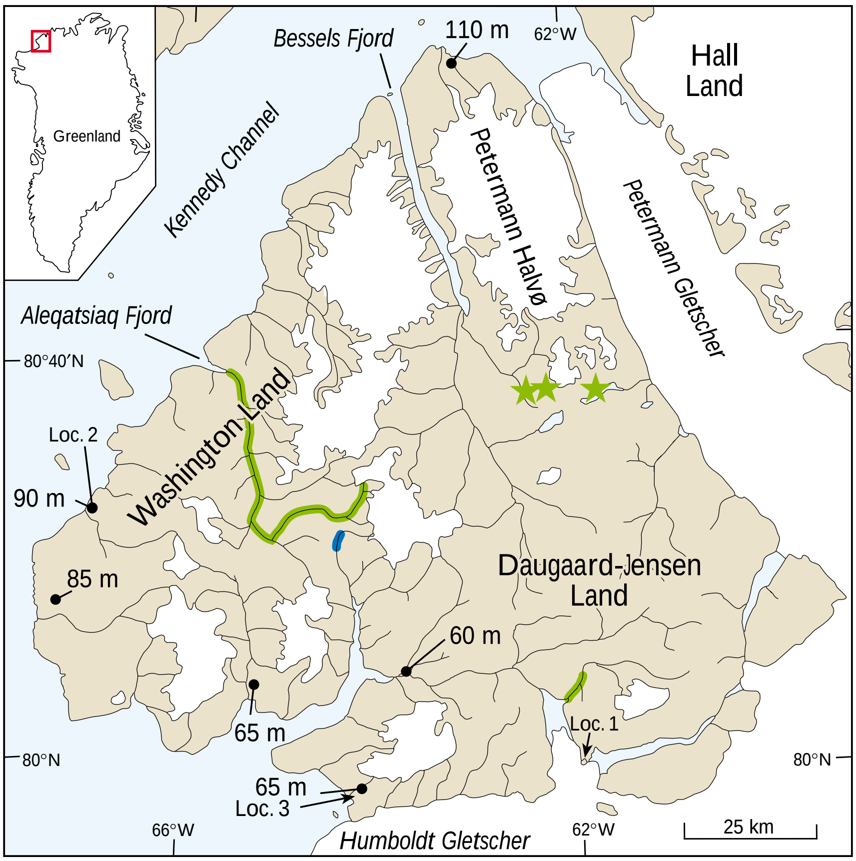
Notes on the late Cenozoic history of the Washington Land area, western North Greenland

Ole Bennike

Information on Late Tertiary and Quaternary deposits in the Washington Land area is extremely limited. This is perhaps surprising since, as a central part of Nares Strait separating Greenland and Canada, the Washington Land area is crucial to the understanding of the much debated Late Quaternary history of the region. Three shell samples, two wood samples and a peat sample, collected in the mid 1970s, have been radiocarbon dated and discussed by Weidick (1977, 1978), Jepsen (1982), Blake (1987) and Bennike & Jepsen (in press); wood samples collected in 1997 were described by Bennike (1998). Much more information is available from Inglefield Land to the south, and Hall Land to the north (Nichols 1969; Dawes 1987; Blake *et al.* 1992; Kelly & Bennike 1992). Thus, when the opportunity to carry out field work in the Washington Land area arose in connection with the project *Kane Basin 1999* (see Dawes 2000a, this volume), the chance was taken to attempt to fill this knowledge gap. The main aim was to locate the source of the wood – hopefully within a sedimentary sequence. In addition, observations and sampling of Quaternary deposits and landforms were planned. However, since the source of the wood proved impossible to locate, more time was spent on Quaternary deposits than originally expected.



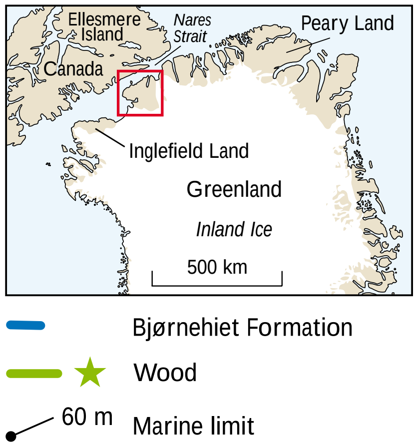


Fig. 1. Location maps showing the Washington Land area (and part of south-western Hall Land) and its central position in the Nares Strait region. Locations are: the Bjørnehiet Formation, wood occurrences, interglacial sites (Locs 1, 2), marine limits, the raised spit shown in Fig. 4 (Loc. 2) and the periglacial phenomena site shown in Fig. 5 (Loc. 3). **Blank** areas on the main map are ice caps and glaciers.

Study area and setting

The study area is referred to in this report as 'the Washington Land area' comprising Washington Land *sensu stricto*, Daugaard-Jensen Land and Petermann Halvø (Fig. 1). It extends from Humboldt Gletscher in the south – the widest outlet glacier from the Inland Ice – to Petermann Gletscher in the east. The latter glacier has a long floating tongue, as do other large outlet glaciers in central North Greenland (Kelly & Bennike 1992), and it is the fastest moving glacier in North Greenland at *c.* 1 km per year (Higgins 1988). The Washington Land area is bordered to the north-west by Kennedy Channel that is about 40 km wide and up to 400 m deep. Many local ice caps occur and the present-day glaciation limit falls from *c.* 1000 m in the south-east to less than 500 m in the north-west (Weidick 1976). Topographically, the study area is characterised by dissected plateaus. The sea ice in Kennedy Channel and in the fjords breaks up in the summer and raised beaches are widespread where lowlands border the sea.

Material and methods

Field work in 1999 was undertaken from ten camps. Numerous samples of wood were collected, comprising whole trunks, branches and wood fragments but unfortunately none were found *in situ*.

From raised marine and littoral deposits, 48 samples of fossil shells were collected. When dated, this material will provide information on the chronology of the last deglaciation and the subsequent relative sea-level changes. In addition, bones of seals, whale, polar bear, muskox and reindeer were collected. This material will give information on the late Quaternary history of these taxa. Samples for macrofossil analyses and luminescence dating were collected from an interglacial sequence. No dates are yet available.

Pliocene (?) wood

Wood was found along the river that drains into Aleqatsiaq Fjord (Fig. 1), and the trail was followed up-stream to a local ice cap where the last wood piece was found a few hundred metres from the ice margin, *c.* 60 km from the sea and at an altitude of *c.* 600 m above sea level. Wood was concentrated at places where the current velocity of the river was low and where fluvial sediments occurred. Over sections of the river with high current velocities, such as canyons, wood was lacking. The wood pieces are all more or less rounded and abraded as a result of river transport (Fig. 2), but closer to the ice cap preservation was better. Some wood has retained some bark, and branches with twigs were also found.

No connection could be established between the wood found in the river bed and the Bjørnehiet Formation of Jepsen (1982). The outcrops of the Bjørnehiet Formation occur south of the river (Fig. 1), but no wood was located there. The formation is located in a canyon which was probably formed during the Quaternary,

Fig. 2. The largest wood pieces found in 1999. The longest trunk measures 176 cm; note the abrasion due to river transport. Photo: Peter K. Warna-Moors.

and a Late Quaternary, rather than a Pliocene age, seems likely. Somewhat similar cemented gravel in south-west Hall Land appears to be of Holocene age (M. Kelly & O. Bennike, unpublished data).

The two longest tree trunks found measure 176 and 156 cm (Fig. 2). Although the top part of the trunks are missing, it is clear from the trunk diameter that the trees were generally very small (Fig. 3).

Unfortunately, we were unable to locate an *in situ* source of the wood, but Pliocene(?) sediments may be present below the ice cap. From Ellesmere Island, Canada, a number of high-elevation Pliocene sedimentary sequences are known, and one of them, the so-called Beaver Pond deposit, has yielded a rich mammalian fauna (Hulbert & Harington 1999).

The only other previously known occurrence of wood from the study area was also visited in 1999 (Weidick 1978). This locality is in Daugaard-Jensen Land, in a gravel river bed and in particular along the shores of a large lake into which the river drains (Fig. 1). Again we were unable to locate an *in situ* source but this river also drains a local ice cap and any Pliocene sediments, if present, may be below the ice.

In 1999 wood was also found in the eastern part of the study area in southern Petermann Halvø (Fig. 1). Samples were collected by S.M. Jensen and F.W. van der Stijl at three localities, viz. on the terrain surface, in a river bed and along the shore of a lake. The elevation range between 134 to 370 m above sea level points to a local source for the wood.

In addition to the Washington Land area, occurrences of presumed Late Tertiary wood are known in Greenland from southern and eastern Peary Land (Bennike 1998). Recently, a piece of wood from northern Peary Land (83°00.8´N, 34°15´W) was radiocarbon dated to > 40,020 years BP (K-7082) indicating a Late Tertiary age (Bennike, unpublished data).

Interglacial site

The first non-marine interglacial site in Greenland was found in the Washington Land area in 1976, although its interglacial age was not proved until 1999 when *Dryas integrifolia* leaves yielded non-finite radiocarbon ages (Bennike & Jepsen in press). In 1999 the site was revisited (Loc. 1 on Fig. 1), and preliminary analyses of plant and animal remains have added several southern extra-limital species. These include the water plant *Potamogeton filiformis* and the Greenlandic seed bug *Nysius groenlandicus*, both of which have been found

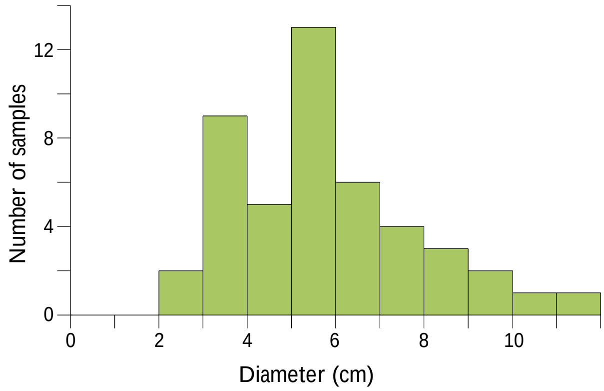


Fig. 3. Histogram showing the diameter of tree trunks of 47 samples from the Washington Land area, including collections from 1997 (Bennike 1998).

in samples from interglacial sites in North-West and East Greenland (Bennike & Böcher 1992, 1994). Samples have been submitted for luminescence dating, which will hopefully better constrain the age of this sequence.

A second possible interglacial site was located in coastal Washington Land in 1999 (Loc. 2 on Fig. 1). Organic detritus recovered contains remains of the ground beetle *Amara alpina* and *Potamogeton filiformis*. *Amara alpina* is the most cold-adapted ground beetle on Earth, and it has also been recovered from interglacial deposits in Greenland, but the species is apparently not a member of the present-day fauna (Böcher 1989).

Glaciation history

Erratic boulders can be found throughout the Washington Land area although their numbers decrease from south-east to north-west. On northernmost Petermann Halvø, at an altitude of 930 m above sea level, a few erratic gneiss and granite boulders were located on top of deeply-weathered bedrock. They are assumed to be derived from the Precambrian shield under the Inland Ice to the south-east (see Dawes *et al.* 2000b, this volume, for provenance study of glacial erratics). Their presence on a summit near Kennedy Channel shows that all of the Washington Land area was inundated by the Greenland ice sheet during the Quaternary, and that the Inland Ice even extended onto adjacent Ellesmere Island (England 1999). Fresh glacial striae, melt-water channels and moraines are common at low-level sites in Washington Land, but no glacial striae, moraines or other landforms were located along Kennedy Channel that could be attributed to a glacier

Fig. 4. Raised Holocene coastal spit from western Washington Land formed during relative sea-level lowering (Loc. 2 on Fig. 1). Raised marine deltas are seen in the foreground. The cliffs to the right reach around 300 m above sea level. For location, see Fig. 1.

in Nares Strait, such as has been documented elsewhere on the Greenland side of the Strait (Blake *et al.* 1992; Kelly & Bennike 1992). At many sites, small melt-water channels show that local ice caps have thinned and diminished in size following their historic maximum probably early this century. Fresh moraines are seen near the snouts of smaller outlet glaciers, with good examples around Bessels Fjord (Fig. 1; Davies & Krinsley 1962). Along the northern margin of Humboldt Gletscher, large fresh, ice-cored moraines with reworked marine shells are found, and the north-western portion of this glacier has evidently receded a few kilometres from its historic maximum.

The marine limit and Holocene marine faunas

Raised Holocene marine, deltaic and littoral deposits occur in low-lying areas. Pre-Holocene reworked faunas were only found at two sites. The sea ice breaks up in the summer, and along Kennedy Channel raised beaches and spits are developed which can be used to define the marine limit (Fig. 4). In other areas the marine limit can be defined from raised marine deltas.

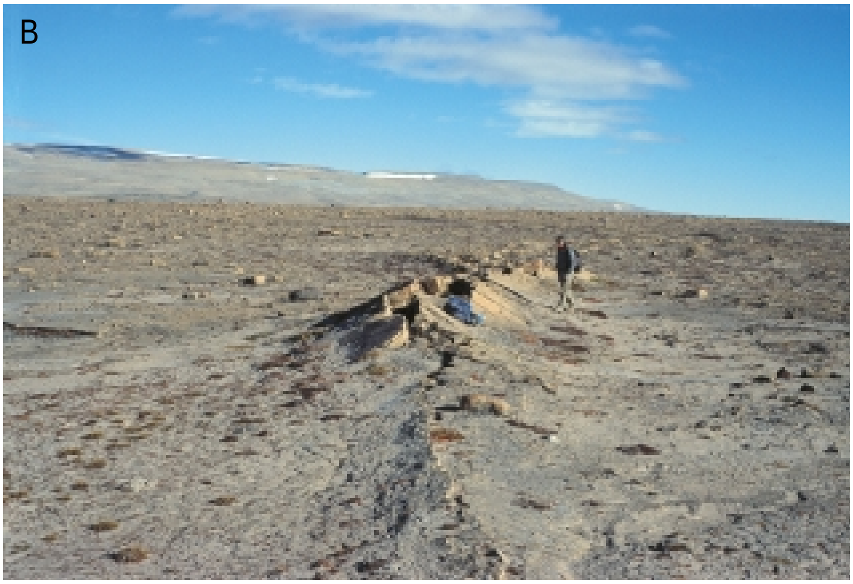
The height of the marine limit was determined at six sites (Fig. 1). It was found to increase from around 60–65 m in the south to around 110 m above sea level in the north. These figures may partly reflect that the northern area was deglaciated earlier than the southern part. The figures suggest an isostatic rise of at least 100–150 m following deglaciation.

Not a single piece of drift wood was found on the raised beaches, but shells of marine invertebrates and bones of vertebrates were seen at a number of sites. The marine invertebrate faunas are dominated by the bivalves *Hiatella arctica* and *Mya truncata* as elsewhere in North Greenland (Bennike *et al.* 1986; Bennike 1987; Kelly & Bennike 1992), but the fossil assemblages include the bivalves *Chlamys islandica* and *Clinocardium ciliatum*, the gastropod *Lepeta caeca* and the barnacle *Balanus balanus* none of which have previously been reported from Holocene deposits in North Greenland. These species probably have their northernmost Greenlandic Holocene occurrences in the Washington Land area.

Periglacial phenomena

On an outwash plain in south-western Daugaard-Jensen Land, small pingo-like features were observed measuring around 5 m in height and 20 m in diameter (Fig. 5A; Loc. 3 on Fig. 1). These features show some resemblance to pingos but they are smaller, not situated in a valley bottom as are other Greenland pingos, and they occur in clusters. Also noteworthy is the common occurrence of sand-wedge polygons, especially on gravel deposits but also sometimes on the carbonate bedrock (Fig. 5B; Loc. 3 on Fig. 1).

Fig. 5. Periglacial phenomena in Daugaard-Jensen Land (Loc. 3 on Fig. 1). **A**: Pingo-like feature about 5 m high. **B**: Sand-wedge formed in carbonate bedrock.



Acknowledgements

David Baker is thanked for his excellent field assistance and Sven Monrad Jensen and Frank W. van der Stijl for collecting wood and bone samples. The project was made possible by financial support from the Carlsberg Foundation and the Danish Polar Center. Jens Böcher kindly confirmed the identification of *Amara alpina* and Klaus Peter Brodersen commented on the manuscript. T.I. Hauge Andersson from the Danish Polar Center and Peter R. Dawes from the Geological Survey of Denmark and Greenland established the logistic platform, without which this study would not have been possible.

References

Bennike, O. 1987: Quaternary geology and biology of the Jørgen Brønlund Fjord area, North Greenland. Meddelelser om Grønland Geoscience **18**, 23 pp.

Bennike, O. 1998: Late Cenozoic wood from Washington Land, North Greenland. Geology of Greenland Survey Bulletin **180**, 155–158.

Bennike, O. & Böcher, J. 1992: Early Weichselian interstadial land biotas at Thule, Northwest Greenland. Boreas **21**, 111–117.

Bennike, O. & Böcher, J. 1994: Land biotas of the last interglacial/glacial cycle on Jameson Land, East Greenland. Boreas **23**, 479–487.

Bennike, O. & Jepsen, H.F. in press: A new interglacial sequence from Washington Land, North Greenland. Polar Research.

Bennike, O., Funder, S. & Hjort, C. 1986: Notes on the Holocene marine fauna of eastern North Greenland. Bulletin of the Geological Society of Denmark **35**, 71–74.

Blake, W. Jr. 1987: Geological Survey of Canada radiocarbon dates XXVI. Geological Survey of Canada Paper **86-7**, 60 pp.

Blake, W. Jr., Boucherle, M.M., Fredskild, B., Janssens, J.A. & Smol, J.P. 1992: The geomorphological setting, glacial history and Holocene development of 'Kap Inglefield Sø', Inglefield Land, North-West Greenland. Meddelelser om Grønland Geoscience **27**, 42 pp. + map.

Böcher, J. 1989: First record of an interstadial insect from Greenland: *Amara alpina* (Paykull, 1790) (Coleoptera: Carabidae). Boreas **18**, 1–4.

Davies, W.E. & Krinsley, D.B. 1962: The recent regimen of the ice cap margin in North Greenland. International Association of Scientific Hydrology Publication **58**, 119–130.

Dawes, P.R. 1987: Topographical and geological maps of Hall Land, North Greenland. Description of a computer-supported photogrammetrical research programme for production of new maps, and the Lower Palaeozoic and surficial geology. Bulletin Grønlands Geologiske Undersøgelse **155**, 88 pp. + 4 maps.

Dawes, P.R. *et al.* 2000a: Kane Basin 1999: mapping, stratigraphic studies and economic assessment of Precambrian and Lower Palaeozoic provinces in north-western Greenland. Geology of Greenland Survey Bulletin **186**, 11–28 (this volume).

Dawes, P.R., Thomassen, B. & Andersson, T.I.H. 2000b: A new volcanic province: evidence from glacial erratics in western North Greenland. Geology of Greenland Survey Bulletin **186**, 35–41 (this volume).

England, J. 1999: Coalescent Greenland and Innuitian ice during the last glacial maximum: revising the Quaternary of the Canadian High Arctic. Quaternary Science Reviews **18**, 421–456.

Higgins, A.K. 1988: Glacier velocities from aerial photographs in North and North-East Greenland. Rapport Grønlands Geologiske Undersøgelse **140**, 102–105.

Hulbert Jr., R.C. & Harington, C.R. 1999: An early Pliocene Hipparionine horse from the Canadian Arctic. Palaeontology **42**, 1017–1025.

Jepsen, H.F. 1982: The Bjørnehiet Formation: a faulted preglacial conglomerate, Washington Land, North Greenland. In: Dawes, P.R. & Kerr, J.W. (eds): Nares Strait and the drift of Greenland: a conflict in plate tectonics. Meddelelser om Grønland Geoscience **8**, 151–155.

Kelly, M. & Bennike, O. 1992: Quaternary geology of western and central North Greenland. Rapport Grønlands Geologiske Undersøgelse **153**, 34 pp.

Nichols, R.L. 1969: Geomorphology of Inglefield Land, North Greenland. Meddelelser om Grønland **188**(1), 109 pp.

Weidick, A. 1976: Glaciation and the Quaternary of Greenland. In: Escher, A. & Watt, W.S. (eds): Geology of Greenland, 430–458. Copenhagen: Geological Survey of Greenland.

Weidick, A. 1977: C^{14} dating of Survey material carried out in 1976. Rapport Grønlands Geologiske Undersøgelse **85**, 127–129.

Weidick, A. 1978: C^{14} dating of Survey material carried out in 1977. Rapport Grønlands Geologiske Undersøgelse **90**, 119–124.

Author's address

Geological Survey of Denmark and Greenland, Thoravej 8, DK-2400 Copenhagen NV, Denmark. E-mail: *obe@geus.dk*