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HISTORICAL ASPECTS IN THE GEOLOGICAL INVESTIGATION OF NORTHERN GREENLAND

PART 1:

New maps and photographs from the 2nd Thule Expedition 1916–1918 and the Bicentenary Jubilee Expedition 1920–1923

BY

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WITH 13 FIGURES AND 4 PLATES

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Abstract

Certain geological maps and photographs, prepared for publication by the late Dr. LAUGE KOCH, are presented here together with an explanatory text. The material stems from the first expeditions that carried out systematic topographical and geological mapping in northern Greenland, viz. the *2nd Thule Expedition* 1916–18 and the *Bicentenary Jubilee Expedition* 1920–23. The latter expedition traversed the entire coast from Melville Bugt around the northern tip of Greenland and into eastern Peary Land. Regrettably the geological results of this expedition were never published in full.

Geological map coverage of northern Greenland was planned by KOCH as a series of coloured map sheets to be issued with descriptive texts in *Meddelelser om Grønland*. Only two, of a series of five, actually were published, in 1929 and 1933; the three outstanding maps, originally in proof print in 1931, are presented here. Several annotated photographs that were to have appeared as figures to illustrate the descriptive texts, are also reproduced.

The main significance of the maps and photographs is that they define for the first time the regional outcrop pattern of some of the rock units that became part of the established stratigraphical column of northern Greenland. Of particular importance is the illustration of the Silurian geology and a definition of which rock sequences were actually referred to a given formation. The maps and photographs are valuable reference material and they are essential for a full appraisal of the early ideas about the Silurian geology, as well as in any subdivision and eventual redefinition of the existing Silurian formations.

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INTRODUCTION

Northern Greenland is the northernmost land on Earth. As the search for natural resources continues with increased momentum moving northwards across the Arctic, the last poorly known areas in the far north are becoming the object of increased scrutiny. The past few years have seen a remarkable increase in the geological exploration of Greenland—an activity that has reached its northernmost coast. Intensified investigations are to be expected in northern Greenland in the next decade.

It thus seems an appropriate time to describe the history of geological exploration of northern Greenland. In this paper, part 1 of an intended series, some pertinent and hitherto unpublished information from the early geological investigation in northern Greenland has been gathered; information that we consider to be both of scientific and historical importance.

The material stems from the investigations carried out between 1916 to 1923 by the late LAUGE KOCH, whose contribution to the understanding of the geology of northern Greenland is well established. The circumstances that governed the first Danish activity in this part of Greenland at the beginning of the century, provide the historical context to the *2nd Thule Expedition* 1916–1918 and the *Bicentenary Jubilee Expedition* 1920–1923, on both of which KOCH undertook all the surveying work.

A summary of the history of geological investigations in northern Greenland will be attempted in forthcoming parts of this series in the form of chronological accounts of all those expeditions which gathered geological data.

The present authors' interest in the geology and history of northern Greenland has arisen in different ways. One of us (J. H.) worked closely with LAUGE KOCH for many years on his East Greenland expeditions and thus heard and learned at first hand a wealth of detailed information about the early days of exploration. The other (P. R. D.) has worked in various parts of northern Greenland since 1965 and thus has had some opportunity to revisit many localities quoted by the earlier explorers. In this way a multitude of written and oral reports have accumulated.

The idea leading to the writing of a paper of historical aspects arose some years after the death of LAUGE KOCH, when a coloured map of

the geology of the Kap York district needed the preparation of an explanatory text to accompany its publication. This map reproduced by the Geodetic Institute in 1960, and printed in 1000 copies, was stored in Copenhagen at the *Meddelelser om Grønland* offices. The map was intended to accompany a paper by KOCH to be issued by *Meddelelser om Grønland*, as volume 164, nr. 4.[1])

It was known to one of us (J. H.) that the Geological Map of the Kap York District was but one of a series that KOCH had intended to publish. Following field work in northern Greenland in 1965 and 1966, the geological importance of the other unpublished maps of the series became duly apparent and a brief comment to them was made by DAWES (1971). Their significance widened considerably the scope of the proposed historical paper, and led also to the assessment of several annotated photographs that held important geological information. These photographs had been prepared by KOCH as illustrations to planned publications, in which the maps were to figure as plates.

THE MAP AND PHOTOGRAPHIC MATERIAL

The documents presented here for the first time originate from observations made by LAUGE KOCH on two expeditions, viz. the *2nd Thule Expedition* 1916–1918 led by KNUD RASMUSSEN and more particularly the *Bicentenary Jubilee Expedition* 1920–1923 led by KOCH himself. The material is briefly classified below.

1) Printed colour maps of three regions of northern Greenland. These maps were all originally reproduced by the Geodetic Institute and each bears a *Meddelelser om Grønland* volume number and a plate number. The maps are published here as plates 1, 2 and 3, but with all reference to earlier volume and plate numbers erased. The three maps are:

   a) "The Cape York District" from Melville Bugt to southern Inglefield Land at the scale of about 1:1,000,000. Two editions of this map exist; the original is dated 1931 and bears "Medd. om Grønl. LXXIII A.", "Pl. 1" while a slightly modified edition dates from 1960 and is printed with "Medd. om Grønl. Bd. 164, Nr. 4", "Pl. 1". It is this later version that is published here.

   b) "North-Greenland" from Hall Basin to eastern Peary Land at the scale of about 1:2,000,000. The map is dated 1931 and is printed with "Medd. om Grønl. LXXIII A.", "Pl. V".

[1]) Article number 4 of this volume had since been filled by a bulletin of the Geological Survey of Greenland.

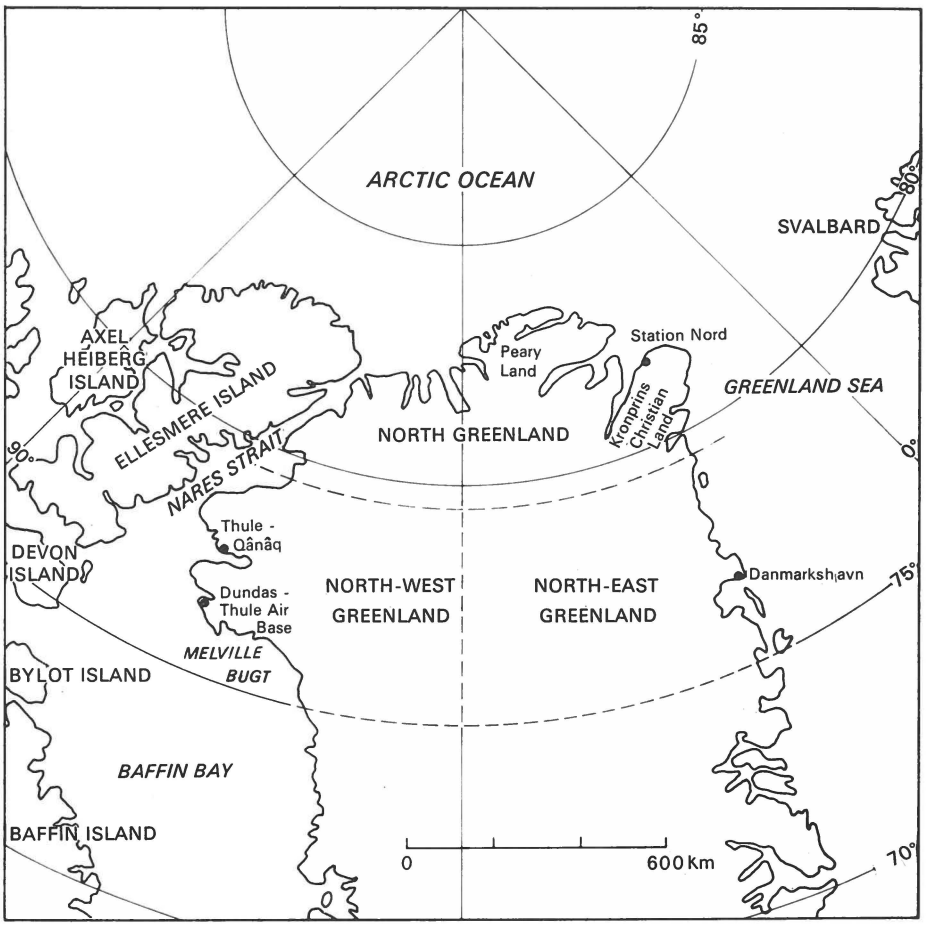

Fig. 1. Index map showing position of northern Greenland.

c) "Washington Land" from Morris Bugt to Petermann Gletscher at the scale of 1:500,000. The map is dated 1931 and printed with "Medd. om Grønl. LXXIII A.", "Pl. IV".

2) Selected photographs that had been prepared for publication and numbered as text-figures (see Figs. 4, 5, 6, 7, 8, 9, 10, 11 & 13 and plate 4). The photographs have been annotated and are block prints made by *Meddelelser om Grønland* in the early 1930's. These photographs, as part of a much larger series, were intended to illustrate papers in which the Washington Land and North Greenland maps were to figure as plates. Apart from the ten photographs included here, that are critical in any explanation of KOCH's interpretation of the Silurian geology, one other block print chosen by KOCH to describe the Silurian of Washington Land, is not printed here since it has already been published (KOCH, 1929b, fig. 56).

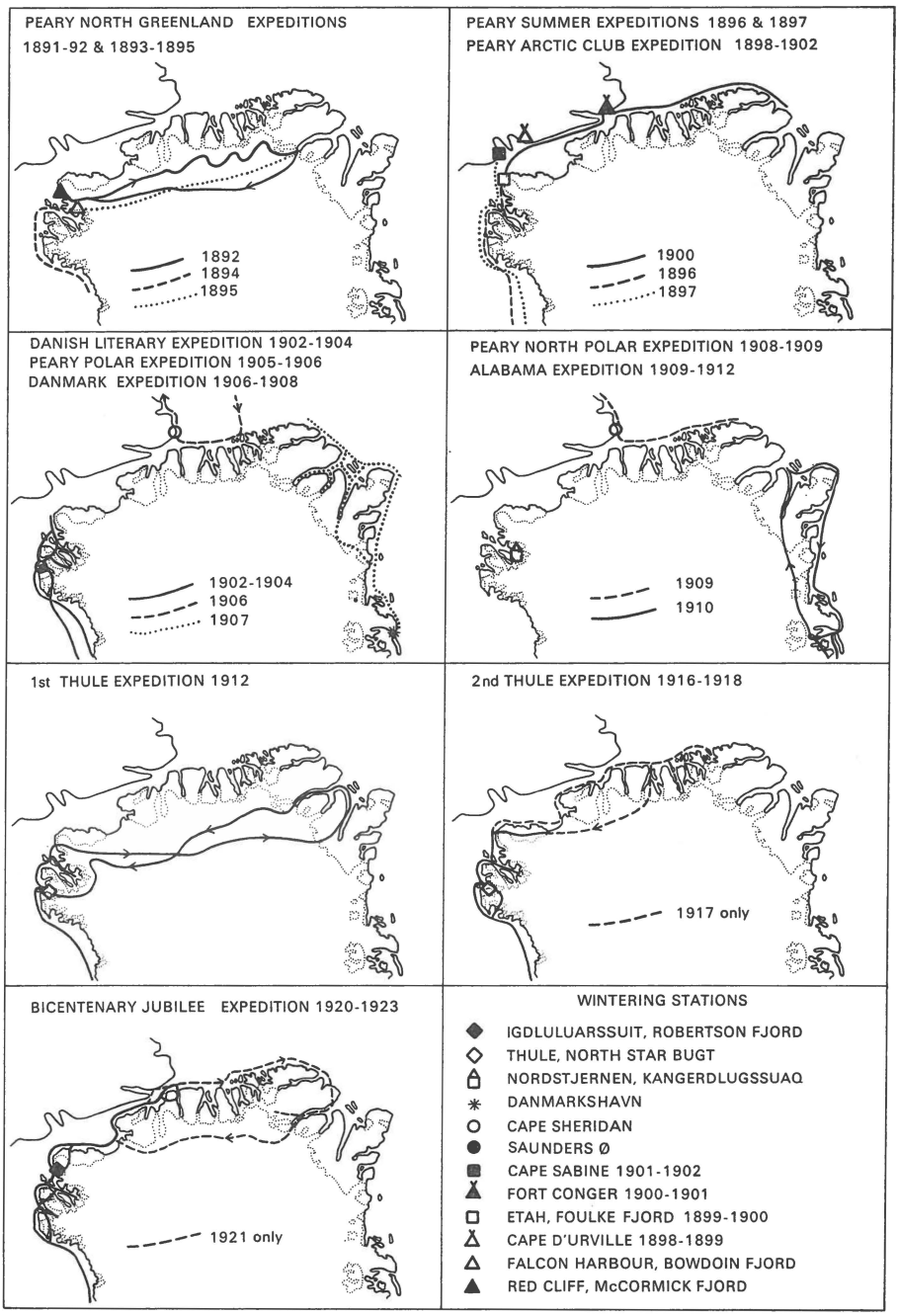

Fig. 2. Sketch maps showing the main travelling routes of ROBERT E. PEARY'S Arctic expeditions and the early DANISH expeditions to northern Greenland. The ship routes to and from the region are not shown, except in the cases of the Peary "Meteorite" Expeditions of 1896 and 1897 that were summer expeditions. The many journeys made by PEARY, the Danish Literary and the Bicentenary Jubilee expeditions in the Thule district cannot be shown in detail.

HISTORICAL BACKGROUND

The map and photographic material described has to be viewed in the historical context that governed the nature and aim of Danish expeditions to northern Greenland, particularly those on which LAUGE KOCH made his investigations, both as cartographer and geologist.

It is generally acknowledged that the Danish exploration in northern Greenland at the beginning of this century was awakened by the extensive surveys of the American explorer ROBERT E. PEARY in his efforts to geographical discovery. Danish activity, therefore, was motivated for both political and humanitarian reasons.

During PEARY's seven expeditions to northern Greenland and adjacent Arctic Canada between 1891 and 1909, during which time he spent four winters in Greenland (Fig. 2), close association was fostered with the small tribe of Polar Eskimos that inhabited the region between Melville Bugt and Inglefield Land. These Eskimos became, as sledge drivers and hunters an integral part of the expeditions and they are now legendary in PEARY's exploits.

For over a decade PEARY's expeditions were more or less the only contact the Polar Eskimos had with the rest of the west coast and with the outside world in general. It was not until the *Danish Literary Expedition* 1902–1904 led by LUDVIG MYLIUS-ERICHSEN, that the Melville Bugt sledge route to West Greenland was reopened. The modern arms, ammunition and utensils brought up to Greenland by PEARY were acquired by the Eskimos in repayment for services rendered. These articles gradually replaced bows and arrows and other primitive hunting and cooking implements. Naturally as time went by, the Eskimos became dependent on them, and on the trade offered by PEARY. Following the expedition of 1898 to 1902 when PEARY concluded his programme of geographical work in northern Greenland, his "continuous" association with the Polar Eskimos ceased. It was not until the North Pole expeditions of 1905–1906 and 1908–1909 that PEARY again visited Greenland but on these occasions only en route northwards to the Arctic Ocean and his unrelentless quest of the North Pole.

The abandonment of the Thule district as a base for operations led directly to the *Greenland Administration's Expedition* of 1905 and the journeys of KNUD RASMUSSEN in 1906–08 in order to assess, and to meet where possible, the needs of the Eskimos, now without regular replenishment of supplies. This led to the establishment of the Danish Mission and Trading Post "Nordstjernen" at Kangerdlugssuaq in Inglefield Bredning in 1909 and, following PEARY's total retirement from Arctic exploration, the trading post at North Star Bugt in 1910 by PETER FREUCHEN

and KNUD RASMUSSEN. This latter station duly became known as Thule. As well as being the capital and trading centre of the whole district, it served as a base for scientific research. Thule became the operational base for the celebrated early *Thule Expeditions*, and it was during the second of these that the first systematic geological work in northern Greenland was carried out.

The 19th and early 20th century expeditions to northern Greenland have been American and to a lesser extent British. Until 1907, when the *Danmark Expedition* of 1906–08 reached eastern Peary Land, the Thule district was the northern limit of Danish activity. PEARY's long association with the Thule district, his topographical mapping of it, and his many geographical discoveries farther north, naturally held a strong political implication.

In particular his journey in 1892 across the Inland Ice to the head of Independence Fjord at Navy Cliff from where he claimed a view over the large, mountainous and unknown land that now bears his name, and his journey in 1900 along the nothern coast on which Kap Morris Jesup was found to be the northernmost piece of land thus establishing the insularity of Greenland, were of vital importance to the claim of territorial rights over northern Greenland by the United States.

Hence as a counter challenge for sovereignty, the Danish expeditions despatched to northernmost Greenland for a decade from 1906, namely the *Danmark Expedition* 1906–1908, the *1st Thule Expedition* 1912 and the *2nd Thule Expedition* 1916–1918 all had surveying and cartography as their highest priority. The only exception to this was the *Alabama Expedition* 1909–1912 whose purpose was the search for the bodies and records of HØEG-HAGEN and MYLIUS-ERICHSEN who perished on the *Danmark Expedition* in 1907.

As it turned out, the United States relinguished all territorial claim over northern Greenland in 1917 in the transactions that led to the purchase of the Danish West Indies, the Virgin Islands from Denmark. Nevertheless, on the *Bicentenary Jubilee Expedition* despatched three years later and so named to mark 200 years of Danish colonisation of Greenland (HANS EGEDE having landed in West Greenland in 1721) topographical mapping was of foremost importance. Moreover, consolidation of Danish sovereignty became an overriding motif. It is therefore that the northern coast of Peary Land from de Long Fjord (the farthest point reached from the west by the *2nd Thule Expedition*) to the south of Kap Bridgman (farthest point reached from the east by the *Danmark Expedition*) was a primary aim of the expedition, since this was "the only portion of the coast of Greenland that has never yet been traversed by any Dane" (in KOCH, 1926b, p. 11).

Thus, in addition to natural constraints that spring and autumn

dog-sledging entails, LAUGE KOCH's geological field work during the *2nd Thule and Bicentenary Jubilee Expeditions* was governed by national motifs as well. The purpose and aims of the expeditions are quoted below in order to illustrate the emphasis on the topographical mapping programme, for which KOCH was also responsible.

2nd Thule Expedition 1916–1918, led by Knud Rasmussen

> "The principal object of the Expedition is to explore and survey the last unknown range of the North Coast of Greenland between St. George Fjord and de Long Fjord. We shall of course be most particularly interested in visiting the country linking up Nordenskiöld Inlet and Independence Fjord.[2])
> I am setting out at present with but a single companion, Lauge Koch, who accompanies me in the capacity of geologist and cartographer. We shall afterwards engage Eskimos in addition . . .[3])
> As regards geological aims in view on this expedition, it will suffice to mention the following: During the past century, the whole of West and East Greenland has been investigated, from the geological point of view, by various expeditions. But the range from Sherard Osborne Fjord to Peary Land, with the unknown fjords of the latter region, still remains as a missing link between the east coast and the west; and until this gap has been filled in, the geological survey of the country remains incomplete. Just as the coasts and fjords here in the extreme north still remain to be charted, so also, the final stage of geological exploration can only be covered by the investigation of these regions. And we should make it a point of honour that this, the concluding portion of the work, should be carried out by a Danish geologist" (RASMUSSEN, 1927, p. 3–4).

Bicentenary Jubilee Expedition 1920–1923, led by Lauge Koch

> "Your expedition will have for its main objective
> 1) to procure a topographical map on the scale of 1:500,000 of such portions of Northern Greenland as will be possible. The ideal will be to get a detailed, uniformly made map of the whole northwestern Greenland from Upernavik to Independence Fjord on a scale of 1:500,000.

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[2]) This was the supposed site of the *Peary Channel* (envisaged by PEARY and ASTRUP in 1892 from their vantage point at Navy Cliff, the position and geographical character of which concerned all Danish expeditions to northern Greenland between 1906 and 1923).

[3]) The Swedish botanist THORILD WULFF joined the expedition at Thule at the end of the summer 1916.

> 2) to collect such quantities of fossils that will convey a clear impression of the fauna of the sediments in Northern Greenland.
> It is expected that you will be able to carry considerable collections across the ice cap by the aid of a motor. You should make a map showing the geological details in the northwestern Greenland based on the collections".....
> "Finally the committee expresses the expectation that however circumstances may be, you will constantly bear in mind the two main objectives of the expedition and with reference to the Bicentenary Jubilee for Greenland try to map the north coast of Peary Land, the only portion of the coast of Greenland that has never yet been traversed by any Dane" (in KOCH, 1926b, p. 10–11).

Such were the aims of the Danish expeditions to northern Greenland; aims that carried—at least officially—strong political overtones. For the purpose of fund raising national pride was surely a timely motif. The personalities carrying out the aims set forth, however, should be looked at as individuals strongly motivated by scientific curiosity as well as by the challenge of venturing the unknown. It was the towering strength of these men that made them legendary figures, not at least through the writings of the unforgettable PETER FREUCHEN who happened to serve as cartographer on KNUD RASMUSSEN's 1st Thule Expedition.

Since PEARY's activity in the region was an important factor leading to the ultimate decision of mounting these Danish expeditions it should be kept in mind that, first of all, PEARY's achievements were tremendously inspiring. PEARY had shown what can be done by a well planned operation that combines traditional Eskimo travelling technique with the advances of 19th century technology (such as his invention of the kerosene stove and the canned "men's-pemmican"). Like FRIDTJOF NANSEN's dash across the Inland Ice in 1888 and his bold attempt to reach the Pole on ski in 1895, ROBERT PEARY aroused the passion for the Arctic venture. In addition, PEARY had created the model for successful exploration work in the High Arctic. KOCH (1940, p. 92) acknowledges this by writing:

> "I think it is safe to say that without the influence of PEARY the subsequent Danish expeditions starting out from the Kap York district (1st and 2nd Thule Expeditions and the Jubilee Expedition) would have taken a different course; for they were based on the experience and tradition which had been created by PEARY."

Also, from conversations with LAUGE KOCH it is quite apparent that he had considered himself an admirer and student of PEARY, rather than a competitor.

RESULTS OF THE 2nd THULE AND BICENTENARY JUBILEE EXPEDITIONS

The region between the Thule district and western Peary Land was visited by both the *2nd Thule and the Bicentenary Jubilee Expeditions*. Thus some difficulty arises in attempting to categorise the geological results in terms of what was accomplished on each of the expeditions. The map and photographic material treated in this paper were intended for publication in *Meddelelser om Grønland* in a volume pertaining to the results of the *Bicentenary Jubilee Expedition*. Indeed, the photographs were all taken during that expedition but the maps, most particularly the North Greenland map, should be seen as a product of both expeditions.

Knud Rasmussen (1927, p. 6) refers to the agreement between himself and Koch that all the geological material collected during both expeditions should be treated as the results of the *Bicentenary Jubilee Expedition*, while the glaciological material should be assembled with papers dealing with the *2nd Thule Expedition*. Hence the extensive paper "Contributions to the glaciology of North Greenland" (Koch, 1928a) appeared in *Meddelelser om Grønland*, volume 65 as part of the *2nd Thule Expedition* report although parts of the coast described therein (for example northernmost and eastern Peary Land) were only visited during the *Bicentenary Jubilee Expedition*.

On the *2nd Thule Expedition* Koch acquired invaluable experience about the life in the frozen lands and gained a first insight into the regional geology of northern Greenland. It was only on the basis of this preparation that he was able to cover much greater distances and carry out in a systematic way topographical and geological mapping during the *Bicentenary Jubilee Expedition*.

The hardships endured by the members of the *2nd Thule Expedition* which culminated with the deaths of Henrik Olsen and Thorild Wulff during the retreat from the Arctic coast are well known (Rasmussen, 1927). The despair and plight on the journey back across the Inland Ice to Thule permitted only a small number of rock samples and fossils to be carried along for documentation and examination. Furthermore, sledging difficulties encountered on the sea-ice, unfavourable weather conditions and towards the end of the journey, the constant threat of starvation too often led the geological field work to become cursory in nature.

Apart from short summary articles (Koch, 1918, 1919, 1923a, b, c), the preliminary geological results of the *2nd Thule Expedition* were published in the *Meddelelser fra Dansk geologisk Forening* under the title "Stratigraphy of Northwest Greenland", including a coloured geo-

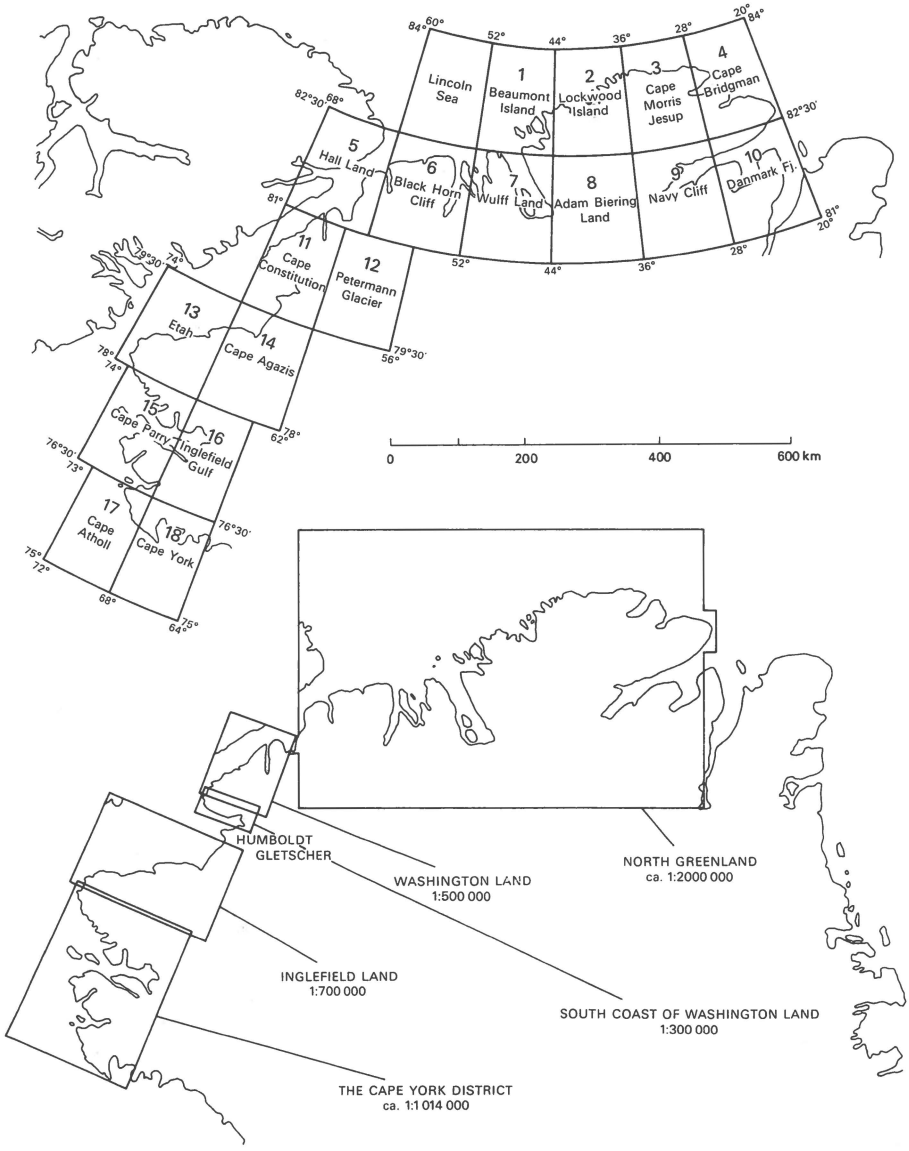

Fig. 3. The main objectives of the Danish Bicentenary Jubilee Expedition: topographical and geological map coverage of northern Greenland. Above: index map of 18 topographical sheets at scale 1:300,000. Redrawn from KOCH (1932). Below: index map of 5 geological sheets. Presentation of 3 of these maps in this paper completes the published series.

logic map at a scale of 1:2,000,000 (KOCH, 1920). The main cartographical results were published in the form of two maps at a scale of 1:500,000 of Melville Bugt, "Wilcox Point to Cape York" and of central North Greenland from Nyeboe Land to western Peary Land (KOCH, 1922). Both these accounts appeared after KOCH had left for Greenland with the *Bicentenary Jubilee Expedition.* KOCH had a good opportunity now to improve and complete his earlier observations since his expedition spent three years in northern Greenland, for much of the time in regions only briefly visited during the *2nd Thule Expedition.*

In accordance with the aims of the *Bicentenary Jubilee Expedition* formulated by the organising committee, it was planned to publish a topographical as well as a geological map series, both covering the entire coastline from Melville Bugt to eastern Peary Land and as much of the inland area as possible. For reasons mentioned above, priority was given to the topographical map series, which was published by the Geodetic Institute in 1932 (Fig. 3) in the form of a portfolio of 18 sheets at a scale of 1:300,000. The geological map series, however, was published only in part and it is in this respect that the three maps presented here are of particular interest.

The original plan called for geological maps on a common scale, but this was later abandoned in view of the fact that many areas had not been visited or had been seen from a distance only. Furthermore, many areas although traversed by the party were not thoroughly studied because of lack of time, unfavourable travel conditions or other priorities. KOCH's modified plan, therefore, envisaged a map series of 5 sheets of varying scale (Fig. 3) to be published as plates in his reports describing the regional geology. Indeed, maps of this series were published in 1929 and 1933 respectively, namely the geological map of southern Washington Land at a scale of ca. 1:300,000 (dated 1929) and the geological map of Inglefield Land at a scale of 1:700,000 (dated 1931). Both maps are integral parts of the papers No. 1 and 2 in volume 73 (I) of *Meddelelser om Grønland* (KOCH, 1929a, 1933). The question of why the remaining three maps were not issued (although printed as a batch in 1931) requires some background information.

The two decades following the armistice of 1918 have been overshadowed by a trend of national ambition and territorial claims, which tragically led into yet another war of annihilation. It was in this political climate that Danish sovereignty over all Greenland, proclaimed in 1916, was challenged by Norway for historical reasons. In 1924, Denmark formally conceded hunting rights to Norwegian trappers and fishermen in East Greenland. Included in this treaty was also any scientific exploration, except for the Angmagssalik and Scoresby Sund districts. In 1928, Norway proclaimed sovereignty over Jan Mayen, which up to

that time had been considered belonging to Denmark. The Norwegian involvement in East Greenland climaxed with the formal annexation of "Eric the Red Land" (territory between 71°30′N and 73°40′N) on July 10, 1931. The dispute was finally settled by the International Court in the Hague, which reaffirmed Danish sovereignty over all Greenland on April 5, 1933.

The treaty of 1924 between Denmark and Norway specifically tolerated scientific investigations in East Greenland and with this, competitive exploration activities were inevitably invited. It is in view of these circumstances that LAUGE KOCH, immediately after his return from the *Bicentenary Jubilee Expedition* in 1923, had to plan on exploration work in East Greenland. With the winter base at the newly established settlement Scoresbysund (70°N), on his first expedition of 1926–1927 KOCH carried out geological reconnaissance mapping northwards to Danmarkshavn (76°N). This was followed by his ship-based *East Greenland Expeditions* of 1929 and 1930, the *Three-Year Expedition* 1931–1934 and the *Two-Year Expedition* 1936–1938 (see KOCH, 1955).

The development outlined above makes it quite apparent why the exploration of northern Greenland had lost momentum. In spite of his preoccupation with the surveying of East Greenland, KOCH still attempted to publish a full account of the results of the *Bicentenary Jubilee Expedition* and the detailed description of the regional geology started with the southern Washington Land and Inglefield Land maps (KOCH, 1929a, 1933). The three other maps would undoubtedly have been published in due course but for an unfortunate accident. During an air raid on Copenhagen in the war, a storage room of the Geodetic Institute was damaged and the completed prints of the three maps were destroyed. However, several copies of the maps were still in existence and the reprinting of them was planned. Nevertheless, reproduction of the maps was geared to publication budgets and partly controlled by the workload at the Geodetic Institute, and, with the post-war East Greenland expeditions in full swing, the plan was temporarily shelved.

It is fair to say that KOCH kept a constant interest in the geology of northern Greenland, at least until the 1930's when the structure and age of the North Greenland fold belt in particular became the subject of controversy (see KOCH, 1936, 1937; FREBOLD, 1934; BØGGILD, 1938). Moreover, in the course of his joint flight-programme with the Geodetic Institute pioneering photogrammetrical survey in East Greenland, KOCH seized the opportunity to carry out one extended flight over North Greenland in 1933 (KOCH, 1935a). In 1938, the surmised existence of an island off the north-east tip of Greenland gave rise to KOCH's *Seaplane Expedition* from Spitsbergen to Peary Land (KOCH, 1940, pp. 330–337). At the same time members of the *Danish Expedition to Northeast Green-*

land 1938–1939 carried out the first geological field work in Kronprins Christian Land (SØLVER, 1940; NIELSEN, 1941).

Although the post-war expeditions to East Greenland had available twin-engine seaplanes and single-engine floatplanes, KOCH was well aware that in his time any systematic geological survey of northern Greenland was out of the question. He himself had experienced the hardship and hazards of pioneer travel techniques in that region and helicopter-borne field parties were still a dream in the 1950's. As a matter of fact, it was EIGIL KNUTH's *Danish Peary Land Expedition* 1947–1951 that tested the first "air-borne" operation in North Greenland. At that time, however, airlifting meant the dropping of men and equipment at the site of the winter headquarters from where the geologists worked, again with dog-teams, in the springtime mainly. Eventually, with the establishment of Station Nord, on the northeast tip of Greenland, geological field parties were able to operate with floatplanes in Kronprins Christian Land in 1952 and 1953 (ADAMS & COWIE, 1953; FRÄNKL, 1954, 1955a). In 1953 also, KOCH staged the outmost venture from the operational base in East Greenland—a geological traverse of the North Greenland fold belt in northern Peary Land (FRÄNKL, 1955b). As it happened due to unexpected weather hazards, this trip nearly ended in a catastrophe for both field party and the rescue floatplane.

The renewed interest in one of KOCH's three unpublished maps, the one of the Kap York district, came with the increased activity in northern Greenland, which began in the 1950's with the construction of the Thule Air Base by the United States. This facility opened up hitherto unknown possibilities for geological and for other research in the region. As a result, and following a brief visit to the Air Base, a geologic description of the "Thule Area" was soon published by two American authors (KURTZ & WALES, 1951). Other more systematic surveys followed (DAVIES, 1954; DAVIES *et al.*, 1963). It was somehow in response to these activities that KOCH had the geological map of the Kap York district reprinted and assigned a new *Meddelelser om Grønland* volume number[4]). However, KOCH was taken ill before his manuscript to accompany this map was ready for publication. He died in 1964.

[4]) This was necessary because volume 73 (I), originally reserved for papers presenting results of the *Bicentenary Jubilee Expedition* and containing the Inglefield Land and southern Washington Land maps, had been completed with addition of a paper by one of us (J. H.) stemming from KOCH's East Greenland expeditions.

DISCUSSION OF THE MATERIAL

The publication of the three maps completes the initial aim of the *Bicentenary Jubilee Expedition*—that of topographical and geological coverage of the coast of northern Greenland from Melville Bugt to eastern Peary Land. Thus the maps are of historical importance. In addition, and despite recent advances in field work in many of the areas covered by the maps, the maps and the photographs chosen here as illustrations, portray pertinent geological information. Since the results of the *Bicentenary Jubilee Expedition*, as explained in the foregoing, were never published in full, the material gives for the first time an indication of the regional extent of some of the rock units recognised by KOCH, units that became part of the established stratigraphical column of northern Greenland. This is particularly true for the Silurian as shown on the Washington Land and North Greenland maps.

Most of the photographs presented here supplement the Silurian geology depicted by the Washington Land map. All illustrate significant localities that have been referred to briefly in general review papers (KOCH, 1920, 1923b, 1925, 1929b) but which contain interpretative detail that is essential for the full assessment of the regional geology as presented by KOCH. All the photographs were taken by KOCH during the sledging season from the sea-ice—the best vantage point from which to see the main geological features of the steep, often spectacular cliffed coastline in this part of Greenland. Such views of the coastline must often be forfeited during the modern field operations carried out in summer.

Kap York district map

This map (Plate 1) overlaps in the north with the map of Inglefield Land (KOCH, 1933), the area between Foulke Fjord and "Pandora Harbour" being common to both. The place marked "Thule" is the original trading station at North Star Bugt and the present site of Dundas and Thule Air Base. Present-day Thule (Qânâq, see fig. 1) on the south-western coast of "Red Cliff Pen." is not marked. This did not become a town until the construction of Thule Air Base in the early 1950's and the subsequent resettlement of the Thule Eskimos to this site.

A geological sketch map of the Kap York district was published by KOCH (1926a, 1928b) to accompany a short description of the tectonics of the Thule district. However, the present map, of larger scale and in colour, gives more geological detail and portrays KOCH's tripartite division of the *Thule Formation* (now raised to group status). In the type locality around "Thule" this is seen to differ from the tripartite division of KURTZ & WALES (1951) and DAVIES *et al.* (1963). The main variance

concerns the age of a redbed sequence exposed north of Kap Atholl (included in the Lower and Upper Sandstone units of KOCH or the Narssârssuk Formation of KURTZ & WALES, 1951) and its age relationship to the "Dolomite and Shales" outcropping around "Thule" (the Danish Village Formation of KURTZ & WALES and the Dundas Formation of DAVIES *et al.*). To the north in Steensby Land and Prudhoe Land the Lower and Upper Sandstone units represent members of the Wolstenholme Formation overlying the crystalline basement (cf. DAWES, 1976).

The map illustrates for the first time KOCH's impression of the distribution of basic intrusions, both sills and dykes that penetrate the *Thule Group*. The well developed sill complexes on the coasts of Wolstenholme Fjord (see MUNCK, 1941) and in southern Steensby Land (mentioned by DAWES, 1975), as well as the regional WNW-trending basic dyke swarm, for example around Bardin Bugt and traceable onto Northumberland Ø are portrayed on the map. The distribution of Precambrian basement (Archaean-Algonkian of KOCH) and the overlying Thule Group sediments agrees in broad outline with present-day maps (cf. DAWES, 1976) and several important faults in the Olrik Fjord-Prudhoe Land area are shown. However, it is of some interest to note that the map shows a somewhat modified block fault system from that initially described (KOCH, 1926a). Several faults mentioned in the literature, e.g. an E-W trending one with northerly downthrow that causes stratigraphical repetition in "Barden Bay", and a fault between basement and Thule Group sediments on Wolstenholme Ø, are not shown.

Washington Land and North Greenland maps

The main significance of these maps (Plates 2 and 3) lies in the regional distribution of the Lower Palaeozoic, particularly Silurian, strata which forms a broad and continuous belt across northern Greenland, from Washington Land to eastern Peary Land. Although it is over 50 years since the information for the maps was collected, some areas remain unvisited since that time. This applies for example to the deep fjord regions between Nyeboe Land and Freuchen Land in central North Greenland. Another region, that south of Independence Fjord, was only revisited in 1978 by the Geological Survey of Greenland. Apart from a brief visit to Kap Schuchert by B. S. NORFORD of the Geological Survey of Canada in 1966 (NORFORD, 1972), the whole of the region shown on the Washington Land map remained unstudied until the recent field work by the Geological Survey of Greenland in 1976 and 1977. Thus in regional accounts on North Greenland geology the maps have proved valuable and have been referred to (DAWES, 1971, 1976).

The Washington Land map is continuous with that of the southern coast of Washington Land (KOCH, 1929a) and it roughly joins the North Greenland map at Petermann Gletscher. The smaller scale of the North Greenland map is attributed to the fact that much less time was spent on geological studies north of 81°N; for example, the eastern part, Peary Land, was only seen during KOCH's sea-ice circum-traverse in 1921.

In "Stratigraphy of Greenland" (KOCH, 1929b), the Lower Palaeozoic strata of the North Greenland platform was described in terms of 17 formations. The outcrop of Cambrian and Ordovician formations in and around the type areas was illustrated by the Inglefield Land and southern coast of Washington Land maps (KOCH, 1929a, 1933). The youngest 4 formations, of Silurian age, outcropping farther to the north have not hitherto been shown on maps. Previous geological sketch maps covering Washington Land and northern Greenland published after the *Bicentenary Jubilee Expedition* (KOCH, 1925, 1935b) portray the regional stratigraphy in terms of systems, not formations. Thus the essential geological conditions in and around the type localities of the Cape Schuchert Formation, the Offley Island Formation, the Cape Tyson Formation and the Polaris Harbour Formation—the four Silurian formations erected by KOCH—have had to be interpreted from other sources, mainly KOCH (1929b). Similarly, the precise regional distribution of these formations as envisaged by KOCH has not been hitherto fully established. Consequently, the maps are essential reference material in any study and future subdivision of the Silurian and/or eventual redefinition of these formations, and their publication helps considerably to clarify some of the discussion that has so far surrounded recent reinterpretation of the Silurian stratigraphy (e.g. NORFORD, 1972).

The Silurian of North Greenland is now interpreted in terms of a regional carbonate platform which includes on its seaward edge an extensive reef complex with prominent and intricate facies relationships involving lateral transitions between strata of diverse lithologies (KERR, 1967; DAWES, 1971; NORFORD, 1972). This led to a significant revision of the stratigraphical scheme proposed by KOCH (1929b) and C. POULSEN, who described many of the fossils collected (POULSEN, 1934, 1941, 1943). The original scheme was based on a layer-cake stratigraphy with major unconformities separating formations of different ages. However, the descriptions in the papers by KOCH and POULSEN make it clear that the Silurian rocks comprise many different lithologies that vary from area to area. POULSEN (1941, p. 8), in fact remarks that the Offley Island Formation has in some localities "the character of a reef facies". Both the map material described below and the explanatory annotated photographs, show that some evidence had been accumulated to demonstrate that certain lateral facies relationships had been recognised

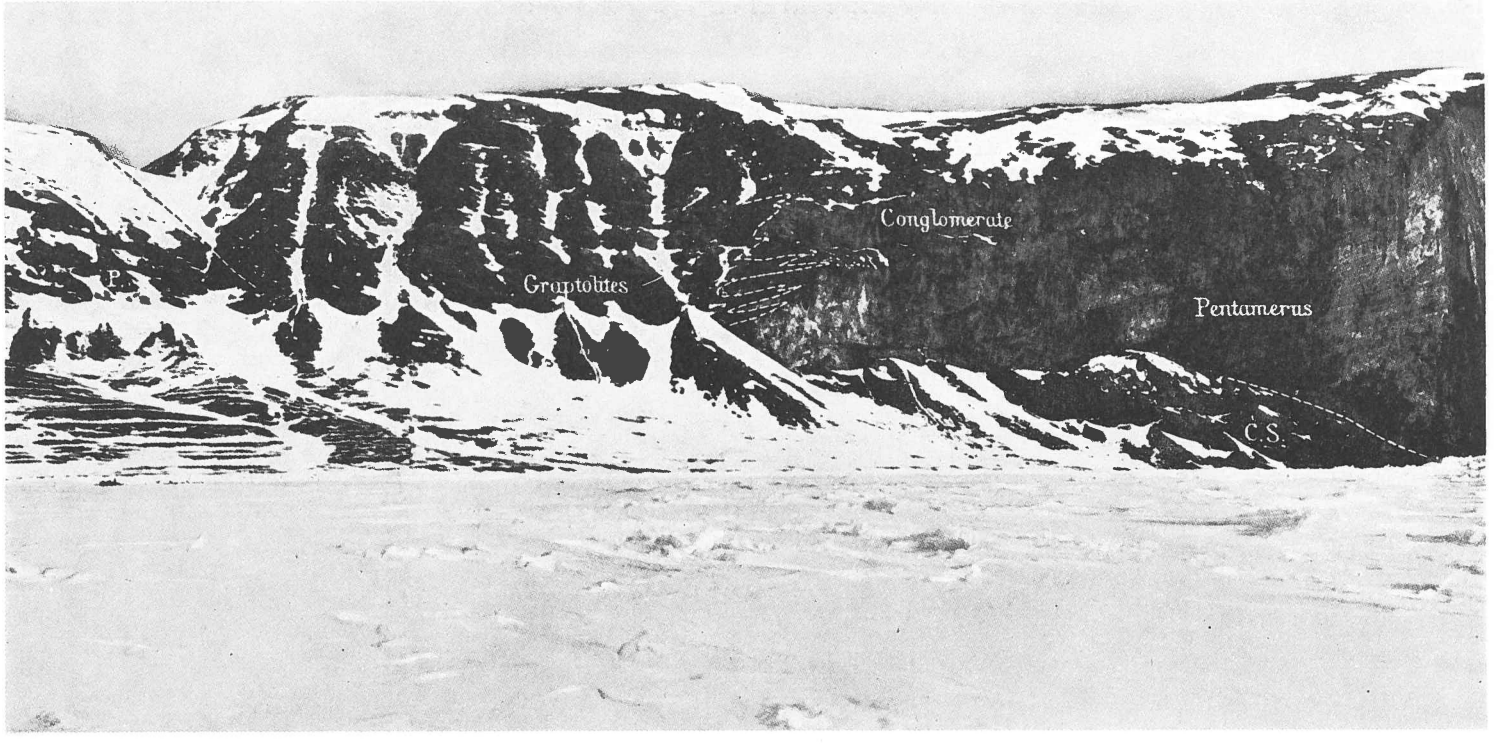

Fig. 4. Stratigraphical detail on the north side of Kap Constitution, Washington Land, illustrating the intertonguing relationship between graptolitic shales, and reef conglomerates and limestone. For full explanation see the text p. 23. Cf. Fig. 5.

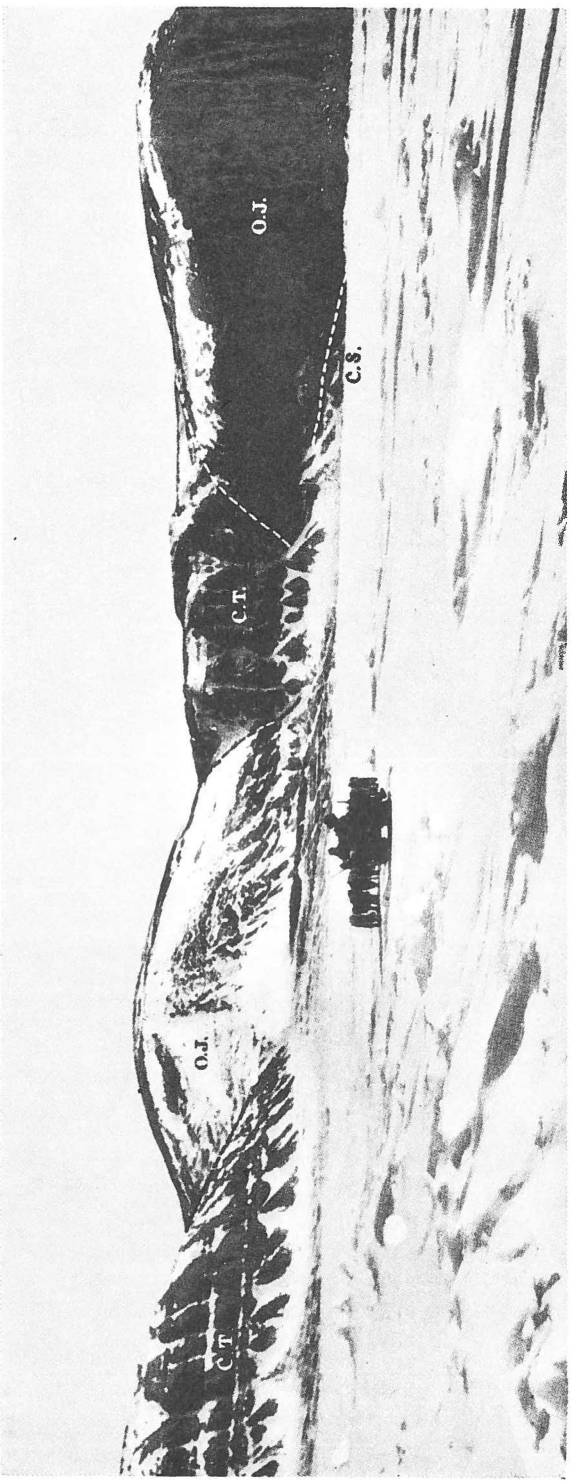

Fig. 5. Geological conditions at the coast to the north of Kap Constitution, Washington Land. KOCH's Silurian limestone "islands" (O.J.) surrounded by graptolitic shale (C.T.). From KOCH, 1929b, fig. 57. For explanation see the text p. 23. Cf. Fig. 4.

within the Silurian, although it is unknown in detail how KOCH would have interpreted these in his proposed paper dealing with the Silurian of northern Greenland.

The *Washington Land map* contains perhaps the most noteworthy new geological information in that it demonstrates that KOCH recognised, and indeed was able to accurately map out, the regional distribution of different facies (shale and limestone) within the younger Silurian rocks; facies that are now known to be prominent in the later development of the Silurian of the platform throughout the whole of northern Greenland. These two facies referred by KOCH to the same formation, were considered to be, at least in part, stratigraphic equivalents. In this context the annotated photograph showing the detail relationship of Silurian strata on the north side of Kap Constitution is of considerable interest (Fig. 4). KOCH (1929b, p. 278) published a smaller scale photograph of this part of the coast (reproduced here as Fig. 5) to illustrate the relationship of graptolitic shales ("C. T."—Cape Tyson Formation) to the lighter coloured limestones forming the high ground and capes ("O. J."[5])—Offley Island Formation), assuming a regional erosion surface at the base of the shales. The annotated larger scale version suggests in detail something essentially different—an intertonguing relationship between graptolitic shale and carbonate, i.e. a facies contact between strata that are at least in part of similar age.[6]) Moreover, the absence of an annotated boundary between the conglomerates and the "Pentamerus" limestone, suggests recognition of the close association and perhaps transition between these two carbonate lithologies (see below).

Kap Constitution to the right (marked "O. J.") represents a large bioherm, the inclined strata marked "Pentamerus" are beds on the bioherm flanks, with the rocks marked "Conglomerate" representing reef talus eroded off the rapidly growing reefs. The well-bedded, darker strata (marked "C. T." and "graptolites") are off-reefal argillaceous rocks, that are, at least in part, the facies equivalents of the reef strata. The nature of the boundaries between shales and the more massive lighter coloured limestone beds is undoubtably complex (as recognised by KOCH, 1920, see below) but are best interpreted as involving lateral

[5]) This should read "O. I.".

[6]) It is interesting to note that it was partly on the basis of such intertonguing and intricate lateral facies relationships involving KOCH's Offley Island Formation and Cape Tyson Formation (both of which contain different facies away from the type localities) that the need for a critical revision of the Silurian stratigraphy in northern Greenland was initially suggested (DAWES, 1966; KERR, 1967). NORFORD (1972) considered the name Cape Tyson Formation obsolete and introduced from Arctic Canada the name Cape Phillips Formation to cover certain, mainly argillaceous strata, not included in the Offley Island Formation.

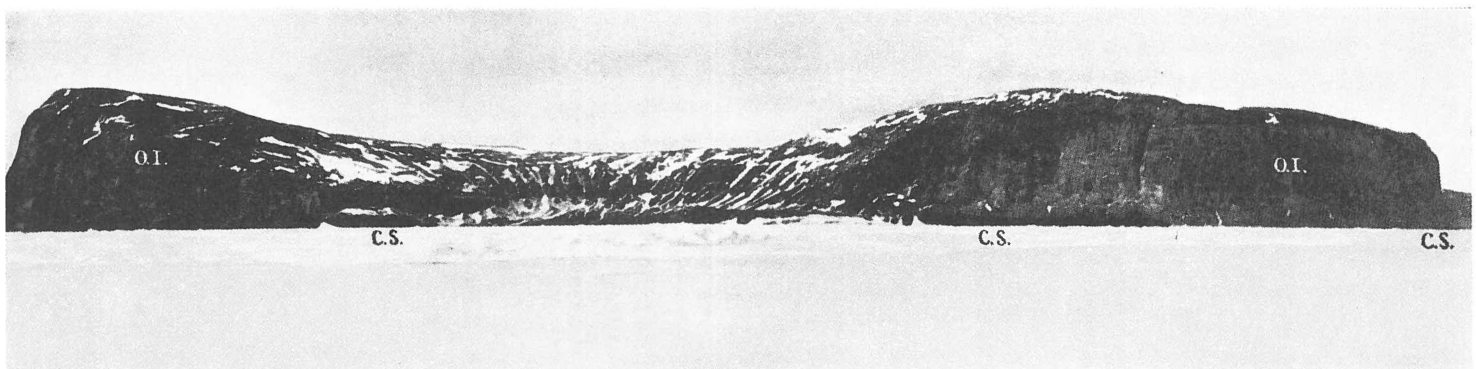

Fig. 6. Large bluff-forming reefs at Kap Constitution (left) and Kap Independence separated by lower lying terrain of argillaceous rocks. Coastal Washington Land, seen from the north-west. O. I. = Offley Island Formation; C. S. = Cape Schuchert Formation.

facies changes, rather than the product of a profound regional erosional unconformity.

KOCH's initial comments about the Kap Constitution—Kap Independence—"Kap Lafayette" coast following the *2nd Thule Expedition* (KOCH, 1920, pp. 41–46) leaves no doubt that he recognised the intimate and complicated association of a number of different rock lithologies and that stratigraphic relationships are complex. He noted various inclined and disturbed beds, "tumbled-down conglomerates" within dark shales, unconformities between various strata, as well as transitions between limestone, conglomerate and argillaceous rocks. KOCH concluded that "the highly-varied stratification requires to be investigated in detail, in order that one may be able to pronounce, with any certainty, an opinion as regards the significance of the discordances between the strata". KOCH managed to see this coast again during the *Bicentenary Jubilee Expedition* although as asserted in this paper, the detail results of his observations were never published. A photograph of Kap Constitution and Kap Independence (Fig. 6) might suggest that KOCH surmised a lateral transition (within his Offley Island Formation) between the conglomerates and limestones forming the bold capes and at least some of the thinner bedded argillaceous rocks separating them. The detail shown in Fig. 4 provides collaborative evidence for such a supposition.

Nevertheless, despite this recognition of lateral facies relationships between shale, limestone and conglomerate in local exposures, and the regional mapping of the shale and limestone facies in the later part of the Silurian, the stratigraphical pattern on the Washington Land map appears to be essentially the same as described in "Stratigraphy of Greenland" (KOCH, 1929b).

The main reasoning for this may not be immediately apparent and, as explanation, some background biostratigraphic information is offered. It should not be overlooked that POULSEN's (1934, 1941, 1943) investigations of the faunas collected by KOCH, conclusively demonstrated that a wide age range of Silurian strata outcrops in northern Greenland. For example, fossil evidence showed that in the Kap Constitution area alone, strata of Llandovery age to at least early Ludlow age exists. The rocks forming the bold capes themselves (i.e. among others, the reef masses at Kap Constitution and Kap Independence), referred to the Offley Island Formation, were known to contain a shelly fauna of Llandovery age (POULSEN, 1941, 1943), while at least part of the shale facies, (that also contained thin beds of limestone, KOCH, 1929b, p. 240) showed "graptolite zones embracing the Tarannon, the Wenlock, and the lowermost part of the Ludlow" (POULSEN, 1934, p. 45). KOCH (1920) initially reported that stratigraphical conditions around Kap Constitution

are complex, and while he inferred that part of the graptolitic shale facies was a stratigraphical equivalent of the limestones (Fig. 4), graptolitic faunas containing such species as *Cyrtograptus murchisoni*, *Monograptus vomerinus basilicus* and *Monograptus bohemicus* (and elsewhere *Cyrtograptus* cf. *C. multiramis*) (PÖULSEN, 1934), clearly indicate a shale facies of younger age.

Moreover, and rather illuminating for the explanation, is the fact that, in areas such as Kap Constitution, where reefs are over 400 m thick and form appreciable topographical relief in contrast to the low-lying shales, it must be that unconformities exist between late Silurian (e.g. Ludlow) shales that overlap onto the older Silurian (Llandovery) reefs. It was presumably this stratigraphical condition of having Wenlock and Ludlow shales lying in the same general areas as, and in close association with, Llandovery limestones, that radically influenced KOCH's interpretation towards an explanation involving an erosional unconformity. Hence, the limestone relief formed by the numerous and widespread carbonate build-ups was interpreted as a product of a period of intense erosion (limestone "dissected by valleys several hundred meters deep", KOCH, 1929b, p. 240) that after inundation by the sea produced "islands" of limestone surrounded by graptolitic shale (KOCH, 1929b, fig. 57). The prominent, and often very coarse conglomerates, with large limestone boulders, were interpreted as basal rudites—the product of the regional erosional hiatus.

A particularly conspicuous feature of the map (Plate 2) is the boundary between the rather extensive outcrops of shales, that as a westerly-facing embayment, form a large part of the low-lying coast, and the limestones of the Offley Island Formation that form the much higher inland terrain. This inland ground contains several reef developments, for example, the conspicuous build-ups that make up KOCH's "Pentamerus Mts". Moreover, KOCH recognised outcrops of more regularly bedded limestones, of similar age to those inland, at various places along the coast underlying the shales (Figs. 7 & 8). KOCH (1920, p. 42) initially suggested faulting to have been important in the formation of some of the features of the Washington Land coast, but, presumably from observations made during the *Bicentenary Jubilee Expedition*, he revised his views and no faults are indicated on the map. Thus, the difference in elevation of the flat-lying to shallow northwards dipping strata inland and in the central coastal area, i.e. the expression of the shale embayment, was presumably to be referred to the period of intense erosion, rather than to a regional facies front.

There is some difficulty in correlating the informal Silurian rock units of KOCH's early publications (prior to the *Bicentenary Jubilee Expedition*; KOCH, 1918, 1920, 1923b) with the formal descriptions of

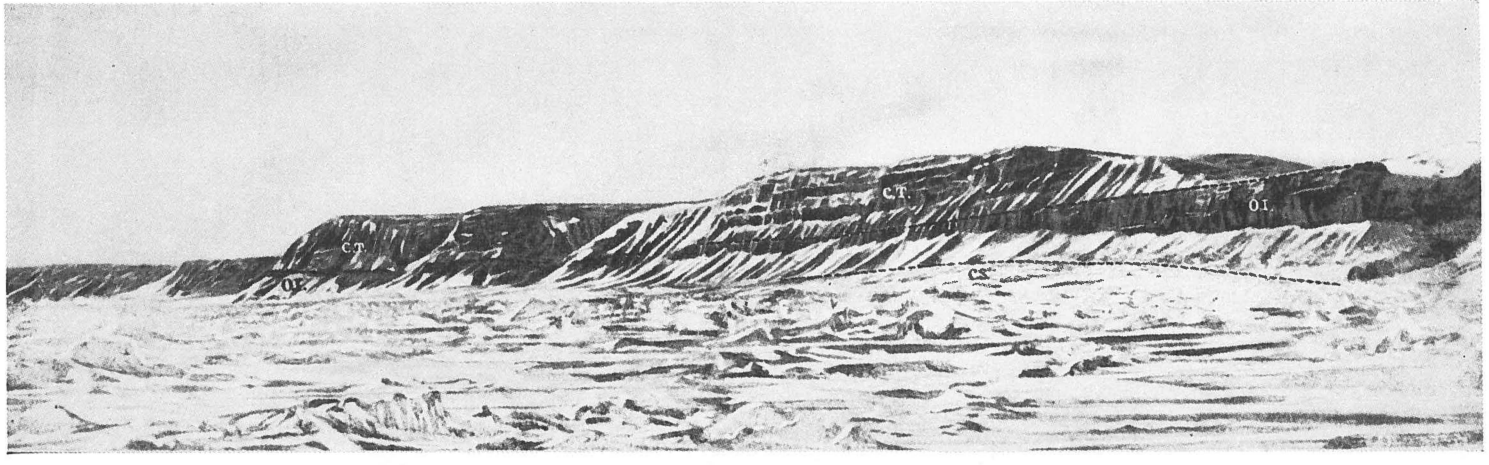

Fig. 7. View from the south-west of the coast north of Kap Jefferson, Washington Land. Limestones of Koch's Cape Schuchert Formation (C. S.) and Offley Island Formation (O. I.) overlain by the predominantly shale facies of his Cape Tyson Formation (C. T.).

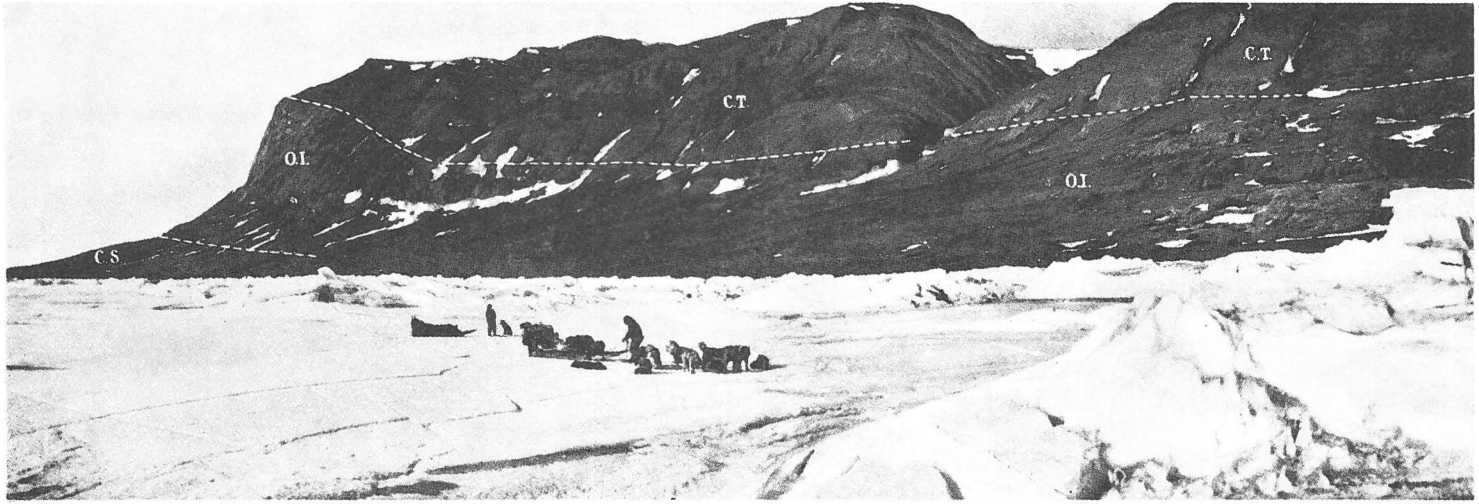

Fig. 8. View of the coast at Kap Resser, Washington Land, seen from the south. A reef, forming the steep cliff of Kap Resser (O. I., extreme left), overlain by a thick sequence of predominantly shales. C. S. = Cape Schuchert Formation; O. I. = Offley Island Formation; C. T. = Cape Tyson Formation.

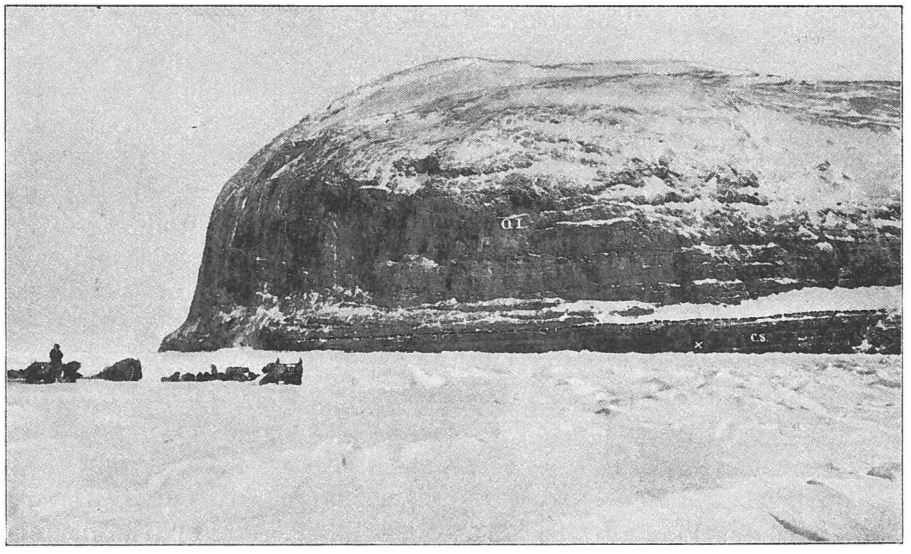

Fig. 9. The Kap Constitution reef, Washington Land, seen from the west. O. I. = Offley Island Formation; C. S. = Cape Schuchert Formation. "X" marks a locality that was to be described by KOCH. For full explanation see the text below.

formations in "Stratigraphy of Greenland" (KOCH, 1929b). The Washington Land and North Greenland maps help considerably in correcting this. Hence such units as the "Coral Limestone", "Pentamerus Limestone" or the "Arethusina Zone" can be stratigraphically and spatially correlated. A photograph (Fig. 9) of Kap Constitution is presented here for comparison with KOCH's earlier published illustration of this cape (KOCH, 1920, fig. 6). This, and figures 6 and 10, show that the basal strata at Kap Constitution, Kap Independence and "Kap Lafayette" forming part of the Cape Schuchert Formation, underlying the spectacular reef limestones, correspond to rocks of the earlier defined Arethusina Zone or the Arethusina Formation (KOCH, 1920, 1925).

On the *North Greenland map*, in contrast to the Washington Land map, no indication is given about the distribution of the different facies within the Silurian. However, elsewhere KOCH (1929b, p. 240) drew attention to the fact that the Cape Tyson Formation is, for example, to the east of Kap Tyson generally of limestone facies, while in some areas, for example, northern Warming Land and southern Peary Land, main exposures are of graptolitic shale. One pertinent feature of the map, confirmed by recent field work, is the outcrop of the Kap Tyson Formation as a line of outliers corresponding to an E-W mountain range across Hall Land and Nyeboe Land. The Hauge Bjerge in Hall Land are a chain of reef mountains; their topography is closely controlled by

the Silurian geology with many of the individual summits representing main centres of carbonate build-up.

The North Greenland map also fixes the distribution of the problematical Polaris Harbour Formation. In view of the prevalence of Quaternary deposits at the type locality—the plain south of Polaris Harbour —the name has proved unfortunate and it has been discontinued (DAWES, 1966). The map indicates that the formation, is equivalent to the dominantly argillaceous fore-reef facies of the Silurian reef limestones, passing north into a more arenaceous transitional facies towards the clastic beds of the North Greenland geosyncline. However, KOCH (1929b, p. 241) described the formation as unfossiliferous, "coarse, loose, unbanded sandstone, occasionally containing slaty bands". This description is difficult to reconcile with the well-bedded fine- to medium-grained Silurian bedrock that is known from the Hall Land-Nyeboe Land area. Thus the recent discovery by HANS F. JEPSEN (personal communication) in Washington Land of a loose but consolidated, coarse fluvial deposit, several tens of metres thick and of unknown but relatively young age (Quaternary or possibly Tertiary), is most tantalising in this respect. This deposit matches in general terms KOCH's description of the clastic strata referred to the Polaris Harbour Formation. Until the entire Polaris Harbour Formation belt between Hall Land and Nares Land has been studied in the field, the age and significance of the coarse, loose sandstone seen by KOCH remains uncertain.

Geological conditions at Kap Schuchert

The geology of coastal Washington Land around Kap Schuchert was discussed by KOCH in his description of the Cape Schuchert Formation in "Stratigraphy of Greenland" (KOCH, 1929b, p. 237). He states that "the best locality" for the formation is "the beach below Cape Schuchert" (Plate 4) but regards exposures "just south of Cape Independence in Lafayette Bay" as the type locality (Fig. 10). The geological conditions at Kap Schuchert have been the subject of a study by NORFORD (1972) and more recently in 1976 by J. M. HURST of the Geological Survey of Greenland.

NORFORD's publication contains a discussion about the exact location of the sections described and interpreted by KOCH, as well as an enquiry into which strata was referred to different formations (NORFORD, op. cit. p. 15–17). He writes "It is difficult to decide which horizon KOCH picked as the top of the Cape Schuchert Formation at Kap Schuchert. He assigned some rocks at Kap Schuchert to the Offley Island Formation (1929, p. 239). These may have been the rocks in the upper part of the succession, or the bioherms and biostromes within the middle part, or

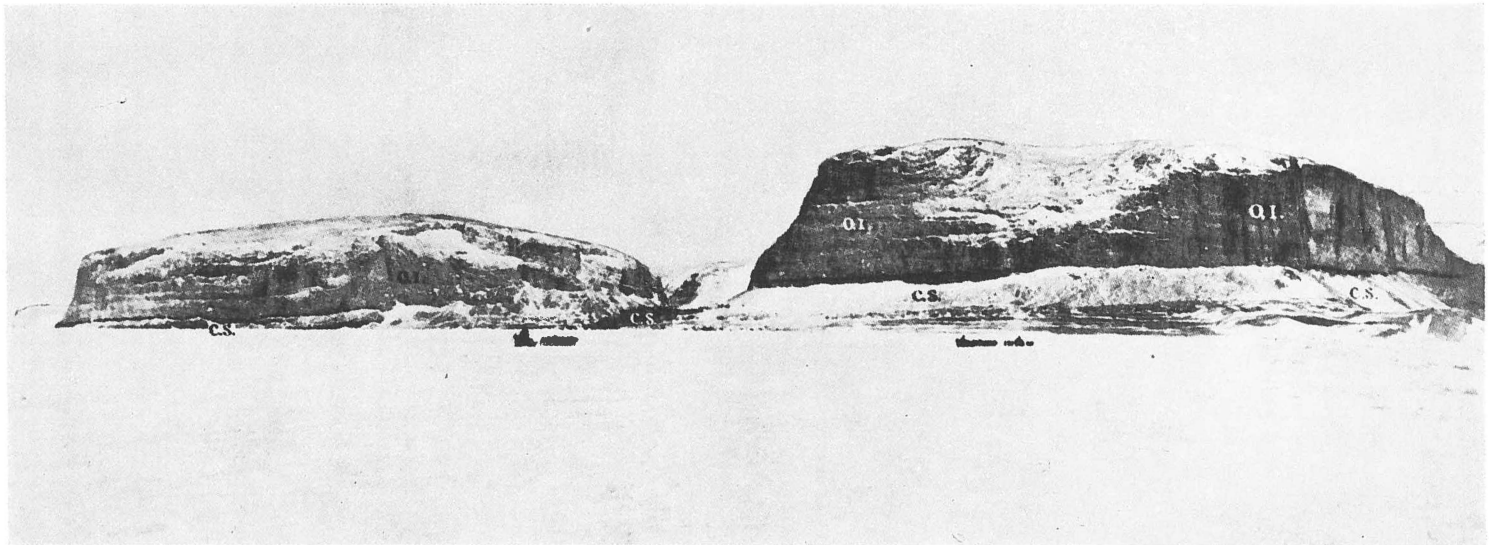

Fig. 10. Spectacular reefs forming Kap Independence (left) and "Kap Lafayette", Washington Land, overlying the Cape Schuchert Formation (C. S.). This is the type locality of that formation—"just south of Cape Independence in Lafayette Bay". O. I. = Offley Island Formation. View from the south-west.

possibly a bioherm within the lower part". The annotated photograph published here as plate 4 helps to clarify these and other uncertainties in interpretation.

This photograph, taken by KOCH in 1922, shows the coast south of Kap Schuchert and the cliff section can readily be recognised on the Washington Land map and on figure 7 in NORFORD (1972). It indicates a tripartite division of the Cape Schuchert Formation that corresponds with KOCH's published description (1929b, p. 237): that is, a lower unit of dark limestone and an upper unit of black limestone (marked "L"), separated by "black, very bituminous and fossiliferous shales" (marked "Sl"). A basal unit of conglomerate (not marked, and apparently not present) is mentioned by KOCH as outcropping "where the formation is most completely developed". The rest of the section consists of well-bedded limestone with reefs (O.J.) overlain by darker, thin bedded argillaceous limestones and shales (C.T.), and being capped by more massive and lighter coloured limestone and conglomerate.

This profile, from sea-level up to and along the southern slope of the hill, corresponds to the "Kap Schuchert section" traversed and described by NORFORD (personal communication; 1972, p. 33). The photograph is invaluable in fixing the location of KOCH's units within the Kap Schuchert section and it considerably reduces any discussion about what KOCH actually referred to by his descriptions.

The Kap Schuchert section is described by NORFORD (op. cit. p. 15 and fig. 5) as showing "a threefold sequence," i.e. the lower part is composed of units 1 to 3, the middle part consists of units 4 to 11, while the upper part is represented by unit 12. NORFORD suggested correlation of this tripartite division with the units described by KOCH. He states that "all of the lower part of the succession probably corresponds to KOCH's dark limestones. The middle part corresponds to his black fossiliferous shales" while the upper black limestone of KOCH is either not developed at Kap Schuchert or it corresponds to "dark argillaceous limestones developed within the sequence of graptolitic rocks" higher in the section. Plate 4 proves that these correlations cannot be upheld.

Furthermore, another annotated photograph (Fig. 11) showing detail of part of the succession can be located in plate 4 by reference to snow patches. The detail indicates a sharp, flat-lying but undulating contact between lower, light-coloured biohermal and biostromal limestones with well-developed pinnacle reefs (O.J.) and overlying darker, argillaceous limestones and shales (C.T.). The very top of the cliff is composed of more massive, lighter coloured limestone and conglomerate. NORFORD (1972, Plate 6, fig. 2) also figures the same locality. The conspicuous contact corresponds to the top of the string of bioherms mentioned by him (op. cit. p. 15, fig. 7) and represents the junction between units 8 and 9 of the

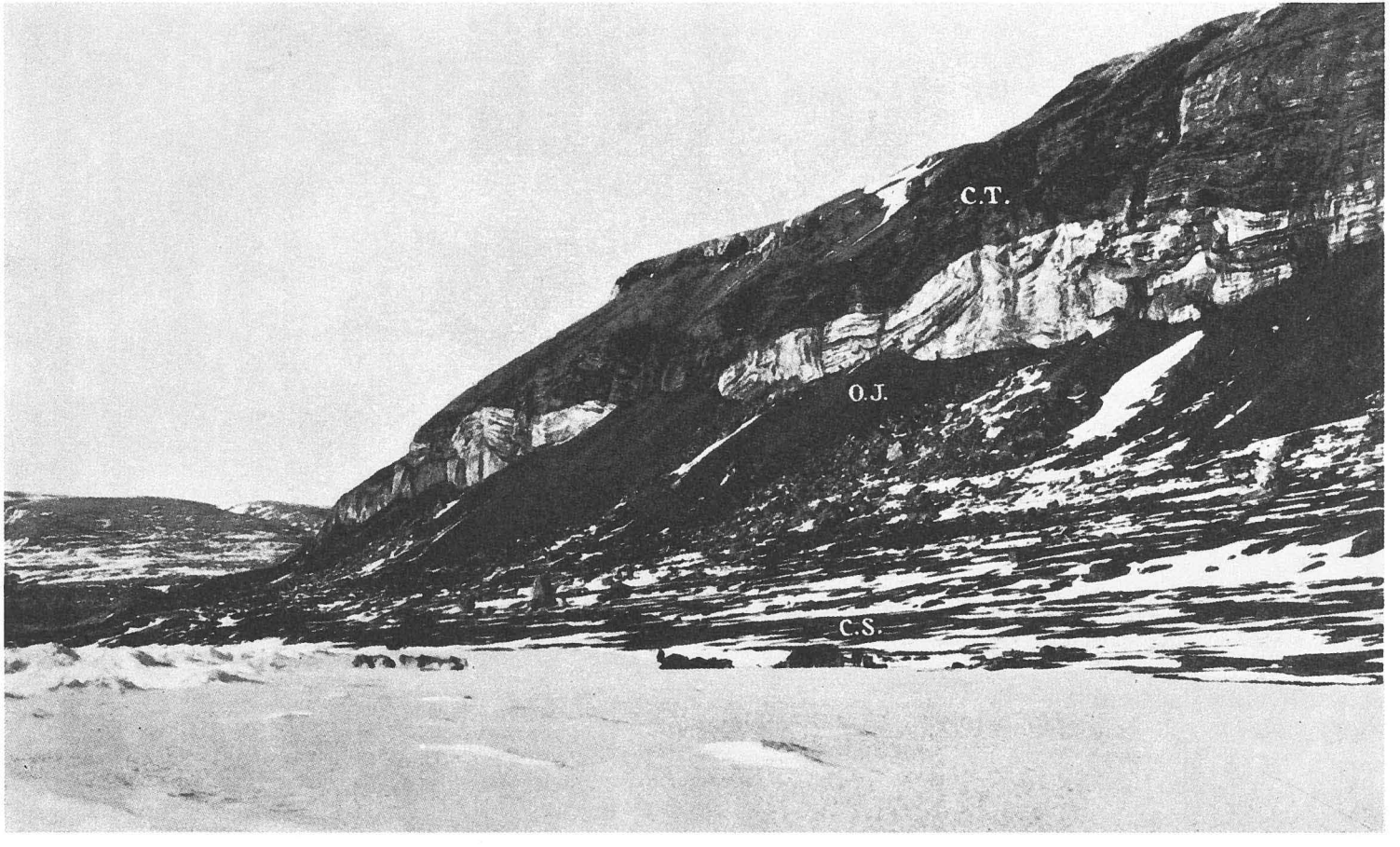

Fig. 11. Stratigraphical detail of part of the Kap Schuchert cliff section seen in plate 4. Well-developed pinnacle reefs characterise the pronounced light-coloured unit. For full explanation see the text p. 32.

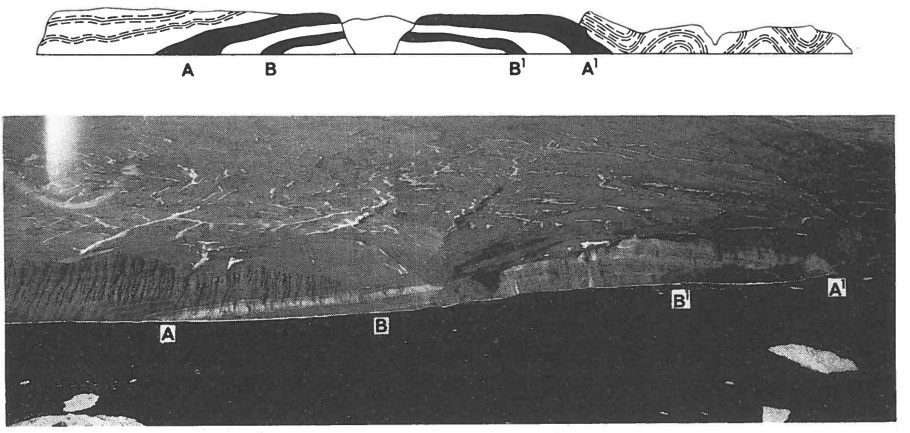

Fig. 12. Aerial view of the northern coast of Hall Land showing the Ordovician-Silurian carbonate group overlain by the Silurian-Devonian clastic group. For comparison LAUGE KOCH's sketch of 1917 from the same coast redrawn from KOCH (1920). Photograph (546 K, nr. 2190) reproduced with permission of the Geodætisk Institut, Copenhagen.

Kap Schuchert section (op. cit. p. 13). The more massive beds at the top of the succession represent unit 12 of NORFORD.

The precise correlation of NORFORD's detail section with KOCH's original interpretation of the Kap Schuchert profile resolves many of the uncertainties of correlation mentioned in NORFORD's paper (1972, pp. 16–17). It is apparent that the "redefinition" of the Cape Schuchert Formation "to the lower part of the succession at Kap Schuchert" (NORFORD, 1972, p. 17) does actually correspond with KOCH's original limits of the formation, with the upper boundary more or less at the break in slope, i.e. at the top of unit 3. The Offley Island Formation was redefined by NORFORD to include only the uppermost conglomeratic strata of the section (unit 12), thus corresponding to the topmost exposures of KOCH's Cape Tyson Formation. The intervening section, units 4 to 11, showing a wide variety of facies from shales, argillaceous limestones, limestone, chert and reefs and corresponding to KOCH's Offley Island and Cape Tyson Formations, was referred to the Cape Phillips Formation of Arctic Canada. In view of the intricate facies changes that characterise the region around Kap Schuchert it remains a question how far these formations, as now defined by NORFORD, can be traced along the coast of Washington Land.

Geological conditions along the northern coast of Hall Land

The more westerly exposures of the North Greenland fold belt are in Hall Land. KOCH (1920, Plate 1) as a result of his journey on the *2nd*

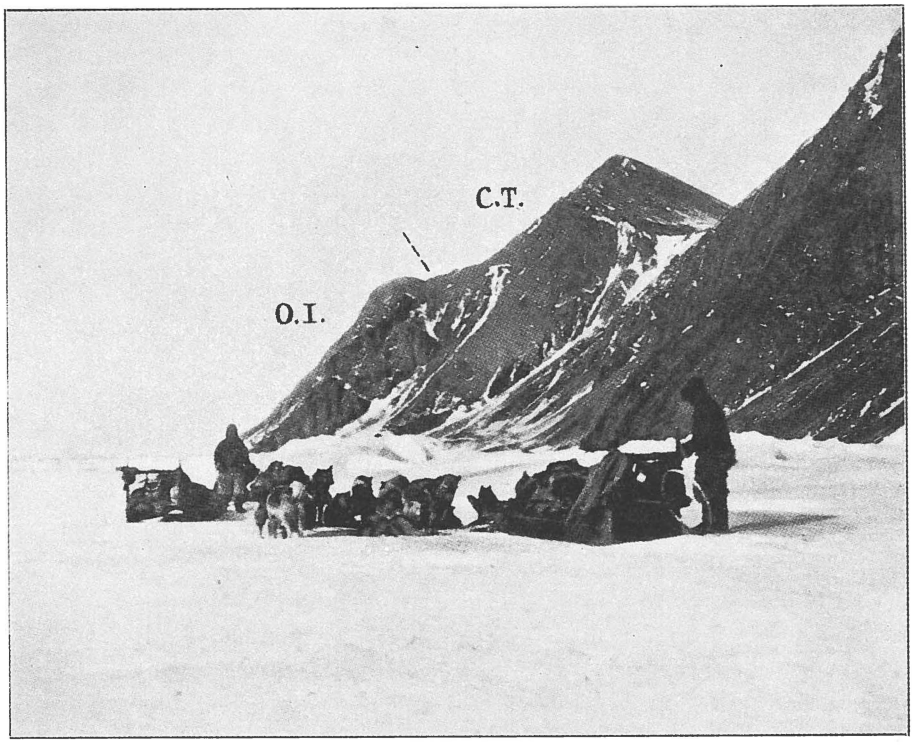

Fig. 13. View of Kap Porter on the northern coast of Hall Land, seen from the south-west. The cape is marked A^1 on Fig. 12. O. I. = Offley Island Formation; C. T. = Cape Tyson Formation. For full explanation see the text p. 36.

Thule Expedition published the first structural sections through the fold belt. Conspicuous in these are the indication of "gneiss" in the core zones of some major folds. Thus along the coast of Hall Land, gneiss units were indicated at the base of the succession passing upwards into low-grade metamorphic, folded sandstones. KOCH's original section and a photograph of the same coast are given here for comparison (Fig. 12).

The close portrayal of the structure of the coast by the sketch is well apparent, but the interpretation of the composition of the massive basal part of the succession is incorrect. The conspicuous dark and light coloured formations at the base make up a fossiliferous carbonate group of late Ordovician to Silurian age (DAWES, 1971).

The *2nd Thule Expedition* passed this part of the coast by dog-sledge on the 2nd May, 1917 in appalling weather conditions during an arduous 14 hour journey from Halls Grav to Kap Sumner (the northern point of Hall Land)(RASMUSSEN, 1927, p. 47). KOCH did not get the opportunity to examine or to sample the base of the succession. However, he chose to make an assumption about the presence of gneiss that turned out to be

incorrect. In 1922, KOCH was able to study the geological conditions of northern Hall Land during several days in May and June (KOCH, 1926b, p. 171–178) and consequently discovered his earlier misinterpretation.

Thus, in the description of the fold belt in "Stratigraphy of Greenland" KOCH (1929b, p. 280) states that "in the northern part of Hall Land even fossils occur," that is, in the carbonates at the base of the succession, and that "it is possible, in the folded mountains, to distinguish the Offley Island formation from the Cape Tyson formation" (see also KOCH, 1925, p. 275). A photograph taken from the sea-ice in 1922 (Fig. 13) shows the western part of the northern coast of Hall Land with this division marked. The boundary indicated is that between the lower carbonate group and the overlying darker, clastic group, mainly intercalated sandstones and shales, as illustrated in figure 12. Perhaps understandably, but nevertheless unfortunately, it so happened that the gneiss misinterpretation of 1917 still figured in the literature many years after the *Bicentenary Jubilee Expedition*, for example in TEICHERT's (1939, fig. 9) compilatory paper.

The reinterpretation of the Hall Land section, interesting in itself, is also important since it is the earliest record suggesting direct correlation of the upper part of the Silurian carbonate platform sequence (KOCH's Cape Tyson Formation, east of Kap Tyson, 1929b, p. 240) with certain clastic deposits of the fold belt — a correlation for which there is now faunal evidence (DAWES, 1971, 1976). Furthermore, the bluff-shaped carbonate mass within the uppermost formation of the carbonate group at Kap Porter, seen clearly at position A^1 in figure 12, resembles a reef, that from faunal evidence elsewhere in the carbonate group in northern Hall Land, is of probable Llandovery age. The occurrence of such a bluff-forming carbonate mass within the fold belt may well have been an important factor in KOCH's assignment of this carbonate section to the Offley Island Formation.

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THE CAPE YORK DISTRICT.

Topographically and geologically mapped 1922–23 by

Lauge Koch

ca 1:1014000

Fault line ——————

" . " ——————

72° 70° 68° 66°

78° 77° 76°

Sunrise Pt
Foulke Fj
Etah
Pandora Hbr
C Alexander
Prudhoe Land
Somtag B
C Chalon
Morris Jesup Gl
C Robertson
Robertson B
Mc Cormick B
Red Cliff Pen.
Bowdoin B
Hubbard Gl.
Murchison Sd
Inglefield Gulf
Kangerdluksuak
Hakluyt I
Herbert I
Northumberland I
Whale Sd
Olrik Fjord
Barden Bay
Steensby Land
C Parry
Booth Fj
Carey Isl
Saunters I
Wolstenholme Fj
Thule
Nunatarssuak
Wolstenholme I
C Atholl
De dödes Fjord
Parker Snow B
Conical Rock
C York

Legend

		Land ice
		Quaternary
Late Algonkian	Thule Formation	Diabase
		Dolomite and Shales
		Upper Sandstone
		Lower Sandstone
Archean - Algonkian		

WASHINGTON LAND

Topographically and geologically mapped 1922

by

Lauge Koch

1 : 500000

10 0 10 20 km

67° 65° 63°

81° 45' 30' 15'

C.Defosse
Joe Island
C.Morton
C.Lucie Marie
C.Handy
C.Maynard
Hannah isl
C.Bryan
C.Pusey
C.Schurz
C.Mc Ritchie
C.Field
C.Back
Carl Ritter Bay
C.Ulrich
C.Godfred Hansen
C.L.von Buch
Hans Isl.
Fossil
C.Schuckert
Bay
Graptolit Næsset
Pentamerus Mts
Alakatiak Fjord
C.Ressen
Franklin Island
C.Constitution
Mirage R.
C.Independence
Crozier Isl.
Lafayette Bay
C.Jefferson
C.Hamilton
Nicolaj Nielsen Coast
McAdams
C Madison
Morris Bay
C.Thorsen
Faith Gl.
Cecil Gl.
Hessels Fjord
JOHN BROWN ICE CAP
PETERMANN PENINSULA
KENNEDY CHANNEL
WASHINGTON LAND

Legend

- Land-ice
- Qauternary
- Silurian
  - C. Tyson Formation
    - Shales
    - Limestone
  - Offley Isl ..."
  - C. Schuckert ..."
- Ordovician

NORTH - GREENLAND

Topographically and geologically mapped
1917 - 21 - 22 by
Lauge Koch

- Land-ice
- Quaternary
- Carboniferous
- Caledonian Folding
- Silurian
  - Polaris Hbr. Formation
  - C. Tyson "
  - Offley Isl. "
- Upper Ordovician
- Cambrian and Lower Ordovician
- Late Algonkian — Thule Formation

ca 1: 2000000

10 0 100 km

50° 45° 40° 35° 30° 25° 20°

83°

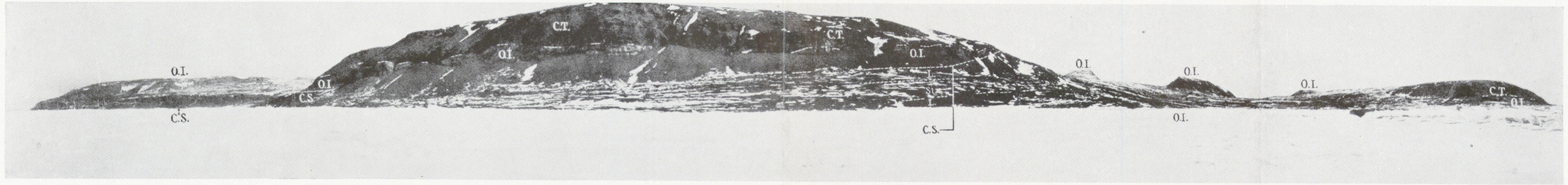
82°

81°

55° 50° 45 40° 35° 30°

C Bridgman
C John Flagler
C Morris Jesup
C Washington
C Hammock
C Mohn
Distant Cape
C Sabine
Beaumont I.
C Brevoort
C Bryant
C Heiberg-Jürgensen
C Troedsson
C Lucie Marie
Falkon Mts
Polaris Hbr.
C Tyson
Offley I.

ROOSEVELT RANGE
FREDERICK E HYDE FJ.
G.B. SCHLEY FJ.
HANS EGEDE MTS
NANSEN LAND
PEARY LAND
FREUCHEN LD
NARES LAND
VICTORIA FJ.
HENDRIK I
SHERARD OSBORNE FJ.
ST. GEORGE FJ.
RYDER GL.
HALL LAND
NYEBOE LAND
WARMING LD
WULLF LAND
BJØRNDALSBRÆEN
HERLUFSHOLM STRAND
ERLANDSEN LD
MELVILLE LD
Wandel Valley
INDEPENDENCE FJORD
C CHRISTENSEN LD
HAGEN FJ.
VILDTLAND
MYLIUS ERICHSEN LAND



View of the coastal cliff south of Kap Schuchert, Fossil Bugt, Washington Land, seen from the west. This section is Koch's "best locality" for the Cape Schuchert Formation (C. S.). O. I. = Offley Island Formation; C. T. = Cape Tyson Formation.
For full explanation see the text pp. 30–32.