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Silurian stratigraphy and facies distribution in Washington Land and western Hall Land, North Greenland

by

John M. Hurst

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Abstract

A new lithostratigraphic scheme is erected for the Silurian rocks of Washington Land and western Hall Land, North Greenland. The lowermost Silurian sediments are grouped with underlying Ordovician rocks in the Morris Bugt Group. The remaining Silurian platform carbonate sediments are included in the Washington Land Group (new) whilst basin slope rocks are assigned to the Peary Land Group (new).

Following the Morris Bugt Group Silurian sediments were deposited in two main environments, platform and basin slope. Sediments in these settings are completely different, the platform is characterised by carbonates and the basin slope by mudstones, cherts and resedimented conglomerates. The hinge between platform and basin slope is characterised by abrupt and complex facies changes and in some areas carbonate buildups and megabreccias. The platform succession is at maximum 2 km thick whilst the basin slope sediments are about 600 m thick. The platform region subsided very unequally and two major periods of platform subsidence are recognisable; late Cincinnatian to early Llandovery and late Llandovery to early Wenlock.

Four formations are included in the Morris Bugt Group, of which the uppermost Aleqatsiaq Fjord Formation straddles the Ordovician – Silurian boundary. The Washington Land Group is divisible into 10 formations including: Adams Bjerg Formation (new) composed of marginal marine stromatolitic dolomites with a carbonate buildup – Early(?) to Middle Llandovery Age; Pentamerus Bjerge Formation (new) a carbonate buildup, fringing reef, complex – Middle(?) Llandovery to Wenlock Age; Kap Godfred Hansen Formation (new) composed of submarine fan calcarenites and megabreccias – Middle (?) Llandovery to Wenlock Age; Petermann Halvø Formation (new) composed of marginal to open marine dolomites – Early Llandovery Age (?); Bessels Fjord Formation (new) a carbonate buildup complex – Middle (?) to Late Llandovery age; Offley Island Formation composed of shallow platform biostromes – Late Llandovery Age; Kap Lucie Marie Formation (new) composed of offshore to slope calcarenites and shales – Late Llandovery Age; Kap Morton Formation (new) composed of offshore platform to basin slope (peri-platform) lime mudstones – Wenlock to Ludlow Age; Kap Maynard Formation(new) divisible into Dolomite and Limestone Members (new) composed of offshore platform to basin slope (peri-platform) dolomites, shales and lime mudstones – Wenlock to Ludlow Age; Hauge Bjerge Formation (new) divisible into Cape Tyson Member and Kap Independence Member (new) a carbonate buildup complex – Middle (?) Llandovery to Wenlock Age. The Peary Land Group is divisible into two formations including: Cape Schuchert Formation composed of basin slope and starved basin, calcarenites, cherts and black limestones – Middle to early Late Llandovery Age; Lafayette Bugt Formation (new) composed of basin slope shales and conglomerates – Middle Llandovery to Ludlow Age.

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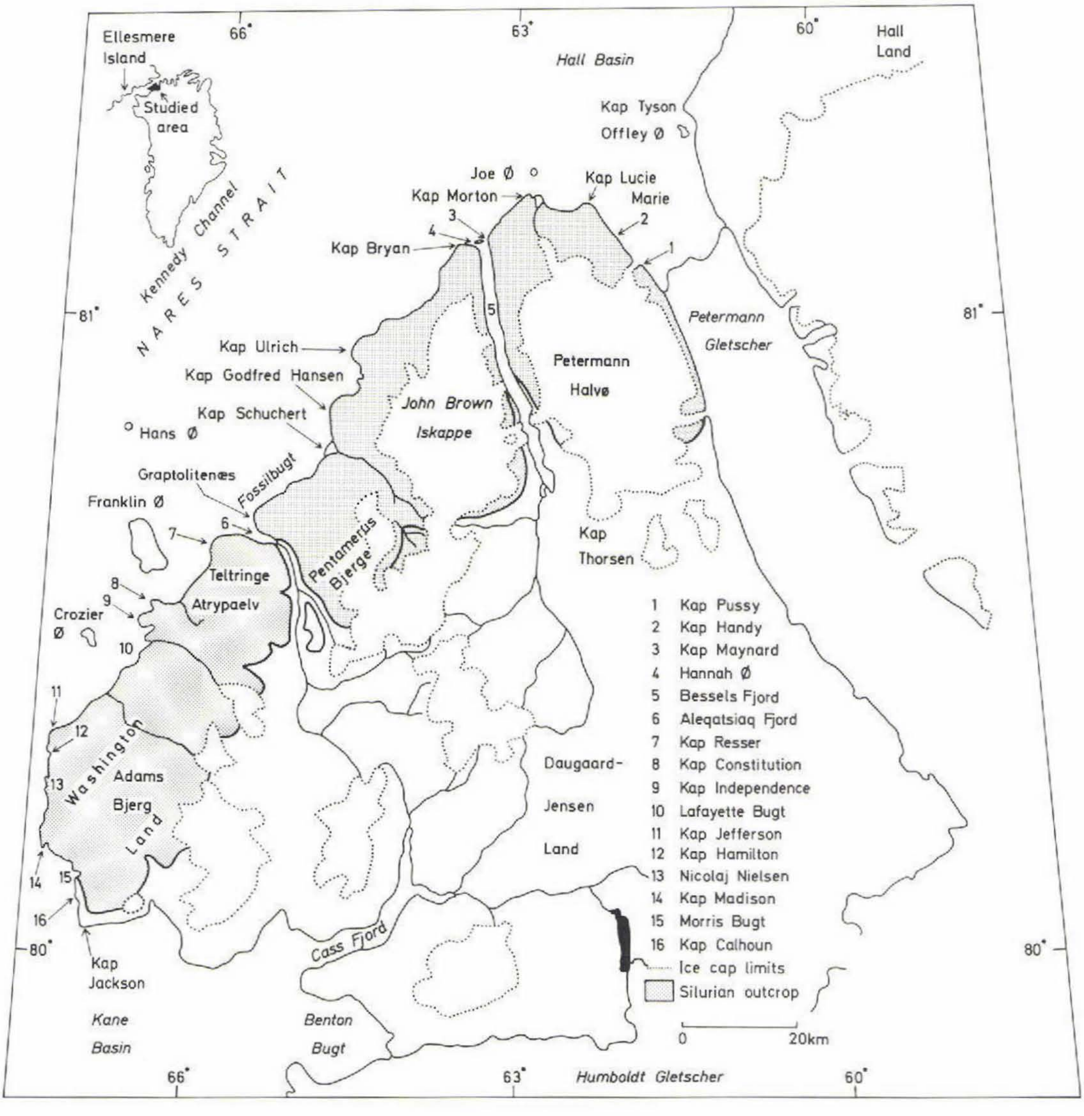


Fig. 1. Locality map of Washington Land and western Hall Land showing areas mentioned in the text.

INTRODUCTION

Silurian sediments of Washington Land and western Hall Land (figs 1, 2) were laid down in two major depositional environments. Platform carbonates, here referred to the uppermost part of the Morris Bugt Group and the Washington Land Group, are best developed in north Washington Land. Predominantly clastic basin slope rocks, referred to the Peary Land Group, constitute the second major unit. Facies changes both within and between the slope and platform are complex and abrupt.

The object of the present investigation was to map the Silurian rocks of Washington Land and western Hall Land to erect a lithostratigraphical scheme (tables 1 & 2 and plate 2). Geologically this region is one of the better known areas of North Greenland and contains the type sections of the four previously described Silurian lithostratigraphic units.

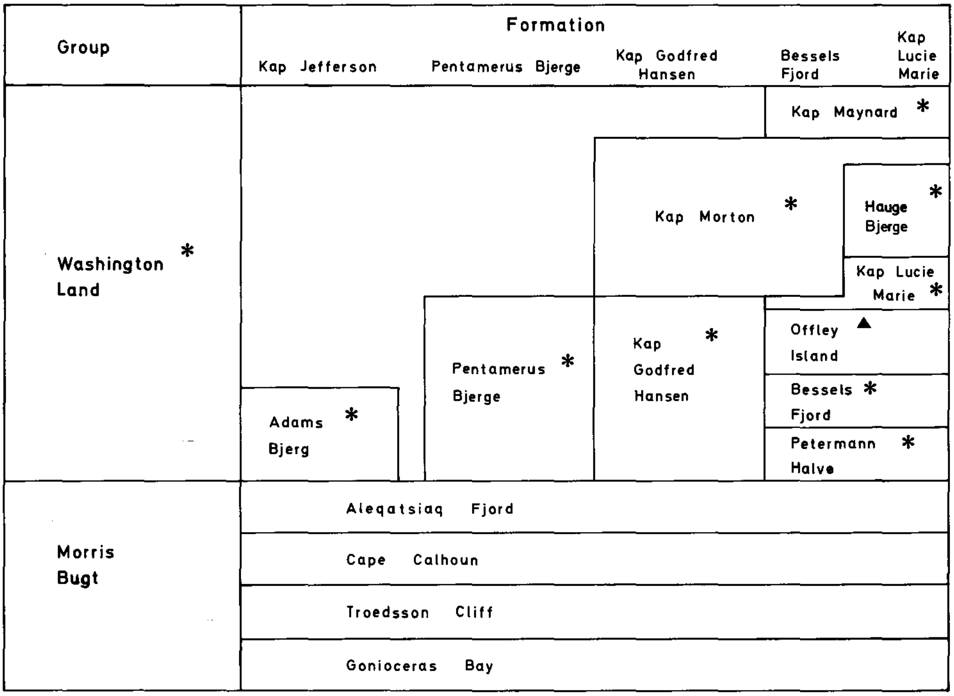
Strictly speaking, the name Washington Land only refers to the coastal area of the region shown in fig. 1. Lately, the name has been used synonymously with the whole land area, between Humboldt Gletscher and Petermann Gletscher (including Daugaard-Jensen Land) and for the sake of convenience is so in this report. A

Table 1. Lithostratigraphic scheme of the basin slope Silurian sediments of Washington Land and western Hall Land

Group	Formation		
	SW ⟺ NE		
Peary Land *	Lafayette Bugt *	Hauge Bjerge * 2	Hauge Bjerge * 1
			Lafayette Bugt *
	Cape Schuchert ▲		
Morris Bugt	Aleqatsiaq Fjord		

The Aleqatsiaq Fjord Formation is indicated for reference. Asterisk indicates new formation, and triangle redefined formation. The Hauge Bjerge Formation at 2, although surrounded by the Peary Land Group, is assigned to the Washington Land Group with which it is contemporaneous at 1 in Hall Land. The Hauge Bjerge Formation is included on both table 1 and 2 for reference.

Table 2. Lithostratigraphic scheme of the shelf carbonate Silurian sediments of Washington Land and western Hall Land



Symbols as table 1.
The Gonioceras Bay, Troedsson Cliff, Cape Calhoun and part of the Aleqatsiaq Fjord Formation are Ordovician in age.

total of three months were spent in the field, with helicopter support, during the summers of 1976 and 1977. In the summer of 1977 H. F. Jepsen investigated the platform carbonates along Bessels Fjord.

Following a general review of previous work in the region, the succession of new and redefined units, shown in tables 1 & 2 and plate 2 is discussed in ascending order starting with the platform deposits of the Morris Bugt Group and Washington Land Group.

PREVIOUS WORK

Following initial comments on the geology of western North Greenland (Fielden & de Rance, 1878) the first stratigraphic framework for the Silurian rock units of Washington Land and western Hall Land (figs 3, 4) was proposed by Koch (1920, 1925, 1929) after the first of two sledge expeditions through the area in 1916 to

1918 and 1920 to 1922. Initially Koch (1920) proposed a simple informal quadripartite division of the Silurian strata, above the supposed Ordovician Orthoceratite Limestone, which is in ascending order; *Pentamerus* Limestone, the *Arethusina* Zone, Coral Limestone and finally Graptolite Slates. He assigned the *Pentamerus* Limestone to the Middle Silurian and the remaining to the Upper Silurian. The Graptolite Slates of Upper Silurian age (Koch, 1920, p. 51) apparently did not occur in Washington Land. From his descriptions, the *Pentamerus* Limestone appears to be the oldest Silurian strata found and to have a limited areal extent. He reported the *Arethusina* Zone to be well developed in Lafayette Bugt (fig. 1), and to be separated from overlying limestones at Kap Independence and Kap Constitution by conglomerates. The limestone he alludes to here is presumably Coral Limestone, although he does not refer to it as such.

This initial account is rather confused and demonstrably incorrect in places. Judging from his later work and the now known distribution of the rocks, he even miscorrelated rocks now known to be Lower and Middle Ordovician with Lower Silurian. However, it is important to remember that this account could be no more than preliminary, as many of the faunas collected by Koch had not been studied.

In a later résumé paper on the geology of North Greenland Koch (1925, p. 280–282) refers to the lowest Silurian strata of the area as the *Arethusina* Formation and reports that this formation is separated from the underlying Ordovician and also from the overlying *Pentamerus* Limestone by conglomerates. It is not clear whether Koch had discontinued the usage of his 1920 name *Pentamerus* Limestone or whether in fact had simply inverted it stratigraphically in relation to the *Arethusina* Formation. Of course, the latter would depend on the *Arethusina* Formation of 1925 equalling the *Arethusina* Zone of 1920, an assumption which seems justified. The uppermost Silurian strata are referred to as *Monograptus* shales and Koch notes (1925, p. 281) that they also start with a basal conglomerate.

In 1929 Koch published a comprehensive paper entitled *Stratigraphy of Greenland.* In this he erects a formalised quadripartite lithostratigraphical subdivision of the Silurian of North Greenland (fig. 3). He gave the name Cape Schuchert Formation to the lowest unit and attributed the foundation of the name to Koch (1922). However, no such publication exists, and the date most likely refers to the year of the field work that Koch coined the formation name (P. R. Dawes, personal communication, 1979).

From Koch's descriptions it is apparent that the Cape Schuchert Formation equates with at least part if not all of his previously described *Arethusina* Formation and *Arethusina* Zone. This is further corroborated by the fact that he cites the type locality for the Cape Schuchert Formation as 'just south of Kap Independence in Lafayette Bugt', the place which nine years previously (Koch, 1920) he indicated as the best locality for seeing the *Arethusina* Zone beds (see plate 1). He reported that the unit starts with a conglomerate which passed up into black bituminous and fossiliferous shales and limestones.

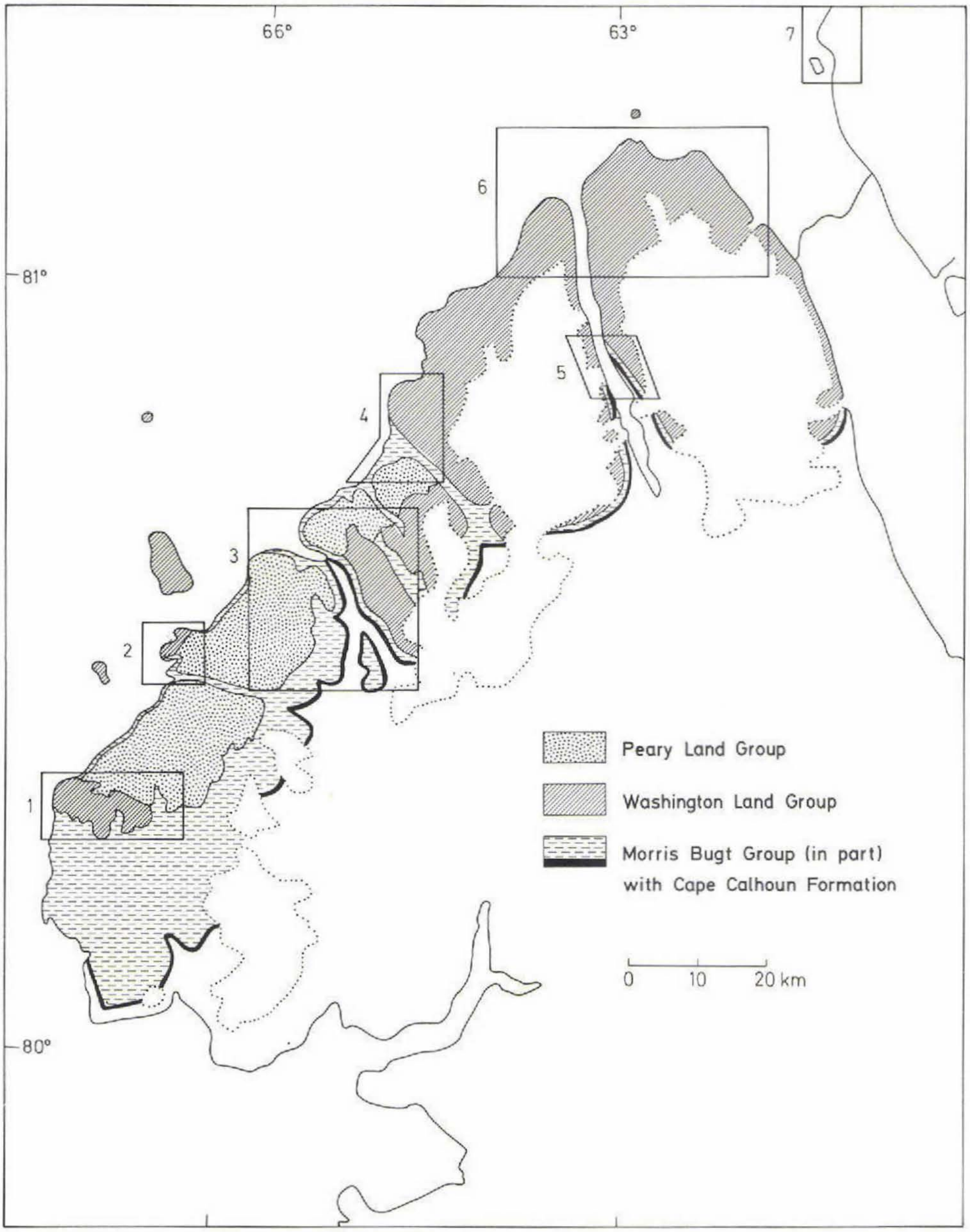


Fig. 2. Simplified geological map indicating the distribution of three groups to which Silurian sediments are assigned. Figures refer to geological maps in text, including, 1 (fig. 14); 2 (fig. 55); 3 (fig. 6); 4 (fig. 24); 5 (fig. 33); 6 (fig. 44) and 7 (fig. 40).

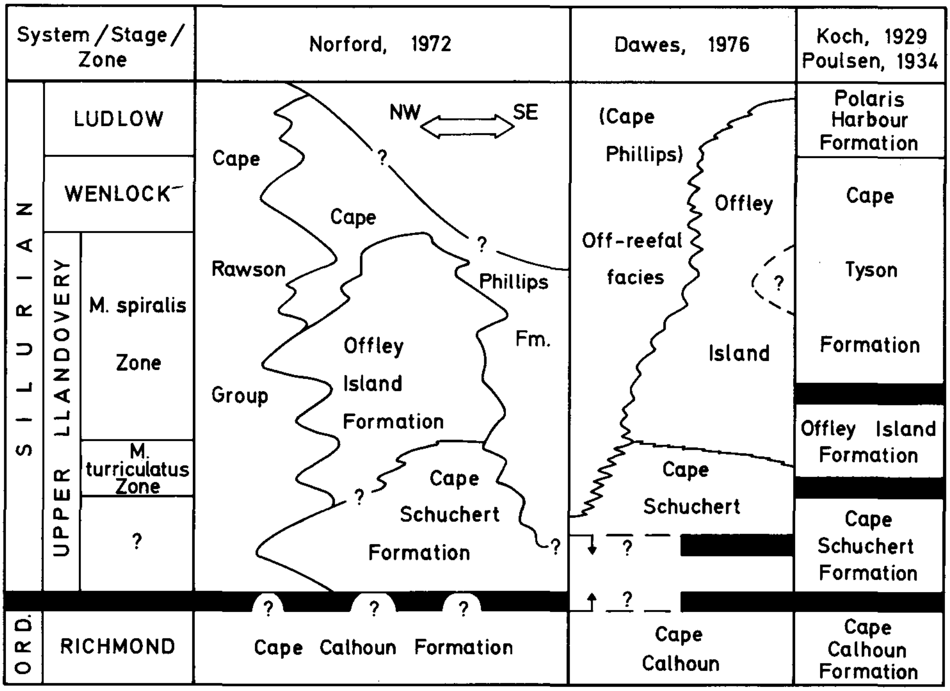


Fig. 3. Some previous schematic stratigraphic relations, including biozonal scheme, of the Silurian formations of Washington Land and Hall Land.

Overlying beds are referred to the Offley Island Formation, which he attributes to Koch (1917), again a non-existent publication. Essentially, this consists of massive bedded limestone overlying arenaceous limestones and shales (Koch, 1929, p. 238) and probably equates in part or wholly with the previously mentioned *Pentamerus* Limestone and Coral Limestone (Koch, 1920, p. 35). Koch reports it to be separated from the underlying formation by a basal conglomerate.

The Cape Tyson Formation (again attributed to Koch, 1917) overlies the Offley Island Formation and is reported to consist of a basal limestone breccia and conglomerate followed by graptolitic shales or, as at the type locality, massive limestone. It is apparent from Koch's descriptions that he intended this formation to include a variety of facies which he probably previously referred to as *Pentamerus* Limestone, Coral Limestone and *Monograptus* shales.

All three formations were assumed to be of Upper Llandovery–Lower Wenlock age. He gave a series of sandstones and slates above these the name Polaris Harbour Formation (again referred to Koch, 1917) and, on the basis of a fauna obtained from an erratic boulder, possibly from this formation, assigned it doubtfully to the Ludlow. Earlier, he (Koch, 1920) had suggested a Devonian age. This formation is not exposed in the study area.

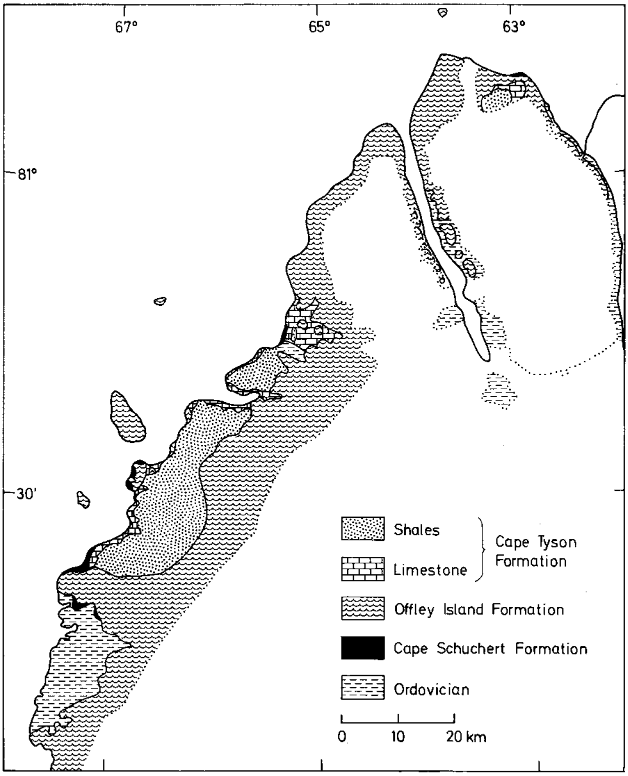


Fig. 4. Distribution of Silurian sediments and formations according to Lauge Koch's 1931 1:500 000 map. Published in Dawes & Haller (1979).

In summary, it is very easy to be hypercritical of Koch's results. However, considering the appalling conditions he worked under, the scope of his work which included cartographical mapping and the inherently complicated facies changes so typical of the Silurian, his contributions are outstanding. Furthermore, it is not widely appreciated that much of Koch's background work on the Silurian, particularly the Bicentenary Expedition results (1920–23), have remained unpublished due to a series of misfortunes. It is evident from Koch's maps and photographs, now published by Dawes & Haller (1979) (see fig. 4 and plate 1) that his understanding of the complicated Silurian stratigraphy and facies changes was much more advanced than is apparent from his publications. Detailed discussion of the various correlations, miscorrelations and stratigraphic terms erected, utilized and redefined by Koch is given in sections concerning pertinent groups and formations, below.

Poulsen (1934, 1941, 1943) described the faunas collected by Koch and followed the established stratigraphical nomenclature. This nomenclature remained intact until Dawes (1966) suggested the discontinuation of the term Polaris Harbour Formation as the type locality only consisted of glacial debris.

It was not until the investigations of Allaart (1965, 1966), Kerr (1967), Norford

(1967, 1972) and Dawes (1971) that it was shown that the Cape Schuchert Formation, Offley Island Formation and Cape Tyson Formation did not simply represent platform carbonate layercake stratigraphic units. These authors demonstrated that the formations preserve a complex record of intricate facies changes associated with enormous carbonate buildups. Dawes (1971) extended the Offley Island Formation to include limestones and associated rocks of the Cape Tyson Formation.

The most recent and major revision of Koch's stratigraphic nomenclature has been attempted by Norford (1972). 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 redefined the Offley Island and Cape Schuchert Formations and imported the name Cape Phillips Formation from Arctic Canada to cover off-reefal argillaceous graptolitic rocks.

The most recent review of the stratigraphy and setting of the whole of northern Greenland is given by Dawes (1976). An enlightening account including the social, economic and scientific background to Koch's expeditions is given by Dawes & Haller (1979). This later publication has clarified many of the ambiguous statements in Koch's publications.

STRATIGRAPHY

Stratigraphic nomenclature

Original lithostratigraphic names (see Koch, 1929) were proposed in English after geographical features which were named in English. In recent years Danish spelling of geographic features has become official. In accordance with Hedberg (1976) original spelling of formations is kept. Consequently, formation name and type locality spelling do not always coincide e.g. Offley Island Formation type locality is now at Offley Ø.

In some cases it has been possible to relate the Silurian sequences to the standard graptolite sequences of the British Isles (Rickards, 1976). This is a very tentative step in such a virgin geological area (plate 2). Eventually, it may be possible and more meaningful to relate Washington Land graptolite sequences with the original graptolite zonation established in the Cape Phillips Formation of Canada (Thorsteinsson, 1958) and the more comprehensive and elaborate Lower Palaeozoic scheme now in use throughout the Canadian Arctic (Jackson, 1979).

In the chronostratigraphic scheme (plate 2) North American Series and Stages are used in the Ordovician whilst all British (European) Series and Stages are used in the Silurian. It is impossible to relate with any degree of certainty strata to Stages younger than the Llandovery and Stages of that Series are only used tentatively. In the graptolitic sequence, the base of the Silurian is conveniently taken at the base of the *Glyptograptus persculptus* Zone in Europe and the top of the *Dicellograptus*

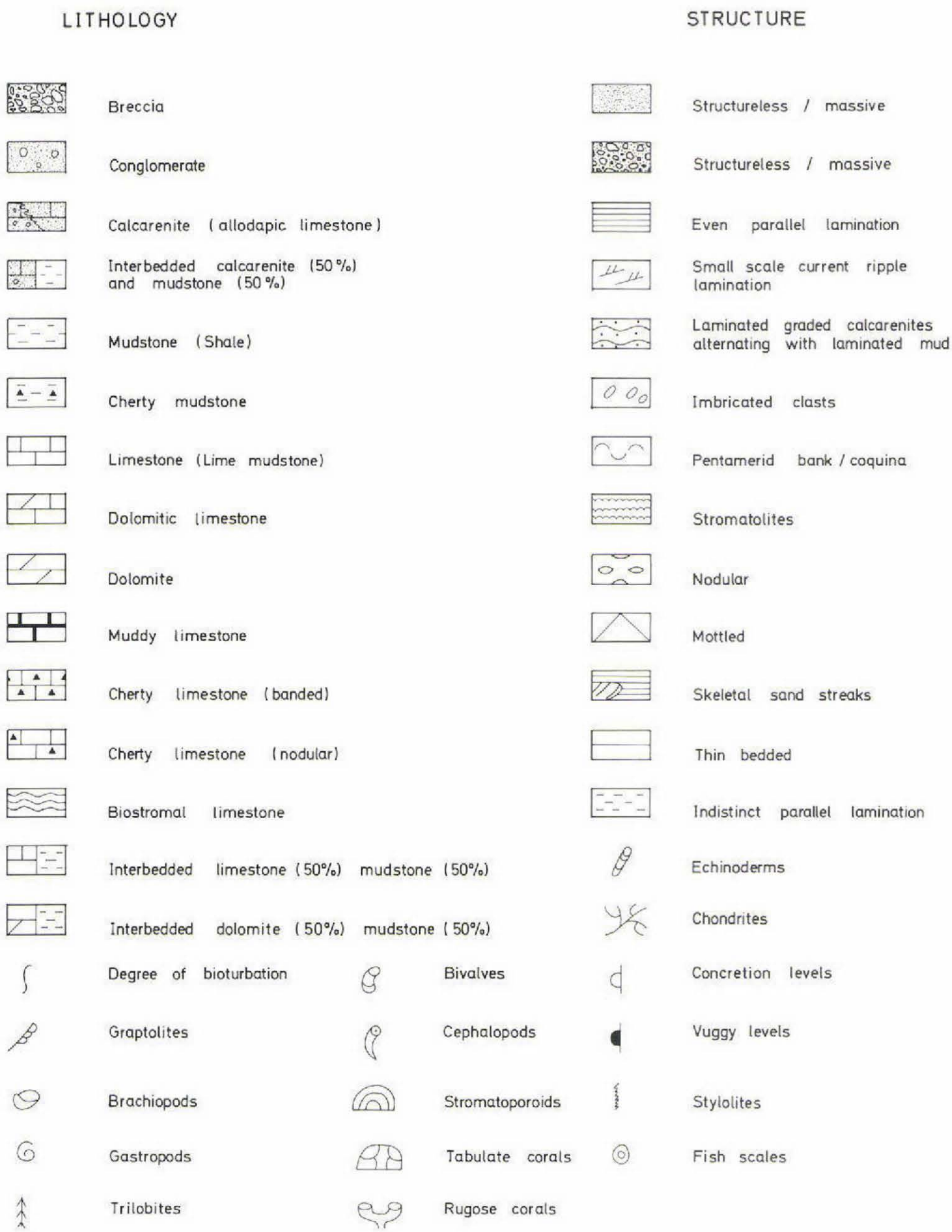


Fig. 5. Legend covering all figured sections. Silurian sediments are a complex mixture of both clastic and carbonate, and the latter are often resedimented. Sedimentary logs are based on a grain size scale for clastics, which is also suitable for resedimented carbonates. This scale is not in any way meant to pertain to the remaining carbonates. The stepped nature of their outcrop pattern (right line) indicates weathering characteristics.

complanatus ornatus Zone in America. In shelly facies the lower boundary of the North American Silurian is the top of the Richmond Stage (Berry & Boucot, 1970) whilst in Britain it is the top of the Hirnantian Stage of the Ashgill Series (Cocks *et al.,* 1970). Needless to say this is a very difficult boundary to locate especially in non graptolitic facies (e.g. Cocks & Price, 1975).

All sedimentary logs of the type and reference sections are standardised (fig. 5).

Carbonate buildups and lithostratigraphy

The Silurian sediments contain many carbonate buildups and these are conventionally difficult to define lithostratigraphically. This is mainly due to rapid facies changes in and around buildups.

Buildups and immediately associated breccia and conglomerate sediments (i.e. adjacent resedimented carbonates) are included in the buildup lithostratigraphic definition. Away from buildups the resedimented carbonates thin into the surrounding sediments. It is impossible to define precisely the limits of lithostratigraphic units in such cases. Some resedimented carbonates, especially conglomerates, may be so widespread and thick as to eventually warrant lithostratigraphic recognition. This may be the case with the conglomerates of the Kap Godfred Hansen Formation which are derived from the platform edge fringing reef complex, the Pentamerus Bjerge Formation. Obviously, at some point these two formations must interfinger.

There is no difficulty in qualitatively (visually) assessing the limits of buildup units, especially when they are surrounded by shales and cherts. The problem arises when the buildups are surrounded by other carbonates. For this reason the carbonate buildup in the Adams Bjerg Formation at Kap Jefferson has not been nomenclatorially recognised. Also the Bessels Fjord Formation as defined here, consists of carbonate buildups and associated resedimented carbonates together with more level bottom inter-buildup carbonate sediments. From a purely lithostratigraphical point of view, the Bessels Fjord Formation could be split into two, with buildups representing one formation and the remaining sediments the other. The data available at the moment do not allow for this, but it is envisaged that with further work a comprehensive lithostratigraphic sub-division of the Bessels Fjord Formation will be possible.

Faunal identification

The biostratigraphic scheme is based primarily on my own collections. These have been supplemented greatly, especially in the Bessels Fjord region, by H. F. Jepsen (GGU), and material collected by P. R. Dawes (GGU) and J. H. Allaart (GGU) from contemporaneous sequences in Hall Land has direct bearing on this study. B. S. Norford (Geol. Survey Canada) kindly donated his brachiopod collection from his 1966 fieldwork in Greenland. The remainder of this fauna is being described or has already been so (e.g. McLean, 1977). Finally, the Silurian collections of Lauge Koch (described by C. Poulsen, 1934, 1941, 1943) are of great importance.

Faunal determinations from my collections have been made by: R. J. Aldridge (Nottingham), conodonts; M. Bjerreskov (Copenhagen), graptolites; P. D. Lane (Keele), trilobites; J. S. Peel (GGU), gastropods; A. J. Boucot (Corvallis) and myself, brachiopods.

Morris Bugt Group

History

This group was erected by Peel & Hurst (1980) who revised the nomenclatorial chaos surrounding the component formations.

Name

After the bay Morris Bugt in south-west Washington Land (fig. 1).

Type area

In the cliffs and coastline surrounding and adjacent to Morris Bugt.

Thickness

Maximum 760 m.

Dominant lithology

The group commences with mottled, nodular bedded, massive rubbly weathering brownish grey lime mudstones of the Gonioceras Bay Formation. These are followed by an alternation of rubbly and more massive silty lime mudstones of the Troedsson Cliff Formation. Above come very recessive thin bedded skeletal lime mudstones with thin green shale interbeds of the Cape Calhoun Formation. Finally, massive to nodular bedded mottled greyish brown partially dolomitised lime mudstones and wackestones of the Aleqatsiaq Fjord Formation, complete the succession.

Boundaries

The group rests conformably upon and grades up from the Cape Webster Formation throughout Washington Land and probably south-west Hall Land. It is conformably followed in the west of Washington Land by the Peary Land Group, and in central and north Washington Land by the Washington Land Group (fig. 2).

Distribution

The main part of the group occurs to the west and the north of Cass Fjord and it extends up to south Bessels Fjord and Petermann Gletscher (figs 1, 2). The upper part of the group forms the large peneplained area immediately adjacent to the coast of Nicolaj Nielsen in south-west Washington Land (fig. 1) and the lowest deposits of the coast and major valleys between Kap Jefferson and Kap Godfred Hansen (fig. 2).

Geological age

Middle Ordovician (Champlainian Series; Blackriveran Stage?) to Silurian, Early Llandovery (Rhuddanian – Idwian Stages?). Further details are given in Peel & Hurst (1980) and under the Aleqatsiaq Fjord Formation.

Subdivisions

Four formations, in ascending order, constitute the group; Gonioceras Bay Formation (70–80 m), Troedsson Cliff Formation (240–250 m), Cape Calhoun Formation (65–70 m) and Aleqatsiaq Fjord Formation (250–360 m). The uppermost formation straddles the Ordovician Silurian boundary and is the only one dealt with in detail in this report.

Aleqatsiaq Fjord Formation

History

The Aleqatsiaq Fjord Formation probably includes strata which Koch (1920, p. 46) referred to the Upper Silurian Coral Limestone along the coast between Kap Calhoun and Kap Jefferson. It also probably partly includes strata Koch (1920) referred to either the Middle Silurian *Pentamerus* Limestone or the underlying Ordovician Orthoceratite Limestone.

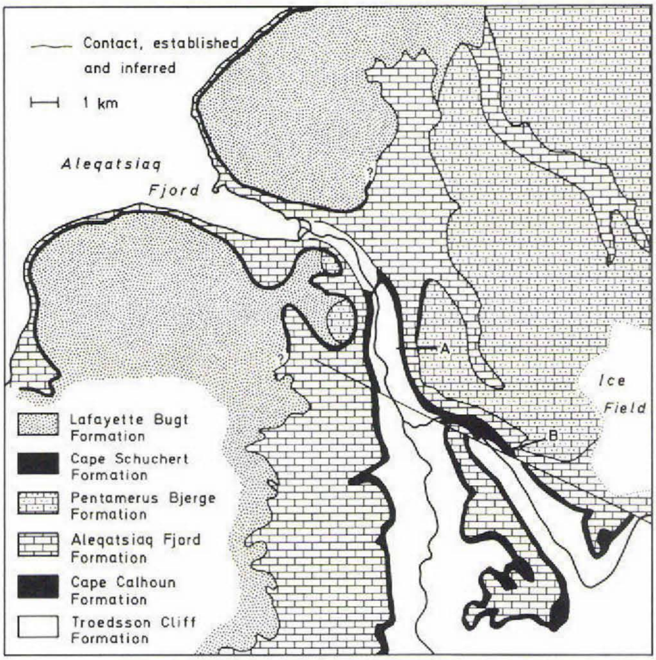


Fig. 6. Detailed geological map of the Aleqatsiaq Fjord region, Washington Land. Type locality of the Aleqatsiaq Fjord Formation is along the line of section A. Immediately above this point is the type area for the Pentamerus Bjerge Formation. Section B is the type section in the Pentamerus Bjerge Formation. The Hauge Bjerge Formation at Kap Resser (cape on north side of Aleqatsiaq Fjord) is not shown.

Subsequently, Koch (1929) appears to have included strata now referred to the Aleqatsiaq Fjord Formation partly in his comprehensive Cape Calhoun Formation (Ordovician) and partly in the overlying Cape Schuchert Formation (compare photograph of Nicolaj Nielsen coast Koch, 1929, p. 276 with fig. 15 this report). Koch's map of Washington Land (Dawes & Haller, 1979, fig. 4) indicates that part of the Offley Island Formation and probably limestones of the Cape Tyson Formation, are now included in the Aleqatsiaq Fjord Formation.

Norford (1972) included the upper part of the Aleqatsiaq Fjord Formation south of Kap Schuchert, in the Cape Schuchert Formation. The Aleqatsiaq Fjord Formation was proposed as a constituent formation of the Morris Bugt Group by Peel & Hurst (1980).

Name

After Aleqatsiaq Fjord on the north-west coast of Washington Land (fig. 1). On old maps the fjord is referred to as Alekratiak fjord.

Type and reference sections

The type section is on the east side of the major north-south valley, approximately 2 km south of the head of Aleqatsiaq Fjord (fig. 6). Many good sections occur on the south-west slopes of the Pentamerus Bjerge; the type is shown in fig. 7.

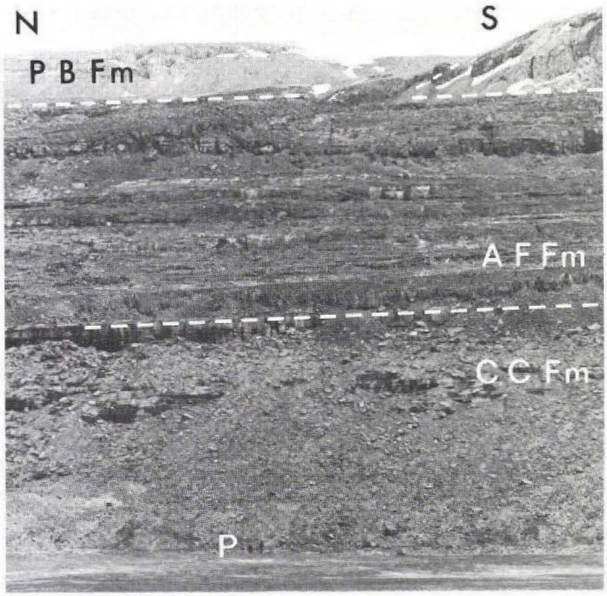


Fig. 7. Location of the type section of the Aleqatsiaq Fjord Formation, east side of valley leading south from mouth of Aleqatsiaq Fjord. Location in fig. 6. Pentamerus Bjerge Formation (P B Fm), Aleqatsiaq Fjord Formation (AF Fm) and Cape Calhoun Formation (CC Fm). Scale indicated by person (P) at base of section.

Thickness

On the carbonate platform in south Bessels Fjord the formation develops its maximum thickness of 360 m (figs 7, 8). At the carbonate platform edge in the southern Pentamerus Bjerge it is only 250 m thick. The maximum thickness in the coastal areas is unknown as only the top 50 to 80 m are seen.

Lithology

Units in the lower half are of massive, grey brown, lime mudstones and wackestones in tabular beds up to 50 cm thick alternating with thinner more platy units 10–30 cm thick. All beds weather with a nodular appearance and are mottled light yellowish grey (fig. 9). Pervasive dolomitisation occurs throughout but rarely forms distinct horizons. At Aleqatsiaq Fjord a distinctive 2–5 m thick unit of interbedded laminated black mudstone (2–5 cm thick) and cherty black lime mudstones (2–5 cm) occur some 70 m above the base (fig. 8). The only distinctive feature in the Bessels Fjord region is a tabulate coral horizon 130 m above the base.

Between Aleqatsiaq Fjord and Pentamerus Bjerge the top 120 to 150 m are composed of a distinctive black, thin bedded to nodular lime mudstone with chert nodules or horizons. The top 40 m of the formation at Bessels Fjord and Kap Jefferson are black platy or nodular laminated limestone, with thin shale interbeds,

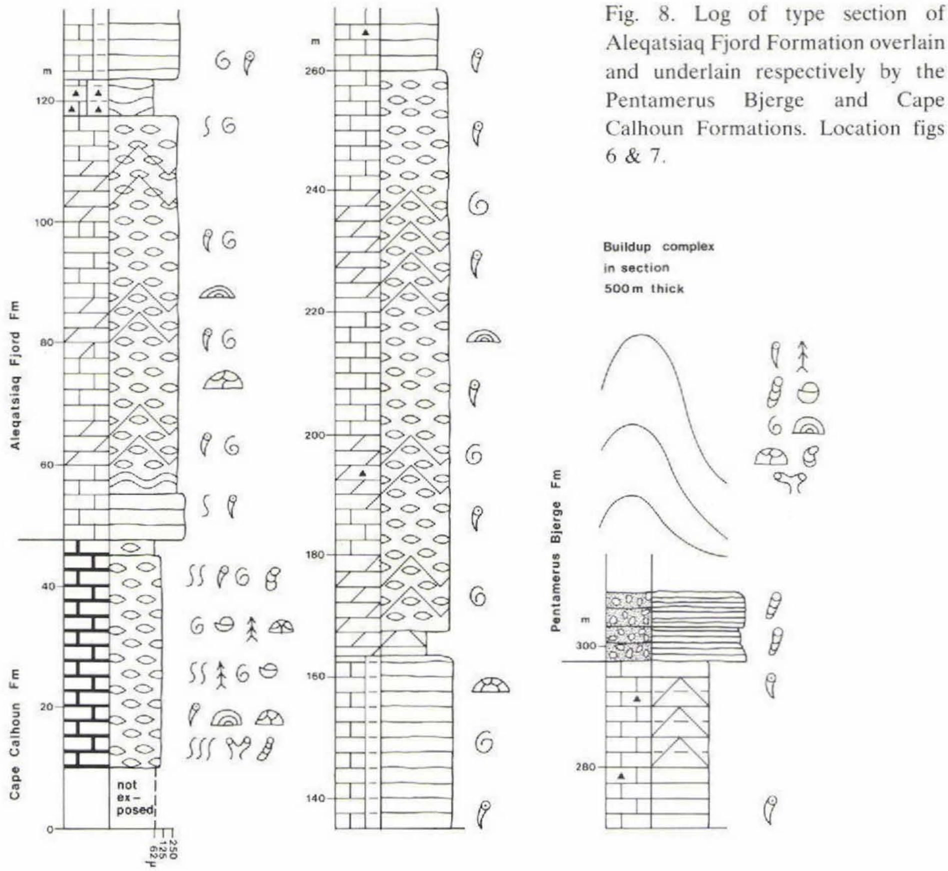


Fig. 8. Log of type section of Aleqatsiaq Fjord Formation overlain and underlain respectively by the Pentamerus Bjerge and Cape Calhoun Formations. Location figs 6 & 7.

rich in corals and stromatoporoids (fig. 10). This may be the Coral Limestone of Koch (1920). In the coastal areas at Kap Independence and, particularly, at the promontory to the south of Kap Schuchert the top of the formation contains distinctive knolls of tabulate corals and stromatoporoids (up to 2 m diameter). The level bottom sediments consist almost entirely of laminated and graded crinoidal debris in beds up to 50 cm thick. The sediments are poorly sorted and cemented, forming a crinoid sand.

Boundaries

The lower boundary is exposed in the cliffs on the west side of Petermann Gletscher and loops around Pentamerus Halvø into south Bessels Fjord (fig. 7). From here it trends south-west around John Brown Iskappe, through the base of the south Pentamerus Bjerge and into Kennedy Channel at the mouth of Aleqat-

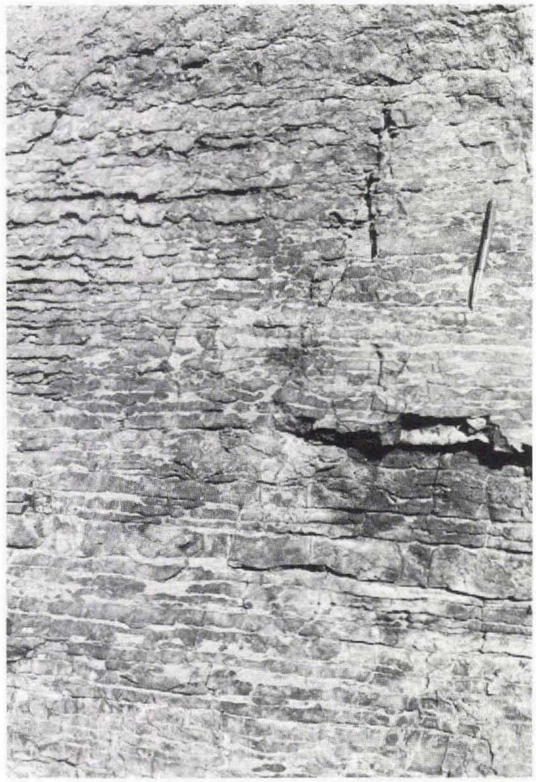


Fig. 9. Mottled, nodular to platy bedded dolomitic limestones of the Aleqatsiaq Fjord Formation. Type section (figs 6, 7 & 8).

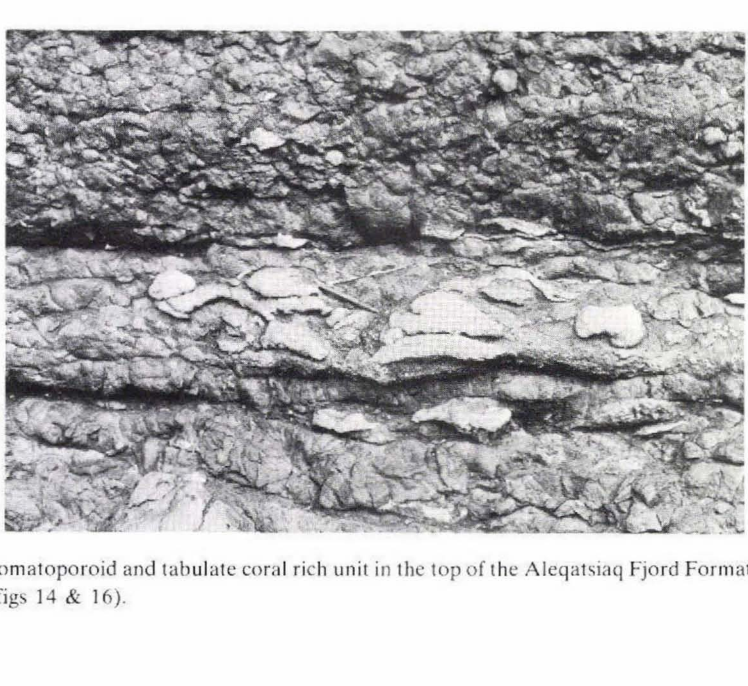


Fig. 10. Stromatoporoid and tabulate coral rich unit in the top of the Aleqatsiaq Fjord Formation at Kap Jefferson (figs 14 & 16).

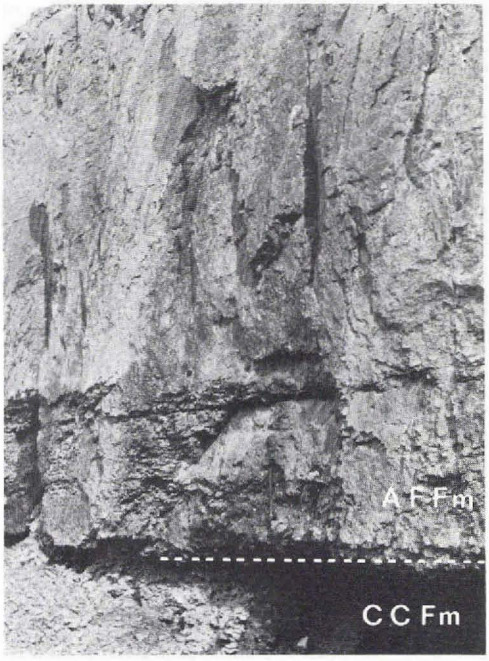


Fig. 11. The contact of the lower boundary of the Aleqatsiaq Fjord Formation (A F Fm) on the Cape Calhoun Formation (C C Fm), in the type section (figs 6 & 7).

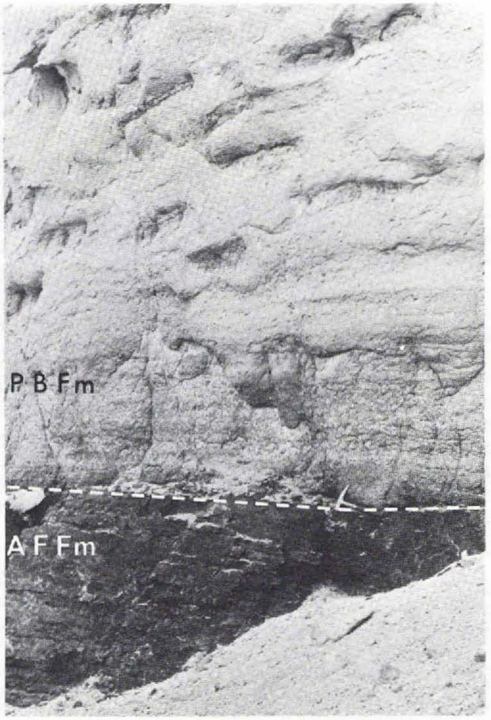


Fig. 12. The contact of the upper boundary of the Aleqatsiaq Fjord Formation (A F Fm) overlain by the Pentamerus Bjerge Formation (P B Fm), in the type section (figs 6 & 7). Note the laminated crinoidal debris of the latter formation.

siaq Fjord. To the south it is parallel to the coast and progressively forms the higher parts of the hills until it again reaches sea level at Morris Bugt in south-west Washington Land. The Aleqatsiaq Fjord Formation rests everywhere conformably on the Cape Calhoun Formation (fig. 11).

Around Bessels Fjord and to the north the upper boundary trends parallel to the lower one. Along the western coastal areas the upper boundary occurs at Kap Jefferson and is traceable all along the coast and up the deepest, inland, east–west trending valleys, up to Kap Godfred Hansen. South and west of Aleqatsiaq Fjord the formation is conformably followed by the Cape Schuchert Formation. To the north-east of the fjord the Kap Godfred Hansen, Pentamerus Bjerge and Petermann Halvø Formations all follow conformably.

In the type section (fig. 8) the base of the formation is taken at the point where green weathering muddy limestones of the Cape Calhoun Formation give way to more resistant thin bedded units with no clastic interbeds (fig. 11). The top is well defined by white, graded, parallel laminated bioclastic breccias and calcarenites of the Pentamerus Bjerge Formation (fig. 12). In areas where it is overlain by the Cape Schuchert Formation of the Peary Land Group the top is defined by the change from light coloured lime wackestones, often crinoidal to massive black, bituminous and cherty limestone and shales.

Distribution

West and north Washington Land.

Fauna and geological age

Generally the formation is not very fossiliferous, the fauna mainly represented by scattered actinoceratid cephalopods (fig. 13), tabulate corals, both *Favosites* sp. and *Halysites* sp., and stromatoporoids.

In the type section (fig. 8) conodont material is fairly abundant in samples from the lower half but steadily decreases and is very rare in the uppermost 40 m. R. J. Aldridge reports unequivocal Ordovician conodonts up to 150 m above the Cape Calhoun Formation. At this point assemblages with *Amorphognathus superbus* indicate, in American terms, the strata to be at youngest, Early Maysvillian (Sweet & Bergström, 1976). Stratigraphically 60 m higher the presence of *Belodina dispansa* is some evidence that this horizon is also Ordovician. If this represents the top of the Ordovician, at most only some 40 m of strata is referable to the Silurian. This in fact is a generous estimate because it assumes that the whole of the Late Ordovician Richmondian is barely represented.

The section in Bessels Fjord (fig. 36) did not yield many diagnostic conodonts.

Fig. 13. Actinoceratid cephalopods weather out conspicuously on bedding planes in the upper part of the Aleqatsiaq Fjord Formation. From section shown in fig. 58. 1 m long.

Aldridge considers conodonts from 214 m above the base to be undoubtedly Ordovician. At this point *Belodina* sp. A of Sweet *et al.* (1971) still indicates a fauna 11 of at youngest Middle Maysvillian Age (see Sweet & Bergström, 1976). Ten metres below, a sample yielded *Belodina compressa,* a form which terminates within fauna 11. About 248 m above the base, the occurrence of *Drepanodus suberectus* may still indicate Ordovician. The uppermost 120 m yield conodont faunas but no diagnostic species. Clearly a substantial portion of this is probably of Richmondian Age. At Kap Independence, Ordovician conodont faunas occur to within 40 m of the top of the Aleqatsiaq Fjord Formation.

Through both these sections there is no evidence of an unconformity or a condensed sequence in the upper part. On balance only a fraction of the Aleqatsiaq Fjord Formation (40 m at maximum in Aleqatsiaq Fjord) is possibly Silurian. In this context the gastropod *Maclurites* spp., indicative of the Ordovician, occurred up to 70 m from the top of the formation in both sections.

The top 40 m of the formation at the point south of Kap Schuchert (fig. 59) is exceedingly fossiliferous, containing bryozoans, corals, bivalves, rostroconchs, primitiid ostracods, gastropods, trilobites and brachiopods. Lane (1979) reported 28 forms of trilobite including, *Bumastus* spp., *Kosovopeltis* sp., ? scutelluid indet., *Stenopareia somnifer, Proetus (Lacunoporaspis)* sp., *Cyphoproetus? alyo, Cyphoproetus externus,* Tropidocoryphine gen. indet., *Harpidella (Harpidella?) helenae, Scotoharpes* sp., *Hadromeros* sp., *Deiphon* cf. *D. dikella, Youngia* sp., *Encrinurus* spp., *Acernaspis (Eskaspis)* sp., *Hemiarges* sp., *Platylichas* spp.and *Leonaspis* sp. The fauna agrees with a B_1Idwian or Late Rhuddanian (plate 2), Llandovery (Early to Middle) Age. Four forms in particular, *C. externus, Acernaspis (Eskaspis)* sp., *Kosovopeltis* sp. and *Deiphon* cf. *D. dikella* are known, or are very close to forms known from strata of this age in Scotland.

McLean (1977) described the rugose corals *Grewingkia cuneata* and *Palaeophyllum schuchertense* from the same locality and concluded that their age was

Late Llandovery (Fronian). This was based on the stratigraphy of Norford (1972) who did not find Middle Llandovery graptolites above the Aleqatsiaq Fjord Formation probably because they were contained within the covered interval of his section (see below). It is pertinent to note that McLean (1977 p. 11, 35) reports that both genera are common in Late Ordovician strata and, in the case of *Palaeophyllum,* Early Silurian. Bearing in mind the trilobite and graptolite data the corals now appear more in accord with the suggested age of the Aleqatsiaq Fjord Formation.

The precise age range of the Aleqatsiaq Fjord Formation is uncertain, as faunal evidence is conflicting. The conodont faunas of the supposed Canadian correlative (Irene Bay Formation) of the underlying Cape Calhoun Formation do not agree (cf. Barnes *et al.,* 1976). Further, Ludvigsen (1975) correlates the underlying Cape Calhoun Formation with Trentonian and Edenian strata in Canada. Thus, the precise Ordovician age of the base of the Aleqatsiaq Fjord Formation, in more regional terms is equivocal, but it is apparent that the Richmond Stage and possibly most of the Early Llandovery must be very thin. In one locality the top of the formation is near the Rhuddanian – Idwian (Early – Middle Llandovery) boundary, but it is not known if this is a synchronous boundary throughout Washington Land.

Washington Land Group

new group

Name

After Washington Land (fig. 1).

Type area

North Washington Land around John Brown Iskappe, Bessels Fjord, Petermann Halvø and Petermann Gletscher (figs 1, 2).

Thickness

Maximum 1500 m.

Dominant lithology

The group commences with stromatoporoidal, tabulate coral and echinoderm rich skeletal limestones (carbonate buildup fringing reef complex) in the Pentamerus Bjerge region. Northwards in the Bessels Fjord and Petermann Halvø area the group commences with dolomitic limestones which are often totally recrystallised, followed by mud and skeletal limestone muds interbedded with shale and black cherty lime mudstones. Higher units consist of blue-grey lime mudstones and thick skeletal debris beds (biostromes) with thick resedimented carbonate conglomerates. Distinctive dolomites and green siltstones occur in the uppermost part.

Boundaries

Throughout the area the group rests conformably on the Morris Bugt Group. In central west Washington Land it grades into the Peary Land Group.

Distribution

An outlier belonging to the group occurs at Kap Jefferson and the Adams Bjerg. The strata occur at Aleqatsiaq Fjord and cover the whole of Washington Land north and east of Kap Godfred Hansen (fig. 2). Hans Ø in Kennedy Channel is composed of rocks assigned to this group. It extends into the western Hall Land cliffs, bordering Petermann Gletscher.

Geological age

Early Silurian (Early to Middle Llandovery) to Late Silurian (possibly Late Wenlock or Early Ludlow). For further details see the discussion under the individual formations (plate 2, table 1).

Subdivisions

The group includes the Adams Bjerg Formation, Pentamerus Bjerge Formation, Kap Godfred Hansen Formation, Petermann Halvø Formation, Bessels Fjord Formation, Offley Island Formation, Kap Lucie Marie Formation, Kap Morton Formation, Kap Maynard Formation and Hauge Bjerge Formation.

Adams Bjerg Formation

new formation

History

Koch (1929) included strata referred to this formation in his Offley Island Formation.

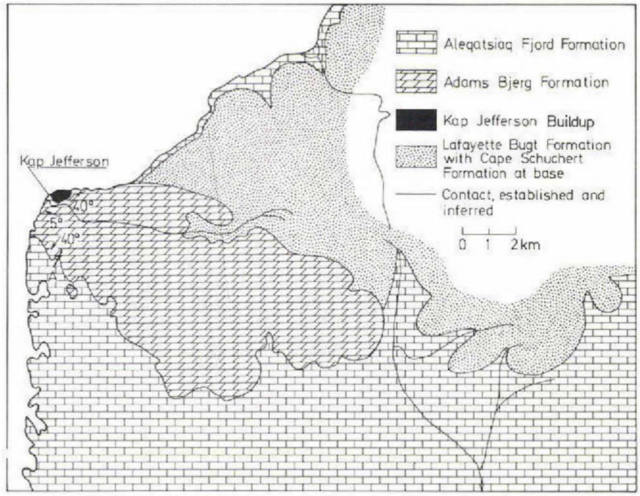


Fig. 14. Detailed geological map of the Adams Bjerg Kap Jefferson region (reference map fig. 2). Type locality of the Adams Bjerg Formation is along the line of section A.

Name

After the elongate range of hills in south-west Washington Land (fig. 14).

Type and reference sections

The location of the type section is indicated in fig 14 and is on the south facing slope of the hill 1 km east of the coastline and 2 km south of Kap Jefferson (fig. 15). Along this southerly outcrop many good reference sections occur.

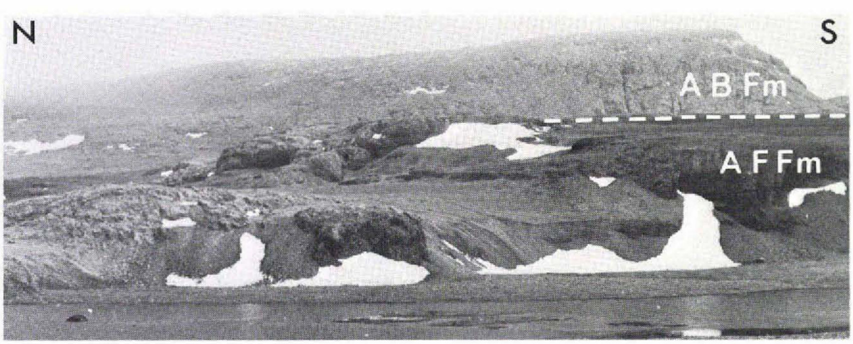


Fig. 15. Location of the type section of the Adams Bjerg Formation, on the south side of the range of hills running due east from Kap Jefferson (fig. 20). Aleqatsiaq Fjord Formation (A F Fm) and Adams Bjerg Formation (A B Fm). Hill 250 m high.

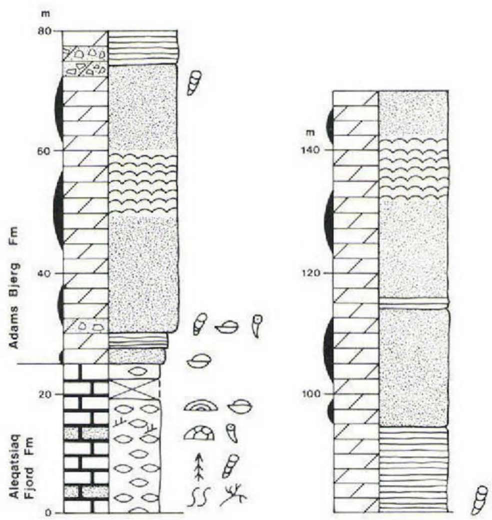


Fig. 16. Log of the type section of the Adams Bjerg Formation, underlain by the Aleqatsiaq Fjord Formation. Breccias shown are diagenetic. No grain size scale as sediments are all carbonates.

Thickness

The flat lying beds reach a maximum thickness of 130 m. In the region of the Kap Jefferson carbonate buildup, the stratigraphic thickness may reach 200 m (fig. 16).

Fig. 17. Vuggy, sugary, recrystallised cream coloured dolomite of the Adams Bjerg Formation, in the type section.

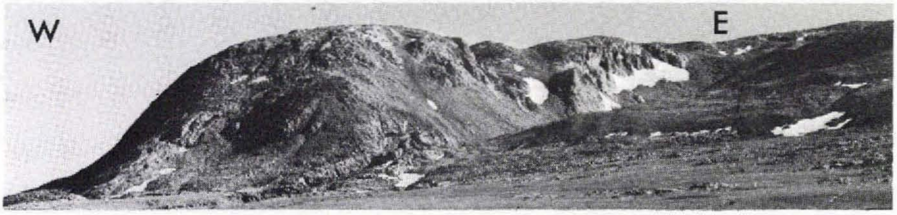


Fig. 18. Mound like Kap Jefferson buildup, located in figs 14 & 20. Height 150 m. See fig. 19.

Lithology

The formation consists predominantly of massive creamy white crystalline dolomite (fig. 17). Flat lamination often with fenestral cavities lined with dolomite crystals and distinctive bulbous or crinkly laminae (stromatolitic) occur throughout. Discontinuous beds and pockets of breccia set in a sparry dolomite cement are characteristic.

A mound like structure, termed the Kap Jefferson buildup, is developed within this dolomitic sequence at Kap Jefferson itself (fig. 18). The central part is composed of massive white dolomite riddled with fenestrae. Steeply dipping flat laminated dark grey dolomites with subordinate breccia beds flank the buildup. The whole sequence is capped by a coarse-grained crinoidal limestone (fig. 19).

Boundaries

The Adams Bjerg Formation rests conformably on the Aleqatsiaq Fjord Formation. Brecciation and slumping along joints affecting both formations, led Koch (1929, p. 13) to infer an unconformity with a lag conglomerate. The top is the present day landscape. To the north of Kap Jefferson the formation interdigitates with the Cape Schuchert Formation of the Peary Land Group. The Lafayette Bugt Formation appears to overlap the Adams Bjerg Formation (fig. 20).

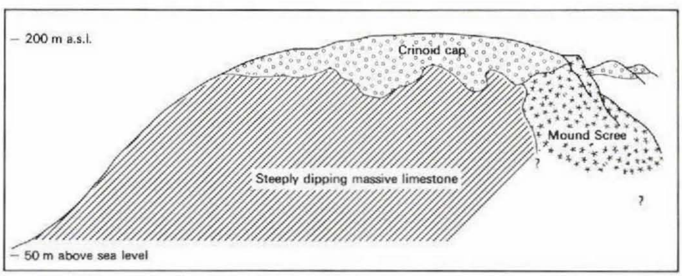


Fig. 19. Schematic representation of Kap Jefferson buildup facies, to go with fig. 18.

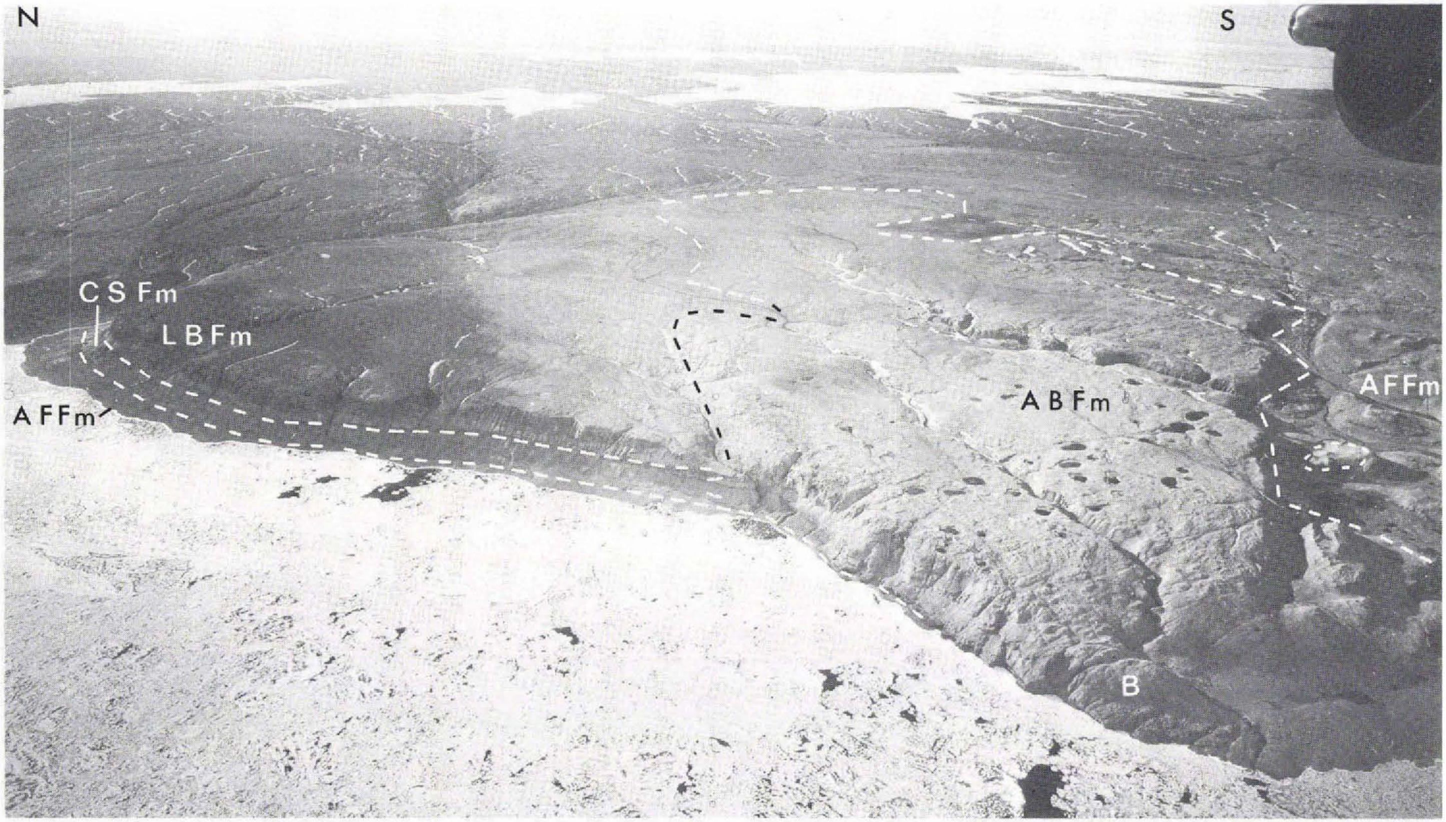


Fig. 20. The coastal areas of Kap Jefferson and the Adams Bjerg inland, showing facies changes between the Cape Schuchert Formation (C S Fm) and Adams Bjerg Formation (A B Fm). Note the Lafayette Bugt Formation (L B Fm) banked against the Adams Bjerg Formation. Aleqatsiaq Fjord Formation (A F Fm). Kap Jefferson buildup (B). Aerial photograph 545 K – SØ, no. 10495. Copyright Geodætisk Institut, Denmark.

In the type section the base of the formation is taken at the base of the first dolomite bed. At this point a distinctive colour change from grey-black limestones to creamy yellow dolomites also occurs (fig. 16).

Distribution

The formation is only known in the Kap Jefferson – Adams Bjerg area, of south-west Washington Land (fig. 20).

Fauna and geological age

If the top of the Aleqatsiaq Fjord Formation is synchronous, the base of the Adams Bjerg Formation would appear to be Early or Middle Llandovery (possibly Late Rhuddanian or Early Idwian). However, there is no direct fossil evidence in the Kap Jefferson – Adams Bjerg area to corroborate this suggestion.

The formation is generally very poorly fossiliferous with only the occasional brachiopod or cephalopod and crinoid debris, much of which is totally recrystallised. However, in the Kap Jefferson buildup, at the top of the unit a single smooth brachiopod, *Virgiana* sp. was collected. North American occurrences of this genus are restricted to pre-Upper Llandovery (Fronian) strata (cf. Berry & Boucot, 1970; Boucot *et al.,* 1971). Thus, the scant evidence available suggests that the Adams Bjerg Formation may be wholly contained within the Middle Llandovery (Idwian). It appears unlikely that any of the formation is of Late Llandovery Age.

Pentamerus Bjerge Formation

new formation

History

Koch's 1:500 000 map (plate 2 in Dawes & Haller, 1979; fig. 4) indicates that this formation is part of the Offley Island Formation of Koch (1929).

Name

After the Pentamerus Bjerge which trend north-east from Aleqatsiaq Fjord under John Brown Iskappe (fig. 1).

Type locality and reference section

The inherent variation in the facies of the carbonate buildup fringing reefs together with poor cross-section exposure and inaccessibility of the core facies (due

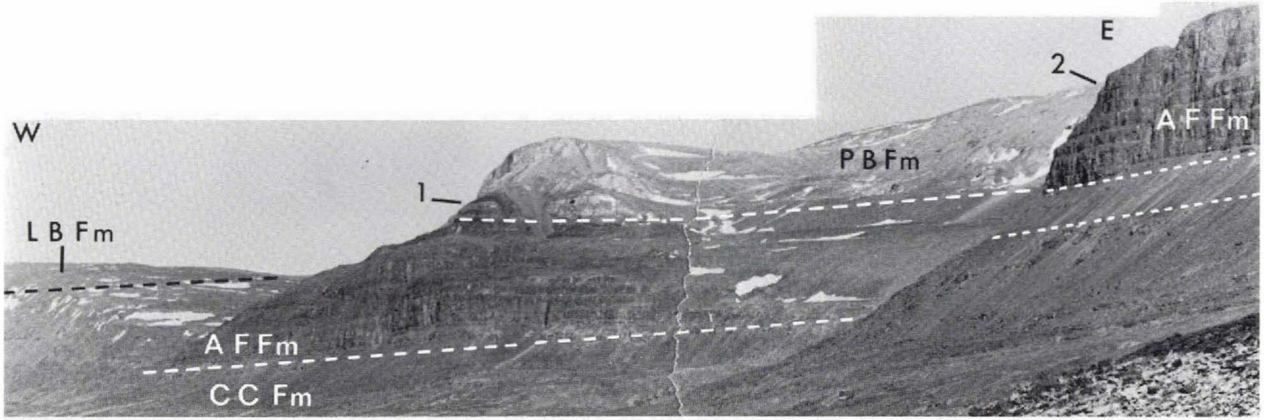


Fig. 21. East side of valley leading south from Aleqatsiaq Fjord showing type area for the Pentamerus Bjerge Formation (P B Fm) overlying Aleqatsiaq Fjord Formation (A F Fm) and Cape Calhoun Formation (C C Fm). Towards the west Lafayette Bugt Formation overlies the Aleqatsiaq Fjord Formation. Note the steep palaeoslope between the Pentamerus Bjerge Formation and Lafayette Bugt Formation. Point 1 indicates the direction of fig. 22. Point 2 indicates the position of type section in fig. 23.

Fig. 22. Type area for the Pentamerus Bjerge Formation (P B Fm), located at the southern end of the Pentamerus Bjerge (Fig. 21) lying comformably upon the Aleqatsiaq Fjord Formation (A F Fm). Point 1 marks the top of the measured section through the Aleqatsiaq Fjord Formation (fig. 8) and the location of the boundary between the formations , shown in fig. 12. Point 2 consists of interbedded cherty lime mudstones and calcarenites; inter-buildup facies.

to domal dips) renders it impossible to erect a representative type section. Hedberg (1976 p. 16) maintains that the definition of impractical units need not be based on stratotypes but on accurate illustration and description of the features of the unit. The definition of the Pentamerus Bjerge Formation is based partly on a type section in the back reef area (fig. 23) together with a type area in the southernmost buildup in Aleqatsiaq Fjord (fig. 6). The type area is approximately three km from the fjord mouth, immediately adjacent to a major east–west valley (figs 21 & 22). The base of the formation is defined in the section on the west side of the type area (fig. 8).

Thickness

Up to 500 m.

Lithology

Units of lime mudstone with interbedded, massive, lamellar and bulbous stromatoporoidal and tabulate coral rudstones are very common in the more central regions of individual buildup masses. Flank deposits consist of thick chaotic

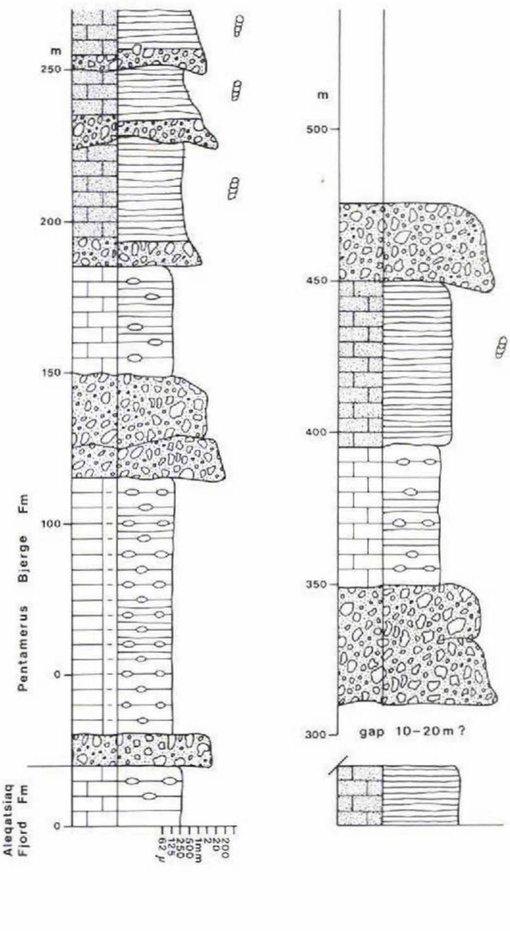


Fig. 23. Log of the type section of the Pentamerus Bjerge Formation, overlying the Aleqatsiaq Fjord Formation. Location shown in figs 6 & 21.

megabreccia beds and coarse graded, occasionally laminated, calcarenites composed primarily of crinoidal debris (fig. 12). In the troughs between reef masses black, poorly laminated, cherty lime mudstones are interbedded with thin black shale partings and discrete tabular, graded and often laminated calcarenites (fig. 22). In back reef areas chaotic megabreccias and calcarenites are interbedded with thicker units of nodular grey-brown lime mudstones and wackestones with some thin black shale partings. Further information is available in Hurst (1980).

Boundaries

The Pentamerus Bjerge Formation rests conformably on the Aleqatsiaq Fjord Formation (fig. 21). Between John Brown Iskappe and Aleqatsiaq Fjord the western boundary of the formation interdigitates with the Lafayette Bugt Formation and possibly the Cape Schuchert Formation, both of the Peary Land Group. The formation disappears below John Brown Iskappe and thus is not seen directly in contact with any of the Silurian formations of Bessels Fjord. However, on structural and stratigraphic grounds it must interdigitate with the Petermann Halvø Formation, Bessels Fjord Formation, Offley Island Formation, Kap Lucie Marie Formation and at least part of the Kap Morton Formation. To the west it also

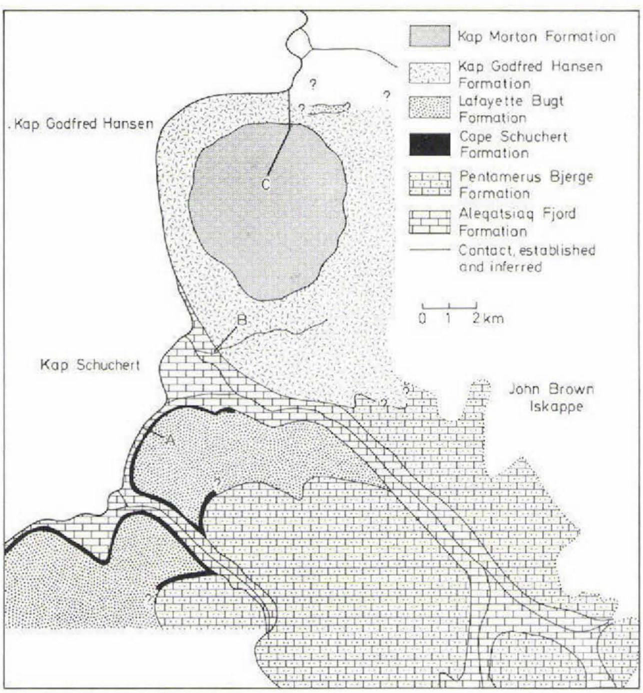


Fig. 24. Geological map of the environs of Kap Godfred Hansen and Kap Schuchert (reference map fig. 2). Type and reference sections of the Kap Godfred Hansen Formation, respectively along line of sections B and C.

Section A at the locality termed Kap Schuchert (fig. 59). Section N of Norford (1972; see plate 1 & fig. 41).

interdigitates with the Kap Godfred Hansen Formation (fig. 24). The top is the present day land surface.

In the type area and the section given in fig. 8, the base of the formation is taken at the base of the first crinoidal calcarenite above the Aleqatsiaq Fjord Formation (fig. 12) and in the type section at the base of the first resedimented carbonate conglomerate.

Distribution

The formation occurs in the region between Aleqatsiaq Fjord and John Brown Iskappe in a belt 10 km inland and parallel with the coast.

Fauna and geological age

If the top of the Aleqatsiaq Fjord Formation is synchronous then the base of the Pentamerus Bjerge Formation would appear to be Early – Middle Llandovery (possibly Late Rhuddanian or Early Idwian). There is no direct fossil evidence in the type area to corroborate this possibility.

Breccia beds at the top of the Lafayette Bugt Formation in the section south of Kap Schuchert (fig. 59) drape off the Pentamerus Bjerge Formation. Regional mapping suggests that they derive from the uppermost part of the Pentamerus Bjerge Formation. One breccia block has yielded a conodont fauna which R. J. Aldridge considers indicative of the Lower Wenlock part of the *amorphognathoides* Zone in the European sense (Walliser, 1971; Aldridge, 1975). Thus, it appears likely that the Pentamerus Bjerge Formation ranges through the Middle and Late Llandovery into at least the Early Wenlock.

Other notable elements of fauna from the formation (from breccia blocks) include the gastropods; *Cyclonema* sp., *Onychochilus* (?) sp., *Gyronema* sp. and *Liospira* sp.; the trilobites; *Meroperix* sp., *Sphaerexochus* sp., *Ceratocephala* sp., cf. *Platylichas* sp., *Hyrokybe (?Youngia);* effaced scutelluid gen. nov. and *Xenocybe* sp. The latter is only previously known from the late Ordovician reef facies of Norway (see Owens, 1973).

Kap Godfred Hansen Formation

new formation

History

Koch (1929; fig. 4) included strata now referred to this formation in the Offley Island Formation.

Name

After Kap Godfred Hansen the prominent cape at the northern end of Fossilbugt (fig. 1).

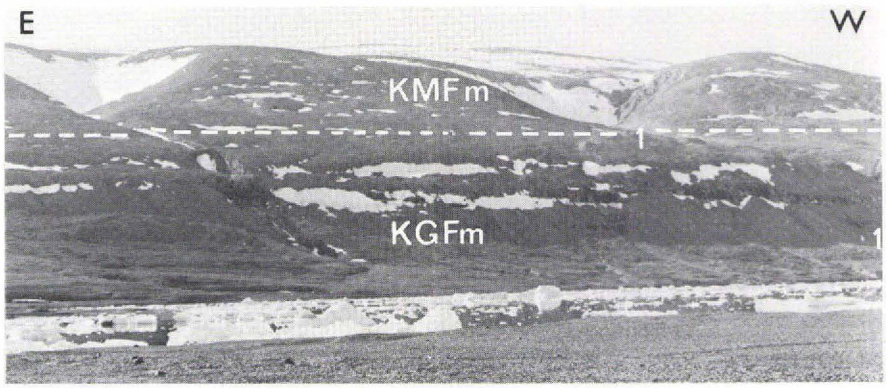


Fig. 25. Location of the reference section (1) of the Kap Godfred Hansen Formation (K G Fm), overlain by the Kap Morton Formation (K M Fm). Note the bench at the top of the Kap Godfred Hansen Formation.

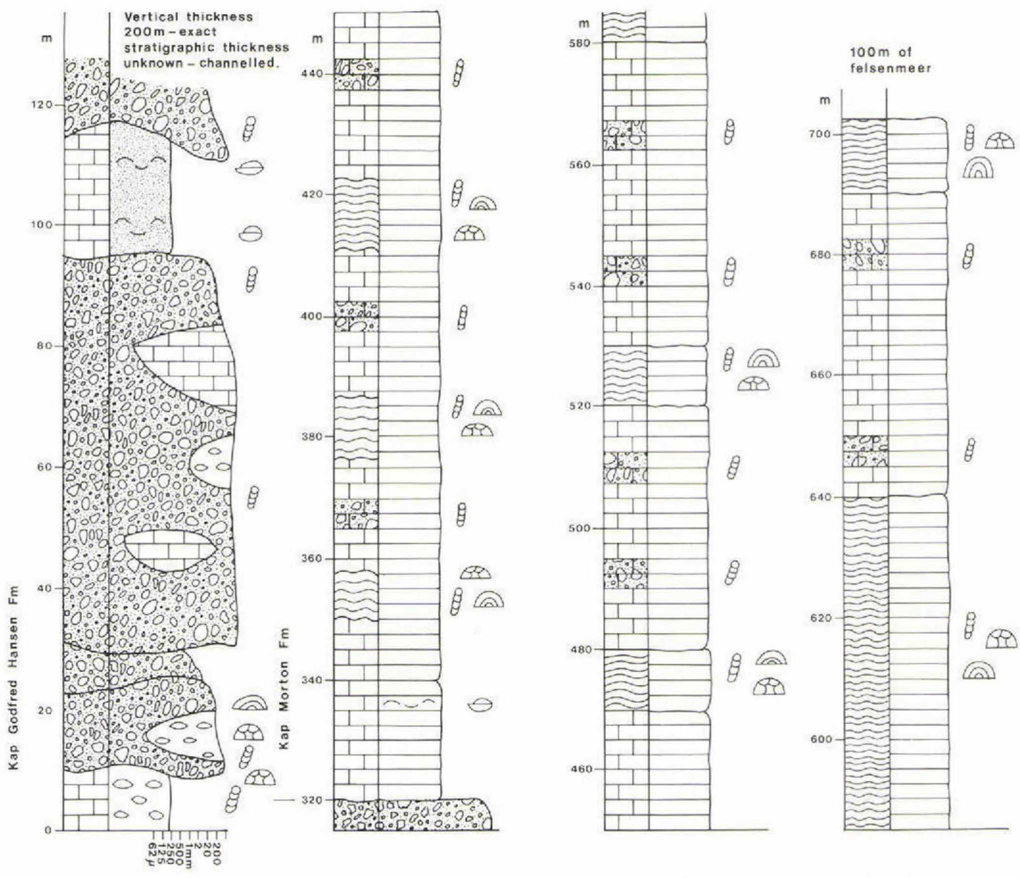


Fig. 26. Log of the reference section of the Kap Godfred Hansen Formation overlain by the Kap Morton Formation. Location figs 24 & 25.

Type and reference sections

The type section is on the south side of Kap Godfred Hansen (figs 24 & 29) in a prominent gully (fig. 30). A reference section in which the top of the formation is defined occurs on the north side of Kap Godfred Hansen in a prominent gully formed by outwash from a small glacier (figs 24, 25 & 26). Numerous other well exposed reference sections occur in the streams, gullies and corries of Kap Godfred Hansen.

Thickness

Between 250 and 350 m. On the north side of Kap Godfred Hansen the true stratigraphic thickness of this member is difficult to assess. The base is not seen in accessible sections and the deposits are grossly channelled, dipping irregularly (sedimentary dips) and at high angles. Vertical thickness is at least 320 m. Stratigraphic thickness is probably far greater (fig. 26).

Lithology

The formation is a wedge of varied resedimented carbonates characterised by thick, extensive, occasionally channelled carbonate conglomerates derived mainly from the Pentamerus Bjerge Formation but with rarer platform carbonates and slope sediments.

On the north side of the cape the formation is composed of thick boulder and cobble breccias of angular blocks of platform carbonates and Pentamerus Bjerge

Fig. 27. Chaotic clast supported conglomerate of the Kap Godfred Hansen Formation, in the type section (figs 25 & 26). Height 15 m.

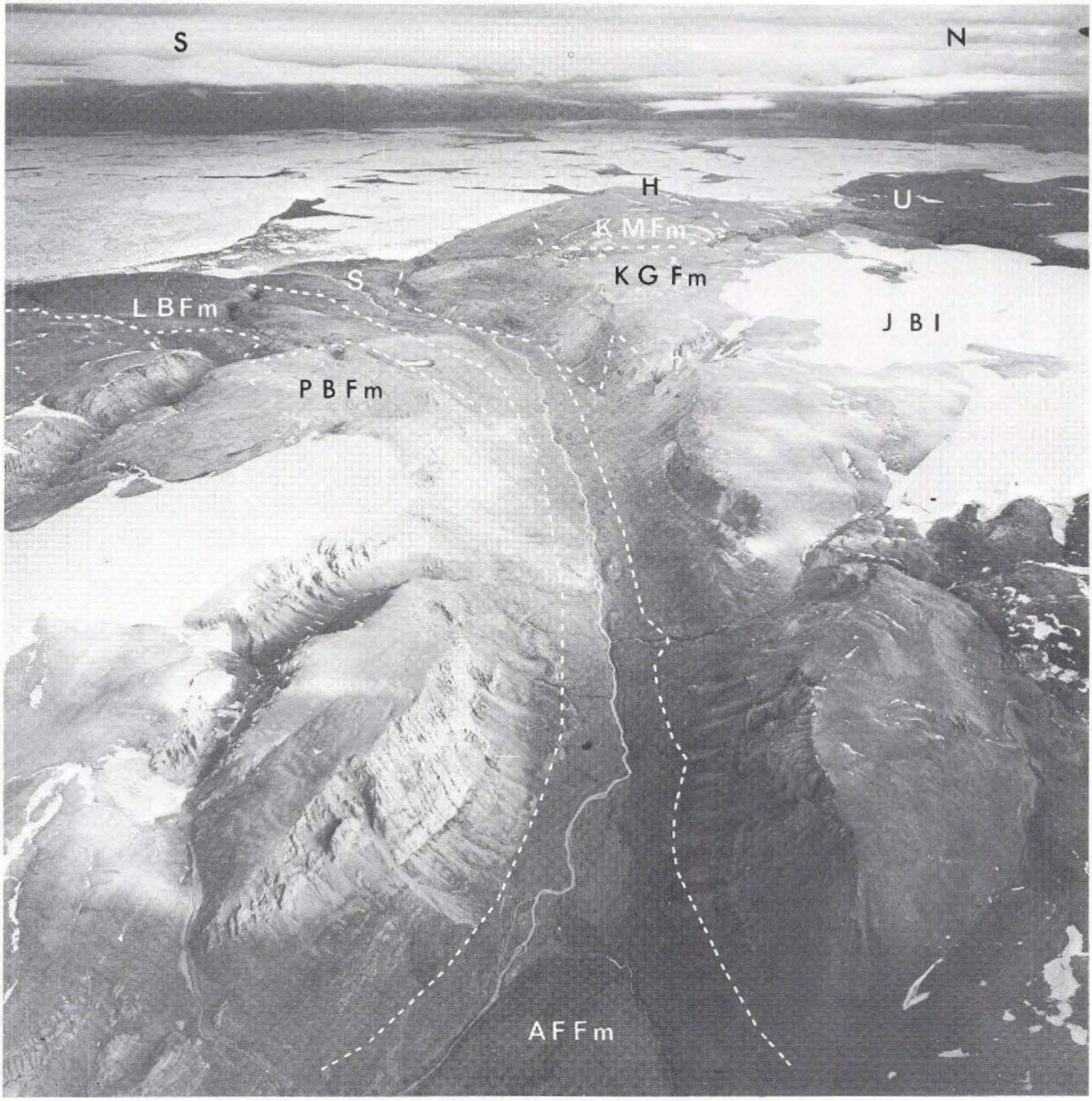


Fig. 28 Northern extension of the Pentamerus Bjerge Formation (P B Fm) forming the Pentamerus Bjerge and covered by John Brown Iskappe (J B I). Note facies changes into the Kap Godfred Hansen Formation (K G Fm) and the Lafayette Bugt Formation (L B Fm). Kap Godfred Hansen (H), Kap Ulrich (U) and Kap Schuchert (S). Kap Morton Formation (K M Fm), Aleqatsiaq Fjord Formation (A F Fm). Aerial photograph 545 B-NV, no. 10536. Copyright Geodætisk Institut, Denmark.

Formation (fig. 27). Subordinate clasts include cherts and dark limestones. The blocks reach up to 20 m in dimension forming huge rafts, set in a matrix of coarse sand and fine pebble carbonates. The breccias have deeply channelled bases. Sub-

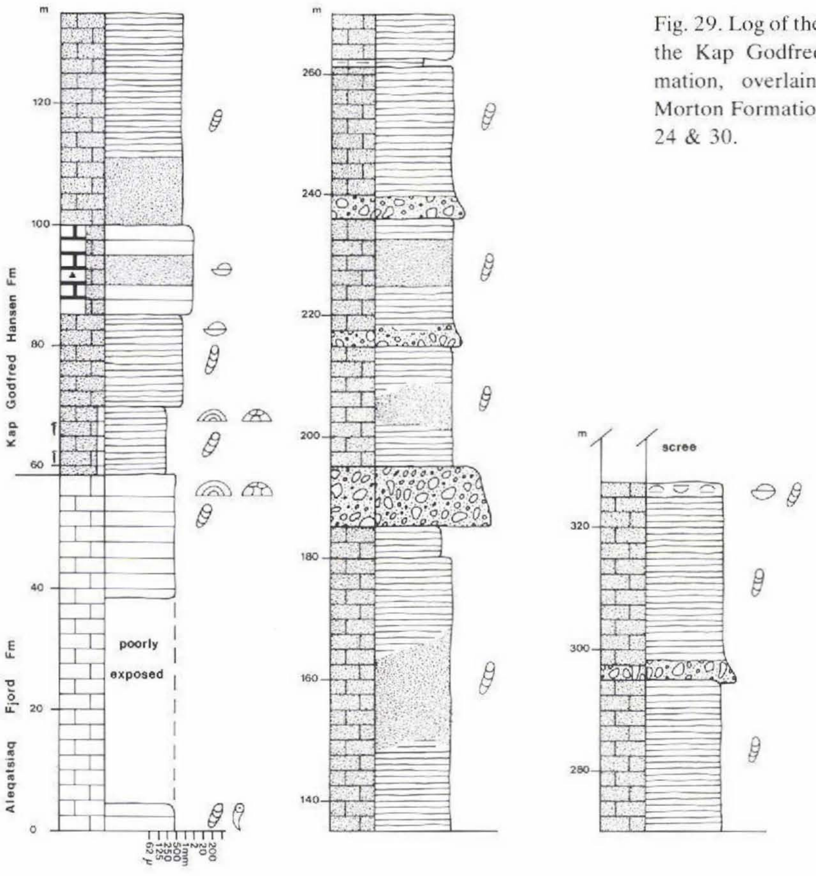


Fig. 29. Log of the type section of the Kap Godfred Hansen Formation, overlain by the Kap Morton Formation. Location figs 24 & 30.

ordinate rocks include units of grade and/or laminated calcarenites and fine pebble calcareous conglomerates, and nodular dark grey lime mudstones.

On the south side of the cape the formation consists of tabular units of graded and/or laminated calcarenites and massive calcarenites together with pure crinoidal sand beds (figs 31 & 32). Subordinate lime mudstone interbeds occur. Conglomerates and disturbed laminae calcarenites are rare (fig. 32). A distinctive 10 m thick cobble breccia with platform carbonate clasts set in a matrix of carbonate sand occurs, in the middle of the unit.

Boundaries

The formation rests conformably on the Aleqatsiaq Fjord Formation and is conformably succeeded by the Kap Morton Formation. The lower boundary is only exposed on the south side of Kap Godfred Hansen. A small outcrop of Lafayette

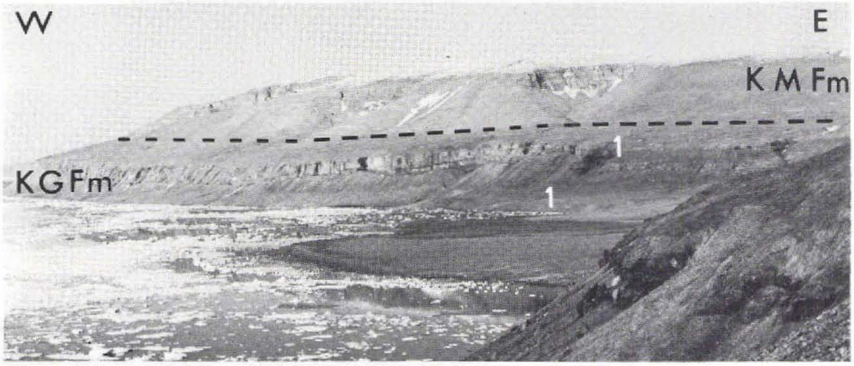


Fig. 30. Location of the type locality and section (1) of the Kap Godfred Hansen Formation (K G Fm), overlain by the Kap Morton Formation (K M Fm). Note the bench at the top of the Kap Godfred Hansen Formation.

Bugt Formation (fig. 24) indicates that this formation interdigitates with the Kap Godfred Hansen Formation on the north side of the cape. On the south side of Kap Godfred Hansen the formation presumably once interdigitated with the Lafayette Bugt Formation, but due to present day erosion this is not seen in outcrop. Towards the east the Kap Godfred Hansen Formation grades into the Pentamerus Bjerge Formation (figs 24 & 28; see earlier discussion).

In the type section (fig. 29) the base of the formation is taken at the base of the first calcarenites. Due to excessive weathering the top of the formation could not be examined. In the reference section (fig. 24) the top of the formation is well exposed and taken at the top of the last breccia bed. For mapping purposes this upper boundary is easily located around the whole of Kap Godfred Hansen as the softer light grey lime muds of the overlying Kap Morton Formation are stripped back to form a prominent bench (figs 25 & 30).

Distribution

The formation is centered on Kap Godfred Hansen. It extends some way up the valley running south-east from the cape, but the exact extent is unknown (fig. 28).

Fauna and geological age

If the top of the Aleqatsiaq Fjord Formation is synchronous then the base of the Kap Godfred Hansen Formation could be Early or Middle Llandovery Age. There is no direct faunal evidence to corroborate this.

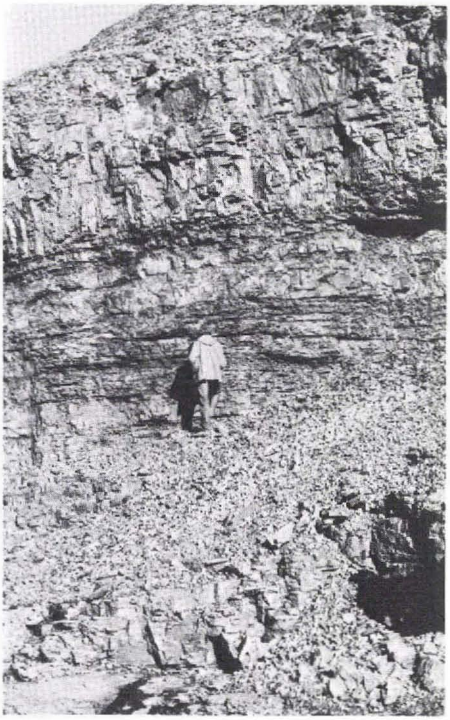


Fig. 31. Massive and laminated tabular calcarenites of the Kap Godfred Hansen Formation. From the type section.

Fig. 32. Laminated and tabular crinoidal calcarenites. Type section of Kap Godfred Hansen Formation.

At the very base of the reference section conodonts indicative of the *celloni* Zone of the Late Llandovery (Telychian) occur. As the Kap Godfred Hansen Formation is essentially a sequence of redeposited carbonates derived from the Pentamerus Bjerge Formation it is probable that the base is synchronous. If so there is a considerable age gap between the base of the formation and the lowest sediments seen in the reference section indicating that the formation may be much thicker on the north side of the cape.

In a small subsiduary section through the interdigitating Lafayette Bugt Formation (fig. 24) on a level equivalent to approximately 50 m above the base of the reference section, M. Bjerreskov has identified; *Stomatograptus grandis grandis* and *Monograptus priodon* probably indicating a Late Llandovery Age but close to the Wenlock boundary. *Dictyonema* aff. *D. polymorpham, Retiolites geinitzianus angustidens, Monoclimacis vomerina, M. priodon* and *Cyrtograptus* sp. from some 80 m higher possibly indicate transitional strata between the Llandovery and Wenlock.

Near the top of the type section coquinas of *Kirkidium (Khodalovechia)* sp.

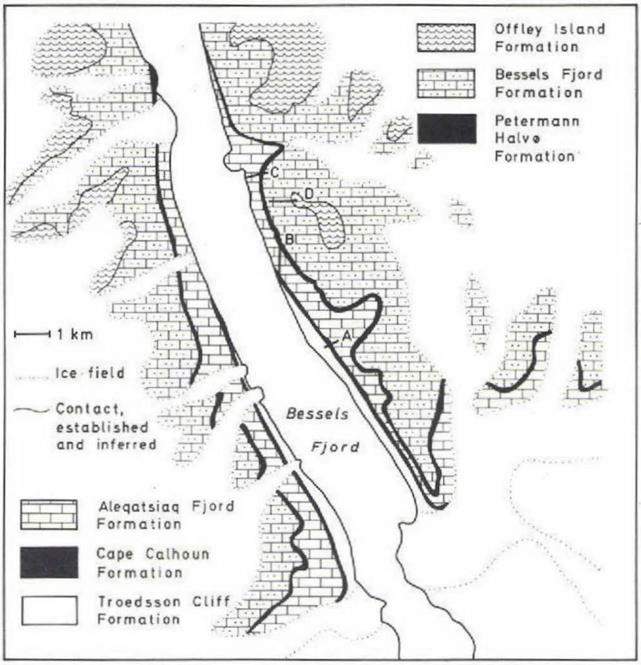


Fig. 33. Geological map of the central and southern region of Bessels Fjord (reference map fig. 2). The letters A, B, C, D indicate line of sections and refer to section logs in fig. 36. The line of sections C and D are the types for the Petermann Halvø and Bessels Fjord Formations respectively.

occur. According to Boucot & Johnson (1979) this genus of pentamerid brachiopod (and many closely related forms) is unknown in the Silurian before the Middle Wenlock. Thus, the formation must be at least as young as this.

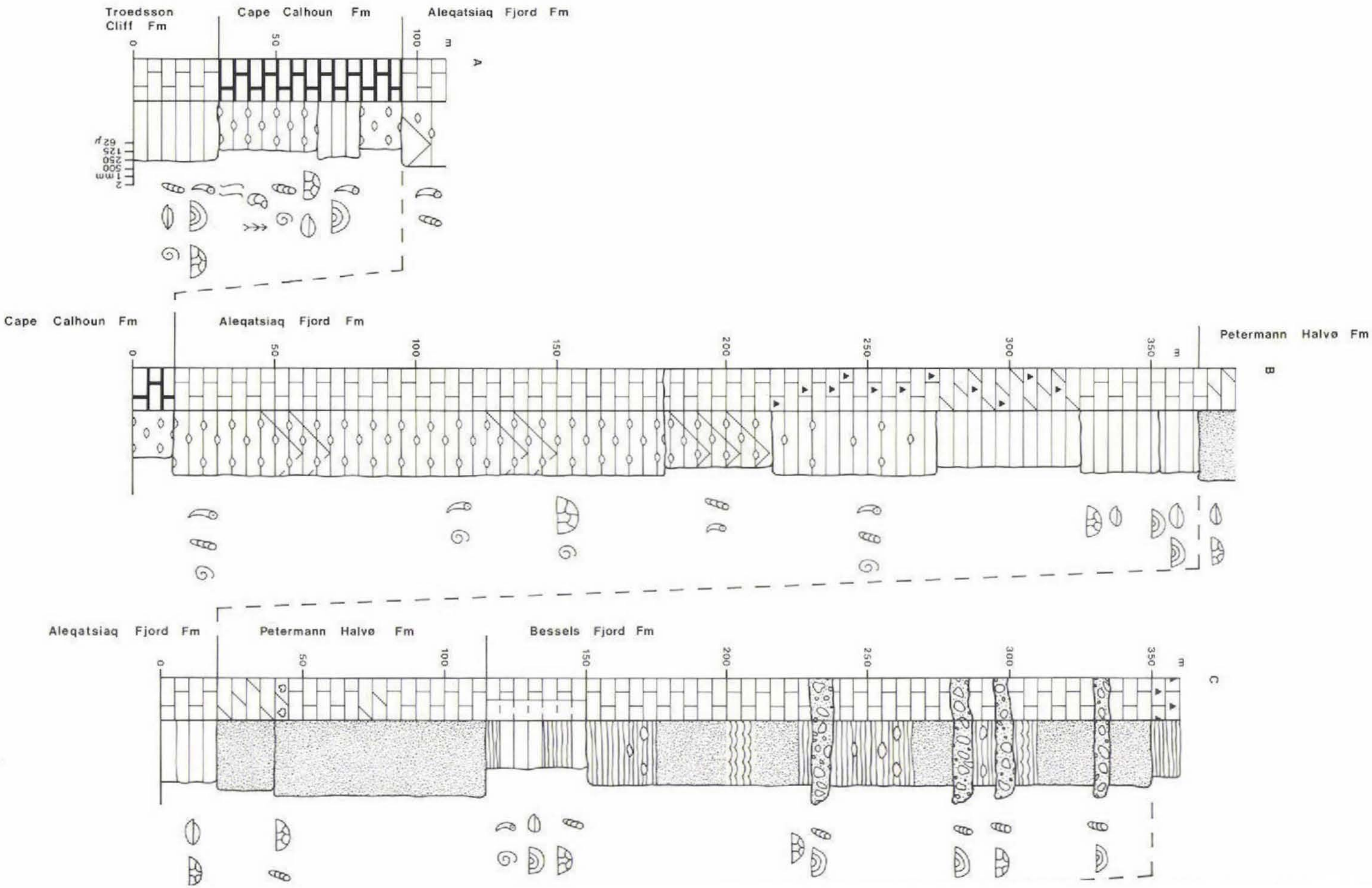
To summarise, the age span of the formation appears to be at least Middle Llandovery to Middle Wenlock.

Fig. 34. Location of the type sections through the Petermann Halvø (P H Fm) and Bessels Fjord (B F Fm) Formations. For location in wider context see fig. 35. Offley Island Formation (O I Fm) and Aleqatsiaq Fjord Formation (A F Fm). Note inclined strata of carbonate mounds in Bessels Fjord Formation. H. F. Jepsen, 1977.

Fig. 35. Aerial photograph of Bessels Fjord and environs. Numbers indicate: location of fig. 34 (1); location of section A_1 in fig. 36 (2); location of section B_1 including type section of Kap Maynard Formation in fig. 36 (3); type section for Kap Morton Formation at Kap Morton (4); section at Kap Lucie Marie, including the type section of the Kap Lucie Marie Formation (5). Line a indicates base of the Petermann Halvø Formation and line b base of Offley Island Formation. Kap Maynard Formation (K M Fm). Aerial photographs 545 K1 – SØ 2220 and 2221. Copyright Geodætisk Institut, Denmark.


N
S
OIFm
BF Fm
PHFm
A F Fm


E
W
KMFm
5
1
3
2
a
b
4



Troedsson Cliff Fm
Cape Calhoun Fm
Aleqatsiaq Fjord Fm
0
50
100
m
A
Cape Calhoun Fm
Aleqatsiaq Fjord Fm
Petermann Halvø Fm
0
50
100
150
200
250
300
350
m
B
Aleqatsiaq Fjord Fm
Petermann Halvø Fm
Bessels Fjord Fm
0
50
100
150
200
250
300
350
m
C

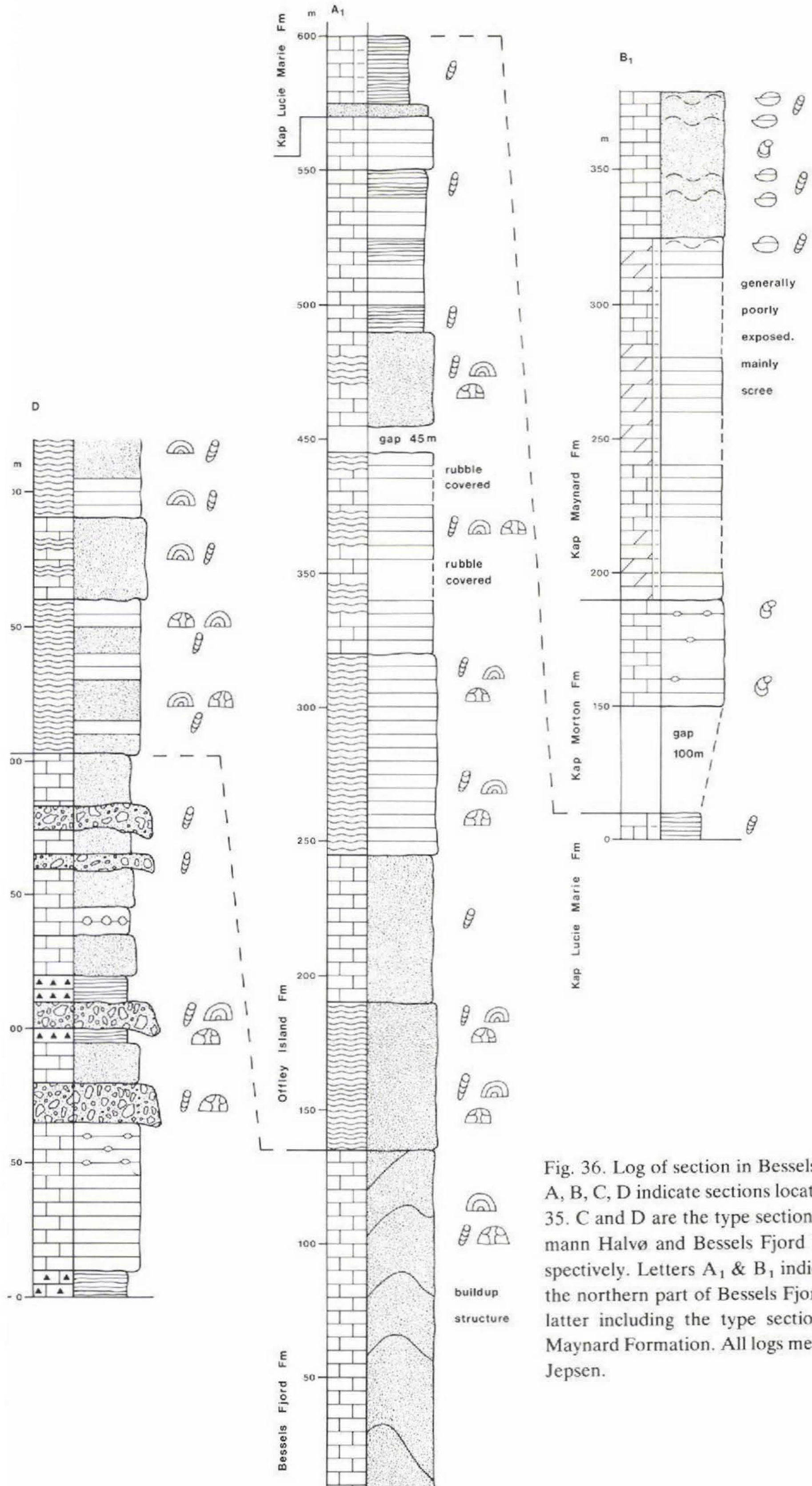


Fig. 36. Log of section in Bessels Fjord. Letters A, B, C, D indicate sections located on figs 33 & 35. C and D are the type sections for the Petermann Halvø and Bessels Fjord Formations respectively. Letters A_1 & B_1 indicate sections in the northern part of Bessels Fjord (fig. 35), the latter including the type section for the Kap Maynard Formation. All logs measured by Hans Jepsen.

Petermann Halvø Formation

new formation

History

Strata of this formation occur approximately at the Ordovician Silurian boundary as mapped by Koch on his 1:500 000 map (Dawes & Haller, 1979, pl. 2; fig. 4).

Name

After Petermann Halvø between Bessels Fjord and Petermann Gletscher.

Type and reference sections

Accessible sections are rare due to the precipitous nature of the exposure in fjord walls. The type section is in south Bessels Fjord (figs 33, 34 & 35).

Thickness

95 m.

Lithology

The basal 20 m are composed of massive yellowish cream coloured (fresh surface colour) dolomite (fig. 36). The remainder consists of massive light grey, mottled limestone, occasionally dolomitic, interbedded with rare calcareous pebble breccias and laminated crinoidal calcarenites (fig. 37).

Fig. 37. Mottled dolomitic limestone of the Petermann Halvø Formation, from the type section. H. F. Jepsen, 1977.

Boundaries

The formation rests conformably on the Aleqatsiaq Fjord Formation and is conformably succeeded by the Bessels Fjord Formation in the type area (figs 34 & 36). It probably interdigitates with the Pentamerus Bjerge Formation to the west of Bessels Fjord, under John Brown Iskappe.

In the type section (fig. 34) the base of the formation is taken at the base of the thick massive yellowish dolomite. This is an easily distinguished boundary with the dark, nodular, cherty and fossiliferous limestone of the Aleqatsiaq Fjord Formation below. The upper boundary is also readily distinguishable at the top of the massive limestone. This is overlain by black shales and limestones of the Bessels Fjord Formation (fig. 38).

Distribution

The Petermann Halvø Formation outcrops in the steep cliffs of south Bessels Fjord (fig. 35), and disappears below sea level on the east side of Petermann Halvø in the steep cliffs surrounding Petermann Gletscher. It also appears to be present in the cliffs of south-west Hall Land.

In the vicinity of some carbonate buildups in the overlying Bessels Fjord Formation, the Petermann Halvø Formation is difficult to define. This may indicate contemporaneity between some of the buildups and the Petermann Halvø Formation, a possibility corroborated by the occurrence of conglomerates and crinoidal calcarenites (probably buildup derived), in the upper Petermann Halvø Formation.

Fauna and geological age

There is no diagnostic fauna from the formation. If the top of the Aleqatsiaq Fjord Formation is synchronous then the Petermann Halvø Formation possibly starts in the Early or Middle Llandovery, but again there is no faunal evidence to substantiate this possibility. The overlying Bessels Fjord Formation probably predates the Late Llandovery Telychian Stage (see discussion below) and thus the Petermann Halvø Formation cannot extend later than early Late Llandovery (Fronian).

Bessels Fjord Formation

new formation

History

It is probable that Koch (1920) included in his Coral Limestone strata now referred to this formation, whilst Koch (1929) included them in the Ordovician Cape Calhoun Formation and the Silurian Offley Island Formation. On Koch's 1:500 000 map (fig. 4) strata now referred to this formation were partially included in unnamed Ordovician strata and partly in the Silurian Offley Island Formation.

Name

After Bessels Fjord.

Type and reference sections

Accessible sections are rare as the rocks form the precipitous fjord walls. The type section is in a gully in central Bessels Fjord (fig. 33, 34, 35 & 36).

Thickness

550 to 600 m.

Lithology

This consists of a complex unit of carbonate buildups intercalated with more flat lying sediments (figs 34 & 38). The buildups are massive and composed of lime mudstone with rarer crinoidal and stromatoporoidal rudstones. Pebble breccias and conglomerates up to several metres thick, in the flat-lying sediments, derive from the mounds. Clasts rarely exceed 10–20 cm and are set in a crinoidal and stromatoporoidal fragment matrix.

Sediments between the buildups consist of (1) interbedded black poorly laminated dolomitic limestone, often with chert bands and black laminated shale (fig. 39), (2) nodular bedded, dark grey, lime mudstone and wackestone with chert nodules, (3) massive to thinly bedded, light grey, poorly laminated lime mudstone

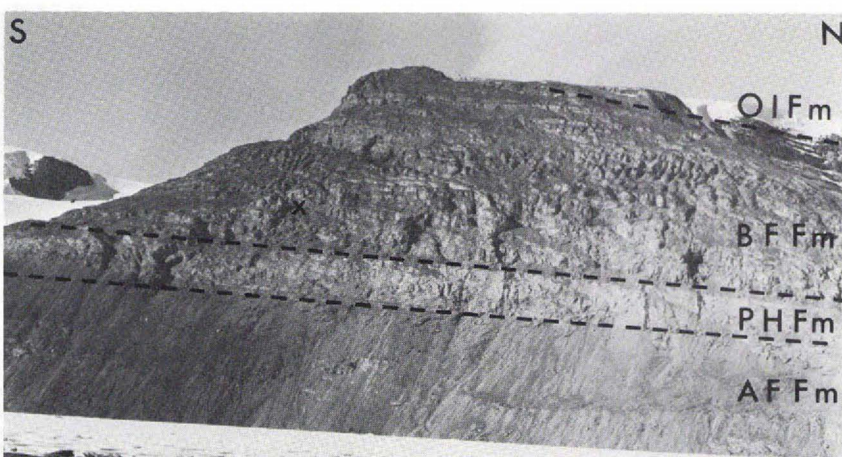


Fig. 38. Outcrop of Aleqatsiaq Fjord Formation (A F Fm), Petermann Halvø Formation (P H Fm), Bessels Fjord Formation (B F Fm) and Offley Island Formation (O I Fm) in the western cliffs of Bessels Fjord, opposite fig. 34. Note recessive black lime mudstone/shale unit at the base of the Bessels Fjord Formation, and the inclined strata of the carbonate buildup at x. H. J. Jepsen, 1977.

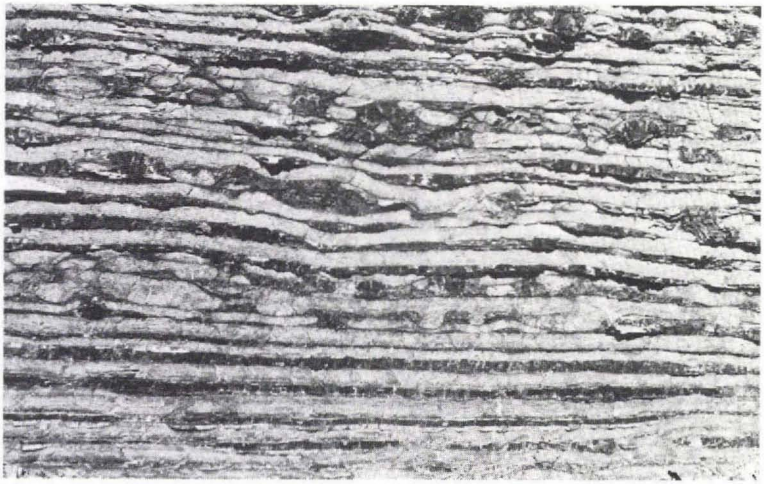


Fig. 39. Interbedded black chert and laminated dolomitic limestone, in the type section of the Bessels Fjord Formation (fig. 33). H. J. Jepsen, 1977.

and (4) graded, laminated, or graded and laminated crinoidal calcarenites and skeletal calcarenites (fig. 36).

Boundaries

The formation follows conformably from the Petermann Halvø Formation. In some localities e.g. the vertical cliff face of Kap Lucie Marie, it may be unconformably overlain by the Offley Island Formation. In the Bessels Fjord region the upper contact appears conformable although it is wildly undulating due to differential sedimentation and compaction. It may be this undulation and variable dip which makes the contact in freshly cut vertical faces, such as Kap Lucie Marie, appear unconformable. To the west of Bessels Fjord, under John Brown Iskappe the Bessels Fjord Formation presumably interdigitates with the Pentamerus Bjerge Formation.

In the type section (figs 34 & 36) the base of the formation is taken at the base of a unit of recessive shale and cherty black limestones. The top of the formation is defined by the base of the Offley Island Formation (figs 34 & 36).

Distribution

The Bessels Fjord Formation forms the very base of the cliffs at the mouth of Bessels Fjord (fig. 34). Towards the south in the central region of the fjord, the full thickness of the formation is exposed in the vertical cliffs. Approaching the head of the fjord, the formation forms the highest parts of the hills and the outcrop swings around the southern extension of the ice cap on Petermann Halvø. The formation is well exposed in both sides of Petermann Gletscher and reaches sea level at the foot of Kap Lucie Marie in Washington Land. From aerial photographic interpretation P. R. Dawes (personal communication, 1979) reports a carbonate buildup horizon within platform carbonates in south central Hall Land. This may well correlate with the Bessels Fjord Formation.

Fauna and geological age

Unfortunately, there is little precise evidence as to the age of the formation. Conodont faunas proved non-diagnostic other than Silurian. Some 150 m from the top of the formation coquinas of *Harpidium* sp. indicate this upper part of the formation to be Late Llandovery or later (cf. Boucot & Johnson, 1979). As at least part of the overlying Offley Island Formation belongs to the conodont *celloni* Zone of the Late Llandovery (Telychian), this affords an upper age limit for the Bessels Fjord Formation. The age of the lower part of the formation is unknown, but it may be as old as Middle Llandovery.

Offley Island Formation

History

This is perhaps the most famous as well as the most embracing of all the formations erected by Koch (1929). According to Koch's coloured maps (Dawes & Haller, 1979, pl. 2 & 3; fig. 4) the vast majority of Washington Land and a major belt across North Greenland was assigned to this formation. Strata of this formation were included by Koch (1920, p. 35, 62) in both the Coral Limestone and Pentamerus Limestone (Dawes & Haller, 1979).

More recent fieldwork in Washington Land and Hall Land (Allaart, 1965, 1966; Dawes, 1967; Norford, 1967) led Dawes (1971) to extend the Offley Island Formation to include limestones and associated rocks of Koch's Cape Tyson Formation. Subsequently, Norford (1972) followed the same procedure and also included conglomerates, in a predominantly shaly sequence, (here included in the new Lafayette Bugt Formation) at the cape just south of Kap Schuchert. Norford also referred 30 m of limestone at the base of Kap Tyson (Offley Island Formation of Dawes, 1971) to the Cape Schuchert Formation. These facies rarely occur in the Offley Island Formation type section, but are not known from the Cape Schuchert Formation.

Clearly the Offley Island Formation has come to include many differing facies units and is in need of revision.

Name

After the small island Offley Ø, in the Hall Basin, approximately 2 km due west of Kap Tyson.

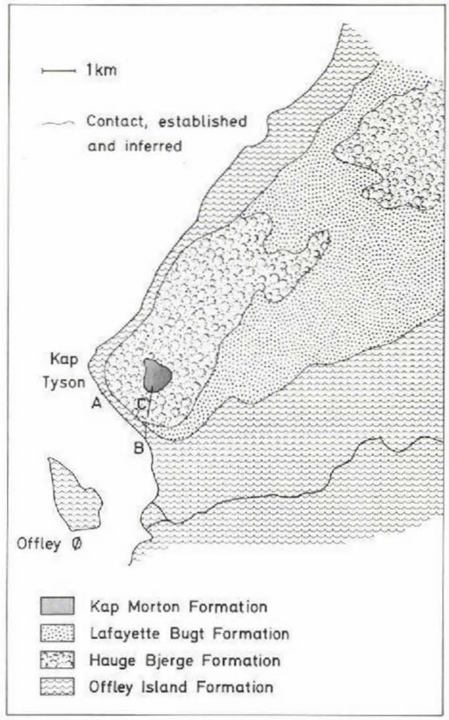


Fig. 40. Geological map of the Kap Tyson–Offley Island region in Hall Land (reference map fig. 2). The numbers A, B, C refer to lines of section, located precisely in fig. 42, and depicted in fig. 43. Sections A and B are reference sections through the Offley Island Formation and the top of the formation is defined in B. Section C is the type section for the Hauge Bjerge Formation and Cape Tyson Member.

Type and reference section

There is no doubt that Offley Ø is the type locality although Koch (1929 p. 238) referred to Offley Islands (fig. 40). Due to logistical problems I was unable to measure a section on the island itself although I examined the strata. Many good sections exist (see fig. 41), although the top and bottom of the formation are not exposed. A comparative section through the Offley Island Formation was measured at Kap Tyson and the upper boundary to the formation is defined here (figs 42 & 43).

In the restricted sense employed here the Offley Island Formation is traceable with precision into northern Washington Land and the base of the formation is defined in Bessels Fjord (figs 35, 36, 44).

Thickness

Maximum 450 km.

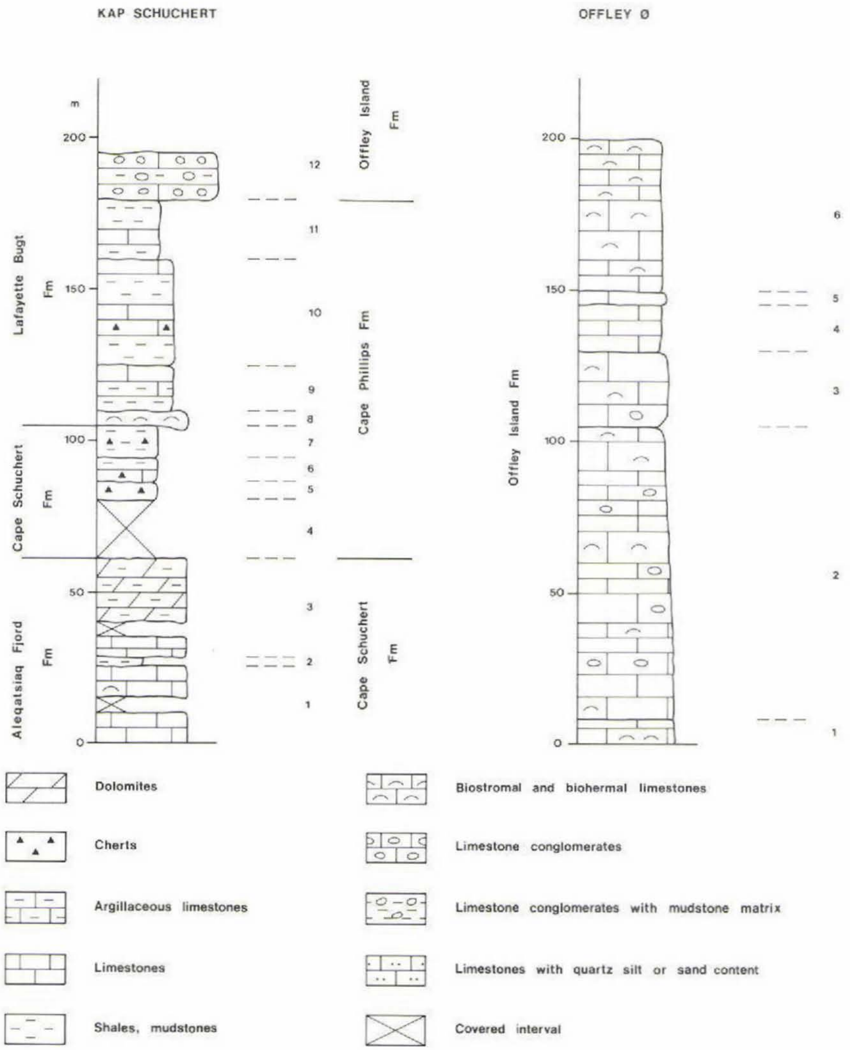


Fig. 41. Stratigraphic sections at Kap Schuchert and Offley Ø taken from Norford (1972). The Offley Ø section is the only recorded log of Offley Island Formation and the numbers indicate units referred to in Norford. The Kap Schuchert section relates Norford's (see fig. 24) lithostratigraphic units (right margin) to those proposed here (left margin).

Lithology

The Offley Island Formation shows rapid interdigitating facies variations and consists of a complicated mixture of:

(1) intraformational bioclastic conglomerates and breccias, composed primarily

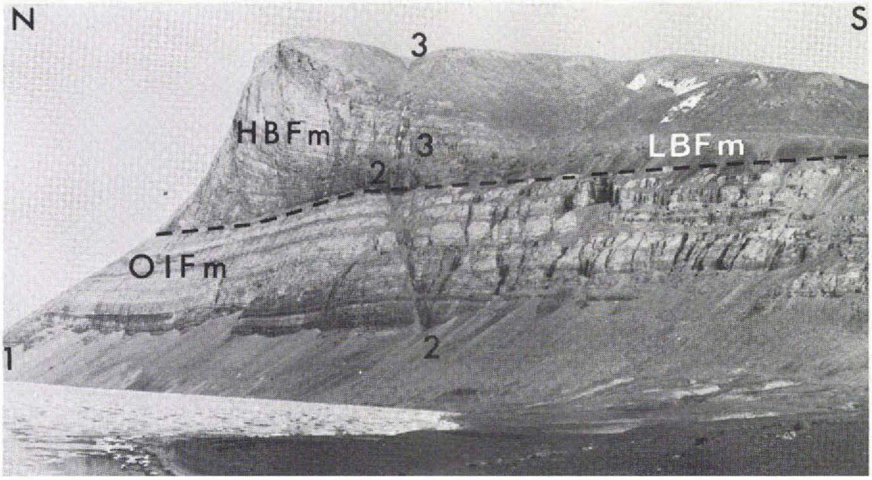


Fig. 42. Kap Tyson, opposite Offley Ø, showing the Offley Island Formation (O I Fm) overlain by the Hauge Bjerge Formation, Kap Tyson Member (H B Fm) and the Lafayette Bugt Formation (L B Fm). Numbers 1, 2, 3 indicate sections A, B, C in fig. 40. The top contact of the Offley Island Formation is in section 2. Section 3 is the type for the Hauge Bjerge Formation and Kap Tyson Member. Note the facies interdigitation between the Hauge Bjerge and Lafayette Bugt Formations. This cliff section was figured earlier in Norford (1972) and Dawes & Soper (1973).

of huge cauliform and lamellar stromatoporoids, tabulate corals and consolidated plate like limestone clasts (up to 50 cm long) set in a matrix of coarse crinoidal debris. These units are massive and up to 20 m thick. These biostromes are the diagnostic unit of the formation and are extremely fossiliferous (fig. 45).

(2) graded, laminated or graded and laminated crinoidal and skeletal calcarenites in beds up to 50 cm thick.

(3) black silty lime mudstones with occasional, weak, parallel lamination and paper thin black shale.

(4) massive light grey lime mudstone.

(5) occasional thin laminated black shale units with graded skeletal calcarenites in the upper part of the formation.

Dawes (1976) reports local patch bioherms at Kap Tyson, and these are probably intimately associated with the characteristic biostromal units (see Norford, 1972, pls 1, 4, pp. 11, 32). At Kap Lucie Marie (fig. 46) there is a distinctive thin laminated black shale unit with graded skeletal calcarenites in the upper part of the formation. Also here the massive light grey lime mudstone contains small channelled (up to 20 cm deep) intraformational conglomerates. This facies is more common in Bessels Fjord (fig. 36) than at Kap Tyson or Offley Ø.

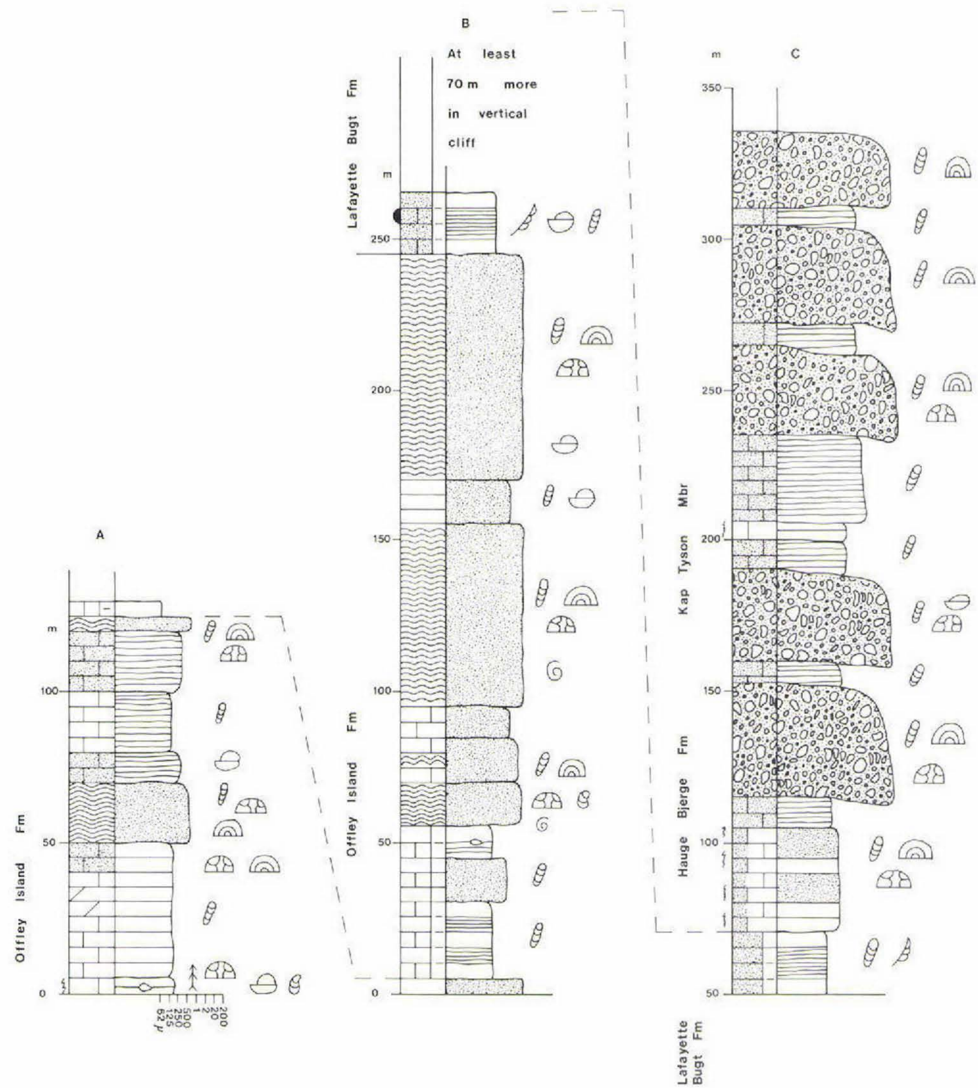


Fig. 43. Sedimentary log of sections A, B, C (left to right) at Kap Tyson. Location fig. 42.

Boundaries

The base of the formation follows conformably from the Bessels Fjord Formation in most areas, although at Kap Lucie Marie there is possibly an unconformity (see discussion under Bessels Fjord Formation). The base of the formation is defined in Bessels Fjord (fig. 36) at the base of the first thick bioclastic limestone conglomerate. In practice this is a very distinctive white marker horizon which can

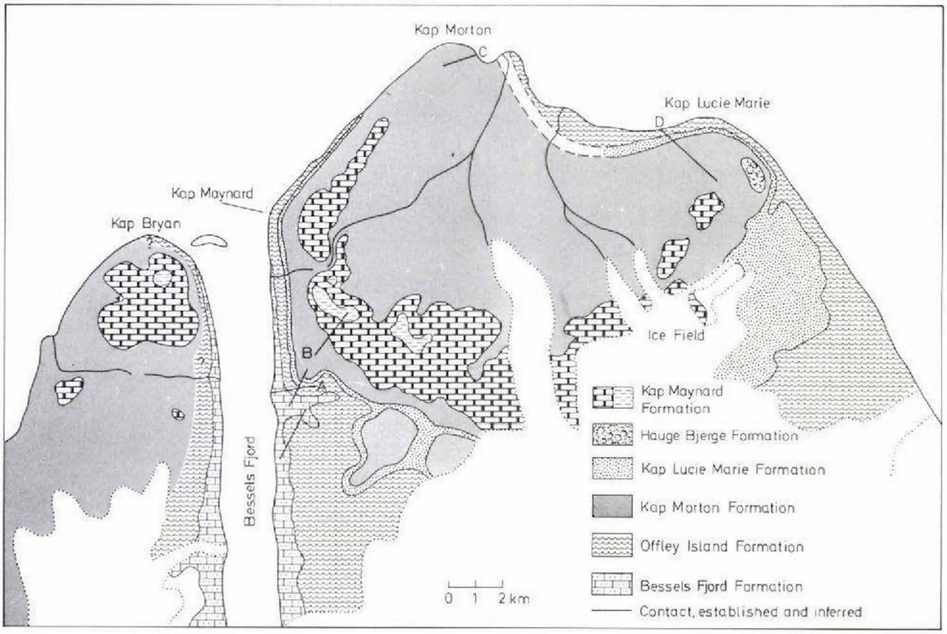


Fig. 44. Geological map of north Washington Land (reference map fig. 2). Letters A and B refer to the sections shown as A1 B1 respectively in fig. 36. The base of the Offley Island Formation is defined in section A, whilst B is the type section for the Kap Maynard Formation (see fig. 35). Sections C and D are located in fig. 35. The former is the type for the Kap Morton Formation whilst the latter starts in the Offley Island Formation (fig. 46).

be followed from a distance and meets sea level at the head of Bessels Fjord (fig. 35). The formation is followed conformably by the Hauge Bjerge Formation or Lafayette Bugt Formation in Hall Land, and the Kap Lucie Marie Formation in Washington Land. West of Bessels Fjord, under John Brown Iskappe, the Offley Island Formation presumably interdigitates with the Pentamerus Bjerge Formation. Also towards the north and west the formation probably interdigitates with the Lafayette Bugt Formation (cf. Kerr, 1967).

At the type locality of Offley Ø neither the top nor bottom of the formation is exposed. Consequently, the top of the formation is defined in the nearby section through the cliff at Kap Tyson (fig. 43) at the top of a massive white bioclastic conglomerate which is overlain by recessive, interbedded, black laminated shale and laminated calcarenites of the Lafayette Bugt Formation (fig. 42). This boundary coincides with the top of the formation as defined by Koch (see plate 3 in Dawes & Haller, 1979). The boundary is a distinct feature around the southern and eastern part of Kap Tyson, but it is more difficult to recognise towards the north of the hill, where the Offley Island Formation is succeeded by the Hauge Bjerge Formation (see Norford, 1972, pl. 2.1).

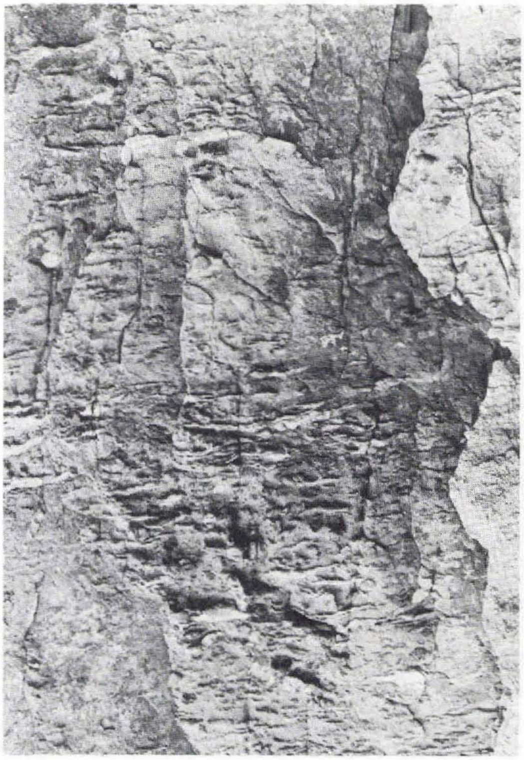


Fig. 45. Characteristic biostromal limestone of the Offley Island Formation. In section B fig. 40. Scale, hammer shaft showing at bottom c. 10 cm.

Distribution

The Offley Island Formation forms Offley Ø and the lower half of the cliffs at Kap Tyson. Southwards, the upper part of the cliffs along the north part of Petermann Gletscher, in both Hall Land and Washington Land, are of this formation. The outcrop swings under the ice field on Petermann Halvø and forms the major part of the cliffs along north Bessels Fjord. There is a white marker horizon at Kap Ulrich on the Kennedy Channel possibly indicating the presence of the formation. It also forms large parts of southern Hall Land.

Fauna and geological age

Many fossils have been described from rocks which have been assigned to the Offley Island Formation at various times (Etheridge, 1878; Poulsen, 1941, 1943, 1974; Peel, 1979). Unfortunately, all the early material described by Etheridge and Poulsen is of uncertain stratigraphic position unless it is derived solely from

Offley Ø. The studies of Poulsen (1941, p. 9) led him to state that "the Offley Island formation and the sedimentary breaks below and above this formation lie between the zone with *Monograptus convolutus* (Hisinger) and the zone with *Monograptus turriculatus* (Barrande); accordingly, the Offley Island formation is the stratigraphical equivalent of the zone with *Monograptus sedgwicki* (Portlock), and it can with certainty be referred to the middle Clinton (Upper Llandovery)". Subsequently, Norford (1972) independently concluded that the Offley Island Formation was of Late Llandovery Age.

The present study confirms these conclusions. The rich mainly undescribed brachiopod faunas are indicative of a Late Llandovery Age. In particular the presence of *Harpidium* spp. (for numerous species names see Poulsen, 1943) throughout this formation indicates that the base is unlikely to be earlier than the Late Llandovery, Telychian Stage (cf. Boucot & Johnson, 1979). Fortunately,

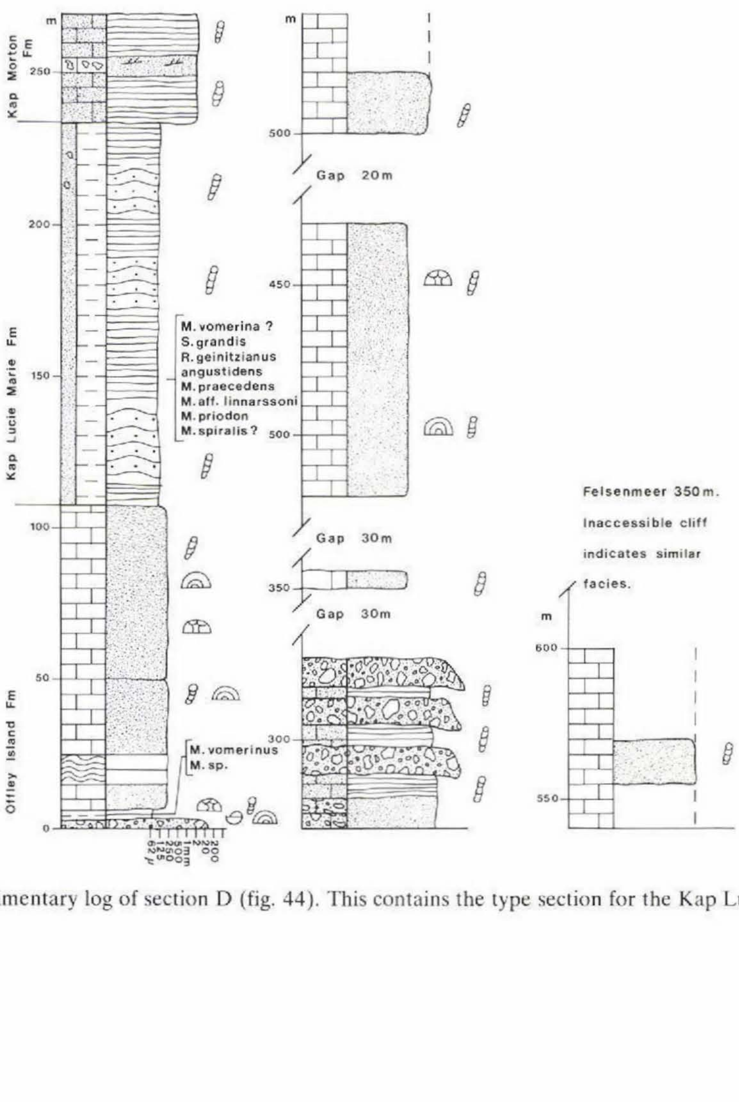


Fig. 46. Sedimentary log of section D (fig. 44). This contains the type section for the Kap Lucie Marie Formation.

there is a little precise evidence for the age of the formation from conodont faunas. At Kap Tyson, 135 m below the top of the formation, R. J. Aldridge reports a *celloni* Zone fauna of Late Llandovery (Telychian) Age. At the very top of the formation a conodont assemblage of the *celloni* or the *amorphognathoides* Zone again indicates an age range for the formation compatible with that suggested by the brachiopods. An *amorphognathoides* Zone conodont fauna was obtained some 150 m below the top of the formation at Kap Lucie Marie. This zone transgresses the Llandovery-Wenlock boundary in Europe (Aldridge, 1975), but the graptolite faunas in Greenland rule out the possibility that the Offley Island Formation extends into the Wenlock.

Graptolite faunas immediately above the Offley Island Formation at Kap Lucie Marie and Kap Tyson, in the Kap Lucie Marie Formation and Lafayette Bugt Formation, indicate the Late Llandovery *Monograptus spiralis* Zone (see discussion below and Norford, 1972).

Other fauna from the Offley Island Formation include the gastropods *Offleya inexpectata, Liospira perdepressa, Murchisonia (?Murchisonia) latifascata* and *Offleyotrochus naresi* (see Poulsen, 1974 and Peel, 1979). Rugose corals include (McLean, 1977), *Kodonophyllum? pussilum, Crassilasma offleyense? Cystilasma? rarum, Ptychophyllum* sp. A, *Amplexoides poulseni Kenophyllum? congestum, Ptychophyllum tysonense, Pseudophaulactis plectilis* and *Hedstroemophyllum rhaphis.*

Kap Lucie Marie Formation

new formation

History

From Koch's 1:500 000 map (fig. 4) it is apparent that Koch recognised a shale unit at Kap Lucie Marie, but its geographic extent does not coincide closely with that of the Kap Lucie Marie Formation.

Name

After Kap Lucie Marie in north Washington Land (fig. 1)

Type and reference sections

The type section is in the main stream which drains the north slope of Kap Lucie Marie into Hall Basin (figs 47, 48). As the formation is recessive, there are no other good sections except in the inaccessible face of the cape. A thinner reference section occurs in north Bessels Fjord (fig. 36).

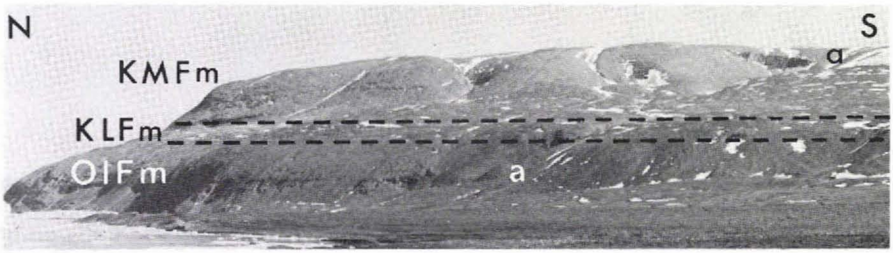


Fig. 47. Kap Lucie Marie showing section (a) measured in fig. 46. Offley Island Formation (O I Fm), Kap Lucie Marie Formation (K L Fm) and Kap Morton Formation (K M Fm).

Thickness

Between 25 and 135 m (fig. 46).

Lithology

This formation consists of units of faintly laminated mudstone, up to 50 cm thick, interbedded with parallel laminated silty limy mudstones. Tabular units up to 50

Fig. 48. Type section of the Kap Lucie Marie Formation (within section a-a in fig. 46) showing alternating shale tabular calcarenite lithology.

cm thick of graded and/or laminated calcarenites are common particularly towards the top of the formation (fig. 48). In the Bessels Fjord section a distinctive orange yellow dolomitic sandstone (1 m thick) occurs at the base of the formation.

Boundaries

The formation conformably overlies the Offley Island Formation, and it is itself conformably followed by the Kap Morton Formation (fig. 46). Towards the north and west it presumably interdigitates with the Lafayette Bugt Formation of the Peary Land Group. This assumption is based on regional facies considerations.

In the type section the base of the formation is taken at the first occurrence of shale. At this point a distinctive topographic feature is produced as the softer recessive shale is stripped back to form a platform at the top of the Offley Island Formation. The top is defined at the base of thick tabular calcarenites with conglomerate layers totally lacking shale interbeds.

Distribution

The formation occurs around Kap Lucie Marie and disappears southward into the ice cap on Petermann Halvø. It reappears at the north end of Bessels Fjord near Kap Maynard (fig. 44). Between Kap Lucie Marie and Kap Morton it disappears below glacial outwash and till.

Fauna and geological age

Some 35 m above the base of the formation at Kap Lucie Marie graptolites from three collections indicate the Late Llandovery *Monograptus spiralis* Zone and include; *Retiolites geinitzianus angustidens, Stomatograptus grandis grandis, Monograptus* aff. *M. linnarssoni, M. vomerina?, M. priodon, M. praecedens* and *M. spiralis?* There is no evidence for the age of the upper part of the formation or the immediately overlying Kap Morton Formation.

Kap Morton Formation

new formation

History

Koch (1920) included strata now referred to this unit in the Coral Limestone and subsequently the Offley Island Formation (Koch, 1929).

Name

After Kap Morton in north Washington Land.

Type and reference sections

The type section is on the north facing steep slope of the cape (fig. 44). This is the only well exposed and accessible section in this formation, as it forms steep cliffs everywhere. However, neither boundary to the formation is exposed here so they are defined in reference sections at Kap Lucie Marie (lower boundary, fig. 46) and north Bessels Fjord (upper boundary, fig. 36).

Thickness

Minimum thickness 150 m, maximum seen approximately 700 m.

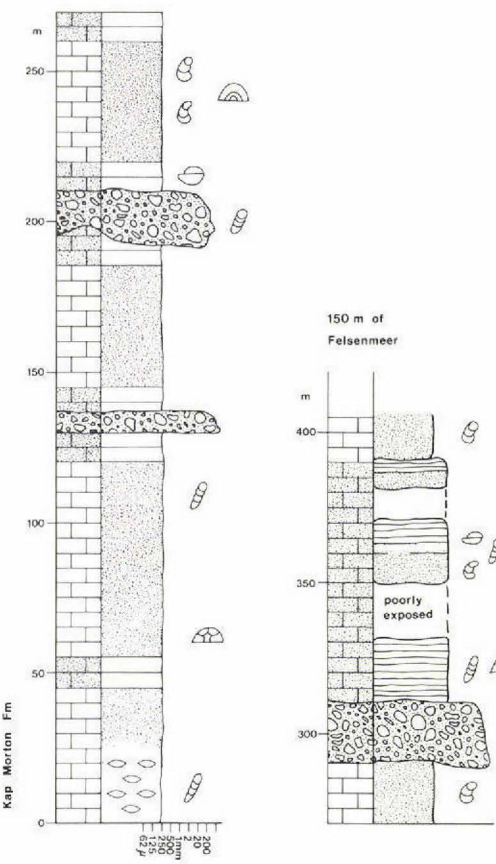


Fig. 49. Sedimentary log of the type section of the Kap Morton Formation, located along the line C in fig. 44.

Fig. 50. Typical lime mudstones of the Kap Morton Formation with megalamoid bivalves.

Lithology

The formation is variable in its lithologies, but it is characterised by the massive, monotonous, light grey, lime mudstone (fig. 50).

Rocks of the type section consist mainly of massive bedded, light grey, lime mudstones and subordinate wackestones, with patchy dark grey mottling. Nodular, dark grey lime mudstones occur rarely in the lower part of the section. Interbedded are thick pebble breccias and conglomerates with blocks of lime mudstone up to several metres across. The breccias and conglomerates wedge out rapidly towards the north and individual blocks are set in a matrix of pebbles, cobbles and bioclastic debris. Graded, or graded laminated, and laminated, calcarenites and massive calcarenites are associated with the conglomerates (fig. 49).

Towards Kap Lucie Marie there is a greater proportion of breccias and calcarenites in the lower part of the formation presumably reflecting the proximity of the Hauge Bjerge Formation carbonate buildup (fig. 46). Southwards from Kap Morton into north Bessels Fjord (fig. 36) the formation thins and is composed entirely of the light grey lime mudstone. At Kap Godfred Hansen the formation consists primarily of massive, light grey lime mudstone interbedded with subordinate bioclastic limestone conglomerates typical of the Offley Island Formation. No resedimented breccias are known here, but intraformational conglomerates are common in the lower part of the formation (fig. 26).

Boundaries

The formation follows conformably upon the Kap Lucie Marie Formation and it is conformably overlain by the Kap Maynard Formation, in the region of north

Bessels Fjord and Kap Lucie Marie (figs 36 & 46). It has not been possible to locate the Kap Lucie Marie Formation at Kap Morton suggesting that the base of the formation is below sea level (fig. 35). However, the possibility cannot be ruled out that the Kap Morton Formation is partially equivalent to the Kap Lucie Marie Formation, especially considering the abrupt facies changes in these platform edge – basin slope environments. At Kap Godfred Hansen, the Kap Morton Formation conformably follows the Kap Godfred Hansen Formation.

The base of the formation is defined at the base of the thick laminated and/or graded calcarenites immediately above the Kap Lucie Marie Formation at Kap Lucie Marie (fig. 46). The top is defined in the reference section in north Bessels Fjord (fig. 36) and is taken at the top of the last massive light grey lime mudstone unit. Both boundaries of the cliff forming Kap Morton Formation are distinct mapping features as the overlying and underlying rocks are recessive.

Distribution

The formation occurs in the very northern part of Petermann Halvø. Towards the west of Bessels Fjord it occurs all along the coast of Washington Land, up to John Brown Iskappe and as far south as Kap Godfred Hansen. From field note descriptions (R. L. Christie, personal communication, 1978) Hans Ø in Kennedy Channel (fig. 1) is formed of this formation. Joe Ø to the north of Kap Morton is composed of the same rocks. The formation is known in Hall Land, on the top of Kap Tyson (fig. 40), but is possibly more extensive.

Fauna and geological age

Conodont faunas occur throughout the formation but surprisingly nothing diagnostic (other than Silurian) has been isolated. Thus, there is very little substantial evidence concerning the precise age of the formation. At Kap Lucie Marie it follows the Late Llandovery *M. spiralis* Zone whilst at Kap Godfred Hansen it follows brachiopod faunas of possible Middle Wenlock age (see earlier). This suggests that the base of the formation is diachronous and that its age range is Late Llandovery to Wenlock and possibly younger.

Kap Maynard Formation

new formation

History

Koch (1920) included strata now referred to this formation in the Coral Limestone whilst he later (Koch, 1929) included it in the Offley Island Formation. Koch's 1:500 000 map (fig. 4) indicates that strata now included in this formation were, in the main, assigned to the Offley Island Formation.

Name

After Kap Maynard, the cape east of the mouth of Bessels Fjord (fig. 1).

Type and reference sections

The type section is on the top of the hill immediately to the south-east of Kap Maynard (figs 35, 44 & 51). The formation is only partially exposed, but due to its general recessive character no well exposed sections are known.

Thickness

Up to 200 m.

Lithology

Dolomites, resistant light grey lime mudstones and green lime shales.

Boundaries

The formation conformably overlies the Kap Morton Formation, but the top is a present day erosion surface. Due to the regional outcrop pattern, it is not known how the formation relates to the thicker Kap Morton Formation section at Kap Godfred Hansen. Regional mapping (fig. 44) indicates that the base of the Kap Maynard Formation, when traced northwards, falls above the whole of the Kap Morton Formation section, at the type locality. However, taking into account the local disparity in thickness of the Kap Morton Formation at north Bessels Fjord (fig. 36) and Kap Morton (fig. 49) it is possible that some of the lower part of the Kap Maynard Formation interdigitates with the Kap Morton Formation.

In the type section the base of the formation is taken at the first incoming of

Fig. 51. Type section of the Kap Maynard Formation (cf. figs 35 & 44). Note the recessive Dolomite Member (base at a) overlain by the cliff forming Limestone Member (base at b).

dolomite and green lime shales. Although the boundary is not normally exposed, in practice it is simple to delineate, as the Kap Maynard Formation is recessive (fig. 51), above the more cliff-forming Kap Morton Formation.

Distribution

The formation occurs on the hilltop of Kap Bryan, west of Bessels Fjord and north of the ice cap on Petermann Halvø, between Bessels Fjord and Petermann Gletscher (fig. 44).

Fauna and geological age

Silurian (Wenlock to Ludlow?). For further details see the discussion under the individual members.

Dolomite Member

new member

General

History, type and reference sections and distribution of the member are as for the Kap Maynard Formation. The member name relates to the dominant rock type in the lower part of the formation.

Thickness

Up to 125 m.

Lithology

Units of interbedded poorly laminated green lime shales and thinly bedded to nodular orange dolomites dominate the succession. Occasional thin bedded, light grey, lime mudstones are interspersed throughout.

Boundaries

The Dolomite Member conformably follows the Kap Morton Formation and is conformably followed by the cliff forming Limestone Member of the Kap Maynard Formation. In the type section the lower boundary is defined as for the formation and the upper boundary is taken at the base of the overlying massive limestones (fig. 51).

Fauna and geological age

Some 20 m from the top of the formation *Kirkidium (Kirkidium)* sp. occurs suggesting a Middle Wenlock Age or younger (cf. Boucot & Johnson, 1979). Considering the possible age span of the underlying formations it appears likely that the whole of this member is of Wenlock Age. The upper age limit is unknown.

Limestone Member

new member

General

History, type and reference sections are as for the Kap Maynard Formation. The member name relates to the dominant rock type in the upper part of the formation.

Thickness

60 m seen.

Lithology

This member is composed of massive light grey lime mudstones and wackestones with recrystallised *Megalamoidea* sp., other bivalves and tabular coquinas of pentamerid brachiopods.

Boundaries

The Limestone Member conformably follows the Dolomite Member, but its upper surface is a present day erosion surface.

Distribution

This member is very restricted in its distribution, being known only from the highest points of the hills at Kap Bryan and south-east of Kap Maynard (fig. 44).

Fauna and geological age

Throughout the Limestone Member coquinas of *Kirkidium (Khodalovechia)* sp. and *Kirkidium (Kirkidium)* sp. probably indicate a Middle Wenlock to Ludlow Age.

Hauge Bjerge Formation

new formation

History

This formation is in part equivalent to the Coral Limestone and *Arethusina* Zone of Koch (1920). Koch (1929) included strata, now referred to this unit, in the Cape Tyson Formation and Offley Island Formation. The Hauge Bjerge Formation is partially equivalent to the greatly extended Offley Island Formation of both Dawes (1971, 1976) and Norford (1972).

Name

After the Hauge Bjerge, the prominent range of hills trending east from Kap Tyson in Hall Land (fig. 1).

Fig. 52. The coastal areas of Washington Land, between Lafayette Bugt and Aleqatsiaq Fjord. Hans Ø (HØ), Kap Resser (KR), Kap Constitution (KC), Kap Independence (KI) and Franklin Ø (FØ). Aleqatsiaq Fjord Formation (a), Cape Schuchert Formation (b), Lafayette Bugt Formation (c) and Hauge Bjerge Formation, Kap Independence Member (d). The type section for the Kap Independence Member is at x. Note the distribution of this unit as isolated mounds e.g. Kap Resser. Hans Ø is probably composed of Kap Morton Formation. Transition between Kap Independence Member and Lafayette Bugt Formation shown in fig. 54 is at y. Aerial photograph 545 H-N, no. 11803. Copyright Geodætisk Institut, Denmark.

Type and reference sections

The type section for the formation is the same as for the Cape Tyson Member (figs 40, 42, 43). Numerous reference sections occur in the Hauge Bjerge as well as at Kap Independence (figs 42 & 52).

Thickness

Maximum of 300 to 400 m seen.

Lithology

This formation is a carbonate buildup complex including both core and flank deposits. The core unit consists of more than 60 per cent of tabular and bulbous stromatoporoids with discrete lenses as well as interbedded horizons of lime mudstone, skeletal wackestones and, very commonly, crinoidal rudstone. The flank deposits of individual buildups are characterised by graded and occasionally laminated skeletal calcirudites and calcarenites, the latter dominated by crinoidal material. Breccias composed of huge angular blocks up to several metres flank the buildups. Behind the buildup core (towards the platform) a highly distinctive lime mudstone with fenestral fabric occurs. This is stylolitised, imparting a pseudo-wavy bedding to the unit and along the stylolite contacts faint layers of limonitic green and red mud and pyrite pseudomorphs occur (fig. 53).

Boundaries

The formation rests conformably upon or may even slightly interdigitate with the top of the Cape Schuchert Formation (fig. 52, plate 1) at Kap Independence, Washington Land. In western Hall Land the formation rests conformably upon the Offley Island Formation (fig. 42 & 43). Its upper surface is either eroded or

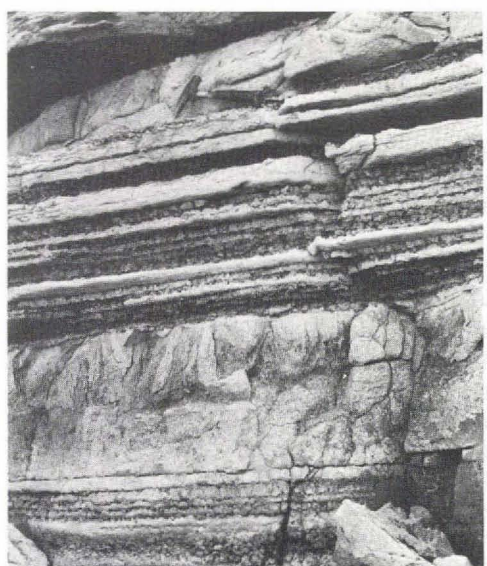


Fig. 53. Interbedded stylolitised lime mudstone and tabular, graded calcarenites. From type section of Kap Independence Member (see fig. 52).

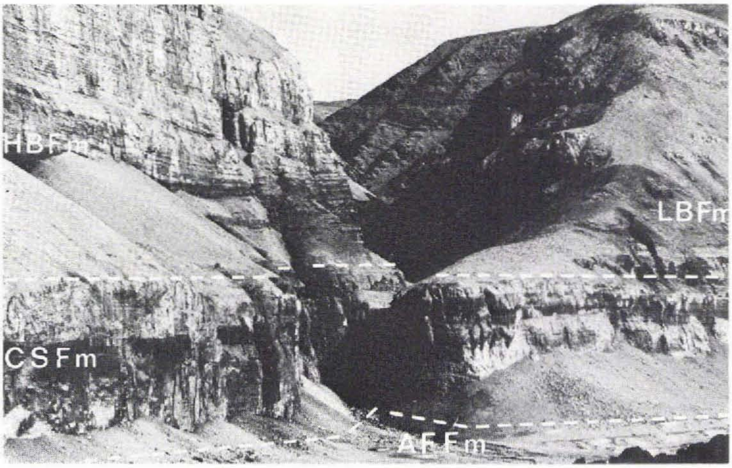


Fig. 54. Interdigitation of the Hauge Bjerge Formation (H B Fm) and Lafayette Bugt Formation (L B Fm), overlying the Cape Schuchert Formation (C S Fm) and Aleqatsiaq Fjord Formation (A F Fm). Location at y in fig. 52.

conformably overlain by the Kap Morton Formation (fig. 40). The formation interdigitates with the Lafayette Bugt Formation (fig. 54) and partially with the Kap Morton Formation and possibly partly with the Kap Lucie Marie Formation.

In the type section the base of the formation is defined at the beginning of steeply dipping breccias and associated facies. The top is poorly exposed but is taken at the base of flat lying blue grey lime mudstones of the Kap Morton Formation (fig. 43).

Distribution

The formation occurs in north and west Washington Land with its best developments around Kap Independence, Kap Lucie Marie and at Kap Resser (fig. 52). In Hall Land it constitutes a major part of the Hauge Bjerge and may possibly extend into Nyeboe Land.

Fauna and geological age

Middle Llandovery to Late Llandovery or Early Wenlock. For further details see the discussion under individual members.

Discussion

The Hauge Bjerge Formation has been erected to cover one of the major carbonate buildup belts of North Greenland. Following Hedberg (1976) it is permissible to unite spatially separate reefs into one formation if they are approximately of the same age and facies. The buildups at Kap Independence are substantially separated geographically from those in the Hauge Bjerge but are identical in facies associations at least with the type section through Kap Tyson. The critical factors in this recognition are the presence of the stylolitised lime muds, a facies not yet known in any other buildups and breccias on the summit of the buildups. However, the buildups at Kap Independence differ greatly in age range from the Hauge Bjerge, although they do appear to overlap (see below). Consequently, it is proposed to unite the Kap Independence with the Hauge Bjerge buildups (exemplified by Kap Tyson) into one formation, but with two members (Kap Independence and Cape Tyson) to emphasise the age differences.

The Hauge Bjerge Formation is part of the Washington Land Group, although each of the members is surrounded by sediments of the Peary Land Group.

Cape Tyson Member

History

It is evident that Koch (1929; Dawes & Haller 1979; fig. 4) partly recognised the complicated nature of the buildup and shales forming this unit because he separated them into two facies in one formation (Dawes & Haller 1979; plate 1). Dawes (1971, 1976) variously referred to this member as the Kap Tyson reef or included it in an extended Offley Island Formation. The latter procedure was followed by Norford (1972).

Name

After Kap Tyson, opposite Offley Ø in western Hall Land.

Type and reference sections

At the western edge of the cape immediately above a deep cleft in the Offley Island Formation (fig. 42). Most other sections near the cape are inaccessible.

Thickness

At least 350 m, not all of which is accessible.

Lithology, boundaries and distribution

As for Hauge Bjerge Formation, but the distribution is so far limited to Kap Lucie Marie in Washington Land and the Hauge Bjerge in Hall Land, possibly, to western Nyeboe Land.

Fauna and geological age

The top of the Offley Island Formation is probably of Late Llandovery Age, possibly indicating that the base of the conformable Cape Tyson Member is also of the same age. Graptolites collected by Norford (1972) from what he calls the Kap Tyson east outcrops are derived from very near to the summit of the buildup itself, in a small sliver of shale plastered on the carbonates. These indicate *spiralis* Zone (Upper Llandovery), suggesting that the greater part of the Cape Tyson Member must have been deposited in a relatively short time.

Towards the east, approximately 500 m from the precipitous cliff and about 50 to 100 m topographically below the summit of the buildup, there is an isolated outcrop of shale and interbedded calcarenite. The relation of this to the Kap Tyson outcrop is unknown in detail, but it probably represents a small shale basin on the side of the buildup. No graptolites were found, but basal coquinas in laminated calcarenites of the pentamerid brachiopod *Kirkidium (Pinguaella)* sp. are common. According to Boucot & Johnson (1979) this genus is not known at present prior to Middle Wenlock. The brachiopods may have been derived from Kap Tyson indicating possibly that the buildup was once slightly younger and now eroded. Alternatively, the brachiopods may have been derived from a nearby high with Kap Morton Formation sediments, or represent the earliest occurrence to date of the genus. Dawes (1976) reports Wenlock and Ludlow shelly faunas from the Hauge Bjerge of Hall Land.

Kap Independence Member

new member

History

These strata were included in the Offley Island Formation by Koch (1929; fig. 4, plate 1).

Name

After Kap Independence on the west coast of Washington Land (fig. 1).

Type and reference sections

The type section is at the east end of the large buildup immediately south-east of Kap Independence (fig. 55 & 56). The cliffs are steep and thus most sections are inaccessible. The top of the member terminates at the present day land surface.

Thickness

At least 300 m, not all of which is accessible.

Lithologies, boundaries and distribution

Lithologies are identical with those of the Hauge Bjerge Formation. The member is mainly limited in its distribution to the Kap Independence – Kap Constitution area. The deposits of Franklin Ø, Crozier Ø and the isolated small mass at Kap Resser are tentatively referred to this member (fig. 52). The base is defined at

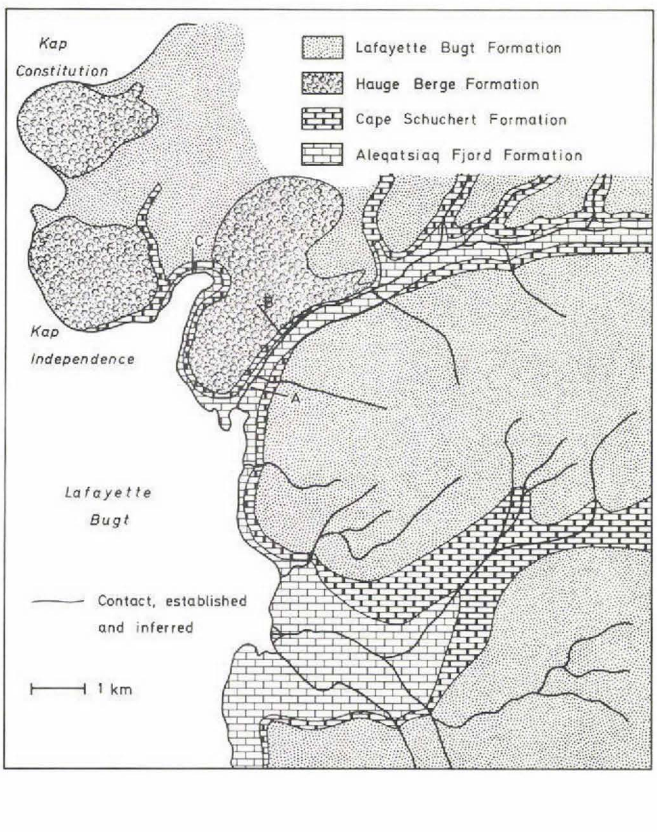


Fig. 55. Geological map of the Kap Independence and Lafayette Bugt region (reference map fig. 2). Type locality for the Kap Independence Member (B) and Lafayette Bugt Formation (C) and the Cape Schuchert Formation (A).

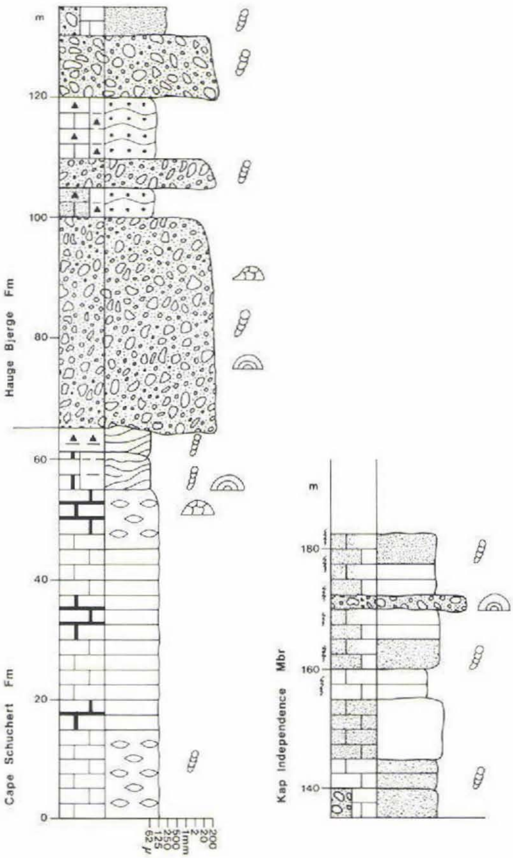


Fig. 56. Log of the type section of the Kap Independence Member, of the Hauge Bjerge Formation. Location in fig. 55.

the base of conglomerates immediately above the recessive black Cape Schuchert Formation (fig. 56). The top of the member is a present day erosion surface.

Fauna and geological age

The Kap Independence Member lies upon the Cape Schuchert Formation in the type area, and thus lower beds of the former may be of a similar Middle Llandovery *(convolutus* Zone) Age (see below).

Many loose blocks from the inaccessible core of the buildup with the type section contain conodonts which R. J. Aldridge considers indicative of the Late Llandovery *celloni* Zone. A small accessory buildup with debris apron also contains conodonts of this zone. At the top of the type section conodonts indicate the *celloni/amorphognathoides* Zone of late Late Llandovery Age.

To summarise, the age span of the Kap Independence Member appears to be Middle Llandovery, to late Late Llandovery. There is no internal faunal evidence of Middle Llandovery Age for this member, but considering facies relationships it appears likely that some of the member is of that age.

Peary Land Group

new group

Definition and name

Erected 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 is in North Greenland, and the group derives its name from Peary Land. A full description of the extent of the group from Peary Land to Hall Land in North Greenland is being prepared by F. Surlyk and the author.

Lithology

In Washington Land and western Hall land the group commences with black cherty limestones and subordinate cherty shales. These are followed by a complex of interbedded black, laminated shales, calcarenites and limestone conglomerates.

Boundaries

The group rests conformably on the Aleqatsiaq Fjord Formation, of the Morris Bugt Group. Towards the south, east and north it interdigitates with the Adams Bjerg Formation, Pentamerus Bjerge Formation and Kap Godfred Hansen Formation respectively of the Washington Land Group.

In western Hall Land the group rests upon the Offley Island Formation. If outcrop would allow it could probably be shown to interdigitate with all formations of the Washington Land Group, in addition to possibly parts of the Morris Bugt Group.

Distribution

The group occurs along the coastal regions of Washington Land, between Kap Jefferson and Kap Godfred Hansen and up to the Pentamerus Bjerge (fig. 2). It also occurs in western Hall Land, surrounding the Hauge Bjerge. These outcrops form the westernmost extension of sediments belonging to the Peary Land Group.

Geological age

In Washington Land and western Hall Land from Early Llandovery to Ludlow. For further details see the discussion under the individual formations.

Subdivisions

The group includes the Cape Schuchert Formation and Lafayette Bugt Formation, which are only found in Washington Land and Hall Land.

Cape Schuchert Formation

History

Aspects of this formation are the most contentious of any Silurian formation in North Greenland. Consequently, there is a need to delve deeply into the historical aspect with the aim of defining the formation. Kap Schuchert itself is a gravel delta with no outcrops of Silurian rocks. A low headland with a Silurian succession approximately 2 km to the south is central to the argument (plate 1, fig. 28). For the purpose of this discussion this headland is referred to simply as Kap Schuchert.

Koch (1920) erected the *Arethusina* Zone for what he considered was a sequence of Upper Silurian conglomerates, black foliated slate and light coloured hard limestone. He leaves no doubt (p. 42) that "the most perfect section through the black slate is met with south of Cape Independence, within the so-called Lafayette Bay", (see plate 1). Subsequently, Koch (1929) erected the Cape Schuchert Formation and with regard to type locality states that (p. 237) "Beds of this formation were first noticed by me just south of Cape Independence in Lafayette Bay, where I collected several small specimens of a trilobite which, in the field, I first determined as *Olenus* (upper Cambrian). However, after my return from the expedition, I identified the trilobite as *Arethusina* (= *Aulacopleura*). Owing to a misinterpretation of the very intricate stratigraphic conditions I first assumed this formation to be of Upper Silurian age. In 1922 I traced the formation in several localities along the west coast of Washington Land". However, later he states that the best locality for the formation and one in which he found graptolites was Kap Schuchert.

Unfortunately, what sediments Koch included in the Cape Schuchert Formation and what subsequent authors described as Cape Schuchert sediments are two slightly different things. For instance, Poulsen (1934, p. 42) was of the opinion that "judging from the numerous rock specimens at hand, the formation consists exclusively of thin-bedded, very bituminous stinkstone".

Although Koch's published work is slightly ambiguous, Dawes & Haller's (1979) presentation of Koch's map and photographic material (see plate 1, fig. 4) leaves no doubt as to what Koch meant by the Cape Schuchert Formation. Not only did he trace the formation between Kap Independence (Lafayette Bugt) and Kap Godfred Hansen but he delineated the areal extent of the strata which he considered belonged to this formation. Unfortunately, Norford (1972) was apparently not aware of the extent of Koch's unpublished work which shows that on an informal basis the Cape Schuchert Formation was very adequately defined. Some discussion of Norford's interpretation of the Cape Schuchert Formation seen in the light of the new Koch material is given by Dawes & Haller (1979). The annotated photographs in that paper (e.g. plate 2) indicate that it was only at Kap Schuchert that Koch undoubtedly included a white limestone unit (top of Aleqatsiaq Fjord Formation) within the formation, which was not included anywhere else.

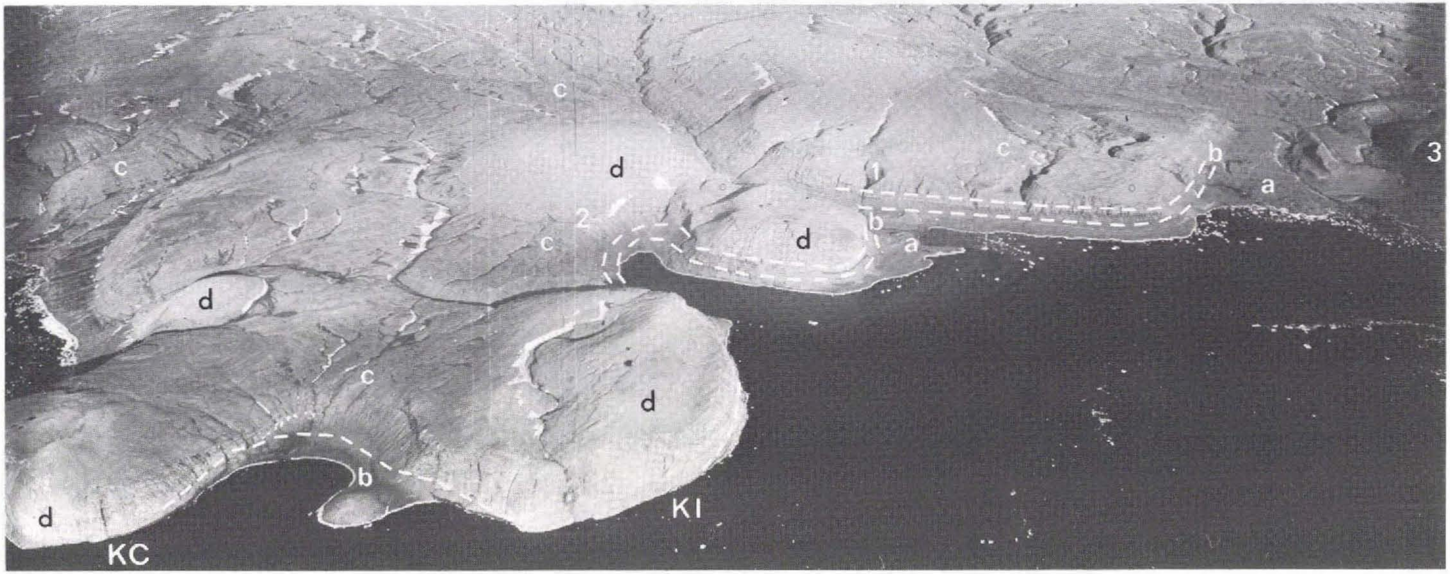


Fig. 57. Coastal areas of Washington Land at Lafayette Bugt. Kap Constitution (KC) and Kap Independence (KI). Aleqatsiaq Fjord Formation (a). Cape Schuchert Formation (b), Lafayette Bugt Formation (c) and Kap Independence Member (d). Type locality and section for the Cape Schuchert Formation and Lafayette Bugt Formation 1 and 2 respectively. Locality 3 is a section in which the top of the Cape Schuchert Formation possibly extends into the early Late Llandovery. Aerial photograph 545 K1-SØ, no. 2259. Copyright Geodætisk Institut, Denmark.

Another problem concerns the type locality of the formation. Koch (1929) leaves no doubt of his choice of Lafayette Bugt as the type locality, but subsequently Troelsen (1956) cited Kap Schuchert as the type locality. Norford (1972, p. 15) states that "According to Prof. V. Poulsen (Grønlands Geologiske Undersøgelse, personal communication) Troelsen's statement reflected the opinions of both Lauge Koch and Christian Poulsen. Thus the type locality of the Cape Schuchert Formation can be considered to be Kap Schuchert and not the locality near Kap Independence". Norford (1972) included rocks now assigned to the upper part of the Aleqatsiaq Fjord Formation in a redefined Cape Schuchert Formation, on the basis of a section through the formation at Kap Schuchert. As redefined in this manuscript the Cape Schuchert Formation includes some of the Cape Phillips Formation of Norford.

Clearly there is a need to redefine the Cape Schuchert Formation. This is attempted on the basis of the original type locality as south of Kap Independence in Lafayette Bugt (fig. 57). The formation is restricted to the 'bituminous stinkstones' from which it has become known in the literature (Poulsen, 1934). Following modern stratigraphic procedure (Hedberg, 1976) the Kap Schuchert section is treated as a reference profile.

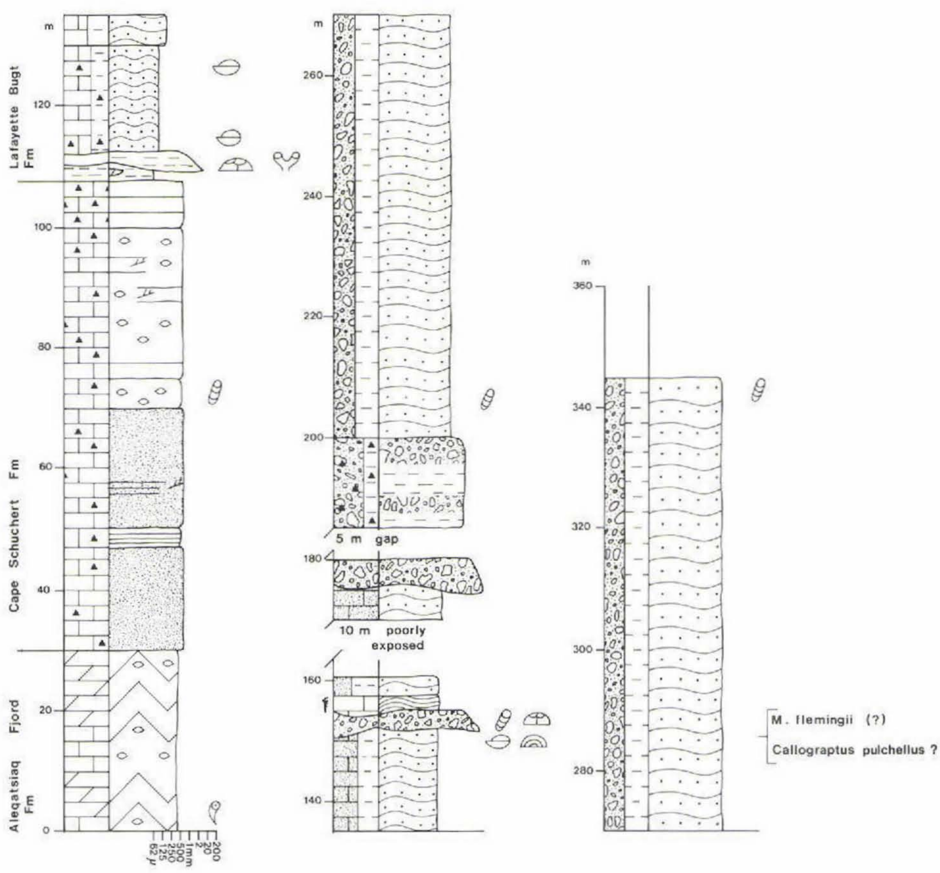


Fig. 58. Sedimentary log of section at point A in fig. 55. Also the type section for the Cape Schuchert Formation (fig. 57).

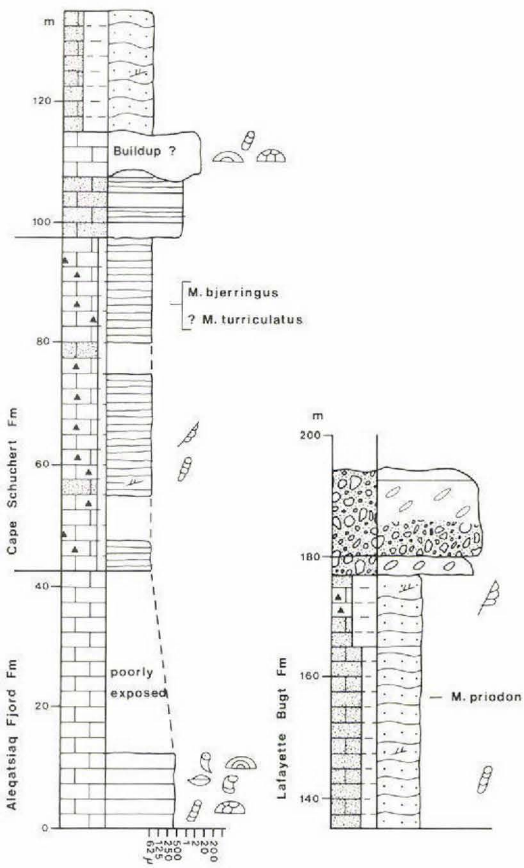


Fig. 59. Sedimentary log of section at Kap Schuchert. Compare with Norford's (1972) section redrawn in fig. 41. Due to abrupt facies changes within the Cape Schuchert Formation, no two sections are very similar.

Name

After Kap Schuchert, a low lying gravel delta, in Fossilbugt.

Type and reference sections

The type section is in a narrow gully on the west facing slope of a major north–south valley from Lafayette Bugt (figs 57 & 58). The locality is just to the south of Kap Independence. Many good reference profiles occur in and around Kap Independence (fig. 57) as well as at Kap Schuchert (fig. 59).

Thickness

55 to 80 m.

Lithology

Throughout the area the formation is dominated by thin bedded, black, bituminous cherty lime mudstones which are occasionally faintly laminated (fig. 60). In the type section chert bands are thick (up to 25 cm) and common. The lower part of the formation is more massive and riddled with chert nodules. Shale beds are common and these increase in thickness and abundance upwards. Rare, thin calcarenites also occur.

Boundaries

The formation follows conformably upon the Aleqatsiaq Fjord Formation and it is conformably overlain by the Lafayette Bugt Formation and Kap Independence Member (figs 58 & 59). It probably interdigitates with the Adams Bjerg Formation to the south, with the Pentamerus Bjerge Formation to the east and with the Kap Godfred Hansen Formation to the north.

The base of the formation is defined at the base of the massive, black bituminous and cherty limestone (fig. 58). This is a distinctive boundary above the light col-

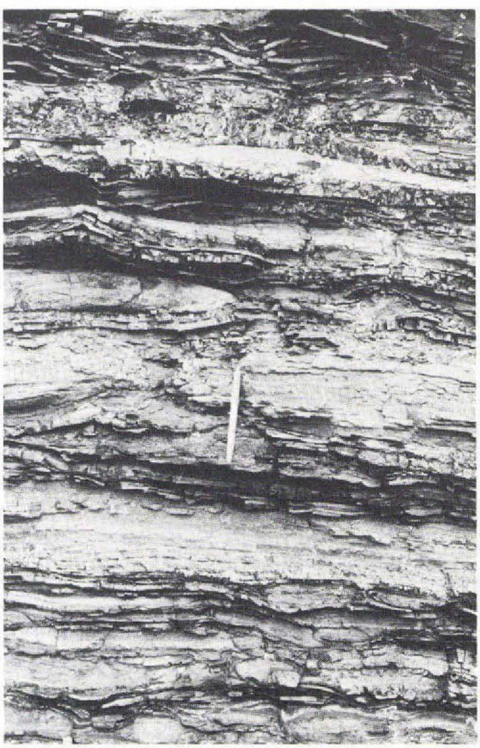


Fig. 60. Interbedded lime mudstones, cherts and calcarenites in the Cape Schuchert Formation in the reference section (fig. 41).

oured, crinoidal Aleqatsiaq Fjord Formation (cf. fig. 54). The top of the formation, in and around the type section, is defined at the base of a predominantly shale unit (fig. 58).

Distribution

The formation occurs along the west coast of Washington Land between Kap Jefferson and Kap Godfred Hansen. It extends east up the major valleys and towards the Pentamerus Bjerge.

Fauna and geological age

If the top of the Aleqatsiaq Fjord Formation is synchronous, then the base of the Cape Schuchert Formation is possibly Early or Middle Llandovery. In the type section 2 m above the formation graptolites identified by M. Bjerreskov including *Pseudoclimacograptus hughesi, M. decipiens?, Monograptus lobiferus lobiferus* and *M. crenularis?* indicate the Middle Llandovery (Idwian) *convolutus* Zone. In the bay immediately east of Kap Independence (fig. 57) a loose block of shale 2 m above the Cape Schuchert Formation yielded *Glyptograptus* (*?Pseudoglyptograptus*), *M. crenularis, P. regularis, Monograptus* sp. and *Rastrites* sp. an assemblage which M. Bjerreskov considers indicative of the *convolutus* Zone (see fig. 61).

Approximately 10 km to the south of the type section (fig. 57) graptolites 5 m above the Cape Schuchert Formation include *Petalograptus conicus?, M. s.l. exiguus, M. exiguus primulus, M. planus, Monograptus* aff. *M. proteus, M. richardsi* and *Monograptus turriculatus* an assemblage indicative of the Late Llandovery *turriculatus* Zone.

At Kap Schuchert the Cape Schuchert Formation pinches and swells along strike (plate 1). Approximately 300 m south of the reference section (fig. 59) graptolites were located including *Pseudoclimacograptus* n. sp., *Petalograptus minor, Pribylograptus leptotheca, Monograptus* n. sp., *M. argenteus* and *Monograptus* n. sp. 2, an assemblage indicative of the upper part of the *gregarius* (*triangulatus, magnus* and *argenteus* Zones here) Zone (Middle Llandovery). The horizon correlates with the lower 10 to 20 m of the reference section. Some 10 m below the top of the formation in the reference section the graptolites *Monograptus bjerringus* n. subsp. and ? *Monograptus turriculatus* possibly indicate the Late Llandovery *turriculatus* Zone. From approximately the same horizon Norford (1972) located graptolites indicative of low *turriculatus* Zone.

To summarise, in and around the type section the age span of the Cape Schuchert Formation is contained within the Middle Llandovery, although the lowest beds may be of Early Llandovery Age. Away from this area the upper age

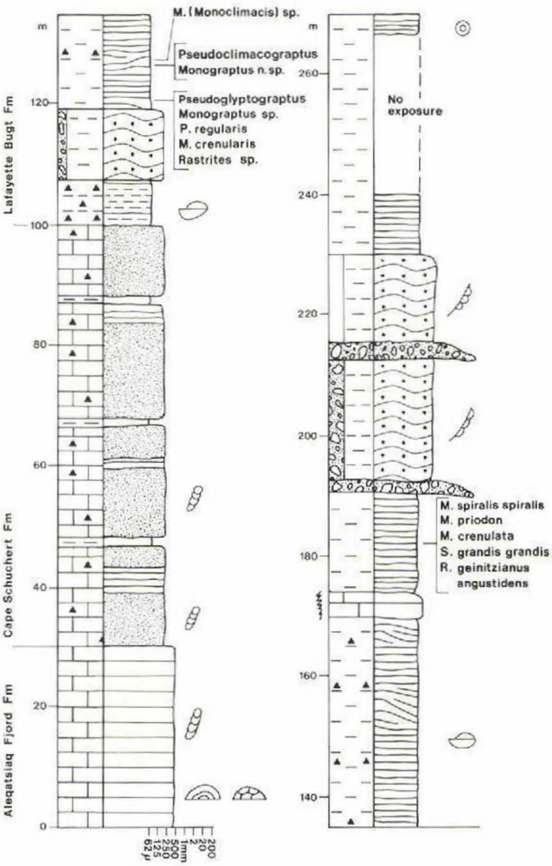


Fig. 61. Sedimentary log of section at point C in fig. 55. Also the type section of the Lafayette Bugt Formation (fig. 57) and a reference section for the Cape Schuchert Formation.

limit of the formation extends into the early Late Llandovery (Fronian). Thus, the upper boundary of the formation is diachronous.

Lafayette Bugt Formation

new formation

History

Koch (1920) partly included strata referred to this formation in his 'Upper Silurian *Arethusina* Zone' rocks and later (Koch, 1929) in the Cape Tyson Formation. In part the Lafayette Bugt Formation is equivalent to the Cape Phillips Formation of Norford (1972).

Name

After Lafayette Bugt the broad bay south of Kap Independence (fig. 1).

Type and reference sections

The type section is in the centre of the small bay to the east of Kap Independence (figs 57 & 61). Many other reference sections along the coast are accessible, but often poorly exposed as the shale is very recessive.

Thickness

Up to 300 m in and around the type section. Everywhere the top of the formation is a present day erosion surface, so a maximum thickness is impossible to give.

Lithology

The formation consists primarily of thick shale units interbedded with poorly laminated lime mudstones, and limestone conglomerates, up to 10 m thick (fig. 61). With increasing distance away from the carbonates of the Washington Land Group the shale is interbedded with thin laminated, or graded and laminated

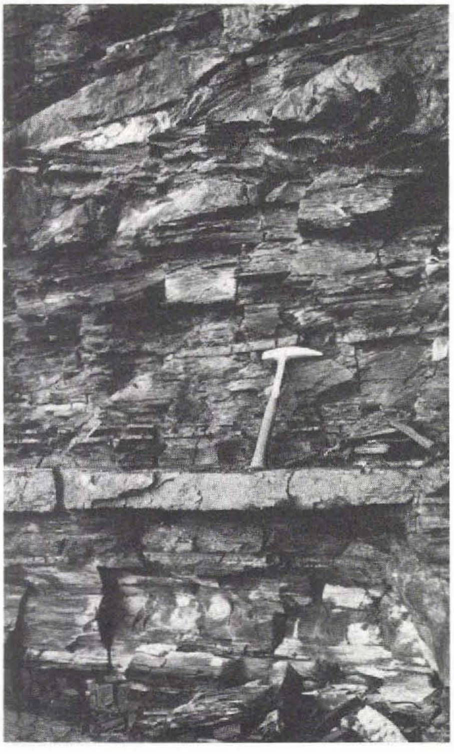


Fig. 62. Interbedded calcarenites and shales of the Lafayette Bugt Formation. From the reference section (fig. 61). Length of hammer 33 cm.

calcarenites and fine cobble conglomerates (fig. 62). Occasional chert nodules occur and they rarely form bands. At Kap Schuchert a thin string of stromatoporoid mounds (?) and associated debris rocks is developed. Their lateral extent is unknown in detail and for the purposes of this report, this local development (fig. 59, plate 1) is included in the Lafayette Bugt Formation.

Boundaries

The formation follows comformably upon the Cape Schuchert Formation, but its upper surface is a present day erosion surface (fig. 61). It probably interdigitates with all formations of the Washington Land Group although in the field it has only definitely been seen to interdigitate with the Hauge Bjerge Formation (Cape Tyson Member and Kap Independence Member), Pentamerus Bjerge Formation and Kap Godfred Hansen Formation.

Distribution

In the coastal regions of Washington Land between Kap Jefferson and Kap Godfred Hansen and inland for approximately 5–10 km. It also occurs in western Hall Land.

Fauna and geological age

In the type section graptolites 2 m above base are considered by M. Bjerreskov to indicate a Middle Llandovery Age. Some 36 m higher *Retiolites geinitzianus angustidens, Stomatograptus grandis grandis, Monoclimacis crenulata, M. priodon* and *M. spiralis spiralis* indicate the *spiralis* Zone (Late Llandovery Age). At the top of the section, possibly 200 m stratigraphically higher, the presence of *Monograptus dubius* indicates a Late Wenlock or Ludlow Age.

In the reference section south of Kap Independence (fig. 57) conodonts determined by R. J. Aldridge from samples between 50 and 100 m above the base of the formation are indicative of the Late Llandovery *celloni* Zone. Some 180 m from the base *Callograptus pulchellus*? and *Monograptus flemingii*? indicate a Late Wenlock Age. About 10 km south of the type section (fig. 57) the base of the Lafayette Bugt Formation is slightly younger; the *turriculatus* Zone. Over 50 m higher stratigraphically, *M. vomerina, M. priodon* and *Monograptus spiralis spiralis* again indicate the Late Llandovery *spiralis* Zone (cf. Norford, 1972, p. 19).

At Graptolitenæs 20 km north of Kap Independence *Bohemograptus bohemicus bohemicus* collected by Lauge Koch 340 m above sea level, indicate the Ludlow *nilsonni* Zone or younger (M. Bjerreskov, personal communication, 1979). Based on regional considerations, this horizon is probably at least 200 m above the base of the Lafayette Bugt Formation in this locality.

In the reference section at Kap Schuchert (fig. 59) the base of the Lafayette Bugt Formation starts in earliest *turriculatus* Zone. Conodonts possibly indicative of the Late Llandovery *celloni* Zone occur 35 m above the base of the formation. This zone is followed 25 m higher by *Monograptus priodon* indicating a Late Llandovery Age, possibly *griestoniensis* Zone or younger. Stratigraphically 15 m higher conodonts indicate the *amorphognathoides* Zone of Late Llandovery to Early Wenlock Age (Walliser, 1971). A similar fauna occurs in the boulders of the conglomerates at the top of the section in the southern part of the headland indicating that here the Lafayette Bugt Formation is no younger than the Late Llandovery (*spiralis* Zone).

To the north of Kap Godfred Hansen a small section through the Lafayette Bugt Formation produced graptolites indicative of Late Llandovery to Early Wenlock Age (see details in Kap Godfred Hansen Formation). Isolated occurrences of the formation near the summit of Kap Tyson have also yielded graptolites of this Late Llandovery – Early Wenlock interval (Norford, 1972). Towards the east of Kap Tyson *Retiolites geinitzianus angustidens, Monograptus vomerinus* aff. *M. nudus* and *Monograptus* sp. occur topographically at least 200 m below the summit of Kap Tyson and indicate a Late Llandovery to Early Wenlock Age.

To summarise, the base of the Lafayette Bugt Formation is diachronous between Middle and early Late Llandovery. As the formation is traced elsewhere in North Greenland it will probably prove to be much more diachronous. In and around the type section and at Graptolitenæs the formation stretches into the Ludlow. The succession is thin and there is little evidence of Wenlock strata. However, there is no evidence for non-sequences, and a full Wenlock succession, albeit thin, can be expected with further collecting. The majority of the outcrops of the Lafayette Bugt Formation appear to be of Late Llandovery Age.

ENVIRONMENTS AND FACIES DISTRIBUTION

A general account of the Silurian facies distributions and environments is given below, based on the stratigraphic data and unpublished sedimentological studies (plate 2, fig. 63). Briefly, throughout the Silurian of Washington Land sediments were deposited on or at the margin of a carbonate platform and on the southern side of the Hazen Trough (fig. 63). This feature represents the eastern extension of the carbonate platform and clastic trough with a northerly dipping palaeoslope known from the Canadian Arctic Islands (see Kerr, 1967, 1976; Trettin, 1972; Norford, 1972; Morrow & Kerr, 1977), and can be traced across North Greenland

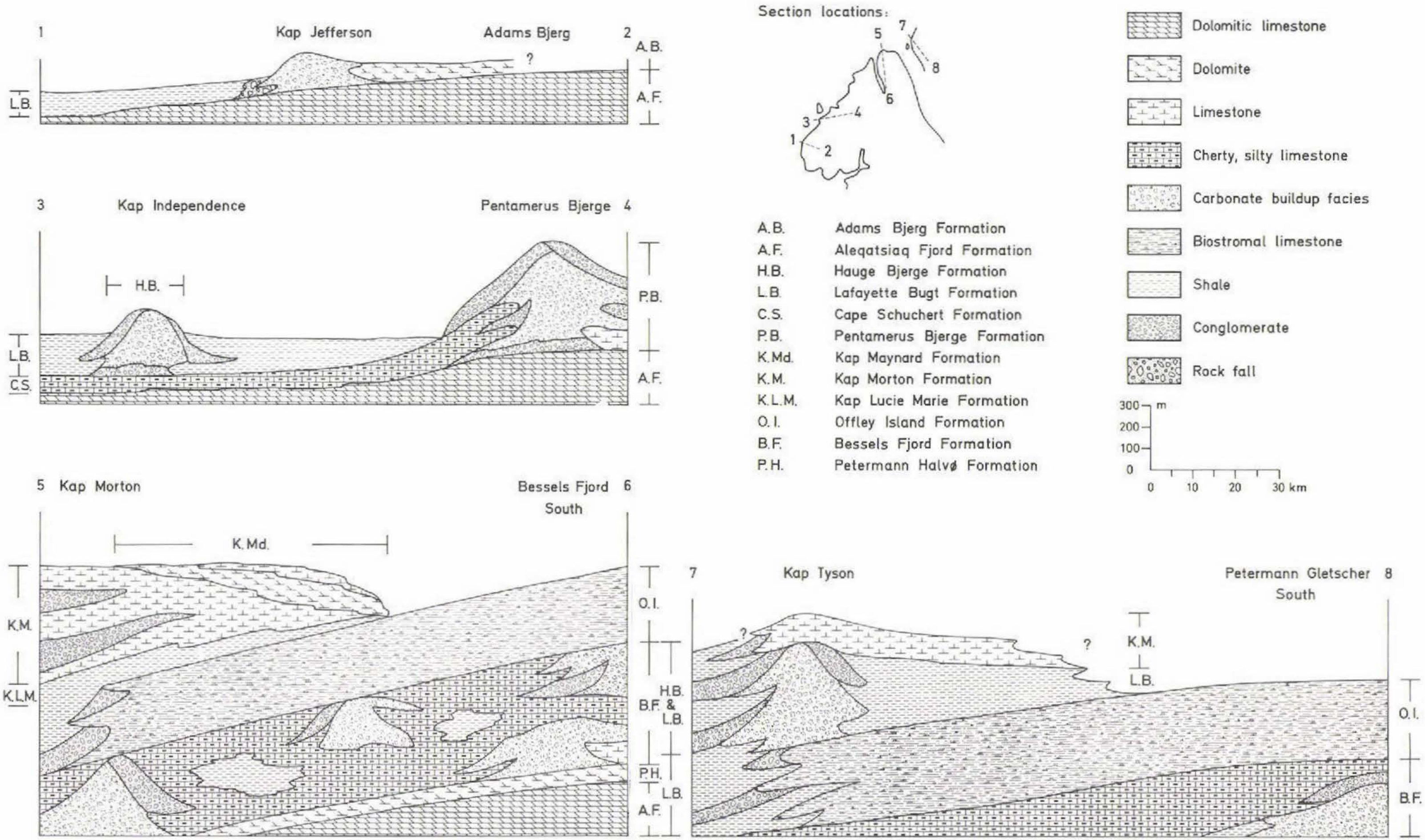


Fig. 63. Schematic cross sections through the platform basin slope contact in Washington Land and western Hall Land.

as far as Peary Land (see Dawes, 1971, 1976). There is little evidence of intertidal, supratidal or beach deposits during Silurian deposition (plate 2).

Cincinnatian and Lower Llandovery

Upper Ordovician sediments of the Aleqatsiaq Fjord Formation are mainly uniform lime mudstones and wackestones with little or no predictive spatial and temporal variation, indicating that the carbonate platform was probably very uniform with little evidence of topography.

Subsequent generally unequal subsidence of the carbonate platform produced a topographically irregular shelf and resulted in the production of monotonous black lime mudstones (occasionally dolomitic) and rarely wackestones with chert nodules and layers, between the Pentamerus Bjerge and Bessels fjord. No evidence for any storm, wave or current activity has been seen. This, taken in conjunction with the paucity of benthic fauna suggests that bottom conditions may have been reducing. Platform irregularity is evident from the occurrence of small localised biostromes with drapes of laminated and graded calcarenites at Kap Schuchert and Kap Independence. These, together with the thin graded calcarenites interbedded with lime muds at Kap Jefferson are reminiscent of clastic storm beds (see Goldring & Bridges, 1973; Kumar & Sanders, 1976) and at least indicate deposition above storm wave base. This varied unit of sediments comprise the upper part of the Aleqatsiaq Fjord Formation.

Slope development was also initiated in connection with the subsidence and production of the irregular platform. This south-east movement of the southern margin of the Hazen Trough appears to have been initiated in Ellesmere Island, Canada in Upper Ordovician, Richmondian, times (Trettin, 1971, 1972; Trettin & Balkwill 1979; Trettin *et al.* 1979) and appears to be recognisable in sediments from other localities of comparable age (see Morrow & Kerr, 1977). Although definite slope deposits in Washington Land do not pre-date the Middle Llandovery, the sediments of the upper Aleqatsiaq Fjord Formation between Pentamerus Bjerge and Bessels Fjord (Richmondian–Lower Llandovery?) are strongly influenced by the Hazen Trough which was situated in Ellesmere Island.

Middle Llandovery

At the beginning of the Middle Llandovery (fig. 64) the major subsidence of the previous outer platform was complete culminating in a highly irregular topography on which the succeeding sediments were deposited. Initially the platform sediments are succeeded by slope and starved basin deposits such as thinly bedded cherts, shales and calcarenites, between Kap Jefferson and Kap Godfred Hansen in west

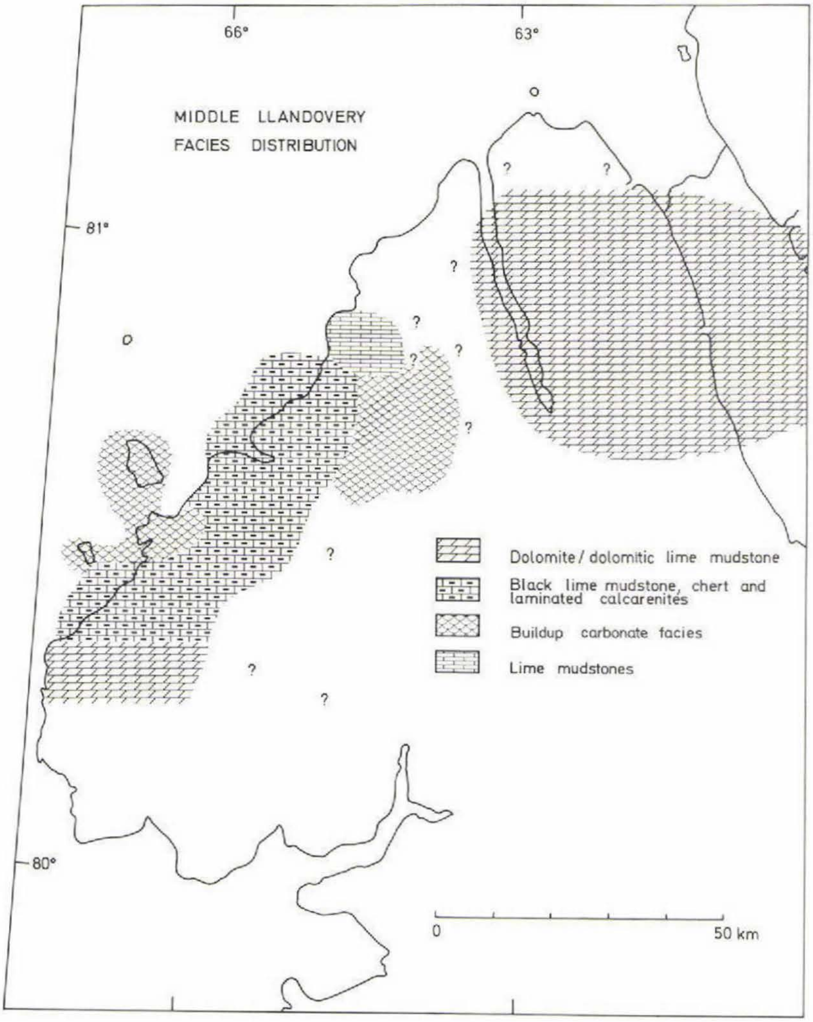


Fig. 64. Middle Llandovery facies distribution, Washington Land.

Washington Land. The inplace sediments are indicative of fairly deep quiet water conditions and again the total lack of benthic fauna implies unfavourable bottom conditions which were possibly reducing. The calcarenites are distal turbidites derived via small submarine fans spilling off the carbonate platform which had receded to the south-east. Sediments of this event comprise the Cape Schuchert Formation. Somewhat later, local carbonate buildups with talus and calcarenite drapes were initiated on the slope.

At Kap Godfred Hansen lime mudstones developed whilst towards the east and

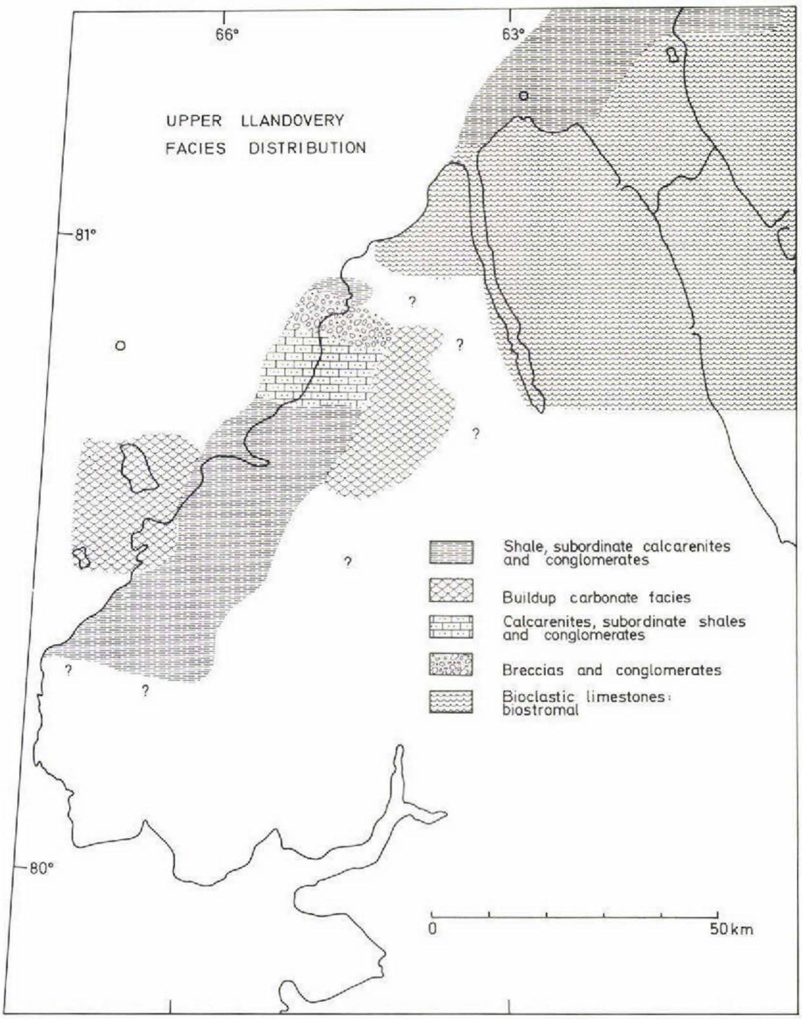


Fig. 65. Upper Llandovery facies distribution, Washington Land.

south a carbonate buildup, fringing reef belt (Pentamerus Bjerge Formation; cf. Heckel, 1974) developed at the hinge of the platform and slope. The fore reef areas interdigitated westwards with the slope and basin deposits. Conglomerates , breccias and finer grained calcarenites were resedimented down slope. Similarly, eastwards in back reef areas conglomerates with calcarenites and level, quiet bottom, lime muds occurred.

In the Bessels Fjord region initial deposits are sugary dolomites and dolomitic lime muds. They show no evidence of wave, tidal or current activity. Their formation may in part be due to the barrier effect of the Pentamerus Bjerge fringing reef, but it is unknown if they represent fully marine or marginal marine conditions. These deposits comprise the Petermann Halvø Formation. A following thick complex sequence includes small buildups and intervening local starved basins with cherts, calcarenites, fine breccias, black lime mudstones and subordinate shales (Bessels Fjord Formation). These sediments are thick, approaching 600 m in total, and indicate an intimate interplay between platform and slope probably as a result of differential and great platform subsidence to accommodate this very thick sediment pile.

During the Middle Llandovery most of the Washington Land platform subsided differentially. However, in the Kap Jefferson – Adams Bjerg region in the south there is a definite shoaling producing the marginal marine stromatolitic dolomites of the Adams Bjerg Formation. The gradation in sedimentation from normal to marginal marine is a local feature and suggests shoaling due to some localised tectonic control. There is no evidence of shore line deposits possibly indicating local block uplift on the platform.

Upper Llandovery

Carbonate buildups persisted on the slope and at the slope platform margin during the Upper Llandovery (fig 65, 66). The surrounding slope sediments are predominantly shales with calcarenites and thin resedimented limestone conglomerates and breccias derived from the platform margin (cf. Mountjoy *et al.*, 1972; Krebs & Mountjoy, 1972). South of Kap Independence the conglomerates thin drastically and calcarenites are reduced in frequency indicating that sediment input from the Kap Jefferson platform was negligible. The majority of the authochthonous sediment on the slope derives from the Pentamerus Bjerge fringing reef. In the vicinity of Kap Godfred Hansen the whole of the Upper Llandovery is represented by a complex sequence of resedimented conglomerates associated with one or more submarine fan lobes.

In north Washington Land, Petermann Halvø and western Hall Land buildup and intervening starved basin sediments (Bessels Fjord Formation) extended into the Upper Llandovery and were then replaced by thick biostromal limestones (bioclastic conglomerates) and lime mudstones comprising the Offley Island Formation (fig. 66). These localised thick shallow marine sediments are possibly the product of a rapidly subsiding platform which in the Upper Llandovery quickly subsided to become temporarily inundated with black shales, lime muds and thin calcarenites comprising the Kap Lucie Marie Formation. The calcarenites were presumably derived from the surrounding platform which had not been drowned. Simultaneous with this submergent event a carbonate buildup developed at Kap Lucie Marie and at the west end of the Hauge Bjerge, Hall Land.

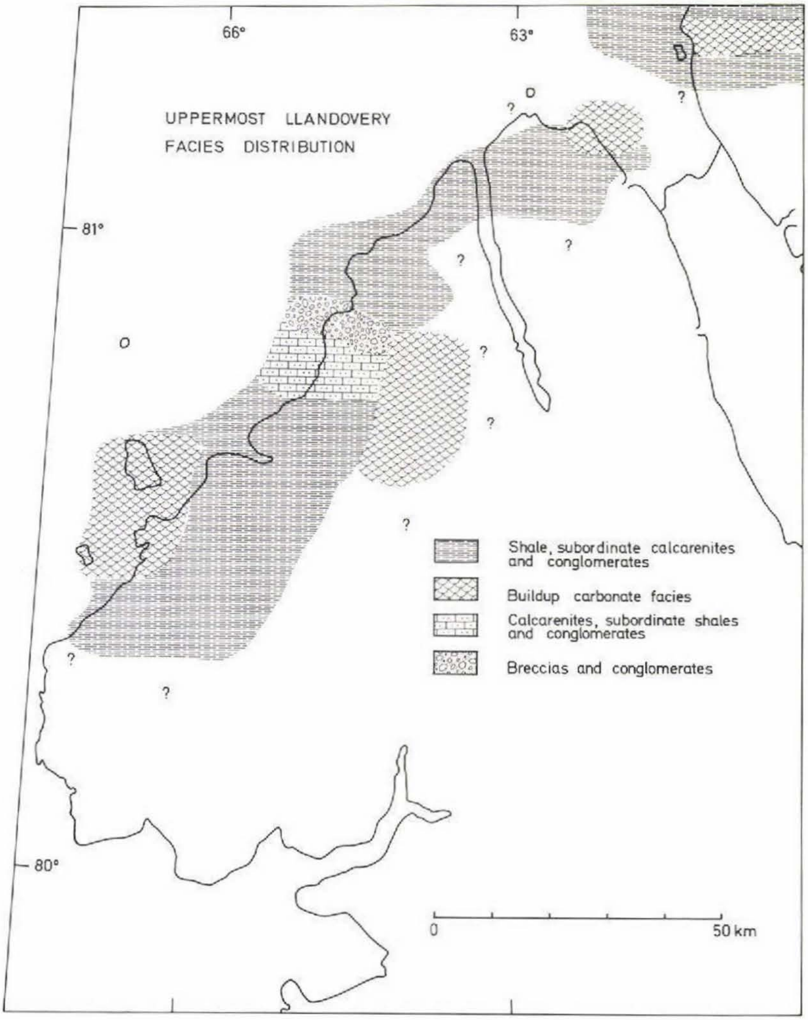


Fig. 66. Uppermost Llandovery facies distribution, Washington Land.

Wenlock and Ludlow

The Upper Llandovery and Lower Wenlock appears to be an important period in the development of the Washington Land Silurian. Carbonate buildup development over the whole region was terminated, probably due to drowning (cf. Krebs & Mountjoy, 1972), either caused by a eustatic rise in sea level, tectonic activity, or both. This is probably an extension of the event which temporarily inundated the platform in north Washington Land forming the Kap Lucie Marie Formation. It may coincide with the movement southward of the axis of the Hazen Trough in

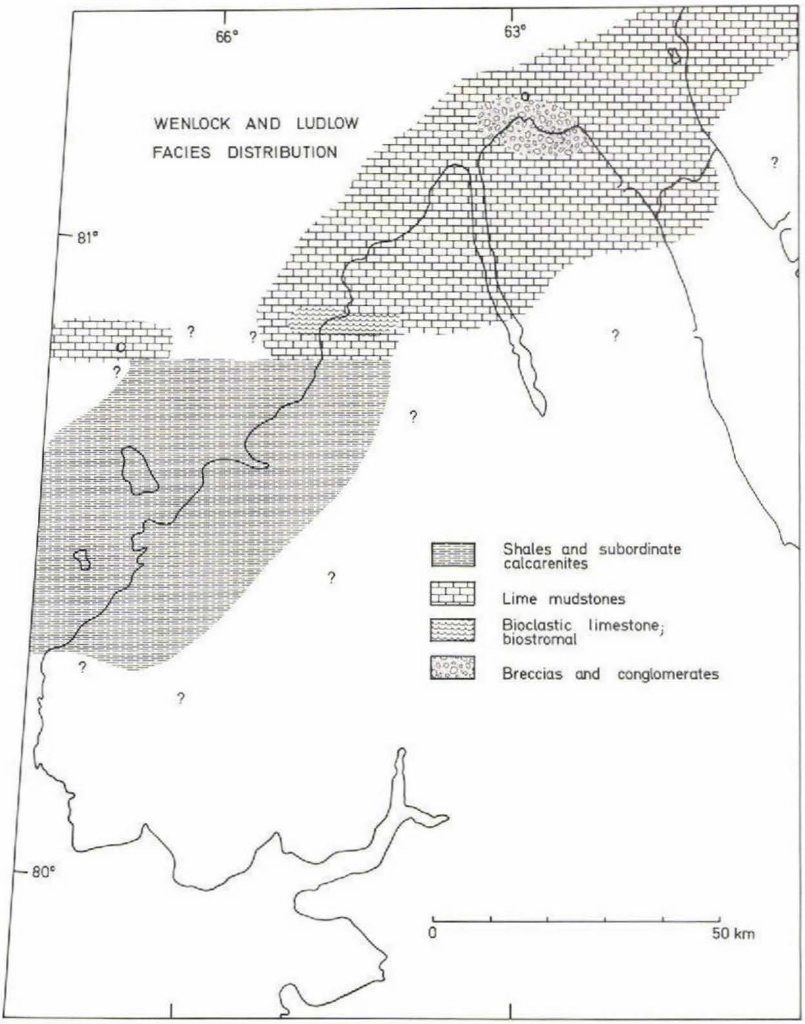


Fig. 67. Wenlock and Ludlow facies distribution, Washington Land.

Ellesmere Island (Trettin, 1971). Of more importance, is the record in other parts of the Canadian Arctic Islands (Kerr, 1977) or an unconformity at the base (Upper Llandovery) of the Cape Storm Formation and interpreted as the initial pulse of the Cornwallis disturbance. Such uplift which may eventually prove to be more widespread, may account for the shale inundation and partially for the sea level changes.

In the west of Washington Land between Kap Jefferson and Kap Godfred Hansen basin slope shales, lime muds and thin calcarenites and limestone conglomerates (Lafayette Bugt Formation) persist into the Ludlow (fig. 67). The sequence of

Wenlock rocks is particularly thin but there is no evidence of non-sequences or unconformities. Shale deposition does not even appear to have inundated the buildup bodies other than at Kap Resser. The calcarenites and conglomerates are presumably derived from the shelf to the north and probably the slope buildups and Pentamerus Bjerge fringing reef.

North Washington Land, Petermann Halvø and western Hall Land are the site of deposition of monotonous lime mudstones (Kap Morton Formation) indicative of open platform to initial basin slope environments below wave base and with very occasional coquinas of pentamerid brachiopods (cf. peri-platform of McIlreath & James, 1978). Local variation is apparent with the development of thin biostromal units at Kap Godfred Hansen. The thick sequence at Kap Morton is riddled with thick amalgamated calcarenites and thick resedimented limestone conglomerates indicative of the slope northwards from the platform into the Hazen Trough. These sediments appear to form downslope of the platform and in the hollows between certain carbonate buildups of the Hauge Bjerge Formation, probably partially contemporaneously.

Although not depicted on fig. 67 the final unit in Washington Land is a mixture of green lime shales, limestones and grey dolomites (Kap Maynard Formation) located on the platform edge in north Bessels Fjord. These deposits are again very similar to peri-platform deposits described by McIlreath & James (1978). There is no evidence of wave or current activity, but occasional coquinas of pentamerids possibly indicate storm events.

Summary

During the Silurian, Washington Land and western Hall Land were a mosaic of basin slope and platform environments in which clastic and carbonate rocks interfingered. Deposition, on the south edge of the Hazen Trough, was marked by great thickness variation. Predominantly clastic slope sediments are nowhere greater than 600 m thick whilst platform carbonate sequences vary between 200 and 2000 m in thickness. The latter figures indicate that the platform subsided very unequally. The Bessels Fjord region with a sediment pile totalling 1800 m indicates an area of great subsidence. Areas at the slope platform hinge (Pentamerus Bjerge) were not areas of great subsidence whilst Kap Jefferson may even have been an area of relative uplift.

Finally, what controlled the position of the platform basin slope margin is unknown. The platform margin in the rest of North Greenland (Nyeboe Land to Peary Land) appears to terminate at a series of faults, with resultant abrupt facies changes (Hurst & Surlyk, 1980; Surlyk *et al.,* 1980). This is not the case in Washington Land, as platform and slope facies interfinger along the hinge. Although the cherts, shales, lime mudstones and resedimented carbonates are referred to a slope environment, they appear to develop on a drowned platform and as such the environment may not be directly analogous to other slope environments in Greenland or Ellesmere Island. This problem, along with the apparent total absence of trough turbidites in Washington Land, may well be related to the nature of the platform margin in Ellesmere Island.

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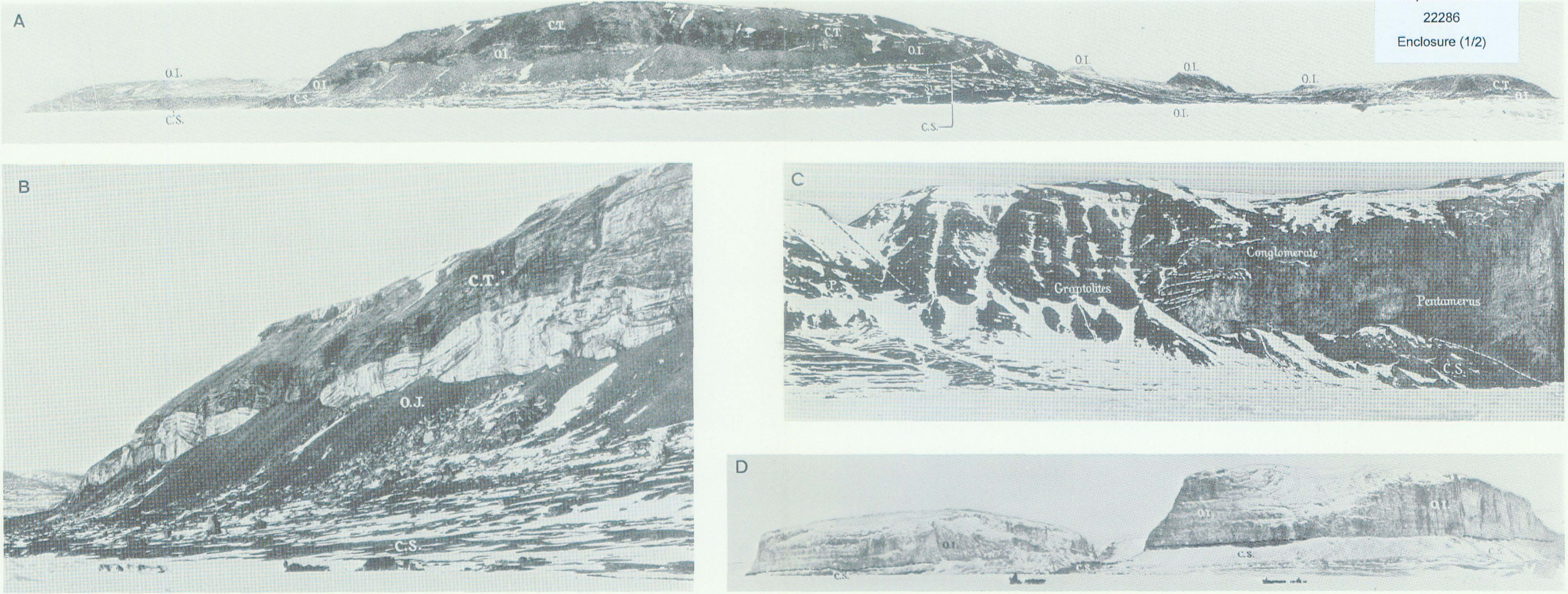
Plate 1

Views of the Washington Land coastal Silurian, taken by Lauge Koch, (from Dawes & Haller, 1979). **A.** Coastal areas immediately to the south of Kap Schuchert (fig. 1). O.I.= Offley Island Formation, C. T. = Cape Tyson Formation and C.S. = Cape Schuchert Formation containing limestone (L) and platy black limestone (SL). Kap Godfred Hansen is the cape in the far distance on the left of the view. Norford's (1972) measured section was on the centre left of the hill referred to as Kap Schuchert (B. S. Norford, personal communication, 1980). My section (fig. 59) is in the gully in the far left of the cliff. Middle Llandovery silicified faunas occur in the rubble of the middle part of the cape, corresponding to the black limestone (SL). Note that the redefinition of the Cape Schuchert Formation presented herein only includes Koch's L and SL of his Cape Schuchert Formation. The lower L is now referred to the Aleqatsiaq Fjord Formation. **B.** Close up of the cliff in A. Symbols as in A except O.J. = Offley Island Formation. Middle Llandovery faunas occur near the symbols C.S. Note the peculiar undulating stromatoporoidal buildup (?) level at the base of Koch's Cape Tyson Formation (= Lafayette Bugt Formation). **C.** Interdigitation of the Lafayette Bugt Formation (Graptolites) with the conglomerates of the Hauge Bjerge Formation (P or *Pentamerus)* on the north side of Kap Independence. At Kap Constitution Koch (1920, 1929) undoubtedly recognised the facies changes but interpreted them in terms of transgressions, regressions and concomitant erosive events, producing valleys in which shale was deposited. Koch referred to the shale as the Cape Tyson Formation and P or *Pentamerus* as the Offley Island Formation. C.S. Cape Schuchert Formation. **D.** Long distance view of Kap Constitution (extreme left), Kap Independence (centre left) and unnamed cape containing type section of the Kap Independence Member of the Hauge Bjerge Formation. Symbols as in A, B, C. This is the area for the type locality of the Cape Schuchert Formation (C.S.) that Koch delineated precisely in his unpublished notes. This definition is followed here.

Plate 2

Stratigraphic scheme for the Silurian sediments of Washington Land and western Hall Land. K.L.M.F. = Kap Lucie Marie Formation, Kap M.F. = Kap Morton Formation, H.B.F. = Hauge Bjerge Formation, L. B. F. = Lafayette Bugt Formation. Asterisks indicate graptolite zones which are present and those which may prove to be present. It is emphasised that correlation is conveniently expressed in terms of the British graptolite sequence, although this is in no way meant to imply that a full British Silurian graptolite sequence occurs in Washington Land. The Cape Phillips graptolite zones are based on Thorsteinsson (1958) modified by Jackson (1979). For further information see Jackson & Etherington (1969).


A
C.T.
O.I.
C.T.
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C.T.
B
C.T.
O.J.
C.S.
C
P.
Graptolites
Conglomerate
Pentamerus
C.S.
D
O.I.
O.I.
O.I.
C.S.
C.S.
C.S.

SILURIAN STRATIGRAPHY OF WASHINGTON LAND AND WESTERN HALL LAND, NORTH GREENLAND