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ICE MARGIN FEATURES IN THE JULIANEHÅB DISTRICT, SOUTH GREENLAND

BY

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WITH 36 FIGURES IN THE TEXT
AND 4 PLATES

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Abstract.

The present report deals with the extension of the ice margin deposits in the Julianehåb district, South Greenland. An attempt is made to establish a Holocene chronology for the ice margin deposits within the region on the basis of their association with raised marine shore lines, combined with a determination of fluctuations of the glaciation limits of the individual stages in Holocene times.

As the Narssarssuaq region in the northeastern part of the district contains numerous extensive ice deposits, this region is treated in more detail than the other localities within the district. On the basis outlined above, it is attempted to establish a relative chronology for the ice margin deposits in the Narssarssuaq region. The remaining deposits within the district are then tentatively incorporated in the chronological scheme for the Narssarssuaq region.

After the deglaciation of the district during the last phases of the Wisconsin, four periods of stagnation or readvance of the glacier lobes and the ice caps (four "stages") seem to have given rise to the formation of ice deposits. The earliest of these stages is the Niaqornakasik stage (older Dryas ??), succeeded by the Tunugdliarfik stage (probably younger Dryas), the Narssarssuaq stage (probably Roman time), and the maximum extension of the ice in historic times (ca. 1750–1900 A.D.).

The variation in the volume of the ice coverings (the inland ice and the Julianehåb ice cap) during the period from the Tunugdliarfik stage to the present day is studied. The superficial conditions of the ice covering above an altitude of ca. 1,700 m do not seem to have altered much since the Tunugdliarfik stage.

Finally, deposits from former ice-dammed lakes in the Narssarssuaq region are treated. All the deposits from such lakes found here seem to show that all the lakes at the glacier front had a maximum height of the water level of 120–150 m. This is in accordance with J. W. GLEN's theory of subglacial outbursts of ice-dammed lakes.

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[1]) The name has not been authorised.

INTRODUCTION

As part of the surveying carried out by the Geological Survey of Greenland (abb. G.G.U.) in Southwest Greenland, the author, in the summers of 1957, 1958, and 1960, reconnoitred the Quaternary deposits in the Julianehåb district. In 1957 the primary object of the journey was to investigate the fluctuations of the glacier lobes in historical times, as determined by the glacial deposits. These investigations provided a supplement to the information on the glacier fluctuations within the district, previously collected and published by the author, based on a study of historical material (Weidick 1959). By combining the historical data on the alterations of some glaciers and ice lobes with geological investigations of the marginal area of the inland ice in large continuous sectors, it was attempted to acquire a general idea not only of the fluctuations of the individual ice lobes, but also of the glaciers' total loss of ice by melting during the last half century.

In the summer of 1957 the author was assisted in the field by Nicolaj Vahl, Narssaq, and Poul Motzfeldt, Igaliko, both attending the post-primary school. During the reconnaissance that summer, especially within the Narssarssuaq region, deposits from glacier advances before historical times were encountered. It was of interest, therefore, to carry out a more detailed mapping of these lines of glaciation. In addition we tried, by investigating the relation of raised shore lines to the ice margin deposits, to establish a relative chronology for the individual stages marked by these deposits.

In the summer of 1958 we therefore measured the altitudes of the shore lines within a large part of the Julianehåb district. In addition, deposits derived from local glaciations were visited in the southern part of the district: This work was carried out with the assistance of Mr. Vetle Jørgensen. As will appear from the description of the observed beach ridges (pp. 16–20), it was impossible from the localities found to get a general idea of the progress of the uplift of the land within the district. A definite correlation of the various ice margin stages cannot, therefore, be made for the whole district.

In the summer of 1960 our work was concentrated exclusively around the Narssaq and Narssarssuaq regions. The reason for our visit to Narssaq was the discovery of presumed interglacial deposits at Narssap ilua, reported to G.G.U. by the geochemist Dr. E. HAMILTON. The reason for investigating the region of Narssarssuaq was a desire to obtain a more detailed map of the numerous ice margin deposits in this area, which offer a possibility for accurate delimitation of the extent of the individual stages. In the summer of 1960 Mr. PER KIRKEBY participated in the work.

The author wishes to express his thanks to the leaders of the Geological Survey of Greenland (G.G.U.) for permission to carry out the above-mentioned work, in the field and in Copenhagen, and to the Photogrammetrical Section of the Geodetic Institute, as well as to Mr. SILAS BOWLIN, warrant officer, U.S. Army, for valuable help in carrying out the reconnaissance in the Narssarssuaq region in 1957.

I also wish to thank SV. TH. ANDERSEN, Dr. phil., of the Geological Survey of Denmark for palynological investigation of some marine concretions, K. JACOBSEN, M.Sc., of the Botanical Institute, Copenhagen, for determination of plant samples and counting of tree growth rings, A. SKYTTE CHRISTIANSEN, M. Sc., of the Botanical Institute, Copenhagen, for determination of lichens, Mr. U. MØHL, The Zoological Museum, Copenhagen, for determination of reindeer bones, the physicists W. DANSGÅRD, Dr. phil., of the Biophysical Laboratory, Copenhagen, and J. W. GLEN, Dr. phil., The University of Birmingham, for criticism of chapters dealing with the physics of the ice, and J. WATTERSON, B.Sc., the Geological Survey of Greenland, for review and criticism of the text.

The drawings for the present paper were executed by Miss HEIDE JØRGENSEN and Mr. JACK LARSEN, of the Geological Survey of Greenland. The photographs were made by Mr. P. POULSEN, of the Geological Survey of Greenland, and the translation of the text into English by Miss E. GLEERUP.

Earlier investigations of the Quaternary geology of the region:

Such investigations were carried out by K. J. V. STEENSTRUP on several expeditions in the 1870's and in 1899 (K. J. V. STEENSTRUP and A. KORNERUP 1881, K. J. V. STEENSTRUP 1881 and 1909), by N. V. USSING 1900 (1912), by A. JESSEN and C. MOLTKE 1894 (1896), and by H. ØDUM 1926 (1927).

Descriptions of the general morphology of the area have been published by H. RINK (1857), K. BIRKET-SMITH (1928), and C. E. WEGMANN (1938). A treatment of the earlier glaciation of the district, with a special view to the floristic conditions, was published by T. W. BØCHER in 1956. Finally, the Narssarssuaq region has been treated by R. E. FROST (1957) and by R. D. LEIGHTY and A. POULIN (1960).

GENERAL MORPHOLOGY OF THE JULIANEHÅB DISTRICT

Relief of the Landscape.

According to C. E. WEGMANN, the northern part of the Julianehåb district can be divided into the lowland around Qagssimiut and the highland in the inner eastern part of the district. The boundary between the two areas runs approximately from the inner part of Bredefjord in the north to the island of Sermersôq in the south. Both these areas are distinctly shown on all the recent maps of the district, that is to say, the map sheets published by the Geodetic Institute, the U.S. Hydrographic Office Sea Chart "Kap Farvel to Sermerssut", H.O. 5610, 1:250,000, the U.S. Army Maps 1:50,000, and the U.S. Aeronautical Approach Chart 1:250,000, sheets 109 CI, Narssarssuaq and 109 C IV, Sydprøven.

The lowland of Qagssimiut is formed by a strandflat at the coast towards Julianehåb Bugt, which to the north and east passes evenly into a plateau 300–500 m high. North of Qagssimiut the plateau disappears below the inland ice. The plateau is most characteristically developed within the area around Manîtsoq island north of Bredefjord.

The highland east of the Qagssimiut lowland (see plate 1) is dominated by a lower plateau at an altitude of 500–700 m, which continues eastward until it disappears below the inland ice between Narssarssuaq and Qôroq fjord. The plateau is most markedly developed on the top of the Qáqarssuaq mountain east of the town of Narssaq and in the area between Narssarssuaq and Qôroq fjord, but seems to set its mark on large portions of the northern Julianehåb district. In the same region, however, occur the more isolated peaks of Ilímaussaq (ca. 1400 m) and Igdlerfigssalik (ca. 1700 m). These peaks probably constitute the remnants of the other, upper, plateau of the highland, which plateau continues towards the inland ice in the form of high alpine peaks. In the area around the Niviarsiat nunataks this upper plateau attains an altitude of ca. 2,200 m.

In the southern part of the Julianehåb district the landscape is dominated right out to the coast by high mountain peaks, whose summit areas indicate that the land here almost exclusively developed from the upper plateau of the highland.

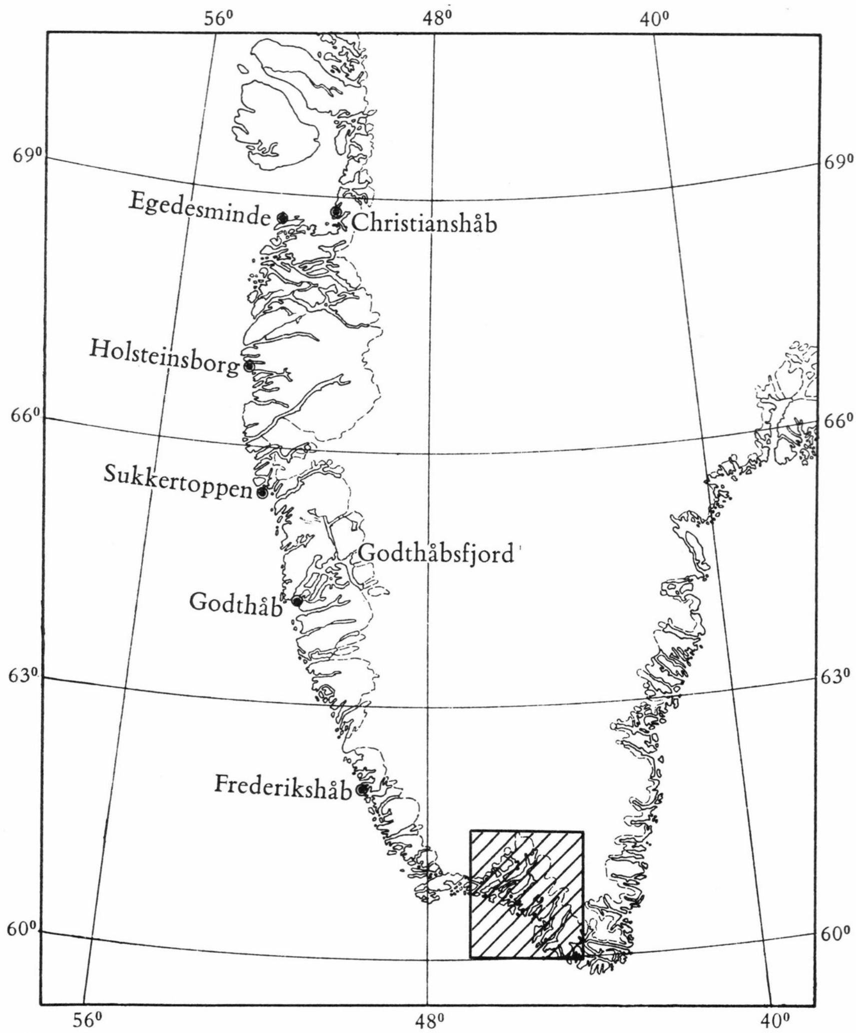

Fig. 1. Position of the described area in South Greenland.

It will be seen from the map in pl. 1 that the lower plateau, located between Narssarssuaq and Qôroq fjord, as a broad valley separates the high mountain regions around Niviarsiat from the mountains of similar height south of Qôrqup sermia. This large depression, below termed the Qôroq depression, seems to continue in below the inland ice. This is apparent from the surface of the ice immediately east of Niviarsiat, where the U.S.A.F. Aeronautical Approach Chart 109, C1, shows a saddle with its highest point at an altitude of ca. 1,900 m. However, from the surface of the ice cap as shown on the map, it cannot be decided whether the Qôroq depression continues right across to Puiagtoq Fjord on the east coast of Greenland. Still, the said saddle suggests that a minor exudation basin, directing a large part of the ice out towards Narssarssuaq and Qôroq, is located within the Narssarssuaq region. Furthermore, it must be assumed that this basin forms the boundary between the inland ice proper in the north, where the Niviarsiat mountains and their eastern continuation form the margin of the cup-shaped depression in which the inland ice rests (the shape of this cup is indicated by A. Bauer 1954 and P. E. Victor 1956) and the plateau located south thereof and covered by a separate ice cap. This ice cap is termed the Julianehåb ice cap.

All the above-mentioned plateaus are intersected by fjords extending from Julianehåb Bugt to the inland ice or to the Julianehåb ice cap. Most of the fjords have an east-northeastward trend. The depths of the fjords, shown in pl. 1, are for the most part based on a few series of soundings. Very likely, however, Bredefjord is the deepest fjord within the district (maximum depth ca. 400 fathoms).

As it must be assumed that the general direction of the fjords is determined by a single tectonic structure, which seems to be independent of the distribution of the rocks, the greater depths of the northernmost fjords must be due to the transportation of ice through the area during the ice ages. It is in accordance with this view that the maximum depths are often found near localities where glacier tongues formerly coalesced.

Apart from two of the northernmost and longest fjords in the district (Bredefjord and Julianehåbsfjord), all the fjords terminate as glacially excavated troughs on the broad shelf along the shore, but do not continue to the edge of the shelf. The marginal ice age deposits must therefore be found on the shelf at depths between 0 and 100 fathoms.

Only Bredefjord and Julianehåbsfjord have deep channels right out to the continental socle. It is remarkable, however, that the communication takes place through channels which in the outer parts of the shelf run in a southeasterly direction, that is to say, almost at right angles to the direction of the fjords. This southeastern direction is parallel with the tectonic structure in the area between Bredefjord and the edge of the inland ice north thereof, where all the tributaries to Bredefjord extend in this direction. The same direction is found in the general outline of the coast in the Julianehåb district.

Pre-Wisconsin and Wisconsin.

Pre-Wisconsin.

Deposits older than the Wisconsin and the Holocene are restricted to the localities Narssarssuaq and Narssaq, where the boulder clay, presumably deposited by the ice sheet during the Wisconsin, contains some few casts of marine shells. As the deposits in both the above-mentioned localities are covered by Holocene material, the profiles found are treated in more detail in the description of the postglacial development of the localities (Narssaq p. 98, Kiagtût pp. 46–49).

Possibly of interglacial age are some concretions found along the margin of the inland ice in the northern part of the district. The concretions occur only in the area laid bare by the inland ice after the great advance during the Middle Ages. This area did not become ice-free till after 1890. The concretions often contain shells of *Balanus*, as well as of *Mya truncata*, *Cardium edule*, *Saxicava arctica*, and *Mytilus edulis*, and, in a single case, of the echinoid *Strongylocentrotus droebachiensis*.

Outside the aforementioned zone along the edge of the inland ice (the "trim line zone") no concretions occur, which must be due to their rapid disintegration. Concretions were found up to an altitude of ca. 300 m near the margin of the ice. Similar finds were made along the whole west coast of Greenland as far north as the Umanak district (lat. 70° N.). Thus the finds made in the Julianehåb district only extend the area of occurrence to the southernmost margin of the inland ice proper.

The concretions were not found at the margin of the Julianehåb ice cap, not even in places where such occurrences might be expected, that is to say, on the extensive outwash plains in front of the ice lobes. The fauna enclosed in concretions of this type from the Godthåb district is described by K. GRIPP (1932).

Nothing is known of the age of these concretions. M. BRYAN (1954), after studying similar concretions found at Frederikshåb Isblink and in Godthåbsfjord, refer them to the interglacial period owing to the presence of *Picea mariana* and *Filipendula ulmaria* pollen. It is solely on this basis that the concretions in the Julianehåb district are referred to an interglacial period, as two of them from Bredefjord area, investigated by Dr. SV. TH. ANDERSEN of the Danish Geological Survey, were found to contain no pollen.

Glacial topography and Wisconsin.

It is unknown whether the district was totally covered by ice during the Wisconsin period, but it is very likely. It will be seen from pl. 1 that glacial striae occur in several places. They have very frequently been observed along the fjords, where polished surfaces, striation, and friction cracks as well as glacial striae are preserved under a covering of ground moraines which was not removed by the sea till quite recent times. As might be expected, these glacial features indicate a movement of the ice along and through the fjords. Of greater interest are some glacial striae on the higher plateau between the fjords, where the direction of the ice movements has been less influenced by the subglacial topography than along the fjords. However, glacial striae and other faint glacial features are considerably less frequent here than along the fjords, owing to the intense nivation since the last ice age. Moreover, these plateaus are largely covered by boulder fields.

With regard to the direction of ice movements, the Ilímaussaq peninsula between the fjords Tunugdliarfik and Bredefjord in the northern part of the district is of particular interest. Here it is possible to distinguish between two different ice movements. The earliest of these was due to ice which moved westward and northwestward from Tunugdliarfik fjord to Bredefjord. The ice moved across the lower plateau between Ilímaussaq and Narssaq, here located at a height of 600 m above sea-level. Near the town of Narssaq this ice stream moved north-northwestward through the small sound connecting the fjords Tunugdliarfik and Bredefjord. At the place where the sound joins Bredefjord, there occurs, as mentioned above, a deep of ca. 400 fathoms, which may be assumed to be the greatest fjord depth within the district. The glacial striae seen in the inner eastern part of Tunugdliarfik fjord indicate that the ice moved from Qagssiarssuk towards Bredefjord, that is, due west, and further across the narrow spit of land at Igaliko southwards to Julianehåbsfjord.

It seems probable, therefore, that in glacial times the area between Narssarssuaq and Qôroq, that is to say, the Qôroq depression, was of importance as a feeding area for the largest ice masses in the northern part of the Julianehåb district.

The younger system of glacial striae on the Ilímaussaq peninsula (especially around the town of Narssaq) bears witness of a later local glaciation which issued from the Ilímaussaq massif.

Only few glacial striae were observed in the alpine area south of Julianehåb town and fjord. They everywhere show that the ice moved through the fjords and valleys. The skerries on the strandflat off the shore have not been investigated. There might here be a better possibility of distinguishing between the different ice movements.

Holocene.

As will appear from the preceding section, the erosion during the ice ages set its mark on the relief of the landscape. It will also be seen that although deposits from the latest ice age are scattered all over the district, they occur for the most part in the form of boulder fields or ground moraines, which offer no possibility for a closer correlation of the distribution of the ice in the various parts of the district.

As might be expected, however, Holocene deposits are abundantly distributed all over the district. Thus, a much greater material is available for the description of the Holocene epoch than was the case with the Pleistocene period dealt with above.

For the sake of clarity, the Holocene deposits are therefore treated in the following three chapters: 1) shore lines, 2) ice margin deposits in the Narssarssuaq region, and 3) ice margin deposits outside the Narssarssuaq region.

RAISED SHORE LINES

The term shore-lines as here applied includes both ancient beach ridges and terrace-notches formed by the sea. In the summer of 1958 a total of 51 profiles, distributed over 24 localities, were measured.

The majority of the shore-lines in the district are beach ridges, washed out in ground moraines. They contain no shells, so it is impossible, on a faunal basis, to make a safe correlation of them.

However, K. J. V. Steenstrup already described profiles of marine clay in cliffs at Narssaq and Siorarssuit containing a recent fauna (Steenstrup 1881, p. 39). The profiles, however, rise only few metres above the present level of the sea.

Measurements of shore-lines in the Julianehåb district were formerly made by K. J. V. Steenstrup in 1876, 1877, and 1888, by A. Jessen in 1894 (A. Jessen 1896), and R. Bøgvad in 1932 (R. Bøgvad 1940). A. Jessen published all his own as well as Steenstrup's measurements in the Meddelelser om Grønland, Bd. 16, pp. 149–152, where the altitudes of the shore-lines are tabulated with indication of the measuring instruments employed. The table includes both beach ridges and coast cliffs. However, the table contains measurements of shore lines from Godthåb to the southernmost part of the Julianehåb district but only 29 localities are tabulated from the Julianehåb district, which, considering the size of the area, is insufficient to tell anything about the character of the uplift. The paper by Bøgvad deals especially with Southeast Greenland, only very few localities being recorded from the southwestern part of the Julianehåb district.

As stated by A. Jessen, his and Steenstrup's measurements recorded in the table are reckoned from the recent high-water mark, which must, on the whole, correspond to the following record of the measurements from 1958. These latter are reckoned from the upper limit of the seaweed, which is regarded by the author as more clearly defined.

Beach ridges.

According to A. Schou (A. Schou 1945, fig. 12, p. 62), the recent beach ridges are reported to be formed between the springtide mark and the low-water mark, while reefs (most frequently consisting of finer material than the actual beach ridges) are formed below the low-water mark. As reefs are built up of fine-grained material, they are of no importance in the present considerations, all the more so since, as far as is known to the author, no accumulations of such finer-grained material which may be associated with the deposition of beach ridges have been observed in the district outside major delta areas. A. SCHOU states, however, that no extremes are indicated in his figure illustrating the formation of beach ridges.

V. CORNISH (1898) states that the height of the ridges depends on the material of which they are built up; thus, fine-grained material and a heavy swell of the sea will result in the formation of the lowest ridges.

The beach ridges in the Julianehåb district investigated by the author show an astounding uniformity of material, the ridges being everywhere built up of rounded boulders with a diameter of 3 to 10 cm, that is to say, ranging between pebble boulders and cobble boulders. The material shows some sorting according to the different ridges, but not according to locality. Similarly, all the ridges have been washed out of earlier moraines. It must be assumed, therefore, that all the beach ridges were formed under fairly equal conditions. It should be mentioned that according to A. JESSEN (1896, p. 149) the beach ridges on the most exposed shores may exceptionally contain boulders up to $^1/_2$ m^2 in size.

Only few of the measurements carried out by the author were made on exposed shores, the remainder in sheltered coves and bays, and the material of the beach ridges is everywhere derived from morainic outwash. In profiles along brooklets and in cliffs facing the sea, moraines are met with half a score of centimetres below the depressions between the beach ridges or roughly 40 cm, on an average, below the beach ridge deposits as a whole. Thus, the deposits contain but little more than 0.4 m^3 of pebble boulders or cobble boulders per square metre of surface. In one place, Igdlorssuit near Julianehåb, no ordinary moraines, but unmixed fragmented clay was found below the beach ridge material.

On the skerries around the island Akia immediately south of the Julianehåb town as well as at the town itself, beach ridge deposits which here, too, must be regarded as redeposited ground moraines, were observed in trenches formed by preferential erosion of dykes. Of these beach ridges, only that at Julianehåb was measured.

As to the recent position of the beach ridges, an extraordinarily high-lying ridge was encountered at Igpik, Ûnartoq island, ca. 2 m above the present high-water mark. As the following high-water values (spring tide and neap tide) are known, it must be assumed that during a hypothetic equilibrium between land and sea there must be a range of variation for

	Spring tide	Mean	Neap tide
Kap Farvel	1.6 m	?	?
Frederiksdal	2.7 -	?	?
Nanortalik	2.5 -	?	1.0 m
Julianehåb	2.4 -	?	1.1 -
Narssarssuaq	ca. 4 -	2.6 m	–

the formation of beach ridges of ca. 2.5 m (variation at spring tide). This means that the range of variation for the formation of beach ridges in general below one and the same sea-level far exceeds the accuracy of measurement for the profiles measured (cf. also below, the description of the measuring technique). The above-given values for tide-water variations are quoted from "Den Grønlandske Lods", 1948, p. 66, with the exception of the records for Narssarssuaq, which are quoted from Leighty and Poulin (1960, p. 3).

Measurement techniques. – The heights of the shore-lines were in most cases made by means of hand level.

Where larger areas were to be measured, minor triangulations were carried out to check the profiles measured by hand level. It turned out that if the inclination of the ground exceeded ca. 3°, the error due to the use of hand level would be less than ca. 5 per cent of the values found by triangulation.

The measured values are not given in metres above the mean water level, but in metres above the upper seaweed limit. According to K. J. V. Steenstrup (K. J. V. Steenstrup 1907), this seaweed limit has a certain relation to the mean water-level, and must most often be equivalent to, or be located near, the "high-water mark" employed by A. Jessen as datum point.

It should be mentioned that V. Tanner (1944) under similar conditions in Labrador and on Newfoundland used the *Balanidae* line (upper limit of *Balanus balanoides*) as starting point for measurements of raised shore lines. It is added that this line occurs 0.2–0.6 m below the limit of *Fucus vesiculosus* (loc. cit. p. 240).

Where the heights of the individual beach ridges varied considerably, a mean of the height was taken in case of one profile measurement, otherwise where the individual profiles cut the beach ridges. The values given in the table on pp. 16–20 all have reference to the top of the beach ridges.

Raised wave-cut cliffs and delta terraces.

As regards the distribution of these forms, it is largely agreed that the foot of a cliff is formed between the high-water mark and the spring-tide marks (Schultz and Cleaves 1955, pp. 213–214). The heights given here therefore have reference to the mean height of the terrace-notch measured in metres above the upper limit of seaweed.

Greater problems are presented by the delta terraces. In the various localities an attempt was made to find out where the transition from the river terraces to wave-built terraces occurred, and where it was possible to measure the height of the inner terrace-notch. As the inclination of the terraces is often inconsiderable at the river mouths, ranging between 2 and 5 degrees, it is reasonable on this basis to assume a margin of error of ± 5 metres.

In measurements of cliffs and delta terraces the same procedure was employed as in the case of beach ridges, viz. datum point at the upper limit of seaweed, and measurement of the profile by means of hand level, sometimes checked by triangulation. The measures indicate the inner notch of the terraces.

Observations.

Area of northern Sermilik-Tunug̊dliarfik.

Niaqornaq, Kangerdluarssuk, northern Sermilik:

Profile 1 (northernmost): 14.0, 16.7, 21.0 m .... beach ridge
– 2 (northernmost): 14.0, 16.5, 21.0 m .... – –
– 3 (southernmost): 14.5, 15.5, 18.5, 19.5, 20.5, 22.5 m .... – –

Qeqertaq, Kangerdluarssuk, northern Sermilik:

Profile 1 (easternmost): 9.7, 14.2, 16.6, 20.3, 20.9, 28.7 m .... beach ridges
– 2 (westernmost): 4.0, 6.0, 7.9, 10.5, 12.6, 14.0, 14.3, 15.9, 17.0, 18.0, 18.9, 20.3, 21.4, 28.9 m .... beach ridges

Narssap ilua:

Profile at Panernaq: 5.0, 7.9, 8.4–10.3, 11.6, 12.4, 13.4, 15.3, 17.0, 18.0, 21,0 –26.2, 28.5, 36.0 m .... beach ridges

Except the last altitude, 36.0 m, which is an obliterated terrace.

Profiles from Narssap ilua eastward in the direction of the valley towards Ilímaussaq:

Profile 1 (northernmost): 16.7, 20.0, 24.0, 27.7 m .... beach ridges
– 2 (southernmost): 3.4, 4.5, 5.4, 7.8, 8.9, 10.1, 10.8–11.3, 17.3, 20.0, 21.7, 37.7 m .... beach ridges

Nûgarssuk ("Narssaq Point") south of Narssaq:

Profile 1 (northernmost): 16.8–18.5, 20.2, 25.2, 33.6 m .... beach ridges
– 2 (southernmost): 18.5, 20.2, 21.8, 25.2, 33.6 m .... – –

Area around Julianehåbsfjord:

Julianehåb naze, ca. 1 km SE of the town: 13.4, 16.0, *23.5*, 24.0, 24.8, 25.2, 25.5, 28.6, 30.0, 30.4, 31.7, 32.4, *33.5* m .... beach ridges

Arpatsivik:

Profile 1 (westernmost): 8.7, 10.1, 10.4, 11.8, 21.5, 21.8, 22.1, *22.3*, 26.4, 27.1, 28.5 m .... beach ridges

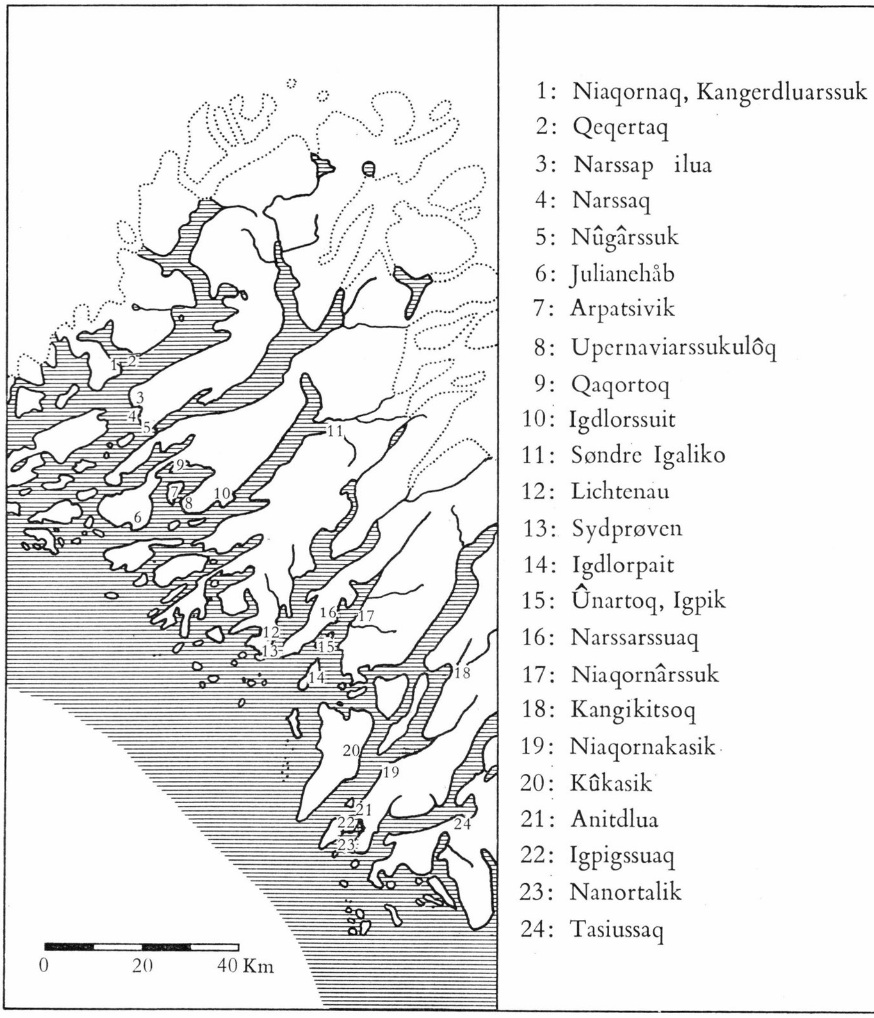

Fig. 2. Position of localities with shore lines.

Profile 2 (westernmost): 5.8, 8.4, 10.1, 11.9, 28.6 m .... beach ridges
– 3 (easternmost): 9.9, 10.8, 12.5, 13.2, 14.0, 15.8, 17.0, 17.8, 19.2, 19.7, 21.0, 22.9, 26.1, 27.5, 28.9, 31.0, 32.0, 34.1, 36.9, 38.3, 38.8, 39.2, 39.5, 40.3 m .... beach ridges

Upernaviarssukulôq:

Profile 1 (northwestern-most): 10.5 m................................ inner terrace
– 2 (northwestern-most): 11.0, 13.3, 14.0, 15.8, 19.4, 22.4, 24.3, 25.4, 26.3, 26.8, 28.8, *29.3*, 31.4, 33.6 m .... beach ridges
– 3 (southeastern-most): 9.3, 11.0, 14.8, 16.4, 19.4, 21.0, 23.1, 25.4, 27.1, 28.0, 29.8, 32.4, 34.4 m .... beach ridges

Qaqortoq, southeast of the church ruin:

Profile 1 (easternmost): 13.5, 15.5, 21.4, 23.2, 24.2, 26.3, *27.2*, 28.2, *30.6*, 31.9, 33.3, 34.0, 34.6, *35.0*, 36.0, 36.3, 36.6, 36.9, 37.2, *38.2*, *38.6*, 40.2, 41.2 m .... beach ridges
– 2 (westernmost): 8.8, 10.1, 12.0, *15.5*, *16.8*, 42.3, 43.6 m .... beach ridges

Igdlorssuit in Julianehåbsfjord:

Profile 1 (northernmost): 11.7, *12.8*, 13.3, 14.0, *15.2*, 16.3, *17.2*, 17.9, 18.5, 19.7, *21.0*, 21.6, 22.2, *23.6*, 25.9, 26.2, 27.3, 27.8, *29.8*, 30.9, 31.6, 32.0, 32.3, *33.3*, 34.3, 34.9, 35.5, *35.9*, 36.7, 37.4 m beach ridges

Sdr. Igaliko:

Profile 1 (southernmost): 16.8 and 22.6 m .... inner terrace
– 2 (at mouth of river): terrace planes at following altitudes: ca. 8 m, 18.5–21.8 m, and possibly terrace remnant at 27.0–28.5 m.

Area from Aĝdluitsoq fjord to Sermersôq.

Lichtenau:

Profile 1 (westernmost): 20.2 m .... beach ridges
– 2 (westernmost): 6.7, *7.0*, 8.8, 10.6, *12.0*, *13.4*, *16.6*, 17.9, 18.5, 20.0, 21.6, 22.0 m .... beach ridges
20.0 m though at the same time foot of small cliff.
– 3 (easternmost): *19.2*, *22.0*, 23.5, *33.6*, *34.9* m .... beach ridges

Sydprøven:

Profile 1 (westernmost): 17.6 m .... beach ridge
– 2 (easternmost): 21.8–26.9, 28.6 m .... beach ridges

Igdlorpait:

Profile 1 (westernmost): 3.4, 11.8, 12.6 m .... beach ridges
except 3.4 m, which is the foot of a small cliff.
– 2 (westernmost): 20.1, 23.1, 25.2, 26.0 m .... beach ridges
– 3 (westernmost): 6.0, 7.0, 15.0, 16.8, 19.3, 20.2 m .... inner terrace
– 4 (easternmost): 21.0 m .... foot of cliff

Ûnartoq island at the small village Igpik:

Profile 1 (westernmost): Flat plain above 16.7, *19.0*, 20.4, 26.0 m... beach ridges
– 2 (westernmost): *20.4*, 21.1, 21.6, *22.0*, 23.2, 23.7, *24.5*, *25.4*, *26.6*, 27.3, 27.9, *28.7*, 29.6, 30.4, 30.8, 31.2, 31.6, *32.3*, 32.7 m beach ridges
– 3 (westernmost): *12.7*, 14.0, *16.8*, 18.5, 20.1, *21.6*, *23.1*, *23.8*, *24.7*, 25.4, 26.0, 26.9, *28.1*, *28.8*, 29.8, 30.3, 30.6, 30.8, 30.9 m beach ridges
– 4 (easternmost): 15.1, 18.5, 19.3, 33.6, 33.8, 34.0 m........ beach ridges

Narssarssuaq in Ûnartoq Fjord:

Profile 1 (northernmost): 3.3, 4.9, 13.4, *15.0*, 15.4, 15.8, 16.2, 16.9, 17.4, 17.8, *19.3*, *20.0*, 20.4, *21.8*, *22.6*, *25.0*, *26.9*, *27.1*, *28.4*, *30.3*, *35.3* m beach ridges

Profile 2 (northernmost): 4.3, 15.0, *18.4*, 18.9, *19.5*, 20.1, 20.3, *20.4*, 20.5, 20.8, 20.9 m................................ beach ridges except 4.3 and 15.0, which form the lower limit of ancient cliffs.

– 3 (southernmost): *3.5*, *4.5*, *5.1*, 5.4, 5.7, *6.0*, 6.3, 6.7 m........ beach ridges

– 4. In a south-facing bay west of profiles 1, 2, and 3. The shore line was not measured in this place, but by taking bearings from profile 1. The uppermost shore line (beach ridge) in this locality is located at an altitude of 35.3 m.

Niaqornârssuk in Ûnartoq Fjord:

At this locality there are several delta terraces. The heights of the upper points of these are 4.8, 6.9, and 13.6 m. Further, there is a level area with obscured beach ridges between 21 and 35 m. Higher-lying terrace plains (possibly ancient remnants of outwash plains) occur at an altitude of 60–70 m.

In a locality west of the river, which here passes through the delta, the following heights were measured for the above-mentioned terrace-notch: 7.8 and 11.8 m.

Quvnermiut north of Sermersôq:

Profile 1 (northernmost): Possibly an upper beach ridge at 24.8 m.

– 2 (northernmost): Possibly an upper beach ridge between 16 and 17 m.

– 3 (westernmost): Lower terrace at 17.5 m, raised beach ridge at 18.5 m.

– 4 (southernmost): 5.5, 7.0, 7.6, 8.0, 8.4, 8.9, *10.5*, 12.4, 12.8, *13.3*, 14.0, 14.7 m................................ beach ridges

Kangikitsoq at Søndre Sermilik:

Profile 1 (westernmost): Distinct ancient foot of cliff, several kilometres long. Height 40.2 m.

– 2 (easternmost): Terrace plains around a large river at altitudes 12–15 m and 23–24 m.

Niaqornakasik north of Nanortalik:

Foot of cliff at 24.3 m.

Kûkasik on Sermersôq island:

Foot of cliffs at altitudes 38.4 and 52.6 m.

Area from Nanortalik to Tasermiut fjord.

Anitdlua:

Marked beach ridge at 8.4 m.

Igpigssuaq:

At a profile at the north side of the locality, obscured beach ridges and a stone plain were found on a level plain at an altitude of 23.5–25.0 m. Further, the foot of a terrace at 29.7 m.

In the same area beach ridges occurred at altitudes 3.4, 16.8, 18.0, 31.4, 38.6, 47.7, and 55.5 m.

Nanortalik town: Small island southwest of the harbour.

Two shore lines: a lower line at altitude 5.0–6.7 m, and an upper one at altitude 8.4–10.1 m.

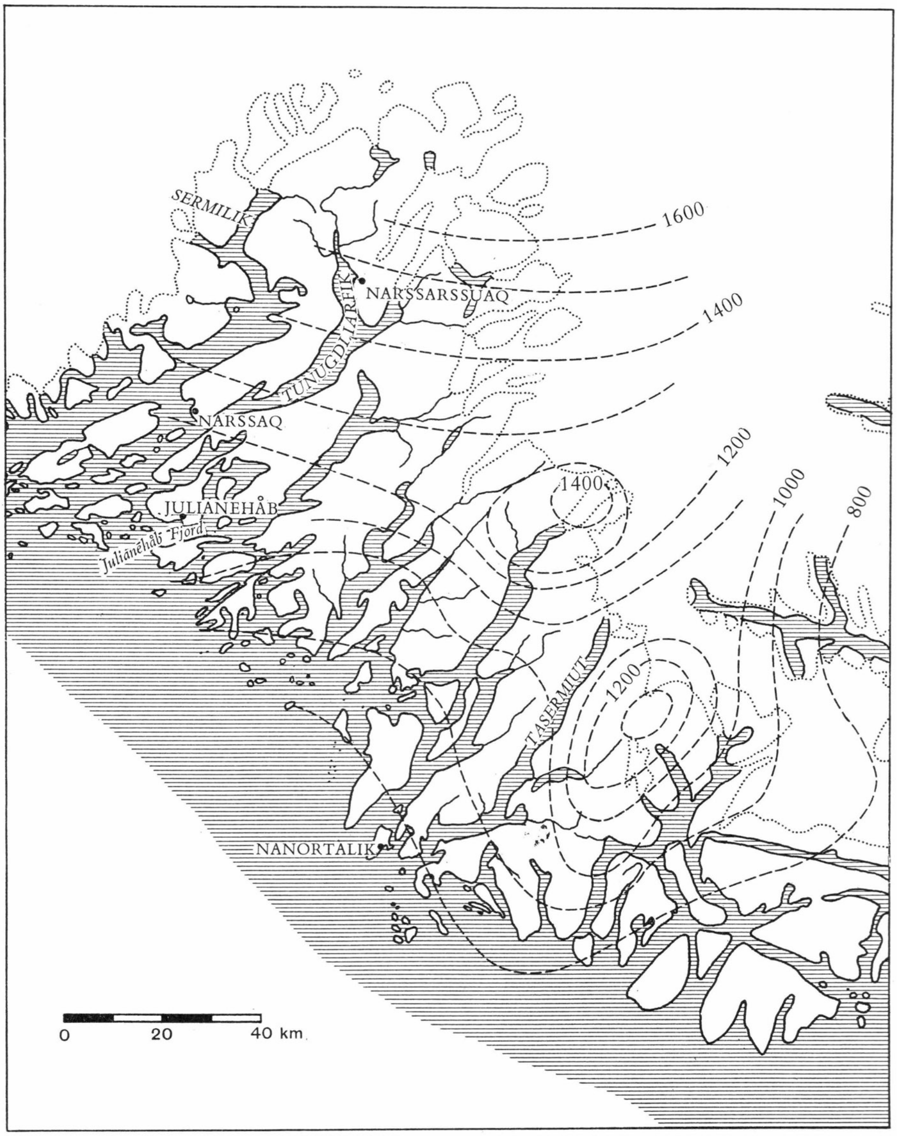

Fig. 3. Isoglacihypses in the Julianehåb district. The figures indicate the height above sea level (in metres) of the glaciation limit.

Tasiussaq, Tasermiut fjord:

Profile 1 (westernmost): Delta terraces at 22.7 and 40.0 m.
– 2 (easternmost): Minor terrace at 5.0–11.7 m, larger ones at 25–28 m.

In the above survey of altitudes of shore lines, two values connected by a dash indicate an indistinct transition between the particular two shore lines. Values in italics indicate marked shore lines.

Even though the above-given values are supplemented by the measurements carried out by K. J. V. Steenstrup, A. Jessen, and R. Bøgvad, a survey of the shore lines in the district seems only to indicate that the uppermost shore-line level occurs between 50 and 60 m above the recent water level. This height is met with at the coast farthest west (Ũmánartût, Kitsigsut) as well as in the interior of the fjords (Eqaluit iluat at Bredefjord, Igaliko, Julianehåbsfjord). It is not possible, however, on the basis of the measured shore line fragments, to measure any inclination of certain distinct shore line levels. Thus, the possibility of a correlation of the shore line levels of the individual localities must be excluded.

Provided that the above-mentioned shore line level at 50–60 m above the sea in the Julianehåb district approximately represents the upper marine limit, it is remarkable that terraces belonging to this level are also found in the inner fjord areas only 20–30 km from the recent ice front. Thus, even during the earliest phases of the uplift of the land indicated by the shore lines the inland ice hardly extended very far beyond its present position. Similar conditions are known from North Greenland, where Dan Laursen (1950, pp. 93–95) found a horizon A in shell-bearing marine terraces at Sydostbugten, Christianshåb district. The age of the horizon was regarded by Laursen as Lower Dryas. Thus, the maximum extension of the inland ice in the early Holocene time should have been located less than ca. 10 km in front of the recent ice margin.

Similar conditions are also reported from Godthåbsfjord, where the inland ice in the interior of the fjord has not, at any rate since the beginning of boreal times, extended more than ca. 10 km beyond its present position (J. Iversen 1952/53, p. 95).

The above-mentioned findings of high-lying shore lines at the heads of the fjords in the Julianehåb district as well as the two aforementioned attempts at dating the deposits in the interior of the Godthåb and Christianshåb districts would seem to suggest that the greater part of the now ice-free coastland in West Greenland became free of ice very soon after the Wisconsin or possibly during the last phases of this ice age.

ICE MARGIN DEPOSITS IN THE NARSSARSSUAQ REGION

As applied in the following pages, the Narssarssuaq region comprises the landscape between the innermost ramifications of Tunugdliarfik fjord in the southwest and the Niviarsiat mountains in the northeast. The area is bounded on the north by the southern margin of the inland ice and its lobe, Eqalorutsit kangigdlît sermia, descending towards Bredefjord, and on the south by the Julianehåb ice cap, the southern shore of the lake Motzfeldt Sø, and the Agdlerulik mountain. A topographic map of the area is given in pl. 2. The ice margin deposits are indicated on the map in pl. 3.

The ice margin deposits are constituted by outwash plains, marginal moraines, kame terraces, and deposits derived from ice-marginal lakes. They are abundantly scattered all over the area ca. 1350 km^2 in size. Owing to the difficult accessibility of the inner parts of the region, it has not been possible to visit all the deposits mentioned here. The work in the field has therefore been concentrated around the ice margin deposits in the valleys, where they are particularly well developed. The rest of the deposits are indicated on pl. 3 on the evidence of aerial photographs. A brief description of the deposits seen on the air photographs is given on pp. 72–76. A more detailed description of the localities visited is found on pp. 22–72.

In spite of zealous search, fragments of organic material were nowhere found in the ice front deposits. Hence only a relative chronology, based on the marine levels during the formation of the deposits, could be employed.

Hullet.

The locality is situated ca. 10 km WSW of the Niviarsiat nunataks and north of the glacier lobe Kiagtût sermia. An ice-dammed lake, Hullet, covering 2.7 km^2, forms the central part of the area visited. The lake is bounded to the south by a northward flowing glacier tongue issuing from Kiagtût sermia. It receives water from two glaciers situated ca. 3 km north of (Nordgletscher) and ca. 6 km east (Østgletscher) of

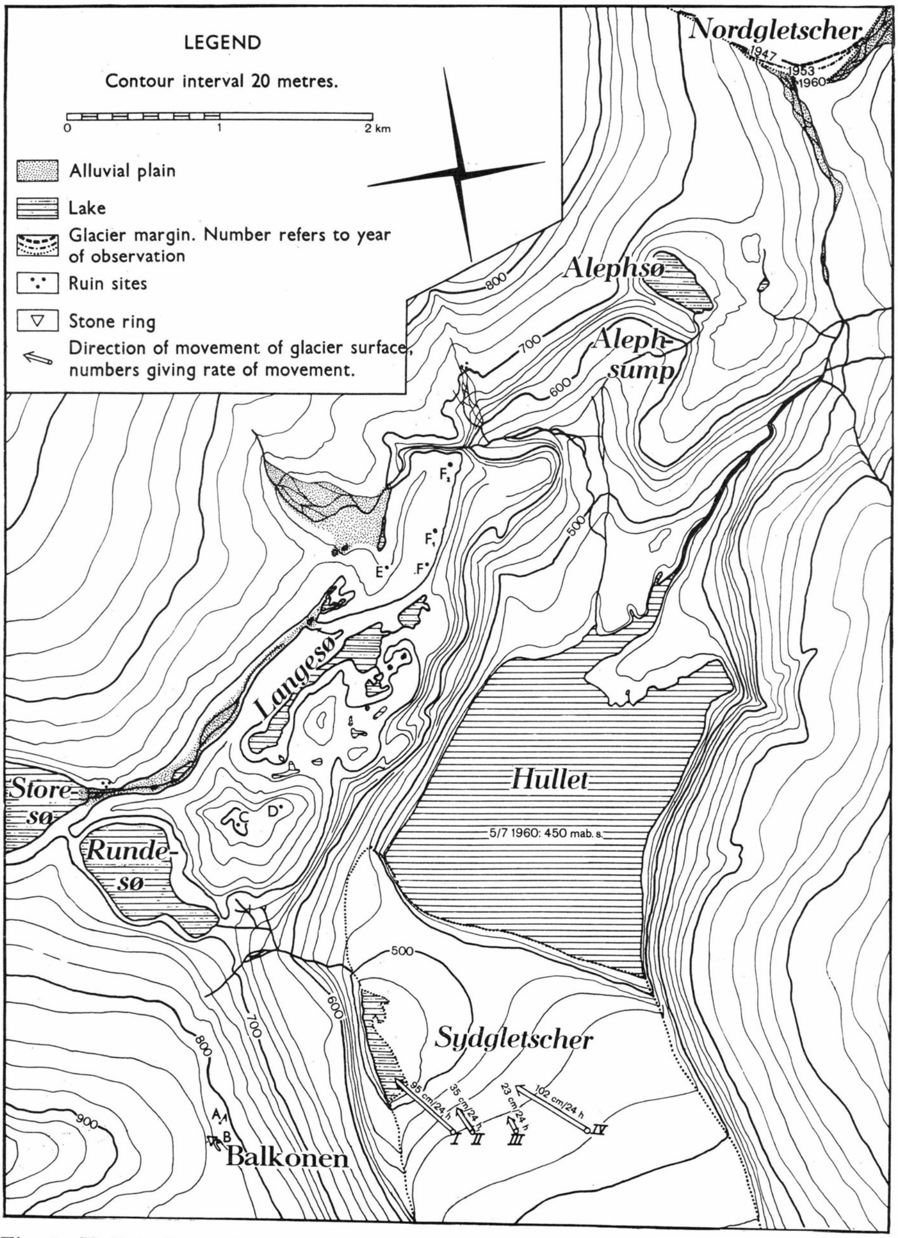

Fig. 4. Hullet. General map of the area. The figures indicate heights a.s.l. in metres

the lake, respectively. The lake is drained by periodical outbursts beneath Kiagtût sermia.

Both in the nearest surroundings of Hullet and in the valleys extending westward from this lake to Nordbosø, numerous morainic deposits and terraces are met with. The area visited extends from Nordbosø in the west to the front of Østgletscher in the east, and from Nordgletscher to Kiagtût sermia.

The locality can be approached on foot from the Narssarssuaq air base by a route across the land between Kiagtût sermia and Qôrqup sermia (Mellemlandet) to the tip of this land area. Thence via Kiagtût sermia to the west side of Hullet at Balkonen (see the map in fig. 4). The surface of the glacier is here rather even, but suitable equipment for glacier traversing is nevertheless required. Another route runs from the head of Tunugdliarfik fjord northeast- and eastward along the river system. This latter route is rather difficult to negotiate owing to the presence of broad canyons and large rivers. Passage by way of Kiagtût sermia is possible with suitable equipment for travelling on the glaciers, but owing to three crevassed areas ca. 3 and ca. 12 km back from the glacier front such a passage is very exhausting.

Only two usable maps of the area were available, viz. the U.S. Air Force Map, 1:250,000, with 1000 feet contour intervals, and a skeleton map, scale 1:100,000, for the use of the Geodetic Institute, prepared by this institute without height contours.

The present map (fig. 4) is therefore based on the author's own surveying. The contours are drawn on the basis of altimeter readings, inserted on air photographs, scale 1:8,000, taken by G.G.U. For checking of the altimeter readings, a net of 15 points was measured across the terrain.

Geomorphology.

The area around Hullet is elevated 500–1100 m above the sea. Actual ground moraines are of rare occurrence, while marginal moraines with associated outwash deposits fill the valleys. The mountain sides are most frequently uncovered, or with occasional screes or boulder fields. The mountain tops form a plateau at an altitude of 900–1100 m, apparently a continuation of the lower plateau in the northeastern part of the Julianehåb district around Narssarssuaq. The dominant rock is gneiss, which often, due to intense nivation at these altitudes, forms extensive blockfields. Patterned ground is rarely seen, even on the plateau.

The glacial deposits and erosion forms within the area may be divided into:

1) The terrain outside the above-mentioned morainic deposits. Besides boulder fields, this terrain is characterised by strongly weathered roches moutonnées, where glacial striae are but sparsely preserved, while the coarser glacial features such as sichelwannen, crescentic gouges, and conchoidal fractures (terms after E. LJUNGNER 1930) are more prominent.

2) The terrain around and inside of the said ice margin deposits, where all the exposed rock faces exhibit fresh polishing and glacial striation.

Thus there is reason to distinguish between these two areas, as a fairly long space of time must have elapsed between their formation.

The glacial forms mentioned under 1) were probably formed by a continuous ice cover across the area, and should therefore be referred to the Wisconsin. The terrain proximal to and at the morainic landscapes mentioned under 2) must be much younger. The morainic landscape proper is seen to consist locally of two ice margin lines, which will be referred to below as stages I and II. A dense cover of vegetation in these landscapes suggests that they are older than historic times. House ruins have been found on the deposits of these stages. It is unknown, however, to what period the ruins date back, so it is impossible on this basis to indicate a minimum age for the stages. The ruins are marked on the map in fig. 4 and fig. 5. They are described in more detail in the appendix, pp. 118–120.

The individual stages will be treated below in a chronological order, beginning with the Wisconsin landscape, succeeded by stage I and stage II, and finally the maximum extension of the ice in historical times.

Description of the deposits.

Wisconsin. – From this period there occurs, throughout the areas outside the ice front landscapes, ground moraines, boulder fields, and various glacial erosion forms.

As might be expected, the erosion forms preserved show a direction of ice motion through the valleys from the east and north towards the west and south. Immediately east of Ruinnæs (cf. fig. 5 and pl. 1) some coarse glacial striae, pointing towards the south-southwest, show that the ice stream through Nordbosø from the north and the ice stream through Storesø from the east were united here into one ice stream. Judging by the same glacial striae, it seems probable that at no time since the retreat of the inland ice from the inner parts of the Julianehåb district at the end of the Wisconsin, was the extension of Nordbogletscher very much larger than at present. This also appears from the later stages

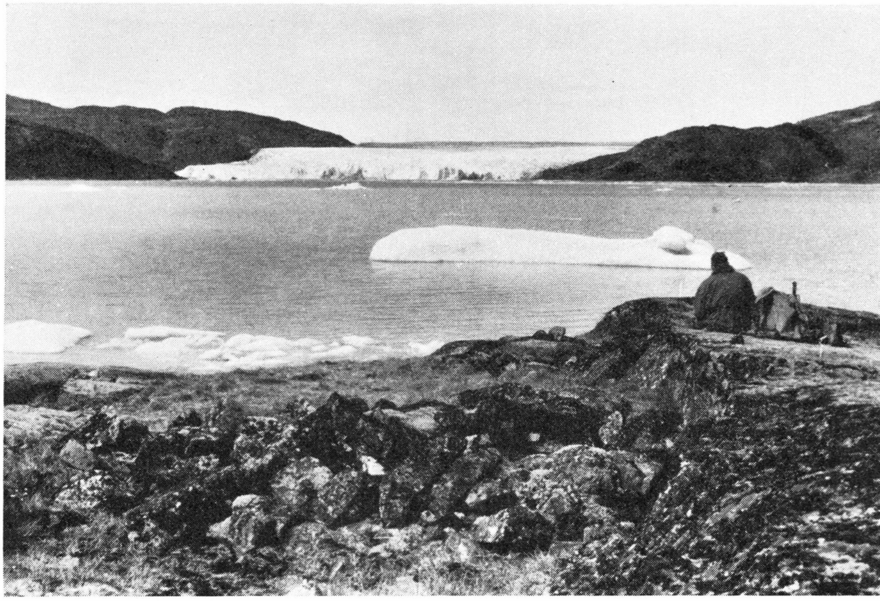

Fig. 5. Nordbogletscher and Nordbosø, in the foreground a ruin. ("Ruinnæs") Phot. A. WEIDICK 3/7 1960.

produced by ice streams from the south and east, but never from the north, a circumstance which may be of importance for an understanding of the drainage of the inland ice within this sector.

Deposits from stage I.

The eastern part of Nordbosø (pl. 2) forms a channel-like branch ca. 3 km long. It is excavated in a morainic landscape which in the outer part towards Nordbosø forms large outwash plains south and north of the branch of the lake, farther eastward passing into lateral and terminal moraines, alternating with extramarginal outwash deposits.

The terminal moraines along the mountain sides, especially in the north side of the valley, pass into lateral moraines or kame terraces. The outermost moraines, like the outermost outwash plain to the east, are characterised by dead ice topography. Numerous kettle-holes up to 10 m deep and 15 m in diameter, often interrupt the shape of both moraines and outwash plains.

The morainic material is composed of rounded to subangular boulders with a gravelly or sandy matrix. Gradually as one passes from the west towards the east, the moraines develop into more marked separate rows with less dead-ice topography. At the same time the moraines are crowned by large boulders without any matrix, the easternmost moraines in the landscape accordingly assuming the character of

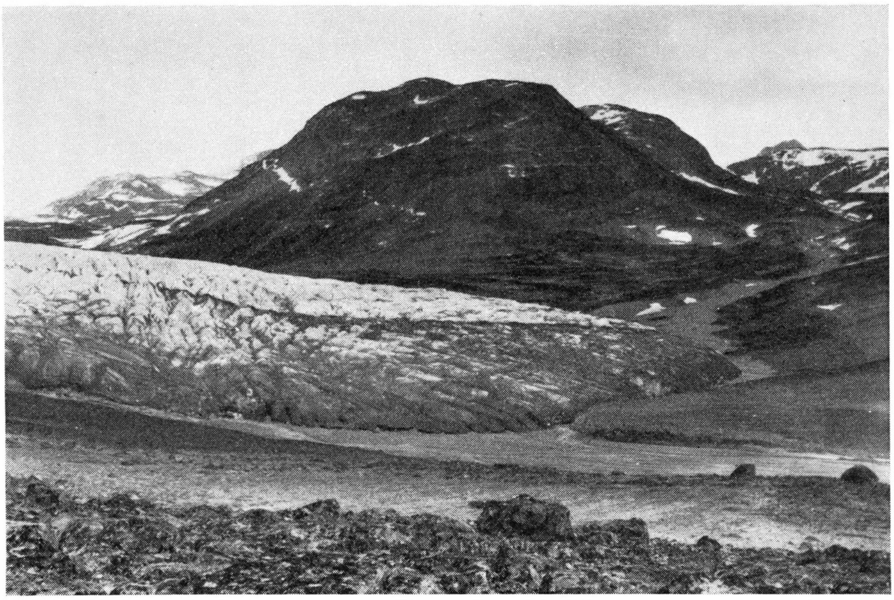

Fig. 6a. Nordgletscher. The profile with the two moraines described on p. 29 is seen immediately in front of the glacier termination. Phot. A. Weidick 4/7 1960.

Fig. 6b. Front of Nordgletscher. Close-up, showing the glacier front to the left. The person to the right in the picture is standing on the profile with two moraines described on p. 29. Phot. A. Weidick 4/7 1960.

block moraines. This landscape is terminated proximally to the east, at the west end of Storesø, by a smaller outwash plain formed by the succeeding ice front stage II.

The whole landscape deposited by stage II forms two terraces located north and south, respectively, of the eastern branch of Nordbosø. The altitude of the terrace surface is ca. 730 m, while the surface of Nordbosø itself occurs ca. 690 m above the sea.

The shape of the moraines suggests that they were formed by a glacier coming from the east. The development of the landscape some 30–40 m above the more easterly younger morainic landscape around and east of Storesø shows that it should be regarded as deposited by an isolated advance, from which only the westernmost remnants in the valley around Nordbosø are preserved. The advance must be separated by a prolonged space of time from the subsequent stage, hereinafter termed stage II.

It must be assumed that the deposits from stage I at Storesø were removed by erosion by the subsequent advance of the ice during stage II. The landscape around Storesø was thereby lowered about 30 m. Remnants of boulder and gravel terraces around Storesø at altitudes of 800–900 m probably give evidence of kame terraces or terraces from ice-marginal lakes from stage I.

The profiles, 30–40 m high, along the eastern branch of Nordbosø where this branch cuts into the above-mentioned morainic landscape from stage I, along the whole length (ca. 3 km) and height of the profile exhibit only stony and sandy till with large rounded to subangular boulders. As mentioned above, the innermost, easternmost, terminal moraines are crowned by large blocks up to 4 m in diameter with no enclosing matrix. The profile through these block moraines along the lake shows that only the tops of the moraines are made up of large blocks, the material grading rapidly downward into rounded to subangular blocks embedded in a matrix of gravel or sand. As can be observed at the present limit of Nordgletscher (see also p. 37), these block moraines must be assumed to have been formed by upthrusting of coarse material in connection with outwash of finer material along extra-marginal streams.

Lateral moraines near the same profile show that these meltwater streams had a steep gradient and accordingly a considerable power of transportation, which is also evidenced by the circumstance that it is difficult to distinguish between actual morainic material and outwash deposits. The similarity of the materials may perhaps also be due to the fact that during its advance to stage I, the inland ice must have moved across outwash deposits. This appears from the rounded character of the morainic blocks.

To the advance of stage I must also be referred a moraine observed in a profile at the front of Nordgletscher. This profile, ca. 6.5 m high, was found to contain:

	top	
0–0.5 m	Sandy till with large rounded boulders	
0.5–1.5 -	Sandy till, sometimes passing into cross-bedded alluvial deposits with few rounded boulders	glacial beds
1.5–1.8 m	Red layer of large rounded boulders with a sandy matrix, cemented together by hematite	glacio-fluvial beds
1.8–2.1 -	Sandy-gravelly cross-bedded layers with sub-angular boulders	
2.1–2.7 m	Sandy till, exclusively with subangular boulders	glacial beds
2.7–6.5 m	Cross-bedded sand with rounded boulders, passing gradually downwards into almost varved silt and clay	glacio-fluvial beds
	base	

As will be seen, there are two moraines, the uppermost of which geomorphologically forms part of a landscape shaped by the succeeding glacial advance during stage II. It is natural to assume, therefore, that the older moraine was deposited during stage I. The morainic layer terminates less than 100 m south of the front of Nordgletscher in a similar profile (fig. 6 a) facing the glacier stream which drains Nordgletscher. The deposits of the two profiles at Nordgletscher indicate an extension of Nordgletscher during stage I hardly very much beyond its present position.

The varved clay underlying the older moraine at Nordgletscher bears witness of quiet conditions of sedimentation prior to stage I. This must be due to less intense melting of Nordgletscher at the beginning of the cold period, which resulted in the advance of the glacier during stage I. Precisely in this area, a lowering of few hundred metres of the firn line will mean an immense decrease of the ablation of the inland ice. At the same time it must be assumed that the sedimentation took place in an ice-dammed lake bounded on the south by Sydgletscher. This glacier must accordingly have extended much farther northward than at present.

Deposits from stage II.

Provided that the lower moraine at the profile near the front of Nordgletscher is indicative of stage I, we must conclude, judging by the following glacio-fluvial beds present here, that a recession of Nordgletscher took place, succeeded by an advance of the glacier during

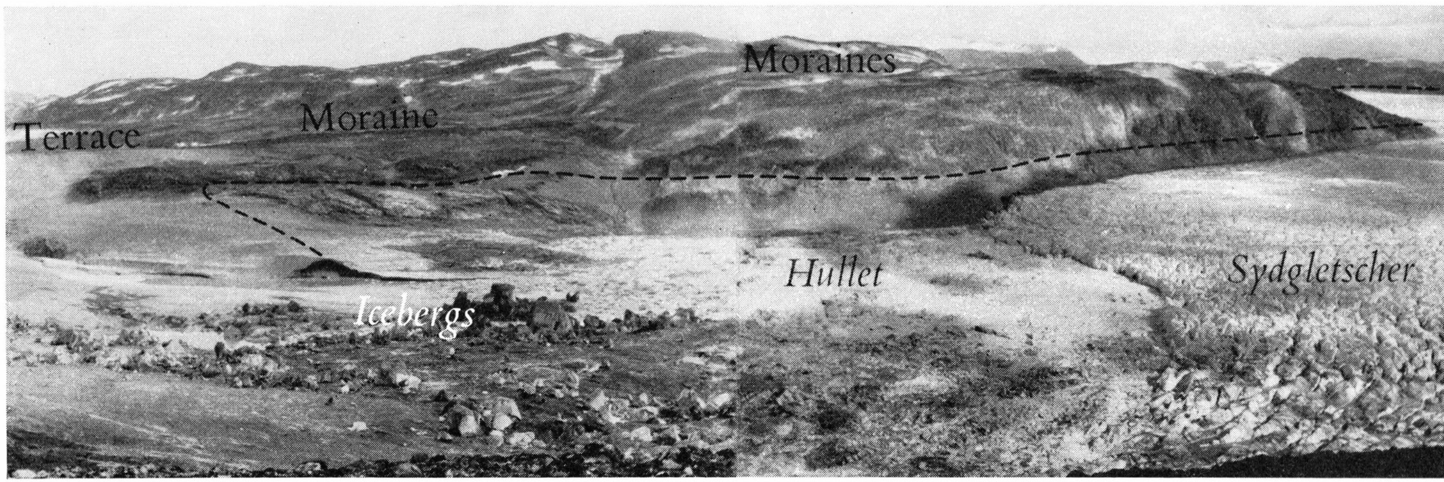

Fig. 7. Sydgletscher and Hullet, seen from the west. The stippled line shows the maximum extension of Sydgletscher in historic times. Phot. A. Weidick 16/7 1960.

stage II. The same must be assumed to have happened all along the front of Sydgletscher, though it cannot be demonstrated on the basis of the deposits found there.

Thus, it is impossible to ascertain whether the inland ice in general receded in the interval between stages I and II, or it merely retreated from the inner stationary lines resulting from stage I to the outer portions of stage II (marginal line IIa). As will appear from the attempted correlation of the ice margins in the whole Narssarssuaq region in a later part of this description of localities (pp. 76–77), it seems probable, from a comparison of the Narssarssuaq moraines, that stage I is older than the post-glacial climatic optimum, while stage II is most likely younger than this climatic optimum. It is possible, therefore, that in the intermediate period the ice margin generally had a much more limited extent than it has at the present time. The assumption that stage II should be the result of an isolated advance, may likewise be based on the rounded character of the morainic material from this stage.

Stage II itself can be divided into three phases, passing from the maximum extension of the inland ice during stage II (phase a in fig. 11) to the last phase (c), when the extent of the inland ice hardly exceeded its maximum extension in historical times.

Shortly after the end of stage II, the drainage of Hullet changed, the lake, formerly drained through Nordbosø, now being emptied by outbursts beneath the Kiagtût sermia glacier.

The whole stage II must be regarded as a landscape unit, and must accordingly be of importance outside the locality. Phases IIa, IIb, and IIc, however, are only of local importance.

Stage IIa:

At the western end of Storesø, a single morainic row is seen (shown on pl. 3). It surrounds the banks of the lake immediately below and east of the innermost moraines of stage I. The northwestern portion of the terminal moraine is separated from the older higher-lying moraines of stage I by an extramarginal outwash valley. This moraine, which characterises the maximum extension of the ice during stage II, is termed IIa below, like the phase it indicates (cf. also fig. 11). The landscape inside the moraine forms an extensive terrace around Storesø some few metres above its water level.

Moraine IIa appears only as a fragment, but still indicates by its shape that the ice came from the east. Similar morainic fragments are found at Nordgletscher and Sydgletscher, all located some distance outside the line marking the main stationary line, that is to say, phase IIb. Thus, occasional morainic fragments are seen northeast of Sydgletscher, sometimes in contact with the main stationary line, sometimes extending some few hundred metres beyond its front. Owing to its close contact with line IIb, we are here probably concerned with two phases of the same stage. Of special interest are here the moraines of phase IIa northeast of Sydgletscher and immediately south of Nordgletscher.

After constituting, for several kilometres along the east side of Sydgletscher, the outer part of the moraines of the main stationary line IIb, moraine IIa, east of the present ice-dammed lake Hullet, suddenly swerves northeastward along a stretch of ca. 2 km south of the river descending from Østgletscher. It is not continued by any moraine on the north side of the river; the continuation of the moraine, however, forms the approximate boundary of the large terrace at ca. 700 m altitude in this place.

Farther northward, near the front of Nordgletscher these terraces end abruptly at a moraine running almost in a straight line across the valley which connects Nordgletscher with the present ice-dammed lake in Hullet. Similar terrace remains, though considerably smaller, occur at an altitude of ca. 700 m along the mountain wall forming the west side of the aforementioned valley between Nordgletscher and Hullet.

It must be assumed, therefore, that Sydgletscher during its maximum extension in phase IIa formed the outer limit of the nearly horizontal terrace at 700 m altitude, which was thus a kame terrace during this phase. The straight course of the moraine across the valley from Nordgletscher would indicate that at times it was a median moraine between Nordgletscher and Sydgletscher. The drainage of this large eastern kame terrace must be supposed to have taken place beneath the glacier front proper. The drainage during phase IIa must be assumed to have continued farther westward through Nordbosø to the head of Tunugdliarfik fjord.

Stage IIb:

This phase characterised the main stationary line during stage II. From this numerous morainic ridges extending close to each other and parallel with the glaciers Kiagtût sermia and Sydgletscher issue from this line. As in the case of moraine IIa, the material consists predominantly of numerous large subangular boulders enclosed in stony or sandy till. To the west this line marked the boundary between Rundesø and Storesø, while to the north it separated Alephsump from Alephsø. Farther eastward it again turns gradually towards the south.

Fragments of shore lines washed out very nearly 720 m above sea-level, suggest that at times an ice-dammed lake existed between Sydgletscher and Nordgletscher. Nordgletscher probably extended about 100 m farther southward than at present, the shore lines ending here.

Fig. 8. Upper part of Qôrqup sermia and Annekssø, seen from the northeast looking toward the southwest. Air photo 501 E–SW, No. 237. Copyright: Geodetic Institute, Copenhagen.

Similarly, between the mountain sides and the outer moraines north of Hullet there occurs a well defined extramarginal outwash valley extending from the northwestern part of the main stationary line along the outermost distal parts of the moraines down to Storesø, whence the water flowed onwards through Nordbosø to Tunugdliarfik fjord. The highest point of the pass at the proximal part of this outwash valley occurs at an altitude of 720 m, the distal part at the western end of Storesø at ca. 705 m altitude. The outwash valley is indicated in fig. 11.

Outside the locality described here, the moraines of the main stationary line extend close to each other northeastward along Kiagtût sermia and Qôrqup sermia to another small ice-dammed lake, Annekssø, situated ca. 7 km east of Hullet (fig. 8). Here, as in the main locality around Hullet, the line indicating the former ice margin runs conformably with the present ice margin, but ca. 200 m above this latter.

South of the locality described above, lateral moraines along the northwestern margin of Kiagtût sermia can be traced uninterruptedly to a point ca. 6 km southwest of Hullet. Farther on, towards Narssarssuaq, only fragments of moraines are to be seen.

Stage II c:

The large number of marginal moraines between stage II b and the last phase, II c, suggest that the retreat of the ice during the latter part of stage II b was interrupted by frequent periods of stagnation or perhaps even by advances.

Throughout the recession of the ice between phases II b and II c the outwash from Nordgletscher, Østgletscher, and Sydgletscher passed through Nordbosø. However, the drainage conditions changed in pace with the recession. In the period between phases II b and II c shore lines on the proximal sides of moraines II b indicate that the meltwater made its way from an ice-dammed lake north of Sydgletscher, along Langesø, back of moraines II b, to Storesø. All the lines marking the water levels show that the surface of the ice-dammed lake was ca. 700 m above sea level. Simultaneous with the formation of this extramarginal river inside moraines II b at the northwestern part of Sydgletscher another outwash stream passed through Rundesø draining the western portion of Sydgletscher south of the rock knoll C shown in fig. 4.

That the two outwash streams were synchronous, is inferred from the circumstance that the terraces formed by them join at the west end of Storesø at the above-mentioned altitude of ca. 700 m. Terraces at altitudes of 700 m completely surround Storesø, occurring only few metres above the present level of the lake. They form a natural continuation of the above-mentioned outwash deposits at Rundesø and the 700 m terrace at Langesø.

To the north the ice-dammed lake at 700 m a. s. l. covered the lower parts of the moraines formed by phase II b. This is evident from the circumstance that near Alephsump and Alephsø the moraines descend towards Hullet to an altitude of ca. 600 m, while the shore lines continue as a large terrace-notch in moraines II b at 700 m altitude.

While the ice still stood at the inner moraines II c, the meltwater made its way through Rundesø and Langesø westward via Storesø. This appears from the fact that the inner moraines at Rundesø, deposited during phase II c, are partially buried in the 700 m terrace. However, the outwash terrace ends abruptly only a few metres behind the innermost moraine II c. After the retreat of the ice from this terrace, the meltwater must therefore have found other ways out, for no lower threshold here leads towards Storesø.

Terraces along the sides of Hullet, especially its east side, bear evidence of a step-like lowering of the water level. Thus, the water level of the lake must have remained for a rather long time at these terrace

Fig. 9. Moraines around Langesø. Phot. A. WEIDICK 11/7 1960.

steps, which terminate downward in a marked outwash terrace at 600 m altitude at the north side of Hullet, along the south side of the river issuing from Østgletscher.

Thus, the only form of drainage that may be taken into consideration is outbursts of the water of Hullet beneath the ice to the front of Kiagtût sermia near Narssarssuaq. As will appear from the terrace at Rundesø, this must have started immediately after the deposition of ice margin IIc. At this stage the terrace at Langesø, Rundesø, and the proximal sides of moraine IIb indicate a water level approximately 700 m a.s.l., while the minimum altitude of the inner moraine IIc in Hullet marks the maximum depth of the ice-dammed lake as ca. 550 m a.s.l. at the glacier front. Thus the outbursts set in at a maximum water level at the glacier front of ca. 150 m.

Maximum extension of glaciers in historic times.

After the final phase, IIc, the ice probably receded to its present position, or perhaps not quite as far back. However, no unmistakable evidence thereof is available.

This recession was succeeded by the advance in historical times. The maximum extension during this advance is indicated by the sharply delimited vegetation-free "trim line zone" around the glaciers. At Hullet the height of the zone is 30 to 50 m above the present glacier surface. In Hullet, the glacier front would seem to have stood 1–2 km in front of its present position, as shown by moraines, indicated below points C and D in fig. 4, and by the outfall into Hullet of the large glacier stream from Nordgletscher. The latter locality, now normally found at the bottom of the ice-dammed lake, can be observed only after an outburst from the lake. The moraine is situated ca. 460 m above sea-level. It is only 5–10 m high, with the outline poorly preserved, and in the profile facing the river is seen to consist of gravel and stones underlain by dark ice in the portions nearest the glacier (the proximal part of the moraine). The dark-coloured ice probably indicates the maximum extension of the ice in historical times, and the overlying folded sediments must then be assumed to have been deposited during subsequent minor readvances.

The profile shown in fig. 7 must therefore give very nearly the maximum extension of the glacier in historic times, and accordingly the lowermost portions of the glacier must at that time have been located at an altitude of ca. 460–450 m, while judging by the trim line, the maximum water level of the lake must have occurred ca. 600 m above sea-level. The maximum depth of the water during the outbursts must accordingly have been ca. 150 m. Here, as in the case of phase IIc, the drainage can only have taken place by outbursts, the inclination of Sydgletscher towards Hullet to-day as in former times being too steep to allow drainage of the lake across the surface of the glacier or along its sides.

As regards the dating of the retreat of Sydgletscher from its maximum extension in historical times, it can only be stated that the trim line zone is entirely devoid of lichens as far as some few metres from its uppermost limit. Irrespective of the possibility of a more accurate lichenometric dating, as devised by R. BESCHEL (1958), this may only be interpreted as a relatively late recession of the ice from its maximum extension. This agrees well with the report by K. J. V. STEENSTRUP of the recession of the front of the Kiagtût sermia glacier. As late as 1876 this glacier retained its maximum extension, and still in 1890 showed but slight shrinkage (A. WEIDICK 1959, p. 43). Accordingly, at the front of Kiagtût sermia only a sparse migration of lichens across the trim line can be observed. It must be assumed, therefore, that at Hullet, also, the retreat of the glacier has largely taken place after the year 1900. The area immediately south of Hullet around Kiagtût sermia was visited in 1876 by K. J. V. STEENSTRUP, G. HOLM, and J. DAHL (Medd. om Grønl., Bd. 2, pp. 8–11), but no description or figure of the position of the ice front at that time is available.

To the northeast, the trim line zone continues almost as far as the firn line, that is to say, to an altitude of ca. 1600 m, where it disappears. However, up to ca. 1700 m some very small patches, which may be interpreted as remnants of a trim line zone, are to be seen locally along the margin of Qôrqup sermia.

The lower portions of Østgletscher are likewise seen to be surrounded by a trim line zone with dimensions similar to those of the zone at the upper part of Sydgletscher near its issue from Kiagtût sermia. Owing to the position of the glacier tongue near the firn line, the trim line zone is seen to thin out rapidly over a distance of some 1200 m, and to disappear entirely at an altitude of ca. 1600 m. Here, as at Sydgletscher, the recession of the glacier must be assumed to have commenced about or after the year 1900.

Nordgletscher, however, would seem to have behaved differently. No trim line zone is observable along this glacier. Along its west side there is a zone, a few metres broad and bare of vegetation, formed by the agency of an extramarginal stream. Some block moraines 2–5 m high are situated immediately outside the glacier front or embedded in its lower portions. Outside the moraines, a stream has cut its way deep into the morainic deposits from stages I and II. It is in this cliff that the profile mentioned under stage I (described on p. 29) is located. Over an area ca. 100 m broad the southern front of the glacier has pushed across the above-mentioned older moraines and the extramarginal stream. To-day the glacier front has forced its way into the old morainic deposits from stages I and II on the southern shore of the stream (see fig. 6). The stream therefore now flows beneath the glacier front to the east, where, emerging through a glacier vault, it bends sharply southwards again, in the direction of Hullet. The front of Nordgletscher is almost vertical along the lowermost 20 m, but subsequently flattens rapidly out at higher altitudes. The front is highly intersected by radial crevasses.

To the east, the lower parts of Nordgletscher are bounded by the aforementioned block moraines, and the extramarginal stream beyond them which comes from a valley east of the glacier. Farther northward, above the stream, the glacier is bounded by similar small narrow moraines, but no trim line zone is present. Here, as at the front, the moraines are block moraines with no very great content of fine-grained material, which must be due to outwash from the extramarginal meltwater streams. The moraines are assumed to be push moraines.

The absence of a trim line zone and the strongly vaulted character of the glacier front at the above-mentioned small moraines must indicate that the glacier is advancing. The blocks in the moraines are much rounded, suggesting that the glacier has advanced across alluvial deposits.

Only few data on the advance of the glacier in historical times are available. According to Mr. S. Bowlin, warrant officer, U.S. Army, who was stationed at the Narssarssuaq air base in the summer of 1957, Nordgletscher had then probably been advancing for the last five years, the advance of the glacier front during this period having amounted to ca. 200 m. As stated below, the supposed advance of Nordgletscher in recent time is confirmed by air photographs taken in 1947, 1953, 1957, and 1960.

A similar absence of a trim line zone is observed at Nordbogletscher, which is known to have had the same extension, at any rate at the time of our visit in 1960, as seen on the air photographs from 1953 (cf. also below) and when visited by the author in 1957.

It is further known that the glacier Eqalorutsit kangigdlît sermia east of Nordbogletscher has been stationary since 1894, and that in 1955 the glacier was swelling (A. WEIDICK 1959, pp. 59–61). It must be assumed, therefore, that the whole sector of the inland ice from Eqalorutsit kangigdlît sermia in the west to the Niviarsiat nunataks in the east has in the main been stationary in the present century, but that it has been advancing, at any rate partially, in the most recent years.

Conditions of Hullet and Sydgletscher in the summer of 1960.

The recent conditions of Nordgletscher and Sydgletscher having been treated above, only the conditions at Sydgletscher and Hullet will be dealt with in more detail here. The ice-dammed lake in Hullet is only one of the many ice-dammed lakes located along the margin of the Greenland ice caps which are drained periodically by outbursts. Only few data are available concerning the process and period of the outbursts from these lakes in West Greenland. Hence, I consider it justifiable to give here a more detailed description of the lake in Hullet, all the more so since the period for outbursts from this lake (about once annually, most often in May or June) is well known.

The reason of our detailed knowledge of the outbursts from the lake, although the lake itself is little known, is the establishment of the Narssarssuaq air base. The Base is located at the front of Kiagtût sermia, near the river draining this glacier. When an outburst begins, the water level of the river rises several metres, and a wooden bridge built across the river near the Base has repeatedly been washed away by the current.

The periodical processes of outbursts from the lake are known as fare back as 1950. The shape of the lake at the following dates is known:

1947: air photograph (502 D-N no. 82, taken on 4/7 1947). The level of the lake was then apparently located ca. 490 m above the sea.

1953: Air photographs (201 N no. 12623 and 202 C no. 12648, both taken on 21/8 1953). The photographs show that at the beginning of August the level of the lake was elevated ca. 470 m above the sea. It is natural to assume that outbursts had taken place earlier

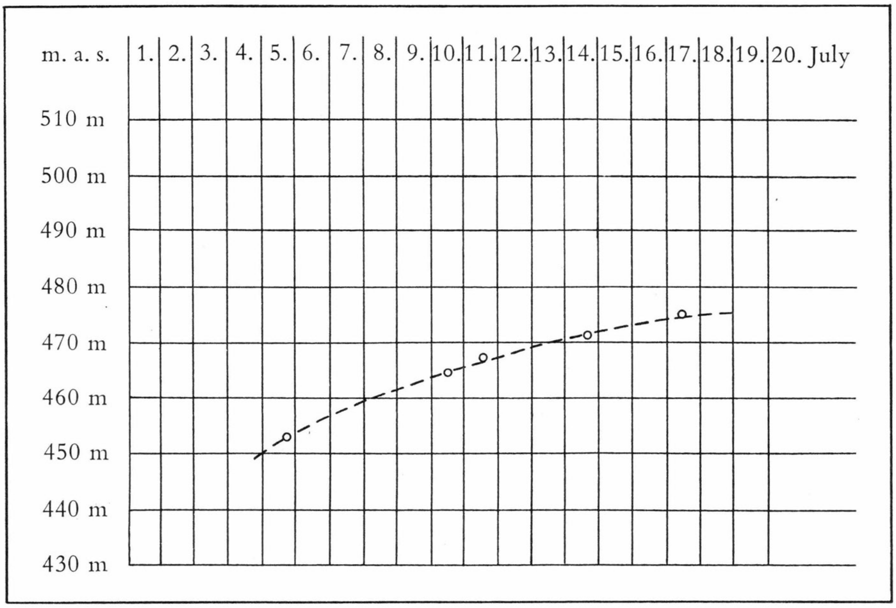

Fig. 10. Measurement of the depth of the water in Hullet, July 1960. Ordinate: water level above the sea in metres, abscissa: date.

in the year, and that on August 21st the lake was in process of filling.

1957: During the author's visit at Hullet (27–30/7 1957) the following profile was measured:

Surface of 700 m terrace	700 m a.s.l.
Trim line begins	600 - –
Uppermost stranded icebergs	540 - –
Water level of lake on 27/7	525 - –

Outbursts from the lake are known to have taken place at the beginning of June that year (P. Leighty and A. Poulin 1960, p. 7). The filling of the lake must therefore be assumed to have commenced about mid-June.

1960: Outburst from the lake took place by the middle of June. This assumption is based on the fact that no rise of the river at Narssarssuaq was observed during the author's stay in this locality (28/5–12/6). Moreover, at this time the personnel at the air base informed me that no rise of the water level of the river had been observed earlier that year. On the author's arrival at Hullet on June 30, however, the water level was situated at only ca. 430 m, but, as shown in fig. 10, it rose continually during the month of July. It is assumed, therefore, that the outbursts occurred between June 12th and 30th. The gradually decreasing rate in the rise of the water level during the period of observation would be expected by consideration of the shape of the lake.

The presence of large numbers of icebergs on the lake bottom up to a height of ca. 530 m a.s.l. might suggest that the outbursts took place at this altitude. The glacier front, which in the years 1947, 1953, 1957, and 1960 seems to have occupied the same position, probably rests on the bottom of the lake. At any rate, the bottom of the lake slopes gradually from an altitude of ca. 470 m to ca. 430 m, only interrupted by a river groove in the sand and gravel which everywhere cover the lake bottom. If this level bottom continues southward merely along a distance of ca. 1 km, the glacier front must rest on the lake bottom at a depth of ca. 400 m a.s.l.

At the west side of the glacier front, Sydgletscher is seen to cling to the lateral wall at an altitude of ca. 540 m, while the glacier front nearby is situated at a height of ca. 500 m a.s.l. (see the map in fig. 4). This shrinkage of the glacier front is traceable southwestward as far as the small ice-dammed lake located below points A and B (on Balkonen). It must be assumed that the outbursts follow this route, and that a minor subglacial groove exists forming a continuation of the glacier stream draining Nordgletscher and Østgletscher.

The said data from 1953, 1957, and 1960 are suggestive of a particularly marked periodicity, which seems to be but slightly associated with the meteorological conditions as registered in the individual years. Similarly, the glacier front seems to be stationary. To find out the order of magnitude of the filling of the lake by calf-ice, the surface velocity of the glacier was measured by Mr. Per Kirkeby. Four points were measured by intersection from the base A-B (fig. 4) during the period July 1–18. The interval between the individual measurements was 1–4 days, except for I, which was only measured on July 1st and 5th. During the period of measurement, the motion of the ice seemed to be gradual and of the following order of magnitude:

Point	I–	95 cm/24	hours
–	II–	35 cm/24	–
–	III–	23 cm/24	–
–	IV–	102 cm/24	–

The position of the rods and the direction of movement are shown in fig. 4.

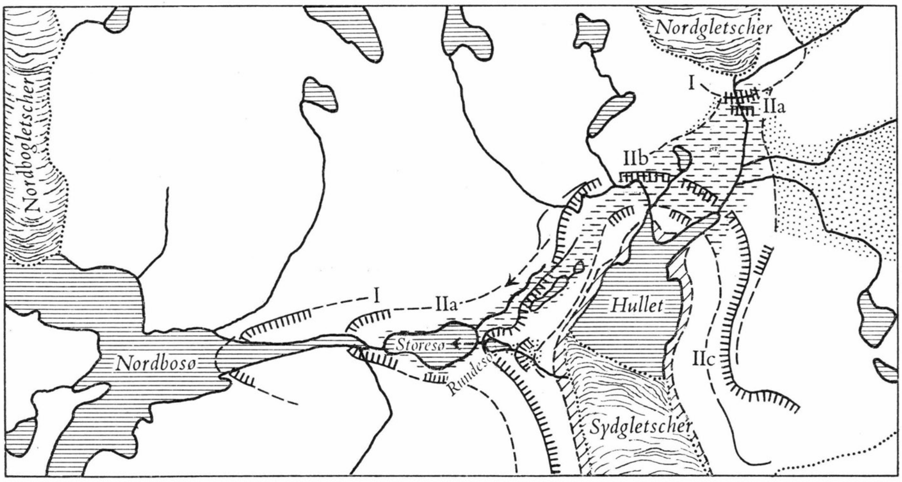

Fig. 11. Map showing the development of the landscape around Hullet. Horizontally hatched areas: lake and river deposits, obliquely hatched areas: trim line, dotted areas: terraces.

During the period of measurement the rods showed a melting of the ice of the order of ca. 3 cm/24 hours.

The measurements of the movements of the points were made with a Wild theodolite T1. The great velocity of point I may be due to the unreliability of making only two measurements, but may also be due to the filling of the subglacial tunnel formed during the outbursts.

Narssarssuaq-Kiagtût.

The area extends from Tunugdliarfik fjord in the west to the glacier Kiagtût sermia in the east ca. 8 km from the fjord and, at the shore of Tunugdliarfik fjord, from a locality ca. 2 km north of the outfall of the river from Kiagtût sermia into Tunugdliarfik fjord to the harbour area of the Narssarssuaq base located ca. 3 km south of the river mouth. The area consists of a large northeast-southwest running valley which connects Tunugdliarfik fjord with a branch of the inland ice: Kiagtût sermia.

The lowermost part of the valley is separated from the fjord by well defined ice margin deposits for the most part developed as terminal and lateral moraines and as kame terraces. The ice-margin deposits are divided into two lobes, a ca. 100 m high rock knob immediately north of Narssarssuaq river having presented a material obstruction to the earlier ice flows from the east which deposited the ice front lines.

The establishment of the Narssarssuaq base in the years after 1941 caused disturbances of large portions of these deposits. This especially applies to the southern parts of the southern lobes located south

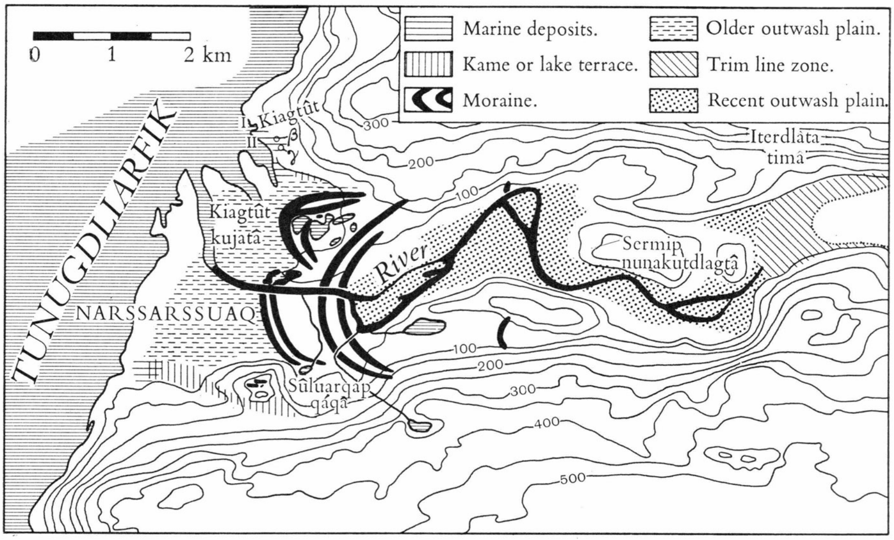

Fig. 12. Narssarssuaq. Sketch map of the area. Ice margin deposits and areas with marine shore lines.

of Narssarssuaq river. Here tank plants and part of the town were built on kame terraces, while the large runway cuts across the outermost two terminal moraines. Similarly, the building of houses still farther eastward in the Base area necessitated a removal of the innermost moraines.

The present condition of the area will appear most distinctly from a photograph of the Base reproduced in several papers (E. BRUN 1946, p. 49, BIRKET-SMITH, MENTZE, and FRIIS MØLLER 1950, vol. 1, p. 313, G. A. AGRANAT 1953, p. 305). However, so many features of the ice front lines are still preserved that a reconstruction is possible. Very helpful in this respect is also an aerial photograph of the area, taken by the Geodetic Institute in 1937, that is to say, prior to the building of the air base. For information of the existence of this picture the author is indebted to Colonel J. HELK.

The portion of the southern lobe which is situated north of the river, and the whole northern lobe are in a better state of preservation. Apart from a gravel pit located on the northern bank of the river, and various minor antennal arrays, this area is well preserved. The area is called Camp Corbett by the Americans, but the name now authorised for the region north of the river is Kiagtût kujatâ.

Geomorphology.

The older glacial features, that is to say, rôches moutonnées, glacial striae, and friction cracks, all seem to bear witness of having been over-flowed by ice moving from the east through Narssarssuaq valley. The marks are, as a rule, poorly preserved.

Geomorphologically and chronologically the loose deposits may be divided into three groups:

1) The shore formations and kame terraces north of Kiagtût kujatâ at the locality Kiagtût.
2) The moraines and the outwash plains at Kiagtût kujatâ and Narssarssuaq.
3) The landscape at the front of the glacier Kiagtût sermia, developed during and after the maximum extension of the glacier in historical times.

The material building up the area consists almost exclusively of gravel with rounded boulders, overlain by wind-blown sand, so a chronology, with the exception of the oldest deposits, must be based almost exclusively on the morphological conditions.

Shore lines at Kiagtût.

Evidence of shore lines is found in two bays near Kiagtût (see fig. 12). In both places outwashed material from moraine deposits is found ca. 10 and ca. 30 m above sea level, indicating temporarily static sea levels at these altitudes. As will be seen from the profile on p. 47, fig. 13, profile in the southern bay (bay II), prior to the formation of the uppermost sea-level, marine clay was first deposited, which was later partially covered by morainic material from a glacier advancing from the southeast, i. e. across Kiagtût kujatâ. This direction of the ice motion is also indicated by the orientation of the embedded blocks.

Near Kiagtût kujatâ, on the north side of the valley, two terrace fragments occur, the surface of the upper one sloping from an altitude of 33 m to ca. 30 m a. s. l. at the lowermost western portion, and apparently continuing in a lower, more westerly terrace. The surface of the lower terrace has a maximum altitude (to the east) of ca. 25 m a. s. l., sloping towards the west to an altitude of ca. 10 m. The lower part of the terrace terminates in an abrupt cliff towards the sea. The terraces are indicated in fig. 12. Towards the valley they are bounded by a lower-lying outwash plain, morphologically associated with the large terminal moraines in the area. The gradual inclination of the terraces down to ca. 15 m a. s. l., whence they flatten out westward to the lowermost 10 m a. s. l., suggests that they were formed at a time when the water level was some 10–15 m above the present level of the sea.

In the southern part of Narssarssuaq a similar terrace is met with. It is situated immediately south of the town, the southernmost houses being even built on sites dug out in the terrace. Judging by the course of the terrace, as appearing from the map in fig. 12, it is a kame terrace, for it slopes steeply from a distinct ice contact at an altitude of 150–200 m east of the town to the tank plants west of it. The tank plants are situated on the terrace at an altitude of 10–15 m a.s.l. Here, too, the part of the terrace between 10 and 15 m slopes much more evenly than the higher-lying portions of the terrace, indicating that the deposition took place at a sea-level elevated 10–15 m above the present level of the sea. Furthermore, two well defined lateral moraines are found on a small, ca. 200 m high, rock knob, Sûluarqap qáqâ, located east of the town and bounding the upper part of the kame terrace. At the time of their formation the glacier probably descended into Tunugdliarfik fjord with a calving front, for soundings to the bottom of the fjord off Narssarssuaq reveal only a delta cone extending some few hundred metres out into the fjord from Narssarssuaq, but no terminal moraines.

Considering the extension of the glacier, estimated on the basis of the two terrace systems on the north and the south side, respectively, of Narssarssuaq valley, and the flattening of the kame terraces at 10–15 m altitude, it is natural to assume that they were formed by one and the same stage.

The morainic landscapes on Kiagtût kujatâ and Narssarssuaq.

Four well delimited morainic zones occur here. Near Kiagtût kujatâ the outermost two moraines enclose two lakes, called by the Americans "Pine Lake" and "Cedar Lake". "Pine Lake" occupies the terminal basin of the outermost morainic landscape, "Cedar Lake" that of the outermost but one. The lobes are separated from the corresponding lobes on Narssarssuaq south thereof by the nearly one hundred metres high mountain knob which during these advances almost had the character of a nunatak.

Also in the area south of the river running through Narssarssuaq the two outer moraines are seen to extend entirely parallel across the plain to the south side of Narssarssuaq valley. The terminal moraines here pass into somewhat obliterated lateral moraines. As mentioned above, a substantial part of the two terminal moraines was removed at the erection of the air base.

The third and the fourth morainic row east of the first two likewise form a closely parallel system of double moraines. The two moraine rows form only a single lobe, only the outermost moraine extending so far northward as to get into contact with the isolated mountain knob, ca. 100 m high, north of the river. On the south side of the river this double system of moraines is traceable as far as the mountain walls at the south side of Narssarssuaq valley, where the moraines pass into a system of small kame terraces and marginal channels.

Inside these four main stationary lines, a morainic fragment is seen on the north side of the river between the moraines and the front of Kiagtût sermia. Their continuation on the south side of the river should probably be looked for in corresponding morainic remnants located east of the former Base hospital. The actual terminal moraine formerly connecting these two small morainic fragments was probably washed away during the formation of the large recent outwash plain extending from the innermost main stationary line in the west to the area around Kiagtût sermia in the east. The northern morainic fragment contains gravel with rounded boulders, while the southern one, consisting of two parallel ridges, has developed into block moraines.

The probability is that all the four main stationary lines should be characterised as deposited by the same stage, while the moraines farther eastward, near the hospital, should be regarded as a phase of the recession of the ice from this stage. This conclusion is drawn from the fact that all these moraines were formed at a time when the level of the sea was almost at its present height. Moreover, the two outwash plains from the outermost main stationary lines, separable by their top points, soon unite at sea-level and likewise show no trace of marine sedimentation or outwash at other altitudes than the present one. All the moraines are located on a terrace elevated ca. 10 m above the present river. Thus, they constitute a morphological unit.

All the moraines are overlain, particularly on their west sides, by blown sand deposits, due to the severe easterly winds blowing through the valley even at the present day. In the area north of the river, from the third main moraine to the eastern moraines, the landscape is characterised by dunes which are often covered by willow scrub. Towards the river the landscape forms steep cliffs down to the recent outwash plain, which must mean that the sand-drift largely took place during or immediately after the retreat of the ice.

The landscape at the front of Kiagtût sermia.

The front of the glacier Kiagtût sermia is to-day (1960) merely a zone, ca. 1 km broad, completely covered by surface moraines. A delimitation of the actual glacier from the land west of it is therefore difficult. From the area with unmixed glacier ice, situated ca. 1 km behind the front, the surface passes in a distal direction through banding, formed by upward transport of ground moraines along shear planes (shear moraines), into a dead-ice landscape at the marginal area of the glacier. The dead-ice landscape is chiefly made up of rounded boulders and gravel. Sometimes, however, minor isolated areas with stratified sand are met with, which areas have a maximum surface of several square metres and a thickness of 1.5 m. This form could also be observed in process of formation in depressions in the dead-ice landscape, and must accordingly most adequately be regarded as hat-shaped hills or kames, according to V. MILTHERS (V. MILTHERS 1948, p. 56), though most often without a morainic covering.

The river which drains the glacier, rises on the north side of the glacier front. Along the whole northern part of the glacier front the river has a sub-glacial course, which, however, is partially traceable at the collapsed dead-ice patches above the river. After emerging at the glacier front, the river flows southward along the whole front, subsequently turning westward to Narssarssuaq and Tunugdliarfik fjord. Two moraine rows, possibly with dead-ice cores, occur off the glacier front on the west side of the river. The outer row must mark the maximum extension of the glacier in historical times, for even this lacks every form of a vegetational covering.

In continuation of the outer moraine, trim lines, likewise indicating the size of the glacier during its maximum extension in historical times, are seen on the mountain walls north and south of the glacier. During this period the drainage of the glacier did not take the same course as at present; the greater part of the drainage took place across a small valley immediately west of the glacier front between the north side of Narssarssuaq valley and a rock knob, ca. 200 m high, Sermip nunakutdlagtâ, situated in the middle of the valley. At that time, the water in the valley was pent up so as to form an ice-dammed lake, which also was drained southward through a small pass on the west side of Sermip nunakutdlagtâ. The lake existed as late as 1899 (WEIDICK 1959, p. 43), but was later, at some unknown time between that year and the 1940's, emptied during the recession and shrinkage of the glacier. Remnants of terraces formed around the lake are to be seen to the west and south in the valley.

The changes of the glacier in historical times will be dealt with under "Interpretations", p. 52.

Profiles in the deposits.

In respect to material, the terrain is fairly homogeneous, and the numerous profiles found in the area can be divided into three groups:

1) Profiles in the deposits at Kiagtût.
2) Profiles in outwash plains and kame terraces and in the major moraines.
3) Blown-sand deposits.

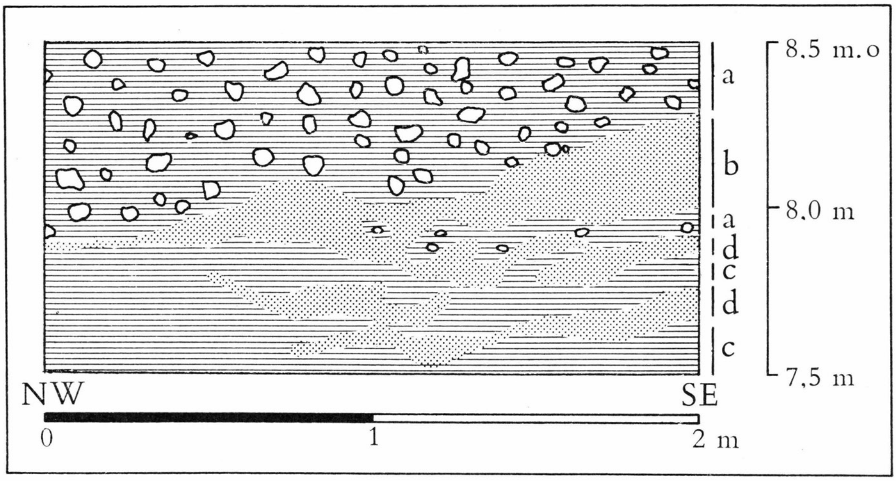

Fig. 13. Profile through the boulder clay at Kiagtût. Ordinate: height of profile above the sea in metres. a = jointed clay with subangular to rounded boulders up to the size of a clenched fist. b = sandy till with boulders as in a, sometimes, however, with gravelly instead of sandy matrix. c = jointed clay poor in stones. d = gravel, poor in stones. The map in fig. 12 shows the position of this profile at Kiagtût (γ).

Profiles in the deposits at Kiagtût.

The aforementioned two profiles in the area are morphologically uniform, but differ greatly in regard to material. Both profiles show traces of outwash ca. 10 m above sea level. This can be seen most distinctly by measurement of profile I (see fig. 12), where an accumulation of rounded boulders was found precisely at this level on an otherwise evenly sloping surface. In profile II, however, a terrace notch, though obscured by later solifluction, is seen at this level.

Above the 10 m level, profile I is covered by a dense vegetation. Minor cliffs along a river cutting across profile I, suggest that throughout its extent the profile developed in sandy or stony till with a high content of subangular to rounded blocks. The profile flattens out upward, to be sharply bounded by cliffs at its top at altitudes of 31 to 33 m a.s.l. The flattening and the abrupt limitation at this altitude is taken to be an unmistakable proof of marine outwash of the ground moraine which forms the profile.

The conditions at profile II are more complicated. Here, in the northern part of the locality from ca. 10 to ca. 33 m a.s.l. confluent beach ridges were deposited on (and no doubt washed out from) an underlying moraine built up of sandy till with abundant angular and some subangular blocks. In most cases the diameter of the blocks does not exceed ca. 10 cm, that is to say that they are of slightly larger dimensions than the pebbles found in the overlying beach ridges (maximum diameter ca. 7 cm).

To the south, in an excavation at locality β (see fig. 12) 7.35 m a.s.l., profile II was found to contain, at the top, 2 m of sandy till with big subangular boulders, underlain by a transitional bed, ca. 60 cm thick, containing smaller and more sharp-edged blocks. This transitional layer grades downward into lenses of gravel (ca. 5 cm thick) and block-bearing silt. At the base of the profile, immediately below the transitional layer, silt and clay with a sparse content of boulders were observed.

Another locality near the same profile, termed γ in fig. 12, must be regarded as located in the transitional layer between the overlying moraine in profile β and the underlying "jointed clay". The main content is probably silt, not clay. The top of the profile is found ca. 8.5 m a.s.l. The uppermost layer was formed by a moraine 0.5–1.0 m thick, the matrix of which was jointed clay and the boulders subangular to rounded in shape, with a maximum diameter of ca. 8 cm. The orientation of the boulders was often horizontal, with the longitudinal axis of the boulders pointing northwestward.

The morainic layer was underlain by wedges and lenses of silt with boulders as in the overlying bed, or of coarse gravel with angular grains. The wedges and lenses are folded into beds of jointed clay poor in stones and gravel poor in boulders. The base of the profile consisted throughout its extent (ca. 2 m) of jointed clay poor in stones, but with a single shell cast. Owing to the high content of silt in the jointed clay, shell fragments are probably rarely preserved.

The wedges and lenses found between the upper stony till and the underlying jointed clay, which is here taken to be boulder clay, may be due both to glacier pressure and to solifluction. The size of the flakes, however, points to glacier pressure. Thus, the two moraines: the upper stony till and the lower boulder clay, are indicative of two glacial advances. That we are here confronted by boulder clay, not marine clay, is evidenced by the clay's content of boulders. Shell material, if any, would show whether the clay was at any rate partially derived from marine deposits during the earliest advance, during which the jointed clay was deposited. It was not possible to trace the jointed clay down to sea-level in any single profile. The cleared area at the sea, where an antennal plant for the wireless station at Kiagtût kujatâ ("Camp Corbett") is situated, rests entirely on this silty substratum. In a small cliff, ca. 1 m high, facing the fjord below this plant, sandy till is seen, probably belonging to the upper bed of stony till. It is probable, therefore, that an upper moraine of stony or sandy till, 1–20 m thick, everywhere overlies the lower boulder clay. The lower boulder clay has only been observed to heights of ca. 9 m above sea level. The difficulty in carrying

Fig. 14. Narssarssuaq valley. Phot. A. Weidick 11/6 1960.

out a more accurate mapping of the moraines is due to the high content of silt in the lower moraine, which together with the high water content of the material, due to its position against a mountain wall, gives rise to solifluction, and thus renders large-scale profile excavation impossible.

Profiles in outwash plains, kame terraces, and moraines.

In the numerous intersections of moraines both at Kiagtût kujatâ and on Narssarssuaq, very coarse stony till with large rounded boulders are to be seen. The rounded character of the material might suggest that it was derived by the glacier from an alluvial deposit.

A similar material is seen in the numerous excavations in the kame terraces at Kiagtût kujatâ and on the outwash plains. In most cases the transition from moraine to outwash plain cannot be decided on the basis of the material, while in a morphological respect it presents no difficulties.

The only exception in respect to material is the large kame terrace south of Narssarssuaq town. In profiles to the east, nearest the ice contact, this terrace exhibits stony till, which passes downwards into cross-bedded sand and gravel. This can be seen in profiles immediately south of the town. The lowermost profiles near Tunugdliarfik fjord here show pure clay without boulders. These last-mentioned profiles are located ca. 10 m above sea level.

Deposits of blown sand.

As mentioned in the description of the morphological conditions, the moraines are covered by a layer of blown sand sometimes several metres thick. The blown sand may in places be so coarse that it must be characterised as gravel. These deposits owe their existence to the strong eddy winds blowing from the inland ice and experienced in the area also at the present day. The blown sand in the profiles is "cross-bedded", sometimes with beds of organic material (twigs, branches, humus colouring).

Interpretation of the deposits in the Narssarssuaq-Kiagtût area.

An interpretation of the glacial deposits of the area must be based almost exclusively on the geomorphological conditions. An exception, however, is formed by the oldest deposits north of Camp Corbett and the lower parts of the kame terrace south of the town of Narssarssuaq.

The earliest deposits must be assumed to be the shell-bearing lower moraine at Kiagtût. The shell content shows it to be a re-worked marine deposit. The marine deposit was succeeded by an advance of glacier ice, to which the formation of the lower moraine is due. During this advance the previously formed marine deposits must have been disturbed and intermixed, at any rate partially, with the lower boulder clay.

A later advance of the ice is indicated by the overlying moraine consisting of stony and sandy till. The highly rounded character of the boulders in the moraine suggests that a recession of the ice took place in the interval between the two advances, giving rise to the formation of an outwash plain whose material was embedded, at any rate partially, in the moraine resulting from this second advance.

Both these moraines are older than the highest marine limit in the area (30–33 m a.s.l.), this marine level having been eroded out in the younger moraine (the younger sandy or stony till).

If we assume that the oldest marine deposits are of Holocene age, the marine deposits at Kiagtût must be supposed to have been laid down in Holocene times at a water level ca. 10 m above the present water level, after which the country subsided to ca. 30 m below its present level. Nowhere in Greenland has such a transgression succeeded by the present regression of such an extent in Holocene times been ascertained.

It seems probable, therefore, that the shell-bearing clay should be referred to an interglacial period, and the boulder clay probably to the Wisconsin ice age. The overlying stony or sandy till probably belongs to an early Holocene phase. At any rate, the uppermost shore lines in this moraine developed at an altitude of ca. 30 m a.s.l.

In addition to a marked marine limit at ca. 30 m altitude, the regression of the sea after the Wisconsin was interrupted ca. 10 m a.s.l. A dating of these two levels is impossible. Provided that the upper marine limit in the area is situated 30–35 m a.s.l., and the dating of the post-glacial uplift of the land area at Godthåbsfjord, carried out by J. IVERSEN (1952/53), can be transferred to the Julianehåb district, it must be assumed that the 30–35 m level was formed before boreal time, and the 10 m level before the post-glacial climatic optimum. Thus, it is assumed that the uplift in the Julianehåb district, as at Godthåbsfjord and in Scandinavia, took place at a decreasing rate during the whole Holocene time, and accordingly more than 50 per cent of the uplift took place before boreal times (F. NANSEN 1928, fig. 4).

The earliest Holocene glacier advance on Narssarssuaq is characterised by kame terraces on the north and south sides of Narssarssuaq valley. As stated above, it was formed at a sea level ca. 10 m above the present sea level. This advance, termed the Tunugdliarfik stage in the following text, should therefore probably, but not without doubt, be referred to the younger Dryas time. Irrespective of whether the glaciers otherwise followed the climatic changes, it is difficult to imagine a glacier advance of this extent during the subsequent Holocene warm period.

The large moraines on Narssarssuaq and at Kiagtût kujatâ, however, were deposited with the sea level similar to that at the present time. The stage during which these moraines were deposited must therefore be much younger than the Tunugdliarfik stage, and will be termed below the Narssarssuaq stage.

The Narssarssuaq stage must at any rate be older than the historic Middle Ages, Norse house ruins being found on the outwash plains belonging to the moraines. The deposition of the moraines with a sea level similar to that of the present time shows, however, that they must be of comparatively young age.

In a survey of the climatic development in Holocene times, H. W: son AHLMANN (1953, p. 41) states that a rapid increase of the glaciers at the beginning of sub-Atlantic time gave rise to glacier advances. These advances were possibly of the same extent as, or possibly a little more extensive than those in historical times. The examples mentioned by AHLMANN are derived from Scandinavia, Iceland, and the Alps. Considering the accord in glacier fluctuations in the most recent time between the Alps, Scandinavia, and West Greenland (WEIDICK 1959), it is possible that a similar accord prevailed at the beginning of subatlantic time. This agreement in connection with the formation of the moraines at a sea level which was not elevated above the present level of the sea, speaks in favour of referring, though with reservation, the Narssarssuaq stage to the beginning of the subatlantic time.

The existence of Norse house ruins on the outwash plains of the Narssarssuaq stage shows that the deposition of this stage was succeeded by a recession of the Kiagtût sermia glacier from Tunugdliarfik fjord to the position of the glacier front in modern times. The large number of moraines on the Narssarssuaq plain must indicate breaks in the recession of the ice.

A subsequent glacier advance occurred in historical times. Trim lines, terminal moraines, and terraces around the glacier front bear witness of a much smaller extent of this advance than that of the Narssarssuaq stage.

While the time of the glacier advance is unknown, but must be assumed to have taken place between 1600 and 1700, a number of particulars concerning the recession of the glacier are available, thus from the following years:

Year	Character of information
1876	Photograph taken by K. J. V. Steenstrup. Archives of the Mineralogical Museum, Copenhagen.
1899	Photograph taken by K. J. V. Steenstrup, in the Archives of the Mineralogical Museum of Copenhagen, and a description of the changes of the glacier front since 1876, in the Medd. om Grønl., Bd. 34, 1909, p. 131.
1942 ?	U.S. Army map, scale 1:50,000, probably based on air photographs taken that year.
1950	Private photograph, owned by Mr. Bent Søndergård M. Sc., The Geogical Survey of Denmark.
1953	Air photograph, owned by the Geodetic Institute, Copenhagen.
1955	Photograph, taken by the author.
1958	– – - - –
1960	– – - - –

According to the data given above, as late as 1876 the glacier still retained its maximum extension in historic times, and likewise exhibited a steep glacier front. In 1899 the outermost frontal portion of the glacier had shrunk somewhat, but otherwise it had the same distribution as in 1876. The period from 1899 to 1960 seems to be characterised by a continual shrinkage and recession of the glacier front. In 1960, in a locality of an altitude of ca. 100 m on the south side of the glacier, the active white part of the glacier immediately behind the dead-ice zone, was observed to have increased a few metres in the period 1958–1960.

The Narssârssuk area.

The area is located south of the iceberg bank which separates the icefjord Qôroq from Tunugdliarfik fjord. N. V. Ussing already took the iceberg bank proper to be a terminal moraine, drawing this conclusion from the deposits on the north and south sides of the bank. The Greenlandic name of the locality (Narssârssuk, i.e. "the peculiarly shaped

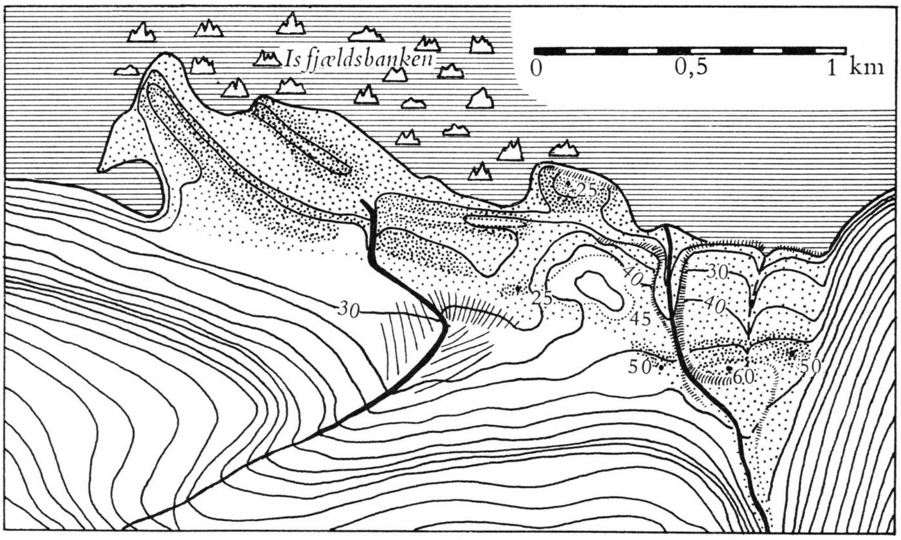

Fig. 15. The Narssârssuk region. Iceberg bank. Equidistance: 10 m.

plain") has reference to the morphological development of the ice front deposits, which at the south side of the iceberg bank formed a small ledge at the foot of a mountain wall ca. 100 m high.

The sketch map of the area shown in fig. 15 was drawn on the basis of air photographs and altimeter measurements.

Geomorphology.

The morainic deposits at Narssârssuk extend from the north side of Igdlerfigssalik mountain in the east to the iceberg bank in the west. The area is 300–400 m broad and ca. 2 km long.

Three moraines are seen in the area. Where the distally outermost moraine turns from the land towards the iceberg bank, a small outwash plain is seen. The outermost two moraines are high and steep. At the foot of Igdlerfigssalik they attain a height of ca. 60 m above the sea, whence they slope evenly towards the iceberg bank. In a cut at a river descending from Igdlerfigssalik the material of the moraines is seen to consist of large, most often rounded to subangular boulders embedded in a matrix of sand or gravel. At fresh slips in the moraines the river revealed an apparently initial erosion of these, which, combined with the steepness of the moraines, conveyed the impression of a young landscape, where solifluction and slips had occurred to a limited extent only. However, in favour of the prehistoric age of the moraines speak their dense cover of vegetation, the distance from the present ice margin at Qôrqup sermia, and the historical sources. From a map of the Julianehåb district, drawn in 1779 by A. ARCTANDER, we know that even at this time the glacier at any rate stood east of Igdlerfigssalik. Trim lines are likewise only found immediately adjacent to the recent glacier.

The outermost two moraines have a distinct course, both beginning at the steep northern wall of Igdlerfigssalik in the east and terminating in a cliff at the iceberg bank in the west. The cliff bears witness of erosion at the present sea level and is the only evidence of marine erosion in the moraines, nor are marine outwash or shoreline deposits to be seen on the extramarginal outwash plain outside the moraines.

The third, innermost, moraine at Narssârssuk is only present as a small knoll, the remainder having disappeared into the sea. Stony till seems to indicate the presence of an inner moraine following the outer two at some distance. The continuation of the ridge below the water level is traceable near the coast in a minor iceberg bank behind the larger outer one. In the profile in the cliff facing the sea there occurred, below ca. 0.3 m of mull, ca. 25 m of moraine containing in its upper part a number of patches of fine-bedded sand. However, the dimensions of these patches in the profile face rarely exceeded ca. 600 cm^2. Otherwise the moraine, like the outer two, was made up of stony or sandy till with large rounded boulders. The inner moraine likewise showed no sign of marine outwash at any other level than the present sea level.

It must be assumed, therefore, that the moraines were formed at the present sea level, and that they are all referable to the Narssarssuaq stage described in the section on the Narssarssuaq region.

The area around Qôrqup kûa (Gieseckes Dal).

The valley Qôrqup kûa forms an east-west directed branch of the icefjord Qôroq. To the east the valley is connected with the glacier in Kujatdleq valley at an altitude of ca. 150 m a.s.l. To the southwest it is connected with Igaliko fjord by a pass at ca. 600 m altitude on the south side of Igdlerfigssalik. Throughout its length (ca. 10 km) the valley is bounded by mountains 1000–1500 m high.

In the period from the beginning of June to the beginning of September it is possible to get to the valley by boat from Tunugdliarfik fjord. The valley is sometimes visited by sheep-farmers from Igaliko, who use the valley as grazing for their sheep. During the summer months, however, navigation may for long periods be impeded by calf-ice discharged from Qôrqup sermia.

The area is partially covered by the map sheets published by the Geodetic Institute.

Geomorphology.

In a morphological respect the western part of the valley is dominated by large terraces. All the terraces are horizontal and thus indicate the extent and the water level at different times of a lake which can only have been formed by penning up of water by a glacier located in the present Qôroq fjord. Possibly also a western branch of Kujatdleq glacier filled the eastern part of the valley Qôrqup kûa, as suggested by the absence of terraces in the easternmost part of the valley. However, such a glacier was not essential for the existence of the lake, for the pass point at Kujatdleq glacier occurs at any rate 150 m a.s.l., while the altitude of the uppermost terrace in Qôrqup kûa is only 140 m. This uppermost terrace as well as the downward succeeding terraces have developed partly in the valley sides partly in a mound of boulders and gravel which extends in a straight line across the middle of Qôrqup kûa. On the sides of the valley the mound attains an altitude of 140 m. At this altitude the uppermost shore line has formed small plateaus in both the north and the south side of the valley. The mound continues in a lateral moraine on the sides of the valley. The lateral moraine is most markedly developed on the south side of the valley where, from the plateau at 140 m, it gradually rises westward to an altitude of ca. 300 m a.s.l. at the boundary between Qôrqup kûa and Qôroq fjord (plate 4). It is not traceable further along the south side of Qôroq fjord, the steep sides of Igdlerfigssalik offering no possibilities for the deposition of morainic material in any great measure.

On the opposite side of Qôroq fjord, however, two lateral moraines are distinctly seen at an altitude of ca. 400 m a.s.l., one immediately above the other; they are parallel and slope towards the mouth of Qôroq fjord.

Quite probably these lateral moraines in Qôrqup kûa and on the north side of Qôroq fjord, together with the continuation of the latter moraines in a "schliffgrenze" sloping towards the iceberg bank between Tunugdliarfik and Qôroq fjords, were formed by one and the same glacier. The front of this glacier must be indicated by the iceberg bank and accordingly by the moraines at Narssârssuk. Hence the glacier must be identified with the Narssarssuaq stage.

The extension of this stage is marked in Qôrqup kûa by the previously described morainic ridge running in a straight line across the inner part of the valley. The straight course of the ridge might indicate that it was formed as a medial moraine, squeezed up between two glaciers, one coming from Qôroq fjord in the west, the other from the Kujatdleq glacier in the east.

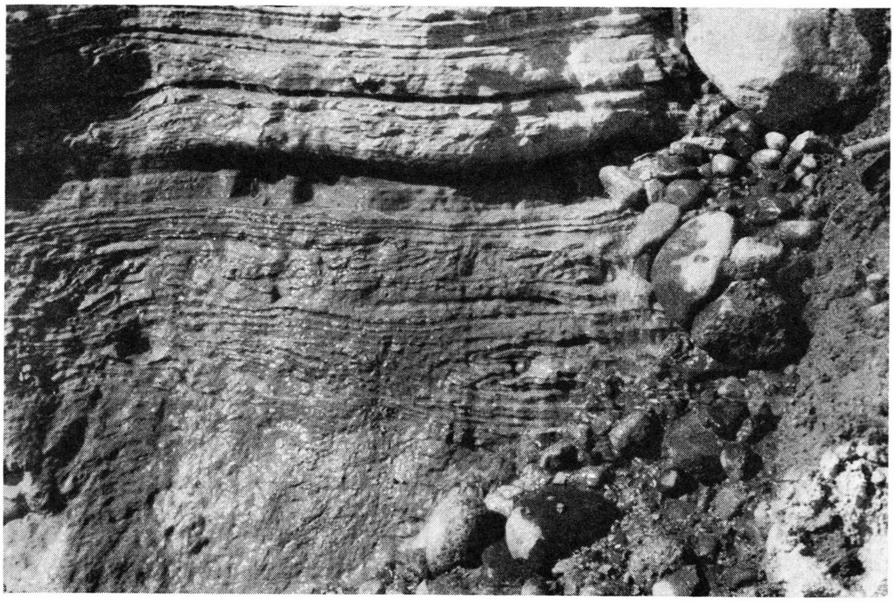

Fig. 16. Fold in varved clay. Qôrqup kûa. Phot. A. Weidick 15/6 1960.

The upper, and accordingly oldest, terrace level 140 m a.s.l. as well as the underlying younger terrace levels are all cut out in the medial moraine and must thus be younger than that moraine.

The valley bottom is formed by an extensive terrace 20–60 m a.s.l. In the following pages the terrace will be termed the main terrace. Its surface is quite even and slopes from ca. 60 m at the medial moraine down to ca. 20 m a.s.l. near Qôroq fjord. Only to the northwest is its even surface interrupted by some few minor morainic ridges. Besides at Qôroq fjord, low-lying portions of the terrace occur as isolated patches immediately west of the medial moraine. The subsided portions, here located on the south shore of the river, must be regarded as slides. The tendency to sliding is due to the circumstance that an upper layer, several metres thick, of boulders and gravel rests on silt underlain by impermeable clay beds.

The major terrace must be regarded as the bottom of the valley during the period when the ice-dammed lake was present, for upper terraces continue uninterruptedly down on to the main terrace to an altitude of ca. 50 m a.s.l. at the northeastern part of the medial moraine.

At the disappearance of the glacier into Qôroq fjord after the Narssarssuaq stage, the erosion base was so much lowered that the present river cut profiles, 10–20 m high, in the major terrace. Similarly, in the period from the Narssarssuaq stage to the present time several systems

Fig. 17. Median moraine, main terrace, and recent river plain. Qôrqup kûa. Dark lower layer in the main terrace: varved clay. Phot. A. Weidick 11/6 1960.

of secondary delta terraces have been cut in the major terrace. These secondary terraces are located chiefly around minor streams flowing from Igdlerfigssalik to the main river in Qôrqup kûa.

Profiles.

All the profiles dealt with above were excavated by the recent river in the main terrace. Their location is shown in the air photograph reproduced in Pl. 4.

Profile C.

Southwest side of the river. The surface shows that the profile extends through two secondary terraces cut in the main terrace by a tributary river from Igdlerfigssalik to the main river in Qôrqup kûa.

Top – 40–17 m a.s.l.	Large rounded boulders, matrix gravel and sand.
17–16 - –	Minor rounded boulders in sand. Gradual downward transition to cross-bedding.
16–12 - –	Cross-bedded silt and sand sometimes with embedded lenses of gravel with angular fragments. Downward, tendency to horizontal stratification of cross-bedded layers.
12–4 - –	Cross-bedded silt and clay with a tendency to horizontal stratification.

Base of profile.

Profile K.

North side of main river at its outfall into Qôroq fjord.

Top – 20–11 m a.s.l.	Cross-bedded gravel and sand with rounded boulders. Large size of boulders (diameter 0.1–1 m) in the upper part of the profile, decreasing downwards.
11–7 - –	Cross-bedded river gravel, sand, and minor boulders.
Base.	

Profile D.

Top – 69–37 m a.s.l.	Gravel with sand and large rounded boulders.
37–22 - –	Cross-bedded silty and sandy layers with subordinate clayey beds. The clay beds increase in thickness downwards, and in the lower parts the lenses attain a thickness of ca. 5 cm, while the intermediate silty beds are twice as thick. At the same time the cross-bedding assumes the character of horizontal stratification.
22–16 - –	Transitional zone. Contains a mixture of silt and clay. Owing to the impermeability of the underlaying varved clay, all the profiles excavated are somewhat obliterated here. It must be assumed that a transitional zone occurs here between the overlying cross-bedded silt and sand and the underlying varved clay.
16–13 - –	Varved clay with some few small ice-scoured boulders. The boulders are rounded to subangular in shape. At the top, the varves are 2–4 cm thick, but decrease in thickness downwards, being ca. 0.5 cm thick at an altitude of 13 m. Around the boulders in the varved clay, which are most frequent and largest at the base of the profile, the clay can be seen to have been subjected to pressure and folding.
13–8 - –	Finely cross-bedded sand with dark silty stripes. The bed is sharply marked off from the overlying varved clay. Clay beds and clay lenses occasionally occur. The beds, however, attain a maximum thickness of ca. 1 cm only.
Base.	

Profile E.

On the south side of the river. No unobscured profile is found here, but below a boulder terrace a scree-covered stratification of silt is seen at an altitude of ca. 48–37 m a.s.l. Farther down, at ca. 30–ca. 20 m, clay is oozing out.

Profile I.

On the north side of the river.

Top – 51–45 m a.s.l.	Gravel and sand with rounded boulders in cross-bedded strata and lenses, which have later been forced upward and folded.
45–40 - –	Transitional zone, where the cross-bedded gravel with rounded boulders decreasing in size downwards, passes gradually downwards into cross-bedded clay and silt, which assume a horizontal stratification at the boundary with the varved clay.

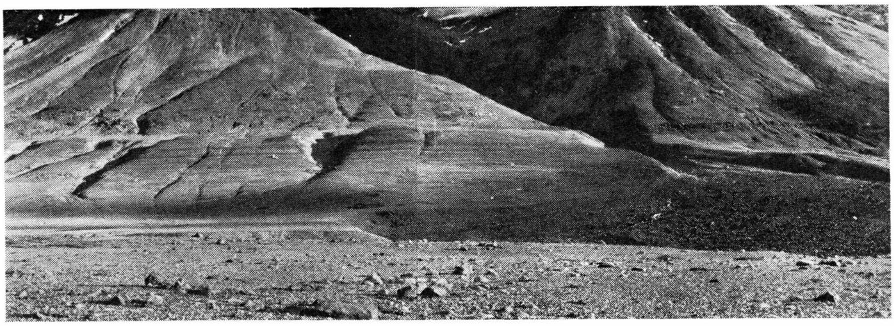

Fig. 18. Upper terraces at Igdlerfigssalik, seen from the main terrace in Qôrqup kûa. Phot. A. Weidick 23/6 1960.

40–28 m a.s.l.	Varved clay, passing evenly upward into the transitional zone. In the upper part the varves have a thickness of 3–1 cm, but grow thinner with increasing depth. At ca. 38.5 m a.s.l. their thickness is 1–0.5 cm. Below an altitude of ca. 35.5 m the clay has been pressed up into folds and overthrusts, so there is no possibility of distinguishing the individual varves. In this zone their thickness still ranges between 1 and 0.5 cm, but at the base of the profile, at ca. 31–28.5 m, they grow thicker again (0.5–3.0 cm). The uppermost 3.30 m of the varved clay cover ca. 440 cycles.
Base of profile.	

Profile A.

On the south side of the river.

Top – 30–23 m a.s.l.	Gravel with rounded boulders. Apparently sharp boundary towards the underlying varved clay.
23–20 - –	Varved clay. Here, as in profile I, the thickness of the varves decreases downward, the upper varves being 1.4 cm thick, the basal ones 0.5–1 cm. Only in the lowermost part (20.8–20.2 m a.s.l.) coarser strata, 1–3 cm thick, are met with. These strata are situated immediately below a strongly folded zone, ca. 1 m thick, of thin varves. The varves in this profile are estimated to cover ca. 355 cycles. The fold axes of the folded varved clay extend almost at right angles to the longitudinal direction of the valley.
Base of profile.	

Profile B.

Located on the south side of the river, east of the large medial moraine extending across Qôrqup kûa.

Top – 40–35.5 m a.s.l.	Gravel with rounded boulders.
35.5–35 - –	Coarse angular gravel, downward with 20 cm transitional beds (alternately clay and gravel) to the underlying varved clay.

35–32.5 m a.s.l.	Varved clay. From ca. 1 m below the upper edge of the varved clay to the base of this bed: strongly folded beds. The axes of the folds extend at right angles to the surface of the profile. The thickness of the individual varves vary from 2–0.5 cm.
32.5–30 - –	Gravel with rounded boulders. Zones with larger boulders sloping 5° towards the northwest. The boulder zone here marks the lower boundary of the varves.

Base of profile.

Profile F_2.

The profile was measured in the same slope as profile B, but 200 m northeast of that profile. Only gravel with rounded boulders is found here. Between the two profiles, F_2 and B, the varved clay is seen to wedge out between an upper and a lower boulder bed, probably indicating the boundary of the basin in which the varved clay was deposited. As will be seen from the following profiles, the varved clay on the north side of the river can be traced as far as ca. 1 km east of F_2.

Profile H.

Located on the north side of the river and on the east side of the large medial moraine.

Top – 107–66 m a.s.l.	Gravel with rounded boulders, in which the moraine and the terraces described on pp. 55–56 developed.
66–58 - –	Gravel with rounded boulders. The size of the boulders decreases downward from a maximum of 5 m in diameter in the upper beds to a maximum of 0.1 m in the lower beds. At the same time the cross-bedding grows more distinct downwards.
58–59 - –	Transitional zone. Uppermost: cross-bedded gravel and sand, lower part: almost stratified silt and clay.
49–40 - –	Varved clay. In the upper part horizontal beds 1–5 cm thick, passing downwards into thinner folded beds.

Base of profile.

Profile G.

Located on the south side of the river. A clayey cliff occurs here at an altitude of ca. 36–ca. 38 m a.s.l.

Profile G_1.

Located in a terrace ca. 65 m a.s.l. The surface of the terrace is a stony plain. Here the river had excavated the following profile:

Top – 65–58 m a.s.l.	Gravel with rounded boulders.
58–41.5 - –	Talus, probably with underlying clay, for clay slipped out in several places at this altitude.

Base of profile.

East of profile G_1 only large alluvial cones were found around the tributary streams. In these, terraces had often developed at altitudes of 140 m, 100 m, and ca. 60 m a.s.l. Only in a single place was clay observed in such a talus cone. However, this clay showed no sign of stratification, and it must therefore be assumed to have been deposited in a pocket in the cone formed by the tributary river. Thus, profile G_1 is the easternmost place in which varved clay has been met with. The part of the valley Qôrqup kûa lying east thereof is dominated by the recent river plain, and older terrace levels are rarely met with. When present, they have developed in alluvial cones around tributary streams.

Interpretation of the deposits in Qôrqup kûa (Gieseckes Dal).

It will be evident from the profiles described in the preceding pages that the oldest deposits must be the varved clay and the underlying silt and gravel, found in profiles D and B. It will be seen that at a height of ca. 8 m above the present river in profile D, and ca. 6 m above the same river in profile B, the varved clay presents a sharp lower boundary. The substratum of the varved clay must be regarded as alluvial deposits, which, as might be expected, are of a coarser character upstream at profile B than nearer the sea at profile D. In both these places the deposits must be assumed to occur *in situ*, and their fine-grained and sedimentary character at profile D, not only in the excavated profile but several metres on either side of it, must indicate that the sedimentation in this locality took place near the sea. It will be reasonable, therefore, to assume that the deposition of the substratum of the varved clay took place at a sea level elevated ca. 10 m above the present level of the sea. That we are not concerned here with a casual sedimentation in a river pocket, is evident from the comparatively wide horizontal extent of the profile combined with the thickness of the deposit.

In profile A the varved clay is seen to lie very near the surface of the river. The surroundings are indicative of a depression in the main terrace around the profile. It must be assumed, therefore, that profile A is situated in a slide, and that the deposits are accordingly not found *in situ*. Thus, profile A cannot be taken as evidence against the above interpretation of profile D as marking an erosion base at a sea level located ca. 10 m above the present level of the sea.

The varved clay is everywhere overlain by gravel with rounded boulders. The total thickness of the varved clay is not known, the clay beds having been disturbed by subsequent glacial advances. The profiles seem to show that a total thickness of ca. 20 m is not unlikely, which, considering the incomplete counting of varves at profiles A and I, may be taken to cover a sedimentation of ca. 2,000 cycles, that is to say, presumably annual varves.

It is rather peculiar that the varved clay increases in thickness towards the interior of the valley. The gradual transition from the varved clay to cross-bedded material (sand and silt) in the larger profiles must indicate that there can be no question of a later destruction and removal of the upper varved beds in the outer parts of the valley. Hence, the explanation must probably be that the outer parts of Qôrqup kûa were covered by glaciers during the earlier phases of the varve sedimentation.

The advance of the glacier which gave rise to the formation of an ice-dammed lake in the valley Qôrqup kûa must, as indicated by profile D, have taken place at a sea level ca. 10 m above the present level of the sea. It is natural, therefore, to correlate this advance with the Tunugdliarfik stage at Narssarssuaq, all the more so since all the morphological features of the succeeding and last advance of the ice through the valley would seem to suggest that it belongs to the Narssarssuaq stage.

As the distribution of the varved clay terminates some few kilometres east of the large medial moraine in the valley, it seems likely that during the period of existence of the ice-dammed lake, probably at the end of the Tunugdliarfik stage, an east-flowing lobe from Kujatdleq glacier occurred at the same time in the eastern part of Qôrqup kûa. No features suggestive of ice contact or deposits from the glacier can be demonstrated, which must be due to the very steep mountain walls surrounding the eastern part of Qôrqup kûa.

After the deposition of the varved clay there followed a period of coarser sedimentation, beginning with the deposition of silt and ending with the deposition of gravel and large rounded boulders. The total thickness of these sedimentary deposits is probably 20–30 m. When the sedimentation ceased, the bottom of the valley was constituted by the main terrace.

It must be assumed that the thickness of the sediment as well as its coarse character can be ascribed to a strong flow of water in the rivers, due to melting of the glaciers during a lengthy period. Although this does not furnish any proof thereof, it seems natural to assume that this period must be identical with the climatic optimum. The Tunugdliarfik stage should accordingly be assumed to be older than this optimum.

The upward pressure of the varved clay as well as the overlying coarser sediment testify to a later glacial advance the phases of which set their mark on the topography of the area. The pressure must be ascribed to the glacier advance as far as, and forming, the medial moraine. As will appear from the straight course of this moraine across the valley, we are probably confronted by a medial moraine: a glacier lobe from Kujatdleq glacier must have covered the eastern part of the valley.

During the retreat of the glacier lobe in the valley from Qôroq fjord in the west and from Kujatdleq glacier in the east, minor recessional moraines were formed in the northwest side of the valley. They are likewise located on the main terrace near Qôroq fjord. Both moraines are pronounced block moraines. Not till the glacier had receded to the mouth of Qôrqup kûa in Qôroq fjord, did the uppermost shore-line level at 140 m a.s.l. in Qôrqup kûa develop. This appears from the extension of the terrace level to the mouth of the valley. The extension of the same terrace level east of the median moraine in the valley suggests that also the glacier issuing from Kujatdleq glacier must at this time have receded several kilometres from the median moraine. As the threshold between Kujatdleq glacier and Qôrqup kûa is situated ca. 150 m a.s.l., the ice-dammed lake in Qôrqup kûa must have been drained subglacially through the glacier in Qôroq fjord.

All the moraines resulting from the latest advance from Qôroq fjord through Qôrqup kûa seem to be built up of the fluviatile material deposited in the valley before the advance of the glacier.

During the recession and shrinkage of the ice in Qôroq fjord the water level fell gradually, as indicated by the various terrace levels on the valley sides.

An interesting feature is presented by the median moraine, in that shore lines are only found on its east side. The explanation is, no doubt, that the wave action of the ice-dammed lake was heaviest on the east side of the median moraine. Then, as now, the valley was marked climatically by strong easterly winds (Greenlandic: "nigeq").

After the retreat of the ice from Qôrqup kûa, the river cut its way ca. 10 m down into the old river bed. While the last advance of the glacier through the valley Qôrqup kûa, as stated in the description of the morphology of the area, should undoubtedly be correlated with the Narssarssuaq stage of the Narssarssuaq region, it must be assumed that this erosion took place during the period from the beginning of subatlantic time to the present day.

K. J. V. Steenstrup Nunatak.

The locality is situated south of the upper part of the glacier Qôrqup sermia, near the point where this glacier branches out from Kiagtût sermia. The area has not been described before, and the names K. J. V. Steenstrup Nunatak proposed here for the locality visited, and G. F. Holm Nunatak for the large nunataq east of the locality have reference to K. J. V. Steenstrup's and G. Holm's journey to the ice front near these two nunataks in 1876 (Steenstrup and Kornerup 1881, p. 11).

On the reconnaissance in the summer of 1960 the transportation to this locality took place in a helicopter. As seen from the air, the most convenient route on foot seems to be a traverse of Qôrqup sermia from the land between Narssarssuaq and Qôroq (Mellemlandet) farthest east to Nordtop or Sydtop on Steenstrup Nunatak (see pls. 2 and 3).

There exists a skeleton map of the area on a scale of 1:100,000 without height contours, prepared by the Geodetic Institute, and a

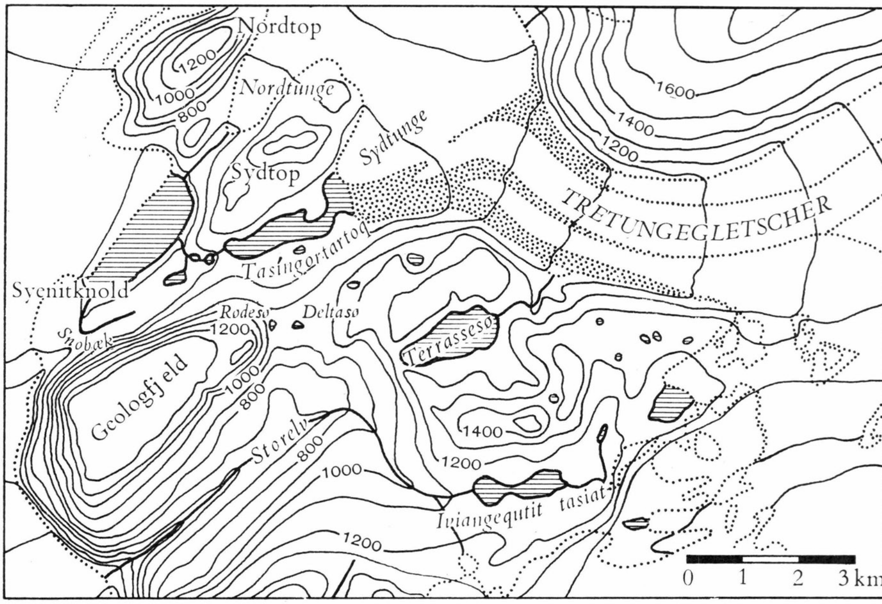

Fig. 19. K. J. V. Steenstrup Nunatak. General map.

United States Air Force map, scale 1:250,000, with 1000 ft. contour intervals. The maps reproduced in pls. 2 and 3 of the present paper were drawn in the field on the basis of readings of two altimeters. To control the absolute height above the sea, bearings were taken to the Niviarsiat mountain, whose height is known.

Geomorphology.

Considered as a landscape, this large nunatak must be regarded as a transitional area between the Qôroq depression, mentioned on pp. 8–9, and the high plateau south thereof, which extends from the region around Igdlerfigssalik (1700 m a.s.l.) in the west to the Julianehåb ice cap in the east. At the margin of the Julianehåb ice cap this plateau has developed into nunataks rising to altitudes of 2000–2200 m a.s.l.

The nunataks are separated from the area around Qôrqup kûa (Gieseckes Dal) by a valley surrounded by steep sides, whose tops are constituted by the above-mentioned high-lying plateau. The tops here occur ca. 1700 m a.s.l., while the bottom of the valley is occupied by a south-flowing ice lobe from Qôrqup sermia, with the surface of the glacier occurring at altitudes between 200 and 400 m a.s.l., and partly by a large ice-dammed lake, Motzfeldt Sø, whose surface is estimated to be elevated some 100–150 m above the sea.

Some lower mountain knolls (Sydtop and Nordtop) are found to the west, presenting altitudes between 900 and 1200 m. To the east the land

Fig. 20. Moraines at the Tretungegletscher between Geologfjeld and Sydtop, seen from Geologfjeld. The lake in the background is Tasíngortartoq. Phot. A. Weidick 23/7 1960.

rises evenly to altitudes about 1700 m. Above this altitude, the land disappears gradually under local firns, which at still higher altitudes coalesce to form the firn area of the Julianehåb ice cap.

K. J. V. Steenstrup Nunatak is bounded on the east by the abovementioned firn area, and on the south and north by lobes issuing from the firn area, while on the west it is bounded by the glacier Qôrqup sermia, which is fed both by the inland ice proper and by the Julianehåb ice cap. The lobe from the Julianehåb ice cap which bounds the southern part of Steenstrup Nunatak, terminates in Motzfeldt Sø. The lobe from the Julianehåb ice cap bounding K. J. V. Steenstrup Nunatak on the north, is termed below Tretungegletscher, the three lobes at K. J. V. Steenstrup Nunatak uniting into a tongue, bounding southward on Qôrqup sermia. In its present shape, however, Tretungegletscher does not seem to be a tributary to Qôrqup sermia, but more likely a separate ablation area, separated from Qôrqup sermia by a large median moraine.

Only a single valley, extending from the southern part of the nunatak down to Motzfeldt Sø, interrupts in some measure the above-mentioned gradual rise of the terrain from the northwest towards the southeast.

The morphological features of the nunatak are rather obscure. This must be due to the prevalent high-arctic conditions, which give rise to intense nivation. The character of the plateau as a whole much resembles that of the Thule region near the sea-level. As in the Thule region, the glacial landscape forms are somewhat obliterated. The fairly level portions of the nunataks are covered by boulder fields, and the ice margin features are characterised by block moraines. An exception, however, is formed by the lowest-lying areas around Snobæk and Tasíngortartoq. In the moraines near these localities, the material consists of gravel and sand with rounded boulders, pointing to a glacial advance across fluviatile deposits. However, somewhat similar material is also seen in a moraine situated at an altitude of ca. 1000 m on the north side of Nordtop.

The highest-lying and hence probably oldest moraine in the region is found on the north side of Geologfjeld. Its continuation in the lowland is constituted by several minor rows of moraines containing stony or sandy till. In this part, located immediately south of Tasíngortartoq, delta terraces and extra-marginal river valleys are seen in contact with these moraines, indicating that this part of the ice front stage was drained southward to the valley of Storelv. To the east, this ice front line is traceable again along the mountain sides in systems of more or less washed-out moraines (block moraines).

At the easternmost part of Terrassesø, also, some block moraines are seen which only in the lowest-lying portions of the valley from Terrassesø to Tretungegletscher continue in moraines of stony till with large rounded boulders. A similar material to that of the moraines is seen in the shore line deposits, the material consisting here of angular to rounded boulders with no matrix. The boulders are for the most part of such a large size that a recognition of the shore lines on the spot may be difficult unless the illumination of the area is favourable. On the air photographs, however, the extension of the shore lines is distinctly marked. The very coarse material of which the shore bars are built up must show that we are not confronted with a deposition or washing-out of the lake, but with pressure ridges formed during the freezing of the lake.

In the valley of Storelv and towards Iviangequtit tasiat only moraines and shore lines made up of very coarse material are seen, thus the boulders of the moraines are angular to subangular, while those of the shore lines are for the most part rounded to subangular. The whole valley of Storelv is covered by a boulderfield with large boulders. Here, as in the moraines and the terraces, the average diameter of the boulders generally ranges between 10 and 50 cm. As this boulder field passes gradually into the above-mentioned geomorphological features, it may often be difficult to distinguish between the various forms, and similarly, it may be difficult to decide whether a stone ridge should be regarded as a moraine or a snow-fan talus. In the lower parts of the valley of Storelv, near the glacier connecting Qôrqup sermia and Motzfeldt Sø,

Fig. 21. Valley of Storelv. South side with moraines. Phot. A. Weidick 6/8 1960.

two large terraces, to-day situated some 100–200 m above the margin of the glacier, are to be found. The material is here sand and gravel.

The said brief description shows that an unravelling of the individual ice front stages must be based exclusively on a geomorphological analysis of the area. As the individual stationary lines are of scattered occurrence, it is a prerequisite for a correlation of the ice front deposits that the earlier glaciers, like the present ones, sloped from the east and south towards the north and west, as is also indicated by the direction of the ice front deposits.

All the above-mentioned stationary lines seem to be referable, though with some doubt, to two stages, termed below merely the oldest and the youngest stage.

Interpretation of the geomorphological features.

Oldest stage.

Two moraines, located on steep mountain sides of Nordtop and the north side of Geologfjeld respectively, must be characterised as the oldest stage. As stated in the description of the geomorphology of the area, these moraines are for the most part made up of rounded to subangular boulders without matrix, more rarely (in the lower-lying portions) of stony till. The latter type is most markedly developed in the 900 m high pass between Tasíngortartoq and the valley of Storelv, at the localities Rødesø and Deltasø (see pls. 2 and 3). A well defined double row of moraines is found here, where now dry delta cones and outwash plains bear witness of drainage across the pass southward to Storelv via Rødesø and Deltasø.

It must be assumed that during the recession of the glacier from the innermost of these morainic rows, the drainage of this part of the glacier changed its direction, subsequently taking place westward to Snobæk. This is assumed owing to the absence of Kame terraces or terrace notches in the proximal surroundings of the moraines. Minor moraines in the valley of Snobæk and south of the eastern part of Tasíngortartoq testify to minor interruptions of the recession of the ice after the oldest stage.

The moraines on the north side of Geologfjeld, like those on Nordtop, are situated ca. 400 m above the present glacier front, and it is likely, therefore, that they were formed by the same glacier. At that time, Sydtop must have been covered with ice.

The moraine on Geologfjeld terminates on a steep mountain wall south of Snobæk. If we assume that the surface of the then existing glacier sloped westward conformably with that of the present glacier, this advance must have covered the outer part of the valley of Storelv along a distance of several kilometres. Some obscure block moraines in the valley of Storelv 700–800 m a.s.l., indicating a glacier tongue coming from the west, would seem to correspond to this extension of the glacier. It is probable, therefore, that the moraines indicate the extension of the oldest stage in the valley of Storelv.

If we follow the corresponding morainic stretch indicating the oldest stage on the north side of Geologfjeld, eastward past Rødesø and Deltasø, it will be seen to terminate at the steep mountain walls facing Tretungegletscher. On the assumption that the earlier glacier surface, as in the valley of Storelv, was roughly conformable with the present one, the glacier must have covered Terrassesø and possibly have issued a tongue down through a pass at an altitude of ca. 1140 m a.s.l. eastward to the valley of Storelv. Even at the present day a snow-fan glacier is still found in this pass, so it must be regarded as quite possible that minor local glaciations in the area around Terrassesø at the time of the existence of the oldest stage contributed to the feeding of this glacier tongue, for the mere presence of an ice covering over large parts of Terrassesø must have contributed to a lowering of the glaciation limit. This lowering of the limit of glaciation might further have contributed to an advance across Terrassesø down into the valley of Storelv.

The block moraines indicate an advance across the aforementioned pass at 1140 m, leading from Terrassesø down into the valley of Storelv. It is natural, therefore, to correlate these moraines with the oldest stage. In the valley of Storelv the oldest stage probably experienced several

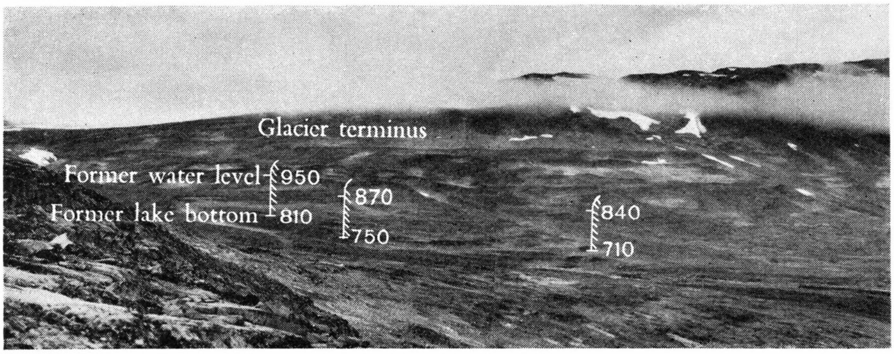

Fig. 22. Valley of Storelv. South side with moraines and terraces. Three stages of the ice-dammed lake (a, b and c) are indicated here as well as on the map in fig. 35. Phot. A. WEIDICK 28/7 1960.

interruptions of its retreat from its maximum extension. During its maximum extension the glacier lobe flowing across Terrassesø into the valley of Storelv almost coalesced with a glacier lobe entering the valley from the west, and most likely also with a glacier coming from the south across Iviangequtit tasiat. Thus, the present Steenstrup Nunatak must then have been divided into several nunataks. A terrace located ca. 1000 m a.s.l. in the valley of Storelv indicates that the glacier moving through the area now containing the lakes Iviangequtit tasiat, was drained westward to Motzfeldt Sø.

As to the recession of the glacier lobe from Motzfeldt Sø, terrace remnants and lateral moraines in the western part of Storelv valley show a succession of terrace steps subsiding slowly during the westward retreat of the glacier. The drainage of the ice-dammed lake then located in the central part of the valley south of Deltasø, can only be supposed to have taken place beneath the ice down to the Motzfeldt Sø area. The individual terrace steps show a constant height above the valley bottom of 120–140 m at the coalescence of the lateral moraine with the terrace, that is to say, at the glacier front the maximum depth of the lake was then constantly of this order of magnitude.

Youngest stage.

Along the stretch from the northernmost part of Snobæk in the west to the surroundings of Tasíngortartoq in the east, at the front of Nordtunge between Nordtop and Sydtop, and at the present outlet of Terrassesø to Tretungegletscher, extensive terminal and lateral moraines are seen, suggestive of a stage when the surface of the glacier was found 100–200 m above the present glacier surface. All the moraines from this stage are situated in valleys, and their material is generally sandy or stony till with rounded to subangular boulders, only few patches being built up of boulders without matrix (block moraines). However, block moraines may be met with in patches south of Tasíngortartoq and south of the outlet from Terrassesø to Tretungegletscher. Besides, the record of the altitude of this stage as 100–200 m above that of the present glacier surface only applies to the area immediately adjacent to Tasíngortartoq. Already at Terrassesø the stage shows an altitude above the recent glacier surface of only 100–150 m, and moraines belonging to this youngest stage show that the height of the stage above that of the recent glacier surface decreases towards the upper parts of Tretungegletscher.

During this youngest stage, both Nordtop and Sydtop were nunataks. Nordtop was entirely isolated from the remaining part of Steenstrup Nunatak, and Sydtop was only connected by a median moraine with the land south of Tasíngortartoq.

At Tasíngortartoq, in addition to a lobe extending westward from Tretungegletscher, a broad ice lobe extended from the north towards the valley of Snobæk. The mountain ridge separating this valley from the present ice-dammed lake farther north, formed the southern boundary of the ice. Here terminal moraines, one below the other, are seen to have been deposited from the top of the mountain threshold (670 m a.s.l.) to the present trim line, indicating several interruptions of the recession of the ice after the maximum extension of the youngest stage. During all the phases of the recession of this stage, the lobe must have been partially drained around the south of Syenitknold. Evidence thereof is supplied by the large terraces at altitudes of ca. 610 m a.s.l. at the point where Snobæk changes its southwestward to a northward course.

Owing to the steep northwestward gradient of Geologfjeld, it is impossible to find further deposits from this stage here. Not till the mouth of Storelv, at the glacier lobe flowing towards Motzfeldt Sø from Qôrqup sermia, are ice margin terraces seen at ca. 510 m altitude. These terraces continue in the valley of Storelv. The terrace the material of which is cross-bedded gravel and sand, terminates in a steep cliff facing the present glacier, whose surface in this locality occurs at an altitude of 200 m. Presumably this ice contact deposit here indicates the position of the ice front during the youngest stage.

No localities farther to the southeast were visited.

In the east, the deposits of the youngest stage are met with again around the outlet from Terrassesø. Above the valley of this outlet, two moraines occur which in the south pass into a system of several parallel, isolated morainic ridges. The upper terrace (shore line) around Terrassesø forms a notch in the moraines and must accordingly be younger than them. To the north, the terrace terminates abruptly 50–100 m north of the moraines on the rock wall towards Tretungegletscher.

The western passpoint of Terrassesø occurs at an altitude of 1140 m, and it must be assumed that during its maximum extension Tretungegletscher was drained across this pass down to the Storelv valley. Along the whole lake this highest terrace indicates the maximum water level, and its abrupt termination in an evenly sloping terrain at Tretungegletscher would suggest that at the time the glacier was found at the termination of the terrace, its drainage changed so as to take place along Tretungegletscher instead of via Terrassesø. At the time of the change of drainage, the glacier front was located behind the outermost moraines of the youngest stage, the terrace, as mentioned above, cutting into the moraines indicating the maximum extent of the stage. The position of the glacier front at the ice-dammed lake at the time when the drainage changed, must be indicated by the termination of the terrace on the mountain side. The height of the glacier front towards the ice-dammed lake must then have been ca. 150 m. Whether the lake was drained subglacially or superglacially, it is impossible to decide.

Present distribution of the glaciers and the maximum extension of the ice cover in historical times.

Trim lines and moraines everywhere bear witness of a former wider extent of the glaciers than at present. As at Hullet, no patches of the lichen *Rhizocarbon* were found below the trim line, and *Umbilicaria* and *Lecidea* species occurred scattered and in small patches some few millimetres in diameter, immediately below this line. The retreat of the ice from its maximum extension in recent times must therefore be assumed to have taken place after the year 1900. The trim line zone wedges out with increasing height of the surface of the recent glacier, and upwards it gradually unites by level plateaus with snow-fan patches. However, even at an altitude of ca. 1400 m at Iviangequtit tasiat a retreat of minor glacier tongues, formed by superimposed ice, can be observed. Although locally the horizontal retreat may amount to up to ca. 200 m, the vertical lowering of the surface of the ice here is only 20–30 m.

In addition to rather widely distributed superimposed ice on the margin of the Julianehåb ice cap at Iviangequtit tasiat, some shear moraines also occurred, and similarly, the Julianehåb ice cap along a distance of several hundred metres immediately south of Iviangequtit tasiat terminated in an ice cliff 50–100 m high. All these features suggest a similarity to the high-arctic glacier such as it is described by Bishop (1957). As mentioned above, the area is situated at an altitude of 1300 –1400 m a.s.l.

It will be seen from the above that the maximum subsidence of the ice surface in recent time at an altitude of ca. 1400 m of the recent glacier surface, amounts to only ca. 25 m (maximum). Similarly, at lower altitudes of the recent glacier surface the following heights of the trim line zone were found:

Height of recent glacier surface (h)		Height of trim line zone (Δ h)
1010 m a.s.l.	(Tretungegletscher)	40 m
1050 - –	(Tretungegletscher)	50 -
730 - –	(Nordtunge)	70 -
610 - –	(Geologfjeld)	70 -
610 - –	(Geologfjeld)	50 -
200 - –	(Mouth of Storelv)	100 -

It will be seen that at the mouth of Storelv the glacier surface occurs at ca. 200 m and the trim line zone at ca. 300 m altitude. However, along the margin of the glacier some small moraines are seen, which were forced up during the advance of the glacier side across the alluvial material from Storelv (sand, gravel, and rounded boulders). Hence, it is natural to assume that the glacier had expanded somewhat in this place, at any rate in that year (1960). The steep front of the glacier may also be an indication of this. Quite possibly, therefore, the original height of the trim line zone was somewhat greater than that measured here, though hardly many metres.

Ice margin deposits in the Narssarssuaq region, indicated on the basis of air photographs.

Besides in the localities visited, moraines and terraces indicating former ice margins, have been found in several localities within the Narssarssuaq region by the aid of air photographs. In the field as well as on the air photographs, the moraines within this area can often be divided into two groups: younger and older moraines.

The younger moraines (and terraces) are distinguished by forms which are still sharply marked in the terrain, where accordingly no erosion or solifluction of importance has taken place since their deposition. The material of the moraines consists largely of gravel or sand.

The older moraines are much coarser than the younger ones. Thus, on the air photographs they appear to be much broader and more obliterated, and they are for the most part built of large boulders without very much fine-grained material. The boulders are generally sharp-edged, unlike those of the younger moraines, which are, as a rule, much rounded. The fine striation often observed on air photographs of the areas occupied by the younger moraines, indicating the limits of earlier ice-dammed lakes, are not found at the older moraines.

The difference between the two types of ice margins must to some extent be ascribed to differences in position. In all the ice front deposits, irrespective of their age, the boulder material reveals a tendency to predominate, and the boulders are often angular at levels above 700 –900 m a. s. l. Below that height, i. e. in the valleys, the ice margin deposits consist for the most part of finer and more rounded material. The phenomenon must be ascribed to the intense nivation at great altitudes which here supplies the material of the glacier, while in the valleys the material is most frequently derived from earlier fluviatile deposits. However, this does not seem to be the whole explanation, for the difference between older and younger moraines may also be observed at the ice front deposits under otherwise equal conditions, near the aforementioned limit at 700–900 m a. s. l.

It is possible, therefore, to give a rough estimate of the age of the moraines near the ice front deposits found. The numbers of the air photographs in the following survey have reference to the catalogues of the Geodetic Institute.

The area north of Kiagtût sermia.

Some few minor morainic fragments have been observed on the north side of Kiagtût sermia between Sydgletscher and Narssarssuaq. The moraines are so small and isolated that nothing can be stated about their age.

As previously mentioned, only few ice margin deposits have been encountered outside the eastern branch of Nordbosø (cf. the maps pls. 2 and 3). Nordbogletscher is seen in the air photographs to lack a trim line. The extension of the glacier is the same on air photographs from July 4, 1947 (air photo 502 D-N no. 80) and August 21, 1953 (291 M, no. 12581) as at the time of the author's visit on June 3, 1960. A photograph of the glacier taken in 1960 is reproduced in fig. 5.

The area between Kiagtût and Qôrqup sermia-Qôroq fjord.

A marginal moraine northwest of the front of Qôrqup sermia seems, by its outwashed shape, to indicate an older stage. Judging by the moraines, the front of the ice during its maximum extension must be assumed to have covered Mellemlandet as far as a line running from the front of Kiagtût sermia to the front of Qôrqup sermia.

Lower-lying, more clearly defined ice front features, with several morainic rows and terraces, are seen to have developed both at 300 –400 m above the recent surface of Qôrqup sermia, and on the south side of Kiagtût sermia also at 300–400 m above the recent glacier surface. The direction of the moraines indicates that the southwestern part of

Mellemlandet was free of ice during this stage. The ice front lines are most distinctly seen on the air photographs 201 K, nos. 12497–98, 21/8 1953, and 201 L, nos. 12551–52, 21/8 1953.

The recent glacier front at Qôrqup sermia.

The following particulars concerning the position of the glacier front in the most recent time are at hand:

Year	Character of information.
July 1942	Glacier front indicated with information of data for its position on the U.S. Army Map 1:50.000 Sheet 1814, II, Igdlerfigssalik.
July 4, 1947	Air photograph, Geodetic Institute. Route 502 D-S No. 331.
August 21, 1953	Air photograph, Geodetic Institute. Route 201 L No. 12550.
July 22, 1957	Photograph by the author, taken from a helicopter at the glacier front.
June 11, 1960	Photograph by the author, taken from a helicopter at some distance from the glacier front.

According to these particulars, the position of the glacier front hardly changed in the interval between 1942 and 1960. The glacier is surrounded by a trim line zone, indicating that in historical times the front reached 1–2 km (maximum) farther westward. The shrinkage and retreat of Qôrqup sermia, as indicated by this trim line, probably took place in the period 1900 to 1940, probably most markedly between ca. 1920 and 1940 (A. WEIDICK 1959).

The area between Qôrqup sermia and Qôrorssuatsiaq.

On the south side of the innermost part of Qôroq fjord some well-defined lateral moraines are seen at altitudes of 300–400 m a.s.l. The continuation of the ice front deposits at the mouth of Qôrorssuatsiaq (Flinks Valley) was not observed. However, a large stretch of the lower part of the valley is occupied by a terrace at altitudes varying between 120 and 140 m (aerial photograph 201 K, 21/8 1953, no. 12500). The southwestern part of the terrace, at the mouth of the valley, probably indicates the continuation of the ice front deposit just mentioned. Both the moraine and the terrace must belong to the younger morainic stage.

Motzfeldt Sø.

This lake is probably drained across the large outwash plain west of it, through Qôrqup kûa to Qôroq fjord. Only ca. 1 km south of the lake, a glacier (Kujatdleq glacier) flows from the southwest towards Qôrqup kûa and the lake Motzfeldt Sø. The glacier front is seen to be surrounded by trim lines and moraines, indicating that in historical times the glacier had a maximum extension with a position 0.5–1 km nearer Qôrqup kûa and Motzfeldt Sø. Between the moraine from historical times and Motzfeldt Sø, three morainic curves whose shapes suggest that they were deposited by a glacier moving from the north through Motzfeldt Sø, can be seen on air photographs (201 L, no. 12545, 21/8 1953). Judging by the trim lines, the moraines cannot be of historical age, though they exhibit a marked relief and accordingly must be very young. The moraines possibly represent a phase of that stage which in Qôrqup kûa was termed the Narssarssuaq stage (see p. 63). The moraines at Motzfeldt Sø are seen on an air photograph, reproduced by T. W. Böcher (Böcher 1956, fig. 7, p. 25).

A large glacier descends with a calving front into the eastern part of Motzfeldt Sø. Lateral moraines around the glacier show that during its maximum extension in historical times it reached some 1–2 km farther out into the lake. Information on the position of the glacier front is derived from two air photographs, 502 D-S, no. 335 from 4/7 1947, and 201 M, no. 12592, taken on 21/8 1953. No change in the position of the glacier front from 1947 to 1953 can be ascertained on this basis.

Another glacier, coming from Qôrqup sermia, bounds Motzfeldt Sø on the west. This glacier is likewise seen on the two air photographs mentioned above. Lateral moraines around the glacier show that in historical times it extended some 100–200 m farther out in the lake. No change in the position of the glacier front can be seen on the air photographs. As stated under the description of the locality K. J. V. Steenstrup Nunatak, some push moraines at the glacier side, near the opening of Storelv valley into this glacier (cf. p. 72) seem to testify to a swelling of the glacier in recent years.

Jomfrulandet.

The area around Hullet is described on pp. 22–41. East thereof, as appears from the air photographs, stage II continues in several close-set rows of younger moraines. The morainic belt continues along the south side of Jomfrulandet northeastward to a locality ca. 6 km northeast of Annekssø, whence it descends to a level near the recent surface of Qôrqup sermia, but cannot be traced farther northeastward.

Inside this belt of younger moraines, isolated areas with belts of older moraines can be observed. Such moraines are also found on some of the larger nunataks northeast of Jomfrulandet. As will be seen from pl. 3, the geographical distribution of these belts seems to indicate that the deposits originate from one and the same stage.

The air photographs of the area examined are all from 1953 and 1947. Compared with the author's own observations, no differences in the extent of the glaciers in the years 1947, 1953, and 1960 could be anywhere detected.

G. F. Holm Nunatak.

In this locality, also, distinct morainic deposits are met with. They appear to be all coarser than younger deposits, probably indicating the same stage as the older moraines of Jomfrulandet.

Correlation of the deposits of the individual localities in the Narssarssuaq region.

Narssarssuaq was selected as a reference locality for the region. This is due to the wide distribution of the Quaternary deposits here, in time as well as in space. A further advantage is the close proximity of the deposits to the coast, as this offers a possibility for assessing the level of the sea at the time some of the deposits were laid down. As stated on pp. 50–52, the following relative chronology would seem to be valid for the deposits of this locality:

Age	Locality	Sea-level
Interglacial ?	Kiagtût	?
Wisconsin ?	Kiagtût	?
Deposition of upper marine limit in the area	Kiagtût, Narssarssuaq	ca. 30 m a.s.l.
Tunugdliarfik stage	Kiagtût kujatâ, Narssarssuaq	10–15 - –
Narssarssuaq stage	Narssarssuaq	0 - –
Maximum extension of gls. in historical times	Kiagtût sermia	0 - –
Recession of glaciers after 1900 A.D.		0 - –

It will be seen from the description of ice front landscapes detected on air photographs (pp. 72–76) that the Tunugdliarfik and Narssarssuaq stages on the land between Kiagtût sermia and Qôrqup sermia are traceable from the south side of Narssarssuaq valley to the eastern part of this land area, that is to say, the area immediately south of Hullet.

The ice margin landscapes are sometimes divisible into two main morphological groups. Since to the west, at Narssarssuaq, they represent the Tunugdliarfik and Narssarssuaq stages, and at Hullet stages I and II, there is hardly any doubt that the Tunugdliarfik stage is identical with stage I at Hullet, and the Narssarssuaq stage with stage II in the same place. Moreover, the deposits at Nordbosø in the area around Hullet bear witness of a considerable difference in time of development between the two stages, and similarly, the deposition of the two stages at 10–15 m altitude and 0 m altitude respectively at Narssarssuaq, indicates a great difference in time between the stages.

Both at Narssarssuaq and at Hullet the Tunugdliarfik stage seems to represent the first ice margin deposited after the Wisconsin age. It should be added that the inland ice north of Hullet in the area from the Niviarsiat nunataks to Eqalorutsit kangigdlît sermia seems to have been almost stationary during the greater part of the Holocene period.

The ice margin deposits in the eastern part of the landscape between Qôrqup sermia and Kiagtût sermia likewise permit us to trace the deposits of the Tunugdliarfik and Narssarssuaq stages to an area near the northern part of K. J. V. Steenstrup Nunatak. The moraine at ca. 1000 m altitude on Nordtop would seem to correspond to the uppermost moraine deposited in this landscape. Owing to the marked division of the ice front deposits at Steenstrup Nunatak into an "older" and a "younger" stage, it is likewise probable that these two stages are identical with the Tunugdliarfik and the Narssarssuaq stage, respectively, at Narssarssuaq. Moreover, the deposits of the Narssarssuaq stage show a gradual transition to the deposits from the succeeding glacial maximum in historical times by a series of minor ice front deposits behind the outermost stationary line. This is observable both at Narssarssuaq, at Hullet, and on K. J. V. Steenstrup Nunatak, where only the difference in the cover of vegetation reveals that the deposits are derived from two different stages.

The two stages can be followed eastward from Hullet almost to an area south of the Niviarsiat nunataks. They clearly show that the deposits of both stages wedge out in the immediate proximity of Niviarsiat, the ice farther northward thus having an extension and thickness corresponding to its extension and thickness during the Tunugdliarfik and Narssarssuaq stages.

South of the upper united Kiagtût sermia and Qôrqup sermia glaciers and northeast of K. J. V. Steenstrup Nunatak, the deposits of the Tunugdliarfik stage can be followed eastward across G. F. Holm Nunatak.

The stationary lines of both stages are traceable on the north side of Qôrqup sermia from the locality immediately west of K. J. V. Steenstrup Nunatak in the east to the iceberg bank at the mouth of Qôroq fjord in the west. However, only deposits from the Narssarssuaq stage here reach the sea. That only the Narssarssuaq stage can be considered at the iceberg bank, appears moreover from the conditions in the locality south thereof (Narssârssuk), where the moraines investigated all seem to have been formed at a sea-level like the present.

Apart from the steep walls at the north side of Igdlerfigssalik, the Narssarssuaq stage is also traceable on the south side of Qôroq fjord from Narssârssuk in the west to Qôrqup kûa in the east, and onwards across Qôrorssuatsiaq (Flinks Dal) to Steenstrup Nunatak. Around Qôrqup kûa, however, it is impossible to find a stationary line corresponding to the Tunugdliarfik stage. In this area the Tunugdliarfik stage is only indicated by the deposition of varved clay, which may be taken to show that Qôrqup sermia during the greater part of the stage possibly only separated the Qôrqup kûa valley from the fjord, but did not push into the valley, while it is obvious that during the Narssarssuaq stage the glacier pushed far into the valley, depositing there the median moraine described in the section dealing with that locality.

That the period for deposition of the varved clay is identical with the Tunugdliarfik stage, seems evident from the initial formation of the then-existing ice-dammed lake at an erosion base ca. 10 m above the present one. As for the Narssarssuaq stage, the ice-dammed lake, formed during the recession of Qôrqup sermia, has only revealed itself by terraces at altitudes between 140 and 60 m, but not through varved sedimentation.

As regards the extension of the ice in historical times, only few comments will be given here. On air photographs it appears clearly from the trim line how much greater was the extent of the inland ice during the maximum glaciation than at present. However, as mentioned above, an exception is formed by the margin of the inland ice between Eqalorutsit kangigdlît sermia and Niviarsiat. Considering STEENSTRUP's report of the earliest phase of the melting of the ice at Kiagtût sermia in connection with the absence of lichen vegetation throughout the trim line zone, it seems probable that the recession of the glacier all over the area took place after ca. 1900. Owing to the presence of minor push moraines on the south side of Kiagtût sermia, the west side of Hullet, and at the outlet of Storelv on K. J. V. Steenstrup Nunatak, it is quite possible that the inland ice is increasing in thickness again. However, a closer investigation of the marginal area is required, as we may be confronted by local alterations of the ice margin, and similarly, no evidence of glacier advances at greater altitudes has been observed here. Considering the rapid disappearance of the trim line above an altitude of 1100 m, it seems likely, however, that the inland ice and the Julianehåb ice cap in the Narssarssuaq region are swelling in their upper parts.

Changes in the volume of the ice cover within the Narssarssuaq region in Holocene times.

While on the basis of the available information, it is impossible to determine the altitudinal conditions of the inland ice during the Wisconsin ice age, the Holocene ice margin stages within the area offer good possibilities for estimating the thickness of the ice sheet at different times. The widely distributed stationary lines which from the Tunugdliarfik fjord in the west extend eastward to altitudes of ca. 1700 m are helpful in this respect.

This applies to the Tunugdliarfik and Narssarssuaq stages, and it is likewise possible, from the distribution of the trim line zone, to arrive at an estimate of the thickness of the inland ice and the Julianehåb ice cap behind Narssarssuaq during the glacial maximum in historical times.

As the most readily applicable expression of the altitudinal conditions of the ice cover in earlier times in relation to its present thickness, we use the height (Δh) of the earlier stages above the recent glacier surface at the height h (cf. fig. 23). This mode of expression has previously been employed by R. FINSTERWALDER in a calculation of the shrinkage of eight Austrian glaciers in historical times, and later by R. HAEFELI in similar computations of Swiss glaciers (R. FINSTERWALDER 1953, P. KASSER 1953, R. HAEFELI 1955/56). The results of the investigations made by these three authors are compiled by R. HAEFELI (1955/56) and it appears clearly from his compilation that in the present century the alpine glaciers show a shrinkage increasing progressively with the decreasing height of the recent glacier surface above sea-level (HAEFELI 1955/56, p. 9).

Fig. 23 shows the altitudinal conditions of the ice sheet during the Tunugdliarfik and Narssarssuaq stages and during the glacial maximum in historical times. In spite of the spread of the points, all the three stages will be seen to indicate the same strong increase of Δh with a decreasing h.

Only the contour showing the maximum extent of the ice cover in historical times (where Δh is identical with the height of the trim line) is comparable with that given by HAEFELI for the glaciers of the Alps, and this is only possible on the assumption that the trim line for the Narssarssuaq region indicates the total melting of the ice during the period from ca. 1900 to ca. 1950. The course of the contours for the Alpine glaciers and for the glaciers in the Narssarssuaq region is the same, but while the Alpine glaciers even at the firn line are indicated to undergo a decrease in height of ca. 0.5 m/year = ca. 25 metres during the period 1900–1950, the Δh in the Narssarssuaq region for an altitude of the firn line of ca. 1700 m is seen to be almost nil.

That this is the rule, not an exception, within the Julianehåb district, appears from a comparison of measurements of trim line heights (Δh) in the Narssarssuaq region and at lobes issuing from the inland ice and the Julianehåb ice cap outside this area (fig. 23, upper "trim line height"-curve). Irrespective of the spreading of the points, the two contours seem to be rather similar. The ice lobes in the Narssarssuaq region, in reaction

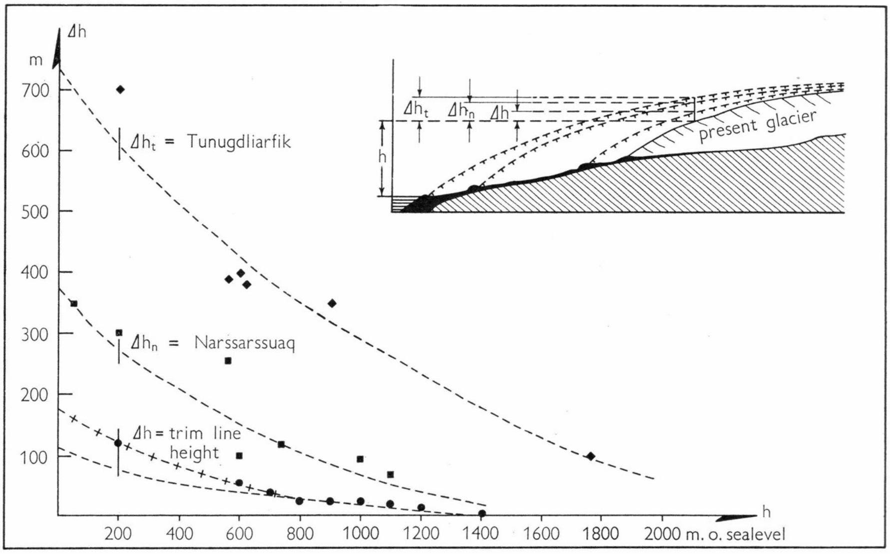

Fig. 23. Amount of shrinkage of the ice covering in proportion to the altitude of the recent glacier surface. Δh = height of the preceding stage above the recent glacier surface; height of this (h) above the sea. Δh_t = Tunugdliarfik stage, Δh_n = Narssarssuaq stage and Δh = trim line height or the maximum extension of the glaciers in historic times.
Lowermost Δh (trim line height) curve: Amount of shrinkage of the ice caps inside the Narssarssuaq region.
Uppermost Δh (trim line height) curve: Amount of shrinkage of the ice caps in the Julianehåb district outside the Narssarssuaq region in historic times. The measurements recorded in this curve were carried out at Qaleragdlit sermia, Kangerdluarssuk, Eqalorutsit kitdlît sermia, the glacier in Kujatdleq valley, and Jespersens Bræ. The two trim line height curves indicate in all essentials the shrinkage of the glaciers in the period ca. 1920–1940.

to the climate alterations of the 20th century, show full agreement with the remaining sectors of the inland ice and the Julianehåb ice cap in the district.

Moreover it appears from fig. 23 that ever since the formation of the Tunugdliarfik stage the ice sheet above the firn line hardly attained a much greater thickness than at present. Thus, the altitudinal conditions of the ice above ca. 1700 m must have been fairly constant during a large part of the Holocene time. This is also in accord with the considerations on the plastic flow of the ice sheet put forward in recent time (E. Orowan 1949, J. F. Nye 1952), for it appears from them that even alterations in the extent of the ice cover by several kilometres will result only in inconsiderable alterations of its height.

ICE MARGIN DEPOSITS OUTSIDE THE NARSSARSSUAQ REGION

In the preceding pages a comparison was made between the shrinkage of the ice lobes in the Narssarssuaq region and outside this region in the period from ca. 1900 to ca. 1950. It was presumed that the trim line expresses the loss in volume precisely during that period. It seems possible to state with certainty that the trim line within the Narssarssuaq region precisely indicates the shrinkage during the same period. The subjoined description of glaciers and ice lobes in the remaining part of the Julianehåb district accordingly has two purposes:

1) An attempt to estimate the extension of the ice lobes, in time as well as in area, during and after the glacial maximum in historical times. As mentioned in the description of the Narssarssuaq region, even in this area there is a great difference between the ice sectors north and south of the Niviarsiat nunataks. This estimate must be based on information given in the literature of the alterations of the glaciers, combined with observations of the immigration of lichens across the trim line after the beginning of the deglaciation.

2) As in the Narssarssuaq region, by studying pre-historic glacier stages, to try to estimate alterations in the volume of the glaciers also in pre-historic, Holocene times.

The descriptions in the following pages comprise:

A) The lobes issuing from the inland ice north of Bredefjord (Ikerssuaq) and Nordre Sermilik. The area is located west and north of the Narssarssuaq region (cf. pl. 1).
B) Glacier lobes in Sdr. Igaliko and in Agdluitsoq and Tasermiut fjords south of the Narssarssuaq region.
C) Local glaciations in the Julianehåb district.

The lobes of the inland ice north of Bredefjord (Ikerssuaq) and Nordre Sermilik.

In this area numerous minor lobes issue from the front of the inland ice, most of them extending right out to the sea. As these lobes can be easily visited in summer, their production of calf-ice being inconsiderable,

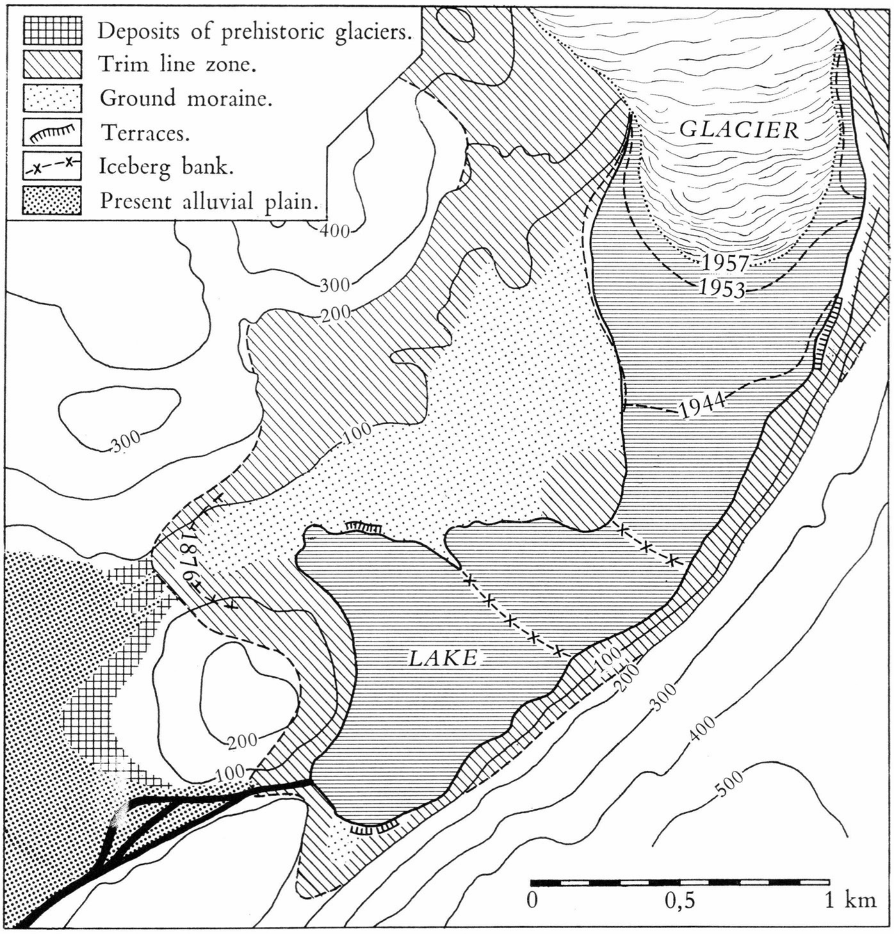

Fig. 24. Eastern glacier in Kangerdluarssuk fjord. The trim line indicates the maximum extension in historical times. The position of the glacier front in the years 1876, 1944, 1953, and 1957 is also given. Pre-historic ice margin deposits are seen immediately in front of the trim line.

a good deal of information on glacier fluctuations in recent times is available. Throughout the terrain there is a marked trim line and back of it often minor stationary lines, while very few ice margin deposits are found outside the trim line, that is to say, lines deposited by stages older than the maximum glacial advance in historical times.

Ice margin deposits of pre-historic age.

Along the above-mentioned sector of the margin of the inland ice, three ice margin deposits of prehistoric age were found:

a) On the west side of Qaleragdlît sermia (see fig. 27) somewhat obliterated morainic ridges is found along the east side of a large lake located 100 m above the sea (Kangerdluatsiaup tasia). This ridge consisted exclusively of large boulders without any finer matrix.

b) Easternmost branch of Kangerdluarssuk fjord. As shown in fig. 24, three ancient, prehistoric deposits occur immediately outside the trim line. The three deposits are associated, and were not separated by meltwater streams till the maximum glaciation in historical times. They were found at the foot of a rock threshold about 80 m high, on which the trim line was located, descending to ca. 30 m altitude.

At this threshold, a much overgrown terrace, now split up into the three deposits just mentioned, occurs 0–20 m a.s.l. The lower portions of the terrace exhibit in profiles ca. 8 m high stratified sand, which passes upwards into large boulders with gravel. The terrace was covered with the same dense vegetation as the surrounding terrain outside the trim line, and the block moraine which forms the proximal termination of this glacial series, is situated immediately outside the trim line indicating the maximum extension of the inland ice in historical times.

From the coarse character of the sediment in the deposit, as well as from its shape and its low position above the sea, it may be assumed that it was formed at a sea level like, or but few metres above, the present level of the sea.

c) Eqaluit iluat. At the head of this large bay in the interior Bredefjord, a series of minor fragments of lateral and terminal moraines are seen, together indicating an ice lobe coming from the north. The material building up the moraines consists of large subangular to rounded boulders with a sparse gravelly matrix. The lower portions of the moraines are cut off by, or disappear into, a valley terrace which towards the head of Eqaluit iluat passes gradually into a system of beach ridges at altitudes of 30–40 m, which constitutes the upper marine limit in this place.

It is probable, therefore, that the moraines were formed by an ice front older than or synchronous with the formation of the upper shore line in the area.

Ice front deposits back of the trim line.

The earlier literature on the area (Weidick 1959) shows that the western part of the sector of the margin of the inland ice dealt with here, i.e. Sermilik (Sermitsialik), had its maximum extension between the years 1890 and 1900, while the eastern part of the sector, that is to say, from Qaleragdlit imâ to Eqalorutsit kitdlît sermia as indicated on pl. 1, attained this extent much earlier. Thus, on a photograph taken by J. C. D. Bloch in 1890, the glacier at Manîtsup tunua is seen already then to have had a marked trim line. Also the middle glacier at the head of Kangerdluarssuk fjord was described already by K. J. V. STEENSTRUP as receding, and A. JESSEN's photographs and descriptions from 1894 of the glacier Eqalorutsit kitdlît sermia (called by him Sermilik Gletscher) indicate that the glacier was then surrounded by a broad trim line.

A similar agreement is presented by the ice margin deposits. At the majority of the glacier lobes issuing from the inland ice in this region, a sharp distinction can be made between older (outer) moraines, in the following pages termed "older historical moraines", and younger (inner) moraines, termed below "younger historical moraines".

The older historical moraines mark the outermost boundary of the trim line in valleys and depressions. They are characteristic by their thick lichenous covering, which renders the dark-coloured moraines readily recognisable from a great distance. The lichens belong to the genera *Lecidea* and *Umbilicaria*, while *Rhizocarbon geographicum* has not been found. The moraines are, in addition, covered locally by birch and willow scrubs. Where most conspicuously developed, the moraines form two parallel ridges (the localities Imángûjuk and Kangerdluarssuk, fig. 28). The material everywhere consists of stony and sandy till with rounded to subangular boulders. The ridges only are covered by lichens, while in contrast, the morainic plain proximal to them is always free from lichens.

The younger historical moraines are situated on the areas between the trim line and the recent glacier lobe. As will appear from the description of the moraine plains of the older morainic ridges (on which plains the younger moraines are situated), the younger historical moraines are devoid of lichens. The only vegetation encountered here is scattered willow shrubs and small birch trees. Moreover, unlike the older moraines, the morainic ridges are generally small and of scattered occurrence in one or two zones back of the trim line. They are built up of the same sort of material as the older moraines.

It appears from the above-mentioned visits (K. J. V. STEENSTRUP 1876, J. C. D. BLOCH 1890, and A. JESSEN 1894) that already at the end of the last century the margins of the lobes in the area in question were located behind the older historical moraines. This is particularly conspicuous in a photograph taken by J. C. D. BLOCH in 1890. The ice margin shown in fig. 27 was drawn from this photograph.

At the large westernmost ice lobe in *Kangerdluarssuk* fjord an attempt was made, in the summer of 1957, to determine the minimum ages of the older and younger moraines by counting the year-rings in the largest (and hence probably oldest) trees. The year-rings were counted by Mr. KNUD JAKOBSEN, of the Botanical Institute, Copenhagen. Six samples, taken on the outermost of the older historical morainic ridges,

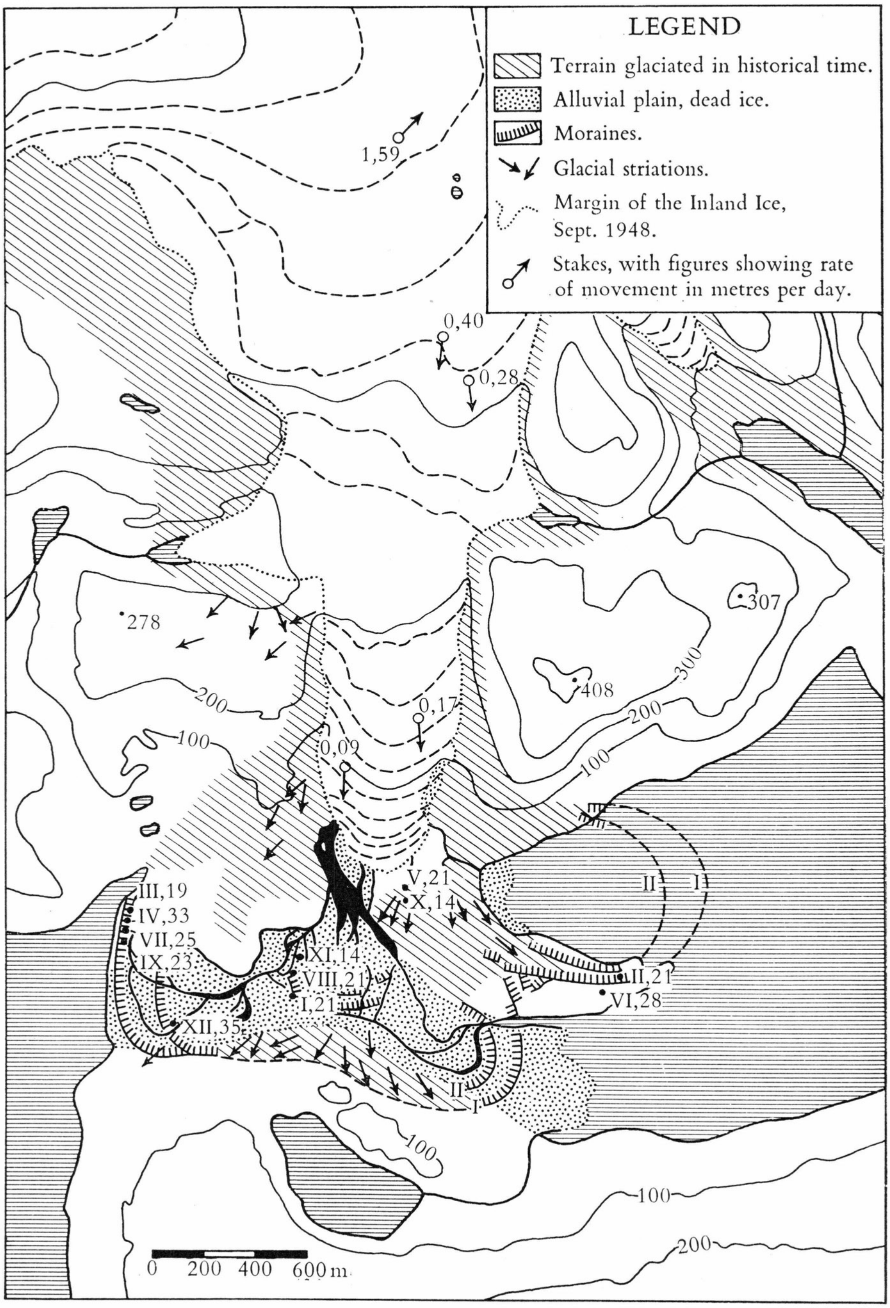

Fig. 25. General map of the western glacier in Kangerdluarssuk fjord. I and II = the two older moraines. Roman numerals: numbers of samples for counting of annual rings. Arabic numerals: annual rings counted, determined 1958.

yielded 19, 21, 23, 25, 28, and 33 years, respectively. Thus, the age of the moraine must be at least 33 years. From the inner one of the two older historical morainic ridges, only one sample, revealing an age of 35 years, is at hand.

The younger morainic systems are represented by two samples, indicating an age of 14 and 21 years, respectively. These younger historical morainic ridges are located ca. $^1/_2$ km from the recent glacier front. Two other samples, taken only ca. 200 m from this glacier front (i.e. the glacier front in 1957) showed an age of 21 and 14 years.

As will be seen, we can only conclude that the two older moraines were deposited prior to 1922, and that the younger moraine ridges must have been formed before 1936. The comparatively high age (21 years) of the vegetation only ca. 200 m from the ice front, is very peculiar. According to K. J. V. Steenstrup, and judging by the hydrographic map of the area surveyed in 1890, in 1876 and 1890 the ice front at the western glacier of Kangerdluarssuk was located immediately behind the older historical morainic ridges. Subsequently, in the period from ca. 1900 to 1944, the ice must have retreated ca. 1 km. The position of the ice front about 1944 is known from the U.S. Army Map of the area on a scale of 1:50,000. Between ca. 1900 and 1944 the recession of the ice was interrupted by some few advances or standstills, which gave rise to the formation of the younger historical moraines. Thus, in the period 1900–1944 the average retreat of the ice front was ca. 23 m annually.

In the period from 1944 to 5/9 1953, the total linear retreat of the glacier front was ca. 50 m, that is to say, hardly more than 5.6 m annually. The position of the glacier front in 1953 is known from air photograph 202 H, no. 13034, of the Geodetic Institute.

The retreat of the glacier front continued from 5/9 1953 to June 1957, totalling ca. 30 m, or ca. 8 m annually. On measurements of the position of the glacier front on June 5 and September 1, 1957, a maximum retreat of ca. 30 m during this period was registered. Both these measurements were made by the author, and the position of the glacier front is indicated in fig. 26. When visited in June of the following year, the glacier front was situated 0–20 m behind its position on September 1, 1957.

Thus it would seem that the recession of the glacier front has generally taken place at a reduced rate during the last fourteen years. A further indication hereof is the age, at least 23 years, of the vegetation only ca. 200 m from the present position of the glacier front. An explanation of the reduced rate of recession must, no doubt, largely be found in the altered shape of the glacier lobe during the recession. While in the period 1890–1944 the glacier lobe extended over a large plane, and accordingly was subject to considerable ablation, in the succeeding period 1944–1958 it assumed an ordinary tongue-shape.

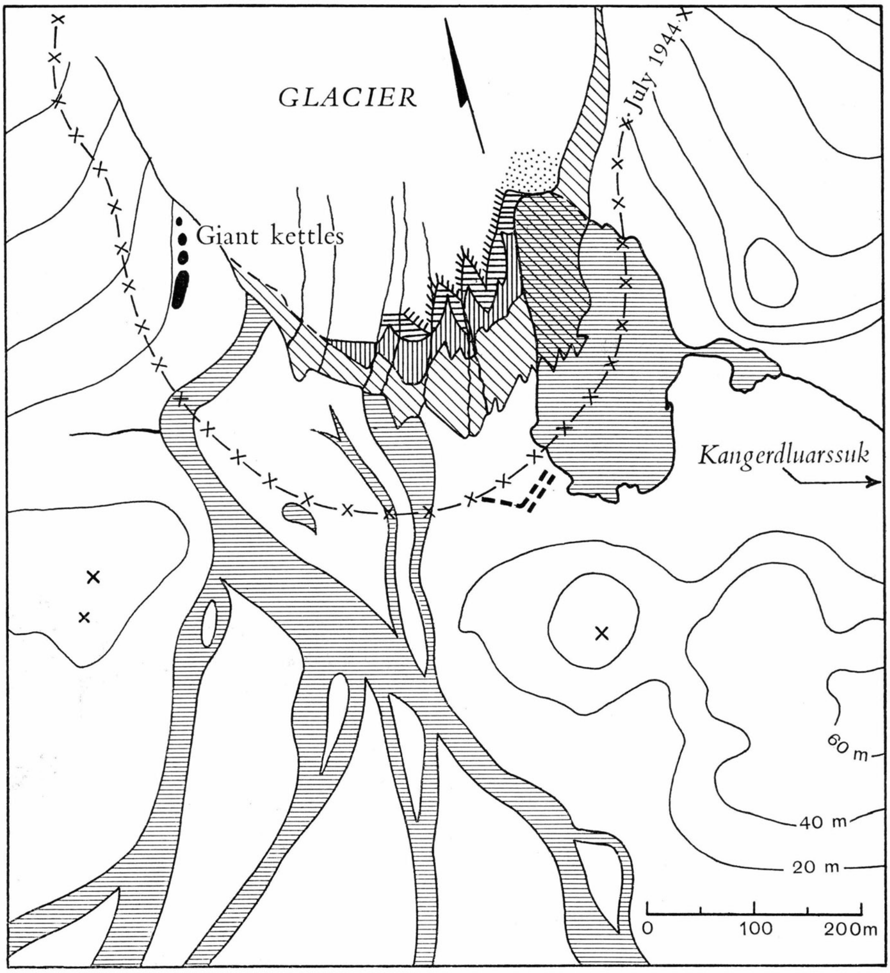

Fig. 26. Western glacier in Kangerdluarssuk fjord. Stippled line: position of glacier front in July 1944. Obliquely hatched area: recession of the glacier 5/9 1953–5/6 1957. Vertically hatched area: recession of the glacier 5/6 1957–1/9 1957. Horizontally hatched area: recession of the glacier 1/9 1957–June 1958.

Besides at Kangerdluarssuk, the older historical moraines are met with at the localities Qaleragdlit sermia, Qaleragdlit imâ, and Imángûjuk at Manîtsup tunua. In all these localities a sharp contrast was noted between the older historical moraines and the younger morainic landscape immediately behind them.

Qaleragdlit sermia.

On the west side of the glacier lobe Qaleragdlit sermia two valleys, 2 km long, connect the glacier Qaleragdlit sermia with a large lake west

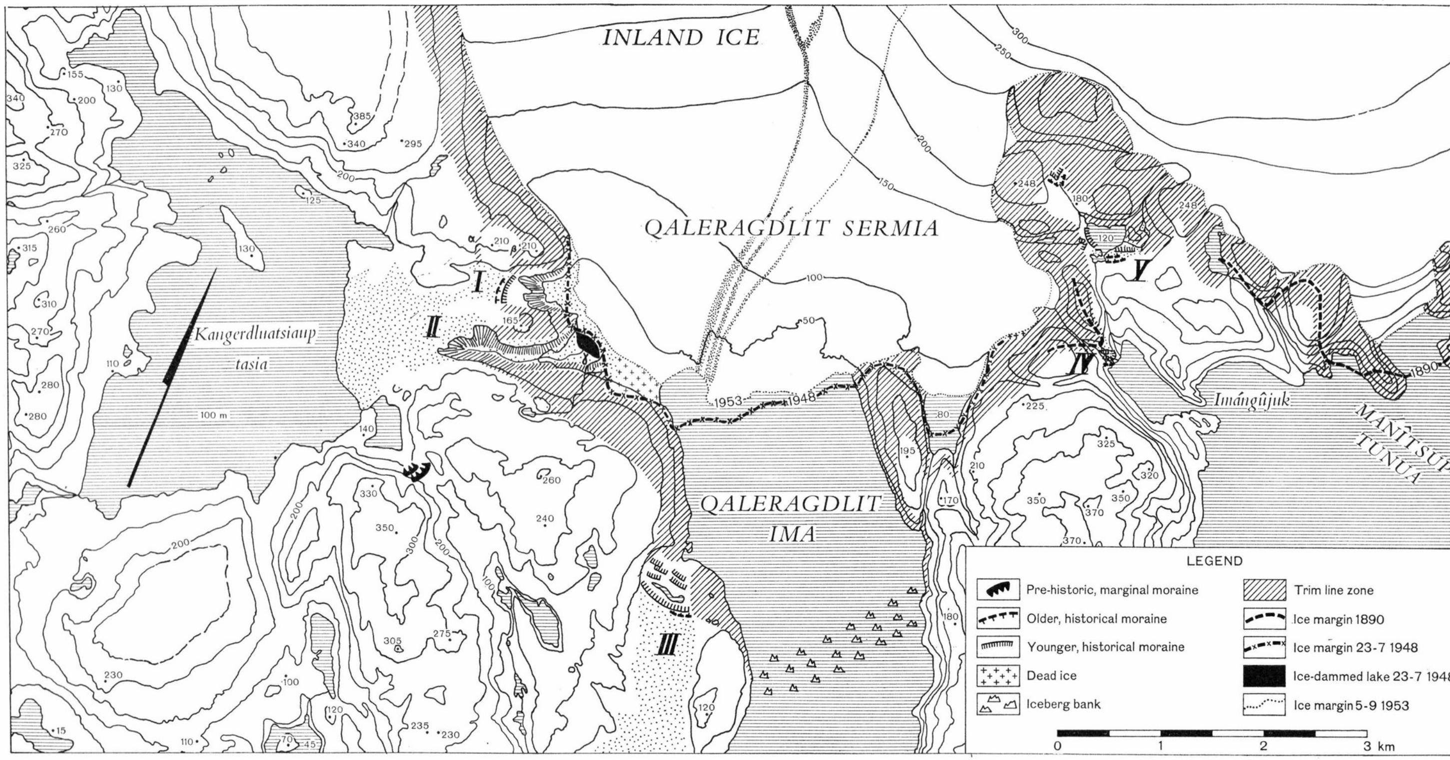

Fig. 27. Margin of the inland ice at Qaleragdlit sermia, Qaleragdlit imâ, and Manîtsup tunua. Based on the map sheets published by the Geodetic Institute, scale 1:20.000.

of it, Kangerdluatsiaup tasia. The water level of the Kangerdluatsiaup tasia occurs 100 m above the sea. The two valleys are separated from one another by a rock knoll whose top rises to ca. 165 m altitude; both contains big outwash plains.

The northernmost outwash plain (plain I in fig. 27) is bounded proximally by several morainic ridges, of which the oldest overgrown ridge is partially buried beneath younger historical morainic deposits. The outwash plain extending from the moraines towards Kangerdluatsiaup tasia lake, nearest the moraines attains an altitude of ca. 120 m, and at the lake ca. 100 m.

Proximally this morainic landscape is terminated by a steep slope ca. 80 m high, descending towards the margin of the inland ice (i.e. the front of Qaleragdlit sermia), which is here situated ca. 30 m above the sea. The upper part of the slope is formed by alternating sand and gravel, passing downwards into clay and sand. The stratification is horizontal, and the individual alternations sand-gravel or clay-sand have a thickness varying between 20 and 60 cm. If we are here confronted with annual varves, the deposits must have been laid down in the course of ca. 200 years.

On the mountains north of the outwash plain, light-coloured belts without vegetation are seen, indicating earlier outlets from the inland ice, which at that time (probably 1890–1900 and ca. 1750) was situated ca. 100 m above the present surface of the ice.

The formation of the outwash plain and the moraines in this valley must be assumed to comprise the following stages:

1) The front of the inland ice (Qaleragdlit sermia) occupied the same position as at present. The lake 100 m was drained through the valleys (later outwash plains) I and II shown in fig. 27, down towards the inland ice, a consequence of the fact that the lake, apart from the two valleys, is everywhere bounded by mountain thresholds occurring above or at heights of 100 m a.s.l.
2) The ice advanced, a) forming an ice-dammed lake, and b) by damming up water in the Kangerdluatsiaup tasia, compelled this lake to seek outlets across mountain thresholds towards Torssukátak sound.
3) The ice formed the moraines, an old historical moraine and several younger ones. It must be assumed that the front of the inland ice between the two phases, characterised by the older and the younger historical moraines, receded only very little.
4) The ice receded. The recession is assumed to have taken place in the period ca. 1900–1950. Air photographs from July 23, 1948 (Geodetic Institute route 502 H-S, nos. 43–45) and from September 5, 1953

(Geodetic Institute route 202 01 H, nos. 13031–32) show that the glacier front receded ca. 100 m during this period.

The southernmost outwash plain (termed II in fig. 27) developed like plain I, only frontal moraines terminating the proximal part of the valley being absent. Only a steep wall, ca. 100 m high, is found here. A trim line around the upper part of this profile suggests that terminal moraines like those in valley I were hardly formed. Profiles through the outwash plain reveal, as in plain I, horizontal beds of alternating gravel and sand at the top, grading into sand-silty beds at the base. Here, too, the thickness of the beds is ca. half a metre. The following stages must be assumed to have occurred during the formation of outwash plain II:

1) Damming of water to an altitude of 100 m, consequential to ice-damming of valleys I and II.
2) The ice had its maximum extension at the moraine on knoll 165 m above the ice-dammed lake. The valley was filled with sediments ("varves") to the present altitude. While the clay beds must be assumed to have been deposited subaquatically, the uppermost very coarse sedimentary beds were presumably laid down during the development of the actual outwash plain.
3) Recession of the ice. A lower terrace step ca. 50 m a.s.l. was formed during the interruption of the eastward retreat of the ice. Then followed the recession to the present position of the glacier front. On the air photograph taken on July 23, 1948, a small ice lake was observed, whose surface was hardly elevated more than 40 m above the sea, and into which Qaleragdlit sermia descended with a steep calving front. On the air photograph taken on September 5, 1953, this small ice-dammed lake is seen to have disappeared, and the ice front to have receded ca. 200 m in the valley of the outwash plain, while immediately south thereof, over an area ca. 300 m broad, it had shrunk to form dead ice. During the same period the front of Qaleragdlit sermia retreated ca. 450 m. During a visit to the locality on June 26–28, 1957, large ice-blocks were observed in several places in the lower part of the stratified sand and gravel (lowermost ten metres). In 1957 no variations in the position of the ice front since 1953 could be ascertained. On the other hand, the present dead ice, the position of which agrees fairly well with the position of the ice front in 1953, was now observed to be situated up to 20 m below the surface of the fresh glacier ice.

Qaleragdlit imâ.

Through a depression separating the peninsula Nûk from the land north of Torssukátak sound, a very level gravel plain is seen which hardly anywhere rises more than ca. 10 m above the level of the sea (III, fig. 27). The gravel plain ends northward (proximally) in a series of terminal moraines which must be assumed to have been formed by Qaleragdlit sermia during its maximum extension in historical times. Many concretions were found both in the moraines and on the outwash plains (mentioned on p. 10 above).

The moraines, of which there are several rows, at their highest points rise only 4 m above the remaining terrain. The terminal moraines sometimes join, at other times they are separated from one another, so it is only possible to distinguish between the two groups: 1) the older historical moraine, which hardly rises one metre above the terrain, and which only in the southern part of the moraine belt projected below the younger historical moraines; and 2) the younger historical moraines, which to the north, towards Qaleragdlit sermia, pass gradually into a broken morainic landscape in which it is impossible to distinguish between individual systems of ridges. That both moraine groups are of historical age, is indicated by the trim line extending along the mountain sides and ending at the outermost moraines.

Manîtsup tunua.

Near this locality, large systems of moraines have developed in two places in connection with the outer limitation of the trim line zone. One area is situated at the very front of the inland ice immediately north of Manîtsup tunua, the other at the sea, in a small bay cutting its way inland from the northernmost part of Manîtsup tunua. In this last-mentioned place the inland ice formerly extended right out to the sea, while at present the ice front here occurs at an altitude of 120 m.

Older as well as younger historical moraines are found in both places. As at Qaleragdlit sermia and Qaleragdlit imâ, the older moraine at the bay (called Imángûjuk by the population) is partially covered by younger historical moraines. The locality at the inland ice shows, however, two close-set older historical morainic ridges. Profiles through these localities are given in fig. 28.

As will appear from the above description, there must be a considerable difference in age between the older and the younger historical moraines. The historical data show that the younger morainic landscape largely developed between 1890 and 1950. The age of the older morainic landscape, however, is unknown.

The melting of the front of the inland ice in South Greenland seems on the whole to agree with that of the glaciers in Iceland, fluctuations of which are described by A. THORARINSSON (THORARINSSON 1943). It is natural to assume, therefore, that the older historical moraines were formed during glacier advances, taking place in Iceland in 1850, ca.

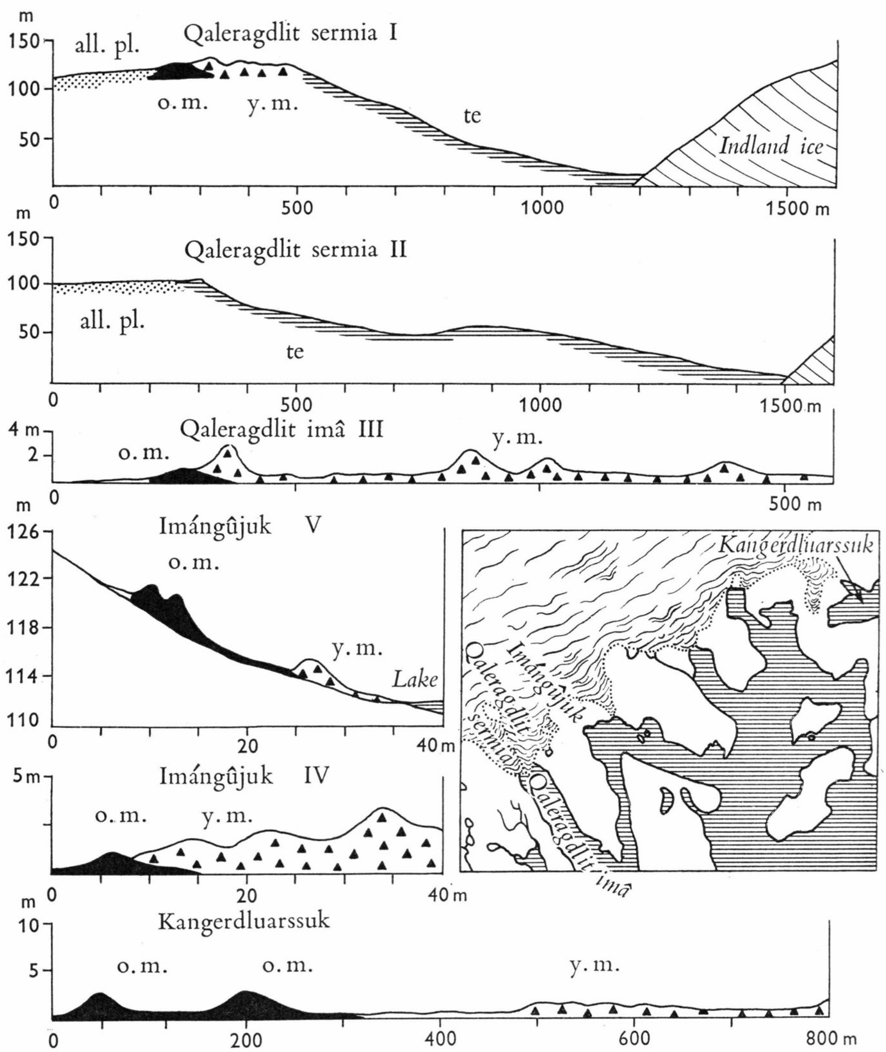

Fig. 28. Profiles through moraines at the margin of the trim line north of Bredefjord. all.pl. = alluvial plain, o.m. = older moraines, y.m. = younger moraines, te. = terraces.

1800 or ca. 1750. As both the older moraines seem to be of great age, they should probably be referred to the advance about 1750, provided that the Icelandic glaciers and the front of the inland ice in the area dealt with here reacted synchronously.

Profiles through all the older and younger historical moraines in the sector of the inland ice treated here are shown in fig. 28. It is a fact that the Sermilik (Sermitsialik) glacier west of the sector described here had its maximum extension as late as 1890 during an advance then in progress. From the profiles reproduced in fig. 28 it will further be seen that while the older moraines of the western localities are almost all of them buried below deposits from the period 1890–1900 (Qaleragdlit sermia and Qaleragdlit imâ), to the east, at Kangerdluarssuk, no later advance has disturbed the older historical moraines.

As mentioned above, it is further known that as early as about 1890 the margin of the inland ice around Manîtsup tunua, Kangerdluarssuk, and the glacier Eqalorutsit kitdlît sermia east of Kangerdluarssuk were receding. Hence, it must be assumed that the maximum extension of the inland ice in a sector from Qaleragdlit imâ in the west to Eqalorutsit kitdlît sermia in the east dates back to ca. 1750, while moraines formed during advances in the 18th and the 19th centuries must have been covered or disturbed by an advance in 1890–1900 in a sector of the inland ice which had its eastern boundary at Sermilik (Sermitsialik) glacier north of Qagssimiut. It would seem that this sector of the inland ice, where the maximum extension of the ice occurred ca. 1890–1900, extends from Sermilik (Sermitsialik) in the southeast to the front of the inland ice south of the Ivigtût region in the Frederikshåb district. Arsuk Bræ, east of Ivigtût, attained its maximum extent about 1870, and in the period 1890–1900 was in process of recession (A. Weidick 1959, pp. 92–102).

However, the absence of a vegetational cover immediately behind the older moraines, even where these latter are well preserved, suggests that even in these localities the advance about 1890–1900 was almost of the same extent as the earlier advances. Only farthest east, in the sector of the inland ice treated here, viz. the area around Eqalorutsit kitdlît sermia, was the glacier, as far as is known, much less extensive in 1894 than during its maximum extension, as indicated by the trim line.

Glacier lobes in Sdr. Igaliko, Agdluitsoq, and Tasermiut fjords.

In the following pages the three localities will be treated in the order given above, from north to south. In a certain respect, this gives at the same time the chronological order of the material, for only at Sdr. Igaliko have ice front deposits older than historic times been encountered.

Sdr. Igaliko.

Ice margin deposits outside the trim line.

On the south side of the large river east of Sdr. Igaliko, delta terraces are seen at an altitude of ca. 20 m (see also the survey of raised beaches p. 18). In addition, in a single place a morainic ridge rises above the surface of the terrace. Accordingly the ridge must be older than the terrace. More markedly developed morainic ridges are found on the mountain sides only few hundred metres farther off. These moraines, too, must be older than the terrace, being located outside it.

All the moraines contain only blocks (block moraines). The terrace contains coarse gravel and rounded blocks in cross-bedding, hence they must be regarded as deposited above sea level. It is impossible, therefore, to state at what marine level the morainic ridges were deposited, except that this level must have been elevated less than 20 m above the present sea level. Thus, there is a possibility that the moraines should be referred to the Tunugdliarfik stage dealt with under the description of the Narssarssuaq region.

Ice front deposits inside the trim line.

Two recent ice lobes issuing from the Julianehåb ice cap are found in valleys ca. 15 km east of Sdr. Igaliko. These two lobes, Kujatdleq glacier and Jespersens Bræ, are surrounded by broad trim lines, showing that the glaciers during their maximum extension in historical times reached 1–2 km farther westward. At the same time the position of the Norse ruins immediately west of Jespersens Bræ indicate that since the time of the Vikings this glacier has not spread very much beyond the position indicated by the trim line.

As the moraines in this locality have not been investigated, we do not know whether older historical moraines are present here. Judging by a report, supplied by the vicar Mr. E. JESPERSEN, of a visit to the ice front in 1911 (JESPERSEN 1912), the glacier probably attained its maximum extension in 1890–1900, and no older historical moraines are present here. Nor are such moraines to be seen on air photographs of the area (Geodetic Institute route 201 J, no. 1245, taken on 21/8 1953).

Ice margin deposits back of the head of Agdluitsoq fjord.

A visit to the edge of the Julianehåb ice cap behind this fjord was made by the author in 1958. The landscape is here formed by a large valley which connects numerous lobes issuing from the Julianehåb ice cap and local glaciations in the surrounding mountains in the east with the head of Agdluitsoq fjord in the west. Throughout its extent the valley is dominated by a terrace lying 5–10 m above the present river. However, no other moraines than those deposited in historical times were found.

Broad trim lines were present everywhere along the recent ice lobes, testifying to a wider distribution of the glaciers in historical times. Towards the valley, the trim lines passed for the most part into large terminal moraines. Of particular interest was the largest ice lobe in the valley, located ca. 17 km from the head of Agdluitsoq fjord. In historical times the ice lobe has spread beyond the valley. Of deposits resulting from this advance, an older historical moraine, of the same appearance as those described from the lobes of the inland ice on the north side of Bredefjord, occurred in the outermost part of the valley.

Immediately inside this older moraine, a large morainic ridge was found which locally covered the older historical moraine. Like the younger historical moraines at Bredefjord, this moraine presented only few and scattered colonies of the lichens *Umbilicaria* sp. and *Lecidea* sp. The determination of the lichens on morainic blocks collected here and at Kangerdluarssuk in the northern part of the district and at Tasermiut in the outer part of the district, was made by M. Skytte Christiansen, M.Sc., of the Botanical Institute, Copenhagen.

The large younger morainic ridge described above passed proximally into a hilly morainic landscape continuing as far as the recent ice front. Only a group of minor morainic ridges situated midway between the outer moraines and the ice front, testified to a minor interruption of the recession of the ice.

Thus, the whole character of the landscape around this glacier lobe much resembles that at Kangerdluarssuk fjord described on pp. 83–87. It must be assumed, therefore, that the older moraine indicates an advance about the year 1750, and the younger historical moraine an advance between 1890 and 1900. The youngest advance had a similar extent to that of the older one.

Sermeq and Sermitsiaq in Tasermiut fjord.

The two glaciers at the head of Tasermiut may both of them, judging by the map, be regarded as lobes issuing from the Julianehåb ice cap, but probably the southernmost lobe has a separate firn area and accumulation basin. The southernmost glacier is called Sermitsiaq, the easternmost Sermeq.

No ice front deposits older than historical times have been found at the two glaciers. On air photographs, however, distinct ice margin deposits of prehistoric age were seen on the south coast of Tasermiut and west of the locality Uiluit kûat (see pl. 1). However, these deposits do not reach the shore and have not been investigated.

Ice front deposits back of the trim line.

Detailed descriptions of both glaciers are available from the previous century, so it should be possible to compare the fluctuations of the glaciers ascertained and recorded in the descriptions with data concerning the vegetation of the moraines. The historical data give the following information (A. Weidick 1959):

Sermitsiaq:	?–1833:	Advance.
	1833–1876:	Stationary?
	1876–1894:	Stationary or slightly retreating.
	1894–1926:	Retreating.
	1926–1943:	Retreating.
	1943–1958:	Retreating.

The extent of the glacier in the years 1833, 1876, and 1894 was very nearly the same.

Sermeq:	1876–1881:	Stationary.
	1881–1889:	Stationary or slightly advancing.
	1889–1894:	Retreating.
	1894–1926:	Stationary, melting.
	1926–1943:	Retreating.
	1943–1949:	Stationary?
	1949–1958:	Stationary.

The maximum extension of the glacier occurred in the period about 1890–1900.

The morphological conditions around Sermitsiaq glacier in the summer of 1958 were as follows: An outermost remnant of two older historical morainic ridges has developed into terminal moraines. Proximally these moraines are partially buried below a large younger morainic ridge. It is known that in 1894 the glacier stood immediately behind the older moraines, and hence it must be assumed that the older historical moraines were not affected by the advance in 1890–1900. Provided that the extent of the glaciers, as indicated by Weidick (1959, map fig. 5, p. 19), was the same in 1833, 1876, and 1894, it must be assumed that the older moraines date farther back than to 1833. In 1833 the glacier was described as advancing, and as slightly calving into Tasermiut fjord. Thus, according to historical data, the "older historical moraine" dates back at any rate to the first decades of the 19th century.

While, thus, the maximum advance of Sermitsiaq must have taken place prior to 1833, the maximum extension of Sermeq occurred about 1890–1900, and this is the reason why no older historical moraines are observed here.

Local glaciations in the Julianehåb district.

The local glaciations described below, with the exception of the first one, the Ilímaussaq glaciation, are restricted to the alpine-like southern part of the district. On the more level and lower-lying plateaus in the northern part of the district, the possibilities for development of local glaciations after the Ice Age are few.

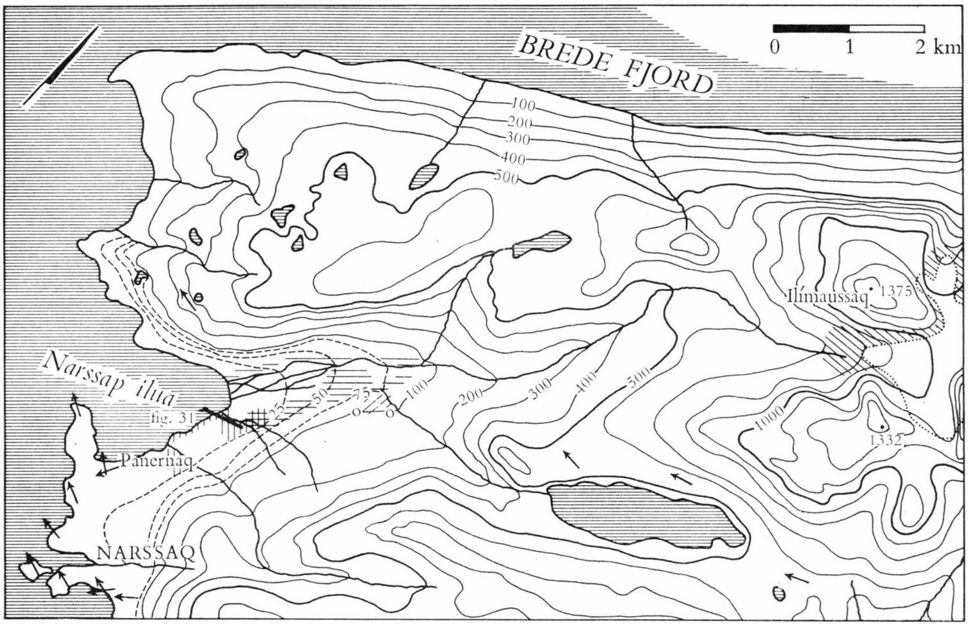

Fig. 29. Narssaq region: Oblique hatching; north-south at line o-o: upper terrace, east-west: trim line around the recent glacier. Horizontal hatching: main terrace. Vertical hatching: localities with raised shore lines, arrows: direction of glacial striae.

The Ilímaussaq region at the town of Narssaq.

The area is situated north of the town of Narssaq. From a bay, Narssap ilua, a valley extends eastward to the Ilímaussaq massif ca. 1400 m high. A main terrace, elevated ca. 10 m above the present river bed, extends from the bay at Narssap ilua through the outermost 3 km of the valley. The terrace is most distinctly developed on the south side of the valley. In addition to this terrace, two terrace remnants, elevated about 40 m above the present river level, are seen above its eastern part on the south side of the valley. Both these terraces are covered by boulders. Towards the sides of the valley the boulder bed is thin ($^1/_2$–1 m) and overlain by boulder clay or silt. However, the more central parts of the main terrace near the river are seen to contain cross-bedded boulders, sand and silt. The coarsest material is found at the top, while beds or lenses of clay may be encountered only 2–4 m below the surface.

To the east the main terrace is terminated abruptly by a large plane formed by the recent river. Along a distance of 1 km eastward from this point, small portions of the main terrace are seen only on the north side of the valley. They disappear in the east at a rocky threshold 70 m above the sea. The abrupt termination of the main terrace in the interior of the valley must be interpreted as an ice contact, that is to say that the

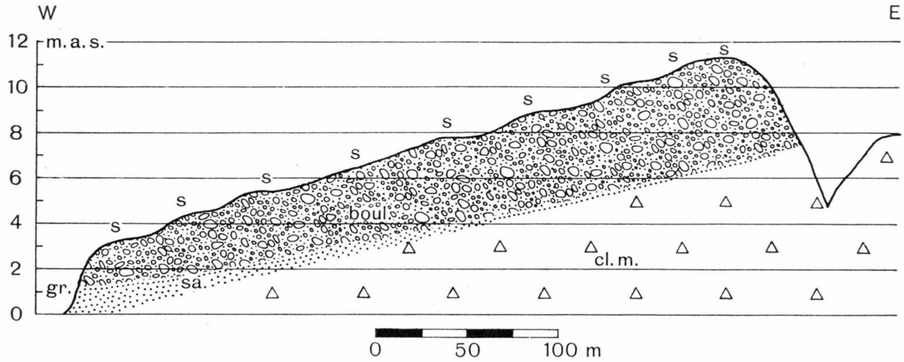

Fig. 30. Profile through beach ridges at Narssap ilua. s = beach ridges, boul. = boulders with gravel, sa = beach sand, cl.m. = boulder clay.

main terrace acts as an outwash plain for a glacier which was situated in the middle of the valley, and whose terminal moraines were either removed by erosion later on, or were not formed at all. The valley as developed east of the main terrace must accordingly be interpreted as a terminal basin (Zungenbecken).

No terminal moraine of prehistoric age was ascertained in the valley. Two ridges on the north side of the valley ca. 400 m a.s.l. and situated ca. 6 km east of Narssap ilua, may perhaps be interpreted as terminal moraines. Possibly, however, some parts of the ridges may be mountain thresholds.

On the main terrace there occur farthest westward some beach ridges, the upper parts of which are found at ca. 30 m, the lowermost, nearest the shore, at ca. 2 m a.s.l. The main terrace ends in a cliff, and hence it cannot be taken for granted that the lowermost beach ridge of the main terrace was originally that which is now located ca. 2 m above the sea. Altogether, beach ridges, cliffs, and washed-out moraines throughout the area around Narssaq seem to indicate that the upper marine limit within the area is found ca. 40 m a.s.l. (cf. also the survey on shore lines in this area, p. 16).

Thus, marine levels very near the upper marine limit within the area are found in the valley between Narssap ilua and Ilímaussaq on the main terrace. In the outermost part of the main terrace, below beach ridges deposited 2–12 m a.s.l., the profile shown in fig. 30 was found. At the top there was a boulder bed made up of rounded boulders, gravel, and sand, passing downward into finer material. A thin sandy layer, wedging out towards the east, marks the lower boundary between this upper fluviatile bed and an underlying bed of boulder clay. Upwards as well as downwards, the sandy bed was sharply separated from the surrounding deposits.

Near this locality, impressions of shell fragments were found locally in the lower boulder clay. It is presumably due to the high content of silt in the boulder clay that the shells are rapidly dissolved. It was impossible, therefore, to secure intact samples. The content of subangular boulders in the clay and the very heterogeneous character of the deposit clearly show that it should be characterised as a moraine. Accordingly the shells must have been redeposited. Similar shell impressions were found in boulder clay cliffs on the north side of Narssap ilua in the innermost part of this bay. This boulder clay entirely resembled the shelly clay found at Narssarssuaq (cf. pp. 47–49), only the content of boulders and stones at Narssaq somewhat exceeds that at Narssarssuaq.

Interpretation of the Holocene deposits outside the trim line.

The shell fragments in the boulder clay no doubt belong to the earliest Quaternary deposits in the area. As at Narssarssuaq, the moraine must have been laid down prior to the deposition of the uppermost beach ridge in the area, and the moraine must accordingly be assumed to have been deposited during the Wisconsin. The uppermost terrace as well as the underlying main terrace must have been formed during an early phase of the deglaciation after the Wisconsin, the upper altitude of the beach ridges also on the main terrace being ca. 40 m a.s.l. The supposed stage characterised by the easternmost part of the main terrace must therefore likewise have been formed soon after the close of the Ice Age.

It is impossible to determine the age of the presumed terminal moraines at an altitude of 400 m a.s.l.

Information concerning deposits inside the trim line in Ilímaussaq.

The innermost eastern part of the valley is terminated to-day by a small glacier tongue, fed by the firn on the Ilimaussaq massif. The maximum extension of the glacier in historical times is revealed by the moraines destitute of vegetation which surround its lower portion as a continuation of the trim line. It is known that as late as 1900 the glacier had an extent which, judging by the trim line, must have equalled its maximum extension in historic times (N. V. Ussing 1910), but that between this date and 1952 it retreated ca. 1 km. During the subsequent years, 1952–1960, the glacier would seem to have been stationary. The position of the glacier front is known for the years 1952, 1953, 1957, 1958, and 1960.

Sermersôq.

In a small south-north directed valley on the west side of the island Sermersôq there is a terminal moraine which entirely separates the valley from the sea. The moraine was figured as early as 1857 by H. RINK. It extends as an unbroken ridge from one side of the valley to the other, and consists exclusively of large boulders up to 10 m in diameter. The morainic ridge descends to ca. 30 m a.s.l. A river makes its way in between the large boulders without cutting through the ridge. The valley was called Kûkasik by H. RINK.

Distally to the moraine, the river traversing the morainic ridge cuts into an alluvial cone built up of large rounded boulders. A tributary river to Kûkasik, coming from a small valley connecting the mouth of Kûkasik valley in the west with a larger southwardly exposed valley, reveals in a profile that the material here is stony till with rounded boulders. The profile is ca. 10 m high. Morphologically, the alluvial cone might be an extramarginal outwash deposit laid down in association with the large terminal moraine. If so, however, it is peculiar that the material of the alluvial deposit some few metres from the moraine is rounded, while no rounded boulder is found in the moraine.

At the shore, two shore lines are seen at 38.4 and 52.6 m altitude, respectively. Both of them are shown by the bases of ancient cliffs.

As regards the relative difference in age between the raised beaches and the large terminal moraine off Kûkasik valley, it seems to appear clearly from the extent of Rink's moraine that this latter is younger than the two shore lines just mentioned.

The large moraine surrounds a terminal basin with a lake. The basin is covered by large angular morainic blocks. The valley itself, described by RINK as sterile and barren, exhibits a luxuriant vegetation, but possibly it is the surrounding barren and steep mountain sides which are referred to by RINK.

Behind the lake forming the terminal basin of the moraine, the valley is seen to narrow, and to be barred by a block moraine, which seen from the outside has rather the character of a talus cone than of a moraine, but seen from the valley appears as a ridge distinguished from the remaining valley bottom. From the map in fig. 31 the lake is seen to be situated 55 m a.s.l.

The head of the valley ends in a pass leading to a northward trending valley on the island. On the west side of the valley several more or less glacier-filled cirques are seen. Around the recent glaciers on the mountain sides and in the cirques, trim lines are often observed, indicating a recession of the glaciers in historic times. As compared with a picture reproduced by H. RINK in his book "Grønland" (1857, vol. II, p. 356), fig. 32 might indicate that the glacier in the small cirque on the west side of the valley has receded some 300 to 400 m in the intervening years. Judging by the trim line, in 1852 the glacier attained its maximum extension in historic times.

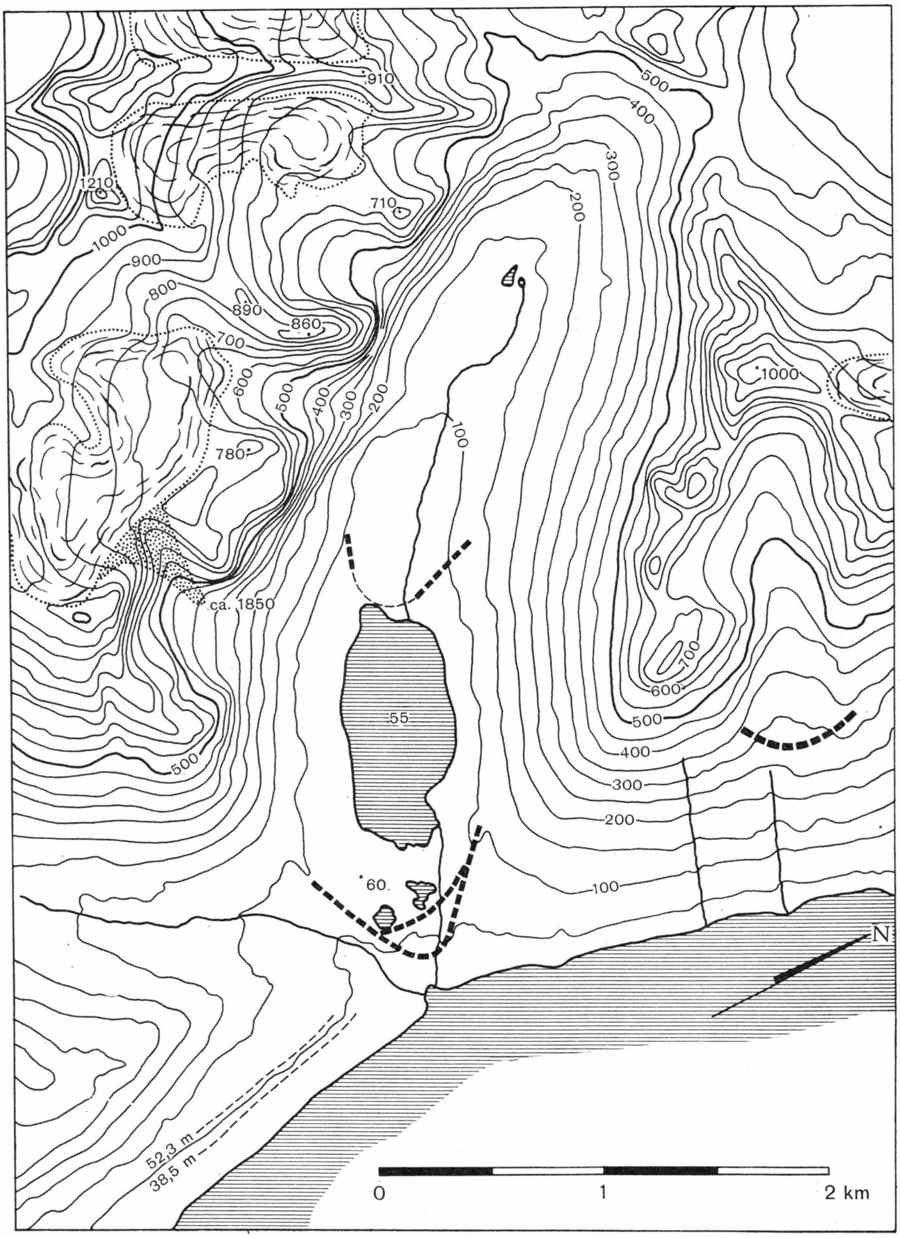

Fig. 31. Moraines at Kûkasik on the island of Sermersôq. Drawn on the basis of the maps published by the Geodetic Institute, scale 1:20.000.

On the northern mountain wall of Kûkasik valley a well developed terminal moraine occurs in a small cirque facing to the south. The moraine, seen in figs. 31 and 32, may be assumed to belong to the same stage as Rink's large terminal moraine at the mouth of Kûkasik valley. Both

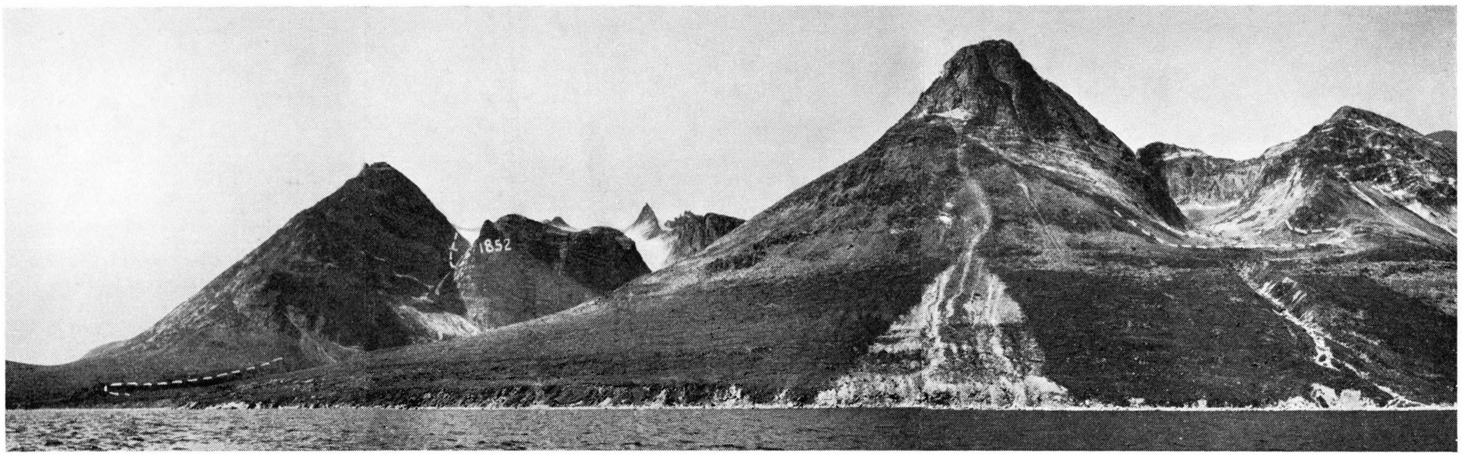

Fig. 32. Moraines at Kûkasik, seen from the east. The moraines are underlined by a white, stippled line. The figure 1852 indicates the extent of the glacier in that year. Phot. A. Weidick 26/7 1958.

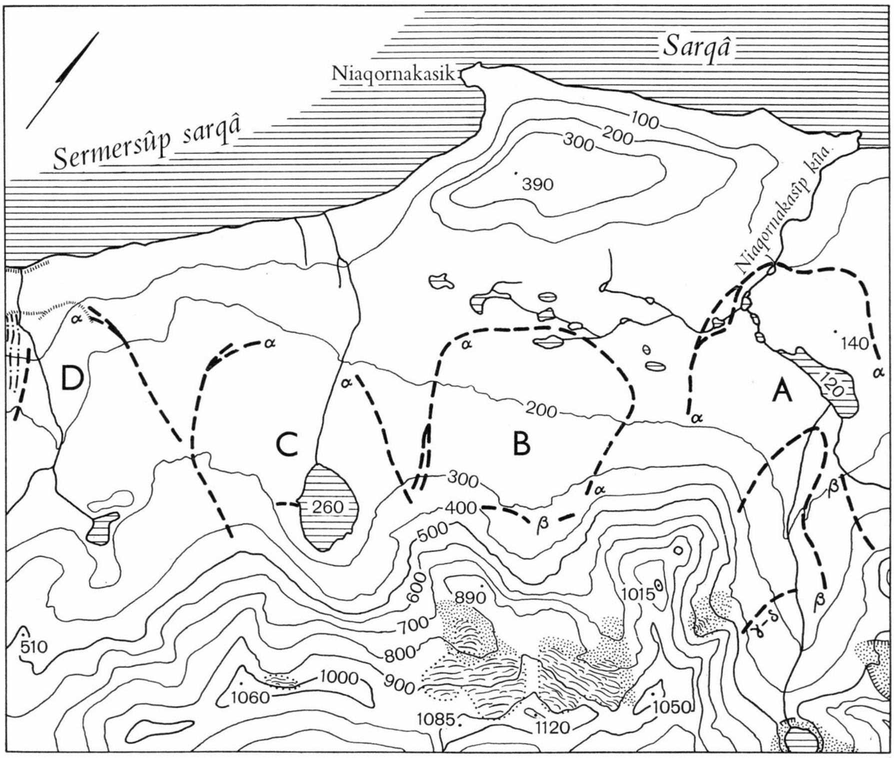

Fig. 33. Moraines at Niaqornakasik. Base map: Geodetic Institute's map sheet, scale 1:20.000.

these terminal moraines seem to have been deposited by glaciers at a glaciation limit ca. 450 m a.s.l., while from the map in fig. 3 the limit is seen to occur to-day at ca. 850 m. At the same time it may be stated that Rink's moraine must be younger than a sea-level situated at an altitude of ca. 40 m.

Niaqornakasik.

Around and in four trough heads or cirques on the northwest side of a mountain mass up to 1200 m high at Niaqornakasik some well developed morainic systems are found, which extend almost right out to the shore. The mountain mass itself is of an alpine character. Only along the shore of the fjord separating this locality from the island Amitsoq, glacial striae and friction cracks are found, indicating an ice motion parallel with the direction of the fjord.

A map of the area is reproduced in fig. 33. The deposits of the individual valleys will be described below, from east to west.

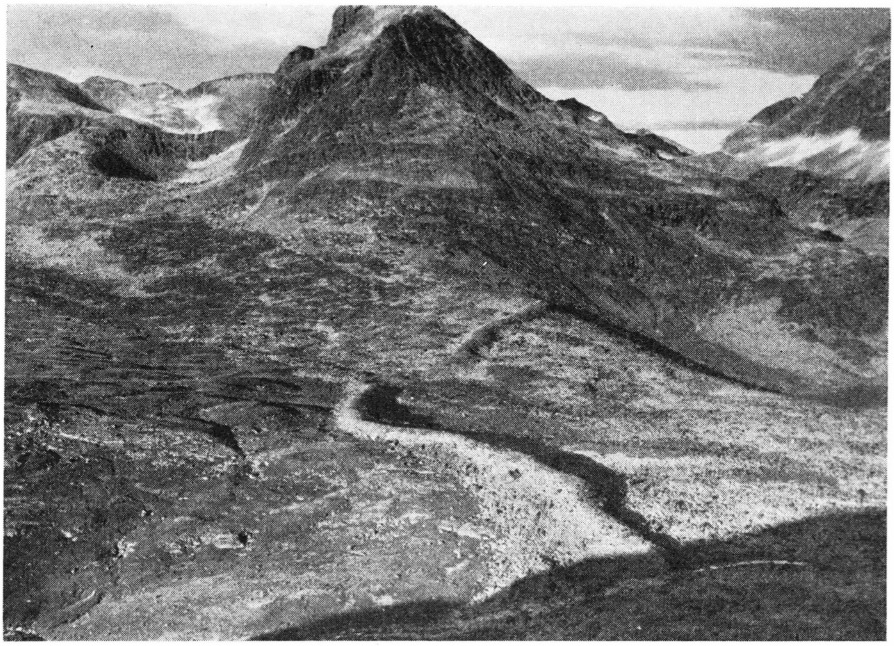

Fig. 34. Moraine Aα at Niaqornakasik. Phot. A. WEIDICK 19/7 1958.

Trough head A. – The outermost moraine α extends through the terrain as a ridge up to 15 m high. The ridge is shown in fig. 34. It is composed of large subangular to mostly angular blocks without matrix. The diameter of the blocks as a rule ranges between $^1/_2$ and 1 m.

In some few places to the west, the morainic ridge divides over short distances into two parallel ridges with an interval of up to 20 m.

The morainic ridge passes distally into an outwash plain elevated 10–15 m above the level of the present river and descending with the same inclination towards the sea. The outwash plain terminates in a cliff 10 m high rising from the recent surface of the sea. Grooves in the terrain in the eastern part of the outwash plain must be interpreted as marginal channels. The outwash plain should not, probably, be interpreted as belonging entirely to moraine α, for this moraine is partially buried by the plain.

The terrain between moraine α and lake 120 m (fig. 33), like the moraine itself, is made up of large angular blocks with no matrix. The lake and the surrounding terrain must be regarded as a terminal basin for moraine α.

Moraine β. Another ice margin is indicated by moraine β back of moraine α and behind lake 120 m. However, this morainic ridge is less well defined than moraine α, the boulder terrain around lake 120 m merely forming a ridge which it is difficult to recognise in the terrain on its proximal side, where, as a boulder field it rises to the same height in its terminal basin as in its lateral moraine.

Moraines γ and δ. Back of moraine β, the terrain rises towards three cirques, all of which contributed to the filling of the main valley with moraines and boulders, so the individual morainic ridges can hardly be distinguished from the subsequently formed talus cones. Moraines γ and δ, as indicated in fig. 33, are possibly morainic ridges whose material, like the morainic covering of the valley, is constituted by large angular blocks without matrix.

Outside the recent glaciers in the cirques, morainic ridges and trim lines occur, indicating the maximum extent of the glaciers in historic times. Two cirques contained, in their outer parts, a moraine which owing to its dense cover of lichens resembled the older historical moraines at Kangerdluarssuk fjord. At these cirques, however, unlike at Kangerdluarssuk fjord, there was no sharp delimitation of the vegetation proximally to the older historical moraines, but only a slow thinning of the lichenous cover towards the interior. Thus, no very great glacier advances seem to have taken place here in the 19th century.

Cirque B.

Moraine α. As at trough head A, the moraine extends as an unbroken single semicircular ridge across the mouth of a large cirque. Only to the west, the ridge divides into two parallel ridges. To the north the material consists for the most part of large angular blocks without matrix, in the northeast sometimes also with a gravelly matrix. The terminal basin behind the moraine, as at trough head A, consists of large angular blocks without matrix.

Moraine β. Behind the large outermost moraine α, there is a smaller one which in places is much obliterated. Here, too, the moraine is a block moraine.

Cirque C.

While the outer moraines α deposited by a glacier in this cirque can be distinctly distinguished on the aerial photographs, when visited they are often hidden by the vegetation of the terrain and the boulder field. The northernmost portions of moraine α, however, are not recognisable in aerial photographs either, but as the western lateral moraine α terminates in a fan of moraines (see fig. 33), it must be assumed that the glacier front has undergone considerable fluctuations which prevented the deposition of actual terminal moraines. Like moraine α in trough head A, moraine α here indicates a stage with a distinct glacial overdeepening with a lake.

Cirque D.

The outer moraines in this cirque are highly obliterated. Only lateral moraine α on the west side of the valley seems to be entirely well defined. Moraine α terminates on a rock threshold. In the terrain below this ledge, a terrace is seen which possibly forms part of the outwash plain corresponding to moraine α. This terrace occurs at an altitude of 33–38 m. It ends in an ancient cliff, whose foot is situated 24.3 m above the present level of the sea. Accordingly the moraine seems to be older than a sea-level ca. 24 m above the present sea-level.

During the maximum extension of the glaciers in localities A, B, C, and D, the limit of glaciation in the area seems to have occurred ca. 300 m a.s.l. It must be assumed, however, that the general glaciation limit in the area at that time was somewhat higher, for all the above-mentioned cirques are situated on the north side of a mountain range. The general limit of glaciation at the time when the glaciers terminated at moraines α must therefore be assumed to have been elevated ca. 500 m a.s.l. The present limit of glaciation is seen from fig. 3 to occur ca. 800–1000 m a.s.l.

Other ice margin deposits, observed on air photographs.

During an examination of the air photographs of the district taken by the Geodetic Institute, marked stationary ice lines were seen in several localities in the southern part of the district. They are all lateral or terminal moraines, situated at the mouths of small valleys or cirques. At these deposits the limit of glaciation during the maximum extension of the local glaciations seems to have been 300–500 m lower than to-day. Only in localities on the west coast of Sermersôq and at Îpatit kûa (see pl. 1) the moraines are seen to reach the sea. A dating in relation to the sea-level should therefore be possible during visits to these localities.

Correlation of ice margin deposits outside the Narssarssuaq region.

Ice margin deposits of prehistoric age.

An account of the individual stages in the Narssarssuaq region after the Wisconsin ice age is given on p. 76. The ice margin deposits in the area may be grouped as follows:

Wisconsin?, the Tunugdliarfik stage, the Narssarssuaq stage, and finally the maximum extension of the ice in historic times.

Outside the Narssarssuaq region, prehistoric ice margin deposits at the margin of the inland ice have been found in the localities Qaleragdlit imâ, Kangerdluarssuk, and Eqaluit iluat. Owing to the limited extent of the moraines at Qaleragdlit imâ, it is impossible to give the age of this stage there.

The locality at the inner eastern branch of Kangerdluarssuk must have been formed at a time when the level of the sea occurred near the present sea level. Hence it is natural to assume that the stage indicated by these moraines is identical with the Narssarssuaq stage.

The Eqaluit iluat moraines, however, were formed at a sea level ca. 30 m above the present one. They must accordingly indicate a stage which is older than the Tunugdliarfik stage. It is a prerequisite for this decision, however, that the upheaval of the land at Eqaluit iluat took place almost at the same rate of uplift as at Narssarssuaq. The two localities are only distant ca. 10 km from each other.

Of prehistoric ice margin deposits laid down at the margin of the Julianehåb ice cap only the locality at Sdr. Igaliko has been investigated. As stated on p. 94, we can only say that these deposits were formed with a level of the sea less than 20 m above the present sea level. Possibly, therefore, we are here concerned with the Tunugdliarfik stage, though it cannot be demonstrated with certainty.

Several ice front deposits are, however, known from local glaciations. All of them, with the exception of the area at the town of Narssaq, are associated with the alpine southern part of the district.

At Narssap ilua a stage occurs between this locality and the Ilimaussaq massif which is characterised by an upstream termination of the main terrace and an upstream continuation of this stationary line at a much obliterated "schliffgrenze" on the mountain sides. This glacier probably had its glaciation limit between 700 and 900 m a.s.l. As the stage was formed above the uppermost marine limit in the area, like the stage at the nearby Eqaluit iluat, it must be assumed that the two stationary lines represent the same stage. The presumed stage, which is represented by the possible terminal moraines between the end of the main terrace and the recent glacier (see also p. 98) must then represent a younger stage in the valley and should possibly be interpreted as a local Narssarssuaq or Tunugdliarfik stage.

Of the numerous deposits originating from prehistoric local glaciations in the southern part of the district, two which are associated with raised shore lines were visited, namely the two local glaciations Kûkasik and Niaqornakasik. At Kûkasik the outer moraine is younger than a level ca. 38 m a.s.l., and at Niaqornakasik it is older than a level at ca. 24 m a.s.l. This, together with the common tendency of these stages to indicate a glaciation limit situated 400–500 m below the present one during the maximum extension of the then existing glaciers, may perhaps be taken as an indication that the outer moraines deposited by these local glaciations belong to one and the same stage. In the following pages this stage will be termed the Niaqornakasik stage.

The glacier which formed the main terrace in the valley between Narssap ilua and Ilímaussaq had a glaciation limit between 700 and 900 m a.s.l. According to fig. 3, the present limit of glaciation in this area is 1300–1400 m a.s.l. Thus the glaciation limit for the stage represented by the main terrace was situated 400–700 m lower than that of the present day. It seems natural to assume, therefore, though with great hesitation, that the main terrace at Narssap ilua-Ilímaussaq here represents the Niaqornakasik stage. Provided that this assumption is correct, the subjoined table may be erected for the glaciation sequence in the Julianehåb district in Holocene time:

Locality	Niaqornakasik stage	Tunugdliarfik stage	Narssarssuaq stage
1) Kangerdluarssuk . .	–	–	+
Eqaluit iluat	+	–	–
2) Sdr. Igaliko	–	+	–
3) Narssap ilua-Ilímaussaq	+ (main terrace)	+?	+?
Kûkasik	+ ("Rink's moraine")	+?	–
Niaqornakasik	+ (moraine α)	+? (moraine β)	+? (moraines $\gamma-\delta$)

In this table, 1) indicates the lobes of the inland ice, 2) the lobe issuing from the Julianehåb ice cap at Sdr. Igaliko, and 3) local glaciations.

In addition, the local glaciations might indicate the following glaciation limits of the individual stages:

Niaqornakasik stage, 700–400 m below the present glaciation limit
Tunugdliarfik stage, 300–200 - – – – – –
Narssarssuaq stage, 200–100 - – – – – –

The trim line zone.

An examination of the air photographs of the various areas within the district outside the Narssarssuaq region reveals that, irrespective of the type of glacier, all the lower portions of the glaciers are surrounded by a broad trim line zone. Moreover two advances, represented by the older historic and the younger historic moraines, show that these two advances were of approximately the same extent. The earliest advance probably dates back to ca. 1750, and it is known that the youngest one dates from 1890–1900. From this it appears that the trim line zone roughly marks the shrinkage of the glacier lobes in the period ca. 1900–1950. Here as in the Narssarssuaq region the melting must be assumed to have been most intense between ca. 1920 and ca. 1940.

As to differences in the extension of the glaciers during their advances ca. 1750 and ca. 1900, the following table may be erected for the individual localities outside the Narssarssuaq region:

Widest extension, year:	ca. 1750	ca. 1900	ca. 1950
1) Sermilik (Sermilitsialik)		+	
Qaleragdlit	+		
Kangerdluarssuk	+		
Eqalorutsit kitdlît sermia	+		
Eqalorutsit kangigdlît sermia			+
2) Sdr. Sermilik (Weidick 1959)		+	
Agdluitsoq	+		
Sermitsiaq (Tasermiut)	+		
Sermeq (Tasermiut)		+	
3) Narssaq glacier		+	
Kûkasik	+?	+?	
Niaqornakasik	+		

As in the table on p. 108, 1) indicates the lobes of the inland ice, 2) lobes issuing from the Julianehåb ice cap, and 3) local glaciations. It will be seen that it is quite casual whether the advance ca. 1750 or that ca. 1900 constituted the maximum, and, as mentioned above, the difference in the extension of the glaciers during these two advances is inconsiderable. Further, it will be seen that only the front of the inland ice at Eqalorutsit kangigdlît sermia behaves differently, for it is known that as late as 1955 the glacier had an extent which on the basis of the trim line must be characterised as its maximum extension in historic times, and that in 1955 it was expanding.

Changes in the volume of the glaciers outside the Narssarssuaq region in Holocene times.

As stated in the preceding pages, it seems probable that the stages outside the Narssarssuaq stage may be incorporated in the chronology of the Narssarssuaq region via the deposits at Eqaluit iluat and Narssaq-Ilímaussaq.

The relatively few and scattered ice-front deposits of prehistoric age outside the Narssarssuaq region do not permit us to determine the volume of the glaciers here during the various stages. As the extension of the glacier tongues must in some degree reflect their volume, the following sectorial extension during the various stages must be assumed:

a. Niaqornakasik stage.

Margin of the inland ice north of Bredefjord.

The moraines at Eqaluit iluat and possibly two block moraines developed as lateral moraines and situated at Tasiussaq in the innermost part of Bredefjord, must indicate that the margin of the inland ice occupied a position ca. 10 km in front of its present position.

Eqalorutsit kangigdlît sermia-Narssarssuaq region.

Nothing is known of the extension of the ice during this stage. Possibly the upper younger moraine with rounded boulders at Kiagtût (see p. 50) represents this stage.

Julianehåb ice cap.

Some morainic ridges at the mouth of a valley at Niaqornârssuk in Ûnartoq Fjord are decidedly older than an upper marine limit at 35 m altitude (see also p. 19), and hence the stage indicated by these morainic ridges can probably be identified with the Niaqornakasik stage. However, we are not concerned here with an actual lobe issuing from the Julianehåb ice cap, but more likely with a local glaciation which coalesced in part with the Julianehåb ice cap.

Local glaciations.

Glacier tongues at Narssaq-Ilímaussaq, Kûkasik, and Niaqornakasik show that during this stage the ice extended 1–5 km farther beyond the front of the present glacier tongues, and that the glacier fronts were situated some 700–1100 m lower than to-day.

b. Tunugdliarfik stage.

Front of the inland ice north of northern Sermilik.

Extent of the stage in this sector unknown. However, the presence of the Niaqornakasik stage at Eqaluit iluat must indicate that the glacier lobes extended ca. 10 km, at the most, beyond the present ice margin.

Eqalorutsit kangigdlît sermia-Niviarsiat.

It is assumed (see p. 25) that the extension and thickness of the inland ice in this sector was almost the same as at present.

Narssarssuaq region.

The extent of this stage is known in details here, cf. pl. 3 and pp. 41–52.

Julianehåb ice cap.

The extension of an ice lobe to the head of Julianehåbsfjord at Sdr. Igaliko, immediately south of the Narssarssuaq region, is known. Here, as in the Narssarssuaq region, the glacier lobes extended some 10–15 km farther westward than at present.

Local glaciations.

Behind the Niaqornakasik stage deposits, several large well defined single moraines occur, indicating stagnation or re-advance after this stage. It is assumed, but not known with certainty, that the β-moraines marked at Niaqornakasik belong to this stage.

c. Narssarssuaq stage.

Front of inland ice north of northern Sermilik.

The extent of the stage is known from the moraines at the innermost eastern branch of Kangerdluarssuk fjord. Here the glacier ice did not push very far beyond its maximum extension in historic times.

Eqalorutsit kangigdlît sermia-Niviarsiat.

It is assumed (cf. p. 25) that the extension and thickness of the inland ice in this sector was about the same as it is to-day.

Narssarssuaq region.

The extent of the stage here is known in detail, see pl. 3 and pp. 41–52.

Julianehåb ice cap.

Extent of the stage unknown.

Local glaciations.

The extent of the stage is assumed to be indicated by moraines γ and δ at Niaqornakasik.

d. Maximum extension of the glaciers in historic times.

As stated on p. 109, the trim line marks the maximum extension of the glaciers in historic times, that is, either about 1750 or 1890–1900. The two maxima of glaciation seem to have been of approximately equal magnitude.

Fig. 23 indicates that the rate of shrinkage of the glacier lobes issuing from the northern part of the inland ice in the district, from the Julianehåb ice cap and from the Narssarssuaq region, has remained nearly the same throughout historic times (cf. also pp. 79–80).

EARLIER AND PRESENT ICE-DAMMED LAKES IN THE NARSSARSSUAQ REGION

In the northern part of the district, several large ice-dammed lakes occur near the margins of the inland ice and the Julianehåb ice cap. In most cases we are concerned with tributary valleys which are barred by the large ice lobes occupying the major valleys. According to their run-off, the ice-dammed lakes in the district may be divided into three categories:

1) Lakes with superglacial or englacial run-off. Most commonly the drainage takes place along the margin of the glacier lobe, sometimes, however, on the very surface of the glacier. In the last-mentioned case, however, only over a short distance before the water sinks to the bottom of the glacier through crevasses and glacier mills. Lakes of this type are generally small, their surface area within the district being less than ca. 1 km^2, in most cases under 0.25 km^2.

2) Ice-dammed lakes with run-off across thresholds to other valley systems. Such ice-dammed lakes may be observed along the whole margin of the inland ice. The lakes generally attain a size of 1–3 km^2, and arose as a result of barring of a minor valley system. The conditions for sedimentation in these lakes must be quiet, for in former lakes of this type, sedimentation of a "varved character" is seen at the bottom (Qaleragdlit sermia, Qôrqup kûa during the Tunugdliarfik stage?), while large deltas and outwash plains occur at the front of the glacier (Motzfeldt Sø, Nordbosø).

3) Ice-dammed lakes which are drained by subglacial outbursts. The lakes have for the most part a surface area ranging between 1 and 3 km^2. While types 1) and 2) are subject to continual drainage, the greater part of the drainage of this type is effected by rapid outbursts beneath the glacier. The outbursts generally last from a few hours to some few days. After such an outburst the lakes will be slowly filled, which will generally take one to several years, and when the water level has reached a certain height, outbursts will begin again. Owing to the heavy run-off, sedimentation of finer material is rarely seen at these lakes. While

geologically type 1) must be associated with the formation of kame terraces, and type 2) with outwash plains with boulders and gravel proximally, and varved clay distally, around type 3) only ordinary terrace notches, lateral moraines, and push moraines seem to occur, but no finer sedimentation.

Rather early it was recognised that the lakes of type 3) are filled to a certain height, after which they are emptied (H. Rink 1862, ref. Charlesworth I, p. 181, 1957, and Weidick p. 108, 1959, concerning Imaersartoq lake in the Frederikshåb district, West Greenland). Since the lakes, as stated above, are always of a considerable size, both H. Rink (1862, Imaersartoq) and S. Thorarinsson (1953, Grimsvötn, Iceland) explain the emptying of the lakes as due to hydrostatic uplift. A different explanation was given for Tulsequah Lake, Canada (F. A. Kerr, ref. by J. W. Glen). This ice-dammed lake is stated to be filled to the ice margin, and then, by superglacial run-off, gradually to cut a tunnel down into the ice.

An explanation comprising both hydrostatic uplift and superglacial initial run-off, was already given by O. Fabricius for the ice-dammed lake of Imaersartoq near Frederikshåb, Greenland (Fabricius 1788, p. 72).

O. Liestøl (1955/56) and M. G. Marcus (1960) mention the possibility of the importance of hydrostatic uplift as well as heat given off by the meltwater. The author is indebted to Dr. J. W. Glen for this information.

In several places along the margin of the inland ice there occur lakes with periodical outbursts. The name used by the West Greenland population for such lakes is Imaersartut (plural, in singular: Imaersartoq). Like the majority of Greenlandic place-names, it is no name in the general sense of the word, but merely a description (Imaersartoq = "that which used to be emptied").

Considering the theory of a hydrostatic uplift of the glacier, it is difficult to conceive a complete emptying of the ice-dammed lake. The possibility cannot be excluded that the explanation may occasionally be true. Thus it might perhaps account for the outbursts from the Taserssuaq lake at Sarfartôq, Sdr. Strømfjord in the Sukkertoppen district, West Greenland. The outbursts were described in the 19th century by Mr. S. Kleinschmidt, Godthåb, in a letter to Mr. J. A. D. Jensen. The letter is published by J. A. D. Jensen in the "Meddelelser om Grønland", vol. 2, p. 132. The area was later mapped by the Oxford University Greenland Expedition, and the map was published in the Geographical Journal 1937. From this it appears that the outbursts in the locality took place by the water masses pushing across or through a glacier tongue whose outermost portion formed a barrier across Sarfartôq valley. Thus, the glacier tongue probably burst owing to the pressure of the water masses. However, the outbursts from the lake ceased in the present century at the recession of the glacier.

The explanation of the overrunning of the glacier tongue may possibly likewise be applied to the Sarfartôq locality. However, these theories can hardly be applied to the drainage of the ice-dammed lakes in the investigated area in the Julianehåb district owing to the shape and surface conditions of the barring glacier tongues (Annekssø, Snobæk, Hullet on pl. 2 and fig. 19) and to the position of the lakes far behind the glacier front.

A more recent explanation of the phenomenon was advanced by J. W. GLEN (1954), who assumed that the outbursts from the ice-dammed lake take place through the lower parts of the glacier, when the lake has reached a maximum water level in the deepest place at the glacier front of 150–200 m. The outbursts are due to the difference in the specific gravity of the water and the ice, which at the said depth of 150–200 m will exert a pressure on the glacier front of 1.5–2 bar owing to the pressure of the water. J. W. GLEN assumes, on the basis of laboratory experiments and the investigations by J. F. NYE on the closing of boreholes in the glacier (NYE 1953), that a significant creep will take place in ice with a normal stress of ca. 2 bar. Transferred to the lower part of the glacier front at an ice-dammed lake, the water will be able to make its way out through the lower part of the glacier, when the pressure of the water masses surpasses this limit of ca. 2 bar.

During the mapping of the Narssarssuaq region, deposits from several ice-dammed lakes have been found, which lakes can only have been drained englacially or subglacially. The outlines of the lakes are indicated by horizontal ruling on the sketch maps in fig. 35. The extent of all the lakes found here was determined from terraces and lateral moraines. Some uncertainty exists as to the three lake stages in Storelv valley (K. J. V. Steenstrup Nunatak, fig. 35a, b, c), the extent of these stages being only known from minor, rather obliterated terracic and morainic fragments on the south side of the valley. The conditions around Terrassesø and Hullet are clearer. As for all the deposits derived from ice-dammed lakes found here, interest attaches to the connection between the terrace marking the upper water level of the lake and the position of the associated glacier front. If these two phenomena are known, the maximum height of the water level and the maximum depth of the lake at the glacier front are likewise known. A terrace or terrace notch merely indicates that the water level remained at the terrace level for a comparatively long time. During the filling of an ice-dammed lake, the rise of the water level of the lake during the constant afflux will decrease owing to the shape of the basin. It might be expected, therefore, that a marked terrace level will be washed out or deposited primarily at

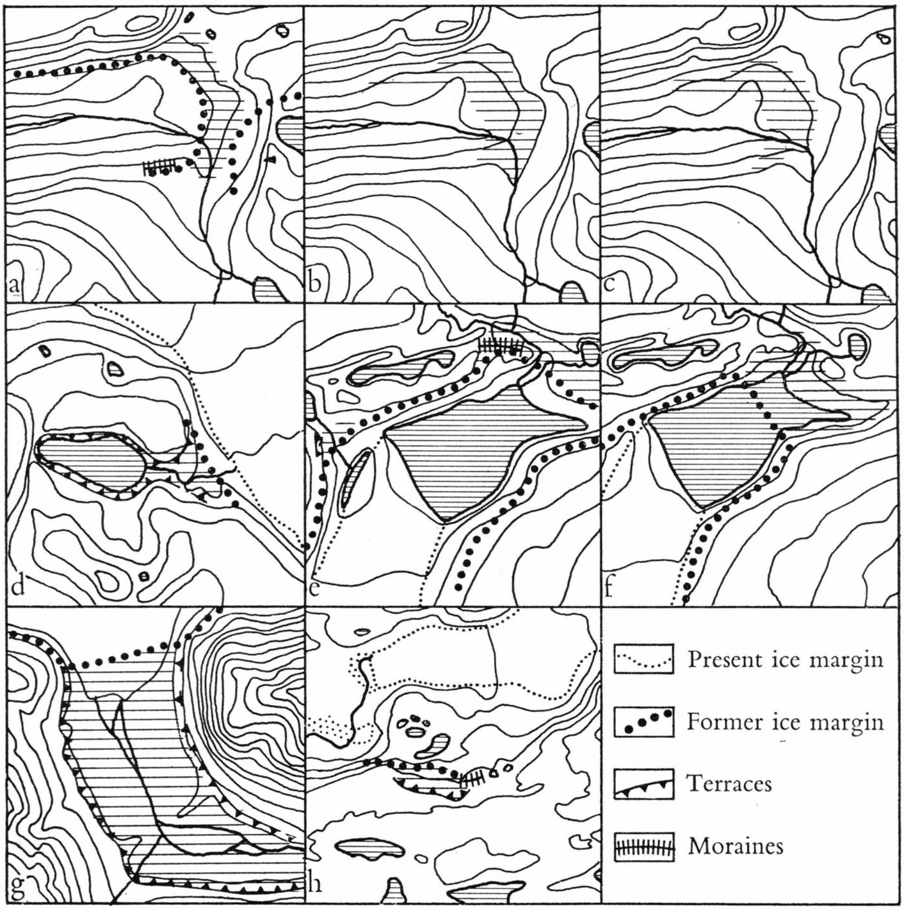

Fig. 35. Ice-dammed lakes in the Narssarssuaq region. a, b and c stages in the valley of Storelv, K. J. V. Steenstrup Nunatak. d: Terrassesø, K. J. V. Steenstrup Nunatak. e: Hullet, recent time and Narssuarssuaq stage. f: Hullet during maximum extension of the glacier in historical time (around 1900 A. D.). g: Qôrqup kûa, f: Area immediately south of the front of Kiagtût sermia.

the maximum height of the water level. The position of the glacier front can for the most part be determined with a margin of uncertainty of several hundred metres,-but as the bottom of these lakes as a rule slopes evenly towards the glacier front with a slight inclination, this uncertainty only means that the maximum water level can be determined with a margin of uncertainty of $\pm$ ca. 10 metres.

In the cases observed the morphological conditions exclude the possibility of a drainage of the ice-dammed lakes across thresholds to other drainage basins. Similarly, the estimated course of the surface of the glaciers excludes a superficial run-off, for the surface always slopes towards the ice-dammed lake. There remain, then, the possibility of a sub- or englacial drainage. On the basis of the deposits present, it cannot be decided which of the two drainage forms was active.

In the above-mentioned mapped lakes, the following altitudinal differences between the uppermost terrace and the lowermost part of the corresponding glacier front have been registered:

Locality	Relative age	Altitudinal difference
Storelv I (Steenstrup Nunatak) ...	Tunugdliarfik stage..	ca. 140 m
– II	– ..	- 120 -
– III	– ..	- 130 -
Terrassesø	Narssarssuaq stage ..	150 -
Qôrqup kûa	– ..	140 -
Mellemlandet	– ..	130 -
Hullet I	– ..	150 -
– II	Maximum extension of ice in historic times .... ("Little Ice Age")	150 -
– III	1960	130 -

These agreements in altitudinal differences at the glacier fronts, 120–150 m, are remarkable. However, the altitudes given cannot be taken as a proof that all the lakes were drained by subglacial outbursts; they merely indicate the maximum water level at the glacier front. The inconsiderable variation in these heights found under very nearly the same morphological conditions seem to point to a uniformity of their drainage mechanism, which can be most adequately explained by accepting GLEN's theory of outbursts from ice-dammed lakes.

On the assumption of the validity of this hypothesis, it is remarkable that the outbursts of all the stages occur at about the same altitude. Since according to GLEN's investigations, the empirically determined limit of significant creep depends largely on the temperature of the ice (GLEN 1955), it is natural to assume that the same maximum water level during subglacial or englacial outbursts from the lakes indicates that during all the stages mentioned, the glacier ice had very nearly the same temperature.

In principle there seems to be a possibility of assessing the temperature of former glaciers by determining the maximum water level of associated major ice-dammed lakes. However, the phenomenon must be studied under other known temperature conditions before it can be confirmed that practical possibilities for such a determination exist. If a glacier front is in contact with an ice-dammed lake, the ice at the plane of contact will always be heated to 0°C. Hence, in the lower part of the glacier an initial flow will always take place, if the water level is above

150 m at the base of the glacier. The question is therefore merely whether the penetration of the water into colder ice which is first to be heated to 0° C, will inhibit the mechanism of the outbursts to such an extent that the water level at the ice-dammed lake will be measurably higher at tongues issuing from polar glaciers than at tongues from temperate glaciers.

However, the only proof of this can be supplied by investigations of the water level in many lakes along the ice front within the whole of Greenland, not only in a small area like the northern part of the Julianehåb district.

In spite of the frequent occurrence of these lakes at the ice front in West Greenland, information is only available from Ilulialik north of Sdr. Isortoq fjord, the Sukkertoppen district. This lake is 10–12 km long and 1–2 km broad. It is debarred from Sdr. Isortoq fjord by a large lobe issuing from the Sukkertoppen ice cap. The lake was described in detail in a lecture entitled "Ice-dammed lakes in Greenland", and delivered by Colonel J. Helk, at a meeting of the Dansk Geofysisk Forening on February 17th, 1955. Unfortunately the lecture has neither been published nor reviewed, but the most important data are laid down in the Geodetic Institute map sheet 1:250,000 of the area (map sheet 65V2). It will be seen from the map that the water level in 1936 was 370 m a.s.l., maximum 400 m, minimum 220 m a.s.l., that is to say, a difference of 180 m at the glacier front.

Other ice-dammed lakes in West Greenland formerly described are either ice marginal lakes of type 1), mentioned on p. 112, or lakes for which only the maximum water level, or only the outburst period, is known (thus E. v. Drygalski in the Umanak district 1897, Sigurd Hansen in the Godthåb district, 1932).

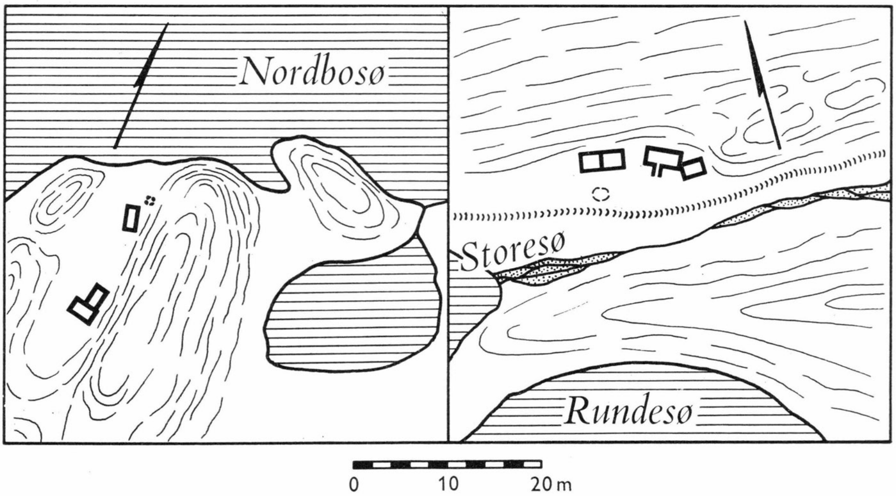

Fig. 36. Sketch map of groups of ruins north of Kiagtût sermia in the area around Hullet.

NEW HOUSE RUINS OBSERVED IN THE NARSSARSSUAQ REGION

During the mapping of the glacial deposits in the Narssarssuaq region, traces of former human activity were observed along the stretch between Nordbosø and Hullet. These findings are indicated on the maps in fig. 4 and fig. 36.

Of the four localities indicated on the maps, three are house ruins and one a stone ring. Whether the house ruins are of Eskimo or of Norse origin, the author is unable to decide, and the purpose of the ensuing summary description of the remains is merely to call attention to a possibility of elucidation of the age of the Narssarssuaq stage in these regions.

Two ruins and the stone ring are situated on the deposits of the Narssarssuaq stage. A later dating of the house ruins may therefore possibly indicate a minimum age of the Narssarssuaq stage in this place, similarly to the Norse ruins within the Narssarssuaq region, which clearly testify to an age of the Narssarssuaq stage greater than that of the Norse period, while at the same time the position of the Narssarssuaq moraines near the present sea-level show that they are younger than the post-glacial climatic optimum.

1. Nordbosø.

House ruins outside the moraines of the Tunugdliarfik stage. Between two rock ledges on the south side of this lake, the sites of three small houses and an open fire place were found. The small depression in which the ruins lie, opens only towards the north, looking towards Nordbogletscher. All the houses are situated close to the foot of the eastern steep side of the depression, probably to be sheltered against the easterly winds which are characteristic of the area.

The location of the houses and their approximate dimensions are shown on the sketch in fig. 36. The southernmost two sites are fairly well preserved, thus the lower parts of the brickwork (up to ca. $^1/_2$ m above the terrain) are still preserved, while the northern site is in a poor state of preservation. A large erect stone stood at the north end of this northern site. Further a stone circle, probably a fire place. occurred near the ruin. Occasional bone fragments were found among the stones of the ruins. All these bones were determined by Mr. U. Møhl, of the Zoological Museum, to be reindeer bones.

2. Storesø.

On the east side of this lake, near an outwash plain from the Narssarssuaq stage, the ruins of four houses, much larger than those at Nordbosø, were observed near the recent river delta in Storesø. The ruins are situated ca. 10 m above the river in a small depression between originally ice-scoured, now partially disintegrated rock ledges. Here, too, the site was obviously chosen with a view to being sheltered against the easterly winds.

The two easternmost houses are best preserved, remains of brickwork here rising to ca. half a metre above the terrain. The western house of the two not only exhibits a rectangular outline ca. 3×4 m, but also remnants of a small south-facing entrance (passage?). The westernmost two ruins are only recognisable as two rectangular depressions in the terrain. This group of ruins, like that at Nordbosø, is surrounded by a vegetation which by its intense green colour forms a sharp contrast to the surrounding dwarf shrub heath.

At these ruins, also, a circle of small stones, possibly a fire place, was found few metres south of the westernmost house.

3. Hullet.

On a large terrace developed during the Narssarssuaq stage, a group of highly overgrown blocks, arranged in two rectangles both ca. 2×4 m, were found in a cleft. These presumed house ruins are sheltered on the east side by a steep wall formed by large slide blocks from the terrace.

4. Balkonen.

On a kame terrace, formed in association with the Narssarssuaq stage II, a large ring of blocks is found. The diameter of the stone ring is ca. 2 m, it is made up of closely joined blocks, all of a diameter of ca. $^1/_2$ m. The locality is situated at an altitude of ca. 820 m. The blocks are densely covered with lichens, which must indicate an age of several hundreds of years. No larger stones are found in the proximity of the ring, so there seems to be no question of a ruin, and similarly the placing of the stones close to each other must indicate that we are not concerned with a tent ring either.

CONCLUSIONS

In the Narssarssuaq region treated here, two ice margins, each representing its particular stage, seem to be clearly distinguishable. The oldest, the Tunugdliarfik stage, was formed at a sea level 10–15 m above the present, and the youngest, the Narssarssuaq stage, was formed at a sea level like the present level of the sea. The deposits of the Narssarssuaq stage were formed prior to the Norse period, ruins of Norse farms being situated on the deposits of this stage between the localities Kiagtût and Narssarssuaq. It must be assumed, however, that the Narssarssuaq stage was deposited after the post-glacial climatic optimum, or possibly at the beginning of subatlantic times, when the change of the climate may be assumed to have exerted a considerable influence on the economy of the glaciers.

The Tunugdliarfik stage was presumably formed before the post-glacial heat optimum, and hence it should probably be referred to the Younger Dryas. This determination, however, is only based on the deposition of the features at a sea-level 10–15 m above the sea. It is not improbable that the inland ice even at this early time in the Holocene period had an extension not much exceeding its present extension. Thus, D. Laursen (1950, p. 133) states that his horizon A dates back to the Older Dryas, and (ibid. p. 99) that it was found at Orpigsôq in the Disko bugt, that is to say, in a locality situated less than 10 km from the recent ice front. Similarly, J. Iversen (1952/53, pp. 91–94) states that deposits from the boreal time have been found in the interior of Godthåbsfjord in a similar proximity to the Greenland inland ice.

The Tunugdliarfik stage can be traced to some extent, and the Narssarssuaq stage in a marked degree, along the whole recent ice front of the glaciers Kiagtût sermia and Qôrqup sermia in the Narssarssuaq region. It is possible, therefore, to indicate rather accurately the position of the ice front during the maximum extension of the ice at these stages, and it is likewise possible to trace the maximum extension of the ice along the trim line in historic times. Considering the maximum extension of the ice cover during the above-mentioned three stages, as compared with the altitudinal conditions of the present ice cover, we shall see that already during the Tunugdliarfik stage the firn area of the inland ice occurred at about the same altitude as at present, and that only the marginal zone below the present glaciation limit was subject to considerable fluctuations. This is what might be expected, as OROWAN (1949, pp. 234–236) for an ice cap in permanent equilibrium and situated on a level substratum, found: $^1/_2\,rgh^2 = YR$, where r is the specific gravity of the ice (0.9 g/cm/), g is the gravitational acceleration (981 cm/sec^2), h is the height of the ice cap, Y the yield stress in shear (10^6 dyn/cm^2), and R the radius, i.e. the distance from the centre of the ice cover to the ice margin. From this it will be seen that even large-scale alterations of the ice margin involves only small alterations of the altitudinal conditions of the ice cover. Although the substratum of the ice is highly broken, as is the case in the interior of the Julianehåb district, similar considerations must be applicable here.

However, the above-mentioned alterations in the extension and altitude of the ice cover from the Tunugdliarfik stage to the present day can only be ascertained around Qôrqup sermia and Kiagtût sermia. In a sector of the inland ice north thereof, from the Niviarsiat nunataks in the east to Eqalorutsit kangigdlît sermia in the west at Nordre Sermilik fjord, no substantial alterations in the extent of the margin of the inland ice seem to have taken place during this period, that is to say, a large part of Holocene times. This is inferred from the fact that the landscape immediately outside the ice margin in this sector is marked by the same intense disintegration which characterises the landscape outside the moraines of the Tunugdliarfik stage.

An attempt to arrive at a chronology of corresponding stages outside the Narssarssuaq region failed, in so far as it is impossible to trace certain shore line levels over great distances. It is not possible, therefore, to chronologise the other stages found in the Julianehåb district with those found in the Narssarssuaq region in an entirely reliable way. Ice front stages at the margin of the inland ice north of Bredefjord and at a local glaciation at Narssaq-Ilímaussaq are, however, all situated so near Narssarssuaq that a connection by means of shore lines must be possible. A corresponding argument must also apply to the locality Sdr. Igaliko south of the Narssarssuaq region.

Marginal deposits derived from local glaciations are frequently seen in the alpine-like southern part of the district. As mentioned above, there is no possibility of correlating these advances either locally or with the deposits of the Narssarssuaq region on the basis of their relations to marine levels. That the outer moraines at these local glaciations everywhere indicate a lowering of the glaciation limit of ca. 400 m in relation to the present level, might perhaps point to the possibility that they all belong to the same stage (Niaqornakasik stage). If so, the stage at Sermersôq was formed at a level some 38 to 24 m above the present level of the sea. Considering the position of the Niaqornakasik stage at a very high sea level, and its low glaciation limit, it is probable that a stage in the northern part of the district, at Bredefjord (Eqaluit iluat) and Narssaq-Ilímaussaq, belongs to the Niaqornakasik stage. From the close proximity of these localities to the Narssarssuaq region it is known that this stage must be older than the Tunugdliarfik stage.

Thus, the following table for ice front landscapes may be erected:

oldest:	Niaqornakasik stage	(age?)
	Tunugdliarfik stage	(age: Younger Dryas?)
	Narssarssuaq stage	(age: beginning of subatlantic time)
youngest:	Maximum extension of the glaciers in historic times (1750?, 1890–1900).	

Extension of the ice cover during the individual stages.

If we are to sum up below what is indicated by the individual stages about the extension of the ice cover within the district, we must to some extent disregard the Niaqornakasik stage. This is due to the fact that the ice front deposits from this stage are by preference associated with the local glaciations in the southern part of the district. Marginal moraines at Bredefjord and at Niaqornakasik and the ground moraine at Narssarssuaq, however, approximately mark the boundaries of an ice cap whose extent must be indicated by: the north side of Nordre Sermilik fjord, Eqaluit iluat, Tasiussaq, possibly the land spit at Igaliko between Igaliko and Tunugdliarfik fjord, an area west of Sdr. Igaliko, and, farthest south, at Unartoq Fjord: Niaqornakasik.

The Tunugdliarfik stage is best known from the Narssarssuaq region, where its moraines testify to a much wider extension than that of the present ice covering. Similar conditions can be recorded for the localities Sdr. Igaliko immediately south of the Narssarssuaq region and from the local glaciations Narssaq-Ilímaussaq and Niaqornakasik. In the sector Eqalorutsit kangigdlît sermia the extension of the ice cover, however, was less than, or probably like, that of the present ice cover. The area west of Eqalorutsit kangigdlît sermia (north of northern Sermilik) seems likewise to be stabilised, and the Niaqornakasik moraines at Eqaluit iluat show that the margin of the inland ice hardly stood more than ca. 7 km south of the present ice front.

The Narssarssuaq stage is well known from the Narssarssuaq region and is further known from a single locality at Kangerdluarssuk

Fjord north of Bredefjord. The stage is seen to have a distribution which in the Narssarssuaq region is much wider than that of the recent ice cover. In the sector Niviarsiat-Eqalorutsit kangigdlît sermia the extent of the ice was less than, or more probably equal to that of the present ice cover, like the Tunugdliarfik stage. The locality at Kangerdluarssuk shows that here, also, the stage must have had an extension almost equal to the maximum extension of the inland ice in historic times.

The Narssarssuaq stage is not known with certainty from the southern part of the district.

Maximum extension of the ice in historic times (the "Little Ice Age").

Trim lines and moraines here offer good possibilities for obtaining an intimate knowledge of the extension of this stage and the vegetation covering the deposits, as well as of the dating of its advances. This also applies to the southern part of the district, i. e. the marginal zone of the Julianehåb ice cap and the local glaciations. Two glacier advances, about ca. 1750 and 1890–1900, indicate their maximum extension in historic times. In accordance with the table of glacier fluctuations in Scandinavia published by AHLMANN (H. W: SON AHLMANN 1953, p. 38), it must be assumed that the glaciers in Greenland likewise began to advance about the year 1600, that they reached their maximum extension about 1750, and that in the period between ca. 1750 and 1900 they occupied a very advanced position. After the general glacier advance in 1890–1900, during which the glaciers again attained their maximum extension, a period of recession of almost all the glaciers in the Julianehåb district set in, irrespective of the type of the glacier.

The recession during the present century was least in the period between 1900 and 1920, and it must be assumed that the glaciers experienced minor advances during this period. The main recession set in between 1920 and 1940, after which year it took place at a decreasing rate or partially ceased.

As regards the order of magnitude of the recession, the trim line indicates that it was almost the same throughout the district irrespective of the glacier type (cf. also below, the notes on the fluctuations in the volume of the glaciers). The only exception is presented by the sector of the margin of the inland ice between Eqalorutsit kangigdlît sermia and Niviarsiat, where the glacier seems to be stationary and to have had a constant extent, which is indicated by the trim line to be the maximum extension in historic times. In the most recent years this sector of the inland ice has even been advancing.

Fluctuations in the volume of the glaciers.

Only within the Narssarssuaq region has it been possible, on the basis of the ice margin deposits, to get an idea of the volume of the ice cover during the Tunugdliarfik and the Narssarssuaq stages. The altitudinal conditions of these stages are shown in fig. 23 as a function of the altitude of the present glaciers. Although the contours given only apply to Narssarssuaq, it must be assumed that similar conditions prevailed all over the district with the exception of the sector of the margin of the inland ice between Eqalorutsit kangigdlît sermia and Niviarsiat. In this sector the altitudinal conditions of the inland ice would seem to have been fairly constant since the Tunugdliarfik stage.

It will appear from the contours shown that during the two stages the ice coverings (the inland ice and the Julianehåb ice cap) had approximately the same altitude as to-day, as mentioned on p. 122.

The investigations on the fluctuations of the volume of the ice cover in the period 1900–1950 are based on the altitude of the trim line. The result of the investigations is shown in fig. 23, where, as for the older stages, it is given as the amount of the shrinkage 1900–1950 in proportion to the altitude of the recent glacier surface above the sea. The course of the contour agrees with that found for the alpine glaciers by R. Finsterwalder, P. Kasser, and R. Haefeli (Haefeli 1956, p. 9), where the subsidence of the glacier surface increases strongly with the decreasing height of this latter. However, the subsidence of the glacier surface decreases much more rapidly with the height in the Julianehåb district than in the case of the alpine glaciers. This is in accordance with the determination of the ablation per unit area as a function of the altitude of the glacier surface, published by H. Ahlmann (Ahlmann 1948, p. 40). From this it will be seen to apply to a greater extent to the inland ice than to the three local glaciations: Freyagletscher (East Greenland), Fjortende Juli Glacier (Spitsbergen), and Hoffell Glacier (Iceland), that the ablation is largely restricted to the lower parts of the glaciers.

Another possibility which may explain the rapid disappearance of the trim line at the recent snow-line in the Julianehåb district is an initial increase in size of the marginal area of the inland ice near the firn. This problem, however, can only be settled by careful investigations. The occurrence of push moraines in several localities in the Narssarssuaq region likewise seem to support this explanation.

Outburst from ice-dammed lakes.

During the mapping of the Narssarssuaq region, traces of several ice-dammed lakes whose drainage must have been either subglacial or englacial, were found in association with the ice-margin deposits. All these lakes seem to have had a maximum depth of water at the glacier front of 120–150 m. This water level must indicate the height of the maximum water column at the glacier front when the outbursts set in. Observations of these heights of the water level agree with the theory of outbursts of ice-dammed lakes put forward by J. W. GLEN (1954). The water in the ice-dammed lake should itself be able to make its way through the glacier ice at the bottom of the lake when the height of the water produces a horizontal stress component of 2 bar at the lower part of the glacier. This will take place at a maximum water column at the glacier front of 150–200 m. It will be seen that the values found at ice-dammed lakes in the Narssarssuaq region are of the same order of magnitude.

INDEX OF LOCALITIES

BIBLIOGRAPHY

AHLMANN, H. W: son: Glaciological Research on the North Atlantic Coasts. The Royal Geographical Society, London, 1948.

— Glacier Variations and Climatic Fluctuations. Bowmann Memorial Lectures, Series 3, The American Geographical Society, New York, 1953.

ARCTANDER, AARON: Udskrivt af en Dagbog, holden i Grønland af AARON ARCTANDER paa en Reckognoscerings-Reise i Julianæhaabs District i Aarene 1777 –1779. Edited by H. P. EGGERS in the periodical "Samleren" 1793. Edited by H. OSTERMANN in "Norges Svalbard- og Ishavsundersøkelser", Medd. No. 58, 1944.

BAUER, A. and HOLTZSCHERER, J.-J.: Contribution á la Connaissance de l'Indlandsis du Groenland. Expeditions Polaires Françaises 1954.

BESCHEL, R.: Ricerche lichenometriche sulle Morene del Gruppo del Gran Paradiso. Nuovo Giornale Botanico Italiano, n.s. vol. LXV, No. 3, pagg. 538–591. 1958.

BISHOP, B. C.: Shear Moraines in the Thule Area, Northwest Greenland. SIPRE Research Report 17, 1957.

BIRKET-SMITH, K.: Physiography of West Greenland, in "Greenland", Vol. 1. Copenhagen 1928.

— , MENTZE, E. and FRIIS MØLLER, M.: "Grønlandsbogen". J. H. Schultz, 1950.

— , MENTZE, E. and FRIIS MØLLER, M.: Grenlandija. Russian edition of "Grønlandsbogen" by G. A. Agranat, Moskva, 1953.

BRUN, ESKE: Grønlands Administration i Adskillelsens Aar. Det grønlandske Selskabs Aarsskrift 1946. København, 1946.

BRYAN, M.: Interglacial Pollen Spectra from Greenland, in: "Studies in vegetational History" in honour of KNUD JESSEN, 29th nov. 1954. Danmarks Geologiske Undersøgelse. II. Række Nr. 80, pp. 65–72. 1954.

BØGVAD, R.: Quaternary geological Observations etc. in South-East and South Greenland. Meddelelser om Grønland, vol. 107, 1940.

BÖCHER, T. W.: Area-limits and Isolations of Plants in Relation to the Physiography of the Southern Parts of Greenland. Meddelelser om Grønland, vol. 124, 8, 1956.

CHARLESWORTH, J. K.: The Quaternary Era, with special Reference to its Glaciation. Vol. 1–2. E. Arnold publ., 1957.

CLEAVES, A. and SCHULTZ, J.: Geology in Engineering, 1955.

CORNISH, V.: On Sea Beaches and Sand Banks. The Geographical Journal, vol. XI, 1898.

"Den Grønlandske Lods". Ed. by E. RIIS-CARSTENSEN, Søkortarkivet, København, 1948.

DRYGALSKI, E. v.: Grönland-Expedition der Gesellschaft für Erdkunde zu Berlin 1891–1893. Erster Band. Berlin, 1897.

FABRICIUS, O.: Om Driv-Iisen i de Nordlige Vande og fornemmelig i Davids-Strædet. Nye Samling af det Kongelige Danske Videnskabers Selskabs Skrivter, Tredie

Deel, Kiøbenhavn 1788, pp. 65–84. Translations in English in "The Geographical Review", vol. 45, No. 3, 1955 (ed. H. DILLON) and in German in "Polarforschung", Band IV, Jahrgang 28, 1958, Heft 1/2, 1958 (ed. J. Georgi).

FINSTERWALDER, R.: Die zahlenmässige Erfassung des Gletscherrückgangs an Ostalpengletschern seit 1850. Zeitschrift für Gletscherkunde und Glazialgeologie. Bd. II, H. 2, 1953.

FLINT, R. F.: Glacial Geology and the Pleistocene Epoch. Wiley, 1947.

FROST, R. E.: A Reconnaissance for a Southern Greenland Ice-Cap Access for Military Purposes. SIPRE Technical Report 46, 1957.

GLEN, J. W.: Rate of Flow of Polycrystalline Ice. Nature, October 17, 1953, pp. 721–722.

— The Stability of ice-dammed Lakes and other water-filled Holes in Glaciers. The Journal of Glaciology vol. 2, No. 15, April 1954, pp. 316–318.

— The Creep of Polycrystalline Ice. Proceedings of the Royal Society A. Volume 228, pp. 519–538, 1955.

— The mechanical Properties of Ice. Philosophical Magazine Supplement. Vol. 7, No. 26, pp. 254–265. April 1958.

GRIPP, K.: Einige besondere Fossilen in Geschieben aus dem Inlandeis Grönlands. Meddelelser om Grønland, vol. 91, 1932.

HAEFELI, R.: Gletscherschwankung und Gletscherbewegung. Schweitzer. Bauzeitung. 73/74 Jahrgang. 1955/56, pp. 1–16.

HANSEN, SIGURD: Nyere Opfattelser af Bevægelsesmekanikken for Gletscheris belyste ved egne Iagttagelser på Frederikshaab Isblink i Grønland. Naturens Verden. 16. Aargang 1932, pp. 357–376.

HOLMSEN, A.: En isdemt Sjö i Norge i Nutiden. Norsk Geografisk Tidsskrift, Bd. 6, Ht. 8, 1937, pp. 425–449.

HORSTED, SV. AA. and SMIDT, E.: The Deep Sea Prawn (Pandalus borealis Kr.) in Greenland Waters. Meddelelser fra Danmarks Fiskeri- og Havundersøgelser. Ny Serie, Bd. 1, 1956.

IVERSEN, JOHS.: Origin of the Flora of Western Greenland in the Light of Pollen Analysis. Oikos 4:2, 1952–1953, pp. 85–103.

JENSEN, J. A. D.: Beretning om en Undersøgelse af Grønlands Vestkyst fra 66°55′ –68°30′. Meddelelser om Grønland, vol. 2, 5, 1881.

JESPERSEN, E.: Nyopdagede Nordboruiner i Julianehaab Distrikt 1911. Meddelelser om Grønland, vol. 50, 2, 1912.

JESSEN A. and MOLTKE, C.: Undersøgelser af Nordre-Sermilik Bræ. Meddelelser om Grønland, vol. 16, 1896.

JESSEN, A.: Geologiske Iagttagelser. Julianehaab Distrikt. Meddelelser om Grønland, vol. 16, 1896.

KASSER, P.: Ablation und Schwund am grossen Aletschgletscher. Verhandlungen der S.N.G., Lugano, 1953. V.A.W.E. Mitteil. No. 30.

KERR, F. A.: The Ice Dam and Floods of the Talsekwe, British Colombia. Geographical Review. Vol. 24, No. 4, 1934, pp. 643–645.

KLEBELSBERG, R. v.: Handbuch der Gletscherkunde und Glazialgeologie, Wien, Springer Verlag, 1948.

KOCH, LAUGE: Contributions to the Glaciology of North Greenland. Meddelelser om Grønland, vol. 65, 1928.

KORNERUP, A. and STEENSTRUP, K. J. V.: Beretning om Ekspeditionen til Julianehaabs Distrikt i 1876. Meddelelser om Grønland, vol. 2, 1, 1881.

LAURSEN, D.: Contributions to the Quaternary Geology of Northern West Greenland. Especially the raised marine Deposits. Meddelelser om Grønland, vol. 135, 8, 1944.

LAURSEN, D.: The Stratigraphy of the marine Quaternary Deposits in West Greenland. Meddelelser om Grønland, vol. 151,1, 1950.

LAURSEN, D., HARDER, P. and JENSEN, AD. S.: The marine Quarternary Sediments in Disko Bugt. Meddelelser om Grønland, vol. 149, 1, 1949.

LEIGHTY, ROBERT D. and POULIN, AMBROSE, O.: Ice-Cap Access Route, Narssarssuaq, Greenland. Location and Engineering Evaluation. SIPRE Technical Report, No. 48, 1960.

LIESTÖL, O.: Glacier-dammed Lakes in Norway. Norsk Geografisk Tidsskrift, vol. 15, 1955–56, pp. 122–149.

LJUNGNER, E.: Spaltentektonik und Morphologie der Schwedischen Skagerakküste. Bulletin Geolog. Institut. Uppsala. Vol. 21, pp. 1–478, 1930.

MARCUS, M. G.: Periodic Drainage of glacier-dammed Tulsequah Lake. British Colombia. The Geographical Review, vol. 50, No. 1, 1960, pp. 89–106.

MILTHERS, V.: Det danske Istidslandskabs Terrænformer og deres Opstaaen. Danmarks Geologiske Undersøgelser, II. Række, Nr. 28, 1948.

MOTT, P. G.: The Oxford University Greenland Expedition. West Greenland 1936. The Geographical Journal Oct. 1937. Vol. XC, No. 4, pp. 315–334.

NANSEN, F.: The Earth's Crust, its Surface-Forms and Isostatic Adjustment. Norsk. Vidensk. Akad. Mat.-Naturvid. Kl. 12, Oslo, 1928.

NYE, J. F.: A Method of Calculating the Thickness of the Ice-Sheets. Nature. March 29, 1952, pp. 529–530.

— The Flow Law of Ice from Measurements in Glacier Tunnels, Laboratory Experiments and the Jungfraufirn Borehole Experiment. Proceedings of the Royal Society of London. Series A, vol. 219, No. 1139, 1953, pp. 477–489.

OROWAN, E.: In: "Joint-Meeting of the British Glaciological Society, British Rheologists' Club and the Institute of Metals." The Journal of Glaciology. Vol. 1, pp. 233–237. March 1949.

ORVIG, SV.: The glaciological Studies of the Baffin Island Expedition. Part 5. On the Variation of the Shear Stress on the Bed of an Ice Cap. The Journal of Glaciology. Vol. 2, No. 14, 1953.

RINK, H.: Grønland, geographisk og statistisk beskrevet, vols. I–II, 1857.

— Om Vandets Afløb fra det Indre af Grønland ved Kilder under Isen. Naturhistorisk Tidsskrift, 3. Række, vol. 1, 1862.

ROSENDAHL, H.: Rembesdalskåki og Demmevatn på Hardangerjøkulen. Naturen, vol. 62, heft. 1, 1938, pp. 1–19.

SCHOU, A.: Det marine Forland. København, 1945.

STEENSTRUP, K. J. V.: Bemærkninger til et geognostisk Oversigtskaart over en Del af Julianehaabs Distrikt. Meddelelser om Grønland, vol. 2, 2, 1881.

— Kan Tangranden benyttes til Bestemmelse af Forandringer i Vandstanden? Et Foredrag holdt i det Kongelige Danske Videnskabernes Selskabs Møde den 24. Marts 1905. Meddelelser om Grønland, vol. 33, 1907.

— Geologiske og antikvariske Iagttagelser i Julianehaabs Distrikt. Meddelelser om Grønland, vol. 34, 1909.

STEINEMANN, S.: Results of Preliminary Experiments on the Plasticity of Ice Crystals. The Journal of Glaciology, pp. 404–412. Vol. 2, No. 16, 1954.

— Thermodynamics and Mechanics of Ice at the Melting Point. Union Géodésique et Géophysique Internationale. Symposium de Chamonix 16.–24. Sept. 1958, pp. 254–265.

— Experimentelle Untersuchungen zur Plastizität von Eis. Beiträge zur Geologie der Schweitz. Geotechnische Serie. Hydrologie, No. 10, 1958.

STRØM, K.: The catastrophic Emptying of a glacier-dammed Lake in Norway 1937. Geologie der Meere und Binnengewässer. Bd. 2. Ht. 3, 1938, pp. 443–444.

SVENSSON, H.: Glaciation och Morfologi. Meddelanden från Lunds Universitets Geografiska Institution. Avhandling XXXVI, 1959.

TANNER, V.: New Foundland-Labrador. Part I, The Land, its Structure and Surface Forms. Changes of Level in Labrador in late-Quaternary Time. Acta Geographica 8, No. 1. Societas Geographica Fenniae 1944, pp. 223–253.

THORARINSSON, S.: Oscillations of the Iceland Glaciers in the last 250 Years. Geografiska annaler. Vol. 25, 1943.

— Some new Aspects of the Grímsvötn Problem. The Journal of Glaciology vol. 2, No. 14, 1953, pp. 267–274.

USSING, N.V.: Geology of the Country around Julianehaab. Meddelelser om Grønland, vol. 38, 1912.

WEGMANN, C. E.: Geological Investigations in Southern Greenland. Meddelelser om Grønland, vol. 113, 2, 1938.

WEIDICK, A.: Glacial Variations in West Greenland in historical Time. Meddelelser om Grønland, vol. 158, 4, 1959.

VICTOR, P.-E.: Wringing Secrets from Greenland's Icecap. The National Geographic Magazine. Jan. 1956. Vol. CIX, No. 1, pp. 121–147.

ØDUM, H.: Geologiske Iagttagelser i Landet Øst for Igaliko Fjord. Meddelelser om Grønland, vol. 74, 4, 1927.

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Plate 1.

Julianehåb district. Depths, preglacial morphology, and ice margin deposits. Ocean depths drawn on the basis of the US. Navy Hydrographic Office map No. 5610, Kap Farvel to Sermersok, scale 1:250.000. Fjord depths based on map sheets of the Danish Hydrographic Office and on soundings in the fjords as given by S. Aa. Horsted and E. Smidt (1956).


LEGEND
Landscape, dominated by the Strandflat.
Landscape, dominated by the lower plateau.
Landscape, dominated by the upper plateau.
Concretions of Pleistocene age.
Direction of glacier movement observed by the author.
Direction of " " compiled from other sources.
Pre-historic holocene marginal stages of the ice lobes.
Areas, ice-covered in recent historic time.
Boundary between the Inland Ice proper and the Julianehåb Ice-Cap.
Ice margin, advancing in 1955–1960.
0 10 20 30 km
Countour intervals on the Inland-ice and the Julianehåb ice-cap at 200 m.
SEA DEPTHS:
0-100 Fathoms
100-200
200-300
Under 300
47°30' 47° 46°30' 46° 45°30' 45° 44°30' 44°
61° 30'
61°
60° 30'
60°
Niviarsiat
Ulunguarssuaq
Narssarssuaq
Igdlerfigssalik
Ilimaussaq
Igaliko
Sdr. Igaliko
Manîtsoq
NARSSAQ
BREDEFJORD
TUNUGDLIARFIK
Qaqortoq
JULIANEHÅB
IGALIKO FJORD
KANGERDLUA
Ipatit
Maggat
Qôrormiut
Niaqornarssuk
Ûnartoq
Sydprøven
Kânajormiut
Angmalortoq
Quagssugaussat
Niaqornaq
Kûkasik
Niaqornakasik
Anitdlua
Igpigssuaq
NANORTALIK
SERMILIK
TASERMIUT
ILUA
Lindenows Fjord
Sermeq
Sermitsiaq
Sulugssugut
FREDERIKSDAL
Ikigait
Kap Farvel
Eqalorutsit kitdlît sermiat
Sermilik
Torssukâtak
Qagssiarssuk
Kujatdleq
Qôroq
1600 1400 1200 1000 800 600 1800 2000

Plate 2.

The Narssarssuaq region. Topographic map, drawn on the basis of air photographs taken by the Geodetic Institute and the Greenland Geological Survey. The western areas were drawn on the basis of the maps published by the Geodetic Institute (i.e. the areas immediately around Tunugdliarfik and Qôroq fjords), the eastern areas on the basis of the skeleton maps, scale 1:100.000, of the Geodetic Institute.


JOHAN DAHL LAND
JOMFRULANDET
Niviarsiat
Kiagtût sermia
Qôrqup sermia
MELLEMLAND
NARSSARSSUAQ
QAGSSIARSSUK
Kiagtût
Kiagtût kujatâ
Sermip nunakurdlagta
Akuliarûseq
Augpalugtût iterdla
Sûluarqap qâqâ
TUNUGDLIARFIK
QÔROQ
AKULIARUSEQ
Iynârâ
Qôrorssuatsiaq
Qôrqup qâqai
Perqigsût
Igdlerfik
Niaqornârssuk
Narssârssuk
Igánarssuánguaq
Igdlerfigssalik
Agdlerulik
Qôrorssuaq
Motzfeldt Sø
ca. 100 m
K. J. V. STEENSTRUP
NUNATAQ
G. HOLM NUNATAQ
Geologfjeld
Syenitknold
Nordtop
Sydtop
Nordtunge
Sydtunge
Tasingortartoq
Terrassesø
Storelv
Iviangeqútit tasiat
Nordbosø
Nordgletscher
Hullet
Østgletscher
Sydgletscher
Annekssø
Qordlortoq
Qôrnup kûa
Qôrqup kûa
Inungûarssuaq
Trekantgletscher
Rødesø
Deltasø
1134
1262
1230
700
805
1600
650
1250
1000
580
950
1390
940
1140
1580
1230
1803
867
886
1525
1700
1336
1600
1570
1693
61°10'
45°15'
Contour interval ca. 100 m
1 0 5 10 km

Plate 3.

The Narssarssuaq region. Geomorphological map. Ice margin deposits and raised shore lines.

GRØNLANDS GEOLOGISKE UNDERSØGELSE
THE GEOLOGICAL SURVEY OF GREENLAND

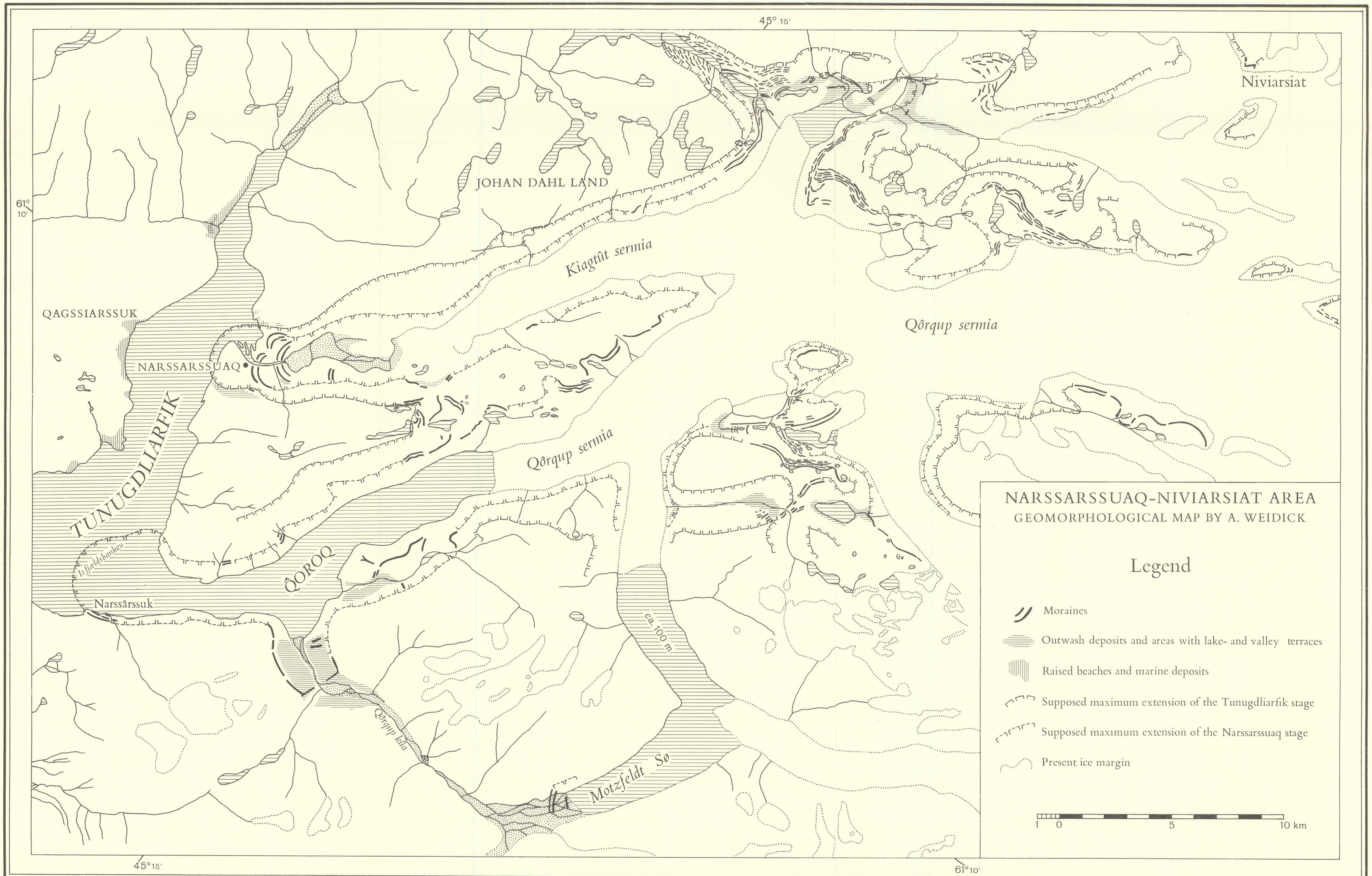

Plate 4.

Qôrqup kûa. Aerial photograph, with profiles measured in the field. Inserted: Air photo 201 G, No. 12915, 2/9 1953. Copyright: Geodetic Institute, Copenhagen.


Qôrqup kûa
C
K
D
E
I
H
A
Igdlerfigssalik
B
F2
G1
G
Agdlerulik