

MEDDELELSER OM GRØNLAND

UDGIVNE AF

KOMMISSIONEN FOR VIDENSKABELIGE UNDERSØGELSER I GRØNLAND

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CONTRIBUTIONS TO THE GLACIOLOGY OF
NORTH-WEST GREENLAND

BY

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WITH 3 FIGURES IN THE TEXT,
6 PLATES AND 3 MAPS

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I. INTRODUCTION

The observations described in this paper were made during the course of a year spent in Thule, North-West Greenland, by the writer, while a member of the 1937—38 British Expedition led by Mr. David Haig-Thomas. Mr. R. A. Hamilton was the third member of the Expedition. Our main work lay in Ellesmere Land, but for various reasons it was more convenient to winter in Greenland, and actually only two months—April and May 1938—were spent in Ellesmere Land. The scientific work in Greenland, however, had always to be subordinated to such considerations as establishing depôts, laying in a good stock of dog food for the winter, and other preparations for the main journey in the spring of 1938. In addition the unusually poor summer of 1938 made it impossible to do much after the middle of July.

These disadvantages were offset to a certain extent by the presence of an United States Expedition at Etah, led by Mr. C. F. MacGregor of the U. S. Weather Bureau. Their generous hospitality gave us in effect a northern base at which we could recuperate both before and after our journey to Ellesmere Land. Their help also made possible the journey on the Greenland icecap, the results of which form the first section of this paper; the original idea came from them. However, it must be remembered that all the observations recorded here were subsidiary to the work in Ellesmere Land, and that very little in the way of comprehensive plans for them could be made. I hope that this will extenuate their rather haphazard nature, which would otherwise be difficult to excuse.

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II. JOURNEY ON THE GREENLAND ICECAP EAST OF ETAH

The part of the Greenland icecap lying between Inglefield Gulf and the Humbolt Glacier basin has been traversed more often than any other, but until 1938 there was surprisingly little information available about its configuration. The journeys previous to this date have been fully described by Dr. Lauge Koch, and need only be briefly summarized here. For further details the reader is referred to his account (15).

The first journey made by a white man on the icecap here was that of Hayes in 1860 (11). He travelled for six days and claimed to have penetrated 60 miles (100 km), and to have reached a height of 5000 feet (1500 m). No astronomical sights are mentioned in his account, and the route described in it differs considerably from that shown on his map. It is probable that the journey was not so long as he claimed.

Next came the long and enterprising crossings of the icecap by Peary in 1892 and 1895 (23). In these two years he sledged from McCormick and Bowdoin Bays respectively across to Navy Cliff and back. In 1894 he made a journey of about 120 miles which was cut short by the very cold conditions experienced. At the furthest limit of this journey he made a depot which was never afterwards found. Unfortunately no adequate account of these journeys from the scientific point of view has been published, and no map of them with reliable heights exists.

In 1912 Knud Rasmussen crossed from the Clements Markham Glacier to Navy Cliff in search of Mylius Erichsen's party, and returned to Thule. A very good account is given by him and Herr Peter Freuchen, with astronomical positions and computed heights of each camp on the outward route. The camps were, however, very widely spaced owing to the high rate of travel, and only five of them lie within the area with which we are concerned. Unfortunately no heights could be measured on the return because their aneroid had been spoiled by water during the summer on the east coast (24, 7).

By far the most important work on the icecap in N.W. Greenland was that of Dr. Lauge Koch in the years 1917—1921. He made a series of traverses of Prudhoe Land and along the northern edge of the icecap

from Etah to the September Lakes, with frequent height observations and astronomical positions (15, 16, 17). Journeys were made at this time by Knud Rasmussen also, (25) but they were too far north to lie within our scope.

Except for those of Koch and Hayes, all these journeys were made with the object of reaching the east coast in the neighbourhood of Peary Land. The icecap was regarded rather as a highway than as an object of research, so that astronomical sights and height determinations were reduced to a minimum. It was however known at the time of our Expedition that the interior icecap in this region was unbroken by any nunataks, except possibly between the outward and returning routes of Knud Rasmussen in 1912. Furthermore, it did not seem probable from a consideration of the structure of the fringing land areas that there would be nunataks there.

On our return from Ellesmere Land at the end of May we were therefore considerably surprised to hear that a member of MacGregor's Expedition had sighted land in the interior of Greenland east of Etah. During a flight over the icecap north-east from Etah, Commander I. Schlossbach thought that he had seen a nunatak in about Lat. N. $78^{\circ} 30'$, Long. W. 63° . Unfortunately a layer of low cloud covered the coast and the extension of this land westward, so that he could not be sure whether it terminated on the icecap, or was merely a continuation of the land at the head of Inglefield Gulf. Considering that more definite knowledge about the nunatak would be of great value, he and I made preparations for another flight over it on a clear day, but owing to an accident to the aeroplane this became impossible.

We then decided to sledge in as far as its supposed site, and if we found land, to determine its position and extent as accurately as possible. The journey could not be a long one, as he could not be spared from work on the ship for more than a fortnight, and MacGregor did not wish to stay after the ice had gone from the harbour, which was expected to happen in early July.

We therefore set out on the 18th of June with dog food for fourteen days, and man food for a few days longer. Owing to the short time available, the sledge was by no means heavily laden; and we had eight fairly fit dogs. Considerable difficulty was experienced in getting up the Brother John Glacier at the head of Foulke Fjord, and we should have taken much longer without the help given to us by members of the MacGregor Expedition, and the three Eskimos who had come from Sioropaluk a few days before. Above the region of thaw, conditions were very much better.

We travelled by night, from about eight p. m. local time to about six a. m. The temperature during this period of the twentyfour hours

varied between -8° C. and freezing point. Unfortunately we had only a thermometer reading up to -5° C., so that accurate observation of the temperature was impossible unless it was low.

The weather was poor almost the whole time, with low cloud and often snow, but there was seldom much wind, and it was never more than 10 m sec (about 20 m. p. h.). Such wind as there was came usually from the South or Southwest. During this time almost continuous sunshine was recorded at Etah. The Eskimos had told us to expect such weather on the icecap, and it can therefore be regarded as normal for the locality at this time of the year. On only one day did we fail to travel, and then it was because visibility was exceptionally bad when we were in the area where the nunatak was thought to lie.

The normal method of travel was for each of us in turn to ski in front, while the other skied with the sledge and whipped and shouted to the dogs when necessary. Without skilled driving the attraction of a man in front enabled us to keep up a steady four kilometres per hour¹), and this was occasionally increased to seven.

We steered by means of an aeroplane compass, (British Admiralty, type P4), as used by all recent British polar expeditions. It was lashed to the top of the sledge load, and checked by hand compass several times a day. In view of the difficulties experienced by previous travellers in this region, it is perhaps worth recording that we had very little trouble in keeping a constant course in spite of the prevailing misty conditions. It must be admitted, however, that the compass sometimes appeared to vary considerably. On one occasion, shortly after leaving Camp VI, (see Map I) it actually turned through over ninety degrees while the sledge travelled about a kilometre in a straight line. I was by the sledge at the time, and I am quite certain of the facts, because although there was unfortunately no sun to give an absolute direction, Schlossbach was considerably more than a kilometre in front when this movement began, so that there was no question of my following him round in a circle. In addition, a slight wind and the sastrugi visible on the surface were enough to make such a large unconscious change of direction quite impossible. It must be presumed that we passed near a large buried magnetic body.

Distance was recorded by sledge wheel, until about eighty kilometres from Etah on the return journey, when the wheel was unfortunately broken beyond repair. By that time, however, we had a fairly good judgement of speed, and the estimated distances from there to Etah check very well with the astronomical observations.

These were made with a Wild universal theodolite, the property of the Royal Geographical Society. Time was kept by a half chronometer

¹) Eight kilometres are equal to approximately five English statute miles.

watch lent by the British Admiralty. It was not considered necessary to take a time signal set, and the following figures for the chronometer watch rate would appear to justify this decision.

		Secs. per Day
Rate from two time signals at Etah before the start:	Gaining	2.5
Rate from two time signals at Etah after return:	—	2.8
Gain during intermediate period of 18 days, was		
53.7 seconds, giving a rate of:	—	3.0

When one considers that in this latitude about 10 seconds of time correspond to one kilometre, it can be seen that no fears need be entertained for the accuracy on this count.

After adjusting the traverse to the astronomical observations, I am sure that the error of the final route marked on the map does not exceed 8 km anywhere, and only approaches this figure near the eastern end. Here the icecap is substantially the same height over a large area, so that such a large error does not seriously affect the value of the results. During the whole journey no nunataks were seen other than those shown on the existing maps. We traversed in all a distance of about five hundred kilometres (three hundred miles).

We covered fairly thoroughly the region in which the nunatak seen by Schlossbach was supposed to lie, and general considerations make it improbable that such a nunatak should exist, unless it takes the form of a large mountain, which would then be visible from a long distance away.

Schlossbach was alone in the aeroplane when he saw this land, and therefore was unable to make any observations for drift or land speed, although he had some idea of the winds at the height he was flying, from pilot balloon observations at Etah. He could not, therefore, be certain of his position; after our journey he considered that what he had seen was the land at the head of Inglefield Gulf.

In compiling Map I. I have taken the coast and icecap edge entirely from Koch's large scale map (17), with the exception of one or two details enumerated below. The most important is the part of the icecap edge between the ice-filled valley north of Robertson Bay and the September Lakes. The small number of our astronomical positions makes me hesitate to suggest an error in Koch's observations, but I am almost certain that the discrepancy is caused by one or other of the sets of observations being wrong, and not by a retreat of the ice. My reason for this is that we saw two lakes at the edge of the ice in just the positions they are marked by Koch, one on each side of this valley, and it is reasonable to suppose that they are the same. From the icecap we did not see any other lakes further away which might have been those marked

by Koch. In addition, there is no evidence of a retreat of the icecap on anything approaching this scale elsewhere in this region; and it appears very improbable that it should have occurred here.

Our observations for this part of the icecap edge consisted of two latitude sights by the sun, one at the midnight halt on June 19th.—20th, and the other at midday at Camp XII on July 1st. Longitude in both cases was by dead reckoning, and agrees well with Koch's. From the first position, a rough sun azimuth observation gave the bearing of the icecap edge, which was clearly visible. The error in azimuth of this observation cannot possibly be more than five degrees, and is probably of the order of a few minutes of arc. The icecap edge appeared to be almost straight, and was behind, i. e. south-east of this ray all the way along. The site of the second astronomical position was a point well down on the northern end of the valley, estimated to be certainly not more than 5 km from the ice edge. According to Koch, the edge of the icecap is more than 14 km to the north at this point.

In answer to a request for more details of his work, Dr. Koch generously replied that he considered it very probable that his own observations were at fault. They were all taken under extremely difficult conditions, and without any satisfactory control on the watch times, as he had no wireless set. He sums up the matter as follows—(Translation from the original Danish):—"It is therefore quite possible that my icecap edge lies too far to the north, and that your observations are more nearly correct. My September journey was my last and only chance to fix the ice edge, and I can easily imagine that my material is a little uncertain, because of the advanced time of the year, and the very cold conditions."

The final decision rests with future surveyors in this region, but it is justifiable to say that probably most of the discrepancy between the two positions of the ice edge can be put down to errors in Koch's observations, due to the difficult conditions in which they were taken, and particularly the impossibility of keeping correct time without a wireless set. In my opinion the discrepancy is not, in any case, due to a retreat of the icecap edge.

The other detail in which we differed from Koch was the head of the Verhoeff Glacier. We appear to have passed right over two nunataks which he marks there, and we must place the head of this glacier several kilometres to the south of his position.

The heights were measured with a single aneroid, the property of the Royal Geographical Society. The limit of this aneroid was 26 inches, corresponding to a height of 5,000 ft., (1500 m). By adjustment it was made to read approximately 4 inches above normal during the part of the journey in which it would otherwise have been working outside

its limit. Careful tests which have been carried out by the British Meteorological Office since my return to England indicate that these readings, when adjusted for the change of zero, were not in error by more than .05 inch. Dr. C. E. P. Brooks, of the Meteorological Office, was kind enough to undertake the whole computation of the heights measured on this journey, and in his opinion their probable error is of the order of 30 metres, so that we can say that it is unlikely that the heights are wrong by more than 50 metres. This comparatively high accuracy is very largely due to the excellent control furnished by the continuous recording barograph belonging to the MacGregor Expedition at Etah, and to the steadiness of the weather during the course of the journey. Pressure at Etah during the whole period varied only between 29.85 and 30.27 inches.

The only other heights which I have used in compiling the accompanying map are those given by Peter Freuchen from his journey with Knud Rasmussen in 1912, and those given by Koch (7, 17). I have not hesitated to reject even these where they conflict with ours, because our good fortune in having such excellent control for our heights gives them unavoidably much greater weight. No previous height readings in this area were controlled at all by simultaneous sea-level observations, and may therefore easily have been error by over a hundred metres. In the circumstances the agreement of these previous heights with ours may be considered extraordinarily good.

The main fact which our traverse has brought out is that there is evidently a much greater extension into this area of the central ice plateau than was previously supposed. At our highest point (just N.E. of Camp VI), we reached 1810 m above sea-level. From a consideration of the slope in that neighbourhood it is reasonable to suppose that the 2,000 m contour cannot be much more than 25 km to the East of this point, while previous maps of this area (8, 15) show it as nearly 200 km away. A corresponding shift of the 1500 m contour is naturally also involved. The cause of this error in the previous maps was the lack of sufficient data in the most important part of the region. The part containing this high ridge lies rather to the south of the area, and no heights were available from there, though there were several further north. This ridge had only been crossed once, during the return in 1912 of Knud Rasmussen's party. They were unable to make any height measurements because they had unfortunately broken their only aneroid during their summer on the East coast.

III. SURFACE CONDITIONS ON THE ICECAP

Before describing the surface conditions experienced on this journey, I shall give a short account of those we found on this part of the icecap on incidental journeys between Sioropaluk in Robertson Bay and Etah in the spring and early summer of 1938. The first of these was in the middle of March, when we first came to Etah over the icecap, having ascended by the Clements Markham Glacier. The temperature for most of this journey was about -30° C., and the snow almost everywhere very hard. While climbing up this glacier, and particularly at the top, we had to cross a series of very steep, hard sastrugi, nearly a metre high (Cf. Peter Freuchen 7). Outside its drainage basin, the surface was typical of icecap conditions at this time of the year, that is to say there were patches of loose snow, and patches of thin crust, all overlying an old hard crust which was occasionally bare. Nowhere on the plateau did the height of the sastrugi exceed a few centimetres, and ski could be used with comfort and advantage. When we passed the head of the Morris Jesup Glacier, and when finally we came to the drainage basin of the Brother John Glacier, these sastrugi again increased in size until they reached a height of half a metre. From there to the bottom of the glacier the surface was badly hummocked, and many of the tops of the hummocks were bare of snow. This was not surprising, since there was a nearly continuous wind, sometimes reaching 30 m sec (60 m. p. h.), blowing down this glacier in the winter months, so that the fjord ice below was almost completely bare of snow. (Plate I.) According to the Eskimos these conditions are quite normal in the winter in this region (Cf. Koch, 15, p. 354).

The next traverse we made of this icecap was in the beginning of June, when I had to go to Sioropaluk for a few days, and we found conditions little changed, except that the snow was naturally not so dry, nor the drifts so hard. The temperature was then from -5° to -10° C. The sastrugi at the heads of the glaciers were still there, though not quite so high. When the wind, which is an almost continuous feature of the weather on this icecap, is blowing, it is directed down

all the glaciers from Etah to Neqe with a great funnelling effect which seems to be particularly strongly developed where the glaciers debouche from the main icecap.

On the return journey to Etah from Sioropaluk on June 14th, we were forced to camp on the Meehan Glacier because a wind of this kind was blowing. At this time the surface had settled down considerably in the lower parts of the glaciers, and there was no drift; but on the col, where the glacier leaves the icecap, we could see a great deal of drift, and there can be little doubt that the wind was stronger on the col. On this crossing we found that the sastrugi had become considerably smaller. On Brother John Glacier the hummocks were as large as before, because they were formed almost entirely of ice. The decrease in size of the snow sastrugi was due to the comparative infrequency of the wind, the falling supply of drift resulting from the settling down of the surface with the coming of warmer conditions, and the effect of the sun on the sastrugi themselves. On the Brother John Glacier the hummocks, which were formed of ice, were naturally scarcely diminished at all.

Up to this time no signs of thaw had been observed above 600 m, and on the Brother John Glacier there was very little sign of it even down to sea-level. On the 18th of June, when we made our last ascent of this glacier, the snow was still lying down to sea-level, but only in the gullies between the hummocks. The snow was soft up to a height of about 1,000 m, which we reached at 10 p. m. local time (Plate 2). Here a crust had formed, and we travelled on dry snow from this time until on July 1st we came down again to thaw conditions near Inglefield Land, again about 1,000 m up. On the night of June 28th—29th, however, at a height of about 1400 m, we had a fall of new snow which was at a high enough temperature to stick to our skis, and make the use of wax very desirable. Usually in the daytime, when we were not travelling, the snow would be soft, but no water was seen on the surface except where dark objects, such as the tent, greatly increased locally the effect of the sun's rays. No wind stronger than about 10 m sec (estimated) was experienced, and no sastrugi higher than a few centimetres, except on the slopes just above Robertson Bay. No crevasses were seen above a height of 1,000 m.

On our return on July 2rd, the Brother John Glacier had undergone an astonishing transformation. During nearly the whole time we had been away sunshine had been recorded at Etah, and presumably therefore the sun had been shining on the glacier also. It was bare of snow to a height of 700 metres, (Plate 4), and intersected by innumerable streams. At a height of 1,000 m we found streams running, though here they were still in water-soaked snow, which was never more than a metre, and usually about half a metre, deep. At the snout of the glacier, down

the western half, ran a stream in a gulley about 15 m deep, which had been choked by snow a month before, and had been the route by which we had climbed up on the first journey to Sioropaluk. This stream can be clearly seen in Plate I, and also in Koch's photograph of the glacier taken in about 1916. (Koch: 15, p. 269).

I had had some previous experience of summer travel on icecaps, and it was interesting to compare the conditions we now saw. In 1935—36 I spent a year in North East Land, Spitsbergen, (Lat. 80° N.), and travelled almost continuously on the icecaps there in the summer of 1936 (9).

Conditions were very much the same, except that the thaw occurred in North East Land nearly a month later than in north-west Greenland at the corresponding heights on the icecap, and it was considerably more marked in its effects. This retardation I ascribe to two causes: first the colder summer weather, and secondly the greater snowfall in North East Land. In Greenland in 1938 there was sunshine throughout nearly the whole of May, and, except in the interior, through most of June also. In North East Land in 1936, on the other hand, we had practically continuous snow storms in May and the latter half of June, so that the sun did not begin to work on the surface until the beginning of July.

The snowfall in this part of Greenland was difficult to estimate because of the prevalent wind. I should reckon the winter's accumulation at about half a metre, and certainly the year's layer of snow on the Brother John Glacier was not, on the average, more than a metre thick, though this of course is only an estimate. In North East Land, the accumulation due to drift and precipitation in the middle of the icecap in 1935—6 was 160 cm. (20). On the margin it was certainly more, for the flag poles two metres high, erected on one of the glaciers in August 1935, were quite buried by June 1936. I saw nothing in Greenland of the deep, almost impassable morasses which were experienced there (9, p. 296), and which Martin Lindsay found further south in Greenland in 1934 (18). It must be remembered, however, that we left the icecap early in July, and that the thaw may be supposed to have continued for at least another fourteen days, and possibly for as much as a month. As late as August, 20th in 1917, Knud Rasmussen and Koch experienced bad thaw conditions on the icecap east of the Humboldt Glacier (25); there is, however, some reason for supposing that 1917 was an unusually warm season.

I realise that these notes are rather superficial in the light of recent developments in glaciology, and my excuse must be the short notice at which the journey had to be undertaken. Our instrumental equipment was quite inadequate for detailed research, and we had in addition

little time to spare from travelling, because of the limited period at our disposal. We had to travel as fast as we could during that period, in order to achieve the main purposes of the journey, which were to find out definitely if there was a nunatak in this area, and to secure a good series of heights. Modern refinements of glaciological research were thus impossible for us, and I hope that in their place these rough notes of the conditions encountered will not be entirely without value.

IV. SURVEY OF WOLSTENHOLME FJORD

Previous Surveys.

It would be beyond the scope of this paper to give in detail the history of the exploration of North-West Greenland, or even to enumerate the many visitors to so small a part as Wolstenholme Fjord. We can, however, give some account of the successive surveys of the fjord. It was first discovered in 1616 by Baffin and Bylot, and named after one of their supporters, Sir John Wolstenholme (3). It was rediscovered by Sir John Ross on his famous voyage in 1818, but was not entered (27). In 1849, Captain Saunders, in the *North Star*, wintered in the bay which bears that name. (Saunders Island, at the mouth of the fjord, was called after him.) The Master's Assistant, J. F. R. Aylen, made a map of the whole fjord, which was a great advance on anything done up to that time (2). The chart was never published as a whole, which was unfortunate, for although the head of the fjord was not very accurate, this chart was important because the three glaciers were shown for the first time. North Star Bay itself, was however, carefully mapped, and a reproduction of his survey, with its several soundings, is given on the present day British Admiralty charts (1). It is curious to find that, although the shape and position of this Bay, and the height of Mount Dundas (Umanak) are quite accurate, this inset, as given, is three times too large. The depth of the bay is shown as some six miles, instead of two.

In 1850 Lieutenant J. Elliott, of the *Assistance* (Captain Ommanney) made a rough survey of Wolstenholme Fjord (5); but this was considerably less accurate than that made by Aylen.

In 1852, Commander E. A. Inglefield, in the course of his very successful voyage to Smith Sound, sailed round the shores of Wolstenholme Fjord, and improved considerably on Aylen's chart (12). On his chart he shows also a special large scale inset of the anchorage in North Star Bay. This appears to have been largely copied from Aylen's survey, but the scale on it was now given correctly for the first time, though it was never corrected on the Admiralty charts. He named Cape

Abernethy and the Manson Islands on the northern side of the fjord entrance.

Peary, wintering from 1892 to 1895 in Inglefield gulf, was too far north to make any detailed study of Wolstenholme Fjord, and the same applies to the geologists Chamberlin and Salisbury, who accompanied his relief Expeditions in 1894 and 1895 (23, 4). However, he named for the first time the glaciers at the head of the fjord, calling them after Moore, who was a supporter of the Expedition, and after Chamberlin and Salisbury. It would appear therefore that the present names for these glaciers: Moltke, Knud Rasmussen, and Chamberlin respectively, are incorrect, but they have been in common use now for so long that it might cause inconvenience to change them back again. These altered names were due to Mylius Erichsen, leader of the Danish Literary Expedition of 1902, who spent the summer in this region (6). He made no contributions to the cartography of the fjord. The first two were, of course, called after members of his expedition.

Finally, Dr. Lauge Koch made in 1916 a detailed survey of the fjord and the land surrounding it which practically superseded all previous work (17). His map showed nearly all the main features of the district in great detail, though it was not accurate to the published scale of 1:300,000. The question of its accuracy is discussed in a later section.

Aims of the 1937—38 Expedition.

When, therefore, our Expedition arrived in Thule in 1937, it was evident that we should achieve little of value by attempting to cover a large area with a sketch map, and it would be better to concentrate on the regions where accurate mapping was required, and to survey them on a large scale. The most important of these was the edge of the icecap; especially the glacier fronts. We suspected that before many years had elapsed the whole country would be mapped accurately with all the resources of the Danish Geodetic Survey, and it therefore seemed of great importance to fix accurately the present positions of these changing features. In this way we should provide the basis for an interesting and reliable comparison when the later survey should come to be made.

The second region where accurate mapping was specially desired was the area of lakes behind Thule, which were known to be the breeding grounds of the Greater Snow Geese (*Chen hyperboreus nivalis*). These were Haig-Thomas' special study, and he wanted a detailed map of the lakes so that the nests and feeding grounds of the birds could be accurately plotted. For various reasons the biological part of this work was unfortunately never carried out, but the map was made and is available for the use of biologists visiting this area in the future.

One of my main objects was to establish a reliable astronomical position in the neighbourhood. We appear to have been the first expedition visiting the region equipped with an accurate instrument, with a wireless set, and with the time to carry out the observations. I understood from Hr. Henry Mortensen, a member of the Danish Polar Year Expedition to Thule in 1932—33, that they took a few observations of the sun, but it was not part of their official programme and no results of great accuracy were obtained.

The Survey Work.

The work finally accomplished consisted of:—

- (1) An Astronomical fix at Thule.
- (2) A triangulation of the inner part of Wolstenholme Fjord with nine occupied, and five intersected stations.
- (3) An accurate map of the coast as far west as Thule on both sides of the fjord, with special concentration on the three tidewater glaciers, and detailed mapping of some of the surrounding land.

(1) The astronomical observations were made with a Wild theodolite, the property of the Royal Geographical Society. They consisted of 60 observations of stars, 20 for latitude, 18 for longitude, and 22 for position, giving as result:—

Lat. $76^{\circ}34'01''$ N., Long. $68^{\circ}48'37''$ W.

The probable accuracy of the fix was about $3''$ of arc, or roughly 100 m. Considering the number of observations it is not very high, but this may be fairly ascribed to the comparatively difficult conditions and the probably anomalous refraction resulting from temperatures down to -20° F. (-30° C.), in which the observations were taken. The effects of refraction were eliminated as far as possible by taking batches of four stars, equally distributed in azimuth, and of roughly equal altitude, in as short a time as possible. Unfortunately, stars of greater altitude than 44° could not be observed owing to difficulties with the lighting system, which was improvised. In addition, all observations had to be made with the circle to the left. The proper lighting was not available when we took the theodolite from England.

I took all the observations myself, and Hamilton recorded all except four, which were done by Haig-Thomas. Time was kept by a half chronometer watch worn in the recorder's clothing except at the moment of observation. This watch was checked at least once a day by wireless time signals, and the recorded times were well within the accuracy given by the observations themselves. The Scientific Computing Service, directed by Dr. L. J. Comrie, worked out the results.

The observations were taken a few yards from the house at Thule lent us by the Greenlander, Isak Kristiansen, then Udstedsbestyrer of Savigsivik. Hamilton built a large cairn on the site of the observations, surrounding a wooden pole, and we left in this cairn a short account of the work done there.

It may be worth mentioning that, in spite of the low temperature in which the observations were made, no special precautions were taken, or serious discomfort involved. The work was done only in calm weather; by wearing the normal winter sledging dress of furs, and thin fur mitts, with a separate forefinger, we were able to observe for half-an-hour or so at a time without suffering from the cold. Naturally the proximity of a house in which we could get well warmed before and after the work, contributed greatly to our comfort.

(2) The triangulation of Wolstenholme Fjord was rough, but the relative error of the positions should be not more than ten metres. The methods used were the same as I had employed in North-East Land in 1935—36, and have been fully described elsewhere (30). Cairns about one and a half metres high mark all the occupied triangulation points except the point 525 m south of the Moltke Clacier. The heights of these points were measured to the nearest metre, and may be taken as having an error very little in excess of this. In this connection I may note that Hr. Mortensen told me that the Polar Year Expedition measured the height of Mt. Dundas with the same result, to the nearest metre, as we obtained.

In addition to these marked and occupied stations, there were a number of points intersected from them, which were used as control for the plane table, and which are shown on the map. Their positions are probably in error by not more than fifty metres, and their heights by not more than ten metres. They could be used for detail mapping in this area on the same scale in the future, except that they may be difficult to identify. A list of these stations, with some indications of the accuracy are given in Appendix II.

Scale was given by a 385 m base measured with a steel tape on the flat beaches behind the hospital at Thule. This base was measured twice and appeared to have an error of about 1:50,000, giving an accuracy considerably in excess of that necessary for the scale of the map. It was extended by two not very well conditioned triangles, but the angles of these triangles were measured with extra care. Azimuth was obtained by a single series of observations of the sun outside our house at Thule, on the site of the winter star observations. It is probable that this is not very reliable.

(3) The coast was fixed partly by plane tabling, and partly by depression angles from the triangulation points. Great care was taken in

checking the fronts of the glaciers, and the error in the 1937—38 positions of these should nowhere exceed a hundred metres. A higher accuracy than this, relative to certain triangulation stations, was obtained by special photographs. These are dealt with in a later section. Other parts of the coast may have a slightly larger error. The detail survey was by plane table, and is accurate within the scale of the map, on the land east of Thule. On the opposite side of the fjord, which had to be surveyed rather rapidly, and in bad conditions, there may, however, be errors as large as half a kilometre. They should reach this magnitude only at the limits of the map to the North and East, which were surveyed entirely by intersection from rather short bases, without actually visiting the ground. The 1937—38 map has not been joined up to that published by Koch in 1932, as the increased scale and more accurate methods we were able to use made any satisfactory connection impossible. The environs of the Salisbury glacier have, however, been sketched in from Koch's map and my own rough observations, in order to illustrate certain points in this paper (p. 29).

Mr. Wordie, who visited Thule in 1937, and made a survey of the Cary Islands (29), gave us some photographic copies of Koch's map of this area, and we were able to compare it with our own observations on the spot. It must be admitted that we did not find it entirely accurate. This is not meant in any way as a criticism of Dr. Koch's work, which was carried out under quite different conditions and intended for a different purpose from our survey. He covered a very large area, and was naturally forced to use rapid and rough methods in order to finish the work in the time at his disposal. It is worth recording, I think, that in all our journeys in this part of Greenland, except north of Etah and in the interior, we found his map extremely good; and without instrumental methods it was almost impossible to detect any errors, so that it served admirably its main purpose as a guide to the country. We found in the nunataks on the north side of the fjord, which he had not visited, considerable differences, but some of these at least are certainly due to changes which have occurred since Dr. Koch's map was drawn.

Apart from these, the only important discovery we made was that of a small island or rock about 11 km North-West (true) of Thule, which had not been marked on any previous map, though it was, of course, known to all the inhabitants of the district. The approximate position of another small island just north of this, and the names of both of them were given me by Hr. Nielsen. The second island was probably hidden by icebergs when an survey was made. The submerged rock in North Star Bay, which appears only at low spring tides, had been observed

before (2), but we managed to fix it more accurately. It evidently forms the end of a submarine ridge forming a continuation of the peninsula Pitufik.

As we expected, therefore, our survey has not produced any startling discoveries; but it should be of some use until the Geodetic Survey can visit the region, and it will then afford an accurate basis for some interesting comparisons of the icecap edge.

V. THE MOLTKE GLACIER

1. Rate of Flow.

The data for measuring the flow of this glacier during 1937—38 consist of two photographs, taken from the same point (triangulation point 416 m) on the south side of the glacier, in September, 1937, and August, 1938, respectively. They were taken with a light photo-theodolite made from an Exaktar camera fitted with collimation marks, fixed above a Wild Theodolite. (A full description of this instrument will be given in the report of the Expedition on the work done in Ellesmere Land.) For both photographs the theodolite was pointed on the same azimuth, which made an angle of $105^{\circ}22'30''$ with the bearing to the cairn on the triangulation point 326 m. During the eleven months between the photographs, the camera had shifted slightly with respect to the theodolite, so that a small correction had to be made to the second photograph, whose orientation was different by about $20'$ from that of the first. This correction was made by comparison of the positions of land features identifiable in the two photographs.

Unfortunately, while taking the first photograph, the temperature was low enough to slow down considerably the action of the camera shutter, with the result that the negative was so badly over-exposed, that it is not worth reproducing. It has been possible, however, definitely to identify several crevasses in this photograph with some of those shown in that taken in 1938 (plate 5). The best examples of these are marked with rings in that photograph. By measurement from the photographs of the depression angles to these crevasses, their positions on the glacier have been found approximately. The furthest is about 5 km from the point of observation, and thus nearly in the middle of the glacier. It ought, therefore, to give a representative idea of the glacier's movement. The displacement of the image of this crevasse on the original negatives is of the order of $\frac{1}{2}$ mm, and the focal length of the camera is 7 cm. At a distance of 5 km we have therefore a corresponding movement of the crevasse itself of:—

5000 ($\frac{1}{2}/70$) m, or approximately 30 metres.

Measurement of the other crevasses gave a similar result.

The error of these observations certainly does not exceed 30 m, so that we may say definitely that the total movement of the southern half of this glacier during the eleven months was not more than 60 m, and that it may have been nothing at all. This appears to be a rather small movement, judging from the activity of the glacier, and the large changes which have taken place in its front in recent years. According to Kayser (13), Peary found the Bowdoin Glacier to have a movement of less than a metre per month, but I have no details of his observations. It is worth comparing with the movement of some of the glaciers of Northern West Greenland which were measured by Hammer and Steenstrup in 1880 (10, 28). The movement of these glaciers was found to be up to 15 m per day during April and May, or approximately 5 km per year if this movement was maintained. As will be brought out below, it is evident that the movement of the Moltke Glacier as measured by us, was considerably less than it had been during certain previous periods. Our measurements cannot be taken as representing the average rate of motion.

2. Movements of the Front.

The record of accurate observations of the front of this glacier begins with Koch's work in 1916, and no reliable or accurate records are available from before that date. Such accounts as there were have been dealt with adequately by Koch (15), and nothing would be gained by repeating them here. After 1916, we have an unusually complete record of the glacier's movements, considering its comparative inaccessibility. According to Koch, the glacier front in 1916 was formed of two tongues, separated by a wide bay about 2 km deep. The southern of the two tongues was the most active, but the whole glacier showed great signs of activity: calvings were frequent, and the northern tongue appeared to be afloat. The Eskimos told Koch that the glacier had been advancing up to this time, and it had been possible in previous years to sledge directly from Uvdle to the western headland of Nunatarssuak.

Koch observed the glacier again in 1923, when it had retreated very considerably. In his sketch (15 plate 3) the front appears as almost straight, and evidently the retreat had been most marked, as one would expect, in the two tongues. It was still impossible, however, to travel direct to the western end of Nunatarssuak.

Kolonibestyryer Hans Nielsen, of Thule, told me that the retreat continued until 1926, mostly at the northern part of the front. Since that year there has always been open water in front of the northern part of the glacier, because there is a very strong stream at that point, and this stream is generally supposed to come from underneath the glacier.

Pastor Olsen and some of the Eskimos were of the opinion that this stream came from de Dødes Fjord, over 50 km away to the South-East. I could not myself find any evidence for or against this startling suggestion, and I must admit that such an immense sub-glacial tunnel seems unlikely. It would be quite unparalleled anywhere else in the world, except during the formation of Jökulhlaups (21, 22) in Iceland, where the circumstances are rather different. The evidence for this suggestion (apart from the strong stream referred to), I understand to be something to do with the behaviour of seals and narwhals in this part of the fjord, and I am not at all qualified to judge it. The suggestion seems to me worth mentioning in view of the generally reliable nature of Polar Eskimo reports, and its great interest if it does happen to be true.

From 1926 until 1932 the glacier advanced, at first very rapidly. In 1928 the "Godthaab" Expedition visited Wolstenholme Fjord (26), and Magister Kiilerich was able to take a series of measurements and sketches of the glacier from the points above Uvdle visited previously by Koch. Hr. Kiilerich was kind enough to provide me with a copy of these original observations in order to supplement the short paper which he wrote on the history of the glacier up to that time (14).

After 1928, the glacier continued to advance until 1932, when, according to Hr. Nielsen, it lay roughly midway between the positions in 1916 and 1928. Thereafter the history has been one of retreat, which was still continuing, though much less rapidly, when we observed the glacier. The two photographs which gave the amount of flow during our stay also show that the glacier retreated approximately 150 m during the eleven months between their exposure (Plate 5).

A summary of these observations is shown in Map (III), and in Figure 1. The positions of the glacier front were plotted in the map in the following way. First, I drew from our map and photographs the positions in 1937 and 1938. Then from Kiilerich's observations, I plotted as accurately as possible the front in 1928. By comparison of his sketches with those of Koch, I then interpolated the positions in 1916 and 1923. After I had prepared the map so far, Hr. Nielsen sketched in what he considered were the positions in 1926 and 1932.

It will thus be seen that the results differ considerably in accuracy, but I doubt if they are anywhere more than a kilometre in error, and I am certain that the sequence of advance and retreat is correct. From the finally completed map I measured the area of the glacier tongue during the different years, and thus produced figure 1. The 1938 position is taken as zero.

These rather haphazard records raise several interesting questions which can only be answered by detailed and continuous observation of the glacier throughout a period of several years. It is evident that the

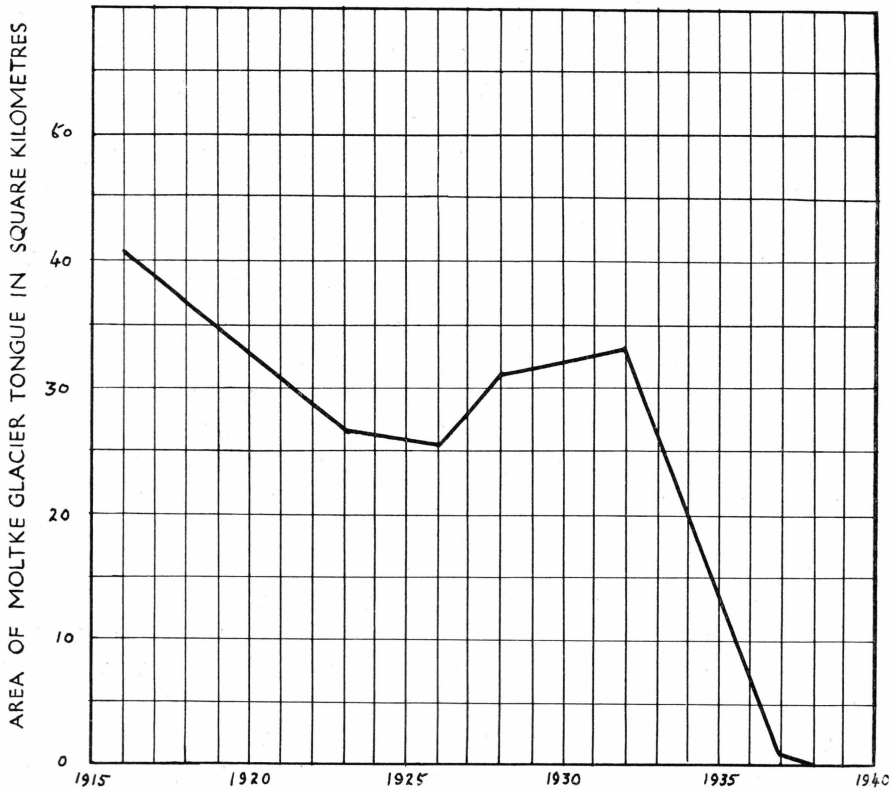


Fig. 1. Changes in the Moltke Glacier Tongue, 1916—1938.

glacier has something of a periodic movement probably more closely related to topography than to climate. From evidence which is dealt with more fully below, it seems that there has been a decided amelioration of climate in this region since about 1920. Yet during that time the glacier has undergone one considerable advance; while other glaciers in the neighbourhood have been almost stationary.

The two factors which are involved in these changes of the front's position are, of course, the rate of flow of the ice, and the rate at which ice breaks or melts off the front. Variation of either, or both, of these would be sufficient to cause the changes we have noted. Inadequate as the present records are, they do at least prove unequivocally that not only one, but both factors can vary considerably. We know that during the year 1937—38 the glacier did not flow more than 60 m. Yet, between 1926 and 1928 the front advanced over two kilometres, entailing an average movement of at least one kilometre per year. Again, in 1937—38 the actual length of glacier calved off was not more than 200 m, while for the previous five years the retreat was nearly a kilometre a year, and the actual calving may have been considerably more.

This variation in the rate of calving is evidently largely due to the size of the pieces calved rather than to their frequency. Pastor Olsen of Thule told me that much of the retreat of 1932—37 took place early in that period by calving off of huge tabular bergs. I never saw bergs of any size formed, though during the few days I spent near the glacier in September, 1937, and August, 1938, the calving of small pieces was very frequent, and sometimes continuously prolonged for several minutes.

Whether the glacier is aground or floating is obviously important in this connection. From my own observation, I would say that the glacier is now aground along most of its length, but I cannot be sure of this. Soundings along the front both near, and up to several kilometres away, would have been of great value, but unfortunately we were not adequately equipped for making them. At present there is available only the single sounding taken by the "Godthaab" Expedition in front of the southern tongue of the glacier. They found a depth of 150 m, which is scarcely sufficient to float the glacier, whose cliff has usually a height exceeding 30 m.

It is to be hoped that future expeditions to this region will be able to spare the time to repeat ours or Koch's observations, now that we have a respectable body of evidence about this glacier. Both the points which have been used for observations are only a few hour's walk or boat voyage from Thule, and the observations themselves would only take a few minutes. Perhaps also such an expedition will be better equipped than we were for carrying out a series of soundings in front of the glacier. Finally, when as must eventually happen, a regular meteorological station is established at Thule, one hopes that its programme will include frequent and detailed observations of the glacier flow and calving. These would entail little extra cost of time or labour, and their results would be of very great value to glaciology.

VI. THE KNUD RASMUSSEN AND CHAMBERLIN GLACIERS

(Plate 6).

1. Observation of the Rate of Flow.

The data for calculating the rate of flow of the Knud Rasmussen Glacier were as follows:—

Theodolite rays were taken to two solitary and very striking moraine cones on this glacier from a point on the hill bounding the Chamberlin Glacier on the West. From this point the approximate distance to the cones was taken from our map, and found to be 14 km. The angles were measured between rays to these cones and the ray to the triangulation station 405 m on the south side of the fjord, above the old Eskimo settlement at Uvdle.

The following results were obtained on September 18th, 1937:

Angle: Pt. 405 to first moraine cone	103°11'
— Pt. 405 to second moraine cone.....	102°14'
and on August 7th, 1938, eleven months later, the following:—	
Angle: Pt. 405 to first moraine cone	102°47'
— Pt. 405 to second moraine cone.....	101°52'

Thus the angular changes were 24 and 22 minutes of arc respectively, giving as mean 23'. At a distance of 14 km this gives a movement at right angles to the ray of:

$23 \times 14000 \times .0002909$ metres, or approximately 93 metres. The main direction of the Knud Rasmussen Glacier, and therefore presumably of its movement, makes an angle of about thirty degrees with this ray. Thus the displacement of these cones along the probable line of movement is roughly double the component at right angles to the theodolite ray. The displacement was therefore about 186 m. This was in the course of eleven months, so that we may take the movement for the whole year as being 200 m, with an error probably not exceeding fifty metres. There are, however, certain facts which seem to conflict with this result. They are dealt with below.

The observations to these cones will have a greater value than that represented by these calculations alone, if they can be repeated by future visitors to this district. Unfortunately no other rays were taken to the cones, which are not therefore accurately fixed in position, and it is only by repeating the observations which we took, from the same spot, that a good comparison will be obtained. A fix of high accuracy (to a few metres) would serve, if made from our triangulation points. With this idea in mind a cairn was built on the point where the observations were taken, and the following directions for finding this cairn are copied from my angle book:—

“Follow up the stream which runs down the west side of the Chamberlin Glacier, until it begins to run in a gorge between the screes and the glacier moraine. The screes have here a little cliff about two metres high. After climbing up this, one finds a steep slope, which eases off after about 50 metres. Above can then be seen some slate outcrops which form the obvious site for a base overlooking the Chamberlain Glacier. The cairn will be found on the north end of one of these.”

The approximate site of the cairn is marked on the map; it was about 100 m. above sea-level, and was thus about a third of the way up the slopes of the hill.

No instrumental observations of the flow of the Chamberlin Glacier were made, but we have some idea of what it was doing during the year 1937—38. While near the glacier in September, 1937, I noticed that the western corner of the glacier snout was tilted up as though it was being pushed over a submarine hummock. The tilt was about fifteen degrees, and at the front several metres of the lower part of the glacier, which had been partly melted by the sea, were now out of the water. The melting had produced a very striking series of pillars in the ice, like a grotto, and the effect was quite unmistakable.

In August, 1938, when I visited the glacier again, this grotto-like piece of the snout was no longer there, but there were several icebergs near the front showing the same characteristic structure. Evidently in the course of the year this part of the snout had been pushed over the hummock and into deeper water, so that it had been able to float away. I should estimate its length to have been about 50 m, so that we can say with some certainty that this part of the glacier had at least that amount of movement during that time.

Two streams of ice unite to form this glacier, and in Koch's drawing of it, he shows a short line of medial moraine running down to the snout. This no longer existed in 1937, but on the site of it there was a small bay in the glacier face, (see map), and at the back of this bay could be seen the mouth of a large tunnel. The little bay was thronged with

sea birds, and from this one can assume that a considerable quantity of fresh water flowed out through this tunnel. It will be interesting to see what further changes take place in this part of the glacier front.

I drew on the map as accurately as possible the fronts of the Knud Rasmussen and Chamberlin Glaciers according to Koch, who surveyed them in 1916—23. For reasons already stated, these positions cannot be relied upon, and so I asked Hr. Nielsen whether he thought that such retreats as they indicate could have occurred. His answer was interesting, and in one case definite. He said that for the Chamberlin Glacier such a retreat was quite possible, and the formation of the bay referred to (which he said was new) supports the idea. For the Knud Rasmussen Glacier, however, he said that such a retreat was impossible, because since 1920, when he first came to Thule, the southern part of this glacier front had lain against a small island. I saw in this position what I took to be dirty ice, but I was not able to go very close, and I have no doubt that Hr. Nielsen is correct. From Koch's sketch and Kiilerich's photograph one can see that the northern end of this glacier front has since 1923 been in line with the deep gorge west of the points 750 m and 536 m. Hence it is certain that there can have been no large movement of the whole front during the period we are considering.

The presence of this island also makes it a little difficult to understand how the movement of 200 m of the moraine cones referred to above can have occurred. It is probable, however, that this movement was taken up to a certain extent by the closing of crevasses between these cones and the glacier front. In any case we do not know that the movement had necessarily so great a component in this direction.

VII. NOTES ON THE RECESSION OF THE ICECAP NEAR THULE

The evidence for the recession of icecaps nearly always takes the form of observations on the relatively fast flowing glaciers to which the icecap is parent, particularly when they finish in the sea or in lakes. The comparative rapidity of the advances and retreats of such glaciers makes them easily observed not only by explorers, but often by the local inhabitants also. The changes are often very marked and well authenticated, but it is questionable to what extent they reflect conditions which affect the icecap as a whole. Professor Mason's observations in the Himalayas (19) show definitely that there, at any rate, advance and retreat of valley glaciers is more dependent on local topography than on climatic conditions.

The movement of these glaciers is evidently not steady but cyclic, and advance and retreat alternate with a fairly regular period, which is peculiar to each glacier itself. There are not yet sufficient observations to establish how far this holds good in the high arctic, but certainly the records of the Moltke Glacier seem to support this view. It should be remembered, therefore, that although we have very definite and detailed evidence of the retreat of some of the glaciers near Thule, we do not know how far we should be justified in deducing from them alone a retreat of the icecap as a whole, accompanying a real amelioration of the climatic conditions.

We have fortunately, however, a certain amount of other evidence of these two processes, which appear to be very much in action at the present moment.

As has been mentioned above, we found several nunataks in places where they were not marked on Koch's map (17). Many of these cannot be taken as definitely new since his time, but some of them were pointed out to me by Hr. Nielsen and his wife, and by the Eskimos, as having appeared in the last ten years. The best marked of these were the flat areas of land at the head of the Salesbury Glacier. Unfortunately I was not able to survey these accurately, but they are indicated on the map.

The fact that they are flat is rather significant, for it indicates how thin the icecap must have become in this region. The retreat is evidently in many places more a matter of wasting away of the whole, rather than a mere retraction of the icecap edge, whose movement may resemble that of the valley glaciers in being to a certain extent independent of the climatic conditions. Such wasting away is therefore of considerably greater significance.

In addition, there has appeared recently another new nunatak east of Nunatarssuak. I did not definitely identify this, nor was I able to make any survey of it, but I obtained through Hr. Nielsen a convincing account of its first appearance. It is outside the area covered in Map II. When the Eskimos wish to travel between Thule and the settlements of Inglefield Gulf in the summer, or early autumn, they have to sledge round by icecap, as there is no ice on the fjords. This journey round the end of Wolstenholme Fjord has often been made. In 1932, Inukitsorujuk and Qarviarssuaq, two very reliable Eskimos, who had travelled with Knud Rasmussen on the First and Fifth Thule Expeditions, tried to make this icecap detour. They found it impossible, because in one place behind the Moltke Glacier, a new nunatak had appeared. This took the form of a hill with the steep side facing northwards, and the icecap had apparently subsided suddenly on that side, leaving a precipitous rock cliff, which effectively barred all travel.

In the same area I myself observed, in 1938, a fact which also pointed towards a retreat of the icecap edge. On the north side of Nunatarssuak there lies a long narrow lake which runs approximately Northwest-Southeast, and which is bounded on the Northwest by the icecap. This lake, when I saw it, had evidently just undergone a drop in level, for I observed the plain mark of a former strand line about 20 metres above the present. This was evidently quite recently vacated, because a number of small bergs still lay on the shore below it. The lake drains into a stream running down the south side of the Knud Rasmussen Glacier, and presumably the outlet had been dammed by the icecap, which had now retreated sufficiently to open it again. This cause of the drop in the level is only hypothetical, as I was not able to visit the outlet, but it is undoubtedly the most probable explanation. Examples of this phenomenon are known wherever glaciers exist.

In addition to these particular evidences of retreat of parts of the icecap, there were almost everywhere general signs of recession and thinning of the ice. The land near the present margins of the icecaps is distinguished from that further away by its lighter colour, and this distinction is often very striking. It is caused by the absence of lichen from the rocks, an absence which in this case can only be due to their having been recently covered by ice. This band of lichen-free rocks is

sometimes several hundred metres broad. It is also noticeable round all the large permanent snow drifts, which lie on the northern and western sides of the hills in this district. Some of these drifts cover more than a square kilometre, and have in quite recent times apparently shrunk from almost double their present size.

Furthermore, Hr. Nielsen told me that until 1923 the top of Saunders Island had been covered by a dome of ice. At that date this began to get thinner, and the rock showed through in two places on the side visible from Thule. It is not now possible to see from Thule any trace at all of icecap on the top, though there are probably a few permanent snow drifts in the hollows, which are not visible from below. Hr. Nielsen and his wife also told me that ten years ago there were perennial snow drifts on the slopes east of the Thule Hospital which are now covered with grass. These observations seem to me to give sufficient evidence of a considerable amelioration of the climate, in spite of their being unsupported by a proper series of meteorological observations.

VIII. ACKNOWLEDGEMENTS

The field work described in this paper was only made possible by the help I received from a number of sources. First I must thank Mr. Haig-Thomas for the opportunity to spend a year in such an interesting district and for the help he and Mr. Hamilton gave me with much of the work.

The kindness of the members of Grønlands Styrelse at Thule will always be one of my most grateful memories, and to Kolonibestyrer Hans Nielsen especially I owe a great deal, both for this, and for the help he gave me in collecting information about conditions in previous years. I also owe a great debt to Mr. C. F. MacGregor and the members of his expedition for their unfailing help and hospitality. The Ice-cap journey would have been impossible had Commander Schlossbach not accompanied me, and I could not have wished for a better companion.

I wish also to record my debt to several of the Polar Eskimos who helped me in this work, particularly Karkutsiak, Porsiman Nasaitsordlvarssuk ("Baadsmand") and Ole. They always took an intelligent interest in the work, and I gained from them a considerable amount of reliable information about the ice-cap, and weather conditions in the district.

I wish to thank the following for their help in the preparation of this paper: Mr. Cranna, Mr. J. M. Dines and Dr. C. E. P. Brooks of the Meteorological Office at Kensington for their help in calculating the heights of the icecap journey; Dr. L. J. Comrie and Mr. R. W. Pring for the computation of the astronomical observations; the Staff of the Charts Department at the Admiralty for their help in collecting records of previous maps of Wolstenholme Fjord; Messrs. Derek Leaf and Douglas Baldwin and Miss Dorothy Grose for the preparation of the maps and final text; and Messrs. Brian Roberts and J. M. Wordie and Herr Hans Nielsen for reading through the manuscript and making many valuable suggestions and corrections.

IX. SUMMARY

I. Introduction.

II. A Summary of the previous work done in this region is followed by an account of the journey made by J. W. Wright and Lieut-Commander I. Schlossbach from Etah to Longitude $61^{\circ}30'$ W. Travelling was easy, and the weather, though cloudy, generally calm and warm. Temperatures from 0° C. down to -8° C. were experienced. Heights were measured with an accuracy of about 50 m and are shown on Map I. There was found to be a much larger extension of the central plateau of the ice-cap into this area than was previously supposed. The original reason for this journey was the supposed sighting of a new nunatak in Lat. $78^{\circ}30'$ N., Long 63° W. by Schlossbach, while flying alone over the ice-cap in May. No sign of this nunatak was found by the sledge party and Schlossbach admitted that he was probably mistaken in his position, and had seen the land at the head of Inglefield Gulf.

III. This account includes information gained during traverses of Prudhoe Land in March and June 1938, as well as during the above journey. No thaw was seen above 1000 m, but on the return from the main journey early in July thaw conditions were found to extend to that height east of Etah. No crevasses were seen above that level.

IV. The survey work completed in Wolstenholme Fjord consisted of a plane table map (Map II), made originally on a scale of 1:100,000. It was controlled by 14 triangulation points, of which 9 were occupied and marked with cairns. The azimuth was given by a single set of observations to the sun at the station in Thule, and is not very reliable. Scale was given by a very accurately measured base on the level ground near the hospital at Thule. The triangulation station in Thule was fixed by 60 star observations with an accuracy of about $3''$ of arc.

The heights of occupied stations are accurate to at most 5 m, and of intersected points to 10 m. The detail is accurate to the scale of the map on the land east of Thule, but may have errors up to half a kilometre in the limits of the map to the north and east. An account of

previous surveys of the fjord is given. The best of these was that of Lauge Koch, published in 1932, which was found to contain nearly all relevant topographical detail, but to be rather inaccurate on its published scale.

V. The rate of flow of the Moltke Glacier was measured by comparing photographs taken in September 1937 and August 1938 from the triangulation point 416 m south of it. The movement in this period was determined as lying between 0 and 60 m. The positions of the glacier tongue, and its area for certain years between 1916 and 1938 are shown on Map III and figure (1). Since 1916 there has been a period of retreat followed by one of advance, followed in turn by a much larger retreat. The rate of flow is evidently very irregular and the 1937—38 determination cannot be taken as typical.

VI. Two moraine cones on the Knud Rasmussen Glacier were observed from a point west of the Chamberlin Glacier in 1937 and 1938 and found to have a movement whose component in a S.S.E. direction was 100 m. The precise direction of the movement was not determined. The front has had almost no change of direction since 1916. The Chamberlin Glacier had a movement in 11 months of probably at least 50 m. No accurate records of former positions of its front exist, but it is probable that this has retreated.

VII. The following are the items of evidence showing general retreat of the icecap and amelioration of the climate in this region:—

New nunataks behind the Salisbury and Moltke Glaciers.

Drop in level of the lake north of Nunatarssuak.

The existence along the icecap edge of an area of lichen-free rock, which was presumably covered by ice until recently.

Disappearance in the last ten years of a small icecap covering most of Saunders Island, and of perennial snow drifts on the slopes east of Thule.

X. APPENDIX

I.

Height Observations made during Journey on the Greenland Icecap in June and July 1938

by

J. W. WRIGHT and Commander I. SCHLOSSBACH, U.S.N.

Greenwich Mean Date	G. M. T.	Approx. distance from Etah Miles	Travelling Aneroid, Inches	Etah Aneroid, Inches	Travelling Temp. ° F.	Etah Temp. ° F.	Calculated Height, Metres
June 19	0030	10	28.46	28.98	34	30	407
— 19	0200	..	27.55	.97	..	30	660
— 19	0400	15	27.06	.97	..	30	802
— 19	0440	..	27.03	.97	..	30	811
— 19 } *I..... {	0800	20	26.54	.98	..	30	963
— 19 } {	2200	20	26.55	30.00	..	30	965
— 20	0430	40	26.02	29.95	..	33	1125
— 20	0800	..	25.78	.92	..	33	1200
— 20 } *II..... {	0850	50	26.03	.91	..	33	1120
— 20 } {	2400	50	26.03	.86	..	33	1105
— 21	0400	60	29.95	.84	..	33	1180
— 21 } *III..... {	1215	80	29.20	.85	..	36	1420
— 21 } {	2350	80	29.23	.85	30	39	1425
— 22	0400	85	29.02	.87	30	39	1495
— 22 } *IV..... {	1300	100	28.85	.90	28	39	1555
— 23 } {	0100	100	28.76	.92	..	47	1605
— 23 } *V..... {	1400	130	28.45	.93	28	52	1725
— 24 } {	0200	130	28.44	.95	23	40	1700
— 24 } *VI..... {	1400	150	28.24	.98	28	47	1805
— 25 } {	0800	150	28.28	30.05	25	44	1800
— 26 } {	0830	150	28.28	.07	..	44	1810
— 26	0500	160	28.37	.20	28	42	1810
— 27 *VII.....	0200	175	28.56	.20	32	48	1760
— 27 } *VIII..... {	1300	140	29.13	30.17	(36)†	49	1565
— 28 } {	0230	140	29.13	.17	(36)†	49	1565

Aneroid being used with adjustment

Greenwich Mean Date	G. M. T.	Approx. distance from Etah Miles	Travelling Aneroid, Inches	Etah Aneroid Inches	Travelling Temp. ° F.	Etah Temp. ° F.	Calculated Height, Metres
June 28	0800	120	29.48	30.15	(37)†	49	1450
— 28	1000	115	29.77	.15	(38)†	49	1355
— 28	1100	110	30.02	.14	(39)†	49	1275
— 28 } *IX..... {	1200	110	30.02	.13	(40)†	50	1275
— 29 } {	0230	110	{30.20 26.13	.13	(40)†	50	1220
— 29	0420	100	26.38	30.14	(40)†	49	1140
— 29	0530	95	26.40	.14	(39)†	48	1150
— 29	0645	95	26.36	.15	(39)†	..	1145
— 29	0815	90	26.53	.15	(39)†	..	1095
— 29	1100	80	26.76	.15	(39)†	..	1020
— 29 } *X..... {	1200	75	26.80	.15	(48)†	56	1030
— 30 } {	0200	75	26.80	.25	(32)†	40	1020
— 30	0730	65	26.91	.27	(32)†	40	995
— 30	1115	50	27.32	.27	(33)†	40	875
— 30	1200	50	27.38	.26	(39)†	46	865
— 30 } *XI..... {	1330	45	27.32	.26	(43)†	50	890
July 1 } {	0300	45	27.28	.24	(43)†	..	895
— 1	0400	40	27.12	.22	(42)†	..	935
— 1	0600	40	26.90	.21	(42)†	..	1000
— 1	0725	30	26.69	.20	(30)†	39	1040
— 1	1200	20	27.08	.15	(32)†	..	910
— 1	1250	20	27.52	.15	(33)†	..	780
— 1 } *XII..... {	1315	15	27.56	.15	(42)†	48	820
— 2 } {	0300	15	27.36	29.95	(42)†	..	790
— 2	0615	10	27.57	29.95	(42)†	..	725

* Roman figures and brackets refer to Camps.

† These temperatures were obtained by calculation from the Etah temperature at that time.

The following comparisons of the Etah and Travelling barometers were made:—

(1) On May 30th.

Etah barometer 29.75

Travelling barometer..... 29.72

(2) On July 8th.

Etah barometer 29.73

Travelling barometer..... 29.69

Winds were from the South-west as a whole, and averaged about 5 m/sec., never exceeding 10 m/sec. No special notes of them, or of the general weather conditions were made.

II.

Elements of the Triangulation in Wolstenholme Fjord.

This appendix gives the essential data of the triangulation carried out in Wolstenholme Fjord in 1937—38, together with two examples of checks to indicate the order of accuracy obtained in different parts of the triangulation. The elements of the triangulations are given rather than the coordinates of the points because the absence of a reliable azimuth would make the latter untrustworthy. A purely arbitrary origin and azimuth were used in computing the triangulation in order to plot the points on the plane table. Figure 2 shows the principal rays which were used in the computation. Several other rays were taken and used as checks, but these are not shown for the sake of clarity.

The first check on the accuracy is obtained by finding the distance between the western end of the base and the point 170 m in two different ways. It can be found firstly from the triangle formed by this point and the base, and the distance thus computed is:

7073 metres.

This distance can also be obtained from the triangle:

Umanak 212 m.
West end of Base
Point 170 m.

as the side

Umanak—West end of base

is given by the triangle formed by Umanak and the base. The elements of this triangle are given in the list below, and the angles of the other triangle are:

Umanak 212 m	120	57	10
W. end of base	44	20	15
Point 170 m	14	42	35

From this and the given side the length

West end of base — Point 170 m

is by calculation 7063 metres. There is thus a difference of 10 metres between the two values. The first value was adopted in carrying on the triangulation, because the difficulty of establishing a satisfactory station on Umanak made the connection through it less reliable than the direct measurement from the base.

The second check is a general one for the western portion of the triangulation, and is given by the closeness of the intersection of the

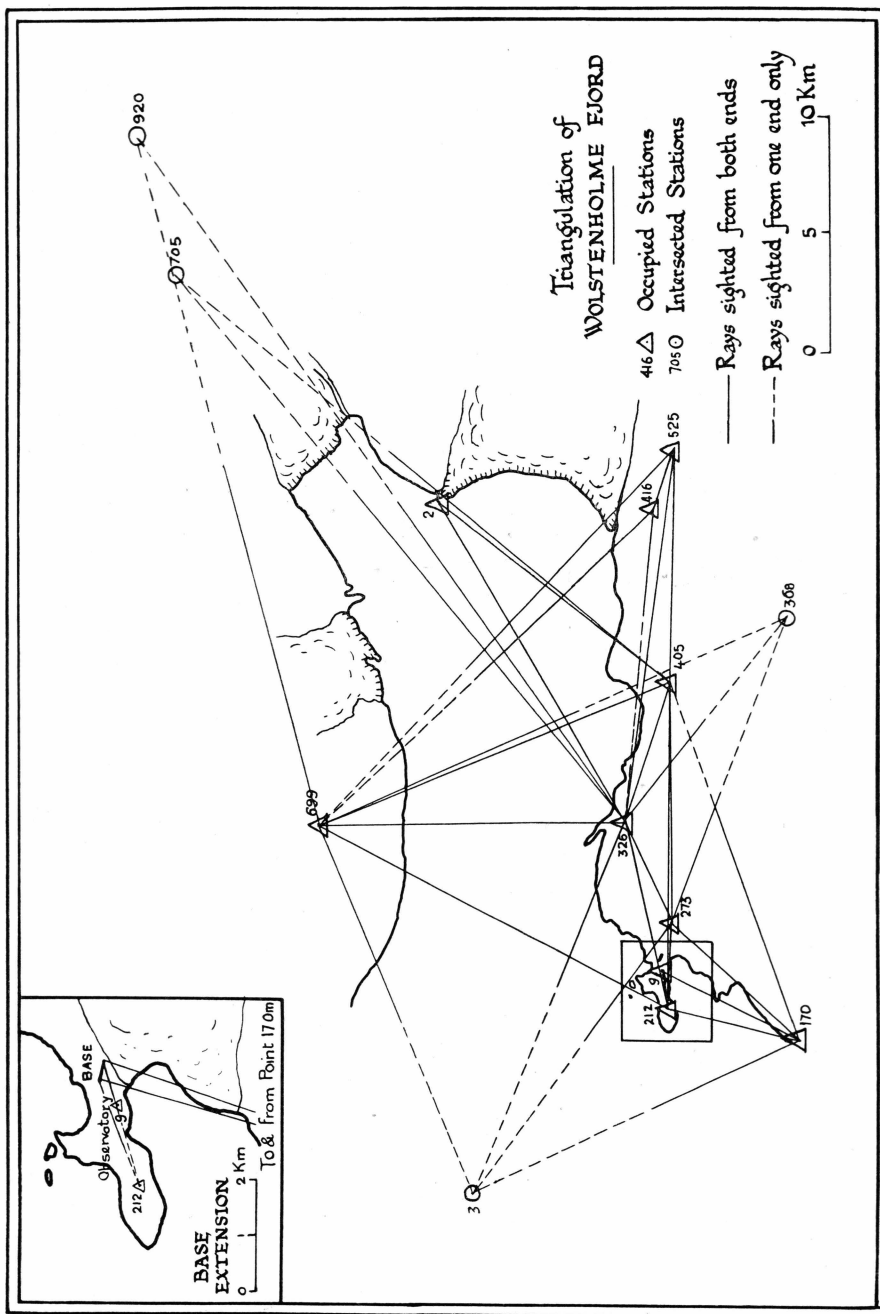


Fig. 2.

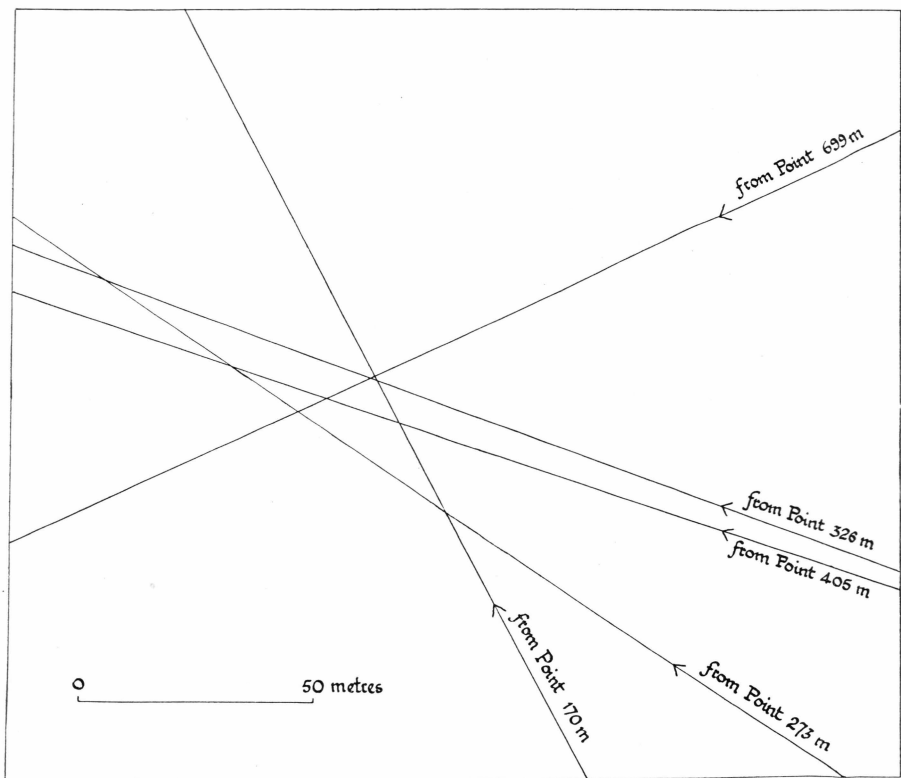


Fig. 3. Semi-Graphic Intersection of Avagdliarssupaluk.

island Avagdliarssupaluk from five of the stations. Figure 3 shows the rays from these points plotted on a large scale, using a semi-graphic method of computation. The result indicates that the errors in position of these stations are still of the order of ten metres.

Unfortunately there is not sufficient data to provide a check on the accuracy further east, but the poor nature of the control makes it evident that errors there are much larger than in the west. The four points 416 m, 525 m, 705 m, and 920 m should be fixed within the plottable error of the map (about fifty metres), but it is doubtful if their positions are more accurately defined.

Names & Heights of Triangulation Points	Corrected Angles			Length of the side opposite each point metres	Loga- rithm of side length	Remarks
	°	'	''			
Base East end.....	83	05	48	7,073	3.8496	Closing error of tri- angle 11''
Base West end.....	93	48	20	7,110	3.8519	
Point 170 m.....	03	05	52	385.1	2.5855	
Base East end.....	35	41	26	2,091	3.3204	Angle at Umanak not measured, but the centering and measurements at the base ends were carried out with great care.
Base West end.....	138	08	40	2,391	3.3786	
Umanak 212 m.....	06	09	54	385.1	2.5855	
Umanak 212 m.....	104	38	..	16,135	4.2078	Angle not measured
Point 170 m.....	55	08	..	13,680	4.1362	
Point 405 m.....	20	14	..	5,768	3.7610	
Umanak 212 m.....	14	06	..	6,229	3.7944	
Point 405 m.....	18	14	..	8,010	3.9036	
Point 326 m.....	147	40	..	13,675	4.1362	
Umanak 212 m.....	116	08	..	6,587	3.8187	Closing error 1'30''
Point 170 m.....	12	02	..	1,527	3.1840	
Observatory 9 m.....	51	50	..	5,768	3.7610	
Point 405 m.....	19	01	..	4,705	3.6726	Closing error 3'
Point 326 m.....	135	26	..	10,135	4.0058	
Point 273 m.....	25	33	..	6,229	3.7944	
Point 326 m.....	09	52	..	9,780	3.9903	Closing error 45''
Point 405 m.....	163	52	..	15,850	4.2002	
Point 525 m.....	06	16	..	6,229	3.7944	
Umanak 212 m.....	62	56	..	16,030	4.2049	Closing error 01'15''
Point 405 m.....	67	35	..	16,640	4.2212	
Point 699 m.....	49	29	..	13,685	4.1362	
Point 525 m.....	22	23	..	19,590	4.2920	Angle not measured
Point 699 m.....	02	55	..	2,618	3.4179	
Point 416 m.....	154	42	..	21,985	4.3421	
Point 326 m.....	47	54	..	12,330	4.0909	Closing error 55''
Point 405 m.....	100	05	..	15,605	4.1933	
Point 2 m.....	22	01	..	6,229	3.7944	

Names & Heights of Triangulation Points	Corrected Angles			Length of the side opposite each point metres	Loga- rithm of side length	Remarks
	°	'	"			
	Intersected Points					
Point 405 m	46	18	..	16,850	4.2267	
Point 699 m	90	08	..	23,310	4.3676	
Avagdluarssupaluk 3 m	43	34	..	16,030	4.2049	Angle not measured
Point 326 m	114	50	..	13,770	4.1390	
Point 273 m	47	03	..	11,110	4.0457	
Point 368 m	18	07	..	4,705	3.6726	Angle not measured
Point 326 m	57	34	..	27,190	4.4344	
Point 405 m	111	17	..	30,010	4.4773	
Point 705 m	11	09	..	6,229	3.7944	Angle not measured
Point 326 m	55	43	..	30,430	4.4833	
Point 699 m	103	50	..	35,760	4.5534	
Point 920 m	20	27	..	12,870	4.1095	Angle not measured

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PLATES



Plate 1.

The Brother John Glacier from a point near Etah. Note the windswept surface of Foulke Fjord. Photo by A. Inglis, Mac Gregor Expedition.

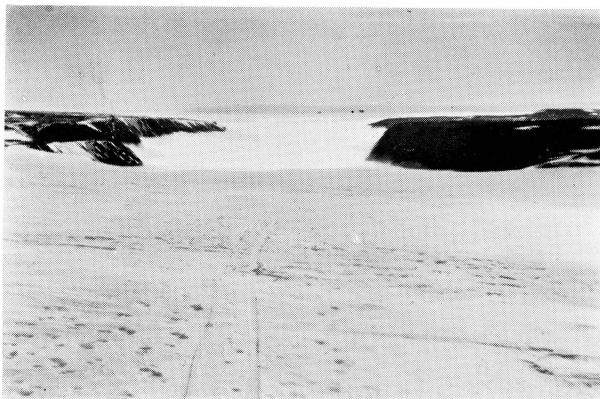


Plate 2.

Looking West over Foulke Fjord from a height of about 1000 m on June 18th 1938. The picture shows snow conditions typical of those experienced. Mist lying over Smith Sound and in the Fjord.

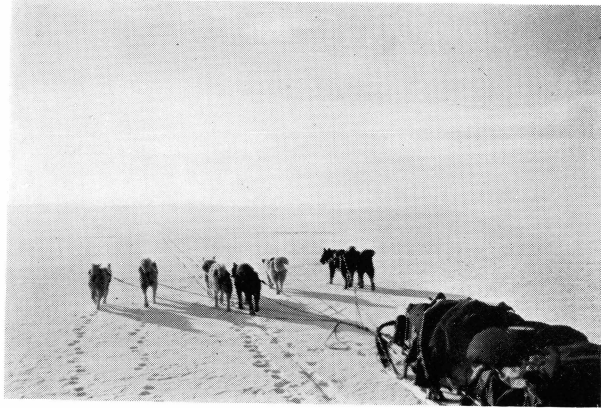


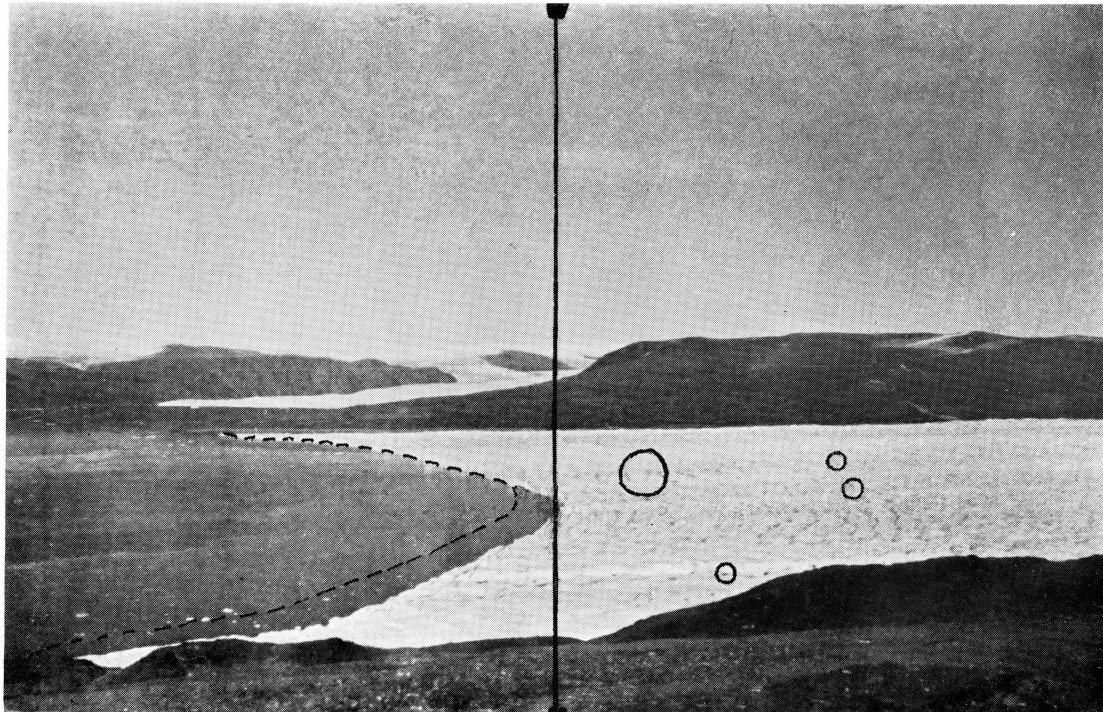
Plate 3.

Typical surface conditions in the interior of Prudhoc Land, June 1938.



Plate 4.

Looking west over Foulke Fjord on July 2nd 1938, from a height of about 600 m.



The retreat of the Moltke Glacier between September 1937 (dotted line) and August 1938. Circles mark the crevasses whose movement was measured.



The head of Wolstenholme Fjord from the triangulation point 525 m. The photograph was taken on a bearing 60° east of the bearing to the point 416 m. Chamberlin and Knud Rasmussen Glaciers in the distance.

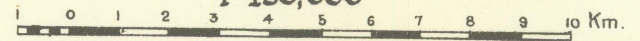


ICE CAP CONTOURS IN NORTH WEST GREENLAND. J.W. WRIGHT
 Coast and Ice Cap Edge from L. Koch, with two alterations by the author.
 Scale 1:750,000
 5 0 10 20 Km.
 5 0 5 10 15 Miles
 Route of J.W. Wright and Lieut. Comand. I. Schlossbach 1938.
 Camp with astronomical observation \odot 1710
 Height Stations of Knud Rasmussen and Peter Freuchen 1912. + 1240
 Heights according to Lauge Koch. \odot 1080

WOLSTENHOLME FJORD

SURVEYED BY J.W. WRIGHT
1937-8

1:150,000



Heights in metres Occupied Triangulation Station ∇^{212}
100 metre contours Intersected Station ∇^{705}

Moraine $\times\times\times\times$ Cliff ||||| Lake ---
Astronomical Position at Thule ∇^9

Lat. $76^{\circ} 34' 01''$ N. Long. $68^{\circ} 48' 37''$ E

o Patorfigarsuk

∇^3 Avadliarssupakuk

WOLSTENHOLME FJORD

