the Repulse Havn Member (a) within the Lauge Koch Land Formation. Numbers 21 and 22 refer to reference sections 21 and 22 respectively for the Lauge Koch Land Formation and section 22 contains the type section of the Repulse Havn Member (plate 2; fig. 80). Aerial photograph 546 K, no. 2170. Copyright Geodætisk Institut, Denmark. Coastal cliffs approximately 400 m high.

Depositional environment. The member probably represents basin plain and lower slope mudstones formed during a period of basin starvation. The characteristic bioturbation of the silty mudstones probably indicates a period of oxygenation of the bottom sediments over a wide area of the basin.

Boundaries. The member interfingers with the Lauge Koch Land Formation (figs 86, 87). The lower boundary of the Repulse Havn Member is placed at the base of the first thick unit of dark grey siltstone or mudstone turbidites. The member rests conformably on the buff-yellow fine sandstone turbidites of the Lauge Koch Land Formation (fig. 88). The upper boundary is placed at the top of the last thin-bedded siltstone turbidite unit, which is succeeded by buff-yellow fine sandstone turbidites of the Lauge Koch Land Formation.

Distribution. The member occurs in a distinct band (due to vertical dips) across the whole of northern Nyeboe Land from just west of Repulse Havn on the north coast of Nyeboe Land to the east coast just south of Kap Fulford (plate 4; fig. 79). It is also known as a distinct narrow strip across northern Hendrik Ø (fig. 81). The member is also identified in northern Hall Land on the basis of the intensely bioturbated silty mudstone unit. Bioturbation on the scale of that seen in the Repulse Havn Member in Nyeboe Land and Hendrik Ø is not known from any other part of the Wulff Land Formation or indeed the Peary Land Group. Thus,



bioturbation is taken as a diagnostic feature of the member, and it probably reflects a basin wide synchronous event.

Geological age. In Hendrik Ø *Monoclimacis* sp., *Pristiograptus dubius ?ludlowensis, Pristiograptus dubius* and *Bohemograptus bohemicus* occur throughout the formation. Besides these graptolites Berry *et al.* (1974) and Dawes (1976) report *Pristiograptus* sp., *Bohemograptus bohemicus* (?)*tenuis* and *Saetograptus fritschi* indicating a Lower to Middle Ludlow horizon. Ten metres below the member in the type section *Bohemograptus ?bohemicus* occurs and indicates that at least the base of the member occurs in the Lower Ludlow as in the reference section of Hendrik Ø. It is likely that in Nyeboe Land the member belongs to the same zone. In Hall Land *P. dubius* is the only graptolite recovered from the base of the unit and its age range is in agreement with the age of the member in Hendrik Ø and Nyeboe Land. As the characteristic bioturbation is probably the result of a synchronous event, it is also likely that the member in Hall Land is Lower Ludlow.

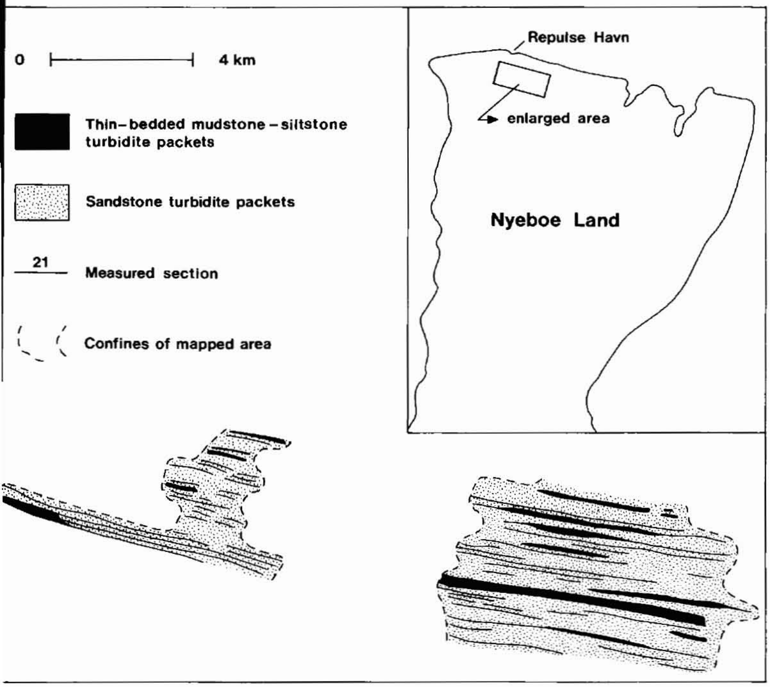


Fig. 80. Map showing the distribution of sandstone turbidite units (in the main Lauge Koch Land Formation) and muddy turbidite packets (in the main Wulff Land Formation) including the thick Repulse Havn Member. Sections 21 and 22 located on fig. 79 (see also plate 2). Figure 2 on plate 4.

Thors Fjord Member

new member

History. The member corresponds to the 'Un-named Silurian black shale formation' of Christie & Peel (1977).

Name. After Thors Fjord, the north–south trending fjord on the south side of Frederick E. Hyde Fjord, Peary Land (fig. 7).

Type section. On the east side of Thors Fjord, several kilometres south of the fjord mouth (figs 89, 90; plate 3, section 32).

Thickness. 12 to 150 m thick (plate 3, section 32).

Lithology. The member is characterised by black mudstones with starved ripples, in units ranging from 50 cm to 5 m thick (fig. 91). Thin fine sandstone or siltstone Tc/e and Tde turbidites 5 to 10 cm thick are ubiquitous (figs 92, 93). Units of fine sandstone and siltstone turbidites occur rarely and are up to 10 m thick. They consist of Ta/c, Tbc and Tb/e combinations up to 1 m thick. Along the southern area of outcrop in central Peary Land the black mudstone units increase up to 10 m

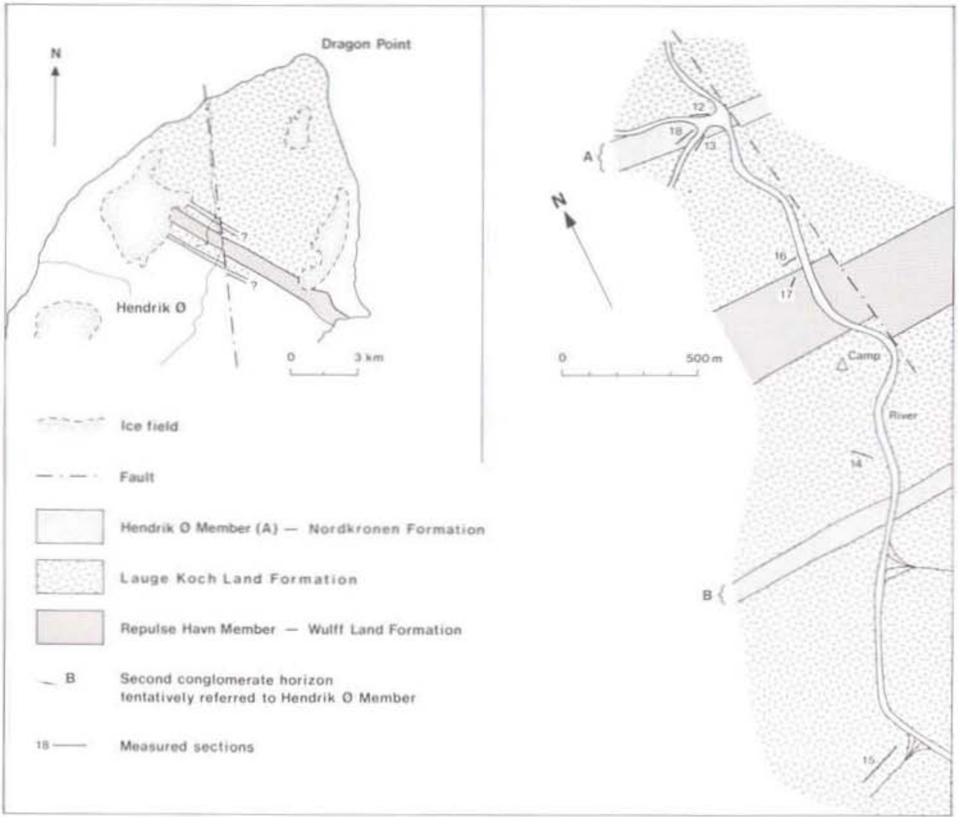


Fig. 81. Geological map of northern Hendrik Ø showing distribution of various units, as well as reference sections 12, 14, 15 and 16 (plates 2 and 3) of the Lauge Koch Land Formation, and reference section 17 (plate 3) through the base of the Repulse Havn Member. Section 18 (plate 3) is the type section for the Hendrik Ø Member and 13 (plate 3) is a reference section.

Fig. 82. Geology of the north coast of Hall Land. Platform carbonates (a), interfingering Lauge Koch Land Formation and Wulff Land Formation (b) with Repulse Havn Member (fig. 78) and Chester Bjerg Formation (c). 19 refers to section 19 (fig. 78; plate 2), reference section for the Lauge Koch Land Formation, Wulff Land Formation and Repulse Havn Member. 1 refers to main study areas of Chester Bjerg Formation. Aerial photograph 546 K, no. 2194. Copyright Geodætisk Institut, Denmark. Cliff height approximately 1000 m.

Fig. 83. Muddy and silty turbidites in a background of silty mudstone. Repulse Havn Member section 19, Hall Land (fig. 78; plate 2). Scale bar 1 cm.

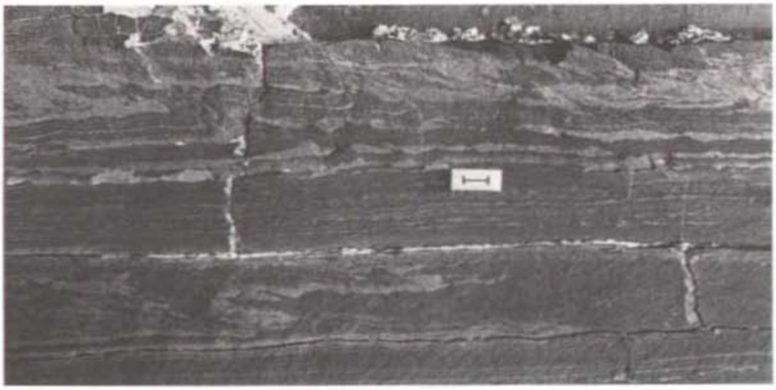


Fig. 84. Contorted muddy and silty turbidites and starved ripples, sometimes weakly bioturbated. Repulse Havn Member section 19, Hall Land (fig. 78; plate 2). Scale bar 1 cm.

Fig. 85. Strongly bioturbated mudstone and siltstone turbidites of the Repulse Havn Member in section 22 Nyeboe Land (fig. 79; plate 2). Scale bar 1 cm.

Fig. 86. Upper part of section 19 in Hall Land showing the Repulse Havn Member of the Wulff Land Formation (fig. 78; plate 2). Cliff height approximately 500 m.

Fig. 87. Faulted Repulse Havn Member (a) interfingering with the Lauge Koch Land Formation in northern Hendrik Ø, opposite section 17 (fig. 81, plate 3). River cliff height approximately 50 m.

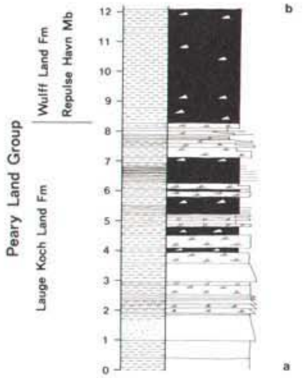


Fig. 88. Detailed sediment log of contact between Lauge Koch Land Formation and Repulse Havn Member of Wulff Land Formation in reference section 17 (plate 3, a–b), Hendrik Ø (fig. 81).

Fig. 89. Geology of the area around Thors Fjord. Merqujôq Formation (a), Thors Fjord Member of the Wulff Land Formation (b) and the Lauge Koch Land Formation (c). 32a is reference section 32 for the Merqujôq Formation and 32b is the type section 32 for the Thors Fjord Member (plate 3). Area to west of fjord is essentially Lauge Koch Land Formation; to the north of the east–west trending Frederick E. Hyde Fjord, Cambro-Ordovician clastics outcrop. Note typical plateau topped hill outcrop of the sandy turbidites. Aerial Photograph 548 B–N, no. 2057. Copyright Geodætisk Institut, Denmark. Mouth of the fjord approximately 2 to 3 km wide.

thick, and starved ripples are very rare. This facies dominates the basal third of the member and is common in the upper part. The upper part of the member also contains silty Tc/e and Tde turbidites with very rare, thin fine sandstone turbidite units. The north–south facies change is well documented throughout the whole of Peary Land. The sandstone turbidite pods are not known in the lower half of the member and only rarely occur in the upper part along the southern outcrop belt of the member.

Depositional environment. The member represents the proximal eastern part of the Wulff Land Formation. It includes slope mudstones which to the north incorporate an increasing amount of thin-bedded, basin plain mudstone and siltstone turbidites.

Boundaries. The lower boundary of the Thors Fjord Member is placed at the base of the first thick unit of black mudstone (with or without starved ripples) overlying the sandy turbidites of the Merqujôq Formation or, to the south, platform carbonates. In Peary Land immediately south of Frederick E. Hyde Fjord and between Freja Fjord and Thors Fjord the member rests directly on the buff-yellow fine

Fig. 90. Outcrop of the type section of the Thors Fjord Member (fig. 89; plate 3).

Fig. 92. Outcrop style of the Thors Fjord Member in eastern Lauge Koch Land, directly above section 1 (fig. 28). Cliff approximately 20 m high.

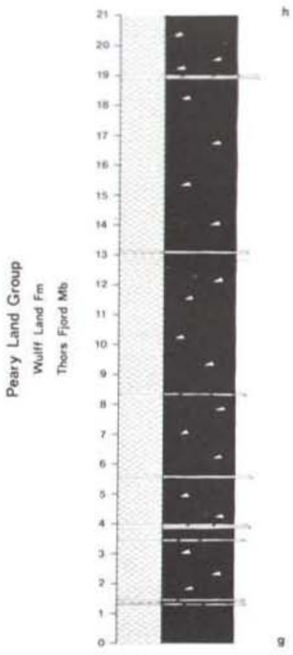


Fig. 91. Detailed sediment log of the Thors Fjord Member in the type section 32 (fig. 89; plate 3, g–h).

Fig. 93. Starved ripples and thin silty Td turbidites in a background of black mudstone. From location in fig. 92.

sandstone turbidites of the Merqujôq Formation. A similar relationship is present in the valley leading south from Adolf Jensen Fjord (fig. 94), central J. P. Koch Fjord (fig. 95) and central Navarana Fjord. The presence of thick sandstone turbidite pods in the predominantly black mudstone and siltstone turbidite unit in the northern area of outcrop of the member hinders precise boundary definitions in some areas. Here it is difficult to discern boundaries as parts of the member may be represented by classical turbidites typical of the underlying Merqujôq Formation or the overlying Lauge Koch Land Formation. In such areas the lower and upper boundaries have to be determined by consideration of the regional distribution of the member. In central and southern Peary Land east of Hans Tavsens Iskappe and through to G. B. Schley Fjord the Thors Fjord Member rests conformably on black limestones of the 'Un-named Silurian limestone formation' as well as Silurian

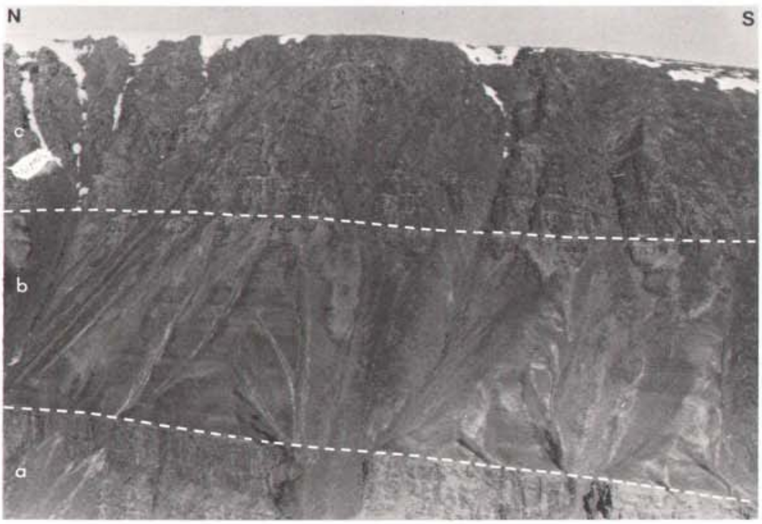


Fig. 94. Eastern side of the valley leading south from Adolf Jensen Fjord (fig. 7) with Merqujôq Formation (a), Thors Fjord Member (b) and Lauge Koch Land Formation (c). Cliff height approximately 300 m.

Fig. 95. Western coast of J. P. Koch Fjord (fig. 7) immediately south of box fold (fig. 28) showing Merqujôq Formation (a), Thors Fjord Member (b) and Lauge Koch Land Formation (c). Cliff height in background approximately 300 m.

carbonate mounds. A similar relationship is known from the valley leading south from Adolf Jensen Fjord, Lauge Koch Land (fig. 96) and eastern Freuchen Land.

The upper boundary of the member is defined in section 32 (fig. 89) where black mudstones give way abruptly to fine sandstone turbidites of the Lauge Koch Land Formation (fig. 97).

Distribution. The member is widespread in Peary Land, occurring from the south-east coast at Vitsköl Bugt to J. P. Koch Fjord in the west (fig. 11). It fringes the northern edge of the platform carbonates in Lauge Koch Land and eastern Freuchen Land. The Thors Fjord Member is erected to cover sediments east of the Victoria Fjord Arch of Dawes (1976). However, at this juncture it is not possible to say whether the western limit of the member should be Nordenskjöld Fjord or Victoria Fjord. Until the sediments are examined in Nares Land this problem cannot be solved. In eastern Peary Land, around G. B. Schley Fjord, the formation thins to 12 m.

Geological age. In the type section of the member graptolites are scarce, but throughout the whole member they probably indicate the *spiralis* Zone (*sakmaricus-laqueus* Zone ?) of the uppermost Llandovery. There is no unequivocal evidence to suggest that the member in the type section extends into the Wenlock. Twenty kilometres to the west in Odins Fjord graptolites from no more than 5 m above the base of the member include *Monoclimacis vomerina* aff. *M. crenulata, Monograptus priodon* and *Monograptus spiralis spiralis* indicating the *spiralis* Zone

Fig. 96. West side of J. P. Koch Fjord opposite Merqujôq (fig. 7). In the lower right the gully is eroded between the platform limestone to Merqujôq Formation (a) contact. The overlying Thors Fjord Member (b) occasionally covers the carbonates. Lauge Koch Land Formation (c). Cliff height in left foreground 200 m.

of the Upper Llandovery. In the same area an assemblage 3 m from the top of the member includes *Monograptus priodon* and *Monograptus spiralis spiralis* indicating the *spiralis* Zone. Scanty graptolite evidence throughout the member in Lauge Koch Land suggests a similar age range as in Thors Fjord and Odins Fjord.

Further south in Peary Land large, scattered collections from the basal part of the member contain rich 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 Llandovery *sakmaricus-laqueus* Zone. A collection of graptolites from the upper part of the member not far below the overlying Lauge Koch Land Formation in Ugledal, central Peary Land, (Christie & Peel, 1977; Peel, personal communication, 1981) yielded *Monograptus flexilis flexilis, Monograptus* sp., *Monograptus* aff. *M. riccartonensis* and *Cyrtograptus* sp. and indicates the *flexilis* or *linnarssoni* Zone of the Middle Wenlock.

To summarise, the base of the Thors Fjord Member in Peary Land south of Frederick E. Hyde Fjord, between Lauge Koch Land and Freja Fjord is synchronous in the *spiralis* Zone (*sakmaricus-laqueus* Zone ?). In Peary Land south of Frederick E. Hyde Fjord the ubiquitous presence of *Cyrtograptus sakmaricus* indicates the *sakmaricus-laqueus* Zone of the uppermost Llandovery (Rickards *et al.,*

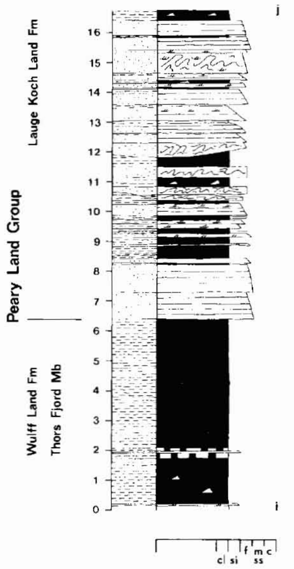


Fig. 97. Detailed sediment log across the Thors Fjord Member – Lauge Koch Land Formation boundary. Section 32 (fig. 89; plate 3, i–j).

1977; Lenz, 1978) suggesting that from north to south the Thors Fjord Member is weakly diachronous. In the northern areas the member is contained totally within the Upper Llandovery *spiralis* Zone, but to the south the top of the member extends into the Middle Wenlock *flexilis* or *linnarssoni* Zone. Thus, the top of the member is strongly diachronous, becoming younger southwards.

Lauge Koch Land Formation

new formation

History. The formation includes the 'Kjoveslette Sandstones' (Fränkl, 1956) and part of the 'Polaris Harbour Formation' (Koch, 1929) and the 'Cape Tyson Formation' in Peary Land (see Dawes & Haller, 1979). It corresponds to the 'Un-named Silurian flysch formation' of Christie & Peel (1977).

Name. From Lauge Koch Land, situated between Freuchen Land and Peary Land (fig. 1).

Type and reference sections. The type section is on the eastern coast of Lauge Koch Land (fig. 28; plate 3, section 4), situated along the western shore of J. P. Koch Fjord. Reference sections are located in Thors Fjord (figs 89, 97; plate 3, section 32), Citronens Fjord (plate 2, section 34), Hall Land (figs 98, 99; plate 2, section 19), on Hendrik Ø (fig. 88; plate 3, sections 14, 15, 17), in Nyboe Land (plate 2, sections 21 and 22) and in Kronprins Christian Land (plate 3, section 8).

Thickness. It is difficult to accurately estimate the thickness of the formation, but it is probably in the order of 1.5 km to possibly 2 km.

Lithology. The Lauge Koch Land Formation covers a variety of lithologies. In the main the formation is characterised by yellow to brown weathering siltstone and sandstone turbidites of 'classical flysch' appearance. Turbidite beds vary from a few centimetres to 5 m in thickness. The thicker sandstone beds (over 1 m thick) are not very common, but are normally fine grained, non-graded, amalgamated and mainly structureless, although scarce mudstone rip-up clasts and small loads and slumps occur (figs 100, 101, 102). Sandstones are well-sorted and rounded and a high content of fine-grained carbonate matrix or cement is characteristic. In eastern Kronprins Christian Land such units occasionally consist of coarse or medium-grained channel-fill sandstones which grade upwards from quartzite cobble conglomerates. The thicker turbidite beds (fig. 101) occur: (1) in units up to 30 m thick (e.g. Nyeboe Land) separated by thinner-bedded fine sandstone turbidites and mudstones (fig. 100) and (2) as sandstones forming the base of distinct fining upwards cycles.

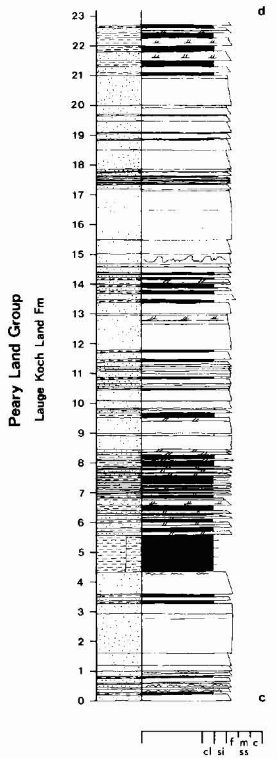


Fig. 98. Detailed sediment log of one of the interdigitating wedges of the Lauge Koch Land Formation in reference section 19, Hall Land (figs 82, 86; plate 2, c–d).

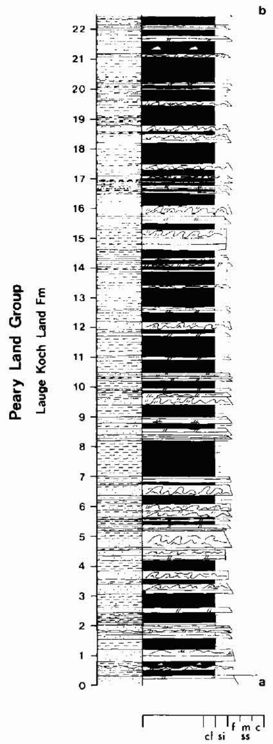


Fig. 99. Detailed sediment log of one of the interdigitating wedges of the Lauge Koch Land Formation in reference section 19, Hall Land (figs 82, 86; plate 2, a–b).

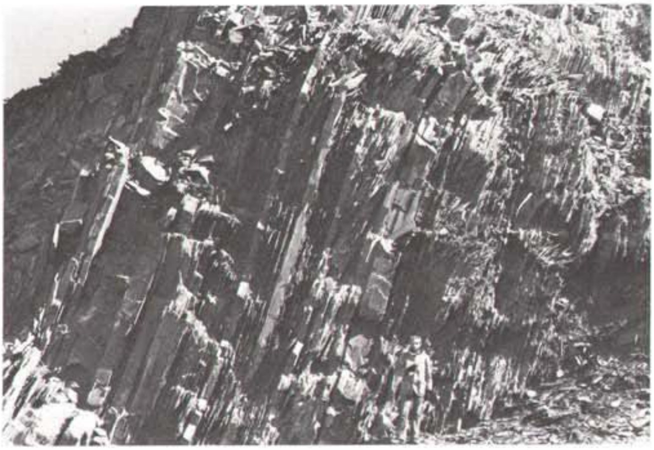


Fig. 100. Outcrop pattern of the thin-bedded turbidites of the Lauge Koch Land Group. Reference section 22 Nyeboe Land (plate 2; fig. 79).

The fining upwards cycles are only known from around Esrum Elv, Citronens Fjord (figs 103, 104, 105). They start with fine-grained structureless and amalgamated turbidite sandstones which do not show any clear-cut fining upwards trend. They abruptly pass up into silty thin-bedded turbidites in units several metres thick separated by thin laminated fine sandstones (fig. 106). The top of each cycle consists of thick upwards fining units of black turbiditic mudstone with starved ripples and thin silty Tc/e and Tde turbidites (fig. 107). Each cycle is in the order of 60 to

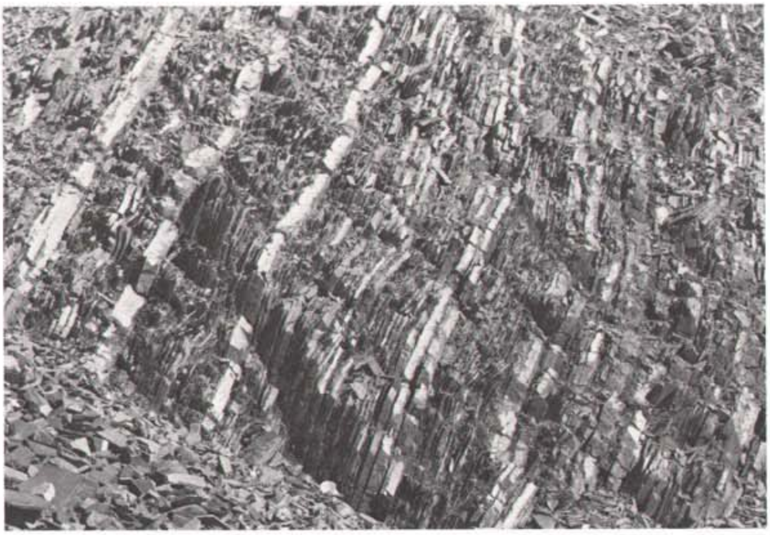


Fig. 101. Thicker-bedded turbidites of the Lauge Koch Land Formation from reference section 22 Nyeboe Land (plate 2; fig. 79). Cliff height 20 m.

Fig. 102. Thin to medium-bedded silty to fine sandstone turbidites of the Lauge Koch Land Formation. Note starved ripples and thick Tc divisions. Reference section 22 Nyeboe Land (plate 2; fig. 79).

100 m thick and at least five distinct cycles are represented in the Esrum Elv district, but not all occur in one section.

Within the higher cycles the basal part of individual turbidites often consists of fine to medium pebble chert conglomerates, heralding the incoming of the chert conglomerates of the Nordkronen Formation. The clasts consist predominantly of green and black chert with rare quartzite and basement gneiss pebbles, and they may be structureless or display sub-horizontal lamination or weak imbrication. Distinct conglomerate beds are rare and thin (*c.* 150 cm); they normally occur at the base of beds up to 150 or 200 cm thick and grade upwards into medium or fine quartz dominated sandstones. Chert pebble conglomerates at the base of beds are common in the higher parts of the formation over much of the Citronens Fjord and Esrum Elv district. They are never very thick and do not form horizons which can be mapped continuously over large areas. Some of the relatively thin turbiditic mudstone dominated horizons may correspond to the eastern feather edge of the Thors Fjord Member of the Wulff Land Formation. As sandstones dominate over mudstones in the fining upwards cycles, and as they do not form one well-defined mappable sequence, they are considered part of the Lauge Koch Land Formation.

The overall bulk of the Lauge Koch Land Formation, particularly in western North Greenland, consists of thin sandstone and siltstone beds (5–100 cm) displaying a variety of typical 'Bouma sequence' combinations with loaded and fluted soles together with chevron marks, grooves and prods (figs 97, 98, 99). Ta/e, Tb/e

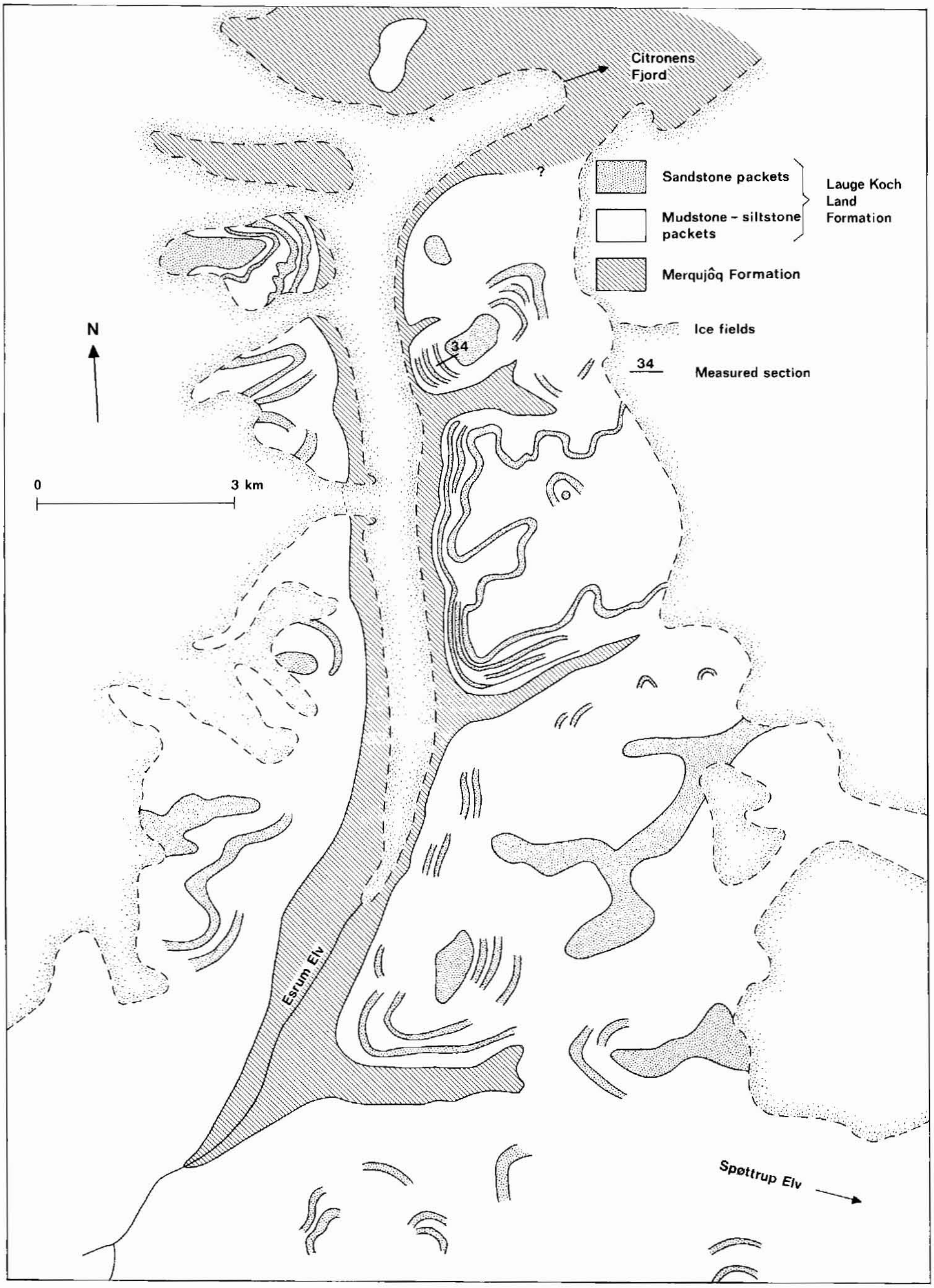


Fig. 103. Geological map of Esrum Elv, around the inner reaches of Citronens Fjord showing the distribution of sandstone and mud-siltstone packets in the Lauge Koch Land Formation. The base of the sandstone packets is the base of the fining-upward cycles. Section 34 (plate 2) is a reference section of the Lauge Koch Land Formation through the top two fining-upward cycles. Section 37, reference section in the Merqujôq Formation (plate 1), is located just to the north of the glacier leading to Citronens Fjord.

Fig. 104. Fining-upward cycles of the Lauge Koch Land Formation (1 to 4) in section 34 (fig. 103; plate 2) of Esrum Elv, Peary Land. Dashed lines are the base of the cycles 1 to 4 which correspond to mapped sandstones in fig. 103. Top of the Merqujôq Formation (a–a). Lauge Koch Land Formation (b). Cliff height approximately 400 m.

and Tc/e combinations are most typical with rarer Ta-e combinations (figs 100, 101, 102).

In Kronprins Christian and Valdemar Glückstadt Land the base of the formation is characterised by local thin developments of black mudstone with starved ripples together with thin-bedded siltstone and mudstone turbidites.

Fig. 105. Details of two fining-upward cycles (2 and 3) in section 34 (figs 103, 104; plate 2). Note sharp bases to each cycle (dotted line). Fining-upward cycle numbers correspond to those in fig. 104. Cliff height approximately 100 m.

Fig. 106. Silty thin-bedded turbidites in the middle part of a fining-upward sequence in section 34 (figs 103, 104, 105, plate 2).

The general sandstone turbidites of the Lauge Koch Land Formation are similar to the lower Merqujôq Formation. The sediments of the Lauge Koch Land Formation are thinner bedded and do not contain the very thick-bedded, structureless, amalgamated fine-grained sandstone turbidites which occur in the Merqujôq Formation.

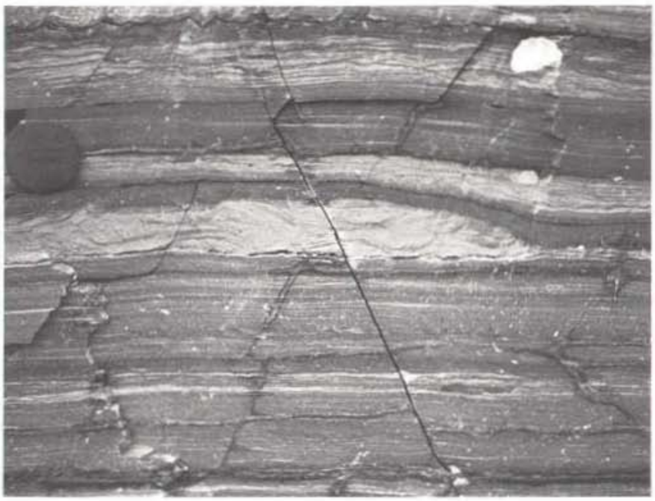


Fig. 107. Black mudstones with starved ripples and convoluted Tc/e and Tde turbidites in the top of a fining-upward sequence in section 34 (figs 103, 104, 105, plate 2).

Fig. 108. Aerial photograph of Tvilum Elv and Thors Fjord (middle distance) in Peary Land (fig. 7), (a) Merqujôq Formation; (b) Thors Fjord Member of the Wulff Land Formation; (c) Lauge Koch Land Formation. Note distinct weathering change from the recessive Thors Fjord Member to the overlying Lauge Koch Land Formation and the step-like topography of the hills formed by the sandstone turbidite beds in the Lauge Koch Land Formation. Aerial photograph 548 G–V, no. 10185. Copyright Geodætisk Institut, Denmark. Cliff heights approximately 1000 m.

Depositional environment. The thick fining upwards cycles in the Esrum Elv area can be traced laterally as sheets over many kilometres, and while channel shaped cross sections cannot be directly observed, the cycles may represent fillings of major inner fan valleys. They are probably the uppermost, up the axis time-equivalent of the Thors Fjord Member of the Wulff Land Formation. Higher portions of the formation in central and western Peary Land include proximal basin plain, fan fringe, outer fan and braided midfan. In the distal western region the main depositional environment was a distal basin plain.

Boundaries. The lower boundary of the Lauge Koch Land Formation from central Nyeboe Land to eastern Peary Land (plate 4; fig. 11) is placed at the base of the first unit of buff-yellow fine sand turbidites conformably overlying the thick black

Fig. 109. Location of section 22 in northern Nyeboe Land with interdigitating Lauge Koch Land Formation and Wulff Land Formation (figs 79, 80). Note that as the beds are vertical, outcrop is poor, other than in streams (plate 2). Width of the valley approximately 20 m.

mudstone with starved ripples and black-grey thin-bedded siltstone turbidites of the Wulff Land Formation, which in the east is represented by the Thors Fjord Member (fig. 97). Because of the distinct colour change in the sediments of the two formations, the boundary is easy to locate (fig. 108).

Around Esrum Elv to Citronens Fjord, the Wulff Land Formation (Thors Fjord Member) has wedged out and therefore the Lauge Koch Land Formation rests directly on the Merqujôq Formation (figs 103, 104). Thus the base of the Lauge Koch Land Formation is conveniently taken at the base of the fining upwards cycles present in the area described above. This is a distinct boundary as the underlying Merqujôq Formation is not large scale cyclic here. The base of the Lauge Koch Land Formation in northern Nyeboe Land, and northern Wulff Land may rest on the Merqujôq Formation. If there is no intervening Wulff Land Formation, then a convenient mappable horizon will have to be taken to differentiate the two formations.

The Lauge Koch Land Formation interdigitates with the Repulse Havn Member of the Wulff Land Formation in northern Hall Land and in northern Nyeboe Land (cf. figs 80, 109).

Over the whole of Kronprins Christian Land and north-east Valdemar Glückstadt Land the Lauge Koch Land Formation rests directly on platform carbonates of the 'Un-named Silurian limestone formation'. In northern Hall Land, and possibly northern Nyeboe Land, it rests on Silurian carbonate rocks.

The Lauge Koch Land Formation is the topmost exposed unit of Kronprins Christian Land. In central and eastern Peary Land it is patchily overlain by the Nordkronen Formation. In western Peary Land through to Nyeboe Land it is the topmost unit (fig. 108). In eastern Peary Land it is overlain, with angular unconformity, by Upper Carboniferous conglomerates and sandstones in red bed facies of the Mallemuk Mountain Group (Håkansson, 1979). In Hall Land the formation is conformably overlain by green, well laminated mudstones of the Chester Bjerg Formation (see below). Sediments of the latter formation are normally highly folded and faulted.

Distribution. The formation is widely distributed over all the land areas of North Greenland from Kronprins Christian Land in the east to Hall Land in the west. Washington Land is the only area it is not known from (plate 4; fig. 11).

Geological age. Based on graptolites in the underlying Thors Fjord Member of the Wulff Land Formation the base of the formation between Lauge Koch Land and Freja Fjord is synchronous along strike in the *spiralis* Zone (*sakmaricus-laqueus* Zone ?) of the Upper Llandovery. Similarly in southern Peary Land the base of the formation is no older than the *flexis* or *linnarssoni* Zone of the Middle Wenlock. Thus in Peary Land the base of the member is strongly diachronous, becoming younger southwards.

In Kronprins Christian Land and Valdemar Glückstadt Land the base of the formation is in the *sakmaricus-laqueus* Zone (uppermost Llandovery) in the north–west, but towards the east it is of the preceding *griestoniensis* Zone, and in the very south it is of Middle Wenlock *rigidus* Zone (for details see section on Profilfjeldet Member). Thus south of Independence Fjord the base of the formation is diachronous, younging southwards, and becoming older eastwards.

Between eastern and western North Greenland the base of the Lauge Koch Land Formation is also diachronous. In central Wulff Land, in the type section of the Wulff Land Formation, the base of the Lauge Koch Land Formation is in the Lower Ludlow. This relationship is probably present along the whole southern outcrop of the formation.

In northern Hall Land poor graptolite faunas give no precise indication of the age of the Lauge Koch Land Formation. *Monograptus priodon* and *Monograptus* aff. *M. dubius* near the base indicate it is in the Upper Llandovery to Lower Wenlock interval. Other graptolites from the lower half of the formation indicate a similar age. The top of the formation in this area probably postdates the Lower Ludlow as it interdigitates with the Wulff Land Formation (for details see section on Repulse Havn Member).

In northern Nyeboe Land the graptolites *Retiolites geinitzianus geinitzianus, ?Pristiograptus sp., Cyrtograptus lapworthi* and *Cyrtograptus sakmaricus* indicate the uppermost Llandovery *sakmaricus-laqueus* Zone (cf. Lenz, 1978). It is not known how far above the base they come from, but they are in agreement with the basal age from northern Hall Land. Thus all evidence indicates that the formation base is diachronous in western North Greenland, again younging southwards. In the Nyeboe Land section *Monograptus flemingii* first occurs at least 500 m above the base indicating at the oldest a Middle Wenlock horizon. Twenty five metres higher *Monograptus flemingii* and *Cyrtograptus* cf. *C. mancki* probably indicate the Upper Wenlock *lundgreni* Zone. Some 200 m higher in the same section the Repulse Havn Member of the interdigitating Wulff Land Formation is dated as Lower Ludlow. Above comes more Lauge Koch Land Formation which indicates that its top in this region is not older than Lower Ludlow, and probably somewhat younger. The same relationship is present on Hendrik Ø. There is no other information regarding the upper age limit of the formation in western North Greenland.

In Peary Land graptolites are common throughout the formation, but mainly restricted to one species, *Monograptus priodon*. Whilst this species is not precisely age diagnostic, it does indicate that the formation is no younger than Middle Wenlock. Thus the top of the Lauge Koch Land Formation is strongly diachronous, younging westwards from Middle Wenlock (at youngest) in Peary Land (and Kronprins Christian Land) to Lower Ludlow and probably younger in Wulff Land, Hendrik Ø, Nyeboe Land and probably Hall Land.

Subdivisions. The Lauge Koch Land Formation has not been subdivided into members although one unit, the Profilfjeldet Member, is recognised.

Profilfjeldet Member

new member

History and procedure. The member is equivalent to the sequence described by Nielsen (1941, p. 24) at 'Profilfjældet' and later termed the 'Profilfjeldet Shales' by Fränkl (1954, 1955a; see also Lane, 1972) or the 'Profilfjeldet Formation' (Scrutton, 1975). It also includes the 'Un-named Silurian black shale formation' and the 'Un-named Silurian flysch formation' of Peary Land (Christie & Peel, 1977) which Peel (1980) recognised in Kronprins Christian Land. As redefined here the member is restricted to Valdemar Glückstadt Land and Kronprins Christian Land to incorporate discontinuous black mudstone and muddy siltstones together with the overlying sandstone turbidites. These deposits are often highly folded, faulted and thrusted and thus difficult to relate precisely to the Silurian turbidites of the rest of North Greenland. The Profilfjeldet Member is generally more muddy at the base, particularly in north–west Kronprins Christian Land and Valdemar Glückstadt Land, whilst becoming sandy upwards. In this it mirrors the situation in Peary Land where the black mudstone dominated unit of the Wulff Land Formation (Thors Fjord Member) passes upwards into the sandy Lauge Koch Land Formation. However, in Valdemar Glückstadt Land and Kronprins Christian Land the basal mudstone horizon is so thin, discontinuous and restricted that only a single member of the Lauge Koch Land Formation is recognised.

Name. After Profilfjeldet, the prominent hill on the north side of Sødalen, at the western arm of Ingolf Fjord (figs 110, 111).

Type section. In the valley immediately east of Profilfjeldet (fig. 111; plate 3, section 8).

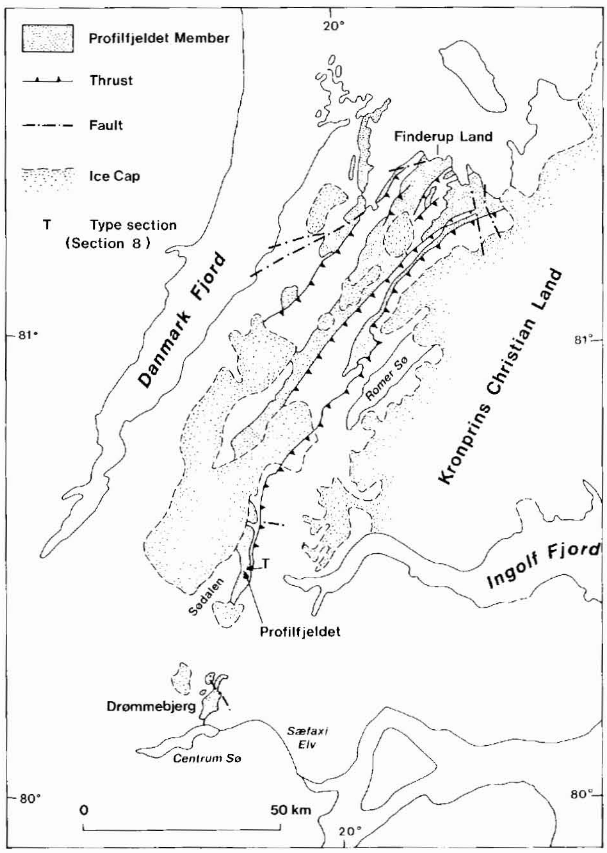
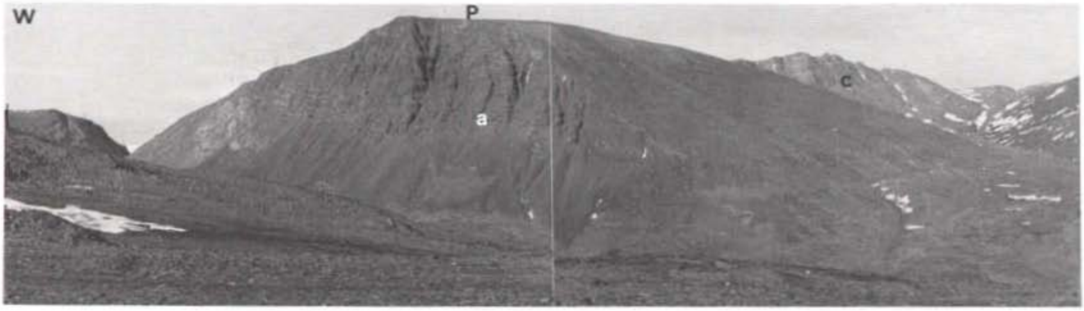


Fig. 110. Geological map of Kronprins Christian Land showing the distribution of the Profilfjeldet Member of the Lauge Koch Land Formation. Section 8, measured in 1980 by Hurst and W. S. McKerrow, is the type section of the member and a reference section for the formation (plate 3). Mapping of the formation in north-west Kronpris Christian Land by J. S. Peel.

Thickness. Due to intense folding it is difficult to accurately estimate the thickness of the formation. Fränkl (1954, 1955a) estimated a thickness of between 200 and 400 m. Our investigations suggest the member is up to 400 m.

Lithology. At the base of the member black mudstone units with rare starved ripples as well as thin-bedded muddy siltstones are locally developed, particularly in the north-western part of Kronprins Christian Land and Valdemar Glückstadt Land. In Kronprins Christian Land these sediments quickly pass into units of graded quartzite pebble or cobble conglomerates to fine or medium-grained sandstone alternating with amalgamated fine sandstone, siltstone and subordinate mudstone (fig. 112). The conglomerates are dominated (98%) by quartzite clasts derived from the Proterozoic sandstones described by Collinson (1979, 1980), and have erosive bases. The amalgamated fine-grained sandstones are generally well-sorted and structureless, but thinner (*c.* 50 cm) laminated fine-grained sandstones occur. The siltstones are thin-bedded and ripple laminated. Mudstone layers are



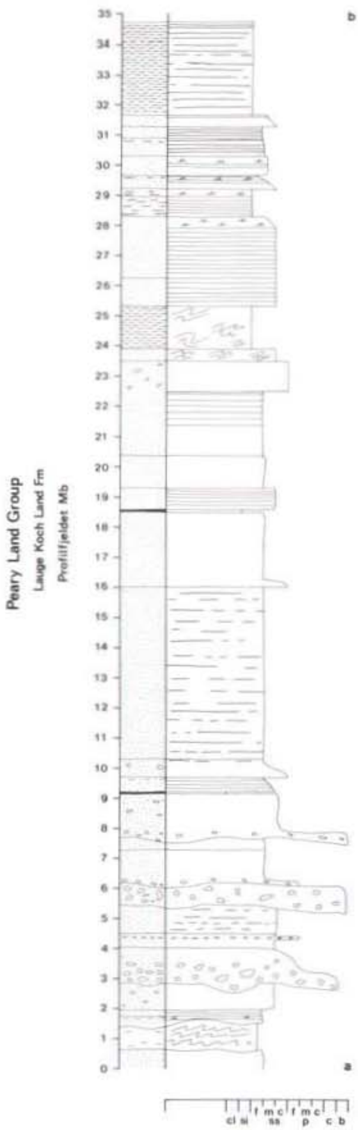


Fig. 112. Detailed sediment log from the type section of the Profilfjeldet Member of the Lauge Koch Land Group (figs 110, 111; plate 3, section 8, a–b).

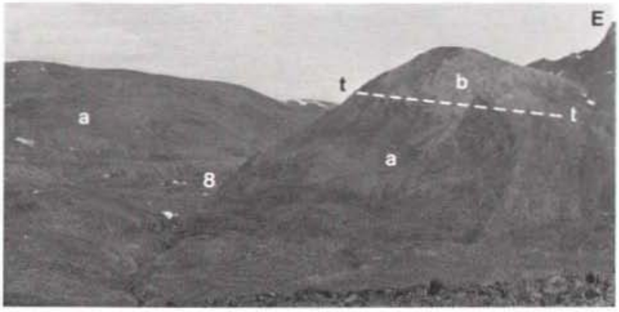


Fig. 111. Panorama of the north side of Sødalen (fig. 110), showing typical outcrop style of the Profilfjeldet Member (a) to the west of the Caledonian nappes (b). Silurian reef (c) and thrust (t). P is Profilfjeldet, and type section 8 (plate 3) of the member is just behind the hill at point 8. Hills are approximately 1000 m high.

very thin and discontinuous. In eastern Kronprins Christian Land the coarse sandstones and conglomerates start directly at the base. The coarser sandstone turbidites and conglomerates are not present in Valdemar Glückstadt Land.

Depositional environment. The tectonic disruption of the sequence precludes a precise interpretation. The proximal position compared to the main east to west organised North Greenland turbidite basin, together with the coarse-grained facies types, possibly suggest an inner fan channel and base-of-slope environment for the bulk of the member.

Boundaries. Everywhere the member once rested conformably on flat-bedded Silurian limestones and interfingered with Silurian carbonate buildups. In eastern and north-eastern Kronprins Christian Land it was involved in the thrusting of the Caledonian nappes and therefore it is in thrust contact with a variety of Lower Palaeozoic or even Precambrian sediments. It forms the top unit of the area.

Distribution. The member occurs extensively in northern and western Kronprins Christian Land west of Romer Sø (fig. 110). It is not known south of Centrum Sø and Sæfaxi Elv. It is also known from the northernmost part of Valdemar Glückstadt Land (fig. 11).

Geological age. In Finderup Land, north–east Kronprins Christian Land, graptolites from the very base of the Profilfjeldet Member include ?*Dictyonema* sp., *Monoclimacis griestoniensis, Monoclimacis* aff. *M. crenulata* sensu Elles & Wood, *Monograptus spiralis, Monograptus* aff. *M. richardsii minor* or early *Monograptus priodon* and *Monograptus* sp., and indicate the *griestoniensis* Zone or the very lowest part of the *spiralis* Zone of the middle Upper Llandovery (C_5, Telychian).

In western Kronprins Christian Land an assemblage of graptolites from near the base of the member includes *Retiolites geinitzianus geinitzianus, Retiolites geinitzianus angustidens, Stomatograptus grandis grandis, Monoclimacis vomerinus vomerinus, Monograptus priodon* and *Monograptus spiralis spiralis* indicating the

Upper Llandovery *spiralis* Zone (possibly *sakmaricus-laqueus* Zone). Near the base of the member in Valdemar Glückstadt Land *Monograptus spiralis spiralis, Monograptus priodon, Cyrtograptus lapworthi* Tullberg and *Cyrtograptus sakmaricus* indicate the uppermost Llandovery *sakmaricus-laqueus* Zone.

In the most southerly outcrop of the member, Lane (1972) reports an Upper Wenlock graptolite fauna. The species identified, *Monograptus ?flemingii* and *Cyrtograptus* ex gr. *C. rigidus* are indicative of the *rigidus* Zone (Rickards, 1976; Lenz, 1978, 1980), and according to Lenz (1978) in the Arctic regions more likely indicative of the Middle Wenlock.

Thus the base of the Profilfjeldet Member is highly diachronous. It appears to be oldest in the east (*griestoniensis* Zone), younging slightly westwards (*spiralis* Zone) and even more northwards (*sakmaricus-laqueus* Zone). Towards the south the base is approximately Middle Wenlock and thus it youngs considerably southwards.

No faunas diagnostic of age are known from the type section area. A few scattered specimens of *Monograptus priodon* from the higher parts of the member in northern Kronprins Christian Land and Valdemar Glückstadt Land indicate that here it may extend into the Wenlock. There is no definite age data for the top of the member. Taking into consideration the Middle Wenlock age for the top of the Lauge Koch Land Formation in Peary Land, it is thought unlikely that the top of the Profilfjeldet Member is younger than this.

Nordkronen Formation

new formation

History. Includes the 'Silurian conglomerate' of Christie & Ineson (1979) and the conglomerate mentioned by Pedersen (1979) as occurring on the top of Nordkronen, as well as the 'Hendrik Conglomerate' of Dawes (1966, 1976).

Name. After Nordkronen, the highest point of Peary Land south of Frederick E. Hyde Fjord, situated midway between Freja Fjord and Thors Fjord (fig. 7).

Type section. The type section is in Herluf Trolle Land on the south side of Spøttrup Elv 40 km due east of the confluence of Spøttrup Elv and Esrum Elv (figs 113, 114; plate 3, section 38), and reference sections are on Nordkronen and in Hendrik Ø (plate 3, sections 13^1, 13^2 and 18), the type section of the Hendrik Ø Member (plate 3, section 18).

Thickness. At least 100 m in Peary Land, diminishing to between 10 and 25 m in Hendrik Ø (plate 3).

Lithology. Units of conglomerate, pebbly sandstone and sandstone (fig. 115). The conglomerates range in thickness from 50 cm to 7 m and are only rarely with erosive bases. The thinner conglomerate units (50 cm to 1 m) are typically com-

Fig. 113. Aerial photograph of Herluf Trolle Land showing the typical step-like topography formed by the Lauge Koch Land Formation. Hill tops are capped by the Nordkronen Formation and the type section 38 is at 38 (plate 3). Aerial photograph 874 G, no. 146. Copyright Geodætisk Institut, Denmark. River width in main east–west valley, approximately 200 m.

posed of medium to coarse pebble clasts, are non-graded or weakly-graded and very rarely reverse-graded (fig. 116). The clast orientation is generally sub-horizontal, or weakly imbricated. The thicker conglomerates are composed of coarse pebbles or cobbles either non-graded, weakly-graded or commonly reverse-graded in the basal 50 cm. Disorganised conglomerates (fig. 117) account for 10% of the succession whilst wavy sub-horizontal or imbricated fabrics are ubiquitous. The pebbly sandstones are between 10 and 40 cm thick and generally consist of

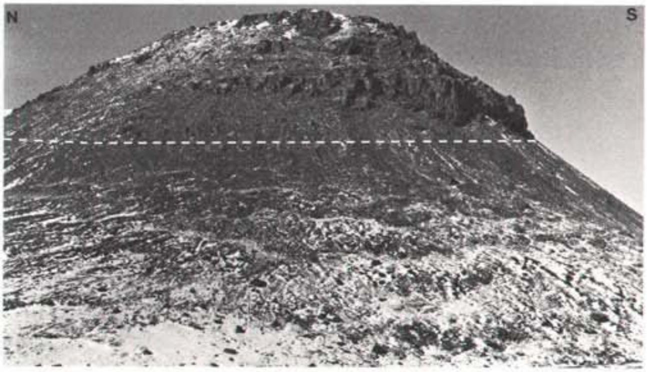


Fig. 114. Type section of the Nordkronen Formation (see fig. 113; plate 3) showing the massive outcrop pattern of the conglomerates (above dotted line) above the Lauge Koch Land Formation. Hill height approximately 200 m.

non-graded fine pebbles in a medium to coarse sand matrix (fig. 118). Sandstone beds are thin (*c.* 10 cm), normally laminated throughout and graded from coarse to fine sand. Conglomerate clasts are predominantly black and green cherts (*c.* 90%), the remainder consists of quartzites and crystalline basement rocks. Conglomerate matrix, the pebbly sandstones and sandstone interbeds consist of well-sorted quartz sand with a high content of carbonate matrix or cement.

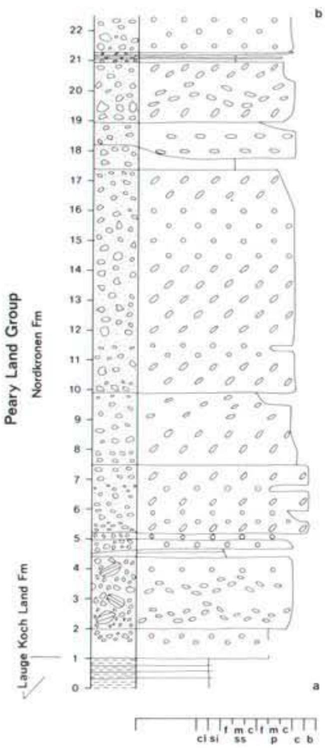


Fig. 115. Detailed sediment log of the type section (38) of the Nordkronen Formation (location figs 113, 114; plate 3, a–b).

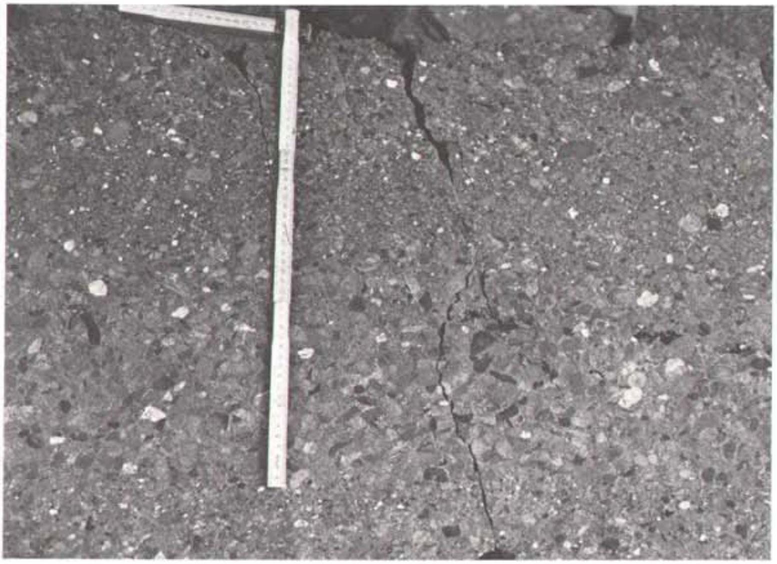


Fig. 116. Thin chert pebble conglomerate units of the Nordkronen Formation from the type section (figs 113, 114, plate 3).

The Nordkronen Formation is thus a sequence of turbidites dominated by resedimented chert pebble conglomerates.

Depositional environment. The Nordkronen Formation is taken to represent a

Fig. 117. Disorganised conglomerate of the Nordkronen Formation from the type section (figs 113, 114, plate 3).

Fig. 118. Sandstone and pebbly sandstone unit of the Nordkronen Formation from the type section (figs 113, 114, plate 3). Bar = 1 cm.

phase of eastern uplift, erosion and redeposition of chert pebble conglomerates in a fan or base-of-slope environment close to the eastern source regions. Chert pebble conglomerate deposition starts progressively later towards the west reflecting continued source area uplift and westwards progradation of the pebbly depositional system. The depositional mechanism seems mainly to have been very high density turbidity currents, transitional to grain flows as well as rare debris flows in the east.

Boundaries. The lower boundary is exposed in the flat topped hills to the south and east of Spøttrup Elv, and also in Nordkronen (figs 113, 114). The lower boundary of the formation is taken at the base of the first conglomerate bed which, in the scattered exposures over the whole region, is in marked contrast to the siltstone and mudstone turbidite units which occur below, belonging to the Lauge Koch Land Formation (fig. 114). The formation is the top unit in eastern and northern Peary Land. In western North Greenland the lower and upper boundary of the formation is taken at the base and top respectively of the first and last resedimented chert pebble conglomerate within the sandstone turbidites of the Lauge Koch Land Formation.

Distribution. The Nordkronen Formation which forms massive bluffs (fig. 119) outcrops on several small hill tops in Herluf Trolle Land, south-eastern Peary Land. A more general area of outcrop is probably present in this area, but it has not been delineated or mapped. Other outcrops of the formation are restricted to the hilltops of Nordkronen and Tordenskjold Fjeld. The formation also occurs on

Fig. 119. Base of the type section (figs 113, 114, plate 3) of the Nordkronen Formation showing the massive conglomerate beds.

northern Hendrik Ø, Castle Ø, Reef Ø and possibly the western coast of Wulff Land (P. R. Dawes, personal communication, 1981). It is not known west of Hendrik Ø.

Geological age. In spite of the coarse grain size of the formation numerous graptolites have been found in the type section. These are all restricted to one species *Monograptus ?priodon* indicating an Upper Llandovery to Middle Wenlock range. Considering regional facies relationships and their age, it appears likely that the Nordkronen Formation at the type locality belongs to the latter part of this age range, i.e. Middle Wenlock. In western North Greenland the age of the formation is not known precisely, but probably falls within the Wenlock to Lower Ludlow span. The resedimented chert pebbles contain Ordovician radiolarians.

Subdivisions. The Nordkronen Formation includes the Hendrik Ø Member of western North Greenland.

Hendrik Ø Member

new member

History. The presence of this conglomerate unit in western North Greenland was discovered by L. H. Beaumont on Castle Ø, during the Nares Expedition to the area (P. R. Dawes, personal communication, 1982). The member corresponds to the 'Hendrik Conglomerate' of Dawes (1966, 1976).

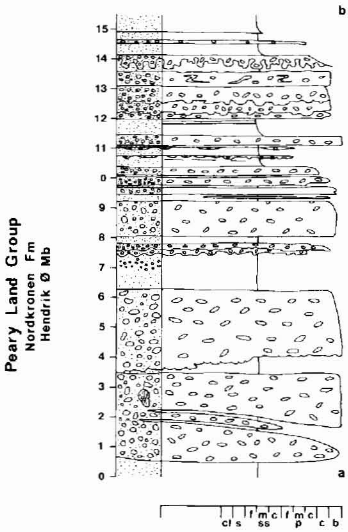
Name. After the island, Hendrik Ø, situated due north of Warming Land, in between Nyeboe Land and Wulff Land (plate 4).

Type and reference sections. The type and reference sections (figs 120, 121; plate 3, sections 13^1, 13^2 and 18) are located in the north-south directed valley at the north end of Hendrik Ø (figs 81, 122).

Thickness. Dawes (1966, 1976) stated that the conglomerate is up to 250 m thick. Our investigations indicate that the thickness of the Hendrik Ø Member is probably more in the order of 10 to 25 m (plate 3, sections 13^1, 13^2 and 18).

Lithology. The member is dominated by conglomerates and pebbly sandstone with subordinate sandstones. The conglomerate beds range in thickness from 10 cm to 2 m as tabular units, or with small scale channelled base, which are commonly loaded, emphasing the original channelled nature of the base (fig. 123). Individual conglomerate beds up to 2 m thick occur as big loads. Individual clast stringers follow the contours of the loads.

All conglomerates are composed predominantly of black, green and grey chert



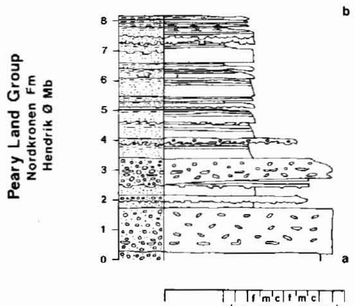


Fig. 121. Detailed sediment log of the reference section 13^2 of the Hendrik Ø Member of the Nordkronen Formation (see fig. 81; plate 3, a–b).

Fig. 120. Detailed sediment log of the type section 18 of the Hendrik Ø Member of the Nordkronen Formation (see fig. 81; plate 3, a–b).

Fig. 122. Type section of the Hendrik Ø Member (a) of the Nordkronen Formation (fig. 81; plate 3). Lauge Koch Land Formation (b). Cliff height approximately 10 m.

clasts (*c.* 90–95%), together with rare quartzite and very rare crystalline basement gneiss fragments set in a matrix of brown sandstone. The thinner conglomerate beds (10–20 cm) are typically composed of structureless, non-graded, fine to very fine pebble clasts. Units up to 50 cm thick are rarely composed of very coarse cobble clasts, and are typically non-graded, although grading to fine pebble clasts or rarely reverse grading occurs. Units of this thickness appear to be composed of many 'beds' with alternating coarser and finer pebble layers. Some units appear structureless, but sub-horizontal texture is characteristic. The thickest conglomerate beds (*c.* 2 m) are typically composed of coarse cobble clasts, normally structureless and non-graded, but rarely with weak grading, sub-horizontal orientation of clasts, internal loads and slumps. Ubiquitous loading and water escape structures, together with a possible original wavy texture, imply that textural measurements cannot be used for palaeocurrent analysis, and direction of transport is thus essentially unknown.

Pebbly sandstones and fine to very fine-grained sandstones occur in units up to 50 cm thick. They are normally graded and structureless, passing upwards into laminated silt ('Bouma sequences' Ta/e, Tab/e). Bases of beds are strongly loaded and only rarely planar.

Depositional environment. The conglomerates of this member contrast with the base-of-slope debris flow conglomerates of the Citronens Fjord and Freja Fjord Members in showing much greater affinity to the associated sandy turbidites. Emplacement by high-density turbidity currents with a basal grain-flow carpet is envisaged as the main depositional mechanism. The clasts may have been derived

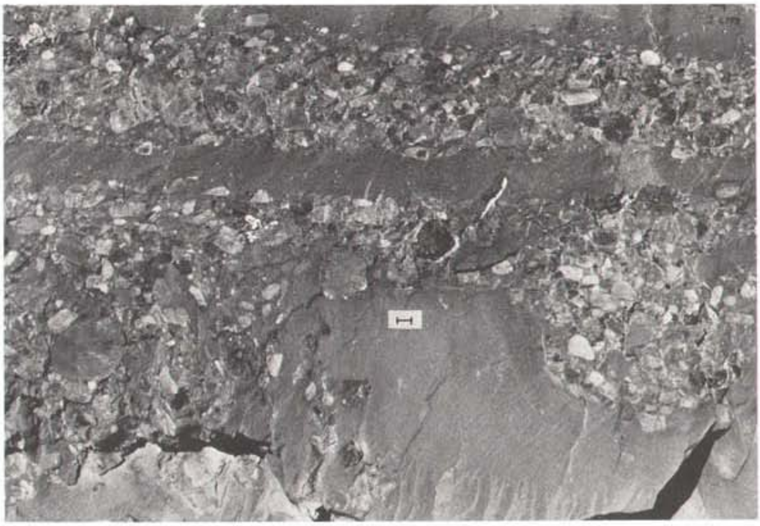


Fig. 123. Typical chert pebble conglomerate with loaded base and pebbly sandstone interbeds in the type section 18 of the Hendrik Ø Member of the Nordkronen Formation (plate 3). Bar = 1 cm.

from erosion of uplifted cherts of the Ordovician Amundsen Land Group of Friderichsen *et al.* (1982). Since the Lauge Koch Land Formation, with which the Hendrik Ø Member interdigitates, oversteps the Amundsen Land Group by hundreds of kilometres towards the south, it is most probable that the uplift took place at the eastern proximal part of the basin. This fits well with an eastwards increase in number, thickness and grain-sizes of chert conglomerates culminating in the Nordkronen Formation.

Boundaries. The lower boundary of the Hendrik Ø Member is taken at the base of the first resedimented chert pebble conglomerate above buff-yellow fine sandstone turbidites of the Lauge Koch Land Formation. Similarly, the top of the member is taken at the top of the last resedimented conglomerate, which is overlain by the fine sandstone turbidites of the Lauge Koch Land Formation. Both boundaries are exposed across the northern part of Hendrik Ø (fig. 81).

Distribution. The Hendrik Ø Member outcrops as a thin strip across the northern tip of Hendrik Ø (plate 4; fig. 81). A similar conglomerate on Castle Ø, Reef Ø and the western coast of Wulff Land (P. R. Dawes, personal communication, 1981) is probably the Hendrik Ø Member.

Geological age. There is no faunal evidence from the conglomerate to indicate age. The Repulse Havn Member of the Wulff Land Formation occurs at least 100 m stratigraphically above the Hendrik Ø Member in the Lower Ludlow. Consequently, all that can be definitely stated is that the Hendrik Ø Member predates known Lower Ludlow rocks, but could itself be Lower Ludlow. Taking into account regional considerations and its assumed association to the eastern outcrops of the Nordkronen Formation, it is unlikely to be of Llandovery or Early Wenlock age, and thus a general Middle Wenlock to Lower Ludlow age can be assumed.

General. The Hendrik Ø Member is defined essentially as a sandy turbidite unit characterised by resedimented chert pebble conglomerates.

In northern Hendrik Ø the Silurian rocks are folded and faulted. However, the river valley in which the type section of the Hendrik Ø Member occurs is essentially in sequence. In this valley two turbidite units characterised by resedimented chert pebble conglomerates occur. The lower one is the Hendrik Ø Member. Due to folding and faulting it is not known if the upper one is the same member or a discrete unit. For the purposes of this account it is only tentatively referred to the Hendrik Ø Member. It is anticipated that faunal control will never be precise enough to confirm or disprove the contemporaneity of the two units, and detailed structural mapping is probably the only tool which may solve the problem. If both units eventually prove to be separate from each other, we recommend that the upper turbidite unit characterised by resedimented chert pebble conglomerates be recognised as another member of the Nordkronen Formation, in line with the Hendrik Ø Member itself. The two resedimented chert pebble conglomerate units can both be traced from Hendrik Ø to the west coast of Wulff Land (Dawes, personal communication, 1981). They apparently do not occur west of Hendrik Ø.

The present known distribution of the Hendrik Ø Member of the Nordkronen Formation is isolated from the main outcrop of the Nordkronen Formation in Peary Land. The Hendrik Ø Member is considered part of the Nordkronen Formation because they are both dominated by chert pebble conglomerates which are products of a fundamental change in sedimentation patterns throughout the North Greenland deep-water basin. As such they are considered to be genetically related with the Hendrik Ø Member forming the distal fringe of the Nordkronen Formation.

It may never be possible to establish outcrop continuity between the Hendrik Ø Member and eastern outcrops of the Nordkronen Formation. Alternatively, the Hendrik Ø Member may be an isolated interdigitation of chert pebble conglomerate unrelated to the Nordkronen Formation. If so, it may be more logical to transfer the Hendrik Ø Member to the Lauge Koch Land Formation.

If there is continuity of outcrop of the Nordkronen Formation across North Greenland, then we recommend that the eastern limit of the Hendrik Ø Member is taken at the point where sediments primarily composed of pebbly sandstone turbidites and conglomerates (Hendrik Ø Member) are replaced by sediments primarily composed of conglomerates (Nordkronen Formation).

Chester Bjerg Formation

new formation

History. The formation partly corresponds to the uppermost of four informal subunits briefly described by Dawes (1976, p. 279).

Name. After the range of hills, Chester Bjerg, along the northern coast of Hall Land (plate 4).

Type area. No type section is defined as the sediments are so intensely folded and faulted that it was not possible to measure an accurate section. Due to the strong deformation it is in many areas difficult to discern primary sedimentary structures. The type area is on the dip slope of the sediments forming the northern cliffs of the Chester Bjerg, up to 5 km inland from Kap Ammen, northern Hall Land (fig. 82).

Thickness. Our investigations indicate that the formation is at least 500 m thick, whereas Dawes (1976) estimates at least 800 m.

Lithology. In the type area (fig. 82) the formation is dominated by laminated light grey mudstones, which weather to a light green colour. Sandy streaks are common, and thin silt laminae (both weather to a yellow colour) increase in abundance up the sequence in the type area. The mudstones contain abundant starved ripples and climbing ripples, and slumped sand units are common. Flutes and undetermined convex ridges occur rarely on the base of some rare, thin fine sandstone beds.

Dawes (1976, p. 279) reports that "Towards the top some thin fragmental limestone beds occur" in the western part of the outcrop belt in Hall Land.

Depositional environment. The Chester Bjerg Formation includes the youngest preserved sediments of the deep-water basin. The well-laminated nature of the sediments, the absence of trace fossils and the rarity of current produced structures suggest hemipelagic deposition in an anoxic environment in a period of waning turbidity current activity.

Boundaries. The lower boundary has not been observed, but it probably rests conformably on the underlying Lauge Koch Land Formation. The formation forms the top unit of the area (fig. 82; plate 4).

Distribution. The formation occurs in an east–west strip in northern Hall Land. It may extend to the west coast of Nyeboe Land (fig. 82; plate 4).

Geological age. In the type area no graptolites have been recorded. Near the west coast of Hall Land at Halls Grav, possibly within the general area of outcrop of the formation, *Monograptus* of the *M. vomerinus* group (Upper Llandovery to Wenlock range) (cf. Berry & Boucot, 1970) was collected, but due to general exposure, folding and faulting the collection cannot be confidently placed in the context of any formation. Indeed, Dawes (personal communication, 1981) suggests that it cannot yet be eliminated that the graptolites derive from a horizon in the top of the Lauge Koch Land Formation brought up in isoclinal folds or by faults, within the Chester Bjerg Formation. Further, evidence from northern Hall Land indicates that the Chester Bjerg Formation is younger than Lower Ludlow as it overlies the Repulse Havn Member of the Wulff Land Formation.

Graptolites from near the top of the formation in western Hall Land were identified as *Monograptus* sp. of *M. transgrediens* type and *Monograptus* cf. *M. aequabilis* (Berry, Boucot, Dawes & Peel, 1974). Berry *et al.* (1974, p. 12) indicated that "the presence of abundant monograptids similar to *M. transgrediens* indicates a Pridoli, probably later part of Pridoli, age. A single specimen closely similar to *M. aequabilis* indicates an earliest Devonian age from the strata from which it was collected". Jaeger (personal communication, 1980) recently re-identified *M.* cf. *M. aequabilis* as *Monograptus* cf. *M. transgrediens* Perner, probably of Pridoli (latest Silurian) age.

The graptolite horizon was overlain by strata containing supposed Devonian vertebrates which were assigned a Devonian age partly on the basis of the underlying graptolites (Bendix-Almgreen & Peel, 1974). Lane *et al.* (1980) described the trilobite *Hemiarges ethnikos* from sandstone boulders collected by Koch in the Newman Bugt area of Hall Land, western North Greenland. Re-examination of Koch's (1940) travel route indicates that the boulders probably derive from the outcrop area of the Chester Bjerg Formation, although not definitely from the formation itself. Although the trilobite is not diagnostic of age, Lane *et al.* (1980) conclude that comparative material indicates that Lower Pridoli rocks are represented in the Newman Bugt area. If this is so, regional considerations indicate that they are the Chester Bjerg Formation.

To summarise, the exact age of the base of the Chester Bjerg Formation is not known, but it cannot be older than Lower Ludlow. The top part of the formation is of Pridoli (latest Silurian) age. There is as yet no faunal evidence that the top of the formation, which is the topmost unit of western North Greenland as well as the youngest Lower Palaeozoic in North Greenland, extends into the Devonian. However, as there is a considerable sequence of strata above the last graptolite horizon, it is likely that the formation may just extend into the Devonian.

BASIN EVOLUTION

During the main part of the Ordovician the deep-water basin of North Greenland was characterized by deposition, partly under euxinic conditions, of black mudstones, cherts, thin-bedded turbidites and occasional resedimented chert and limestone conglomerates.

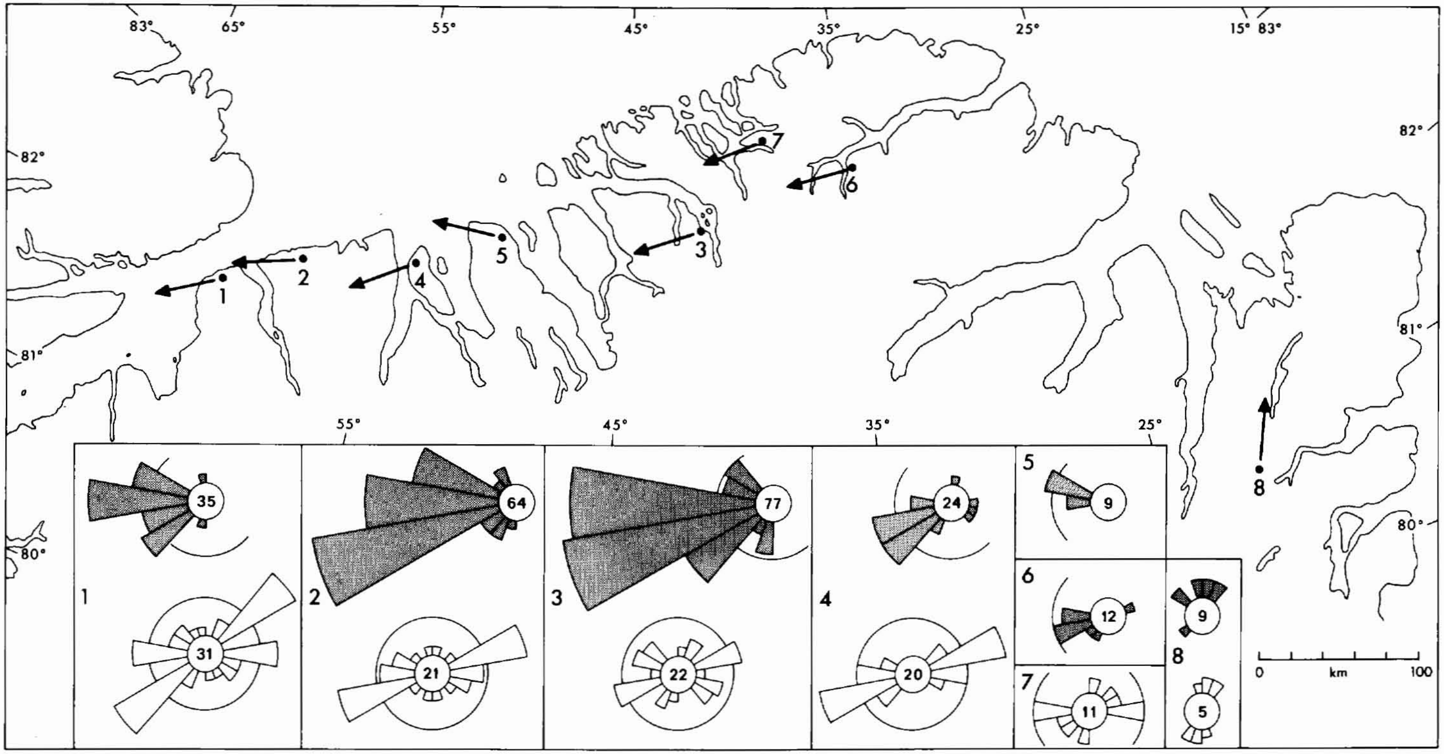


Fig. 124. Grouped palaeocurrent data of the Silurian turbidites. Stippled rose diagrams are directional measurements (e.g. flutes) and open rose diagrams are trend measurements (e.g. grooves).

A major phase of turbidite deposition was initiated in latest Ordovician time, and during the Silurian the basin received enormous quantities of clastic material primarily transported by turbidity currents, travelling from east to west following the basin axis (fig. 124). In the deepest, axial parts of the basin in Johannes V. Jensen Land (north Peary Land) the change in sedimentary regime was heralded by deposition of up to 30 m thick, non-graded sandstones deposited by catastrophic high-density turbidity currents (Sydgletscher Formation).

In the Peary Land area the early Silurian turbidite basin was limited to the south by the major E–W Navarana Fjord fault (fig. 2). This fault controlled the margin of the southern carbonate platform until the latest Llandovery. Further towards the west the platform-basin transition was situated north of the present northern coastline of North Greenland. The turbidite sequence from this period is grouped in the Merqujôq Formation, and deposition took place in basin plain followed by fan fringe and fan lobe environments. The top parts of the formation are characterized by numerous channels and scours representing braided midfan environments. The sequence was extremely sand-rich with sand:mud ratios approaching infinity, and the fan system was highly elongate in an east–west direction, with its southern margin merging into the slope deposits fringing the carbonate platform (fig. 2). The proximal portion of the system is not known, but the uniform palaeocurrent pattern indicates that the source area was the rising Caledonides to the east. Northwards flowing palaeocurrents in Kronprins Christian Land (fig. 124) suggest an additional turbidite system following the north–south orientated Caledonian front. These turbidites were deflected towards the west somewhere to the south-east of Peary Land, where they merged with the main fan system.

In the southern base-of-slope environment turbidite deposition was punctuated by thick resedimented conglomerates of the Citronens Fjord and Freja Fjord Members. The conglomerates are composed of clasts derived from the carbonates of the platform and were transported mainly by debris flows. They compare well with the debris sheets described by Crevello & Schlager (1980) from the Exuma Sound of the Bahamas. Some of the thicker conglomerate beds are overlain by very fine grained, thin-bedded turbidite sequences deposited by overflow of longitudinal low density turbidity currents draping the submarine topographic highs formed by the conglomerates.

In latest Llandovery time the carbonate platform collapsed in the Peary Land region, and deposition of clastic fine-grained sediments of the Thors Fjord Member of the Wulff Land Formation draped the foundering platform. This member is composed of black mudstones with thin turbidites and starved ripples, also probably of turbidite origin. The northernmost sediments are characterized by ubiquitous slumping, and upslope towards the south the sand component disappears. Towards the north the mudstones pass imperceptibly into the basin plain turbidites of the transition from the Merqujôq to the Lauge Koch Land Formation.

The Thors Fjord Member thus represents a slope sequence deposited partly under anoxic conditions during a major regional transgression mainly caused by the foundering of the carbonate platform.

Rapid subsidence continued, and deposition of mudstones gave way to the outer fan, fan fringe and deep-water basin plain turbidites of the Lauge Koch Land Formation. The southern margin of the expanded deep-water basin is not preserved in Peary Land due to later erosion. West of Freuchen Land the outer part of the platform foundered at approximately the same time as in Peary Land, and deposition of the overlying mudstones and turbidites of the Wulff Land and Lauge Koch Land Formations respectively was initiated in latest Llandovery time.

Towards the south and south-west, the Llandovery carbonate ramp (Hurst, 1980) subsided slowly. On this ramp carbonate buildups and top-of-slope mudstones with resedimented conglomerates of the Lafayette Bugt Formation were deposited. In Washington Land this subsidence phase was initiated earlier, in the Middle Llandovery, and slope mudstones and hemipelagic lime mudstones of the Lafayette Bugt Formation and Cape Schuchert Formation developed with carbonate buildups (Hurst, 1980).

Turbidite transport was still longitudinal, to the west (fig. 124), and the Lauge Koch Land Formation represents wide inner fan valleys, braided midfan, outer fan and basin plain environments. Grain size, bed thickness and sand:mud ratios decrease markedly towards the west. The turbiditic Lauge Koch Land Formation thus interfingers downcurrent with the basinal part of the Wulff Land Formation mudstones and upslope towards the south with the slope and rise part of the Wulff Land Formation mudstones (fig. 2). Further upslope, towards the south, the Wulff Land Formation mudstones interfinger with the top-of-slope Lafayette Bugt Formation. In the most distal western part of the turbidite basin in Hall Land turbidite units and mudstone sequences with thin-bedded discontinuous turbidites characteristically alternate. The latter are highly reminiscent of levée deposits, and it is tentatively suggested that deposition took place in wide deep-sea channels bounded by levées. The general trend of these channels was towards the west, but they are thought to have migrated laterally across the basin plain. The alternating coarse and fine-grained units are thus thought to correspond to channel and levée sequences respectively.

Turbidity current activity seems to have waned in the late Silurian, and the highest wedge of the Wulff Land Formation is the widespread, highly bioturbated Repulse Havn Member of early Ludlow age (fig. 2).

The general evolution of the Silurian deep-water basin reflects extensional tectonics, platform collapse and rapid subsidence. A phase of uplift in the source areas to the east of the basin was, however, initiated in mid-Wenlock time as demonstrated by the incoming of the thick chert pebble conglomerates of the Nordkronen Formation. The pebbles are well-rounded and well-sorted, indicating that the parent rock was lithified at the time of erosion and that considerable transport and sorting had taken place in the coastal zone before redeposition into deep water by turbidity and related currents. The chert pebbles were probably derived from an uplifted thick chert sequence of mainly Ordovician age (Vølvedal and Amundsen Land Groups), since no other known units contain sufficiently thick units of chert. The conglomeratic system prograded westwards with time and apparently reached the Hendrik Ø area in ?late Wenlock or early Ludlow time (Hendrik Ø Member). In these distal occurrences the conglomerates are finer grained, thinnerbedded and alternate with normal turbidites. Deposition of the conglomerates took place in the inner and midfan and base-of-slope environments in eastern Peary Land, while the western localities probably represent outer fan lobes.

However, the generally waning turbidity current activity continued. The youngest unit in the basin is the Chester Bjerg Formation, of latest Silurian and possibly Devonian age. It consists of laminated light grey, non-bioturbated mudstones deposited from muddy contour currents, very dilute turbidity currents, or nepheloid layers in a distal basin plain, which towards the south passed imperceptibly into the continental rise.

The geotectonic nature of the deep-water basin is not fully understood as the northern margin is unknown in North Greenland (Surlyk, 1982). One possibility is that the platform-basin transition represents a normal, passive margin of an ocean basin. The general setting, as visualised by Surlyk *et al.* (1980), suggests the presence of highly attenuated crust, possibly of transitional type beneath the basin. This is supported by Parsons' (1981) tentative interpretation of the spilite-serpentinite assemblage found in volcanic centres adjacent to the intrabasinal Harder Fjord fault zone as representing a marginal ocean-floor crust beneath the deep-water deposits. Continental type rocks are known to underlie the platform carbonates, but there is little direct evidence of the type of crust underlying the deep-water basin, although Soper *et al.* (1980, p. 96) accept that the deep-water basin is ensialic.

A remarkable feature of the basin is the longitudinal east to west transport of the turbidites parallel to the continental margin (fig. 124). This indicates the presence of a northern barrier of some sort. If the presence of a narrow ocean basin is accepted, the mid oceanic ridge would have been situated fairly close to the present-day north coast of Greenland. The elevated topography of the ridge would imply a southerly directed topographic gradient away from the ridge, changing to a northwards dipping continental slope and rise outside the platform. The intervening basinal axis probably followed the east–west axis of Johannes V. Jensen Land in Cambrian – Early Silurian time and may have been shifted southwards in later Silurian time. If this general hypothesis is correct, the basin can be seen as a close analogue to the deep turbidite basins described by Pilkey *et al.* (1980) from the Atlantic coast of the U.S.A.

An alternative hypothesis is that active spreading never occurred, and that the basin was formed by rift controlled subsidence of the area situated between the

System	Series	Subseries	Stage	Zone	BRITAIN (Rickards, 1976)	BORNHOLM (Bjerreskov, 1975)	CANADIAN CORDILLERA (Lenz, 1979)	CANADIAN ARCTIC (Jackson, 1978)	CANADIAN ARCTIC (Lenz, 1978)	N.W. CANADA (Lenz, 1980)	NEVADA - U.S.A. Berry & Murphy, 1975)	GERMANY (Jaeger, 1962)
SILURIAN	Pridoli							*Monograptus angustidens*			*Monograptus birchensis*	*M. transgradiens*
								Pristiograptus transgradiens				
								Monograptus bouceki			*Saetograptus willowensis*	
								Pristiograptus chelmiensis				
								Pristiograptus bugensius			*Monograptus* sp. of *M. transgradiens* type	
								Monograptus formosus				
	Ludlow		Ludfordian		Higher zones not recorded in Britain			*Saetograptus leintwardinensis primus*			*Bohemograptus bohemicus*	*M. dubius thuringicus*
					Bohemograptus proliferation			*Pristiograptus bohemicus*				
					Saetograptus leintwardinensis						*Saetograptus chimaera*	*M. leintwardinensis* & *M. fritschi linearis*
			Gorstian		*Pristiograptus tumescens*							*M. chimaera* & *M. scanicus*
					Lobograptus scanicus						*Saetograptus colonus*	
					Neodiversograptus nilsonni			*Neodiversograptus nilsonni*				*M. nilsonni* & *M. colonus*
	Wenlock	Gleedon	Homerian		*Monograptus ludensis*			Interregnum of *Pristiograptus dubius*		Beds with *Pristiograptus etheringtoni*	*Pristiograptus ludensis*	*Monograptus ludensis* & *Monograptus deubeli*
					Gothagraptus nassa			*Monograptus testis*	*Monograptus testis* & *Cyrtograptus lundgreni*	*Monograptus testis* & *Cyrtograptus lundgreni*	*Pristio dubius frequens*	
		Whitwell			*Cyrtograptus lundgreni*			*Cyrtograptus lundgreni*			*Monograptus testis*	*M. dubius / G. nassa* & *M. testis*
			Sheinwoodian		*Cyrtograptus ellesae*							*Cyrtograptus radians*
					Cyrtograptus linnarssoni			*Cyrtograptus perneri*	*Cyrtograptus perneri* ?	Beds with *Monograptus firmus nahanniensis*	*Cyrtograptus perneri*	
					Cyrtograptus rigidus			*Cyrtograptus rigidus*	*Cyrtograptus rigidus*	*Cyrtograptus rigidus*	*Cyrtograptus rigidus*	*Monograptus flexilis*
					Monograptus riccartonensis			*Monograptus riccartonensis*				
					Cyrtograptus murchisoni			*Cyrtograptus murchisoni*		Beds with *Cyrtograptus* cf. *perneri*		
					Cyrtograptus centrifugus	*Cyrtograptus centrifugus*	? *Cyrtograptus centrifugus*		*Cyrtograptus centrifugus*	*Cyrtograptus centrifugus*		*Cyrtograptus murchisoni*
	Llandovery	Upper	Telychian	C_6	*Monoclimacis crenulata*	*Cyrtograptus lapworthii*	*Cyrtograptus sakmaricus* & *Cyrtograptus laqueus*	*Stomatograptus grandis*	*Cyrtograptus sakmaricus* & *Cyrtograptus laqueus*	*Cyrtograptus sakmaricus* & *Cyrtograptus laqueus*	*Cyrtograptus* cf. *sakmaricus*	
						Monograptus spiralis						*Monograptus spiralis* (*Monograptus crenulatus*)
				C_5	*Monoclimacis griestoniensis*	*Monoclimacis griestoniensis*	*Monograptus spiralis*	*Monograptus spiralis*			*Monograptus spiralis*	*Monograptus griestoniensis*
				C_4	*Monograptus crispus*	*Monograptus crispus*						*Monograptus crispus*
			Fronian	C_{2-3}	*Monograptus turriculatus* / *Rastrites maximus*	*Monograptus turriculatus*	*Monograptus turriculatus*	*Monograptus turriculatus*				*Monograptus turriculatus*
				C_1	*Monograptus sedgwickii*		*Monograptus sedgwickii*	*Monograptus sedgwickii* & *Monograptus convolutus*				*Monograptus sedgwickii*
		Middle	Idwian	B_3	*Monograptus convolutus*	*Monograptus convolutus*	*Monograptus convolutus*					*Monograptus convolutus*
				B_2	*Monograptus argenteus*	*Monograptus gregarius*	*Monograptus argenteus*	*Monograptus millipeda*				*Monograptus gregarius*
				B_1	*Diplograptus magnus*		*Diplograptus magnus*	*Monograptus gregarius*				
					Monograptus triangulatus		*Monograptus triangulatus*					
		Lower	Rhuddanian	A_4	*Coronograptus cyphus*	*Monograptus revolutus*	*Coronograptus gregarius*	*Monograptus cyphus*				*Monograptus cyphus*
				A_3	*Lagarograptus acinaes*	*Monograptus acinaes*	*Lagarograptus acinaes*	*Diplograptus modestus* & *Glyptograptus* aff *G. trifilis*				*Orthograptus vesiculosus*
					Atavograptus atavus		*Atavograptus atavus*					
				A_2	*Orthograptus acuminatus*	*Akidograptus ? acuminatus*	*Orthograptus acuminatus*					*Akidograptus acuminatus*
				A_1	*Glyptograptus persculptus*	*Glyptograptus persculptus*	*Glyptograptus persculptus*					

carbonate platform and a northern landmass. If this landmass represented a volcanic arc, as appears to be the case with 'Pearya' in Ellesmere Island (Trettin & Balkwill, 1979), the basin was formed during the early rifting stages preceding true back-arc spreading. If, on the other hand, this hypothetic northern landmass is of normal continental nature, the basin compares well with the aulacogen model as it was formed by rifting, extends deeply into the old continental landmass and forms a right angle to the Caledonian front to the east (Hurst *et al.,* 1983; Surlyk, 1982).

BIOSTRATIGRAPHY

All formations of the Peary Land Group contain marine fossils. The only common forms are different species of graptolites, which often occur in great abundances in the more muddy or silty facies. Unfortunately, they are rare in the sandy turbidite sequences. Many graptolites are preserved as flattened carbon films, particularly in the more folded and faulted sequences. However, three-dimensional material is commonly preserved in the more limy mud rocks or even calcarenites.

The biostratigraphic scheme is based totally on graptolites. In some cases it has been possible to relate the Silurian sequences to the standard graptolite sequences of the British Isles (Rickards, 1976). Of much greater relevance is the Silurian graptolite zonation, which has become established in the Canadian Arctic over the last twenty years (Thorsteinsson, 1958; Lenz, 1978, 1979, 1980). A correlation of the various zones is shown in fig. 125.

Zonation

Orthograptus quadrimucronatus Zone

One collection of poorly preserved graptolites 20 m below the base of the Peary Land Group in Johannes V. Jensen Land suggests the presence of the *quadrimucronatus* Zone. The graptolites include *Climacograptus miserablis* and *Orthograptus* sp. resembling *O. quadrimucronatus.*

The diversity and abundance of species of the zone, together with the thickness and extent of the zone are not known.

Dicellograptus complanatus ornatus Zone

This latest Ordovician zone has not yet been recognised in North Greenland.

Fig. 125. Correlation of the various Silurian graptolite zones around the North American craton and in Europe.

Glyptograptus persculptus Zone

Probably equivalent to the *Diplograptus modestus* Zone (Jackson, 1978). At the present time it has not been recognised in North Greenland.

Orthograptus acuminatus Zone

Not yet known from North Greenland.

Atavograptus atavus Zone, *Lagarograptus acinaces* Zone, *Coronograptus cyphus* Zone

A single collection of graptolites from one locality in Johannes V. Jensen Land, north Peary Land, 60 m below the base of the Sydgletscher Formation (Peary Land Group) suggests the presence of one of these three zones (Surlyk *et al.*, 1980). The graptolites include *Climacograptus rectangularis* and *Atavograptus* aff. *A. atavus*. The diversity and abundance of species of the zone, together with the thickness and extent of the zone are not known.

Coronograptus gregarius Zone

Graptolites indicative of the upper part of this zone have been found in two collections from one locality in the Cape Schuchert Formation of Washington Land, western North Greenland. Diversity and abundance of species is high, including: *Pseudoclimacograptus (Clinoclimacograptus) ?washingtoni, Petalograptus minor, Pribylograptus ?leptotheca, Monograptus argenteus, Monograptus kochi* and *Monograptus teicherti* indicating the *argenteus* Zone (Bjerreskov, 1981).

The zone occurs in the Cape Schuchert Formation of Washington Land, and although its thickness is not known, it can only be in the order of several metres at maximum.

The two lowermost subzones (British Standard), *triangulatus* and *magnus* are included in the *gregarius* Zone. In North Greenland there is no evidence of either subzone.

Monograptus convolutus Zone

This zone is known from two collections in two separate localities from the very base of the Lafayette Bugt Formation of Washington Land. The zone may also be represented in central Hall Land, probably in the Lafayette Bugt Formation (cf. Etheridge, 1878), and also in the Citronens Fjord Member of the Merqujôq Formation in Peary Land. There is little evidence as to the exact thickness of the zone, but it can only be in the order of several metres at maximum in most areas; it possibly reaches several hundred metres in the Citronens Fjord Member.

Diversity and abundance of species is high. Species known from the zone include *Pseudoclimacograptus (Metaclimacograptus) hughesi, ?Glyptograptus (Pseudoglyptograptus)* sp., *Pristiograptus regularis regularis, Pribylograptus leptotheca, Monoclimacis ?crenularis, Monograptus* sp., *Monograptus ?decipiens, Monograp-*

tus lobiferus lobiferus, Monograptus convolutus, Monograptus cf. *M. concinnus, Monograptus* cf. *M. pandus, Monograptus sedgwickii* and *Rastrites* sp.

Monograptus sedgwickii Zone. The zone has not yet been recognised in North Greenland, but evidence from Arctic Canada (Jackson, 1978) suggests it may be inseparable from the *convolutus* Zone.

Monograptus turriculatus Zone

This zone has been documented in several collections at several different localities ranging from Washington Land to Warming Land, western North Greenland. It has only been located in the Lafayette Bugt and Cape Schuchert Formations, and the thickness of the zone, although not known in detail, is in the order of 10 to 20 m.

The index fossil is never common, but the diversity of species is high, including *Petalograptus ?conicus, Pristiograptus bjerringus schucherti, Monograptus exiguus* ?n. ssp., *Monograptus exiguus primulus, Monograptus planus, Monograptus* aff. *M. proteus, Monograptus rickardsi* ?n. ssp. and *Monograptus turriculatus.*

Monoclimacis griestoniensis Zone

As Lenz (1979) pointed out it has long been known that a thick *Monograptus spiralis* Zone occurs above the *turriculatus* Zone in Arctic Canada, and that this zone appears to equate with the *crispus, griestoniensis* and *crenulata (spiralis)* Zones of Britain. There is no evidence of the *crispus* Zone in North Greenland. However, a single collection of well preserved graptolites from the lowest part of the Profilfjeldet Member of the Lauge Koch Land Formation of Kronprins Christian Land suggests the presence of the *griestoniensis* Zone or, at the youngest, lowest *spiralis* Zone. There is no evidence as to the thickness of the zone. Species recorded include ?*Dictyonema* sp., *Monoclimacis griestoniensis, Monoclimacis* aff. *M. crenulata, Monograptus* aff. *M. richardsi minor* or very early *Monograptus priodon, Monograptus spiralis* and *Monograptus* sp.

Monograptus spiralis Zone

This zone is represented by numerous collections from every major land area in North Greenland, from the Lafayette Bugt Formation, Wulff Land Formation and Lauge Koch Land Formation. It is undoubtedly the thickest Silurian graptolite zone, in the order of 100 to 500 m. The index species is common and widespread and occurs together with the most abundant and diverse fauna of any zone, including *Retiolites geinitzianus geinitzianus, Retiolites geinitzianus angustidens, Stomatograptus grandis grandis, Stomatograptus grandis major, Pristiograptus ?dubius, Pristiograptus* sp., *Monoclimacis vomerina vomerina, Monograptus priodon, Monograptus parapriodon, Monograptus* aff. *M. speciosus, Monograptus* aff. *M. dextrorsus, Monograptus* aff. *M. tullbergii.*

Cyrtograptus sakmaricus-Cyrtograptus laqueus Zone

Originally this zone, which is only known from the Cordillera and Arctic parts of North America, was included in the underlying zone. Due to the work of Jackson & Etherington (1969) and later Berry & Murphy (1975), Carter & Churkin (1977) and Lenz (1978, 1979), the individuality and extent of this zone has been recognised.

In North Greenland it is known from many collections across the whole area in the Lafayette Bugt Formation, Wulff Land Formation and Lauge Koch Land Formation. It is not possible to give accurate estimates of the thickness of the zone, but it is probably in the order of a few metres rather than tens of metres. As Lenz (1979) pointed out, age assignment of the zone is difficult, but it is considered to be of latest Llandovery age due to the common occurrence of species known from the previous *spiralis* Zone. The *sakmaricus-laqueus* Zone probably correlates with the *Stomatograptus grandis* Zone of Jackson (1978).

The fauna of this zone is diverse and abundant in number of individuals. *Retiolites geinitzianus geinitzianus, Retiolites geinitzianus angustidens* and *Stomatograptus grandis grandis* are common and ubiquitous, more so than in the underlying *spiralis* Zone. Other species include *Monoclimacis vomerina vomerina, Monograptus priodon, Monograptus parapriodon, Monograptus ?praecedens, Monograptus ?tullbergi, Monograptus spiralis, Cyrtograptus lapworthi, Cyrtograptus sakmaricus, Cyrtograptus laqueus* and *?Barrandeograptus* sp.

Cyrtograptus centrifugus Zone

There is no evidence of this earliest Wenlock graptolite zone in North Greenland.

Cyrtograptus murchisoni Zone

Not yet recorded from North Greenland.

Monograptus riccartonensis Zone

A single collection from the middle of the Lafayette Bugt Formation in Wulff Land yielded a fauna which may indicate this zone. Species recorded include *Monoclimacis vomerina* (very slender form), *Monograptus priodon* and *Monograptus ?riccartonensis.* Two collections made by Lauge Koch from the Lafayette Bugt Formation of Washington Land may also indicate the presence of the zone (see Bjerreskov, 1981). No other information is known about this zone except that it can only be several metres thick at most.

Cyrtograptus rigidus Zone

This zone is only tentatively identified in Kronprins Christian Land, eastern North Greenland.

Monograptus flexilis Zone (= *Cyrtograptus linnarssoni* Zone)

One collection from the top of the Thors Fjord Member of the Wulff Land Formation in Peary Land is the only evidence to date of this zone. Species recorded include *Monograptus flexilis flexilis*, *Monograptus* aff. *M. riccartonensis*, *Monograptus* sp. and *Cyrtograptus* sp. No other information is known regarding the zone.

Cyrtograptus lundgreni Zone (= *Monograptus testis* Zone)

A single collection from the Lauge Koch Land Formation of Nyeboe Land contains *Cyrtograptus* sp. aff. *C. mancki*, which may indicate the presence of this zone.

Interregnum of *Pristiograptus dubius nassa*

Recognisable in the Canadian Arctic, but no evidence of it yet exists in North Greenland. The *P. dubius* interregnum is apparently the topmost zone of the Wenlock in the Canadian Arctic and there is no mention of the *Monograptus ludensis* Zone from the type area for the Wenlock (see Jackson, 1978). In Greenland no evidence of the *M. ludensis* Zone exists.

Neodiversograptus nilssonni Zone

This basal Ludlow zone is probably represented by one collection from the Wulff Land Formation in Wulff Land, western North Greenland, including the species *Pristiograptus ?dubius*, *Saetograptus ?colonus* and *Neodiversograptus nilssonni*.

Bohemograptus bohemicus Zone

The zone is probably represented by several collections from the Lafayette Bugt Formation of Washington Land and from the Repulse Havn Member of the Wulff Land Formation in Nyeboe Land and Hendrik Ø. *Pristiograptus dubius dubius*, *Pristiograptus dubius ?ludlowensis*, *Monoclimacis* sp., *Saetograptus fritschi* and *Bohemograptus bohemicus tenuis* are rare, whilst *Bohemograptus bohemicus bohemicus* is widespread and fairly common. This zone may be represented in sediments up to 200 m thick, and it is widely distributed throughout western North Greenland.

Monograptus leintwardinensis primus Zone

This is the uppermost Ludlow zone of the Canadian Arctic (Jackson, 1978). No evidence of it exists in North Greenland.

Monograptus formosus, *Pristiograptus bugensius*, *Pristiograptus chelmiensis* and *Monograptus bouceki* Zones

No evidence of these Canadian Arctic Pridoli zones has yet been found in North Greenland.

Pristiograptus transgrediens Zone

This Upper Pridoli zone is represented by one graptolite collection from the Chester Bjerg Formation of Hall Land. The only graptolites known are *Pristiograptus* cf. *P. transgrediens.*

Monograptus angustidens Zone

The highest Pridoli zone has not yet been recognised in North Greenland.

Approximately half of the Silurian graptolite zones known from Arctic regions can be positively identified in the Peary Land Group of North Greenland. There is no direct evidence of gaps or non-sequences, and with further collecting most zones can be expected to occur. Of particular note is (1) the thin nature of the Middle Llandovery zones; (2) the thicker *turriculatus* Zone and extremely thick *spiralis* Zone of the Upper Llandovery; (3) the very diverse and widespread *Cyrtograptus sakmaricus-Cyrtograptus laqueus* Zone; (4) the absence and evidently thin nature of the Wenlock zones; and (5) the paucity of evidence concerning Upper Ludlow and Pridoli zones.

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Addendum

Some of the fossils collected by the Greenarctic Consortium are now housed in the Paleontological Collections, University of Alberta, Edmonton, Canada. Recently Dr. B. Jones has relocated all the specimens referred to under the geological age discussion of the Citronens Fjord Member and informed us that no new locality data on the specimens are yet available. He has kindly offered to investigate whether it is possible to accurately locate the specimens, which will also require re-identification.

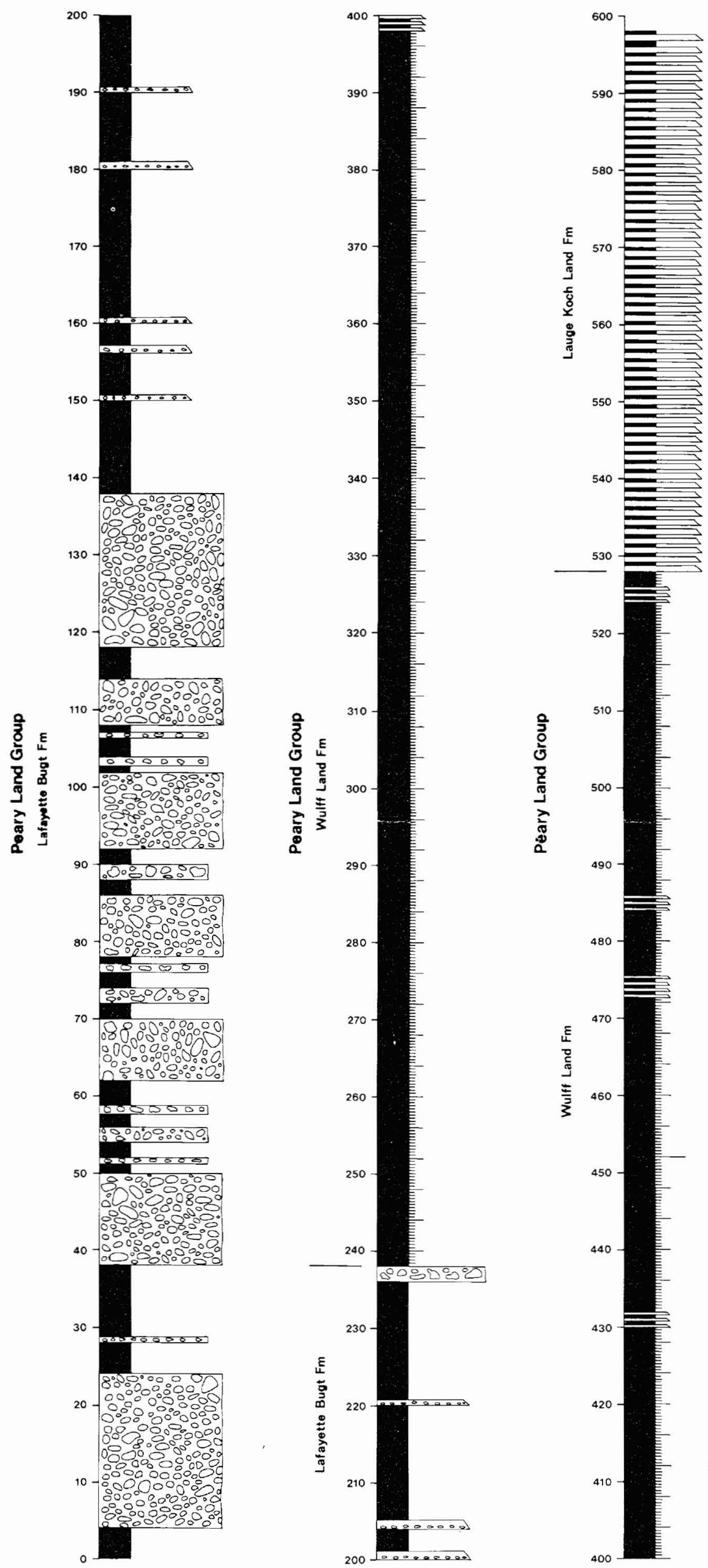
Thus, in this connection it is emphasised that the base of the Citronens Fjord Member cannot be conclusively shown to extend down into the Middle Llandovery.

Plate 1. Facies logs of the main sections forming the basis of this report. Section numbers are not continuous as they were designated during field work and for convenience and future reference are maintained.

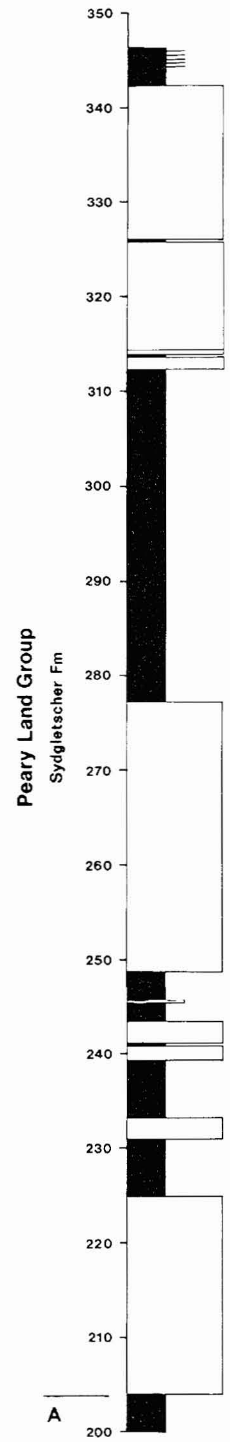
Plate 2. Facies logs of the main sections forming the basis of this report. Section numbers are not continuous as they were designated during field work and for convenience and future reference are maintained.

Plate 3. Facies logs of the main sections forming the basis of this report. Section numbers are not continuous as they were designated during field work and for convenience and future reference are maintained.

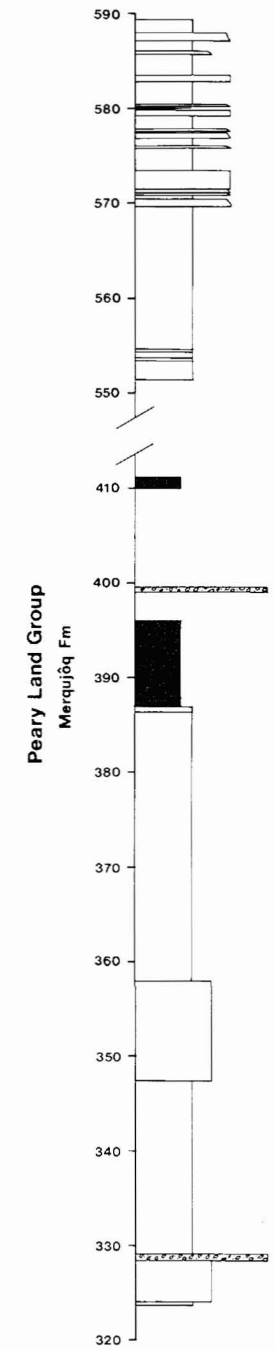
Plate 4. Geological map showing the distribution of the component formations and members of the Peary Land Group in western North Greenland, as well as localities mentioned in the text. Figures refer to geological maps in the text, including 1 (fig. 19), 2 (fig. 80), 3 (fig. 81) and 4 (fig. 17). Northernmost Nyeboe Land following Dawes (1982). Northernmost Hall Land is greatly simplified.



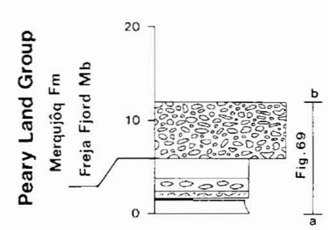
Section 14 measured by Hurst in 1978, showing the Llandovery to Wenlock Lafayette Bugt Formation, the type section of the Wenlock to Ludlow Wulff Land Formation and the Ludlow Lauge Koch Land Formation, in central Wulff Land (figs 17, 18).



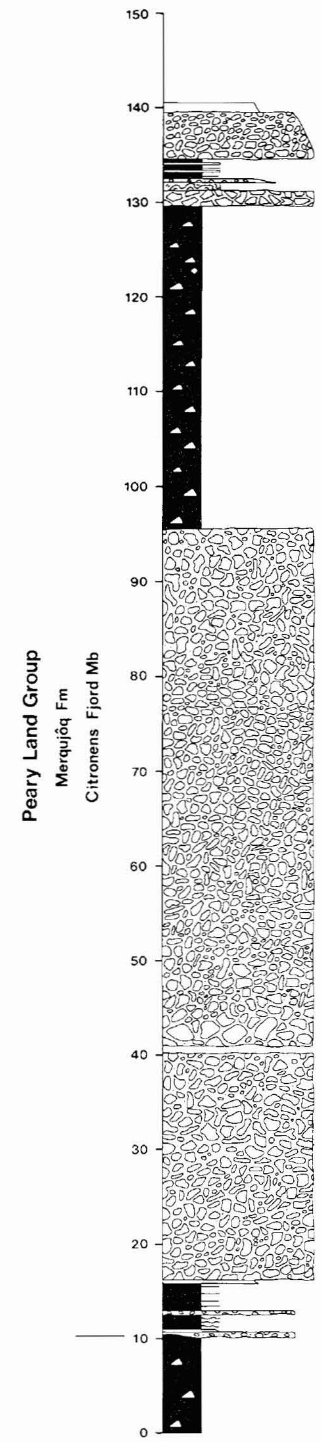
Section 31 measured in 1979, showing the type section of the Llandovery Sydgletscher Formation in Johannes V. Jensen Land (figs 8, 9). A = top part of the Amundsen Land Group (Friderichsen *et al.* 1982).



Section 10 measured in 1979, showing a reference section of the Llandovery Merqujôq Formation in Amundsen Land (fig. 29).

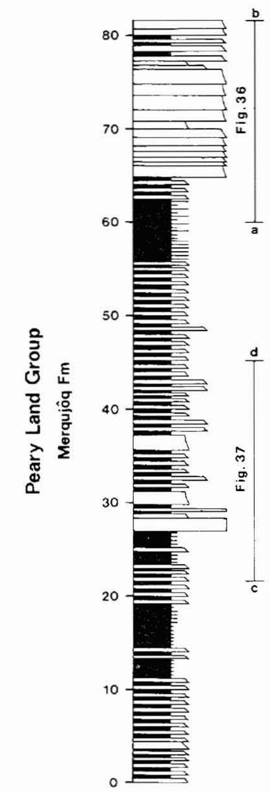


Section 35 measured in 1979, showing the Llandovery Freja Fjord Member of the Merqujôq Formation of north central Peary Land (figs 11, 35). Line a–b indicates that part of the section which has been expanded and incorporated in the text under the appropriate figure.

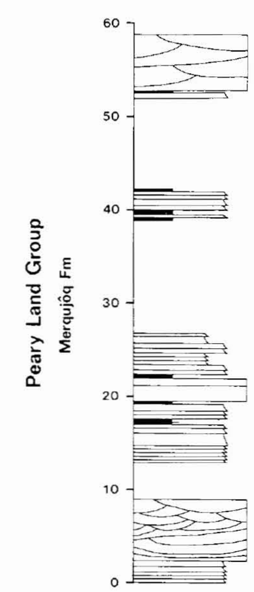


Section 33 measured in 1979, showing the type section of the Llandovery Citronens Fjord Member of the Merqujôq Formation of north central Peary Land (figs 58, 59).

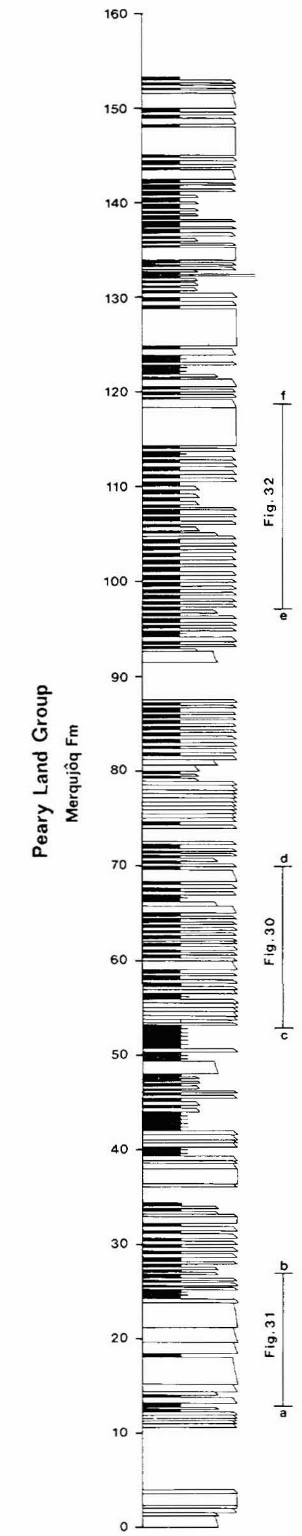
Section 37 measured in 1979, showing reference section in the Llandovery Merqujôq Formation of north-east Peary Land (fig. 103). Lines a–b and c–d indicate parts of the section which have been expanded and incorporated in the text under the appropriate figure.



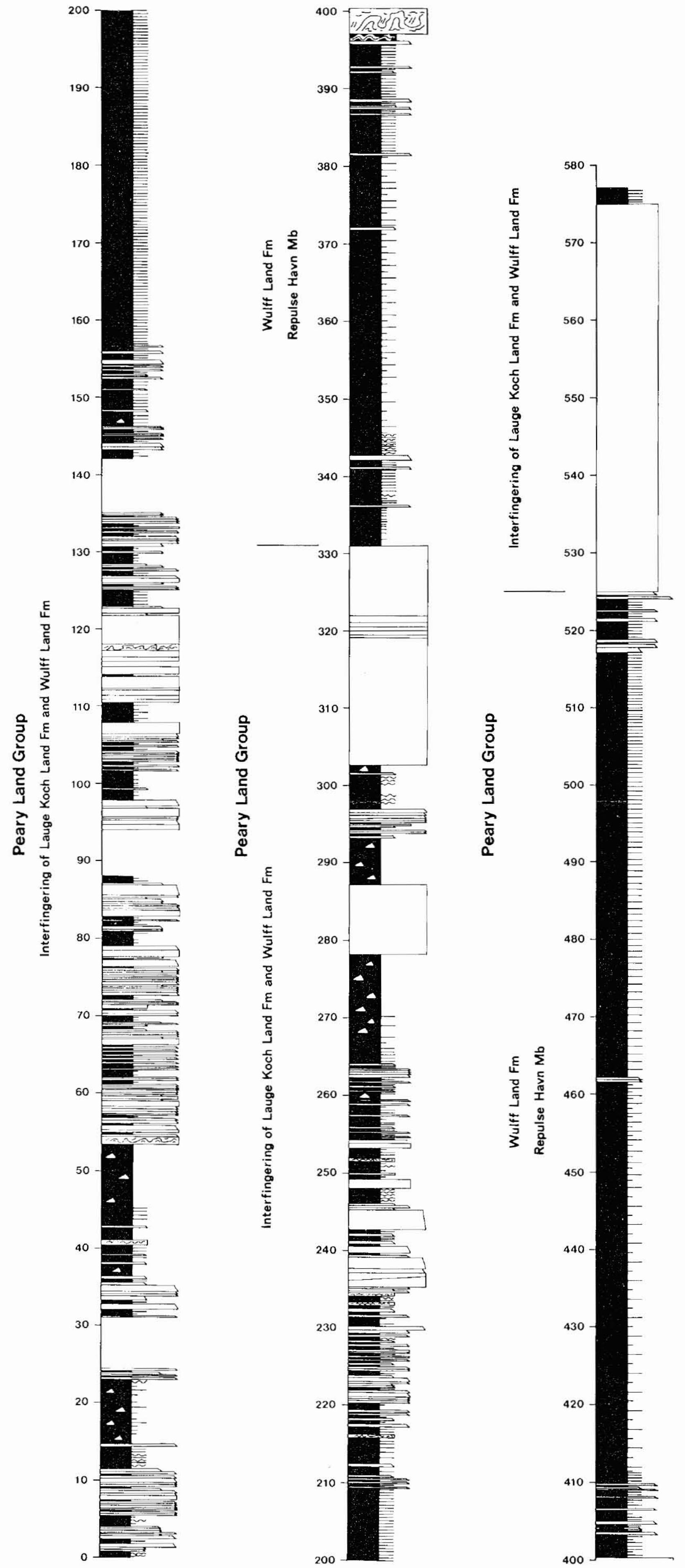
Section 37 measured in 1979, showing reference section in the Llandovery Merqujôq Formation of north-east Peary Land (fig. 103). Lines a–b and c–d indicate parts of the section which have been expanded and incorporated in the text under the appropriate figure.

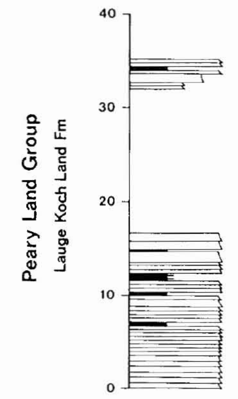


Section 5 measured in 1979, showing a reference section through the Llandovery Merqujôq Formation in eastern Lauge Koch Land (figs 27, 28).

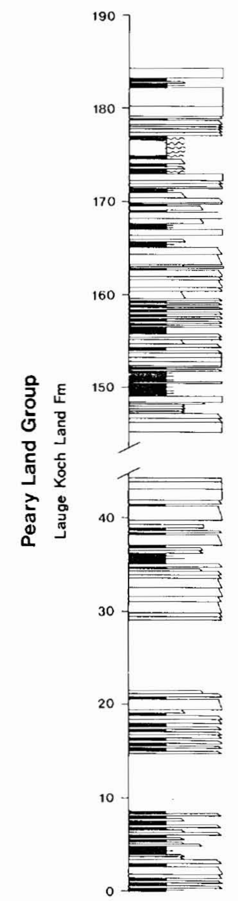


Section 1 measured in 1979, showing the type section of the Llandovery Merqujôq Formation in eastern Lauge Koch Land (figs 27, 28). Lines a–b, c–d and e–f indicate parts of the section which have been expanded and incorporated in the text under the appropriate figure.



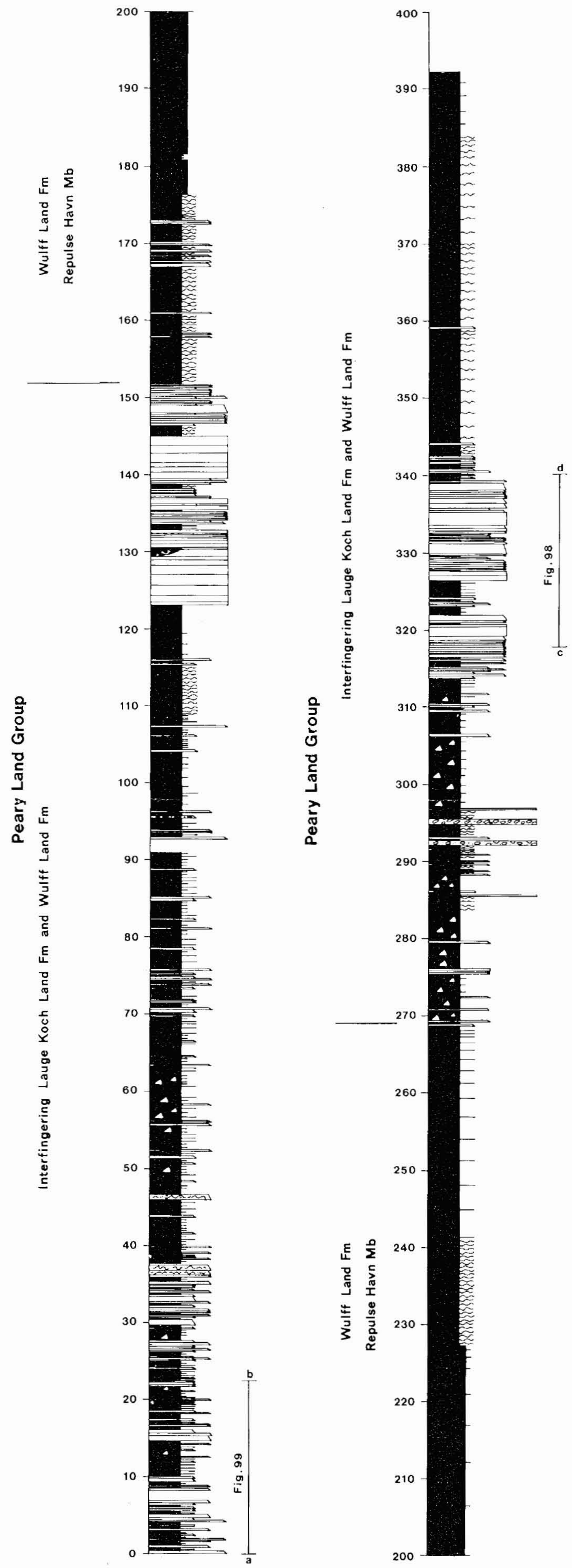


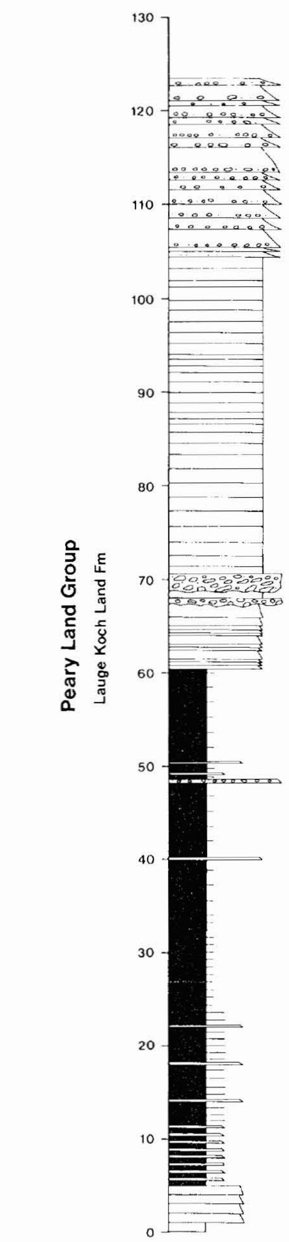
Section 4 measured in 1979, showing the Llandovery part of the Lauge Koch Land Formation type section in eastern Lauge Koch Land (figs 27, 28).

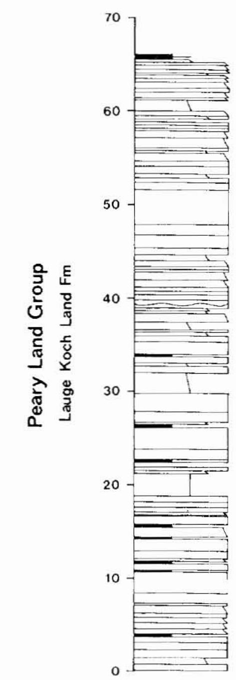


Section 21 measured in 1979, showing a reference section through part of the Lauge Koch Land Formation in northern Nyeboe Land (figs 79, 80).

Section 22 measured in 1979, showing reference sections through interfingering Lauge Koch Land Formation and Wulff land Formation (Llandovery to Ludlow) as well as the type section of the Repulse Havn Member of the Wulff Land Formation in northern Nyeboe Land (figs 79, 80).

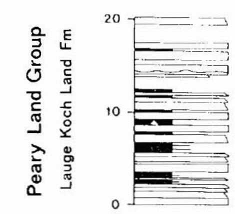




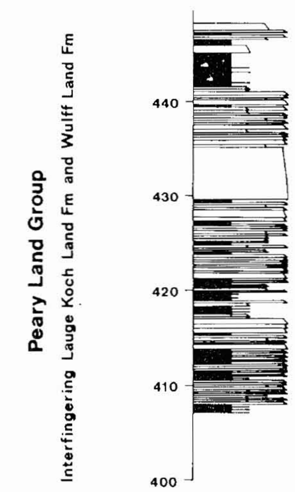


Section 16 measured in 1979, showing a reference section through the Ludlow part of the Lauge Koch Land Formation of northern Hendrik Ø (fig. 81).

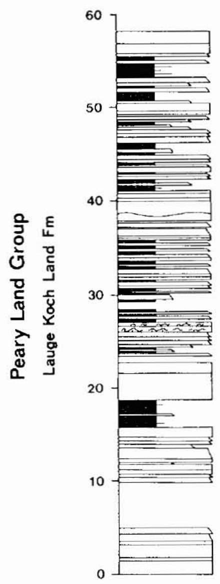
Section 34 measured in 1979, showing a reference section through the Llandovery to Wenlock part of the Lauge Koch Land Formation in north-east Peary Land (figs 103, 104).



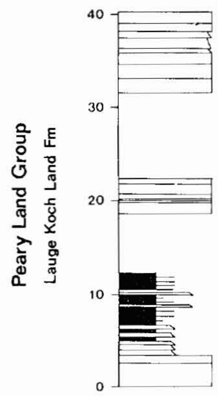
Section 12 measured in 1979, showing a reference section through the Ludlow part of the Lauge Koch Land Formation in northern Hendrik Ø (fig. 81).



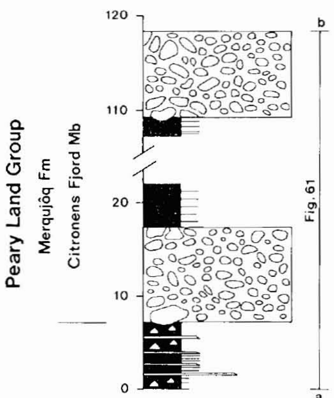
Section 19 measured in 1979, showing a reference section through interfingering Lauge Koch Land Formation and Wulff Land Formation (Llandovery to Ludlow) and a reference section through the Repulse Havn Member of the Wulff Land Formation in northern Hall Land (figs 78, 82). Lines a–b and c–d indicate parts of the section which have been expanded and incorporated in the text under the appropriate figure.



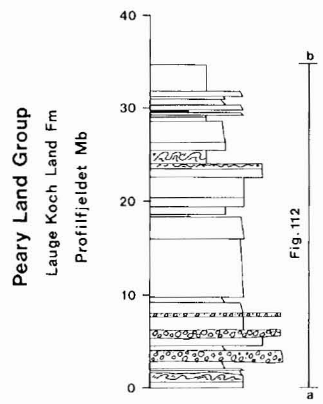
Section 15 measured in 1979, showing a reference section through the Ludlow part of the Lauge Koch Land Formation in northern Hendrik Ø (fig. 81).



Section 14 measured in 1979, showing a reference section through the Ludlow part of the Lauge Koch Land Formation in northern Hendrik Ø (fig. 81).

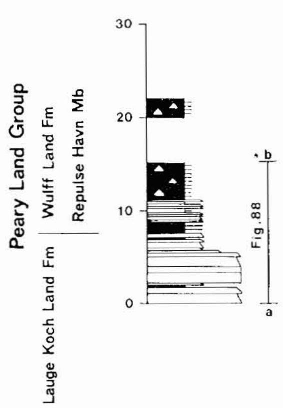


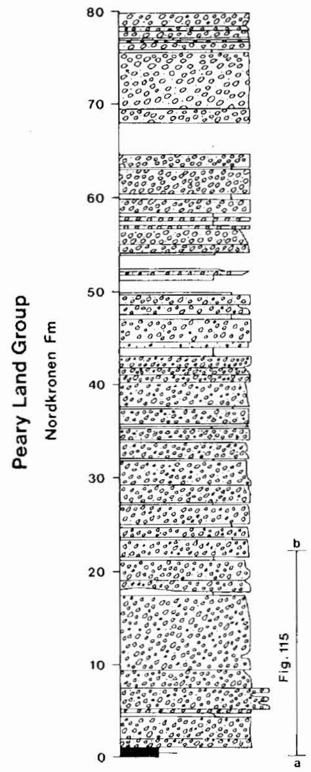
Section 36 measured in 1979, showing a reference section through the Llandovery Citronens Fjord Member in north central Peary Land (fig. 60). Line a–b indicates that part of the section which has been expanded and incorporated in the text under the appropriate figure.



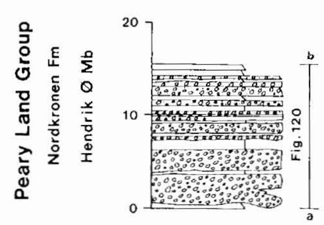
Section 8 measured by Hurst and McKerrow in 1980, showing the type section of the Profilfjeldet Member of the Lauge Koch Land Formation in central Kronprins Christian Land (figs 110, 111). Line a–b indicates that part of the section which has been expanded and incorporated in the text under the appropriate figure.

Section 17 measured in 1979, showing a reference section for the Ludlow part of the Lauge Koch Land Formation and the Ludlow Repulse Havn Member of the Wulff Land Formation, and the transition between the two, in northern Hendrik Ø (fig. 81). Line a–b indicates that part of the section which has been expanded and incorporated in the text under the appropriate figure.

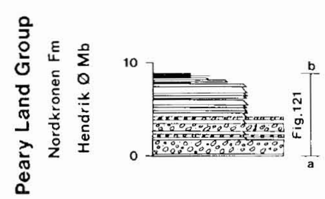




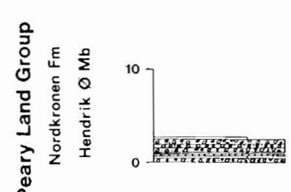
Section 38 measured in 1979, showing the type section of the Wenlock Nordkronen Formation in central Peary Land (figs 113, 114). Line a–b indicates that part of the section which has been expanded and incorporated in the text under the appropriate figure.



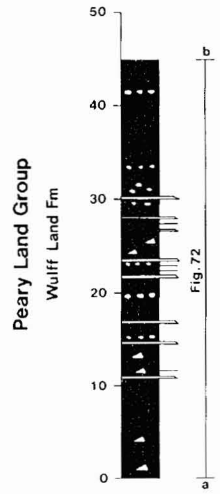
Section 18 measured in 1979, showing the type section of the ? Ludlow Hendrik Ø Member of the Nordkronen Formation in northern Hendrik Ø (fig. 81). Line a–b indicates that part of the section which has been expanded and incorporated in the text under the appropriate figure.



Section 13[2] measured in 1979, showing a reference section through the ? Ludlow Hendrik Ø Member of the Nordkronen Formation in northern Hendrik Ø (fig. 81). Line a–b indicates that part of the section which has been expanded and incorporated in the text under the appropriate figure.

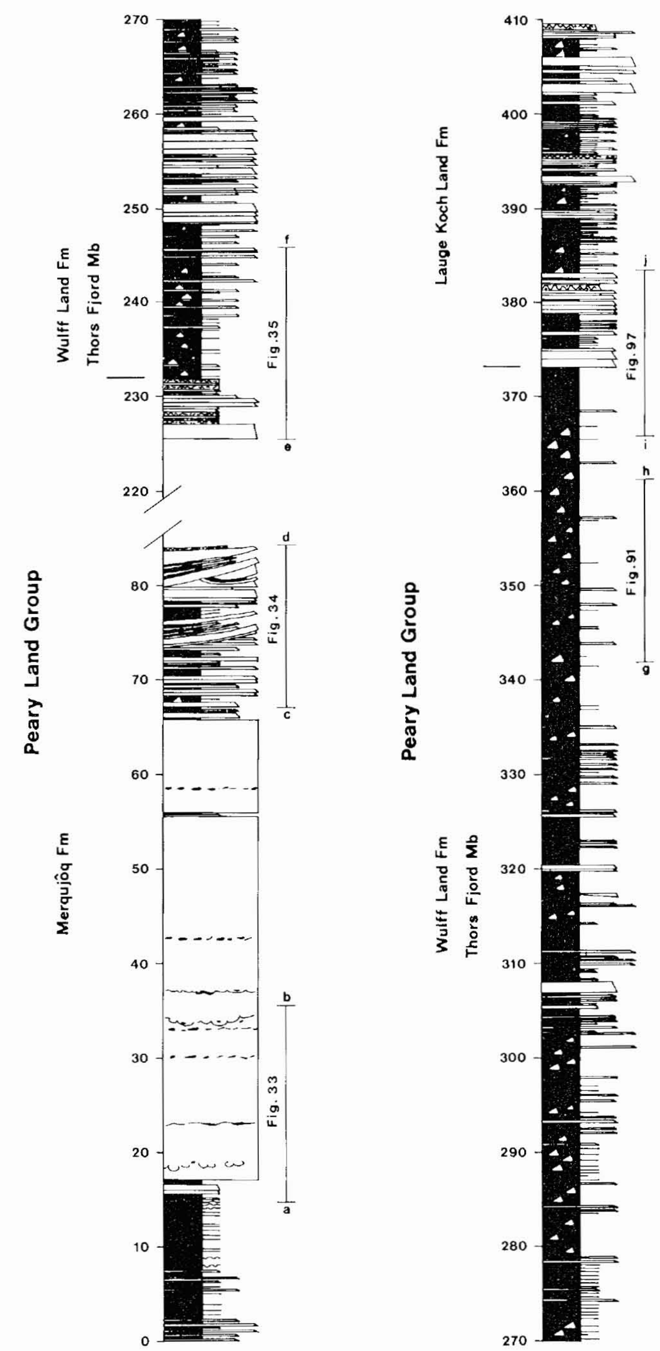


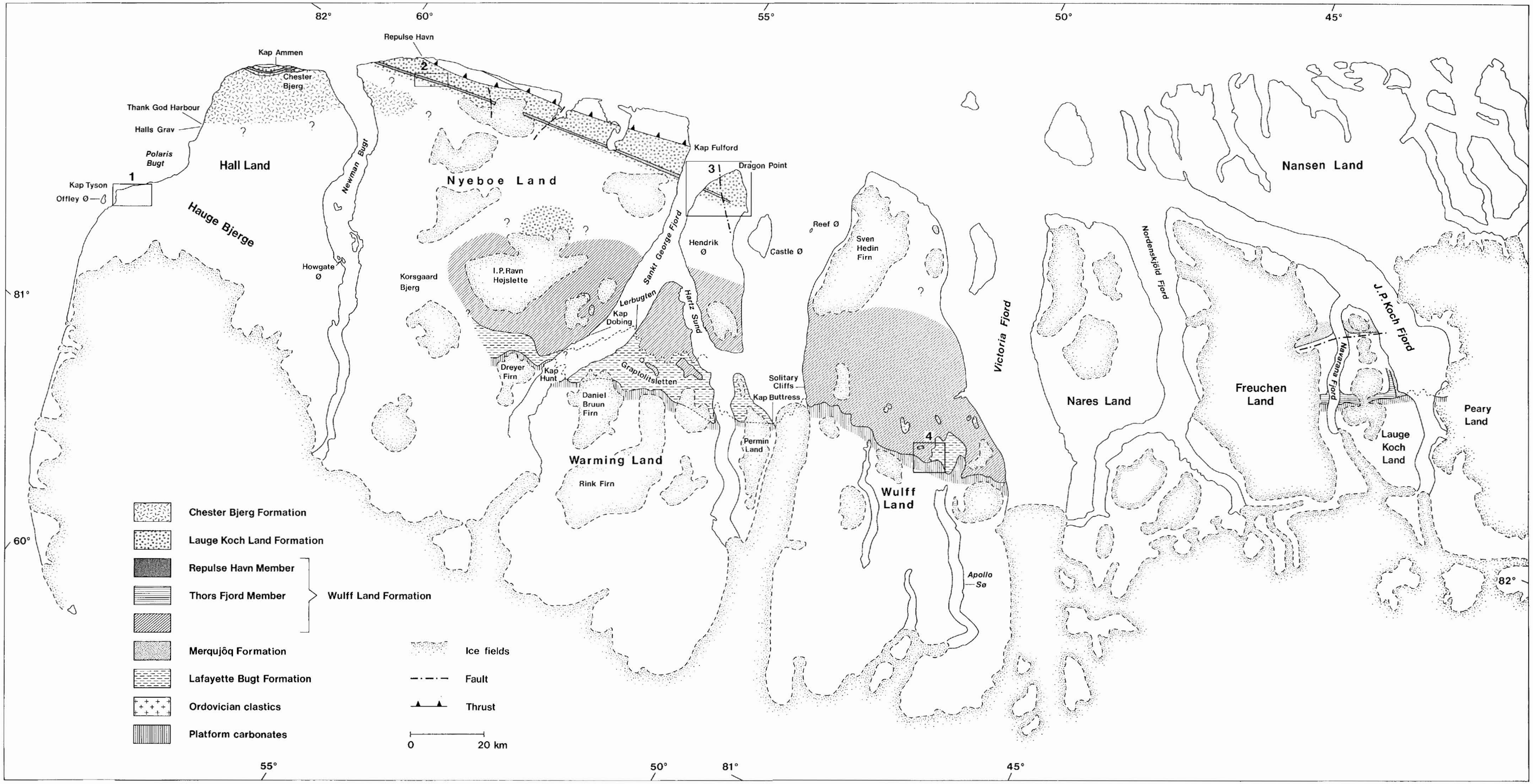
Section 13[1] measured in 1979, showing a reference section through the ? Ludlow Hendrik Ø Member of the Nordkronen Formation in northern Hendrik Ø (fig. 81).



Section 23 measured in 1979, showing a reference section through the Ludlow part of the Wulff Land Formation in the eastern part of Nyeboe Land (figs 76, 76). Line a–b indicates that part of the section which has been expanded and incorporated in the text under the appropriate figure.

Section 32 measured in 1979, showing a reference section for the Llandovery Merqujôq Formation, the type section for the Wulff Land Formation and a reference section for the Lauge Koch Land Formation and the boundaries between them, in north central Peary land (fig. 89). Lines a–b, c–d, e–f, g–h and i–j indicate parts of the section which have been expanded and incorporated in the text under the appropriate figure.




82°
60°
55°
50°
45°
81°
60°
82°
55°
50°
81°
45°
Repulse Havn
Kap Ammen
Chester Bjerg
Thank God Harbour
Halls Grav
Polaris Bugt
Hall Land
Kap Tyson
Offley Ø
Hauge Bjerge
Newman Bugt
Nyeboe Land
Howgate Ø
Korsgaard Bjerg
I. P. Ravn Højslette
Kap Fulford
Dragon Point
Sankt George Fjord
Hendrik Ø
Castle Ø
Reef Ø
Sven Hedin Firn
Lerbugten
Kap Dobing
Hartz Sund
Dreyer Firn
Kap Hunt
Graptolitsletten
Daniel Bruun Firn
Solitary Cliffs
Kap Buttress
Permin Land
Warming Land
Rink Firn
Wulff Land
Victoria Fjord
Apollo Sø
Nares Land
Nordenskjöld Fjord
Freuchen Land
J.P. Koch Fjord
Navarana Fjord
Lauge Koch Land
Peary Land
Nansen Land
Chester Bjerg Formation
Lauge Koch Land Formation
Repulse Havn Member
Thors Fjord Member
Wulff Land Formation
Merqujôq Formation
Lafayette Bugt Formation
Ordovician clastics
Platform carbonates
Ice fields
Fault
Thrust
0
20 km