

Late Quaternary stratigraphy and glaciology in the Thule area, Northwest Greenland

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This report contains the geological and glaciological results of the NORDQUA 86 expedition to Thule, Northwest Greenland.

Coastal sections along Wolstenholme Fjord provide a detailed record of glacial and marine events during isotope stage 5 (74–134 ka), on the northern perimeter of Baffin Bay.

The record has been dated by a combination of thermoluminescence and C-14 dating. Amino acid analyses of marine mollusc shells afford local and regional correlations, while periods with penetration of warm subarctic water have been identified by their foraminifer and mollusc faunas. There were two marine episodes with influx of subarctic water. Between the two marine episodes (at 114 ± 10 ka) maximum, although restricted, Weichselian ice coverage was attained. After this, and until the Late Weichselian, ice coverage was similar to or smaller than at present. In Late Weichselian times there was a readvance of glaciers, also associated with influx of subarctic water.

The record provides for the first time a link between events in arctic Canada and Greenland, and shows that in the northern Baffin Bay region there is a causal relationship between hydrography and glaciation.

Samples of glacier ice from two cross sections of the ice margin all show a Holocene stable isotope signal. Although there are several possible explanations for this, this finding is in agreement with the small extent of ice cover during the Weichselian. It also seems likely that the local "Tuto ice dome" did not exist during the Holocene climatic optimum.

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Introduction

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The Baffin Bay region is a climate-sensitive area, and climatic and hydrographic changes in this region have been held responsible for the initial formation and growth of the Laurentide Ice Sheet over North America during the last ice age.

The present report describes results of a study in the Thule area, northwest Greenland, which yielded new evidence on this issue, and for the first time provides a link between events in North America and Greenland at the beginning of the last ice age. The evidence supports the theory that in this region glaciation is associated with influx of warm subarctic water along the coast.

The results are a product of the "NORDQUA 86 Project", based on field work carried out in August 1986 by 33 Quaternary scientists from the five Nordic countries and Britain, under the auspices of NORDQUA – the association of Quaternary scientists from the Nordic countries. The organisers were S. Funder, then President, and Kaj Strand Petersen, General Secretary of NORDQUA.

Preliminary results have been presented in a series of papers at the 18. Nordic Geologic Winter Meeting in Copenhagen (Feyling-Hanssen 1988; Funder 1988; Houmark-Nielsen 1988; Mörner 1988; Sejrup 1988; Sorby 1988; Reeh & Thomsen 1988), and NORDQUA 86 Participants (1989).

Although responsibilities for interpretation and conclusions lie with the authors of each section, it must be noted that the results are due to all participants (see below).

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Previous studies of Quaternary geology

Observations on geomorphology, and its relevance to earlier glaciation in the Thule area were discussed by Chamberlin (1895), Koch (1928) and Schytt (1956). A comprehensive study and mapping of the Quaternary geology in the region here dealt with was carried out by Krinsley (1963). Non-finite C-14 ages, the first in Greenland, from a coastal cliff on Saunders Ø played an important part in the stratigraphical outline, showing

that although the entire region had been overridden by ice, the ice cover began to melt before 32 000 yrs BP and "marine till" with *in situ* molluscs was deposited in front of the receding Wolstenholme Fjord glacier. This was followed by sea-level rise which reached a culmination before 8500 yrs BP, and after this the glacier receded up to 24 kilometres behind its present boundary. Goldthwait (1960) and Crane & Griffin (1954) obtained C-14 dates from Nunatarssuaq on the north side of Wolstenholme Fjord supporting the early recession, and showing that the present extent of glaciation was attained before 9000 yrs BP. This was supported by later C-14 dates from Thule and Narssárssuk (Weidick 1977).

Blake (1975, 1977, 1987) revisited and reinterpreted the sections on Saunders Ø, and made the important observations that below an upper till bed there are marine sediments with a thermophilous mollusc fauna which again overlie an older bed of till. The marine sediments had non-finite C-14 ages, and were correlated with a similar occurrence on Coburg Island to the east of Thule, and referred to the Sangamonian interglaciation (Blake 1973: 56).

At Qarmat in the interior Wolstenholme Fjord, Kelly (1980a, 1986) found a somewhat similar sequence of marine sediments with thermophilous molluscs, non-finite C-14 age, and amino acid ratios comparable to those of occurrences in Melville Bugt to the south, and correlated them with the "intra last glaciation" Kogalu aminozone of Baffin Island (Miller *et al.* 1977).

From these studies it emerged that the Thule region, and especially the coastal cliffs on Saunders Ø, had a longer and more complex record of Late Quaternary glacial and marine events than known elsewhere in West Greenland, and in general stratigraphic reviews the Saunders Ø occurrence attained a key role for the Eemian-Weichselian stratigraphy of West Greenland (e.g. Funder 1984, 1989; Kelly 1985, 1986), a role that probably had not been anticipated by the field workers.

With this background one objective of the NORDQUA 86 expedition was to make detailed sedimentological investigations supplemented by modern dating techniques at the sites on Saunders Ø and Qarmat. During the field work a third site for pre-Holocene sediment, Narssárssuk, was discovered.

Methods and organisation of this report

The field work comprised two projects: Quaternary geological work on the ice free land, and glaciological work on the adjacent ice sheet. The work on land was concentrated on three sites where coastal sections in raised alluvial cones give a detailed record of isotope stage 5 (74–134 ka) marine and glacial events (Fig. 1). The results of lithologic logging at these sites are de-

scribed in the first section, and summarised in Figs 4, 8 and 9. Periods of cold and warm water influx are identified by micro- and macropalaentological analyses, as described in the second section, and summarised in Fig. 11 and Tables 4, 5 and 6. Absolute dates are provided by thermoluminescence and C-14 ages, described in the third section and appendix, and summarised in Table 9. The third section also gives a description of amino acid analyses of marine bivalve shells, essential for correlating between sites, and listed in Table 10. Finally, in the fourth and fifth sections this evidence is combined into an event-stratigraphy (Fig. 24), and compared to that from adjacent areas in Baffin Bay (Fig. 27).

Throughout this part of the work samples are referred to by their field numbers and the lithologic units to which they belong. The location of samples and lithologic units appear from Figs 4, 8 and 9.

The sixth section deals with glaciological work aimed at unravelling the dynamic and climatic history of the Northwest Greenland ice cover by studying stable isotopes in surface samples of glacier ice. Two sites were selected for this work: one on the Inland Ice margin north of Wolstenholme Fjord, and the other on the margin of the "Tuto ice dome" south of the fjord.

Chronostratigraphic nomenclature follows the recommendation of Mangerud *et al.* (1979), and isotopic substage 5e (123–130 ka) is regarded as equivalent to the Eemian interglaciation, while the Weichselian glaciation covers isotopic stages 2–5d (12–123 ka). Ages cited for isotopic stages are from Martinson *et al.* (1987).

Acknowledgements

There is no precedence for bringing a large group of scientists to work on a single project in this part of Greenland, and had it not been for the extraordinary goodwill and helpfulness offered by many persons and institutions, the project would have foundered long before the departure from Copenhagen.

During the planning phase the Commission for Scientific Research in Greenland, and Sven Adsersen, of the then Ministry for Greenland cleared many obstacles for us. The Geological Survey of Denmark kindly undertook the printing of an 80 page excursion guide "Istiden i Thule – Nordqua 1986, Grønland".

The field work took place in the period 7-21.8. 1986, and in Thule smooth cooperation with the air base authorities was handled efficiently by the Danish liaison officer, Commander Erik Thomsen and his staff, whose advice and help was essential for the success of the field work in spite of bad weather and ice-filled waters. Also the help from Hans J. Østergaard, commissary, was important for our general well-being. A major problem was the transportation within the area of such a large group of people. Here we had the unexpected luck to be able to use a U.S. Army landing vessel under the command of sgt. W. Turner, as well as the Danish naval vessel Tuluaq.

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