MEDDELELSER OM GRØNLAND
UDGIVNE AF
KOMMISSIONEN FOR VIDENSKABELIGE UNDERSØGELSER I GRØNLAND
Bd. 164 · Nr. 3

CONTRIBUTIONS TO THE GEOLOGY OF NORTH GREENLAND

BY

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WITH 9 FIGURES IN THE TEXT

KØBENHAVN
C. A. REITZELS FORLAG
BIANCO LUNOS BOGTRYKKERI A/S
1961

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I. INTRODUCTION

At the beginning of August, 1957, the author landed on the north coast of Inglefield Land accompanied by F. R. Farley (Bristol, England), and Sigdluk Miunge (Qeqertarssuaq, Thule District, North Greenland). The party travelled on foot in Inglefield Land for a month and concentrated attention mainly on the unmetamorphosed sediments. The eastern boundary of travel was the strong river running into Rensselaer Bugt (fig. 1) while to the south the ice-cap effectively delimited the field for outcrop examination. The area across the fjord from Etah was not visited, nor were those inland tracts of the metamorphic basement terrain which are more than approximately 12 kilometres from the coast.

The western coast of Inglefield Land is often relatively free of pack-ice for a few weeks in the summer and can be reached with comparative ease by ships penetrating from the south through Baffin Bay. Northwards along the coast the normal limit of navigation for vessels which are not strengthened against ice is soon reached. Consequently the Etah district has been frequently visited by ship-based expeditions but Inglefield Land north-east of Cairn Pynt has seldom been explored, and then mainly by means of sledging in the colder months of the year when a covering of snow restricts observations. North of Cape Sabine, in Ellesmere Island, Canada,—immediately opposite to Kap Inglefield (figs. 1 & 4)—the coast is also usually severely beset by ice and is difficult to approach with an ordinary ship, although navigation as far as Bache Peninsula, and northwards, has occasionally been possible.

Of the early expeditions which travelled along the coasts of north-west Greenland and Ellesmere Island the most important from the geological point of view was the British Arctic Expedition, 1874–6, under Nares (Feilden & De Rance, 1878; Etheridge, 1878). It was not until 1898, however, that the first geologist set foot in the area, when Per Schei spent a brief period ashore from the "Fram" in south-west Inglefield Land (Schei, 1903; Holtedahl, 1917, 1–6, 17–18). The "Fram" lay for the following winter near Cape Sabine ,and in 1899 Schei was able to sledge north along the Canadian coast to Bache Peninsula (fig. 4), where his discoveries included Pre-Cambrian and Lower Palaeozoic sediments

(Holtedahl, 1913a). A. P. Low's visit in 1903 was short: his main work, like Schei's, lay in other regions (Low, 1906, 43–50, 185–216, map).

In 1917 Lauge Koch commenced his research in the area as part of his wide-ranging explorations of northern Greenland, and he was able, intermittently until 1922, to devote time to the establishment of a stratigraphical succession and the collection of Cambrian and Ordovician fossils, chiefly from the coast of north-east Inglefield Land (Koch, 1933). R. Bentham wintered in Inglefield Land from 1934 to 1935 and published comments on the geology of its south-western part and parts of Bache Peninsula in 1936. J. M. Wordie led an expedition to north-west Greenland and the Canadian Arctic in 1937 and, assisted by H. I. Drever, he made geological observations on Bache Peninsula (Wordie, 1938, 399). From 1939 to 1941 J. C. Troelsen visited Inglefield Land and Bache Peninsula during his geological reconnaissances (Troelsen, 1950). Fossil material collected by Koch, Bentham and Troelsen was described by Chr. Poulsen (1927; 1946; 1958). J. Malaurie visited the same areas in 1951 and his studies included geomorphology (1955, 211–214.)

The topographical basis for the accompanying geological sketch map is the Etah sheet of the 1 : 250,000 maps of Greenland prepared by the Army Map Service, Corps of Engineers, U. S. Army. Field observations were aided and supplemented by the interpretation of oblique aerial photographs supplied by the Geodetic Institute in Denmark. In figure 1 boundaries and faults which were seen on the ground, through binoculars or from an aerial photograph are recorded by a solid line. Inferred boundaries and faults, shown on the map by broken lines, indicate that the geology was obscured by superficial deposits, vegetation or snow, or in other ways has not been seen.

The sections described from localities near Kap Ingersoll and Etah have been examined metre by metre and measured by stick or tape: descriptions are only given of rocks which were truly exposed. The field notes have been amplified and supplemented by laboratory study of lithological samples from *in situ* rock outcrops. In the descriptions of the sediments which follow, the main rock classification adopted has the three components—silica, clay and carbonate—giving composite terms based on sandstone, shale and limestone or dolomite; the method has been outlined in more detail previously (Cowie & Adams, 1957, 18).

The main purpose in visiting the area was to examine the Pre-Cambrian and Lower Palaeozoic sediments in order to obtain further information on the stratigraphical succession and the fossil faunas. The oldest rocks in the region, the metamorphic rocks of the basement, and the superficial deposits which overlie the Lower Palaeozoic, were not examined in any detail. It was hoped that air transport support would enable the expedition to visit north-east Inglefield Land where the Lower

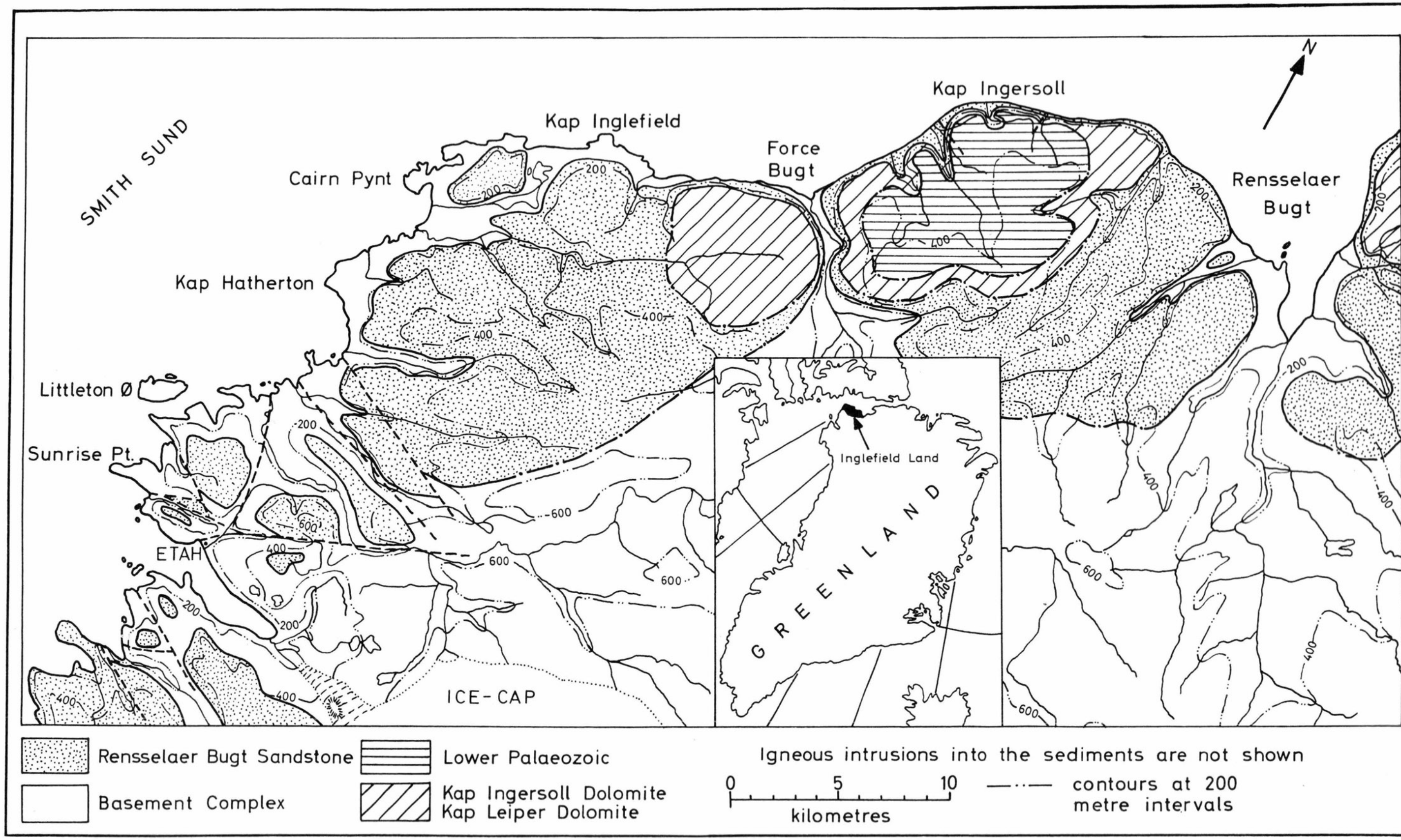


Fig. 1. Geological sketch map of south-west Inglefield Land with inset showing location in north Greenland.

Palaeozoic rocks appear to be at their thickest, where extensive fossil collections have been made by Koch and Troelsen, and where the type localities of the Cambrian formations are situated. This proved impossible to arrange and the more accessible objective of south-west Inglefield Land was substituted: it turned out that in this area no fossils were found *in situ* in the thinly-developed series of strata which can nevertheless with fair certainty be assigned on lithological grounds to the Cambro-Ordovician.

The expedition was made possible by grants from the Churchill Endowment Fund and the Royal Society, and this help is gratefully acknowledged. It is also a great pleasure to acknowledge the advice and help I have received from friends in Denmark, Greenland and the United Kingdom. In particular I should like to thank Professor W. F. Whittard for his continued encouragement and support, and also to express gratitude to Dr. Lauge Koch, Sir James Wordie, Dr. J. C. Troelsen, Dr. J. Malaurie and Dr. B. Fristrup for advice drawn from their special knowledge of the region. Professor Chr. Poulsen and Mr. V. Poulsen enabled me to see collections from Inglefield Land which are lodged in Copenhagen and I thank them for their assistance. Dr. F. Coles Phillips kindly commented on specimens of the igneous and metamorphic rocks. Thanks to Colonel J. V. Helk of the Danish Geodetic Institute, who was instrumental in providing aerial photographs, and the Assistant Air Attache at the U. S. Embassy in London, who obtained maps for my use, it was possible to travel and map with greater facility. The Greenland Department of the Danish Government is thanked for permitting and assisting us to travel to and in the country.

The assistance and companionship of Mr. F. R. Farley in the field is gratefully remembered and also that the help of Inspektor Mørk-Rasmussen, Kalepalouk and Sigdluk Miunge, all of the Thule District, made our journeys in N. W. Greenland possible.

University of Bristol, July, 1960

II. STRATIGRAPHY

A. Measured sections

1. *Kap Ingersoll*

Gneisses, schists and granite outcrop in the valley-bottom of the river flowing into Force Bugt (fig. 1). These metamorphic and igneous rocks, which are part of the basement complex, are overlain unconformably by red ferruginous sandstone which is occasionally felspathic. As the coastal cliff section is traversed towards Kap Ingersoll, successively younger beds are found near the shore. Approximately $3^1/_2$ kilometres from the highest point of the cape[1]) two streams enter the sea 100 metres apart. In the canyon of the south-eastern stream a section was measured which commenced in the red sandstone. Marker horizons near the top of the canyon section could be found in the upper part of the Kap Ingersoll cliff and measuring was continued to the highest point. This composite section is shown to scale in figure 3. Throughout S. W. Inglefield Land the dip of the sediments is only a few degrees; this, and the presence of hard bands in the series and igneous sills, causes many areas to be difficult of access so that there are few continuous sections. The succession was divided into beds which were given arbitrary consecutive numbers: these are retained for convenience in the following descriptions:–

Bed 43. Ruddy-brown, medium to coarse-grained, felspathic, ferruginous sandstone,conglomeratic in part. Buff patches are seen which are calcareous. Well-rounded grains vary considerably in size from medium grain up to scattered rounded quartz pebbles which attain 1.5 cm as their longest dimension. Occasional bands of fine-grained sandstone are usually cream-coloured but may be irregularly banded in maroon and cream. Anastamosing calcite veins are often oblique to the bedding. Well- developed cross-bedding occurs. Thin-section: – well-rounded quartz grains with cloudy interstitial cryptocrystalline silica; small amounts of microcline; interstitial iron-ore and haematite. Thickness: 22 m.

Bed 44. Cream to buff, fine to medium-grained sandstone interbedded with buff, fine-grained siltstone. The sandstone occurs in massive beds 2 to 3 m thick.

[1]) Kap Ingersoll is here taken to be the slight prominence associated with the highest point of the coastal cliff between Force Bugt and Rensselaer Bugt, as checked by Abney level. This is the place illustrated as Kap Ingersoll by Koch (1933, figs. 7 & 13, pl. II).

The siltstone, which is consistently developed in three bands equally spaced in the subdivision, is fissile and flaggy with laminae varying between 1.5 and 7 mm. There is little variation in grain-size in the sandstone but occasionally a quartz-pebble is encountered. Ripple-marking is well developed but cross-bedding is unusual.

About the middle of the bed a 3 m band of maroon to dusky-red, medium-grained sandstone occurs which contains quartz pebbles, is micaceous, and ferruginous with haematite around the grains. At 11 m above base a 1.5 m thick bed of quartzite is found with chlorite patches and a considerable number of quartz pebbles. Immediately below the overlying igneous sill the sandstone shows signs of contact metamorphism. Thickness: 18 m.

Bed 45. Medium-grained, dark-grey to green dolerite with purple patches which weathers dark purple and dark green to black; a massive subdivision usually causing steep cliffs. The junction with the overlying sediments is universally obscured by scree. Thin-section:– dolerite containing quartz and/or devitrified glass with plagioclase partly scapolitized. Thickness: 30 m.

Bed 46. Frequently a part of the succession at this level is obscured and the top of the underlying dolerite is never seen. Fine-grained, buff dolomite weathering buff. Thickness: 5 m.

Bed 47. Grey, orange-flecked, fine to medium-grained arenaceous dolomite with equally-spaced small macroscopic quartz grains (up to $^1/_2$ mm), weathers dark-buff to orange and is very hard with a brittle fracture. Stylolites occur. Near the base a 5 cm band of orange, friable, calcareous, arenaceous dolomite shows $^1/_2$ mm quartz grains. In the upper half of the subdivision the quartz grains are not macroscopic and the rock is a uniform, fine-grained, hard, brittle, arenaceous dolomite weathering buff. Thin-section:- large, irregular, somewhat rounded quartz grains set in a matrix of extremely fine-grained dolomite which also surrounds some smaller irregular quartz grains. The larger quartz grains show internal interlocking sutures and differing optical orientation in their parts suggesting a secondary character and probable derivation from a quartzite. Thickness: 5 m.

Bed 48. Pale-grey, arenaceous dolomite which is fine-grained, hard with conchoidal fracture and weathers buff with an orange tinge. Well-bedded with an average thickness of 10 cm and stylolitic in places. Thinner bands occur and irregular bedding may be associated with an increased percentage of argillaceous material. One 5 cm band consists of medium-grained, grey, massive dolomite which weathers pale-buff. The bed forms almost vertical cliffs in most localities. Thickness: 21 m.

Bed 49. Medium-grey, fine-grained limestone containing large irregular-shaped blebs of buff, medium-grained, crystalline dolomite which branch and form connecting channels. The aggregate composition of the rock is dolomitic limestone. Thickness: 10 m.

Bed 50. Fissile, irregularly-bedded siltstone mottled in grey, buff, green and brown and weathering mottled yellow and brown; occasional grains of glauconite occur. Thin bands (1.5 cm) of pale-grey sandstone weathering grey; a considerable percentage of small flecks of black phosphatic material. Thickness: 30 cms.

Bed 51. Bedding which is irregular, convolute and contorted is seen in medium-grey and green, fine-grained, glauconitic siltstone which weathers grey-green to brown. Thickness: 1 m.

Bed 52. Grey, fine-grained, calcareous, glauconitic siltstone which weathers grey. Thickness: 0.8 m

Bed 53. Irregularly-bedded, grey, glauconitic sandstone mottled in brown and green; bedding-planes show brown ferruginous staining. Thickness: 0.8 m.

Bed 54. Grey, fine-grained, argillaceous, glauconitic siltstone weathering grey which is irregularly-bedded, shows linear markings on bedding-surfaces which are probably due to organisms, and contains some phosphatic material. Thickness: 1 m.

Bed 55. Fine-grained, grey, dolomite weathering buff with irregular bedding which is often stylolitic; an intraformational conglomerate occurs at one horizon. This lithology grades upwards into coarser-grained, more crystalline, grey dolomite weathering a ruddy-buff colour. Thickness: 1.9 m.

Bed 56. A thinly-bedded subdivision varying from grey, fissile, glauconitic, micaceous, sandstone through dark-grey, hard, glauconitic arenaceous shale to dark-grey, soft, glauconitic shale. Irregular bedding and cross-bedding is seen. Thickness: 5 m.

Bed 57. Thinly and irregularly-bedded grey dolomite which weathers buff, with intercalations of grey, arenaceous shales. Thickness: 1.4 m.

Bed 58. A succession of limestones and dolomites with some shale which is characterised by an abundance of intraformational conglomerates and breccias; bedding is in general very irregular and commonly nodular. The limestone and dolomite are often argillaceous and occasionally, with the shales, are glauconitic. The intraformational conglomerates and breccias are characteristically 10–15 cm thick but enormous edgewise breccias up to 90 cm thick are common with lath-shaped fragments of 5–7 cm long dimension and approximately 6 mm thick. The uppermost 10 m are more thinly-bedded argillaceous limestones and dolomites with a higher percentage of shale, and are more glauconitic. Thickness: 29.5 m.

Bed 59. Purple-maroon and green, extremely fine-grained, argillaceous, arenaceous dolomite weathering purple and brown with an irregular fracture; in general thin-bedded with fissility approaching that of a shale in places. Thickness: 7 m.

Bed 60. Fine-grained, thinly-bedded, grey dolomite which develops a green tinge on weathering and is then easily shattered. Thickness: 4.5 m.

Bed 61. Irregular thin beds of grey, argillaceous limestone with shaly partings. Intraformational conglomerates make up a considerable proportion of the limestone bands and occur also as impersistent lenses and pockets. Weathering produces a pale-green tinge and a nodular pebbly appearance which is characteristic of the Cass Fjord Formation in both Northwest and East Greenland. This subdivision forms the top of the cliff and the maximum thickness preserved is 13 m.

In screes associated with, and slightly below, Bed 58, specimens of limestone were collected which contained fragments of trilobites and brachiopods. The fossils are too fragmentary for identification. In two specimens the fossil fragments are contained in a discoidal grey limestone nodule which has weathered a buff colour: one disc has a diameter of 5 cm and a thickness of 1 cm and the framentary genal spines and thoracic segments appear to have been swirled together on deposition in the nodular "pocket". In the other specimen the grey limestone is associated with a percentage of buff dolomite concentrated in patches and the disc has a depressed axial region and is slightly elliptical (dimensions 13 cm × 11 cm × 5 cm): the fossils in this case are fragmentary horny brachiopods. Another specimen is of a grey limestone breccia which weathers brown and contains fossil-fragments including part of the genal spine of a trilobite.

Discoidal limestone nodules were seen partly exposed *in situ* within Bed 58 but fragments which were broken off them were unfossiliferous: it was not found possible to extract the complete nodules. It is probable that Bed 58 is the source of the fossils in the scree. Beds above cannot be entirely ruled out in considering provenance, however, and glacial erratics occur in the area.

The correlations suggested for this succession are shown in figure 3 and discussed on page 16–29.

2. *Hatherton Bugt*

An incompletely-exposed section in the older sediments was examined, but could not be accurately measured, $4^1/_2$ kilometers south-east of Kap Hatherton, in cliffs which overlook low ground on the shores of Hatherton Bugt. This is close to the locality mentioned by Bentham (1936, 429). At the base of the cliff the metamorphic series shows diverse petrological types but acid gneiss predominates. Resting unconformably on the foliated gneiss with a slight westerly dip of two to three degrees are the following sediments and igneous sills:–

Lower Beds. At the base flaggy, micaceous sandstone with irregular, cream, maroon and green coloration shows ripple-marking. This type is interbedded at higher levels with more fissile micaceous sandstone and green and maroon, arenaceous shales. The more argillaceous bands show mud-cracking. Near the middle of the series grey, dolomitic, stromatolitic structures of the "Collenia" type are well-developed (Cloud, 1942). Towards the top cream and maroon flaggy sandstone outcrops below the overlying basic sill. In most places in S. W. Inglefield Land these beds are covered by scree. Approximate thickness: 50 m.

Lower Basic Sill. Coarse to medium-grained, black dolerite, weathering green-black, is well exposed in a steep step in the cliff. Approximate thickness: 20 m.

Middle Sandstones. Massive, well-bedded, cream or yellow, medium to coarse -grained sandstone is frequently ripple-marked and occasionally cross-bedded. Weathered surfaces are almost the same colour as when fresh. Approximate thickness: 30 m.

Upper Basic Sill. Medium-grained black dolerite, weathering black, forms a second steep part of the feature. Approximate thickness: 25 m.

Upper Sandstones. This series is similiar to the Middle Sandstones and forms the top of the cliff with a maximum thickness of approximately 20 metres.

The sediments belong to the Rensselaer Bay Sandstone of the Thule Group.

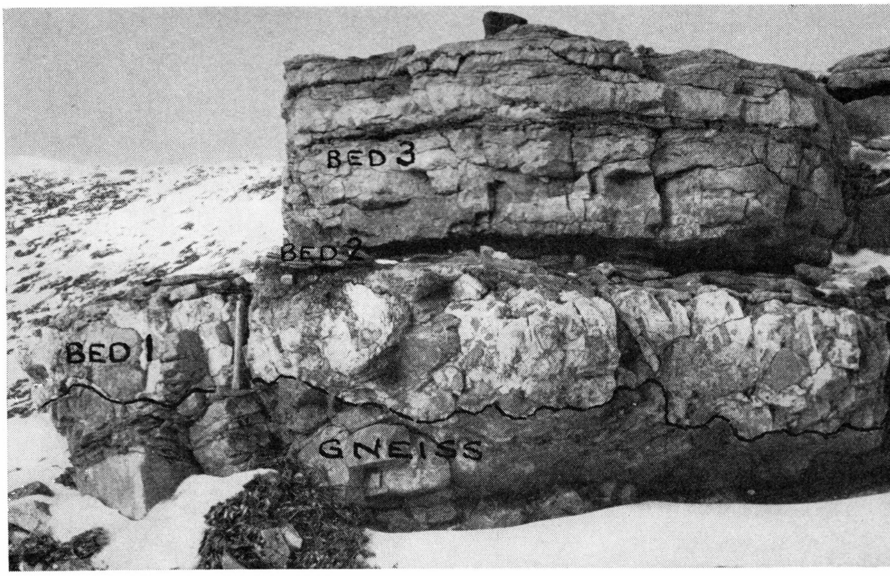


Fig.2. Unconformable contact between gneiss and Thule Group. Bed 1 – coarse conglomerate of blocks of gneiss in matrix of dolomite. Bed 2 – sandstone and shale. Bed 3 – dolomite.

3. Etah

A poorly-exposed section was measured in the hill, approximately $2^1/_2$ kilometres due west of Etah, which was visited by Schei (Holtedahl, 1917, 5, 18). Arbitrary numbering of beds is again used for convenience.

Bed 1. Overlying the red acid gneiss with marked unconformity is a coarse conglomerate (fig. 2) made up of blocks of garnetiferous acid gneiss set in a matrix of cream, extremely fine-grained, "chinastone" dolomite which weathers cream and pink. The dolomite contains quartz pebbles and grains and shows patches of glauconite. Thickness: 66 cm.

Bed 2. Flaggy, maroon and green sandstone with arenaceous shale. Thickness: 33 cm.

Bed 3. Pink, maroon and purple, fine to medium-grained arenaceous dolomite which weathers maroon. Large grains of quartz are visible in the hand-specimen and weathered surfaces are rough and show small-scale brecciation. In thin-section it is apparent that the quartz grains are polygenetic. Some of them have been derived from a metamorphic rock and were enlarged by secondary growth before incorporation in the present rock; many quartz grains show strain and most are angular and not water-worn. The subdivision is thinly-bedded and bedding surfaces are stylolitic. Thickness: 66 cm.

Bed 4. Covered by scree. Thickness: 3 m.

Bed 5. Grey-green, white and cream, arenaceous dolomite weathering buff and green, which contains bodies of chalcedony and quartz. Abundant stromatolites

("Collenia") show up well both on cross-section and in bedding-planes. Thickness: 1.98 m.

Bed 6. Grey-green, white, cream and maroon arenaceous dolomite weathering buff, green and maroon is developed with irregular bedding, and conglomeratic bands occur at a number of horizons. Thickness: 1.65 m.

Bed 7. Grey-green, white and cream arenaceous dolomite interbedded with pale-grey, massive sandstone. Thichness: 5 m.

Bed 8. Covered. Thickness: 3 m.

Bed 9. Maroon and green, heterogeneous conglomerate with rounded pebbles of sandstone and dolomite which are 2-5 cm across. Thickness: 2 m.

Bed 10. Covered. Thickness: 6.6 m.

Bed 11. Buff-brown flecked with green, medium-grained, felspathic, dolomitic sandstone interbedded with grey-green, grey and maroon siltstone. The underside of a bed shows raised polygonal structures, averaging 1 cm across, which are probably infilled mudcracks. Thickness: 3 m.

Bed 12. Covered. Thickness: 15 m.

Bed 13. Grey-green, buff and maroon, thinly-bedded, medium to coarse-grained sandstone, which shows ripple-marks very extensively developed and cross-bedding and is interbedded with pale-grey, fine to medium-grained, felspathic, dolomitic sandstone. Thickness: 2 m.

Bed 14. Covered. Thickness: 20 m.

Bed 15. Maroon and buff sandstone weathering to similiar colours shows ripple-marking and cross-bedding. Thickness: 5 m.

Bed 16. Scree made up of dolerite blocks. Thickness: 20 m.

Bed 17. Dolerite sill which has partings parallel to the bedding of the country-rock and 2.5 cm to 30 cm apart. A variation in texture is seen from coarse to medium-grain; the fresh colour is black with a slightly green tinge and weathering produces a black or dark-brown appearance. Thin-sections indicate that the composition is acid and the rock contains some quartz.

Bed 18. Grey, fine-grained siltstone weathering grey. Thickness: 3 m.

Bed 19. Medium-grained, black, ophitic dolerite, which has suffered some secondary alteration, caps the hill and some 60 m thickness of it has escaped erosion.

The sediments belong to the Rensselaer Bay Sandstone of the Thule Group.

B. Systematic

1. Basement Complex

The igneous and metamorphic rocks of the basement complex, which evidently were intruded, deposited and metamorphosed in Pre-Cambrian times, are widely exposed. They are of considerable diversity and would probably repay close study; apart from schists and gneisses, which are in places garnetiferous, graphitic, felspathic or rich in biotite, there are igneous rocks varying in composition from granite to gabbro and with apparently a high proportion of quartz-rich diorite.

Krueger in 1928 descibed from the Umanak Disrict (71°–72° N.) of West Greenland a series of metamorphosed sediments which has a basal conglomerate resting unconformably on gneiss; he named these rocks the Agpat Formation. Koch (1929, 14) suggested that rocks occur near Upernavik, Melville Bugt and Olrik Fjord (72°–77° N.) which "owing to their hardness and generally horizontal position have a strong resemblance morphologially to the typical Agpat formation as developed in the southern portion of Umanak Fiord. Hence I assume, although with reservation, that the Agpat formation can be traced from Umanak Fiord northward as far as Inglefield Bredning." This assumption, which was originally made by Koch with dubiety and is still so regarded by him (verbal information in 1959), has been followed up by later authors. Teichert in 1939 remarked regarding this correlation that "nothing definite is known" but Kurtz and Wales in 1950 referred schists, gneisses, granites and pegmatites found in the Thule District (76°–77° N.) to the Agpat Formation. In the descriptions of the geology of Inglefield Land by Koch (1933) and Troelsen (1950) no correlation of the basement complex was made with the Agpat Formation. Blackadar in 1957 correlated part of the metamorphic series in Inglefield Land with the Agpat Formation for the first time. Inglefield Land is approximately 140 kms north-west of Inglefield Bredning. This concatenation of correlations from Umanak Fjord to Inglefield Land seems to be based on a slender foundation of facts and its hypothetical character should be emphasised.

Lauge Koch's Etah Formation, with its type-locality in S. W. Inglefield Land (Koch, 1929, 15–16), includes sandstone and limestone penetrated by diorite. Bentham (1936, 429) ascribes to this formation limestone and arkosic grit (presumably little metamorphosed) in addition to igneous and metamorphic rocks. It would be inappropriate for the author to give an opinion as to whether the Etah Formation is viable as a separate subdivision after such short acquaintance with the complexities.

Both the "Agpat Formation" and the "Etah Formation", which are neither clearly defined nor easily separable, would appear to be part of the North American Shield; they are equally sharply truncated by the major unconformity at the base of the Thule Group.

The basement complex shows strong foliation which is clearly displayed in the area north of Etah and along the coast to Cairn Pynt (fig. 5). The strike is approximately WSW–ENE, the dip is often vertical but is in places steeply to the NNW.

Metamorphic rocks are also found as far north in Inglefield Land as the Humboldt Gletscher, and in Bache Peninsula and neighbouring parts of the Canadian coast. It is characteristic of all these localities that the older rocks were peneplained to a remarkably level surface, a phenomenon beautifully illustrated by Wordie from the Bache Peninsula (1938, 398).

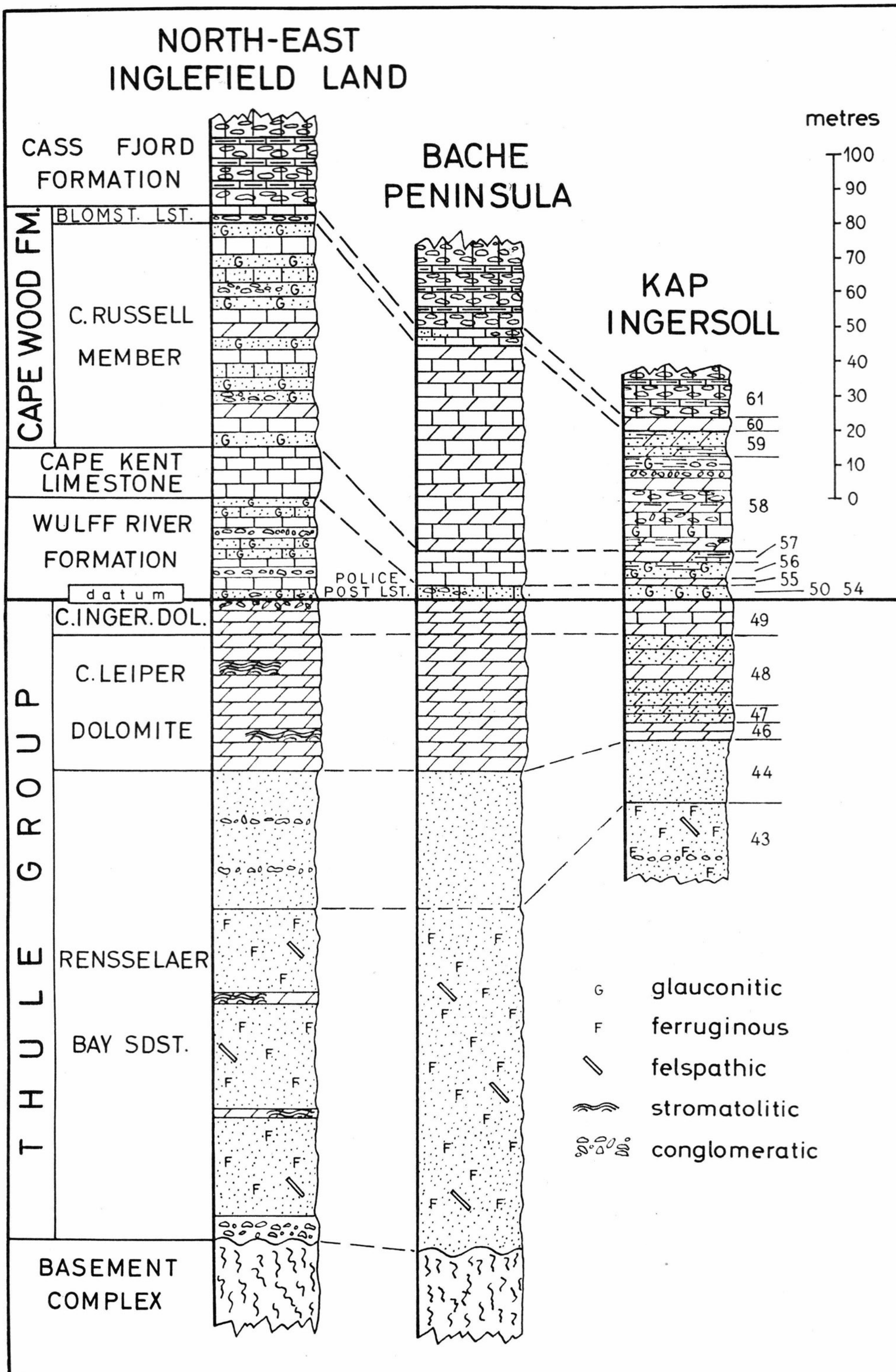
2. Thule Group

The basement complex is succeeded with marked unconformity by the sediments of the Thule Group (Koch, 1929, 16–18; Troelsen, 1956a, 74–77; 1956b, 84–85). The age of the unmetamorphosed sediments of the Thule Group in the Thule District, found overlying metamorphic rocks in the coastal strip between Kap York and Etah, cannot be based on palaeontological evidence as no fossils have been found there. The Thule Group can only be indirectly referred to the Pre-Cambrian in its type area by lithological correlations with sediments referred to the same group in Inglefield Land where they are overlain by Lower Cambrian strata with slight unconformity. The correlation between the Thule District and Inglefield Land at this level in the stratigraphical column cannot be made in detail and there are many differences in sedimentary types and thicknesses: it can be argued that it is based on insufficient grounds but it has been generally made in the past and is provisionally accepted here. The most recent summary of the evidence has been given by Blackadar (1957, 93–100).

Troelsen has divided the Thule Group into the Rensselaer Bay Sandstone at the base overlain by the Cape Leiper Dolomite and the Cape Ingersoll Dolomite (1950, 35–37), mainly on the basis of observations in Inglefield Land. The correlations shown in figure 3 can be put forward with some confidence. No evidence is known to the author from field observations that precludes the correlation of Pre-Cambrian sediments in the Kap Ingersoll area and the Bache Peninsula with the closely comparable succession in N. E. Inglefield Land.

The Rensselaer Bay Sandstone has a conglomerate at its base and the lower part is characteristically red in appearance due to its high iron content; it is felspathic, conglomeratic on a small scale, cross-bedded and ripple-marked; stromatolites in dolomite are developed at a number of horizons. The upper part is typically a cream or yellow sandstone in which ripple-markings and cross-bedding are also found. The outcrops of the sandstone are extensive, and, as figure 1 indicates, they are more important north-west and north-east of Etah than has been previously reported.

Fig. 3. Vertical sections of Pre-Cambrian and Cambro-Ordovician strata from Greenland and Canada. The localities are shown in figure 4. Igneous sills (for example Bed 45 at Kap Ingersoll) are not shown.


NORTH-EAST INGLEFIELD LAND
BACHE PENINSULA
KAP INGERSOLL
metres
100
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80
70
60
50
40
30
20
10
0
CASS FJORD FORMATION
CAPE WOOD FM.
BLOMST. LST.
C. RUSSELL MEMBER
CAPE KENT LIMESTONE
WULFF RIVER FORMATION
datum
POLICE POST LST.
THULE GROUP
C.INGER.DOL.
C. LEIPER DOLOMITE
RENSSELAER BAY SDST.
BASEMENT COMPLEX
61
60
59
58
57
56
55
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44
43
G glauconitic
F ferruginous
felspathic
stromatolitic
conglomeratic

Fig. 3.

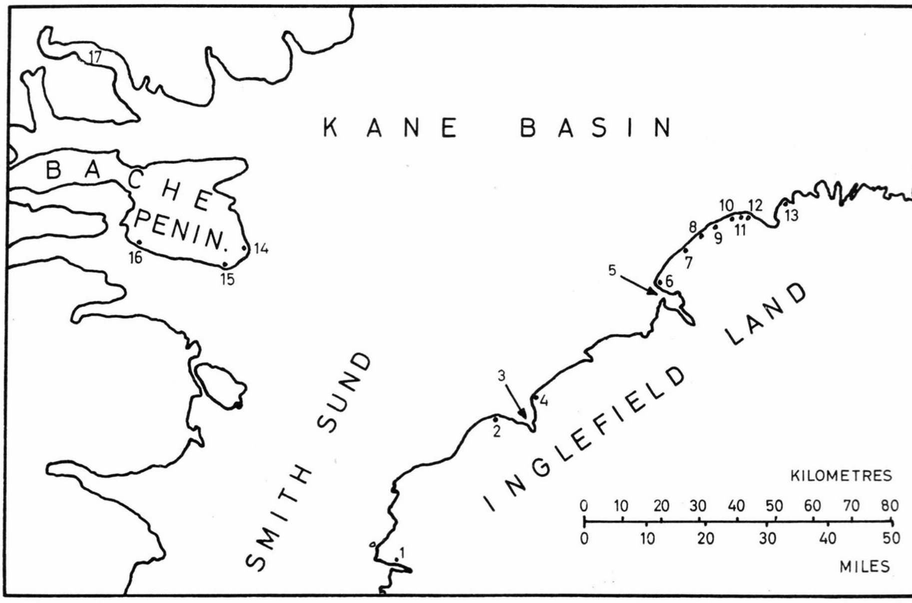

Fig. 4. Sketch of parts of the lands bordering Smith Sund and Kane Basin; on the east is part of Greenland, on the west is part of Ellesmere Island in Canada. 1. Etah (abandoned), 2. Kap Ingersoll, 3. Rensselaer Bugt, 4. Kap Leiper, 5. Marshall Bugt, 6. Kap Russell, 7. Blomsterbækken, 8. Kap Frederik VII, 9. Pemmikan Elv, 10. Kap Wood, 11. Wulff Elv, 12. Kap Kent, 13. Kap Scott, 14. Cape Albert, 15. Cape Camperdown, 16. Royal Canadian Mounted Police (R.C.M.P.) post (abandoned), 17. Copes Bay.

The Cape Leiper Dolomite, which is arenaceous and stylolitic in its considerable outcrop in the Kap Ingersoll plateau, also forms the tops of the hills to the south-west of Force Bugt.

The Cape Ingersoll Dolomite was first described by Troelsen (1950, 35-36) evidently from occurrences at a) Kap Leiper in Inglefield Land, b) a locality between Capes Camperdown and Albert, and c) the R.C.M.P. post, the last two on Bache Peninsula. It can also be clearly distinguished at Kap Ingersoll by the branching blebs and channels of dolomite. From thin-sections and chemical tests it was found that the specimens collected were of a dolomitic limestone.

In view of the current interest in Pre-Cambrian tillites as marker-horizons and the problem of the status of the "Eo-Cambrian" which has been related by some authors to them, it may be useful to state clearly that the author found no evidence of their occurrence in the Thule Group in S. W. Inglefield Land and the group is here placed in the late Pre-Cambrian and not in the "Eo-Cambrian".

"Eo-Cambrian", as first used by Brögger in 1900 and subsequently by other Scandinavian geologists, referred to sedimentary successions without faunas lying without angular unconformity beneath fossiliferous Lower Cambrian rocks and resting on crystalline basement rocks. Pruvost (1951) expanded the definition of "Infracambrian" to cover a similiar situation. Neuman & Palmer (1956) examined the Eo-Cambrian and the Infra-Cambrian as "geologic systems" and presented many arguments against the use of these terms. Poulsen and Troelsen assign sediments in Greenland to the Eo-Cambrian using the term in a more restricted sense. Poulsen (1956, 60) regarded the Eo-Cambrian as early Lower Cambrian while Troelsen (1956a, 71–72) did not include the Eo-Cambrian in either the Pre-Cambrian or the Lower Cambrian in his tabulations (*op. cit.*, 74–81). The top of the Eo-Cambrian is defined by both authors as the disconformity which precedes the first occurrence of fossils in the Lower Cambrian and the base is defined as the last occurence of tillites. Although "the deposition of the tillites and the first appearance of Cambrian fossils (Olenellidae) must be regarded as stratigraphic criteria of great value" (Troelsen, 1956a, 71), doubt must be expressed as to either the utility or the validity of this removal from the Pre-Cambrian and inclusion in the Cambrian of rocks which are stratigraphically far below any beds found to contain fossils of the *Olenellus* zone. Stratigraphical subdivisions in the Pre-Cambrian and Lower Cambrian must, perforce, be much coarser and more loosely-defined than those for younger rocks. Nevertheless, diachronism will affect tillites, in common with all sedimentary rocks, and can be expected in correlations ranging from North and South America, through Greenland, Europe, Africa and Asia to Australia. Until more certainty is reached as to the cause of ice ages and the possible migrations of the cold poles at various times in the past there can be no certainty that these older glacial deposits are contemporaneous. With reference to a later glaciation L. C. King has pointed out that the correlation of Late Palaeozoic and Mesozoic facies in Gondwanaland indicates that the glacial phase ended in the Early Carboniferous in South America, in the Late Carboniferous in South Africa and India, and in the mid-Permian in Australia (1958, Table 1). Also glacial deposits may be expected to occur at most levels in the geological column as ice bodies may nearly always have been present somewhere during the periods represented by sediments. In Brazil and Argentina nine glacial episodes are recorded (Oliviera, 1956; Harrington, 1956) ranging in age from Cambrian to Lower Permian, which (if they are correctly determined) represents a high average frequency. There is a paucity at present of age data for the relatively unmetamorphosed sedimentary rocks which are older than the *Olenellus* zone. Approximate limits can be determined by examining relationships with underlying or intruding igneous bodies which can be given absolute ages from the decay of radioactive isotopes. This limiting data (which will, presumably, be superseded in this context by potassum-argon and rubidium-strontium methods applied directly to authigenic minerals in the sedimentary rocks) indicate that in Canada the Proterozoic rocks may have commenced their sedimentation from 1100 to 2300 million years ago, although later dates are inherently possible in the determinations (Farquhar & Russell, 1957). There is thus probably ample time available for many periods of glaciation in diverse localities within the pre-*Olenellus*-zone succession of sediments.

In Greenland three regions have been described as yielding tillites in the older sedimentary successions. The occurrences in Central East Greenland have been known since 1929 and their glacial character is apparently well-established on numerous criteria (Schaub, 1955, 10–14). In Kronprins Christian Land (North-East Greenland) Fränkl (1954) described as a tillite a bed which is 1–2 m thick, contains rounded and polished porphyries and quartzites (1–4 mm in diameter) in a matrix of well-rounded quartz grains and tiny carbonate crystals and compared it with the upper tillite of Central East Greenland. The tillite bed is part of a succession of varied lithology which lies about 400 metres below beds which may be considered, on lithological and diastrophic grounds, to be Lower Cambrian in age (the oldest fossils so far found in Kronprins Christian Land are Lower Ordovician in age). Troelsen visited Peary Land in the period 1947–49 and published preliminary reports in 1949 and 1950. In 1956 he gave the first full account of a tillite he had discovered in southern Peary Land which varied in thickness from less than one metre to approximately a hundred metres; its correlation with tillites in East Greenland, Spitzbergen and Scandinavia was suggested (*op. cit.*, 85). The tillite lies 750–800 metres lower down in the succession than the disconformity which underlies the fossiliferous Lower Cambrian and occurs within a series which is predominantly sandstones. In view of arguments put forward above it is suggested that until further facts are available undue importance should not be attached to these occurrences in Kronprins Christian Land and Peary Land as a marker horizon for age correlations. Another aspect of the problem is the caution needed in distinguishing between a true tillite and other rocks which resemble it. This has recently been reemphasized by Pettijohn (1957, 275) and Read (1958, 88). Schaub (1955, 12–14) identified nine out of the eleven salient features of glacial till postulated by Pettijohn (1949, 221–222; 1957, 273–275) in the Tillite Series in Ella Ø, East Greenland. The published details from the northern areas leave much greater uncertainty.

Igneous Sills. For the sake of clarity the dolerite sills mentioned in the descriptions of the measured sections are not portrayed in the geological sketch map (fig. 1); the major outcrops have already been mapped by Koch (1933, Plate II). There is no evidence of the assimilation of country-rock and, although contact metamorphism was only observed at the lower and not at the upper surface of the sills, on textural evidence they are clearly not lavas: they are therefore omitted from figure 3 also.

These concordant intrusions are only found in Inglefield Land in its south-western part; followed north-east from Kap Ingersoll they thin out and disappear, and are not seen around Rensselaer Bugt. The fact that the intrusions are only found within the Thule Group, and are not unconformably overlain by solid rocks, would suggest that they have been injected at any time later than the deposition of these sediments. Koch, however, found diabase pebbles in the Lower Cambrian conglomerates of N. E. Inglefield Land and suggests that the diabase sills were intruded before Cambrian times (1933, 34–35). Troelsen agreed with this view in 1950 (19), but his most recent opinion (1956a, 77, 84) leaves open the possibility that the basic intrusions into the Thule Group in North Greenland (including Peary Land) may be of more than one age. The sill at Kap Ingersoll was apparently intruded into the sequence at the junction of the Rensselaer Bay Sandstone and the Cape Leiper Dolomite although the actual contact of the sill with the dolomite is obscured by scree. Now that the author has visited Inglefield Land the statement made previously—which was based on study of the literature only—that the intrusions are found only in association with sandstone (Cowie & Adams, 1953, 16), must be somewhat modified, although no transgression into the overlying dolomite has been observed. It is possible that the dolerite was intruded only into the Rensselaer Bay Sandstone and that erosion exposed the sill so that the Cape Leiper Dolomite was deposited on to the dolerite, but where the dolomite rests directly on the sandstone to the north of Kap Ingersoll no unconformity was seen by the author and Troelsen (1956a, 76–77) specifically excludes the possibility. From the field evidence available there is little support for the suggestion (Cowie & Adams, 1953, 16, pl. II) that an unconformity exists at the top of the Rensselaer Bay Sandstone, nor that the igneous sills and dykes are exclusively associated with it, so that Fränkl's removal of the dolomites from the Thule Group (1954, 52–53) lacks support on diastrophic grounds.

There is, however, an increasing body of evidence from North Greenland that the younger beds in the late Pre-Cambrian are not penetrated by dykes and sills which are widely found associated with the beds below. Observations in Campanuladal near Kap Holbæk (on the shores of Danmark Fjord, North-East Greenland) first suggested this to the author; there the Norsemandal Sandstone (a possible equivalent of the Rensselaer Bay Sandstone) is traversed by dykes which are not found in younger formations (Cowie & Adams, 1953). Information published by Troelsen (1950, 1956a) seems to suggest that in Peary Land the intrusives are found mainly in the lower sandstones of his pre-Lower Cambrian succession. In 1953 the author visited a limited area in J. C. Christensen Land (across Independence Fjord from Peary Land and east of Hagen Fjord) where quartzites interbedded with maroon and green sandstones were found but no dykes and sills were to be seen. Such negative evidence as the absence of igneous intrusions is, it is suggested, of importance when numerous intrusions are found in sediments on one side of a valley but not in sediments of a quite different lithology on the other side, as is the case in Campanuladal, even though a fault intervenes; it carries much less force when distances across which comparisons are made is much greater. For example, the absence of dolerites in N. E. Inglefield Land in any part of the succession may be purely because igneous activity did not penetrate there.

Nevertheless, the subdivision of the Pre-Cambrian of North Greenland into an older series cut by intrusions followed unconformably by younger beds without intrusions, or with only a poorly-developed younger generation of intrusions, may yet be achieved, although the evidence for a concomitant split of the Thule Group in Inglefield Land is lacking.

3. *Cambro-Ordovician*

The beds overlying the Cape Ingersoll Dolomite at Kap Ingersoll show a marked change in lithology. Siltstones and sandstones predominate in Beds 50–54 which are glauconitic throughout and at some horizons are phosphatic. The bedding is irregular with some contortion but there is no angular discordance and no conglomerates occur. The phosphatic and glauconitic content of these beds coupled with the lithological change suggest that they are associated with an unconformity in the broadest sense of the word (Krumbein, 1942, 36–62) and that erosion took place during a time hiatus between the Kap Ingersoll Dolomite and Bed 50: the relationship may be termed a non-sequence or paraconformity (Dunbar & Rogers, 1957, 119), although it must be pointed out that these terms are not synonymous.

In north-east Inglefield Land the upper surface of the Cape Ingersoll Dolomite indicates "a certain amount of erosion before the beginning of the Cambrian...." (Troelsen, 1950, 36). The overlying Wulff River Formation is Lower Cambrian in age, conglomeratic at many levels, and glauconitic (Koch, 1933, 23–24). Troelsen terms the relationship an erosional disconformity. At Kap Leiper, which is only some 18 kilometres north of Kap Ingersoll no conglomerates were seen by Troelsen (1950, 41), in the Wulff River Formation, and he states that a detailed correlation between the formation at Kap Leiper and N. E. Inglefield Land is not possible: evidently here the relationship is closer to the non-sequence found at Kap Ingersoll. In Ellesmere Island the exposures on Bache Peninsula at the R.C.M.P. post and on the coast between Cape Albert and Cape Camperdown, show the Cape Ingersoll Dolomite overlain by the Lower Cambrian Police Post Limestone: according to Troelsen there is a disconformity (1956a, 77). This disconformity on Bache Peninsula was not observed by Schei or by Bentham (which may be significant) and Wordie (1938, 399) plainly states that no apparent break was observed between the Thule group and the Lower Cambrian limestones in the well-exposed section at the R.C.M.P. post. Possibly on Bache Peninsula also, the Thule Group/Lower Cambrian relationship is closer to a non-sequence. At Copes Bay (fig. 4), 30 kilometres north of Bache Peninsula, a part of the Central Ellesmere Island folded belt displays a thick succession which can be correlated with the Thule Group (Blackadar, 1957, 96–97). A predominantly dolomitic unit, evidently equivalent to the Cape Leiper-Cape Ingersoll Dolomites is separated by a sharp but apparently conformable contact from dark grey limestone which has yielded Middle Cambrian trilobites at a thickness of 24 metres above its base. The thickness of limestone below the Middle Cambrian fossil horizon may be partly Lower Cambrian in age but, as there is no lithological change, it could well be entirely Middle Cambrian. In that case an important unconformity with considerable time-gap is present in this area between the Pre-Cambrian Thule Group and the Middle Cambrian limestone.

These sedimentary relationships showing disconformity or non-sequence, the consistent character and thickness of the Cape Ingersoll Dolomite in Inglefield Land and Bache Peninsula, the variation of lithology of the immediately overlying sediments (Wulff River Formation, Beds 50–54, and the Police Post Limestone) and the incoming of Lower Cambrian fossils indicate that there is an unconformity (in the broad sense of the word) at this level but with small time hiatus. The unconformity between Pre-Cambrian and Lower Palaeozoic appears to represent a greater interval of time at Copes Bay.

Beds 50–54 of the Kap Ingersoll section can be considered penecontemporaneous with the basal Lower Cambrian sediments elsewhere in the region. Probably the Wulff River Formation, Beds 50–54 and the Police Post Limestome are of slightly different age but the contrast in lithology may be largely due to lateral variation in the conditions of sedimentation in the Lower Cambrian sea. Poulsen in 1946 (301, 305) stated that the fauna of the Police Post Limestone is older than any in

Inglefield Land on the grounds that *Acrothele ?pulchra* Poulsen is found in the matrix of a conglomerate from the Police Post Limestone and also in pebbles of a conglomerate in the Wulff River Formation (Poulsen, 1927, 239). If the Wulff River Formation conglomerate was not collected from the base of the formation the *remanié* fossils contained in it may have come from as yet undescribed beds lower in the formation. It is also possible that the brachiopod *Acrothele ?pulchra* may have a considerable time range. A comparison of the faunas described by Poulsen from N. E. Inglefield Land (1927 & 1958) with Lower Cambrian fossils listed from Central East Greenland (Cowie & Adams, 1957) suggests that the Wulff River Formation is equivalent to the lower part of the Ella Ø Formation and part of the Bastion Formation.

On lithological grounds the unfossiliferous Beds 55 to 57, consisting of dolomites, sandstones, arenaceous shales and shales, cannot be closely correlated with beds in N. E. Inglefield Land or Ellesmere Island. From their position in the succession, and the high percentage of carbonate rocks, they may represent a lateral variation of the fossiliferous Cape Kent Limestone, which is Lower Cambrian in age. Kurtz, McNair and Wales suggested (1952) that the Cape Kent Limestone ranges in age from Lower to Middle Cambrian and is equivalent to part of the Rabbit Point Sandstone and part of the Bear Point Limestone developed in Devon Island, one of the southernmost of the Queen Elizabeth Islands[1]). The fauna of the Rabbit Point Sandstone includes *Olenellus* and this Lower Cambrian formation is overlain by the Bear Point Limestone which contains *Dolichometopsis* associated with faunas of the *Albertella* zone and is Middle Cambrian in age. The Cape Kent Limestone yields *Dolichometopsis* but *Olenellus* is also present with *Kochiella*, *Inglefieldia* and *Poulsenia*. Occurrences of *Dolichometopsis* in the Middle Cambrian are widespread but Lower Cambrian associations of this genus are also on record:– 1) Kobayashi (1936) described an "Upper Lower Cambrian" fauna from the Mackenzie District of Canada with *Dolichometopsis humei* Kobayashi, *Redlichia* ?sp. and *Chancia canadensis* Kobayashi. In 1937 Resser assigned the latter species to *Pytchoparella* and the age of the horizon to Middle Cambrian, 2) Rasetti (1948) found cranidia and an entire shield which agree well with *Dolichometopsis* in boulders from conglomerates in the Province of Quebec. Undoubted Lower Cambrian types—*Protypus* and Olenellidae—were found in the same boulder as specimens of *Dolichometopsis*. Poulsen has confirmed the association in the Cape Kent Limestone of *Kochiella* and *Inglefieldia* with olenellids

[1]) The Queen Elizabeth Islands comprise that part of the Canadian Arctic Archipelago which lies north of the Lancaster Sound – M'Clure Strait channel (approx. 74° N.).

(Rasetti, 1951; 85–86) and has restated the association of *Dolichometopsis* with olenellids (*in* Troelsen, 1956a, 79). The author examined the Cape Kent Limestone collections in Copenhagen: olenellids as well as *Dolichometopsis*, *Kochiella*, *Inglefieldia* and *Poulsenia* are all found in the same lithology of buff, fine-grained, oolitic limestone. The evidence to show that more than one fossil horizon is represented is lacking and the formation should therefore remain entirely in the Lower Cambrian. It is hoped that more detailed investigations, with fossils collected from measured sections, can be made in N. E. Inglefield Land.

The alokistocarid trilobites, *Kochiella* and *Inglefieldia*, were listed as characteristic genera of a "*Syspacephalus* Zone" of the highest, post-olenellid, Lower Cambrian by Howell *et al.* (1944). Rasetti (1951, 85–86) concluded that the *Syspacephalus* zone was not post-olenellid and Lochman (1953, 487–488) discarded the zone. In place of the previous zonal subdivisions Lochman has proposed that the Lower Cambrian be split into a Lower *Olenellus* sub-zone and an Upper *Olenellus* sub-zone. In the lower sub-zone olenellids are the only trilobites present but in the upper they are associated with primitive opisthoparian genera (1958, 318). *Poulsenia* and *Proliostracus* are both members of the subfamily Antagminae Hupé, 1953: the former genus is associated with *Kochiella* and *Inglefieldia* in Inglefield Land and both *Poulsenia* and *Proliostracus* are found with olenellids in Central East Greenland. The specimens of *Proliostracus* collected *in situ* from measured sections (Cowie & Adams, 1957) occur only in the Upper Limestones of the Ella Ø Formation in both Ella Ø and Hudson Land. It is concluded that the upper part of the Ella Ø Formation is equivalent in age to the Cape Kent Limestone and that both represent the younger part of the Upper *Olenellus* sub-zone of the Lower Cambrian.

Beds 58 and 59 consist of alternating limestones and dolomites, contain an abundance of intraformational conglomerates and breccias, and are often argillaceous and occasionally glauconitic. The Cape Russell Member of the Cape Wood Formation contains Middle Cambrian fossils in N. E. Inglefield Land and Bache Peninsula and has a lithological character varying from bed to bed and also laterally. In the north-east it includes glauconitic sandstone, arenaceous limestone, limestone and dolomite and is conglomeratic (Koch, 1933, 29: Troelsen, 1950, 42–46) while at the police post on Bache Peninsula it consists of alternating beds of limestone and dolomite. Schei (1903b.) describes outcrops at Cape Camperdown of a series of arenaceous and marly shales and limestone conglomerates interbedded with limestone. A scree boulder thought to come from this series yielded Middle Cambrian fossils—*Blaini-*

opsis spp.–and Bentham described beds of impure, flaggy limestone and limestone conglomerate from the coastal cliffs between Cape Albert and Cape Camperdown (Poulsen, 1946, 302, 330). The beds at these two localities may be tentatively correlated with the Cape Russell Member and bear stronger lithological resemblance to Beds 58 and 59 at Kap Ingersoll than do the beds of the member seen at the R.C.M.P. post approximately 25 kilometres further west.

The dolomite of Bed 60 at Kap Ingersoll may correspond to the carbonate-rich beds of the Blomsterbaek Limestone, the upper division of the Cape Wood Formation. Bed 61 is unfossiliferous but correlates closely on lithological grounds with the Cass Fjord Formation of North-West and Central East Greenland which is Lower Ordovician (Canadian) in age. This formation of thinly-stratified, nodular, muddy limestones and shales with many intraformational conglomerates has been described in detail from Central East Greenland (Cowie & Adams, 1957). The peculiar character of the Greenland rocks and those of similar type and age found in North America could be due to deposition in shallow-water with rapid variation in currents and depth of water coupled with changing proportions between fractions of chemical and clastic origin. R. G. McCrossan in 1958 described sedimentary "boudinage" structures in the Devonian of Alberta, Canada. These structures occur in calcareous shale with variable amounts of interbedded nodular limestones. The limestones vary from thin relatively undeformed beds to those which show pinching and swelling and those with completely isolated lenses or nodules that are variously orientated. These features, which are strikingly similiar to those found in the Cass Fjord Formation in Greenland, are thought by McCrossan to be formed during compaction when the less plastic beds were pulled apart by the plastic beds which moved laterally.

To summarise, the following correlations are suggested:–

Age		Beds
Lower Ordovican	Cass Fjord Formation	61
Middle Cambrian	Blomsterbaek Limestone (Cape Wood Formation)	60
	Cape Russell Member (Cape Wood Formation)	58 & 59
Lower Cambrian	Cape Kent Limestone	55–57
	Wulff River Formation	50–54

Comparison of the sedimentary rocks of Inglefield Land and Bache Peninsula (as described in the literature) with the foregoing new observations from Kap Ingersoll suggests a greater degree of lateral variation in lithological character than has previously been interpreted. The Cambro-Ordovician succession at Kap Ingersoll is also considerably thinner than that of Bache Peninsula which is in its turn thinner than the developments in N. E. Inglefield Land. This reduced thickness in the most southerly outcrops of Lower Palaeozoic rocks in N. W. Greenland suggests that the Cambrian Basin had its south-eastern boundary not far from S. W. Inglefield Land: the absence or paucity of fossil faunas at Kap Ingersoll may be due to these environmental conditions.

III. THE BASE OF THE CAMBRIAN IN GREENLAND AND THE QUEEN ELIZABETH ISLANDS, CANADA

The upper limit suggested by Poulsen and Troelsen for the Eo-Cambrian (p. 18) is practically the same level taken by many stratigraphers for the base of the Cambrian: two recent examples are Stubblefield (1956, 30) and Okulitch (1956, 728–729). It cannot be expected, however, as Stubblefield and Neuman and Palmer (1956, 428–429) point out, that the horizon selected as the base of the Cambrian in various regions will be truly contemporaneous, even though the horizon is linked to fossil evidence. This uncertainty is the greater because of the dubiety and lack of precision attaching to any system of fossil zones which has so far been suggested for the Lower Cambrian. Further contributions by Poulsen and Stubblefield in 1958 revealed no fundamental change of attitude to the problem of the stratigraphical criteria to be used in defining the base of the Cambrian System.

If the base of the Cambrian System is placed at the first unconformity (using the term without implications of angular discordance of bedding) below the earliest occurrence in the succession of Lower Cambrian *Olenellus*-zone faunas, then in Inglefield Land it is found at the bottom of the Wulff River Formation. In Ellesmere Island three occurrences of Cambrian faunas have been reported to date:– 1) on Bache Peninsula the base of the System lies at the bottom of the Police Post Limestone, 2) at Copes Bay the boundary is not fully established but it is probably represented by an unconformity with Middle Cambrian resting on Pre-Cambrian, 3) in the area along the south coast between Craig Harbour and Hell's Gate a Middle Cambrian trilobite was collected by Schei but the stratigraphy remains uncertain (Holtedahl, 1913b). Further south, across Jones Sound, a succession, already mentioned (p. 26), has been described from Dundas Harbour on Devon Island (Kurtz, McNair & Wales, 1952). Here the Rabbit Point Sandstone, which yields *Olenellus* at about 7 metres above its base, rests unconformably on a peneplained surface of Pre-Cambrian igneous and metamorphic rocks. In southern Washington Land (*ca.* 80° N. on the coast of N. W. Greenland) Koch found limestones which he assigned, on lithological grounds, to the

Cambrian (1929, 8–9, Pl. III). Apart from this observation no other outcrops of this age have been reported going north-eastwards along the strip of ice-free land in North Greenland until Peary Land is reached: the Brønlund Fjord Dolomite in the south and the Schley Fjord Shale in the northeast have been found to contain olenellids (Troelsen, 1956a, 87–88), in the former case in the basal stratum. The contact of the dolomite with underlying sandstone is a simple erosional disconformity; the Schley Fjord Shale apparently overlies black shales which are in turn underlain by sandstone but the junction was not seen. The beds underlying these formations with *Olenellus*-zone fossils are referred by Troelsen, with question, to the Thule Group.

In the region around Danmark Fjord the earliest fossils known, of Lower Ordovician age (Cowie & Adams, 1953), were found at the base of the Centrum Limestone. The underlying Danmark Fjord Dolomite (Fränkl, 1955, 13) was searched for fossils without success in 1952 and 1953, it is conformable with the limestone above, is of variable lithology and thickness, and is considered to be unconformable on the underlying formation although there is no observable change of dip. The Kap Holbæk Sandstone (fig. 6) below the unconformity is a series of quartzites, sandstones and arenaceous shales; an interesting feature in the Lower Quartzite subdivision is the existence of tubes at right-angles to the bedding, similiar in some respects to "scolithid" tubes. In the southern part of the Danmark Fjord region the author did not observe a stratigraphical break at the base of the Kap Holbæk Sandstone but the succession was usually obscured at this level. Fränkl reported (1955, 18–20) that the Kap Holbæk Sandstone outcrops near the lower reaches of Sæfaxi Elv, about 50 kilometres east of Centrumsø and 70 kilometres south-east of the type-localities in Danmark Fjord. The geology in this eastern crop is complex with nappe structures but the outcrops in question are thought to belong to the autochthonous substratum. In this area also, the unconformity between the Danmark Fjord Dolomite and the Kap Holbæk Sandstone is very marked with an irregular erosion surface at the top of the sandstone series. More remarkable, however, is the unconformity at the base of the Kap Holbæk Sandstone. There is an irregular erosion surface at the top of the underlying Fyn Sø Dolomite, and the Cone-in-Cone horizon (20 m) and the Shale (4 m), which were observed in the Danmark Fjord region, are absent. An angular discordance between the beds of the Fyn Sø Dolomite and those of the Kap Holbæk Sandstone may also be inferred from Fränkl's observations and this gives added weight to the importance of the unconformity at this level. Haller, from his observations on the shores of Independence Fjord in 1958 (personal communication), concluded that there is an unconformity in that region at the base of beds which correlate with the Kap Holbæk Sandstone. These sandstone beds rest on an eroded surface of the Fyn Sø Dolomite. In addition Haller observed block-faulting in Glückstadt Land (between Danmark Fjord and Hagen Fjord) which has displaced the Fyn Sø Dolomite and older beds but has not moved the overlying sandstones which are correlated with the Kap Holbæk Sandstone.

The lower beds of the Centrum Limestone appear to be equivalent in faunas and lithology to the Wandel Valley Limestone of Peary Land, both being Canadian in age. The Danmark Fjord Dolomite can be correlated with the Brønlund Fjord Dolomite on the grounds of stratigraphical position and lithological type (fig. 6): as the latter dolomite has a Lower Cambrian fauna and both formations have an unconformity at the base and rest on sandstones it is considered that the Danmark Fjord Dolomite is also Lower Cambrian in age. The Pre-Cambrian/Cambrian junction is thought to lie further down in the succession, however, although there is no faunal evidence (the poorly-developed "scolithid" tubes which occur in one subdivision of the Kap Holbæk Sandstone have frequently been found in sandstones and quartzites which have been referred to the Lower Cambrian but cannot be regarded as index fossils on present evidence). The grounds for including the Kap Holbæk Sandstone in the Lower Cambrian are:– a) on diastrophic grounds the base of the Cambrian System may appropriately be inferred to be at the base of this predominantly arenaceous series, b) the unconformity at the base of the sandstones is clearly of considerable importance, with evidence of angular discordance, as is shown by outcrops bordering Independence Fjord, in Glückstadt Land and in eastern Kronprins Christian Land. The base of the Cambrian in Peary Land and North-East Greenland is therefore placed at the base of the Kap Holbæk Sandstone and sandstones which can be correlated with it. These sandstones and shales may then be considered equivalent to the sandstones and shales found at the corresponding stratigraphical level in the Thule District of N. W. Greenland (Cowie & Adams, 1953, pl. II) which have not previously been thought to belong to the Lower Cambrian: such a correlation must, however, be no more than speculation.

The Fyn Sø Dolomite, which is found below the Kap Holbæk Sandstone, is largely built up of concentric stromatolitic structures of the "Collenia" type; it was suggested in 1953 (*op. cit.*, 16 & Pl. II) that this formation has its counterpart in Peary Land and is also equivalent to the Cape Leiper & Cape Ingersoll Dolomites in N. W. Greenland. The upper beds were referred to as the Cone-in-Cone horizon. Rezak (1957) has found eight zones established on the basis of stromatolites to be useful for local correlation in the Late Pre-Cambrian Belt Series of Montana. *Conophyton*, as index type for two of these zones, is described as "colonies of nested conical laminae with basal apex attached to the substratum": the apex is directed downwards in the Montana specimens and in similiar ones from S. Africa and the

U.S.S.R., but in other descriptions from the U.S.S.R. the apices are directed upwards; nevertheless, Rezak refers all these occurrences to *Conophyton* regardless of the attitude of the cones. There is a striking resemblance between the cones found near the shores of Danmark Fjord and those from Montana which are ascribed to *Conophyton*. In view of 1) the lithology of the Cone-in Cone horizon is massive dolomite, 2) previous descriptions of cone-in-cone structure developed in single layers indicate the apices to be directed downwards, 3) the undisturbed state of the Danmark Fjord region, and 4) the persistence of the cones through a thickness of 20 metres, it may be that the cones were depositional in origin (either through the agency of organisms, or not) and were not due to tectonic or gravitational forces. No long-range correlation on the basis of stromatolites will be made.

Lauge Koch in 1933 visited the Norske Öer (18° W., 79°05′N.), a group of small islands lying 90 kilometres to the south-east of Kronprins Christian Land, finding gneiss *in situ* but also loose blocks with fossil fragments which were taken to be of Lower Cambrian age (Koch, 1935, 617). Dr. Koch has kindly sent the author specimens from these fossiliferous blocks. The rock is a dark-grey to black limestone with minor dolomitic patches; the fossils consist of small cephalic fragments and a pleural fragment from trilobites which are indeterminable. The nearest known fossiliferous limestone of this lithological type is the Centrum Limestone; from the general character of the fossil fragments it is suggested that they are not Lower Cambrian but may be Ordovician or Silurian. The specimens probably come from erratic blocks of Centrum Limestone carried south and east from the mainland outcrops on Kronprins Christian Land.

Southwards along the ice-free coastal areas of East Greenland the first known Cambrian outcrops are in Hudson Land (74° N.) and scattered exposures occur in the fjord region from there to Scoresby Land (72° N.). The Cambro-Ordovician outcrops display a remarkably consistent succession along this tract and there is only limited lateral variation, evidently the deposits all belonged to the same north-south zone of the geosyncline and there was no variation in facies. This close lithological correlation over considerable distances, supported by fossils, of the formations which have been assigned to the Cambro-Ordovician (Cowie & Adams, 1957), serves to emphasise the significance of the variable relationships discovered below what is considered to be the oldest Lower Cambrian formation—the Kløftelv Formation. Throughout the region the earliest known fossils of the *Olenellus*-zone occur in the Bastion Formation, at a level approximately a third of its thickness above its base. This lowest fossil horizon, at the base of the upper Bastion Formation, is found in a shell-limestone which is glauconitic and in places conglomeratic, suggesting a non-sequence. There is also a glauconitic, siliceous conglomerate at the base of the whole formation and in this is found bodies of phosphatic material. The presence of conglomerates,

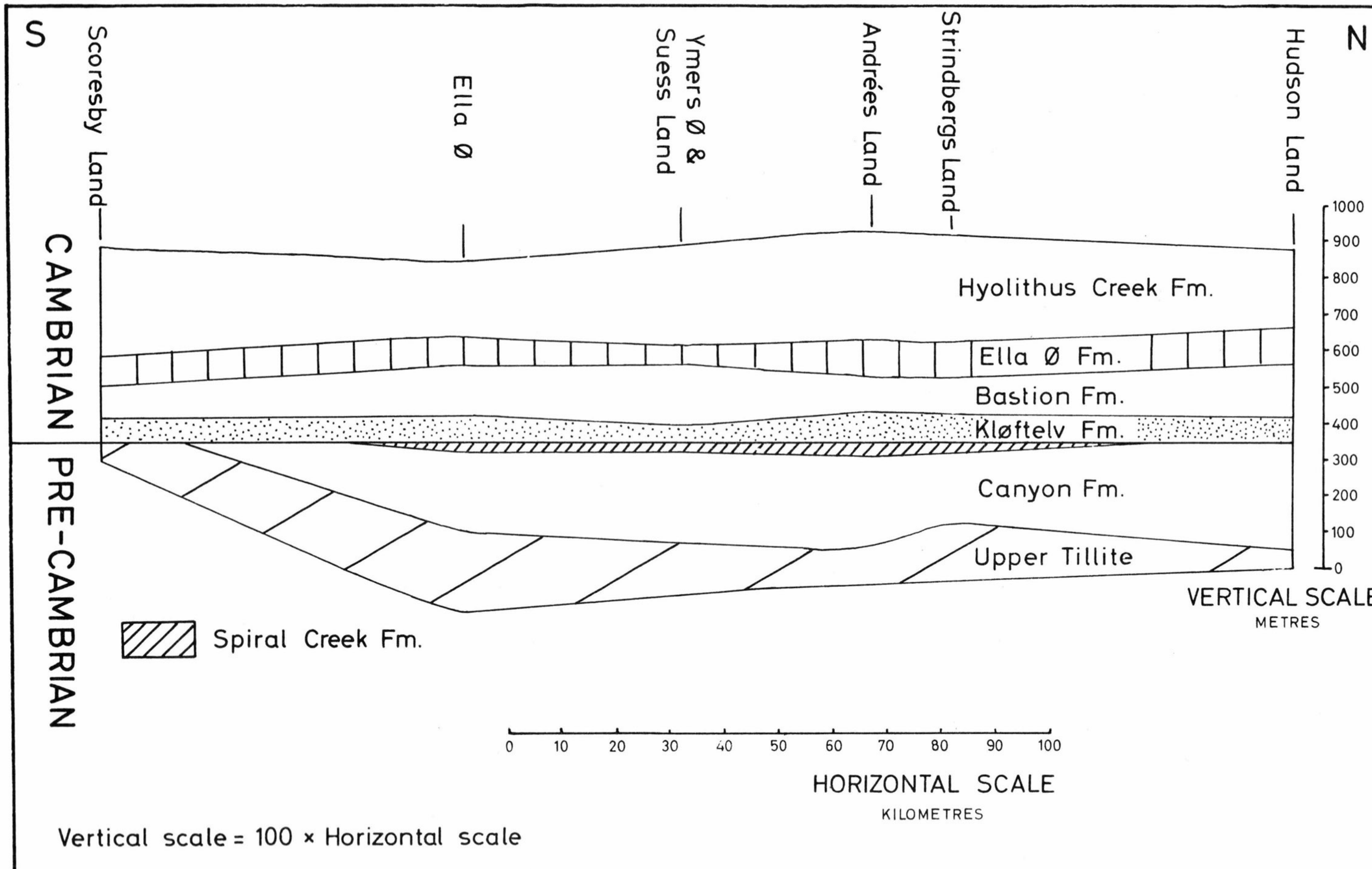

Fig. 5. The Pre-Cambrian/Cambrian unconformity in central East Greenland.

glauconite and phosphatic nodules is considered to be good evidence of another non-sequence. If the phosphatic material is organic in origin and *remanié* in nature, its presence as a part of the conglomerate suggests that animals with sufficiently well organised parts to leave phosphatic remains, may have existed during the period of non-sequence and also during the period of deposition of the underlying formation. The Kløftelv Formation may thus belong to the *Olenellus*-zone, it is mainly massive quartzite, has five subdivisions which can be made out clearly throughout all the outcrops examined by the author in East Greenland, and there is little variation in thickness. On Ella Ø (73° N.) there is probably a disconformity at the base of the quartzites with, in places, an irregular, eroded, upper surface to the underlying Spiral Creek Formation. The sequence from younger to older, with no observable angular discordance of bedding, is Bastion Fm., Kløftelv Fm., Spiral Creek Fm., Canyon Fm., Upper Tillite; this constitutes the main crop north to Strindbergs Land. To the north of this in Hudson Land the Spiral Creek Fm. is missing and the Kløftelv Fm. rests on the Canyon Fm. To the south of Ella Ø in Scoresby Land the Spiral Creek Fm. and the Canyon Fm. are absent and the Kløftelv Fm. rests on the Upper Tillite. Discounting the possibility of extensive lateral variation or diachronism (Cowie & Adams, 1957, 148–150), there is thus a major unconformity at the base of the Kløftelv Formation with a prolonged break in sedimentation in the north and south but less interruption in the central area (fig. 5). The distances involved in conjunction with the thicknesses suggest that the angular discordance in the transgression would be so slight (a fraction of a degree) that it could not in any case be observed in any known exposure.

For these reasons the Kløftelv Formation is included in the Lower Cambrian and the major unconformity at its base is considered to be the most suitable level to select as the base of the Cambrian System and the top of the Pre-Cambrian.

In this short survey of the relationships pertinent to the selection of suitable horizons for the base of the Cambrian in various regions it has been evident that in Greenland and the Queen Elizabeth Islands of Canada there is rarely an angular discordance in the sedimentary sequences which have been referred to the earliest Cambrian or the latest Pre-Cambrian. By utilising all available criteria, however, it is possible to hold the conclusions outlined (fig. 6) until new evidence demands a revision.

<table>
<tr><th colspan="2" rowspan="3"></th><th colspan="3">CANADA</th><th colspan="5">GREENLAND</th></tr>
<tr><th rowspan="2">Devon Island</th><th rowspan="2">Bache Peninsula</th><th rowspan="2">Copes Bay</th><th rowspan="2">Inglefield Land</th><th colspan="2">Peary Land</th><th rowspan="2">Danmark Fjord</th><th rowspan="2">East Greenland</th></tr>
<tr><th>South</th><th>North-East</th></tr>
<tr><td colspan="2">OVERLYING FORMATION</td><td>Bear Point Limestone Mid. Camb.</td><td>Cape Wood Formation Mid. Camb.</td><td>Limestone Mid. Camb.</td><td>Cape Wood Formation Mid. Camb.</td><td>Wandel Valley Lst. L.Ordovic.</td><td>Wandel Valley Lst. L.Ordovic.</td><td>Centrum Limestone L.Ordovic.</td><td>Hyolithus Creek Fm. L-? M.Camb.</td></tr>
<tr><td rowspan="2">LOWER CAMBRIAN Olenellus-zone</td><td>Upper <u>Olenellus</u> sub-zone</td><td rowspan="2">Rabbit Point Sandstone</td><td>Cape Kent Limestone</td><td rowspan="2"></td><td>Cape Kent Limestone</td><td>Brønlund Fjord Dolomite</td><td>Schley Fjord Shale</td><td>Danmark Fjord Dolomite</td><td>Ella Ø Formation
Bastion Formation</td></tr>
<tr><td>Lower <u>Olenellus</u> sub-zone</td><td>Police Post Limestone</td><td>Wulff River Formation</td><td colspan="2">Sandstone & shale</td><td>Kap Holbæk Sandstone</td><td>Kløftelv Formation</td></tr>
<tr><td colspan="2" rowspan="2">LATE PRE-CAMBRIAN SEDIMENTS</td><td rowspan="2"></td><td colspan="3">Cape Leiper & Cape Ingersoll Dolomites</td><td colspan="2">Dolomite</td><td>Fyn Sø Dolomite ⇕ Campanula-dal Sdst</td><td rowspan="2">Spiral Creek, Canyon, Tillite & Eleonore Bay Formations</td></tr>
<tr><td colspan="3">Rensselaer Bay Sandstone</td><td colspan="2">Sandstone</td><td>Norseman-dal Sandstone</td></tr>
</table>

Fig. 6. Table to illustrate the Pre-Cambrian/Cambrian boundary in Greenland and the Queen Elizabeth Islands, Canada; periods of non-deposition or erosion which are unrepresented by strata are not shown, except at Devon Island and Copes Bay; the late Pre-Cambrian sediments in East Greenland may not be the same age as those in North Greenland and Canada.

IV. STRUCTURAL AND PHYSICAL FEATURES

The late Pre-Cambrian and Lower Palaezoic[1]) sediments of S. W. Inglefield Land are typical cover rocks which are unfolded and little faulted; they rest upon the Greenland Shield which is part of the North American Shield. Northwards and westwards of Inglefield Land and Bache Peninsula the sediments of this age apparently alter in facies and participate in the tectonics of the Ellesmere-Greenland Fold Belt which is part of the Innuitian Orogenic System of North Greenland and the Canadian Arctic Archipelago.

The basement complex, including the Etah Formation, provides evidence of a number of sedimentary, tectonic, metamorphic and igneous episodes before the late Pre-Cambrian sediments were laid down. The foliated and intrusive rocks are truncated by a peneplain surface which is remarkably level and undisturbed in the exposures around Rensselaer Bugt and Force Bugt but has been faulted in the area around Etah (fig. 1). In the coastal areas and the valleys between Kap Hatherton and Rensselaer Bugt the peneplained surface of unconformity can be clearly seen to be tilted, rising inland so that the areas away from the coast are made up of basement rocks even though the land there is in many cases at greater altitudes than the coastal cliffs which are formed in younger sediments. The dip of the peneplain is slight with a gradient of 100 metres in $2^1/_2$ kilometres, approximately 2°, and was not measured instrumentally but was obtained from observed altitudes of the surface at various points. The direction of dip is approximately 330° true.

The late Pre-Cambrian and Cambro-Ordovician sediments which unconformably overlie the basement have a slight dip, approximately towards 320° true at an angle of 2°, so that the bedding-surfaces of the sediments are almost exactly parallel to the peneplain. The peneplain surface and overlying sediments may have been tilted together after Cass Fjord Formation times (Lower Ordovician) but the 2° angle of the sediments could almost equally well have been a depositional dip on an already sloping sea-floor.

[1]) Comments in this section have been made fuller and more general because of the relatively unexplored character of the terrain and in the hope that they will prove useful to future field-workers.

There are only a few small faults affecting the Pre-Cambrian and Cambro-Ordovician rocks and the igneous sills. The highest point at Kap Ingersoll is flanked by faults; the south-westerly upthrows to the north-east 60 metres, the fault to the north-east is upthrown on the south-west side. Kap Ingersoll may thus owe its superior height partly to the action of these two faults in elevating the resistant dolerite and the Thule Group dolomites.

North and south of Etah the tilt of the peneplain is not so simply defined but, in general, the dip of this surface is towards the sector between north-west and west at an angle of only a few degrees. The area is considerably faulted and many faults trend WNW-ESE but a few parallel the strike of the foliation in the basement rocks. The Thule Group has only one small outcrop, at high altitude, between a major fault which is inferred for more than 15 kilometres in a NE-SW direction to the north of Etah and the line of the long fjord, Foulke Fjord (Etah lies on its shore). This sector is upthrown by about 200 metres. At least a part of the movements of these faults is probably post-Thule Group.

The nature of the land surfaces and coasts of S. W. Inglefield Land is closely related to the solid geology: the basement rocks produce a rugged, irregular topography and an indented coastline while the younger sediments produce featureless upland plateaus and smooth coastlines with steep cliffs. The contrast is exemplified in figures 7 and 8. In the areas visited by the author (p. 1) the largest expanse of terrain where basement rocks outcrop is around Etah and northwards along the coast to Kap Inglefield. Foulke Fjord has steep cliff walls which continue inland in cliffs overlooking Brother John Gletscher: these features were evidently glacially eroded in part. The area to the north of Foulke Fjord lies mainly above 300 metres and is comparatively flat but with a gently undulating surface and occasional lakes; the surface is made up of frost-shattered blocks of basement rocks riven from the underlying bed-rock. They are between 50 cms and 5 metres in size, with deep gaps between which contain practically no smaller fraction. They are usually covered with lichen and moss. This area of shattered rock waste is tedious to travel across. The impression is gained that the erosion of the uplands is extremely slow and indeed the cliffs and screes of inner Foulke Fjord and the valley below Brother John Gletscher are so thoroughly covered with bright orange lichen that comparatively little transport of weathered material can be going on to-day.

North-west and north of Etah the uplands are of rolling relief with valleys following fault-lines: in two cases steep-sided gorges have been cut in the basement rocks. Outliers of Rensselaer Bay Sandstone form the highest points in this area, often associated with remnants of

Fig. 7. The Etah area with Littleton Ø in the foreground. See figure 1.

igneous sills which resist erosion. The coastal area between Littleton Ø and Kap Hatherton is low-lying and dissected, with an irregular rocky coastline rising slowly to magnificent series of raised terraces.

South-west and north-east of the valley leading to Force Bugt are upland areas, only slightly dissected by small streams, formed in the Rensselaer Bay Sandstone with its associated dolerite intrusions. These plateaus, where outcrops are seldom found (fig. 8) are arid with very little vegetation, and little morainic material is associated with the uniform covering of boulders, cobbles and gravel which is often angular and appears to have been little transported. These well-drained uplands have very little relief and often provide a surface of small stones and gravel which makes walking relatively easy. This is in marked contrast to the surfaces produced from basement rocks. Where the sandstone is capped by dolomite, and also in the area south-east of Kap Ingersoll where Cambro-Ordovician rocks occur, the topography is of a very similiar character. The sediment plateaus apparently merge to the south-east with areas of basement outcrop which rise slowly towards the inland ice—these areas farthest from the coast were not visited but appear from aerial photographs to be of low relief although rising gently to an altitude of over 600 metres in places. It is likely that here the surface is similiar to that described from the plateau north of Foulke Fjord. In the coastal area between Littleton Ø and Kap Inglefield the sandstone plateau ends in cliffs standing above the coastal basement area. The dolerite sills which are prominent features of the cliffs no doubt largely account for their steepness and resistance to erosion. Between Kap Inglefield and Cairn Pynt an outlier of sandstone is preserved and in this sector the coast rises steeply in low cliffs. The plateaus are terminated in the north coast by steep cliffs with extensive screes; small outwash fans are produced by the streams draining the uplands. On account of the feeble insolation on the north-facing steep coast it is often fringed by ice-foot during the summer months, even when there are extensive areas of open water in Smith Sund and the Kane Basin. This provides a route for travel. The smooth scree-aproned coastline north-east of Kap Inglefield contrasts with the rugged small bays and headlands running south from that point, reflecting the nature of the bed-rock. This is shown in the inner parts of Force Bugt and Rensselaer Bugt where the outcropping basement is associated with a coastline which is also irregular and rocky. At the present time, however, the erosion by the ice-free seas in the milder weeks of the year must be more pronounced on the west coast. Even in the height of the summer the northern shore is protected by extensive fields of pack-ice (compare figs. 7 & 8) which reduce the fetch of the waves and calm the seas. In colder seasons this effect will be further augmented by the ice-foot (fig. 8).

Fig. 8. Kap Ingersoll in the foreground; Force Bugt in the middle distance. See figure 1.

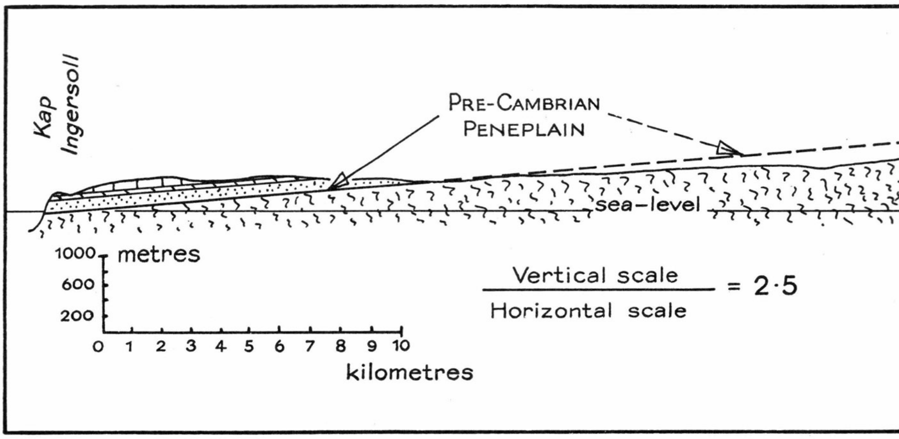

Fig. 9. Longitudinal dip-section inland from Kap Ingersoll.

In the valleys of the rivers draining into Force Bugt and Rensselaer Bugt the basement igneous and metamorphic rocks produce rugged topography which is ill-drained and comparatively rich in vegetation and wild life. The main rivers drain melt-water from the ice-cap and their tributaries obtain snow-melt from a large area so that at times of rapid thaw they attain a considerable volume.

Lauge Koch in 1933 (14, 34), and in earlier papers, described and illustrated the peneplain at the junction of the older metamorphic series and the Thule Group. He states (34) "... the plains of Inglefield Land, which descend slightly towards the north and northwest, represent the original surface of the old Algonkian peneplain, which has remained almost undisturbed up to the present day." Koch's observations refer to the whole of Inglefield Land but perhaps in this remark he is drawing mainly from his experience of the north-eastern part: his illustrations (figs. 1, 4 & 6) are all from that area. He has been followed in this opinion by Bentham (1936, 428) and Malaurie (1955, 212–214) who worked mainly in the south-west. Both these authors, however, postulate that the exhumed Pre-Cambrian peneplain has been modified by later erosion. Troelsen (1950, 13) cautiously remarked that "careful mapping may show whether more than one erosion surface exist in the area, or whether the variations in altitude are due to the destruction of the plateau remnants in connection with lithologic control." In S. W. Inglefield Land —and the following comments apply only to that area—the peneplain rises to the south-east at an angle of approximately 2° where it can be clearly seen below the Thule Group in the valleys leading to Force Bugt and Rensselaer Bugt. The land surface also has a general rise towards the ice-cap in the same direction but at a smaller gradient. A longitudinal section across the south-western part of Inglefield Land (fig. 9) indicates that the peneplained surface of unconformity rises inland above the surface of the ground. Probably limited areas of the Pre-Cambrian erosion surface form the present ground surface but over the greater part of the inland plateaus of basement rocks, and also in the coastal areas, this seems unlikely. It would be reasonable to expect, if the present topography of the interior is an exhumed Pre-Cambrian peneplain which extends inland with uniform tilt, that isolated outliers of Thule Group would be found forming the low, rounded hills rising above the general relief in the interior: such outcrops have yet to be described.

V. HISTORICAL GEOLOGY OF INGLEFIELD LAND AND BACHE PENINSULA

The igneous and metamorphic rocks of the basement complex represent periods of sedimentation, igneous intrusion and tectonic deformation which were presumably of great length and complexity. The foliated rocks and intrusions are truncated by an erosion surface which probably indicates that in Pre-Cambrian times the sea transgressed across the area: it is considered that the remarkably flat peneplain was produced by submarine erosion and is not subaerial in origin. The beds of the Thule Group were then laid down on the basement rocks with strong angular discordance. The attitude of the erosion surface was unaltered between the time of planing-off and this period of deposition, and the dip of the overlying sedimentary rocks is parallel to the surface of unconformity.

The basal beds of the Rensselaer Bay Sandstone were laid down in shallow water and a basal conglomerate was formed by the breaking up of the basement substratum (fig. 2). Possibly deserts surrounding the sea provided the well-rounded, red, felspathic, ferruginous sand and also conglomeratic deposits, much of which shows its derivation from local basement rocks. Cross-bedding indicates variation in the direction of depositing currents and it is possible that transport was partly by wind but the sandstone which has resulted occasionally contains mica. Intermittent drying-out near shore (resulting in mud-cracking), ripple-marking, and penecontemporaneous erosion (resulting in the deposition of conglomerates at various horizons), indicate instability of conditions and shallow-water conditions. The production of algal reefs may be shown by the presence of stromatolites.

The desert conditions were possibly ameliorated at the time of the deposition of the upper cream to buff sandstones and siltstones, and somewhat deeper water may be indicated by the finer grade though ripple-marking is still present and coarser deposits at some horizons suggest continued instability. The supply of psammitic material was much reduced and of finer grade at the commencement of Cape Leiper Dolomite times and chemical deposition assumed importance. Increased distance from land and slightly deeper water may be suggested by the finer-grained quartz and pelitic material contained in the dolomite in the later part of the division. The chemical conditions in the sea at that time were favourable to the formation of dolomite but changes occurred at the beginning of Kap Ingersoll Dolomite times. In this youngest part of the Thule Group period conditions favoured the deposition of magnesium, and calcium was introduced later. The Thule Group thus shows a gradual change in sedimentation from coarser to finer clastic types with the introduction and eventual predominance of chemical deposition, firstly magnesium-rich and finally predonderantly lime-rich. Slight erosion and intraformational brecciation of the youngest deposits then took place in some parts of the area probably associated with regression of the sea and there was a pause in deposition causing an unconformity in the most general sense of the word. Igneous activity occurred during this stratigraphical break resulting in the intrusion of basic sills and dykes.

The renewed submergence which commenced the Cambrian Period is shown by the association of glauconite and phosphate with the clastic deposits in the Wulff River Formation; the phospate may be organic in origin and undoubted Lower Cambrian fossils which indicate a marine environment are found for the first time at this level in the succession. Calcium carbonate was deposited during this time and the Police Post Limestone indicates that in the west it was a predominant constituent with clastic material of less importance. The prevalence of unstable conditions is shown by this lateral variation in deposits, in the laying down of conglomerates at several levels, and in the irregularity of bedding-surfaces. Throughout the region deposition of carbonate became dominant in Cape Kent Limestone times and greater stability is evident in the west and north-east, but rapid variations in the sedimentary enviroment were still prevailing in the south-west where intraformational conglomerates and glauconite occur with a proportion of pelitic material. The unstable conditions during the deposition of the Cape Wood Formation is universally evident with clastic and chemical deposition accompanied at frequent intervals by penecontemporaneous brecciation and the formation of conglomerates. Deepening as well as shallowing of the sea is suggested during this period by the presence of shales. During Cass Fjord Formation times these unsettled conditions were continued and in Inglefield Land and Bache Peninsula evidence from only the earliest part of the Ordovician is preserved.

North of Inglefield Land and Bache Peninsula younger deposits were laid down in the Ordovician and Silurian Periods: it is not known whether this occurred in the south. Elsewhere the Lower Palaeozoic sedimentation was interrupted or concluded by an orogeny with strong folding and faulting. This was not so in our area but the rocks may have been tilted downwards towards the north-west—the direction of the area of maximum deformation in the orogeny—at some date later than the early Ordovician. This tilt of the sediments and the Pre-Cambrian peneplain may have been caused by the Lower Palaeozoic orogeny or may have been later and was possibly accompanied by slight faulting. The subsequent geological history gives every indication of having been uneventful. After the tilting of the solid rocks a further peneplanation occurred; igneous intrusions may have occurred in Tertiary times as part of the activity in the Brito-Arctic Province; and the land was overridden by ice in Quaternary times. The recent re-exposure of this post-Ordovician erosion surface is leading to modification and dissection, although in many areas the impression is gained that transport of weathered material is extremely slow.

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