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Holocene shore-lines and glacial stages in Greenland – an attempt at correlation

by

Anker Weidick

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GRØNLANDS GEOLOGISKE UNDERSØGELSE
RAPPORT Nr. 41

HOLOCENE SHORE-LINES AND GLACIAL STAGES IN GREENLAND — AN ATTEMPT AT CORRELATION

by
Anker Weidick

1972

Abstract

Post-Wisconsinian uplift of West, North and East Greenland has been estimated on the basis of information in current literature and compared to the data collected by the author in central West Greenland. For West and North Greenland the dated uplift allows an estimate to be made of the age of former shore-lines, which in turn have been used to date the stages of the extent of the Inland Ice. The results have been compared with published information on the age of glacial stages in East Greenland.

The estimated ages of the ice margin stages imply a history of deglaciation in West (and North?) Greenland comparable to that of North America. In both areas the major deglaciation took place after the Younger Dryas and a marked halt took place in Boreal times. It is possible that the history of East Greenland is more closely related to that of Scandinavia where a widespread deglaciation took place prior to the Younger Dryas.

The deglaciation of North Greenland was interrupted by a marked readvance or readvances during the climatic optimum. It is possible that the northward shift of the low pressure centres during this period led to an increased accumulation on the northern part of the Inland Ice.

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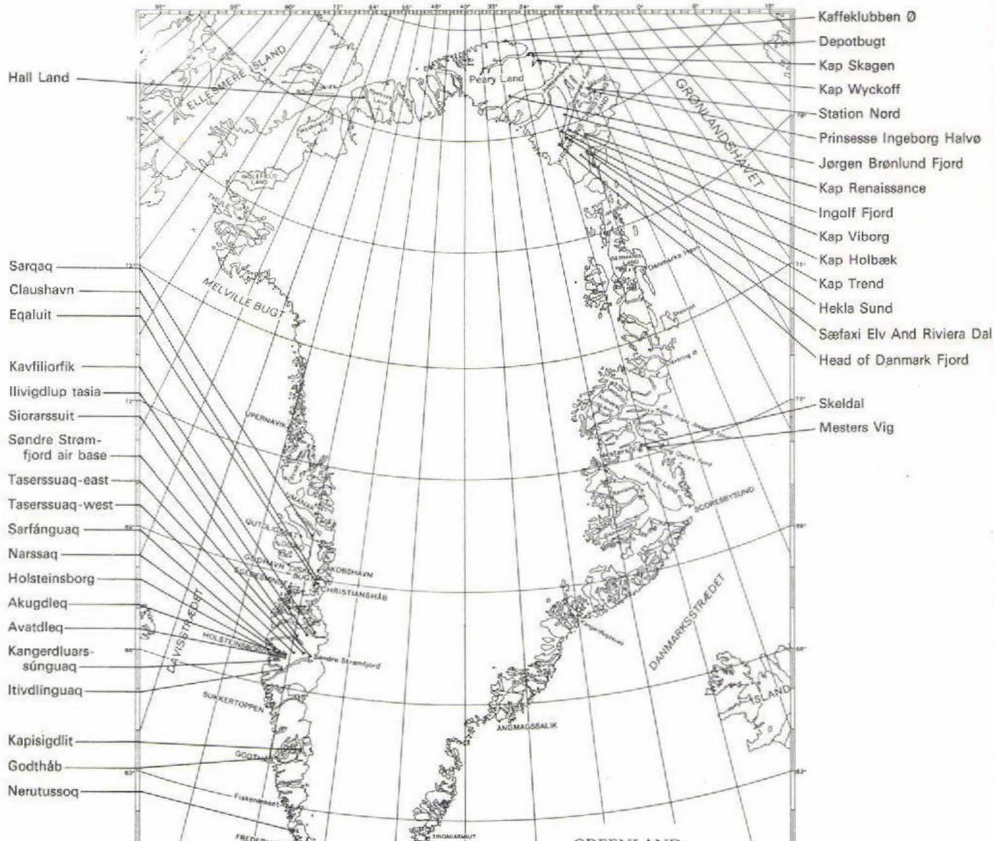


Fig. 1. Localities given in the appendices 1 to 9.

INTRODUCTION

Throughout the last century extensive work was undertaken in order to locate and investigate marine deposits in Greenland (Rink, 1853; Jensen, 1917; Koch, 1928; Bretz, 1935; Bøgvad, 1940; Laursen, 1950, 1954) and a reasonable amount of data exists concerning the nature of marine deposits and their faunas in relation to the heights of former shore-lines. A relative chronology based essentially on the fauna of the marine deposits was given by Laursen (1950), who also made the first correlations of altitudes of West Greenland shore-lines with those of North Greenland (Laursen 1944).

In an interesting attempt to date sea levels Vogt (1933) constructed isobases over the coastal areas of the southern parts of West and East Greenland from the published information on terrace and other shore-line levels. On this basis he found a pronounced '*Tapes* level' rising from approximately 25 m a.s.l. at the outer coast to approximately 40 m inland. The name refers to his correlation with a pronounced marine level in Norway, the maximum age of which was given later as 7800-7900 years B.P. (Andersen 1965).

In contrast to the above mentioned work made on marine deposits, little attention was paid in earlier years to the mapping of deposits from former ice margins. The first observations of this nature were made by Koch (1928) in North Greenland and these have been supplemented by Troelsen (1952), Davies (1963) and Krinsley (1961). Subsequent investigations in West Greenland have revealed the same occurrence of ice margin deposits indicative of certain halts in the Inland Ice recession throughout most of the coastal area between Disko Bugt and Julianehåb district (Weidick, 1963, 1968). The features are especially well-developed in the Holsteinsborg-Sukkertoppen districts and in the southern parts of Egedesminde district.

In East Greenland (Scoresby Sund and Mesters Vig area), moraine features were investigated by Sugden & John (1965) and Lasca (1969), and a few other ice margin deposits were mapped from aerial photographs and plotted on the Quaternary Map of Greenland 1:2 500 000 by Weidick (1971). More recent and detailed mapping in this region by Funder (1970, 1971) from the central and inner parts of Scoresby Sund, has revealed the possibilities of defining several phases in the deglaciation of East Greenland.

A prerequisite in determining the age of ice margin deposits must be the dating of former sea levels by related marine deposits. The main work of the author has been concentrated in certain areas in West Greenland with a special emphasis on the Holsteinsborg district, from where he has obtained shell samples, which have been dated by H. Tauber of the Carbon-14 Dating Laboratory of the National Museum and Geological Survey of Denmark, Copenhagen. In order to obtain a check on the deduced uplift of West Greenland, the results from here have been compared to published information from other parts of Greenland. Finally, the results have been used in the correlation of glacial events in determining the extent of the Inland Ice.

DATED MARINE LEVELS

The bulk of information on the age of marine deposits in West Greenland is based on shell radiocarbon dates. This information is supplemented by dates of sea levels derived from radiocarbon dates of gyttja on top of marine sediments (Kelly *in* Tauber, 1968; Fredskild, 1967) or based on evidence from pollen sequences (Iversen, 1953).

Most East Greenland samples have been treated in detail in the relevant papers (Washburn & Stuiver, 1962; Washburn, 1965; Lasca, 1969; Fredskild, 1969). In the following list, p. 29-36, therefore, these as well as other published dates, for comparison outside Holsteinsborg district, are not accompanied by any comments other than the type and reference.

In order to standardise the information, the following have been included in the tables of age determinations related to former shore-lines:

1) Laboratory code letter and number, and 2) measured radiocarbon date. The different laboratory numbers may indicate small differences in ages, which are not taken into consideration here. For shell dates in North Greenland, the ages in brackets are the original values corrected for an apparent age of 1200 years (see below, p. 10-11).

3) Field altitude, which is obtained on different bases at different localities. Town maps published by the Greenland Technical Organization (Ministry for Greenland) of Godthåb and Holsteinsborg, are available in the scale of 1:2 000 with contour intervals of 2 m, and the altitudes of the deposits can be obtained here very accurately. At other localities in West Greenland the altitude is determined by altimeter or hand level and is within an estimated error of ± 3 to ± 5 m in the coastal areas where a tidal range of 3-4 m makes short-time, level determinations difficult. In the inland areas, long distance levelling increases the difficulty of obtaining exact altitudes of marine deposits and it is therefore realistic in remote parts of the inland to estimate an error of ± 10 m.

4) Field altitudes corrected for eustatic rise of sea level. The correction is the same as that used by Washburn & Stuiver (1962) – 9 m per millennium prior to 6000 years B.P. Height values cited from other sources are given as rounded means where the original information gave height interval. For these, as for most West Greenland data, the error involved is not more than ± 5 m.

5) Locality and description or reference.

ISOSTATIC RECOVERY

On the assumption that the uplift of a single locality follows a simple relaxation curve, such as given for example from Canada and compared with the Mesters Vig uplift in Greenland by Andrews (1966), a semi-logarithmic plot of measured ages against the corrected field altitudes must give a rectilinear function if the ages have a connection to their related altitudes. The semi-logarithmic plot of the data for localities in West Greenland is shown in fig. 2 and for East and North Greenland in fig. 3.

In general, the curves of fig. 2 and 3 must represent a minimum sea level for the related ages. The reason for this is that the dated shells are believed to originate from shore-line facies and, at least for terraces this must imply that the shells still lived at a certain depth of water.

The shell species do not furnish much information on depth because the majority are found from the shore down to several hundred metres' depth. A check has been carried out for the localities of Holsteinsborg and Taserssuaq in central West Greenland by dating shells of *Balanus balanus* attached to boulders, and bivalves in the same deposits. *Balanus balanus* mostly lives only down to depths of 10 m and should therefore be better suited for the dating of former sea levels than bivalves. However, as seen from the dates, no great difference has been encountered from different shells in the same locality.

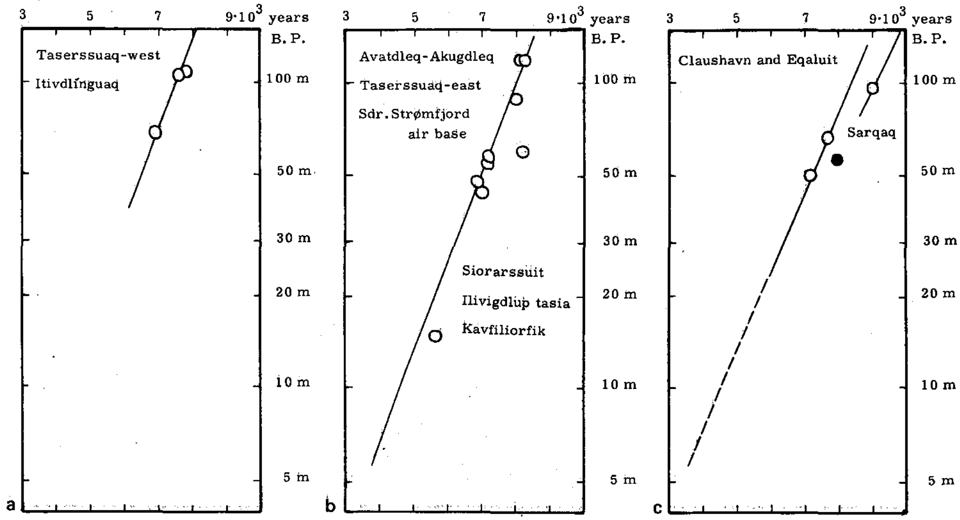
A few of the shell samples are seen to occur deep below related shore-lines. At least the shells from Holsteinsborg dated as K-1034 and K-1377 must belong to submarine shell banks.

Theoretically, gyttja overlying marine silt should be a better dating subject, giving a marked facies limit. The published examples, however, furnish no better relationship to an uplift curve than do those of shells.

For drift-wood, redeposition by wave action or human activity cannot be excluded, the more so because most drift-wood samples are from the last 4000 years, i.e. the time of human habitation in Greenland. Nevertheless, many drift-wood dates fit fairly well into a general uplift trend and they have been used in Peary Land as a control to the dating of the uplift by other means (see below).

Drift-wood and shells in beach ridges on an exposed coast must represent maximum altitudes of former shore-lines, being deposited mainly during severe storms. Examples of this are the two shell dates of K-1035 and K-1376 (from 20 m and 24 m respectively) from Holsteinsborg. They are both taken from beach ridges in narrow creeks which at the time of deposition were unprotected from the surf. In this area a control of the two dates is the age of a delta 10-15 m a.s.l. only 15 km further east (Narssaq in Amerdloq) which was formed between 6030 and 4930 years B.P. (K-1562 and K-1563).

Like storm-beach ridges, the dating of former sea levels by charcoal in archaeo-



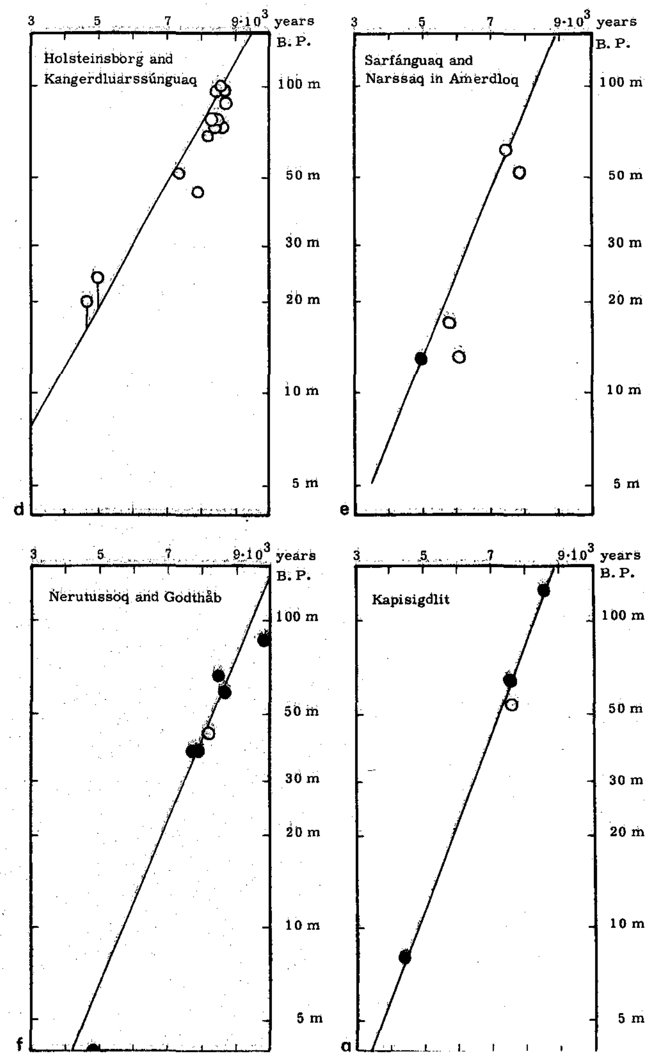


Fig. 2. Corrected sample altitudes plotted against related ages.
West Greenland.
○ shell dates.
● other dates.

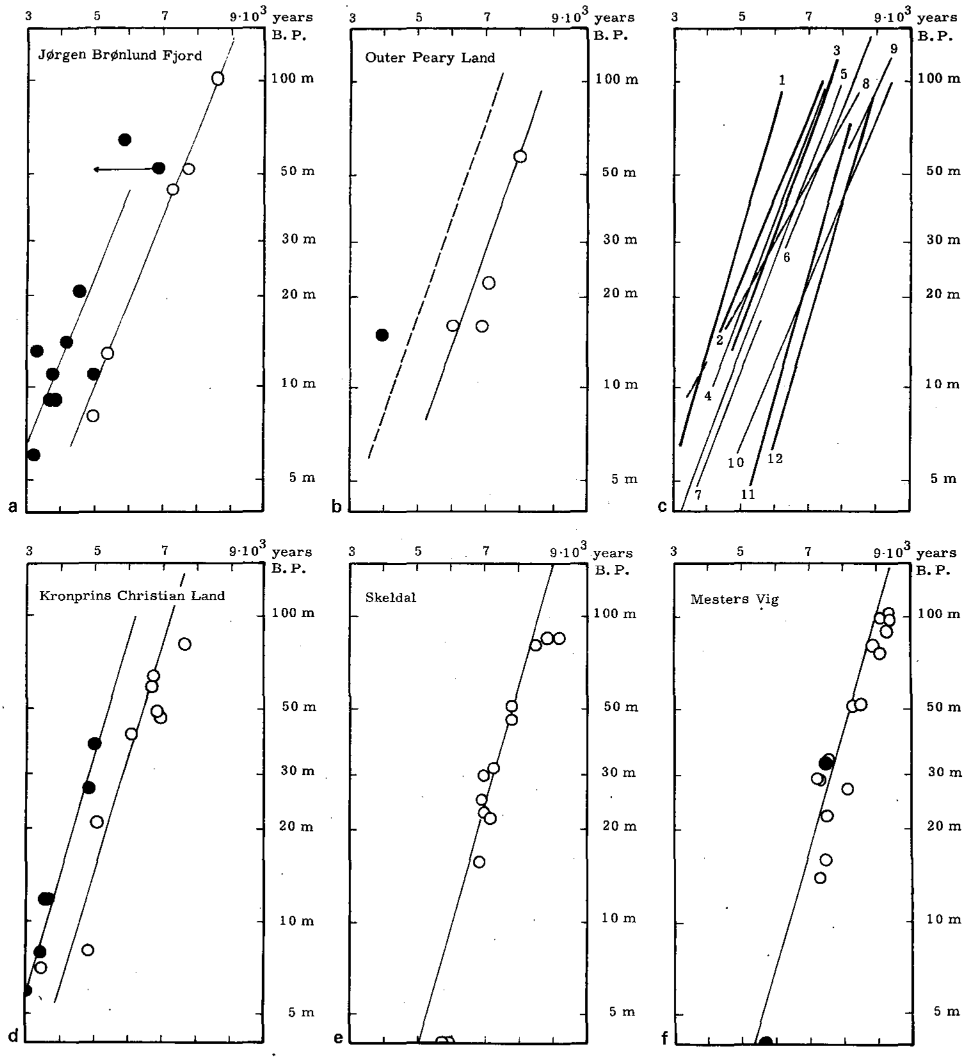


Fig. 3. Corrected sample altitudes plotted against related ages for East Greenland and eastern North Greenland. ○ shell dates. ● other dates. Fig. 3 c shows a comparison of the curves of East Greenland and eastern North Greenland with those of West Greenland shown in fig. 2. The numerals indicate:

North Greenland:

1. Kronprins Christian Land (corrected shell dates and other dates).
2. Jørgen Brønlund Fjord (corrected shell dates and other dates).
3. Outer Peary Land (corrected shell dates).

West Greenland:

4. Taserssuaq-west and Itivdlínguaq, Holsteinsborg district.
5. Avatdleq-Akugdleq, Taserssuaq-east, Søndre Strømfjord air base. Siorarssuit, Ilivigdlup tasia and Kavfiliorfik, Holsteinsborg and Egedesminde districts.

Continued at bottom of next page

logical sites may also furnish data, giving a position above an uplift curve. The method implies that the original dwellings were always situated close to the contemporaneous coast and that a continuous uplift took place during the time of habitation. The method has been used in Peary Land, North Greenland, by Knuth (1963, 1964, 1967). Knuth stated that while the oldest Independence I cultural sites (age: 4070-3730 years B.P.) are confined to levels of 10 m a.s.l. the younger Independence II cultural sites (age: around 2600 years B.P.) seem to be contemporaneous with a sea level 4 m above the present one.

Fredskild (1969) has used the same method using dates from charcoal collected from archaeological sites and drift-wood as a control on the date of the uplift of the lower levels in Jørgen Brønlund Fjord obtained from calcareous gyttja on marine silt. For a sea level of 45 m Fredskild concluded that the age of calcareous gyttja should be corrected to 1900 years (K-868).

For North Greenland localities the wide occurrence of Palaeozoic calcareous deposits may be a serious source of error in the age dating, especially of shells. In fig. 3 a comparison of shell dates with dates from other materials (charcoal and drift-wood) has been made for the inner parts of Kronprins Christian Land and Jørgen Brønlund Fjord. At both localities the plots show a systematic error of around 1200 years between the dates from shells compared with dates from other material. Therefore, a correction of an apparent age of 1200 years has also been applied to the shell dates of outer Peary Land when they are used to determine the uplift of this area as shown in figs. 4 and 5. However, the possibilities of a control on dates with this type of error are very limited for outer Peary Land. Three dates on drift-wood collected by P. Dawes in the central parts of Frederick E. Hyde Fjord indicate an uplift pattern very like that of Jørgen Brønlund Fjord (appendix 6 b).

If the origin of the errors in shell dates from North Greenland is due to the calcareous environment, the published age determinations from Hall Land (W-815 and W-816), as well as those for the western continuation of the belt of Palaeozoic sediments over the Canadian archipelago, will have to be corrected. In the references given here, the North Greenland dates from Hall Land are not corrected because of lack of control by other dates nor are those from Kaffeklubben Ø corrected because they are situated within the metamorphic crystalline part of the North Greenland fold belt as given by Dawes (1971).

Text to fig. 3 cont.

6. Sarfánguaq and Narssaq, Holsteinsborg district, and Claushavn and Eqaluit, Disko Bugt.
7. Kapisigdlit, Godthåb district.
8. Holsteinsborg and Kangerdluarssúnguaq, Holsteinsborg district.
9. Sarqaq, Disko Bugt.
10. Nerutussoq, Frederikshåb district, and Godthåb town, Godthåb district.

East Greenland:

11. Skeldal.
12. Mesters Vig.

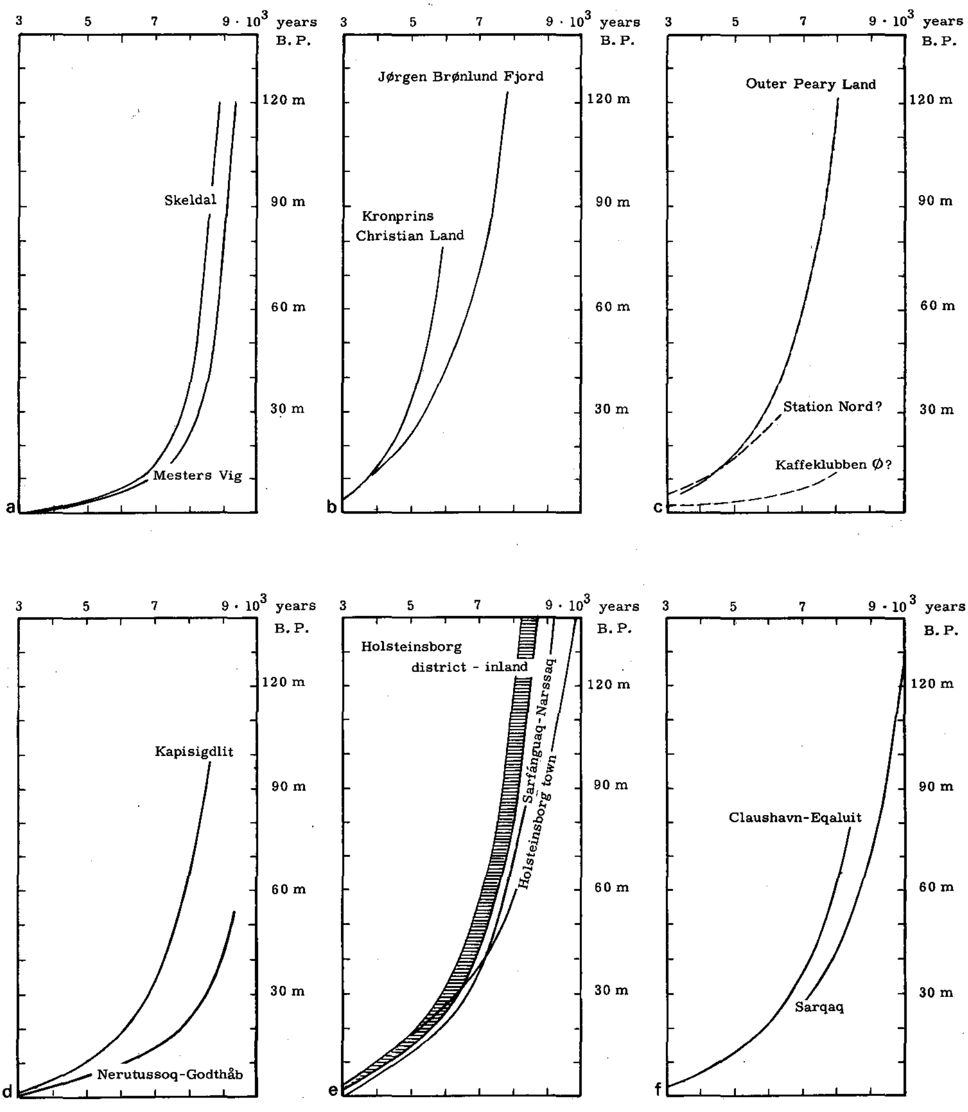


Fig. 4. Uplift curves expressed as field altitudes plotted against age. The curves are based on the relationships given in fig. 2 and fig. 3.

For Mesters Vig and Skeldal (Washburn & Stuiver, 1962; Lasca, 1969) a correction of 550 years was introduced to shell dates of all levels, on the basis of an apparent age of 550 years for a fresh, dredged shell sample (Y-606). Also in this area the occurrence of calcareous deposits of Permo-Carboniferous and Triassic age may be a source of error of shell dates. However, a subsequently dredged sample (Y-1267, Stuiver, 1969) indicated only an apparent age of 200 years, and this smaller age for the sample, taken near the locality of Y-606, was explained by possible contamination by radioactive fall-out in the intervening period. In the uplift curves presented here, the shell dates for Mesters Vig and Skeldal are not corrected.

For West Greenland no estimate can be given for the correction of apparent ages, but the few controls of dates of sea levels by means of material other than shells do not indicate any influence by older carbonate sources; the whole area treated here consists of Precambrian bedrock, poor in carbonate.

In general, it must be concluded that no single material is preferred for dating, and that they all may give deviations from a theoretical uplift trend of several hundred years as shown by the best dated curves of fig. 2. Nevertheless, the amount of data shows a tendency for early uplift and low slope of the curves for the coastal parts and a relatively steep slope and later uplift of the inland parts. The inland part of West Greenland is only covered by a few dates for each locality but they all seem to be related to a rate of uplift very similar to that given from Mesters Vig and Skeldal in East Greenland.

While the rates of uplift (the slopes of the curves in fig. 2) for inner West Greenland and East Greenland localities are alike, it is seen that the uplift of inner West Greenland is approximately 1000 years later relative to that of East Greenland (fig. 3 c).

Where there is only a single height-age determination the trend of uplift of neighbouring areas has been included in the determination of the slopes of the uplift curves of fig. 3. This is made in order to make the data comparable in altitude or in age. With regard to the spread of data even in well investigated localities, this procedure must be taken to be of more formal than real value, but at least provides that all data have been treated in a uniform way. In spite of the geographical spread of the sampling localities in the inner part of Holsteinsborg district, most of the data is confined to a single curve indicating a uniform uplift over a wide area.

In order to compare directly the measured isostatic recovery from one area to another in Greenland, the curves of fig. 2 and 3 have been converted in fig. 4 to uplift curves of uncorrected radiocarbon dates against field altitudes. Due to the scarcity of data for levels below 20 m, very little can be concluded about this youngest and smallest part of the uplift, except that the uplift here was slow and in West Greenland, as in East Greenland, ended nearly 4000 years ago.

For the oldest parts of the curves (older than 6000 years B.P.) there are clear indications that the uplift curves of fig. 3 show a trend of up-doming of inner parts of Greenland.

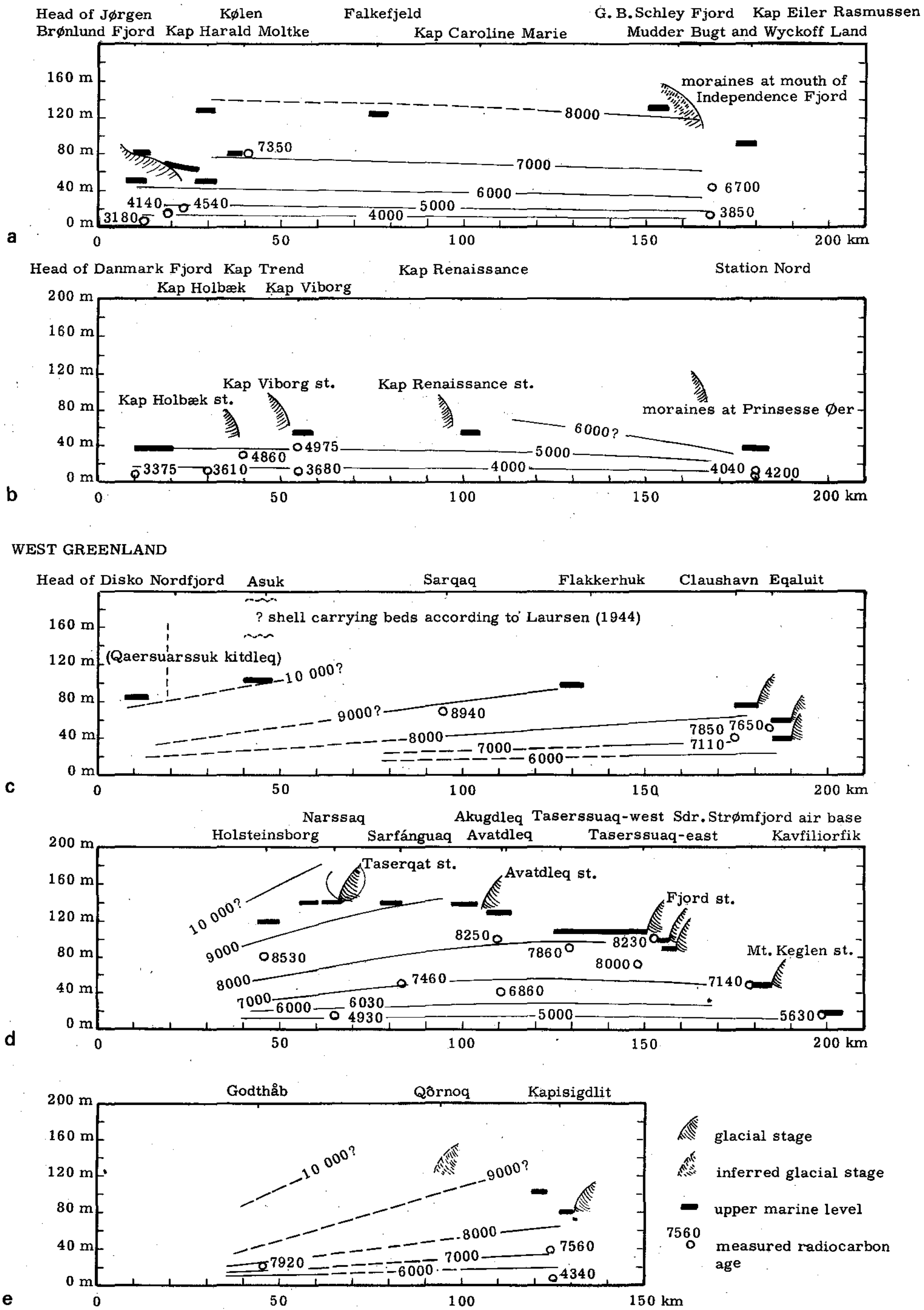


Fig. 5. Shore-line diagrams for sections of eastern North Greenland and from West Greenland. The relation of the shore-lines to former stages in the deglaciation is shown schematically.

SHORE-LINE DIAGRAMS OF WEST GREENLAND

In order to smooth the raw data (field altitudes and radiocarbon ages) the shore-line diagrams for West Greenland (fig. 5) are taken from the values of the curves in fig. 4. An increase in height of the contemporaneous shore-lines from the outer coast towards the inland area is detectable, and seemingly the shore-lines dome up to a maximum over the central inland of the Holsteinsborg district; a slight fall can then be traced towards the present Inland Ice margin. This fall, however, is only indicated by a single date from Søndre Strømfjord and as shown above, it cannot be demonstrated with certainty on the basis of the present material.

The general assumption of a rise of contemporaneous shore-lines from the south to the north seems only partly to be shown for West Greenland. Even taking into consideration the spread of dates from Claushavn in Disko Bugt where the same level furnishes ages differing by 740 years (K-987 and K-992), the uplift of inner Disko Bugt seems to follow more the trends of those in the coastal parts of Holsteinsborg than of the inland parts of the Holsteinsborg district around Søndre Strømfjord air base. If this is true the inference must be that Disko Bugt has been ice-free longer than great parts of the Holsteinsborg district.

Regarding the possible up-doming of central coastal areas, the coincidence of this with the north-south trending zone of minimum gravity anomalies, given in the map of Saxov (1958), must be pointed out. Connections between such minima and formerly ice-loaded areas are known from Scandinavia and North America (e.g. Gutenberg, 1951) where the areas are under continuous uplift at present; as seen from above, the West Greenland uplift seems to have been achieved around 4000 years ago and in this area the distribution of gravity anomalies cannot be explained as a glacio-isostatic after-effect.

SHORE-LINE DIAGRAMS OF NORTH GREENLAND

The shore-line diagrams of North Greenland (fig. 5) are based on the curves of fig. 4, i.e. on corrected shell dates together with the uncorrected ones on drift-wood and charcoal. Compared to the shore-line diagrams of West Greenland, those of eastern North Greenland show essentially smaller slopes towards the outer coastal areas. Apparently the Danmark Fjord area warped up later than Peary Land. If this is true, the main terraces of 25-37 m south of Independence Fjord (Danmark Fjord area) are not to be correlated to the main terrace system of 45 to 57 m in Peary Land as was done by Davies (1963), although his results fit with a tilt of these levels from Danmark Fjord towards the north-east of a few centimetres per kilometre, as also given by the shore-line diagrams of fig. 5 a & b.

In East Greenland, Mesters Vig and Skeldal are situated too close to give any indication of the slope of the shore-lines. However, together with the data published from Scoresby Sund (Tauber, 1970) there seems to have occurred an uplift with a pattern which is similar to that of West Greenland, though the data are still too limited to be conclusive.

THE UPPER MARINE LIMIT IN GREENLAND

As would be expected from other glaciated areas, the uppermost marine limit in Greenland, according to the shore-line diagrams, is a metachronous level with a maximum age above the outer coast and a maximum altitude over the central parts of the inland areas.

Information on the measured upper marine limits in Greenland is sparse; it is collected together here as table 1.

Table 1. Upper marine limit in Greenland

Region	District or area	Altitude metres	Source of information
West Greenland			
	Julianehåb	50– 60	Jessen (1896), Bøgvad (1940), Weidick (1963)
	Frederikshåb	94	Jessen (1896)
	Godthåb	100–110	Kornerup (1879), Iversen (1953)
	Holsteinsborg	110–140	Weidick (1968), Weidick & TenBrink (1970)
	Egedesminde	108–150	Pjetursson (1898), Kelly (1969)
	Disko Bugt	130–150	Steenstrup (1883), Laursen (1950)
	Umanak	130–200	Steenstrup (1883), Laursen (1944, 1950), Weidick (1968)
North Greenland			
	Hall Land	107–110	Davies (1963)
	Peary Land	130	Troelsen (1952), Davies (1963)
East Greenland			
	Fjord region	100–216	Bretz (1935), Noe-Nygaard (1932)
	Mesters Vig	120	Washburn (1965), Lasca (1969)
	Scoresby Sund	134	Sugden & John (1964)

The uppermost marine limits are defined here by shell-containing terrace sediments, by beach ridges of wide extent or perched boulders. Formerly cited higher levels which do not satisfy these requirements have been omitted.

A north-south trend of the maximum upper marine limit in the central parts of the coast-land seems to be a general feature throughout western Greenland. For the Holsteinsborg district this feature can be explained by the retreat of the Inland Ice margin and the related glacial rebound as shown in the profile of fig. 5, and the same explanation is therefore suggested for the other districts as well.

However, the similarity of the uplift of inner Godthåb district and Disko Bugt to the coast-land of Holsteinsborg may infer that these two inland areas became ice-free earlier than the inland of Holsteinsborg district. A consequence of this assumption must be that shell-carrying sediments at Asuk in the central parts of Disko Bugt (see fig. 5) described by Laursen (1944) from altitudes 125-150 m a.s.l. must have an age greater than those of the high marine sediments in Holsteinsborg district (i.e. K-1037 and K-1663). This however, has still to be demonstrated. Also in Umanak district marine deposits are known at high levels near Qaersuarssuk kangigdleq where shell-carrying clay beds occur at the localities of Lillebæk and Vibekes Elv up to altitudes of 200 and 190 m a.s.l. respectively (Laursen, 1944). Subsequent dates on shells from this area however, gave an age of more than 35 000 years (Rosenkrantz, 1968). At a neighbouring locality, Qaersuarssuk kitdleq, dates on shells in a delta 10-15 m a.s.l. gave an age of 8610 years B.P. (*ibid.*) which fits into the given trend of the shore-line diagram shown in fig. 5. This being so, then in Umanak Fjord, as in Disko Bugt, there is the same tendency for relatively high ages for low terraces in the central parts of the areas.

For eastern North Greenland the upper marine limits have the same altitudes as for most of West Greenland but they must be essentially younger. A central zone of high marine levels is also known from this area (Davies, 1963; Krinsley, 1961) but it is not so clear, which may be due to the lower inclination of the former shore-lines.

The scattered data on the upper marine limit in the East Greenland fjord region also show a pattern of a central zone of maximum heights. Any estimate of the age of the different parts of the upper marine limit is not yet possible here.

CORRELATION OF WEST GREENLAND ICE MARGIN STAGES TO FORMER SEA LEVELS

Ice margin deposits in West Greenland have been tentatively grouped by their occurrence into certain zones (Weidick, 1968), namely (fig. 6):

The nunataq zone, occurring in the central parts of West Greenland, i.e. Holsteinsborg and Egedesminde districts. Detailed mapping has revealed a division into the following stages:

1) Taserqat stage, formed at a sea level 130-140 m a.s.l.
2) Avatdleq stage, formed at a sea level at about 130 m a.s.l.

The outer zone, which occurs parallel to the present Inland Ice margin from Disko Bugt in the north to Godthåb district in the south, with a possible southern continuation in Frederikshåb district (Kelly, 1966).

In Disko Bugt, the outer zone contains two moraine systems, which are cut by beach ridges at 35-60 m a.s.l. and 70-80 m a.s.l., while mapping of Søndre Strømfjord area has revealed several stages formed at sea levels between 90 m a.s.l. and 110 m a.s.l. In Godthåb district moraines of this zone are cut by beach ridges up to 80 m a.s.l. The zone was originally divided into two 'fjord stages' (Weidick, 1968).

The inner zone, the main definition of which is that the moraines of this zone around Disko Bugt are older than those formed in historical time (around 1600-1900 A.D.), but nevertheless so young that they are formed at a sea level close to the present one. With some doubt, the Mt. Keglen stage in Søndre Strømfjord has also been referred to this zone in spite of its formation at a former sea level of 40-50 m a.s.l. (Weidick, 1968). Most inner zone moraines are believed to have been formed after the Holocene climatic optimum.

According to the uplift curves of fig. 4 and the shore-lines of fig. 5, it seems that the moraines and their alluvial plains have been formed at related sea levels with ages as given in table 2.

The generally low altitudes of the marine deposits of southernmost Greenland (Julianehåb district) may indicate only slight glaciation and early deglaciation of the

Table 2. Approximate ages of stages in the recession of the West Greenland Inland Ice margin

Stage	Godthåb district years B.P.	Holsteinsborg district years B.P.	Disko Bugt years B.P.
Taserqat (T)	?	9500	–
Avatdleq (A)	–	8700	–
Fjord	–	8400	–
Fjord	8300	8300	8300–8100
Fjord	–	8100	
Mt. Keglen (K)	–	7200	7000–7600

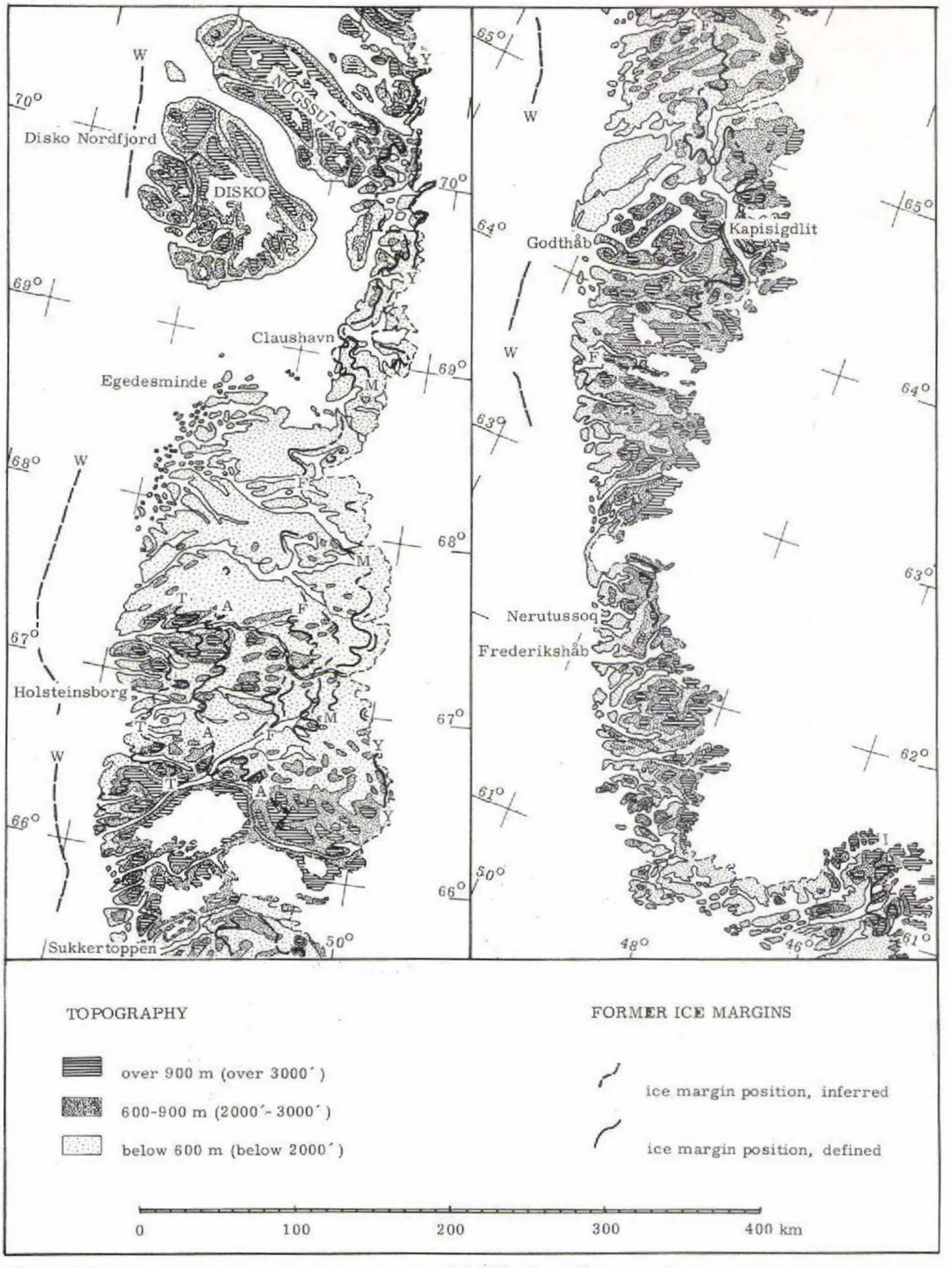


Fig. 6. West Greenland and South Greenland. Altitudinal conditions and stages in the deglaciation of the coastal area (simplified).

Stages indicated are:

T: Taserqat M: Mt. Keglen F: Fjord

A: Avatdleq Y: Undifferentiated stages, younger than Mt. Keglen. I: Tunugdliarfik coast-land. It is therefore possible that the stage of Tunugdliarfik (Weidick, 1963, 1968) should be correlated to the fjord stages in spite of its occurrence at a former sea level of not more than 10-15 m above the present one.

AGE OF NORTH GREENLAND ICE MARGIN STAGES

The moraine systems of Hall Land (shown in fig. 7) were mapped in detail by Davies (Davies *et al.*, 1959) on whose map several moraine systems are given. They are here only believed to represent phases in a single advance through Newman Bugt and Polaris Bugt (in Hall Basin). The date of W-816 is from shells in marine clay-silt which pre-dates the advance, while W-815 is from shells in a marine terrace, cut into the moraines, thus giving an age younger than the advance. The age of the advance is therefore placed between 3780 (W-815) and 6100 B.P. (W-816) and Davies also seemingly uses this age for an advance through the fjords in the Peary Land area. The age given must be considered as a maximum one considering the possible correction of shell dates of North Greenland (see p. 10).

Large moraine systems have been described from eastern North Greenland by Davies (1963) and Krinsley (1961) and, especially in Kronprins Christian Land, the inland area shows numerous systems of recessional moraines very like those which can be observed around inner Søndre Strømfjord area in West Greenland.

The main stages shown in fig. 7 are essentially those mapped by Davies and Krinsley. In order to describe the stages, they have here been classified by the localities of their occurrence (fig. 7). Unfortunately very little is known about their relation to former sea levels. According to Troelsen (1952) Jørgen Brønlund Fjord was formed in connection with a 65 m sea level, while for the same locality Davies (1963) states that the advance through the fjord disrupted terraces higher than around 50 m. In Zigzagdal in Valdemar Glückstadt Land, a large moraine delta is graded to a flat level of 65 m according to Krinsley (1961) who further suggested (*ibid.*, p. 749) that for this locality, "the position and orientation of the moraine delta indicates that deglaciation of the western tributary valleys preceded the retreat of the Danmarks Glacier towards the head of Danmarks Fjord", which is the reason for the delineation of the stage at Kap Renaissance in fig. 7.

In general, the age of the moraines must be judged from the highest marine levels of the surrounding areas which in general furnish a minimum age. As given from the shore-line profiles of fig. 5, the ages in table 3 are proposed.

The stage at Deichmans Øer (D) cannot be dated on the basis of the current information, but morphologically it may be correlated with that of Jørgen Brønlund Fjord or Kap Renaissance.

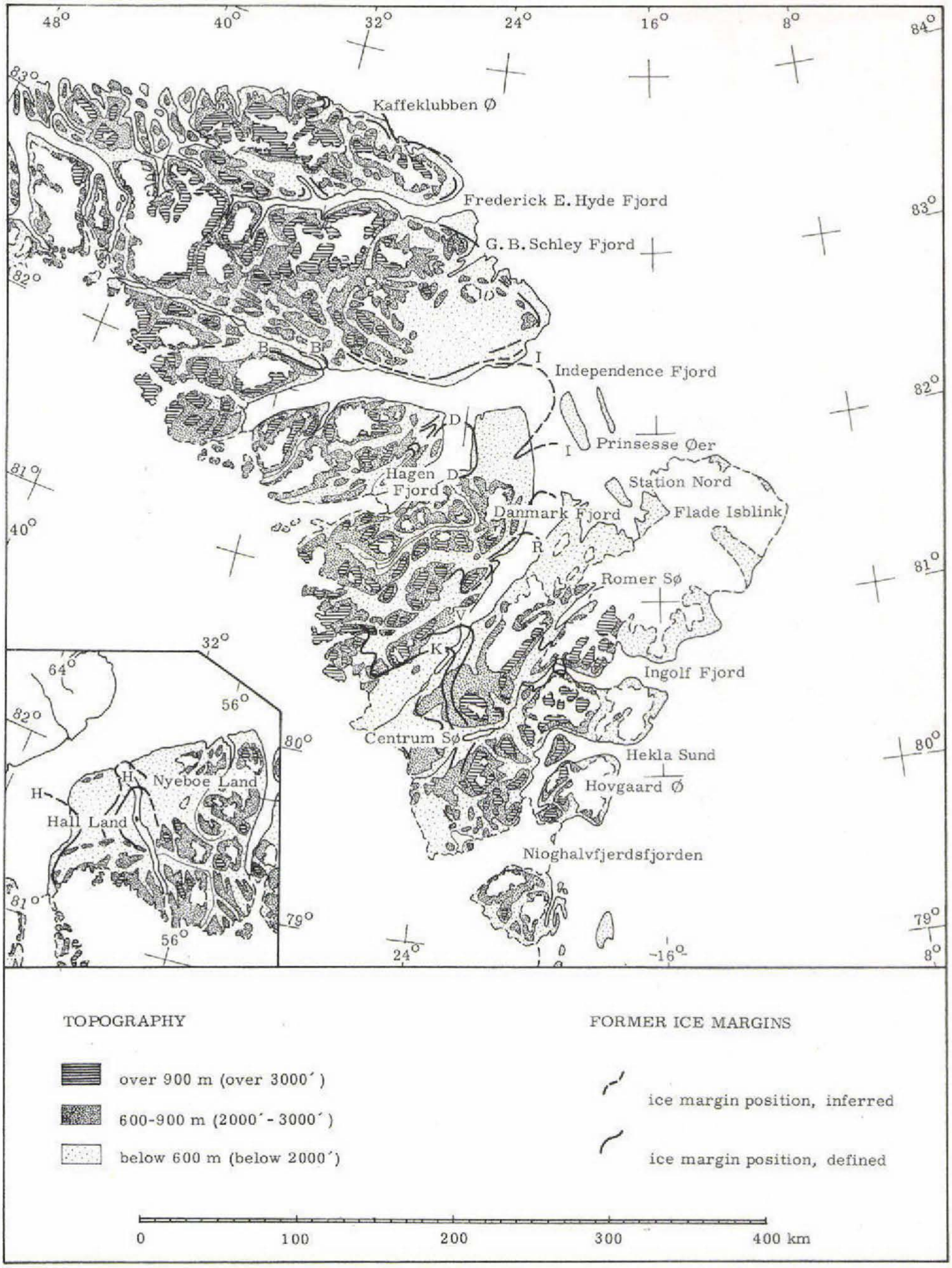


Fig. 7. Eastern North Greenland. Altitudinal conditions and former stages in the deglaciation of the coastal area (simplified).

Stages indicated are:

I: mouth of Independence Fjord
B: Jørgen Brønlund Fjord
V: Kap Viborg, K: Kap Holbæk
R: Kap Renaissance
D: Deichmanns Øer
H: Hall Land

Table 3, Approximate ages of stages in the extent of the Inland Ice in eastern North Greenland

Stage	approximate age years B.P.
Entrance of Independence Fjord (I)	8200 B.P.
Jørgen Brønlund Fjord (B)	6100
Kap Renaissance (R)	5600
Kap Viborg (V)	5500
Kap Holbæk (H)	5200

According to Krinsley (1961) a great ice dammed lake was formed around the present Centrum Sø in connection with the moraines of, what is here called, the Kap Holbæk stage. This implies a correlation of this stage to moraines from local glaciers in Sæfaxi Dal, Revieradal and at Hjørnegletscher, barring the lake area from its present drainage to Ingolf Fjord and to Hekla Sund. Moraines south-west of Romer Sø created by local glaciers must therefore also be correlated to the Kap Holbæk stage. It is possible that the lake existed also in connection with the Kap Viborg and Kap Renaissance stages, but according to the radiocarbon dates from Ingolf Fjord (see p. 32) during some periods the sea must have inundated parts of the area of the former ice dammed lake.

STAGES IN THE ICE RECESSION OF EAST GREENLAND

Washburn (1965) stated that the Mesters Vig area was open to the sea and therefore deglaciated, at least in part, by 9000-8500 years B.P. and that it has not been reglaciated since. A date of 9030 years B.P. (Y-712) 6 to 10 km from local glacier fronts also furnishes evidence that the climatic conditions about 9000 B.P. supported, at least, a little more glaciation of the area than that of today.

From the neighbouring Skeldal area, Lasca (1969) concluded an upper marine limit of around 120 m and preceding this three phases of early glaciation:

I a '500 m-level' moraine system Würm/Wisconsin?

II separation of the main glacier in Kong Oscar Fjord and the tributary in Skeldal.

III a readvance of a glacier through Skeldal at a '300 m level'.

Lasca's phase III was followed by deglaciation until hypothermal time when a readvance of small extent is indicated by fresh moraines around present glaciers.

As in Skeldal, the hitherto given information from the Scoresby Sund area indicates a similar early deglaciation which has not been followed by any essential readvance, even in hypothermal time. From Schuchert Dal dates on turf (peat) (W-1378) buried under fresh moraine around Ivar Baardsøns Gletscher gave a maximum age of the last small advance as 1490 years B.P. (Schafer *in* Levin *et al.*, 1965).

In the areas around the entrance of Schuchert Dal from Scoresby Sund Sugden & John (1965) reported that there are two moraine systems of which the oldest was older than the highest marine limit of 134 m and the youngest was related to a 101 m sea level. It was suggested that the oldest of these moraine systems was believed to be of possible Wisconsin/Würm age while the youngest one was referred to as Younger Dryas. South of this area Funder (1970) has reported moraine stages, from the eastern parts of Milne Land, the oldest of which were formed at sea levels of 110-130 m and the youngest at a minimum sea level of 90 m. After this, a moraine was found at a single locality in Mudderbugt formed at a 35 m shore-line 10-15 km from the present local ice cap.

Schuchert Dal was essentially free of ice prior to 7900 years B.P. according to a shell date (W-1381) in the inner part of this valley from a marine terrace approximately 50 m a.s.l. (Schafer *in* Levin *et al.*, 1965). Besides this information the radiocarbon dates of shells (K-1461) from 65 m a.s.l. in the Bjørneøer gives an age of 8640 years B.P. (Kalsbeek *in* Tauber, 1970 a). As pointed out by Funder (1970) the dates of W-1381 and K-1461 indicate an uplift of the central part of Scoresby Sund very like those of Mesters Vig and Skeldal and therefore the following tentative correlation may be established:

East Greenland	West Greenland	age
130 m moraine system	Taserqat	Younger Dryas?
100 m moraine system	Avatdleq	Pre-Boreal

The shell dates in the more remote inner branches of Scoresby Sund, as given by the dates K-1460 (Gåsefjord) of 7040 years B.P. and K-1459 (Rypefjord) of 6800 years B.P. (Tauber, 1970 a), imply that deglaciation of most of Scoresby Sund was achieved before the climatic optimum. This is corroborated by the age of the moraine stages in the inner parts of Scoresby Sund, as given by Funder (1971) from Rødefjord.

HOLOCENE GLACIAL STAGES AND CLIMATIC DEVELOPMENT

The present suggested dates of glacial stages in West, East and North Greenland are shown in fig. 8 where they are compared to the Camp Century climatic record according to Dansgaard *et al.* (1970). A comparison between the West Greenland

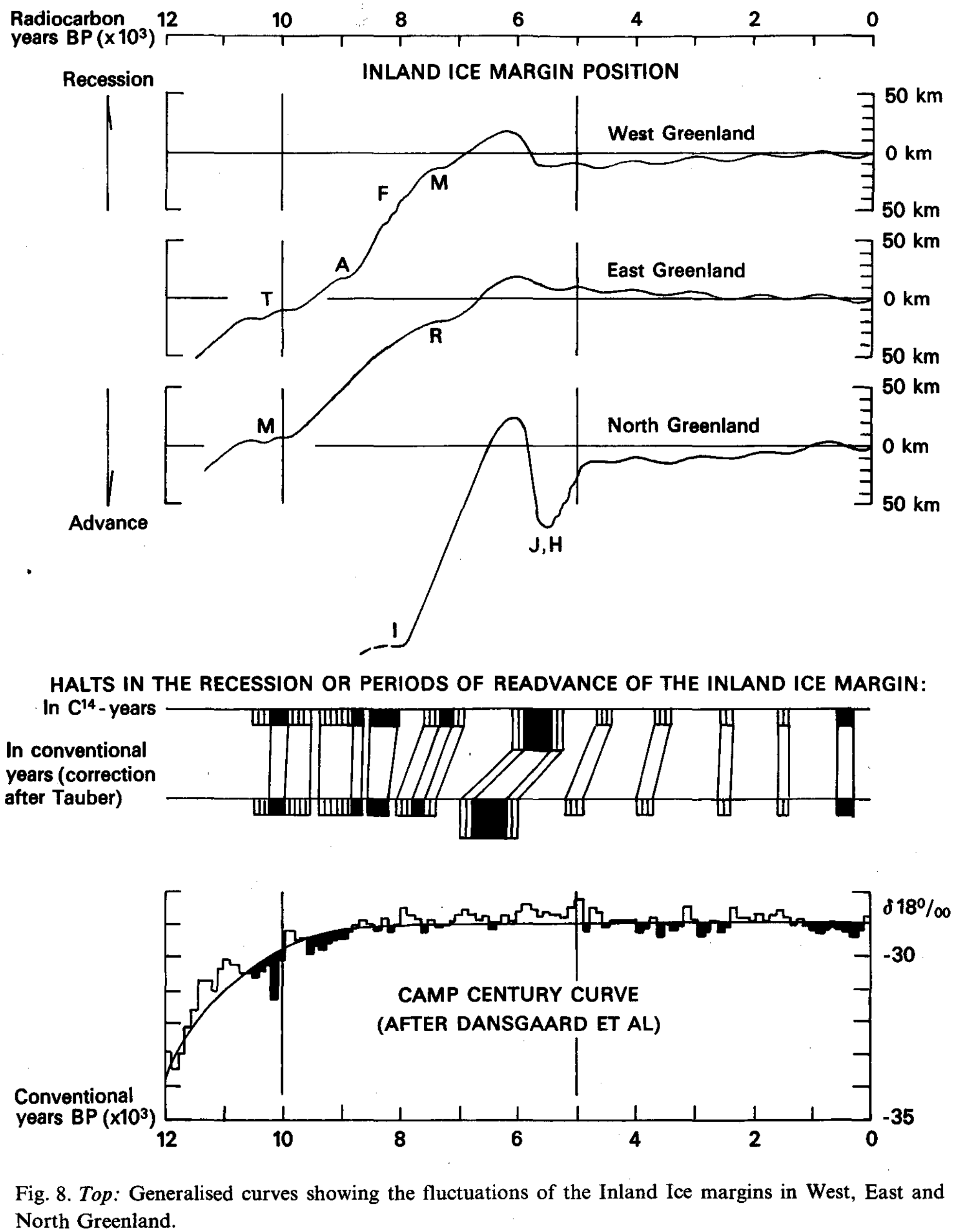


Fig. 8. *Top:* Generalised curves showing the fluctuations of the Inland Ice margins in West, East and North Greenland.
Letters indicate the following stages in the ice margin position:
West Greenland: T = Taserqat, A = Avatdleq, F = Fjord and M = Mt. Keglen stage.
East Greenland: M = Milne Land and R = Rødefjord stages according to Funder (1970, 1971).
North Greenland: I = stages at the entrance of Independence Fjord, J = Jørgen Brønlund Fjord and H = Hall Land stages.

Center: Approximate age of halt periods in the recession, or of readvance of the Inland Ice margin,
Continued at bottom of next page

stages and the present information from East Greenland shows, to some extent, a parallel pattern: in both areas the greater part of the coast-land was essentially free of ice before about 8500 years B.P. and in both areas there has only been a slight development of the local glaciers since that time. In this respect the southernmost West Greenland, i.e. Julianehåb district, must be an exception since a widespread expansion of local glaciers occurred in its southern parts after the retreat of the Inland Ice (Weidick, 1968).

Concerning the differences between the glacial development in East and West Greenland, it must be pointed out that the Boreal stages equivalent to the Cochrane-Cockburn stages of Canada, can only be given with certainty in the fjord stages of the outer zone of West Greenland. A possible equivalent of this may be found in East Greenland in the moraine systems in the innermost branches of Scoresby Sund. Even if this is so, the extent of the Inland Ice during this stage was considerably less than in West Greenland relative to the present Inland Ice margin.

However, the present difference between East and West Greenland may in part be apparent and due to restricted knowledge. Even within West Greenland there may be a difference between the deglaciation of the complex fjord systems in the Godthåb district and in the Disko Bugt-Umanak area (on the one hand) and the continental block of Holsteinsborg district on the other. The fjord systems induced a powerful drainage of the Inland Ice margin causing the deglaciation to occur earlier than in the continental Holsteinsborg district. This difference is accentuated by the mountain barrier of the outer Holsteinsborg district (see the topographic outline of fig. 6) which gave a higher position and therefore a smaller ablation of the Inland Ice margin at the time of the Taserqat and Avatdleq stages. In view of these topographical factors it is conceivable that the deep East Greenland fjords also influenced the recession of the East Greenland ice cover resulting in an early and fast retreat.

In North Greenland it seems that the equivalents to the Cochrane-Cockburn stages of Canada are found near the outer coast and that the deglaciation occurred for the greater part between 8000 and 5000 years B.P. The deglaciation in this region was interrupted by powerful readvances which presumably occurred around 6000 years B.P., i.e. during the climatic optimum, and is the maximum age of the readvances given by Krinsley and Davies.

Possibly, the widespread younger readvances in North Greenland, mentioned above, were due to a northward shift of the depression tracks during the climatic

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according to the top curves. Black: dated periods at present. Hatched areas: alternative ages of dated periods or minor readvances of the last 6000 years.

The uppermost series indicates age of the periods in radiocarbon years, while the lowermost series gives the same periods after the correction proposed by Tauber (1970 b). The ages thus should be more comparable to those of cold periods of the Camp Century record given below.

Bottom: The Camp Century record according to Dansgaard *et al.* (1970). Relative cold spells are given by black colour.

optimum. This would increase the accumulation over the northern part of the Inland Ice more than the contemporaneous slight temperature increase would influence the ablation. The resulting positive mass balance of this part of the Inland Ice therefore could result in widespread readvances.

However, the above explanation would also involve significant alterations of local glaciers. In both West Greenland (Weidick, 1968) and North Greenland the evidence of major Holocene fluctuations of local glaciers is small. In North Greenland they have been given for Kronprins Christian Land in the mapping by Krinsley (1961) where they are confined to the coastal parts. For the inner parts of Kronprins Christian Land it was observed that well-developed moraines made by the Inland Ice were situated close to existing glaciers. The idea of greater accumulation causing advances of the Inland Ice in North Greenland during the Holocene climatic optimum is therefore unsatisfactory unless, in coastal parts of Greenland, it was matched by an increased ablation.

Even with the better known climatic and glacial fluctuations of the last century the same differences occur. For West Greenland, and possibly also for East Greenland, the local glaciers reacted in general more sensitively than the inland parts of the Inland Ice margin. However, the reactions of the Inland Ice margin for single glacier lobes (calving outlets related to ice streams) were extraordinarily great (Weidick, 1968). For North Greenland, Davies & Krinsley (1962) concluded that there has been a slight general recession in this century and that there have been large recessions of single calving outlets of the Inland Ice margin while local glaciers in Peary Land seem to be nearly stationary. The authors concluded that in this century the reaction of glaciers was influenced more by changes in accumulation (precipitation) than by changes in temperature.

Acknowledgements

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APPENDICES

AGE DATES RELATED TO FORMER SHORE-LINES

Appendix 1. Dated marine deposits and levels in the Holsteinsborg area

Lab. no. (GGU no.)	Age B.P.	Field altitude metres	Corrected altitude metres	Comments
K-1559 (88965)	8210±140	50	70	Kangerdluarssúnguaq. Shells of *Mya truncata* from clayey layer 10-20 cm below surface of stony beach ridge.
K-1560 (88966)	7340±130	40	52	Kangerdluarssúnguaq. Shells of *Balanus balanus* in beach ridge of shingle and gravel.
K-1561 (88968)	7900±130	23–30	45	Kangerdluarssúnguaq. Shells of *Mye truncata* and *Hiatella arctica* in beach ridge of shingle and gravel.
K-1716 (122266)	6880±120	60	68	Itivdlínguaq, Aussivit valley. *Mytilus edulis* shells from shell layer 3-5 m under top of extensive silt terrace.
K-1382 (88926)	8530±120	76–80	101	Holsteinsborg. Shells of *Mya truncata* and *Hiatella arctica* from gravel in beach ridge 76 m a.s.l.
K-1381 (88929)	8680±150	72–75	98	Holsteinsborg. *Mya truncata* in gravel from beach ridges.
K-1387 (88928)	8560±120	72–75	97	Same locality as K-1381, but *Balanus balanus* attached to large boulders in the beach ridges.
K-1383 (88932)	8700±120	62–65	89	Holsteinsborg. *Mya truncata* from gravel in beach ridges.
K-1379 (88925)	8290±120	58–60	79	Holsteinsborg. *Mya truncata, Mytilus edulis, Hiatella arctica* and *Chlamys islandica* in beach ridges.

Appendix 1 (continued)

Lab. no. (GGU no.)	Age B.P.	Field altitude metres	Corrected altitude metres	Comments
K-1380 (88931)	8300±140	55–60	79	Holsteinsborg. *Mya truncata* from gravel in beach ridge.
K-1388 (88931)	8460±150	55–60	80	Same locality as K-1380, but shells of *Balanus balanus*.
K-1378 (88930)	8560±120	52	75	Holsteinsborg. *Mya truncata* from gravel in beach ridges.
K-1389 (88927)	8440±150	52	74	Same locality as K-1378, but shells of *Balanus balanus*.
K-1377 (88933)	9070±160	50–52	79	Holsteinsborg. *Mytilus edulis* in clay banks.
K-1034 (79537)	8840±170	48	74	Holsteinsborg. *Mya truncata* from clay bank (Weidick, 1968).
K-1376 (88923)	4970±110	24	24	Holsteinsborg. *Mytilus edulis* from boulder rich gravel in beach ridge.
K-1035 (79532)	4590±110	20	20	Holsteinsborg. Shells of *Mytilus edulis* from sand, covered by shingle in beach ridge (Weidick, 1968).
K-1390 (79533)	recent activity	0		Holsteinsborg. *Mytilus edulis* collected at present beach level.
K-1386 (88938)	7460±130	50	63	Sarfânguaq. *Mytilus edulis* in uppermost metre of gravelly beach ridge covering sterile sandy silt.
K-1385 (88943)	7860±140	35	52	Sarfânguaq. *Mya truncata* in surface of marine terrace covered by small beach ridges.
K-1384 (88934)	5760±120	17	17	Sarfânguaq. *Mya truncata* in gravelly beach ridge.
K-1562 (88951)	6030±120	10–15	13	Narssaq, Amerdloq. *Mya truncata* in marine silt overlain by delta with surface 10-15 m a.s.l. Age must indicate maximum age of delta.
K-1563 (88950)	4930±140	10–15	13	Narssaq, Amerdloq. Moss and twigs from pockets in sandy forset beds of the delta men-

Appendix 1 (continued)

Lab. no. (GGU no.)	Age B.P.	Field altitude metres	Corrected altitude metres	Comments
				tioned above. Must indicate a late episode in the build-up of the delta, and a minimum age for its formation, if the material was fresh during its deposition.
K-1037 (79549, 79552-54)	8250±130	100	120	Avatdleq, Ikertoq. *Mya truncata* from beach gravel (Weidick, 1968).
K-1033 (79558)	6860±150	40	48	Akugdleq, Ikertoq. *Mya truncata* from top of clay horizon overlain by beach ridge (Weidick, 1968).
K-1665 (122259)	7860±140	90	107	Taserssuaq, west end. Shells of *Hiatella arctica* from surface of terrace.
K-1666 (122259)	7610±130	90	105	Same locality as K-1665, but shells of *Chlamys islandica*.
K-1663 (122214)	8230±140	100	120	Qordlortoq, Taserssuaq, east end. Shells of *Macoma calcarea* from laminated sandy silt and silty sand a few metres under the surface of terrace at 95 m a.s.l. close to the uppermost marine level of the area at about 100 m a.s.l.
K-1662 (122218)	8000±110	70	88	*Balanus* profile, Taserssuaq, east end. Shells of *Balanus balanus* attached to boulders a few metres below surface of terrace at 70 m a.s.l.
K-1664 (122203)	7140±130	45–50	58	Søndre Strømfjord air base. Shells of *Balanus balanus* and *Mya truncata* imbedded in terrace 17 m below its surface at 45-50 m a.s.l. The shell layers are close to a transition between underlying marine silts and overlying fluviatile material. Age of shells must therefore indicate a maximum age of a marine level at 45-50 m a.s.l.
K-1717 (122221)	6990±120	35	44	Siorarssuit. *Mytilus edulis* and *Mya truncata* from

Appendix 1 (continued)

Lab. no. (GGU no.)	Age B.P.	Field altitude metres	Corrected altitude metres	Comments
				sand 2 m below the surface of terrace at about 35 m altitude.
K-1719 (122231)	8130±140	41	60	East end of Ilivigdlup tasia. Shells of *Cardium ciliatum* and *Macoma calcarea* in laminated fine sand-silt 28 m a.s.l. The age must indicate connection with a sea level at about 90 m a.s.l.
K-1718 (122225)	7120±130	45	55	South-east side of Ilivigdlup tasia. Shells of *Mytilus edulis* and *Mya truncata* from laminated silt-clay at altitude 30 m from terrace with surface at about 45 m a.s.l.
K-1715 (122241)	5630±110	10–15	15	Kavfiliorfik. *Macoma calcarea* from laminated silt-sand (5 m a.s.l.) in terrace with surface 10-15 m a.s.l. Age presumably the maximum age of the formation of the terrace.

Appendix 2. Published dates from other parts of central West Greenland

(g = gyttja, s = shells)

Lab. no. (GGU no.)	Age B.P.	Field altitude metres	Corrected altitude metres	Comments
K-1149	9840±170	52 (42)	87	Nerutussoq, Frederikshåb district, (g), M. Kelly *in* Tauber (1968).
K-1150	8510±160	44 (33)	67	as above, (g).
K-1151	8680±160	35 (21)	59	as above, (g).
K-1154	8210±160	24 ?	44	as above, (s).
K-1153	7750±150	22	38	as above, (g).
K-1152	4780±120	4	4	as above, (g).

The field altitudes in brackets are given by Tauber (1968), but they have been corrected later to the values given in the list (Kelly, written communication).

Appendix 2 (continued)

Lab. no. (GGU no.)	Age B.P.	Field altitude metres	Corrected altitude metres	Comments
K-956	7920±140	21	38	Godthåb town. Marine algae in sands, M. Kelly *in* Tauber (1968).
	8500 ?	100	123	Kapisigdlit. Present lake at 100 m a.s.l. isolated in early Boreal time, according to pollen stratigraphic sequence by Iversen (1954). Absolute dating of the level has not been performed but the subsequent dating of younger parts of the sequence reveals correlation in age to the floristic periods of Scandinavia. The dating here must be considered as tentative.
	7500 ?	50	64	Kapisigdlit, as above, but close to transition Boreal-Atlantic time.
K-1036 (79513, 79515)	7560±150	40	54	Kapisigdlit, (s), Weidick (1968).
K-802	4340±120	8	8	Kapisigdlit, (g), Fredskild (1967).
K-987	7850±190	40	57	Claushavn, Disko Bugt (g), M. Kelly *in* Tauber (1968), Weidick (1968).
K-992 (61418-19)	7110±140	40	50	Claushavn, Disko Bugt, (s), Weidick (1968).
K-993 (61409)	7650±140	52	66	Eqaluit, Disko Bugt, (s), Weidick (1968).
K-994 (61131-32)	8940±170	70	96	Sarqaq, Disko Bugt, (s), Weidick (1968).

Appendix 3. Published dates from Mesters Vig, East Greenland, after Washburn & Stuiver (1962) and Washburn (1965)

s = shells, d = drift-wood, w = whale baleen

Lab. no.	Age B.P.	Field altitude metres	Corrected altitude metres	Comments
Y-711	9050±250	71	98	(s)
Y-716	9330±210	71	101	(s)
Y-599	9330±250	68	98	(s)
Y-596	9310±250	59	89	(s)
Y-713	8910±140	54	80	(s)
Y-712	9030±140	49	76	(s)
Y-704	8280±210	31	51	(s)
Y-876	8550±160	29	52	(s)
Y-878	7500±150	20	34	(s)
Y-879	7460±130	20	33	(d)
Y-717	7200±200	18	29	(s)
Y-708	7220±250	18	29	(s)
Y-714	7460±200	9	22	(s)
Y-602	8090±180	8	27	(s)
Y-703	2980±120	4	4	(d)
Y-882	5590±140	4	4	(d)
Y-883	7390±210	4	16	(s)
Y-600	7240±210	3	14	(s)
Y-702	735±110	3	3	(d)
Y-884	5510±320	2	2	(s)
Y-606	550± 70	–2 to –15		Dredged modern shells
I-429	7350±190	ca. 50		(w), F. Pessl *in* Trautman (1963)
I-432	6530±200	ca. 40		(s), F. Pessl *in* Trautman (1963)

Appendix 4. Published dates from Skeldal, East Greenland, after Lasca (1969)

All samples are shells

Lab. no.	Age B.P.	Field altitude metres	Corrected altitude metres
M-1612	8490±300	60	82
M-1613	8840±300	60	86
M-1615	9140±300	59	87

Appendix 4 (continued)

Lab. no.	Age B.P.	Field altitude metres	Corrected altitude metres
M-1616	7770±250	36	52
M-1611	7740±250	31	47
M-1617	6960±220	21	30
M-1618	7270±250	21	32
M-1620	6830±200	17	25
M-1614	7010±250	14	23
M-1622	7160±250	11	22
M-1623	6790±220	9	16
M-1619	5980±200	4	4
M-1621	5680±200	3–4	4

Appendix 5. Published dates from Kronprins Christian Land, northern East Greenland, according to the various sources cited in the table

Shell dates in brackets are corrected shell dates. c = charcoal, d = drift-wood, g = gyttja and s = shells

Lab. no.	Age B.P.	Field altitude metres	Corrected altitude metres	Comments and reference
I-371	7580±200 (6380)	67	81	Ingolf Fjord, (s), W. Davies *in* Trautman & Willis (1966).
I-370	6700±150 (5500)	58	64	Ingolf Fjord, (s), W. Davies *in* Trautman (1963).
W-1072	6650±600 (5450)	53	59	Ingolf Fjord, (s), W. Davies *in* Ives *et al*, (1964).
I-367	6800±150 (5600)	42	49	Sæfaxi Elv, (s), W. Davies *in* Trautman (1963).
I-366	6900±150 (5700)	40	48	Sæfaxi Elv, (s), W. Davies *in* Trautman (1963).
I-312	4975±150	38	38	Kap Viborg, (d), W. Davies *in* Trautman & Willis (1966).
I-306	4860±150	27	27	Kap Trend, (d), W. Davies *in* Trautman & Willis (1966).
I-365	5025±150 (3825)	21	21	Rivieradal, (s), W. Davies *in* Trautman (1963).
K-563	3610±120	12	12	Kap Holbæk, (c), E. Knuth *in* Tauber (1960 b, 1961).

Appendix 5 (continued)

Lab. no.	Age B.P.	Field altitude metres	Corrected altitude metres	Comments and reference
K-753	3680±120	12	12	Kap Viborg, (d), E. Knuth *in* Tauber (1964).
I-308	4830±150 (3630)	8	8	Head of Danmark Fjord, (s), W. Davies *in* Trautman & Willis (1966).
I-313	3375±150	8	8	Head of Danmark Fjord, (d), W. Davies *in* Trautman & Willis (1966).
I-369	3375±125	7	7	Sæfaxi Elv, (s), W. Davies *in* Trautman (1963).
K-142	3030±130	6	6	Kap Holbæk, (c), E. Knuth *in* Tauber (1960 a, 1961).
K-565	3000±120	6	6	Kap Holbæk, (c), E. Knuth *in* Tauber (1960 b, 1961).
W-1063	6035±300 (4835)	41	41	Kap Renaissance, (s), W. Davies *in* Ives *et al.* (1964).
K-138	4040±170	12	12	Prinsesse Ingeborg Halvø, (d), E. Knuth *in* Tauber (1960 a, 1961).
W-1066	4200±320	6	6	Station Nord, (d), W. Davies *in* Ives *et al.* (1964).

Appendix 6a. Published dates from Jørgen Brønlund Fjord, innermost part of Independence Fjord

c = charcoal, d = drift-wood, g = gyttja and s = shells

Lab. no.	Age B.P.	Field altitude metres	Corrected altitude metres	Comments and reference
I-311	8550±250 (7350)	80	103	Kølen, (s), W. Davies *in* Trautman & Willis (1966).
Y-19	5870±100	65 ?	65	J. Brønlund Fjord, (d), J. Troelsen *in* Preston *et al.* (1955).
K-868	6850±140 (4950)	45	53	Klaresø (g), Fredskild (1969). In brackets Fredskild's corrected date.

Appendix 6 a (continued)

Lab. no.	Age B.P.	Field altitude metres	Corrected altitude metres	Comments and reference
K-965	7740±140 (6540)	40	56	Klaresø-Lersø area, (s), P. Kirkeby *in* Knuth (1964).
K-964	7290±130 (6090)	33	45	Klaresø-Lersø area, (s), P. Kirkeby *in* Knuth (1964).
K-754	4540±120	21	21	Jørgen Brønlund Fjord, (c), E. Knuth *in* Tauber (1964).
K-755	4140±120	14	14	Jørgen Brønlund Fjord, (c), E. Knuth *in* Tauber (1964).
W-555	5370±200 (4170)	13	13	Kap Moltke, (s), W. Davies *in* Rubin & Alexander (1960). Shells buried under outwash and moraine, 3 m thick.
K-150	3290±130	13	13	Jørgen Brønlund Fjord, (d), E. Knuth *in* Tauber (1960 a).
K-932	3780±120	11	11	Vandfaldsnæs, (c), E. Knuth *in* Tauber (1966).
W-1073	4970±260	11	11	Kap Harald Moltke, (d), W. Davies *in* Ives *et al.* (1964).
K-930	3790±120	9	9	Midsommerelven, Portfjældet, (c), E. Knuth *in* Tauber (1966).
K-929	3860±120	9	9	Midsommerelven, Portfjældet,(c), E. Knuth *in* Tauber (1966).
K-928	3890±120	9	9	Midsommerelven, Portfjældet, (c), E. Knuth *in* Tauber (1966).
I-309	4925±150 (3725)	8	8	Jørgen Brønlund Fjord, (s), W. Davies *in* Trautman & Willis (1966).
K-933	3180±110	6	6	Vandfaldsnæs,(c), E. Knuth *in* Tauber (1966).
K-934	2740±100	6	6	Vandfaldsnæs, (c), E. Knuth *in* Tauber (1966).

Appendix 6 b. Data on drift-wood in raised beaches at Tordenskjold Gletscher, central Frederick E. Hyde Fjord

Samples collected by P. R. Dawes, species determined by J. Dahl Møller

Lab. no. (GGU no.)	Age B.P.	Field altitude metres	Species
I-5591 (100658)	1935± 90	4	*Picea* sp.
I-5592 (100659)	4645±115	15	*Picea* sp.
I-5593 (100660)	4815±115	19	*Larix* sp.

Appendix 7. Published dates from eastern part of Peary Land

d = drift-wood, s = shells

Lab. no.	Age B.P.	Field altitude metres	Corrected altitude metres	Comments and reference
I-310	7900±200 (6700)	41 ?	58	Kap Skagen, (s), W. Davies *in* Trautman & Willis (1966), Davies (1963).
W-1084	5980±300 (4780)	16	16	Depot Bugt, (s), W. Davies *in* Ives *et al.* (1964).
K-756	3850±120	15	15	Wyckoff Land, (c), E. Knuth *in* Tauber (1964).
W-1083	7060±300 (5860)	12	22	Kap Wyckoff, (s), W. Davies *in* Ives *et al.* (1964).
W-1076	6880±300 (5680)	8	17	Kap Wyckoff, (s), W. Davies *in* Ives *et al.* (1964).
I-307	2580±150	8	8	Kap Wyckoff, (d), W. Davies *in* Trautman & Willis (1966).

Appendix 8. Kaffeklubben Ø

Both published dates (W. Davies *in* Ives *et al.*, 1964) are shell dates.

Lab. no.	Age B.P.	Field altitude metres	Corrected altitude metres
W-1090	7730±400	11	27
W-1088	1200±300	3	3

Appendix 9. Published dates from Hall Land, north-west Greenland

Both dates (W. Davies *in* Rubin & Aleksander, 1960) are shell dates

Lab. no.	Age B.P.	Field altitude metres	Comments
W-816	6100±300	ca. 82	Central parts of Polaris Promontory. The age presumably pre-dates an advance through Newman Bugt and Polaris Bugt of lobes of the Inland Ice.
W-815	3780±300	12	Newman Bugt. Marine terrace post-dating the glacial advance mentioned above.

REFERENCES

Andersen, B. G. 1965: The Quaternary of Norway. *In* Rankama, K. (editor) *The Quaternary* **1**, 91-138. Interscience Publ.

Andrews, J. T. 1966: Pattern of coastal uplift and deglacierization West Baffin Island, N.W.T. *Geogrl Bull.* **8**, 174-193.

Bretz, J. H. 1935: Physiographic studies in East Greenland. *In* Boyd, L. A., The fjord region of East Greenland. *Spec. Publ. Am. geogr. Soc.* **18**, 159-266.

Bøgvad, R. 1940: Quaternary geological observations etc. in south-east and south Greenland. *Meddr Grønland* **107**, 3, 42 pp.

Dansgaard, W., Johnsen, S. J., Clausen, H. B. & Langway, C. C., Jr. 1970: Ice cores and paleoclimatology. *In* Olsson, I. U. (editor) *Proc. XIIth Nobel Symposium on radiocarbon variations and absolute chronology.* 337-355. Stockholm: Almqvist & Wiksell; New York: Wiley & Sons.

Dawes, P. R. 1971: The North Greenland fold belt and environs. *Bull. geol. Soc. Denmark* **20**, 197-239.

Davies, W. E. 1963: Glacial geology of northern Greenland. *Polarforschung* **5**, 94-103.

Davies, W. E. & Krinsley, D. B. 1962: The recent regimen of the ice cap margin in North Greenland. IASH Symposium Obergurgl. *Publs Ass. int. Hydrol. scient.* **58**, 119-130.

Davies, W. E., Needleman, S. M. & Klick, D. W. 1959: Report on operation Groundhog (1958) North Greenland. Investigation of ice-free sites for aircraft landings Polaris Promontory, North Greenland. [U.S.] Air Force Cambridge Research Center, 45 pp.

Fredskild, B. 1967: Palaeobotanical investigations at Sermermiut, Jakobshavn, West Greenland. *Meddr Grønland* **178**, 4, 54 pp.

Fredskild, B. 1969: A postglacial standard pollendiagram from Peary Land, North Greenland. *Pollen Spores* **11**, 573-583.

Funder, S. 1970: Notes on the glacial geology of eastern Milne Land, Scoresby Sund, East Greenland. *In* Report on the 1969 geological expedition to Scoresby Sund, East Greenland. *Rapp. Grønlands geol. Unders.* **30**, 37-42.

Funder, S. 1971: Observations on the Quaternary geology of the Rødefjord region, Scoresby Sund, East Greenland. *Rapp. Grønlands geol. Unders.* **37**, 51-55.

Gutenberg, B. 1951: *Internal constitution of the earth.* Dover Publ. Inc., 439 pp.

Iversen, J. 1953: Origin of the flora of western Greenland in the light of pollen analysis. *Oikos* **4**, 85-103.

Ives, P. C., Levin, B., Robinson, R. D. & Rubin, M. 1964: U.S. Geological Survey radiocarbon dates VII. *Radiocarbon* **6**, 37-76.

Jensen, A. S. 1917: Quaternary fossils collected by the Danmark Expedition. *Meddr Grønland* **43**, 21, 619-632.

Jessen, A. 1896: Geologiske Iagttagelser. *In* Opmaalingsexpeditionen til Julianehaabs Distrikt 1894. *Meddr Grønland* **16**, 2, 123-169.

Kelly, M. 1966: Quaternary deposits in the Frederikshåb district, South-West Greenland. *Rapp. Grønlands geol. Unders.* **11**, 35-36.

Kelly, M. 1969: Quaternary geology of Nordre Strømfjord and its environs. *Rapp. Grønlands geol. Unders.* **19**, 27 only.

Knuth, E. 1963: Rapport over den 2den Peary Land ekspedition. (Duplicated) 33 pp.

Knuth, E. 1964: Rapport over den 3die Peary Land ekspedition sommeren 1964. (Duplicated) 41 pp.

Knuth, E. 1967: Archaeology of the Musk-Ox Way. *Contr. Cent. Étud. arct. finno-scand.* **5**, 70 pp.

Koch, L. 1928: Contributions to the glaciology of North Greenland. *Meddr Grønland* **65**, 2, 181-464.

Kornerup, A. 1879: Geologiske Iagttagelser fra Vestkysten af Grønland (62° 15′–64° 15′ N.B.) *Meddr Grønland* **1**, 3, 77-139.

Krinsley, D. B. 1961: Late Pleistocene glaciation in northeast Greenland. *In* Raasch, G. O. (edit.) *Geology of the Arctic* **2**, 747-751.

Lasca, N. P. 1969: The surficial geology of Skeldal, Mesters Vig, Northeast Greenland. *Meddr Grønland* **176**, 3, 56 pp.

Laursen, D. 1944: Contributions to the Quaternary geology of northern West Greenland especially the raised marine deposits. *Meddr Grønland* **135**, 8, 125 pp.

Laursen, D. 1950: The stratigraphy of the marine Quaternary deposits in West Greenland. *Bull. Grønlands geol. Unders.* **2** (also *Meddr Grønland* **151**, 1), 142 pp.

Laursen, D. 1954: Emerged Pleistocene marine deposits of Peary Land (North Greenland). *Meddr Grønland* **127**, 5, Part 2, 26 pp.

Levin, B., Ives, P. C., Oman, C. L. & Rubin, M. 1965: U.S. Geological Survey radiocarbon dates VIII. *Radiocarbon* **7**, 372-398.

Noe-Nygaard, A. 1932: Remarks on *Mytilus edulis* L. in raised beaches in East Greenland. *Meddr Grønland* **95**, 2, 24 pp.

Pjetursson, H. 1898: Geologiske Optegnelser. *In* Opmaalingsexpeditionen til Egedesminde-Distrikt. *Meddr Grønland* **14**, 3, 288-347.

Preston, R. S., Person, E. & Deevey, E. S. 1955: Yale natural radiocarbon measurements II. *Science, N.Y.* **122**, 954-960.

Rink, H. 1853: Om den geographiske Beskaffenhed af de danske Handelsdistrikter i Nordgrönland [og] Udsigt over Nordgrönlands Geognosi. *K. danske Vidensk. Selsk. Skr.* Række 5, Naturv. math. Afd. **3**, 37-98.

Rosenkrantz, A. 1968: Interglaciale og postglaciale skalaflejringer fra Umanak distrikt. *Meddr dansk geol. Foren.* **18**, 146-147.

Rubin, M. & Alexander, C. 1960: U.S. Geological Survey radiocarbon dates V. *Am. J. Sci. Radiocarbon Suppl.* **2**, 129-185.

Saxov, S. 1958: Gravity in western Greenland from 66° N to 69° N. *Geod. Inst. Skr., Kbh.* Række 3, **29**, 34 pp.

Steenstrup, K. J. V. 1883: Bidrag til Kjendskab til de geognostiske og geographiske Forhold i en Del af Nord-Grønland. *Meddr Grønland* **4**, 5, 173-242.

Stuiver, M. 1969: Yale radiocarbon measurements IX. *Radiocarbon* **11**, 545-548.

Sugden, D. E. & John, B. S. 1965: The raised marine features of Kjove Land, East Greenland. *Geogrl J.* **131**, 235-247.

Tauber, H. 1960 a: Copenhagen natural radiocarbon measurements III, corrections to radiocarbon dates made with the solid carbon technique. *Am. J. Sci. Radiocarbon Suppl.* **2**, 5-11.

Tauber, H. 1960 b: Copenhagen radiocarbon dates IV. *Am. J. Sci. Radiocarbon Suppl.* **2**, 12-25.

Tauber, H. 1961: Danske Kulstof-14 dateringsresultater I. *Meddr dansk geol. Foren.* **14**, 386-405.

Tauber, H. 1964: Copenhagen radiocarbon dates VI. *Radiocarbon* **6**, 215-225.

Tauber, H. 1966: Copenhagen radiocarbon dates VII. *Radiocarbon* **8**, 213-234.

Tauber, H. 1968: Copenhagen radiocarbon dates IX. *Radiocarbon* **10**, 295-327.

[Tauber, H.] 1970 a: C^{14}-dates on post-glacial marine shells. *In* Report on the 1969 geological expedition to Scoresby Sund, East Greenland. *Rapp. Grønlands geol. Unders.* **30**, 43-44.

Tauber, H. 1970 b: The Scandinavian varve chronology and C^{14}-dating. *In* Olsson, I. U. (editor) *Proc. XIIth Nobel Symposium on radiocarbon variations and absolute chronology.* 173-196. Stockholm: Almqvist & Wiksell; New York: Wiley & Sons.

Trautman, M. A. 1963: Isotopes, Inc. radiocarbon measurements III. *Radiocarbon* **5**, 62-79.

Trautman, M. A. & Willis, E. H. 1966: Isotopes, Inc. radiocarbon measurements V. *Radiocarbon* **8**, 161-203.

Troelsen, J. C. 1952: Notes on the Pleistocene geology of Peary Land, North Greenland. *Meddr dansk geol. Foren.* **12**, 211-220.

Vogt, T. 1933: Late-Quaternary oscillations of level in southeast-Greenland. *Skr. Svalbard Ishavet* **60**, 44 pp.

Washburn, A. L. 1965: Geomorphic and vegetational studies in the Mesters Vig district, north-east Greenland. *Meddr Grønland* **166**, 1, 60 pp.

Washburn, A. L. & Stuiver, M. 1962: Radiocarbon-dated postglacial delevelling in northeast Greenland and its implications. *Arctic* **15**, 66-73.

Weidick, A. 1963: Ice margin features in the Julianehåb district, South Greenland. *Bull. Grønlands geol. Unders.* **35** (also *Meddr Grønland* **165**, 3) 133 pp.

Weidick, A. 1968: Observations on some Holocene glacier fluctuations in West Greenland. *Bull. Grønlands geol. Unders.* **73** (also *Meddr Grønland* **165**, 6) 202 pp.

Weidick, A. 1971: Quaternary map of Greenland 1: 2 500 000. Copenhagen: Geol. Survey Greenland.

Weidick, A. & Tenbrink, N. 1970: Quaternary deposits between the Sukkertoppen Ice Cap and Nordre Strømfjord. *Rapp. Grønlands geol. Unders.* **28**, 23-25.