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Quaternary geology and biology of the Jørgen Brønlund Fjord area, North Greenland

Ole Bennike

Geoscience
18 · 1987

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Ole Bennike

Contribution from
The Danish Peary Land Expeditions
Leader: Eigil Knuth

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OLE BENNIKE

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Prior to the last deglaciation, probably in the Late Weichselian, glaciers draining the Inland Ice were present in Independence Fjord and Jørgen Brønlund Fjord, and a glacier draining an ice cap in the north was present in the Børglum Elv valley. It is proposed that glacier fronts were situated at the mouth of Jørgen Brønlund Fjord during a halt in the deglaciation 8000-9000 years BP, and that this halt led to a low initial rate of emergence. Jørgen Brønlund Fjord was deglaciated 8000-7600 years BP. The early Holocene marine limit is *c.* 65 m above sea-level in the fjord, and *c.* 80 m east of the fjord. The slow initial rate of emergence was soon followed by rapid emergence. Emergence of the land continued until about 1000 years BP.

Part of the marine invertebrate fauna was established just after deglaciation. The same probably applies to the terrestrial flora and fauna. By 6000 years BP entry of driftwood and southern marine mammals began, and it continues today. Around 4000 years BP the Independence I people made their appearance, later the Independence II people and the Thule eskimos inhabited the area.

The geomorphological features show a resemblance to those from valleys in Antarctica.

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In the summer of 1982 the author participated in the 20th Peary Land Expedition under the leadership of Eigil Knuth. The expedition arrived at Jørgen Brønlund Fjord on 30 May. The author stayed at the Harald Moltke Station until departure on 3 August, except for a period (11–17 July) spent at the south side of the fjord.

The main objective of the work was to study the natural conditions facing the early hunting cultures in the area, and to map the Quaternary deposits and features. Apart from the author's own work, this report also comprises a review of earlier work on the Quaternary geology and related topics.

The location of Jørgen Brønlund Fjord is shown on Fig. 1, and some place names appear from Fig. 2.

Earlier investigations

A number of geologists have visited Jørgen Brønlund Fjord, but only scattered notes on the Quaternary geology have been published.

The first observations were published by Freuchen (1915), who noted raised beaches and a subfossil whale skeleton near Kap Harald Moltke. Koch (1928) presented a map showing raised post-glacial marine layers along the shores of Jørgen Brønlund Fjord, and a terminal moraine at the mouth of the fjord. During the Danish Peary Land Expedition 1947–50 observations on the Quaternary geology were made by Troelsen (1952). Troelsen concluded that an advance of valley glaciers postdated the marine deposits. A list of molluscs from the raised marine deposits, collected by members of the Danish Peary Land Expeditions, was published by Laursen (1954). Davies (1961a, b, 1963) described some periglacial features and dated the advance. In 1963 P. Kirkeby and B. Fredskild participated in the 2nd Peary Land expedition. Kirkeby (1963) concentrated on glacial geology, while Fredskild (1969, 1973) investigated the pollen stratigraphy in Klaresø.

Recently Weidick (1976a, b, 1977a, 1978b) and Funder & Hjort (1980) have made some notes on the Quaternary geology of the area.

The archaeology has been treated by E. Knuth in a number of papers, the most important being Knuth (1967, 1981).

Topography and bedrock geology

The landscape in the vicinity of Jørgen Brønlund Fjord is characterized by 7–800 m high plateaus, dissected by two major valleys. The most important is the east-west

Fig. 1. The location of Jørgen Brønlund Fjord in Peary Land, North Greenland.

Wandel Dal at the head of Jørgen Brønlund Fjord. To the north is the Børglum Elv valley which runs north-south. The valleys are glacially eroded troughs, whereas the plateau surfaces are gently rolling with pre-glacial river valleys.

Jørgen Brønlund Fjord is divided into two parts: an inner part, *c.* 15 km long and *c.* 2 km wide running east-west, and an outer, deeper part, *c.* 10 km long and 1–3 km wide running northwest-southeast. To the south of the fjord, the terrain rises gently, whereas to the north it rises abruptly, forming steep cliffs. To the north of the mouth of the fjord is a low lying plain. Geologically the area is situated in the platform region of north Greenland. The bedrock is formed by Proterozoic to Ordovician sediments, dominated by sandstones and carbonates. They dip slightly to the north-northeast, and are cut by a few vertical faults with small displacements (Jepsen 1971).

Climate

The climate is arctic. The summer is relatively mild, a period of 40–60 days without frost has been reported, and the mean July temperature is 4–6°C, whereas the mean temperature for the coldest month reaches below − 30°C. Precipitation is low (perhaps only about 100 mm/year) and strong winds are frequent, with a maximum wind speed of 40 m/s (Fristrup 1952, 1953, 1961, Knuth 1983b).

The area is situated in the zone of continuous permafrost. The thickness of the active layer may be up to 1 m, depending on moisture content and difference in snow cover.

Mapping

The mapping was done in the field using aerial photographs at a scale of *c.* 1:20000 from routes 625S, 625M and 625N. The results of the mapping are shown in Figs 3 and 6.

The following Quaternary deposits and features have been differentiated:

Talus. Coarse, angular material at the foot of cliffs, deposited at the angle of repose.

Till. Till occurs in a hilly area with dead-ice topography to the northeast of Jørgen Brønlund Fjord, and in small areas to the south of the fjord. The till is coarse with cobbles and boulders in a sandy matrix and is interpreted as a lodgement till. The thickness is probably small, up to a few metres. On the plateaus only small patches of till and scattered erratics are found.

Moraines. Some ridges to the south of Jørgen Brønlund Fjord are interpreted as moraine ridges from the last deglaciation.

Glacial striae. Orientations measured with a compass have been corrected for a declination of 45° west.

Glaciofluvial and fluvial gravel. River deposits form large plains in Børglum Elv valley and along the southern part of Jørgen Brønlund Fjord. The deposits consist of clast-supported imbricated gravel with a crude stratification. Grain size varies from boulders to pebbles. On the air photos longitudinal bars and channels are clearly visible even on the oldest plains, and the palaeocurrent direction is easily measured. This mapping unit also includes a few alluvial cones. The glaciofluvial deposits to the northeast of Kap Harald Moltke and along the south side of the fjord were deposited along the margins of glaciers.

The range of hills from Kap Harald Moltke to the southeastern corner of the plateau Buen is predominantly made up of laminated sand and silt, with a veneer of stones and boulders, and it is interpreted as a range of kames formed between a glacier in Jørgen Brønlund Fjord and one in the Børglum Elv valley.

Glacial meltwater channels. A number of meltwater

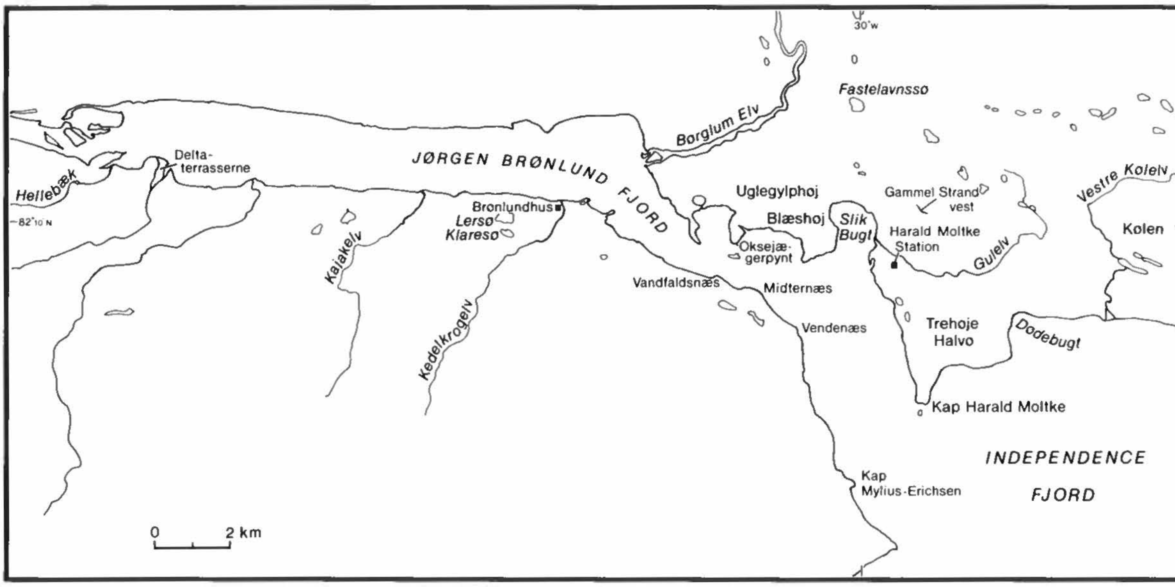


Fig. 2. Map of Jørgen Brønlund Fjord with localities mentioned in the text.

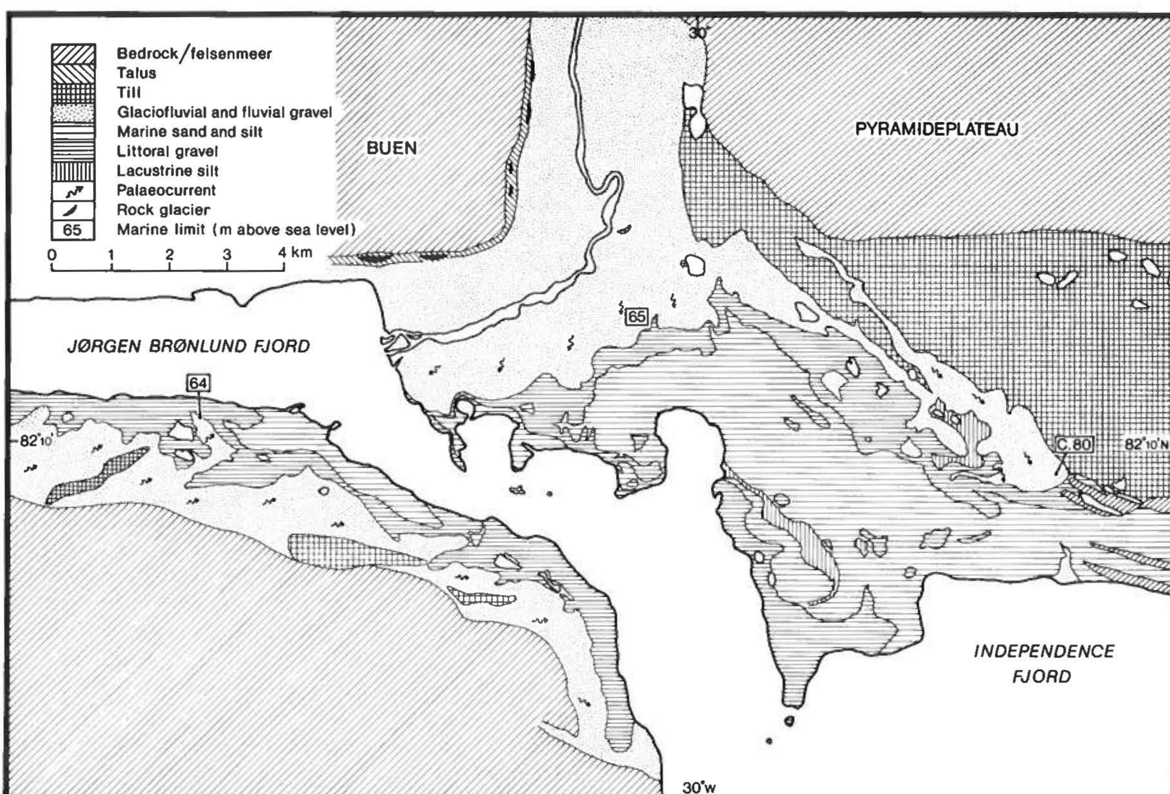


Fig. 3. Simplified Quaternary map of the outer part of the Jørgen Brønlund Fjord area. The till area to the south of Pyramideplateau shows dead ice topography. Topography according to Høy (1970).

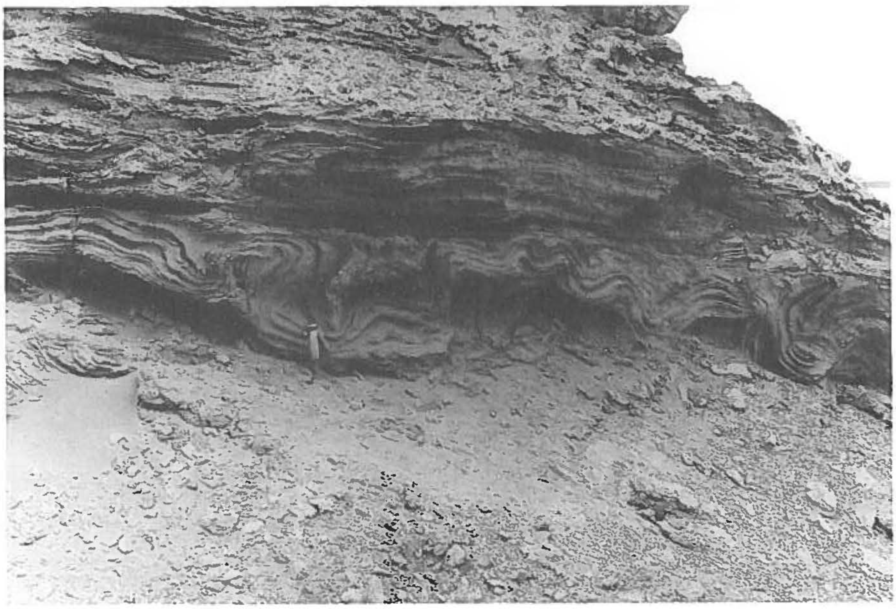


Fig. 4. Slump folds in front of the ancient, but intact delta slope of the proto-Børglum Elv. Slump folds are generally associated with rapid sedimentation, and the sediments are interpreted as proximal pro-delta deposits.

channels and meltwater canyons occur in the area. They were formed marginally to valley glaciers, and can be followed for up to several kilometres. Although oblique to the hill slope, many of them are at present occupied by small rivers.

Marine deposits. Large areas are covered by horizontally or subhorizontally laminated sand, silt and clay. Penecontemporaneous deformation structures are common (Fig. 4). Climbing ripple lamination has been observed in one locality. Stones and mollusc shells are rare in sections, but they often form a discontinuous veneer on the top of the sediment. A prominent badland topography has developed in these sediments.

Littoral gravel. This unit consists of well sorted, clast-supported gravel often with residual boulders, but with little matrix. Littoral gravel is developed in connection with raised or recent strand lines, beach ridges or narrow abrasion terraces.

Lacustrine silt. Such deposits occur in a few areas, notably on the Kap Harald Moltke peninsula, where a large natural airstrip is situated on the largest deposit. The silt has a smooth surface, and is laminated and without stones.

The only periglacial feature shown on the map (Fig. 3) is rock glaciers. However, felsenmeer are widespread on the plateaus. Some periglacial features are described in a later section.

Glaciation history

Koch (1923, 1928) concluded that the Inland Ice margin once extended *c.* 100 km to the north of its present margin, while the northern part of Peary Land was covered by a dynamically independent ice cap. Troelsen (1952) and Christie (1975) found evidence for Inland Ice glaciation on the plateaus to the north of Jørgen Brønlund Fjord, in the form of glacial erratics and till deposits. No glacial striae or other signs of glacial erosion from this phase of glaciation have been identified, as the surfaces of the plateaus are characterized by strong physical weathering leading to felsenmeer. This maximum glaciation has not yet been dated.

The raised Holocene marine deposits in the Kap Harald Moltke area are covered by a thin, more or less continuous layer of gravel, while gravel only rarely is met with in the sediments (Fig. 5). The thin gravel layer was interpreted as a "thin ground moraine" by Stoertz & Needlemann (1957), and it formed the basis for Davis' (1963) "late distinct glacier advance" originally dated to about 3700 years BP. Kirkeby (1963) thought that this advance was somewhat older, but that it still postdated the raised marine deposits.

It is possible, however, that the gravel layer is not the product of a glacial advance. The gravel is dominated by dolerite, Independence Fjord Group quartzite and granitoid gneiss from the Precambrian crystalline basement, an association of rock types which points to a southern provenance. It is suggested that the gravel is a surface lag concentrate of ice-rafted clasts left by deflation of the fine matrix. Academy Gletscher at the head of Independence Fjord produces many icebergs, some of which enter the outer part of Jørgen Brønlund Fjord. A glacier advance through Jørgen Brønlund Fjord would produce a till rich in dolomite from the Portfjeld Formation and sandstones from the Buen Formation. Furthermore, since no glacial disturbances have been observed in the marine deposits, it is assumed that no glaciers have been present in the area after deglaciation in the early Holocene.

Fig. 5. Marine sand and silt covered by a discontinuous layer of cobbly and bouldery gravel, which is interpreted as ice-rafted detritus. North of Dødebugt.

The later part of the glacial geological history is shown in Fig. 6. Traces of valley glaciers in Jørgen Brønlund Fjord, Independence Fjord and Børglum Elv valley are primarily recorded by glacial striae, by meltwater channels and by kame deposits. At *c.* 9000 years BP, marine deposits were laid down at the western end of Kølen.

The oldest dated shells along the shores of Jørgen Brønlund Fjord are *c.* 7600 years old. This period of 1400 years, between the dates of the oldest shells at Kølen and at Jørgen Brønlund Fjord, is the maximum duration of the major halt in the deglaciation, during which the glacier in Jørgen Brønlund Fjord had its front in the Kap Harald Moltke area.

Evidence for a neoglacial advance of glaciers has been obtained from Academy Gletcher (Koch 1928) and from Hagen Bræ (Funder & Hjort 1980). These glaciers advanced up to 20 km in the late Holocene.

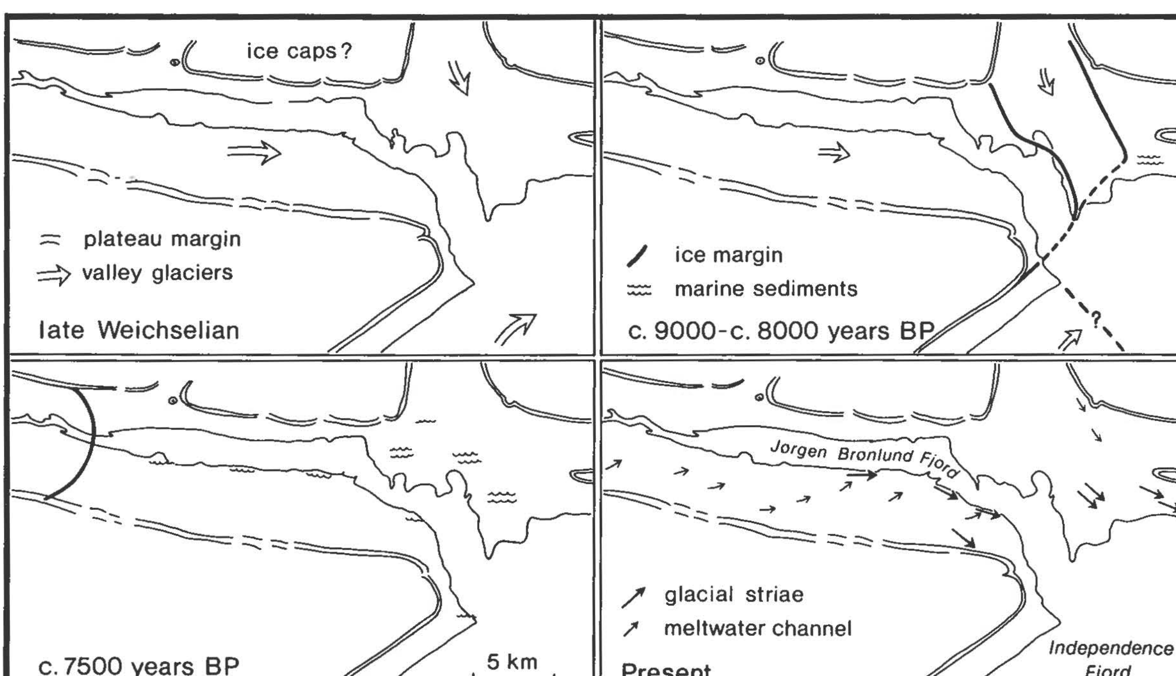


Fig. 6. Palaeogeography of Jørgen Brønlund Fjord during the last deglaciation. Sea-level by *c.* 8000 years BP was around 80 m above present sea-level, by *c.* 7500 years BP it was around 65 m above present.

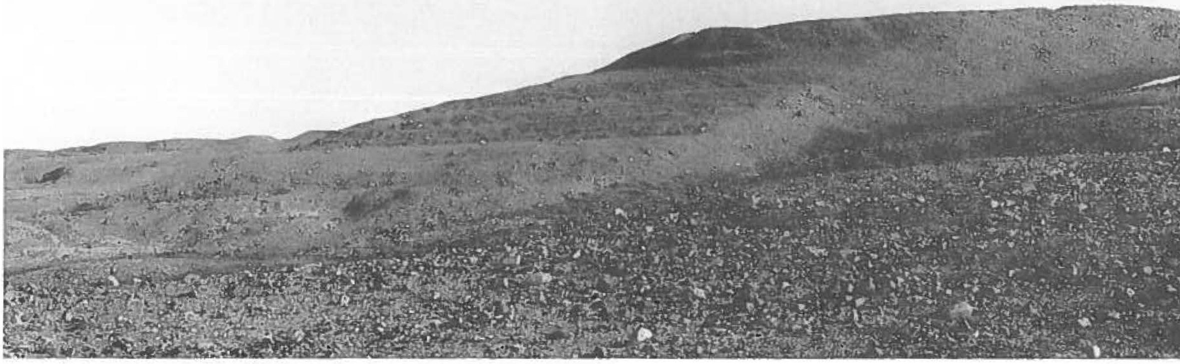


Fig. 7. Strand lines formed in a delta slope west of Vandfaldsnæs, to the south of Jørgen Brønlund Fjord.

Coastal morphology and sea-ice conditions

Jørgen Brønlund Fjord is covered by sea-ice from the beginning of September to the middle of July. During the first week of June, the littoral zone begins to thaw. When the fjord ice breaks up, ice floes drift around. During storms the floes pack on the shore, and may produce ice pack ridges, which are more or less tongue-shaped gravel ridges up to *c.* 2 m in height.

Some icebergs from Academy Gletscher at the head of Independence Fjord enter the outer part of Jørgen Brønlund Fjord, but are stopped by a threshold, and they do not reach the inner part of the fjord.

The strong westerly winds cause an easterly surface current in the fjord, which creates an easterly drift of sediment along the coasts. This is testified by several recurved spits. The westerly exposed coasts are characterized by beach ridges and small cliffs. The beach ridges are small, low-energy forms attaining maximum heights of 0.5 m.

The tidal range is about 30 cm (Johnsen 1953), and the tide hardly influences the morphology of the coasts; no ice foot is formed. The mouth of Gulelv draining into Slikbugt is funnel-shaped, but this appears to be an effect of wind set-up during westerly winds rather than an effect of tide.

Subfossil ice-pack ridges, beach ridges, beach lines and narrow abrasion terraces occur from present sea-level almost to the marine limit (Fig. 7). They are most conspicuous at localities exposed to the west. Their continuous occurrence from sea-level almost up to the marine limit, dated to *c.* 7600 years BP, shows that open water and westerly winds have characterized Jørgen Brønlund Fjord throughout this period. At several places the elevated beaches extend from the marine limit down to sea-level without significant change in slope, indicating that no significant stillstand or transgression took place during their formation in the mid and late Holocene.

Sea-level changes

Methods

Field altitudes were measured by hand-level and precision altimeter. Each point has been measured several times. The measurements have not been corrected for pressure and temperature, but only measurements carried out on days with no significant pressure changes have been used. The topographical map (Høy 1970) has provided many checkpoints. The uncertainty for measurements below 5 m above sea-level is estimated to ± 0.5 m, between 5 m and 100 m above sea-level to ± 2 m, and above 100 m to ± 5 m.

^{14}C-dates

A compilation of ^{14}C-dates from Jørgen Brønlund Fjord is presented in Table 1. Dates from both archaeological and Quaternary geological investigations are included.

All dates are given as conventional ^{14}C-dates. The bone dates have been carried out on the collagen fraction. All shell dates are corrected for isotopic fractionation by normalising to $\delta^{13}C$ = 0.0‰PDB (Funder 1978), and the conventional dates are corrected by − 150 years following Funder (1982) to allow for the sea-water reservoir effect. This value is probably about 35 years too large (Håkansson 1983).

No calibration of the dates with dendrochronology has been attempted.

Table 1. ^{14}C-dates from the Jørgen Brønlund Fjord area.

Lab. No.	Locality	Altitude m a.s.l.	^{14}C age yr BP	Corrected age	Dated material	Reference
I-9688	Uglegylphøj	40–45	>35600		Wood	Weidick 1977b, 1978b
K-1445	Uglegylphøj	*c.* 45	>35000		Wood, *Picea* sp.	Fredskild 1969, Tauber pers. comm.
K-4028	Fastelavnssø	53	24680±540[1]		Driftwood, *Picea* sp.	This study
K-4031	Vestre Kølelv	73–76	9160±95[2]	9010	*Port arctica, H. arctica*	This study
I-311	North of Kølen?	?[3]	8550±250	8400	*Hiatella arctica*	Trautman & Willis 1966
K-3865	Kajakelv	?	7980±115		Reindeer antler	Knuth 1983a
K-4030	Fastelavnssø	61	7740±85[4]	7590	*H. arctica, M. truncata*	This study
K-965	Brønlundhus	27	7740±130	7590	*M. truncata*	Knuth 1964, pers. comm.
I-9665	Børglum Elv	40–45	7710±120	7560	*M. truncata*	Weidick 1978a
I-9615	Trehøje Halvø	45±5	7420±120	7270	*H. arctica, M. truncata*	Weidick 1977b
K-3285	Kedelkrogelv	26–27	7390±110	7240	*M. truncata, H. arctica*	Funder 1982
K-964	Lersø	32–33	7290±130	7140	*M. truncata*	Knuth 1964
K-4029	Fastelavnssø	58	7170±100[5]	7020	*H. arctica, M. truncata*	This study
K-868	Klaresø[6]	40.3	6850±140		Basal gyttja	Fredskild 1973
K-4348	J. Brønlund Fjord	?	6240±100		Reindeer antler	Meldgaard 1986
I-9118	Kap Harald Moltke	12	6235±110	6085	*M. truncata*	Weidick 1977b
Y-19	J. Brønlund Fjord	?	5870±100	5530	Driftwood	Preston et al. 1955
I-9116	Kap Harald Moltke	17	5680±110	5450	*Astarte borealis*	Weidick 1977b
I-9117	Kap Harald Moltke	?2–5	5600±110		*M. truncata*	Weidick 1977b
K-3866	Kap Harald Moltke	?	5470±95	5220	Reindeer antler	Knuth 1983a
W-555	Kap Harald Moltke	12	5370±200		Shells	Rubin & Alexander 1960
W-1073	Kap Harald Moltke	11	4970±260	4775	Driftwood	Ives et al. 1964
I-309	Kap Harald Moltke	8	4925±150		*M. truncata*	Trautman & Willis 1966
K-754	Deltaterrasserne	21.2	4540±120		Charcoal, *Picea* sp.	Tauber 1964, Knuth 1967
K-755	Deltaterrasserne	14.0	4140±120		Charcoal, *Picea* sp.	Tauber 1964, Knuth 1967
K-928	Portfjeld	?	3890±120		Charcoal, *Salix* sp.	Tauber 1966, Knuth 1967
K-929	Portfjeld	?	3860±120		Charcoal, *Salix* sp.	Tauber 1966, Knuth 1967
K-3364	Midternæs	12.8	3830±85		Musk-ox bones	Knuth 1981
K-1062	Vendenæs	11.8	3800±120		Charcoal, *Salix* sp.	Knuth 1967
K-930	Portfjeld	?	3790±120		Charcoal, *Salix* sp.	Tauber 1966, Knuth 1967
K-932	Vandfaldsnæs	11.0	3780±120		Charcoal, *Salix* sp.	Tauber 1966, Knuth 1967
K-1061	Vendenæs	12.3	3760±120		Charcoal, *Salix* sp.	Knuth 1967
K-4059	Near Brønlundhus	?	3710±80		Reindeer antler	Knuth 1983a, Meldgaard 1986
K-1196	Gammel Strand vest	14.3	3620±110		Charcoal, *Salix* sp.	Knuth 1967, 1981
I-9129	Kap Harald Moltke	11–12	3585±100		Driftwood	Weidick 1977b
I-9119	Kap Harald Moltke	11–12	3450±90		Driftwood	Weidick 1977b
K-150	Deltaterrasserne	10.0	3290±130		Driftwood	Tauber 1961, Knuth 1967
K-933	Vandfaldsnæs	6.4	3180±110		Charcoal, *Larix* sp.	Tauber 1966, Knuth 1967
K-934	Vandfaldsnæs	6.4	2740±100		Charcoal, *Picea* sp.	Tauber 1966, Knuth 1967
K-1059	Hellebæk	6.0	2510±110		Charcoal, *Salix* sp.	Knuth 1967, 1981
K-3363	K. Mylius-Erichsen	5.9	2430±75		Musk-ox bones	Knuth 1981
K-3867	Paralleldal	?	2080±75		Reindeer antler	Knuth 1983a

1: Date is average of two measurements 24130±630 and 25240±710, $\delta^{13}C=-22.6‰$. 2: Date is average of two measurements 9150±130 and 9170±135, $\delta^{13}C=+1.7‰$. 3: See text. 4: $\delta^{13}C=+1.6‰$. 5: $\delta^{13}C=+0.9‰$. 6: Nine ^{14}C-dates on gyttja samples from Klaresø are at hand.

Marine limit

The Quaternary map (Fig. 3) shows the height of the marine limit. It has been determined on the basis of the height of the distal part of fluvial deposits forming topset beds in glaciomarine Gilbert deltas. The topset beds rest on foreset and bottomset beds. The last-mentioned consist of silt and sand often with marine molluscs *in situ*.

The marine limit is seen to fall from *c.* 80 m above sea-level in the east to *c.* 65 m above sea-level in the west. This rapid fall is assumed to reflect the invasion of the sea following the halt in deglaciation in the early Holocene. Based on the ^{14}C-dates the marine limit is assigned a Holocene age.

At Øvre Midsommersø to the west of Jørgen Brønlund Fjord pre-Holocene wood, probably redistributed by glaciers, has been found *c.* 90 m above sea-level (Fredskild 1969, Funder & Hjort 1973). If this wood does not originate from local Plio-Pleistocene deposits (Funder et al. 1984), but represents interglacial exotic driftwood, sea-level in pre-Holocene time must have stood at a higher level than has been the case in Holocene time. Reported traces of such an old, high sea-level at Jørgen Brønlund Fjord have not been confirmed by this study, although Troelsen (1949a, 1952) reported terraces at an altitude of 113 m above sea-level at the mouth of Jørgen Brønlund Fjord. However, he did not conclude what sort of terraces they were: "It

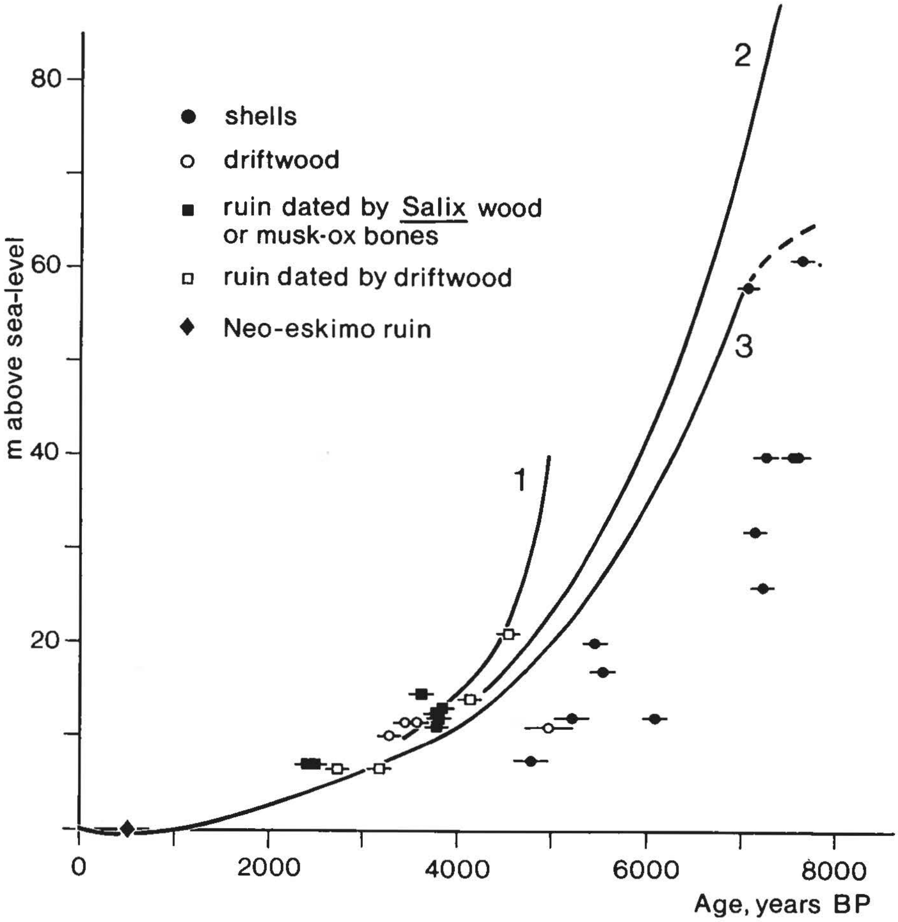


Fig. 8. Emergence curves from Jørgen Brønlund Fjord. Ruin dates from Musk-ox bones and local *Salix* wood are considered more reliable than ruin dates from driftwood. The horizontal bar shows the 2σ counting error. 1: Fredskild (1969), 2: Weidick (1972), 3: this study. Curve plotted by eye. Note that the marine limit is at 65 m above sea-level.

may thus be an open question whether these features really are marine deposits and not for instance kame terraces" (Troelsen 1952, p. 215). Davies (1963) found "major, marine terraces" also at the entrance to Jørgen Brønlund Fjord at an altitude of 129 m above sea-level. Funder & Hjort (1980) however found that some of the "marine terraces" of Davies were of a non-marine origin, and this probably applies also to the high-lying terraces at the mouth of Jørgen Brønlund Fjord.

To conclude, earlier reported marine features above the marine limit as shown in Fig. 3 are believed to be non-marine features, produced along the margins of glaciers.

Emergence

The emergence curve (Fig. 8) shows the development of sea-level relative to the present since deglaciation. No correction for eustatic changes has been made.

Two emergence curves have previously been published for the area. Fredskild (1969) presented a curve based on charred wood found in palaeo-eskimo ruins at different altitudes, and on basal gyttja in Klaresø. Weidick (1972) presented a curve based on shell dates, corrected for an apparent age of 1200 years thought to be caused by contamination of the shells by calcium carbonate from the calcareous bedrock in the area. Recent dating of a sample of modern shells has not substantiated the reality of this correction (Funder 1982).

The curve presented in Fig. 8 takes into account the fact that the marine molluscs lived below sea-level, whereas the eskimo dwellings were situated above sea-level. Driftwood is deposited at sea-level, but it is easily redeposited after initial deposition, and only driftwood embedded in beach gravel ought to be used. It appears that most of the shells have been collected far below their corresponding sea-level. It must be admitted, that the data points allow many different curves to be constructed.

Two dates (I-311 and K-4031) are excluded because the samples have been collected to the east of Jørgen Brønlund Fjord, in an area which experienced a different history from that of Jørgen Brønlund Fjord proper. Furthermore, the altitude and location of I-311 is uncertain. The sample was collected "on the north flank of Kølen at an altitude of 255 feet [*c.* 78 m] above sea level" (Trautman & Willis 1966). During fieldwork in 1982 no shells or other marine features were located north of Kølen, and the area is higher than 150 m.

The curve deviates from other Greenland curves by its low initial uplift rate (compare Funder 1978, Kelly 1985). The evidence for this feature is weak, but it might be supported by the two samples from Kølen. Although this area experienced a different history from that of Jørgen Brønlund Fjord, the difference in emergence rates must be small, because the Kølen area is situated less than 10 km east of Kap Harald Moltke. If the two samples were to be plotted on the emergence curve they would support the proposed low initial uplift rate. It is suggested that the low initial emergence rate reflects the early Holocene halt in deglaciation.

By 7000 years BP relative sea-level began to fall rapidly – by 20–25 m/1000 years. During the Independence I period sea-level fell from *c.* 11 m to *c.* 9 m above the present, and during the Independence II period from *c.* 7 m to *c.* 4 m. A small rise in sea-level in the late Holocene is demonstrated by a Thule eskimo ruin on the south coast of Jørgen Brønlund Fjord which has been transgressed by the sea. This transgression was probably caused by the neoglacial growth of the Inland Ice.

Driftwood

35 pieces of driftwood were located during the fieldwork. It is presumed that the driftwood has been transported to North Greenland from Siberia by the Transpolar Drift although some may have reached the region from North America with the Beaufort Sea Gyre. Anatomical identifications of the driftwood have been carried out in order to attempt to establish the provenance of the driftwood. Unfortunately, identifications are generally only possible at the generic level. 32 pieces were identified accordingly: *Populus* sp. (3), *Larix* sp. (19), *Picea* sp. (6), *Larix/Picea* (4). The three genera grow in Siberia as well as in North America.

The average rate of drift by the Transpolar Drift route is about 600 km/year, and with a distance of 3000 km the driftwood will need only about 5 years to cross the ocean (Häggblom 1982). This estimate is confirmed by ^{14}C-dates of driftwood from recent coasts often giving modern ages (Blake 1972, 1975). For most of the year the wood will be carried by the ice, but some wood will come afloat in summer time, and some of this might sink because of water-logging. In periods with much open water in the Arctic Ocean during the summer much wood is believed to sink (Häggblom 1982).

The driftwood is deposited during storms, when maximum sea-level is attained. Some of the driftwood pieces at Jørgen Brønlund Fjord were incorporated in beach ridges consisting of gravel, but most pieces were lying on the surface of the sediment, which often consists of raised, marine silt. Several processes may redeposit the wood after its initial deposition. Direct or indirect gravitational forces will tend to move it downslope, especially if the wood is deposited on high-angle slopes. Ice packing on the coast can move the wood some metres upwards, and wind can move small pieces upwards or downwards. Also eskimos are known to have moved driftwood pieces.

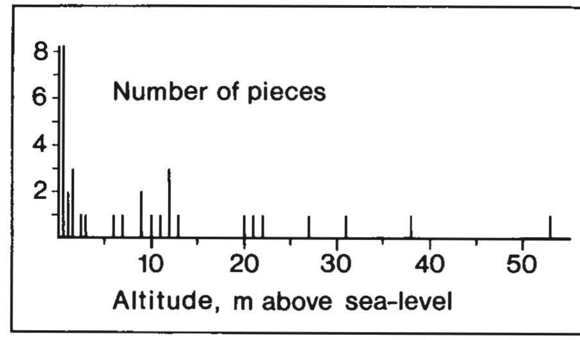


Fig. 9. The distribution of driftwood at different altitudes. The piece at 53 m above sea-level is pre-Holocene and ^{14}C-dated to *c.* 25 ka.

The field altitude for the observed driftwood is shown in Fig. 9. Driftwood is rather common along the present coast-line probably because of stable or slightly transgressing sea-level during the past *c.* 1000 years. The highest piece of driftwood, which was found 53 m above sea-level, turned out to be pre-Holocene (Table 1, K-4028: 24680 ± 540 years BP). The next highest piece is dated by the emergence curve to approximately 6000 years BP in agreement with the oldest Holocene ^{14}C-dated piece (Y-19: 5870 ± 100 years BP from an unknown altitude). A level from 9 to 13 m above sea-level appears to be a zone with much driftwood, but the material is too sparse to allow any definite conclusions.

Nine ^{14}C-dates on Holocene driftwood are available, four of which have been made on charred driftwood from palaeo-eskimo ruins (Fig. 10). The field altitude for the oldest dated non-charred wood is unknown. The remaining 4 non-charred pieces have been collected at 10 to 12 m above sea-level and have given ^{14}C-dates between 4970 ± 260 years BP and 3290 ± 130 years BP. The youngest dated sample (charred) has a ^{14}C-date of 2740 ± 100 years BP, but driftwood common at lower altitudes is presumably younger.

On Svalbard driftwood is far more common than at Jørgen Brønlund Fjord (e. g. Häggblom 1982). Consequently it is not the ice conditions in the Arctic Ocean which are responsible for the sparse occurrence at Jør-

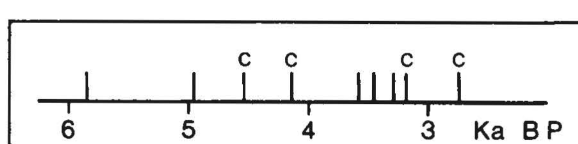


Fig. 10. ^{14}C-dates on Holocene driftwood. c: charred wood from palaeo-eskimo ruins. (Only one date of each group).

gen Brønlund Fjord, but rather the fact that the entrance through Independence Fjord is blocked by ice which only rarely breaks up (Koch 1945). Only when this happens will driftwood from the Arctic Ocean be able to reach Jørgen Brønlund Fjord.

The oldest ^{14}C-dated Holocene driftwood on Svalbard is 9850 ± 80 years old (GSC-3039, Salvigsen 1979) and on northern Ellesmere Island it is 8915 ± 115 years old (S-2211, Stewart & England 1983). Accordingly driftwood was present in the Arctic Ocean in the early Holocene, and it must be the sea-ice conditions in Independence Fjord or the drift pattern in this part of the Arctic Ocean which hindered the driftwood in reaching Jørgen Brønlund Fjord in the period from deglaciation to *c.* 6000 years BP. Whether there have been variations in the amount of driftwood entry after 6000 years BP cannot be decided on the basis of the present material, although driftwood appears to have been most common in the later part of the period, and perhaps during a period corresponding to a sea-level 9–13 m above the present.

The sea-ice conditions in Independence Fjord are only partly controlled by climate. As compared with other North Greenland fjords, it appears that the production of icebergs by the glaciers at the head of the fjord is important. Many icebergs in the fjord cool down the water and hamper the possibility of break-up of the sea ice.

Samples from an occurrence of wood near Uglegylphøj have given infinite ^{14}C-dates. This wood has been interpreted as interglacial driftwood (Weidick 1978b), but it might also originate from local Plio-Pleistocene deposits (Funder et al. 1984).

The driftwood date of 24680 ± 540 years BP (K-4028) is problematical. The sample consisted of a branch 20 cm long and 6 cm in diameter. According to the ^{14}C-laboratory the sample had a very careful treatment to remove humus, and the date is considered reliable (H. Tauber, pers. comm.). The questions are: 1) Where did spruce grow 25 ka ago? It probably did not grow in Beringia at this time, but survived in North America somewhere south of the Laurentide ice sheet (Hopkins et al. 1981), and in southern Europe (Van der Hammen 1979). However, the genus probably persisted in northern Asia (Frenzel 1968), and this area is the most likely source area. 2) When was the spruce wood transported to North Greenland? Did it lie somewhere to the south before transport to North Greenland in the early Holocene, or was it transported to North Greenland *c.* 25 ka ago? In the latter case it must have been redeposited, because it was found lying on the surface of marine silt at an altitude of 53 m above sea-level, a level which constituted the coast about 6800 years ago, according to the emergence curve. The amount and timing of isostatic rebound indicates a rather extensive glaciation in the latest part of the Weichselian, and drift of the wood to the area after deglaciation in the early Holocene is proposed.

Subfossil marine invertebrates

Table 2 presents a summary of the species collected and Fig. 11 shows the sampling localities. Laursen (1954) published a list of molluscs collected by members of the Danish Peary Land Expeditions, and some further information is published in Weidick (1977b, 1978a) and Bennike et al. (1986).

List of invertebrates, with comments

The modern distributions of the species referred to below are primarily based on Lemche (1914a, b), Ockelmann (1958) and Thorson (1944, 1951).

Cyclogyra foliaceae is a large disc-shaped foraminifer which measures 3–5 mm across. It often occurs together with *Portlandia arctica* and *Actinula greenlandicum*. *C. foliaceae* attains its greatest size in arctic waters, but it is also distributed in boreal waters (Feyling-Hanssen 1964).

Trichotropis borealis is the most common gastropod, found at 7 localities. The shells show large morphological variation. The species has a panarctic, circumpolar distribution with boreal outposts. It is known from numerous localities in the Arctic, where it constitutes part of the northernmost faunas. It is common along West Greenland where it has been taken as far north as Hall Land, and along East Greenland where it has been taken between Ammassalik and Danmarkshavn. It has been recorded at depths from 5,5 m to 944 m, and it is primarily an infauna element in the *Macoma calcarea* community.

Natica clausa was found at three localities, abundant at one, situated 4 m above sea-level. The species has a panarctic, circumpolar distribution, and is common along the arctic coasts. In West Greenland it has been taken along the whole coast, and in East Greenland between Lindenow Fjord and Danmarkshavn, at depths between 0 m and 2430 m. *N. clausa* is an infauna species which is most common in the *Arca-Astarte crenata* community.

Oenopota sp. *Oenopota* is a taxonomically difficult genus with a confusing nomenclature. The material from Jørgen Brønlund Fjord comprises at least two species. The genus was found in small numbers at a few localities. It is predominantly an arctic and boreal genus.

Cylicna alba was found in 6 localities in small numbers. The uppermost occurrence was situated 15 m above sea-level. The species is widely distributed in arctic seas. It has been taken along the entire West Greenland coast, and along East Greenland between Lindenow Fjord and Danmarkshavn, at depths from 2.5 m to 23 m. It is most common in the *Macoma calcarea* community.

Cylicna occulta was represented by a single, slightly fragmented shell found 1 m above sea-level. The distribution of this species is panarctic, circumpolar. In West Greenland it has been dredged between lat. 71°40'N and lat. 66°35'N, and in East Greenland between Lindenow Fjord and Danmarkshavn, at depths between 2.5 m and 23 m. It is specially connected with the *Macoma calcarea* community.

Siphonodentalium lobatum was found at 3 localities, up to 23 m above sea-level. It occurred in small numbers only. The species is widely distributed in arctic, boreal and northern lusitanian areas. In East Greenland it is found in the *Arca-Astarte crenata* community (Spärck 1933).

Nuculana pernula was found in 4 localities in small numbers. Highest occurrence was at 15 m above sea-level. The species has a panarctic-boreal, circumpolar distribution. It has been taken in West Greenland from Qaqortoq (Julianehåb) to Etah and in East Greenland from Lindenow Fjord to Jørgen Brønlund Fjord. The species has been found at depths from 3 m to

Table 2. Subfossil marine invertebrates from the Jørgen Brønlund Fjord area

Geological Institute Sample No.	Field altitude m above sea-level	Formanifera	*Cyclogyra foliacea* (Philippi)	Gastropoda	*Trichotropis borealis* Broderip & Sowerby	*Natica clausa* Broderip & Sowerby	*Oenopota* sp.	*Cylichna alba* (Brown)	*Cylichna occulta* (Mighels)	Scaphopoda	*Siphonodentalium lobatum* (Sowerby)	Bivalvia	*Nuculana pernula* (Leche)	*Portlandia arctica* (Gray)	*Portlandia frigida* (Torell)	*Arca glacialis* Gray	*Actinula greenlandicum* (Sowerby)	*Astarte borealis* (Chemnitz)	*Thyasira gouldi* (Philippi)	*Hiatella arctica* (Linné)	*Mya Truncata* Linné	*Thracia devexa* G. O. Sars
53002	53		–		–	–	–	–	–		–		–	–	–	–	–	–	–	s	c	–
53004	2		s		s	–	–	s	–		s		–	–	–	f	s	f	–	f	f	s
53005	58		s		–	–	–	–	–		–		–	f	–	–	–	–	–	–	s	–
53008	8		–		–	–	–	–	–		–		–	–	–	c	–	f	–	f	f	–
53011	15		–		–	–	–	s	–		–		–	–	–	–	–	–	–	–	–	–
53013	10		–		s	s	–	–	–		–		–	–	–	–	–	f	s	f	f	–
53014	½		–		–	–	–	–	–		–		–	f	–	–	–	–	–	–	–	–
53017	60		–		–	–	–	–	–		–		–	–	–	–	–	–	–	f	s	–
53024	1		–		s	–	–	–	–		–		–	s	–	–	–	–	–	–	–	–
53027	15		–		–	–	s	s	–		s		s	–	s	f	s	f	s	f	f	–
53028	3		–		–	–	–	–	–		–		–	–	–	–	f	–	–	–	–	–
53033	1.5–4		–		s	–	–	–	–		–		–	–	–	–	–	–	–	–	–	–
53034	22		–		–	s	–	–	–		–		–	s	–	–	–	c	–	f	c	–
53037	61		–		–	–	–	–	–		–		–	–	–	–	–	–	–	c	c	–
53039	71		c		–	–	–	–	–		–		–	f	–	–	–	–	–	s	–	–
53043	65		–		–	–	–	–	–		–		–	–	–	–	–	–	–	c	c	–
53044	59		–		–	–	–	–	–		–		–	–	–	–	–	–	–	c	c	–
53051	1		–		c	–	s	s	–		s		–	s	–	s	–	s	s	s	c	–
53058	½		–		s	–	–	–	–		–		–	–	–	–	–	–	–	–	–	–
53061	50		–		–	–	–	–	–		–		–	–	–	–	–	–	–	s	c	–
53063	73–76		–		–	–	–	–	–		–		–	f	–	–	–	–	–	s	–	–
53064	56		–		–	–	–	–	–		–		–	–	–	–	–	–	–	f	s	–
53065	53		s		–	–	–	–	–		–		–	–	–	–	–	–	–	c	c	–
53072	4		–		c	c	s	s	s		–		s	s	–	s	s	c	s	c	c	–
53079	13		–		–	–	–	–	–		s		s	–	s	c	s	c	s	f	c	s
53081	53		–		–	–	–	–	–		–		–	–	–	–	–	–	–	s	–	–
53083	14		s		–	–	–	s	–		–		s	s	–	–	s	s	s	s	f	–
53087	21		–		–	–	–	–	–		s		–	–	–	–	–	–	–	c	c	s
53090	54		–		–	–	–	–	–		–		–	–	–	–	–	–	–	c	c	–

f: frequent, c: common, s: scarce

1275 m. It lives mainly on a bottom of clay or mud, being most common in the *Macoma calcarea* community.

Portlandia arctica occurred locally in abundance as the absolutely dominating species, or as an infrequent member of other subfossil communities. The uppermost occurrence was located in a deposit of silt at a height of 76 m above sea-level. The species has an arctic and circumpolar distribution; in West Greenland it is known from the Thule area, along the East Greenland coast it is known between Jørgen Brønlund Fjord and Miki Fjord (lat. 68°10'N). The species is most common at depths between 10 m and 50 m, but it has been taken between 2–3 m and 339 m. *Portlandia arctica* lives in a bottom of mud or clay, its optimal habitats are in front of rivers and glaciers in areas with a high sedimentation rate. The species is thus considered an indicator of environment rather than climate (Funder 1978).

Portlandia frigida was represented by 3 shells found at two localities. The species probably has a high-arctic distribution, and is confined to the North Atlantic sector. In West Greenland it has been taken between Maniitsoq (Sukkertoppen) and the southern part of Melville Bugt and in East Greenland from the Kangerdlugssuaq area to Jørgen Brønlund Fjord. The species lives in a bottom af clay, mud or clay mixed with gravel, and it has a vertical range from 5–25 m to *c.* 400 m.

Arca glacialis was rather common up to about 15 m above sea-level. Its distribution is Arctic and it is confined to the North Atlantic sector. The species has a vertical depth range from 1 to 573 m or even *c.* 4000 m, but it is most common below 40 m. *Arca glacialis* is an epifaunal species and it generally lives on a bottom af clay with stones and gravel in the *Arca-Astarte crenata* community.

Actinula greenlandicum was rather frequent, even though its very thin and delicate shells are quickly eroded and the species is probably underrepresented in the subfossil faunas. *A. greenlandicum* has a panarctic (probably circumpolar) distribution,

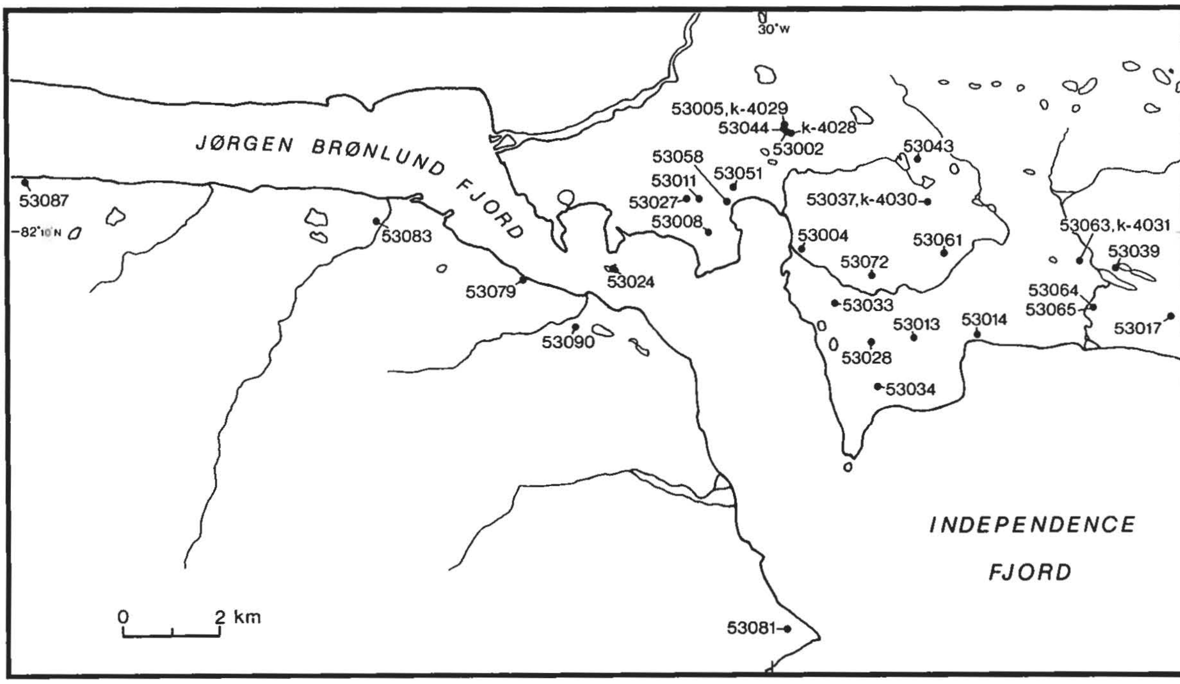


Fig. 11. Localities where invertebrate marine faunas have been collected. Numbers refer to the fauna list, Table 2. The figure also indicates the position of the ^{14}C-dated samples K-4028 to K-4031.

in West Greenland it has been dredged between Uummannaq and Kap York and in East Greenland between Lindenow Fjord and Jørgen Brønlund Fjord, at depths between 4–5 m and 2000 m, being most common at depths between 20 m and 60–70 m. The species is most abundant in the lower part of the *Macoma calcarea* community, where it prefers a bottom of clay with stones, gravel or shells.

Astarte borealis was common, at some localities it was the dominant species. It has a panarctic, circumpolar distribution with boreal outposts. In West Greenland it has been dredged between Qaqortoq (Julianehåb) and Etah, and in East Greenland between Lindenow Fjord and Jørgen Brønlund Fjord. Its depth range is from *c.* 0 m to 463 m. *A. borealis* is an important constituent of the infauna within the *Gomphina fluctuosa* and *Macoma calcarea* communities, where it is most abundant in a bottom of clay, silt or sand.

Thyasira gouldi was found at 6 localities, but it may have been overlooked to some degree because of its small size. The species has a panarctic, probably circumpolar distribution. In West Greenland it has been taken along the whole coast as far north as Thule, and in East Greenland between Lindenow Fjord and Jørgen Brønlund Fjord at depths between 2–3 m and 385 m, but it is rare at depths exceeding 50 m. *T. gouldi* inhabits the uppermost layers of clayey or silty bottoms, reaching its greatest abundance in the *Macoma calcarea* community.

Hiatella arctica is the most common subfossil mollusc species, and is especially abundant in silty sediment with scattered stones. A few individuals were found in the highest deposit with molluscs at 76 m above sea-level. The species is probably cosmopolitan. It is widely distributed and very common in arctic waters, and it is known from the whole of Greenland's east and west coast, at depths from 0 to 2200 m. It belongs to the infauna as well as the epifauna.

Mya truncata is almost as common as *H. arctica*, but it was not met with in the highest fossiliferous deposits. The shells vary much in shape, showing all transitions from typical *M. truncata* to *M. truncata* var. *uddevalensis* Forbes. The species has a panarctic, circumpolar distribution. It has been dredged along the entire east and west coast of Greenland, at depths from 0 m to 625 m. The older animals are deeply burrowing in clay, silt, sand or gravel in the *Macoma calcarea* community, whereas the young animals are part of the epifauna.

Thracia devexa was a rare species, which was only met with at 3 localities in small numbers. The highest occurrence was situated 21 m above sea-level. Soot-Ryen (1941) has pointed out the diagnostic features for this species, which probably has a high-arctic distribution and it is confined to the Atlantic sector. It is known to occur in East Greenland between Lindenow Fjord and Jørgen Brønlund Fjord, at depths from 10–15 m to about 95 m. Contrary to *T. myopsis* this species penetrates into the inner parts of the fjords. *Thracia myopsis* was mentioned by Laursen (1954), but the shells kept in the collections of the Geological Museum of Copenhagen, belong to *T. Devexa*.

Finally it should be mentioned that burrows are present in the marine deposits. They are 5–10 cm long, *c.* 4 mm in diameter and subvertical and rarely branch. They can be attributed to the activity of crustaceans or polychaetes.

The subfossil fauna is less diverse than corresponding Holocene faunas from West Greenland (Laursen 1950, Símonarson 1981) and East Greenland (Jensen 1917, Noe-Nygaard 1932, Funder 1978).

The shells are very well preserved, often with the periostracum intact. This applies even for the most elevated, oldest fossiliferous deposits. The dominance of the thick shelled *Hiatella arctica* and *Mya truncata* therefore must reflect an original feature. These two species are often found in life position on the surface of raised marine silt with the posterior end exposed (Fig. 12) as the surrounding sediment has been eroded away by water.

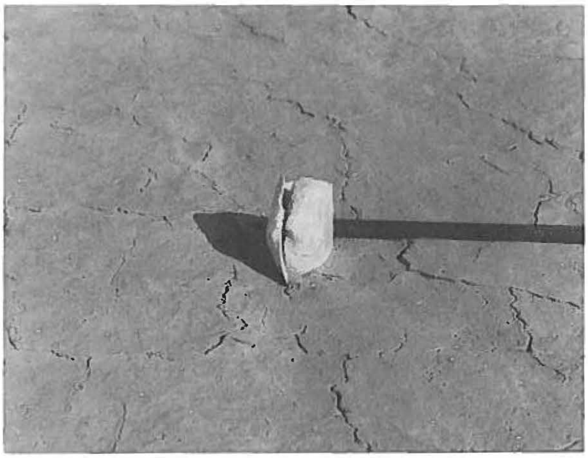


Fig. 12. *Mya truncata* with paired shells and in life position on the surface of marine silt. The surrounding sediment has been removed by meltwater streamlets and by wind erosion. Shells of *Mya truncata* and *Hiatella arctica* are often preserved in this spectacular way. West of Slikbugt.

The overall fauna points to the occurrence of euryhaline waters since deglaciation. The species lived in sublittoral waters at shallow to intermediate depths. Most of the species were members of the infauna.

It is not possible to base a stratigraphy on the subfossil molluscs, although it seems that *Portlandia arctica* and *Hiatella arctica* were the only species present in the area immediately after deglaciation. *Mya truncata* followed soon, whereas the other species immigrated later.

Almost nothing is known about present day marine molluscs from the northern coasts of Greenland. Sampling has however been carried out in Jørgen Brønlund Fjord and a list of bivalves is available (Ockelmann in Andersen & Dietz 1984). All the subfossil bivalve species occur in the fjord today, and this probably applies to the other molluscs as well.

Notes on the vegetational history

Information on the Holocene vegetation history of Peary Land comes from palaeoecological studies of one lake deposit and two peat deposits (Fredskild 1969, 1973, Bennike 1983). The lake (Klaresø) is situated at the south coast of Jørgen Brønlund Fjord, 45 m above sea-level. The ^{14}C-dates obtained on gyttja from the lake were originally corrected by − 1900 years to allow for pre-Quaternary carbonate (Fredskild 1969). Even though carbonates make up the bedrock in the major part of the area, this correction factor is probably too large (Fredskild 1985). According to the emergence curve (Fig. 8) Klaresø was isolated from the sea about 6300 years BP, but according to the corrected ages sediment did not begin to form until 5000 years BP, implying a hiatus of 1300 years. Therefore it is suggested, that a much smaller correction should be applied to the ^{14}C-dates, and that gyttja deposition in the lake began *c.* 6300 years BP. A reindeer antler from Jørgen Brønlund Fjord ^{14}C-dated to *c.* 8000 years BP (Table 1) shows that vegetation was already established at this early date.

Subfossil vertebrates

A number of bones from excavated Independence I and Independence II ruins have been identified, although systematic analyses have not been carried out (Knuth 1967, 1968, 1981, U. Møhl, pers. comm.). No bones have been found in ruins from the Thule culture at Jørgen Brønlund Fjord. Scattered bones lying on the surface of the ground are rather frequent. Such bones decay very slowly and may be hundreds, or probably thousands of years old. All bones are considered Holocene. Table 3 provides a list of species found in the area.

Notes on taxa not present in the area today

Brent Goose *Branta bernicla*. Bones of this species are rather common in the Independence I and Independence II ruins around Jørgen Brønlund Fjord. Today Brent Goose is only a rare visitor in the region (Meltofte 1976), but in the beginning of this century it was apparently common (Johnsen 1953). This pattern probably reflects the species' drastic decline during this cen-

Table 3. Subfossil vertebrates from the Jørgen Brønlund Fjord area.

	Independence I	Independence II	Unknown age
Char *Salvelinus alpinus*	×	×	
Long-tailed Duck *Clangula hyemalis*	×	×	
King Eider *Somateria spectabilis*	×		
Brent Goose *Branta bernicla*	×	×	
Barnacle Goose *Branta leucopsis*	×		
Rock Ptarmigan *Lagopus mutus*	×		
Knot *Calidris canutus*	×		
Ivory Gull *Pagophila eburnea*	×		
Glaucous Gull *Larus hyperboreus*	×	×	
Kittiwake *Rissa tridactyla*	×		
Wolf *Canis lupus*			×
Arctic Fox *Alopex lagopus*	×		
Polar Bear *Thalarctos maritimus*			×
Walrus *Odobenus rosmarus*		(×)	×
Ringed Seal *Pusa hispida*	×	×	×
Reindeer *Rangifer tarandus*	(×)	(×)	×
Musk-ox *Ovibos moschatus*	×	×	×
Narwhale *Monodon monoceros*			×
?Greenland Whale *Balaena mysticetus*			×

Based on Freuchen (1915), Kirkeby (1963), Knuth (1967, 1968, 1981 and pers. comm.), Johnsen (1953) and this study.

tury (Salomonsen 1958, Atkinson-Willis & Matthews 1960).

Barnacle Goose *Branta leucopsis*. A single bone fragment has been recorded from an Independence I ruin (Knuth 1967). In East Greenland the species breeds as far north as Skærfjorden, lat. 76°N (Salomonsen 1981), but it has not been met with in North Greenland.

Kittiwake *Rissa tridactyla*. One record of bones from an Independence I ruin is available (Knuth 1981). The nearest breeding place in recent time was at Mallemukfjeldet, lat. 80°N, but this place is now abandoned (Hjort et al. 1983).

Reindeer *Rangifer tarandus*. Some small fragments of antler have been excavated from Independence I and Independence II ruins (Knuth 1967), which however might originate from old, shed antlers or have been brought to Jørgen Brønlund Fjord from other regions by the palaeo-eskimos. Rare, strongly weathered, shed antlers show that the species has previously populated the area, from which it has now disappeared. A few of these antlers have been ^{14}C-dated, giving ages of *c.* 8000, 6200, 5500, 3700 and 2100 years BP (Table 1). The oldest antler was found at the beach, at a place which was covered by the sea in early Holocene, and the possibility can not be excluded that this antler is ice-rafted from somewhere else in North Greenland or from outside Greenland. However, it is much more likely that it is of local origin.

Johnsen (1953) has proposed that Reindeer became extinct at an earlier date in Peary Land than in East Greenland, where the last animals were seen in 1899 (Degerbøl 1957).

Walrus *Odobenus rosmarus*. A number of artifacts made of Walrus tusk and Walrus rib have been recovered from Independence II ruins (Knuth 1968). These artifacts may have been brought to the area from other regions. Two almost complete skeletons have been found (E. Knuth, pers. comm., H. F. Jepsen, pers. comm.), both lying only a few metres above sea-level, which implies a relatively young age. Walrus occurs today along East Greenland northwards to Kilen in Kronprins Christian Land, lat. 81°N (C. Hjort, pers. comm.).

Narwhal *Monodon monoceros*. An almost complete skeleton has been found northwest of Kap Harald Moltke (Grant 1972). It was partly submerged and is probably of subrecent age.

?Greenland Whale *Balaena mysticetus*. Freuchen (1915) records a number of whale bones, referred with hesitation to *Balaena mysticetus*, *c.* 10 m above sea-level near Kap Harald Moltke. These bones have not been found again, but part of a skeleton of a big whale, presumably a Greenland Whale, has been found near Uglegylphøj at an altitude of 46 m above sea-level (E. Knuth, pers. comm.). According to the emergence curve (Fig. 8) this skeleton would be about 6000 years old. Greenland Whale has almost been exterminated by European whalers in the North Atlantic.

From the foregoing it can be seen that a number of terrestrial and marine species now absent have been recorded as subfossils in the area. Various explanations can be offered for these occurrences. Bones of Barnacle Goose and Kittiwake might have been imported to the area by the palaeo-eskimos, as their limb bones are used for the manufacture of needles (Knuth 1967).

The marine mammals Walrus, Narwhal and Greenland Whale might have been only accidental visitors rather than regular migrants. These species are only able to reach Jørgen Brønlund Fjord if Independence Fjord is more or less free of sea ice. It is proposed that the finds date from about 6000 years BP till today, i.e. during the same period as when driftwood reached the area.

The only species which appears to have lived in the area during much of the Holocene, and which has been totally absent during this century is the Reindeer.

Archaeology

Jørgen Brønlund Fjord has been inhabited during three phases, by the Independence I people (*c.* 3950–3600 years BP), by the Independence II people (*c.* 3100–2400 years BP) and by the Thule Culture people (*c.* 550–450 years BP). The cultural phases are most reliably dated by Musk-ox bones found in the ruins (Knuth 1967, 1981).

The characteristic ruin of the Independence I and II people has a mid-passage hearth. Chert implements are often present at the ruins. Some harpoon heads have been found in Independence II ruins, whereas none have been excavated in Independence I ruins. Another difference between these cultures is that the needles of the Independence I period have a round eye, whereas those from the Independence II period have an oblong eye. The so-called cloven-hoofed lance head is restricted to the Independence II culture.

The palaeo-eskimos primarily hunted Musk-ox but Ringed Seal was also an important game animal for the Independence II people. Both cultures fished for Arctic Char.

Many tent rings and shelter ruins are left from the Thule Culture eskimos, but the ruins usually contain no implements, maybe because they have been occupied for brief periods only. The Thule Culture eskimos were specialized at seal and whale hunting, but they also hunted Musk-ox. Unlike the palaeo-eskimos they used sledge dogs.

It should be emphasized that house ruins have never been located in Peary Land. The same applies to graves or remains of the people themselves.

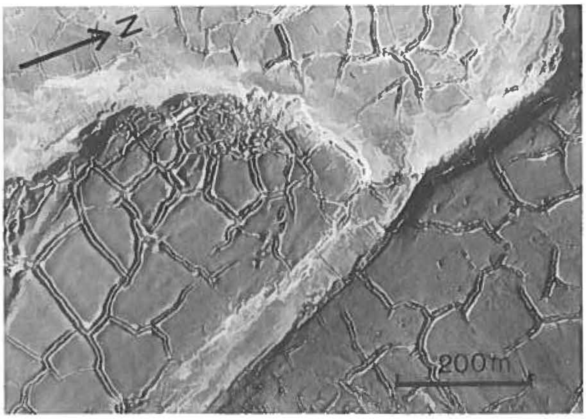


Fig. 13. Sand-wedge polygons on gravelly outwash plain west of Jørgen Brønlund Fjord. Geodetic Institute, Copenhagen, enlarged part of aerial photo 625M No. 6786, 1950.

Periglacial features

Sand-wedge polygons

On the surface of the ground old frost wedges appear as troughs flanked by raised rims, whereas young wedges have troughs without raised rims. The troughs may reach a width of several metres, and the rims a height of two metres. The wedges are especially conspicuous in gravel deposits, where the polygons measure 40–80 m across (Fig. 13), but wedges are also locally developed in bedrock (Fig. 14, Davies 1961b). Here the polygons measure 20–40 m across.

The width of the troughs and the height of the rims reach maximum sizes in the most coarse-grained gravel deposits. No large-scale polygons are developed in silt deposits. In Antarctica Berg & Black (1966) found that the size of the crack grew with the age of the sediment. The same appears to be true for the cracks at Jørgen Brønlund Fjord. Previously Péwé (1974) has classified the frost wedges in the lower part of the Børglum Elv valley as sand-wedges.

This study showed that some frost wedge cracks are filled by stones from the sides of the cracks and by wind-blown sand (Fig. 15), but ice-wedges or combined ice-sand-wedges may also be present.

On the Kap Harald Moltke peninsula and along Slikbugt the marine silt in some places is cut by parallel, more or less straight, vertical joints, with an interval of 15–20 cm. The directions of the joints are determined by the local small-scale topography and vary accordingly from place to place. The joints are probably due to shrinkage of the silt (Christie 1975), and they are thought to represent a modified orthogonal pattern.

Solifluction

As in other arctic areas solifluction is of great importance in the Jørgen Brønlund Fjord area. Especially the raised marine and littoral deposits are strongly solifluсted. Over large areas strand lines and beach ridges are completely obliterated. Often solifluction lobes have low ridges at their fronts (Fig. 16) Normally the movement has stopped, but in a few cases quite fresh forms are present. No dating of the time of movement is possible.

Landslides, where movement has taken place along a well defined plane, and where the transported material has moved as a coherent block, also occur in connection with the raised marine deposits. Strand lines and beach ridges are more or less intact, although not always horizontal, and they are truncated at the plane of the landslide.

Rock glaciers

At the foot of the plateaus around Jørgen Brønlund Fjord are some arcuate bodies interpreted as rock gla-

Fig. 14. Sand-wedge in ice polished and water-washed dolomite of the Portfjeld Formation, at the western end of Kølen, with the Pyramideplateau in the background.

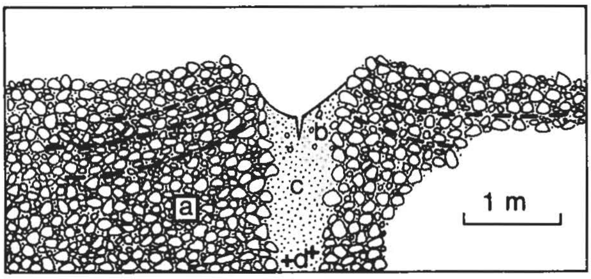


Fig. 15. Section through a sand-wedge on a glaciofluvial terrace in the Børglum Elv valley. a: crudely stratified glaciofluvial gravel, b: aeolian sand with scattered pebbles which have fallen down from the sides, c: pure aeolian sand, d: perenially frozen sand at greater depths than *c.* 1.6 m. Note the small recent fissure in centre of wedge.

ciers (Figs 3 and 17). The bodies are located below screes and their surface consists of talus material. They have a steep front, varying from the angle of repose up to 40°. The top part of the front terminates in a sharp crest, behind which is a depression. Very large boulders occur scattered on the top part of the bodies. On the surface of one of the rock glaciers arcuate ridges and furrows are present. In another frost-wedge polygons have developed, showing that this rock glacier is inactive. These rock glaciers resemble rock glaciers from Svalbard described by Swett et al. (1980).

Wind action

Jørgen Brønlund Fjord is a windy place, where very high wind velocities are frequent. Because of the local topography only easterly and westerly winds are possible. Easterly winds are the most common, but all strong winds are from the west; the latter often occur as foehn winds. The average wind velocity in winter may reach 30 m/s, whereas in summer 20 m/s is reached (Fristrup 1953).

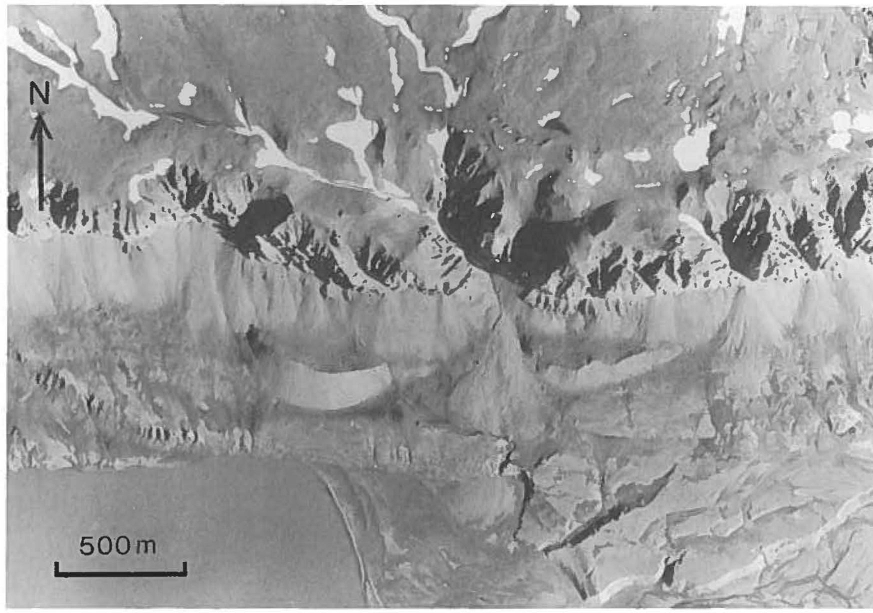
During the winter temperatures are around – 25°C to – 40°C. Ice-needles at these low temperatures reach a hardness of 3–4 on Mohs' hardness scale (Koch & Wegener 1930, Teichert 1939), and have some erosive power. However, apart from ice-needles the wind also carries sand and silt, with a hardness of 7 in the case of quartz, and this material probably accounts for the greater part of the wind erosion, which is very pronounced in places exposed to the west wind. Stones and boulders are strongly polished, and in some cases ventifacts are formed.

The boulders of the palaeo-eskimo ruins, which are usually placed on exposed localities, are also eroded by the wind. One tent ring on Blæshøj has boulders nearly reduced to half-size. This ruin is *c.* 4000 years old, and only the western faces of the boulders are eroded – they had not been eroded before they were used. This implies that only a short period has elapsed from the time when they were raised above sea-level till their removal by the palaeo-eskimos.

Wind is also an important agent in the development of cavernously weathered boulders (Fig. 18), as these are strictly confined to the most wind-swept places, and because the caverns are only developed on the upwind faces of the boulders. The process of cavernous weathering is little understood, but the primary agent is thought to be chemical weathering, caused by hydration or crystallization of soluble salts, and the wind only removes rock meal which has collected around altered ba-

Fig. 16. Solifluction lobe to the west of Oksejægerpynt, in the immediate vicinity of a neo-eskimo ruin site. The degraded appearance of the lobe indicates that it is probably older than the ruin site.

Fig. 17. Two rock glaciers near the southeastern corner of the Buen plateau. The rock glaciers are arcuate in vertical view, but are classified as lobate rock glaciers. In the lower left is Jørgen Brønlund Fjord, in the upper part is Buen, at an altitude of around 650 m. Geodetic Institute, Copenhagen, enlarged part of aerial photo 256-L, No. 697, 1960.



sal parts (Wellman & Wilson 1965, Calkin & Nichols 1972, Péwé 1974). Cavernous weathering at Jørgen Brønlund Fjord is most typical of sandstones.

Aeolian sand and silt deposits occur scattered in the area, but the larger part of this material is carried out into Independence Fjord. Small dunes are present in Børglum Elv valley at the mouth of Paralleldal and at Deltaterrasserne, and minor deposits have accumulated in sheltered places, for instance behind hills, big boulders and in sand-wedges.

Sulphur deposits

Connected to the early Cambrian dolomitic Portfjeld Formation are a number of sulphur precipitations, originally thought to be solfataras by Troelsen (1949a; Fig. 19). Their colour is sulphur yellow, they vary in size from small spots 10 cm in diameter, up to small mounds *c.* 10 m in diameter and 1–2 m heigh. Mineralogically, they consist of sulphur, gypsum, copiapite, pyrite and fibroferrite (Troelsen 1949a). The sulphur deposits are developed by chemical weathering of dolomite with concentrations of pyrite (Troelsen 1949b, 1954).

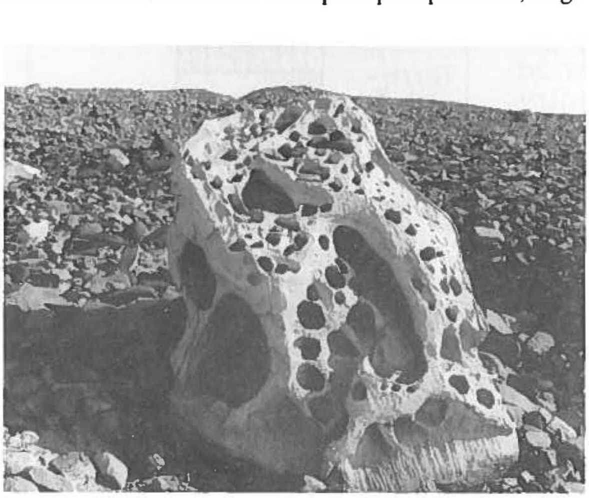


Fig. 18. Cavernously weathered/wind eroded boulder north of Kap Harald Moltke. These bolders may attain very spectacular forms.

Polar desert

To the botanist a desert is an area with little or no plant cover, caused by an arid climate. It has been shown that temperature, rather than water, is generally the limiting factor to vegetation in the high Arctic (Edlund 1983). At Jørgen Brønlund Fjord most precipitation is in winter as snow, which either is blown out into Independence Fjord, or accumulates in snow drifts. Consequently a mosaic of wet and dry plant communities are formed, although the wet areas are small compared to the dry ones.

To the geomorphologist, deserts are characterized by such features as saline lakes, surface and subsurface efflorescences of salts, and desert varnish. In Jørgen Brønlund Fjord carbonate encrustations are developed on the undersides of clasts, and efflorescence of salts on the surface of the raised marine deposits is common. The presence of these features, however, may have been favored by permafrost (Swett 1974). Some lakes on the raised marine sediments have a high content of leached sodium-chloride, but salt lakes proper are not present (Røen 1968).

It is suggested from regional considerations that low temperatures and strong winds in combination with limestone hostile to vegetation, are the primary causes

Fig. 19. One of the biggest "solfataras" in a group to the south of Jørgen Brønlund Fjord, situated 220 m above sea-level.

for the desert-like nature of the Jørgen Brønlund Fjord area, whereas low precipitation relative to evaporation only is of minor importance. It should be emphasized that the desert-like nature is of a very restricted areal extent in eastern North Greenland, being confined to valley bottoms in the interior parts of the region.

Summary and conclusions

Only scanty information is available about the pre-Holocene history of the area. Wood with infinite ^{14}C-age is interglacial driftwood or originates from Plio-Pleistocene local vegetation. By correlation with other parts of

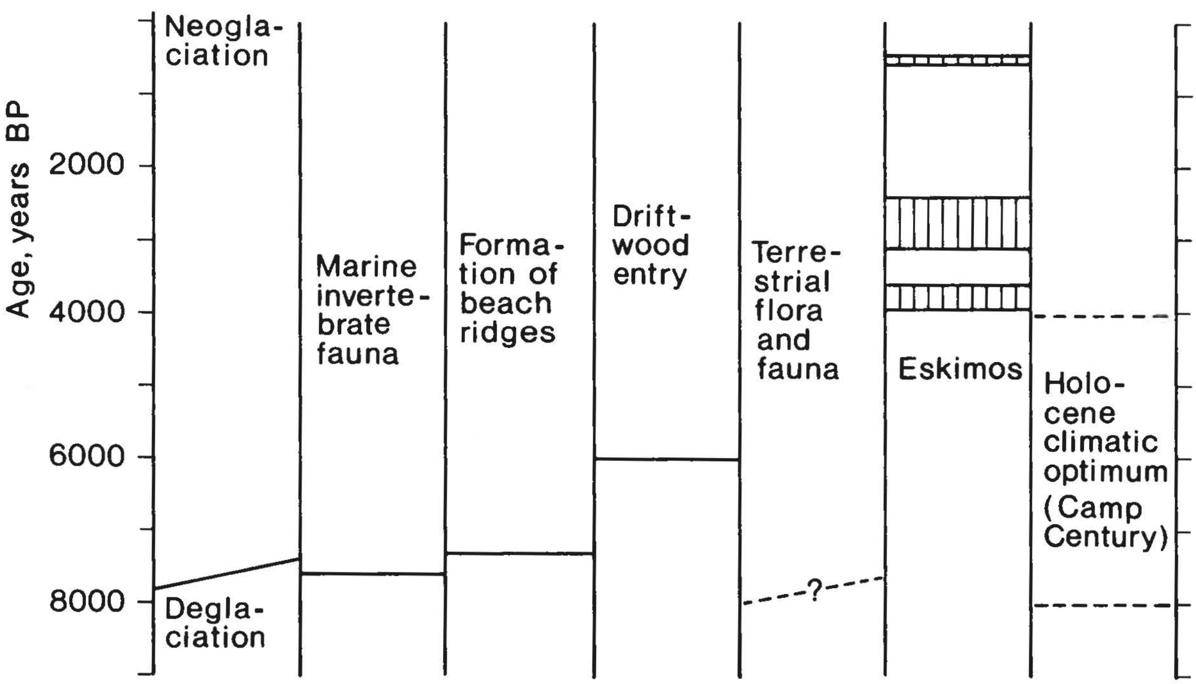


Fig. 20. Summary of the natural conditions of the Jørgen Brønlund Fjord area during the Holocene. Camp Century record according to Dansgaard et al. (1971), eskimo chronology based on Knuth (1981).

North Greenland, the maximum glaciation is tentatively dated as pre-Eemian (Kelly & Bennike 1985). The height of the Holocene marine limit at 65–80 m above sea-level points to a considerable thickness of ice also during the mid or late Weichselian.

A summary of the Holocene events in the Jørgen Brønlund Fjord area is shown in Fig. 20. At 9000 years BP marine sediments accumulated to the east of Jørgen Brønlund Fjord. The oldest dated marine sediments at the shores of Jørgen Brønlund Fjord are 7600 years old, and it is suggested that glacier fronts were situated at the mouth of Jørgen Brønlund Fjord for a considerable period in the early Holocene. Following deglaciation the sea invaded, and with it a fauna at first poor in species.

By *c.* 6000 years BP some glacier fronts in eastern North Greenland were up to 20 km behind their present position (Funder & Hjort 1980), and terrestrial and limnic floras and faunas were richer than today.

No climatic influence on the marine environment has been documented. Driftwood entry probably did not begin until *c.* 6000 years BP.

The strong westerly winds that are typical of Jørgen Brønlund Fjord today, have prevailed since deglaciation, but for the first centuries beach ridges were not formed, perhaps due to heavy sea-ice conditions. No horizons of especially large raised beach ridges are present, and the emergence is therefore thought to have been smooth.

During the last 4000 years the area has been inhabited by eskimos during three periods. The natural conditions during these periods may have deviated only slightly from the present. Positive evidence for a warmer climate or for less severe sea-ice conditions is lacking.

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