Leipziger Geowissenschaften	Band 19	S. 1-22	14 Abb.	2 Tab.	Leipzig, September 2008

Late Pleistocene and Holocene environmental history of northeastern Geographical Society Ø, East Greenland, inferred from Loon Lake's sediment record

M. Klug & B. Wagner

Abstract: A sediment sequence from Loon Lake, Geographical Society Ø, East Greenland, was geophysically, sedimentologically, biogeochemically, and biologically investigated in order to reconstruct the entire history of the lake. The chronology of the 10.25 m long sequence is based on three AMS ^{14}C dating performed on marine fossils. In the basal part of the sedimentary record a diamicton represents the deposition during the Last Glacial Maximum. Subsequent to deglaciation at c. 10,250 cal. yr BP Loon Lake area was inundated by the sea and marine sediments were deposited. A turbidite interspersed into the marine sediments at around 8300 cal. yr BP could be a result of the Storegga Tsunami or of increased meltwater supply after the 8.2 kyr BP cooling event. Marine sedimentation continued at least until c. 7500 cal. yr BP, when the isostatic rebound terminated this state. Full limnic conditions became established at c. 6000 cal. yr BP. Compared with other studies in this area such a late isolation is presumably a result of the delayed retreat of the fjord-filling outlet glacier in the Kejser Franz Josephs Fjord. The climate history documented in the Loon Lake sediments is widely masked by the sea-level history.

Zusammenfassung: *Eine Sedimentsequenz aus dem Loon Lake, Geographical Society Ø, Ostgrönland, wurde geophysikalisch, sedimentologisch, biogeochemisch und biologisch untersucht, um die komplette Geschichte des Sees zu rekonstruieren. Die Chronologie der 10,25 m langen Sequenz basiert auf drei AMS Radiokohlenstoff-Datierungen, die an marinen Fossilien durchgeführt wurden. Der untere Teil des Sedimentrekords repräsentiert die Ablagerungen während des letzten glazialen Maximums. Nach dem Eisrückzug um ca. 10250 Jahren vor heute wurde die Loon Lake Region von einer Transgression erfasst und marine Sedimente wurden abgelagert. Ein Turbidit, der in die marinen Sedimente um ca. 8300 Jahre vor heute eingelagert ist, könnte das Ergebnis des Storegga Tsunamis oder von erhöhtem Schmelzwassereintrag nach dem Abkühlungsereignis vor 8200 Jahren vor heute sein. Die marine Sedimentation hielt bis ca. 7500 Jahre vor heute an und wurde durch die isostatische Ausgleichsbewegung beendet. Rein limnische Bedingungen stellten sich um etwa 6000 Jahre vor heute ein. Im Vergleich zu anderen Untersuchungen der Region könnte diese relativ späte Isolierung das Ergebnis eines verzögerten Eisrückzuges des den Kejser Franz Josephs Fjord ausfüllenden Gletschers gewesen sein. Die Klimageschichte im Sedimentrekord des Loon Lake ist weitestgehend von der marinen Geschichte überlagert.*

Keywords: Paleolimnology, East Greenland, transgression, environmental history, late Quaternary

Anschrift der Autoren: **Martin Klug, Bernd Wagner**
Institut für Geologie und Mineralogie, Universität zu Köln
Zülpicher Str. 49a, D-50674 Köln

e-mail: mklug@uni-koeln.de
wagnerb@uni-koeln.de

1. Introduction

Because East Greenland is a very remote area, only a few studies have been carried out so far to investigate the extent of the glaciation during the Late Pleistocene and Holocene in this region. Also, little is known about the time and procedure of deglaciation and the postglacial climatic and environmental history. The present knowledge is derived from investigations of ice cores, geomorphological features, and marine and lacustrine sediment sequences.

Ice cores drilled on the central Greenland Ice Sheet and on the Renland Ice Cap revealed the most detailed information about the Weichselian and Holocene climate development (ALLEY et al. 1993, JOHNSEN et al. 1992, DANSGAARD et al. 1993). Marine studies on the glacial limits in the fjords and on the shelf are in general based on seismic measurements (DOWDESWELL et al. 1994, EVANS et al. 2002). Supplementary information obtained by the amounts of ice-rafted debris indicates glacial oscillations (MARIENFELD 1990, Ó COFAIG et al. 2001). However, due to the low sedimentation rates, most marine sedimentary records are characterised by a low time-reso-lution. Onshore studies conducted in East Greenland focus predominantly on the investigation of geomorphological features, the occurrence of fossils, and lacustrine sediments. These studies enabled the reconstruction of the glacial extensions, and the periods of glacial recessions and advances in East Greenland (HJORT 1979, FUNDER et al. 1994, FUNDER & HANSEN 1996). The investigations revealed a succession of glacial retreats, advances, and interspersed marine transgressions during Pleistocene and Holocene times. The last significant events at the Pleistocene/Holocene transition were the glaciation of the outer fjord region during the Preboreal Oscillation at c. 11,300-11,150 cal. yr BP, and a subsequent marine transgression during times of glacier recession (FUNDER 1978, HJORT 1979, BJÖRCK et al. 1997). Dating of marine shells from Kap Mackenzie (Fig. 1) suggests that at least parts of the coastal area of Geographical Society Ø remained ice-free during the Last Glacial Maximum (HJORT 1979).

In contrast to marine studies, sediment records from presently existing lakes have a much higher time resolution and enable therefore a detailed reconstruction of the Holocene environmental and climatic history (BATTARBEE 2000). First lakes investigated from East Greenland were rather shallow, with water depths of less than 10 m, in some cases less than 5 m, and therefore wave-action, thick lake-ice cover and/or lake level fluctuations likely have affected the sediments. The studies carried out on sediment sequences from these lakes focused mainly on palynology. Within the last few years, however, an increasing number of studies used a multidisciplinary approach, combining sedimentological, biogeochemical, and biological methods (FUNDER 1978, BJÖRCK et al. 1994b, FREDSKILD 1995, BENNIKE & FUNDER 1997, BENNIKE et al. 1999, WAGNER et al. 2000, WAGNER & MELLES 2002).

Loon Lake, with a maximum water depth of 11.7 m, provides rather undisturbed sediments. The investigation of its sedimentary record by using a multidisciplinary approach that combines geophysical, sedimentological, biogeochemical, and biological methods allows a detailed reconstruction of the environmental history of Loon Lake region. Because Loon Lake is located at the outer coast of East Greenland where ice free regions are reported to have occurred during the Last Glacial Maximum, valuable information to (i) the time and the procedure of deglaciation of the Loon Lake area; (ii) the coincident marine transgression; and (iii) the climatic development of the Loon Lake vicinity during the Holocene can be obtained.

2. Study area

Geographical Society Ø (GSØ) is located off East Greenland at 72°40'-73°04'N and 021°52'-024°35'W (Fig. 1). The island is bordered by the Sofia Sund and the Kejser Franz Josephs Fjord to the north, the Vega Sund to the south, and the Cambridge Bugt to the east. The topography of GSØ is dominated by a mountainous landscape in the central and western parts. Towards the centre of the island, the landscape ascends to an elevation of 1700 m above sea level (a.s.l.). The eastern and southern parts predominantly feature a hilly topography, descending towards the coast. Along the eastern coast several ridges with elevations of up to 100 m a.s.l. separate local basins. The drainage system is adapted to the topography and consists of a large number of small rivers and streams. Seasonally water bearing, this drainage system feeds several lakes and ponds on the island (Fig. 1).

Loon Lake is located 18 m a.s.l. on the northeasternmost part of GSØ within a ridge-separated catchment area of about 15-20 km^2. Towards the west of the lake, the landscape gently ascends to 500 m a.s.l. The vicinity towards the south, east, and north has an undulating surface with maximum elevations of up to 50 m a.s.l.

Echosounding along two crossing profiles revealed that Loon Lake, measuring approximately 1.5 km in diameter, has a simple basin structure with a maximum water depth of 11.7 m in the center of the lake. Two smaller inlets on the western and northwestern lakeshore and the major inlet on the southern lakeshore enter the lake. The outlet is in the northeastern part of the lake

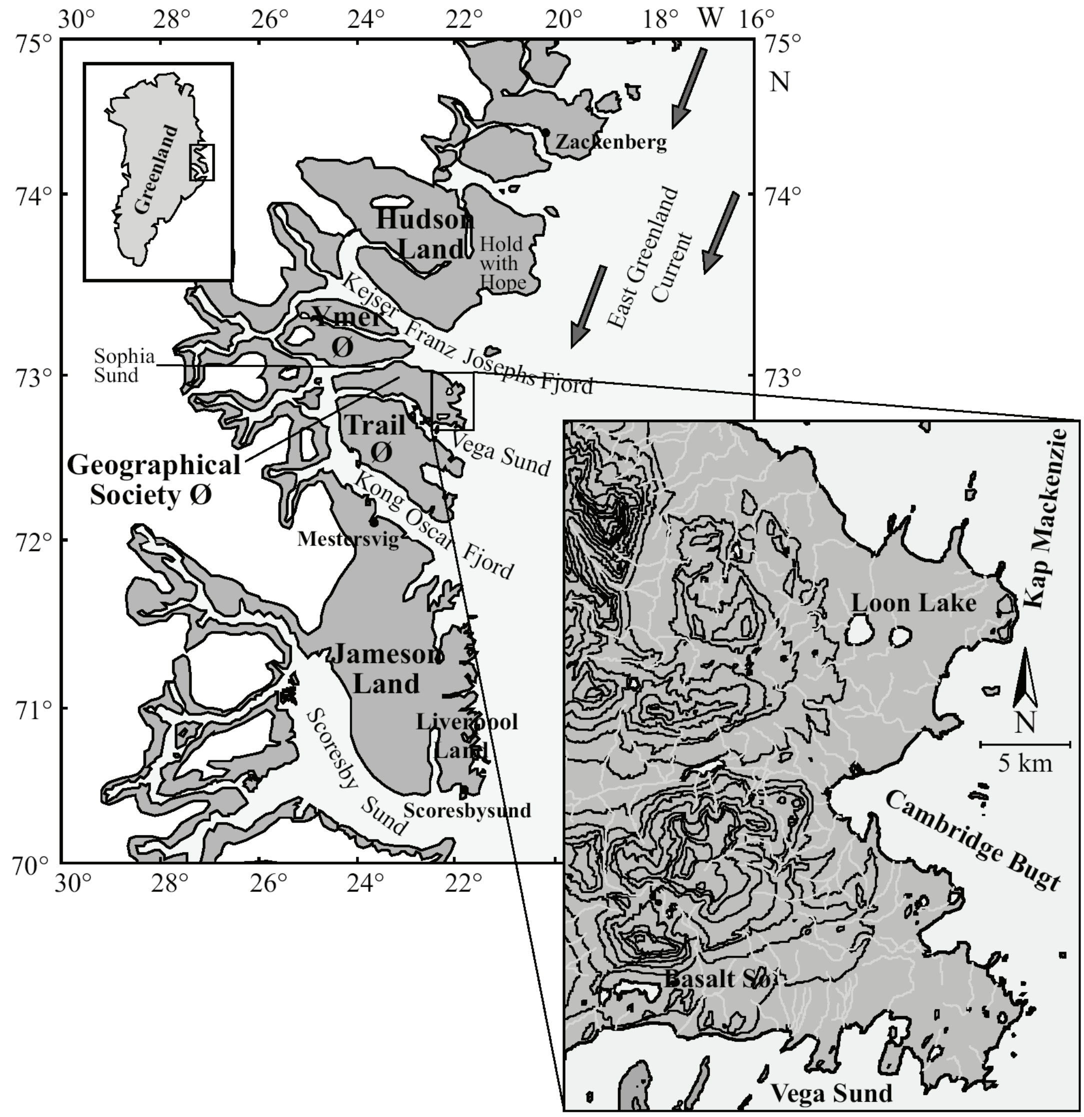


Fig. 1: Map of central East Greenland showing the location of Geographical Society Ø and the surrounding area (after WAGNER et al. 2000); the enlargement (after data from Geological Survey of Denmark and Greenland (GEUS) and Kort & Matrikelstyrelsen) shows the location of Loon Lake on northeastern Geographical Society Ø, altitudes with contour lines in 100 m a.s.l. and the drainage system of the northeastern part of the island.

Abb. 1: Übersichtskarte vom zentralen Bereich Ostgrönlands mit Loon Lake Region und Umgebung (nach Wagner et al., 2000); die Vergrößerung zeigt Loon Lake im nordöstlichen Bereich von Geographical Society Ø mit dem Entwässerungssystem und Höhenlinien im 100 m Intervall (nach Daten des Geological Survey of Denmark and Greenland (GEUS) und Kort & Matrikelstyrelsen).

and drains into Kejser Franz Josephs Fjord (Figs 1 and 2).

The climate in East Greenland shows both longitudinal and latitudinal variations. It is oceanic and dominated by the influence of the cold East Greenland current at the outer coast and shifts to more continental conditions towards the ice sheet margin, located c. 300 km inland (FUNDER 1989a). The climatic shift is reflected in a temperature increase of 2-3°C from the outer coast to the ice margin (FUNDER 1978). A cooling trend towards the north is caused by the decreasing solar radiation and an increasing influence of the East Greenland current (FUNDER 1989a, WAGNER et al. 2000). Measurements at Kap Tobin near Scoresbysund settlement, c. 280 km to the south of the study area, revealed a mean annual temperature of -8°C and a precipitation rate of 476 mm/yr (FUNDER 1978), whilst at Zackenberg station, c. 250 km farther north of GSØ, the mean annual temperature is -10°C and the precipitation rate is 220 mm/yr (MELTOFTE & THINGS 1997). Maritime air masses, following cyclone tracks along the coast, are the main source for precipitation (FUNDER 1989a). Because East Greenland lies within the high arctic bio-climatic zone with mean

July temperatures of 3-5°C in the lowlands, a mean annual precipitation of 300-500 mm, and a continuous permafrost layer (BENNIKE et al. 1999), the vegetation in the study area is characterised by a poor dwarf shrub heath, with dominating *Salix arctica*, *Dryas* and *Cassiope tetragona* (FUNDER 1978). The vegetation cover in the catchment area of Loon Lake is fragmented and patchy.

The bedrock of East Greenland consists mainly of sandstones, pelites, and carbonates accumulated during the Late Proterozoic and Early Palaeozoic. These sediments were folded, thrusted, metamorphosed, migmatized and locally intruded by granite throughout the Early Silurian. Then, thick deposits of Devonian and Carboniferous terrestrial sandstones were deposited. Plateau basalts, as a result of a period of effusive volcanism during the sea floor spreading in early Tertiary times, crop up locally in East Greenland (FUNDER 1989a). Quaternary sediments in East Greenland mainly consist of glacial, glaciofluvial, fluvial, and marine deposits. Glacial deposits, such as moraines and coarse sandy tills are widespread along the fjords, in lowlands and on some high mountain plateaus. Marine deposits, comprised of prodeltaic, massive or laminated silt, littoral and deltaic sand and gravel, are restricted to valley mouths and coastal lowlands. These deposits occur up to 130 m a.s.l., which represents the Holocene marine limit in this region. Cryoturbation structures, such as frost wedge polygons, are common features of the East Greenland continuous permafrost zone (FUNDER 1989b).

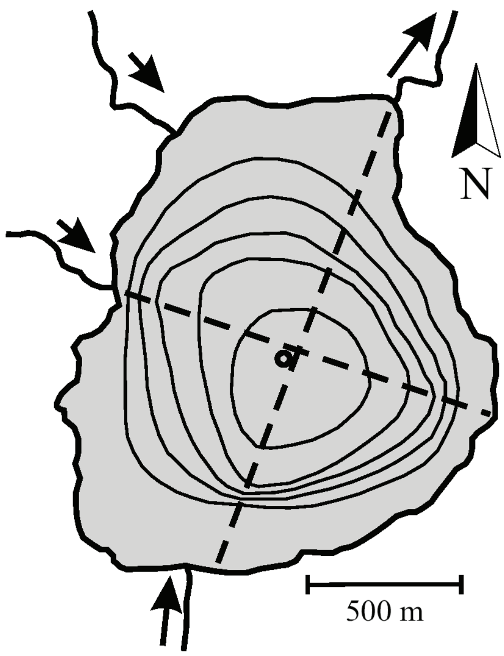


Fig. 2: Bathymetry of Loon Lake (contour lines in 2 m), deduced from echo-sounding measurements along two crossing profiles (dashed lines). Inlets and outlet are indicated by the arrows, the coring site Lz1116 (N 72°53'15.5 W 022°08'21.8) by the circle in the centre of the basin.

Abb. 2: Loon Lake Bathymetrie (Kontourlinien in 2 m Intervallen), abgeleitet von Echolotmessungen entlang zweier Profile (unterbrochene Linien). Zuflüsse und Ausfluss sind durch Pfeile markiert, die Bohrlokation Lz1116 (N 72°53'15.5 W 022°08'21.8) durch einen Kreis im Zentrum des Sees.

Geographical Society Ø is formed by Upper Palaeozoic sediments in its western part and Mesozoic sediments in the eastern part. The latter consist of coarse to fine-grained sandstones, mudstones, and shale. Tertiary volcanic intrusions are common. Patches of unconsolidated marine Cenozoic sediments occur on the low altitude regions of the island (BENNIKE et al. 2004).

3. Field work

Fieldwork was carried out between 11th to 14th September 2003. Detailed information about the fieldwork and first results is given in BENNIKE et al. (2004).

For obtaining a reliable coring position with minimal influence of surrounding subaquatic slopes and, therefore, more or less calm sedimentation conditions, bathymetrical measurements were carried out using a handheld GPS unit and a handheld echosounder. These measurements were performed in 100 m intervals along two crossing profiles from a floating platform (UWITEC Co., Austria). Fig. 2 shows the bathymetric model resulting from the obtained data.

Water sampling and hydrological measurements were performed on 11th September at the central part of the lake, where the maximum water depth of 11.7 m was measured. The Secchi disc transparency of Loon Lake was 3 m (BENNIKE et al. 2004). Water samples were taken at distinct depths along the water column using a 5 l water sampler (UWITEC Co., Austria). About 1 l of the sample was used to evaluate immediately O_2-content and saturation, temperature, pH, and specific conductivity. The oxygen content and saturation as well as temperature were measured using a WTW Oxi 196 probe, the specific conductivity was recorded with a WTW LF 197 probe, and the pH was measured by a WTW pH 197 probe (all WTW Co., Germany).

The measurements of water samples, particularly the relatively constant temperature (Fig. 3), reveal a complete mixture of Loon Lake. Low productivity, caused by low water temperatures, a short ice-free season, and a low nutrient input from the catchment is typical for oligotrophic to ultra-oligotrophic lakes in arctic regions, as it is Loon Lake. Mesozoic and Cenozoic sediments with interspersed volcanic units in the catchment area account for relatively high pH values. Low

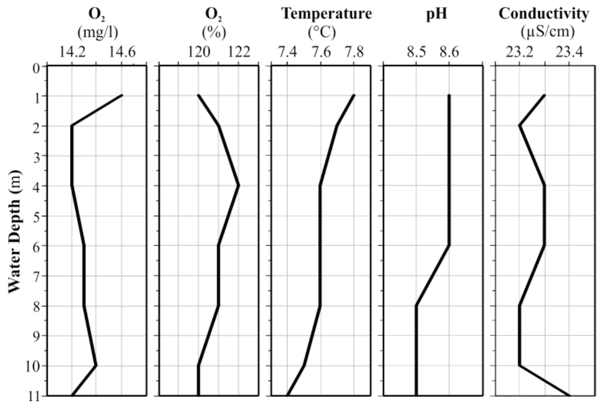


Fig. 3: Measurements of water samples along the water column of Loon Lake at coring site Lz1116 (cf., Fig. 2).

Abb. 3: Messungen von Wasserproben des Loon Lakes an der Kernposition Lz1116 (vgl. Abb. 2).

amounts of solubles are likely due to inflow of solubles depleted meltwater during spring and summer and are documented by low values of conductivity (BENNIKE et al. 2004).

Sediment cores from Loon Lake were recovered using a piston and a gravity corer (both UWITEC Co., Austria) from a floating platform. The gravity corer was used to retrieve undisturbed surface sediments. The corer is equipped with a 60 to 120 cm long PVC plastic tube of 6 cm in diameter. A successful coring process is indicated by a horizontal stratification of the sediment and clear superstanding water. For transport and storage, the superstanding water was removed, the plastic tube cut to the upper edge of the sediment, and the core closed with an artificial sponge and a lid at each end.

The piston corer was used to obtain deeper and especially longer sediment sequences. This system is operated by a platform-mounted tripod and three steel ropes (Fig. 4). The first rope controls the release of the piston, the second the vertical position of the coring tube in the water column, and the third operates a hammer. A metal blade on the top of the coring unit prevents twisting of the coring equipment. The piston corer consists of a 3.30 m metal tube, which contains a 3 m long plastic tube of 6 cm in diameter. For the uppermost sediment core, the piston has to be released c. 50 cm above the sediment surface and the corer is hammered into the sediment by a driving weight. The sediment then becomes gradually captured in the plastic tube. When the piston reaches the upper end of the coring tube, the corer contains about 2.5 m of sediment and water is transferred to its base in order to close a rubber cuff hydraulically, thus preventing loss of sediment. For deeper sediments, the coring system has to be hammered into the sediment before the piston is released. A minimum overlap of 50

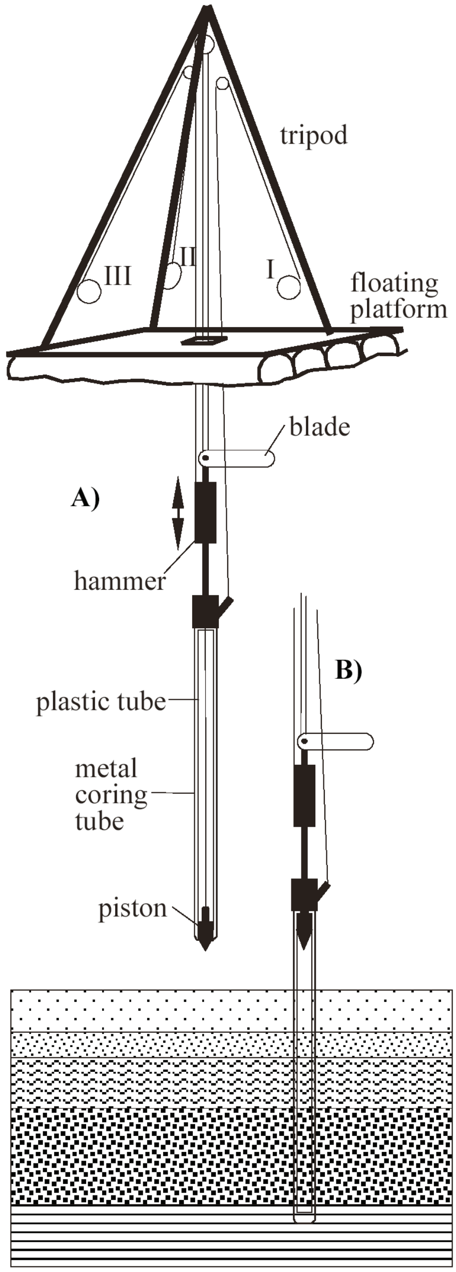


Fig. 4: Sketch of the coring gear and process.

Abb. 4: Darstellung des Kerngerätes und des Kernprozesses.

cm enables a correlation between the single 3 m segments. This procedure can be repeated until stiff sand and coarse layers and/or too consolidated sediments stop further penetration. In polar regions overconsolidated diamictons often indicate the base of lacustrine sediments (WAGNER 2003). A more detailed description of the coring procedure is given in MELLES et al. (1994).

After pulled up to the platform the cores recovered were split into 1 m segments and stored in thermo boxes to prevent any further reaction of the sediment due to temperature fluctuations and the influence of light. During the transport from

Greenland to Germany and later in the laboratory, the cores were stored at a temperature of 4°C in a dark storage room until further processing.

4. Laboratory work

Whole-core measurements were performed using a MultiSensorCoreLogger MSCL 14 (GEOTEK Co., Germany). All cores were logged in one-centimetre intervals. Specification of sensors are reported in DITTMERS & NIESSEN (2002). The magnetic susceptibility, P-wave velocity, wet-bulk density, and porosity were processed according to the processing routine given in WEBER et al. (1997). A first correlation of the overlapping core segments is based on the results of the magnetic susceptibility measurements and was conducted prior to core opening.

For opening of the piston cores Lz1116-5/7/8/9 and the gravity core Lz1116-3, the PVC plastic tubes were lengthwise incised by an electrical circular saw and, in order to avoid contamination by PVC splinters, then fully cut by a knife. The cores were separated into two halves using a fishing line or, depending on sediment texture, two metal blades.

Immediately after separating the two halves and cleaning of the surface, photographic documentation and core description were carried out. Criteria for core description were sediment colour, texture, and structure. Sediment colour was identified using the MUNSELL SOIL COLOR CHART (GRETAGMACBETH Co., USA). Texture determination has been carried out using haptic methods. Structures were visually determined. The correlation of core sequences was optically verified by comparing corresponding horizons.

One half of the complete sequence was stored as archive for future work, whilst the other half was continuously subsampled in 2 cm intervals. From this set of subsamples, each 8^{th} subsample was investigated, thus leading to a set of 61 samples. The samples were freeze-dried at least 48 hr using the LYOVAC GT 2 (FINN-AQUA Co., Germany) to crack clay aggregations and to remove intergranular and organic cellular moisture. The water content was calculated from the mass difference between the wet and dry weights and is given as a percentage of the wet bulk sediment.

Following this process the samples were homogenised and split into aliquots in order to measure all sediment parameters in the same sample horizon. For biogeochemical and grain density measurements about 2 g of sediment were ground 10 min at 200 rpm in the planetary mill PULVERISETTE 5 (FRITSCH Co., Germany). Grain density measurements were conducted using an ACCUPYC 1330 analyser (MICRO-MERITICS Co., USA). For grain-size analysis 6 g of sediment (due to reduced masses, 6 samples had only 3 g) were weighed into 400 ml beakers. With regard to selection and determination of fossils and radiocarbon dating of shell remains, the samples were, contrary to conventional treatment with hydrogen peroxide, dispersed (12 hr, 180 rpm) with about 150 ml distilled water to prevent loss of carbon. Subsequent to dispersing, the gravel, sand, and mud fraction were separated by wet sieving. Samples with remains of undispersed mud aggregations were treated 5 to 10 seconds in an ultrasonic bath. The mud fraction was caught in a 2 l beaker and treated with 30% HNO_3 to enforce the settling rate. Finally, the dry masses of the gravel, sand, and mud fraction were calculated after removal of the water by decanting and oven-drying at 50°C and by relative comparison with the initial sample weight. Because of sediment loss due to adhesion in the beakers and sieves, and to imprecision of the scale, the percentage of the three fractions was recalculated using the relation of the reweighed masses. The fractions are given as percentages of the sample weight, taking the error into account.

Total carbon (TC), total nitrogen (TN), and total sulphur (TS) contents were determined using the VARIO EL III analyser (ELEMENTAR ANALYSEN-SYSTEME Co., Germany). The content of total organic carbon (TOC) was quantified using the METALYT CS1000S analyser (ELTRA Co., Germany). For the TOC measurements carbonate was eliminated from the samples by a successive addition of diluted ethyl alcohol and 10% hydrochloric acid at 80°C. Total inorganic carbon (TIC) was derived from the difference of TC and TOC. The calcium carbonate content was calculated by multiplication of TIC with a factor of 8.33, assuming that TIC is formed completely by calcium carbonate. The amounts of TN, TS, TOC, and calcium carbonate are given as percentages of the dry sample weight. C/N and C/S ratios were calculated using TOC, TN, and TS, respectively.

For the determination of fossils and their remains, such as foraminiferas, ostracods, and bivalves, the sand fraction was divided into 63-125 µm and 125-2000 µm sub-fractions by hand sieving. The enumeration of fossils was carried out on the 125-2000 µm sub-fraction using a light optical microscope (STEMI 1000 ZEISS Co., Germany) with a magnification of 35. In case of high numbers of fossils or increased amounts of sediment mass of the sub-fraction, a repeated subdivision into aliquots was required. After spreading out the aliquot onto a counting plate the enumeration was conducted. The enumeration was repeated until a minimum of 50 fossils (for foraminiferas) was gained or the sample was completely free of fossils. Due to only sporadic findings of planktonic foraminiferas the numbers refer to benthic foraminiferas. For the enumeration of chironomid head capsules about 1 g of fresh sediment was taken from the surface of the archived halves at the corresponding depths. The sediment samples were deflocculated for 5 min in 10% KOH and for another 7 min by adding 50 ml water on a 120 °C heater. After sieving the samples through a 90 µm sieve, the residues were transferred to a grooved Perspex sorting tray and chironomid head capsules were counted using a light optical microscope (STEMI 1000 ZEISS Co., Germany) with a magnification of 25 to 30. The results of fossil enumeration were converted into head capsules/gram (h.c./g) of the initial sample weight.

For radiocarbon dating shell fragments from three different horizons were, directly after opening the cores, selected and cleaned with distilled water. Radiocarbon dating was conducted at the Leibniz Laboratory for Radiometric Dating and Isotope Research, Christian-Albrechts-University, Kiel. For calibration, data were corrected by a marine reservoir effect of 550 yr for East Greenland (TAUBER & FUNDER 1975). All dates obtained were calibrated into calendar years before present (cal. yr BP) using the calibration program CALIB REV4.4.2 (STUIVER & REIMER 1993) with the calibration dataset marine98.14c (STUIVER et al. 1998). Means and uncertainties were calculated from the lowest and highest values at the 2σ probability distribution with 95% confidence interval. The age-depth correlation was set up by polynomial calculation with the best fit to the calibrated dates.

5. Results and Discussion

5.1. Lithology

The sediment record Lz1116 from Loon Lake covers a total length of 1025 cm. Based on core descriptions six major sediment units can be distinguished (Fig. 5). Between 962 and 895 cm below sediment surface (b.s.s.) a gap in the sediment sequence was caused by total loss of sediment during the coring process.

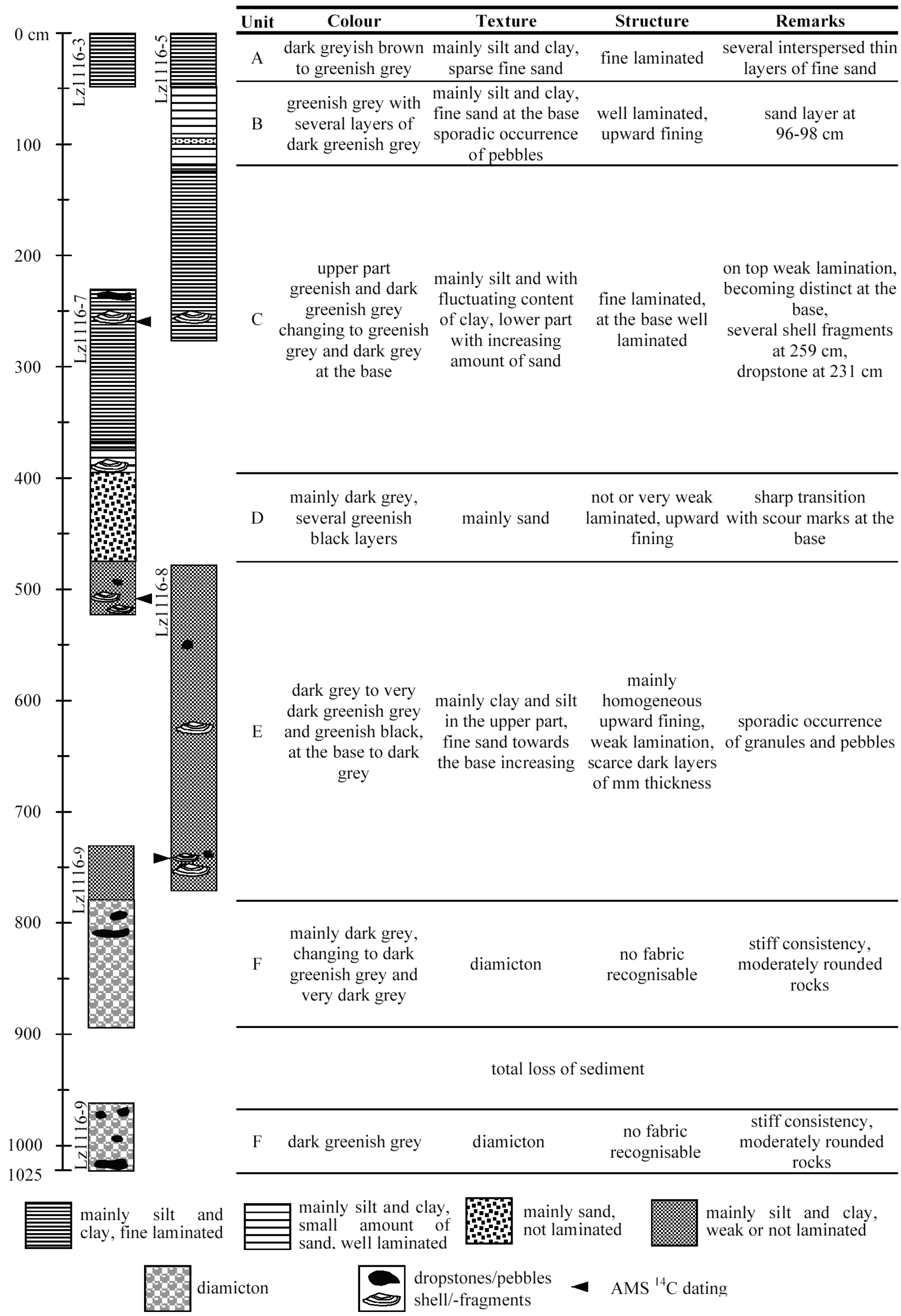
At the base of Loon Lake sediments, from 1025 to 780 cm b.s.s., a mainly dark grey to very dark grey, partly changing to dark greenish grey, diamicton (unit F) occurs. This diamicton features a stiff consistency and a wide range of grain-sizes with a maximum in the mud fraction. Gravel is common and scattered randomly. Sorting or stratification is visually not recognisable. Comparable findings in the Scoresby Sund area were described by BJÖRCK et al. (1994a) and INGÓLFSSON et al. (1994). In Basaltsø, c. 30 km southwest of Loon Lake, similar sediment characteristics have been attributed by WAGNER et al. (2000) to a formation below grounded ice masses (lodgement till). A comparable formation can hence be assumed for the diamicton at the base of Loon Lake sedimentary record.

Unit E overlies the diamicton with a rather sharp transition. This unit comprises between 780 and 475 cm b.s.s. mainly homogeneous, mud-rich sediments with a decreasing amount of fine sand topwards. Sediment colour varies from dark grey to very dark greenish grey and greenish black. Interspersed dark layers of up to several mm thickness suggest a stratification. This stratification does not persist throughout the unit, but increases gradually topwards. Shells and shell fragments imply a deposition in a marine or limnic setting. In contrast to the glaciomarine sediments of Scoresby Sund area (INGÓLFSSON et al. 1994), coarse sediments are widely lacking in unit E and indicate either relatively calm sedimentation conditions after a rapid collapse of ice masses by calving (POWELL & DOMACK 1995), or gradually increasing distances to the receding ice margin (BJÖRCK et al. 1994a). The few irregularly occurring granules and pebbles can be attributed to transport by icebergs and/or ice floes, as been observed in sediments of Kejser Franz Josephs Fjord (MARIENFELD 1991).

The transition to the overlying unit D is characterised by an abrupt change in texture. Unit D, between 475 and 395 cm b.s.s., consists of a predominantly non-stratified, sandy section. Throughout this unit dark grey colours dominate and are interspersed by rather greenish black layers. The lower boundary features score marks, which are common characteristics of turbidity currents. Shell fragments in this unit most likely arise from the reworking of sediments.

Between 395 and 126 cm b.s.s., a finely laminated unit (C) occurs. This unit consists of mud-dominated sediments with a varying content of silt and clay. The colour changes from very dark grey at the base of the unit to more greenish colours in the upper part. Well-defined stratification, changing from cm to mm spacing and increasingly fine-grained sediments upwards indicate gradually calmer sedimentation conditions. A core-filling rock at a depth of 231 cm could originate from floating ice. Shells and shell fragments emerge at 259 cm b.s.s.The transition towards the upwards following unit B from 126 to 50 cm b.s.s. is marked by a change in lamination, which tends to spacing in cm scale, probably due to an increasing sedimentation rate. The colour shows a nearly identical pattern as in the underlying unit C. Grain-size distribution reveals an increasing amount of sand, culminating in well-sorted sandy layers. This implies increased erosion processes and a rather vigorous transportation regime due to increased melting in the catchment area (Wagner et al. 2000).

Unit A forms the uppermost 50 cm of Loon Lake sediment and consists of finely laminated sediments. The lamination is formed by pre-



Unit	Colour	Texture	Structure	Remarks
A	dark greyish brown to greenish grey	mainly silt and clay, sparse fine sand	fine laminated	several interspersed thin layers of fine sand
B	greenish grey with several layers of dark greenish grey	mainly silt and clay, fine sand at the base sporadic occurrence of pebbles	well laminated, upward fining	sand layer at 96-98 cm
C	upper part greenish and dark greenish grey changing to greenish grey and dark grey at the base	mainly silt and with fluctuating content of clay, lower part with increasing amount of sand	fine laminated, at the base well laminated	on top weak lamination, becoming distinct at the base, several shell fragments at 259 cm, dropstone at 231 cm
D	mainly dark grey, several greenish black layers	mainly sand	not or very weak laminated, upward fining	sharp transition with scour marks at the base
E	dark grey to very dark greenish grey and greenish black, at the base to dark grey	mainly clay and silt in the upper part, fine sand towards the base increasing	mainly homogeneous upward fining, weak lamination, scarce dark layers of mm thickness	sporadic occurrence of granules and pebbles
F	mainly dark grey, changing to dark greenish grey and very dark grey	diamicton	no fabric recognisable	stiff consistency, moderately rounded rocks
		total loss of sediment		
F	dark greenish grey	diamicton	no fabric recognisable	stiff consistency, moderately rounded rocks

Fig. 5: Core sequences and descriptions of cores Lz1116-3/5/7/8/9 from Loon Lake. Black arrows indicate remains of marine shells, which were selected for AMS ^{14}C dating.

Abb. 5: Kernsequenzen und Beschreibung der Kerne Lz1116-3/5/7/8/9 von Loon Lake. Schwarze Pfeile markieren Entnahmehorizonte mariner Muschelreste für AMS ^{14}C Datierungen.

dominantly silt and clay horizons of few mm thickness, and interspersed layers of fine sand. Comparable to unit C, this pattern indicates calm sedimentation conditions with single events of increased input of coarser sediments. The colour varies from mainly greenish grey in the lower part to dark greyish brown in the uppermost cm. The latter suggests that the water body is completely mixed and oxygen saturated, thus promoting the formation of iron oxides in the surface sediments.

The greenish grey colour in the deeper sediments indicates reducing conditions due to decomposition of organic matter.

5.2. Geophysical properties

The lowermost part of the sediment record from Loon Lake, according to unit F, shows fluctuating, but overall high values of magnetic susceptibility (MS), P-wave velocity (PWV), and wet bulk density (WBD), and relatively low values of porosity (Fig. 6). Relatively high values of MS, PWV, and WBD are characteristic for a diamicton (NIESSEN & HENSCHEL 1995). The stiff consistency of the diamicton and low values of water content might indicate overconsolidation and the formation as a lodgement till (WAGNER et al. 2000). Similar interpretation has been made by FUNDER et al. (1998), who attributed a high WBD in the basal part of a sediment record from south of Shannon Island to the formation as a basal till deposited during the Last Glacial Maximum. In unit F, highest values of MS correlate with the occurrence of rocks and/or higher concentrations of pebbles, probably originating from basaltic bedrock in the Loon Lake area. Sediment supply from basaltic bedrock is also indicated in relatively high grain density (GD) values of c. 2.7 to 2.8 g/ccm. The decrease of MS and WBD at c. 875 cm b.s.s. and PWV in wider range has to be ascribed to sediment disruption and water filling resulting from problems during the coring process.

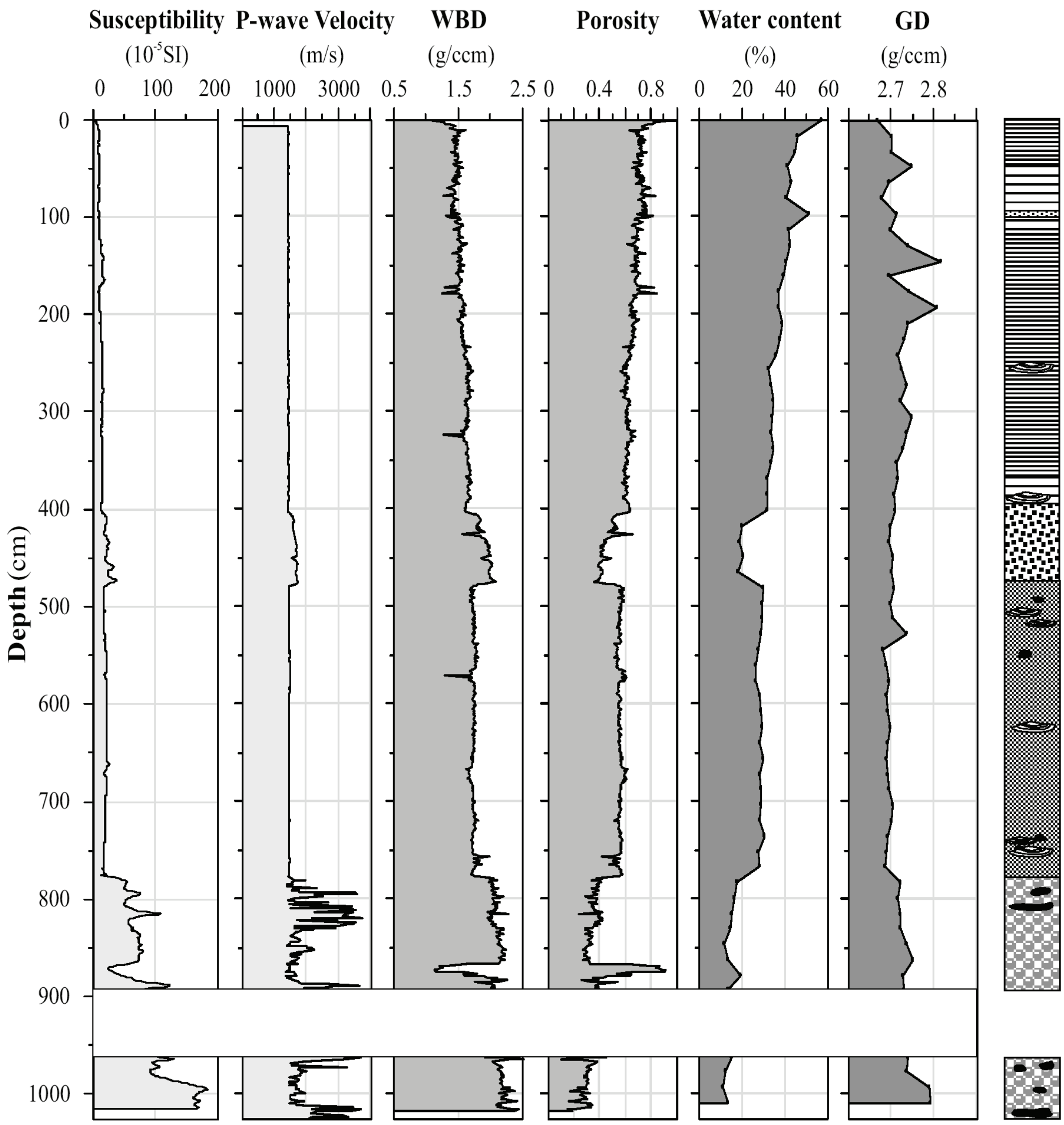


Fig. 6: Geophysical properties of core Lz1116 versus depth with the lithology on the right side. Due to loss of sediment between 894 and 961 cm no data were available at this horizon.

Abb. 6: Geophysikalische Eigenschaften des Kerns Lz1116 gegen die Tiefe. Lithologie der Sedimentsequenz auf der rechten Seite. Aufgrund Sedimentverlustes zwischen 894 und 961 cm Tiefe sind keine Daten für diesen Horizont vorhanden.

The overlying unit E features lower, but almost constant values of MS, PWV, and WBD, and, conversely, higher porosity and water contents. The almost stable geophysical properties of this unit might be a result of relatively constant sedimentation conditions. The low values of MS can be attributed to dilution of magnetite by carbonate in marine sediments (NIESSEN & HENSCHEL 1995), thus supporting the interpretation that unit E has been formed under marine conditions. The relatively high porosity and water content can be explained by less consolidation as consequence of the absence of an overlying ice mass. The relatively low GD might reflect a change in the transport regime from a former glacial or glaciomarine to a marine setting, with promotion of particles with lower densities during the marine setting.

Unit D from 475 to 395 cm b.s.s. indicates a distinct change in the physical properties. At the base of unit D, high values of MS and PWV can be attributed to a higher content of sand. This change in grain-size distribution is also indicated in a higher WBD and, conversely, lower porosity and water content. The gradual decrease of MS, PWV, WBD, porosity, and the coincident increase in porosity and water content topwards implies that unit D has been formed by a single event, such as it is a turbidite.

From 395 cm b.s.s. to the sediment surface the values of MS, PWV, water content, and GD show a rather individual pattern. MS declines constantly topwards, except for a horizon at 170 cm b.s.s. This horizon most likely indicates a change in the sediment supply from the catchment area. The values of PWV remain on a low level to the surface. WBD declines with small-scale fluctuations slightly towards the sediment surface, which can be explained tentatively by a decline of consolidation. This is also reflected in increasing values of porosity and water content. Fluctuations of the water content, especially in the uppermost 100 cm, might be attributed to changes in the organic matter content. The varying values of GD within the uppermost 250 cm might be a result of different sediment sources in the catchment of the Loon Lake area.

5.3. Grain-size distribution

The base of the Loon Lake sediment sequence (unit F) shows a varying composition of gravel, sand, and mud (Fig. 7). The co-occurrence of this composition with moderately rounded rocks and the overconsolidation of this unit point to its generation in a glacial setting, probably below grounded ice (BRODZIKOWSKI & VAN LOON 1991a).

The transition to unit E is documented by a rapid decrease of sand and a moderate decline of gravel, which seems to indicate the end of the glaciation of the Loon Lake area. The dominance of mud, with a relatively constant content throughout unit E, suggests rather calm sedimentation conditions and might be derived from suspension-loaded plumes (POWELL & DOMACK 1995). This supports the interpretation that unit E has been deposited in an aquatic milieu. The deposition of fine-grained muds by glacial meltwater might overwhelm the occurrence of debris released by icebergs (EVANS et al. 2002). The occurrence of gravel and sand particularly in the lowermost part of unit E likely is the result of glacial sediment input during deglaciation.

At a depth of 475 cm b.s.s. the significant and abrupt increase of sand to values of 80 % indi-

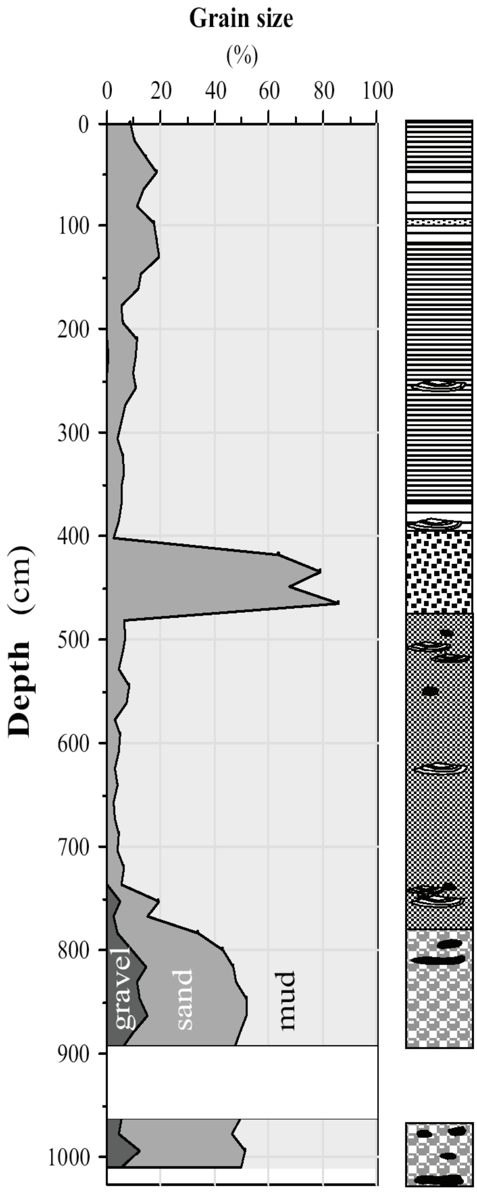


Fig. 7: Grain-size distribution of core Lz1116 versus depth with the lithology on the right side.

Abb. 7: Korngrössenverteilung des Kerns Lz1116 gegen die Tiefe. Lithologie der Sedimentsequenz auf der rechten Seite.

cates the transition to unit D. This supports the assumption that unit E is formed by a single and vigorous event, such as a turbidite. The complete absence of gravel might point either to a well-sorted sediment source, such as foresets of deltas, or a rather distal deposition to the main source (BRODZIKOWSKI & VAN LOON 1991c).

The well-laminated sequence at or shortly above 400 cm b.s.s. does not match with the classification according to lithology and physical properties. Probably it belongs to the topmost part of the turbidite, which is supported by a domination of mud and a smaller amount of sand.

Mud also forms the dominating component topwards. Interspersed sandy horizons indicate sporadically higher transport energies, such as can be produced in a marine lagoon or by lacustrine bottomsets (BRODZIKOWSKI & VAN LOON 1991b). Comparable features in Kejser Franz Josephs Fjord are reported by EVANS et al. (2002), who suggested a deposition from turbid meltwater plumes with variable discharge under comparatively more ice-proximal conditions. The fluctuation of sand content might be attributed to a supply by bottom currents (BRODZIKOWSKI & VAN LOON 1991b). However, sea or lake level changes, influencing the distance of inlets to the coring location, can also produce such a pattern.

5.4. Biogeochemical analyses

The lowermost part of Loon Lake sediments (unit F) shows slightly changing, but significant contents of total nitrogen (TN), total sulphur (TS), and total organic carbon (TOC) (Fig. 8). The C/N ratio varies around 10 and the C/S ratio around 2. The carbonate content changes between 1 and 3 %. Assuming that unit F has been formed as a lodgement till, TN, TS, and TOC contents seem to reflect the organic background of the sediment, which was assimilated, transported and deposited by the glacier. The slight increase of TN and TOC topwards indicates a higher content of organic matter in the till. Varying contents of carbonate might be a result of reworked calcareous sediments or bedrock in the catchment area of the glacier.

Unit E is characterised by a significant decrease in the TS content, while TN and TOC contents remain constant throughout the unit. Assuming that unit E was deposited in an aquatic milieu, the depletion of TS in the sediment might be the result of increased glacial meltwater supply during deglaciation. A significant input of freshwater at the bottom of the unit is also indicated in the relatively high C/S ratio (COHEN 2003). Probably, high temperatures during deglaciation and/or a close distance to the glacial source promoted the meltwater supply. The gradual upward decrease of the C/S ratio reflects a decrease in freshwater supply and, thus, implies less meltwater supply due to lower temperatures or more distal glacial sources. Persisting low TOC and TN contents seem to be a result of low productivity, as it is common in high arctic environments. Higher carbonate contents presumably document the occurrence of bivalves, which would be in line with the findings of shells and shell fragments throughout this unit.

The transition to the overlying unit D features considerable drops in TN, TOC, and carbonate. These abrupt decreases might be attributed to the deposition of coarser sediments, which are in general depleted in TN and TOC. However, a TN and TOC depleted sediment source would cause the same pattern. The most conspicuous change is documented by the increase of the C/N ratio by a factor of four. C/N ratios in sediments higher than 10 are supposed to indicate allochthonous input of organic matter (MEYERS & TERANES 2001). However, because depletion of TN and TOC during the transportation of sediment in turbidity currents can be selective, an autochthonous source of the organic matter cannot be excluded. The distinct increase of carbonate along with the decrease of the C/N ratio towards the uppermost part of unit D probably is the result of settling finer sediment particles at the final stage of the turbidite deposition. TS content shows relatively constant values with a slight increase topwards, following the general trend of TS throughout units E, F, and D.

In unit C TN and TOC increase more or less steadily topwards, which can be traced back to higher productivity and accumulation of organic matter as a result of ameliorated environmental conditions. The relative constant C/N ratio indicates that the higher productivity in the lake seems to be compensated by higher input of allochthonous organic matter from land vascular plants. The TS content shows a distinct rise to a depth of c. 175 cm b.s.s. and drops to very low values above. Conversely, the C/S ratio has a minimum at that depth. This pattern indicates that the content of TS is not influenced by the organic matter accumulation and seems to be more related to reducing bottom water conditions, such as they occur in well-stratified and amictic water bodies. The lack of carbonate above c. 160 depth indicates a distinct change in sedimentation conditions. Assuming that the carbonate content strongly depends on the occurrence of calcareous organisms, the lack of carbonate above c. 160 cm depth could be due to a change of the aquatic environment, probably from a marine to a limnic setting. However, also anoxic conditions in the bottom waters would cause a deterioration of the living conditions of bivalves and other calcareous organisms, and thus lead to a lower carbonate content in the sediment.

Within unit B increased values of TN and TOC (Fig. 8) likely reflect higher productivity in the

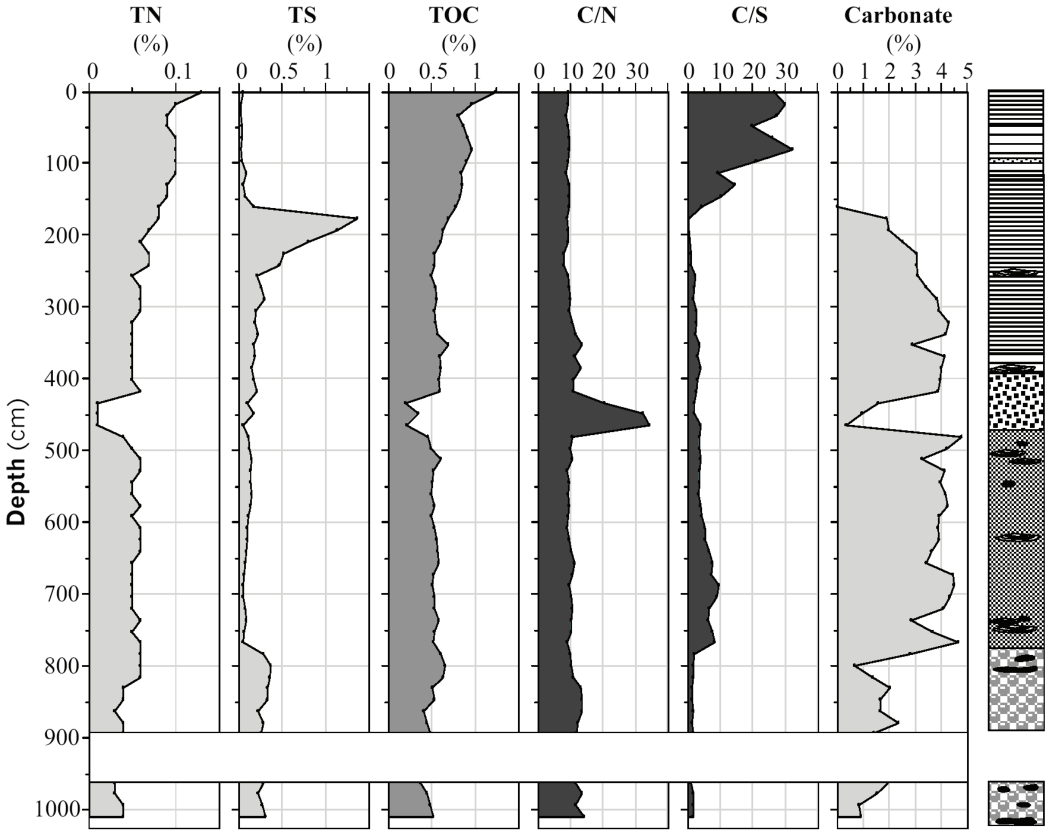


Fig. 8: Results of biogeochemical analyses of core Lz1116 versus depth with the lithology on the right side.

Abb. 8: Ergebnisse der biogeochemischen Untersuchung des Kerns Lz1116 gegen die Tiefe. Lithologie der Sedimentsequenz auf der rechten Seite.

aquatic milieu or in the catchment area. The relatively constant C/N ratio around 10 indicates that the productivity increased in both ecosystems contemporaneously. However, this increase of TOC and TN could also be a result of less organic matter decomposition in the sediment due to a diminished oxygen saturation of the bottom water. The low TS content suggests reduced influence of marine water and, conversely, more limnic conditions in Loon Lake basin. Limnic conditions throughout unit B are strongly supported by the high C/S ratio (COHEN 2003).

Within unit A a further increase of TN and TOC contents topwards with a maximum at the sediment surface can be observed. This can be explained by uncompleted decomposition of organic matter or by highest productivity in the youngest lake history. The low TS content in unit A likely reflects complete oxygen saturation of the water column. As in the unit below, the stable C/N ratio around 10 reflects both autochthonous and allochthonous sources of organic matter. The lack of carbonate documents that calcareous organisms do not occur or that no carbonate-bearing sources are outside the catchment area today.

5.5. Fossils

The lowermost part of unit F in the Loon Lake sediment sequence is completely devoid of fossils (Fig. 9). Above the gap unit F shows a sporadic occurrence of single foraminiferas, bivalves, and ostracods. The poor preservation of these sporadically occurring marine fossils implies a reworking of marine sediments. Increasing numbers of foraminiferas topwards likely can be explained by a better preservation of marine fossils due to less reworking and reduced transport processes. Displacement of foraminiferas as a result of bioturbation seems to be unlikely. Chironomids are not present.

Throughout unit E the occurrence of foraminiferas, ostracods, and bivalves fluctuates significantly (Fig. 9). That unit E has been deposited in a marine or glaciomarine setting is evidenced by the distinct increase of the total number of foraminiferas within this unit. The relatively high abundances of foraminiferas, ostracods, and bivalves throughout unit E are likely caused by amelioration of living conditions due to increased

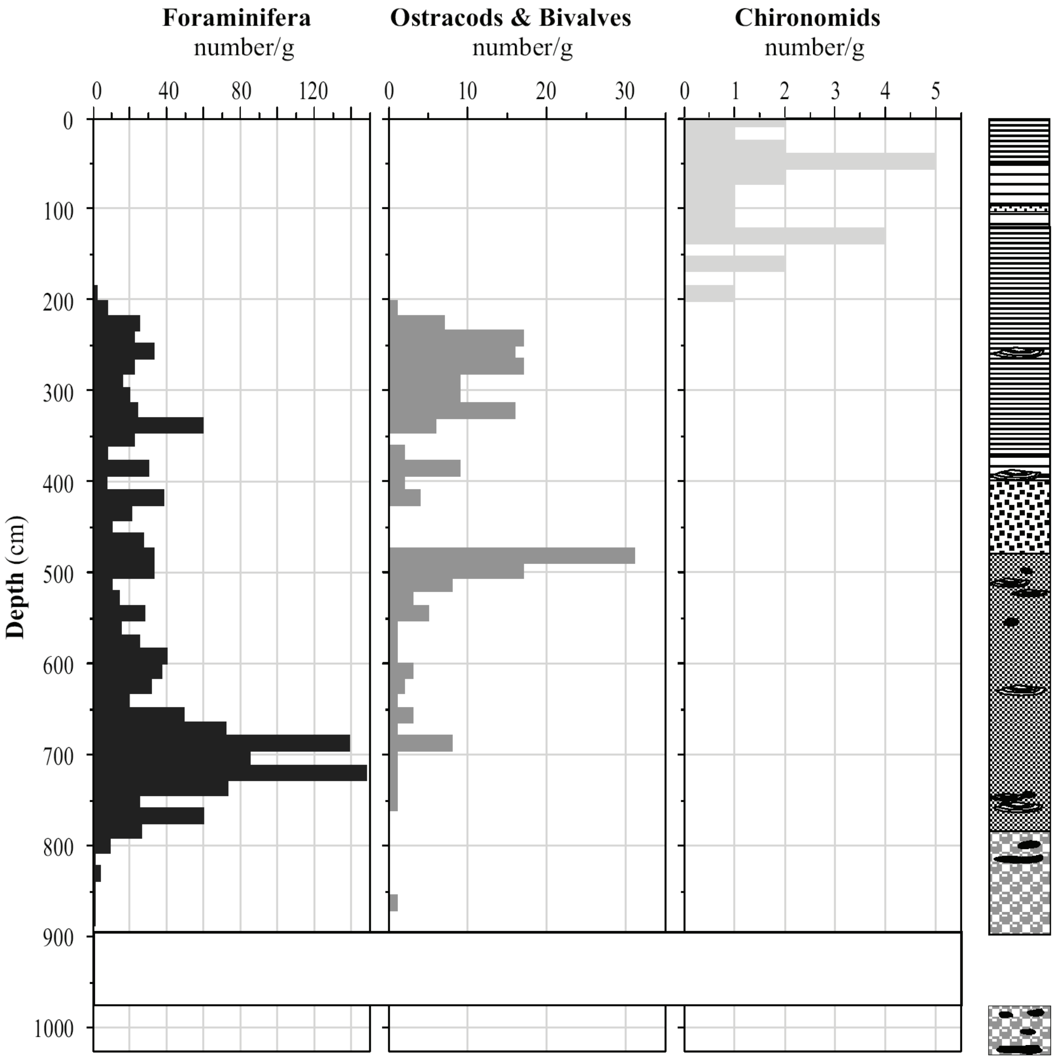


Fig. 9: Results of fossil enumeration of core Lz1116 with the lithology on the right side.

Abb. 9: Ergebnisse der Fossilauszählung des Kerns Lz1116. Lithologie der Sedimentsequenz auf der rechten Seite.

availability of nutrients or increased temperatures. However, the coincident decrease of the C/S ratio and the total abundance of foraminiferas towards the top of unit E infers that some foraminifera species are sensitive to salinity fluctuations. The complete lack of lamination most likely implies a comprehensive bioturbation of this unit.

The overlying unit D is characterised by only sporadic occurrence of foraminiferas and a complete lack of ostracods and bivalves in its lower part. Assuming that unit D reflects a turbidite, the presence of foraminiferas is surprising, because it can hardly be explained by bioturbation. The increased abundance of foraminiferas, ostracodes, and bivalves in the top of unit D probably is due to a lower energy, thus resulting in accumulation of particles with lower density.

At the base of unit C, the occurrence of foraminiferas slightly increases, remains then on a relatively stable level in the middle part and decreases subsequently to total absence in the upper part. The number of ostracods and bivalves increases significantly to a depth of around 250 cm b.s.s. This maximum coincides with other findings of macrofossil remains (cf Fig. 5) and could be due to a shell layer that has accumulated in a littoral setting. The upper half of unit C is characterised by the co-occurrence of marine fossils and chironomids (Fig. 9). Although saltwater species of chironomids are known, their occurrence more likely documents a change from a marine to a limnic setting. Probably, a stratified water body with freshwater conditions in the upper part of the water column and saltwater conditions at the bottom enabled the co-occurrence of both marine and limnic organisms. The high TS content slightly above the final occurrence of foraminiferas indicates that these organisms became extinct by strongly reducing bottom water conditions as a result of lacking mixture of the water body or by too saline conditions. Overall, the distinct shift from marine to limnic fossils in unit C most likely represents the change from a marine to a limnic setting.

The upper units B and A are completely devoid of marine fossils. The total abundance of chironomid head capsules, with a maximum of 5 h.c./g sediment, is low compared with sediments of lake B1, c. 30 km southwest of Loon Lake (100-300 h.c./g sediment; pers. comm. D. HOYER).

5.6. Chronology

The age-depth correlation for the sediment core from Loon Lake (Fig. 10) is based on 3 dating of the remains of marine bivalves (Table 1) and the assumption that the sediment surface represents the present.

Since the turbidite forming unit C is assumed to be a single, short-time event, the relevant data were excluded from the age-depth correlation. Sediment core descriptions revealed a turbidite thickness of 80 cm. However, for the calculation of the age-depth correlation, the thickness of the turbidite was determined on base of the geophysical properties, thus excluding a 73 cm thick horizon from 475 cm to 402 cm b.s.s.

As a result, the age of the upper boundary of unit E, referring to the time of turbidite deposition, has been calculated to c. 8300 cal. yr BP. This age might be slightly erroneous due to erosion of the turbidite and/or compaction as a result of sudden extra load.

Linear sedimentation rates of 165 cm/kyr have been calculated for the lower part of the Loon Lake sediment sequence between 669 and 259 cm b.s.s., and 27.5 cm/kyr for the sequence above 160 cm b.s.s., respectively. However, with respect to the only few radiocarbon dates (Fig. 10), their interpretation should be handled carefully and needs further exploration.

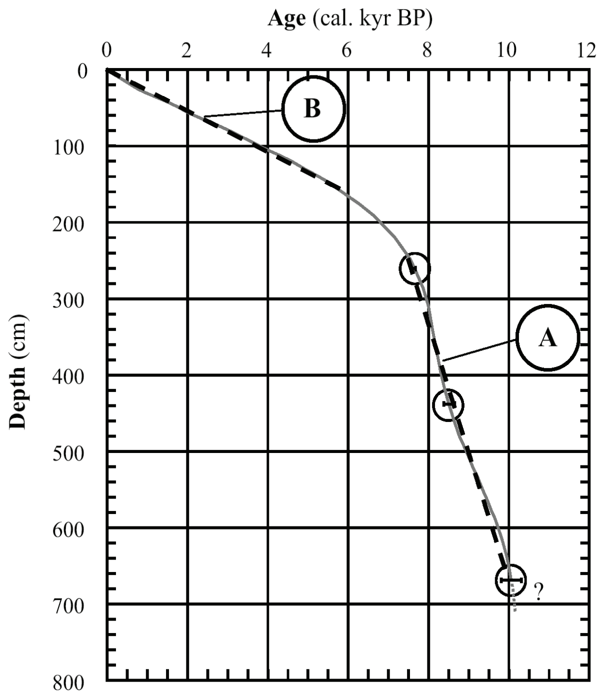


Fig. 10: Age-depth model of core Lz1116. Linear sedimentation rates (dashed lines) of 165 cm/kyr were calculated for the marine (A) and 27.5 cm/kyr for the limnic setting (B), respectively. The transition zone (brackish facies) is between 7250 and 6000 cal. yr BP.

Abb. 10: Alters-Tiefen Modell des Kerns Lz1116. Lineare Sedimentationsraten (unterbrochene Linien) von 165 cm/ka wurden für das marine Milieu (A) bzw. 27.5 cm/ka für das limnische Milieu berechnet. Die Übergangszone (brakische Fazies) liegt zwischen 7250 und 6000 Kalenderjahren vor heute.

Table 1: ^{14}C and calendar ages of bivalves of Loon Lake with corresponding depth after deleting the turbidite.

Tabelle 1: ^{14}C und Kalenderalter von Muscheln aus dem Kern Lz1116 mit den entsprechenden Tiefen nach Abzug der Turbiditlage.

Core Section	Corrected Depth (cm)	Material	Weight (mg)	^{13}C (‰)	^{14}C Age (yr BP)	Cal. Age (yr BP)
Lz1116-7/I	259	remains of bivalves	40	0.41±0.11	7285±40	7612±60
Lz1116-7/III	437	remains of bivalves	1.6	-5.95±0.17	8175±60	8494±138
Lz1116-8/III	669	remains of bivalves	8.3	0.05±0.31	9550±70	10058±251

6. Interpretation

6.1. Deglaciation

The ice margin of the Greenland Ice Sheet during the Last Glacial Maximum (LGM), referring to Flakkerhuk glaciation (FUNDER 1989b), extended to the mid-continental shelf (FUNDER & HANSEN 1996, FUNDER et al. 1998, EVANS et al. 2002) in East Greenland. In Scoresby Sund and northwards the glaciation was restricted to fjord-filling outlet glaciers, whereas the adjacent upland areas remained ice free (FUNDER & HANSEN 1996). The onset of deglaciation occurred around 16-14 kyr BP (HJORT & BJÖRCK 1984, FUNDER 1989b, FUNDER & HANSEN 1996), as it is indicated by a distinct $\delta^{18}O$ isotope minimum after 15 kyr BP on the continental slope (EVANS et al. 2002). This ice recession after the LGM is interrupted by a readvance of fjord glaciers during the Milne Land stade that ended c. 9.5 kyr BP (FUNDER et al. 1998). After the Milne Land stade the fjord glaciers retreated again until they reached their present position at c. 7 kyr BP (FUNDER 1989b). Numerous findings of marine shells both in sedimentary records of lakes and onshore document a subsequent marine inundation (HÅKANSSON 1972, 1973, 1974, 1975, WEIDICK 1976, WAGNER & MELLES 2002, Fig. 11, Table 2).

The overconsolidation of the diamicton at the base of the Loon Lake sediment sequence, best documented in the geophysical properties, implies that the diamicton has been formed below grounded ice. Comparable findings are reported by WAGNER et al. (2000) in Basalt Sø on southern Geographical Society Ø. The occurrence of foraminiferas and shell fragments in the upper part of the diamicton indicates that marine sediments have been incorporated and reworked during the glacial transport. At this stage, it can hardly be determined whether the marine sediments have been deposited during the marine inundation after the Flakkerhuk glaciation or during local oscillations of the glacier front during the Milne Land stade.

The deglaciation of Loon Lake is reflected by an abrupt and sharp change of geophysical properties at a depth of 780 cm b.s.s. and the distinct changes of the grain-size distribution (Figs 6 and 7). Whilst the abrupt change of geophysical properties implies that deglaciation was caused by calving, the slight change in grain-size distribution more favourises a deglaciation due to melting processes. Most likely, both calving and melting caused the deglaciation of Loon Lake basin. The timing of deglaciation can be extrapolated from the radiocarbon dates of marine shell remains at the basis of the marine sequence. The oldest marine shell remain 38 cm above the transition revealed an age of 10,058 cal. yr BP. Assuming a constant sedimentation rate of 165 cm/kyr, Loon Lake area became deglaciated at c. 10,250 cal. yr

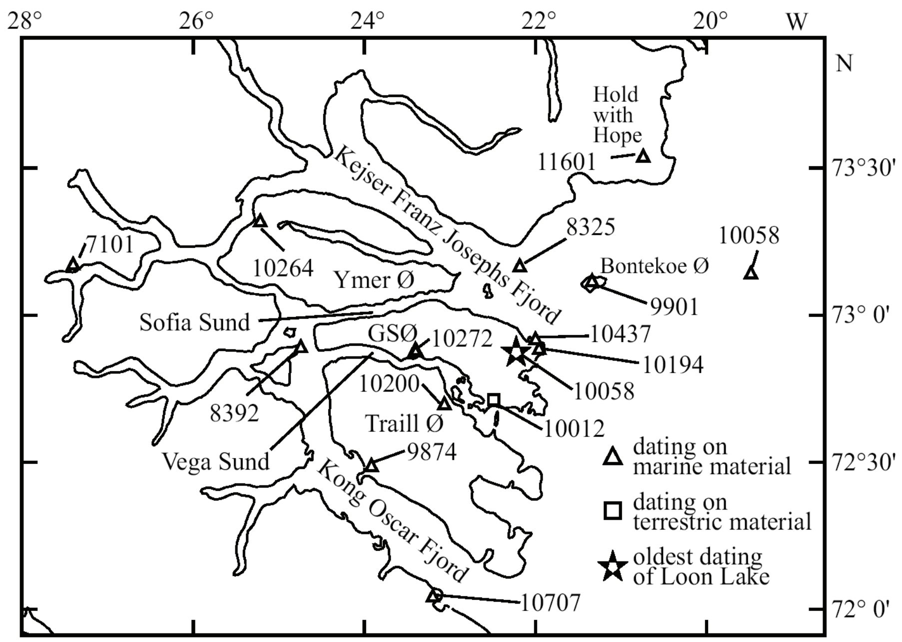


Fig. 11: Map of central East Greenland with selected radiocarbon ages of marine shells and plant remains indicating minimum ages of deglaciation after Milne Land stade (see also Table 2).

Abb. 11: Karte vom zentralen Bereich Ostgrönlands mit ausgewählten Radiokohlenstoffaltern von marinen Muscheln und Pflanzenresten, die das Minimumalter des Eisrückzuges nach dem Milne Land Stadial anzeigen (siehe auch Tabelle 2).

Table 2: ^{14}C and calendar ages of fossils from central East Greenland. Marine fossils were calibrated by subtracting a reservoir effect of 550 yr (TAUBER & FUNDER 1975).

Tabelle 2: Radiokohlenstoff- und Kalenderalter von Fossilien aus dem zentralen Bereich Ostgrönlands. Marine Fossilien wurden nach Abzug eines Reservoireffektes von 550 Jahren (TAUBER & FUNDER 1975) kalibriert.

^{14}C Age (yr BP)	Cal. ^{14}C Age (yr BP)	Latitude	Longitude	Location	Material	Reference
9730±130	10264±440	73°19.6	25°12.4	PG1200 Noa Sø, Ymer Ø	marine shell	Wagner & Melles 2002
7990±210	8325±457	73°10.67	22°11.04	PS2631, Kejser Franz Josephs Fjord	marine shell	Evans et al. 2002
9560±120	10058±269	73°09.34	19°28.93	PS2641, shelf	marine shell	Evans et al. 2002
6760±125	7101±275	73°10	27°25	Kejser Franz Josephs Fjord	marine shell	Weidick 1977
8090±80	8392±138	72°55	24°48	Kap Elisabeth, Ella Ø	marine shell	Håkansson 1973
9320±90	9874±398	72°31	23°58	Holm Bugt, Traill Ø	marine shell	Håkansson 1972
9740±90	10272±412	72°53	23°25	Kap Laura, GSØ	marine shell	Håkansson 1973
9360±110	9901±378	73°6	21°23	Bontekoe Ø	marine shell	Weidick 1976
9610±95	10194±384	72°54	21°58	Kap Mackenzie, GSØ	marine shell	Håkansson 1973
9660±95	10200±388	72°44	23°0	Snævringen, Traill Ø	marine shell	Håkansson 1973
9820±95	10437±366	72°56	22°4	Kap Biot, Kong Oscar Fjord	marine shell	Håkansson 1974
9980±95	10707±416	72°3	23°5	Gudenelv, Traill Ø	marine shell	Håkansson 1974
10720±150	11601±743	73°33	20°45	Glommen, Hold with Hope	marine shell	Håkansson 1975
9550±70	10058±251	72°53	22°08	Loon Lake, GSØ	marine shell	this study
8960±160	10012±414	72°43.36	22°28.18	PG1205 Basalt Sø, GSØ	leaves, twigs	Wagner et al. 2000

BP, which coincides well with other datings from the region (WAGNER et al. 2000, Fig. 11, Table 2).

Deglaciation of the area between 72°0´N and 73°35´N commenced before 10,000 cal. yr BP and coincided in large areas. Findings of marine fossils on Ymer Ø, GSØ and Traill Ø imply that the ice retreat was followed by a marine inundation. The lack of marine fossils with comparable age from the inner Kejser Franz Josephs Fjord does not exclude a deglaciation at the same time. However, EVANS et al. (2002) reported that the glacier retreat in middle Kejser Franz Josephs Fjord was interrupted by several still-stands as a result of topographical barriers. WAGNER & MELLES (2002) suggested that deglaciation of western Ymer Ø occurred relatively early, because the ice flow of Kejser Franz Josephs Fjord was diverted northwards, which would have led to increased input of ice masses to the middle Kejser Franz Josephs Fjord. A similar delayed deglaciation could have taken place in Kong Oscar Fjord, which was supplied with redirected ice masses from areas to the west of Ymer Ø, GSØ, and Traill Ø. This is indicated in relatively young radiocarbon dates of fossils found on the shoreline of Kong Oscar Fjord (HÅKANSSON 1973, 1974). The late deglaciation of Kejser Franz Josephs Fjord and Kong Oscar Fjord implies that the larger fjords in East Greenland were relatively long occupied by outlet glaciers, whilst smaller fjord systems further inland and at high elevated regions have already been ice-free.

6.2. Sea-level history

Loon Lake is located about 50 m below the marine limit. Its basin must have been inundated by marine waters immediately after deglaciation (Hjort 1979, Funder & Hansen 1996). This is documented in the instantaneous occurrence of foraminiferas in the sediments deposited above the diamicton (Fig. 12). A marine inundation subsequent to deglaciation during the early Holocene is comparable to other locations in East Greenland (Funder 1989c, Björck et al. 1994a, Björck et al. 1994b, Christiansen et al. 2002, Wagner & Melles 2002).

The deposition of all grain sizes shortly after deglaciation can be attributed to a rather proxi-

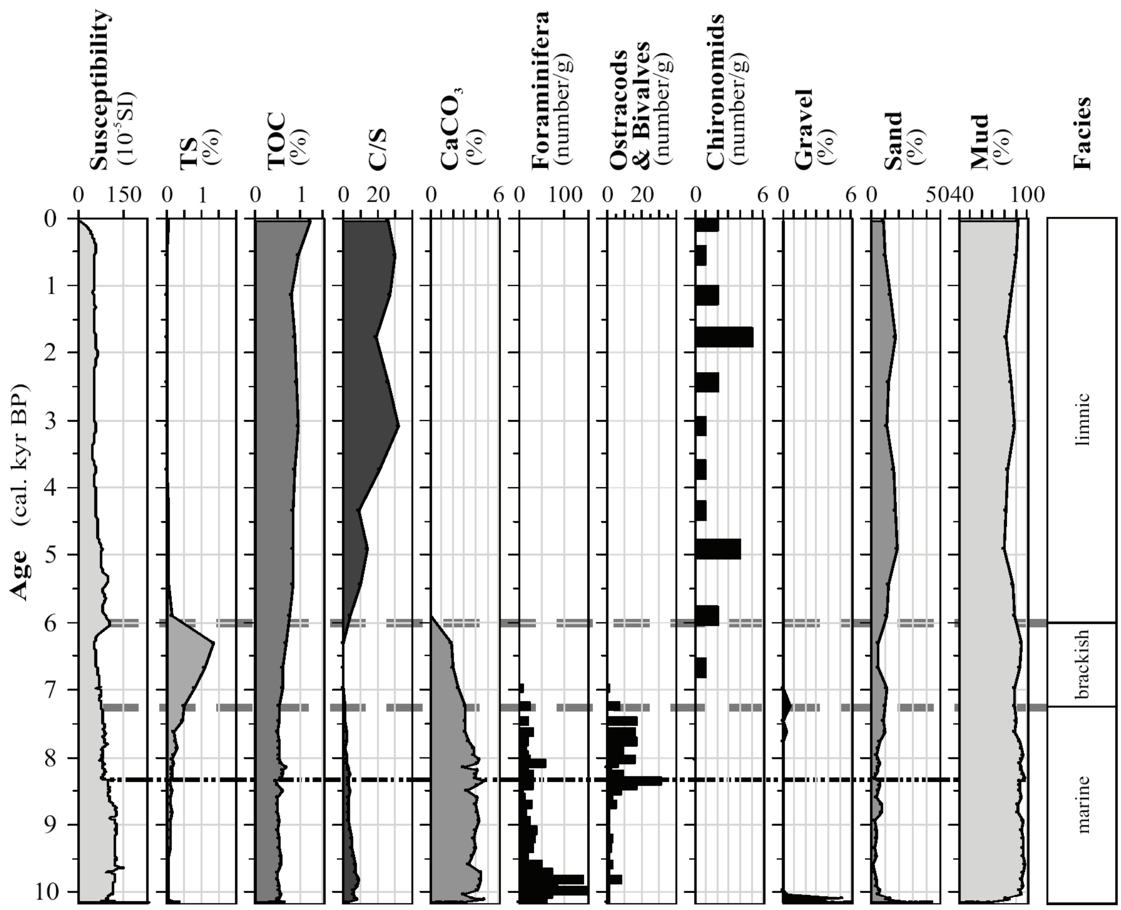


Fig. 12: Selected geophysical, biogeochemical, biological and sedimentological properties of core Lz1116 versus age with deduced facies on the right side. The glacial facies is not presented. The dotted line within the marine facies marks the occurrence of the turbidite. Data belonging to the turbidite were deleted.

Abb. 12: Ausgewählte geophysikalische, biogeochemische und sedimentologische Eigenschaften des Kerns Lz1116, dargestellt gegen das Alter, mit abgeleiteter Fazies auf der rechten Seite. Die glaziale Fazies ist nicht dargestellt. Die gepunktete Linie im marinen Stadium markiert den Bereich des Turbidits. Daten, die zu dem Turbidit gehören, sind nicht gezeigt.

mal ice margin. It is most likely that shortly after deglaciation the glacier stabilisation in Fosters Bugt, which is located to the north of Loon Lake in Kejser Franz Josephs Fjord (EVANS et al. 2002), also influenced sedimentation conditions in Loon Lake basin. Proceeding ice retreat led to calmer sedimentation conditions with a maximum of mud sedimentation at c. 9500 cal. yr BP and was followed by a successive decrease of grain sizes throughout the Holocene. Gradual decline of glacier ice with increased meltwater supply and transport of meltwater plumes towards the south into the Loon Lake region is reflected in increased C/S ratios. Despite the glacial meltwater supply, the relatively high abundance of foraminiferas after deglaciation indicates that their living conditions must have been suitable during this period.

As a result of a retreating ice margin, coastal areas underwent an isostatic rebound (FUNDER 1990). The uplift of the coastal area caused that Loon Lake basin became more and more a topographically isolated basin. In the sediment sequence from Loon Lake the transition from open marine conditions to the formation of a lagoon is expressed by the reduced amount of mud and higher deposition of sand. The higher deposition of sand can be traced back to a successively closer shoreline, which probably was correlated with a higher amount of redeposited littoral sand in the basin centre. The decline of the C/S ratio until c. 6500 cal. yr BP probably indicates reduced meltwater input due to progressive separation from open marine conditions of Kejser Franz Josephs Fjord or a successive ice retreat into inner Kejser Franz Josephs Fjord. The sporadic occurrence of single gravel grains around 7500 cal. yr BP could be a result of iceberg transport from Kejser Franz Josephs Fjord.

From c. 7250 cal. yr BP the sill seperating Loon Lake lagoon from the Kejser Franz Josephs Fjord more and more restricted the exchange of water masses from the fjord into the lagoon. Because freshwater supply from the catchment continued, whilst marine water supply became restricted, the conditions in Loon Lake lagoon gradually changed into brackish (Fig. 12). This brackish period lasted at least until 6000 cal. yr BP, before limnic conditions became established in fully isolated Loon Lake. Comparable transitions from marine via brackish to limnic settings are documented in several lakes in East Green land, e.g., in Lake Boksehandsken (BJÖRCK et al. 1994a), Peters Bugt Sø (BJÖRCK et al. 1994b), and Noa Sø (WAGNER & MELLES 2002). In contrast to Noa Sø on west Ymer Ø, the brackish period of Loon Lake is indicated by an increasing content of TS. This increasing TS content can be interpreted as a result of a density stratified water body with complete lack of mixture. Saline waters at the bottom and a freshwater layer at the surface of the lake led to reducing bottom water conditions and to progressive deterioration of the living conditions for marine organisms. As a result foraminiferas, bivalves, and ostracods completely disappeared at c. 7000 cal. yr BP. The maximum of the C/S ratio around 6250 cal. yr BP (Fig. 12) likely represents the culmination of the brackish state. The subsequent occurrence of chironomid head capsules evidences that fresh-water conditions became established in Loon Lake. However, the sill north of Loon Lake probably continued being flooded in cases of storm events. With the isolation the terrestrial catchment of Loon Lake gained in importance and supplied sediments and organic matter to the lake basin. The smaller size of the catchment area of isolated Loon Lake led to a significant reduction of the sedimentation rate to 27.5 cm/kyr after 6000 cal. yr BP (Fig. 10).

The period of lake isolation, lasting from 7250 to 6000 cal. year BP, is comparable with the pe-

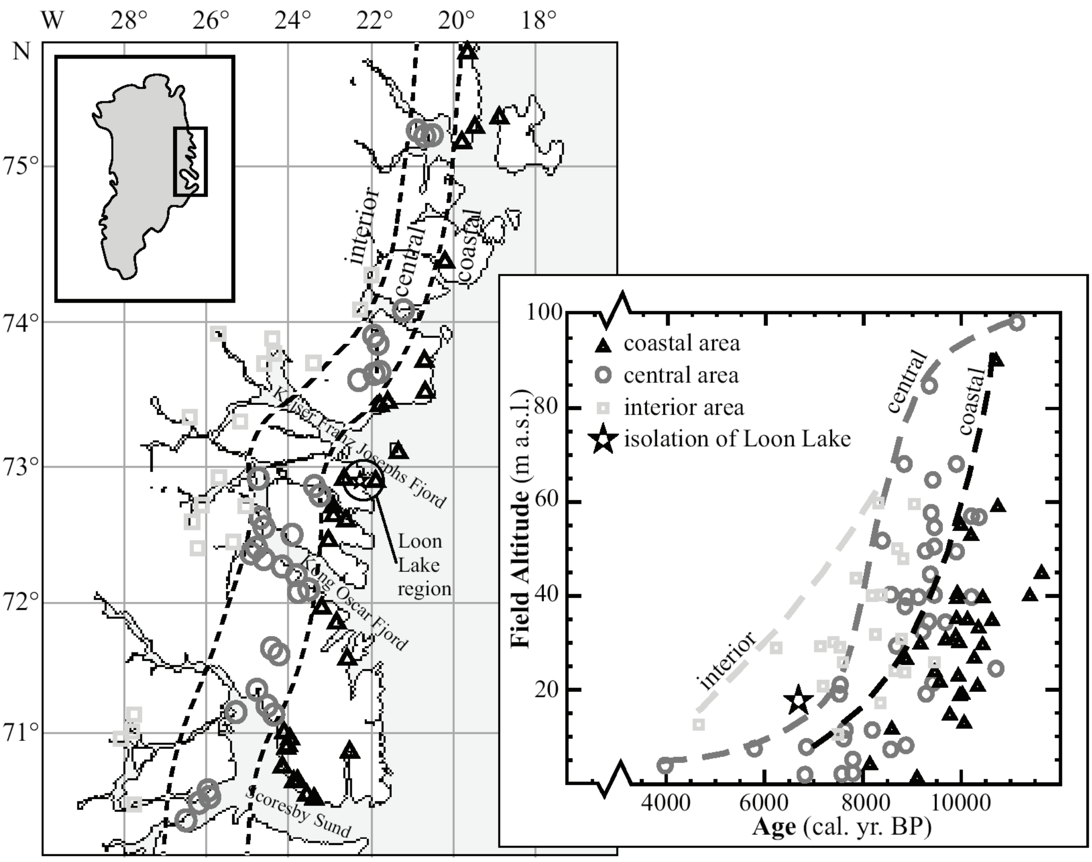


Fig. 13: Comparison of locations and ages of marine fossils versus altitude above sea level of coastal, central, and interior region according to FUNDER (1990) and modified after WAGNER & MELLES (2002). The asterisk indicates the final isolation of Loon Lake. Holocene uplift curves are deduced from the altitudes and calibrated ages of marine fossils (LEVIN et al. 1965, HÅKANSSON 1972, 1973, 1974, 1975, WEIDICK 1976, STREET 1977, WEIDICK 1977, FUNDER 1978, HÅKANSSON 1978, FUNDER 1990, BJÖRCK et al. 1994b, ISRAELSON et al. 1994, LYSÅ & LANDVIK 1994, FUNDER & HANSEN, 1996).

Abb. 13: Gegenüberstellung von Datierungen mariner Fossile und Fundorte in m über Meeresspiegel für die äussere, zentrale und innere Küstenregion (nach FUNDER 1990, verändert nach WAGNER & MELLES 2002). Der Stern markiert Loon Lakes Isolation nach dem marinen Stadium. Holozene Hebungskurven abgeleitet von Fundhöhen und kalibrierten Altern mariner Fossile (LEVIN et al. 1965, HÅKANSSON 1972, 1973, 1974, 1975, WEIDICK 1976, STREET 1977, WEIDICK 1977, FUNDER 1978, HÅKANSSON 1978, FUNDER 1990, BJÖRCK et al. 1994b, ISRAELSON et al. 1994, LYSÅ & LANDVIK 1994, FUNDER & HANSEN, 1996).

riod of brackish conditions in Noa Sø on west Ymer Ø (WAGNER & MELLES 2002). One possible reason for the relatively long duration of brackish conditions in Loon Lake might be a coinciding erosion of the sill north of the lake with ongoing uplift. Another reason could be that the isostatic uplift was slower at the outer coastal region than further inland (Fig. 13, FUNDER 1990, FUNDER & HANSEN 1996).

The final isolation of Loon Lake at c. 6000 cal. yr BP post-dates the uplift of the outer coastal region of East Greenland by up to 1000 years (Fig. 13, FUNDER 1990, WAGNER & MELLES 2002). This relatively late isolation is likely caused by delayed isostatic rebound due to the decelerated ice retreat in Kejser Franz Josephs Fjord (EVANS et al. 2002). Since c. 6000 cal. yr BP the sediment of Loon Lake does not indicate further marine transgressions.

6.3. Climate history

The postglacial sediment record from Loon Lake covers more than the last 10,000 years. Within this period the climate in East Greenland is characterised by significant changes, which are documented, for example, in many limnic sediment records (BJÖRCK et al. 1994a, BJÖRCK et al. 1994b, BENNIKE & FUNDER 1997, WAGNER et al. 2000, WAGNER & MELLES 2002).

Minor biogeochemical and sedimentological changes are documented between c. 10,000 and 6000 cal. yr BP in the sediment record from Loon Lake (Fig. 14). After deglaciation the accumulation of organic matter was mainly influenced by the marine inundation. In comparison to B1 and Basaltsø on southern GSØ (WAGNER et al. 2000) low values of TOC and TN in the sediment record from Loon Lake during the early Holocene are probably a result of the postglacial marine inundation, as it is also documented in Noa Sø on Ymer Ø (WAGNER & MELLES 2002). One possible reason for the dilution of TOC and TN might be the influence of marine currents, which most likely evacuated organic matter. Another reason could be a high sedimentation rate due to supply of organic mat-

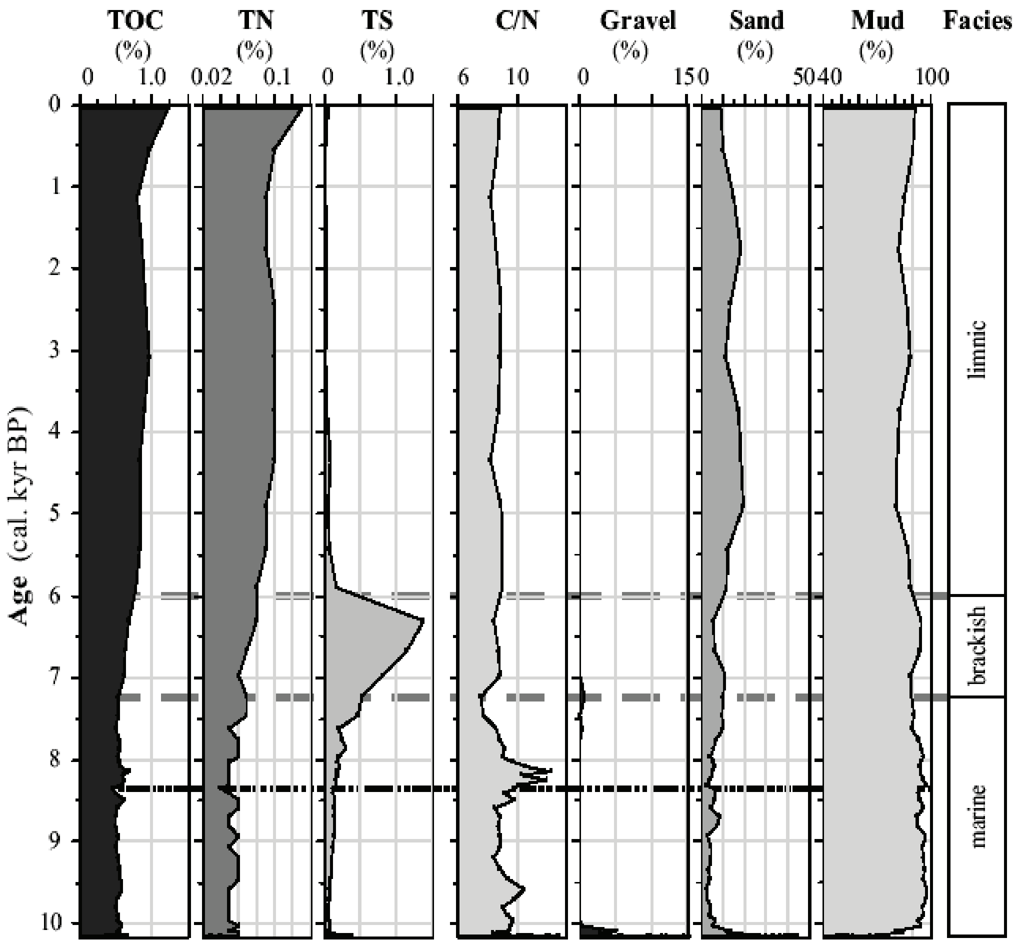


Fig. 14: Selected biogeochemical and sedimentological properties of core Lz1116 versus age with deduced facies on the right side (cf., Fig. 12).

Abb. 14: Ausgewählte biogeochemische und sedimentologische Eigenschaften des Kerns Lz1116, dargestellt gegen das Alter, mit abgeleiteter Fazies auf der rechten Seite (vgl. Abb. 12).

ter depleted sediments from Kejser Franz Josephs Fjord. The most significant change occurs at around 8200 cal. yr BP, with a maximum in the C/N ratio. Because of dating uncertainties, however, it has to remain open at this stage, whether this peak has to be attributed to delayed deposition of allochthonous organic matter from turbidite suspension or to higher erosion in the catchment during the 8.2 kyr cooling event.

After 8200 cal. yr BP the biogeochemical properties and grain sizes change rather moderately. The increase of TS and the occurrence of single gravel grains at c. 7500 cal. yr BP seem to be related to sea level changes rather than to distinct climate changes.

From 6000 cal. yr BP up to the present TOC and TN values change moderately with a slight increase towards the present. The general cooling trend during this period in East Greenland is not reflected in the organic matter accumulation of Loon Lake. Because the C/N ratio remains relatively constant during this period, both autochthonous and allochthonous organic matter supply seems to have been coincident. The grain-size distribution only shows moderate fluctuations and therefore indicates no significant changes in precipitation or erosion in the catchment.

As a result, a detailed reconstruction of the climate history of northeastern GSØ based on the sediment record from Loon Lake seems to be not possible at this stage. After deglaciation, the influence of the marine inundation superimposed the climatic changes. After isolation of Loon Lake the relatively low sedimentation rates led to a poor time resolution between the selected samples, thus inhibiting an adequate evaluation of the climate history.

7. Conclusions

Based on investigations of geophysical, sedimentological, biogeochemical, and biological properties and AMS ^{14}C dating of Loon Lake sediments the following conclusions, concerning the deglaciation of the region, the sea level and climate history, can be drawn.

The sedimentary record of Loon Lake represents a succession from a glacial via a marine to the present limnic setting. Whilst other studies suggest ice-free areas in the vicinity of Loon Lake during the LGM, the overconsolidated diamicton at the base of Loon Lake's sedimentary record indicates that at least the lake basin has been ice covered during this period. Extrapolation of linear sedimentation rates revealed an onset of deglaciation at c. 10,250 cal. yr BP. Geophysical and sedimentological data suggest a rapid ice retreat, which was followed by a marine inundation.

The marine setting in Loon Lake basin is best documented by the occurrence of foraminiferas. Within the marine sequence, a turbidite deposited at c. 8300 cal. yr BP could be a result of increased melt water input related to the 8.2 kyr cooling event, or of the Storegga tsunami. At c. 7250 cal. yr BP Loon Lake basin became due to isostatic rebound of the region a lagoon with brackish conditions. Living conditions for marine organisms deteriorated, whereas the first occurrence of chironomid head capsules indicates the establishment of freshwater conditions at least in the surface water. The final isolation of Loon Lake at c. 6000 cal. yr BP postdates the uplift of this part of coastal East Greenland by up to 1000 yr, which likely can be traced back to delayed ice retreat of the outlet glacier in Kejser Franz Josephs Fjord. Well laminated sediments represent the limnic state of Loon Lake throughout the late Holocene.

A detailed reconstruction of East Greenland's climate, using the sedimentary record of Loon Lake, was not possible. After deglaciation, the immediate marine inundation with high sedimentation rates masks the record of early and middle Holocene climate changes. Within the limnic sequence low sample resolution hampers a detailed climate reconstruction. Further investigations with lower sample intervals will enable to reconstruct a more detailed climate history of Loon Lake.

8. Acknowledgements

Catalina Gebhard is thanked for conducting the whole-core measurements, Ulrike Rantzsch for chironomids head capsule preparation and enumeration. Tanja Kuhnt and Gerhard Schmiedl gave numerous help for the determination and interpretation of the foraminiferas. We would like to thank the field party for the excellent work in East Greenland in summer 2003. Special thanks are given to Ole Bennike (GEUS, Copenhagen) for providing mapping data about East Greenland.

9. References

ALLEY, R.B., MEESE, D.A., SHUMAN, C.A., GOW, A.J., TAYLOR, K.C., GROOTES, P.M., WHITE, J.W.C., RAM, M., WADDINGTON, E.D., MAYEWSKI, P.A. & ZIELINSKI, G.A. (1993): Abrupt increase in Greenland snow accumulation at the end of the Younger Dryas event. Nature 362, 527-529.

BATTARBEE, R.W. (2000): Palaeolimnological approaches to climate change, with special regard to the biological record. Quat. Sci. Rev. 19: 107-124.

BENNIKE, O., BJÖRCK, S., BÖCHER, J., HANSEN, L., HEINEMEIER, J. & WOHLFAHRT, B. (1999): Early Holocene plant and animal remains from North-east Greenland. J. Biogeogr 26, 667-677.

BENNIKE, O., CREMER, H., HÅKANSSON, L., HULTZSCH, N., KLUG, M., KOBABE, S. & WAGNER, B. 2004. Quaternary geological and biological studies on Store Koldewey and on Geographical Society Ø. In W. JOKAT (Ed.), The Expedition ARKTIS XIX/4 of the Research Vessel POLARSTERN in 2003. Reports of Legs 4a and 4b 475. Alfred Wegener Institute for Polar and Marine Research, Bremerhaven, pp 51-74.

BENNIKE, O. & FUNDER, S. (1997): Macrofossil studies of Holocene lake sediments from Jameson Land, East Greenland. Geol. Greenl. Surv. Bull. 176, 80-83.

BJÖRCK, S., BENNIKE, O., INGÓLFSSON, Ó., BARNEKOW, L. & PENNEY, D.N. (1994a): Lake Boksehandsken's earliest postglacial sediments and their palaeoenvironmental implications, Jameson Land, East Greenland. Boreas 23, 1-14.

BJÖRCK, S., RUNDGREN, M., INGÓLFSSON , Ó. & FUNDER, S. (1997): The Preboreal oscillation around the Nordic Seas: terrestrial and lacustrine responses. J. Quat. Sci. 12, 455-465.

BJÖRCK, S. & WOHLFAHRT, B. (2001): ^{14}C Chronostratigraphic Techniques in Paleolimnology. In W.M. LAST & J.P. SMOL (Eds), Tracking Environmental Change Using Lake Sediments; Basin Analysis, Coring, and Chronological Techniques 1. Kluwer Academic Publischers, Dordrecht, pp 205-245.

BJÖRCK, S., WOHLFAHRT, B., BENNIKE, O., HJORT, C. & PERSSON, T. (1994b): Revision of the early Holocene lake sediment based chronology and event stratigraphy on Hochstetter Forland, NE Greenland. Boreas 23, 513-524.

BRODZIKOWSKI, K. & VAN LOON, A.J. (1991a): The Continental Subglacial Subenvironment and its Deposits. In K. BRODZIKOWSKI & A.J. VAN LOON (Eds), Glacigenic Sediments 49. Elsevier, Amsterdam, pp 223-266.

BRODZIKOWSKI, K. & VAN LOON, A.J. (1991b): The Continental Terminoglacial Subenvironment and its Deposits. In K. BRODZIKOWSKI & A.J. VAN LOON (Eds), Glacigenic Sediments 49. Elsevier, Amsterdam, pp 281-360.

BRODZIKOWSKI, K. & VAN LOON, A.J. (1991c): The Marine Terminological Subenvironment and its Deposits. In K. BRODZIKOWSKI & A.J. VAN LOON (Eds), Glacigenic Sediments 49. Elsevier, Amsterdam, pp 499-532.

CHRISTIANSEN, H.H., BENNIKE, O., BÖCHER, J., ELBERLING, B., HUMLUM, O. & JAKOBSEN, B.H. (2002): Holocene environmental reconstruction from deltaic deposits in northeast Greenland. J. Quat. Sci. 17: 145-160.

COHEN, A.S. (2003): Geochemical Archives in Lake Deposits. In A.S. COHEN (Ed.), Paleolimnology The History and Evolution of Lake Systems. Oxford University Press, Oxford, pp 214-272.

DANSGAARD, W., JOHNSEN, S.J., CLAUSEN, H.B., DAHL-JENSEN, D., GUNDESTRUP, N.S., HAMMER, C.U., HVIDBERG, C.S., STEFFERSEN, J.P., SVEINBJÖRNSDOTTIR, A.E., JOUZEL, J. & BOND, G. (1993): Evidence for general instability of past climate from a 250-kyr ice-core record. Nature 364, 218-220.

DITTMERS, K. & NIESSEN, F. (2002): Physical properties of the sediments. In R. STEIN & O. STEPANETS (Eds), Scientific Cruise Report of the Kara-Sea Expedition 2001 of the RV "Akademik Boris Petrov": The German - Russian Project on Siberian River Run-Off (SIRRO) and the EU Project "ESTABLISH". Reports on Polar and Marine Research 419, Alfred Wegener Institute for Polar and Marine Research, Bremerhaven, pp 74-79.

DOWDESWELL, J.A., UENZELMANN-NEBEN, G., WHITTINGTON, R.J. & MARIENFELD, P. (1994): The late Quaternary sedimentary record in Scoresby Sund, East Greenland. Boreas 23, 294-310.

EVANS, J., DOWDESWELL, J.A., GROBE, H., NIESSEN, F., STEIN, R., HUBBERTEN, H.W. & WHITTINGTON, R.J. (2002): Late Quaternary sedimentation in Kejser Franz Joseph Fjord and the continental margin of East Greenland. In J.A. DOWDESWELL & C. Ó COFAIG (Eds), Glacier-Influenced Sedimentation on High-Latitude Continental Margins 203. Geological Society, Special Publications, London, pp 149-179.

FREDSKILD, B. (1995): Palynology and sediment slumping in a high arctic Greenland lake. Boreas 24, 345-354.

FUNDER, S. (1978): Holocene stratigraphy and vegetation history in the Scoresby Sund area, East Greenland. Grønl. Geol. Unders.129, 66.

FUNDER, S. (1989a): Introduction (Quaternary geology of the ice-free areas and adjacent shelves of Greenland). In R.J. FULTON (Ed), Quaternary Geology of Canada and Greenland. Geological Survey of Canada, Toronto, pp 744-749.

FUNDER, S. (1989b): Quaternary Geology of East Greenland. In R.J. FULTON (Ed), Quaternary Geology of Canada and Greenland. Geological Survey of Canada, Toronto, pp 756-763.

FUNDER, S. (1989c): Sea level history. In R.J. FULTON (Ed), Quaternary Geology of Canada and Greenland. Geological Survey of Canada, Toronto, pp 772-774.

FUNDER, S. (1990): Descriptive text to 1:500000 Quaternary map, sheet 12, Scoresby Sund. Grønl. Geol. Unders, 24 pp.

FUNDER, S. & HANSEN, L. (1996): The Greenland ice sheet - a model for its culmination and decay during and after the last glacial maximum. Bull. Geol. Soc. Denm. 42, 137-152.

FUNDER, S., HJORT, C. & LANDVIK, J.Y. (1994): The last glacial cycles in East Greenland, an overview. Boreas 23, 283-293.

FUNDER, S., HJORT, C., LANDVIK, J.Y., NAM, S.I., REEH, N. & STEIN, R. (1998): History of a stable ice margin

- East Greenland during the middle and upper Pleistocene. Quat. Sci. Rev. 17. 77-123.

HÅKANSSON, S. (1972): University of Lund radiocarbon dates V. Radiocarbon 14, 380-400.

HÅKANSSON, S. (1973): University of Lund radiocarbon dates VI. Radiocarbon 15: 504-506.

HÅKANSSON, S. (1974): University of Lund radiocarbon dates VII. Radiocarbon 16: 307-330.

HÅKANSSON, S. (1975): University of Lund radiocarbon dates VIII. Radiocarbon 17: 174-195.

HÅKANSSON, S. (1978): University of Lund radiocarbon dates XI. Radiocarbon 20: 416-435.

HJORT, C. (1979): Glaciation in northern East Greenland during the Late Weichselian and Early Flandrian. Boreas 8, 281-296.

HJORT, C. & BJÖRCK, S. (1984): A re-evaluated glacial chronology for northern East Greenland. Geol. Fören. Stockh. Förhandl. 105, 235-243.

INGÓLFSSON, Ó., LYSÅ, A., FUNDER, S., MÖLLER, P. & BJÖRCK, S. (1994): Late Quaternary glacial history of the central west coast of Jameson Land, East Greenland. Boreas 23, 447-458.

ISRAELSON, C., BUCHARDT, B., FUNDER, S. & HUBBERTEN, H.W. (1994): Oxygen and carbon isotope composition of Quaternary bivalve shells as a water mass indicator: Last interglacial and Holocene, East Greenland. Palaeogeogr. Palaeoclimatol. Palaeoecol. 111, 119-134.

JOHNSEN, S.J., CLAUSEN, H.B., DANSGAARD, W., FUHRER, K., GUNDESTRUP, N.S., HAMMER, C.U., IVERSEN, P., JOUZEL, J., STAUFFER, B. & STEFFERSEN, J.P. (1992): Irregular glacial interstadials recorded in a new Greenland ice core. Nature 359, 311-313.

LEVIN, B., IVES, P.C., OMAN, C.L. & RUBIN, M. (1965): US geological survey radiocarbon dates VIII. Radiocarbon 7, 372-398.

LYSÅ, A. & LANDVIK, J.Y. (1994): The lower Jyllandselv succession: evidence for three Weichselian glacier advances over coastal Jameson Land, East Greenland. Boreas 23, 432-447.

MARIENFELD, P. (1990): Postglacial sedimentary history of Scoresby Sund, East Greenland. Polarforschung 60, 181-195.

MARIENFELD, P. (1991): Holozäne Sedimentationsentwicklung im Scoresby Sund, Ost Grönland. Reports on Polar and Marine Research 96. Alfred Wegener Institute for Polar and Marine Research, Bremerhaven, 162 pp.

MELLES, M., KULBE, T., OVERDUIN, P.P. & VERKULICH, S. (1994): The Expedition Bunger Oasis 1993/94 of the AWI Research Unit Potsdam. In M. MELLES (Ed.), The Expeditions NORILSK/TAYMYR 1993 and BUNGER OASIS 1993/94 of the AWI Research Unit Potsdam. Reports on Polar and Marine Research 148, Alfred-Wegener-Institut for Polar and Marine Research, Bremerhaven, pp 29-80.

MELTOFTE, H. & THINGS, H. (1997): Zackenberg Ecological Research Operations, 2nd Annual Report, 1996. Danish Polar Center, Ministry of Research & Information Technology 2, 80 pp.

MEYERS, P.A. & TERANES, J.L. (2001): Sediment Organic Matter. In W.M. LAST & J.P. SMOL (Eds), Tracking Environmental Change Using Lake Sediments; Physical and Geochemical Methods. Kluwer Academic Publischers, Dordrecht, pp 239-269.

NIESSEN, F. & HENSCHEL, H. (1995): Physical Properties in Marine Sediments. In H.W. HUBBERTEN (Ed.), The Expedition ARKTIS-X/2 of Research Vessel POLARSTERN in 1994. Reports on Polar and Marine Research 174, Alfred Wegener Institute for Polar and Marine Research, Bremerhaven, pp 75-82.

Ó COFAIG, C., DOWDESWELL, J.A. & GROBE, H. (2001): Holocene glacimarine sedimentation, inner Scoresby Sund, East Greenland, the influence of fast-flowing ice-sheet outlet glaciers. Mar. Geol. 175, 103-129.

POWELL, R. & DOMACK, E. (1995): Modern Glaciomarine Environments. In J. MENZIES (Ed.), Modern Glacial Environments; Processes, Dynamics and Sediments. Butterworth-Heinemann Ltd, Oxford, pp 445-486.

STREET, A. (1977): Deglaciation and marine paleoclimates, Schuchert Dal, Scoresby Sund, East Greenland. Arc. Alp. Res. 9, 421-426.

STUIVER, M. & REIMER, P.J. (1993): Extended ^{14}C data base and revised calib. 3.0 ^{14}C calibration. Radiocarbon 35, 215-230.

STUIVER, M., REIMER, P.J., BARD, E., BECK, J.W., BURR, G.S., HUGHEN, K.A., KROMER, B., MCCORMAC, F.G., v.d. PLICHT, J. & SPURK, M. (1998): INTCAL98 Radiocarbon Age Calibration, 24,000-0 BP. Radiocarbon 40, 1041-1083.

TAUBER, H. & FUNDER, S. (1975): C^{14} content of recent molluscs from Scoresby Sund, central East Greenland. Rapp. Grønl. Geol. Unders. 75, 95-99.

WAGNER, B. (2003): The Expeditions Amery Oasis, East Antarctica, in 2001/02 and Taylor Valley, Southern Victoria Land, in 2002. Rep. Pol. Mar. Res. 460, 1-69.

WAGNER, B. & MELLES, M. (2002): Holocene environmental history of western Ymer Ø, East Greenland, inferred from lake sediments. Quat. Intern. 89, 165-176.

Wagner, B., Melles, M., Hahne, J., Niessen, F. & Hubberten, H.W. (2000): Holocene climate history of Geographical Society Ø, East Greenland - evidence from lake sediments. Palaeogeogr. Palaeoclimatol. Palaeoecol. 160, 45-68.

WEBER, M.E., NIESSEN, F., KUHN, G. & WIEDICKE (1997): Calibration and application of marine sedimentary physical properties using a multi-sensor core logger. Mar. Geol. 136, 151-172.

WEIDICK, A. (1976): C^{14} dating of Survey material carried out in 1975. Grønl. Geol. Unders. 80, 136-144.

WEIDICK, A. (1977): C^{14} dating of Survey material carried out in 1976. Grønl. Geol. Unders. 85, 127-129.