Recent marginal changes of the Mittivakkat Glacier, Southeast Greenland and the discovery of remains of reindeer *(Rangifer tarandus)*, polar bear *(Ursus maritimus)* and peaty material.

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Abstract

During field observations in August 2005 antler remains of a reindeer were found at a recently deglaciated site at about 500 m asl., and bones from a polar bear were found at about 300 m asl. along the margin of Mittivakkat Glacier, Southeast Greenland. Radio carbon dating determined the age of the samples to 720 ^{14}C years and 350 ^{14}C years, respectively. In August 2006 old surface vegetation covering peaty material became exposed due to ice recession close to the site where the antler was found. The radio carbon age of small roots from the material was determined to 1530 ^{14}C years, and is in agreement with dating of woody remains of Salix glauca found close by, at the top of a nearby nunatak in 1999. The antler indicates that reindeer lived in the area when the glacier began to advance from a position where it was close to or smaller than today. The vegetation surface and peaty material indicate that the climate was warmer before the onset of the Little Ice Age in Southeast Greenland than today.

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Keywords

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During the past 150 years the mean global and marine surface air temperature has increased about 0.8 ºC (Brohan et al., 2006). As visible evidence of the effects of climate change many mountain glaciers and ice caps have lost substantial amounts of mass and ice cover during the period (Barry, 2006). In Greenland the temperature changes are more diverse, and the annual temperature increase is much less conspicuous (Box, 2002). At two stations in Greenland (Godthåb-Nuuk and Ammassalik), with more than a century long temperature record, measurements show that both the yearly mean and summer temperature were higher during 1905-1955 compared to 1955-2005 (Chylek et al., 2006). During the last 10 years temperature has increased at many coastal stations in Greenland, which has caused increased melt rates in the marginal areas of the Greenland Ice Sheet (Chylik et al., 2006). Recently, a marked thinning and retreat of the South Greenland Ice Sheet margin has been observed and attributed to a late response to the termination of the Little Ice Age (LIA) (Bøggild & Podlich, 2006). Observations at local glaciers in South Greenland has evidenced that they have receded from their most advanced positions, often marked by terminal moraine ridges (Lamb, 1995; Dansgaard et al., 1975).

The glaciation history of Southeast Greenland is not known in much detail. During the last glacial maximum (LGM) the Greenland Ice Sheet expanded onto the shelf (Funder & Hansen, 1996). Most likely ice sheet margins close to the present position were reached about 7-8 ka (Funder & Hansen, 1996), and on Ammassalik Island peat formation had started about 6.5 ka (Bennike & Björk, 2002 citing Bick, 1978). During the LIA glaciers also ex-

panded in Southeast Greenland and many glaciers in the area were close at their outermost moraines early in the 20th century.

This study presents the first evidence of the extent of the Mittivakkat Glacier and when the glacier started to grow before the LIA. The finds potentially indicate when the area was last snow- and ice free before the LIA advance. Large areas covered by ice and snow during the LIA have now become exposed, and finds of previous vegetation and animal remains are appearing, having survived being covered by ice and snow for longer periods of time. The potential for finding samples are probably largest, where the glacier never became more than a few meters thick and the erosion potential therefore was low. This is areas along the ice margins which were first covered by snow, which transformed into ice, and eventually were overridden by a thin layer of ice or was protected due to topographical reasons as the glacier advanced towards its maximum position close at the equilibrium line.

The study area

The Mittivakkat Glacier (65º 42´ N, 31º 48´W) is part of the largest ice field (31 km^2) on Ammassalik Island, Southeast Greenland, drained by several valley glaciers (Figure 1). Probably the glacier, based on unpublished lichenometric studies and the absence of Neoglacial deposits, during the LIA advanced to a maximum since the beginning of the Holocene in the delta area west of the present terminus, where terminal moraines are found (Christiansen et al., 1999). In the area north of the glacier the LIA is also marked by moraine ridges well outside the present glacier margin probably showing the maximum extent of the glacier during the LIA, but so far the age of the moraines have not been confirmed. The period since the first observation in 1933 has been one of almost continuous retreat and has been well documented (Larsen, 1959; Fristrup, 1960; Hasholt, 1986; Knudsen & Hasholt, 1999). During the period of mass balance measurements from 1995-2002, the glacier lost about 4% of the ice volume (Knudsen & Hasholt, 2002), and recent modelling of the mass balance during the period with standard synoptic meteorological data from 1898-2005, recorded at the Danish Meteorological Station in Tasiilaq about 20 km from the glacier, shows that out of 105 balance years the 89 years had a negative mass balance and the cumulative estimated balance was – 57 m w.eq. (Mernild et al., submitted).

Discovery of reindeer antler, bones from polar bear, vegetation surface and peaty material

During field observations in August 2005, inspection of the ice margin and the newly exposed area outside it around and below the nunatak, where plant remnants were found in 1999 (Hasholt, 2000), showed the presence of similar plant remnants in a larger area. Besides, a reindeer antler was found at about 500 m asl. (Figure 1 and Figure 2). The antler was collected and brought back to Denmark in a plastic wrapping. The small and slender antler with only six spikes and a total length of about 50 cm indicates that it is from a female reindeer (Figure 5). A ^{14}C-dating of the antler gave an age in conventional carbon years of 720 ± 50 BP, the δ^{13}C value was -18.4 ‰. The calibrated age was 1210-1330 AD, indicating that reindeer lived and foraged in the area at the time, although the possibility exists that the antler was shed on as a snow-and ice covered surface and subsequently buried by falling snow. This retained the antler for an extended period within the snow- and ice mass.

Across the glacier in the area between an ice-dammed lake and the present glacier margin at about 300 m asl. (Figure 1 and Figure 3) an elongated bone and a dorsal vertebra were found (Figure 6). The finds were wrapped in plastic and brought back to Denmark. The elongated bone was later determined a radius from one of the forelegs of a polar bear and the other as a lumbar vertebra. A ^{14}C-dating of the bones gave an age in conventional carbon years of 350 ± 40 BP. The δ^{13}C value was -14,85 ‰, indicating that the animal was mainly feeding on marine mammals.

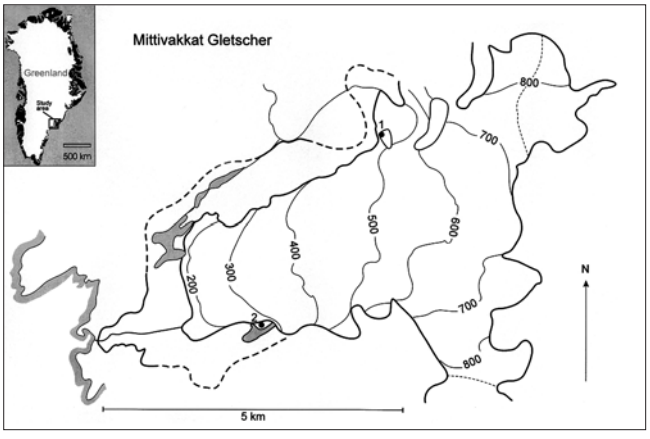

Figure 1: *Location map of Mittivakkat Glacier on Ammassalik Ø, Southeast Greenland. The surface topography, glacier margin and the LIA margin, lakes and rivers and locations where dated materials were found.*

Figure 2: *Location 1 at about 500 m asl., where the reindeer antler and surface vegetation was found. The locations are shown with arrows. The picture is taken with a view from west towards east along the ridge between the main glacier and a smaller glacier in a cirque to the north. The picture is taken in late August, when the first winter snowfall had taken place.*

During field observations in 2006 a preserved vegetation surface overlying peaty material was present both in front of and below the melting ice cover at a site very close to where the antler was found (Figure 2). A photo of a part of the area where the sample was found is shown in Figure 4. The sample was brought to the laboratory in a polyethylene bag and stored in a cold room until two sub samples were used for ^{14}C-dating.

The one sample dated consisted of small roots and the other of a single longer 1 mm thick root. The roots looked

Figure 3: *Location 2 at about 300 m asl, where the animal bones were found. The location is shown with an arrow. The view is from the east towards west along the glacier margin.*

Figure 4: *Surface vegetation melted out of the ice close at location 1, where the reindeer antler was found. The vegetation is preserved downstream of a small impediment overridden by ice.*

almost fresh and were thought to have been growing in situ shortly before the entire vegetation was covered by snow and ice for an extended period of time. The ^{14}C-dating of the small roots gave an age in conventional carbon years of 1548 ± 36 BP, and the δ^{13}C value was -26.91 ‰. The calibrated age was 420 – 640 AD. The thicker root gave an age in conventional ^{14}C-years of 1513 ± 40 BP, and the δ^{13}C value was -22.34 ‰. The calibrated age was 430-600 AD. Obviously the dating gave much the same age for the two samples.

Figure 5: *The reindeer antler found at location 1 at about 500 m asl. A ^{14}C-dating of the antler gave an age in conventional carbon years of 720 ± 50 BP.*

Figure 6: *The polar bear bones found at location 2 at about 300 m asl. A ^{14}C-carbon dating gave an age in conventional carbon years of 350 ± 40 BP.*

Discussion

The advance of glaciers in the period AD 1300-1900 is well documented in the northern hemisphere (Grove, 2001), and in Greenland many glaciers reached a maximum with marked terminal moraines around 1870-1900 (Weidick, 1984; Christiansen et al., 1999). Towards the end of the Medieval Warm Period snow cover was increasing in West Greenland as witnessed by mosses dating between AD 1290 and 1400 from cairns melting out of perennial snow patches (Weidick et al., 1992). On Svalbard, frozen samples of soil and vegetation have been found below Longyearbreen about 2 km from the present margin and 30-35 m below the present glacier surface. ^{14}C-dating indicates that the site was overrun by the glacier about 1100 years ago, and that the site before that was ice-free for at least 800 years (Humlum et al., 2005).

No details of fluctuation of small glaciers in Greenland are available during the period, but many probably began to advance, reaching a maximum around 1900, at many sites representing the Holocene maximum extension (Weidick, 1984; Humlum, 1987) based on observational records or their trim line zone.

The presence of reindeer has been documented for a rather short time span between about 1680 – 870 BP (AD 325-1135) in East Greenland based on findings on the ground in both geological and archaeological contexts (Meldgård, 1986 and1991). Judged from positions shown on a map (Meldgård, 1986, Figure 41) findings have been collected in near coastal positions. The find made at the Mittivakkat Glacier shows that reindeer were foraging also in areas away from the coasts and at higher altitudes. The age of the antler indicates that reindeer lived in the area probably as late as AD 1210-1330, which is about 100-200 years later than previous findings suggest. On the other hand it is in accordance with the suggestion that the population of reindeer in the region first became extinct some time between AD 1200 and 1500 (Meldgård, 1986). The position of the find indicates that it was shed on a snow and ice covered surface during spring, when the female reindeer shed their antlers. Then buried by snow and ice during the following years and incorporated into the glacier not far from where it was found, until it recently, probably within the last few years, melted out of the glacier. From the find it is not possible to determine whether it has been transported for a longer distance, but most likely it has been incorporated in the glacier since it was shed, indicating that the position where it was found has been covered by snow and ice at least since then.

The find of polar bear bones with an age of about 350 years, in an area where the glacier has melted away during the last 10 years, could indicate that the site was covered by ice when the animal parts were left in the area. Judged from the ice eroded and polished appearance of the surrounding surface with dispersed rocks it is not possible to imagine that the bones could survive being overrun and/or transported at the base of the glacier. It is more likely that the animal by itself had moved up on the glacier and fallen into a crevasse, or it was left or dropped on the glacier surface, eventually falling into a crevasse, as it was transported through the area. The total number of bones found within a very small area indicates that it was a larger part of an animal, which hardly could have been brought there by a fox or bird. Although it is not certain that the area was covered by ice where the bones were found, their presence in the area well inside the LIA maximum indicate that there was a glacier on which it was left not far from the site.

The presence of a vegetation surface above peaty material melting out of the ice below the nunatak at about 500 m asl. indicates that about 500-600 AD vegetation flourished in the area and there was probably some distance to the ice margin as similar vegetation today is only found below about 200-300 m asl. in the area. The materials used for dating from the 2006 sample of small roots indicate that they were alive at the time given by the dating. Besides, they would probably not have been preserved very long if not covered by snow, later converted into ice, however showing no appreciable glacier sliding. Probably the vegetation was permanently covered by snow and ice

shortly after AD 600. This also explains the difference in age between the organic materials and the reindeer antler, as it was shed on the surface much later. This indicates that a cold period or a period with more winter precipitation preventing the winter snow fall to melt during the summer, started at about this time, but it cannot be excluded that the period favourable for ice advance started later, but not less than about 700 years ago.

Conclusions

Recently, at the Mittivakkat Glacier just below the equilibrium line at approximately 500 m asl., an exposure of undisturbed vegetation has been found melting out at the glacier margin. Dating shows that about AD 420-640 the area was covered by vegetation that today is only found outside the LIA maximum and at levels below about 200-300 m asl. This indicates that the glacier margin was further back, and that the glacier was probably smaller than at present. This is some of the very first direct evidence about local glacial extent before the LIA advance in this part of Greenland.

A reindeer antler was found on the surface within about 100 m from the vegetation surface. Dating showed an age about AD 1210-1330. The antler was probably shed close to where it was found, and the site was covered by ice and snow at that time. This indicates that the climate was becoming colder and that the glacier had begun to advance across the area.

Bones from a polar bear were found on the surface at about 300 m asl. just south of the present glacial margin in an area that was covered by ice until about 10 years ago. It was probably brought to the site within the ice and released as the ice melted away from the area. The remnants of the animal could have been dumped on the glacier surface or into a crevasse by Eskimos travelling on the glacier at the time of dating of the bones, i.e. about AD 1650. Another possibility is that the animal actually moved up on the glacier and fell into a crevasse. From this find it is not possible to conclude that the ice covered the site where it was found, which is well within the LIA maximum, but that a glacier not far from the site must have been present.

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