
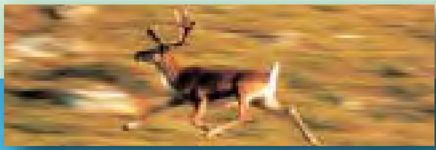
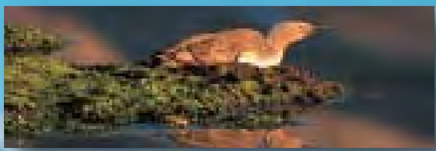
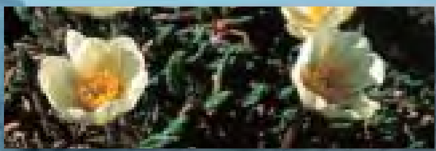

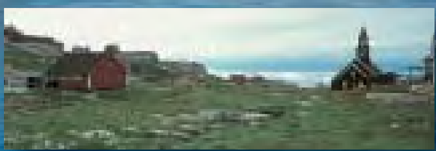

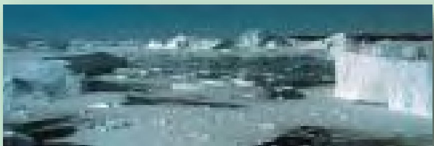

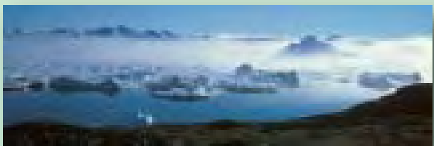
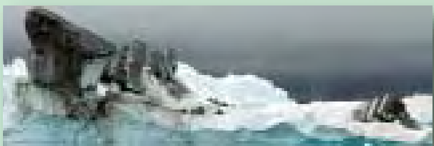
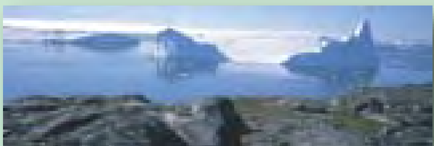

Nomination of the

ILULISSAT ICEFJORD

for inclusion in the World Heritage List

Naja Mikkelsen and Torsten Ingerslev *(eds.)*

ILULISSAT ICEFJORD

TURQUOISE FAIRYTALE CASTLE

As part of the Danish and Greenlandic implementation of the UNESCO World Heritage Convention, the Greenland Home Rule decided in December 2000 to nominate Ilulissat Icefjord for inclusion in the World Heritage List as a natural property.

The Ilulissat Icefjord is a significant Earth science site that includes a remarkable range of internationally important glaciological features where major contributions to science have been undertaken for over hundred years. This importance continues to the present day and inspires leading researchers to work in the area and attracts tourists because of its outstanding beauty.

Since joining UNESCO, the Danish and Greenlandic Governments have been working to affirm its support for the World Heritage Convention, and we are pleased to be able to nominate a natural site in Greenland for inclusion in the prominent list. Local people in Ilulissat and authorities in Greenland approve the nomination.

We therefore fully support the nomination of Ilulissat Icefjord for World Heritage status.

Edward Geisler
Minister of Health and Environment
Greenland

Anthon Frederiksen
Mayor of Ilulissat
Greenland

Photo: Jakob Lautrup, GEUS

MELT WATER RIVER NEAR THE MARGIN OF THE GREENLAND ICE SHEET

Preface

Ilulissat Icefjord is a scientifically unique area and, from an aesthetic point of view, an area of extreme beauty. The present nomination document proposes that the unique nature of the Icefjord be recognised through the award of World Heritage Site status, in particular because of its international importance for the Earth sciences, exhibiting a full range of important glaciological features, and because of its natural beauty. The nomination describes the glaciology and beauty of the site and also the impact that the Icefjord has imposed on the history of human development in this part of Greenland.

Achieving of long-term protection and positive management of the nominated site is a central concern of the proposal. Work towards this nomination has involved active local, national and international consultation, and the principles and priorities for management have been established through thorough debate. A management plan approved by the local authorities outlines the future management of the nominated area.

The Geological Survey of Denmark and Greenland has prepared the nomination document with the assistance and advice of many people and institutions. It is envisaged that a World Heritage Site status would provide an important contribution to the long-term conservation of the Ilulissat Icefjord area and ensure that its Earth science interests are also recognised in the future.

We are delighted, therefore, to commend this nomination to the World Heritage Committee of UNESCO.

The World Heritage steering committee of the Ilulissat Icefjord

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Chairman of Steering committee
Ministry of Environment and Nature, Nuuk
Greenland

Anders Eistrup-Jensen
Co-Chairman of steering committee
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Project co-ordinator
Geological Survey of Denmark and Greenland
Denmark

ICE SCULPTURES IN THE ICEFJORD

Ilulissat Icefjord


Photo: Dieter Zillman/Greenland Tours Elke Meissner

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The present project has recieved financial support from the Danish Environmental Protection Agency as part of the environmental support program Dancea – Danish Cooperation for Environment in the Arctic. The editor is responsible for all results and conclusions presented in the report, which do not necessarily reflect the position of the Danish Environmental Protection Agency.

DANCEA
Danish Cooperation for Environment in the Arctic
Ministry of the Environment

ICEBERG IN ILULISSAT ICEFJORD

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Ministry of the Environment
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List of Contents

1. Identification of the Property

1.a. Country

Denmark / Greenland.

1.b. State, Province or Region

Greenland, Municipality of Ilulissat.

1.c. Name of Property

Ilulissat Icefjord.

1.d. Exact location on map and indication of geographical co-ordinates

The nominated area is bounded by latitude 68°48'N – 69°31'N, and longitude 48°28'W – 51°16'W.

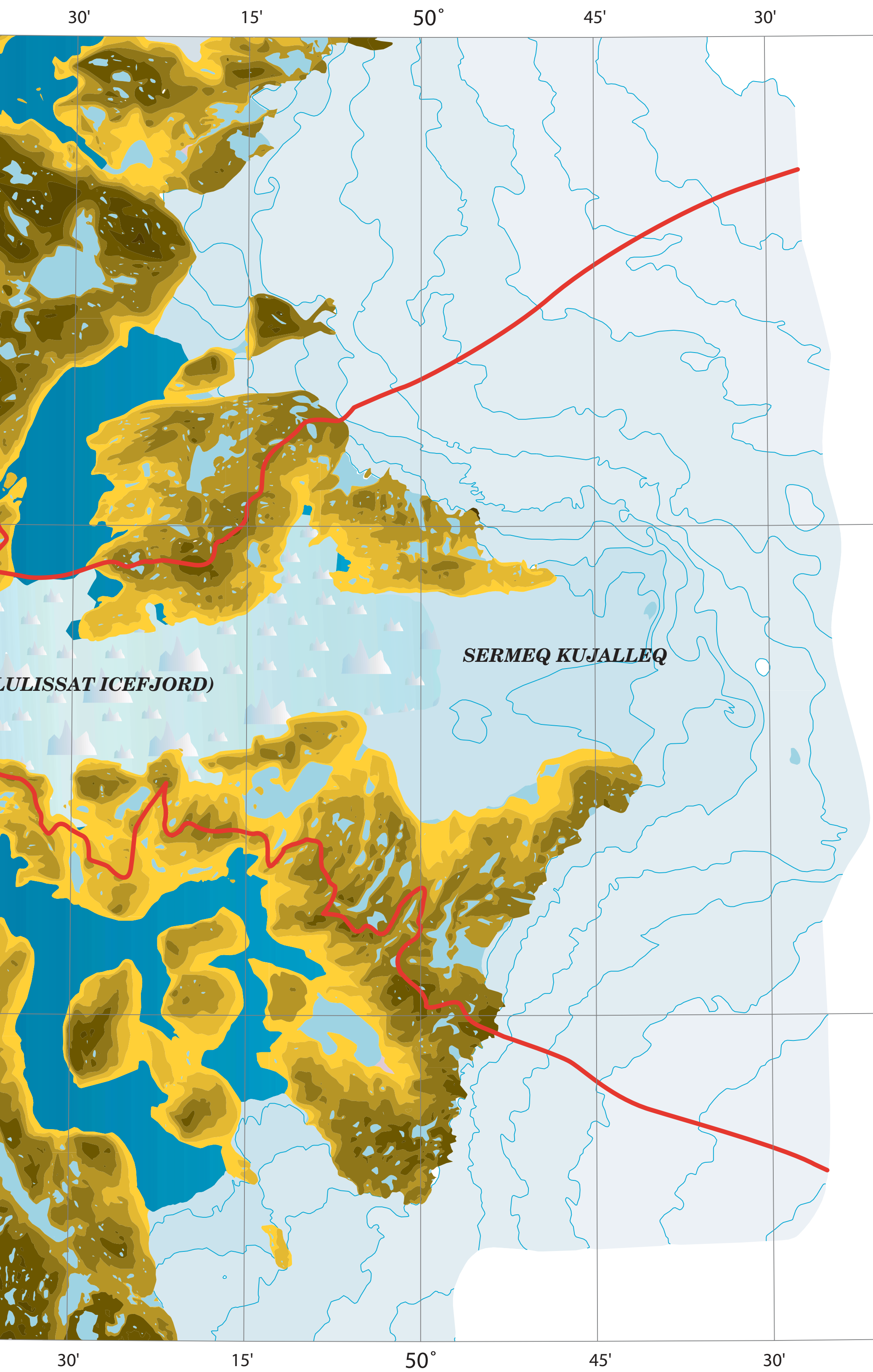
A map showing the nominated area is presented in Appendix 1.

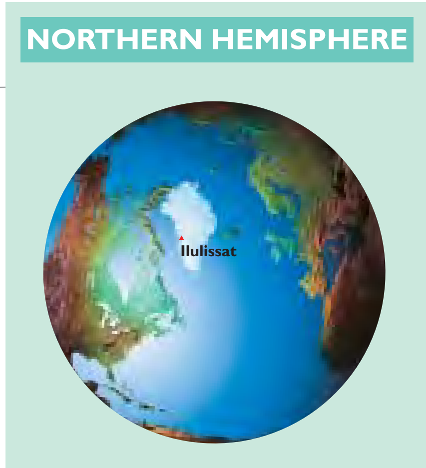
1.e. Maps and/or plans showing boundary of area proposed for inscription

Maps showing the general location and boundaries of the nominated area are given in Fig. 1 and in Appendix 1.

1.f. Area of Property

The protected region, which is nominated for inclusion in the World Heritage List, has an area of approximately 4024 km^2. This is made up of *c.* 397 km^2 land, *c.* 42 km^2 lakes, *c.* 3199 km^2 glacier ice and *c.* 386 km^2 fjord.





Mountain High Maps

The National Survey and Cadastre, Copenhagen (A. 104-02)

Fig. 1. Map of the Ilulissat Icefjord area and the surrounding region, showing the boundaries of part of the nominated area. The location in Greenland and in the northern hemisphere is also given.

ICEBERGS AT THE MOUTH OF
ILULISSAT ICEFJORD

2. Justification for inscription

2.a. Statement of significance

Greenland covers an area of *c.* 2.2 million Km^2 and extends from the zones of sub-arctic climate of the northern Atlantic into the high arctic climate of the Polar Sea. Its dominant landscape feature is the continental ice sheet, the Inland Ice, covering *c.* 1.7 million km^2.

The Greenland Inland Ice represents one of the major stages of Earth's history, the Last Ice Age of the Quaternary. The Inland Ice is the only ice sheet in the Northern Hemisphere that remains from the Ice Age ice sheets, and hence it houses in its interior and basal parts detailed information on climatic changes throughout the last *c.* 250,000 years.

Greenland's continental ice sheet illustrates significant on-going glacial and geomorphological processes related to large ice sheets. The nominated area displays a wide array of these processes including the formation of moraines, isostatic depression and uplift of the Earth's crust, raised shorelines related to the glacial–isostatic uplift, sub-glacial erosion, erosion of fjord troughs and valleys and the active iceberg calving at glacier fronts.

In addition, evidence of previous advances and retreats of the Inland Ice is widespread in the area. The present ice-free coastal zone represents an area that was glaciated during the Last Glacial Maximum when the ice sheet covered the shelf areas offshore West Greenland. After termination of the last Ice Age, retreat of the Northern Hemisphere ice sheets culminated in the disappearance of these ice sheets with the exception of the Greenlandic Inland Ice, the outline of which has remained almost unchanged during the last 8000 to 9000 years.

The Inland Ice rests in a bowl-shaped depression formed by the load of the ice cover on the Earth's crust. The maximum thickness of the ice sheet is *c.* 3.2 km and it represents a volume of 2.9 million km^3 of ice. Its existence is conditioned by an annual snow accumulation, the total amount of which may be up to 600 km^3 ice per year (Reeh, 1994, Zwally & Giovinetto 2001; average of seven estimates). This is compensated by a loss of the same amount via calf ice production and through melting. About half of the total loss is related to iceberg production from the southern and western parts of the ice sheet (Reeh 1994). In its eastern and southern parts, the Greenland ice sheet is essentially barred by large mountain ranges, which implies that major parts of the central ice sheet drain towards the western central areas of Greenland at Disko Bugt and the Uummannaq Fjord complex. The nominated area around Ilulissat represents the southern extension of this major drainage area for the Greenland ice sheet.

Iceberg with pinnacled surface from the Icefjord

Photo: Jakob Lautrup, GEUS

Those parts of the Inland Ice that are within the nominated area display a full range of features related to the dynamics and mass balance influenced by low-Arctic climatic conditions. Most important in this context are areas of extensive melting and re-freezing, calm and fast moving ice as well as active calving. Other impressive features are the lakes and rivers upon the ice sheet, cryoconite holes, ice karst and crevasse areas, which are all typical surface phenomena of the Greenland Inland Ice margin.

One of the fastest ice stream in world, Sermeq Kujalleq, has its outlet in the nominated area. The ice stream terminates in the inner part of the Ilulissat Icefjord, and huge icebergs drift from the so called calving front through the narrow Icefjord towards the ocean. Sermeq Kujalleq is an ice stream of extremely high velocity, producing *c.*10% of all iceberg production originating from the Greenland Inland Ice. The ice stream is thus one of the most productive (*c.* 35 km^3 calf ice per year) and permanently high velocity (19 m/24 hours) ice streams in the world. The size of the released icebergs varies from small blocks to large icebergs measuring 1.5 km^3 or more. Icebergs of the latter size are only released occasionally, but they can be observed at any time at the mouth of Ilulissat Icefjord, where they become stranded at the threshold of the fjord, the Iceberg Bank.

LAYER ON LAYER

Photo: Jakob Laurrup, GEUS

The nominated area is also unique in another respect, as the glacial processes have had a profound impact on the human history of the Ilulissat area. The marine part of the nominated area is a glacially over-deepened fjord where the glacial activity enhances a rich biological productivity. Greenland has been inhabited for 4500 years and the nominated area bears witness to this history. The Ilulissat Icefjord has provided rich hunting grounds for the Inuits throughout the Greenlandic history of human settlement. The prehistoric Inuit hunting grounds and settlements, the remains of which are to be found today along the coasts of the Icefjord, were occupied and subsequently abandoned in time with the retreat and advance of the ice front; in this way, the calving glacier in the fjord changed the living conditions for the indigenous people. Thus, the nominated area illustrates important aspects of the interaction between the ever-changing glacial environment and human development.

In addition to being of major importance to the mass discharge of the Inland Ice, Sermeq Kujalleq is also one of the best-investigated ice streams in the world, and these investigations have contributed significantly to the understanding of ice streams in general. Sermeq Kujalleq is thus a unique natural phenomenon in its own right, not only scientifically but also aesthetically.

Since the first descriptions of the glaciology of Greenland was made in the 18th century, a large number of important scientific studies have been dedicated to Ilulissat Icefjord and document important milestones in the development of Quaternary geology and glaciology. The data and ideas developed from the Icefjord are central to the discussion and understanding of ice stream dynamics and the response of ice masses to climate changes. An almost exponential increase in the number of scientific papers dealing with Sermeq Kujalleq and the Inland Ice has been seen over the last 10–20 years.

The Inland Ice and its outlet in the Ilulissat Icefjord is a renowned natural phenomenon, which since the first descriptions in the 18th century, has inspired interest among both scientists and laymen around the world. The presence of this huge ice field was intriguing and attracted the attention of adventurers and explorers who, in the 19th century, began the "conquest" of the Inland Ice under the rapt attention of the western media. The first crossing of the Inland Ice by Fridtjof Nansen in 1888 created a sensation throughout the world, and is still today regarded as a remarkable feat. Visits to the Ilulissat Icefjord and expeditions crossing the Inland Ice are still favoured by media and sponsors, and attract the attention of people from all over the world. The fame of the Icefjord and the Inland Ice as an extraordinary natural phenomenon and a unique scientific climate archive has been further enhanced in recent years with the revelation that the oldest ice in Greenland is about 250,000 years old.

Tidewater glaciers (glaciers that calve into the sea) and the resultant icebergs are outstanding natural phenomena which can be observed in Ilulissat Icefjord at a scale and with a regularity that is not seen anywhere else in the world. The beauty of the area is indisputable, and is a consequence of the unique combination of the enormous ice production of the Sermeq Kujalleq ice stream and the iceberg-blocking threshold at the mouth of the fjord. The moving landscape of snow and ice, extending from the upper firn areas of the Inland Ice through the marginal

AREAS AND LOCATIONS OF SOME OF THE LARGER GLACIERS AND ICE FIELDS			
Name	**Location**	**Co-ordinates**	**Surface area (km²)**
ICE FIELD RANGES	Alaska and Yukon	61°N, 141°W	*c.* 60,000
U.S. RANGE ICEFIELD	Ellesmere Island, Canada	82°N, 76°W	*c.* 28,210
AGASSIZ ICE CAP	Ellesmere Island, Canada	81°N, 73°W	*c.* 20,400
NOVAYA ZEMLJA	Barents sea, Russia	76°N, 62°E	*c.* 19,000
VESTSPITSBERGEN	Svalbard, Norway	79°N, 18°E	*c.* 15,300
PATAGONIAN ICEFIELD*	Patagonia, Chile	50° S, 74°W	*c.* 13,000
VATNAJÖKULL	Iceland	64°N, 17°W	*c.* 8,400
SIACHEN GLACIER**	Pakistan/India	36°N 77°E	*c.* 1,000

**Parts of the Patagonian Icefield lies within the World Heritage site Los Glaciares, from (Lliboutry 1998). ** From (Bhutiyani 1999).*

Table 1. Statistics of some of the larger glaciers and ice fields of the world (mainly from Cailleaux & Lagarec 1977). For location see Fig. 2.

ablation areas with their dramatic ice streams and glaciers to the narrow fjord, is unique. The majestic icebergs, drifting towards the mouth of the fjord where they become grounded, thus provide a ceaseless drama of changing shapes, colours and sounds from the melting and breaking ice.

The nominated area is easily accessible by aircraft or by boat and will be protected by the Greenland Home Rule Executive Order regarding the protection of Ilulissat Icefjord and by the Ilulissat Icefjord management plan adopted by the Municipality of Ilulissat.

The Ilulissat Icefjord is an outstanding example representing one of the major stages of Earth's history, the Last Ice Age of the Quaternary. The Icefjord is a superlative natural phenomenon and, from an aesthetic point of view, an area of extreme beauty. The nomination therefore proposes that this scientifically unique area be recognised through the award of World Heritage Site status.

2.b. Comparative analysis

Ice fields and other large ice masses

The Greenland Inland Ice and the Antarctic Ice Sheet are the only remnants of the continental Ice Age ice sheets in the world today. The Greenland Inland Ice covers an area of *c.* 1.7 million km^2 and is up to 3.2 km thick in the central part. The oldest ice is found at the bottom of this central part and is *c.* 250,000 years old. By contrast the Antarctic Ice Sheet stretches over an area of *c.* 13.5 million km^2 (Drewry *et al.* 1982), and the oldest ice is assumed to be *c.* 700,000 years old (J.P. Steffensen, personal communication, 2002). The Antarctic Ice Sheet thus contains about ten times more ice than the Greenlandic ice sheet.

All glaciers and ice caps found outside Greenland and Antarctica today are generally of younger age and of smaller size. The locations of some of the larger glaciers and ice fields outside Greenland and Antarctica are listed in Table 1.

Due to their age and enormous extent, the Antarctic Ice Sheet and the Greenland Inland Ice contain information on glaciological and glacial- geological features and processes that cannot be found in any other present-day ice caps or glaciers. The study of these processes and features is of major importance for understanding Ice Age processes, climate history and the relation between global climate change and large ice sheets.

There is, however, an important difference between the Greenland Inland Ice and the Antarctic Ice Sheet in the context of climate-ice sheet interaction. The entire Antarctic Ice Sheet lies within one climatic zone with a polar climate, where only minor ice melting occurs even during the summer period. In contrast, the climate of the Greenland Inland Ice ranges from high Arctic conditions in the north to sub-Arctic and temperate conditions in the south. The dynamics of the glaciers and the ice sheet in Greenland thus react to a wide range of climatic conditions, particularly in contrast to the rather narrow climatic range in Antarctica. The data from Greenland may thus be compared to climatic variations at the transition from the last Ice Age to the recent warm period.

LARGEST ANTARCTIC ICE STREAMS			
Name	**Discharge**	**Velocity at grounding line**	***Note***
THWAITES GLACIER	51 km³/year	3.0 km/year	(Rosanova *et al.* 1998)
PINE ISLAND GLACIER	68 km³/year	1.5 km/year	(Luchitta *et al.* 1995 &1997, Rignot 1998)
ICE STREAM B	17 km³/year	0.8 km/year	(Whillans & van der Veen. 1993)
FOUNDATION ICE STREAM(+MÖLLER)	51(+25) km³/year	0.55 km/year	(Lambrecht *et al.* 1999)
TOTTEN GLACIER	72 km³/year		(Young *et al.* 1989, Vaughan & Bamber 1998)
LAMBERT GLACIER	58 km³/year		(Manson *et al.* 2000, Fricker *et al.* 2000)
BYRD GLACIER	55 km³/year	0.8 km/year	(Scofield *et al.* 1991, Brecher 1986)
ICE STREAM E	26 km³/year	0.55 km/year	(Bindschadler *et al.* 1996)

Table 2. Ice discharge and velocities of the largest Antarctic Ice streams. For location see Fig. 2.

Large glaciers in Greenland and Antarctica

A wide range of glaciological features typical of the low Arctic parts of Greenland is to be found within the nominated area. Many of these can also be found in other parts of Greenland and also at smaller glaciers and ice caps outside Greenland, but nowhere are they so concentrated within a relatively small and yet easily accessible area as in the Ilulissat fjord region. The Sermeq Kujalleq ice stream and the related calving processes, are of a magnitude and speed that is hardly found in other parts of Greenland or in Antarctica.

BRASH ICE

Photo: Jakob Lautrup, GEUS

In Greenland, only few outlet glaciers can be characterised as bona fide ice streams, and of these Sermeq Kujalleq is by far the most prominent. Not only does it show the most pronounced streaming structures, such as well-developed, heavily crevassed lateral shear margins, but it also shows the highest ice velocities and ice transport of the entire ice sheet. The calf ice production of Sermeq Kujalleq is *c.* 35 km³/year corresponding to *c.* 10% of the total calf ice production in Greenland. The drainage area is about 6–7% of the total area of the Greenland Inland Ice. No other glacier or ice stream in Greenland plays such an important role in the mass transport of the Greenlandic Inland Ice. In terms of velocity, Sermeq Kujalleq is one of the fastest persistent ice streams in Greenland, moving *c.* 7 km/year. The only glaciers that on occasion may reach higher velocities are glaciers that display periodic surging. These may be found in Greenland as well as in other glaciated areas of the world. There is, however, an important difference between these surging glaciers and Sermeq Kujalleq. Surging glaciers only surge periodically and may have quiescent build-up periods of up to 100 years, whereas Sermeq Kujalleq shows permanently high velocities.

In comparison to ice streams in Antarctica, Sermeq Kujalleq is a large ice stream in terms of ice discharge (Table 2). Despite the large ice fluxes of the Antarctic ice streams into the Southern Ocean, the Antarctic velocities are almost an order of magnitude smaller than those found at Sermeq Kujalleq.

Another major difference between Sermeq Kujalleq and the Antarctic ice streams is the mode of ice discharge. Although big calving events may occur in Antartica, where the glacier front during calving retreats several kilometres in a short period of time, calving of icebergs at Sermeq Kujalleq is an almost continuous process. Large tabular icebergs with sizes up to *c.* 1.5 km³ or more are released into the Icefjord, where they drift along the narrow fjord towards Disko Bugt and the open ocean. This behaviour is very different from the situation at the Antarctic ice streams, where the prevailing climatic conditions constrain the discharge of ice over the grounding line into ice shelves instead of directly into the sea. A significant amount of the Antarctic ice is actually lost by sub-glacial melting from the ice shelves close to the grounding line, where melting rates can reach several tens of metres per year.

Fast flowing glaciers are also found in Alaska. Thus the Columbia Glacier attains a speed of up to 11 km/year and

Large icebergs on the Iceberg Bank at the mouth of the Icefjord

Photo: Henrik Højmark Thomsen, GEUS

the LeConte Glacier flows at 10 km/year. However, these glaciers are under rapid recession, in contrast to Sermeq Kujalleq with its permanent high velocity (Pfeffer *et al.* 2000).

Glacial geology

The geologic processes related to ice sheets are the same in Greenland today as they were in the now deglaciated areas of the world during the Ice Ages. Therefore, ice sculptured landforms similar to those found in the nominated area, can be observed in other formerly glaciated regions all over the world. Here however, glaciers are either absent or small, local and of younger age than the Inland Ice. In comparison, the link between the present ice sheet and the glacially sculptured landforms is much more evident in the nominated area because the Inland Ice is an integral part of the landscape.

In the Ilulissat Icefjord area modern geological processes of deposition and erosion by the ice can be followed at the present ice margin at a much larger scale than at local glaciers anywhere else in the world. In other parts of Greenland and in Antarctica the scale of many of the processes, such as deposition and erosion at the slow margins of the ice, are comparable to that found in the nominated area. However, the intensive erosion caused by the Sermeq Kujalleq ice stream is unsurpassed by any glacier or ice stream in the world, and may serve as an example for large-scale valley and fjord forming processes.

Glacio-isostatic uplift of the Earth's crust is related to the continental scale ice sheets, evidence of which can be seen at many places in Europe, North America and elsewhere. The High Coast in Sweden has been included on the World Heritage List, as an outstanding example of glacio-isostatic uplift. The prerequisite for this uplift was the depression caused by the Fenno-Scandian ice sheet, which covered extensive parts of Northern Europe during the last Ice Age. This ice sheet was *c.* 3 km thick and caused depression of the Earth's crust in central Scandinavia by at least 800 m. Greenland, including the nominated area, represents a modern analogy to the High Coast, in the sense that the 3 km thick Inland Ice is currently causing depression of the interior parts of Greenland to a degree comparable to that of central Scandinavia during the last Ice Age. In comparison, the Ilulissat Icefjord area represents a marginal part of a continental glaciation, where restricted Late Glacial and Holocene deglaciation of the outer coast has caused limited uplift of the area.

World Heritage Sites with glaciological features

ARCTIC LANDSCAPE

Photo: Jakob Lautrup, GEUS

Areas containing significant glaciological features already included in the World Heritage List are briefly discussed below (Fig. 2). However, the glaciological setting of these sites differ significantly from that of the Ilulissat Icefjord area, as appears from the following notes.

Los Glaciares, Argentina
The Los Glaciares World Heritage Site holds one of the larger icefields outside the polar regions: the South Patagonian Ice Field. The area of this ice cap, however, is about one permille of the Greenland Inland Ice. Despite their relatively large size (up to 600 km^2) even the largest outlet glaciers (Viedma, Upsala, Perito Moreno) are not ice streams in the classical sense. The ice velocities of these glaciers are much slower than Sermeq Kujalleq and the ice discharge occurs where the glaciers reach lakes, which are filling glacier-scoured valleys. The Los Glaciares area shows some important features of glacier dynamics and ice discharge from an ice cap, under extremely humid and temperate conditions. These conditions are decidedly different from the extensive and very dynamic system of Sermeq Kujalleq, which drains and therefore controls a considerable part of a continental scale ice sheet. Moreover, the calving fluxes from Sermeq Kujalleq are much larger and the processes of calving show distinct differences to the Los Glaciares area, due to higher ice velocities, colder ice and tidal influence in the nominated area (Aniya *et al.* 1997).

Glacier Bay, USA
This site contains a large number of alpine glaciers and the entire glacial system is in a state of recession. Sixteen of the glaciers in Glacier Bay are tide water glaciers reaching the sea. Therefore calving from glacier fronts can be observed in this area. However, the focus of this World Heritage site lies on the colonisation of formerly glaciated ground and not primarily on the glaciological conditions. Also, the entire system shows a much more alpine character with smaller glaciers and much less calving than in the Ilulissat area. The fjord system has a similar size, but the character of the landscape and the primary processes of alpine style glaciers do not match those found in the nomination area (UNESCO 2002).

Jungfrau-Aletsch-Bietschhorn, Switzerland
This recently included World Heritage Site holds some of the largest glaciers in Europe (the area of the Aletsch glacier is 128 km^2), and provides a range of classical examples of glaciology in an alpine environment under temperate climatic conditions. The glaciers in the area have a very long research history, which has contributed significantly to the understanding of the response of temperate alpine glaciers to climate change (IUCN 2001). The glaciers of this area have been investigated particularly in the context of the "Little Ice Age" in middle Europe (upper and lower Grindelwald glacier), with very long time series of glacier stands. Glaciological conditions in the Swiss area show a strong alpine character with a reaction time of typically less than 1000 years. The Sermeq Kujalleq glacier and the Greenland Ice Sheet in particular show a much longer response time.

General considerations

In comparison with other World Heritage Sites, the nominated Ilulissat area is unique in the context of its glaciology. Most important is Sermeq Kujalleq, which is regarded as a special feature in its own right. Fed by the only remnant of the continental Ice Age ice sheets in the Northern Hemisphere, it is comparable in size and ice production with the large ice streams of Antarctica. The Antarctic ice streams, however, feed continuously and smoothly into large floating ice shelves, where icebergs

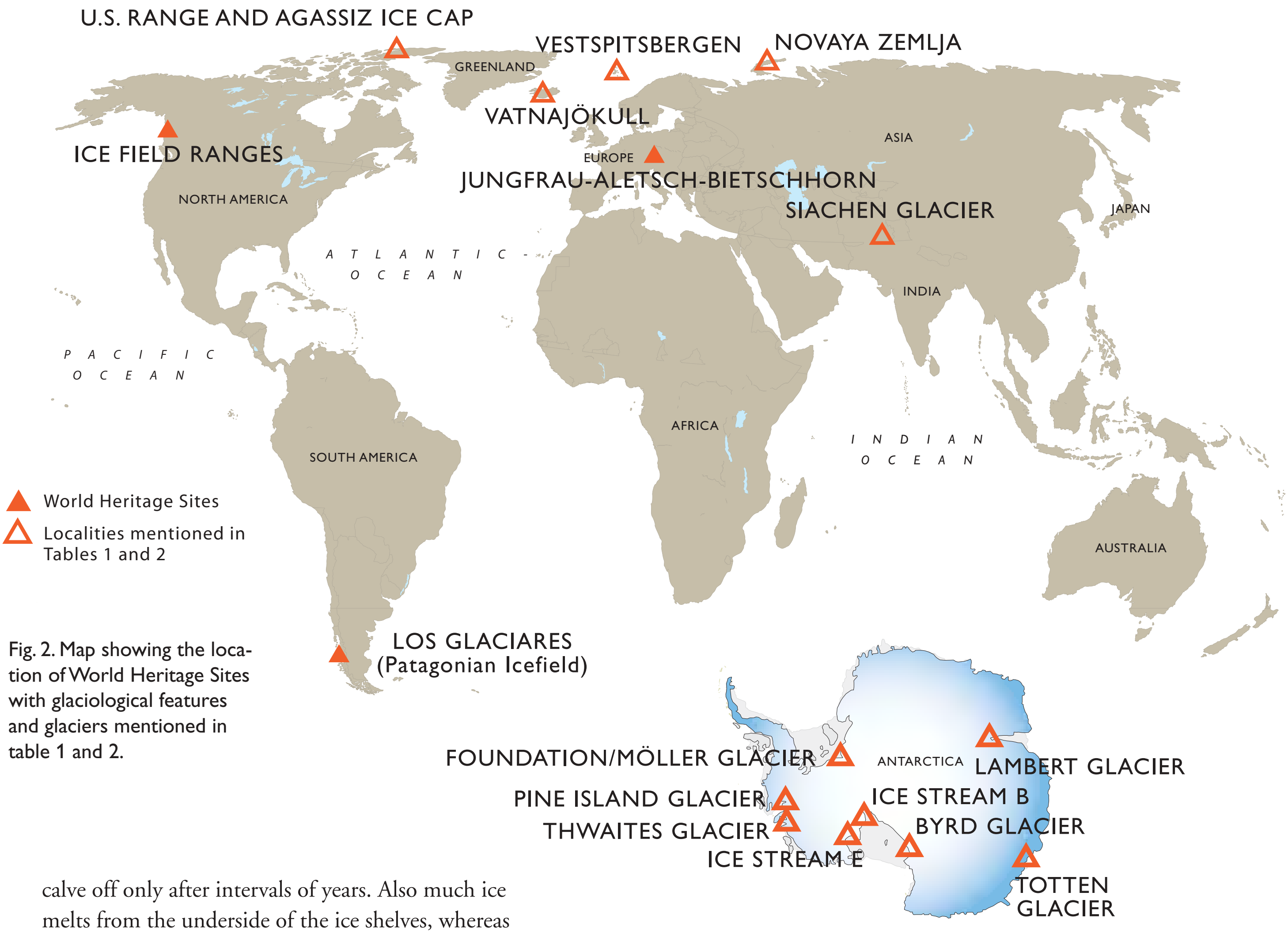


Fig. 2. Map showing the location of World Heritage Sites with glaciological features and glaciers mentioned in table 1 and 2.

calve off only after intervals of years. Also much ice melts from the underside of the ice shelves, whereas Sermeq Kujalleq produces a huge amount of icebergs that are discharged into the Icefjord and adjacent sea. Sermeq Kujalleq has often been regarded as the fastest glacier in Greenland, but new mapping of glacier velocities indicates that Helheim Gletscher in East Greenland (66°15'N) moves somewhat faster, at a rate of 8 km/year (Thomas *et al.* 2001).

The importance of Ilulissat Icefjord to earth science

The Greenland Inland Ice and the Ilulissat Icefjord play a central role in the study of glaciology and climate change. The first descriptions of the huge Inland Ice were published by Rink (1852, 1857, 1877) who provided the basis for theories on the past ice ages when ice sheets covered large areas of the world. Today, the remnants of the ice age ice sheets in Greenland and Antarctica play a central role in the investigation of past climate change and its global effects. Of particular importance is the information retrieved from the 3 kilometre long ice cores which reveal information on past temperatures and precipitation in Greenland almost 250,000 years back in time. No other glacier or icecap in the Northern Hemisphere provides such a long and continuous record of past climate.

The study of ice stream and ice sheet dynamics as well as the mass balance of ice sheets plays a central role in recording the response to climate change both at local and global scales. This can be studied in both Greenland and Antarctica, but fundamental for understanding these processes is the long history of exploration of the Greenland Inland Ice, which began in the 18th century. On the Antarctic ice sheet, these investigations were only initiated in the first half of the 20th century.

More recently, a considerable part of the glaciological research has focussed on understanding the interaction between climatic variations and the dynamic response of large ice sheets. The Greenland Inland Ice is much more sensitive to small changes in climate and therefore much better suited for studies of the coupling between ice sheet dynamics and climate change than the Antarctic ice sheet. As noted earlier, a wide range of climatic conditions acts on the Inland Ice from north to south thus permitting reasearchers to undertake a wealth of climate-related investigations over the entire ice sheet. These investigations add considerably to our understanding of the decay of the large Ice Age ice sheets and may give indications as to how the ice sheets will react during future changes of the world's climate.

The behaviour of the Sermeq Kujalleq ice stream relative to climatic changes is exceptionally well studied and documented. No other ice stream in the world has such a long series of observations of frontal position (*c.* 150 years), or is the topic of such a large volume of scientific papers (see the bibliography). Although the ice streams in Antarctica have attracted much attention from scientists in the latter half of the 20th century, Sermeq Kujalleq still plays an important role in the study of the dynamics of fast flowing ice and the drainage of ice sheets relative to climatic changes. Two recent international symposia at Vancouver, Canada in 1986 and at Yakutat, Alaska in 2002 were devoted to the mechanism of fast glacier flow. At each of these meetings the studies on Sermeq Kujalleq were mentioned as key role studies.

A LARGE ICEBERG IN THE ICEFJORD

Photo: Jakob Lautrup, GEUS

2.c. Authenticity/Integrity

The Ilulissat Icefjord area will be legally protected by Greenland Home Rule executive order (Appendix 3), managed as an IUCN category V area (1994 definitions). The scenic values of the area are thus protected. The ice stream and all the related glaciological features are not threatened by human activities - anthropogenically induced global climate change excepted.

The boundary of the Ilulissat Icefjord area has been drawn so as to include all of the key interdependent elements of the glaciology and related features of glacial geology, on the basis of which the nomination is proposed. These include parts of the Inland Ice, the ice stream, the calving glacier front and the fjord where the icebergs are trapped by the threshold at its mouth. Also included are moraines, kame terraces and marginal deltas of varying ages. Thus, within a limited area, the region includes an exceptionally wide range of such features that make Greenland unique to the sciences of glaciology, glacial geology and climate history.

The beauty of the area is created by the combination of the Inland Ice, the ice stream, the ice-packed fjord, and the Iceberg Bank. With respect to beauty and scenic values, an additional aspect is that the area is a wilderness landscape, where almost no signs of human activity can be seen. The boundary of the area follows the watershed of the fjord, and in this way, the natural beauty of the area is embraced, and protected, by all the slopes facing the Icefjord. Thus any possible intrusive development can only take place on "the outer side" of the watershed and thus cannot harm the scenic value of the Icefjord. It should also be mentioned that only a few kilometres of the border lie adjacent to town development areas south of Ilulissat and north of Ilimanaq. The remaining area is bordered by wilderness areas in which no development is planned.

Delineation of the nominated area

The delineation of the nominated area is drawn to secure the integrity of the site, to underline the natural beauty of the Ilulissat Icefjord and to present the key interrelated and interdependent elements of the natural phenomenon of the Sermeq Kujalleq ice stream (Appendix 1).

The area has a size that amply demonstrates and includes all key aspects of the glaciological processes of the ice stream including those parts of the Inland Ice that feed the ice stream.

The boundaries are drawn so to secure that the integrity of the site is protected from effects of human activities and impacts of resource use outside the nominated area. In addition the boundaries are drawn such that the nominated area appears as one aesthetic unit which underlines the natural phenomena of the ice stream and the exceptional natural beauty of the Ilulissat Icefjord.

The western boundary of the nominated area is located at the mouth of the Icefjord along the distal side of the Iceberg bank. This bank is a shallow shoal placed near the 200 m depth contour as it appears on the local chart. The crest and the proximal east side of the bank are included in the nominated area.

The north-western boundary is based on a map of the Sermermiut/Illumiut area at a scale of 1:8,000 with a 5 m contour interval. Further to the east, a standard map at a scale of 1:250,000 forms the basis for the delineation.

The north-western boundary follows the watershed close to the Ilulissat churchyard, and crosses the Sermermiut valley to the ridge of Holms Bakke, so that the Sermermiut archaeological site is included in the nominated area. From Holms Bakke, the boundary towards the east follows the watershed to the extensive uplands with the large, marginal moraines up to Qaqarsuatsiaq and from here towards the north-east at the uplands of the western shores of the Nalluarsuk bay. From the head of this bay, it follows the watershed of the Nalluarsuup Saqqaa peninsula.

Further to the east, it crosses the mouth of the Sikuiuitsoq fjord thus separating this fjord branch from the Ilulissat Icefjord proper. Further to the east, it reaches the coast of Nunatarsuaq where it follows the watershed towards the north-east, reaching the Inland Ice margin at its highest parts (a little above 300 m a.s.l.). From here it follows a "flow line" separating the catchment area of Sermeq Kujalleq from that of the ice margin further to the north. The estimated flow line is drawn at a right angle to the general trend of the contour lines on the ice surface.

The eastern part of the nominated area includes the lower parts of the Inland Ice sector draining to Kangia (Ilulissat Icefjord). The upper limit follows the 1200 m contour, corresponding approximately to the altitude of the equilibrium line, where the snow melts equals the accumulation. Hence the ablation zone of the ice sheet is included, together with its calving ice front, the ice stream, and the

Large icebergs and brash ice in the Icefjord.

Photo: Jakob Lautrup, GEUS

surrounding "calm" ice landscape with its lakes, crevasse areas, surface streams and glacier mills (moulins). South of the ice stream the nominated area includes the southern border areas of "calm ice" related to the ice stream, in addition to the margin of extensive areas of moraine- and dead ice landscapes formed after the thinning and recession of the ice sheet margin after *c.* 1850.

The southern limitation on the ice sheet is also determined by a line at right angles to the general trend of the contour lines. This ice divide separates the nominated area of the ice sheet, which drains to the Icefjord and its surroundings from the ice further to the south, which drains to the Tasiusaq fjord system.

Photo: Jakob Lautrup, GEUS

FLOATING MOUNTAINS
IN THE ICEFJORD

On the ice-free land, the boundary follows the watershed between the Icefjord to the north and the Tasiusaq fjord system to the south. The nominated area includes the former ice-dammed lake of Qeqertaarsunguit Nunataa Tasia with its terrace systems, developed during the phases of sinking lake level related to the thinning and recession of Sermeq Kujalleq after the 19th century, and also the archaeological site of Qajaa. Further to the west the boundary crosses the mouth of the Tasiusaq fjord thus separating this fjord branch from the Ilulissat Icefjord proper. The continuation west of the fjord mouth follows the watershed separating Ilulissat Icefjord from the large lake of Tasersuaq Qalleq until reaching the coastal areas and the iceberg bank north of Ilimanaq.

MELTING ICEBERGS MAKES FANTASTIC SHAPES

Photo: Jakob Lautrup, GEUS

2.d. Criteria under which inscription is proposed

The Ilulissat Icefjord area is proposed to be inscribed under the criteria of Article 44(a) (i) and (iii).

Criterion (i): *be outstanding exsamples representing major stages of Earth`s history, including the record of life, significant on-going geological processes in the development of land formes, or significant geomorphic of physiographic features;*

The Ilulissat Icefjord area holds a unique combination of a remnant Ice Age ice sheet, a huge ice stream as well as its surrounding "quiet" ice margin with smaller outlet glaciers. Together with the ongoing processes of calving, melting, build up and retreat, they illustrate the most important elements of the dynamics and mass balance of large ice sheets. The key factors for understanding the development and retreat of present and past ice sheets, and their ability to sculpture landforms can be identified in this area. Important land-forming processes such as erosion of troughs and fjords, glacio isostatic uplift/depression and moraine building are ongoing in the area.

No other area in Greenland could be delineated which displays the same elements of glaciology and related glacial geological processes, in such a concentrated and conspicuous way as at Ilulissat Icefjord.

The area is renowned for its contributions to the science of glaciology. Sermeq Kujalleq has the longest record (> 150 years) of frontal descriptions. Due to the unique combination of permanently fast flow, well-defined streaming structures and huge productivity, it is an unparalleled textbook example of streaming ice and related calving processes. Sermeq Kujalleq thus has continuing significance in the quest to understand ice stream and ice sheet dynamics.

No other area in the Northern Hemisphere represents the same values as Ilulissat Icefjord, since all other glaciers and icecaps are much smaller, and represent a shorter history. Thus none of them has the size which is the prerequisite for many of the glaciological and glacial geological processes that are taking place in the nominated area.

Regarding the presence of a huge, continental-scale ice sheet and large ice streams, Antarctica is the only place in the world where glaciological conditions comparable to the Ilulissat Icefjord area may be found. However, the Greenland ice sheet experiences both high-, low- and sub-Arctic climates, and significant surface melting, which makes Greenland and the nominated area significantly different from Antarctica, which lies almost exclusively in the high-Arctic climate zone. Thus, as a consequence of the warmer low-Arctic climate, the glaciology in the nominated area differs markedly from that to be found anywhere in Antarctica.

Furthermore, Sermeq Kujalleq itself differs significantly from Antarctic ice streams. Not only is the velocity of Sermeq Kujalleq almost an order of magnitude higher than most of the ice streams in Antarctica, but it also calves directly into the Icefjord, as opposed to feeding large ice shelves. Thus, Sermeq Kujalleq reveals aspects of ice stream dynamics that can only be studied in Ilulissat Icefjord.

Criterion (iii): *contain superlative natural phenomena or areas of exceptional natural beauty and aesthetic importance;*

The glaciology of the Ilulissat Icefjord area is an outstanding natural phenomenon both when regarded as an entity and when considering separately its components. Such

Front of Sermeq Kujalleq seen from the north

Photo: Jakob Lautrup, GEUS

parts are the Inland Ice, the ice stream, the calving front, and the icebergs in the Icefjord.

The Greenland Inland Ice has been renowned as a unique phenomenon since the first descriptions of this huge ice field in the 19th century, and has attracted a number of famous explorers. Its size, age and the scientific results yielded by the ice are mysterious and fascinating, and exert a broad appeal.

Moving glacier ice, at any scale and velocity, is a fascinating phenomenon. Moving at *c.* 19 m/24 hours, Sermeq Kujalleq is one of the high-velocity ice streams of the world. Its annual production of calf ice may be estimated to *c.* 35 km^3. The most conspicuous feature of Sermeq Kujalleq is the calving, which is ongoing, so the visitor at any time can experience the release of ice and the associated noises at the glacier front.

The ice stream calves into a fjord, where a shallow threshold at 50 km from the front traps the icebergs. The fjord is thus packed with glacier ice for much of the year. This combination of a large ice production and the threshold at the mouth of the fjord is unique, and the resultant landscape of moving ice and floating ice is of almost supernatural beauty. Moreover it ensures that the visitor at any time can see large icebergs from the town of Ilulissat.

The combination of a huge ice sheet and a fast moving glacier, calving into a fjord packed with large icebergs, is only found in other places in Greenland and on Antarctica. However, no other place in the world can offer the visitor so easy access to close views of the calving glacier front and numerous large icebergs, produced with such regularity, as in Ilulissat Icefjord.


GLACIER ICE RICH IN SAND AND STONES

3.a. Description of Property

"Half a mile north of Sant-Bay there is a fjord, which is always full of ice, with frightful tall icebergs. Where they come from is unknown. This fjord is called Icefjord".

From the earliest description of Ilulissat Icefjord, published in 1719 by the Dutch whaler Lourens Feykes Haan (Bobé 1915, Fisker 1984).

Glaciology

The Inland Ice

The Inland Ice of Greenland is the only remnant of the large continental ice sheets in the Northern Hemisphere that covered large parts of the continents and shelves during the ice ages (Fig. 3). The other remnant is the Antarctic ice sheet in the Southern Hemisphere. These two continental ice sheets account for 99.3% of the volume and 96.8% of the area presently covering our planet with glaciers (Williams & Hall 1998). Results of deep drillings in the Greenland Inland Ice reveal that this ice sheet survived the last interglacial and the oldest layers of ice, are *c.* 250,000 years old. (Dansgaard *et al.* 1993, Alley 2000).

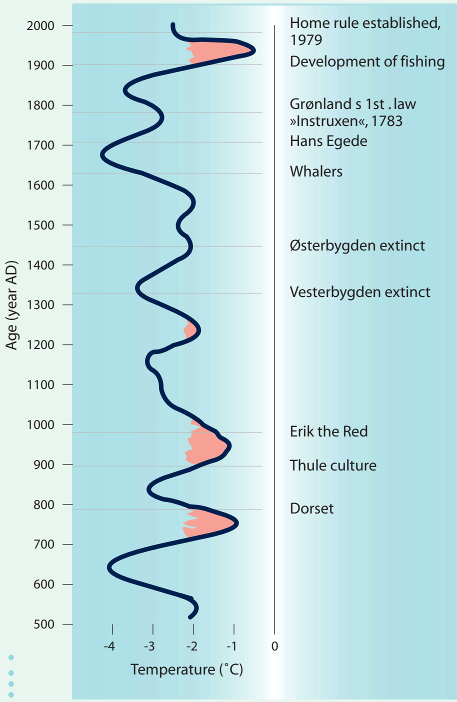
The present area of the Inland Ice is *c.* 1.7 mill. km^2 (Weng 1995) although this figure includes some minor local ice caps, partly merged with the Inland Ice. It rests in a bowl-shaped depression, which in the central parts is close to present sea level, due to the depression of the Earth's crust caused by the weight of the ice. The volume of the Inland Ice has been estimated to *c.* 2.6 mill. km^3 (Holtzscherer & Bauer 1954), recently revised to 2.9 mill. km^3 (Bamber *et al.* 2001).

Its "life" (mass balance) is generally considered maintained by a snow accumulation of up to 600 km^3 ice-equivalent per year, which is matched by loss through calving and melting in the marginal parts of the same magnitude. However, the figures are uncertain, especially the estimates of calf ice production. Thus bottom melting may reduce the calf ice production of North and Northeast Greenland outlets (Reeh *et al.* 1999). Also recent investigations of elevation changes indicate an annual loss near the ice margin in southern Greenland of 51 km^3 ice (Krabill *et al.* 2000).

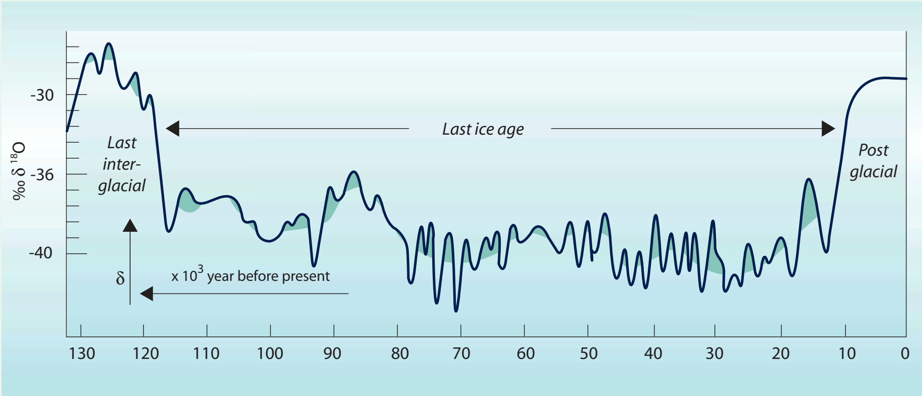
The Inland Ice rests in a bowel-shaped depression caused by the load of the ice cover on the Earth's crust (Fig. 5). If the Inland Ice were removed, the land surface under the ice sheet would rise (isostatic rebound) and form a landscape similar to that indicated in Fig. 6, which depicts the pre-glacial interior of Greenland, much of which was drained by large river systems. Major parts of these river systems drained towards Disko Bugt and continued to the edge of the shelf off Greenland. After the onset of the glaciations in Greenland, these channels were eroded out at the margin of the ice sheet and at the present ice margin these channels can be traced under the ice. In some areas, the ice over-deepened these channels and at different stages of the evolution of the ice sheet, different channels functioned as major drains for the calf ice

Fig. 3. Around 20,000 years ago, the large ice sheets of the northern hemisphere covered an area of around 30,000,000 km^2. By far the largest ice sheet covered major parts of North America. Note that Ilulissat is in the central part of the glaciated regions of the northern hemisphere.

BOX 1. EVIDENCE FOR CLIMATE CHANGES FROM THE INLAND ICE



Source: Dansgaard, 1987



Source: Dansgaard, 1987

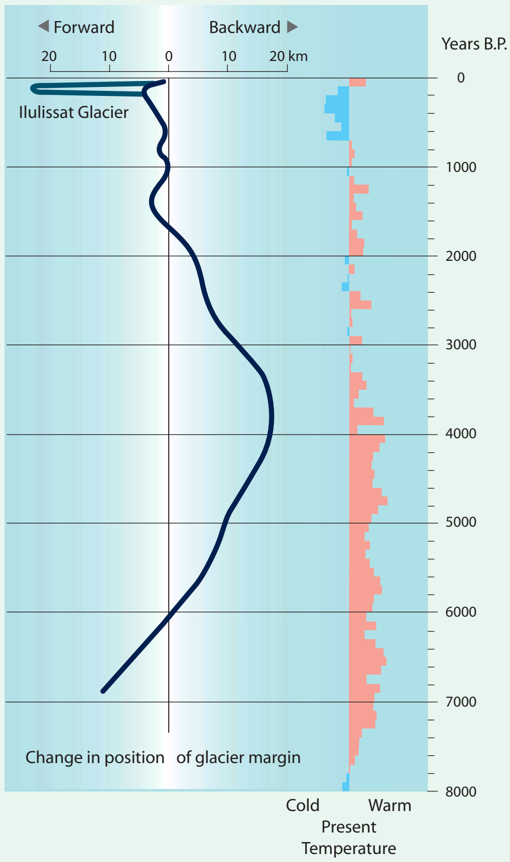
The Inland Ice is an important archive for past climatic changes. Snow falling on the interior of the ice sheet becomes buried by successive snow falls and is gradually transformed into ice by the burden of the overlying snow. Over thousands of years, the snow becomes progressively buried deeper and deeper in the ice sheet, but the original stratigraphy is preserved. The ratio between the different oxygen isotopes in the snow reflects the temperature during the snowfall. Since the isotopes are stable and are preserved in the ice, a continuous record of past temperatures can be obtained by analysing older and older layers of precipitation. In this way a detailed record of past temperatures has been created spanning the last ice age and the time since the last ice age.

These investigations have resulted in a number of remarkable results. Thus it has turned out that the climate during the last ice age was highly unstable, flickering between extreme cold events and somewhat warmer periods. The warmer periods were characterised by an abrupt warming and a gradual cooling. Such rapid climate changes probably reflect changes in ocean currents, notably the North Atlantic drift.

Photo: Jakob Laurup, GEUS

PINNACLED SURFACE AND FRONT OF ILULISSAT ISBRÆ (FRONTAL HIGHT 40–90 M A.S.L)

The last ice age ended abruptly around 11,550 years ago, and the following period up to the present-day has been characterised by much more stable climates. Temperatures peaked during the period from around 8000 to 4000 years ago, followed by a decline that culminated during the Little Ice Age. Minor, but still significant climatic changes have also taken place during the last millennium.



Source: Dansgaard et al., 1987 and Weidick et al., 1990.

The ice sheet does not only preserve old snow layers. The ice also contains small bubbles of air that became trapped as the snow was buried. These air bubbles provide a record of past atmospheric composition.

Large volcanic eruptions are indicated in the ice by layers of sulphuric acid or rare ash particles. Clustered large volcanic eruptions have had a considerable cooling effect on global climate, because the acid aerosols produced by the eruptions lower the greenhouse effect.

The concentration of dust in the snow reflects the number and magnitude of storms back in time. The dust originates from for example central Asia, and it has turned out that the dust content in ice age ice is much higher than in postglacial ice.

The different analyses are performed on samples of ice that are taken from the deep ice cores. At present, a total of five such ice cores have been drilled on the Greenland ice sheet.

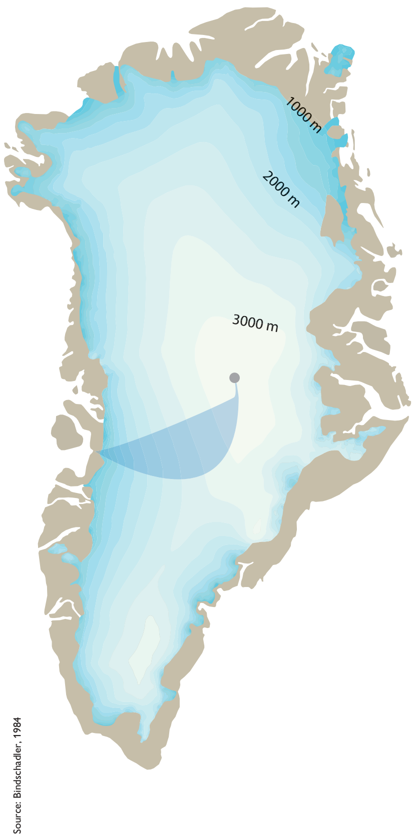


Fig. 4. Simplified map of Greenland with present ice cover and its heights (after Reeh *et al.* 1991). Inset: Approximate catchment area of Sermeq Kujalleq (Jakobshavn Isbræ).

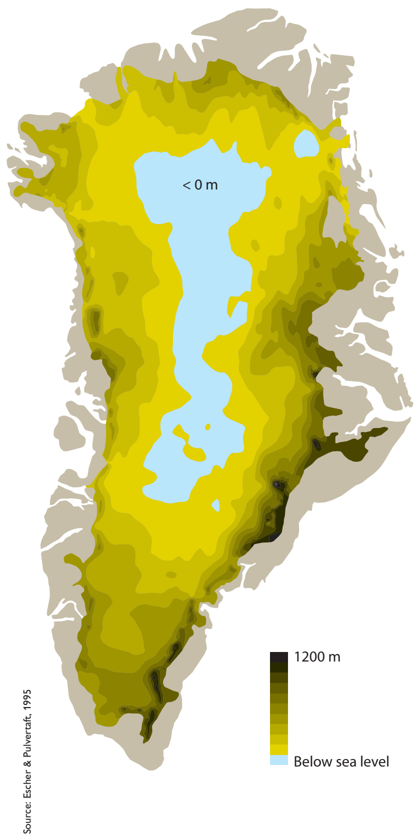


Fig. 5. Strongly generalised topography of the bedrock below the Inland Ice.

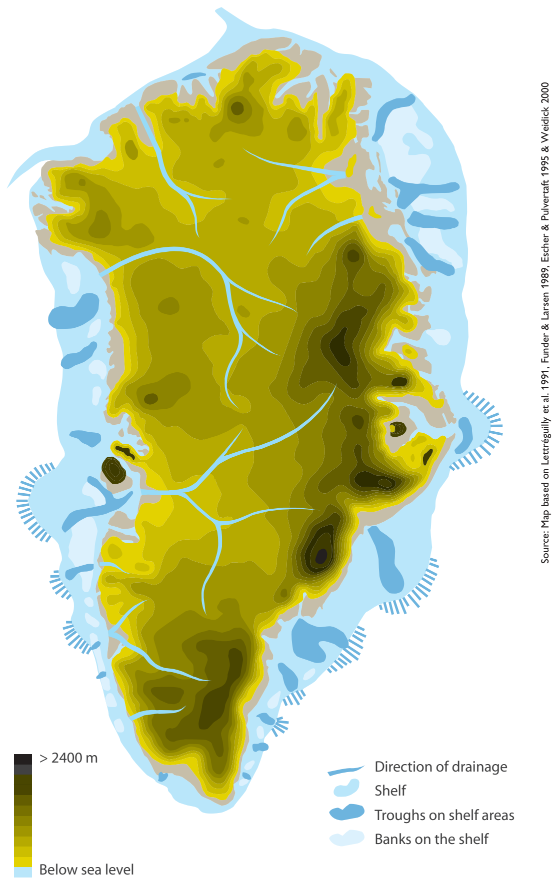


Fig. 6. Simplified map of Greenland without the present ice cover and with the heights of the landscape corrected for the present load of the Inland Ice. Large parts of central Greenland are drained through large rivers to Disko Bugt in West Greenland. The continuation of the old drainage of the inland region can be seen continued as troughs in the offshore areas.

production. The parts of the ice margin producing calf ice today and in the past are confined to well-defined drainage channels. They are found offshore, in the present ice-free land (fjords) and under ice streams where they can be traced as deep depressions underneath the marginal parts of the Inland Ice.

Though calving glaciers are widespread along the coast of Greenland, the annual loss of calf ice from the Inland Ice is concentrated in few outlets within the *c.* 6000 km long perimeter of the Inland Ice. Such outlets are mainly situated on the west coast of Greenland. Approximately 84 km^3 of the production originates from 5 outlets (Table 3). It will be seen that the figures are uncertain.

In comparison with the few, large calf ice producers the production of calf ice from the numerous minor outlets of the ice margin to the ice fjords is low (Fig. 8).

History of glaciations

The change from the pre-glacial landscape (Fig. 6) to the present glacial landscape (Fig. 4) of Greenland is not known in detail. Evidence from sea sediment cores indicates a first marked cooling in Oligocene time (38–24 million years ago, Ma), with formation of the East Antarctic ice sheet. After a relatively warm period in the Middle Miocene, with a temperature optimum at about

CALF ICE PRODUCTION ON THE GREENLAND WEST COAST			
Glacier	**Position**	**Production**	**Velocity**
Sermeq Kujalleq in Ilulissat Icefjord	(69˚ 11˚N)	c. 35 km³/year	c. 6,9 km/year
Sermeq Kujalleq in Torsukattak,	(70˚ 00´N)	8-10 km³/year	2,6-3,5 km/year
Store Gletscher	(70˚ 20´N)	13-18 km³/year	4,2-4,9 km/year
Rink Isbræ	(71˚ 45´N)	11-17 km³/year	3,7-4,5 km/year
Gade Gletscher	(76˚ 20´N)	c. 10 km³/year	--

Table 3. The calf ice production from the five largest outlets on the Greenland west coast (Weidick 1994).

15 Ma, a cooling from *c.* 10 Ma resulted in the occurrence of the first ice-rafted detritus (iceberg transported material) at about 7 Ma. This is taken as the first indication of full glaciation of South Greenland (Larsen *et al.* 1994). Widespread ice-rafted detritus over the North Atlantic region at 2.5-2.4 Ma suggests more widespread glaciation of Greenland during this period.

ICEBERGS IN THE ICEFJORD

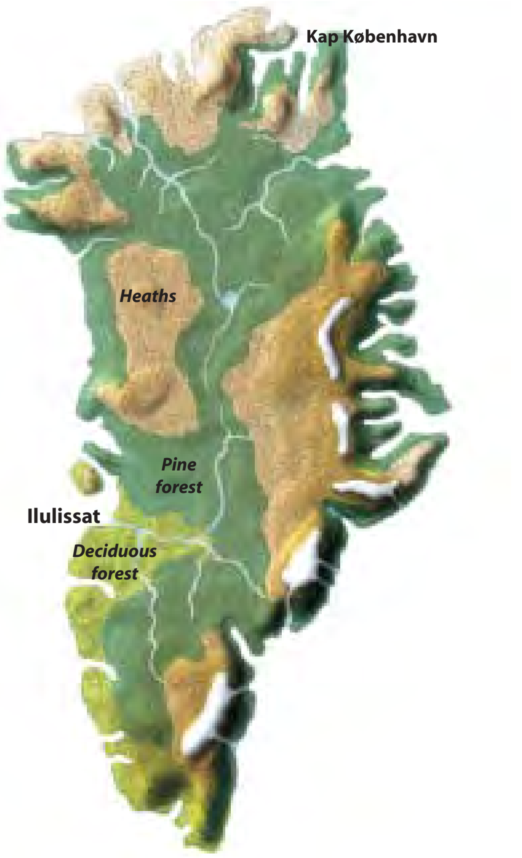
Photo: Jakob Laurrup, GEUS

The first "deglacial event" on land in Greenland, is recorded by the Kap København Formation in northernmost Greenland at *c.* 2.4 Ma. At this time, Greenland is considered to have been free of a continental ice sheet (Fig. 7).

The present Greenland Inland Ice was probably first formed during the Middle and Late Pleistocene with the onset of sufficient cooling (ice ages). The GRIP ice core from the Inland Ice of Greenland (Dansgaard *et al.* 1993) provides a record of the last 250 000 years, which covers the two last glacial stages.

Around Ilulissat Icefjord, the evidence of glaciations mainly covers the last glacial stage (*c.* 100,000–10,000 years ago) and the subsequent deglaciation (Early Holocene, 10,000–5000 years ago) and Neoglaciation (about 5000–100 years ago; Late Holocene). This latter phase culminated in the Little Ice Age (500–100 years ago) when the ice margin expanded to its maximum since the beginning of the deglaciation period. The neoglacial expansion of the ice margin took place in pulses, each successive pulse increasing the ice-covered area.

The Inland Ice probably covered the continental shelf, and hence the nominated area, during the last Ice Age. At this time, loss from the ice margin was through major calf ice producing ice streams. One of the largest streamed through an over 800 m deep trough between Qeqertarsuaq and Aasiaat (Egedesminde Dyb) in the south-western part of Disko Bugt, with minor drainage through the deep Vaigat strait north of Disko island (Fig. 6 and 9). Initial break-up from this ice cover is estimated to have occurred 17,000 to 11,000 years ago (Long *et al.* 1999). However, in a study of sediment cores from Disko Bugt in the vicinity of Ilulissat, a transition from earlier shelf conditions to present open water conditions is suggested



Source: Funder, 1996

Fig. 7. Around 2.3 million years ago, forests covered most of Greenland, with heath-lands on high, elevated regions.

BOX 2. GLACIER ICE

The Greenland Inland Ice is by far the largest glacier in the Northern Hemisphere, and it consists primarily of glacier ice. Ice can form by two different processes: by freezing of water or by putting snow under pressure. The latter process leads to the formation of glacier ice. Due to the low temperatures over the ice sheet, most precipitation falls as snow, and even during the summer temperatures are usually too low for this snow to melt. Thus the snow accumulates from year to year and gradually the snow is compressed because of the pressure from the overlying snow, and hence transformed to ice. Some of the air that is present in the snow disappears, but the major part is trapped in the ice. The presence of these bubbles is the reason for the whitish or milk-like colour of glacier ice. The ice is being squeezed from the central part of the Inland Ice towards the periphery, where melting and calving takes place.

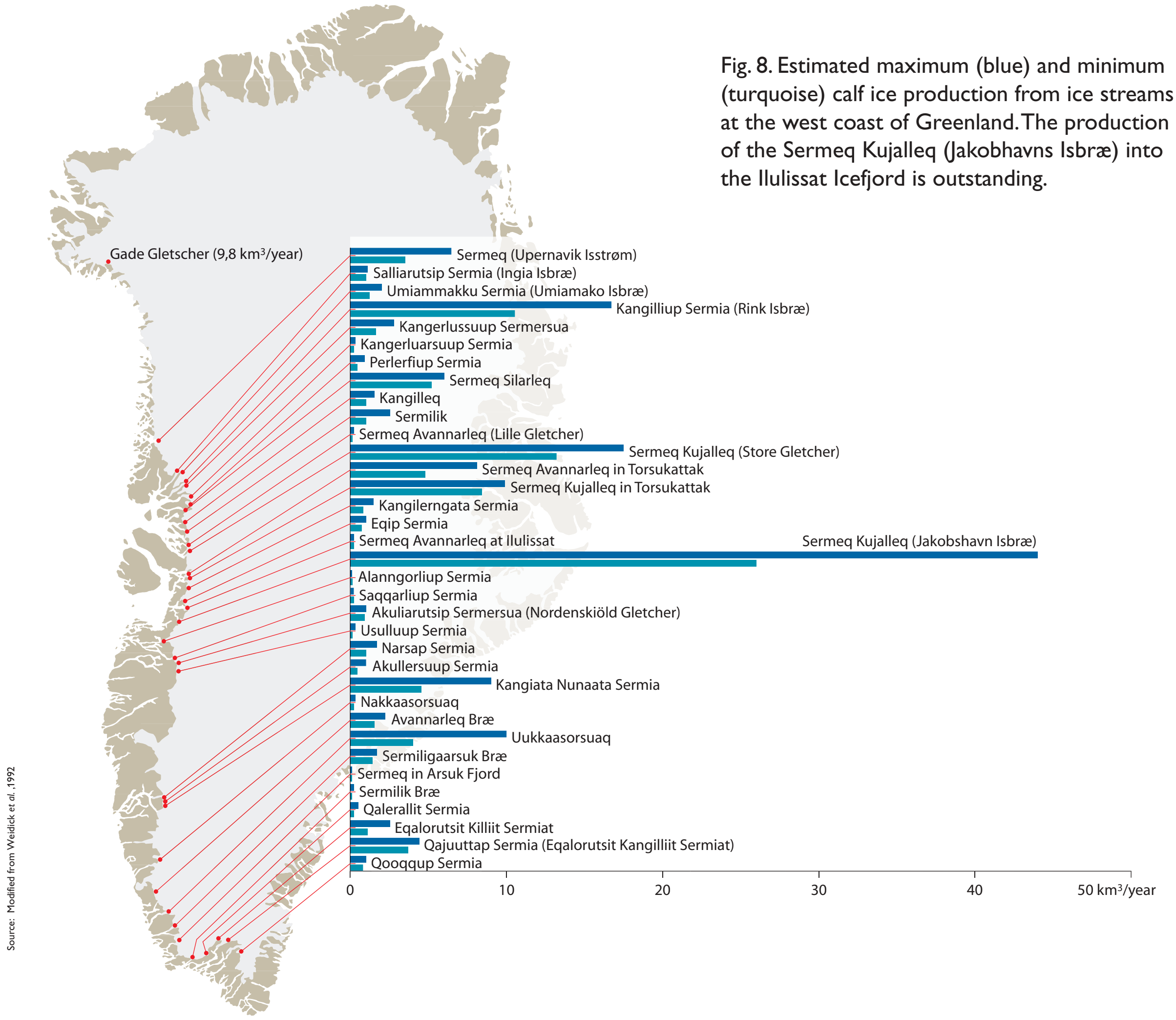


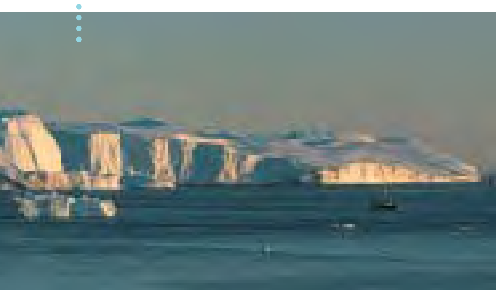
Fig. 8. Estimated maximum (blue) and minimum (turquoise) calf ice production from ice streams at the west coast of Greenland. The production of the Sermeq Kujalleq (Jakobhavns Isbræ) into the Ilulissat Icefjord is outstanding.

to have occured around 8000 years ago (Kuijpers *et al.* 2001).

About 9500 years ago, the ice margin was on land in the area around Ilulissat. This implies a stabilisation in the position of the ice margin for a considerable period (a millennium or more). This static phase, possibly with minor re-advances, could have been in part climatically controlled. However, the topography of the land and the succession of the moraines at the mouth of the Icefjord imply that the ice retreat slowed because much of the ice margin rested on land and did not calve into Disko Bugt.

The subsequent recession of Sermeq Kujalleq ended about 5000–4000 years ago with the fronts of Sermeq Kujalleq and Sermeq Avannarleq and the surrounding ice margin situated 15–20 km east of the present position (Box.1. Weidick *et al.* 1990). This deduction is based on

Fig. 9. Present water depths of Disko Bugt and Davis Strait. The troughs may mark positions of earlier ice streams related to different phases in the former extension of the Inland Ice.



ICEBERGS AT SUNSET

Photo: Jakob Laustrup, GEUS

radar mapping of the landscape under the ice margin including the continuation of the fjords, combined with radiocarbon datings.

The following colder (and perhaps humid?) Neoglacial period led to a re-advance of the ice margin, which culminated in the maximum positions of most glacier lobes and ice margins, during the 19th century. A subsequent overall glacier recession took place in the 20th century. The different positions of the ice margin around Ilulissat Icefjord during the last 9500 years are shown in Fig. 10. The Sermeq Kujalleq ice front retreated *c.* 26 km between AD 1851 and 1950.

The landscapes of ice in the nominated area

The dynamic nature of the Inland Ice contributes significantly to the nominated area with a number of different "icescapes", formed by a combination of subsurface topography, altitude and climate.

In the interior parts of the Inland Ice (the accumulation zone), the accumulated snow is progressively buried and thus sinks deeper into the ice sheet; with increasing compression, the snow is transformed into glacier ice. This process (the metamorphism of the snow) takes place in the upper few hundred metres of the ice sheet. The oldest

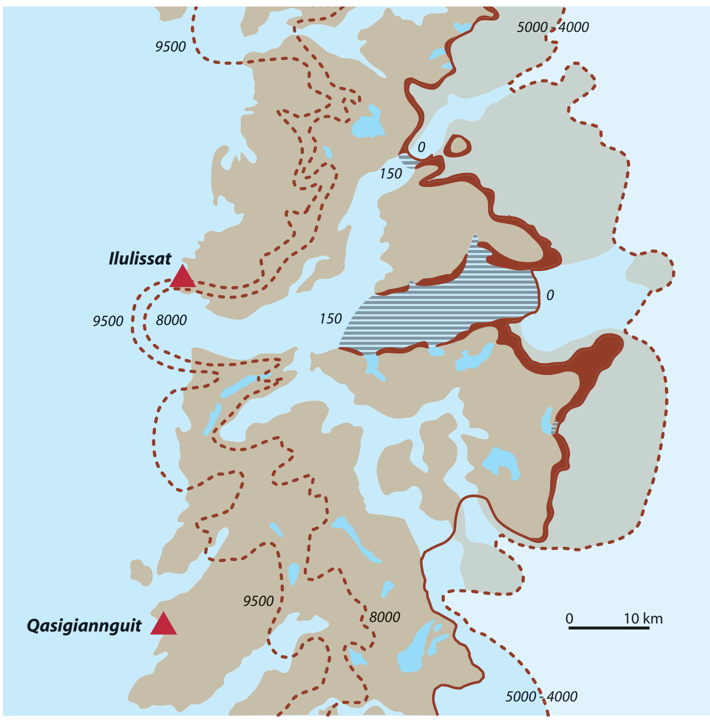


Fig. 10. A tentative reconstruction of the position of the ice margins in the Ilulissat area at c. 9500, 8000, 5000–4000 and 150 years ago. The change of the ice margin between the Little Ice Age maximum and the present situation is shown in brown for land areas and horizontally lined grey for floating glacier fronts.

Fig. 11 shows the even surface at the ice margin near Paakitsoq, where samples for oxygen isotope analyses are being collected.

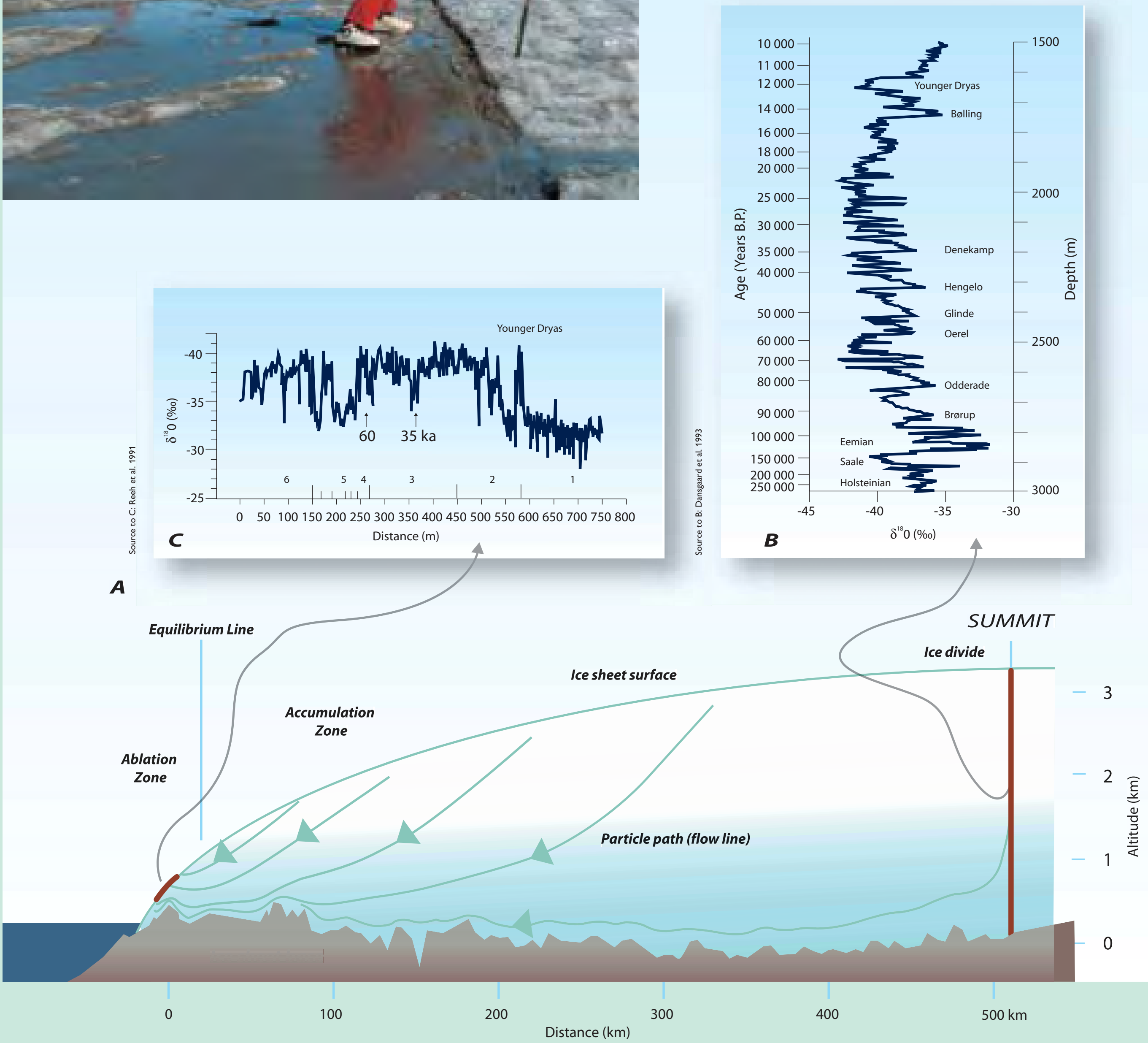
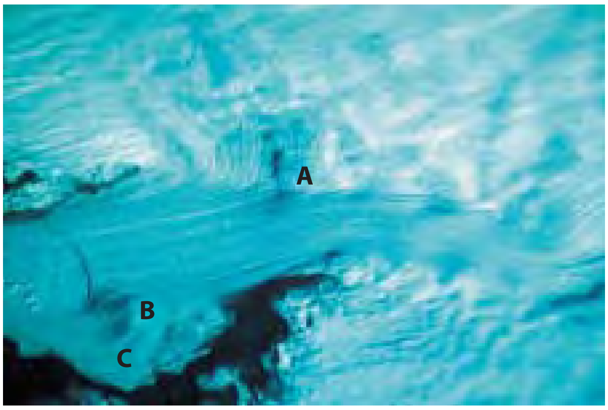


Fig. 12

A. Cross section of the Inland Ice, showing flow lines of the ice, the location of the deep ice core at the summit of the ice sheet and the location of an oxygen isotope record near the margin. Snow falling in central Greenland is transported down in the ice sheet and towards the margin, whereas the movement of the marginal glacier ice (under the equilibrium line) is to higher levels. This means that one can encounter ice of progressively younger age when going from the margin to the equilibrium line at about 1200 m a.s.l.

B. An ice core at Summit reveals successively older layers of snow and ice. The profile shows an oxygen isotope record of climatic changes. The record covers the interval from 1500 m depth to the bottom of the ice sheet corresponding to over 250,000 years. Names of different interstadials as well as the two last interglacial stages (Eemian and Holsteinian) are shown.

C. An oxygen isotope record of climate change taken at the surface of the Inland Ice margin at Paakitsoq, *c.* 27 km NW of the front of Sermeq Kujalleq. Marks for the age of 60 and 35 ka (thousand years B.P.) are inserted. The Younger Dryas cold period (11.5–12.7 ka B.P.), marked the last cold spell before the Holocene. The record covers the last *c.* 150,000 years.



Source: Landsat

Photos and processing: Henrik Højmark Thomsen, GEUS

Fig. 13. Sermeq Kujalleq (Jakobshavn Isbræ). The ice stream near the glacier front. Left: Landsat image from an altitude of 915 km, September 27th, 1979. The glacier front and released icebergs can be seen near the left margin of the picture. The ice stream is marked by linear structures. A tributary from the north can be seen. A and B indicate ice rises or ice rumples, C is an "ice bay" (*cf.* page 39).

Right: Same area seen from a helicopter. Here (as in the satellite scene) the topography under the ice can be seen reflected in the surface forms of the ice.

ice found in Greenland comes from the bottom of the ice sheet beneath the highest parts of the Inland Ice at "Summit". In addition to the vertical movement due to burial and compaction, the ice also moves slowly down slope, away from the ice divide, and eventually ends up at the outermost margin of the Inland Ice. Passing from the ice divide towards the ice margin, a zonation of the ice, dependent on altitude and slope, is apparent.

ICEBERGS AND BRASH ICE IN THE ICEFJORD

Photo: Jakob Lautrup, GEUS

The surfaces of alpine glaciers are zoned into an upper firn (or accumulation) area and a lower ablation area where the glacier ice is exposed by summer melt. In contrast to this, the Inland Ice has several zones (Benson 1961), namely in the highest parts a dry snow zone with negligible melting of the deposited snow. It is followed by a lower percolation zone where melting and percolation of melt water occur (at Sermeq Kujalleq catchment area (Appendix 1) between *c.* 3000 and 2000 m a.s.l.), downward followed by a saturated zone where the snow becomes wet during the melting season. In its lower reaches the refreezing of melted snow results in a zone of superimposed ice. The limit, called the snow line, is in the area situated at about 1300 m a.s.l.

In the zone of superimposed ice the refrozen melt water is added to the glacier ice. The lower boundary of the superimposed zone is at the equilibrium line; here the net gain of mass (snow and superimposed ice) equals the net loss of mass (by melting). The equilibrium line is at *c.* 1200 m a.s.l. in the area, and below this, the ablation zone is found.

In the highest firn areas of the Inland Ice, the movement is slow and essentially in a downward direction. Its horizontal component increases towards the margin. It can reach values of 50–200 m/year near the equilibrium line, decreasing to near zero at the ice margin for non-streaming ice. On the Sermeq Kujalleq ice stream and adjacent areas, different movement patterns influence the surface of the ice. Surface heights and directions and rate of flow of ice around and upon Sermeq Kujalleq are given in Fig. 15. It appears that over much of the ice stream, the normal, slow decrease in flow rates from the equilibrium line towards the margin is not observed. Rather, ice moving towards the ice stream shows a very marked increase in the rate of flow (up to *c.* 7000 m/year). The topography of the ice surface also changes from a relatively smooth surface to the chaotic and broken surface of the ice stream.

The influence of the sub-glacial topography on the surface drainage in and around the ice stream of Sermeq Kujalleq can be seen by comparison of the surface movement (Fig. 15) with the sub-glacial topography of the area under and around the ice stream (Fig. 17).

The sector of the ice sheet margin that shows calm flow, north of the ice stream, has been mapped and described

Photos: Roger Braithwaite

Fig. 14. Landscapes of the marginal zone north of Sermeq Avannarleq.

Left: crevassed glacier ice.

Right: a surface river disappears down a moulin.

in detail (Thomsen *et al.* 1988, Thomsen 2000). In this region, large areas of the ice show an undulating hummocky landscape with relatively few crevasses. The extensive superficial melt during the summer is drained by large meltwater rivers often running in deep canyons and disappearing through moulins into an en- or sub-glacial drainage system (Fig. 14). By analogy with the caves and tunnel systems in limestone karst areas, this ice drainage system is sometimes called "ice karst". In contrast to real karst features, ice karst is subject to fast opening and closure, being dependent on water drainage and flow of the ice. The region south of the ice stream is poorly described but the same features are encountered here.

Meltwater lakes occur frequently where there are only relatively few crevasses, at heights of 1150–1450 m a.s.l., i.e. in the lower firn areas and the superimposed ice zone. At lower altitudes, frequent crevasses occur due to the passage of the relatively thin ice cover (usually up to some hundred metres) over an undulating sub-glacial terrain. These conditions form the basis for the ice karst drainage system described above. Lakes can also exist in this area in depressions that lack coherent drainage systems, mainly at the boundary between the general ice cover and the ice stream.

Description of Sermeq Kujalleq

In a general sense, Sermeq Kujalleq can be described as a river of crevassed ice (Fig. 13). The catchment area on the Inland Ice that feeds Sermeq Kujalleq has been estimated at between 3.7 and 5.8% of the Inland Ice area, corresponding to 63,000–99,000 km^2 (Bindschadler 1984). More recent estimates increased the size of this area to 6.5% of the ice cover, i.e. about 110,000 km^2 (Echelmeyer *et al.* 1991). A detailed and comprehensive description of the ice stream is given by Echelmeyer *et al.* (1991) and a brief summary will be given here.

The ice stream appears as a narrow, 3-6 km wide, well-defined channel that can be followed from the present front of the glacier to about 80–85 km into the ice sheet. There, at heights of 1350–1400 m a.s.l. it loses its identity and splits up in three branches, which gradually disappear in the ordinary surface topography of the surrounding ice cover. Following the course of the ice stream down slope, the surface is relatively smooth until 50 km from the glacier front, where it becomes increasingly crevassed, and lakes and water-filled crevasses disappear. The ice stream shows "sharp boundaries" to the less fractured surrounding ice. The marginal crevasse zone of the main stream extends 5 km or more to each side of the ice stream. About 45 km inland from the front, the crevasse and flow line patterns show a funnel-shaped convergence of movement towards the main stream of ice. From the north, *c.* 10 km behind the front, a tributary ice stream joins Sermeq Kujalleq (Fig. 13). Flow patterns, subsurface mapping north of Sermeq Kujalleq, relatively little crevassing and slower movement all indicate its character

MELTWATER LAKE

Photo: Henrik Højmark Thomsen, GEUS

MELT

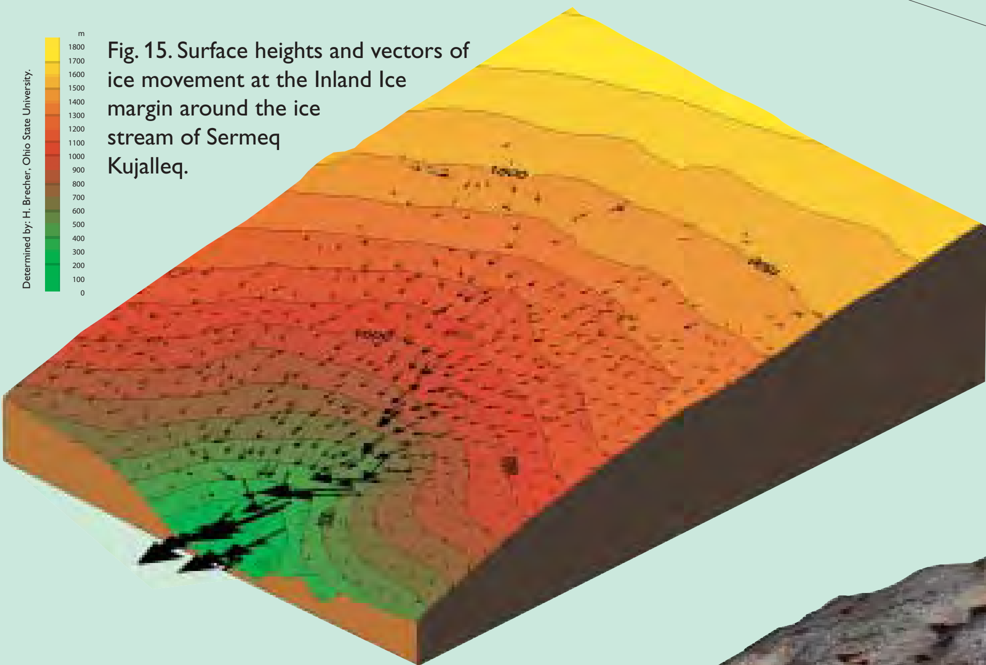


Fig. 15. Surface heights and vectors of ice movement at the Inland Ice margin around the ice stream of Sermeq Kujalleq.

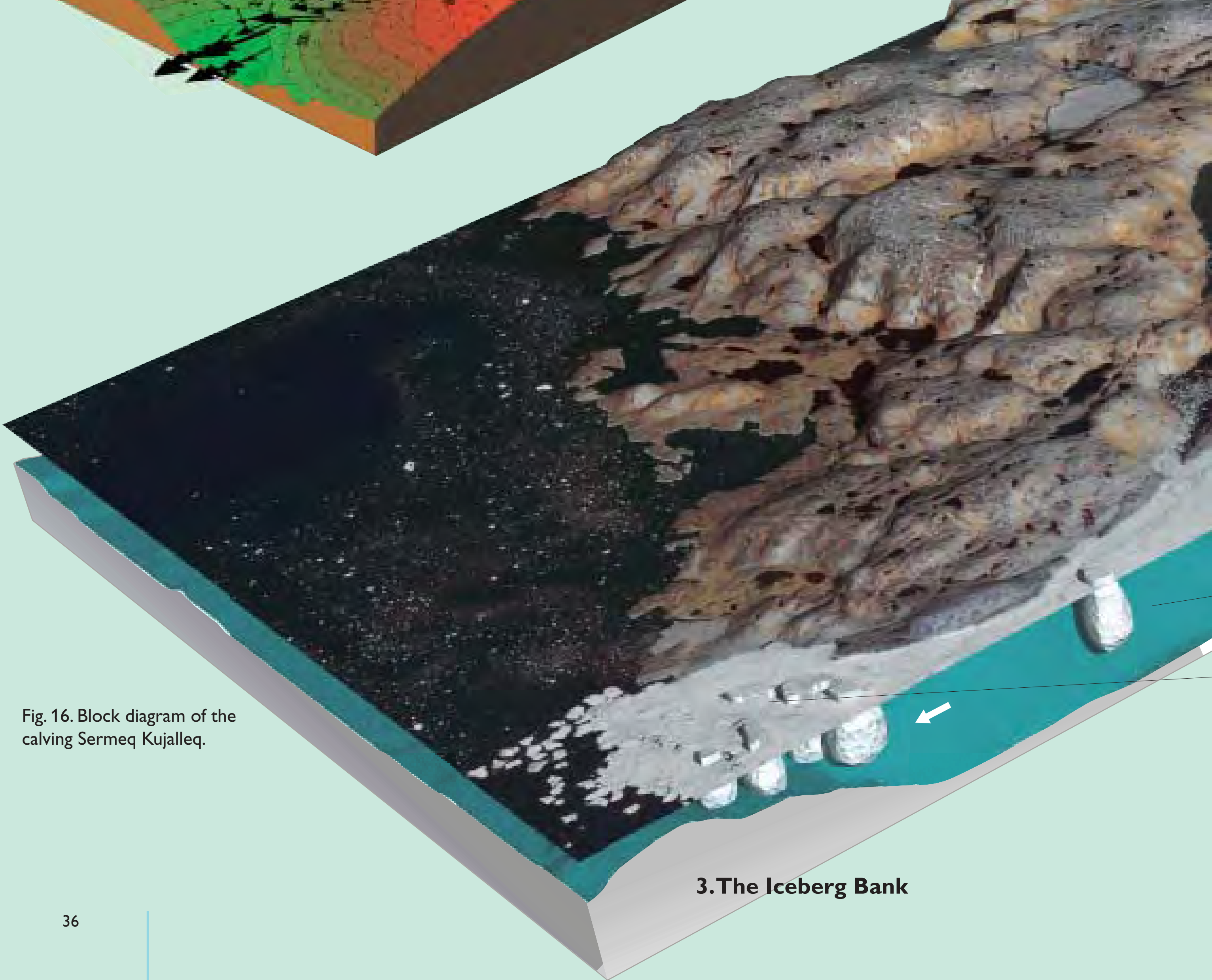


Fig. 16. Block diagram of the calving Sermeq Kujalleq.

WATER STREAM

Photo: Henrik Højmark Thomsen, GEUS

CREVASSES IN THE ICE SURFACE

Photo: Jakob Lautrup, GEUS

HEAVILY CREVASSED ICE SURFACE

Photo: Jakob Lautrup, GEUS

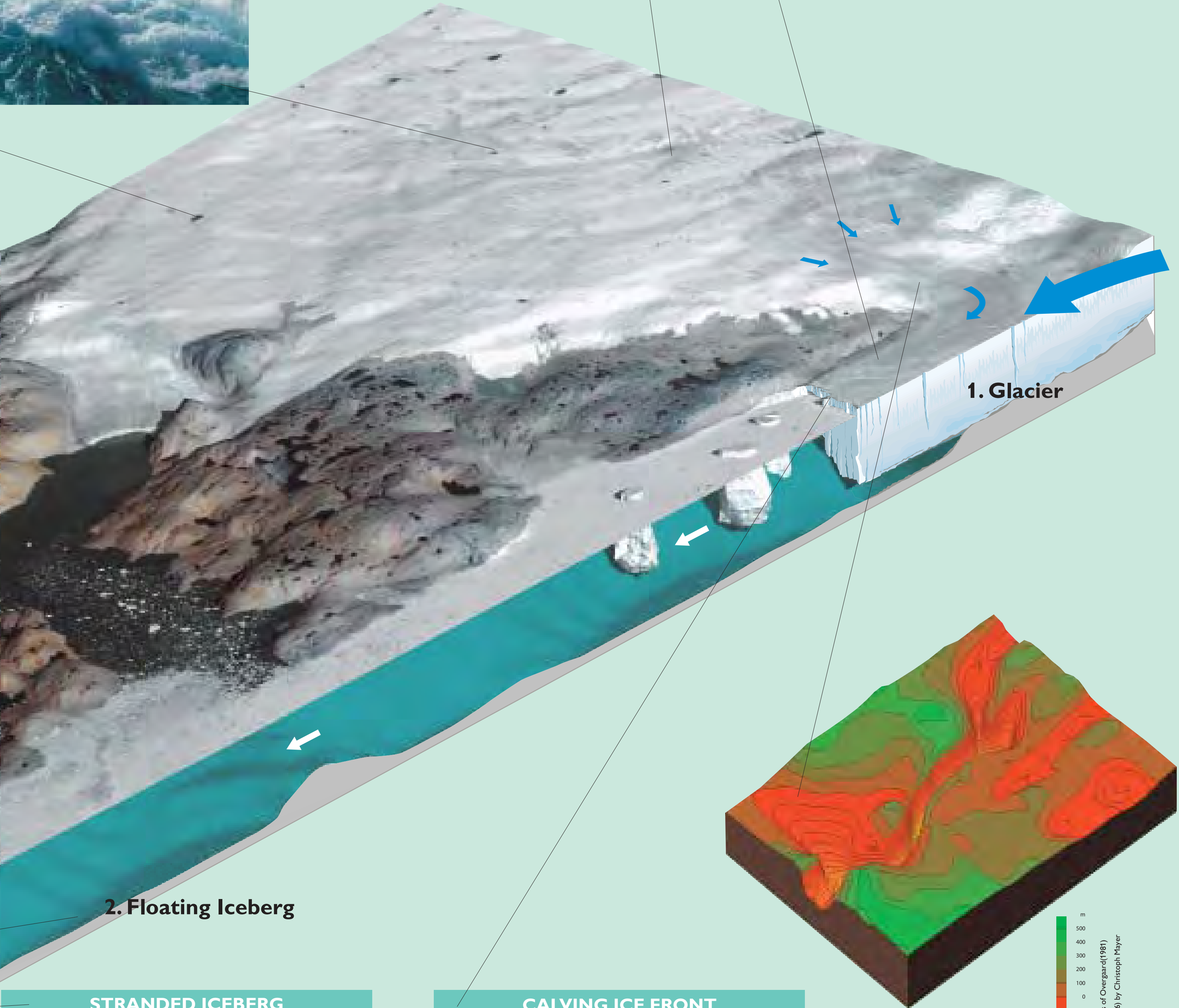


Fig. 17. The sub-surface of the Inland Ice around Sermeq Kujalleq.

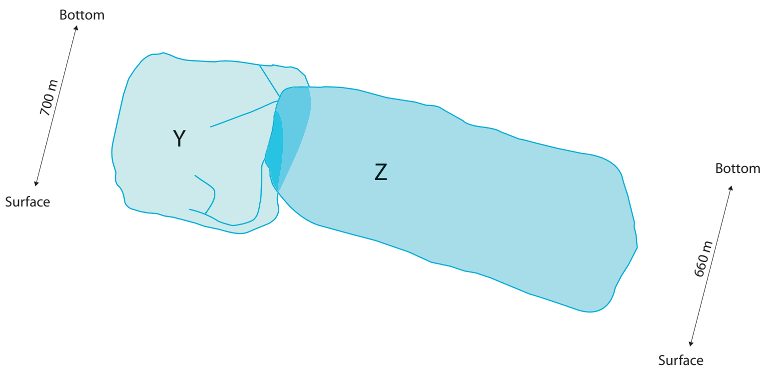
Source: Compiled on the basis of Overgaard (1981) and Clarke & Echelmeyer (1996) by Christoph Mayer

STRANDED ICEBERG

Photo: Henrik Højmark Thomsen, GEUS

CALVING ICE FRONT

Photo: Jakob Lautrup, GEUS



Source: From Bauer et al., 1968

Fig. 18. Icebergs in front of Sermeq Kujalleq.

Right: Aerial photograph with densely packed smaller icebergs and three large icebergs. X: Upright tabular iceberg with pinnacled surface, Y and Z are tilted icebergs.

Left: Sketches of iceberg Y and Z indicating the size and thickness of the floating glacier (660–700 m).

as a tributary. At the junction between the main stream and the northern tributary an "ice rumple" is located (Fig. 13); in fact, this restricts the main stream to a width of only 4 km. This rumple forms a central part of an apparent threshold, which determines the recent position of the grounding zone.

LANDSCAPE NEAR THE ICEFJORD

Photo: Jakob Lautrup, GEUS

The area is not entirely covered by measurements of the subsurface of the ice, i.e. the height distribution of the landscape under the ice sheet margin. However, the present knowledge gives a fairly good idea about the subsurface topography under and adjacent to the ice stream (Fig. 17). The ice stream is situated in a very deep trough. The central stream depth varies from *c.* 1.9 km near the grounding zone, with an ice surface at an altitude of *c.* 400 m a.s.l., to over 2.5 km at a distance 40 km behind the grounding zone, where the ice surface is *c.* 1000 m a.s.l. Thus, the bottom of the sub-glacial trough is found to be situated at depths of 1.5 km below the present sea level (Clarke & Echelmeyer 1988, 1996). Further inland (*c.* 50 km east of the grounding line), the trough under the ice stream gradually levels out. Radar profiles from the large-scale mapping of the Greenland Inland Ice *c.* 120 km east of the grounding zone, seem to show no deep subsurface troughs (e.g. Overgaard 1981).

Frontal appearance

At the present glacier front (Figs 19), Bauer *et al.* (1968) and Carbonnell & Bauer (1968) adopted a mean ice thickness at the ice front of 750 m, whereas other estimates are 600–800 m (Bindschadler 1984), 750–825 (Pelto *et al.* 1989, Sohn *et al.* 1998) and as low as 570 m (Echelmeyer *et al.* 1991). The height above sea level of the 7.5 km long calving front is 40–90 m along the N–S trending part and *c.* 20 m along the E–W trending

Photo: Jakob Lautrup, GEUS

Fig. 19. Calving front of Sermeq Kujalleq, with pinnacled surface, seen from the north.

Photo: Jakob Lautrup, GEUS

Fig. 20. Top: Front of the glacier (northern side). The vegetation-poor zone (trim line zone) is here shown.

Photo: Anker Weidick.

Right: Sermeq Kujalleq (Jakobshavn Isbræ) seen from the southern side of the fjord at a distance of *c.* 10 km. Note the trim line zone on the lower parts of rock walls indicating the former extent of the glacier down the fjord.

southern flank. A simple freeboard calculation for a calving front with an average height of 80 m gives an ice thickness of approximately 700 m; this compares well with measurements further upstream.

The outermost *c.* 15 km of the glacier is, to a large degree, floating. An exception seems to be that part close to the southern margin where an ”ice rumple” (Echelmeyer 1991) or ”ice rise” (Weidick 1992) marks a sub-glacial rise forming part of a threshold. It separates the shallow embayment, or ”ice bay” (Fig. 13) with an ice thickness of *c.* 200 m, from the strongly crevassed surface of the main stream in the north (Weidick 1992).

The floating part of the glacier moves up and down with the tide, with a maximum range of 3 m (Lingle *et al.* 1981, Echelmeyer *et al.* 1991); the amplitude of this tidal effect decreases towards the grounding zone. The tidal variation results in a diurnal to-and-fro migration of the grounding line – hence the use of the term ”grounding zone” (Echelmeyer *et al.* 1991). However, ice quake activity, varying in intensity with the tidal cycle, can be felt up-glacier about 8 km from the grounding zone.

Calving

Estimates of the annual calf ice production of Sermeq Kujalleq is mainly dependent on knowledge of the average flow velocity of the ice and the average thickness and width of the calving front. The estimates of calf ice production vary widely. Bauer *et al.* (1968) and Carbonnell & Bauer (1968) gave figures of 26–37 km^3/ year, possibly (hypothetically) ranging up to 44 km^3/ year, whereas Bindschadler (1984) on the basis of the more recent data of Lingle (1981) proposed a discharge flux (calving amount) of 29–39 km^3/year. Most recently, Pel- to *et al.* (1989) gave values of 34–40 km^3/year. A best-guess on the basis of these figures may be around 35 km^3/ year. To date, the high rate of movement of the glacier has remained constant over the years on record. Measurements of seasonal variations in velocity of Sermeq Kujalleq have been made (Pelto *et al.* 1989, Echelmeyer & Harrison 1990) and no significant variation was found.

The calving, or rather loosening of larger parts of the glacier front, occurs during relatively few events during the summer. In addition to these major events, however, there is a constant release of relatively small amounts of ice from the front, which can be observed at any time of the year.

REFROZEN MELT WATER ON ICEBERG

Photo: Jakob Laurrup, GEUS

The calving events are caused by expanding bottom crevasses that open because of an extending flow (Weertmann 1980), and tidal flexure along grounding lines (Lingle *et al.* 1981), supported by the water pressures in the crevasses. The cyclic changes imparted by the tide also cause de-coupling of the glacier from the cliffs on the sides of the fjord (Lingle *et al.* 1981). Material fatigue in the ice plate connected to the bending of the floating ice on its way out in the fjord causes parts of the front to become detached (Reeh 1968). In the major calving events, parts of the front are released as large tabular icebergs. Carbonnell & Bauer (1968) and Bauer *et al.* (1968) gave examples of such single tabular icebergs with dimensions up to *c.* 0.4 km^3.

In 1982, calving and iceberg production was observed closely by satellite remote sensing (Stove *et al.* 1983) in the period from March to October. Three major events occurred of which the first (17th May to 4th June) produced 14 tabular icebergs, with sizes up to 2 x 1 km. This event was the largest within this study period, and it occurred in connection with the break-up of the sea ice in the inner fjord. It caused a recession of the glacier front of 1–2 km, resulting in a discharge of *c.* 8.4 km^3 of ice. The subsequent events, between 29th July and 16th August and between 20th September and 9th October, produced only minor amounts of calf ice (5 tabular icebergs, 4 large icebergs). During the second calving event, the front was visited and the calving described on the 9th August (Epprecht 1987). On that date, the released ice area was approximately 0.3 x 1.5 km^2. in size. Initially, a large transverse crevasse opened in the glacier, and ”the subsequently detached piece then split into large blocks which toppled forward one after the other in the direction of the fjord, so that finally large, clean ice slabs lay in front of the glacier terminus. The tilting of the blocks pushed the whole mass of fjord water, together with the ice debris that floated on it, in the direction of the sea. The tilting processes had terminated after approximately 8 minutes. Then a wave which had been reflected farther out in the fjord returned to the break-off zone, where it caused the formation of a large amount of debris and high jets of water”.

Hughes (1986) observed another pulse of tabular iceberg detachment in July 1985; the calving front retreated almost 2 km in only 45 minutes. This event took place after some weeks with no major calving. Other reports also associate large ice discharge events with the summer season (e.g. Sohn *et al.* 1998).

After increased calving activity in the summer, the glacier will gradually advance again in winter, the front being stabilised by the sea ice in the fjord. Seasonal fluctuations of the glacier front were investigated during the period 1962 to 1996 and showed a magnitude of *c.* 2.5 km (Stove *et al.* 1983, Sohn *et al.* 1998).

Dynamics of Sermeq Kujalleq

In general, glacier ice moves downward in the direction of the steepest surface slope. This usually happens where the overall topography determines the generation of the typical valley glaciers, which can be found in mountainous regions all over the world. There are only very few places in the world where the ice is not generally forced to follow the underlying topography, but overruns entire landscapes and creates its own pattern of movement. These are the ice sheets and ice caps of the polar and sub-polar regions. Here, ice flow is still directed down slope, but it follows the surface topography of the ice mass and shows distinct differences in flow intensity, not necessarily in correspondence with the bedrock slope below. In most

Photo: Jacob Lautrup, GEUS

Iceberg laden with gravel and mud

Calving at the front of Sermeq Kujalleq produces the icebergs in Ilulissat Icefjord. Due to the threshold at the mouth of the Icefjord, the large icebergs become stranded here, and icebergs are subsequently accumulated in the fjord. The icebergs are extremely variable in size and shape. The size can vary from small pieces to real mountains of ice. The highest can reach altitudes of more than 100 m above sea level. The shape may vary from rounded forms to all kinds of irregular forms, often with pointed peaks. The whitish glacier ice is often cut by bands of transparent bluish ice, which has been formed by the freezing of melt water in crevasses in the marginal zone of the Ice Sheet.

It is often said that what is seen above the sea surface corresponds to 1/10 of the entire iceberg - the rest being hidden in the sea. However, as the icebergs consist of glacier ice rich in air bubbles, about 1/9 is above water. Sometimes icebergs with a heavy load of gravel and boulders may be observed in the Icefjord. This material may be incorporated into the ice when it slides over the ground surface, or it may fall down onto the ice from cliff faces. If the ice contains many stones it will become much heavier, and only a little part remains above water level.

Once the icebergs are released from the Icefjord, they drift out into Disko Bugt and the ocean. Some icebergs travel south of Disko and some travel north of the island, before they enter Davis Strait between Greenland and Canada. Here they meet the West Greenland Current, which carries the icebergs northward along the West Greenland coast. Further north the icebergs are carried by the ocean currents towards Canada, where they follow the Baffin Current and the Labrador Current southwards. Many of the large icebergs do not melt before they reach latitude of 40°N, one of these beeing the fate of Titanic in 1912. During the Little Ice Age icebergs from Greenland could be met over large parts of the North Atlantic.

During the so-called Heinrich events of the last ice age, vast armadas of icebergs episodically drifted all the way across the Atlantic. This resulted in deposition of large amounts of ice-rafted debris in the ocean sediments, as the icebergs melted.

Source: From Wadmams 2000.

Distribution of icebergs in the North Atlantic, and reports of exceptional sightings

Photo: Dieter Zillman/Greenland Tours Elke Meissner

Calving at the glacier front

marginal areas, the ice moves very slowly with only little lateral velocity variation. In other marginal areas, the flow may be concentrated into stream-like channels (cf. Fig. 15). For ice sheets (and ice caps), the tongues that extend down in the valleys and fjords, are generally referred to as outlet glaciers, whether ending on land or in fjords and lakes. In the latter case, there is generally an increase in the rate of movement of up to some hundred metres per year, due to diminished bottom stress. In ice sheets, the movement can locally increase to kilometres per year due to a number of factors, including the subsurface topography, the situation of the outlet and nearby ice margin in deep trenches, diminished basal friction and increased basal sliding. Such features are characteristic of ice streams which are restricted to localities at the ice margin of the Antarctic and Greenland ice sheets. Transition forms between common "calving" outlets and outlets with ice streams can be seen.

ICEBERG WITH LAYERING

Photo: Jakob Lautrup, GEUS

Sermeq Kujalleq is a paramount and classical example of an ice stream, and the high constant ice flow and large calf ice production, draining considerable parts of the Inland Ice, have attracted the attention of scientists for many years. The high velocities of the ice stream essentially result from funnelling of ice from a large drainage basin into a narrow stream. The reason for this flow concentration, however, needs to be further investigated. The basic question is which climatic or other conditions trigger the permanently rapid flow (surge) at the margin of the ice sheet. The large calf ice production and high velocities imply a relatively fast response time to any climatic change, but the causes for the permanently high rates of flow are still under debate. In this context, the concept of the "Jakobshavn effect" (Hughes 1986) has been presented to explain the high discharge rates and the stability of the adjacent ice sheet. This term was coined to describe Sermeq Kujalleq (earlier named Jakobshavn Isbræ).

The Jakobshavn effect is primarily a relationship between crevasse creation due to increased melting and high exterior stress in a heavily crevassed ice stream. Surface melting is greatly enhanced by extensive surface crevassing. When surface meltwater refreezes internally, it will release huge amounts of latent heat thus softening the ice column; meltwater which reaches the bottom will increase the basal sliding rate by lubricating the ice-rock interface. This and other processes in the glacier will increase the glacier flow within a system of positive feedback mechanisms.

It is suggested that the fast velocity of Sermeq Kujalleq began around 1850 (Fastook & Hughes 1994) when the increasing temperatures after the Little Ice Age caused increased surface melting on the lowermost parts of the ice sheet. This surface meltwater drained down into crevasses and moulins, warmed the ice internally and lubricated the bed (Echelmeyer *et al.* 1991, 1992). This caused Sermeq Kujalleq to begin the surge-like fast flow that continues today. The rapid velocity transformed the ice surface into a jumble of crevasses and seracs, features that are characteristic of surging glaciers. The surface area thus increased threefold, increasing both the volume of melting and the conduits through which meltwater warms the interior and lubricates the bed. The warmer ice deforms more readily and the higher velocities lead to an increased export of ice from the interior of the ice sheet. In this Jakobshavn effect, all the agencies act in a positive feedback to maintain the fast velocity of Sermeq Kujalleq.

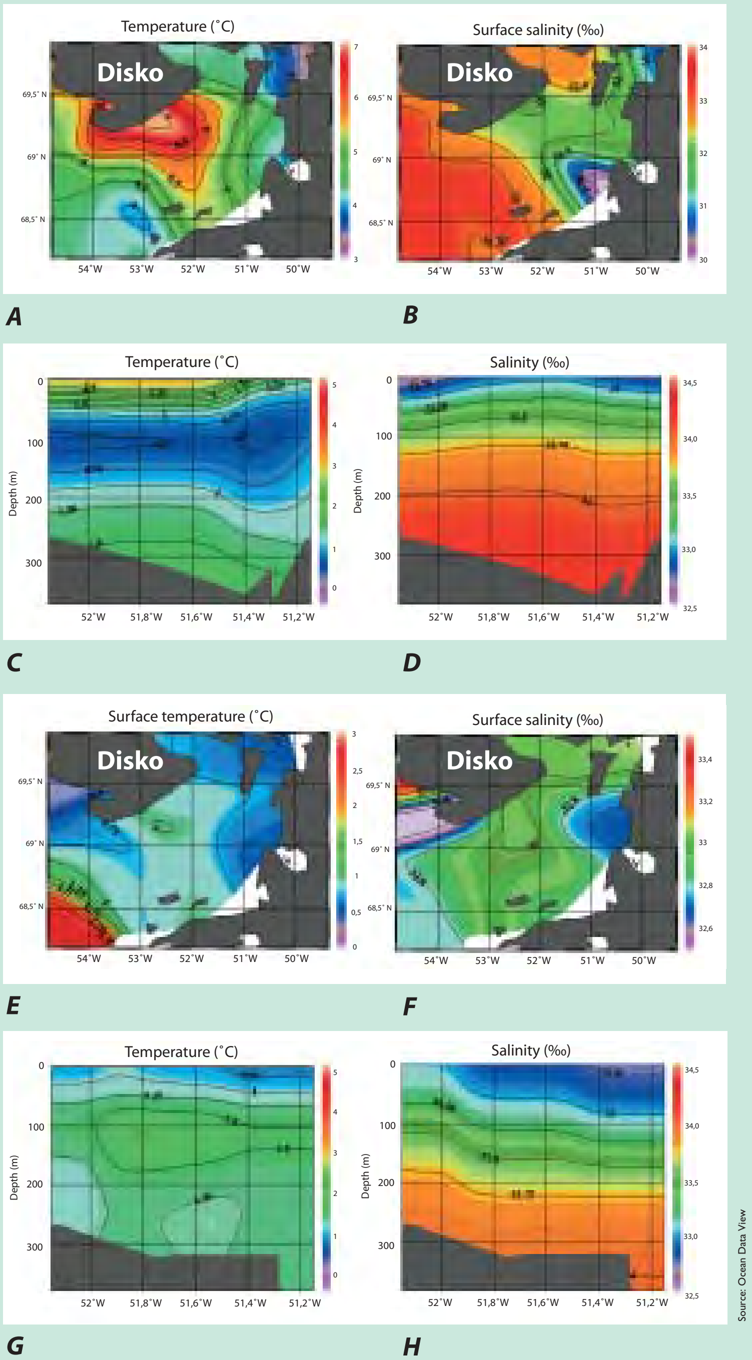
The theory of a positive feedback has also been expanded in time and space to relate to the whole of Greenland since the Last Glacial Maximum. At that time, the Inland Ice extended onto the Greenland continental shelf with ice streams crossing the shelf. With the onset of the Holocene climatic warming, the Jakobshavn effect would have begun first in South Greenland and then moved north where Sermeq Kujalleq (Jakobshavn Isbræ) today acts as the largest drain. Enhanced greenhouse warming in the future could result in the migration of the dominant Jakobshavn effect to ice streams draining the northern part of Greenland (Fastook & Hughes 1994), leaving large parts of central and South Greenland deglaciated. On a global scale, given the predicted greenhouse warming scenario, the Jakobshavn effect could accelerate and thus contribute to the collapse of the large ice age ice covers in general (Hughes 1986), and ultimately to the rapid disintegration of the present-day Greenland and Antarctic ice sheets.

However, other explanations for the permanently high flow rates of ice streams question the necessity of a Jakobshavn effect in order to maintain the high rate of

BOX 5. SALINITIES AND TEMPERATURES IN DISKO BUGT

During summer, the salinity of the surface layer in Disko Bugt is normally below 33.25 ‰ (B) and a strong vertical salinity gradient exists at a depth of 20–30 m (D). The salinity is lower inside the bay than outside, and the highest salinity is found in the south-western part. The salinity decreases towards the north and the east, often with rather strong horizontal gradients. In most summers, a pronounced minimum in the surface salinity is observed just outside Ilulissat. The strong vertical gradients in temperature and salinity as well as the horizontal gradients within the Disko Bugt, especially with respect to the salinity, indicate that a thin surface layer is formed due to the melting glacier ice. Due to the vertical salinity stratification the heat absorbed from the sun is stored in the thin surface layer, explaining the high summer surface temperatures (A, C).

The hydrographical conditions during autumn (October-November) in the upper part of the water column differ from the summer situation, especially with regard to temperature (E, H). The horizontal distribution of temperature at the surface shows much smaller gradients in November than in July. The surface salinity also shows reduced horizontal gradients relative to the summer situation (F, H). This is mainly due to the reduced amount of land drainage and melt water from the Ilulissat glacier, whereby the surface salinity increases within the bay.



flow (van der Veen 2001), and there is an ongoing scientific debate concerning which processes are most important in the creation and maintenance of high velocity zones.

The Icefjord

The Icefjord is poorly investigated regarding depth, salinity, currents etc. However it is clear that the inflow of freshwater and ice from Sermeq Kujalleq has a major influence on the salinity, currents and temperature in the fjord. Freshwater input and melting icebergs from the

BOX 6. KANELING

The phenomenon of "Kaneling" in the Ilulissat harbour is known from olden times and can cause problems for boats anchored in the harbour. Ostermann *et al.* (1921) described it thus: "The water in the harbour is suddenly in total turbulence, sometimes foaming white, and grass and seaweed from the bottom comes to the surface. Rarely it is dangerous for ships or boats, when only the moorings are solid. The whole phenomenon takes a few minutes, and then returns to normal conditions. In the latest years the "Kaneling" seems decreasing and is now completely unimportant".

When planning a new pier in the Ilulissat harbour, the question of the origin of "kaneling" was investigated (Reeh 1985). The phenomenon is connected with pressure waves produced by calving at the ice front and intensified by resonance in the Ilulissat harbour basin. The decreasing importance of "Kaneling", as noted by Ostermann *et al.* (1921), is connected to the significant retreat and thinning of Sermeq Kujalleq since the first half of the 20th century.

FISHING BOATS IN THE HARBOUR OF ILULISSAT

Photo: Jakob Lautrup, GEUS

Turnover (inversion) of large icebergs in the Disko Bugt area can generate large waves that represent a potential hazard for both boats and people. This is exemplified by the report from the Sermermiut valley at the Iceberg Bank that a tourist was overcome by waves generated from foundering icebergs. Such wave formation is not related to the "kaneling" described above.

Another phenomenon closely related to the Iceberg Bank was described by Ostermann *et al.* (1921); it concerns the creation of an ice dam at the Iceberg Bank such that the water level in the fjord is higher than in the waters off Ilulissat Icefjord. According to the description, the Icefjord will eventually "burst out" into Disko Bugt, when the dam can no longer resist the pressure from the dammed water.

BOX 7. CURRENTS IN DISKO BUGT

Source: E. Buch.

Following the currents in the Disko Bugt, icebergs from the Icefjord eventually enter the Davis Strait where they drift in a southerly direction along the coast of Canada (red arrows surface currents, blue arrows at 200 - 400 m depth).

Icebergs have always been considered a hazard for shipping on the sea routes of the North Atlantic. After the Titanic disaster (*cf.* Box. 4), it was decided at an international conference that an ice patrol should be established to track icebergs. The U.S. Coast Guard began this survey in 1914 and since 1928 their efforts have been expanded to include the determination of the origin of the icebergs. Outlets of 21 glaciers extending from the ice sheet in West Greenland have been identified as potential iceberg sources (Stove *et al.* 1983), of which only a few, first of all Sermeq Kujalleq, were deemed important.

The interest in monitoring icebergs and their sources declined in the 1950s and 1960s. This was probably due to a sharp decline in the numbers of icebergs compared with the preceding 50 years. This trend dramatically reversed in the 1970s, with 1972 and 1974 being the worst years on record. This was also a period when oil exploration was in focus both along the Canadian coast and off Greenland (Stove *et al.* 1983). Thus, in addition to the scientific interest into the dynamics of the Greenland ice streams, as discussed above, applied aspects of ice investigations can also be considered. In this context, it is also important to determine the variation in calf ice production, which nowadays is facilitated by satellite observations (e.g. Karlsen *et al.* 2001).

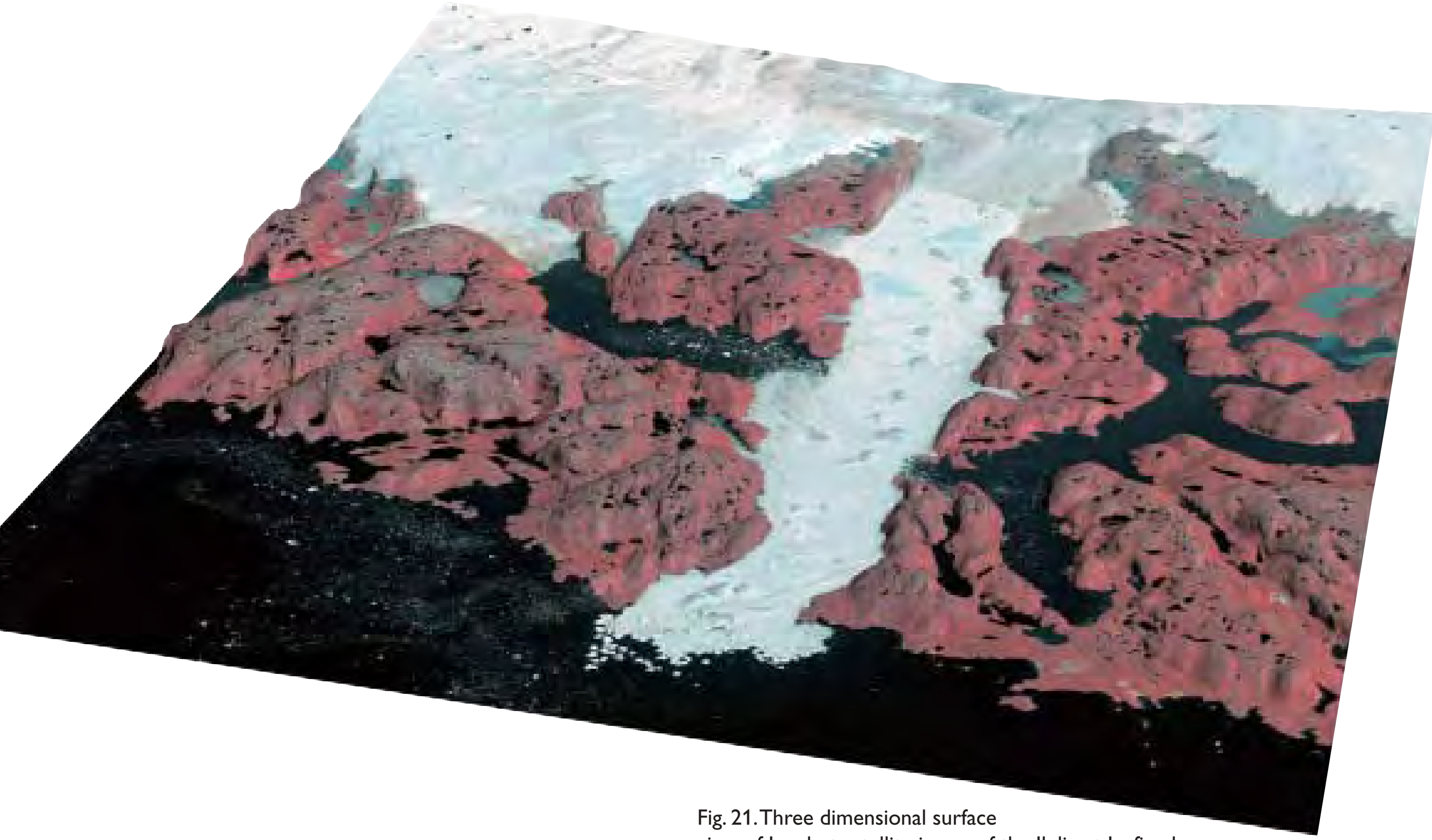


Fig. 21. Three dimensional surface view of Landsat satellite image of the Ilulissat Icefjord region, seen from the west. The satellite image – here draped on a digital terrain model, was acquired by the Landsat 7 satellite using the ETM+ (Enhanced Thematic Mapper) sensor from an altitude of 705 kilometres on 7 th July 2001. The colours of the image are artificial. Areas with vegetation appear brown or reddish. Barren rock surfaces are characterised by hues of grey. For the sake of clarity, the vertical scale has been exaggerated.

Icefjord also significantly influence the waters off Ilulissat Icefjord.

Regarding the depth of the Icefjord, the size of the icebergs indicates that the fjord must be particularly deep between the present glacier front in the east and the Iceberg Bank at the fjord mouth. Given an approximate iceberg height (derived from the thickness of Sermeq Kujalleq) of 700 m, the fjord must be more than 600 m deep. A few measurements have been made from the fjord ice, indicating depths of between 1000 and 1500 m at the confluence of the tributaries of Sikujuitsoq in the north and Tasiusaq in the south (Jacobi 1958, Echelmeyer *et al.* 1991)

The seasonal variations in the ice cover in the fjord have been monitored closely in a series of detailed satellite images (Stove *et al.* 1983). While Sikuijuitsoq is only covered with sea ice during the autumn, winter and spring (*c.* October–June), Ilulissat Icefjord is ice covered all year round. From June to September, the Icefjord is filled with brash ice and drifting icebergs, while sea ice covers the fjord for the rest of the year. (In recent years, however, the outer parts of the fjord have been ice-free during long periods of autumn and early winter). During the autumn, winter and spring, fracture zones are formed in the rigid sea ice due to glacial advance. Fig. 21 shows the ice cover on July 17th 2001.

When icebergs are released from Sermeq Kujalleq, they drift, or rather push their way, towards the mouth of the Icefjord. Here, all icebergs with a draught of more than *c.* 200 m are stranded on the Iceberg Bank. The residence time for icebergs in Ilulissat Icefjord is typically between 12 and 15 months (Stove *et al.* 1983)

The Iceberg Bank

The Iceberg Bank forms a relatively shallow, arch-shaped threshold at the mouth of Ilulissat Icefjord, running from Sermermiut in the North to Avannarliit in the south. On either side of the fjord are large, gravel- and boulder-rich moraines that were deposited at the Inland Ice margin some 9500 to 8000 years ago (Fig. 10). It is assumed that these deposits continue as a submarine end-moraine crossing the mouth of Ilulissat Icefjord. It is likely, however, that these deposits have been deeply eroded by iceberg scouring and the moraine is probably – as in other threshold fjords in Greenland – underlain by a sill of bedrock. The few soundings over the Iceberg Bank on the nautical charts show depths of 200–225 m which suggests that the Iceberg Bank forms the western end of the trench of Ilulissat Icefjord. This threshold separates the deep Ilulissat Icefjord from an undulating sea floor in the interior of Disko Bugt, with depths of 200–400 m; further to the south-west, this passes into the deep trench of Egedesminde Dyb (the ice age Jakobshavn ice stream) with depths over 800 m.

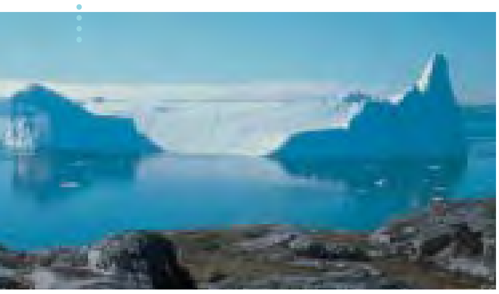

WONDERFULL VIEW FROM THE SHORES

Photo: Jakob Lautrup, GEUS

Large icebergs become stranded at the bank during all seasons. They remain there until they have either melted enough so their draught is reduced sufficiently, or until the pressure from the ice in the Icefjord becomes so large that they are forced over the threshold and into Disko Bugt. The mouth of the fjord can on occasion be free of icebergs, as observed in satellite images from May 1976 (Stäblein 1978) and May 1982 (Stove *et al.* 1983).

Quaternary geology

The landscape of the nominated area has to a large extent been created by glacial erosion during the shifting advances and retreats of the Inland Ice. The glacial erosion of the landscape is an ongoing process, which in some cases can be followed from year to year at the present ice margin. Large erosional features such as fjords and valleys in particular testify to the former ice cover. In addition, the area includes a number of other classic examples of landforms shaped by ice.

Formation of drainage channels and fjords

The landforms in the Ilulissat area have formed over millions of years. Over this immensely long period of time, the area has been repeatedly glaciated and deglaciated. However, before Northern Hemisphere cooling led to the formation of the Greenland Ice Sheet, erosion by rivers draining the interior parts of Greenland played an important role in the early formation of Ilulissat Icefjord and the drainage channel of Sermeq Kujalleq. Fig. 6 shows the approximate relief of an un-glaciated Greenland where the landscape below the present ice cover is shown without the depression caused by the present ice load. It is clear from this reconstruction that a significant portion of central Greenland was drained through the nominated area to Disko Bugt, where the drainage pattern continues as deep channels and fjords as far as the shelf margin (Weidick 1966). Since the watershed was situated in the eastern part of the subcontinent, a large proportion of the precipitation that fell over Greenland drained towards Disko Bugt. Fluvial erosion must therefore have been especially pronounced here and deep river valleys were formed.

When the Inland Ice began to form, much of the precipitation that fell over Greenland still drained towards Disko Bugt but now in the form of glacier ice. The drainage route followed the route created by the rivers. As seen in Fig. 17, ice streams such as Sermeq Kujalleq are capable of eroding deep troughs, the bottoms of which may extend far below sea level. The ice itself has only limited erosional power, but pebbles and boulders plucked from the substratum and carried in the basal part of the ice convert the ice stream into a giant grinding tool. Given sufficient time, wide and deep troughs will be formed.

Troughs resembling beads on a string (Fig. 9) often are separated by thresholds. In the nominated area, such “beads”, are represented by the troughs of Egedesminde Dyb (Fig. 9), the present Ilulissat Icefjord and the trough under the present ice stream of Sermeq Kujalleq, (Fig. 17). The reason for this uneven topography within the drainage channels is that the glacial erosion is concentrated in the marginal areas of the ice sheet, i.e. acts according to the extent of the ice cover. In addition, the intensity of erosion is related to the structures and composition of the bedrock and its zones of weakness.

BOX 8. BUBBLES AND GLACIER ICE

Photo: Jakob Lautrup, GEUS

A major feature of the glacier ice is its granular structure with ice grains of various sizes, interlocked into each other as a jigsaw puzzle. The crystals developed from some of the original snow crystals which, with time and increasing pressure, grow at the cost of neighbouring crystals. During this process the atmospheric air in the snow will be trapped as bubbles in between crystals. An investigation of West Greenland icebergs (including icebergs from Sermeq Kujalleq) showed that most bubbles had a pressure of 4–5 atmospheres, but pressures as high as 20 atmospheres were measured (Scholander & Nutt 1960). The carbon dioxide of the air bubbles can be radiocarbon dated, although large samples are required.

The generally white colour of the ice is due to its content of air bubbles. The icebergs are often penetrated by blue or green bands of clean ice, which is related to earlier crevasses, filled by frozen, bubble free melt water. Individual ice crystals in the glacier ice can be surrounded by an intergranular film of water with chemical constituents or even dust, originating from wind-blown material transported to the ice sheet from the surrounding ice free areas.

After calving from the glacier front, melting and erosion of the iceberg begins. This process is usually slow in Arctic waters. Positive air temperatures and radiation melts its upper parts above sea level, just as the lower parts under the water line are melted by relative warm saline water and by wave action. These processes occur with different rates at different places of the iceberg so that it eventually becomes unstable and tilts.

Fjords created in this way can be seen in many places in Greenland and around the world. Only rarely, however, is the glacial erosion still an active force in the creation of the fjord and the drainage channels in its upland, as seen in the nominated area.

Moraine ridges, kame terraces and marginal deltas

Much of the material eroded by the ice was deposited on the sea floor but some of this debris forms moraine ridges, which can be seen on land (Fig. 22). Large well-developed moraine ridges can be seen winding over the landscape in the nominated area from one fjord to another and extending nearly unbroken from the area between Qasigiannguit (Christianshåb) and Ilimanaq (Claushavn) in the south over the Iceberg Bank to the mouth of the Paakitsoq fjord (Fig. 24). In the Sermermiut valley, the moraine can be divided into two systems that were laid down at times when the sea level was 70–60 m and 50–35 m above the present sea level. This corresponds to ages of approximately 9500 and 8000 years BP, as deduced from sea level changes. The nature of these moraines and the shallow water depths over the Iceberg Bank (depths less than 200 m) indicate that the frontal area (and hence the calving front) was considerably smaller than today. Calf ice production from Sermeq Kujalleq must also have been smaller than at present. The moraine ridges were formed during a pause in the retreat or during a slight re-advance. In addition to marginal moraines, ice margin features found in the nominated area include kame terraces and marginal deltas. More recent moraine ridges, kame terraces and marginal deltas can be seen in the area close to the present ice margin where the ice has recently retreated.

Photo: R. Beschel, 24th July 1961

Fig. 22. Upland landscape (*c.* 600 m a.s.l.) at Tasersuaq lake between Sikuijuitsoq and Paakitsoq fjords, viewed towards the north-west. In the foreground and central part an interlobate moraine with a person on the top is seen. The moraine is part of a system of ice margin features extending from the iceberg bank at the mouth of Ilulissat Icefjord in the south-west to the mouth of Paakitsoq in the north-east. In the background right the present ice margin of the ice sheet around the head of Paakitsup Ilorlia is seen. This is where investigations on hydropower exploitation for the town of Ilulissat took place in the 1980s. In 1886, R. Peary and C. Maigaard visited the ice margin at this site.

PASSAGE DIFFICULT

Photo: Jakob Lautrup, GEUS

Land uplift

Since the last glacial maximum, the ice sheets of the world have either disappeared or shrunk in size, and the release of meltwater has led to a global sea level rise of *c.* 135 m (Lambeck & Chappell 2001). In formerly glaciated regions, such as the ice-free parts of Greenland, where the land has been freed from the weight of the ice, crustal rebound has taken place. In West Greenland, this rebound in general exceeds the global sea level rise, and marine or littoral deposits can be seen above the present sea level in many places, testifying to the uplift. The marine limit denotes the highest shore level since the last deglaciation. In the nominated area, the marine limit falls from *c.* 40 m above present sea level in the western part to *c.* 20 m above present sea level near the margin of the Inland Ice.

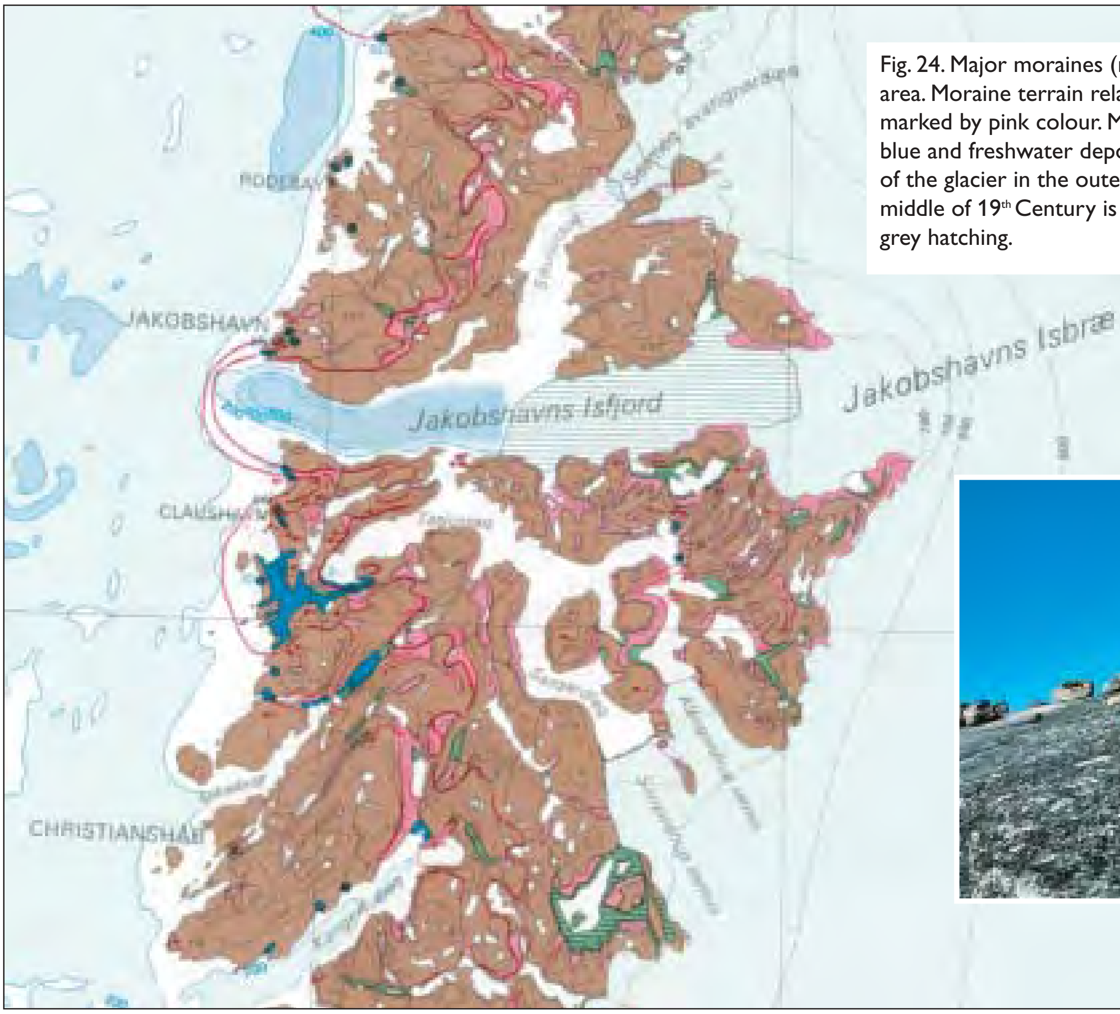
The trend of the early uplift is still subject to discussion although a considerable number of dates are available. However, the rate of uplift decreased with time, so that this period generally ended 4000-2000 years ago. Appreciable subsidence has been observed (e.g. Long *et al.* 1999) and is presumably related to increasing glacier load over the last 4,000 years (Wahr *et al.* 2001).

Raised marine deposits are evident at a number of localities in the nominated area, for example at Sermermiut where sand with shells of marine bivalves are found below the cultural layers described in chapter 3.b.

Smaller glacial landforms and features

In addition to the major glacial landscapes and features mentioned above, the nominated area also exhibits a range of smaller-scale features related to the successive advances and retreats of the ice sheet. The broad outlines of such features are shown on the section of the Quaternary map sheet in Fig. 24. Detailed descriptions of such features south of Ilulissat Icefjord were also given by Warren & Hulton (1990).

Many of the valleys in the region are glacially modified river valleys, as is the case for the Icefjord itself. These are



Source: From GGU 1974, Quaternary map series 1:500.000 Søndre Strømfjord – Nûgssuaq.

Fig. 24. Major moraines (red lines) around the Ilulissat area. Moraine terrain related to the ice recession is marked by pink colour. Marine deposits are shown in blue and freshwater deposits in green. Former extent of the glacier in the outer part of the fjord in the middle of 19th Century is given with horizontal blue-grey hatching.

Fig. 23. Ice-scoured rock surface with perched boulders.

Photo: Jakob Laurup, GEUS

formed in zones of bedrock with many joints and fractures and can be found many places in the nominated area.

Roches moutonées (literally "sheep rocks") are asymmetrical bedrock mounds with a smooth stoss side and a steep lee side. They are produced by ice flowing over the terrain, the smooth side forming by abrasion and the rough side by ice plucking.

Another characteristic feature of the Ilulissat Icefjord area is the numerous lakes that have formed in depressions also caused by glacial erosion. The large concentration and randomly arranged lakes reflects the highly irregular relief.

Small-scale erosional features include glacial striae which are narrow, linear grooves on rock surfaces that formed when the glacier sole embedded with stones slid over the rock. The striae are thus parallel with the ice flow direction. The glacial striae were probably formed during the millennia prior to the last deglaciation of the area, which took place around 9500 years ago.

So-called perched boulders are conspicuous in many places in the nominated area. Perched boulders are large blocks situated in unstable positions on rock surfaces, where they were left by the retreating, melting ice (Fig. 23).

Recent ice margin features in the area are trim lines on cliffs (Fig. 20). Trim lines are lines on bedrock slopes that correspond to the surface of a former glacier. Below the line, the bedrock is light and without lichens whereas above the line, the bedrock is darker, being covered with lichens and other plants.

LARGE ICEBERGS STRANDED ON THE ICEBERG BANK AT THE MOUTH OF ILULISSAT ICEFJORD

Photo: Jakob Lautrup, GEUS

History of Earth science: Ilulissat Icefjord and the Inland Ice

The Greenland Inland Ice and the Ilulissat Icefjord area have a unique historical significance to the founding of the science of glaciology, and they remain at the forefront of modern glaciology and climate research. Published information concerning the nominated area and the Inland Ice spans some 250 years. The factual observations from this period reflect the steps in the development of the glacio-geological and glaciological sciences and also the development in the general scientific understanding of the interactions between the ice and the surrounding environment. In recent years, ice core drillings and the study of ice stream dynamics have been of crucial importance to climate research and. In particular, the understanding of the anthropogenic greenhouse effect and its implications.

ARCTIC VEGETATION IS FOUND CLOSE TO THE ICEFJORD

Photo: Jakob Lautrup, GEUS

The literature on the glaciology of the Ilulissat Icefjord area can be divided into three periods.

a) The period of discovery: *c.* 1700 – *c.* 1845
b) Observations and development of theories: *c.* 1845 – *c.* 1950
c) The period of modern glaciology from *c.* 1950

The period of discovery: c. 1700 – c. 1845
The Danish/Norwegian colonisation of Greenland in 1721 and the establishment of Danish settlements (Jakobshavn/Ilulissat in 1741) led to a marked increase in descriptive accounts of the country and its nature, and also in the compilation of information from the Inuit population. One of the first comprehensive descriptions of Greenland and its natural environment by the missionary D. Cranz (1770) includes attempts to understand the ice cover and the origin of icebergs. Thus, without knowing it, Cranz was the first person to publish a description of a remnant of an ice age ice sheet.

Missionaries and tradesmen travelling along the west coast of Greenland at this time published descriptions of the Ilulissat Icefjord area and the Inland Ice. The information from this period of discovery is unique, extending back to around 1700. A significant proportion of the information regarding Ilulissat Icefjord was collated by Larsen & Meldgaard (1958) and Georgi (1960). Larsen & Meldgaard (1958) concluded from these data that in the early 1700s, at least periodically, the Icefjord was relatively free of ice, whereas the glacier margin advanced in the period 1780–1830. Georgi (1960) proposed that the ice margin advanced between *c.* 1700 and *c.* 1800, and again in the early and middle 1800s. However, information is in most cases difficult to locate and is often also difficult to date precisely; similarly, a clear relationship between calf ice production and the position of glacier front is not evident in these records. In this context, the visit in 1747 of P.O. Walløe should be mentioned (Walløe 1927). He apparently observed the front of Sermeq Kujalleq in the neighbourhood of Qajaa, advancing over old vegetation. If a valid observation, then it indicates that the front of Sermeq Kujalleq in the middle of the 18th century was close to the same maximum documented by H. Rink a century later; it should be acknowledged, however, that the precise location observed by Walløe is uncertain.

Regardless of the uncertainties, the scientific value of the observations in the 18th Century should not be underestimated, and they bear witness to the growing interest in the changes in the ice cover. The observations were compared with European and American glacier changes, (Cranz 1770). This provided impetus for more detailed mapping and descriptions of the Greenland ice cover in the following century, when it was first appreciated that glaciers could be regarded as a kind of ”climatoscope”, recording alternating warm and cold periods with their successive retreats and advances.

Observations and development of theories: c. 1845 – c. 1950
The first decades of this period of glacier research in Greenland were dominated by a single person: H. Rink (1819–1893). Originally educated in chemistry and physics, he conducted geological investigations in West Greenland between l848 and 1852, travelling from Upernavik in northernmost West Greenland to the Qaqortoq area in South Greenland. His aim was to produce a pioneer map of the country based on his own measurements, supplemented with map sketches made by local hunters (Rink 1852). He devoted much of the mapping efforts to the interior, eastern parts of the coastal region, an area that was largely unknown at the time. During these travels he also managed to visit, describe and measure extensive areas of the ice fjords and their glaciers. Rink

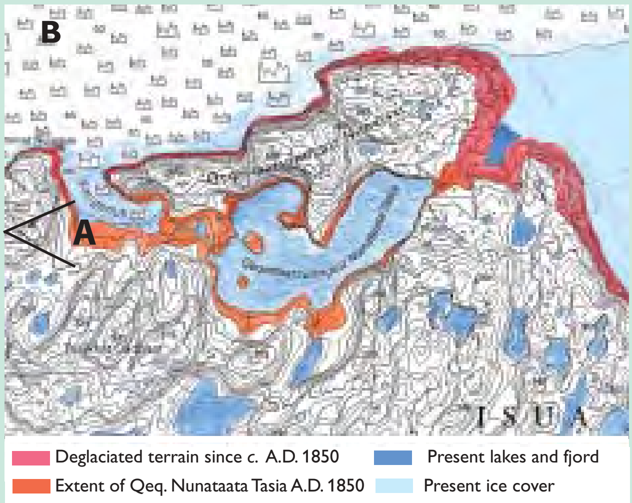
BOX 9. HISTORY OF AN ICE-DAMMED LAKE

Photo: Anker Weidick, 1963

The former ice-dammed lake of Qeqertaarsunguit Nunataa Tasia.

A) View from the western side of the inlet Kangerluk at the south side of Ilulissat Icefjord. The former ice-dammed lake is seen in the background.

B) Sketch map showing the extent of the former ice-dammed lake. The photograph is taken from location A on the map with the angle of view indicated.



Qeqertaarsunngui Nunataata Tasia (Nunatap Tasia) – the history of an ice dammed lake

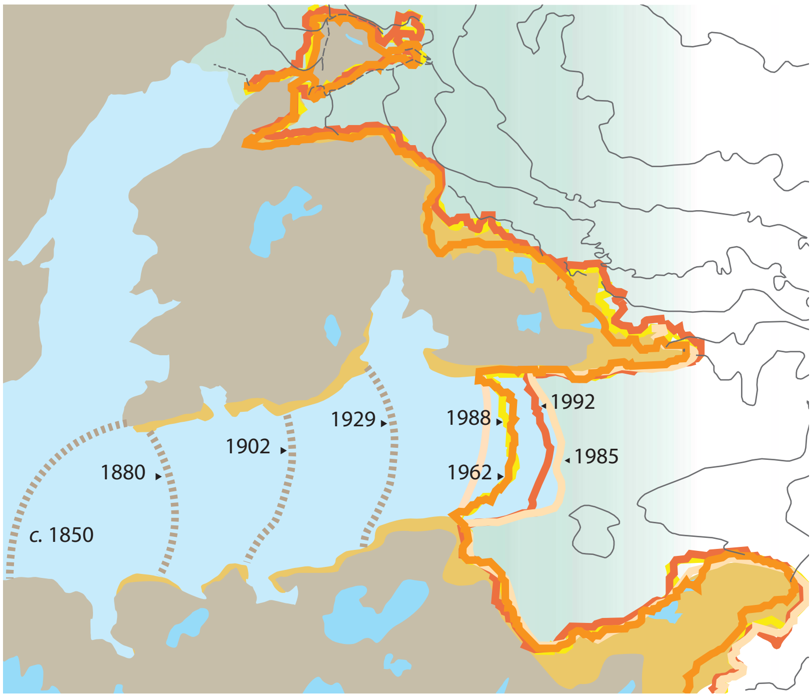
Just south of Sermeq Kujalleq is the large lake of Qeqertaarsunnguit Nunataata Tasia. When Sermeq Kujalleq was at its maximum extent, the lake was dammed by the glacier tongue and the water level reached a height of *c.* 50 m a.s.l. There is no evidence of drainage from the lake towards the south (into Tasiusaq) and the lake was presumably periodically drained under Sermeq Kujalleq into Ilulissat Icefjord. Following the retreat of Sermeq Kujalleq, the lake level gradually fell between 1880 and 1892. In 1892, the level suddenly dropped in the western parts of the lake, whilst the eastern part of the lake became isolated by a rock threshold, which kept the eastern part of the lake at a level of 22 m a.s.l, the level pertaining at the present (Engell 1904). In 1902, the western lake level was still at 11 m a.s.l. but by 1913 the lake level had fallen to present sea level: this part of the lake is now an inlet of Ilulissat Icefjord called Kangerluk. Engell (1904) also described the progressive plant colonisation of the former lake floor.

A small ice lobe from Sermeq Kujalleq extended into the eastern part of the lake when it was at its highest level (*c.* 50 m a.s.l.). After the lake level fell to 22 m a.s.l., a rock threshold was also revealed in this area, although the drainage at that time was still to the west, towards Ilulissat Icefjord. Drainage to the west continued until 1931, when the glacier lobe thinned and a small lake formed at its front. The thinning of this glacier lobe caused the level of this small lake to fall gradually to about 10 m a.s.l. and the drainage of this part of the lake system now takes place under the front of Sermeq Kujalleq.

stayed in Ilulissat over the winter 1850/51 and sailed to the Inland Ice margin at Paakitsoq, north of Ilulissat, in October 1850. He also travelled by sledge to the southern side of the front of Sermeq Kujalleq in April 1851 (Rink 1857, vol. 1). Here he determined the frontal position of Sermeq Kujalleq, which can be seen together with some of the later positions in Figs. 25, 26, 27). Rink's observations at the calf ice-producing lobe of Sermeq Kujalleq were the first in a series of subsequent observations of the ice margin fluctuations in the nominated area that spans 150 years up to the present-day.

The observations of the frontal changes and the movement of Sermeq Kujalleq (from 1875) must, together

Fig. 25. Major stages of the gradually retreating front of Sermeq Kujalleq since *c.* 1850. The general retreat of the glacier front ceased around 1950, and since then the glacier has receded during the summer and advanced during the winter. The positions of 1962 (17th May) and 1988 (30th May) illustrate the position of winter and early spring, those of 1985 (10th July) and 1992 (20th August) the positions in summer and early autumn. The last determinations are made from satellite images and extended to the ice margin north and south of Sermeq Kujalleq.



Source: From Sohn et al., 1997b.

MELTING ICEBERG (STRANDED GROWLER) WITH PEBBLES

Photo: Jakob Lautrup, GEUS

with the meteorological records at Ilulissat (from 1873), be considered as unique for Arctic areas.

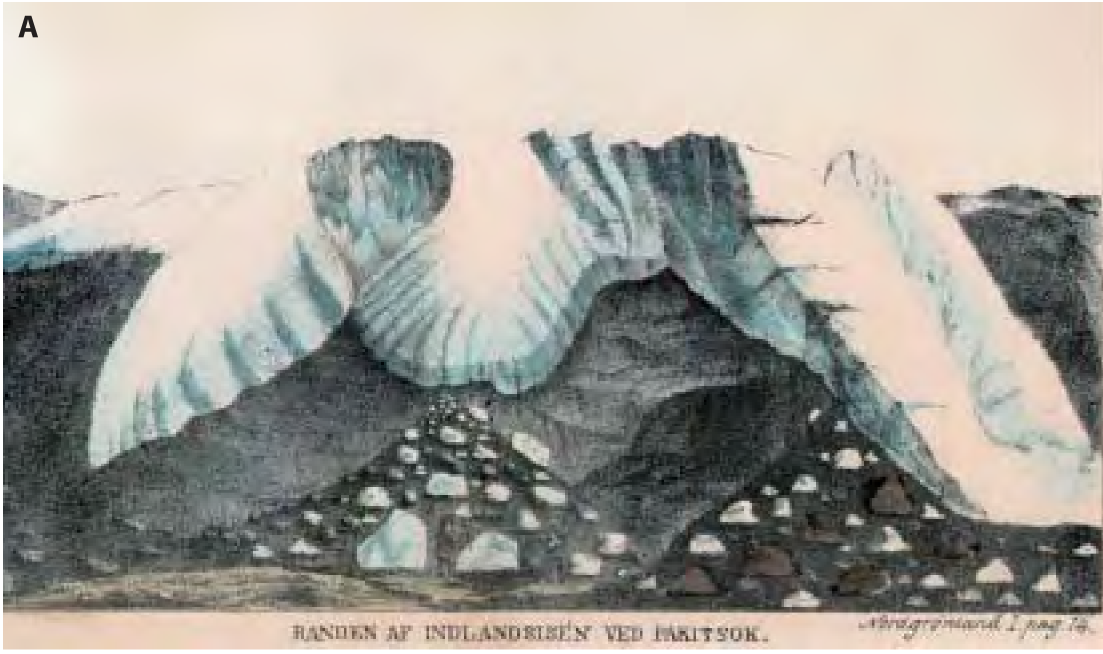
Through his work, Rink (Fig. 28) was probably the first scientist to appreciate the immense extent and special form of the "ice plain" covering the entire landscape of the interior of Greenland ("the Inland Ice" as he called it after a suggestion from the Danish scientist Japetus Steenstrup). It was a glacier quite different from the local glaciers hitherto described. In Europe, at this time, a new idea was emerging, namely that ice had covered large parts of northern Europe in the past. Rink's work therefore woke interest in scientific circles with the sensational news of an existing immense ice sheet, which could support the argument that such ice cover existed in Europe during a glacial age/ages. Rink's descriptions provided the impetus for glaciological expeditions to Greenland and the nominated area in the time to come.

In his attempts to understand the origin and life (in modern terminology: mass balance and dynamics) of the Inland Ice, Rink also ventured into many of the problems concerning the mechanics of calf ice production. Rink's main thesis was that as precipitation over large land areas is drained to the sea by large rivers (Fig. 29) so the ice streams derived from the interior of Greenland are caused by snow accumulation. Ice streams then acted as "rivers" in a surrounding area of quiet ice (Rink 1862).

Rink estimated the calf ice production to the fjords on the basis of glacier size and the amount of ice in the fjords (Rink 1852) and he distinguished five ice fjords of "first order", namely "Jakobshavn" (69° 10´N), "Tossukatek" (69° 50´N), "Den større Kariak" (70° 25´N), "Den større Kangerdlursoak" (71° 25´ N) and "Upernavik" (73° N) (Fig. 29). It should be noted that Rink could discern the large calf ice production from these major outlets, but it was not possible for him at that time to realise the paramount and unique status of Sermeq Kujalleq. This was first recognised by subsequent investigations on these glaciers in the last half of the 19th century. He had recognised, however, the extraordinary size of the ice sheet as can be seen by his evaluation of the necessary catchment areas of these 5 ice streams, being about 1000 Danish square miles (*c.* 50,000 km^2) (Rink 1875). His studies of calf ice production were of crucial importance to the science of glaciology as they stressed that the high rate of movement of Sermeq Kujalleq (and its calf ice production) was apparently not directly related to the extent of the glacier tongue, but was a persistent feature, regardless of the position of the glacier front.

Fig. 26. The lobe of the Inland Ice margin at Paakitsoq north of Ilulissat Icefjord.

In 1850 the glacier front was advancing, reaching a maximum around 1880. Since then a gradual thinning has taken place as seen from the pictures from 1850 (A), 1961 (B) and 1987 (C) respectively.



Drawing by H. Rink in 1850.

B. Photo by A. Weidick in 1961

C. Photo by H.H. Thomsen in 1987.

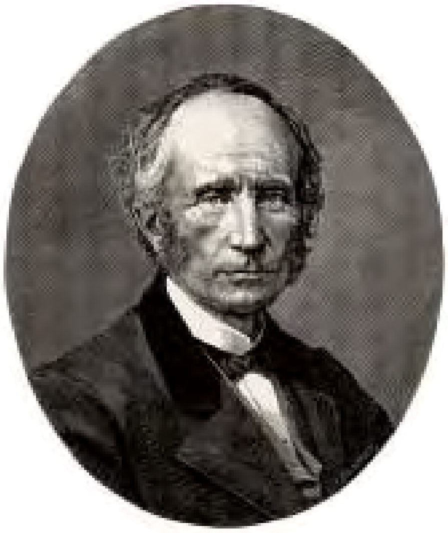
Fig. 27. The lobe of the Inland Ice margin at Paakitsoq, seen from south-west.

Hammer's drawing from 1883 (A) marks the maximum historical extent, and the following pictures of 1961(B) and 1987 (C) illustrate the ongoing thinning of the ice margin.

Drawing by R.R.J. Hammer in 1883.

B. Photo by A. Weidick in 1961.

C. Photo by H.H. Thomsen in 1987.



Source: From Nordenskiöld 1870

Fig. 28. H. Rink (1819-1893) was a pioneer in the investigations of the Greenland ice sheet.

As mentioned above, interest in the glaciology of Greenland increased during the second half of the 19th century. An increasing number of scientists visited Ilulissat Icefjord and Sermeq Kujalleq, nearly all providing a description of the glacier front and its surroundings. The chronological list of these visits is given in Box 10. Among the visitors to the nominated area were some of the leading scientists and explorers of that time, such as E. von Drygalski, Robert Peary and Alfred Wegener.

The period of modern glaciology from c. 1950.
During World War II, the application of airborne photogrammetry was developed to a high standard, so that remote areas like Greenland now could be mapped in detail. Furthermore, the technological advances of terrain-going vehicles and air support facilitated the accessibility to, and mobility in, the interior crevasse-free areas of the Inland Ice.

The new era of glacial investigations

This new era of expeditions began with the Expéditions Polaires Francaises (E.P.F. 1948–1953), which continued the work of the German Alfred Wegener Expedition (19-29–31). The expedition worked on an east–west profile from coast to coast over the central part of Greenland in order to measure a bottom and surface profile, as well as the mass balance along the route. This expedition had little impact on the Ilulissat area itself, although the region south of the outlet glacier of Eqip Sermia, *c.* 70 km north of Ilulissat, formed the western end of the profile and was subject to detailed mapping.

However, the successor of E.P.F., the Expédition Glaciologique Internationale au Groenlande (E.G.I.G. 1957-60, an international collaboration between Austria, Denmark, France, Germany and Switzerland), included in their programme a project that aimed to determine photogrammetrically the rate of movement (and estimate of calf ice production) of all glaciers in Disko Bugt and Uummannaq Fjord (Carbonnell & Bauer 1968, Bauer *et al.* 1968). The project confirmed the paramount role of Sermeq Kujalleq with respect to calf ice production, compared to other productive calving glaciers in West Greenland.

The E.G.I.G. work continued with follow-up projects after 1960. One important task with respect to Ilulissat Icefjord and Sermeq Kujalleq was to determine the thickness of the Inland Ice, and hence also map the height and topography of the landscape below by means of airborne radar. Prior to this initiative, the ice thickness was measured from the ground along only a few profiles over the Inland Ice (e.g. Holtzscherer & Bauer 1954) by means of seismic, gravimetric or radar measurements. The Danish Technical University in collaboration with the U.S. National Science Foundation and the Scott Polar Research Institute in England modified the radar technique for use in aircraft. During 6 seasons between 1968 and l976 more than 60,000 km profiles of the Inland Ice were flown, and although the geographical precision was low, for the first time a large-scale map of the landscape under the Inland Ice became available (Gudmandsen & Jakobsen 1976). At that time, the subsurface map was a major breakthrough with major implications for the understanding of glacier and ice sheet dynamics, Quarternary geomorphology, and climate research. However, details were still lacking, especially concerning information on the continuation of the fjords under the present Inland Ice margin and the real depths of the ice stream channels. Much of this information has been revealed in connection with the investigations of the hydropower potential of meltwater from the Inland Ice, for the towns of Ilulissat (Jakobshavn) and Qassigianguit (Christianshåb) (Thorning & Hansen 1988, Thomsen *et al.* 1988, Thomsen *et al.* 1989). This was achieved by a new technique using helicopter-borne radar, developed by the Danish Technical University and modified by the Geological Survey of Greenland (GGU, now GEUS). The most up-to-date radar ice thickness measurements of the ice sheet (with more details around Sermeq Kujalleq) were given by Goguneni *et al.* (2001).

A)

Source: Rink. 1862.

B)

Source: Rink. 1857.

Fig. 29.

A) The concept of Rink on the original drainage of rivers from the inland region (Rink 1862). The cartography at the time of Rink was not very precise. This is especially evident on the east coast of Greenland and north of Ilulissat on the west coast.

B) The concept of Rink regarding large ice streams from the present Inland Ice (Rink 1857). The five described large ice streams in Disko Bugt and Uummannaq Fjord are shown together with minor ice streams in southern Greenland.

MEETING BETWEEN INUIT AND EUROPEANS IN NORTHERN GREENLAND

Source: J. Ross 1819

Glacier surging

In the second half of the 20th century, scientific interest in the phenomenon of "glacier surging" was growing. It was first described from mountain glaciers (in Greenland, these glaciers have been described from the island of Disko, west of Ilulissat (Weidick 1988, Nielsen 2000)) which usually surge periodically. "Surge" refers to a sudden or rapid periodic increase in the velocity of the glaciers that changes the smooth surface into a chaotic jumble of ice. During the full surge cycle, the glacier accumulates mass (ice) over a long time-span (the quiescent phase: 10–100 years) and then suddenly discharges it in a short, rapid advance (the surge) that lasts some months. Similar high velocities are observed on the ice streams of Antarctica and Greenland where the ice maintains the high velocities due to the large catchment areas (cf. Appendix 1).

The interest in understanding surging glaciers should be seen in the context of the ideas that the ice age ice sheets might have disintegrated in "catastrophic collapses"; such considerations may be relevant today with respect to the potential response of present ice cover to global warming (the anthropogenic "Greenhouse effect"). Interest in ice stream dynamics thus intensified. Sermeq Kujalleq (Jakobshavn Isbræ) was an obvious choice when setting out to investigate ice stream mechanisms, not least because the "Jakobshavn effect" was already serving as a paradigm of theories for the permanent fast movement of ice streams. Furthermore, the longest series of climatic measurements (from 1873) were on hand here, as well as a long historical and scientic record of the ice stream. Last but not least, during the 1980s, GGU (now GEUS) had made continuous measurements of temperature, precipitation and radiation on the margin of the Inland Ice, just north of the nominated area , as part of hydropower investigations to determine meltwater volumes from the Inland Ice margin.

In 1983, therefore, a meeting of an international group of glaciologists at North Western University, Evanston, U.S.A., was devoted to the planning of the investigations around and upon Sermeq Kujalleq. Through the follow-

1870: *A.E. Nordenskiöld (1870). Provided a description of the glacier front, but he could not determine the boundary between the front of the glacier and the calf ice in the fjord (cf. Engell 1904). The visit to Sermeq Kujalleq was undertaken in connection with one of the early attempts to visit the interior of Greenland near Ilulissat. Reconnaissance by Nordenskiöld's expedition in 1870 from the head of Arfersiorfik fjord, c. 90 km south of Ilulissat, reached c. 50 km into the ice sheet to an altitude of 580 m a.s.l. The subsequent main expedition led by Nordenskiöld from the same starting point reached c. 350 km into the Inland Ice to an altitude of 1947 m a.s.l. (Nordenskiöld 1870). The essence of this venture was to survey and describe the landscape of the ice sheet margin. The concept of cryoconite (dust from the ice) and cryoconite holes (large, metre-deep holes in the surface of the ice margin) was coined and the organic content investigated; waterspouts from the ice surface were also described.*

Nils Adolf Erik Nordenskiöld

1875: *A. Helland (1876). Description of the position of the glacier front, first measurement of rate of movement (July).*

1879: *R.R.J. Hammer (1883). Mapping of the entire fjord system, including the glaciers at the heads of the tributaries of Sikuiuitsoq and Tasiusaq. Determination of the position of the glacier front in September.*

1880: *R.R.J. Hammer. Repetition of the visit of 1879 in March and August 1880: winter advance of c. 1 km and subsequent summer retreat of c. 2 km were measured. Measurement of rate of movement from the southern edge of the glacier front to its central parts: increase in movement from the edge, reaching up to 12.5 m/24 h in the central parts. He estimated that movement of up to 16 m/24h was possible. He also stated that the movement was not steady, but that there was no relationship between air temperature and movement. Position of the front was very variable, and he concluded that large icebergs were released by fracturing of the ice front due to the buoyancy of the floating parts of the glacier. Hammer also attempted to evaluate the hydrology of the ice fjord.*

1883: *R.R.J. Hammer (1889). Sketch map made in August of 1883.*

1886: *R. Peary attempted to reach the interior of the Inland Ice. He started at Paakitsoq, c. 40 km north of Ilulissat Icefjord. Together with his companion Chr. Majgaard, he reached c. 185 km into the ice sheet to an altitude of nearly 2300 m a.s.l. They also described the landscape of the ice margin (Peary 1898).*

Robert Edwin Peary

1888: *S. Hansen (Engell 1904). Sketch map made for the Royal Danish Sea Chart Archive. According to Engell, a photograph from this visit showed that the frontal position of the glacier was more easterly than indicated on the map of this year.*

1893: *E.v. Drygalski (1897). The German Polar Explorer visited the glacier front from the south side in February. The front position was difficult to evaluate but plotted on a map.*

1902: *M.C. Engell (Engell 1904). Front position of glacier was measured in July showing a continued net retreat since Rink's observations in 1851. Measurement of rate of movement gave the same order of magnitude as the earlier estimates (Helland 1875, Hammer 1883). In addition, Engell made an extensive description of the whole fjord region including Sikujuitsoq and Tasiusaq.*

1903: *M.C. Engell (Engell 1910a). Engell visited the glacier in July of 1903, but could only with some uncertainty report the ice front position, c. 350 m further to the west than in 1902. Observed the release of a large iceberg.*

1904: *M.C. Engell (Engell 1910a). Visit to the glacier front in the summer (July?) of 1904. Ice front position not determined.*

1913: *J.P. Koch & A. Wegener (Koch & Wegener 1930). After crossing the Inland Ice in 1912/13, the two scientists visited Sermeq Kujalleq in August 1913 and determined the ice front position, indicating a significant retreat since 1902 (cf. Fig. 5).*

1929: *J. Georgi & E. Sorge (Georgi 1930). During preparations for the German Alfred Wegener Expedition to the Inland Ice (1930/31), two of its members, J. Georgi and E. Sorge, determined the ice front position and the movement of the ice front during a visit in the autumn of 1929.*

1931/32: *Glacier position given on the first map sheet (1: 250,000) of the Jakobshavn area, made by the Geodetic Institute, Copenhagen.*

After 1932*: During and after World War II, the techniques of aerial photogrammetry developed apace. The increase of information can be illustrated by the aerial photographs that are available over the Ilulissat Icefjord and Sermeq Kujalleq glacier in the files of National Survey and Cadastre, Copenhagen, covering the years of 1942, 1946, 1948, 1953, 1957, 1958, 1959 and 1985.*

The essential characteristics of the period after 1932 are that the great retreat of the glacier seemed to stop at the end of the 1950s and that technical progress facilitated a more detailed and effective survey and research of glaciers on the basis of aerial photographs.

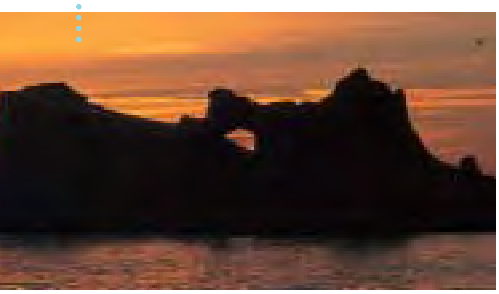
In the 19th century an increasing number of scientific expeditions explored the Inland Ice. Due to the limited technology, the expeditions experienced extreme difficulties and dangers when trying to enter the ice desert.

Painting: A. Kornerup, 1878

ing decades, this has led to a high level of activity on the ice margin, with scientists participating from U.S.A., Denmark, the Netherlands, Germany and Switzerland. The major results from these studies form the basis for the description of the area given above.

The increasing interest of the glaciological problems of Sermeq Kujalleq is illustrated by the increasing amount of literature in especially recent issues of Science, Nature and Journal and Annals of Glaciology. Most references from here can be found in the recent publication of NASA's programme for Arctic Regional Climate Assessment (PARCA): Mass balance of the Greenland ice sheet (PARCA investigators 2001).

Iceberg monitoring
Another reason for increased international interest on Sermeq Kujalleq during the last decades of the 20th century, was that the U.S. Coast Guard needed to update the estimates of calf ice production and release of ice to the Davis Strait. This was important since Greenland icebergs were, and still are, a hazard to shipping along the east coast of North America. As far back as the early 1930´s, Jakobshavn Isbræ (Sermeq Kujalleq) had been identified as the main source for icebergs in the area. In 1968, the ice breaker "Westwind" commenced a new series of cruises along the west coast of Greenland (Kollmeier 1980, Lingle *et al.* 1981) to measure the calf ice productivity and the change in frontal position of the glaciers. Sermeq Kujalleq was visited in 1971, 1976, and 1978.



IN THE SUNSET THE ICEBERGS CHANGE COLOUR

Photo: Jakob Laurup, GEUS

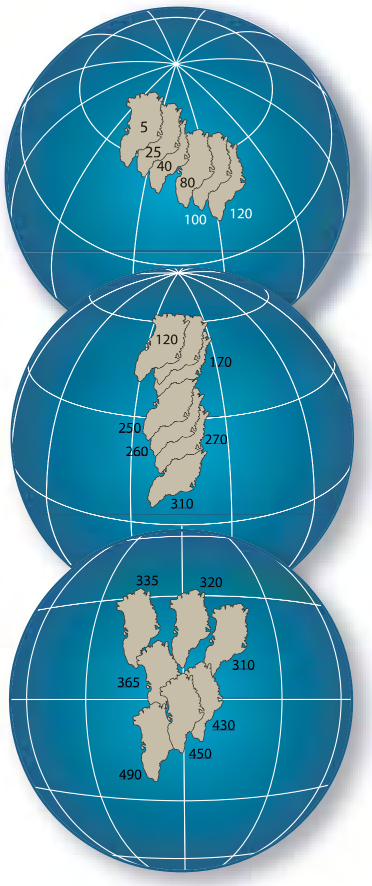
Satellite remote sensing
Modern investigations of the marginal areas are, to a large degree, undertaken by the application of satellite observations. Satellite monitoring of the frontal position has to some degree substituted the aerial photographs since it allows repeated observations of glacier conditions within short time spans. Good examples for Sermeq Kujalleq are given by Stove *et al.* (1983) and by Sohn *et al.* (1998), both presenting information on the most recent changes of the ice stream (cf. Fig. 25). Furthermore, the topography and velocity fields over large areas can now be determined using SAR satellites. With this tool, a new era has begun in large-scale glaciological investigations, both globally and specifically in the nominated area.

Source: Geological Survey of Denmark and Greenland

Fig. 30. Simplified geological map of Greenland.

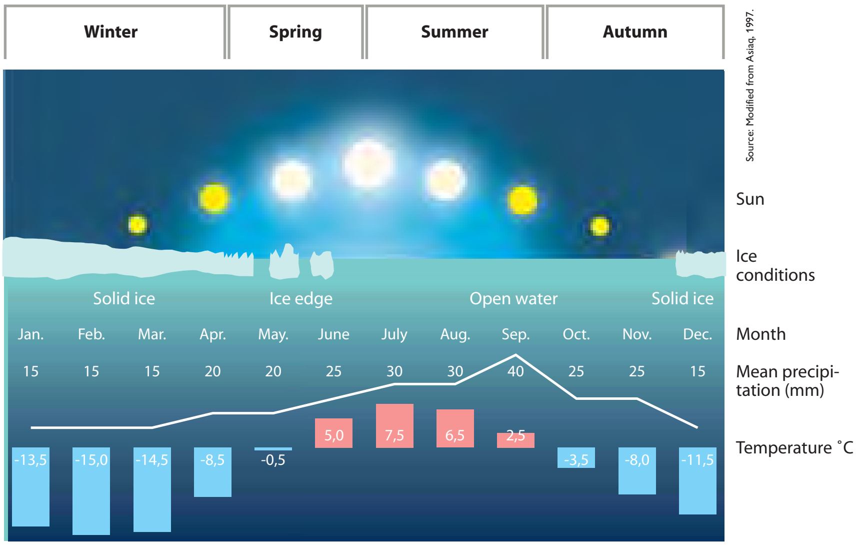
Bedrock geology

Rocks formed during all the geological time periods can be found in Greenland. West Greenland is dominated by Precambrian crystalline basement consisting of rocks such as gneiss, granite and schist that represent old fold belts. Younger fold belts are found in North and East Greenland (Fig. 30) where undeformed sedimentary and volcanic rocks are also widespread.



Source: Modified from Gunver Krarup Petersen.

Fig. 31. The geographical position of Greenland has changed over the millennia as a result of plate tectonic movements, which has also led to the opening of the Atlantic Ocean. The numbers indicate time in million years before the present.



Source: Modified from Asiaq, 1997.

Fig. 32. Distribution of sunlight, sea ice conditions, temperature and precipitation during an annual cycle in the Disko Bugt area.

The bedrock of the Ilulissat Icefjord area consists of crystalline rocks, and is dominated by grey gneiss with minor intercalations of amphibolite. Gneiss is a banded metamorphic rock that was formed under high pressure and temperature deep in the crust of the Earth. The gneiss around Ilulissat Icefjord is orthogneiss and was formed from igneous rocks, presumably granites.

The rocks are of Precambrian age and formed during collision between two continents about 2000 million years ago. At this time, a number of small old continents collided and amalgamated to form one of the earliest major continents on Earth. The rocks represent the deepest parts of an alpine fold belt and are strongly deformed, showing folding and dipping strata. Many kilometres of rock that formed the upper levels of the fold belt and lay above the present land surface have been eroded away. During the last 500 million years, Greenland has moved progressively towards the pole, from the tropics to its present Arctic latitude (Fig. 31).

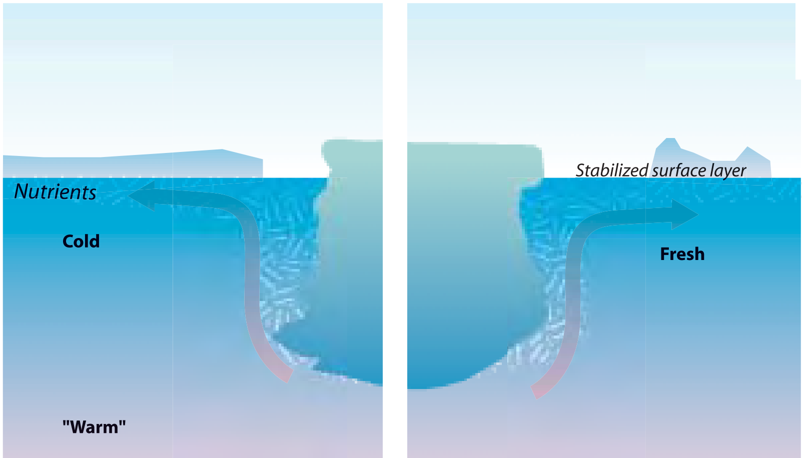
On the island of Disko, west of Ilulissat, Cretaceous sediments and a thick pile of Tertiary plateau basalts are found. These rock types possibly also once covered the Ilulissat Icefjord region, but have been eroded away because of land uplift during the last few million years.

Climate

A high-pressure system prevails over the Greenland Inland Ice. This, in combination with the orographic influence of Greenland, means that westward moving low-pressure systems can be forced to move northward along the west coast of Greenland. Most precipitation in West Greenland is related to the passage of such low-pressure systems (Hansen 1999).

The town of Ilulissat has a continental type of climate. The mean July temperature is 7.5°C, measured over the

Fig. 33. Large icebergs have a positive influence on the primary production in the surface layers. Freshwater from bottom melting of icebergs is lighter than the saltwater in the surrounding waters. Hence the freshwater will move towards the surface, bringing nutrients from deeper parts into the upper part of the water column where primary production takes place.



time period from 1961 to 1990 (Fig. 32). It is thus situated in the low-arctic bio-climatic zone, which can be defined by a mean temperature for the warmest month between 5 and 10°C. The highest mean temperature recorded during the period was 10.3°C. Ilulissat is characterised by low winter temperatures, and the coldest month is March with a mean temperature of –19.9°C. The lowest (mean) temperature recorded is –24.7°C. The mean annual precipitation is only 266 mm, and August/ September has most precipitation, but the yearly variations are small. Calm days are quite frequent, especially during the summer, but the storms can be quite violent. The highest mean wind velocities are found in the wintertime, with a highest mean wind velocity of 22.1m/s recorded in January 1992. Stormy weather occurs in connection with passages of low pressure systems, or in connection with føhn winds, which are relatively warm and dry winds with a westerly direction from the Inland Ice to the outer coast. During a period with føhn winds, the temperature can increase 10–20°C over a few hours, and the air becomes unusually dry. Føhn winds during the winter can lead to widespread thaw of snow and ice, but the føhn normally lasts for a short period only, after which a return to normal weather conditions is seen. In the winter period, this can lead to the formation of a widespread crust of ice on the snow surface. Since 1880, when systematic observations began, marked changes in the climate have occurred. Most notably, an increase in the mean winter air temperature of *c.* 4.5°C was recorded between 1900 and 1925. The summer temperatures also increased, although on a smaller scale. The temperature rise was a consequence of increased inflow of warm Atlantic air masses from the south, but it was enhanced by the albedo effect as a consequence of reduced sea ice formation.

SMALL ICEBERGS (GROWLERS) OFF THE ICEFJORD

Photo: Jakob Lautrup, GEUS

Over the past decades, the area has been characterised by falling temperatures. This is the opposite of the general trend over the Northern Hemisphere, where a marked warming is observed. However, the cooling in West Greenland may now have ceased (Anonymous 2002c).

Ilulissat is located north of the Arctic Circle and thus has a winter period when the sun does not rise above the horizon, and a period during the summer when the sun is above the horizon all 24 hours. However, the altitude of the sun is always low, which is why the polar regions are the coldest parts of the Earth.

Marine ecosystem

The marine flora and fauna associated with Ilulissat Icefjord are closely linked to the glaciological conditions. The permanent ice cover in the fjord and the stranded icebergs at the mouth of the fjord generate an environment with strong turbulence and upwelling in the upper water masses. This is mainly due to melting of the icebergs (Fig. 33) and a strong tide in the area (*c.* 2 m). In addition, subglacial erosion adds nutrients to the water. These factors lead a high production of species belonging to lower trophic levels, which attracts a number of predators such as fishes, seals and whales.

Investigations of the flora and fauna in Ilulissat Icefjord are naturally constrained by the physical conditions in the fjord, with solid ice cover in winter and an almost 100% cover by floating glacier ice in summer time. Therefore, investigations on life in the area have focused on the fjord mouth and waters off Ilulissat Icefjord.

Marine plankton

The knowledge about the occurrence and distribution of marine plankton in Ilulissat Icefjord is extremely limited. However, in an investigated transect from Qeqertarsuaq on Disko island to Ilulissat, the impact of zooplankton feeding on the lower trophic levels was studied off Ilulissat Icefjord (Turner *et al.* 2001). Results from this study emphasised the importance of the local processes in Ilulissat Icefjord with the ice melting and runoff from the glacier creating a transport of freshened surface water (Kiilerich 1939).

Fish and larger crustaceans

Among fish, Greenland halibut (*Reinhardtius hippoglossoides*) constitutes the predominant species in the ecosystem in Ilulissat Icefjord. Unlike other flatfish species, the Greenland halibut occupies both demersal and pelagic habitats. The distribution of Greenland halibut seems to be related to relative cold temperature conditions as the species tends to interact with the warm water species Atlantic cod (*Gadus morhua*), which presently is less abundant in the area. Greenland halibut is distributed in the entire fjord system of Ilulissat Icefjord and is caught deep into the fjord in wintertime. The fish is known to perform seasonal migrations, mainly being distributed in the inner part of the fjord in summer while being more uniformly distributed in wintertime (Boje 2002).

Greenland halibut off Ilulissat Icefjord is subject to one of the world's most concentrated fisheries with regard to amount fished in the relatively small area. Due to ice cover, intensive fishery is prevented inside Ilulissat Icefjord, which therefore constitutes an important habitat for the resident adult Greenland halibut growing as old as 25 years (Boje 2002).

Due to low bottom temperatures (less than 2°C), Greenland halibut in Ilulissat Icefjord is assumed to reabsorb its reproduction product in the body, in order to postpone spawning until better conditions are available (Boje 2002). Hence, the Ilulissat Icefjord stock component is not self-recruiting, but is continuously recruited from an offshore spawning component in Davis Strait. The prevailing theory is that Greenland halibut in the Northwest Greenland fjords are 'trapped' from their spawning stock, and remain resident in the fjords thoughout their entire adult life (Riget & Boje 1988). Whatever strategy on stock exploitation is applied, there will be no effect on the origin spawning stock and the resulting recruitment to Ilulissat Icefjord. However, the fishery affects the composition of the stock component in Ilulissat Icefjord, and consequently the average age of fish in the stock has decreased significantly within recent decades (Simonsen & Boje 2001).

BOX 11. FISH SPECIES IN THE AREA

Fish species recorded during long line investigations in the vicinity of Ilulissat Icefjord:

Arctic skate	*Raja hyperborea*
Doubleline eelpout	*Lycodes eudipleurostictus*
Greater eelpout	*Lycodes esmarkii*
Longear eelpout	*Lycodes seminudus*
American plaice	*Hippoglossoides platessoides*
Sailray	*Raja lintea*
Threadfin rockling	*Onogadus ensis*
Roughhead grenadier	*Macrourus berglax*
Polar sculpin	*Cottunculus microps*
Wolf fish	*Anarhichas lupus*
Longfin snailfish	*Careproctus longipinnis*
Golden redfish	*Sebastes marinus*
Spinetail ray	*Bathyraja spinicauda*
Starry skate	*Raja radiata*
Greenland cod	*Gadus ogac*
Vahl's eelpout	*Lycodes vahlii*
Greenland shark	*Somniosus microcephalus*
Greenland Halibut	*Reinhardtius hippoglossoides*

Also appearing in the nominated area are:

Arctic char	*Salvelinus alpinus*
Snowcrab	*Chionoecetes opilio*

Application of a precautionary approach to management of this resource in and off Ilulissat Icefjord is therefore directed more towards species diversity and effects of fishing activities on habitat, than on sustainability of the resource. Present management thus focuses on a conservative annual yield aiming at stable catch levels and on responsible fishery methods aiming at reducing the effect on the bottom habitat.

The main prey for Greenland halibut, the crustacean northern shrimp (*Pandalus borealis*) is distributed in the

ICEBERGS IN THE ICEFJORD AT SUMMER

Photo: Jakob Lautrup, GEUS

entire Ilulissat Icefjord as well as waters off Ilulissat Icefjord. Northern shrimp constitute an important prey organism for most fish in the benthic-pelagic ecosystem in West Greenland, the adult being benthic in the daytime and pelagic at night. Other important crustacean prey are euphausids, *Boreomysis* and *Themisto* species. A significant fish prey for Greenland halibut is the pelagic species capelin (*Mallotus villosus*), a locally very abundant small salmon fish, which group in small coves before spawning. Capelins northern ecosystem substitute is polar cod, *Boreogadus saida*, an entirely pelagic species, becoming more abundant in Ilulissat Icefjord and adjacent waters within recent years. A number of eelpouts, *Lycodes* species, occupy the benthic habitat in Ilulissat Icefjord, and also represent an important prey for Greenland halibut.

Photo: Jakob Laurrup, GEUS

REINDEER
(RANGIFER TARANDUS GROENLANDICUS)

Greenland shark (*Somniosus microcephalus*) along with ringed seal (*Phoca hispida*), are the main predators on Greenland halibut in the area (Jensen 1935). The Greenland shark is common in Ilulissat Icefjord, although it has been harvested very intensively as a by-catch species in the long line fishery for Greenland halibut (Smidt 1969).

Marine mammals

Very little information on marine mammals at and near Ilulissat Icefjord is published, and the following account is mainly based on unpublished information from people living in the area.

Fin whales (*Balaena physalis)* and minke whales (*Balaena acutorostrata)* are often seen during the summer along the outer edge of the threshold at the mouth of the fjord. Blue whales (*Balaena musculus*) and Greenland whales are very rare visitors. Beluga (*Delphinapterus leucas*) and narwhals (*Monodon monoceros*) are autumn and winter visitors in the Disko Bugt, and may occasionally occur in

Photo: Jakob Laurrup, GEUS0

Red throated diver *(Gavia stellata)* on its nest.

Ilulissat Icefjord. Harp seals (*Phoca groenlandica)* are common in the open waters during the summer and ringed seals (*Phoca hispida)* occur in Ilulissat Icefjord throughout the year (Porsild 1921a, b). Polar bears (*Ursus maritimus*) are extremely rare visitors to the area.

Birds and terrestrial mammals

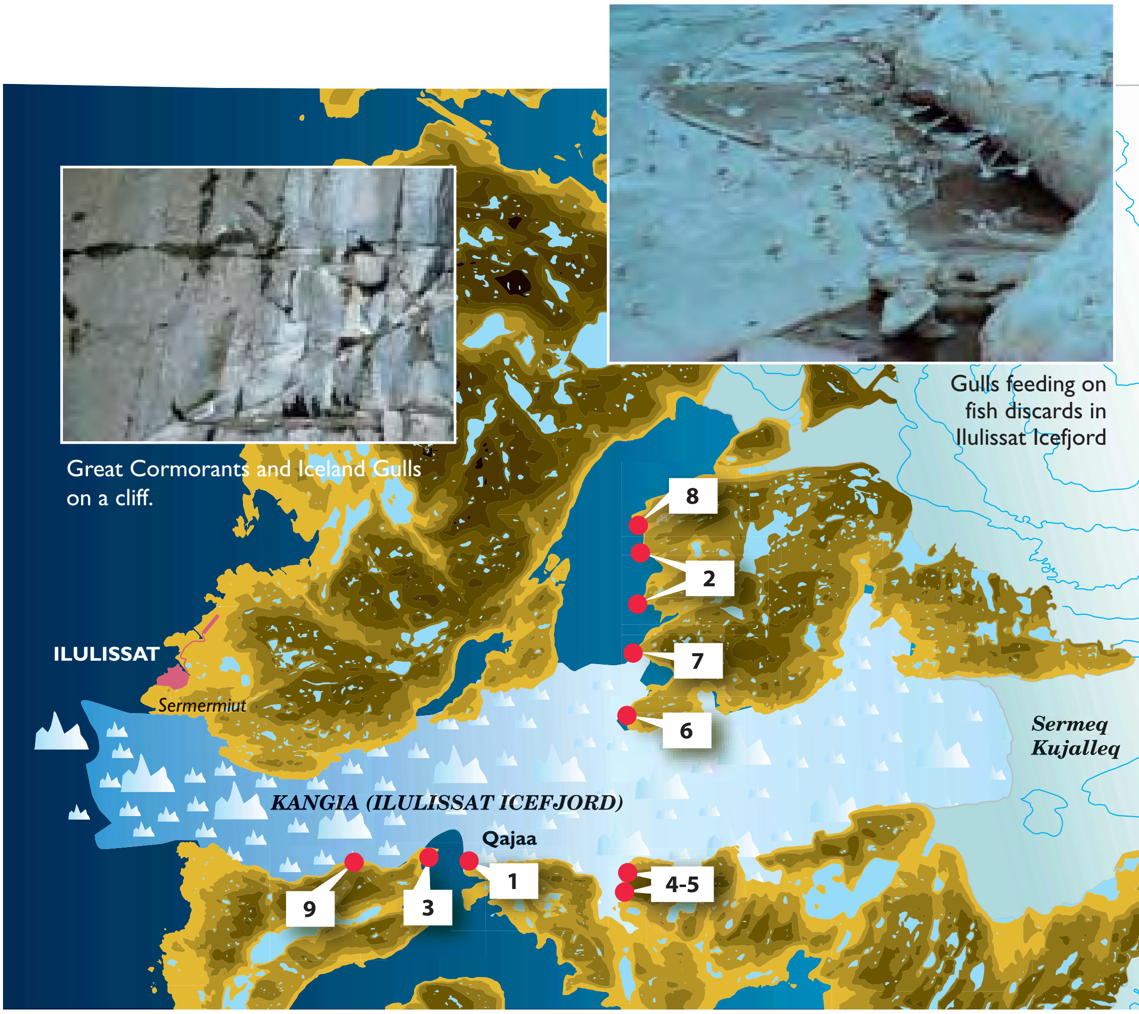
The birdlife of the Ilulissat Icefjord area is typical for the fjords of central West Greenland. The land birds are rather few and occur in low densities, and the seabirds occur mainly in areas with open water. A high primary production in front of the glacier attracts high densities of feeding birds, primarily northern fulmars (*Fulmarus glacialis*).

Very little information on the birdlife at and near Ilulissat Icefjord is published and the following account is mainly based on unpublished information from people living in the area as well as biologists who have made observations when passing through the area in connection with other field activities.

Seabirds

A few seabird breeding colonies are situated within the proposed area (Fig. 34; Boertmann *et al.* 1996).

The most impressive occurrence of seabirds in the area is the large flocks of northern fulmar *(Fulmarus glacialis)*. They feed among the stranded icebergs off the mouth of Ilulissat Icefjord. The nearest breeding colonies for this species are on Disko and Qeqertaq in Disko Fjord *c.* 100



Great Cormorants and Iceland Gulls on a cliff.

Gulls feeding on fish discards in Ilulissat Icefjord

Photos: David Boertmann.

Fig. 34. Map of the Ilulissat Icefjord area showing the locations of seabird colonies.

Number 1 is a Great Cormorant *(Phalacrocorax carbo)* colony. Here the cormorants nest in company with Iceland Gulls *(Larus glaucoides)*. The gulls numbered 170 pairs in 1976, while the number of cormorant nests is unknown. In 1995 cormorants have also been recorded in colony number 2, although breeding was not confirmed. Colony number 3 is a Kittiwake *(Rissa tridactyla)* colony with 15 pairs in company with 100 pairs of Iceland Gulls, counted in 1976. Two cliffs (number 4 and 5) with breeding gulls, probably Iceland Gulls, are known on the eastern coast of the small fjord Sermingguaq, but numbers of birds are unknown. Number 6 is also a breeding colony of probably Iceland Gulls, but no details from this colony are available. On colony number 7 numerous Iceland Gulls nest on the steep cliff. Probable colonies of gulls have been reported at numbers 8 and 9.

km away, where perhaps more than 100,000 pairs nest. Large flocks of gulls also often feed among the grounded icebergs. These are mainly Iceland gulls and glaucous gulls (*Larus hyperboreus)* and lesser numbers of great black-backed gulls (*Larus marinus)* and kittiwakes. Black guillemots (*Cepphus grylle)* occur along the ice-free coasts, and may breed here and there. The fulmars and gulls are attracted by the increased abundance of marine invertebrates in front of the ice-edge of Ilulissat Icefjord. The primary production is increased there due to certain hydrographic conditions, and forms the basis for numerous planktonic invertebrates. Discards from the intensive fishery for Greenland halibut *(Reinhardtius hippoglossoides)* in this area may also contribute to the favourable feeding conditions for the many gulls.

Land birds

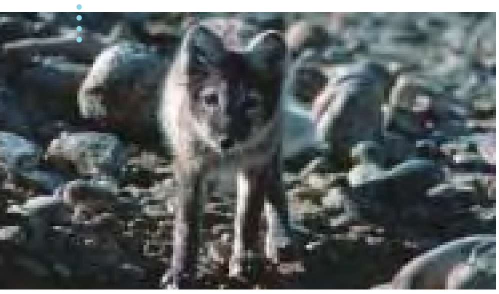
The land-birds are not so numerous as the seabirds in the Ilulissat Icefjord area. All the widespread species in Greenland: snow bunting *(Plectrophenax nivalis)*, Lapland bunting *(Calcarius lapponicus)*, redpoll *(Carduelis rostrata)*, wheatear *(Oenanthe oenanthe)*, Canada goose (*Branta canadensis)* and raven (*Corvus corax)* occur and breed within the area. The Greenland white-fronted goose *(Anser albifrons flavirostris)* also occurs. Satellite tracked birds have been located within the area in spring 1999 (Glahder *et al.* 1999), and according to local hunters the species is breeding on Nunartarsuaq. The breeding range of this particular subspecies is confined to West Greenland. The total population numbers for the time being only 33,000 individuals (Fox *et al.* 1999), which all winter on the British Isles.

Species like the peregrine falcon (*Falco peregrinus)*, the gyr falcon (*Falco rusticolus),* and the rock ptarmigan (*Lagopus mutus)* also occur within the area. They probably breed, at least occasionally. The Arctic redpoll (*Carduelis hornemanni)* is a winter visitor to the area. Other species like the red-throated diver (*Gavia stellata),* the great northern diver (*Gavia immer),* the mallard *(Anas platyrhynchos),* the long-tailed duck *(Clangula hyemalis),* the red-necked phalarope (*Phalaropus lobatus)* and the purple sandpiper (*Calidris maritima)* probably nest within the area, but no information is available.

Visiting birds
More or less regular visitors to the area include the Brent goose (*Branta bernicla),* the common eider (*Somateria mollissima)*, the red-breasted merganser (*Mergus serrator)*, the pomarine skua (*Stercorarius pomarinus)*, the Arctic skua (*Stercorarius parasiticus),* the Arctic tern (*Sterna paradisaea)* and Brünnich's guillemot *(Uria lomvia).*

Terrestrial mammals of Ilulissat Icefjord and surrounding areas
The available information on mammals in the nominated area is very limited.

Arctic fox (*Alopex lagopus)* occurs and is probably common. Arctic hare (*Lepus arcticus)* occur mainly in the higher parts near the Inland Ice (Porsild 1921b). Reindeer (*Rangifer tarandus groenlandicus)* occurs in the Isua area to the south of Ilulissat Icefjord (Meldgaard 1986). Reindeer have never been observed on the northern shores of Ilulissat Icefjord, although some place names indicate that they once existed in this region (Meldgaard 1986).



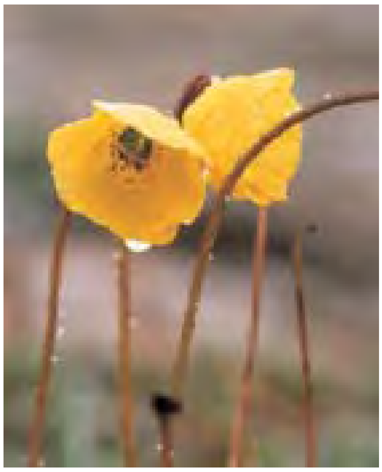
ARCTIC FOX *(ALOPEX LAGOPUS)*

Photo: Jakob Laurrup, GEUS

Terrestrial and limnic plants

The flora of the nominated area is of a low-arctic (Fig. 35), oligotrophic type, which reflects the nutrient-poor and silica-rich bedrock. The humid soils of the area show the typical solifluction phenomena in response to the arctic climate, such as "frost boils". Along the ice margin, plant colonisation in the wake of retreating ice provides examples of plant succession.

Approximately 160 species of phanerogams, three club-mosses (*Lycopodium annotinum*, *Diphasiastrum alpinum* and *Huperzia selago*), two horsetails (*Equisetum arvense* and *E. variegatum*), and four ferns (*Cystopteris fragilis*, *Dryopteris fragrans*, *Woodsia ilvensis* and *Woodsia glabella*) occur in the nominated area. Among the most rare species are Porsilds cat's-paws (*Antennaria porsildii*), Greenland woodrush (*Luzula groenlandica*) and whitish bladderwort (*Utricularia ochroleuca*). A comprehensive plant list from the area is found in Appendix 6.



Arctic poppy *(Papaver radicatum)*

White Arctic bell-heather *(Cassiope tetragona)*

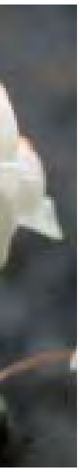
Plant communities

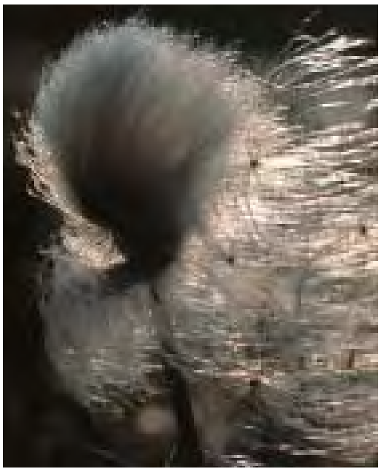
The predominant plant communities in the nominated area are: heath (moor), fell-field, snow-patch, herb-slope, willow-scrub, fen, river- and seashore vegetation. Also mentioned in this chapter are plants living in lakes, ponds and other limnic habitats.

Heath
The most widespread plant community in the Ice Fjord area is heath dominated by dwarf-shrubs. Typical species are dwarf birch (*Betula nana*), Arctic crowberry (*Empetrum nigrum* ssp. *hermaphroditum*) and Arctic blueberry (*Vaccinium uliginosum* ssp. *microphyllum*). Conspicuous species are the very aromatic narrow-leaved Labrador-tea (*Ledum palustre* ssp. *decumbens*) with white flowers and – on more nutrient rich and drier soils – the purple flowered Lapland rose-bay (*Rhododendron lapponicum*).

Fell-field
Fell-field is found on dry, wind-swept areas. Open soil is often seen among the green tussocks. Due to low competition, relatively many species thrive in this community. The white-flowered snow whitlowgrass (*Draba nivalis*) and diapensia (*Diapensia lapponica*), the yellow-flowered Arctic poppy (*Papaver radicatum*) and snow cinquefoil (*Potentilla nivea)* and finally the grass-like northern wood-rush *(Luzula confusa)* all add colour to these sparsely vegetated areas.

Snow-patch
The arctic summer is short, say two to three months.





Cottongrass *(Eriophorum sp.)*

Mountain sorrel *(Oxyria digyna)*

Willow *(Salix sp.)*

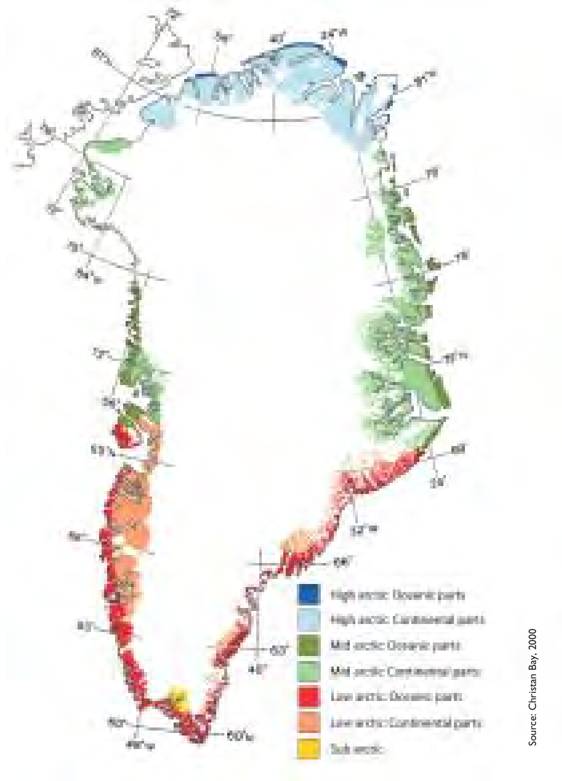
Photos: Jacob Latrup, GEUS

However, in snow-patches it is even shorter, only four to six weeks, as the ground is covered (and protected) by a thick layer of snow the rest of the year. In early snow-patches (about six weeks of growing season) the matted cassiope (*Harrimanella hypnoides*) and dwarf willow *(Salix herbacea)* thrive well. Characteristic species in late snow-patches (about four weeks of growing season) are pigmy buttercup (*Ranunculus pygmaeus*), dandelion (*Taraxacum* sp.) and mountain sorrel (*Oxyria digyna*). Finally the annual Iceland pursuance *(Koenigia islandica)* must be mentioned from this plant community.

Herb-slope
The most lush plant community in the area is the herb-slope, which displays a very species-rich vegetation on sloping ground. Most often herb-slopes are located under high steep mountains, where they receive melt water throughout the summer. Facing south to southwest, the herb-slopes get a maximum influx of light, creating a warm and mild microclimate during the summer, while the ground is protected by snow throughout the winter. On slopes like these as many as 30 different species of phanerogams thrive, among these Alpine bartsia (*Bartsia alpina*), Alpine bistort (*Polygonum viviparum*), Unalaska fleabane (*Erigeron humilis*) and thick-leaved whitlow grass (*Draba crassifolia*) may occur.

Willow scrub
The willow scrubs at Ilulissat Icefjord can reach heights up to 1.5 metres, though heights of approximately one metre are more frequent. However, the height of the scrub is of less importance for the underlying plants, as they grow in shadow and shelter. Typical species are interrupted clubmoss (*Lycopodium annotinum* ssp. *alpestre*), common horsetail (*Equisetum arvense*) and in the drier parts round-leaved wintergreen (*Pyrola grandiflora*).

Seashore
Characteristic plants for the sandy beaches of the area are sea sandwort (*Honckenya peploides*) and lyme-grass



Source: Christan Bay, 2000

Fig. 35. Phytogeographical zonation of Greenland.

Photo: Jakob Lautrup, GEUS

Hairy lousewort (*Pedicularis hirsuta*)

(*Elymus mollis*). On rocky and gravely beaches, gravel sedge (*Carex glareosa*), sea plantain (*Plantago maritima*), Greenland scurvygrass (*Cochlearia groenlandica*) and low stitchwort (*Stellaria humifusa*) are found. Salt marshes are only found here and there in protected inlets, out of the reach of larger icebergs. The lower parts of the salt marshes are dominated by creeping saltmarsh-grass (*Puccinellia phryganodes*), while pacific silverweed (*Potentilla egedii*) blooms on the upper parts of the salt marsh.

PURPLE SAXIFRAGE
(SAXIFRAGA OPPOSITIFOLIA)

Photo: Jakob Lautrup, GEUS

Stony river shores

Stony river shores are widespread in the nominated area. Seasonal variations in the water flow lead to frequent floods of the shore, leaving the riverbanks stony and barren. Only the so-called pioneer plants can match this unstable environment. Most conspicuous is large-flowered willowherb (*Chamaenerion latifolium*) with pink flowers and the poetic Greenlandic name "niviarsiaq", meaning young girl.

Fens

The richest fens have a thick vegetation of grass-like plants, often dominated by Arctic water sedge (*Carex stans*) and mountain bog-sedge (*Carex rariflora*). Arctic marsh willow (*Salix arctophila*) and flame-tipped lousewort (*Pedicularis flammea*) are also frequent, while Lapland buttercup (*Ranunculus lapponicus*) is a less frequent species in these habitats.

Aquatic plants

Of the genuine aquatic plants, mare's-tail (*Hippuris vulgaris*) is especially frequent along the shores of many ponds, smaller lakes and slow flowing streams. Also quite common are northern bur-reed (*Sparganium hyperboreum*), small pondweed (*Potamogeton pusillus* ssp. *groenlandicus*), dwarf water-crowfoot (*Ranunculus confervoides*) and here and there awlwort (*Subularia aquatica*), which only blooms if the pond is totally desiccated. Also found in the area is the quite rare autumnal water-starwort (*Callitriche hermaphroditica*). In desiccated rock pools here and there the mudworm (*Limosella aquatica*) thrives.

Traditional use of plants in Greenland

Though Inuit usually are considered strictly meat eaters, plants traditionally have been on their menu. The use of plants for fuel and handy–craft was common until recently.

Mountain sorrel (*Oxyria digyna*), Arctic crowberry (*Empetrum nigrum* ssp. *hermaphroditum*) and Arctic blueberry (*Vaccinium uliginosum* ssp. *microphyllum*) are among the plants, which were, and still are today collected for eating. The nutritional contribution to the diet has lost its importance, since fresh fruit and vegetables today are flown in from Denmark, even to the most remote settlements. However collecting/hunting and eating traditional Greenlandic food, is seen as a very important way of expressing the Inuit culture.

Due to their resinous shoots, White Arctic bell-heather (*Cassiope tetragona)* and Arctic crowberry (*Empetrum nigrum* ssp. *hermaphroditum)* have been used widely as an outdoor fuel. Northern Willow, on the contrary, is of low calorific value, as the shoots are light and contain no resin.

Archaeological sites at Ilulissat Icefjord

The nominated area holds two important archaeological sites, which have been of major importance to the understanding of human settlement history in West Greenland. These are Sermermiut (Fig. 37) at the mouth of the Ice-

Photo: Jakob Lautrup, GEUS

Entire-leaved mountain aven *(Dryas integrifolia)*

fjord and Qajaa, 25 km into the fjord (Fig. 40). In addition, a number of smaller and less important sites are located on the southern shores near the mouth of the fjord (Fig. 39).

The middens at Sermermiut and Qajaa have a unique sequence of three culture layers separated by sterile layers of peat. At the bottom the Saqqaq culture is clearly separated from the middle culture: the Dorset culture. After a new sterile layer, remains of the Thule culture are found. The layers are visible in a low coastal cliff, exposed to the wave action from the sea, and are being slowly eroded away. Thus the visitor can see the three culture layers in the near-vertical cliff and remnants of old winter dwellings (Figs 37, 40).

Archaeological excavations at Sermermiut began after the Second World War. At that time it was assumed that the prehistory of Greenland was no more than 1,000 years old. The Sermermiut site demonstrated, beyond any doubt, that the prehistory of Greenland was much longer and more complicated than hitherto envisaged (Larsen & Meldgaard 1958). This was corroborated by contemporary investigations in High Arctic North Greenland (Knuth 1958, 1967). The oldest layers at Sermermiut were dated to almost 4,000 years. Greenland prehistory was suddenly 3,000 years longer than previously thought.

The presence of three different cultures in western Greenland was further supported by excavations at Qajaa, which also has a special place in the history of archaeological research in Greenland. The presence of early cultures in Greenland was revealed already in 1871, when the Greenlander Carl Fleisher from Ilulissat undertook the first archaeological excavations at Qajaa. The same summer he reported on several kitchenmiddens separated by

Broad-leaved willow-herb *(Epilobium latifolium)* growing near the Icefjord

Photo: Jakob Lautrup, GEUS

Fig. 36. Overview of the Sermermiut valley, with the Iceberg-Bank in the background.

layers. Based on finds from the kitchenmidden at the bottom he wrote that it represented a period when the "old Greenlanders used stone for their tools" (Fig. 38). Thus he was the first to formulate the idea that another life form had preceded the old traditional way of life. Unfortunately no one noticed his important finding and interpretation until more than 100 years later, when his letters were re-discovered (Meldgaard 1991).

Sermermiut and Qajaa show the same history, but Qajaa was abandoned in the early part of the 18th century, whereas Sermermiut was inhabited until around 1850. Both sites are unique in Greenland with their clear stratigraphy and still offer a large potential for studies of the prehistory of this region.

A HOUSE RUIN FROM THE THULE CULTURE AT SERMERMIUT

Photo: Joel Berglund

3.b. History and Development

Oral tradition

The oral tradition in Greenland is rich and flamboyant. Legends and myths have been recorded by early colonists and missionaries, and still exist to some extent as an oral tradition. Being an outstanding natural phenomenon and an important hunting/fishing ground, Ilulissat Icefjord plays a central role in the oral tradition of the Disko Bugt region.

The oral tradition of the Inuit is an interesting and often much more detailed alternative to the history based on scientific evidence. For instance, the oral tradition provides a name for the first man to settle in the nominated area at Sermermiut. His name was Qingernilik and he and his family experienced a hard first winter. Due to hunger they had to cross Ilulissat Icefjord to get to the settlement Eqi. Here food was abundant, and Qingernilik ate so much that he nearly died. Qingernilik returned to Sermermiut, and he never visited Eqi again, because he would not again risk his life by eating too much (Ostermann 1941).

Another important person in the history of Ilulissat Icefjord is the Angakoq (shaman) who taught the people where to fish for Greenland halibut. It happened when the people from Sermermiut were on their way home from Eqi at the southern shore of the Icefjord. Suddenly the angakoq fell on the ice with a loud "bang". He told his companions that they should start fishing there. They made a fishing line from baleen, made a hole in the ice and started fishing. They immediately caught some good Greenland halibut, and thereby started the fishery, which since then has been the source of wealth and survival for the local population (Ostermann 1941).

That the Icefjord area is of global importance is obvious since the origin of the sun and the moon, according to the oral tradition, should be found in the Ilulissat Icefjord area. The story of the creation of the moon and the sun, is the story of a brother, Anningat, and a sister, Malina or Ajut. Before they became moon and sun, they lived at Ilulissat Icefjord. Their metamorphosis is a consequence of incest. Anningat could not let his beautiful sister alone, and he kept chasing Ajut, until they where both absorbed

Photo: Hans Kabel, National Museum and Archives of Greenland

in the air, where he (the moon) is still chasing her (the sun) (Fisker 1984).

Though the old Inuit legends may sound strange, the visitor at the Icefjord may find it reasonable to conclude that the moon and the sun had their origin in these vast landscapes.

Human settlement

In 1737, sixteen years after colonisation, the Danish missionary Poul Egede wrote in his diary:

> "*Here* [i.e. at Sermermiut] *I found the largest group of people I have seen in Greenland, about 20 fairly large houses, like a peasants village. They boasted of this and asked me if I had elsewhere seen so many people at one site. I sensed immediately from their speech and manner that they were proud of the size of their group and the good hunting they had....*" (Egede 1788).

Source: Modified from Tinna Møbjerg, 1983

Fig. 37. Map of the Sermermiut valley with the location of ruin sites (red marks) mostly winter houses from the Thule culture.

Human settlement in the Icefjord region

About 5–6000 years ago, a number of cultural changes took place around the northern part of the Bering Strait, between Siberia and Alaska. New groups emerged that

Fig. 38. A *c.* 3500 years old burin from the Saqqaq culture: the artefact was found at Qajaa. The stone is attached to the wooden haft with baleen.

Photo: Claus Andreassen

were adapted to life along the Arctic coasts. An eastward migration began across the High Arctic, reaching Greenland around 2500 BC (Fig. 41). The common name for this palaeoeskimo group is the Arctic Small Tool tradition. In some areas, the group has been given local names, in Greenland they are known as the Saqqaq people (Maxwell 1985).

The Saqqaq people settled in the nominated area around 2500 BC, but around 1000 BC they disappeared again. The disappearance of the Saqqaq people was followed by a hiatus in human occupation of West Greenland. Around 500 BC, the Dorset people entered the area. They disappeared again around AD 250 and during the next 1000 years the Disko Bugt area was uninhabited. Around 1000 AD, the Thule people settled in the nominated area at Sermermiut and Qajaa.

BONES OF SEALS FROM A MIDDEN AT SERMERMIUT

Photo: Jakob Laurrup, GEUS

Saqqaq and Dorset: Stone Age People in the Icefjord region

The Stone Age in Greenland is represented by the Independence, Saqqaq and Dorset cultures, of which only the latter two settled in West Greenland. All Eskimo migrations from Canada into Greenland entered in the Thule area of Northwest Greenland (Fig. 41). The Saqqaq and Dorset hunter-fisher groups migrated down the west coast of Greenland and settled at suitable coastal localities. Archaeological research has revealed a great number of Stone Age sites, especially along the coast south of the Icefjord and further south and southwest, but none as big nor as important as Sermermiut and Qajaa (Møbjerg 1986; Fig. 39). The very dense settlement pattern indicates that the local resources at the Icefjord were both stable and abundant over long time periods.

The dominant raw material for pointed or bladed tools in this area was the local silicified slate (killiaq) in the Saqqaq culture and chalcedony in the Dorset culture. For

Photo: Jørgen Meldgaard

Excavations at Qajaa as seen from the tent by the excavation leader Jørgen Meldgaard

hunting, they used lightweight thrusting harpoons sometimes mounted with a stone tip, lances, knives and bow-and-arrows; bow-and-arrows were not used during Dorset time. For domestic purposes, tools such as scrapers, borers, knives and needles of bone were used; for general purposes, knives and burins were used. Most tools had a wooden haft; in some cases, it was a haft made of bone or ivory, with a lashing made from sinew or baleen (Fig. 38; Grønnow 1996).

Kayaks were probably used during the Saqqaq period (Grønnow & Meldgaard 1991). Sledges are first known from the Dorset culture. These sledges were probably drawn by the hunter himself or by a few dogs. The dwelling was a skin-tent that was used all year round. In the middle was a fireplace, sometimes forming a midpassage, i.e. a rectangular stone-frame with partitions for fire, firewood etc., which divided the tent into two equal

Compiled by the National Museum and Archives of Greenland

Fig. 39. Map of the Ilulissat Icefjord region showing the locations of former Inuit settlements (indicated by a circles on the map).

Photo: Jørgen Meldgaard

Fig. 40. Archaeological excavations at Qajaa. Layers of the midden represent the Saqqaq, Dorset and Thule-cultures.

parts. The skin was anchored to the ground by stones or poles (Fog Jensen 1998, Olsen 1998). In addition to the fire, small circular (Saqqaq) or oval (Dorset) lamps of soapstone were used.

At the archaeological site at Sermermiut, organic preservation in the lower layers is poor, and thus detailed information on resource exploitation is not as good as in the permafrost midden at the Qajaa site, where preservation is exceptionally good. Ringed seal (*Phoca hispida)* and harp seal (*Phoca groenlandica)* are the dominant mammals represented by the remains, but the palaeoeskimos also hunted polar fox (*Alopex lagopus)*, polar bear (*Ursus maritimus)*, polar hare (*Lepus arcticus*), walrus (*Odobenus*

Painting by A. Kornerup in 1876

Traditional Inuit winter house from the Thule culture

SKULL OF A SEAL AT SERMERMIUT

Photo: Jakob Laurup, GEUS

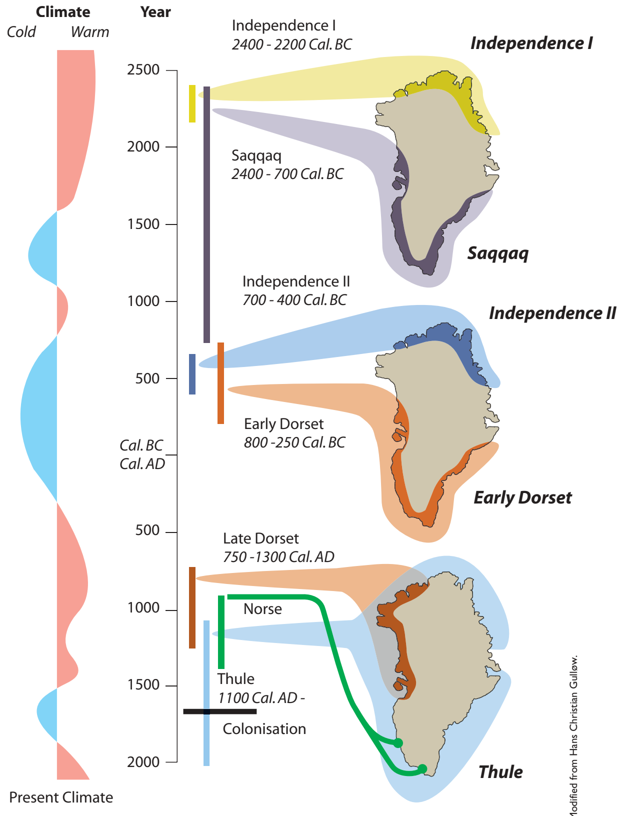
rosmarus*), narwhale (*Monodon monoceros)*, beluga whale (*Delphinapterus leucas*) and seabirds (Grønnow & Meldgaard 1991).

A very important resource for people in and around the Icefjord was driftwood. A constant supply of driftwood from the Canadian and Siberian forests was an essential resource for the construction of for example tents, kayaks, sledges and bows.

The Thule-people at the Icefjord

The Thule people arrived in Greenland around 1100 AD and settled at Sermermiut about 100 years later (Gulløv 1997, Appelt & Gulløv 1999). Their winter dwellings were massive stone-and-turf houses with roof posts made of driftwood or whale ribs. During the summer, they lived in tents, as in previous periods. They exploited the same species as previous cultures but they also actively hunted the big whales, and they fished with long lines and nets made of baleen. Their mobility was considerably increased by their sophisticated kayaks, dog sledges and the big skin-boat, the umiaq, which was used for transporting the whole camp and for whale hunting (Gulløv 1997).

Finds from Sermermiut and Qajaa testify to contacts with the Norse from Europe, who settled in south-west Green-



Source: Modified from Hans Christian Gulløv.

Fig. 41. Chronology of the different cultures that have colonised Greenland, and a generalised climate curve for Greenland covering the last 4500 years.

land around 985 AD (Arneborg 1993). One important material was iron, which the Inuit people obtained partly from the Norse and partly from meteorites in the Thule area in North-west Greenland (Buchwald & Mosdal 1985, Buchwald 2001). The Norsemen left Greenland at about 1450 AD. In the 16th Century, European explorers sailed into Greenland waters. Whalers followed them in the 17th and early 18th Century (Gulløv 1986). Both of these groups had contacts with the local people, and in the Disko Bugt region meeting places for trade were found. A few areas along the West Coast turned into centres with a large population. The largest single site was Sermermiut.

In Greenlandic, Sermermiut means the site of the glacier people – indeed it was. The highly productive and stable ecosystem in and around the Icefjord formed the foundation for the success of Sermermiut as well as Qajaa over centuries. Situated in the middle of the Icefjord, Qajaa was more vulnerable to changes in the position of the glacier, and the settlement periods thus reflect the optimal conditions for human life when the glacier had retreated.

Recent times

The long, but sporadic contact with Europeans became more continuous following Danish colonisation. This began in 1721 in Nuuk, and Ilulissat, a few kilometres north of Sermermiut, was established as a colony in 1742. During the next century, people slowly left Sermermiut. In about 1850, the last inhabitants on this thousand-year-old site left and moved to town – a way of life had ended.

Most of the visible turf-house structures at Sermermiut today reflect this latest occupation. From an archaeological point of view, these structures are particularly valuable since information from excavations of these houses can be compared with information on contemporary and earlier Inuit life from written Danish records and Inuit oral traditions. Due to the early colonial contact, Sermermiut has major potential for further cultural/historical research using an ethno-archaeological and ethno-historical approach.

History of hunting

The exploitation of animals has always been the prerequisite for the existence of man in Greenland. Before colonisation in 1721, the population of Greenland was dependent on mammals, fish and birds that were exploited in a seasonal nomadic fashion. Different species were hunted at different times of the year, and different settlements were used in different seasons.

Inuit at their winter house. In connection with the establishment of colonies, it became more common for the Inuit to stay in their winter houses all year round

After colonisation, guns and other modern tools and materials made hunting more effective, and access to European food, which could be traded for fur, blubber and ivory, made the nomadic lifestyle less important. In general, this meant a concentration of the population around the colonies, where the Greenlanders became more and more settled. However, vestiges of the nomadic lifestyle can still be seen today, for instance when hunter families move their household during summer to live by "their" arctic char (*Salvelinus alpinus*) river or the reindeer (*Rangifer tarandus*) hunting grounds for a couple of weeks.

Many of the traditional hunting tools and modes of transport have now been replaced by guns, motor dinghies, nylon nets etc. In the nominated area, however, the dog sledge is still widely used.

Due to the improved technology, the pressure on the hunted species has increased significantly. To counter this, the authorities have introduced laws and rules to regulate hunting. Today, hunters need a hunting permit, which is granted to those over the age of 12. Permits are given either to "recreational hunters" or "professional hunters".

Hunting in Ilulissat Icefjord today

Hunting and fishing is a very important occupation in Ilulissat today, and Ilulissat Icefjord is a very important fishing ground (Fig. 42). Besides being economically important, hunting and fishing in the nominated area supports the traditional culture expressed in the use of traditional tools, clothes and in particular the dog sledge. The location of the hunting and fishing grounds varies both on short and long time-scales, in response to the prevailing ice.

Photo: Dieter Zillman/Greenland Tours Elke Meissner

Two fishermen standing at a dog sledge with some halibut, on the sea ice of Ilulissat Icefjord

The following description of hunting in Ilulissat Icefjord today is mainly based on interviews with recreational and professional hunters from Ilulissat.

TWO FISHING BOATS MEET ON THE ICEFJORD

Photo: Dieter Zillman/Greenland Tours Elke Meissner

Recreational hunting

Recreational hunting has been underway since the first Greenlanders became engaged in the colonial administration. The word "recreational" may be applied to many hunters in Greenland but is not appropriate to the hunters described in the following text, for whom hunting is significantly more than just recreation, despite their being technically registered as "recreational" hunters.

Recreational hunting in Ilulissat

In Ilulissat, the bag of the recreational hunters includes seals, ptarmigan, hare, fox, seabirds, fish and, if the hunter is willing to travel far, musk ox and reindeer. When there is open water, the dinghy is the most common mode of transport, while winter transport is by dog sledge or snow scooter (the latter is prohibited in the nominated area).

In the winter of 2001/2002, there were about 10 recreational hunters, hunting ringed seal. During the winter, they use nets under the ice. Using this method, the expected bag for a single hunter in a season is between 1 and 30 seals. In October, some hunters may try the "Qaasaq" or "breathing hole" hunting method, while spring is the time for the "Uutoq" method whereby the seal, lying sunbathing on the ice, is stalked using a tiny sledge with a white sail as camouflage. In between these activities, other species can be hunted, for instance on Nunartarsuaq, where traditional fox traps are still in use.

It takes 4–6 hours to travel by dog sledge to Sikuiuitsoq north of the Icefjord from Ilulissat. That these "recreational" hunters undertake this trip almost every weekend through the sledging season gives an indication of the importance of these activities to them. When asked the question why, the answer is immediate: "The economy". This response is understandable when one considers the amount of meat and fish eaten by a family of five with ten dogs, which on average have a monthly intake of about 500 kg (Hertz 1995).

The importance of this kind of recreational hunting for the social status, cultural awareness and maintenance of traditional lifestyle of the hunter and his family, and the society of Ilulissat in general is hard to measure. However, it is clear that the presence of hunters who use traditional modes of transport and hunting techniques, and can share meat from his bag with friends and family, is an important part of the Greenlandic identity.

Professional hunting

At Ilulissat, the main income for professional hunters

Fig. 42. Map of the nominated area showing routes used by dog sledges (red lines) planned huts (red circles) and important winter fishing grounds in the Ilulissat Icefjord (pink lines and areas).

comes from fishing for Greenland halibut and the fishing grounds within the nominated area play a central role in this endeavour (Fig. 42). When the ice conditions are favourable, dinghies and smaller fishing vessels from Ilulissat, Ilimanaq, Oqaatsut and Qasigiannguit enter Ilulissat Icefjord to fish. During winter, however, most of the fishing is done from the ice, where dog sledges are the only forms of transportation. Thus, fishermen on dog sledges from Qasigiannguit occupy fishing grounds in the southern part of the Icefjord, east of Qajaa, while fishermen from Ilulissat occupy the grounds in the northern parts. It is estimated that 60–100 professional fishermen with dog sledges were active in the nominated area in the winter 2001–2002.

In addition to the fishing, ringed seals (*Phoca hispida),* geese, ducks, hares and ptarmigan are hunted. Eggs are collected from some of the gull colonies in Sikuiuitsoq, when snow and ice conditions permit travel by dog sledge in early summer. Very occasionally narwhales can be taken in the outer parts of Ilulissat Icefjord. Reindeer are hunted in the south-eastern part of the nominated area during the autumn. Hunting activities in the nominated area are economically negligible, however, in comparison to fishing for Greenland halibut.

Both fishing and hunting grounds change from year to year as a consequence of the prevailing ice and snow conditions. On a longer time-scale, too, it is clear that the location of fishing and hunting grounds has changed over the decades and centuries, since some of the grounds in use today lie east of the position of the Sermeq Kualleq ice front in 1850 (Fig. 25). Hence, the continued human exploitation of living resources in Ilulissat Icefjord serves as an example of how a human population adapts to the constraints of the environment, in this case one of the important constraints being the glaciological conditions, Polar bears *(Ursus maritimus)* are extremely rare in the area

Photos: Dieter Zillman/Greenland Tours Elke Meissner

under which the site is nominated for inclusion in the World Heritage List.

History of fishery

It is hard to over-emphasise the importance of the fishery for Greenland halibut (*Reinhardtius hippoglossoides*) in Ilulissat Icefjord to the local economy. Through time, the fishery has contributed significantly to the survival and wealth of the population around the Icefjord and to some extent the whole population of the Disko Bugt region. Even today, Greenland halibut is second on the list of Greenland's exports after northern shrimps (*Pandalus borealis*). Greenland is the dominant nation with respect to the Greenland halibut catch, and Ilulissat is the place in Greenland where most Greenland halibut is landed, most of which is caught in or just outside the mouth of Ilulissat Icefjord.

LUNCH IS READY

Photo: Dieter Zillman/Greenland Tours Elke Meissner

Exploitation of Greenland halibut through history
The rich ecosystem of Ilulissat Icefjord has made it possible for a relatively concentrated population to live at its shores. At the end of the 19th century, over 60% of the population of the district lived within a distance of 3 km from Ilulissat Icefjord (Madsen 2000).

Before 1741, the various Inuit cultures doubtless fished for Greenland halibut in Ilulissat Icefjord, but despite the numerous archaeological excavations made in the Disko Bugt region, no fish bones of Greenland halibut have been found (Meldgaard 1991, Grønnov & Meldgaard 1988). It may be that the preservation potential of the Greenland halibut bones is lower than that of fish bones from other species, possibly due to the fatty, cartilaginous nature of the Greenland halibut bones (Meldgaard, personal communication 1999).

The earliest written documentation of fishing for Greenland halibut in Ilulissat Icefjord is from the diary of the missionary Poul Egede from February 1739. He was travelling between Qasigiannguit and the Sermermiut settlement when he met fishermen on the fjord ice at the mouth of Ilulissat Icefjord. They were fishing with lines made of baleen and Poul Egede measured the length of one line to be an impressive 684 m (Lidegaard 1988).

During periods of starvation, the Greenland halibut from Ilulissat Icefjord sustained the populations of the whole Disco Bugt region. In such survival situations, the Greenlanders travelled long distances to fish in Ilulissat Icefjord. The inspector B.J. Schultz, stationed in Qeqertarsuaq, described this during the hard winter of 1792–93. Those starving Greenlanders that lacked dogs even walked the 150–225 km from Qeqertarsuaq and Aasiaat over the sea ice to Ilulissat Icefjord to reach the Greenland halibut fishing grounds (Gad 1969-78). Similar cases have also been recorded from later periods of privation (Reimar 1887, Madsen 2000).

Fig. 43. Fisherman and dog sledge near a hole through which the long line has been sunk.

By the turn of the 19th Century, the main occupation of the population at the colony station of Ilulissat (Jakobshavn) and settlements nearby, was fishing for Greenland halibut and Greenland shark (*Somniosus microcephalus*). While Greenland shark was an important source of income (the liver was sold to The Royal Greenland Trade), Greenland halibut was only of importance as a food source in the informal subsistence economy. However, it is notable that the population around Ilulissat Icefjord were primarily fishermen at a time when the rest of the Greenlandic population was mainly dependent on sea mammals for their income and diet.

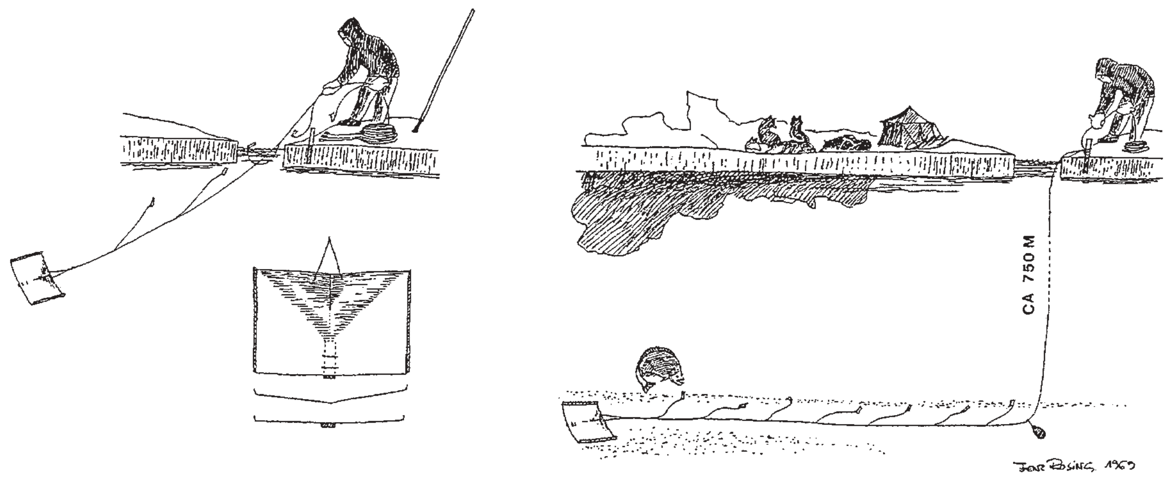
At the end of the 19th Century, a chance event altered the importance of Greenland halibut to the local economy. At this time, the colony managers started to export a few hundred kilos of salted haddock fillets to their friends and families in Denmark. The colony managers were employed by The Royal Greenland Trade (KGH), but were allowed to send to Denmark such items that were not covered by the KGH monopoly, for example Greenland halibut. The private export of Greenland halibut took a large step further when Poul Müller (colony manager in Ilulissat, 1892–1901) established contact with the smokehouses in Copenhagen. On his initiative, the landings of Greenland halibut at Ilulissat soon reached a peak of more than 22 tons in 1899 (Madsen 2000). At this point, KGH set harsh restrictions on the private export of Greenland halibut, and ultimately took over in 1903, receiving a monopoly on the Greenland halibut export. In the first year under KGH, less than 2 tons was exported, but the level of exports soon grew again and since then the export of Greenland halibut has been an essential part of the economy of Ilulissat.

Today, Royal Greenland A/S (the successor to The Royal Greenland Trade) has a fish plant in Ilulissat. It is the biggest in Greenland and processes various fishery products of Greenland halibut and northern shrimps for the international market. The processing of Greenland halibut requires about 210 part-time workers, and the fish plant annually employs 20 full-time employees. Thus, the plant uses a total of c. 150– 200 man-years. Between 1997 and 2001, the sale of Greenland halibut from the fishermen to the Royal Greenland A/S fish plant in Ilulissat was worth 4–5.6 million EURO a year. Thus, the fishing for Greenland halibut and the related fish industry represents one of the dominant sources of employment and income in Ilulissat.

The fish plant uses all parts of the Greenland halibut, and thereby contributes to a clean environment in Ilulissat and the Ilulissat Icefjord area. The fish waste (heads, guts, fins, bones and skin) is used for fish flour, and the fish oil in the waste is used for heating the big plant building and for producing steam for the shrimp-cooker. A great deal of the fish waste is sold as dog food for the more than 4000 sledge dogs in the town of Ilulissat.

Fishing methods, gear and localities

Fishing for Greenland halibut was originally conducted with jigs made of soapstone and bones, with a fishing line made of baleen from the Greenland whale (*Balaena mysticetus*) (Hansen 1997). During the first years of colonisation, iron nails and iron fishhooks were introduced, and the traditional jig was also modified by the partial substitution of the baleen by more modern fishing lines of



Drawing by Jens Rosing

Fig. 44. Greenland halibut has been fished from the ice in the Ilulissat Icefjord using long lines since the beginning of the 19th century. The figure shows the principles behind the technique as it is performed in Ilulissat.

hemp (Madsen 2000). In 1852, however, baleen lines were apparently still preferred to hemp fishing lines in the Greenland halibut fishing in Northwest Greenland because it was considered easier to feel the bite of the fish (Rink 1857).

FISHER BOATS IN ILULISSAT HARBOUR

Photo: Jakob Laurrup, GEUS

The fishing grounds were traditionally at the mouth of Ilulissat Icefjord or not far from the houses of the colony station of Ilulissat and the settlements of Pitoqqeq, Illumiut and Kingittoq (Madsen 2000). Under normal conditions, therefore, it was not necessary to travel far to reach suitable fishing grounds. During the autumn or spring, however, when the fjord ice in front of the houses was unsafe, the fishing ground near the Seqinniarfik (Holms Bakke) was preferred, as the ice is generally thicker there.

During the winter, there were times when there were no Greenland halibut on the northern shores of Ilulissat Icefjord, probably because of the migration of the beluga whales from the end of April to June and again from September to December. Beluga whales prey on Greenland halibut, and their arrival probably caused the halibut to migrate to other areas. At such times, many Greenlanders from the northern shores travelled the long distance over the fjord and down to the Tasiusaq fishing grounds behind the trading station of Ilimanaq.

Inspired by fishermen from the Faroe Islands, long line fishing for Greenland halibut at Ilulissat Icefjord began around 1906, considerably increasing the efficiency of the fishery. However, it was the brilliant innovation of the so-called glider in 1924 by Marius Sivertsen from Ilulissat (Smidt 1969) that made long line fishing possible even during the winter under the fiord ice, thus greatly extending the range and efficiency of the fishery. This opened up for the expansion of the fishing grounds, and in 1929 Nicolai Olsen and others from Ilulissat were the first to travel to the Nunatarsuaq fishing grounds at the head of the Ilulissat Icefjord. Thus began the winter fishery inside the Icefjord and it soon included the fishing grounds of Aallaaniarfik and Nalluarsuk, as a supplement to the traditional winter fishing grounds on the fiord ice between the hill of Seqinniarfik and the town of Ilulissat. The use of gliders in connection with the long line fishing method has now spread to other parts of Greenland. In this way, Ilulissat Icefjord has played a central role in the development of the Greenland fishing industry not just locally but also far outside the nominated area.

Since the 1980s, gill nets have been used both in summer and winter outside the mouth of the Icefjord, but the consumer quality of the fish is not as high as those obtained by long lining. It is an efficient method, mostly used by fishing boats, but the nets can be lost causing "ghost fishing" and therefore many restrictions have been imposed on the use of gill nets.

In the nominated area, travel in connection with winter

BOX 12. INTERACTION BETWEEN CLIMATE, GLACIOLOGY AND MANKIND

Icebergs pack the Ilulissat Icefjord all year round. In addition, sea ice that forms during the winter glues the icebergs together. The ice cover and the stranded icebergs at the mouth of the fjord generate an environment with strong turbulence in the upper water masses. This is mainly due to the melting of the icebergs (Fig. 33) and the large tidal amplitude of *c.* 2 m in the area. The turbulence leads to a high primary production in the area, which is followed by an abundance of invertebrate species belonging to lower trophic levels, which in turn attracts a number of predators such as fish and seals.

Photo: Dieter Zillman/Greenland Tours Elke Meissner

Western view from Ilulissat

This rich animal life has formed the foundation for hunter cultures over the past 4500 years. For three long periods the area has been inhabited, and two of the most important archaeological sites in Greenland are situated on the shores of the Icefjord.

At Sermermiut, the Danish missionary Poul Egede met in 1737 the largest group of people he had ever seen in Greenland. At this time the local population was more sedentary than in other areas in West Greenland. This long lasting and dense habitation shows that seals and fish were stable and abundant resources over long time periods, reflecting the highly productive environment.

fishing is exclusively by dog sledge. During periods with favourable ice conditions, fishing is performed at the mouth of the fjord from motorised dinghies and small fishing vessels.

History of tourism

Ilulissat is often referred to as the tourist capital of Greenland. The magnificent nature, the Inuit culture and the history attracts tourists from all over the world. Growth in the tourist industry is a goal for the Greenland Home Rule, which is currently subsidising the industry (Anonymous 2000a). However, the number of tourists visiting Ilulissat, and Greenland in general, is limited at present.

Tourism in Greenland: a short overview

Tourism in Greenland has a rather short history compared to other places in the North Atlantic. At the beginning of the 20th Century, Iceland and the archipelago of Svalbard were already receiving several thousands of tourists each year by boat on private or organised tours; tourism in Greenland, in contrast, was near to non-existent at this time. This was partly due to the relative remoteness of Greenland combined with ice conditions, which often makes sailing in the area difficult. More importantly, however, the colonial administration in Denmark pursued a policy that was restrictive concerning permission to visit the country. For example, the authorities refused an application from the Danish polar explorer, Mylius-Erichsen, who planned to bring 200 tourists to Greenland in the summer of 1902 (Thalund 2000). This policy was meant to protect the Inuit population from the negative effects of tourism (and colonialism as such), with respect to the socio-economy and culture. Aeroplanes made the first organised tours from Denmark and Iceland in 1959 (Thalund 2000).

In a strategy for tourism development in Greenland, elaborated by the Greenland Home Rule, the goal by the year 2005 is for 61,000 tourists visiting Greenland annually. The Disko Bay region and Ilulissat in particular are expected to be the most important destinations in the country (Anonymous 1998). However, the growth in the turist industry has been slower than expected, and the

LAKE NEAR THE ICEFJORD

Photo: Jakob Lautrup, GEUS

Photo: Dieter Zillman/Greenland Tours Elke Meissner

Local people taking tourists on a dog sledge tour

numbers of tourists in 1999 and 2000 were 26,345 and 31,351 respectively (Anonymous 2001a). The Disko region (Ilulissat, Qeqertarsuaq, Qasigiannguit, Asiat, and Kangatsiaq) was visited by 34% of all tourists in Greenland in 2000, thus being the most important region for tourism in the country (ibid.). The national and regional importance of Ilulissat as a tourist destination is notable.

Almost all tourists visiting Greenland travel by aeroplane, Kangerlussuaq and Narsarsuaq being the most important airports for tourists entering the country. From these airports, most towns are reached by smaller aeroplanes or helicopters. A relatively small number of tourists arrive in Greenland on cruise ships, typically with the last port of call prior to Greenland being in Canada or Iceland. In 2000, the total number of overseas cruise ship arrivals was 125. Though small in number, this was a rise in cruise ship arrivals of about 100% compared to 1999 (Anonymous 2000b).

THE BIRTH PLACE OF KNUD RASMUSSEN IS NOW A MUSEUM

Photo: Jakob Lautrup, GEUS

Since roads are almost absent outside towns in Greenland, the most common mode of travel for tourists at their ultimate destinations are by boat, on foot or by helicopter, on day trips. In winter and spring, tours by dog sledge are popular. Only a small proportion (5–7%) sleep in tents in open country; the remainder (95%) are accommodated in hotels, youth hostels, huts and other forms of organised accommodation (Anonymous 2001a).

Due to the harsh climate and the remote landscape, the majority of tourists engage guides for tours outside developed areas. Residents from countries other than Greenland must seek permission from the Greenland Home Rule before engaging in "expeditions", i.e. mountaineering, icecap crossing etc.

Tourism in Ilulissat.

Ilulissat experienced a period of economic depression in the late 1980s and the early 1990s, primarily due to difficulties in the traditional fishing and hunting economy. Tourism was almost non-existent in the town, and the economic situation deteriorated.

In 1992, the Municipality of Ilulisat took the initiative to start a tourist office, albeit in a primitive hut without any modern facilities, such as heating and water. Despite this rather primitive beginning, this was the start of a new era in Ilulissat tourism.

In 2000, 10,660 tourists visited Ilulissat, corresponding to 34% of all tourists visiting Greenland (Anonymous 2001a). Most tourists arrive in Ilulissat by plane or on local ferries. Cruise ships from countries other than Greenland also visit Ilulissat. In addition to the outstanding nature, tourists can enjoy, in a Greenlandic context, a broad array of facilities and infrastructure.

Facilities

Today, Ilullissat has an airport for fixed winged aircraft, with connections to Denmark (via Kangerlussuaq) four times a week. From the airport, helicopters can be chartered for tours into the nominated area.

The Ilulissat museum, first opened in 1973 in the house

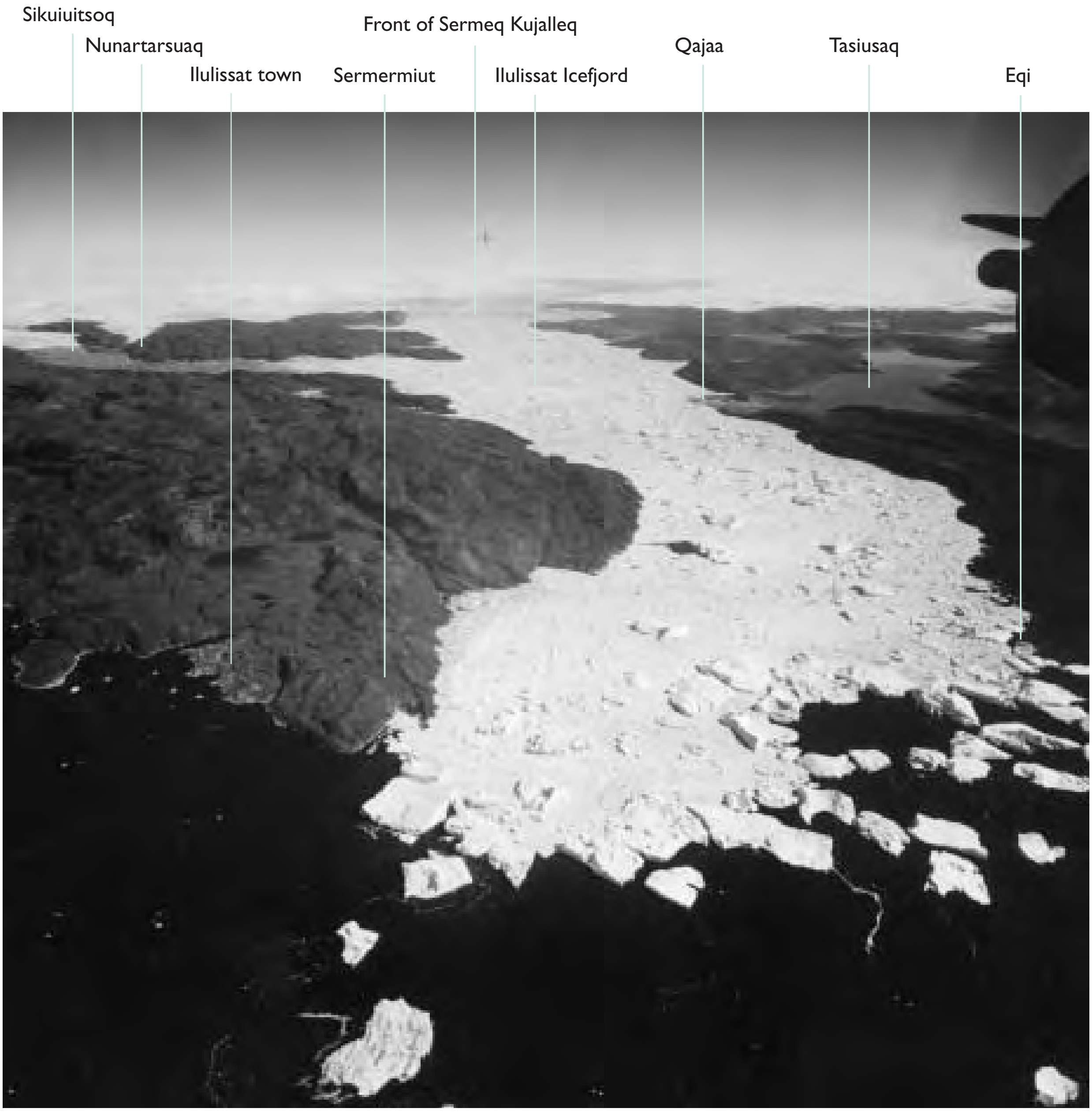


Photo: The National Survey and Cadastre, Copenhagen B 18 B-R no. 86 (06.07.1942.

Fig. 45. Oblique aerial photograph of the Ilulissat Icefjord.

where the famous Arctic explorer Knud Rasmussen was born, has expanded to four buildings, with exhibitions of local art, local history, whaling, hunting and fishing history.

Three tourist offices arrange tours of one to several days length in the nominated area, either by dog sledge or on small boats. From the airport, tourists are offered tours by helicopter, normally with a short stop at the glacier front.

Four hotels and a youth hostel are located in Ilulissat. In addition, a number of huts are located in and around the nominated area and accommodation is available in the nearby settlements of Oqaatsut and Ilimanaq. The hotels are usually fully booked during the summer and late winter/spring.

Future tourism in Ilulissat

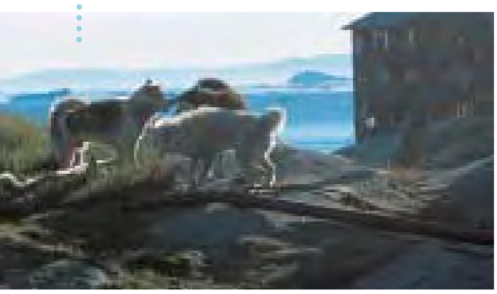
Tourism in Ilulissat has a very short history. Though small compared with other destinations in the world, it is the most important tourist area in Greenland. There is no doubt that this importance is due to the attraction the Icefjord has for visitors, and further growth in the number of tourists visiting Ilulissat must be expected in the future.

Though increasing tourism in the nominated area raises concerns about the fragile Arctic environment, actors both in the industry and in the Municipality of Ilulissat seem to have a high level of environmental awareness.

From an economic point of view, growth in the tourism industry is of high priority, since the local economy is otherwise almost exclusively dependent on fishing and hunting.

3.c. Form and date of most recent records of Property

The glaciology and geology of the nominated area has attracted, and continues to attract, a large number of scientists. Thus, detailed information on the glaciology is to be found in a large number of scientific papers and publications. Many of these are sited in this nomination, and can be found in the bibliography. Broader reviews of the locality (Ilulissat/Kangia/Sermeq Kujalleq) can be found in the papers by Engell (1910a) and Weidick (1966, 1969, 2000).



UNEMPLOYED SLEDGE DOGS IN ILULISSAT

Photo: Jakob Lautrup, GEUS

Aerial photography

A large collection of aerial photographs of the area is available from the files of the National Survey and Cadastre, Copenhagen, covering the period 1942–1985. Most of these are vertical aerial photographs at a range of scales although oblique aerial photographs are available from early surveys (Fig. 45). Sohn *et al.* (1997) presented a review of the satellite image records back to 1969.

Topographical and bathymetrical mapping

The area is covered by the ICAO map sheet 1:1,000,000 (sheet 2057, Disko, published by the Directorate of Civil Aviation, Copenhagen 1953, compiled and printed by the Geodetic Institute (now the National Survey and Cadastre, Copenhagen)). The map displays an outline of the topography of the ice-free land and the surface of the Inland Ice with a 300 m contour interval). More details are presented on the map sheet at a scale of 1:250,000 by the National Survey and Cadastre – map sheet 69 V2, Jakobshavn, published 1975, with 50 m contour intervals. Most recently, a hiking map at a scale of 1:100,000 with a contour interval of 25 m has been published by Greenland Tourism. This latter map adopts the new spelling of Greenland place names (introduced by the Greenland authorities in 1973).

Local detailed maps of the ice margin and its topography were compiled for the area north of Sermeq Kujalleq (1:75,000, 20 m contour interval) by Thomsen *et al.* (1988), together with a map of sub-glacial topography. South of this locality, a map of the surface of the ice stream was presented by H. Brecher, Ohio State University (Fig. 15; Fastook & Hughes 1994). The sub-glacial topography under the ice stream of Sermeq Kujalleq and its surroundings was compiled by C. Mayer on the basis of radar and seismic investigations by Overgaard (1981) and Clarke & Echelmeier (1996).

No bathymetrical map is available from the Icefjord. The perennial ice in the fjord prevents normal echo-sounding surveys from ships, and no point measurements have been conducted from the sea ice. However, the fact that icebergs strand at the mouth shows that the fjord has a threshold here, which is common for fjords in the Arctic.

Geological mapping

General outlines of the bedrock geology are presented on the Geological map of Greenland 1:500,000, sheet 3, Søndre Strømfjord – Nûgssuaq, 1971 and the Quaternary geology is shown on the Quaternary map of Greenland 1:500,000, sheet 3, Søndre Strømfjord – Nûgssuaq, 1974. Despite the large number of geological papers on the area, a general review of the area is lacking.

3.d. Present state of conservation

Even though the nominated area has always played an important role in the daily life of the population of the

Lead between pinnacled icebergs in a marvellous landscape

Photo: Dieter Zillman/Greenland Tours Elke Meissner

Disko Bugt region, the present state of conservation is very good with only very few signs of human activity. At present, the glaciological features of the nominated area have not been affected by human activity (possible anthropogenic climate change excepted).

The beauty of the landscape is to some degree related to the "untouched wilderness" character of the area. Infrastructure is limited to a number of huts used for hunting, fishing and recreational purposes, as indicated on the map in Fig. 42; in the western part of the area, paths may be found here and there. A number of unmarked but frequently used dog sledge routes traverse the area in the season from October to June (Fig. 42). Since the treatment of rubbish, until recent years, has been very poor in Greenland, rubbish may be found sporadically.

Fishing for Greenland halibut in Ilulissat Icefjord is conducted in parts of the nominated area by means of small vessels and dinghies in summer and dog sledge in winter. The exploited stock is not self-recruiting, but is continuously recruited from an offshore spawning component in the Davis Strait. The prevailing theory is that Greenland halibut in the Northwest Greenland fjords are 'trapped' from their spawning stock, and remain resident in the fjords throughout their adult life (Riget & Boje 1988). Whatever strategy on stock exploitation is applied, there will be no effect on the original spawning stock and the resulting recruitment to Ilulissat Icefjord. However, the fishery affects the composition of the stock component in Ilulissat Icefjord and consequently the average age of the fish in the stock has decreased significantly within recent decades (Simonsen & Boje 2001). The precautionary approach to management of this resource in and off Ilulissat Icefjord is therefore more directed towards species diversity and the effects of fishing activities on habitat, than on sustainability of the resource. Present management thus focuses on a conservative annual yield aiming at stable catch levels and on responsible fishery methods, aiming to reduce the effect on the bottom habitat. The age distribution of the stock in Ilulissat Icefjord is monitored on an annual basis by the Greenland Institute of Natural Resources.

Within the nominated area, no population trends of any species of birds or mammals have been documented. Outside this area, however, dramatic declines in the population size of a number of conspicuous and culturally important species have been documented. Amongst others, this applies to the beluga whale (*Delphinapterus leucas*) (Rydahl & Heide-Jørgensen 2001), the walrus (*Odobenus rosmarus*) (Born *et al.* 1995), the king eider (*Somateria spectabilis*) (Mosbech & Boertmann 1999) and Brünnich's guillemot (*Uria lomvia*) (Kamp 1994). It is generally accepted among scientists and managers that harvest of wildlife is a major threat to sea mammals and bird populations in Greenland. Nevertheless, hunting of birds and mammals in the nominated area is currently not a conservation concern, since vulnerable species are either absent or only occur sporadically, so the local hunting bag is negligible.

FLOATING ICE PYRAMID ON ITS WAY TO THE ICEBERGBANK

Photo: Jakob Laurrup, GEUS

Attrition of vegetation in general and on archaeological sites in particular is a problem often discussed in connection with tourism. In the nominated area, one particular archaeological site, the Sermermiut valley, raises concern. Situated only a few kilometres from the town centre of Ilulissat, and with a very interesting history and archaeology as well as beautiful views to the Icefjord, the valley attracts many visitors (estimated at >10,000 persons annually). The soils in the valley consist of sand and gravel, which are covered with heath vegetation. The vegetation, ruins, culture layers as well as the soil in general are experiencing degradation, both due to wear from visitors and to wave erosion on the shore, the waves being created particularly by calving of icebergs on the Icefjord.

3.e. Policies and programmes related to the presentation and promotion of the Property

Although Ilulissat Icefjord may seem barren and overwhelming to strangers, it is the fjord that is the basis for successful settlement in the area, today as in the Stone Age. The Icefjord is therefore a very important part of local identity and everyday life.

One of the aims of the management plan for the nominated area (Appendix 4) is to create a framework to facilitate the presentation of Ilulissat Icefjord and its national and global values to visitors and the local population. This will be done by improving the infrastructure, establishing a visitor centre and providing information about the area to visitors.

The Greenland Home Rule has allocated funds to restore ruins and vegetation in the Sermermiut Valley. In this connection, a new path and a number of information boards will be erected to avoid further degradation of the area. More detailed information about this is to be found in Appendix 4 and 5.

A visitors centre is in the planning phase.


SPECTACULAR SHAPES IN THE FJORDWATER

THE SION CHURCH
IN ILULISSAT

4. Management

The nominated area is protected and conserved by an established framework of government legislation and protective designations and by local planning policies. These arrangements are reinforced through a series of national legislation and local planning documents, which are described in full within the appendices.

The Management Plan for the nominated World Heritage Site, produced and approved by the Municipality of Ilulissat (Appendix 4) sets out agreed objectives for the nominated site. This management plan has been the subject of local public consultations. The nominated area will in addition be protected by the Greenland Home Rule executive order regarding the Protection of Ilulissat Icefjord. This order has also been the subject of public and administrative consultations.

4.a. Ownership

There exists no private property in Greenland. It is an old tradition that the land is common property. All land belongs to the public, and the municipality can grant building permits in a desired area. In practice there is no time limit for how long a building can remain on a particular lot.

Similarly, no persons or companies can claim any exclusive rights to use any area, and there is a general understanding of 'allemandsret' in Greenland i.e. the 'right for everyone to go anywhere'. In addition, hunting huts and other huts outside the Greenlandic towns are unlocked and may always be used by anyone passing by.

Greenland is part of the Kingdom of Denmark and Denmark has shared rights to resources found in the Greenland subsurface.

4.b. Legal status

The nominated site lies entirely within an area that will be protected by the Greenland Home Rule executive order regarding the Protection of Ilulissat Icefjord.

Since 1980, Greenland has been covered by a nature protection act, which is also in force for the nominated Icefjord area (Anonymous 1980a). This nature protection act lays down among other things the framework for the protection of areas and species. A new nature protection act is currently under preparation by the Greenland Parliament.

Ready for the coming winter season

Photo: Jakob Lautrup, GEUS.

Greenland's protected area program is based primarily on species needs, sustainable use of living resources and the uniqueness of the areas. The system uses a combination of traditional area protection approach and hunting/fishing and harvesting regulations, and the weight placed on user group restrictions for species conservation is higher than in most other national systems.

The foundation for nature protection and protected areas in Greenland is the Nature Conservation Act for Greenland (Anonymous 1980a), under which six areas are protected: The National Park (also Man and Biosphere reserve), the Melville Bay, Arnangarup Qoorua (Paradise Valley), Lyngmarken, Akilia Island, Ikka Fjord and Qingua valley. The 7th area will be Ilulissat Icefjord.

The law regarding the protection of nature has as its chief purpose to safeguard and care for Greenland's natural and scenic assets, and it gives the authority to protect plant and animal species. Furthermore, areas can be protected, where, for example, preservation or scientific consideration dictates it. Further regional protection is carried out in all parts of Greenland, primarily to protect species.

FISHING NETS ON THE QUAY

Photo: Jakob Laurrup, GEUS

Activities and sites of interest to archaeology and natural history in Greenland are also regulated and protected by a suite of national laws and preservation orders.

The nominated Icefjord area will, as mentioned above, be protected through the Greenland Home Rule executive order regarding the protection of Ilulissat Icefjord (Appendix 3).

The area bordering the nominated area is further regulated by a number of regulations and orders including national regulations on waste disposal, use of snowmobiles, building constructions and the protection of the landscape. A special hunting law is enforced to regulate the exploitation of biological resources in the area.

Regulation of fishing and hunting

Fishing for Greenland halibut *(Reinhardtius hippoglossoides)* is regulated by the Greenland Home Rule executive order number 2 of 31.5.2001 (Anonymous 2001c). According to this order, fishing with tackle other than long lines is not allowed in Ilulissat Icefjord. Professional fishermen need a license to fish for Greenland halibut. This license must be renewed every year and may exclude the fisherman from certain areas in order to avoid overexploitation of this fish.

Hunting seasons, quotas, etc. are regulated by Greenland Home Rule executive orders regarding the relevant species. Of relevance to the nominated area is Greenland Home Rule executive order number 38 (6.12.2001) regarding the protection of birds (Anonymous 2001b). In addition to regulating the hunting seasons, the notice forbids any shooting of flying birds from motorised boats under power and also forbids shooting or any other kind of unnecessary disturbance close to bird cliffs and other sea bird colonies.

Archaeological sites

Although the present World Heritage nomination is made on the grounds of Earth sciences, it is noteworthy that the nominated area also includes an important cultural heritage.

From an archaeological point of view, Greenland has always been a hunting and fishing community. Therefore all coastal areas in Greenland provide rich archaeological remains representing various stages of the Inuit cultures stretching back *c.* 4500 years. This was the time when the inland ice retreated from the coastal areas and made possible the immigration of the palaeoeskimos into Greenland from Canada.

Archaeological sites in Greenland are protected by Greenland Home Rule order number 5 of 16th October 1980 regarding Protection of Archaeological Sites and Buildings (Anonymous 1980). The executive order forbids camping, campfires, litter deposition, construction etc. at the immovable heritage sites, i.e. buildings, ruins and other constructions that date from before the year 1900. It also defines a protection zone of 20 m around the sites, within which any activity is forbidden that may deface the site.

4.c. Protective measures and means of implementing them

The Greenland Home Rule executive order regarding the

Protection of Ilulissat Icefjord (Appendix 3) outlines the general content of the protective measures for the Ilulissat Icefjord. The implementation of these protective measures is outlined in more detail in the Management plan (Appendix 4), which is approved by the Ilulissat Municipal Authorities.

The Management Plan has been discussed at two public meetings in Ilulissat, which were attended by the local population, and the Ilulissat Municipality subsequently adopted the plan. The Ilulissat Municipality will in pursuance of the Management Plan undertake the responsibility to follow up on the implementation of the plan and keep under surveillance matters mentioned in the plan.

The Management Plan, of which the full text is given in Appendix 4, marks out a number of matters including:

- regulations on visits and transport in the nominated area by boat, foot, helicopter and dog sledge
- management of waste and waste disposal and regulation of building constructions
- restrictions on exploitation of biological resources in the area
- protection and management of the cultural heritage sites within the nominated area

Game wardens, employed by the Greenland Home Rule and with special responsibility for the control of hunters and fishermen, are active in the nominated area. They are entitled to inspect the catch of fishermen and hunters, and if irregularities are observed, to document these and make reports to the police (Anonymous 1998).

The above mentioned framework of protective designations is sufficient to protect the nominated site from threats to its integrity.

4.d. Agencies with management authority

The overall management and responsibility for protection of the nature and environment in Greenland rests with the Greenland Parliament. The Ministry of Environment and Nature has the daily responsibility for managing the overall rules and regulations, including supervision of local management in the municipalities.

Giant wall of ice with large crevasses

Photo: Jakob Lautrup, GEUS.

The Ilulissat municipality is one of 18 municipalities in Greenland. Each of the municipalities is governed by a Municipal Council (Kommunalbestyrelse) and is administered by a Municipal administration located at the local municipal office or town hall. This administration includes a technical department that has the daily responsibility for the observance of the management plans in the municipality.

Archaeological sites in Greenland are also protected by the

Greenland Home Rule regulations. The Greenland National Museum and Archives under the Ministry of Culture, Education, Research and the Church has the national responsibility for the conservation and registration of archaeological sites in Greenland. The Greenland National Museum and Archives oversees the local administration of archaeological matters whereas the local administration of archaeological sites is dealt with by the local museums that undertake the local management of archaeological and historical matters in the area.

Hunting and fishing is regulated on a national level by laws and recommendations issued by the Ministry of Fisheries, Hunting and Settlements. It is the responsibility of this ministry to see that laws and regulations are followed in Greenland. On a local level, game wardens are employed not by local authorities but by the national agency. The game wardens are responsible for controlling the exploitation of biological resources including hunting and fishing activities in the nominated area.

WHALE

Photo: Jakob Lautrup, GEUS

4.e. Level at which management is exercised

There is a range of responsibilities and duties related to the nominated site. These powers are exercised at different levels. On a national level the Ministry of Environment and Nature has the responsibility for international co-operation in relation to nature protection and development of protected areas. The Ministry of Environment and Nature further has the responsibility to see that Greenland conforms with international conventions and strategies in relation to the protection of nature. The Ministry has in addition the responsibility for all the protected areas which they inspect every year. The responsibility for the Greenlandic administration of UNESCO conventions rests in Greenland with the Ministry for Culture, Education, Research and the Church. In relation to foreign affairs as well as international UNESCO matters, Greenland is represented by the Danish UNESCO agency located in the Ministry of Culture in Copenhagen, Denmark.

Management and day-to-day control of the World Heritage nominated area is exercised locally by the Municipality of Ilulissat with the obligations given in the management plan (Appendix 4).

4.f. Agreed plans related to Property

The nominated area is an a contiguous wilderness area and the use of it is regulated by the management plan (Appendix 4).

The Greenland Parliament supports the development of tourism in Greenland and the Parliament has decided that tourism is going to be an important element in the Greenlandic national economy. A Tourist Plan of Action, adopted by the Greenland Parliament in 1998, outlines initiatives to strengthen tourism in Greenland. The plan concludes that the Disko Bugt region including the region of Ilulissat shall be the centre for tourism growth (Anonymous 1998b). This implies that the Greenland government supports the development of tourism in the region and will facilitate visits from abroad to the nominated area.

Several tourist agencies are operating in Ilulissat and plans are underway for the construction of a visitors centre close to the nominated area and to the town of Ilulissat. To facilitate the visits of tourists to the ice front, the construction of a number of small huts is planned, as is the construction of a few small huts for the halibut fishermen.
A survey for minerals has been undertaken in the nominated area but no mineralisation of economic value has been located at present.

4.g. Sources and levels of finance

Denmark is financing the Danish/Greenlandic participation in UNESCO matters and also finances activities in relation to Danish/Greenlandic obligations in relation to UNESCO programmes.

A greenlandic chorus in their national costumes

Photo: Jakob Lautrup, GEUS.

On a national Greenlandic level, the government finances the Greenlandic participation in nature and culture protection. The Greenland Home Rule finances the yearly supervision of the work performed by the institutions involved.

The Greenland Institute of Natural Resources is financed by the Greenland Home Rule. This institution provides biological data for management and monitors and catalogues changes in biological parameters, work that also takes place in the nominated area.

The Municipality of Ilulissat provides funding for the daily management of the nominated area including the supervision and implementation the management plan. The Greenland government decided in August 2002 to have the Ilulissat nomination document, with all its background documentation, re-written and prepared for publication to be used in various ways. It is the intention to prepare the material for educational purposes. In addition, a number of different tourist information brochures and booklets will be prepared.

The Ministry of Culture, Education, Research and Church in Greenland, the Municipality of Ilulissat and funds from the Danish administration will contribute to the re-writing of the nomination document for educational and turist purposes to be ready by July 2004.

4.h. Sources of expertise and training in conservation and management techniques

Trained staff in conservation and management is present in Greenland. Greenland is thus actively engaged in international co-operation especially in relation to conservation and management of Arctic areas and subjects. This situation implies that a capacity building takes place at all levels.

A special educational programme called the 'Greenlandic

Outfitter Education' is focussing on outdoor tourism with special emphasis on eco-tourism. In addition, the educational initiative called 'Takuss' provides an education in general Greenlandic tourism.

The game wardens are also taking a specially designed training course focussing on Greenlandic nature management.

The research institution, the Greenland Institute of Natural Resources, is located in Nuuk, Greenland. This internationally oriented institution has a thorough insight into the wildlife of Greenland, and the institution therefore provides expert advice for the Greenland Home Rule administration regarding exploitation of living resources. When needed, expert advice is also obtained from Danish and international research institutions and management agencies working in relevant fields. The Greenland Institute of Natural Resources has established a number of training positions to train young Greenlanders in biological research and management.

ILULISSAT

Photo: Jakob Lautrup, GEUS

The staff working with conservation and management at the local and national level in Greenland has the necessary expertise to ensure the long-term protection of the nominated area.

4.i. Visitor facilities and statistics

Ilulissat was designated as the centre for development of tourism in Greenland in 1998 by the Greenlandic Board of Tourism, and today Ilulissat is by far the most popular tourist destination in Greenland with the best infrastructure.

The town of Ilulissat is the port of entry to the nominated area. Ilulissat is accessible by aeroplane all year and by boat during the summer months. The town has a range of different hotels ranging from a 'Green-Key-5-star' international hotel, through standard hotels to youth hostels and camping sites. Ilulissat has therefore also become the most popular conference centre in Greenland. The Museum of Local History in Ilulissat has exhibitions of cultural history as well as of local art.

Ilulissat is also a town with all convenience stores ranging from the traditional Greenlandic outdoor meat-market to small fashion stores and tourist shops.

Ilulissat experienced a period of economic depression in the late 1980s and the early 1990s, primarily due to difficulties in the traditional fishing and hunting economy, and tourism was almost non-existent in the town. In 1992, the Municipality of Ilulissat took the initiative to start a tourist office that was the start of a new era in Ilulissat tourism. Three tourist offices arrange tours into the nominated area – providing by far the most efficient and well-organised tourist service in Greenland. In 1998/1999 one of the tourist offices received the Danish World Wildlife Foundation award for nature tourism.

In 2000, 10,660 tourists visited Ilulissat, corresponding to 34% of all tourists visiting Greenland; this illustrates the attraction Ilulissat has for tourists (Anonymous 2001a). Most tourists arrive in Ilulissat by plane or on local ferries. Cruise ships from countries other than Greenland also visit Ilulissat. These cruise ships are generally rather small (20–500 passengers), and the number of visits to Ilulissat is also limited at present (18 ships in 2001) compared to other cruise destinations around the world.

The average expenditure of tourists visiting Greenland is about 1300 Euro (Thalund 2000). Given that *c.* 11,000 tourists visited Ilulissat in 2000, this indicates an estimated income of 14,300,000 Euro.

The framework for tourism activities in the nominated area is given in the management plan (Appendix 4). The tourist offices offer a range of activities, including hiking trips of varied length into the nominated area, helicopter visits to the glacier front, boat trips on the Icefjord and dog sledge trips of varying length.

The security aspect is highly prioritised in the Ilulissat area as in other parts of Greenland. Tourists are always carefully instructed in arctic conditions before they can participate in organised tours. Helicopters from the airport in Ilulissat are always available for search-and-rescue operations in the nominated area.

Though increasing tourism in the nominated area raises concern about the fragile Arctic environment, actors both in the tourist industry and in the Municipality of Ilulissat have a high level of environmental awareness.

4.j. Property management plan and statement of objectives

The Greenland Home Rule executive order regarding the Protection of Ilulissat Icefjord has been discussed in public and within the Greenlandic administrative system qnd will be presented for approval by the Greenland Parliament.

The Management plan has also been thoroughly discussed at public meetings in Ilulissat and after the public consultation, the Municipal Council of Ilulissat subsequently approved the plan.

The overall goal of the management plan is the protection of natural and cultural values in the area and thus to:

- Protect the values that are connected to the nomination of the area for inclusion on the UNESCO World Heritage List, i.e. the glaciology and the beauty of the landscape.
- Protect vegetation and cultural remains against attrition.
- Protect birds and mammals in the area against unnecessary disturbance.

In general the aim for activities in the area is that:

- Hunting and fishing shall continue, so that this unique example of the Greenlandic hunting and fishing industry can continue.
- The tourism in the area shall be developed in such a way that the visitor is given the possibility to see and learn about the cultural and natural values of the area.
- The citizens in the community of Ilulissat shall be given the opportunity to use the area for recreational purposes, while their opportunity to learn about the natural and cultural values shall be enhanced.

The big icebergs are visible from any point in Ilulissat

Photo: Jakob Lautrup, GEUS.

4.k. Staffing levels

As described in 4.d, the staff working with management of the area is located within the Municipality of Ilulissat, and in the Ministries under the Greenland Government in Nuuk.


AMAZING SCENERY

5. Factors Affecting the Property

5.a. Development pressures

Urban development is not planned in the nominated area. Within the nominated area, there is presently no knowledge of mineral resources that could be exploited in the future. Fishing and hunting are regulated regarding mode of transport and fishing techniques.

Travel is only allowed by boat (limited by prevailing ice conditions) or dog sledge and fishing is restricted to the use of long lines. Hence, both the permitted modes of transport and the fishing method in the nominated area are of "low impact type" compared to transport by snow scooter which is only allowed under very special circumstances and to fishing with gill or trawl nets.

Tourism constitutes by far the most significant development pressure in the nominated area. Degradation and erosion of vegetation and archaeological sites and disturbance of wildlife are the greatest concerns. Hence both the Greenland Home Rule executive order regarding the protection of Ilulissat Icefjord (Appendix 3) and the management plan (Appendix 4), as well as other initiatives like the conservation plan (Appendix 5) aim to prevent such effects.

Construction of new huts in the nominated area is limited to a few tourist and fishing huts. The construction of a visitors centre is considered to be important both for educational purposes and for providing tourists with local information.

The Greenland Home Rule executive order regarding the protection of Ilulissat Icefjord and the management plan together create the framework that ensures that these constructions are built and used in a way that respects the values of the nominated area and that tourism is developed in a careful and considerate way.

5.b. Environmental pressures

The environmental pressures on the nominated area are almost exclusively of external origin, and with the possible exception of climate change, these environmental pressures are considered to be negligible.

During summer, the next generation of sledge dogs seek shelter from the warm sunshine

Photo: Jakob Lautrup, GEUS

Climate change may affect the rate of glacial flow and the position of the Sermeq Kujalleq ice front and thereby the Icefjord. The effect of climate change is hard to predict and cannot be dealt with or counteracted on a local scale. Future climate change may also affect the vegetation, wildlife and soils in the area, but these effects are beyond the scope of local initiatives.

5.c. Natural disasters and preparedness

There are no natural disasters threatening Ilulissat Icefjord as such. The archaeological sites at Sermermiut and Qajaa are subject to erosion caused by wave impacts associated with calving of icebergs. Ice and waves from inverting icebergs may also create scars at the shoreline. There is, however, no reasonable means of protecting these shores against wave action.

5.d. Visitor and tourism pressures

The Ilulissat Icefjord is nominated for inclusion in the World Heritage list because of the unique glaciology and natural beauty, and these features are extremely robust to the pressure of tourism.

BACKPACKERS NEAR SERMERMIUT

Photo: Jakob Lautrup, GEUS

Most tourists visiting the Ilulissat Icefjord arrive in the town centre from where a small bus runs to the border of the nominated area at the entrance to the Sermermiut valley. From here a fairly easy walk of approximately 3 kilometres takes the tourists to Holms Bakke from where there is a magnificent view over the Sermermiut valley and over the Icefjord with all the big icebergs stranded at the Iceberg Bank.

At present, the only visible sign of tourism pressure in the nominated area is the attrition of vegetation and the wear on the archaeological sites in the Sermermiut valley (described in chapter 3.d). This attrition, however, is not a measure of the carrying capacity of the area with regard to tourism, since no attempt has been made so far to control the traffic in the Sermermiut area. Initiatives listed in the 'Plejeplan' include the construction of a marked pathways in the Sermermiut area, the aim being to reduce the attrition of the area.

Disruption of the traditional Inuit culture or ways of life in the town of Ilulissat is also an issue. There are clearly socio-economic aspects that must be considered with respect to the development of tourism in a small town where the population lives a semi-traditional Inuit life style. It is important, however, to notice that the present level of tourism in Ilulissat is strengthening the Inuit culture by increasing the demand for traditional handicrafts and involving the local population in tourist activities such as dog sledge driving and boat charter. The importance of the traditional dog sledge is increasing as a consequence of the new source of income which tourism offers dog sledge drivers.

The nominated area can absorb a larger number of visitors than experienced today especially if the tourist traffic is carefully planned and organised. With the framework outlined in the management plan (Appendix 4), the prerequisites for such a planning procedure are ensured.

5.e. Number of inhabitants within Property

Just over 56,000 people live in Greenland. The central parts of West Greenland are the most densely populated, and most of the population – around 45,000 – live in the towns. Nuuk is the largest town in Greenland and Ilulissat the third largest. The rest of the Greenlandic population lives in more than 120 settlements, trading posts and sheep stations.

There are no inhabitants living inside the nominated area of Ilulissat Icefjord. The Municipality of Ilulissat has a population of *c.* 4800 inhabitants, 4200 living in Ilulissat and the remaining 500 living in the villages of Ilimanaq, Oqaatsut, Qeqertaq and Saqqaq.

The population of the Municipality of Ilulissat is spread over an area of *c.* 47,000 km^2.

THE COLOURS OVER THE ICEFJORD ARE
MAGNIFICENT DURING SUNSET

THE FOG MAY SUDDENLY ARRIVE IN THE ICEFJORD

Photo: Jakob Laurup, GEUS

THE BUSY HARBOUR
IN ILULISSAT

6. Monitoring

6.a. Key indicators for measuring the state of conservation

Monitoring the location of the glacier front and the flow rate/calf ice production rate provides key indicators of the response of the glacier to climate change. However, the response of the glaciological features of Ilulissat Icefjord to climate change is not a measure of the state of conservation at the local level. Regarding local pressures, the glaciology in the area essentially conserves itself due to the enormous power inherent in the glacial system; indeed, it is difficult to identify any pressure on conservation, which could be monitored, with respect to the glaciological conditions.

The effect of increased tourism in the area is relevant regarding biological parameters such as attrition and the disturbance of wildlife. However, it is considered unlikely that more than a few tourists will visit the distant parts of the nominated area. This is due to a number of factors including the harsh climate and periodically unstable weather conditions in certain periods of the year, the inaccessibility of the area and its wilderness character.

If tourism were to be substantially increased in the more remote parts of the nominated area, however, monitoring of populations of Greenland white-fronted geese (*Anser albifrons flavirostris*) and Canada geese (*Branta candensis*) should be considered in order to study the possible effects of increased disturbance on distribution, breeding success etc.

6.b. Administrative arrangements for monitoring the Property

There are no plans to establish a detailed monitoring programme of the glaciological features of Ilulissat Icefjord. The area, however, is one of the glaciologically best investigated areas in the world, which frequently attracts scientists. Changes in the location of the glacier front, for example, are very likely to be regularly monitored by satellite images.

The National Museum and Archives of Greenland and the Directorate for Nature and Environment, are currently engaged in a project that on a yearly basis monitors attrition in the Sermermiut valley.

An assessment of the age distribution of the Greenland halibut stock is made on an annual basis in the nominated area by the Greenland Institute of Natural Resources.

Marine and terrestrial mammals as well as the occurrence of bird populations in the nominated area are also monitored regularly by the Greenland Institute of Natural Resources and the National Environmental Research Institute, Denmark. The monitoring normally focuses on regional populations.

Staff from the Directorate for Environment and Nature inspects the protected areas each year. Inspections are normally followed by consultation with the local authorities responsible for the daily supervision of the area. Such inspections are also planned for the Ilulissat Icefjord area.

The management plan (Appendix 4) describes the framework for the annual and day-to-day monitoring of tourism and hunting/fishing activities in the area.

6.c. Results of previous reporting exercises

In the study mentioned in chapter 3.e on attrition in the Sermermiut valley, it is concluded that there is a need for better planning and information for visitors entering the valley. This is already under consideration and the construction of paths and erection of notice boards with information about the locality is being discussed – as outlined in the conservation plan, Appendix 5.

7. Documentation

7.a. Photographs, slides and video

A documentation of the Ilulissat Icefjord area is presented by a set of slides and by a video.

7.b. Copies of management plan and extracts of other plans

A draft of the Greenland Home Rule executive order regarding the protection of Ilulissat Icefjord and the English version of the management plan for Ilulissat Icefjord are included in Appendices 3 and 4 respectively. An English abstract of a plan (in Danish) for the conservation of the Sermermiut archaeological site appears in Appendix 5.

7.c. Bibliography

Abdalati, W. & Krabill, W.B. 1999: Calculation of ice velocities in the Jakobshavn Isbrae area using airborne laser altimetry. Remote sensing of Environment 67, 194-204.

Alley, R. 2000: The two-mile time machine: ice cores, abrupt climate change, and our future. 229 pp. Princeton: Princeton University Press.

Ambach, W. 1972: Zur Schatzung der Eis-Nettoablation im Randgebiet des Grönlandischen Inlandeises. Polarforschung 42, 18-23.

Amdrup, G.C., Bobé, L., Jensen, A.S. & Steensby, H.P. (eds) 1921: Grønland i Tohundredaaret for Hans Egedes Landing. Meddelelser om Grønland 60-61. 567 pp. + 795 pp. + atlas.

Andersen, O.N. 1998. Havets økosystem, In: Born, E.W. & Böcher, J. (eds): Grønlands Økologi – en grundbog, 123-135. Nuuk: Atuakkiorfik Undervisning.

Aniya, M., Sato, H., Naruse, R., Skvarca, P. & Casassa, G. 1997: Recent glacier variations in the Southern Patagonian Icefield, South America. Arctic and Alpine Research 29, 1-12.

Anonymous 1980. Landstingslov om fredning af jordfaste fortidsminder og bygninger, af 16. oktober 1980. Nuuk: Grønlands hjemmestyre.

Anonymous 1998. Hjemmestyrets bekendtgørelse nr. 28 af 30. oktober 1998 om jagt- og fiskeribetjentes opgaver og beføjelser. Nuuk: Grønlands Hjemmestyre.

Anonymous 1998a. Landstingslov nr. 11 af 12 november 1980 om naturfredning i Grønland. Grønlands Hjemmestyre.

Anonymous 1998b. Turistpolitisk redegørelse. Direktoratet for Erhverv. Grønlands Hjemmestyre.

Anonymous 2000a. Hjemmestyrets bekendtgørelse nr.9 af 31. marts 2000 om financieringsstøtte til iværksættere indenfor turisterhvervet. Nuuk: Grønlands Hjemmestyre.

Anonymous 2000b. Årsberetning 2000. Fremtiden i sigte. Greenland tourism. Nuuk. Grønlands Hjemmestyre.

Anonymous 2001a. Flypassagerstatestikken 2000. Turisme 2001:2. Nuuk: Grønlands Statistik.

Anonymous 2001b. Hjemmestyrets bekendtgørelse nr. 38 af 6. december 2001 om beskyttelse af fugle. Nuuk: Grønlands Hjemmestyre.

Anonymous 2001c. Hjemmestyrets bekendtgørelse nr. 22 af 31. maj 2001 om kystnært fiskeri efter hellefisk. Nuuk: Grønlands Hjemmestyre.

Anonymous 2002a. Piniarneq 2002. Nuuk: Grønlands Hjemmestyre, Direktoratet for Erhverv.

Anonymous 2002b. http://www.greenland-guide.gl/brancheinfo/cr-anlobs-plan.htm. Home page for Greenland Tourism.

Anonymous 2002 c. www.dmi.dk. Homepage for Danish Meteorological Institute.

Appelt, M. & Gulløv, H.C. (eds) 1999: Late Dorset in High Arctic Greenland. Final report on the Gateway to Greenland project. Danish Polar Center Publication 7., 83 pp.

Arneborg, J. 1993: Contact between Eskimos and Norsemen in Grenland - a review of the evidence. In: Roesdahl, E. & Sørensen, P.M. (eds): Beretning fra tolvte Tværfaglige Vikingesymposium, Aarhus Universitet 1993. Brabrand: Hikuin.

Astrup, E. 1895: Blandt Nordpolens Naboer, 319 pp.. Oslo: Aschehoug.

Bamber, J.L., Layburry, R.L., & Gogineni, S.P. 2001: A new ice thickness and bedrock dataset for the Greenland ice sheet: Part I. Journal of Geophysical Research 106, D24, 33773-33780.

Bauer, A., Fontanel. A. & Grau, G. 1967: The application of optical filtering in coherent light to the study of aerial photographs of Greenland glaciers. Journal of Glaciology 6, 781-793.

Bauer, A., Baussart, M., Carbonnell, M., Kasser, P. Perroud, P. & Renaud, A. 1968: Missions aériennes de reconnaissance au Groenland 1957-1958. Observations aériennes et terrestres, exploitation des photographies aériennes, determination des vitesses des glaciers vélant dans Disko Bugt et Umanak Fjord. Meddelelser om Grønland 173, 3, 116 pp.

Bay, C. 2000: Planteverden. In: Jakobsen, B.H., Böcher, J., Nielsen, N., Guttesen, R., Humlum, O. & Jensen, E. (eds): Topografisk Atlas, Grønland. Copenhagen: Det Kongelige Danske Geografiske Selskab & Kort- og Matrikelstyrelsen

Bendixen, O. 1930: Grønlandsfiskeriet, dets Historie og Fremtidsmuligheder, 129 pp. Copenhagen: H. Aschehoug & Co.

Benson, C. 1961: Stratigraphical studies in the snow and firn of the Greenland ice sheet. Folia Geographica Danica 9, 13-37.

Bhutiyani, M.R. 1999: Mass-balance studies on Siachen Glacier in the Nubra Valley, Karakoram Himalaya, India. Journal of Glaciology, 45, 112-118.

Bindschadler, R.A. 1984: Jakobshavn Glacier Drainage Basin: A Balance Assessment. Journal of Geophysical Research 89, C2, 2066-2072.

Bindschadler, R., Vornberger, P, Blankenship, D., Scambos, T. & Jacobel, R. 1996: Surface velocity and mass balance of Ice Streams D and E, West Antarctica. Journal of Glaciology 42, 461-475.

Biscaye, P.E. 1994: Sampling for dust studies on the ice margin of Paakitsoq, West Greenland. In: Thomsen, H.H. & Reeh, N. (eds): Field report on palaeo-environmental studies at the Greenland ice sheet margin, Paakitsoq, West Greenland, 1994. Open File Series Grønlands Geologiske Undersøgelse 94/15, 10-15.

Bobé, L. 1915: Lourens Feykes Haans Kursforskrifter for Besejlingen af Grønland, særlig Diskobugten (1719). Det Grønlandske Selskabs Årsskrift 1915, 41-49.

Boertmann, D., Mosbech, A., Falk, K. & Kampp K. 1996: Seabird colonies in western Greenland. NERI Technical Report 170, 148 pp.

Boje, J. 2002: Intermingling and seasonal migrations of Greenland halibut stock components in the Northwest Atlantic based on tagging studies. Fish Bull 100(3), (in press).

Boje, J. & Jørgensen, O.A. 1998: Hellefisk. In: Kapel, F.O., Kanneworff, P. & Nielsen, K.R. (eds): Grønlands Fiskeriundersøgelser gennem 50 år, 88-95. Nuuk: Grønlands Naturinstitut.

Born, E.W., Gjertz, I. & Reeves, R.R. 1995: Population assessment of Atlantic Walrus. Meddelelser fra Norsk polarinstitut 138, 100 pp.

Bourgeois, J.C. 1994: Sampling for pollen on the ice margin at Paakitsoq, West Greenland. In: Thomsen, H.H. & Reeh, N. (eds): Field report on palaeo-environmental studies at the Greenland ice sheet margin. Paakitsoq, West Greenland, 1994. Open File Series, Grønlands Geologiske Undersøgelse 94/15, 16-19.

Brecher, H. & Hughes, T. 1998: Poster. Fast moving Glaciers – Jakobshavn Glacier, Greenland. Mosaic of aerial photos 1985. Byrd Polar Research Center, The Ohio State University.

Buchwald, V.F. 2001: Iron and slags in ancient Greenland. Meddelelser om Grønland, Man & Society 26, 92 pp.

Buchwald, V.F. & Mosdal, G. 1985: Meteoritic iron, telluric iron and wrought iron in Greenland. Meddelelser om Grønland, Man & Society 9, 52 pp.

Burmeister, A. 2000: Bestandsstatus af krabber (Chionoecetes oplio) ved Vestgrønland og biologisk rådgivning for 2000. Teknisk rapport fra Grønlands Naturinstitut 22, 36 pp.

Böcher, J. & Fredskild, B. 1993: Plant and arthropod remains from the Palaeo-Eskimo site at Qeqertasussuk, West Greenland. Meddelelser om Grønland, Geoscience 30, 35 pp.

Cailleux, A. & Lagarec, D. 1977. Nombre, surface et volume des glaciers du globe. Studia Geologica Polonica 52, 83-96.

Carbonnell, M. & Bauer, A. 1968: Exploitation des couvertures photographiques aériennes répétées du front des glaciers vélant dans Disko Bugt et Umanak Fjord, juin-juillet 1964. Meddelelser om Grønland 173, 5, 78 pp.

Clarke, T.S. & Echelmeyer, K. 1988: High-resolution Reflection Profiles Across Jakobshavns Ice Stream, Greenland, EOS, Transactions of the American Geophysical Union 70, 1080 only.

Clarke, T.S. & Echelmeyer, K. 1996: Seismic-reflection evidence for a deep subglacial trough beneath Jakobshavns Isbræ, West Greenland. Journal of Glaciology 42, 219-231.

Cranz, D. 1770: Historie von Groenland enthaltend die Beschreibung des Landes und der Einwohner, 2nd edition. 710 pp. Barby: Heinrich Detlef Ebers.

Dansgaard, W. 1961: The isotopic composition of natural waters, with special reference to the Greenland ice cap. Meddelelser om Grønland 165, 2, 120 pp.

Dansgaard, W., Scholander, P.F., de Vries, H., Coachman, L.K., Nutt, D.C. & Hemmingsen, E. 1962: Radiocarbon Age and Oxygen-18 content of Greenland Icebergs. Meddelelser om Grønland 165, 1, 26 pp.

Dansgaard, W., Johnsen, S.J., Clausen, H.B., Dahl-Jensen, D., Gundestrup, C.U., Hvidberg, C.S., Steffensen, J.-P., Sveinsbjørnsdottir, 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.

Ice-scoured rocks near the shore

Photo: Joel Berglund

Direktoratet for den Kongelige Grønlandske Handel 1902-06: Meddelelser fra Direktoratet for den kongelige grønlandske Handel. Copenhagen: J. H. Schultz.

Donner, J. 1978: Holocene history of the West coast of Greenland, Geografiska Annaler 60A, 63-72.

Drewry, D.J., Jordan, S.R. & Jankowski, E. 1982. Measured properties of the Antarctic Ice Sheet: Surface configuration, ice thickness, volume and bedrock characteristics. Annals of Glaciology 3, 83-91.

Drygalski, E. von 1897: Grönland Expedition der Gesellschaft für Erdkunde zu Berlin 1891-1893. 1, 555 pp. Berlin: W.H. Kuhl.

Echelmeyer, K., & Harrison, W. 1985: Tidal and seasonal fluctuations in the motion of Jakobshavns Glacier and their relation to basal sliding. American Geophysical Union, Chapman Conference on Fast Glacier Flow, Whistler Village, Canada, May 1986, A, 23 only.

Echelmeyer, K. & Harrison, W. D. 1990: Jakobshavn Isbræ, West Greenland: Seasonal variations in velocity – or lack thereof. Journal of Glaciology 36, 82-88.

Echelmeyer, K., Clarke, T. S. & Harrison, W. D. 1991: Surficial glaciology of Jakobshavn Isbræ, West Greenland: Part I, Surface morphology. Journal of Glaciology 37, 368-382.

Echelmeyer, K., Harrison, W. D., Clarke, T. S., & Benson, C. 1992. Surficial glaciology of Jakobshavn Isbræ. Part II, Ablation, accumulation and temperature. Journal of Glaciology 38, 169-181.

Echelmeyer, K., Funk, M. & Iken, A. 1993: Modelled and measured englacial temperatures in Jakobshavn Isbrae. Conclusions on vertical strain in the ice stream. In: Reeh, N. & Oerter, H. (eds): Mass balance and related topics of the Greenland ice sheet. Open File Series Grønlands Geologiske Undersøgelse 93/5, 25-27.

Echelmeyer, K., Funk, M. & Iken, A. 1994: Modelled and measured englacial temperatures in Jakobshavns Isbrae. Conclusions on vertical strain in the ice stream. In: Reeh, N. (editor) Workshop on the calving rate of West Greenland glaciers in response to climate change. Copenhagen. Danish Polar Center.

Egede, P. 1788: Poul Egedes Dagbog. Efterretninger om Grønland, uddragne af en journal holden fra 1721 til 1788. Udgivet ved Mads Lidegaard. Det Grønlandske Selskabs Skrifter 29, 204 pp.

Engell, M. C. 1903: Uber die Schwankungen des Jakobshavns Gletscher. Petermanns Geografische Mitteilungen 49, 121-123.

Engell, M. C. 1904: Undersøgelser og Opmaalinger ved Jakobshavns Isfjord og i Orpigsuit i Sommeren 1902. Meddelelser om Grønland 26, 1, 1-70.

Engell, M. C. 1905: Einige Beobachtungen uber die Kalbungen im Jakobshavns Isfjord und den benachbaren Fjorden. Mitteilungen der Geographische Gesellschaft in Wien 48, 426-433.

Engell, M. C. 1910a: Beretning om Undersøgelserne af Jakobshavns Isfjord og dens Omgivelser fra Foraaret 1903 til Efteraaret 1904. Meddelelser om Grønland 34, 6, 155-251.

Engell, M. C. 1910b: Gletschermessungen in Grönland. Zeitschrift für Gletscherkunde, für Eiszeitforschung und Geschichte des Klimas 4, 295-300.

Engell, M. C. 1910c: Uber die Entstehung der Eisberge. Zeitschrift für Gletscherkunde, für Eiszeitforschung undGeschichte des Klimas 5, 122-132.

Epprecht, W. 1987: A major calving event of Jakobshavn Isbræ, West Greenland, on 9th August 1982. Journal of Glaciology 33, 160-172.

Escher, J.C. & Pulvertaft, T.C.R. 1995: Geological map of Greenland, 1:2,500,000. Copenhagen: Geological Survey of Greenland.

Eyles, N. 1983. Glacial Geology. An Introduction for Engineers and Earth Scientists, 406 pp. Oxford: Pergamon Press.

Fastook, J.L. & Hughes, T. J. 1994: A plan to model iceberg outbursts from Greenland outlet glaciers in respons to Greenhouse warming. In: Reeh, N. (ed.): Workshop on the calving rate of West Greenland glaciers in response to climate change, 13-15 September 1993, Copenhagen, 21-56. Copenhagen: Danish Polar Center.

TRADITIONAL HOUSE IN ILULISSAT

Photo: Jakob Laurrup, GEUS

Fastook, J.L. & Schmidt, W.F. 1982: Finite-element analysis of calving from ice fronts. Annals of Glaciology 3, 103-106.

Fastokk, J.L., Brecher, H.H. & Hughes, T.J. 1995: Derived bedrock elevations, strain rates and stresses from measured surface elevations and velocities: Jakobshavn Glacier, Greenland. Journal of Glaciology 4, 161-173.

Finsterwalder, R. 1959: Expédition Glaciologique Internationale au Groenland 1957-60 (E.G.I.G.). Journal of Glaciology 3, 542-546.

Fisker, J. 1984: Ilulissat Jakobshavn, 303 pp. Uummannak: Nordiske Landes Bogforlag.

Fog Jensen, J. 1998: Dorset Dwellings in West Greenland. Acta Borealia 15.

Fox, A.D., Norriss D.W., Wilson, H.J., Merne, O.J., Stroud, D.A., Sigfusson, A. & Glahder, C. 1999: Greenland White-fronted Goose. In: Madsen, J., Cracknell, G. & Fox, A.D. (eds): Goose populations of the Western Palearctic: a review of status and distribution. Wetlands International publication 48, 130-142.

Fredskild, B. 1961: Floristic and ecological studies near Jakobshavn, West Greenland. - Meddelelser om Grønland 163, 4, 82 pp.

Fredskild, B. 1967: Palaeobotanical Investigations at Sermermiut, Jakobshavn, West Greenland. Meddelelser om Grønland 178, 4, 54 pp.

Fredskild, B. 1996: A phytogeographical study of the vascular plants of West Greenland (62°20'-74°00'N). Meddelelser om Grønland, Bioscience 45, 157 pp.

Fricker, H.A., Warner, P.C. & Allison, I. 2000: Mass balance of the Lambert Glacier – Amery Ice Shelf System, East Antarctica. A comparison of computed balance fluxes and measured fluxes. Journal of Glaciology 46, 561-570.

Fristrup, B. 1966: Grønlands Indlandis, 319 pp. Copenhagen: Rhodos.

Funder, S. & Larsen, H.C. 1989: Quaternary geology of the shelves adjacent to Greenland. In: Fulton, R.J. (ed.): Quaternary geology of Canada and Greenland, 769-772. Ottawa: Geological Survey of Canada.

Funk, K., Echelmeyer, K. & Iken, A. 1994: Mechanisms of fast flow in Jakobshavn Isbræ, West Greenland, Part II, modelling of englacial temperatures. Journal of Glaciology 40, 569-585.

Gad, F. 1969-1978: Grønlands historie. Vol. 1 (1978): Indtil 1700, 461 pp. (Originally published 1967). Vol. 2 (1969): 1700-1782, 760 pp. Vol. 3 (1976): 1782-1808., 615 pp. Copenhagen: Nyt Nordisk Forlag, Arnold Busck.

Garvin, J.B. & Williams, R.S. 1993: Geodetic airborne laser altimetry of Breidammerjøkull, Iceland, and Jakobshavn Isbræ, Greenland. Annals of Glaciology 17, 379-385.

Garvin, J.B., Williams, R.S Jr. & Bufton, J.L. 1994: Geodetic aircraft laser altimetry of Glaciers. EOS, Transactions, American Geophysical Union. 75, l6, 102 only.

Georgi, J. 1930: Im Faltboot zum Jakobshavner Eisstrom. In: Wegener, A. (ed.): Mit Motorboot und Schlitten in Gronland, 158-178. Bielefeld: Verlag von Velhagen.

Georgi, J. 1960a: Otto Fabricius und andere über die Eisverhaltnisse auf Grönland mit einem Exkurs auf dem Jakobshavner Gletscher. Polarforschung 4, Jahrgang 28, 79-91. Erschienen 1960.

Georgi, J. 1960b: Der Rückgang des Jakobshavns Isbræ (West-Grönland 69° N). Meddelelser om Grønland 158, 5, 51-70.

Glahder, C.M., Fox, A.D. & Walsh, A.J. 1999: Satellite tracking of Greenland White-fronted Geese. Dansk Ornitologisk Forenings Tidsskrift 93, 271-276.

Goguneni, S., Tammana, D., Braaten, D., Leuschen, C., Akins, J., Legarski, J., Kanagaratnam, P., Stiles, J., Allen, C. & Jezek, K. 2001: Coherent radar ice thickness measurements over the Greenland ice sheet. Journal of Geophysical Research 106, D24, 33761-33772.

Grønnow, B. 1994: Qeqertasussuk – the Archaeology of a Frozen Saqqaq Site in Disko Bugt, West Greenland. In: Morrison, D. & Pillon, J.-L. (eds): Threads of Arctic Prehistory: Papers in Honour of William E. Taylor, Jr. Canadian Museum of Civilization, Mercury Series. Archaeological Survey of Canada Paper 149, 197-238.

Grønnow, B. 1996: The Saqqaq Tool Kit - Technological and Chronological Evidence from Qeqertasussuk, Disko Bugt. In: Grønnow, B. & Pind, J. (eds): The Paleo-Eskimo Cultures of Greenland – New Perspectives in Greenlandic Archaeolo-gy. Copenhagen: Danish Polar Center Publication No. 1/1996, 17-34.

Grønnow, B. & Meldgaard, M. 1988: Boplads i dybfrost - fra Christianshåb Museums udgravninger på Vestgrønlands ældste boplads. Naturens Verden 1988, 409-440.

Grønnow, B. & Meldgaard, M. 1991: De første vestgrønlændere. Grønland 4-7, 103-144.

Gudmandsen, P. & Jakobsen, G.H. 1976: Radio Echo Sounding of the Greenland Ice Sheet. Europhysics 7, 2-4.

Gulløv, H.C. 1985: Whales, Whalers, and Eskimos: The Impact of European Wha-ling on the Demo-graphy and Economy of Eskimo Soci-ety in West Greenland. In Fitzhugh, W.W. (ed.): Cultures in contact: the European impact on native cultural institutions in Eastern North Amerca, A.D. 1000-1800, 71-96. Washington: Smithsonian Institution Press.

Gulløv, H.C. 1986: Introduction. Arctic Archaeology 23.

Gulløv, H.C. 1997: From Middle Ages to Colonial Times. Archaeological and ethnohistorical studies of the Thule culture in South West Greenland 1300-1800 AD. Meddelelser om Grønland, Man & Society 23, 501 pp.

Hammer, R.R.J. 1883: Undersøgelser ved Jakobshavns Isfjord og nærmeste Omegn i Vinteren 1879-1880. Meddelelser om Grønland 4, 1, 1-68.

Hammer, R.R.J. 1889: Undersøgelse af Grønlands Vestkyst fra 68° 20´til 70° N.B. Meddelelser om Grønland 8, 1, 1-32.

Hansen, K. 1997: Jigs from Greenland. In: Gilberg, R. & Gulløv, H.C. (eds): Fifty Years of Arctic Research. Antropological Studies From Greenland and Siberia, 149-156. Copenhagen: Nationalmuseet. Ethnographical Series 18.

Hansen, B.U. 1999: Klimatet. In: Born, E.W. & Böcher, J. (eds): Grønlands økologi - en grundbog, 66-83. Nuuk: Atuakkiorfik Undervisning, Nuuk.

Hansen, P.M. & Hermann, F. 1953: Fisken og havet ved Grønland. Skrifter fra Danmarks Fiskeri- og Havundersøgelser 15, 128 pp.

Helland, A. 1876: Om de isfyldte Fjorde og de glaciale Dannelser i Nordgrønland. Archiv for Matematik og Naturvidenskab 1, 69 pp.

Helland, A. 1882: Geschwindigkeit der Bewegung der grönlandischen Gletscher im Winter. Zeitschrift der Deutschen Geologischen Gesellschaft 33, 693-694.

Hertz, O. 1995: Økologi og levevilkår i Arktis. Copenhagen: Uummannamiut.

Holdsworth, G. 1977: Tidal interaction with ice shelves. Annales de Geophysique 33, 133-146.

Holtzscherer, J.J. & Bauer, A. 1954: Contribution à la connaissance de l'Inlandsis du Groenland. International Association of Scientific Hydrology 39, 244-296.

Icetowers

Photo: Dieter Zillman/Greenland Tours Elke Meissner

Hovgård, H. 1991: The Fluctuations in Cod (Gadus morhua) fisheries off West Greenland in the twentieth century. NAFO Scientific Council Studies 18: 43–45.

Hughes, T. 1982: The Jakobshavn Glacier Ice Drainage System. 30. August 1982. Addendum to Meeting on Jakobshavn Isbræ at Northwestern University, Evanston, 1982. 8 pp.

Hughes, T. 1986: The Jakobshavn Effect. Grophysical Research Letters 13, 46-48.

Hughes, T. 1992: Theoretical calving rates from glaciers along ice walls grounded in water of variable depths. Journal of Glaciology 38, 129, 282-294.

Hughes, T. 1994: A plan to model iceberg outbursts from Greenland outlet glaciers in response to Greenhouse warming. In: Reeh, N. (ed.): Workshop on Calving Rate of West Greenland Glaciers in Response to Climatic Change 13.-15. September 1993, 21-55. Copenhagen: Danish Polar Center.

Humphrey, N. & Echelmeyer, K. 1990: Hot-water drilling and bore-hole closure in cold ice. Journal of Glaciology 36, 287-298.

Huybrechts, P. 1994: The present evolution of the Greenland ice sheet; an assessment by Modelling. Palaeogeography, Palaeoclimatology, Paleaecology (Global Planetary Section) 9, 39-51.

Huybrechts, P. 2002: Sea-level chances at the LGM from ice-dynamic reconstructions of the Greenland and Antarctic ice sheets during the glacial cycles. Quarternary Science Reviews. 21, 203-231.

Hvingel, C. 2001: The Fishery for Northern Shrimp (Pandalus borealis) off West Greenland, 1970-2001. NAFO Scientific Council Reports and Documents 01/173, 11 pp.

Iken, A. 1990: Tiefbohrungen im Jakobshavn Gletscher, Grönland, Bulletin der Eidgenossischen Technischen Hochschule, Zurich 228, 8-10.

Iken, A., Echelmeyer, K. & Harrison, W. 1989: A leightweight hot water drill for large depth. Experiences with drilling on Jakobshavns Glacier, Greenland. Proceedings of the workshop on Ice Core Drilling, Grenoble, 10-14 October 1988. Laboratoire de Glaciologie et Geophysique de l'Environment. St. Martin d´Heres Cedex, France, 12 pp.

AFTERNOON REST ON SOFT LAYER

Photo: Jakob Laurup, GEUS

Iken, A., Echelmeyer, K. & Funk, M. 1993: Mechanism of fast flow in Jakobshavns Isbræ, West Greenland. Part I, Measurements of temperature and water level in deep bore holes. Journal of Glaciology 39, 15-25.

IUCN 2001: IUCN Evaluation of Nominations of Natural and Mixed Properties to the World Heritage List. Report to the World Heritage Committee twenty-fifth session, 11-16 December 2001-Helsinki, Finland. WHC-01/CONF. 208/INF.12

Jacobi, H. 1958: Nogle betragtninger over Jakobshavns-fiskernes økonomiske og erhvervsmæssige vilkår. Grønland 1958, 368-376.

Jensen, A.S. 1935: The Greenland halibut, (Reinhardtius hippoglossoides (Walb.)) its development and migrations. Skrifter fra det Kongelige Danske Videnskabernes Selskab 9 Række 6, 4, 32 pp.

Kamp, K., Nettleship, D. N. & Evans, P.G.H. 1994: Thick-Billed murres in Greenland: Status and seabirds prospects. In: Nettleship, D.N., Burger, J. & Gochfeld, M. (eds): On Islands. Threats, case studies and action plans. Birdlife conservation series 1, 133-154.

Kapel, H.C. 2002: Bopladsen Sermermiut i Ilulissat kommune, 17 pp. Report, Nationalmuseets Center for Grønlandsforskning, Copenhagen.

Karlsen, H.G., Bille-Hansen, J., Hansen, K.Q., Andersen, H.S. & Skourup, H. 2001: Distribution and variability of icebergs in the Eastern Davis Strait 63∞ N to 68∞ N, 34 pp. Report, Greenland Survey, Nuuk.

Kejlbo, I. 1956: Zenokortet, dets kilder og betydning for den kartografiske udformning af det nordlige Atlanterhav. Fund og Forskning i Det Kongelige Biblioteks Samlinger III, 91-102.

Kiilerich, A.B. 1939: The Godthaab Expedition. A theoretical treatment of the hydrographical observation material. Meddelelser om Grønland 78, 5, 149 pp.

Knuth, E. 1958: Archaeology of the Musk-ox Way. Proceedings of the thirty-second International Congress of Americanists, 1956. Copenhagen.

Knuth, E. 1967: The Ruins of the Musk-ox Way. Folk 8-9, 191- 219.

Koch, J.P. & Wegener, A. 1930: Wissenschaftliche Ergebnisse der dänischen Expedition nach Dronning Louises Land und quer über das Inlandeis von Nordgrönland 1912-13. Meddelelser om Grønland 75, 676 pp.

Kollmeyer, R.C. 1980: West Greenland outlet glaciers: An inventory of the major iceberg producers. International Association of Hydrological Sciences, Publication 126, 57-65.

Krabill, W., Abdalati, W., Frederick, E., Manizade, S., Martin, C., Sonntag, J., Swift, R., Thomas, R., Wright, W. & Yungel, J. 2000: Greenland Ice Sheet: high Elevation Balance and Peripheral Thinning. Science 289, 428-430.

Kristensen, R.M. 2000: Liv på Indlandsisen. In: Jakobsen, B.H., Böcher, J., Nielsen, N., Guttesen, R., Humlum, O. & Jensen, E. (eds): Topografisk Atlas, Grønland, 154-155. Copenhagen: Det Kongelige Danske Geografiske Selskab & Kort- og Matrikelstyrelsen.

Kuijpers, A., Lloyd, J.M., Jensen, J.B., Endler, R., Moros, M., Park, L.A., Schulz, K., Jensen, K.G. & Laier, T. 2001: Late Quaternary circulation changes in Disko Bugt and adjacent fjords, central West Greenland. Geology of Greenland Survey Bulletin 189, 41-47.

Lambeck, K. & Chappell, J. 2001: Sea level change through the Last Glacial cycle. Science 292, 679-686.

Lambrecht, A., Mayer, C., Oerter, H. & Nixdorf, U. 1999: Investigations on the mass balance of southeastern Ronne Ice Shelf, Antartica. Annals of Glaciology 29. 250-254.

Langgård, K. 1999: Fishermen are Weaklings: Perceptions of Fishermen in Atuagalliutit before the First World War. In: Marquardt, O., Holm, P. & Starkey, D.J. (eds): From sealing to fishing. Studia Atlantica 4, 40-61.

Larsen, H. & Meldgaard, J. 1958: Paleo-Eskimo Cultures in Disko Bugt, West Greenland. Meddelelser om Grønland 161, 2, 75 pp.

Larsen, H.C., Saunders, A.D., Clift, P.D., Beget, J., Wei, W., Spezzaferi, & ODP Leg 152 Scientific Party 1994: Seven Million Years of Glaciation in Greenland. Science 264, 952-955.

Laursen, D. 1950: The Stratigraphy of the marine Quaternary Deposits in West Greenland. Meddelelser om Grønland 151, 1, 142 pp.

Lettréguilly, A., Huybrechts, P. & Reeh, N. 1991: Steady-state characteristics of the Greenland ice sheet under different climates. Journal of Glaciology 37, 149-157.

Lidegaard, M. (ed.) 1988: Efterretninger om Grønland, uddragne af en journal holden fra 1721 til 1788 af Poul Egede. Det Grønlandske Selskabs Skrifter 29, 203 pp. (Original edition 1788).

Lingle, C.S. 1978: Tidal flexure of Jakobshavns Glacier. West Greenland. Unpublished masters thesis. University of Maine, Orono, Maine.

Lingle, C.S. 1985: Effect of relative sea-level change on Holocene retreat of a marine ice stream in West Greenland. EOS, Transactions, American Geophysical Union 66, 932 only.

Lingle, C.S., Hughes, T., Thomas, R. & Kollmeyer, R. 1979: Tidal flexure of Jakobshavn. EOS, Transactions American Geophysical Union 61, 49 only.

Lingle, C.S., Hughes, T. & Kollmeyer, R. 1981: Tidal flexure of Jakobshavns Glacier, West Greenland. Journal of Geophysical Research B86, 3960-3968.

List, F.K. & Stäblein, G. 1978: Satellitenbild Diskobugt/Westgrönland. Polares Meer und Arktische Landschaft zwischen Diskoinsel und Inlandeis. Die Erde 109, 122-135.

Lliboutry, L. 1998: Glaciers of Chile and Argentina. In: Williams, R.G. & Ferrigno, J.G. (editors): Satellite Image Atlas of glaciers of the world. South America. U.S. Geological Survey, Professional Papers 1386-I, 1109-1206.

Loewe, F. 1969: Calving from floating glaciers, comments on Dr. Reeh's paper. Journal of Glaciology 8, 321-322.

Long, A.J. & Roberts, D.H. 2001: Holocene glacial History of Disko Bugt, West Greenland: Implications for the Dynamics of the Jakobshavn Ice Stream. Palaeo-ice stream International Symposium, Århus, 17-20 October 2001. Abstracts, 46 only.

Long, A. J., Roberts, D.H. & Wright, M.R. 1999: Isolation basin stratigraphy and Holocene relative sea-level change on Arveprinsen Ejland, Disko Bugt, West Greenland. Journal of Quaternary Science 14, 323-345.

Luchitta, B.K., Rosanova, C.E. & Mullins, K.F. 1995: Velocities of Pine Island Glacier, West Antarctica, from ERS-1 SAR images. Annals of Glaciology 21, 227-283.

Luchitta, B.K. & Rosanova, C.E. 1997: Velocities of Pine Island and Thwaites Glaciers, West Antarctica, from ERS-1 SAR images. ESA Publication SP-414, 3rd ERS-1 Symposium, Space of the Service of Our Environment, Florence, Italy. 17-21 March 1997.

Madsen, L.D. 2000: Fiskeriafhængighed, entreprenørskab og konsumfisk: Kolonibestyrer Poul Müllers eksport af hellefisk fra Ilulissat/Jakobshavn 1892-1901. Publikationer fra Institut for Geografi og Internationale Udviklingsstudier, Roskilde Universitetscenter 160, 145 pp.

Manson, R., Coleman, R., Morgan, P. & King, M. 2000: Ice velocities of the Lambert Glacier from static GPS observations. Earth Planets Space 52, 1031-1036.

Marquardt, O. 1992: Socio-økonomiske tilstande i Vestgrønland på Rinks tid: Befolkningskoncentrationen i kolonibyer og dannelse af lokale "Brædtmarkeder", 147-183. Nuuk: Ilisimatusarfik/Atuarkkiorfik.

Marquardt, O. 1997a: Indkomstspredning i Vestgrønland i anden halvdel af 1800-tallet, 45-68. Nuuk: Ilisimatusarfik/Atuarkkiorfik.

Marquardt, O. 1997b: KGH og de canadiske handelskompagnier: en historisk sammenligning. In: Thuesen, S. (ed.): Kalaallit Nunaanni niuerneq umiartornerlu/Grønlands handel og søfart, 185-203. Seminar at Sisimiut Museum 1995. Sisimiut: Sisimiut Museum.

Marquardt, O. 1998: Lønarbejderne som overklasse – om den grønlandske arbejderklasse i 1800-tallet. Tidskrift for Historie, kultur og politik 1998, 1-14.

Marquardt, O. 1999a: An introduction to Colonial Greenland's Economic History. In: Marquardt, O., Holm, P. & Starkey, D.J. (eds): From sealing to fishing. Studia Atlantica 4, 7-17.

Marquardt, O. 1999b: The Importance of Fish in the Greenlanders' Everyday Economy: the Moravian Congregations of South Greenland, 1850-1880 In: Marquardt, O., Holm, P. & Starkey, D.J. (eds): From sealing to fishing. Studia Atlantica 4, 18-39.

Marquardt, O. & Caulfield, R.A. 1996: Development of West Greenlandic Markets for Country Foods Since the 18th Century. Arctic 49, 107-119.

Tourists visiting front of iceberg

Photo: Dieter Zillman/Greenland Tours Elke Meissner

Marquardt, O., Holm, P. & Starkey, D.J. (eds) 1999: From sealing to fishing: social and Economic Change in Greenland, 1850-1940. Studia Atlantica 4, 106 pp.

Mathiassen, T. 1927: Archaeology of the Central Eskimos, I-II. Report of the Fifth Thule Expedition 1921-24, 4, 1-2, 332 + 208 pp. Copenhagen: Gyldendal.

Mathiassen, T. 1958: The Sermermiut Excavations 1955. Meddelelser om Grønland 161, 3, 52 pp.

Maxwell, M.S. 1985: Prehistory of Eastern Arctic. Orlando: Academic Press. 327 pp.

Meier, M.F. 1994: Columbia Glacier during rapid retreat. Interaction between glacier flow and iceberg calving dynamics. In: Reeh, N. (ed.): Workshop on the calving rate of West Greenland Glaciers in Response to climate change, 13-15 September 1993, 63-85. Copenhagen: Danish Polar Center.

Meldgaard, J. 1984: Qajâ, en køkkenmødding i dybfrost. Feltrapport fra arbejdsmarken i Grønland. Nationalmuseets Arbejdsmark 1983, 83-96.

Meldgaard, J. 1991: Bopladsen Qajaa i Jakobshavn Isfjord. Grønland 4-5-6-7, 191-205.

Meldgaard, M. 1986: The Greenland caribou - zoogeography, taxonomy, and population dymamics. Meddelelser om Grønland, Bioscience 20, 88 pp.

Mercer, J. 1961: The estimation of the regimen and former firn limit of a glacier. Journal of Glaciology 3, 1053-1062.

Mosbech, A. & Boertmann, D. 1999: Distribution, abundance and reaction to aerial surveys of post breeding King Eiders (Somateria spectabilis) in western Greenland. Arctic 52, 188-203.

Mountfield, D. 1974; A History of Polar Exploration, 208 pp. London: Hamlyn.

Møbjerg, T. 1983: An Ethno-archaeological Investigation of the Sermermiut Settlement, West Greenland. Folk 25, 23-50.

Møbjerg, T. 1986: A Contribution to Paleoeskimo Archaeology in Greenland. Arctic Anthropology 23, 19-56.

Møbjerg, T. 1997: New aspects of the Saqqaq Culture in West Greenland. In: Gilberg, R. & Gulløv, H.C. (eds): Fifty Years of Arctic Research. Anthropological Studies From Greenland to Siberia, 227-236. Copenhagen: Nationalmuseet. Ethnographical Series 18.

BRASH ICE IN THE ICEFJORD

Photo: Jakob Laurrup, GEUS

Nielsen, N. 2000: En galopperende gletscher på Disko. In: Jakobsen, B.H., Böcher, J., Nielsen, N., Guttesen, R., Humlum, O. & Jensen, E. (eds): Topografisk Atlas, Grønland, 122-123. Copenhagen: Det Kongelige Danske Geografiske Selskab & Kort- og Matrikelstyrelsen.

Nordenskiöld, A.E. 1870: Redogörelse för 1870 års expedition til Grönland. Öfversigt Kungliga VetenskabsAkademiens Förhandlingar 1870, 10, 973-1082.

Nordenskiöld, A.E. 1886. Grönland, seine Eiswüsten im Inneren und seine Ost-küste. Schilderung der zweiten Dickson'schen Expedition ausgeführt im Jahre 1883, 505 pp. Leipzig: Rock haus.

Olsen, B. 1998: Saqqaq housing and settlement in southern Disko Bay area of western Greenland. Acta Borealia 15, 129-138.

Ostermann, H. 1941: Træk af Kolonien Jakobshavns Historie gennem 200 Aar 1741-1941. Det grønlandske Selskabs Skrifter 11, 171 pp.

Ostermann, H., Porsild, M.J. & Krogh, J.: Jakobshavn Distrikt. In: Amdrup, G.C., Bobé, L., Jensen, A.S. & Steensby, H.P. (eds): Grønland i Tohundredaaret for Hans Egedes Landing. Meddelelser om Grønland 60, 151-208.

Overgaard, S. 1981: Radio-echosounding in Greenland. Data Catalogue 1974: Electromagnetic Institute, Technical University of Denmark, 104 pp.

PARCA investigators 2001: Mass balance of the Greenland Ice Sheet (PARCA). Journal of Geophysical Research 106, D24, 33689-34058.

Peary, R.E. 1898. Northward over the "great ice". 1, 1: Reconnaissance of the Greenland Inland Ice 1886, 40 pp. London: Methuen & Co.

Pelto, M.S., Hughes, T. & Brecher, H. 1989: Equilibrium state of Jakobshavns Isbræ, West Greenland. Annals of Glaciology 12, 127-131.

Pfeffer, W.T., Cohn, J., Meier, M. & Krimmel, R.M 2000: Alaskan glacier beats a dramatic retreat. EOS, Transactionso of the American Geophysical Union. 81, 48, p. 577 & 584.

Porsild, M.P. 1921a: Dyrelivet og Havets Dyreliv. In: Amdrup, G.C., Bobé, L., Jensen, A.S. & Steensby, H.P. (eds): Grønland i Tohundredaaret for Hans Egedes Landing. Meddelelser om Grønland 60, II, 101-104.

Porsild, M. P. 1921b: Dyreliv. In: Amdrup, G.C., Bobé, L., Jensen, A.S. & Steensby, H.P. (eds): Grønland i Tohundredaaret for Hans Egedes Landing. Meddelelser om Grønland 60, II, 164-167.

Rabot, C. 1891: Une Excursion au Groenland. Le glacier de Jakobshavn. Tour du Monde 31, II, 305-320.

Rasmussen, R.O. 1998: Food consumption patterns – the importance of local markets in the Arctic, 58 pp. Arbejdspapir 137/NORS Paper 40, Publikationer fra Geografi, Roskilde Universitetscenter.

Reeh, N. 1968: On the calving of ice from floating glaciers and ice shelves. Journal of Glaciology 7, 215-232.

Reeh, N. 1969: Calving from floating glaciers: a reply to Professor Loewe´s comments. Journal of Glaciology 8, 322-324.

Reeh, N. 1983: Ikke-stationær beregningsmodel for Indlandsisens randzone. Grønlands Geologiske Undersøgelse Gletscher-hydrologiske Meddelelser 83/7, 81 pp.

Reeh, N. 1985a: Ice sheet dynamic modelling with engineering applications: a non-steady state ice flow model for the marginal zone of the Greenland ice sheet. Proceedings, 8th international Conference on Port and Ocean Engineering under Arctic Conditions, Narssarssuaq, 1985, 3, 1328-1329.

Reeh, N. 1985b: Long calving waves. Proceedings, 8th international Conference on Port and Ocean Engineering under Arctic Conditions, Narssarssuaq 1985, 3, 1310-1327.

Reeh, N. 1994: Calving from Greenland glaciers: Observation Balance Estimates of Calving Rates, Calving Laws, In: Reeh, N. (ed.): Workshop on the Calving Rate of West Greenland Glaciers in Response to climate change 13-15 september 1993, 85-109. Copenhagen: Danish Polar Center.

Reeh, N. & Engelund, F. 1971: Longperiod waves generated by calving glaciers. Proceedings from the First International Conference on Port and Ocean Engineering under Arctic Conditions 2, 1257-1261.

Reeh, N., Oerter, H., Lettréguilly, A., Miller, H. & Hubberten, H.W. 1991: A new, detailed ice-age oxygen-18 record from the ice sheet margin in central West Greenland. Palaeogeography, Palaeoclimatology, Palaeoecology (Global and Planetary Change Section) 90, 373-383.

Reeh, N., Thomsen, H. H., Oerter, H. & Bøggild, C. E. 1994: Surface topography, ice ablation, ice deformation and velocity along the Paakitsoq profile sampling line. In: Thomsen, H.H. & Reeh, N. (eds): Field report on palaeo-environmental studies at the Greenland ice sheet margin. Paakitsoq, West Greenland. Open File Series Grønlands Geologiske Undersøgelse 94/15, 20-29.

Reeh, N., Mayer, C., Miller, H., Thomsen, H.H. & Weidick, A. 1999: Present and past climate control on fjord glaciations in Greenland: implications for IRD-deposition in the sea. Geophysical Research Letters 26, 1039-1042.

Reimar, J. 1887: Sinerissame avangnâp tungâne ukívingnit univkât, ukioq 1884 Jânuâre 1. [=Fortællinger fra vinterpladserne langs kysten mod nord, år 1884, 1. januar]. Atuagagdliutit, no. 2, October 13. 17-25.

Riget, F. & Boje, J. 1988: Fishery and some biological aspects of Greenland halibut (Reinhardtius hippoglossoides) in West Greenland waters. NAFO Scientific Council Studies 13, 41-52.

Rignot, E.J. 1998: Fast recession of a West Antarctic Glacier. Science 281, 549-551.

Rink, H. 1853: Om den geographiske Beskaffenhed af de danske Handelsdistrikter i Nordgrönland, tilligemend en Udsigt over Nordgrønlands Geognosi. Det Kongelige Danske Videnskaberns Selskabs Skrifter, 5. Række, naturvidenskabelige og mathematiske Afdeling 3, 37-70.

Rink, H. 1857: Grønland geografisk og statistisk beskrevet, vol. 1: Det nordre Inspectorat, 420 pp, vol. 2: Det søndre Inspectorat, 588 pp. Copenhagen: Andr. Fred. Høst.

Rink, H. 1862: Om Vandets Afløb fra det Indre af Grønland ved Kilder under Isen. Naturhistorisk Tidsskrift 5. Række, 1B, 1-17.

Rink, H. 1875: Om Grønlands Indland og Muligheden for at berejse samme. Videnskabens Verden, 2. 3, 1-51.

Rink, H. 1877a: Danish Greenland, Its People and its Products, 468 pp. London: Henry S. King.

Rink, H. 1877b: Bemærkninger om de grønlandske Jøklers Bevægelse og Produktion af svømmende Isfjelde. Det Kongelige Danske Videnskabernes Selskabs Forhandlinger 1877, 1-9.

Rink, H. 1888: Nogle Bemærkninger om Indlandsisen og Isfjeldenes Oprindelse. Meddelelser om Grønland 8, 273-279.

Robin, G. de Q. 1979: Formation, Flow and disintegration of ice shelves. Journal of Glaciology 24, 259-271.

Rosanova, C.E., Luchitta, B.K. & Ferrigno, J.G. 1998: Velocities of Thwaites Glacier and smaller glaciers along the Marie Byrd Land coast, West Antarctica. Annals of Glaciology 27, 47-53.

Ross, J. 1819: A Voyage of Discovery, made under the orders of the Admirality, in His Majesty's ships Isabella and Alexander, for the purpose of exploring Baffin's Bay, and inquiring into the probability of a North-West Passage, 252 pp. London: Murray.

Ryhdal, K. & Heide-Jørgensen, M.P. 2001: Hvidbog om hvidhvaler: Rapport til fangerne i Grønland om den videnskabelige viden om hvidhvaler. Teknisk rapport fra Pingortitaleriffik/Grønlands Naturinstitut 35, 32 pp.

Scholander, P.F. & Nutt, D.C. 1960: Bubble pressure in Greenland icebergs. Journal of Glaciology 3, 671-678.

Scofield, J.P., Fastook, J.L. & Hughes, T.J. 1991: Evidence for a frozen bed, Byrd Glacier, Antarctica, Journal of Geophysical Research 96, 11649-11655.

Simonsen, C.S. & Boje, J. 1999: An Assessment of the Greenland Halibut Stock. Component in NAFO Division 1A Inshore Dartmouth, 1999, 24 p. NAFO Scientific Council Reports and Documents 99/48, 24 only.

Simonsen, C.S. & Boje, J. 2001: An Assessment of the Greenland Halibut Stock Component in NAFO Division 1A Inshore. NAFO Scientific Council Reports and Documents 01/68.

Simonsen, C.S. & Roepstorff, A. 2000: Udviklingen og adfærd af fisk og fiskere i Diskobugt området. In: Holm, M. & Rasmussen, R.O. (eds): Udviklingsforskning, udviklingspolitik og udviklingsenterprise – 3 faktorer i det grønlandske samfunds forandring og udvikling. Inussuk – Artisk forskningsjournal 1, 29-42.

Smidt, E.L.B. 1969a: The Greenland halibut, Reinhardtius hippoglossoides (Walb.), biology and exploitation in Greenland waters. Meddelelser fra Danmarks Fiskeri- og Havundersøgelser, New series 6, 4, 79-147.

Iceberg, with former water lines carved into the basal parts

Photo: Jakob Lautrup, GEUS

Smidt, E. 1969b: Hellefisken (I-II). Grønland 1969, 257-270 and 353-366.

Sohn, H.G., Jezek, K.C. & van der Veen, C.J. 1997a: Seasonal variations in terminus position of Jakobshavn Glacier, West Greenland. In: van Der Veen, C.J. (ed.): Calving Glaciers. Report of a Workshop February 28 to March 2, 1997. Byrd Polar Research Center Report 15, 137-140.

Sohn, H.G., Jezek, K.C. & van der Veen, C.J. 1997b: Jakobshavn Glacier, West Greenland: 30 years of space-borne observations. Geophysical Research Letters 25, 2699-2702.

Stove, G.C., Green, K., Birnie, R.V., Davidson, G., Bagot, K. Palmer, M., Kearn, G., Ritchie, P.F.S. & Sugden, D.E. 1983: The use of Landsat data to monitor iceberg production; monitoring iceberg production from West Greenland tidewater glaciers using Landsat data. Results of the AGRISPINE experiment for the Jakobshavn Isbræ. Macaulay

Institute for Soil Research, Craigiebuckler, Aberdeen, Scotland and the National Remore Sensing Centre, Space and New Concepts Department, Royal Aircraft Establishment, Farnborough, Hampshire, England, 32 pp.

Swithinbank, C. 1988: Antarctica. In: Williams, R. & Ferrigno, J.G. (eds): Satellite Image Atlas of the World. U.S. Geological Survey, Professional Paper 1386-B, 278 pp.

Thalund, S. 2000: Moderne Turisme i Sisimiut In: Jakobsen, B.H., Böcher, J., Nielsen, N., Guttesen, R., Humlum, O. & Jensen, E. (eds): Topografisk Atlas, Grønland, 236-237. Copenhagen: Det Kongelige Danske Geografiske Selskab & Kort- og Matrikelstyrelsen.

Thomas, R.H., Jezek, K.C., Wilson, D., Krabill, W. & Kuivinen, K. 1992: Changes in the surface topography of the Jakobshavn Glacier. EOS, Transactions American Geophysical Union 73, 43 (Supplement), 175 only.

Thomas, R.H., Krabill, E & Frederick, J.K. 1995: Thickening of Jakobshavn Isbræ, West Greenland, measured by airborne laser altimetry. Annals of Glaciology 21, 259-262.

Thomas, R.H., Atkins, T., Csato, B., Fahnstock. M., Gogineni, P., Kim, C. & Sonntag, J. 2000: Mass Balance of the Greenland Ice Sheet at High Elevations. Science 289, 426-428.

ART OF THE ARCTIC

Photo: Jakob Lautrup, GEUS

Thomas, R.H. and PARCA Investigators 2001: Program for Arctic regional climate assessment (PARCA): goals, key findings, and future directions. Journal of Geophysical Research 106, D24, 33691-33705.

Thomsen, H.H. 1983: Glaciological applications of Landsat images in connection with hydropower investigations in West Greenland. Proc. EARSel/ESA Symposium on Remote Sensing Applications for Environmen-tal Studies. Special Publication European Space Agency 188, 133-136.

Thomsen, H.H. 1986a: Mass balance measurements at the margin of the Inland Ice near Jakobshavn, West Greenland. Polarforschung 54, 37-41.

Thomsen, H.H. 1986b: Is og Vand kraft/Glaciology and Hydropower. The Geological Survey of Greenland. Gletscher-hydrologiske Meddelelser 86/2, 73 pp.

Thomsen, H.H. 1988: Mapping and modelling of glacier drainage in the Pakitsoq basin, central West Greenland. Rapport Grønlands Geologiske Undersøgelse 140, 114-117.

Thomsen, H.H. 2000: De blå floders land. In: Jakobsen, B.H., Böcher, J., Nielsen, N., Guttesen, R., Humlum, O. & Jensen, E. (eds): Topografisk Atlas, Grønland, 100-101. Copenhagen: Det Kongelige Danske Geografiske Selskab & Kort- og Matrikelstyrelsen.

Thomsen, H.H. & Olesen, O.B. 1991: Hydraulics and hydrology on the Inland Ice. Rapport Grønlands Geologiske Undersøgelse 152, 36-38.

Thomsen, H.H., Thorning, L & Braithwaite, R. 1988: Glacier-hydrological conditions on the Inland Ice north-east of Jakobshavn/Ilulissat, West Greenland. Rapport Grønlands Geologiske Undersøgelse 138, mapsheet.

Thomsen, H.H., Thorning, L & Olesen, O.B. 1989: Applied glacier research for planning hydro-electric power, Ilulissat/Jakobshavn, West Greenland. Annals of Glaciology, 13, 257-261.

Thorning, L. & Hansen, E. 1987: Electromagnetic reflection survey 1986 at the Inland Ice margin of the Pakitsoq basin, central West Greenland. Rapport Grønlands Geologiske Undersøgelse 135, 87-95.

Thorning, L. & Hansen, E. 1988: Construction and testing of a light weight radar for ice-thickness determinations on glaciers in the Pakitsoq area, central West Greenland. Rapport Grønlands Geologiske Undersøgelse 140, 116-121.

Turner, J.T., Levinsen, H., Nielsen, T.G. & Hansen, B. 2001: Zooplankton feeding ecology: grazing on phytoplankton and predation on protozoans by copepod and barnacle nauplii in Disko Bay, West Greenland. Marine Ecology, Progress Series 221, 209-219.

UNESCO 2002: http://www.wcmc.org.uk/protected_areas/data/wh/glacbay.html.

Van der Veen, C.J. 2001: Greenland ice sheet response to external forcing. Journal of Geophysical Research 106, D24, 34047-34058.

Vaughan, D.G. & Bamber J.L. 1998: Drainage basin analysis and improved calculation of balances for West Antarctic ice streams and glaciers. Abstract of the AGU Chapman conference on the West Antarctic Ice Sheet, Orono, September 1998.

Venkatesh, S. 1986: On the deterioration of a grounded iceberg. Journal of Glaciology 32, 161-167.

Wadhams, P. 2000: Ice in the Ocean, 351 pp. Amsterdam: Gordon and Breach Science Publishers.

Wahr, J., van Dam, T., Larson, K. & Francis, O. 2001: GPS measurements of vertical crustal motion in Greenland. Journal of Geophysical Research 106, D24, 33755-33759.

Walløe, P.O. 1927: Peder Olsen Walløes Dagbøger fra hans Rejser i Grønland 1739-53. Det Grønlandske Selskabs Skrifter 5, 127 pp.

Warren, C.R. 1994: Climatic versus topographic controls on glacier calving. In: Reeh, N. (ed.): Workshop on the Calving Rate of West Greenland Glaciers in Response to climatic Change, 13-15 September 1993, 111-139. Copenhagen: Danish Polar Center.

Warren, C.R. & Hulton, N.R.J. 1990: Topographic and glaciological controls on Holocene ice-sheet margin dynamics, central West Greenland. Annals of Glaciology 14, 307-310.

Weertmann, J. 1980: Bottom crevasses. Journal of Glaciology 25, 185-188.

Weidick, A. 1966: Jakobshavn Isbræ i Fortid og Nutid. Grønland 1966, 361-386

Weidick, A. 1969: Investigations of the Holocene Deposits around Jakobshavns Isbræ, West Greenland. In: Péwé, T.L. (ed.): The Periglacial Environment, 249-261. Montreal: McGill-Queens University Press.

Weidick, A. 1988: Surging glaciers in Greenland – a status. Rapport Grønlands Geologiske Undersøgelse 140, 106-110.

Weidick, A. 1992: Jakobshavn Isbræ area during the climatic optimum. Rapport Grønlands Geologiske Undersøgelse 155, 67-72.

Weidick, A. 1994: Fluctuations of West Greenland calving glaciers. In: Reeh, N. (ed.): Workshop on the Calving Rate of West Greenland Glaciers in Response to climatic Change 13-15 September 1993, 141-168. Copenhagen: Danish Polar Center.

Weidick, A. 1995: Greenland. In: Williams, R.S. & Ferrigno, J.G. (eds): Satellite Image Atlas of Glaciers of the World. U.S. Geological Survey, Professional Paper 1386-C, 141 pp.

Weidick, A. 2000: Jakobshavn Isbræ – Grønlands største Kalvisproducent. In: Jakobsen, B.H., Böcher, J., Nielsen, N., Guttesen, R., Humlum, O. & Jensen, E. (eds): Topografisk Atlas, Grønland, 112-115. Copenhagen: Det Kongelige Danske Geografiske Selskab & Kort- og Matrikelstyrelsen.

Weidick, A., Oerter, H., Reeh, N., Thomsen, H.H. & Thorning, L. 1990: The recession of the Inland Ice margin during the Holocene climatic optimum in the Jakobshavn Isfjord area of West Greenland. Palaeogeography, Palaeoclimatology, Palaeoecology (Global and Planetary Section) 82, 389-399.

Weidick, A., Bøggild, C.E. & Knudsen, N.T. 1992: Glacier inventory and atlas of West Greenland. Rapport Grønlands Geologiske Undersøgelse 158, 194 pp.

Weng, W. 1995: The area of Greenland and the ice cap. Letter to the editor. Arctic 40, 206 only.

Whillans, I. & van der Veen, C.J. 1993: New and improved determinations of velocity of Ice streams B and C, West Antarctica, Journal of Glaciology 39, 483-490.

Williams, R.S. & Hall, D.K. 1998: Use of remote-sensing technique. In: Haeberli, W., Hoelzle, M. & Suter, S. (eds): Into the second century of world wide glacier monitoring – prospects and strategies. A contribution to the International Hydrological Programme (IHP) and the Global Environment Monitoring System (GEMS). Unesco Publishing, Studies and Reports in Hydrology 56, 97-111.

Young, N.W., Goodwin, I.D., Hazelton, N.W.J. & Thwaites, R.J. 1989: Measures velocities and ice flow in Wilkes Land, Antarctica. Annals of Glaciology 12, 192-197.

Zwally, H.J. & Giovinetto, M.B. 2001: Balance mass flux and ice velocity across the equilibrium line in drainage systems of Greenland. Journal of Geophysical Research 106, D24, 33717-33728.

7.d. Addresses where inventory records and archives are held

Important records for the Ilulissat Icefjord area are held at the following locations:

Greenland Home Rule,
Ministry of Environment and Nature
Box 1614
DK-3900 Nuuk
Greenland

Municipality of Ilulissat
Noah Mølgårdsvej 9
DK-3952 Ilulissat
Greenland

Greenland National Museum and Archives
Box 145, Hans Egedesvej
DK -3900 Nuuk
Greenland

Greenland Institute of Natural Resources
(Pinngortitaleriffik)
Postboks 570
DK- 3900 Nuuk,
Greenland

Geological Survey of Denmark and Greenland (GEUS)

Øster Voldgade 10
DK-1350 Copenhagen K
Denmark

National Environmental Institute (DMU/ NERI)
P.O. box 358
Frederiksborgvej 399
DK-4000 Roskilde
Denmark

8. Signature on behalf of the State Party

Date

Brian Mikkelsen
Minister of Culture

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Joel Berglund, Mag. Art. The Greenland National Museum and Archives, Nuuk, Greenland
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Erik Buch, Lic. Scient., Danish Meteorological Institute, Copenhagen, Denmark
Søren Bundgård, Ilulissat Board of Trade and Commerce, Ilulissat, Greenland
Carl Egede Bøggild, Lic. Scient., Geological Survey of Denmark and Greenland, Copenhagen, Denmark
Adam Garde, Dr. Scient., Geological Survey of Denmark and Greenland, Copenhagen, Denmark
Jon Feilberg, Cand. Scient., Biomedia, Haraldsted, Denmark
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Willy Weng, Cartographer, Geological Survey of Denmark and Greenland, Copenhagen, Denmark
Anker Weidick, Dr. Phil., Geological Survey of Denmark and Greenland, Copenhagen, Denmark

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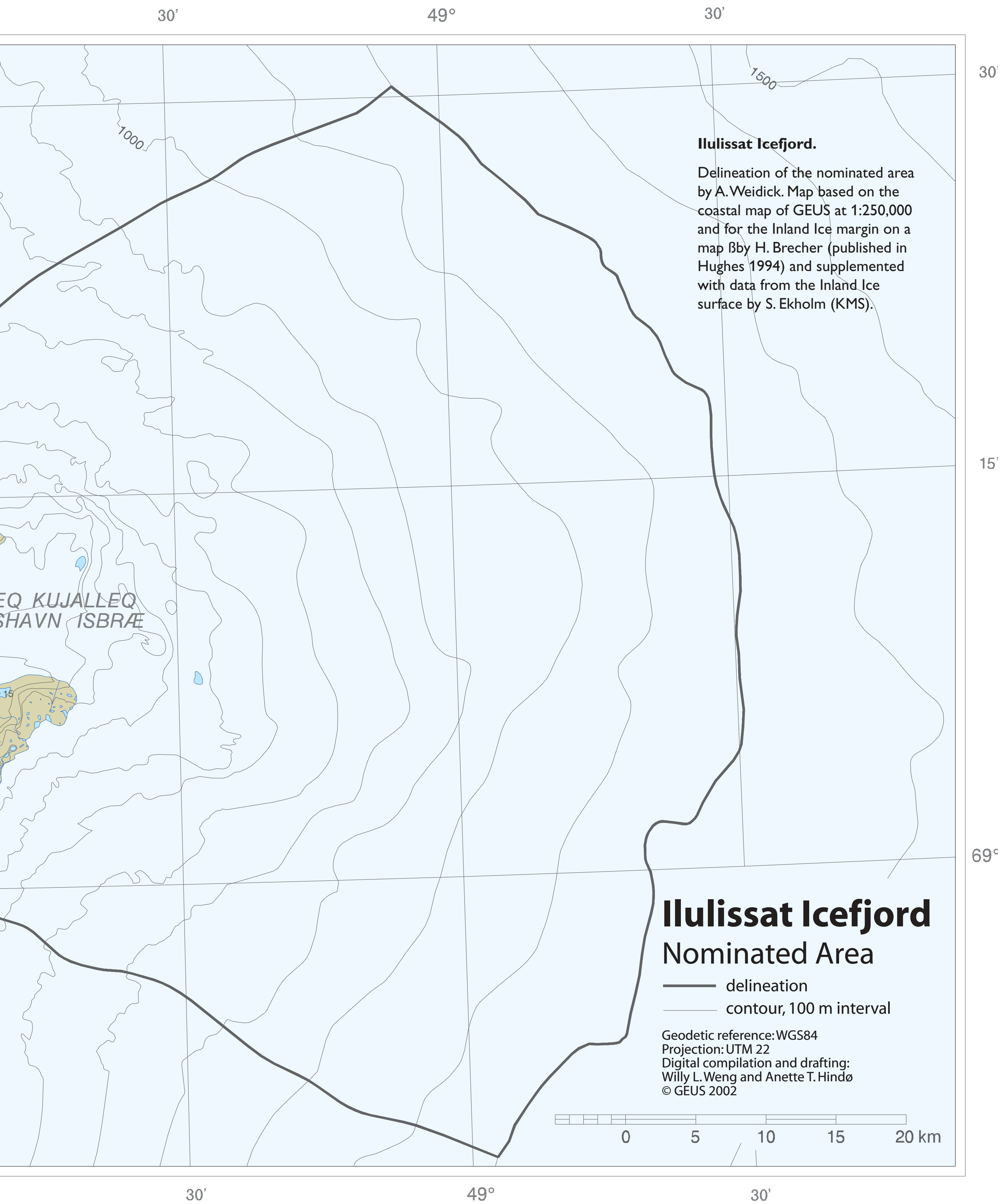
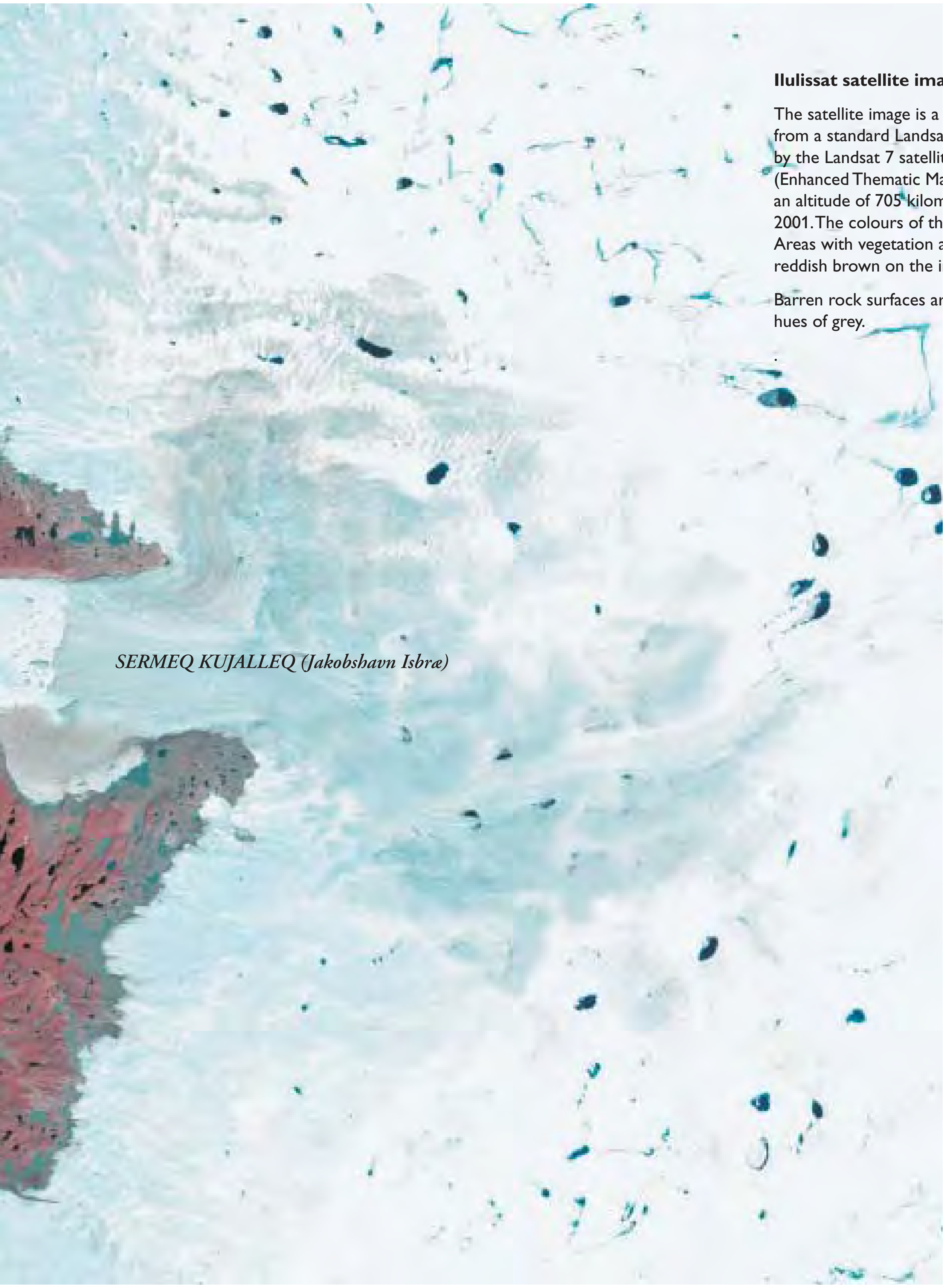
51°
30'
50°
30'
15'
69°
Alluttoq
Klokkerhuk
Paakitsoq
Paakitsup Ilorlia
PAAKITSUP
NUNAA
OQAATSUT
RODEBAY
Tasersuaq
Sermeq Avannarleq
Nunatap
NUNATARSUAQ
Sikuiuitsoq
ILULISSAT
JAKOBSHAVN
KANGIA
ILULISSAT ICEFJORD
SERME
JAKOBS
EQI
AVANNARLIIT
NORDRE HUSE
ILIMANAQ
CLAUSHAVN
Tasiusaq
ISUA
Akullinngiluaq
Salliaruseq
Saqqarleq
Qallunaat
Nunaat
Naajannguit
Mågefjeld
Akiamiut
OQERERSUAQ
ALANNGORLIUP SERMIA
SAQQARLIUP SERMIA
Qeqertasussuk
Jakobsholm
Eqaluit Laksebugt
Angiarliup
Tunulia
Oqaatsuarsuit
Rypeholm
KANGILINAAQ
500

Appendix 1


30'
49°
30'
30'
15'
69°
1000
1500
EQ KUJALLEQ
SHAVN ISBRÆ
Ilulissat Icefjord.
Delineation of the nominated area by A. Weidick. Map based on the coastal map of GEUS at 1:250,000 and for the Inland Ice margin on a map ßby H. Brecher (published in Hughes 1994) and supplemented with data from the Inland Ice surface by S. Ekholm (KMS).
Ilulissat Icefjord
Nominated Area
delineation
contour, 100 m interval
Geodetic reference: WGS84
Projection: UTM 22
Digital compilation and drafting:
Willy L. Weng and Anette T. Hindø
© GEUS 2002
0
5
10
15
20 km
30'
49°
30'


Ilulissat
KANGIA (Ilulissat Icefjord)

Appendix 2



Ilulissat satellite image

The satellite image is a mosaic compiled from a standard Landsat 7 scene, acquired by the Landsat 7 satellite using its ETM+ (Enhanced Thematic Mapper) sensor from an altitude of 705 kilometres on 7th July 2001. The colours of the image are artificial. Areas with vegetation appear brown or reddish brown on the image.

Barren rock surfaces are characterised by hues of grey.

Appendix 3

Draft for approval

Greenland Home Rule executive order no. nn of xx.xx.2003 on the protection of Ilulissat Icefjord

In accordance with §§ 3 and 9 of the Home Rule Law ("Landstingslov") no. 11 of the 12th of November 1980 on nature conservation in Greenland, it is stipulated that:

§ 1. Kangia, Ilulissat Icefjord and the surrounding area, located in the Municipality of Ilulissat, is formally recognised as a protected area on the basis of the natural beauty of the landscape, the aim being to preserve the natural, cultural and aesthetic values of the area. The protection order shall safeguard the area against attrition, as well as ensuring the development potential of traditional hunting/fishing activities in the area.

Section 2. The area is defined as belonging to IUCN category V, following the 1994 definitions.

Section 3. The borders of the protected area are shown on the map in Appendix 1.

Section 4. An area of 1100 m² at 69° 12'23''N, 51° 07'23''W, close to the town of Ilulissat, is excluded from the protection order for the purpose of a proposed visitors centre.

§ 2. It is forbidden, within the protected area, to undertake actions or activities that would impinge on or alter the unique natural landscape of the area, or in any way result in a deterioration of the cultural, natural and recreational values and integrity of the area (see, however, §§ 3, 4, 5, 6, 9, 10, 14 and 15).

§ 3. The general public has access to the protected area under the conditions laid down in this executive order.

§ 4. Camping and the use of open fires is permitted for a maximum of three days at any one locality, in relation to recreational activities and professional hunting/fishing in the protected area.

Section 2. The location of permanent campsites for hunting activities is stipulated by the Directorate for Nature and Environment, after consultation with the Ilulissat municipal authorities, as laid down in the Management Plan for the protected area.

§ 5. Hunting cabins must only be used as support bases for fishing and hunting. It is forbidden to use the hunting cabins as permanent residences.

Section 2. Existing hunting cabins can remain and be main tained. The Directorate for Nature and Environment has the right, after consultation with the Ilulissat municipal authorities, to give permission for the erection of new hunting cabins to replace the existing cabins.

§ 6. Tourist cabins must only be used as support bases for outdoor activities. It is forbidden to use the tourist cabins as permanent residences.

Section 2. Tourist cabins can only be erected in the two areas designated for this purpose.

Section 3. Up to seven single-storey tourist cabins may be built in each of the designated areas.

Section 4. Paths within the areas designated for the tourist cabins can be surfaced with gravel.

Section 5. A helicopter landing place can be established in association with each of the areas designated for the tourist cabins.

§ 7. The location of the hunting and tourist cabins must be chosen so as to cause the least possible intrusion on the natural landscape of the protected area.

§ 8. The materials, colours and style of construction of the hunting/fishing and tourist cabins shall be chosen so as to blend, as far as possible, into the natural surroundings.

Section 1. The plans with respect to location and construction must be approved by the Directorate for Nature and Environment, after consultation with the Ilulissat municipal authorities.

§ 9. It is forbidden to use motorised transport within the protected area.

Section 2. Motorised transport to and from the Icefjord in connection with professional hunting/fishing activities is permitted on the routes defined by the Ilulissat municipal authorities.

§ 10. Use of boats within the protected area is permitted.

Section 2. Storage of boats in the protected area is not permitted. Following consultation with the Ilulissat municipal authorities, the Directorate for Nature and Environment can give permission for the storage of boats that are necessary for the professional hunting/fishing activities in the protected area.

§ 11. Use of helicopters in the protected area is permitted on concessionary flight routes and in connection with emergency search-and-rescue operations. Following consultation with the Ilulissat municipal authorities, the Directorate for Nature and Environment can give permission for helicopter flights and landings in the protected area.

Section 2. Helicopter flights to and from the tourist cabin sites are permitted, conditional on the flight route being direct to the cabin site.

§ 12. Cycling is not permitted within the protected area.

§ 13. Within the protected area, it is forbidden to pollute lakes, streams, fjords, glaciers or land areas in any way or form, or to leave behind any form of rubbish, used fishing tackle, markers or scientific equipment.

Section 2. It is forbidden to damage the vegetation or the terrane within the protected area.

Section 3. The terrain and/or vegetation must be reinstated following construction work in relation to the hunting cabins and the tourist cabins and their associated helicopter landing places.

Section 4. It is not permitted to utilise the vegetation for fuel, unless in relation to the traditional preparation of food associated with professional hunting/fishing.

§ 14. Fishing and hunting is permitted within the protected area, subject to the relevant rules stipulated in this executive order or in other Home Rule legislation.

§ 15. Following consultation with the Ilulissat municipal authorities, the Directorate for Nature and Environment can give dispensation from the stipulations laid down in § 2, §§ 4–6 and §§9–15.

§ 16. Contravention of §§ 2, 4, § 5 section 1, §6 sections 1 and 4, §§ 7–9, § 10 section 2 and §§ 13 –14 can lead to a fine.

§ 17. The executive order comes into force on the xx.xx 2003

Greenland Home Rule, xx. xx 2003

/Hans Høyer

Appendix 4

Management plan for Ilulissat Icefjord

Translated from the Danish version

"Forvaltningsplan for Ilulissat Isfjord".

Approved by the Municipal Council of Ilulissat November 25, 2002

I General description of the protected area

1. Administrative data

Name of the protected area:
Ilulissat Isfjord.

Area:

Ice	*c.* 3199 km^2
Land free of ice	*c.* 397 km^2
Lakes	*c.* 42 km^2
Fjord	*c.* 386 km^2
Total area:	***c.* 4024 km^2**

Location:
The protected area is bounded by the following lines of latitude: 69°31′ and 68°48′ N and lines of longitude 48°28′ and 51°16′ W.

The exact delineation of the area is shown on the map in Appendix 1 in this publication on pages 120–121.

Administrative authorities:
Community of Ilulissat.
Greenland Home Rule
Ministry of Environment and Nature.

2. The decisions of The Greenland Home Rule, and the Community of Ilulissat concerning the protected area

The Greenland Home Rule executive order regarding the protection of Ilulissat Icefjord (Appendix 1) is being prepared to be put before the Parliament.

The Ilulissat municipal authorities passed the present management plan on November 25, 2002.

3. Aim of the management plan

The aim of the present management plan is to ensure natural and cultural values in the protected area at Ilulissat Icefjord. The management plan also provides the framework for continued development of traditional hunting and fishing, as well as the activities of the tourism industry.

In general, the aims concerning the protection of natural and cultural values in the area are:

- To protect the values that are connected to the nomination of the area for inclusion in the UNESCO World Heritage List, i.e. the glaciology and the beauty of the landscape.
- To protect the natural vegetation and the cultural remains against attrition.
- To protect birds and mammals in the area against unnecessary disturbance.

In general, the aims with respect to activities in the area are that:

- Hunting and fishing shall continue, so that this unique example of the Greenlandic hunting/fishing tradition can retain a viable future, both economically and culturally.
- Tourism in the area shall be developed in such a way that the visitor can appreciate and learn about the cultural and natural values of the area.
- The citizens of the community of Ilulissat should be able to use the area for recreational purposes, while the opportunities for them to learn about the natural and cultural values shall be optimised.

4. Description of natural and cultural values, and industrial activities in, and adjacent to, the protected area

A detailed description of the natural and cultural values, as well as the importance of the area to the hunting, fishing and tourism industry, is to be found in the nomination of the Ilulissat Icefjord for inclusion on the UNESCO World Heritage List (This publication).

4.1. Hydroelectric power potential at Pakitsoq, north of the protected area

In the late 1980s, major efforts were made to investigate the potential for the development of hydroelectric power schemes at Pakitsoq, north of the protected area. Part of the catchment area of the proposed dammed reservoir lies under/on the Inland Ice. There is no overlap, however, between the northern boundary of the protected area and the southern limit of the catchment area. It is concluded, therefore, that such a project, should it be realised, would have no implications for the catchment areas within the protected zone. Furthermore, electrical power lines from the proposed hydroelectric scheme would not cross the protected area.

In any event, subsequent to these viability studies in the 1980s, politicians abandoned the idea of a hydroelectric installation at Pakitsoq.

4.2. Mineral exploitation

Minerals have never been exploited commercially in the protected area. Surveys made by GEUS in the area in July 2002 did not reveal any mineral deposits of potential commercial interest at present.

II Plans related to the area

1. Hunting and Fishing industry

Professional hunting and fishing activities in the area mainly revolve around the Greenland halibut, although birds and, in particular, ringed seals are also hunted. The fishery is either done from boats or from the ice using dog sledges for transportation.

In general, the aim of the management plan with respect to these activities in the area is that hunting and fishing should continue to retain a viable future, both economically and culturally, for the citizens of the Ilulissat and Qasigiannguit communities, in tune with the natural and cultural values of the area. It is also deemed important, however, that the harsh working conditions experienced by the hunters and fishermen in the Icefjord area should be improved.

It is thus the intention to organise a sustainable system of waste disposal, to erect hunters cabins and to establish facilities for the collection and transport of fish to Ilulissat.

1.1. Transportation

Travel to and from the fishing grounds in the Icefjord is undertaken by boat when ice conditions permit; at other times, the dog sledge is the sole means of transport.

1.1.1. Dog sledge

The protected area contains a number of traditional unmarked dog sledge routes (see figure 42 on page 79 of this publication). The exact position of these routes may change a little, depending on the prevailing snow conditions. The routes form an important element in the cultural history of the area, and are thus of great conservation value.

All existing dog sledge routes shall be kept in their present condition i.e. as unmarked sledge routes. Furthermore, dog sledges can be used throughout the protected area and are not restricted to the traditional routes shown on figure 42 on page 79 of this publication.

1.1.2. Boat

When ice conditions in the Icefjord are favourable, travel to and from the fishing grounds can be undertaken by boat. Under such conditions, collection boats are allowed into the area to collect the catch both from those fishing from dog sledges on the ice and from small fishing boats in the fjord.

1.2. Permanent constructions

In order to improve the working conditions for fishermen and hunters in the area, it will be permitted to renovate the existing huts or to replace them with new constructions. The cabins can be used for overnight stops and for the storage of equipment

In the Isua area, in the southern part of the area, the construction of new hunting cabins will be allowed.

Permanent campsites can also be identified, in the event of hunting trips of longer duration.

1.2.1. Hunting and fishing cabins

Cabins shall primarily be used in connection with hunting and fishing, as an alternative to camping.

The cabins shall be built with due consideration for the beauty of the landscape. With respect to colour and style of construction, the cabins should uphold the style typical of Greenlandic cabins of this type, as shown on page 133 of this publication. This applies both to new constructions and renovations of existing cabins.
All rubbish must be stored and disposed of responsibly, both at new and existing cabins. Thus, a fox- and windproof room for waste storage shall be constructed at all hunting and fishing cabins in the area.

All the cabins in the area should contain a stove for the burning of paper, cardboard and other environmentally neutral waste materials.

At least once a year, the local authorities (Ilulissat) will inspect the cabins and ensure that rubbish is being dealt with in a responsible manner, and that non-burnable waste is transported back to Ilulissat.

1.2.2. Permanent campsites

Permanent campsites can only be used in connection with fishing and hunting activities in the area. Storage of equipment or rubbish is only allowed for persons using the campsites.

Users of the site have full responsibility for keeping the site clean, and for transporting waste materials back to Ilulissat.

The local authorities of Ilulissat will inspect the campsites on an annual basis.

1.3. Transportation of Greenland halibut by tracked vehicle

The use of tracked vehicles to drive from Ilulissat to the fishing grounds is permitted when ice conditions preclude sailing on the Icefjord. The tracked vehicle should be used to transport the catch back to Ilulissat, and hence relieve dogs and fishermen from this exhausting work. This will also result in a more efficient exploitation of the catch, and thus improve the economy of the individual fishermen.

Use of tracked vehicles is restricted to the dog sledge routes used in connection with fishery activities; driving on the fjord ice is not allowed.

Individual rocks/boulders obstructing the route can be removed by blasting but building activities should be kept to an absolute minimum.

The tracked vehicles can also be used to transport rubbish from the hunters cabins in the area to Ilulissat.

The tracked vehicle may only carry passengers in the event of an emergency. The tracked vehicles may only be used on frozen and snow-covered ground.

Use of the tracked vehicles for activities other than those mentioned above requires special permission from the Community of Ilulissat.

2. Tourism

The general aim regarding tourism is to create an infrastructure that provides the visitor with an overview, and improve their understanding, of the natural and cultural values of the protected area. This development must, however, be undertaken in such a way as to conserve the natural and cultural values of the area.

Specific measures include the maintainance and construction of hiking paths, the erection of information boards, the construction of two groups of cabins at Nunartarsuaq with a helicopter landing place at each, and the creation of a visitors centre.

The coastal area of Isua, south of the Icefjord, shall be protected from development of any kind of tourist infrastructure.

2.1. Transportation

Due to its size, the harsh climate and the wilderness character of the area, it is unlikely that more than a very few tourists will embark on independent hiking or skiing trips of any length. If it is to be possible, therefore, for the average tourist to experience more than a minor fraction of the area, it will be necessary to provide alternative forms of transport.

2.1.1. Hiking

In that part of the protected area that lies close to Ilulissat, a number of marked hiking routes are to be found. These routes are marked by paint flashes on natural rock outcrops/boulders. In addition, unmarked hiking routes are indicated on hiking maps available from Greenland Tourism; these trails extend deep into the more remote parts of the protected area. In order to protect the wilderness character of the area, the number of marked hiking routes will be kept as low as possible. Thus, new marked trails will only be created in areas where it is judged to be absolutely necessary to prevent attrition etc.

2.1.1.1. Marked paths and hiking routes

In order to control the pedestrian traffic, and thereby protect the vegetation and archaeological remains, a number of marked paths have been constructed in the Sermermiut valley.

New marked paths will be constructed in areas where it is deemed necessary to control the walkers.

Marked paths are to be identified by paint on natural rock outcrops/boulders. Marking of paths by the use of poles or signs is discouraged and should only be used where absolutely necessary.

Supervision and maintenance of existing paths is the responsibility of the Community of Ilulissat. New marked paths can only be constructed by permission of the city council of Ilulissat.

2.1.1.2. Unmarked hiking routes

Existing unmarked hiking routes shown on the Greenland Tourism hiking map in the area west of Sikuiutsoq and at Ilimanaq are to be retained in this form. On new editions of the map a number of unmarked trails to areas of special interest on Nunartarsuaq as well as new routes at Ilimanaq may be included; the Isua area will be kept free from any type of hiking routes. The location of the new hiking routes will be finalised in connection with the construction of the tourist cabins on Nunartarsuaq.

2.1.2. Dog sledge routes

Transportation of tourists on dog sledges will continue on the existing sledge routes (Appendix 2). Dog sledge tourism represents an important link with the traditional culture and provides tourists with the possibility to experience the landscape in the protected area while at the same time providing an insight into the traditional hunting and fishing activities in Greenland.

2.1.3. Boat traffic

Only the outer parts of the Icefjord are navigable, and even here sailing is impossible for most of the year due to the ice conditions. In order to give hikers the possibility to reach Nunartarsuaq, smaller boats can be stored at Sikuiuitsoq, albeit with due consideration to the natural surroundings.

The boat storage sites must not be used for the storage of rubbish or other equipment, such as food, tents etc. To avoid attrition at the storage sites, camping is only allowed at a distance of more than 500 metres from the storage sites. The owners of the stored boats are responsible for the maintenance of the sites. The Community of Ilulissat will make at least one annual inspection.

2.1.4. Helicopter

For the majority of tourists intending to visit the ice margin and Sermeq Kujalleq, helicopter is the only possible means of transport. Two helicopter landing places will be constructed in association with the planned tourist cabins. The landing places will be marked with painted stones and may, if necessary, be paved with gravel, in order to avoid attrition.

The tour guide is responsible for keeping the landing places free of rubbish. If there are no guides on the flight, this responsibility falls on the helicopter pilots.
The Community of Ilulissat will inspect the landing places annually for signs of attrition and poor rubbish management.

2.2. Accommodation

There are only two possibilities for tourists who want to stay overnight in the protected area, camping in tents or staying in cabins.

2.2.1. Tourist cabins

Two groups of cabins, each with seven cabins, will be erected on Nunartarsuaq; each site will be equipped with a helicopter-landing place.

The Community of Ilulissat is responsible for the construction*) of the cabins. They shall be constructed according to the concept agreed upon by the city council, with respect to architecture, colour and use of materials, so that the cabins are compatible with the natural surroundings and the Greenland building style as shown on page 133 of this publication.

The Community of Ilulissat also has the responsibility to ensure that the marked paths in the vicinity of the cabins are constructed in such a way as to avoid attrition of the vegetation.

The Community of Ilulissat offers the right to use the cabins to the tourist industry. Companies who want to use the huts shall conform to the following demands:

- All generated rubbish should be carried back to Ilulissat on each return flight.
- The contents of the latrine should be buried at the designated site prior to the departure of each group of guests to Ilulissat.

In addition, the companies shall provide a written record of their activities on Nunartarsuaq. In this report, the following shall be recorded for each stay in the cabins.

1. Date, number of guests, and length of stay.
2. An account of the tourist activities during the stay.
3. An account of procedure with respect to latrines and waste disposal/transport to Ilulissat.

**) the community can give concessions for the construction of one or more cabins, so long as the concession agreement is drawn up such that the community retains ownership, also in the event of bankruptcy, and can terminate the agreement at any time in the event of non-fulfilment.*

4. Relevant observations of wildlife and plants.
5. Other observations.

A resumé and a copy of the report should be delivered to the Community of Ilulissat, on the 1st of December each year.

The Community of Ilulissat will inspect the cabins and the surrounding area annually.

The Community of Ilulissat has the power to extend permits or ban a company from using the cabins, on the basis of the submitted records and the annual inspection.

Prior to the construction of the cabins, the concept will be tested with permanent tents – partly to guage the degree of interest in extended stays in the area and partly to evaluate the impact on the surrounding environment. On the basis of this trial period, a decision will be made concerning the erection of the huts, and the number of huts (up to a maximum of seven at each site).

2.2.2. Camping

Camping is permitted anywhere in the protected area so long as the campsite is not used for more than three consecutive nights. "Semi-permanent" base camps are thus not allowed in the area in connection with tourist activites.

2.3. Information boards and visitors centre

The information boards that are planned for the area will provide the visitors with an insight into the natural surroundings and the culture of the area, and rules concerning behaviour, restricted areas etc. In addition, a visitors centre is planned.

2.3.1. Signboards and other means of information

Information boards on archaeology and tourist behaviour at an archaeological site will be erected at Sermermiut. The information will be given in Greenlandic, Danish and English.

Information boards will be placed at major arrival routes/sites (helicopter landing places, dog sledge routes and hiking routes), at boat storage sites and at tourist cabins. The boards will give information concerning standards of behaviour in the protected area, and give general information about natural and cultural values. Folders with the same information will be made available for tourists at all hotels, youth hostels etc.

Information boards will be constructed and placed in the landscape so as to cause the least possible disturbance to the wilderness character of the area.

The Community of Ilulissat will include information about the protected area on its homepage.

2.3.2. Visitors centre

A visitors centre is currently in a planning phase. The goal is that such a centre, through exhibitions and other activities, will reinforce the knowledge of, and interest in, the natural surroundings and cultural values of the Icefjord area.

In connection with the protected area, such a construction is only permitted in the northern part of the Sermermiut valley; the construction and form of the centre should be compatible with the surrounding landscape.

3. Recreational activities

Recreational activities in the protected area presently enjoyed by the inhabitants of Ilulissat will continue as hitherto, regarding hunting, cross-country skiing, hiking, sailing or dog sledging. To ensure local support for the protection of the Icefjord, it is essential that the improved infrastructure and increased level of information resulting from the increased tourist activities be also of direct benefit to the citizens of Ilulissat.

3.1. Information

Information boards and other sources of information mentioned will be in Greenlandic, Danish and English.

A folder on the protection of the area and its implications will be delivered to each household in the community on the date on which the protection of the area comes into force.

The proposed visitors centre shall not only focus on the information needs of the tourists, but also on information and activities relevant to the citizens of Ilulissat.

3.2. Cross-country skiing

The Community of Ilulissat is responsible for the preparation of cross-country skiing routes. Some of the routes traverse parts of the protected area close to Ilulissat. The location of the routes varies from year to year, as a consequence of the prevailing snow conditions. The routes are prepared with a tracked vehicle.

The routes may only be prepared when the ground is frozen and covered with snow.

3.3. Hunting and hiking activities

Hunting and hiking activities can be performed as described in sections 1 and 2.

4. Other constructions and activities

It is permitted to construct a dirt road across the Sermermiut valley between the old heliport and the cemetery.

5. Management

5.1. Authorities responsible for the management of the protected area

The Community of Ilulissat is responsible for the day-today management of the protected area. The community has the administrative and economic responsibility for the management of the area, as described in the present management plan.

The Ministry for Environment and Nature (Greenland Home Rule) is responsible for the management of the area as described in the Home Rule executive order regarding protection of Ilulissat Icefjord.

5.2. Supervision

The Community of Ilulissat is responsible for the supervision of the protected area, as described in the present management plan.

A report shall be written in connection with each inspection in the area; a written record will also be made of any new arrangement or construction (hiking routes, information boards, cabins etc.), as well as any other important information regarding the area.

Supervision of hunting and fishing activities in the protected area remains the responsibility of rangers from Greenland Home Rule, the Directorate for Industry, as described in the Home Rule Executive Order nr. 28, 30. of October 1998, regarding the duties and rights of rangers.

The Directorate for Environment and Nature, representing the Greenland Home Rule, will undertake an annual inspection of the protected area.

6. Monitoring and science

The glaciology in the protected area is of major significance to science, and Sermeq Kujjaleq is one of the best investigated ice streams in the world. Future glaciological studies in the protected area shall receive the utmost support, insofar as the research is compatible with the natural and cultural values of the area.

Research into the flora, fauna, archaeology and geology of the area should also be supported.

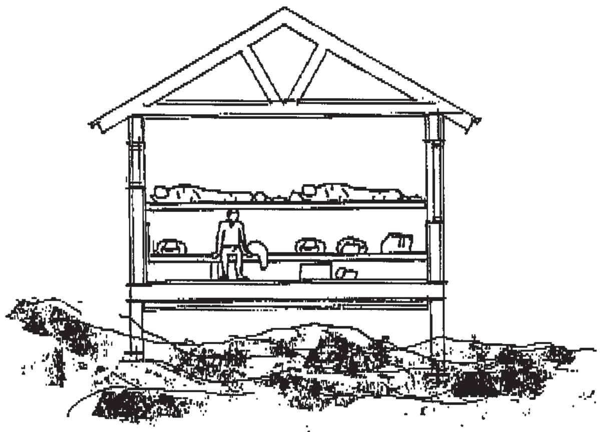
The Greenland Institute of Natural Resources frequently monitors the age distribution of the Greenland halibut population in the fjord. The resulting data represent an important tool in monitoring the implications of the ongoing fishery with respect to the population size, and should thus be supported by the management authorities.

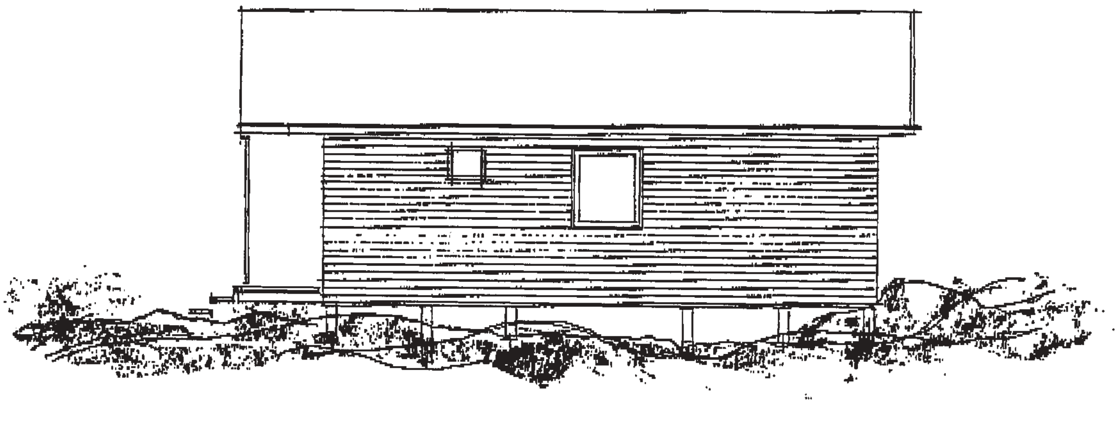
7. Funding for the management

Costs regarding the inspections in the protected area are covered by the Community of Ilulissat. Costs regarding the annual inspection made by the Directorate for Environment and Nature (Greenland Home Rule) and the rangers are covered by the Greenland Home Rule.
The Community of Ilulissat is financially responsible for the building and maintenance of huts and cabins and for maintenance of information boards and hiking routes.

Approved by the Municipal Council of Ilulissat November 25, 2002

Two groups of cabins will be erected on Nunartarsuaq. The cabins shall be constructed according to the concept agreed upon by the city council, with respect to architecture, colour and use of materials, so that the cabins are compatible with the natural surroundings and the Greenland building style





Source: 6B Ilulissat Arkitekter, Kjeld Kemp

Appendix 5

Resumé of the conservation plan for the archaeological site in the Sermermiut valley, Ilulissat Icefjord

Translated from the Danish report
Bopladsen ved Sermermiut i Ilulissat Kommune
Plan for restaurering og pleje af ruinområdet FM nr. 69V2-0II-013.

Udarbejdet for Grønlands Nationalmuseum og Arkiv af Hans Kapel, juni 2002

Background
Based on the fact that the archaeological remains in the Sermermiut valley are vulnerable to tourist-induced degradation, mainly in the form of attrition, a conservation plan for the preservation of the archaeological sites in the Sermermiut valley, Ilulissat Icefjord, has been formulated by the museum of Ilulissat and The National Museum and Archives of Greenland. The conservation plan (in Danish) was drafted during the summer of 2002 and has not yet been adopted nor funded. The resumé presented here provides the broad outlines of the proposed plan.

Introduction
The Sermermiut valley contains one of the most important archaeological sites in Greenland. Three different cultures, Saqqaq, Dorset and Thule have inhabited the area through 4500 years. Evidence of all three cultures can still be seen in the valley, in the form of old ruins and middens.The site is thus very popular with tourists even though many may have difficulties in appreciating the archaeology because most of remains are almost invisible to the layman. Nevertheless, the frequent visits are resulting in attrition at the site. Since tourism in the area is expected to grow in the future as a consequence of the general development of the region and possible inclusion in the UNESCO World Heritage List, the conservation plan aims to improve the infrastructure at the site.

Goals of the conservation plan
The conservation plan has the following goals:

- To improve the hiking trails from Ilulissat to Sermermiut. This will include a net of hiking routes in the area of the archaeological ruins, so that the visitors can better appreciate the archaeological heritage of the area
- To make an up-to-date survey of the archaeological remains
- To make some of the ruins more visible, so as to reveal the architecture of the different time periods/cultures
- To improve the level of information to the visitors, by placing notice boards at the entrance to the area and providing folders and other information material

In addition to enhancing the experience gained by visitors to the area, the measures outlined above are aimed to reduce attrition of the vegetation and the archaeological ruins.

Time frame
Maintenance of the Sermermiut site, as suggested in the conservation plan, is an ongoing process. The plan, however, recognizes that some archaeological work and investigations need to be undertaken before the ruins can be made accessible to visitors. A framework has thus been drafted for a three-year project to ensure that the goals outlined above are achieved.

Appendix 6

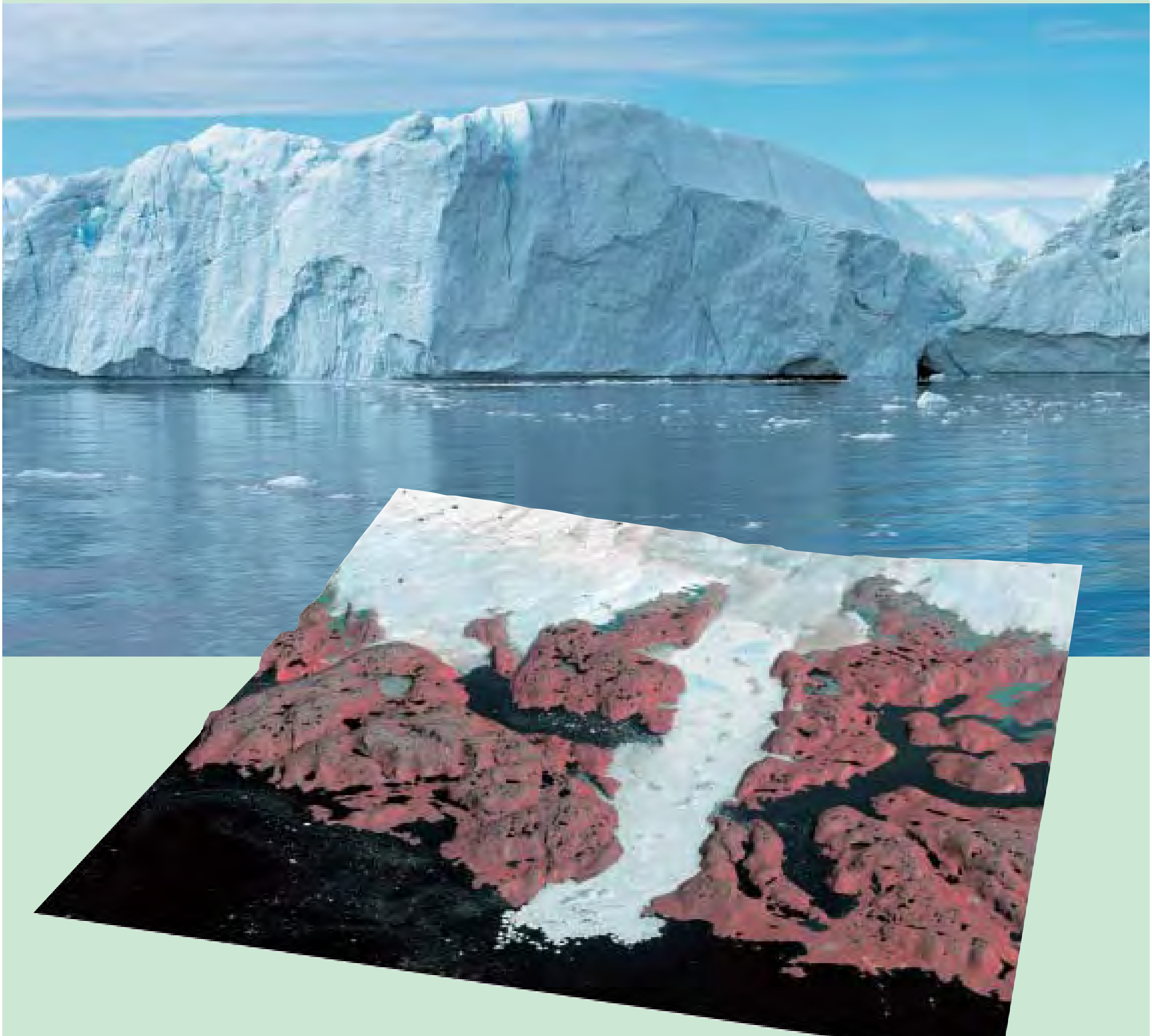
Plant list of the Ilulissat Icefjord area

Agrostis mertensii	Mountain bent
Agrostis hyperborea	Brown bent
Alopecurus alpinus	Alpine foxtail
Antennaria canescens	Greenland cat's-paws
Antennaria ekmanniana	Labrador cat's-paws
Antennaria porsildii	Porsilds cat's-paws
Arabis alpina	Alpine rock-cress
Arenaria humifusa	Dwarf sandwort
Armeria scabra	Thrift
Arnica angustifolia	Alpine arnica
Artemisia borealis	Northern wormwood
Bartsia alpina	Alpine bartsia
Betula nana	Dwarf birch
Calamagrostis langsdorfii	Bluejoint
Calamagrostis stricta	Narrow small-reed
Callitriche anceps	Two edged water-starwort
Callitriche hermaphroditica	Autumnal water-starwort
Callitriche palustris	Lesser water-starwort
Campanula gieseckiana	Arctic harebell
Campanula uniflora	Arctic bellflower
Capsella bursa-pastoris	Shepherd's purse
Cardamine bellidifolia	Alpine bittercress
Cardamine pratensis	Mountain cuckooflower
Carex stans	Water sedge
Carex bicolor	Bicoloured sedge
Carex bigelowii	Stiff sedge
Carex arctogena	Capitate sedge
Carex gynocrates	Arctic dioecious sedge
Carex misandra	Short-leaved sedge
Carex glareosa	Gravel sedge
Carex holostoma	Forked sedge
Carex lachenalii	Hare's-foot sedge
Carex maritima	Curved sedge
Carex microglochin	Bristle sedge
Carex nardina	Nard sedge
Carex norvegica	Close-headed alpine-sedge
Carex rariflora	Mountain bog-sedge
Carex rupestris	Rock sedge
Carex saxatilis	Russet sedge
Carex scirpoidea	Scirpoid sedge
Carex supina	Steppe sedge
Cassiope hypnoides	Matted cassiope, Moss heather
Cassiope tetragona	White Arctic bell-heather
Cerastium alpinum	Alpine mouse-ear
Cerastium arcticum	Arctic mouse-ear
Cochlearia groenlandica	Greenland scurvygrass
Cystopteris fragilis	Brittle bladder-fern
Diapensia lapponica	Diapensia
Diphasiastrum alpinum	Alpine-clubmoss
Draba cinerea	Gray whitlowgrass
Draba crassifolia	Dwarf whitlowgrass
Draba glabella	Smoothing whitlowgrass
Draba lactea	Lapland whitlowgrass
Draba nivalis	Snow whitlowgrass
Draba norvegica	Rock whitlowgrass
Dryas integrifolia	Entire-leaved mountain avens
Dryopteris fragrans	Fragrant buckler-fern
Eleocharis acicularis	Needle spike-rush
Elymus mollis	Lyme-grass
Empetrum nigrum ssp. hermaphroditum	Mountain crowberry
Epilobium latifolium	Broad-leaved willow-herb
Equisetum arvense	Common horsetail

Photo: Jakob Laurrup, GEUS

Equisetum variegatum	Variegated horsetail
Erigeron humilis	Unalaskan fleabane
Erigeron uniflorus	One-flowered fleaebane
Eriophorum angustifolium	Common cottongrass
Euphrasia frigida	Arctic eyebright
Festuca brachyphylla	Alpine fescue
Festuca rubra	Red fescue
Halimolobus mollis	Hooker's thale cress

Hierochloë alpina	Alpine holy-rass	*Ranunculus hyperboreus*	High-arctic buttercup
Hippuris vulgaris	Common mare's-tail	*Ranunculus lapponicus*	Lapland buttercup
Honckenya peploides	Sea sandwort	*Ranunculus nivalis*	Snow buttercup
Huperzia selago	Fir clubmoss	*Ranunculus pygmaeus*	Pigmy buttercup
Juncus arcticus	Arctic rush	*Ranunculus reptans*	Creeping spearwort
Juncus biglumis	Two-flowered rush	*Ranunculus confervoides*	Dwarf water-crowfoot
Juncus castaneus	Chestnut rush	*Rhododendron lapponicum*	Lapland rose-bay
Juncus triglumis	Three-flowered rush	*Rumex acetosella*	Sheep's sorrel
Kobresia myosuroides	Bellard's kobresia	*Sagina intermedia*	Snow pearlwort
Kobresia simpliciuscula	False sedge	*Salix arctophila*	Arctic marsh willow
Koenigia islandica	Iceland purslane	*Salix glauca*	Northern willow
Ledum palustre	Narrow-leaved Labrador-tea	*Salix herbacea*	Dwarf willow
Limosella aquatica	Mudwort	*Saxifraga aizoides*	Yellow saxifrage
Loiseleuria procumbens	Trailing azalea	*Saxifraga caespitosa*	Tufted saxifrage
Luzula confusa	Northern wood-rush	*Saxifraga foliolosa*	Grain saxifrage
Luzula groenlandica	Greenland wood-rush	*Saxifraga hyperborea*	Polar saxifrage
Luzula spicata	Spiked wood-rush	*Saxifraga nivalis*	Alpine saxifrage
Lycopodium annotinum ssp. alpestre	Interrupted clubmoss	*Saxifraga oppositifolia*	Purple saxifrage
Matricaria maritima	Sea mayweed	*Saxifraga paniculata*	White mountain saxifrage
Melandrium triflorum	Arctic lychnis	*Saxifraga rivularis*	Highland saxifrage
Melandrium affine	Three-flowered lychnis	*Saxifraga tenuis*	Pigmy alpine saxifrage
Minuartia biflora	Two-flowered sandwort	*Saxifraga tricuspidata*	Three-toothed saxifrage
Minuartia rubella	Mountain sandwort, reddish S.	*Scirpus caespitosus*	Deergrass
Montia fontana	Blinks	*Sedum villosum*	Hairy stonecrop
Oxyria digyna	Mountain sorrel	*Sibbaldia procumbens*	Sibbaldia
Papaver radicatum	Arctic poppy	*Silene acaulis*	Moss campion
Pedicularis flammea	Hairy lousewort	*Sparganium angustifolium*	Floating bur-reed
Pedicularis lapponica	Lapland lousewort	*Sparganium hyperboreum*	Northern bur-reed
Phippsia algida	Snow-grass	*Stellaria humifusa*	Low chickweed
Phyllodoce coerulea	Blue heath	*Stellaria longipes*	Long-stalked stitchwort
Pinguicula vulgaris	Common butterwort	*Subularia aquatica*	Awlwort
Plantago maritima	Sea plantain	*Taraxacum sp.*	Dandylion
Poa alpina	Alpine meadow-grass	*Thalictrum alpinum*	Alpine meadow-rue
Poa arctica	Arctic meadow-grass	*Tofieldia pusilla*	Scottish asphodel
Poa glauca	Glaucous meadow-grass	*Triglochin palustris*	Marsh arrow-grass
Poa pratensis	Smooth meadow-grass	*Trisetum spicatum*	Spiked oat-grass
Polygonum viviparum	Alpine bistort	*Utricularia ochroleuca*	Whitish bladderwort
Potamogeton pussilus	Small pondweed	*Vaccinium uliginosum ssp.microphyllum*	Arctic blueberry
Potentilla egedii	Pacific silverweed	*Vaccinium vitis-idaea ssp. minus*	Rock cowberry
Potentilla crantzii	Alpine cinquefoil	*Veronica alpina*	Alpine speedwell
Potentilla hookeriana	Hookers's cinquefoil	*Viscaria alpina*	Alpine catchfly
Potentilla hyparctica	Arctic cinquefoil	*Woodsia glabella*	Pigmy woodsia
Potentilla nivea	Snowy cinquefoil	*Woodsia ilvensis*	Oblong woodsia
Potentilla pulchella	Slender cinquefoil		
Potentilla tridentata	Three-toothed cinquefoil		
Puccinellia phryganodes	Creeping saltmarsh-grass		
Puccinellia vaginata	Sheated saltmarsh-grass		
Pyrola grandiflora	Large-flowered wintergreen		



The Greenland Inland Ice represents one of the major stages of Earth`s history. Greenland holds a remnant of the continental Ice Age ice sheet, which illustrates significant glacial and glacial-geological processes and formation of land forms related to this large ice sheet.

These processes represent the same principles as they did during the presence of the now disappeared Ice Age ice sheets in other glaciated part of the world, which where important in creating the landforms that can be seen in deglaciated areas all over the world today.

Thus ongoing moraine building, isostatic depression and uplift of the Earth´s crust and glacial erosion of fjords, troughs and valleys are processes which can be observed in many places in Greenland and especially in the region of the Ilulissat Icefjord.

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