Meddelelser om Grønland

The mummies from Qilakitsoq – Eskimos in the 15th century

compiled and edited by

J. P. Hart Hansen & H. C. Gulløv

Man & Society

12 · 1989

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See page 3 of cover.

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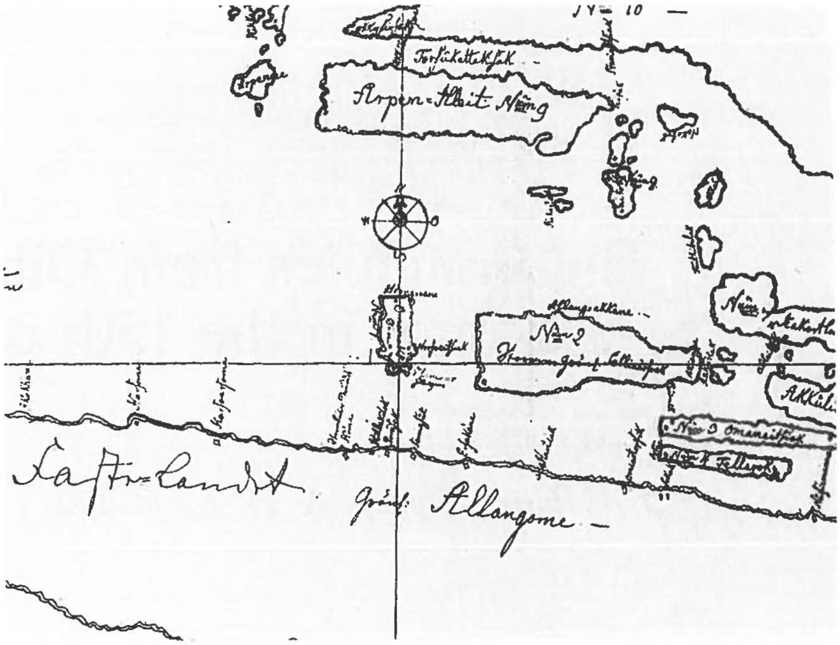
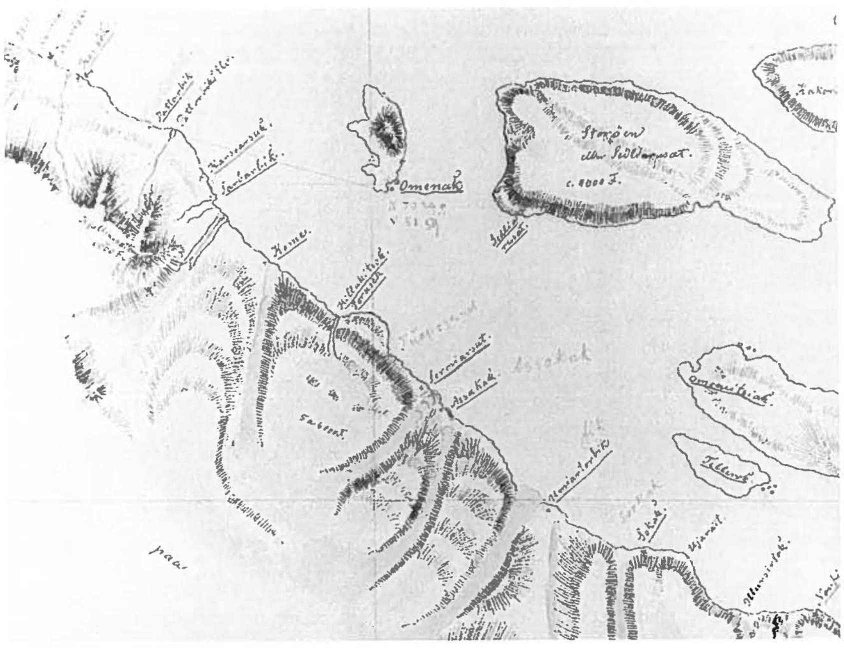


Missionary Peter Andreas von Cappelen's survey of Uummannaq Bay, 1789. The site "Killekitok" is situated on the midpoint of the southern coast-line.



Inspector Hinrich Johannes Rink's survey of Uummannaq Bay, 1850. The site "Killakitsok" is situated to the south of "Omenak"

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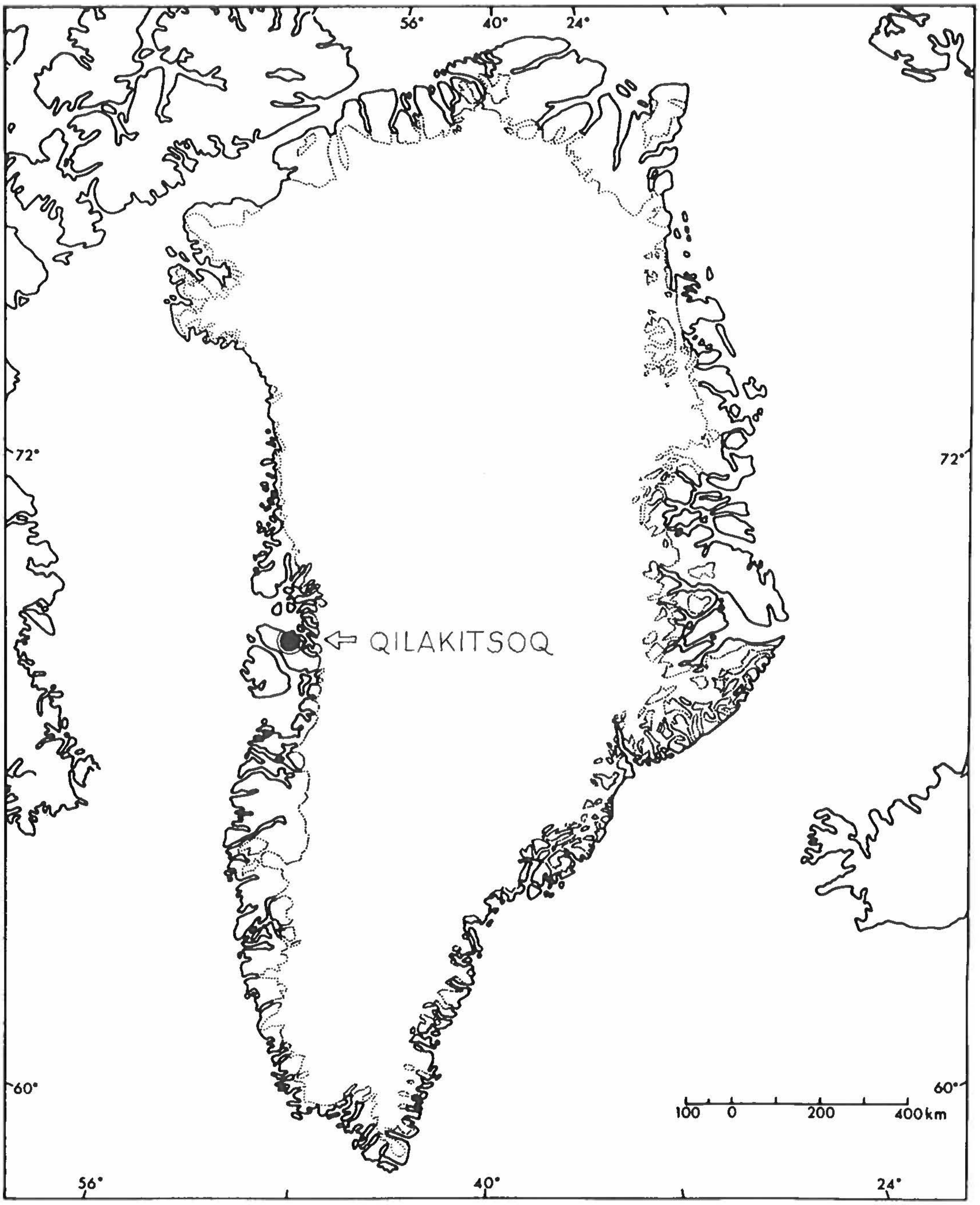

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Introduction

J. P. HART HANSEN, JØRGEN MELDGAARD & CLAUS ANDREASEN

Hart Hansen, J. P., Meldgaard, J. & Andreasen, C. 1989. Introduction.. – Meddr Grønland, Man & Soc. 12: 5–9. Copenhagen 1990–01–26.

This chapter outlines the story of the find of eigth 500-year-old mumified Eskimo bodies at Qilakitsoq in the Uummannaq district of Northwestern Greenland and of the interdisciplinary scientific investigations carried out by researchers in natural science, medicine, and cultural history as an introduction to a volume of 26 scientific reports.

J. P. Hart Hansen, Department of Pathology, Gentofte Hospital, DK-2900 Hellerup, Denmark. Jørgen Meldgaard, Department of Ethnography, The National Museum of Denmark, Ny Vestergade 10, DK-1471 Copenhagen K., Denmark. Claus Andreasen, The Greenland Museum, P.O.Box 145, DK-3900 Nuuk, Denmark (Greenland).

When the two Greenlandic brothers, Hans and Jokum Grønvold, chanced upon the mummified bodies of some deceased Eskimos in two graves in a rock cleft near the abandoned settlement Qilakitsoq in the Uummannaq district of Northwestern Greenland one fine October day in 1972, a fascinating process of interdisciplinary research began.

At first, nothing really happened besides registration of the find in the files of the Greenland Museum. Neither the extent of the find was known, nor the number of buried persons. In early 1978, however, the attention of the new director of the Greenland Museum, Jens Rosing, was drawn to the case and he decided to make a personal investigation of the site.

With Gerda Møller, Curator of the Danish National Museum in Copenhagen, he travelled to Qilakitsoq at Easter 1978, opened the graves, took samples for radio carbon dating, and brought the preserved, mummified bodies og two children, found just below the cap stones, to Copenhagen.

It was something of a sensation when the results of the radio carbon dating appeared. The find dated from about A.D. 1475 (+/÷ 50 years). These were thus the oldest well-preserved bodies in the whole arctic region – and more important still – they were fully dressed in equally well-preserved skin clothing. Moreover, a number of garments and pieces of skin were found in the graves. The find offered a unique opportunity for close insight into the clothing of the Thule culture, giving information about the style and the complicated cut of men's and women's garments and expanding our knowledge about the development of Eskimo culture.

Furthermore, the mummies had lived during the same period as the last Norse descendants of Erik the Red and his followers, who were then still living at the Eastern Settlement (Østerbygden) in Southwestern Greenland. The mummies could be regarded as real "flesh-and-blood" representatives of the *Skrellings* the Norse people had encountered on journeys in Greenland according to the Icelandic and Norwegian Sagas.

So far, it was not even known how many bodies the graves contained. The dating, however, resulted in a thorough investigation of the site the same year, and the graves were emptied. It turned out that the find consisted of eight fully clothed, mummified bodies – two children and six adult females, many loose garments (78 pieces all together), and a number of unprepared skins. Jens Rosing has given his description of Qilakitsoq and the find in a book illustrated with his own drawings (Rosing 1979, 1986).

The reason for the excellent condition of the find, the well-preserved human bodies as well as the totally intact garments, hides etc., was favourable local conditions. Low temperatures, low air humidity, protective sheltering against water (rain and snow) enhanced an extensive drying of the material (natural mummification) and stopped the decaying processes which need water and a temperature above + 4 degrees Celsius.

The Greenland Museum decided to bring the whole find to Copenhagen for restoration and conservation in the laboratories of the National Museum of Denmark. This procedure was adopted first and foremost because of the garments. At the same time, however, many questions arose about the background and origin of the deceased persons. How old were they? Were they males or females? What did they die of? Did they die simultaneously and were they buried at the same time? Did they suffer from any chronic diseases? Could we learn anything about their ways of life and culture through investigating the bodies? What did they eat and how was their life influenced by their environment compared to the present day?

This prompted the initiation of an extensive, interdisciplinary programme of scientific investigations utilizing the various methodologies of archaeology, ethnography, natural science, and medicine in a stimulating collaboration. An overview of the many different investigations was published in 1985 by the Greenland Museum in a popular book (Hansen *et al.* 1985). The book has appeared in Danish, Greenlandic, Norwegian, and Dutch editions so far. An article on the find and the investigations has also been published in the National Geographic Magazine (Hansen *et al.* 1985).

This volume of the Meddelelser om Grønland, Man & Society series presents the greater part of the scientific results. The chapter by Claus Andreasen, Director of the Greenland Museum, outlines the background of the find and presents the known archaeological facts. The people from Qilakitsoq are representatives of the Thule culture which flourished in Greenland from about the year A.D. 1000. Both firm and fainter traces of houses probably contemporary with the mummies have been found at the site.

The garments have provided us with much new information. Gerda Møller, Curator of the National Museum in Copenhagen, has compiled a comprehensive catalogue. The Eskimo clothing seems to have reached a peak in technical terms as early as the 15th century. It was the best clothing for living, hunting and travelling in the harsh climate of arctic Greenland. The women knew how to use the various types of animal skins available to give the highest degree of insulation while at the same time giving the body the opportunity to release surplus heat and avoid dangerous perspiration. In a way, Eskimo clothing expresses better than many words the experience and adaptability of the Eskimos, acquired through hundreds of years in the Arctic. This catalogue by Gerda Møller documents the garments of the Qilakitsoq mummies and is of value to ethnographers and others interested in arctic clothing. The material is provided with a basic description to facilitate more thorough comparative studies.

The paper by Mogens Bencard, Director of the Royal Collections at Rosenborg Palace in Copenhagen, puts the catalogue of the garments of the mummies in fascinating perspective by giving the first detailed description of a tankard and a cup from the 17th century, made of narwhal tusk, gold and silver, and ornamented with two small enamelled sculptures of Eskimos. The artist most probably had real Greenlandic Eskimos as models – three of the four who were brought from Greenland to Denmark against their will in 1654 by David Danell. Like the famous painting made in Bergen, Norway, in 1654 during the four Greenlanders' journey to Copenhagen, and a drawing published by Adam Olearius in his studies of the same Greenlanders in the new edition of his book *Beschreibung der muscowitischen und persischen Reise* in 1656, the sculptures show garments of exactly the same type as those found with the mummies from Qilakitsoq.

The investigation of the bodies themselves aroused great interest. It was decided from the beginning that the four best preserved bodies were to be preserved with the garments *in situ* for exhibition purposes. These bodies could only be investigated through non-invasive methods like radiographic examinations, although small samples of material were removed for various purposes through a small aperture made in the back. The remaining bodies were not particularly well-preserved, so the garments were removed before conservation. These cases presented the best opportunities for close investigation of preserved internal structures.

A number of papers present most of the investigations carried out on the human remains. Many questions were answered by the investigations but many new turned up.

The results of the investigations cannot be called sensational in any sense. However, the studies led to important interdisciplinary contacts and collaboration. During the work on the mummy find a few important new methods were developed for future investigations on similar ancient material, for example the indirect method of HLA typing mummified tissue (Hanna E. Hansen); the biochemical analyses of small pieces of animal skin, of diagnostic importance for the determination of species (T. Ammitzbøll and co-workers); and the photographic method of revealing tattoos on mummified skin (N. Kromann and co-workers). It must also be mentioned that through work on material from the mummies and supplementary present-day material from Greenland and Denmark Niels Foged was able to reject the importance often claimed for diatoms in the forensic diagnosis of drowning. It emerged that it was only possible to state the cause of death with a certain degree of probability in a few of the cases, possibly because the four best preserved bodies were not available for close examination. It was also impossible to determine with certainty if the deceased persons had died and were buried simultaneously or at intervals.

The involvement of other scientists like botanists, zoologists, and geologists in the investigations has also been of value. For example, the paper by Martin Ghisler, Director of the Greenland Geological Survey, shows us how stones and mineral fragments can give information about the mobility or social contacts of a local group of people within an area, when the necessary background knowledge of geological conditions is available.

One of the most important results of the whole Qilakitsoq investigation is undoubtedly that a 500-year-old body of reference material has been obtained for the evaluation of present and future environmental conditions in Greenland. The papers by P. Grandjean and J. C. Hansen and co-workers particularly stress this point. Their investigations support the supposition that toxic substances are ingested by the Greenlanders today at a much higher level than in the days of the Qilakitsoq mummies, and that important micronutrients are not as abundant in the daily diet as before. It seems that modern technology on the global plane and changes in the

Greenlandic cultural pattern towards the living habits of the modern westernized world may influence the state of health in Greenland in the long run. The Qilakitsoq reference material will be of the greatest value in future evaluations of the environmental impact on the population of the eastern Arctic.

As mentioned previously, the Qilakitsoq investigations have been interdisciplinary involving researchers and scientists within many different branches of cultural history, natural science, and medicine. The work has been stimulating and fruitful thanks to the dedicated and enthusiastic collaborators who nearly all undertook to conduct their investigations within their own financial frameworks. Sincere thanks are due to all collaborators in the investigations, to those who are publishing their results in the present volume, and to everybody who has in other ways participated in the project.

The work on the Qilakitsoq material is not over, however. Quite a few investigations are still being carried out, and new ones have started recently. From the very outset the field of immunological investigations of ancient human remains has been a promising and challenging one. It has, however, taken much time to get such work started. Among ongoing research projects the attempts to isolate human DNA from the mummy material must be mentioned. The researchers and scientists who have participated in the Qilakitsoq investigations are continuing their collaboration with the aim of throwing more light on man and his environment at all times in Greenland. The Qilakitsoq investigations centred on a restricted group of people from one period of time and from one distinct locality in Greenland. The continued and enlarged research project – Man and his Environment in Ancient Greenland – takes all ancient human remains from Greenland into consideration, with the aim of applying modern methods of cultural history, the natural sciences, and medicine to the material. This applies to Eskimo as well as Norse human remains. The first basic step in this work is a comprehensive registration of all human remains from Greenland, mostly skeletons and bones, in museums and institutions in Greenland, Denmark, and abroad in order to create a database and a catalogue combining available anthropological and archaeological information. Economic support for this work has been obtained in the form of a generous grant from the Top Foundation, supplemented by grants from the Qilakitsoq Foundation and the Greenland Home Rule Government.

We would like to end this introduction to this volume of scientific papers on the mummy find from Qilakitsoq by noting that the central part of the permanent exhibition area in the Greenland Museum in Nuuk/Godthåb, Greenland, is dedicated to this find. Here the garments can be studied, and three of the adult mummified women and a child about six months old are displayed.

Finally, we would like to thank Hans Christian Gulløv for his constant enthusiastic and constructive involvement in the realization of the popular book about the mummy find and this present volume, both of which have also benefited from his artistic abilities.

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Mummy I/1. Photo: John Lee.

Mummy I/3 Photo: John Lee.

Mummy I/4. Photo: John Lee.

The Archaeology at Qilakitsoq

CLAUS ANDREASEN

Andreasen, C. 1989. The Archaeology at Qilakitsoq. – Meddr Grønland, Man & Soc. 12: 11–22. Copenhagen 1990-01-26.

The following pages describe the site of Qilakitsoq where eight mummified Eskimos were found in two graves in 1972 and the exhumation of the bodies took place in 1978.
The find has been dated to the 15th century AD. At Qilakitsoq several structures have been surveyed and mapped, but excavation has not been carried out. Judging from the different types of structures at the site, the area seems to have been inhabited for the last c. 600 years.
The mummy find contains the bodies of six women , one child and a baby. Besides, a large amount of skins and garments were found, making this find extraordinary in Arctic North America.

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In the autumn of 1972 the brothers Hans and Jokum Grønvold from Uummannaq went hunting ptarmigans on their usual hunting grounds at the north side of the Nuussuaq Peninsula just opposite Uummannaq. The place is called Qilakitsoq. During the hunt Hans Grønvold noticed two graves which he looked into by lifting the stones. He saw two children and several adults all mummified and all dressed in skin garments unlike those he was familiar with. He also saw a number of loose pieces of skin. Returning to Uummannaq, he at once reported his discovery to the local authority, which forwarded the information to The Greenland Museum. In the autumn of 1977 the then Director of the museum, Jens Rosing, became aware of the note in the museum files. When the Grønvold brothers shortly afterwards also showed him pictures from the graves, Jens Rosing immediately took the neccessary steps to secure the find which he knew was unique.

The first exhumations took place during Easter 1978, when the two children and a quantity of skins were taken out and brought to the National Museum in Copenhagen for an assessment of conservation problems and radiocarbon dating.

In August 1978 the first datings were available, based on three samples from the find. The datings were made on seal skin, caribou skin and human tissue from the child. The dates were 1460 AD cal. (K-3018), 1465 AD cal. (K-3019) and 1475 AD cal. (K-3020).

The final exhumation took place in September 1978, concurrently with the first survey of the site. More detailed surveys were carried out later, in September 1983 and September 1984.

In the September 1983 survey, 48 graves and meat caches and eight ruins were registered. The following year another nine structures were discovered, three of which are tent rings.

In 1978 the whole find was shipped to the National Museum in Copenhagen, where in the following years it was conservated and subjected to a number of medical and other scientific analyses. Four years later the whole find was returned to The Greenland Museum where it has been on display since August 1982.

In the following the site, the different ruins, and the exhumation of the graves will be described.

Qilakitsoq

Qilakitsoq is the name of a small site situated in an inlet on the north coast of the Nuussuaq Peninsula in the Uummannaq municipality (see Fig. 1).

Qilakitsoq is mentioned twice in the early written sources. The missionary Peter Andreas v. Cappelen mentions in his report on the district in 1789 that the harbour at Qilakitsoq is very good, but the place is only seldom inhabited (Cappelen 1937). This was said to be due to the problems in the winter time when strong winds and currents might break the ice, destroying the possibilities for seal-hunting on the ice. Twenty-two years later in 1811, the German geologist K. L. Giesecke visited the Uummannaq district. In his diary he wrote that on the northern side of the Nuussuaq Peninsula only three sites are inhabited in winter. Among these is Qilakitsoq (Giesecke 1910). Apart from this scanty archival information it is also known from oral tradition that Qilakitsoq was inhabited in the nineteenth century, although only by a few people. The small inlet,

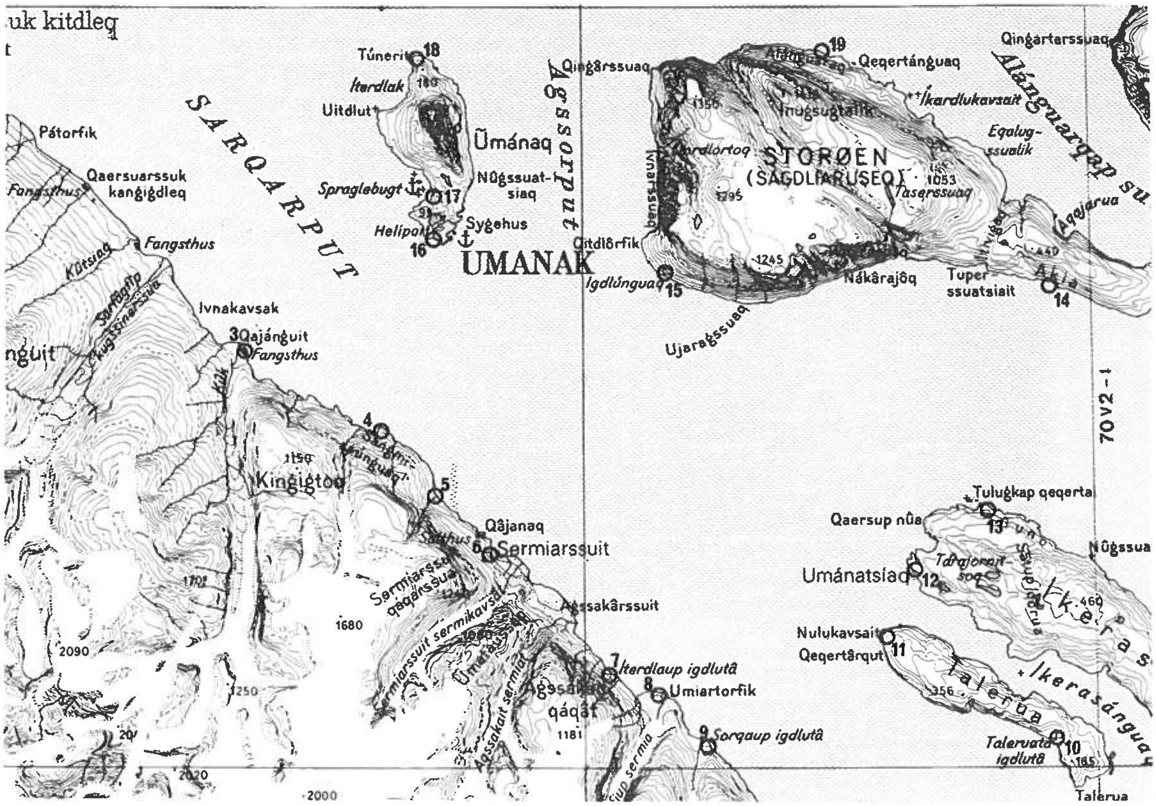

Fig. 1. The Uummannaq area with Qilakitsoq = No. 4. Scale 1:100.000.

which opens to the west, cuts into the coastline, creating a harbour sheltered from most winds (see Fig. 2).

Entering the inlet one sees a gently sloping area delimited by steep mountains. Most of the ruins are on this sloping area.

Fig. 2. Qilakitsoq. View from east to west.

Description of the ruins

All the visible house structures are close to each other (see Fig. 3). Ruins A-E are clearly visible, while F-K are less clear. None of the ruins have been excavated. Their dating is based on typology.

Ruin A

This ruin lies farthest from the shore and is the largest ruin on the site. It appears today as a collapsed grassy mound, measuring 12 × 19 m. The wall contours are fairly clear, rising up to 0.8 m. above surface level.

The ruin does not seem to have been destroyed in any way in modern times. There are traces of ancient rebuilding.

The structure is the ruin of a winter house, probably from the 1700s. The unbroken back wall shows that it was originally built as a long house. The house later seems to have been altered by the addition of two

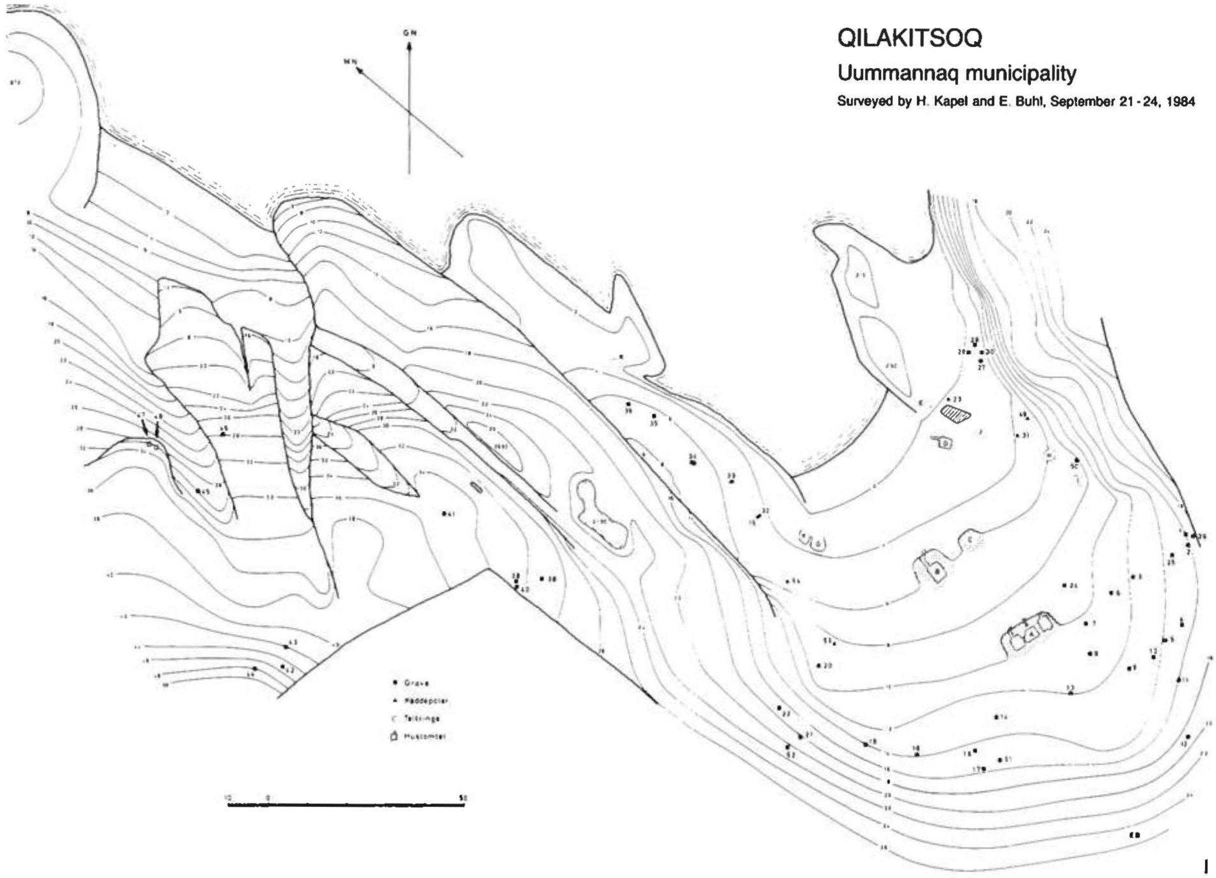

Fig. 3. Survey of Qilakitsoq with house ruins, tent rings, graves and meat caches. (Hanŝ Kapel & Erling Buhl, 1984).

partition walls. The southwestern third must, because of its trapezoid form, be presumed to have been an independent unit which was in use up to the latter half of the nineteenth century. At the eastern end of the house a small depot is built up against a fixed stone block integrated into the wall construction itself.

Outside the house are slight midden traces. These are clearest in front of the youngest part of the house, i.e. the western end.

Ruin B

This ruin of a winter house is situated at the centre of the site and is today the best preserved ruin.

The layout is trapezoid with an asymmetrically placed entrance passage bent at an angle, turning the opening away from the sea. The covering of the innermost 1.5 m of the entrance passage is still intact.. The ruin covers an area of approximately 10 × 15 m. The space of the living room is 3.5 × 5.0 m. The walls stand clearly with their alternating layers of turf and stone. Two recent, minor diggings can be seen in the floor.

Like the younger part of Ruin A, this ruin can also be dated to the nineteenth century when, according to oral tradition, the site was still sometimes used as a winter settlement.

Ruin C

This is situated close to Ruin B. It is a very diffuse, roughly circular dwelling structure, the ground plan of which cannot be established in any great detail. The outer measurements are about 7.5 × 8.0 m. It rises about 0.5 m above surface level with a slight depression in the middle. Judging from the shape and the weak contours it is assumed that the ruin is one of the oldest visible dwellings on the site.

Ruin D

Ruin D is a trapezoid winter house with an asymmetrically placed entrance pointing towards the beach. The outer dimensions are 6 × 11 m, including possible midden remains at the end of the entrance passage. The 0.7 m high walls delimit a floor space of about 3 × 3.5 m.

The form and condition make it likely that the dwelling is contemporary with Ruin B, i.e. from the 1800s.

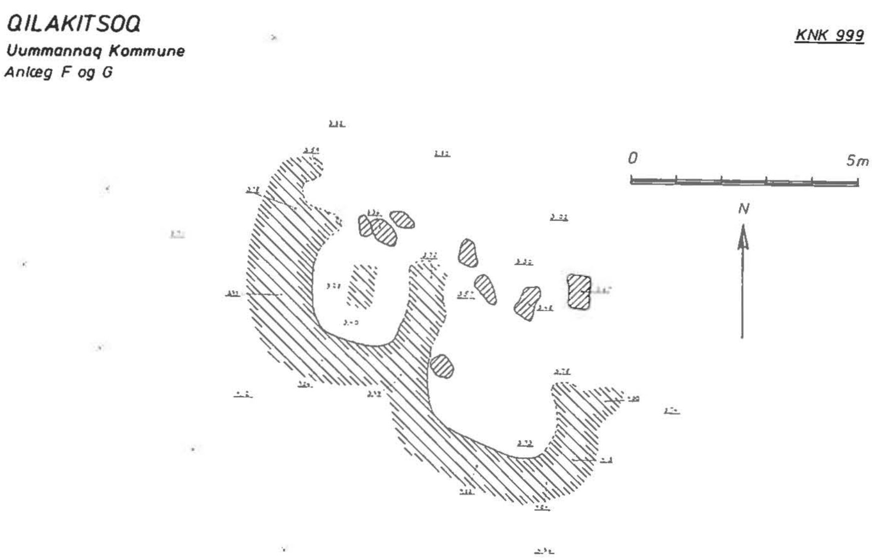

Fig. 4a. Ruins F and G – presumably among the oldest ruins on the site.

Ruin E

This tent ring has an almost circular ground plan with an outer diameter of about 2.6 m. No midden remains appear to be associated with the ruin.

Its state of preservation and overgrowth indicates an age of less than 100 years.

Fig. 4b. Ruins F and G.

Ruins F and G

These are the remains of a double house or two single houses built together at the western part of the site near the beach, cf. Fig. 3.

The ruin is rather decomposed. It was only possible to observe weak traces of the turf-built back walls, while the front was limited to a few loose stones (see Figs. 4a – b). The ruins covered an area of 5 × 9 m. The greatest height above surface level was 0.3 m. There were no traces of midden. Judging from decomposition, vegetation and form it is probable that this is a very old Thule culture dwelling. This round house-type or several round houses built together, were in use on the west coast up to the 1600s.

Ruin H

Ruin H is opposite F and G in the northernmost part of the site. It is a single, round structure of the same kind as F and G. It is seen as a slight depression in the ground with greatly decomposed turf walls measuring about 0.2 m above surface level. Outer dimensions: 3.7 × 4 m. The structure opens towards the west. Opposite the entrance opening, faint traces of a platform can be seen.

This ruin is probably contemporary with F and G, although it cannot be excluded that it might be of palaeo-Eskimo origin.

Ruin I

This tent ring, the outer dimensions of which are 3.5 × 3.8 m, is four-sided with rounded corners. The remains appear as a slight depression in the ground surrounded by head-sized stones. The tent ring is presumably of some age, but a more precise date cannot be established from the present data.

Ruin J

A recent, circular tent ring marked by a single irregular stonecircle. Outer diameter: about 2.8 m. The tent ring is unlikely to be more than 100 years old.

Ruin K

A recent, rectangular tent ring marked by a stonecircle made of a few stones. Outer dimensions: 3.8 × 2.5 m. Inside the ring stands the characteristic flat stone used for the stove ("the primus"). This indicates a date within this century.

The ruins in summary

The surveys have shown eleven ruins scattered over the area. All the registered ruins but one, Ruin A, seem to have maintained their original form. No traces of European buildings have been observed at the site.

The situation of the dwellings within the settlement area does not indicate any kind of horizontal stratigraphy. Similarly the dwellings cannot be dated on the basis of their height above sea-level (cf. Table 1).

Since no archaeological excavations have taken place and no datable objects have been found in connection with the ruins, dating can only be done by comparing their form with other known, dated ruins on the west coast. The most reliable chronology of house forms have been based on dwellings in the Nuuk area (Gulløv 1983). When evaluating the probable dates of the various dwellings given in Table 1, it must be kept in mind that the two areas, the Uummannaq area and the Nuuk area, are far apart and that their cultural development may not have been exactly contemporary. To establish a more precise dating, excavations are necessary. Still, it can be said that the most interesting ruins, seen in relation to the mummies, are Ruins C, F, G, H, and I.

Table 1. Probable datings of the ruins at Qilakitsoq.

ruin	type	m above sea level	probable date
A	long house	10.5	orig. 1700s, rebuilt in the 1800s
B	trapezoid	8.0	winter house, 1800s
C	round	7.0	probably one of oldest
D	trapezoid	3.5	winterhouse, probably 1800s
E	tent ring	1.5	probably 1800s
F+G	roundhouses	4.0	probably one of the oldest
H	roundhouse	6.0	probably one of the oldest
I	tent ring	7.0	old ruin
J	tent ring	3.5	less than 100 years old
K	tent ring	3.5	less than 100 years old

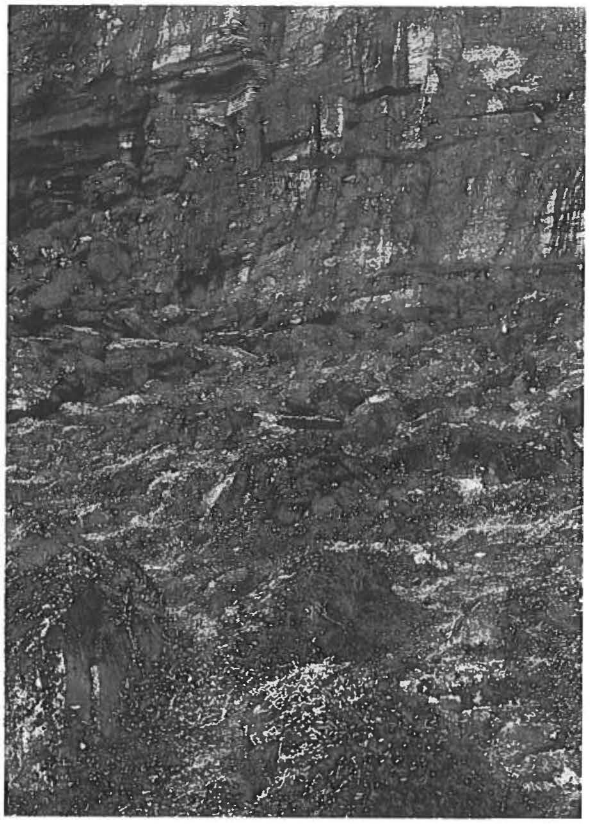

Fig. 5. Grave at the settlement area.

Other structures at Qilakitsoq

Besides the eleven above-mentioned ruins a large number of graves and grave-like stone structures were registered in the settlement area and in the scree slopes between the settlement and the mummy graves. The situation of these structures appears in Fig 3.

When mapping the structures no excavations were carried out but an attempt was made to establish whether they were graves or not. This was done simply by looking into the structures through the stones. Structures with visible human bones were classified as graves, while those with no visible content or no bones at all were classified as meat caches.

General description

All the structures are built of local stones without any cementing material (see Fig. 5). The bottom of the chamber is usually rectangular, while the superstructure makes the structures more dome-shaped. As a rule they are covered with large flat stones on top. A few structures are elongated – mainly those on the rock shelf between the settlement area and the mummy graves.

The stone size is generally 40–50 cm × 30–40 cm – often with rounded stones at the bottom and more flag-like stones at the top. The inner lenght of the chamber rarely exceeds 1.5 m. The lenght varies from 1–1.5 m. The greatest interior height was measured to 1.2 m (no. 22).

Several of the stones were partly overgrown with lichens.

Situation of the structures

A total of 54 structures were mapped, including the two mummy graves. Of these, 37 are situated within the settlement area, mostly at its periphery and with the majority behind Ruin A (cf Fig. 3).

Graves and meat caches

Nineteen of the structures could be classified as graves. In each of these there was at least one skull; in two cases two skulls were seen. The content of other bones varies greatly. The graves in the settlement area contained only skulls while in the graves on the rock shelf more parts of the skeleton were preserved. In three graves pieces of sealskin were observed and in two graves the orientation of the body could be determined. One lay with its head to the northeast, no. 43, and the other with its head to the northwest, no. 44. At one grave a structure resembling a side chamber was observed, no. 39.

Of the remaining 35 structures, nineteen had no contents while this could not be definitely established for the remaining sixteen. The nineteen meat caches are all situated in the actual settlement area and include all the structures on both sides of the cove.

A summary of the content of the structures is given in Table 2.

Table 2. Content of the graves and meat caches at Qilakitsoq.

no.	content
1–2	one skull in each
3	2 skulls
4–5	content not observed
6–9	one skull in each
10	three skulls
11–18	content not observed
19	one skull
20–37	no contents
38	two skulls
39	one skull, possibly one side chamber
40–42	content not observed
43	one skeleton, head in northeast; some fur preserved
44	one skeleton, slightly disturbed; head in northwest; some fur preserved
45	some human bones
46	content not observed
47	mummy grave I; five mummified persons; fur and garments preserved
48	mummy grave II, three mummified persons; fur and garments preserved
49	no content
50	some human bones
51–52	one skull and parts of a skeleton
53–54	content not observed

Dating

No artefacts were observed in any of the graves or the meat caches. Thus we are left with no means of dating these structures.

However, none of the graves were built like Christian graves – that is with rectangular stone cists or with wooden coffins. Generally the structures must therefore be dated to the pre-Christian period, i.e. the period before colonization in the early 1700s.

Till now no graves dating to the pre-Thule period have been found in Greenland. For the time being the graves have therefore been attributed to the Thule culture.

In the Thule culture both individual and communal graves are found, but unfortunately no detailed study has been made of the various grave types of that period. A more precise dating within the Thule culture is therefore not possible.

The mummy graves

The so-called mummy graves are the two graves in which the mummified remains of two children and six adult women were found. The graves were the first to be registered at the site but have later been given nos. 47 and 48. They are situated about 200 m from the settlement and c. 27 m above sea level (cf. Fig. 3).

They can be reached by following the rock shelf westwards from the settlement area. On this shelf several other graves are found, too.

The mummy graves are situated between the solid bedrock and a large boulder. Above the graves the bedrock protrudes slightly, protecting the graves to a certain extent from rain and snow (see Figs. 6 and 6b). Both graves are built of local stones. From the graves there is a clear view through a short, steep gorge towards Uummannaq Island. The gorge is full of loose stones and ends in a small sandy beach.

Description of the graves

Like the other structures these are built of stones with no use of turf or earth as cementing material. The graves are built almost at right angles to each other (see

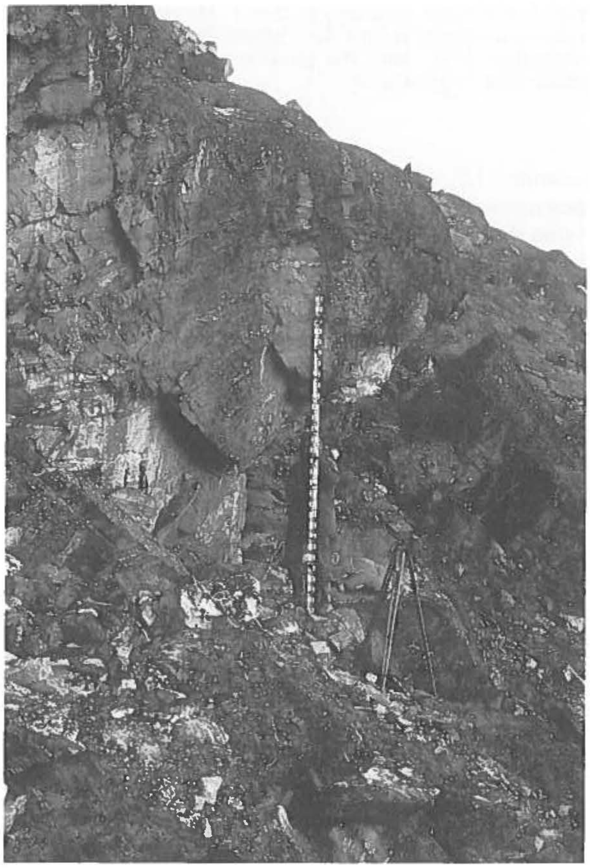

Fig. 6. The graves and the protruding rock.

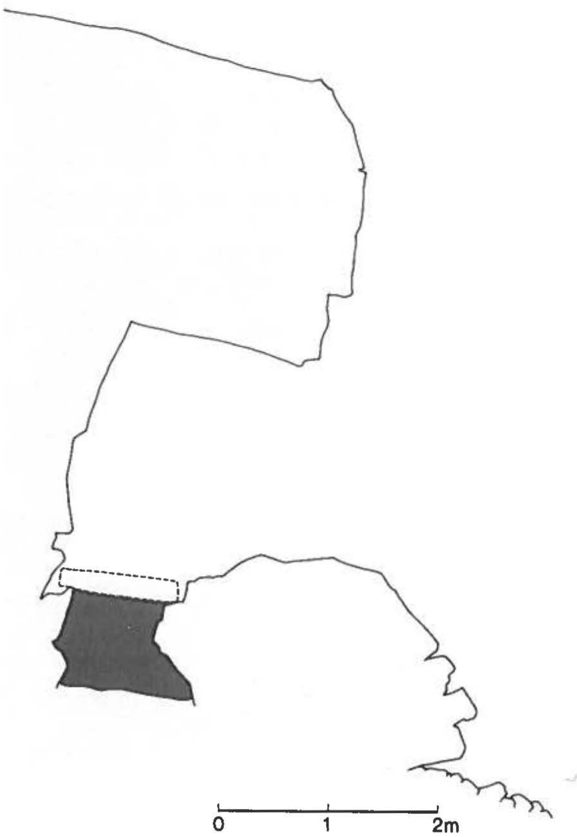

Fig. 6b. Cross-section of grave and rock.

Fig 8), with grave I lying roughly parallel to the coastline. The distance between the graves are about 1.7 m.

Grave I

This grave is about 1.7 m long, 0.9–1.2 m wide and 1 m deep at its deepest point. Its orientation is northwest-southeast. All the adult women had their heads in the northwestern end of the grave. Exhumation revealed two children, three adult women and a large amount of loose skin fragments and garments.

Uppermost lay the two children. At the time of the finders' first visit, the baby (mummy I,1) lay on some skins with its back towards the bedrock, facing the skins covering mummy I,2 and I,3. When they looked into the grave, the finders took up the baby and some skins. The baby was replaced, but the skins were taken to Uummannaq, where they later disappeared.

Next to the baby, the child (mummy I,2) was laying on its back with its head resting on the thighs of the woman below. The legs were strongly bent and spread wide apart. This child does not seem to have been disturbed. According to the finder, Hans Grønvold, the child was covered with a skin. Mummy I,2 was fully dressed in skin garments.

The uppermost woman in the grave (mummy I,3) was lying on her back. Her arms were bent and the hands touched each other in front of the body. The legs were bent and slightly spread, partly because of bending, partly because the right foot had come to rest on a small projection in the rock during the burial (see Fig. 9). The body was partly wrapped in a large seal skin with its hairy side towards the body, leaving the thighs naked. On top of the body and in particular to the right of the head a number of smaller skins were lying (see Fig. 10).

Between mummy I,3 and mummy I,4 a large number of loose skins were found. Mummy I,4 was wrapped in a seal skin, too, the opening of which faced upwards so that the whole body was visible. Orientation and position of the body corresponded to that of mummy I,3. However, the body was lying slightly on its right side pressing the right arm upwards (see Fig. 11). Following the exhumation of mummy I,4, the rest of the grave's content appeared to be one large heap of skins. This was taken up as one unit without separating the skins. During this process it was observed that another

Fig. 7. The stone covering of grave I. The grave is known to have been opened at least twice before the final exhumation in September 1978. Still, the position of the stones probably reflects the original level.

mummy, I,5, was lying at the bottom of the heap wrapped in a caribou skin. This last mummy was lying in the same way as I,3 and I,4. The bottom of the grave was built of stone-flags placed horizontally and strewn with plant material, mostly cassiope and crowberry (see Fig. 12).

Grave II

Like grave I this was also built of loose stones with no cementing material. The grave is partly underneath the overhanging rock. The grave is about 1.5 m long, about 1.15 m wide and 1 m at the deepest point.

The orientation is almost north-south. The three mummies in the grave – all adult females – had their heads towards the south.

Fig. 8. Survey of the graves. Grave 47 = grave I; grave 48 = grave II. Grey area shows extent of overhanging rock. Hatched area is the solid rock.

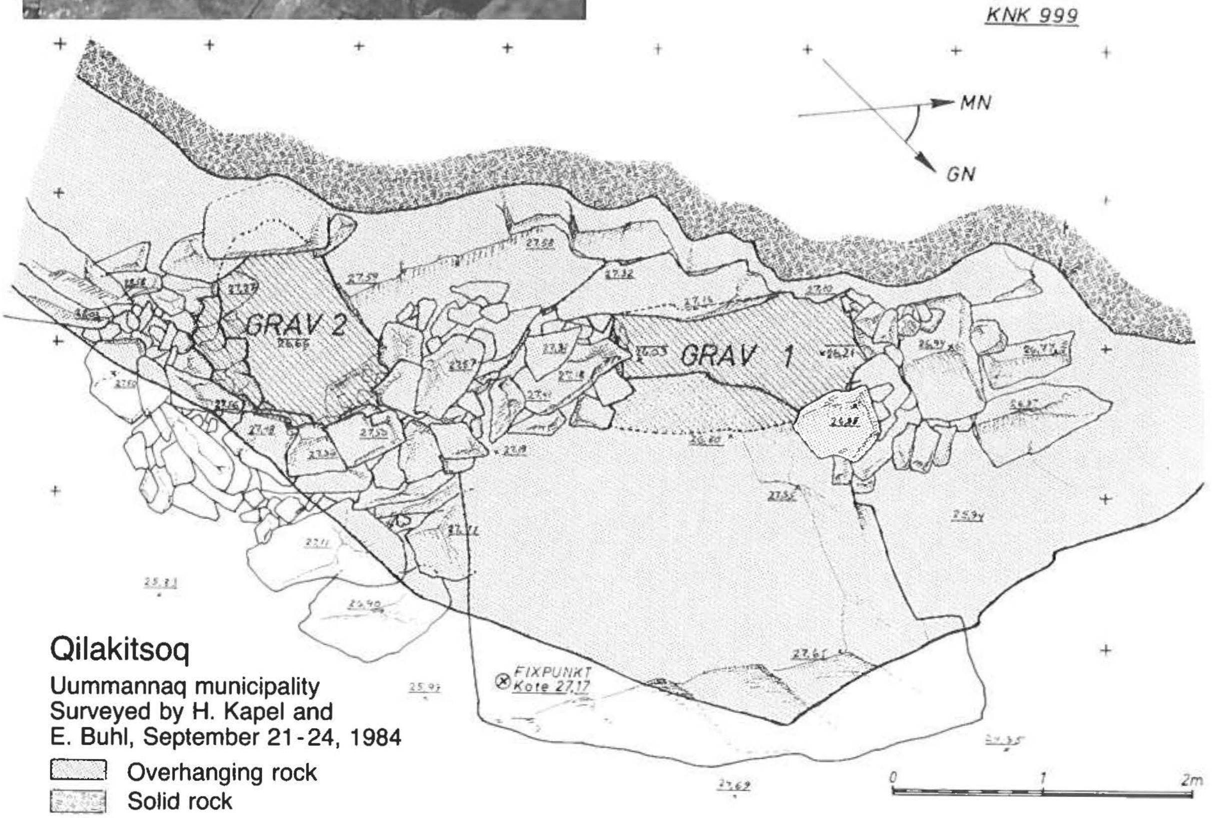

Fig. 9. Mummy I,3 in situ. The skin covering reaches mid-thighs.

Fig. 10. Mummy I,3. This skin-wrapped body was completely covered by loose skins.

Fig. 11. Mummy I,4 in situ. The skin wrapping held aside.

Fig. 12. Vertical photo of the bottom of grave I. All the adults lay with their heads at the wide end.

Fig. 13. Grave II. The skin covering mummy II,6.

After removal of the top stones a large sealskin covering the uppermost body was seen (see Fig. 13). Beneath it lay mummy II,6. The body was lying on its left side with strongly bent legs in a hocker-like position facing westwards. The hands were folded in front of the chest and the face was covered by an edge of the caribou skin which was wrapped around the body.

Again, a number of loose skins were found between this mummy and the next one, no II,7.

Mummy II,7 was lying partly on its side, partly on its back with the head towards the south and facing eastwards. It was not wrapped in skins. The body was partly covered by grass and lyme grass. This appears to have been put into the grave with the loose skins.

Beneath II,7 more loose pieces of skin were found covering the last mummy, II,8. The body was lying on its back with its head towards the south. It had very strongly bent legs, which must be due to the fact that the grave is actually too short for a body of this size. The feet were fairly firmly wedged under some stones. The mummy was not wrapped in skins.

The bottom of the grave was partly solid bedrock, partly loose flag-like stones with a partial cover of grass and cassiope.

Summary of the content of the graves

Grave I contained one baby, one child and three adult women, all fully dressed in skin garments. Above, between, and below the bodies a large number of pieces of skin were found; some of these were garments, but most were ordinary fragments of skin.

The three women were wrapped in skins; the children were not. Some gravel was found between the mummies and the skins. Geological examination shows that most of it is of local origin, i.e. from the settlement area and from the sandy beach in front of the graves. The mineral analysis also showed that some of the small stones embedded in the skins are from other areas in Uummannaq district. This indicates that the skins had been used by these people before their death. It could be demonstrated that some minerals came from localities further to the west on the Nuussuaq Peninsula and from the old settlement at Tupersuatsiaat on Storøen, just north of Qilakitsoq.

Grave II contained three adult women, all fully dressed in skin garments. Only the uppermost, mummy II,6, was wrapped in a skin. In addition, a total of 130 loose skins and garment fragments were found. Most of these are ordinary skins, but 25 pieces are from skin garments. 53 pieces of garments were found on the mummies (cf. Table 3).

The skins derive from harp seal (*Phoca groenlandica*), ringed seal (*Phoca hispida*), caribou (*Rangifer tarandus*), and birds.

Apart from this the find also includes some botanical material, small stones, bees and fish-scales (both probably of a later origin).

No artefacts were found in or near the graves.

Table 3. Types of skin garments in the two graves.

Type of garment	on the mummies	loose-lying	total
Anorak			
outer anorak	8	7	15
inner anorak	7	1	8
anorak between outer and inner	1	0	1
Trousers			
outer trousers	8	3	11
inner trousers	1	0	1
Kamiks (boots)			
kamiks	14	5	19
stockings	14	7	21
Sleeves			
half-sleeves	0	2	2
total	53	25	78

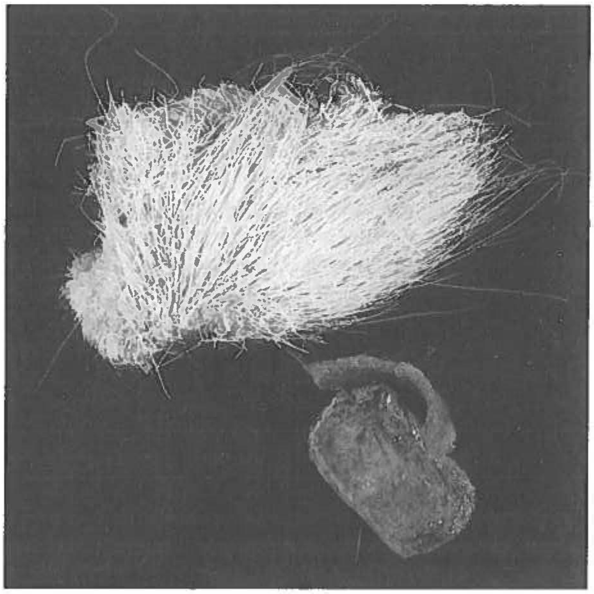

Fig. 14. Amulet from grave I.

Among the loose-lying items in grave I was a piece of caribou skin on which were sewn two small pieces of scraped sealskin in the form of two small kamik soles (see Fig. 14). The item is thought to be an amulet. Judging from its position it belonged to one of the two children.

Dating

The first three radiocarbon datings of the find were carried out on pieces of sealskin, caribou skin and human tissue. The dating turned out to be c. 1460 AD. After the retrieval of the whole find another four samples were delivered for radio carbon dating.
These datings are shown below:

K-3393	sealskin	(mummy I,3)	1470 AD cal.
K-3394	caribou skin	(mummy I,5)	1480 AD cal.
K-3395	caribou skin	(mummy II,6)	1510 AD cal.
K-3396	sealskin	(mummy II,8)	1470 AD cal.

Average dating of the find is 1475 AD cal. according to the radiocarbon laboratory.

The Burial type

The two graves are communal graves, a common burial type for the Thule culture. In communal graves it is

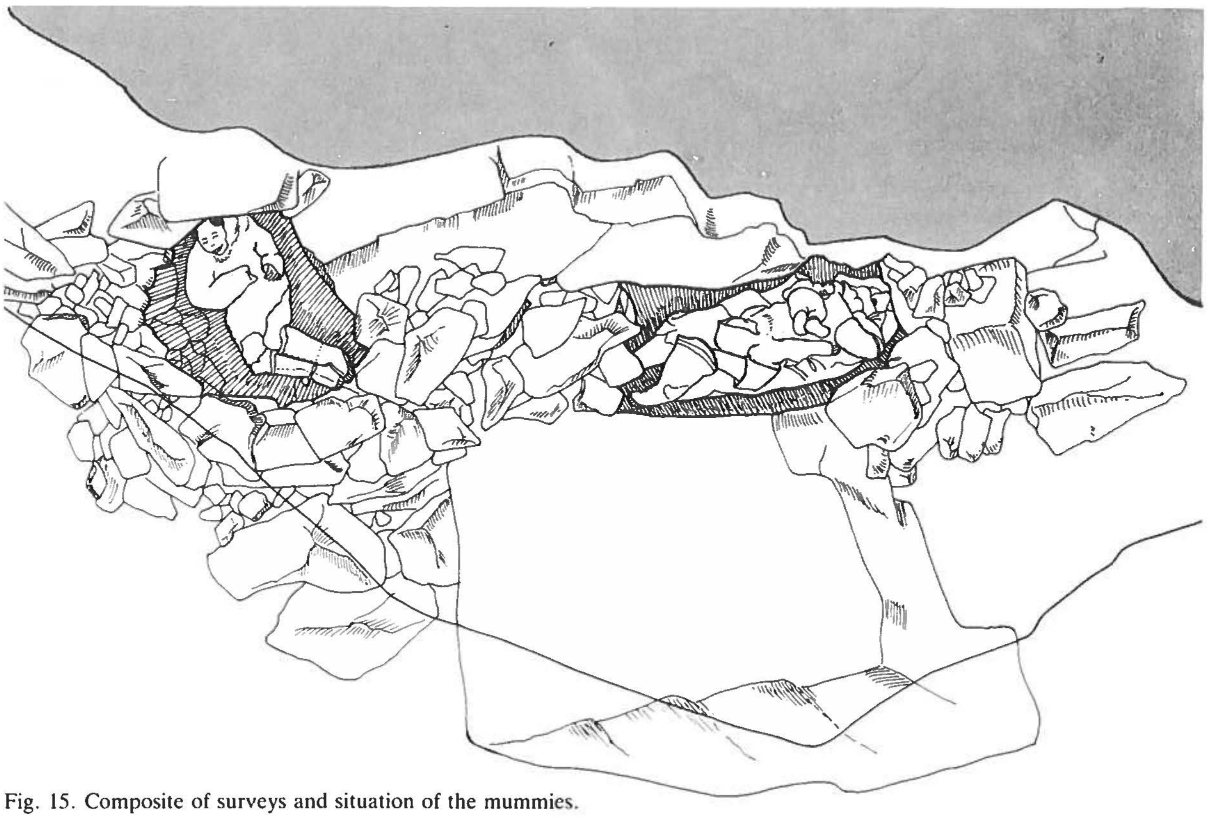

Fig. 15. Composite of surveys and situation of the mummies.

often seen that those buried first are pushed aside to make room for the following burials. This was not the case in these graves. Most communal graves are placed on a flat surface where a covered stone chamber has been built.The mummy graves are of another construction. They might be termed "vertical graves" in which the bodies are laid down one on top of the other. The Thule culture grave types have never been studied in detail. Therefore it is not possible at present to determine whether these graves are a common feature of the Thule culture. It is for instance still a question whether it is a mere coincidence or on purpose that the graves only contained women and children.

Burial in phases?

Since the mummies and the skin fragments lay directly above one another, the question has been whether one could distinguish between different burial phases in each grave.

In grave I, particularly above the skins that covered mummy I,5, a certain amount of small stones and gravel was seen. This might indicate that some time had elapsed between this first burial and the following. However, the "layer" was intermittent, which could be a result of the activities undertaken during the burial. In addition, the activities of the finders and the archaeologists resulted in some precipitation of gravel in particular. Archaeologically, no basis was found to determine whether the bodies were buried at the same time or not. Nor was it possible to establish whether the two graves are contemporary or not – apart from the evidence of the radiocarbon datings and the garments.

Conclusion

At Qilakitsoq two graves were found containing six adult women, two children, and a number of skin garments and skins. The persons were all mummified and fully dressed in skin clothes. Based on seven radio carbon datings the find has been dated to 1475 AD cal. At the Qilakitsoq site eleven dwelling structures and 54 graves and meat caches were found. During the surveys undertaken by The Greenland Museum no excavations in any of these ruins were undertaken. It is therefore not possible at present to establish any contemporaity between the exhumated bodies and any of the structures at the site. Dating the ruins by means of typology and comparison with known house types at other sites on the west coast show that Qilakitsoq must have been inhabited for several hundred years, until the beginning of the twentieth century.

Note

All surveys by Erling Buhl and Hans Kapel, Copenhagen.
All drawings by Hans C. Gulløv in: Qilakitsoq. De grønlandske mumier fra 1400-tallet. – Copenhagen, 1985.
All photos by Kalaallit Nunaata Katersugaasivia/ The Greenland Museum.

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Eskimo Clothing from Qilakitsoq

GERDA MØLLER

Møller, G. 1989. Eskimo Clothing from Qilakitsoq. – Meddr Grønland, Man & Soc. 12: 23–46. Copenhagen 1990–01–26.

The grave find at Qilakitsoq, with its eight fully clad mummified bodies and 25 additional articles of clothing, was so well preserved that it made possible a description of the dress of Eskimo women in the fifteenth century, and of the advantages and apparently few drawbacks of this clothing in the arctic climate.

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Conservation, treatment and description

On reception, this large find was crumpled, stiffened, and covered with fungus, dirt, and a layer of earth and sand.

In order to preserve the find and to measure, draw, and describe the clothing it was necessary to clean articles of skin by washing and drying them to a comparatively soft consistency without shrinkage. Trials showed that of the many methods of conservation, tawing best met these needs.

Tawing with Lutan F (BASF, Ludwigshafen) was chosen, as this was fairly gentle and simple to execute and supervise. The skins could be slowly softened, unfolded and cleaned. They swelled during softening, but dried out without noticeable shrinkage.

However, badly damaged elements were lost during the softening process, and some hair loss could not be avoided. Furthermore, biochemical analysis (Ammitzbøll *et al.*, this volume) showed that glycosaminoglycanes leached out, so after treatment it was not possible to determine the type of seal skin used for the *kamiks* with this investigation.

All the loose items of clothing as well as some of the clothes from mummies 2, 5, 7 and 8 were tawed with Lutan F.

Analysis after tawing showed an Al_2O_3 concentration of 1.2%, revealing adequate tawing. The pH value was 3.90 with a variation of 0.4 which shows that there is no dissociated acid in the skins.

The degree of tawing can be measured by ascertaining the shrinkage temperature of the skin. All skins have the property that, when heated to a certain temperature, an irreversible shrinkage occurs. Some types of tanning raise this s-temperature, showing the formation of strong, unbreakable chemical bonds. This is not the case with alum tawing, which normally has no influence on s-temperature. And the s-temperature was not raised in the case of these skins. A fresh ringed seal skin has an s-temperature of 58°C. For these old skins the s-temperature both before and after tawing was 52°C, that is, no chemical bonds of any great strength have been formed, and one can thus regard the method as being more or less reversible. That the s-temperature is less for the old skins indicates a certain amount of decay.

The best preserved mummies, numbers 1, 3, 4 and 6, were kept in their clothes while these were softened, cleaned and straightened with Lederweicher SR (an anion-active sodium salt of succinic acid ester, Fritz Minke). Finally the mummies were subjected to gamma radiation (see Arne Johansson, this volume).

After this thorough treatment it was possible to measure and draw up patterns of the clothing, and to study the garments, the original skin treatment and sewing technique.

With few exceptions the innermost part of the costume consisted of a bird skin parka with the feathers inward, edged with caribou skin, the outermost of a sealskin parka with the fur turned outward, both with hoods, short or half-length trousers of seal or caribou skin with the fur outwards, *kamiks* (boots) of hairless sealskin and stockings of seal or caribou skin with the fur inwards. Outer parkas and trousers were made either of caribou skin or seal skin – in this case exclusively the skin of the ringed seal.

How the clothing was worn became clear with the cleaning and subsequent study of the mummies. All the mummies wore their trousers hanging from the hips. The half-length trouser legs came to the knee or slightly lower, and the *kamiks* and *kamik* stockings ended slightly above the knee. *Kamik* grass was used both inside the stockings and between the stockings and the *kamiks*. Both outer and inner parkas were waist-length

Table of all the articles of clothing

Type of clothing	Mummy number: 1	2	3	4	5	6	7	8	Number of garments on mummies	Loose garments	Total number of garments
Parkas											
Outer	+	+	+	+	+	+	+	+	8	7	15
Inner		+	+	+	+	+	+	+	7	1	8
Intermediate								+	1		1
Trousers											
Outer	+	+	+	+	+	+	+	+	8	3	11
Inner						+			1		1
Footwear											
Kamiks		+	+	+	+	+	+	+	14	5	19
Stockings		+	+	+	+	+	+	+	14	7	21
Half sleeves										2	2
Totals									53	25	78

at the sides and must have fit snugly. In contrast, the armholes and shoulders were very roomy. The position of the hood on the head could not be ascertained precisely, because in some cases the hood had slid back and in other cases it was partly missing.

The clothes were all presumably sewn with sinew thread, but no study of the thread material has been made. Two kinds of stitches, overcast and running, were used. Overcast stitching was used for parkas, trousers and stockings, while both stitches were used for *kamiks*.

It is characteristic of all the material in the find that the costumes were originally sewn with fine thread and regular stitches. When they were worn out they were repaired, and the repairs are not of same quality as the original work, for they have been sewn with long, crude, uneven stitches and heavy, often frayed thread.

In some cases clothes have been enlarged with gussets which might for example be taken from another garment. Some seams have had narrow bands of newborn or unborn sealskin inserted. Frequently warm pieces of skin were sewn on at the hips and round the facial opening, cuffs were sewn at the wrist and knee, and legs were added to the short trousers. These additions were executed with braided or twisted thread and long stitches.

The clothing was of practical construction, and furthermore reveals a strong æsthetic sense in the execution of an ornamental pattern, often symmetrical, achieved by the use of light and dark skins. But some problems must have arisen with the outer parkas' high, very narrow hoods, which must have left half of the neck exposed, and the fact that the hem sits so high at the waist that much of the hips must also have been exposed.

In all, the material treated comprised fifteen sealskin parkas, eight bird skin parkas, one caribou skin parka, twelve pairs of trousers, nineteen *kamiks*, 21 *kamik* stockings and two halv-sleeves, in all 78 garments, all more or less well preserved. The graves also contained numerous extra skins of ringed seal, harp seal and caribou, either wrapped round the mummies or used as padding together with various crumpled garments. Exhaustive study of the individual garments in this substantial find has turned up a number of recurring features which must be assumed to be typical of their time. A number of basic types on which people have set their individual stamp have emerged.

The basic types were formed as follows. The outer parka is composed of a front, a back, shoulders, a hood and sleeves. The front is made of one sealskin with the dark skin of the back in the middle. This is cut off level with the woman's chest. On the sealskin this is just above or just under the earholes, where the skin is most narrow, and from here the entire width of the skin is used, with the seal's light belly used as side pieces. The extremely wide armholes, which cut into the front, cut away the front flippers of the seal. The skin is then cut

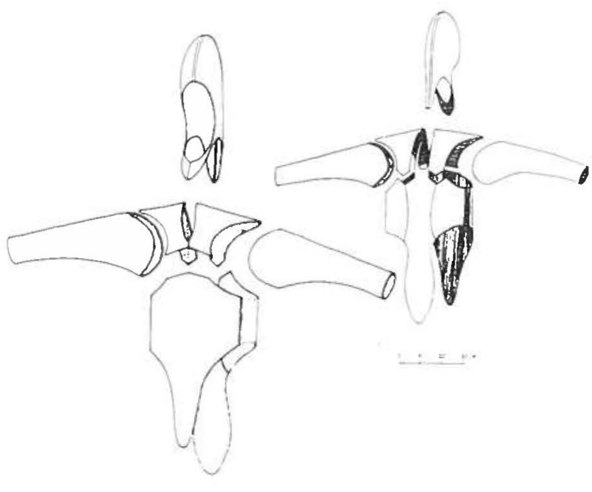

Fig. 1. Drawing of the front and back of the basic type of the parka. Note the placing of the component parts.

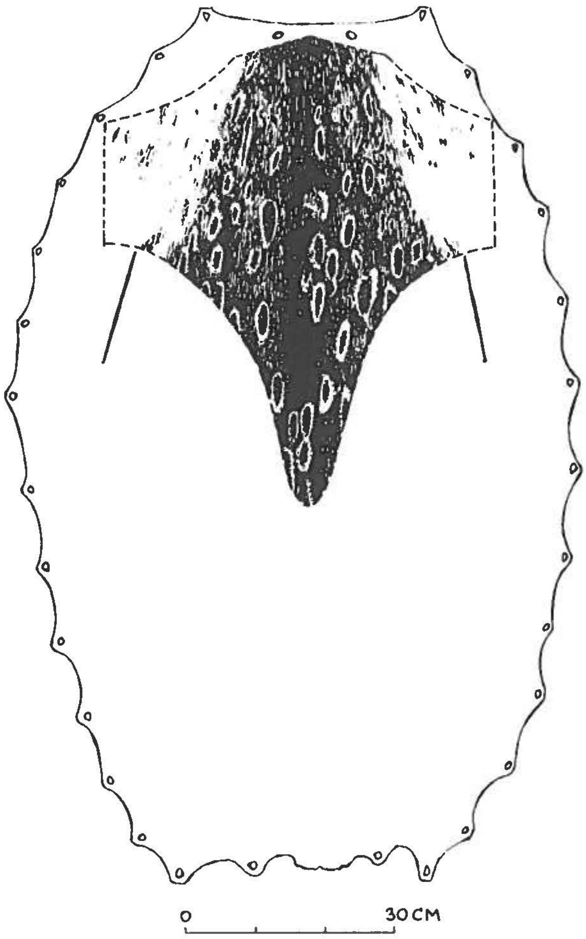

Fig. 2. Drawing of the front of the basic type of the parka placed on the sealskin.

off along the side at the waist and continues downwards in front into a narrow pointed tail reaching about to the knees.

The back is divided into three sections, with a narrow middle section made of the dark skin from the back of the seal. This continues downwards into the back tail, which is longer and slightly wider than the front tail. At the top a deep U-shape is cut into the centre of the skin to allow for the hood. Along the sides it continues in two narrow straps up over the shoulders next to the hood. The two side pieces of the back are made of light belly skin. Together with the shoulder pieces they form the back part of the armhole, and are connected with the front by a seam along the sides.

The shoulder pieces are made of light belly skin. One end is joined to the front from which they go over the shoulders to the middle of the shoulder blades, where they meet the rear side pieces and the dark middle section. The shoulder pieces are widest over the shoulders, where the width is further increased by the addition of a crescent shaped piece towards the sleeves. In front the two pieces are sewn together at the middle for a couple of centimetres, after which they are joined to and divided by a chin piece. Together with the front, they form the front part of the armhole.

The hood is composed of two symmetrical halves of light-coloured skin joined at the middle by the insertion of a dark fur band about one centimetre wide. Both the

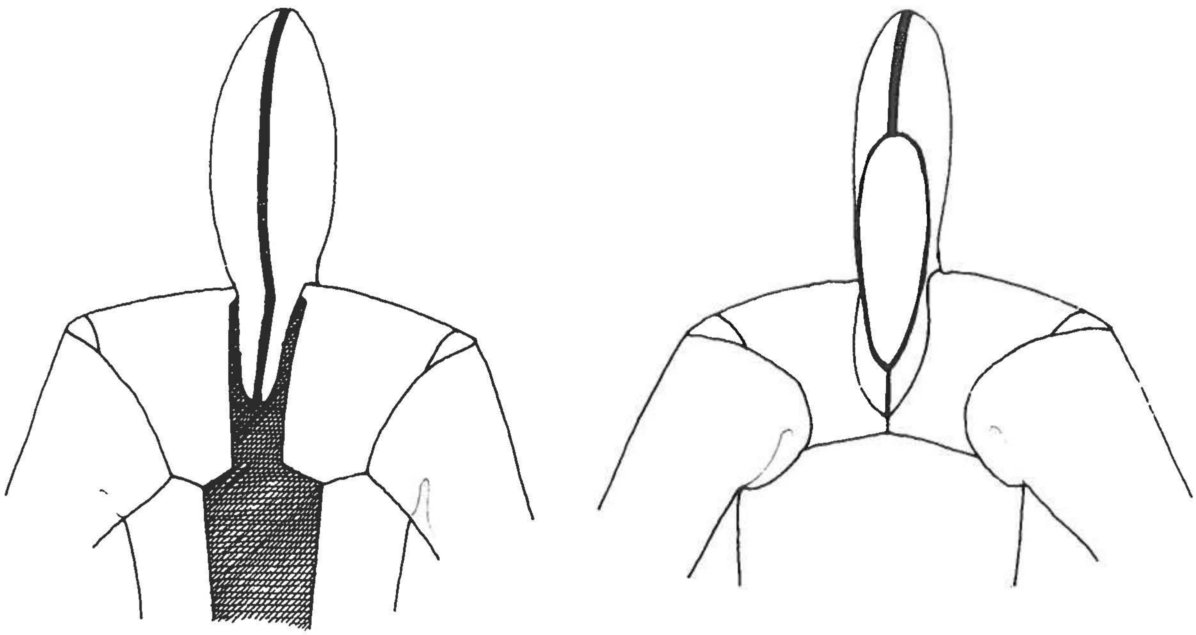

Fig. 3. Drawing of the back and the front of the outer parka with the typical pattern of the basic type.

light skin pieces and the dark band continue at the back down into the U-shaped neck opening of the back, thus creating a striking ornamental effect. In front the side pieces of the hood are elongated by two gussets which together form a U-shaped chin piece. This is joined to the shoulder pieces at the sides.

The hood is edged with a dark, turned-in fur band which also lines the uppermost edge of the chin piece. The hood is quite high and remarkably narrow, especially in relation to the neck piece.

The sleeves are made of the back skin of the seal and composed of two, three, or four parts. They are set in round and extremely wide at the armhole. The armhole is cut deep into the front and shoulder pieces, which makes the garment extremely narrow at the chest – only 22–25 centimetres. There is a band at the wrist with an inset of light belly skin at the front forming part of the cuff.

The inner parka is cut to the same pattern as the outer parka. However, in some instances the same basic elements have been pieced together from innumerable small pieces of skin, such as the of the female eider. In other instances, larger entire skins from various birds have been used. Bird skins are used with the contour feathers intact. The inner parka closely duplicates the front and back pieces of the outer parka; both have tails in front and behind, shoulder pieces, hoods and sleeves. All free edges are set with bands of caribou skin.

The trousers have the fur turned outwards, and the legs are either short or half-length. They are fashioned out of two symmetrical halves joined by a centre seam. Most trousers have a waistband with a belt to be tied at the back.

Kamiks and stockings. The *kamiks* consist of a leg and sole. The sole has upturned edges and is gathered in at heel and toe. On the outer and inner sides there is an ungathered length of six or seven centimetres. At the front of this length on both sides an eye is cut for a *kamik* strap, and in some instances this strap is attached. The leg of the *kamik* has either one front seam or a front and back seam, and there may be various piecings both at the top and bottom. Right and left *kamiks* are rarely identical. The front seam runs straight out to the sole with no instep piece, or else it turns towards the outer or inner edge of the sole. The leg of the *kamik* may go straight up and end in a turnover for a strap that ties at the back, or it may widen towards the top and end in a binding with no strap, or it may end with no binding. Some *kamiks* are very carefully sewn, with front and back gatherings which are small works of art, while others are very loosely sewn.

The *kamik* stockings are made with the fur side innermost. The pattern is the same as the *kamiks*. The sole is turned up and gathered to the leg at front and back, but the pleats are larger and fewer here than on the *kamik*. There may be a turnover at the top with an attached strap; there may be a turned-in fur binding, or there may be no binding at all. The leg is joined either in front or at both back and front. Stockings sewn of sealskin always have the back part of the sealskin towards the back, corresponding to the calf of the leg. The sole is nearly always made of light belly skin with the hair pointing forwards.

Clothing of the six women

The clothing of the six women conformed, with few exceptions, to the types described.

Mummy 3: the costume consists of outer parka, inner parka, short trousers, *kamiks* and stockings.

1. The hood of the outer parka is missing. The area round the neck and shoulders has deteriorated, with some loss of hair. The back tail is about 45 centimetres long with a fur band which is dark on the inside and light on the outside. This band is not sewn together along the edge. The front tail is about ten centimetres shorter and also has a fur band, which is sewn along the edge. The light band also edges the fur at the side. Here between the fur and the band a narrow dark band has been sewn in. The sleeves have no wrist bands, but there are inserts of light skin about 11 centimetres wide.

2. The inner parka also lacks a hood. The back tail is a good 40 centimetres long and the front tail is about ten centimetres shorter. At the hips the caribou skin edgings of the parka are extra wide, with hair about fifteen centimetres long forming a light border below the outer parka.

3. The short trousers, which are of sealskin, have legs about twenty centimetres long, edged with a dark, turned-in fur band. At the top there is a waistband with an attached belt tied at the back. A triangular gusset is inserted at the top front.

4. The *kamiks* are beautifully sewn with fine, regular gatherings at the toe and heel. The leg is about 45 centimetres long and ends at the top with a band of white skin 1.5 centimetres wide. Each *kamik* is sewn together in front with an inset gusset and overcast stitch-

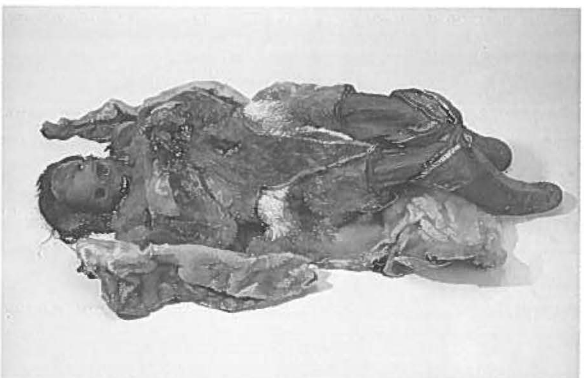

Fig. 4. Mummy 3.

Fig. 5. Mummy 3. The *kamiks*.

Fig. 6. Mummy 4.

braided sinew thread in long crude stitches. The sleeves have insters of pieces of light skin and a turned-in fur band at the wrists. The hood of the outer parka is detached.

2. The inner parka is made of bird skin with a tail at front and rear.

3. The half length trousers are made of light sealskin and reach the middle of the knee. They have a turned-in fur band at the top.

4. The *kamiks* are composed of various pieces of skin, but they are carefully sewn. The leg of each *kamik* is about 32 centimetres long and ends at the top in a white edging 1.5 centimetres wide. The leg is sewn together in front with a single row of running stitching which is doubled at the end of the foot. The soles are attached to the legs with very regular and finely made gathers. A ing. The gusset seems to have been added later, because the *kamiks* were originally sewn together with running stitches. The gusset also goes up over the binding. The right *kamik* has a triangular piecing at the front of the foot. The left *kamik* has a piecing at the bottom of the leg. Both have eyes for *kamik* straps at the side. Both stockings are made of caribou skin. They end at the top in a turned-in band af sealskin fur.

Two samples were taken from the left *kamik* for biochemical analysis (Ammitzbøll *et al.*, this volume). One revealed well preserved harp seal skin, the other decayed skin.

Mummy 4: the costume consists of outer parka and inner parka, half length trousers, *kamiks* and stockings.

1. The outer parka has a back tail of about 45 centimetres and a front tail 10–15 centimetres shorter. Both tails have light, turned-in fur bands, which also edge the parka along the side. Below this on both sides are attached pieces of skin about eighteen centimetres wide; these go from the middle of the front tail to the middle of the back tail, and thus cover the hip areas. These side pieces are made of seal skin (ring seal) with the fur turned inwards, and they are sewn on with

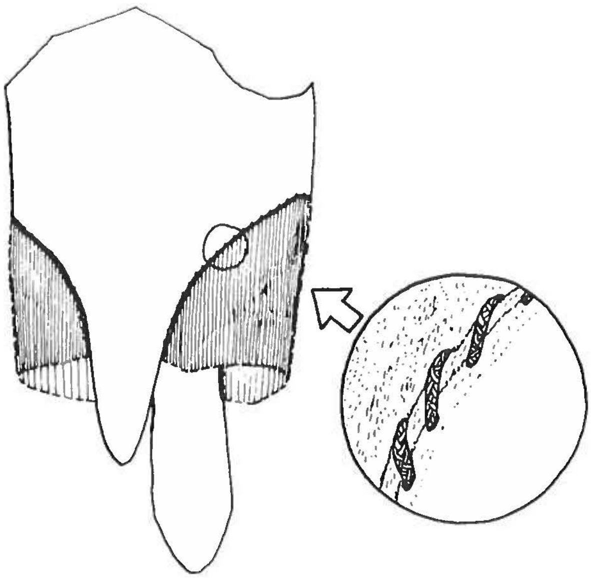

Fig. 7. Drawing of the outer parker of mummy 4 with the attached pieces of skin sewn on with braided sinew thread.

Fig. 8. Mummy 4. *The kamiks.*

Fig. 10. Mummy 5. The front of the outer parka.

sealskin strap 1.5 centimetres wide is tied round the right ankle. There is a patch under the heel of the right sole and traces of a patch on the left. Both *kamiks* have eyes for *kamik* straps at the sides.

The stockings, which are made of sealskin, terminate at the top with a turned-in fur band. On both stockings this band has been extended with a piece of sealskin, 10–11 centimetres wide, pieced together of several skin fragments. This skin has been sewn on with long crude overcast stitching. The fur side is innermost, and the stocking goes over the knee, so as to cover the trousers.

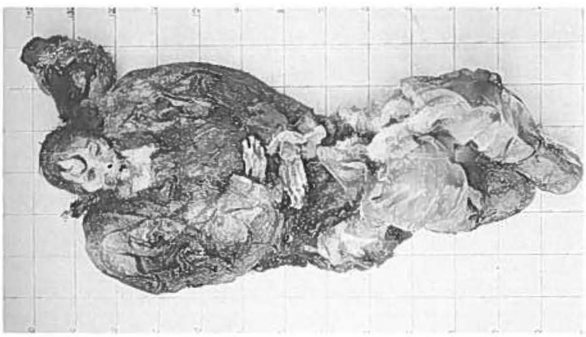

Fig. 9. Mummy 5.

Mummy 5: the costume consists of outer parka, inner parka, half-length trousers, *kamiks* and stockings. Their condition is bad, especially at the back.

1. The outer parka has a tail in front and probably has had one behind as well. Most of the back is missing. However, it is possible to see that this parka has had the characteristic markings over the shoulder blades. The hood is edged with a dark, turned-in fur band, which also follows the outer edge of the chin piece. On both sides of this band are remains of a string made of braided sinew thread and ending in a knot, showing that the hood and chin piece could once be drawn together. The sleeves are edged at the wrist with inserts of light-coloured skin.

2. The inner parka appears to follow the cut of the outer parka.

3. The trousers are made of caribou skin, and are very poorly preserved. Most of the back is missing. The

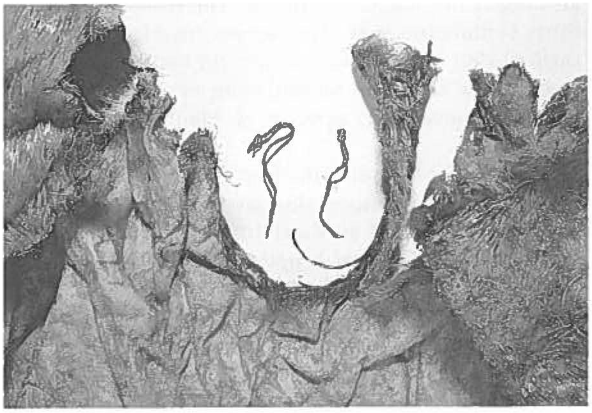

Fig. 11. Mummy 5. Remains of a string from the hood and chin piece.

trousers are about 40 centimetres long from the waistband to the legs, which end just above the knees. There is a fur band at the top with an attached belt to be tied at the back. The trousers appear to have been built up symmetrically with a right and left half, each composed

Fig. 12. Mummy 5. The right *kamik*.

Fig. 13. Mummy 5. The right stocking.

of various pieces of skin, and the play of light and brownish tones makes for a lovely ornamental effect.

4. The *kamiks* have well preserved legs, but the soles are by and large missing. The legs are about 50 centimetres high an go up over the knees. There is a front seam running over the instep towards the innermost edge of the sole. Another seam runs across the toes. The sole is finely and regularly gathered to the leg at the toe. The remains of a strap lie on the instep. The leg goes straight up at the back but in front it runs upward diagonally so that at the top it measures 30 centimetres. The skin was de-furred by cutting off the fur, a procedure that left stripes of short hair which clearly show that the hair ran downwards on the left *kamik* but horizontally on the right one.

The stockings are made of caribou skin. The legs are well preserved but the feet are completely gone. The stockings are 50–55 centimetres long and sewn together both at the front and back. They have been widened by piecing at the top.

Mummy 6: the costume consists of outer parka, inner parka, outer trousers and inner trousers, *kamiks* and stockings.

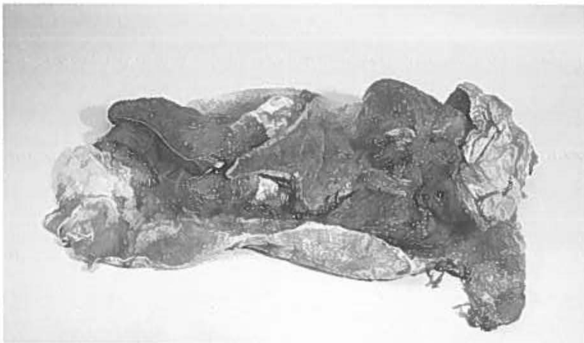

Fig. 14. Mummy 6.

1. The outer parka has a piecing under the side running from tail to tail. This extension is widest at the back, where it measures about six centimetres. It differs in character from the piece tacked onto Mummy 4's parka. This piecing is unusually well sewn and must be considered a decorative border. Both the front and back tails are edged with a light-coloured fur band, which also edges the side of the parka. The front tail is about thirty centimetres long. The sleeves are edged, first with caribou skin and next with a light fur band. The hood is stuck to the head and pushed somewhat out of shape.

Fig. 15. Mummy 6. The *kamiks*.

2. The inner parka appears to follow the cut of the outer parka.

3. The outer trousers are of caribou skin with sealskin legs added. The caribou skin trousers must have been originally fashioned as short trousers. They are most ingeniously cut, pieced together of various skin fragments in beige, brown and whitish tones. However, no clear pattern is evident. The added-on sealskin trouser legs were worn under the *kamiks*.

When the outer trousers were cleaned, the woman was seen to be wearing a pair of short inner trousers underneath.

4. The legs of the *kamiks* extend about 45 centimetres, ending above the knees. They are sewn together in front with fairly loose overcast stitches, which divide at the top to make room for a piecing. The soles are quite crudely gathered at the toe and heel and sewn to the leg with overcast stitching. Beneath the soles there are traces of both wool and guard hair. Both *kamiks* have a strap wrapped round the ankle and knotted at the front.

The woman appear to be wearing stockings inside the *kamiks*, but it has not been possible to uncover them enough to describe them.

A sample was taken from the left *kamik* for biochemical analysis (Ammitzbøll *et al.*, this volume). The sample revealed well preserved harp seal skin.

Mummy 7: the costume consists of outer parka, inner parka, trousers, *kamiks* and stockings.

1. The outer parka is greatly worn an often mended. In the grave it disintegrated further, particularly at the back, where only the bottom part of the tail and a detached piece of fur from the middle of the back are preserved. The front tail is about 30 centimetres long and edged with light-coloured skin, which also borders the fur at the side. At the bottom on both sides pieces of skin about twenty centimetres wide have been sewn on;

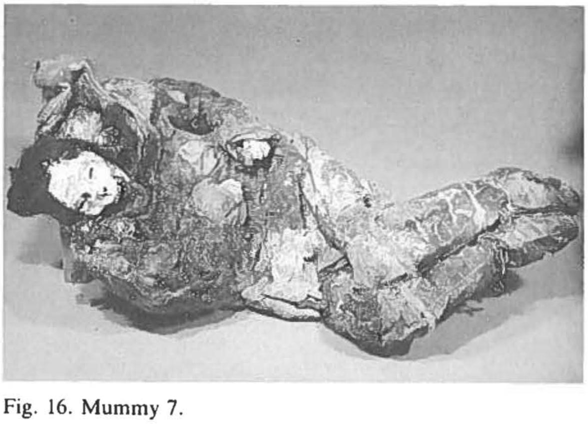

Fig. 16. Mummy 7.

Fig. 17. Mummy 7. The front of the outer parka with the attached skin pieces.

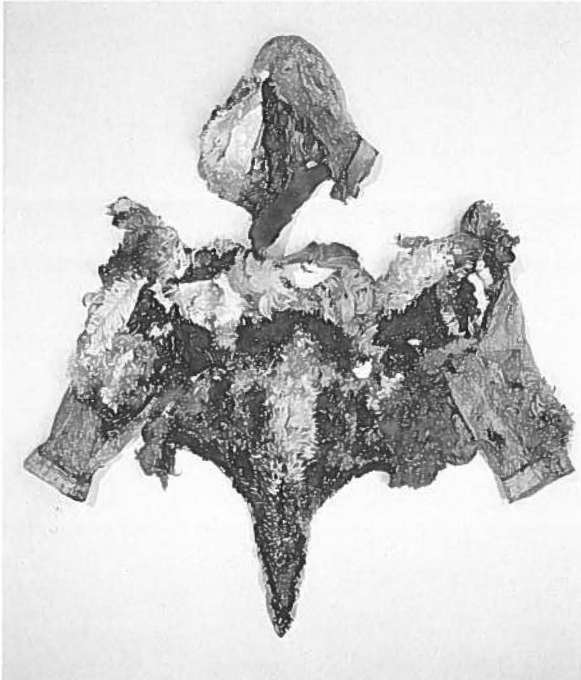

Fig. 19. Mummy 7. The front of the inner parka.

Fig. 18. Mummy 7. The lower part of the sleeve.

these pieces extend from the middle of the front tail round the side and to the back, where they are sewn onto the back tail. These skin pieces are made from the flippers of newborn seal, placed with the fur inwards. The pieces are bordered at the bottom by a band. The stitches, made from braided sinew thread, are long and crude.

The sleeves are very worn. They were mended on the lower side and at the armholes with patches roughly sewn on with large stitches. The sleeves have light fur bands at the wrists. Below these bands ten centimetre wide cuffs of sealskin, pieced together out of skin scraps, are tacked on with braided sinew thread. Inset in one of the piecing seams is a narrow woolly strip of newborn seal skin, which project about five centimetres beyond the cuff. In the middle of the sleeves, nineteen centimetres from the shoulder seam, smaller pieces of light skin are sewn in. The side pieces on both sides run into the undersides of the sleeves with gussets.

The hood is edged with a turned-in binding of dark fur, which also edges the chin piece. To this is added a piece of sealskin, fur turned inwards, about five centimetres wide. As with the other additions, the stitching here has been done – crudely – with braided sinew thread.

2. The inner parka has lost most of the back. However, the front, sleeves and hood were in such good condition that after conservation it was possible to identify the types of birdskin that had been used. All the skins have their contour feathers intact and are placed

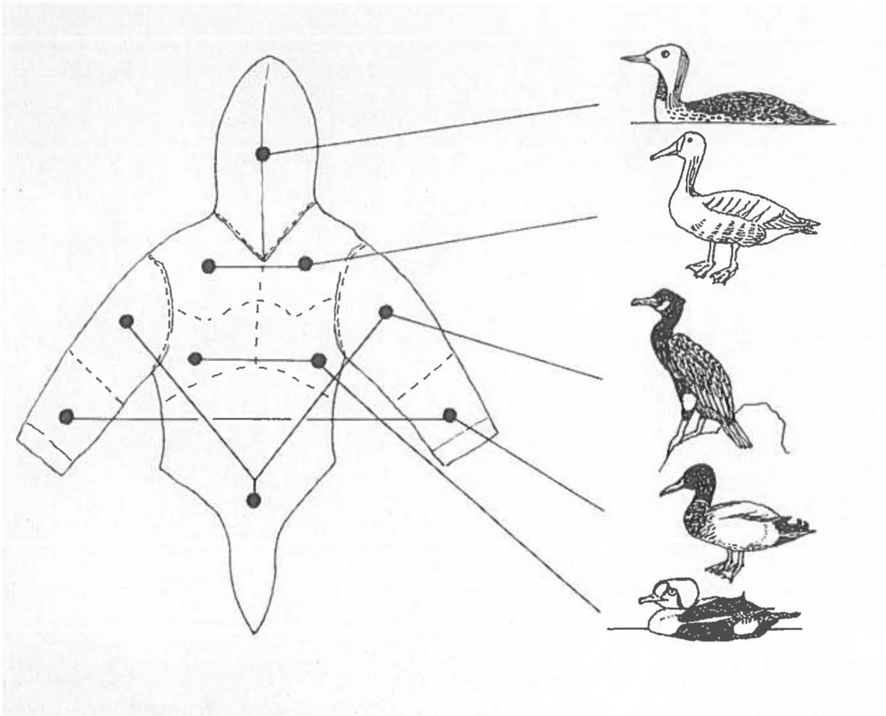

Fig. 20. Mummy 7. Drawing of the front of the inner parka showing how the skins from 5 different types of bird are placed.

to best advantage in the garment. Thus skins with short, dense plumage are used at spots where warmth is most important, and more open-feathered skins are placed by the wrist and neck openings to let heat out. The middle of the front panel is formed from the skin of a young cormorant. The neck hangs downward, forming the front tail, and the anus is seen just under the cut-off point on the chest. There are side pieces of female eider. The two chest pieces, which join in the chin piece at the neck, are made of white-fronted goose, which has loose feathers. The chest pieces continue to the back, interrupted by a transverse shoulder piece made of cormorant. The hood is assembled from two red-throated

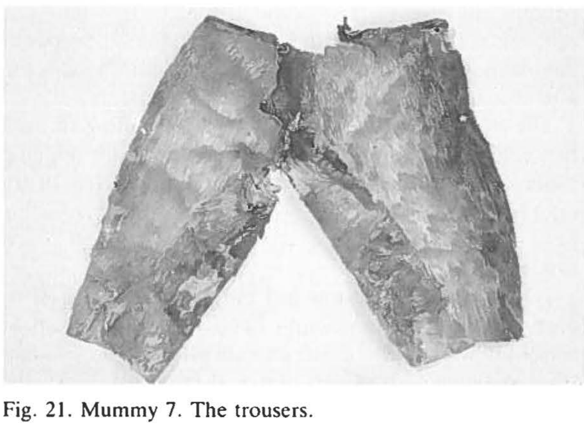

Fig. 21. Mummy 7. The trousers.

Fig. 22. Mummy 7. The left *kamik*.

diver skins. These have dense, short feathers which can fit the head closely. The sleeves are built up symmetrically with cormorant above and mallard downwards as a storm cuff. There are edgings of caribou skin.

3. The trousers are half-length and made of sealskin. They are somewhat delapidated, with loss of hair here and there, they are also badly worn and much mended. They are about 52 centimetres long, with the legs ending respectively twelve and six centimetres below the knee. There is a piecing in the seat of the trousers which runs down the inside right leg. It consists of three ten centimetre wide scraps of skin joined together. The right trouser leg is thus made ten centimetres broader than the left. The scraps are lined along the edge and appear to come from another garment. A strip of woolly newborn seal skin, 0.3 centimetres wide, has been sewn between the piecings and the original trousers. The long irregular overcast stitches used here are done with thick sinew thread. Originally the trousers were sewn with very neat, regular stitches. Below, on the inside of each trouser leg, light-coloured skin pieces measuring about 20 × 10 centimetres have been sewn in.

Fig. 23. Mummy 7. The left *kamik* with the strap tied with many knots.

Fig. 24. Mummy 7. The foot of the right caribou skin stocking. Note the marking from the strap just over the woman's heel.

4. The *kamiks* are well preserved. The legs are 36 centimetres high and sewn together in front with regular running stitches. At the top there is a sealskin casing with an attached strap, tied at the back. The sole is attached to the leg in regular gathers at toe and heel, and there are eyes for *kamik* straps in the sides of the soles. The woman, who is wearing both stockings and *kamiks,* has both feet lying above the ankle, where a strapp has been wound tightly round, and tied in front with many knots. On the left *kamik* the strap lies under the woman's heel, on the right *kamik* just above. There are traces of wool and guard hair under the sole.

The caribou skin stockings are in good condition. They have piecings at the top of the legs and above the front part of the foot. The legs are 33–35 centimetres high and seamed at both front and back. At the top they are edged by a fur band. Tacked onto this band is an edging of sealskin, about fifteen centimetres wide, with the fur turned inwards. Sewn into the right edging is a woolly band, 0.3 centimetres wide, of newborn seal skin.

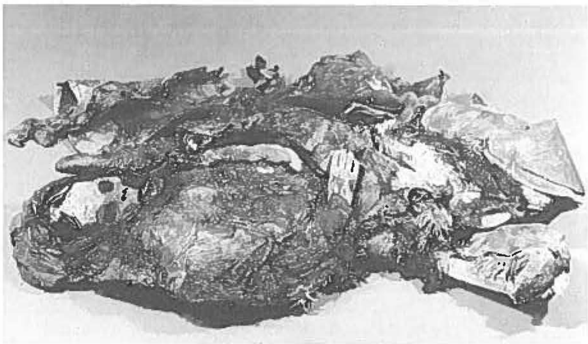

Fig. 25. Mummy 8.

Mummy 8: the costume consists of an outer parka, intermediate parka and inner parka, trousers, *kamiks* and stockings. This costume is the worst preserved of all.

1. The outer parka lacks the back entirely. There is extensive hair loss from the front and sleeves, but the remains show that the parka was of the same type as the other outer parkas. In the middle of the front, in the seam connecting it with the shoulders, a loop has been sewn in. The sleeves have a band of light skin at the wrist.

2. The intermediate parka, of bird skin, also lacks the back entirely, together with the left sleeve. What remains is formed from the front of a skin with the neck turned downwards; thick, dense skin across the shoulder with the neck side towards the sleeve. The edges are trimmed with caribou skin.

3. The innermost parka is of caribou skin, with the fur worn against the body. Only parts of the front are preserved with the hood and tail. These preserved parts are very well sewn. An impressive ornamental pattern has been made with areas of dark and light skin and narrow bands. Two white flaps corresponding to the chest area have been set in, and a narrow white stripe runs down the centre line. The tail has a band of skin scraps whose hair acts as a border, and just within a narrow dark stripe. In the centre a little tail has been sewn in, surrounded and thus emphasized by dark skin strips in which the fur has been trimmed to the same length. The hood is made of light skin edged with a

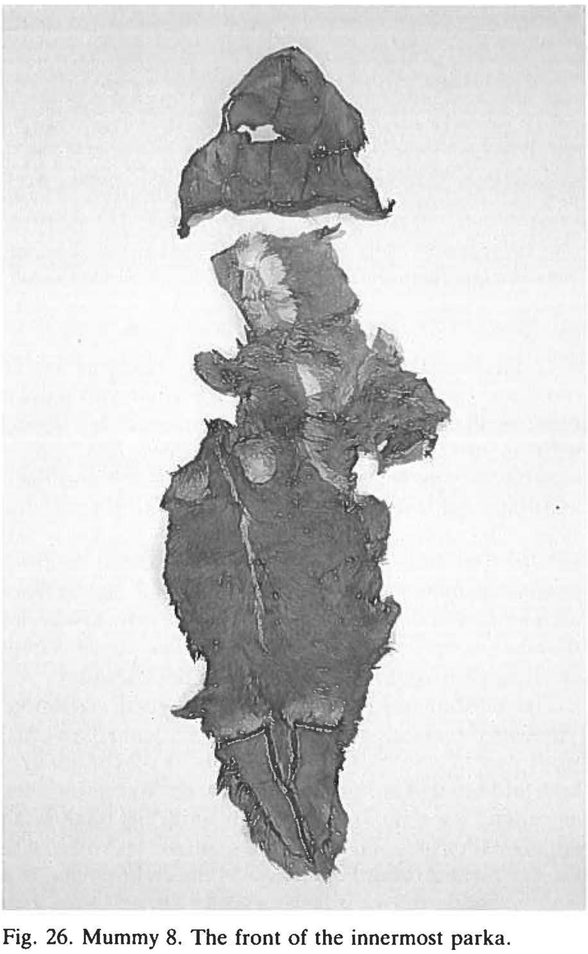

Fig. 26. Mummy 8. The front of the innermost parka.

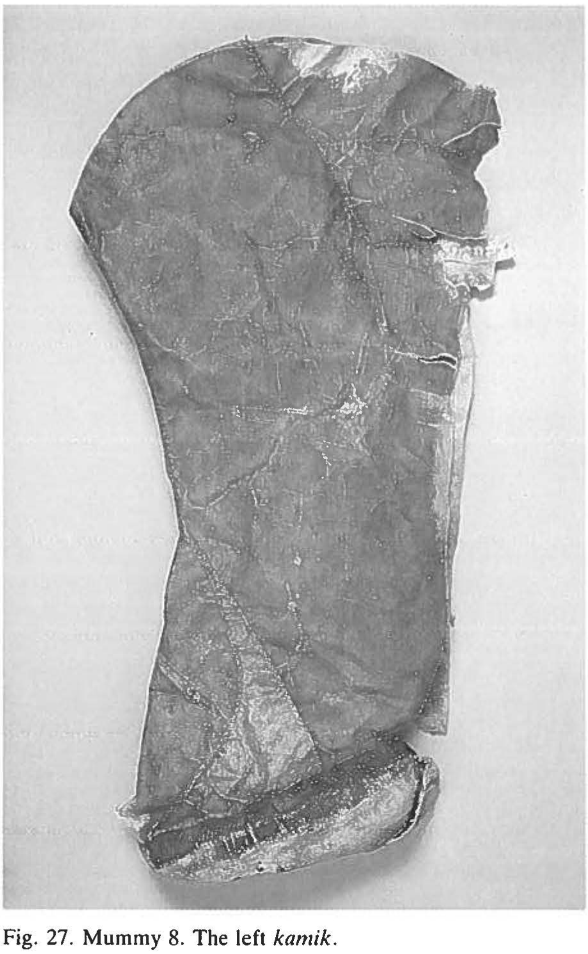

Fig. 27. Mummy 8. The left *kamik*.

Fig. 28. Mummy 8. The left stocking.

dark, turned-in fur binding. Running back from the forehead, two unhaired pieces of skin measuring about 25 × 5 centimetres have been tacked on to the outer side with just a few stitches. There is a very fine pattern at the nape of the neck, made by an inlay of dark and light pieces of fur.

4. The trousers are very badly preserved. The entire seat is missing. These trousers are made of sealskin, with half-length legs reaching the knee and measuring about 42 centimetres. There is a turned-in fur waistband at the top.

5. The *kamiks* are also poorly preserved, especially the right one, whose back and right side have rotted away. The legs are about 50 centimetres high, with a seam at the front. This seam divides over the instep and turns down over each side. There are triangular piecings at top and bottom. The sole is attached to the leg with regular gathers, and there are eyes for a *kamik* strap at the sides. At the back the leg goes straight up; in front it widens to about thirty centimetres at the top.

The stockings are made of caribou skin with very thick, coarse fur. The left stocking is well preserved. The leg is 53 centimetres long, with a good deal of piecing out on the inner side. The leg is topped by a turned-in fur band of caribou skin, and sewn together in front with a gore. The sole is gathered at the toe and heel and attached to the leg by two narrow strips of skin which run all the way round the foot. The right stocking is poorly preserved, but matches the left one closely. The whole of the back and some of the outer side have rotted away. The leg is about 50 centimetres long.

The childrens's clothes

The infant *mummy 1*: is clothed in a sealskin parka and leggings.

1. The sealskin parka is made of dark skin at the front and rear with somewhat lighter sleeves. It has a sewn-on hood of light skin with a dark, turned-in fur band containing a cord, so that the hood can be closed over the baby's face and tied over the forehead. An insewn skin strip joins the two halves of the hood in the middle. This strip is dark in the middle with a light strip on each side.

Fig. 29. Mummy 1. The baby.

Fig. 30. Mummy 1. The fur band on the top of the hood.

The hood has disintegrated at the back, but it looks as if the strip went down over the back of the head. The parka is waist-length all the way round. In the middle of the front there is a little skin bag sewn together at the bottom and side and fastened to the parka with a sinew thread.

Fig. 31. Mummy 2. The skin clothing of the four-year-old boy.

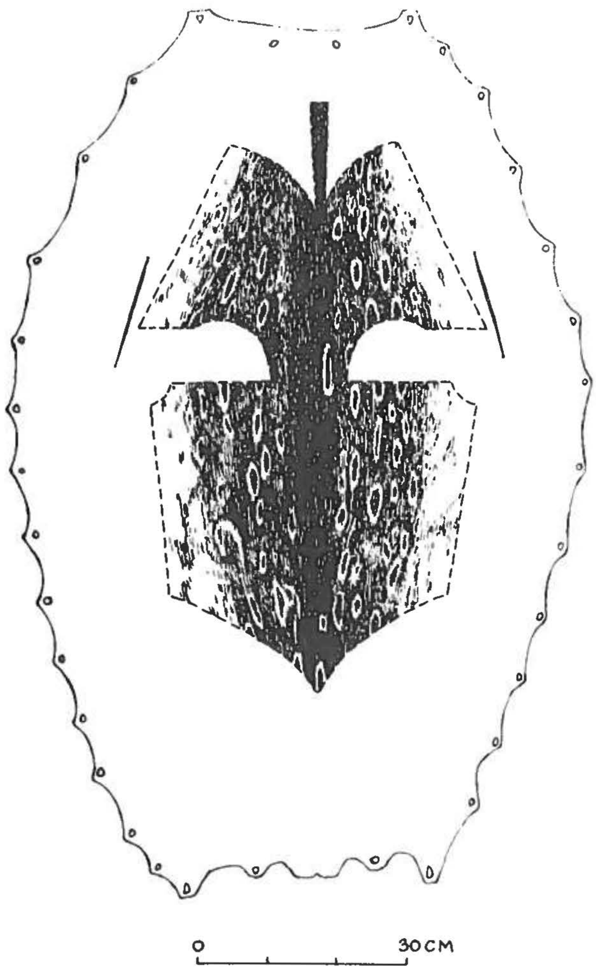

Fig. 32. Mummy 2. Drawing of the back piece and hood of the outer parka placed on the sealskin.

2. The leggings are made of soft skin, with the fur worn next to the body. They seem to have been cut in two symmetrical halves and sewn together in the middle. Round each ankle there is a strap, tied in front.

Mummy 2: The skin clothing of the four-year-old boy consists of an outer parka and an inner parka, both hooded, trousers, *kamiks* and stockings. All the clothes are made of sealskin. Both inner and outer parkas are delapidated at the bottom, especially in front, where much is missing.

1. The outer parka has the fur on the outside. Back piece and hood are cut out in one piece with the dark back of seal in the middle. The front of the hood has a short decorative strip of skin, the rear part of which is dark, cut out in one piece with the hood, while the front part is an insert of light skin. There is a casing round the facial opening of the hood. The front is made of one piece of dark skin with inset chin piece, and joined to the back by light shoulder pieces. At the bottom there is

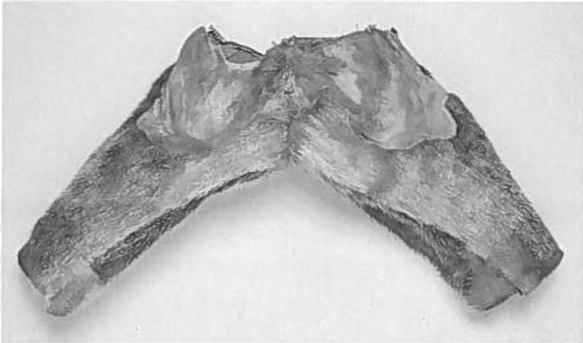

Fig. 33. Mummy 2. The front of the trousers.

an edge, five centimetres wide, which descends to a broad point at front and rear. The sleeves are set in straight.

2. The fur on the inner parka is turned inwards. The back and hood are cut out in one piece as in the outer parka, but the tailoring is more complicated. The short skin strip to the front of the hood is divided into three, with one dark one centrally, and two light stripes at the sides. The hood has a dark casing round the face opening. The shoulder pieces are pieced out at the back and a gusset has been inserted to the front. The front is made in one piece. The sleeves are set in straight , but

Fig. 34. Mummy 2. The *kamiks* and the stockings.

Fig. 35. Mummy 2. The right stocking.

with the insertion of a triangular gusset towards the shoulders. The parka has a hem, just like the outer parka, but only half as broad.

3. The trousers are half-length, with the fur turned outwards. They are badly deteriorated at the top, with a loss of hair both in front and at the seat. A right and a left half have been sewn together in the middle. Both trouser legs have been made of two pieces of skin, with an inner seam between the legs and a side seam turning into the back of the legs. There are triangular piecings of light skin at the bottom and a waistband at the top. This band has a lacing of a good two centimetres at the back. The trousers are very badly sewn, clumsily and roughly done, with loose ends, large knots and long stitches.

4. The *kamiks* are well sewn, but very worn with scratches on the legs and patches under the soles. The left *kamik* is made up of two pieces of skin, the right *kamik* of one, both seamed at the front. From the instep the stitching runs towards the outer edge of the *kamik*. The sole is attached to the leg with very regular gathers at front and rear. At the sides of the soles there are eyes for a *kamik* strap, and an attached strap. Traces of

stitching indicate that there was originally a band at the top of the legs.

The stockings, with the fur turned inwards, are similarly well sewn and well cared for. Each is made of two pieces of skin with a piecing at the top of the leg. The seam is in front. The legs are 27 centimetres high and terminate at the top in a fur band.

Garments found loose in the graves

These garments are identified with "ED" numbers, where "ED" stands for *EskimoDragt,* i.e. Eskimo Garment.

Outer parkas: Of seven outer parkas, four answer closely to the basic type worn by the six women, with minor variations, two (ED 30 and 78), have a quite different cut, while of one (ED 25) there is so little left that it must stand alone. The skins are all from the ringed seal.

ED 25: The parka is very worn and only partly preserved (the right arm and the side under the arm down to the hem, the upper part of the front with the neck opening and about thirty centimetres of the back). The garment is made up of many small pieces of skin, and there is no trace of a hood or of any ornament. The armhole is round, and there are several piecings at the wrist. The back and sleeve are patched. A scrap of bird skin has been sewn on the inside, just above the hem. Braided sinew thread is sewn into the seams in the arm, the armhole and by the hem.

ED 26: The fur has been worn away at the front, where there are many holes. The back is torn to pieces, and there are many pieces missing. Both sleeves are cut off just below the armholes. The rear tail is 43 centimetres long, the front one about ten centimetres shorter. Both are edged with a turned-in fur band. In this band have been set long crude stitches from the middle of the forward to the middle of the rear tail. On the right hand side are traces of a fur which has been sewn on, and subsequently ripped off. The parka is otherwise well sewn.

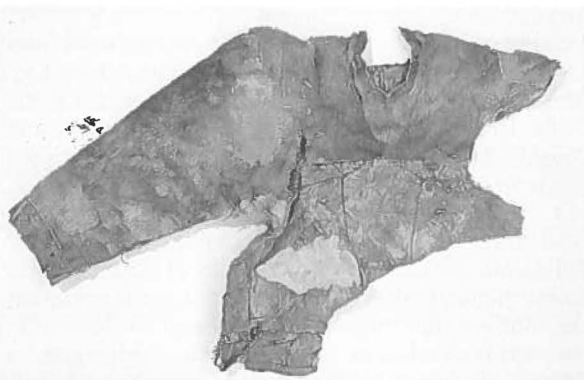

Fig. 36. The parka ED 25.

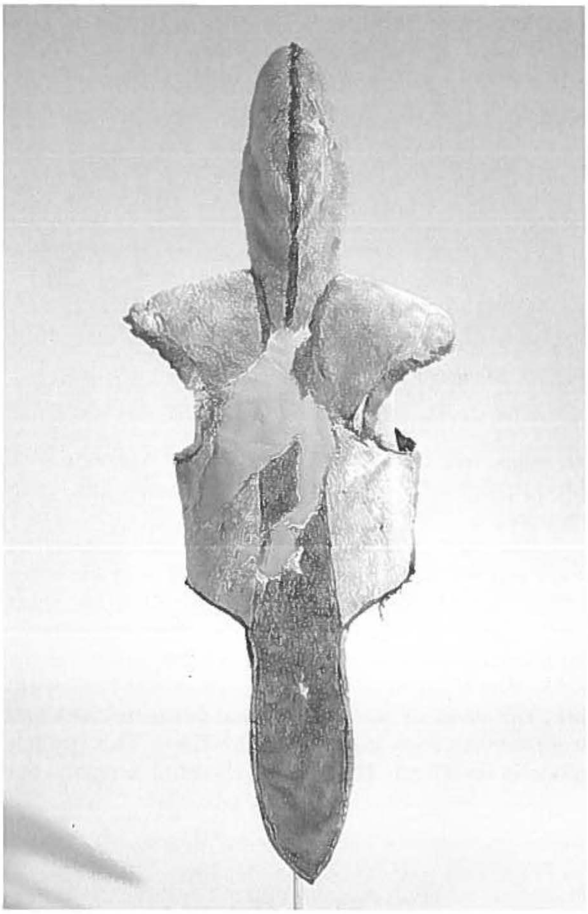

Fig. 37. The parka ED 26.

ED 27: The parka is damaged around the collar, where the breast and the top of the back are missing. Also missing are the lowest, rearmost part of the hood and the lowest portion of the right sleeve. The rear tail is 46 centimetres long, the front about ten centimetres shorter. Both are edged with a light fur band, which also trims the side of the parka. Under this border a small piece of light skin has been sewn on, which goes from the front to the rear tail. There are piecings on both sides between back and front pieces. The sleeves are in four pieces, the left one with a border to the hand. A piece of black bird skin is sewn onto the back of the front tail about 22 centimetres from the end. It is the head of one of the *alcidæ,* and measures 3.5 × 2.5 centimetres. It is sewn on with sinew thread.

ED 28: The left sleeve is torn across the upper arm, where there is also some loss of fur. The hood is also damaged on the right hand side and at the top. The rear

Fig. 38. The parka ED 27.

Fig. 40. The parka ED 28.

tail is 43 centimetres long, the forward one about seven centimetres shorter, both with a light turned-in fur band. The sleeves are in two parts with a similar turned-in fur band at the cuff and piecings of light skin.

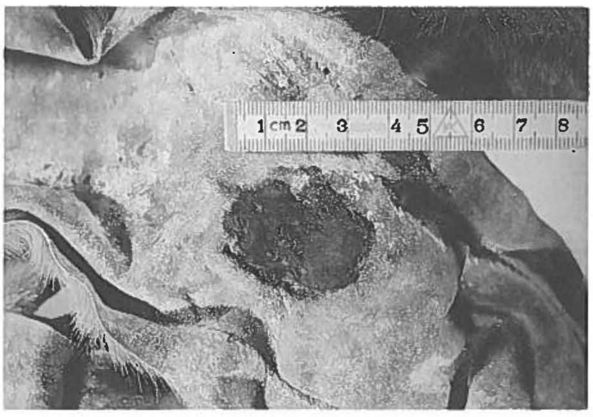

Fig. 39. ED 27. The black bird skin on the back of the front tail.

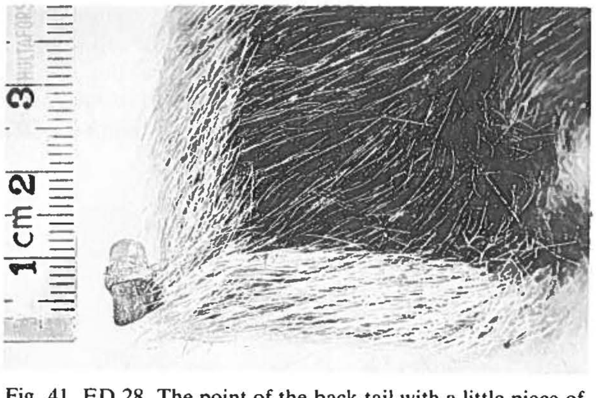

Fig. 41. ED 28. The point of the back tail with a little piece of bone hanging in a loop of braided sinew thread.

There are further piecings on both sides, between back and front pieces. The rear tail has two bands of white skin sewn at the bottom of the dark skin. From the point of the front tail there hang a braided sinew thread, one centimetre long, with a knot. The point of the back tail

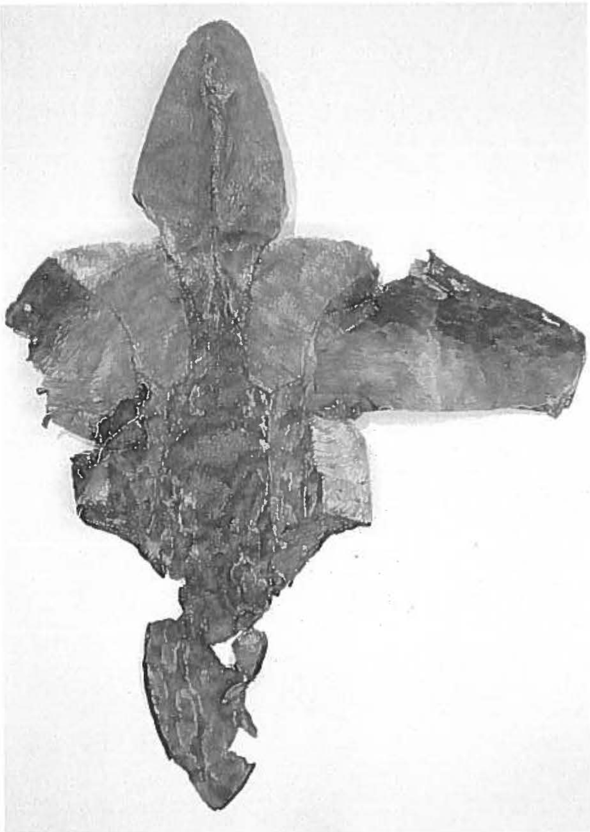

Fig. 42. The parka ED 29.

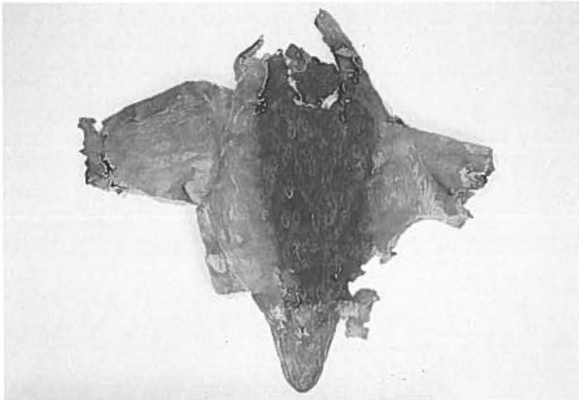

Fig. 43. The parka ED 30.

has a loop of braided sinew thread enclosing a little piece of bone. The back of the front tail bears traces of something having been sewn on about twenty centimetres from the point.

ED 29: Much of the parka is missing: the left sleeve, the tail at the front and about half of the rear tail. This is the largest of all the parkas, and the only one where all three parts of the back are of dark skin. Otherwise the sewing and cut are the same as for the other parkas. The rear tail is about fifty centimetres long with a border. The right sleeve is of two parts with a band at the cuff.

ED 30 is very badly preserved, and much is missing from the front, from one sleeve and the hood. It appears to have been sewn as an *amaat,* that is a parka with room to bear a child pick-a-back. The child is stopped from sliding down by a strap round the back which fastens at the front, for example with a toggle. The front is made of a single sealskin. It ends at the bottom in a tail and is cut off at the top across the breast. There are light shoulder pieces, sewn to the front. In the centre of this seam is a toggle. The shoulder pieces are connected to a light chin piece. The back and the hood are cut in one piece out of a single sealskin. The parka was cut off at the hips, and a rear tail, of which most is missing, was sewn on. The shoulder pieces, six or seven centimetres wide at the back, are sewed to the back over the shoulder blades. Over the shoulders they broaden towards the sleeves in a tongue form and measure about twenty centimetres. It is difficult to describe the hood because of its poor condition, but forward it forms a chin piece with the aid of two gussets,

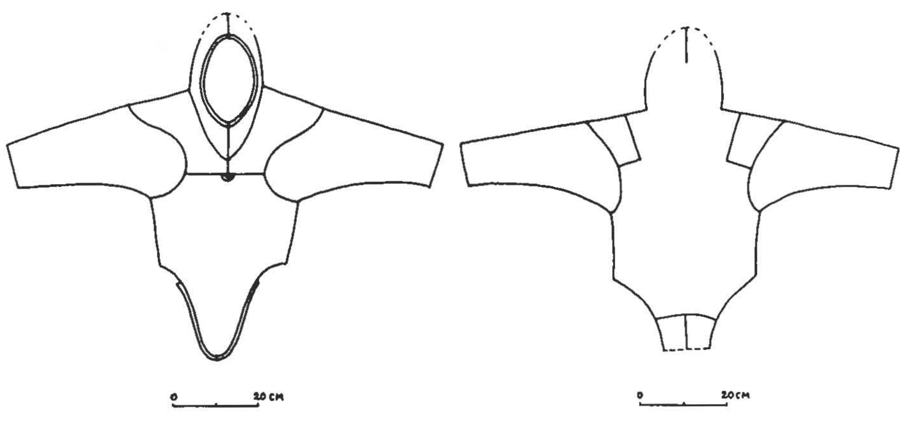

Fig. 44. ED 30. Reconstructed pattern of front and back sides.

Fig. 45. The front of the parka ED 78.

and the sides are joined to the shoulder pieces. The hood is bordered with a dark, turned-in fur band. A thick sinew thread is crudely stitched along this band. The armholes are round and the sleeves very full.

ED 78: The parka has a tendency to lose hair, and most of the hood is missing. The parka consists of front, back, hood and sleeves. The front is a single sealskin. It reaches to the shoulders where is is joined to the back with a shoulder seam. The back is also formed from one skin, which runs down to form a broad, tongue-shaped tail, quite unlike the tails on the other parkas. The bottom ten centimetres are an added piece of dark skin.

Fig. 47. The trousers ED 12.

The hood, the top of which is missing, is edged with a dark turned-in fur band. Forward it forms a light chin piece, which is joined to the front and at the back is slightly curved and joined to the back. The very wide armholes are straight or slightly rounded, and the sleeves very full over the shoulders. In front, at the end of the sleeves a 21 centimetre wide light skin piecing is sewn in as a cuff. This parka is fashioned quite differently from the others.

Inner parka ED 77: The parka is of bird skin edged with caribou skin. It is poorly preserved, in that the front, most of the back, one sleve and part of the hood are missing.

The right shoulder is formed from one skin, which falls down at the back, and at the front joins onto the chin piece. The hood is of one skin at the back and one forward with additions.

Trousers ED 12: This is a well preserved pair of short

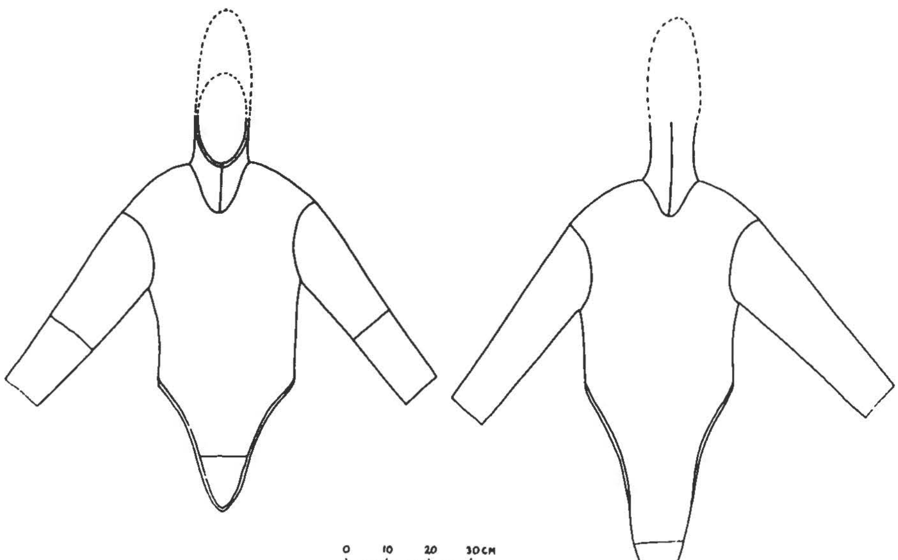

Fig. 46. ED 78. Reconstructed pattern of the front and back sides.

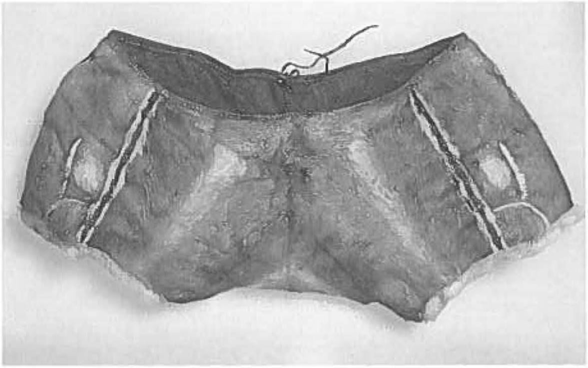

Fig. 48. The trousers ED 13.

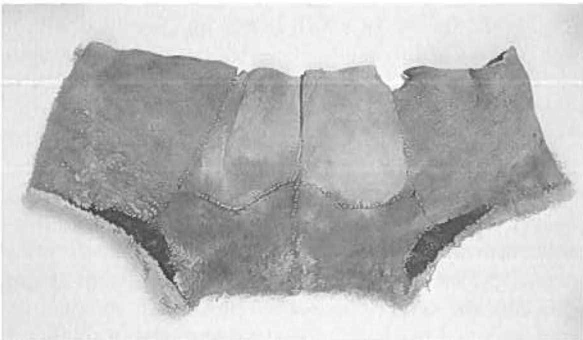

Fig. 49. The trousers ED 24.

sealskin trousers. They are fashioned in two symmetrical halves with a central seam. They have a waist band of de-furred sealskin containing a belt that ties behind, and a turned-in fur band at the end of the leg. Each half is composed of ten pieces of skin, so that the light and dark colours form a highly decorative pattern on the back.

ED 13 is a pair of short caribou skin trousers. They are fashioned similarly to ED 12. They have a waistband with a belt that ties at the back. Cut and pattern employ over twenty pieces and strips of skin in each half. The larger pieces are taken from a caribou's hind leg, where two skins have been placed at the front, so that both a white spot and a light stripe in the skin sit symmetrically on each side of the midline. The rest of the ornamentation is made by the insertion of white and dark strips of skin. Into the middle of the back seam have been sewn two small patches so as to protrude freely. The trousers are worn, particularly at the seat, where the fur has been worn away.

ED 24 is a pair of short caribou skin trousers. The fur is worn down and worn away at both front and back, and the waistband is missing. Each half is composed of seven pieces of skin. The legs are banded at the edge. Just over this band at the back a piece of dark sealskin, about twelve centimetres long, has been sewn in. Below each leg hang a number of cut thick sinew threads, indicating that earlier there have been extensions.

Kamiks

ED 1: This *kamik*, made of de-furred sealskin, was paired with the stocking ED 2. The top of the leg is cut away. There are two patches under the sole, and eyes for a *kamik* strap on both sides. It is seamed down the front with a single row of running stitches, which divides over the instep and runs out to each side. There was *kamik* grass inside the stocking, and also between the stocking and the kamik.

ED 4: This *kamik* of de-furred sealskin was paired with stocking ED 3. It has two patches under the sole and there are eyes for a *kamik* strap on both sides. The leg is seamed at the front with a single row of running stitches, which divides over the instep and runs out to each side. The leg goes straight up at the back; in front it gets wider. It is edged with turned-over white skin. There was *kamik* grass inside the stocking and between the stocking and the *kamik*.

ED 14: A *kamik* of de-furred sealskin. There are two patches in the sole, eyes for a *kamik* strap on both sides and a *kamik* strap threaded through. The leg measures

Fig. 50. The *kamik* ED 1 with stocking.

Fig. 51. The *kamik* ED 4.

Fig. 52. The *kamik* ED 14.

Fig. 53. The *kamik* ED 15.

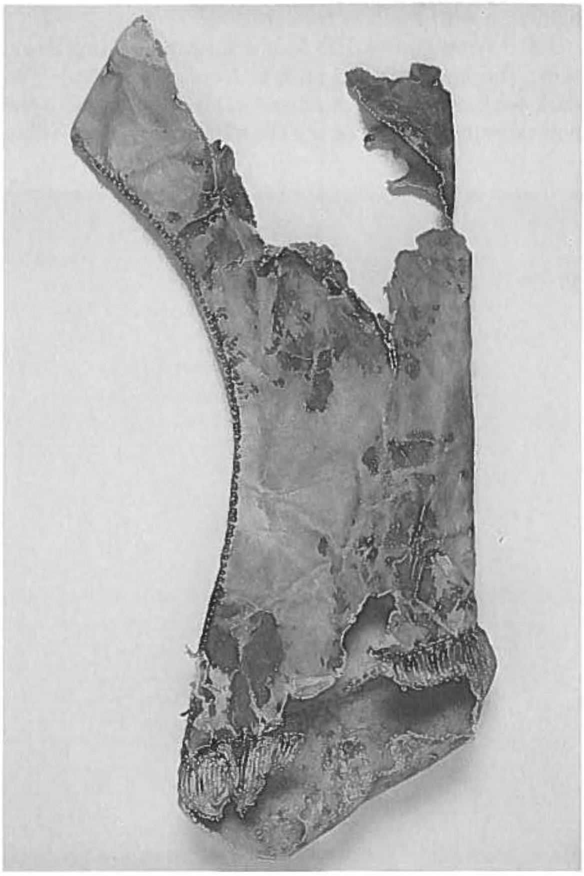

Fig. 54. The *kamik* ED 17.

about 34 centimetres and has double seams of running stitching both before and behind. At the top there is casing with a strap that ties at the back.

ED 15: A *kamik* of de-furred sealskin. There is a patch under the heel and a big hole at the top of the leg. There are eyes for a *kamik* strap on both sides of the sole with remains of a strap. The leg measures 36 centimetres and is joined at the front with a single seam of running stitches, which becomes double over the instep. At the top there is casing with a strap which ties at the back.

ED 17: This *kamik* of de-furred sealskin was paired with stocking ED 18. Its condition is poor with a big hole on the side of the sole and with bits missing from the top. The 35 centimetre long leg is joined at the front with a single row of running stitches. There are two eyes for a *kamik* strap. There was *kamik* grass in the stocking and between the stocking and the *kamik.*

Stockings

ED 2 (from *kamik* ED 1) is a stocking of ringed seal skin. The leg is joined at the front. The dark back of the skin is positioned behind the leg with the hair pointing downwards. Light skin is added over the instep and at the top of the leg with the hair horizontal. The sole is of light skin with the hair forward.

ED 3 (from *kamik* ED 4) is a stocking of ringed seal skin. The lig is seamed both in front and behind. The dark back of the skin is placed behind the leg with the hair pointing down. The leg has a turned-in edge. There are pieces added at the instep. The sole is of light skin with the hair pointing forward.

Fig. 55. The stocking ED 16.

Fig. 56. The stocking ED 18.

ED 16 is a stocking of ringed seal skin. The leg is 36 centimetres high and seamed at the front. The seam divides to each side over the instep. The dark back of the skin is placed over the calf. A casing of about one centimetre's breadth at the top of the leg contains a cord that ties at the back. The sole is of light skin with the hair pointing forward.

ED 18 (from *kamik* ED 17) is a stocking of ringed seal skin. Large bits are missing from the top, and there is a big hole in the sole. The leg is 35 centimetres high and seamed at the front with running stitching. A fold has been impressed at the back. The sole is of light skin with the hair pointing forward.

ED 19 is a stocking of ringed seal skin. The leg, about 35 centimetres high, is seamed in front with running stitching. The dark back of the skin forms the back of the leg and the hair points downward. The top of the leg is trimmed with a band one centimetre wide.

ED 20 is a stocking of unborn or newborn seal skin. The foot has rotted away. The leg, which has several

Fig. 57. The stocking ED 19.

Fig. 58. The stocking ED 20.

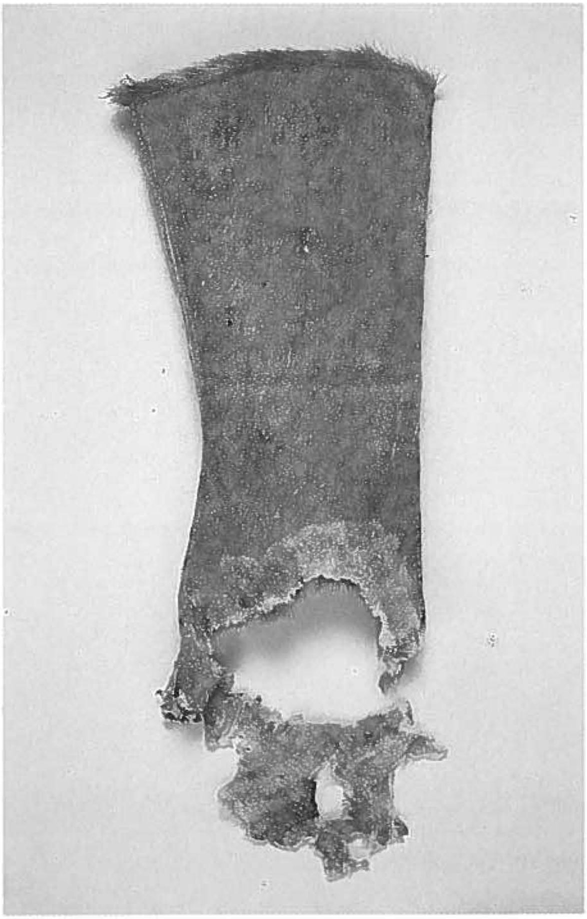

Fig. 59. The stocking ED 21.

piecings at the front as well as high up at the back, is 34 centimetres high. The calf covering is made of a piece of skin that shows stretch holes on both sides. The top of the leg is trimmed with a sealskin band about one centimetre wide.

ED 21 is a stocking of ringed seal skin. The leg, 33 centimetres high, is seamed with overcast stitches front and rear. Belly skin has been used for one side, back skin for the other. The top of the leg is trimmed with a sealskin band about half a centimetre wide. The sole is of light skin with the hair pointing forward.

Half-sleeves

ED 22 is a half-sleeve of ringed seal skin. It is formed of three bits of skin with a triangular piecing above. Only the upper half of the sleeve is preserved, plus a complete seam down to the edge of the cuff. It can thus be seen that the sleeve was 23 centimetres long. In the uppermost corner hang two sinew threads with knots, so it could have been fastened to another garment.

Fig. 60. The half-sleve ED 22.

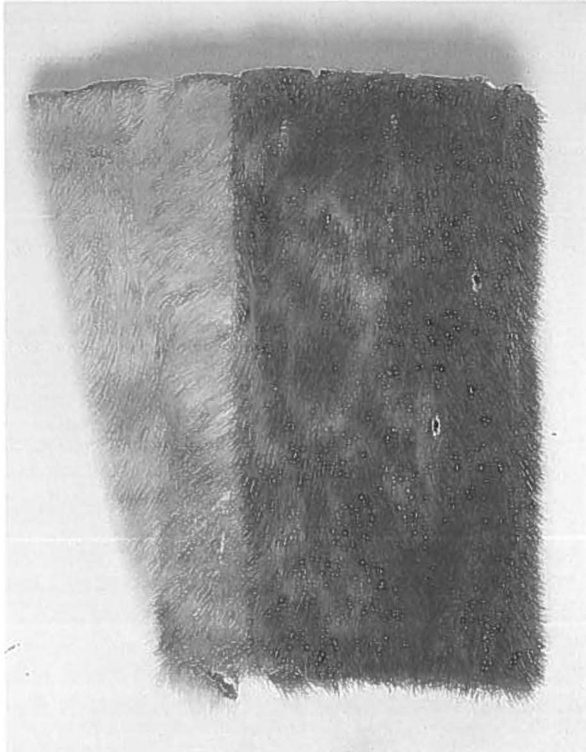

Fig. 61. The half-sleeve ED 23.

ED 23 is a half sleeve of ringed seal skin. It is formed of three bits of skin, and has a turned-in fur lining at the cuff, where it is narrowest. It widens upwards by about seven centimetres.

Acknowledgements

The author wishes to thank John Lee, The National Museum, who has taken all the photographs, and H. C. Gulløv for the line drawings.

Two 17th-century Eskimos at Rosenborg Palace

MOGENS BENCARD

Bencard, M. 1989. Two 17th-century Eskimos at Rosenborg Palace. – Meddr Grønland, Man & Soc. 12: 47–55. Copenhagen 1990–01–26.

Two seventeenth-century drinking vessels or cups, made of narwhal tusk and mounted in precious metals, have as part of their fittings miniature sculptures of Eskimos. The two figures are rendered in extremely naturalistic detail, making it possible to study their costume. This makes them 'missing links' in the evolution of Eskimo costume between the fifteenth-century mummies and modern dress. This paper presents the cups, and places them in their historical context, but leaves the evaluation of the costume-historical evidence to the ethnographers.

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Rosenborg Palace was built at the beginning of the seventeenth-century as a 'maison de plaisance' just outside the walls of Copenhagen. It was inhabited by four generations of Danish Kings for about a hundred years, after which it was considered old-fashioned and unsuitable for Royal residence. From then on it was used to store Royal treasures and family heirlooms such as portraits, unusual furniture and other precious objects.

In 1833 it was turned into a public museum, with the declared purpose of illustrating Danish National history chronologically from around 1600 till the present day. In fact, it illustrated Royal family history rather than national history, but in the days of absolute monarchy this distinction seemed irrelevant, since these histories were considered one and the same.

It may seem surprising that such a collection, standing almost unchanged since the middle of the last century, holds evidence of Eskimo costume of such importance to ethnographers that it represents a link between the mummies of the fifteenth century and the present day. As will be seen, however, this is nonetheless the case.

This evidence is not costume as such, which is probably why it has never been published in an Eskimo context. It is two small figures, one in enamelled copper, the other in silver gilt, both mounted on cups made of narwhal tusk. Both cups can be dated to the middle of the seventeenth century, the figures thus being the oldest known sculptures dipicting Eskimos. Their importance, of course, is due to the fact that this is the first time since the mummies that Eskimo costume can be seen from the back.

This paper will not try to evaluate the importance for costume history as the present author is not familiar with the topic. Instead, an attempt will be made to date the cups with their figures, and to relate them to the historical situation from which they arose. The cups

Fig. 1. Cup. Dated 1663. Narwhal tusk mounted in gold with enamel. On top a figure of an Eskimo in enamelled copper. Height 33 cm.




have been illustrated, and briefly, but not altogether correctly, described (Hart Hansen *et al.* 1985: 165).

The larger of the two cups is 33 cm high.[1)] Cup and cover are made of narwhal tusk and mounted in gold. The cup, which is beaker-shaped, has a flat base made of three pieces of tusk, the body consisting of fourteen panels with grooved edges interspersed with tongues of gold. The panels are held together by three enamelled bands of gold, all decorated with varicoloured flowers. The curved cover with fourteen panels is constructed in the same way and is topped by an 8.3 cm high figure of an Eskimo, made of copper and enamelled in natural colours. The figure stands on a grass mound of enamelled copper, joined to a conical piece of narwhal tusk. The latter has a thread, so that, when screwed in tightly, it ingeniously holds the panels locked against the flower-enamelled gold rim. The figure, which obviously represents a man, stands with a narwhal tusk in its left hand and with the middle finger of the right hand pointing to the ground. He has a black bow slung over his shoulder and a quiver with arrows on his back. The coat, trousers and boots are light brown with black spots, depicting sealskin (probably the ringed seal, *Phoca hispida*). The short trousers as well as the coat with its high hood and lobed ends hanging down at the front and back represent a female costume. This discrepancy between the man and the costume will be dealt with below.

Under the cover and attached to the central piece of tusk is a circular plate of enamelled gold showing crowned initials within a wreath on a blue ground. The many-lettered initials have not been interpreted, but 'F3' refers undoubtedly to Frederik III, who was King of Denmark from 1648 to 1670. This is corroborated by the accompanying date 1663.

The cup was recorded in 1696 in the oldest existing inventory of Rosenborg Palace in the following manner: 'A large Unicorn's Cup with three enamelled Gold Bands around its Cover (sic!), on which a Greenlander of Gold, enamelled, with his Bow on his Back.'[2)] This description leaves no doubt as to the identity of the object, but it should be added that new inventories were made at Rosenborg every thirty years, and the cup can be followed through all inventories up to the present.[3)] There is no information as to the whereabouts of this and the other cup with an Eskimo prior to 1696, unless one chooses to identify them with the entry: 'Two slender Beakers of Unicorn's Horn' in the 1673 inventory of the Royal 'Kunstkammer' (Cabinet of Curiosities) at Copenhagen Castle (Liisberg 1897: 166). The identification is all the more uncertain since quite a number of cups made of unicorn's horn were mentioned at the time, some of which still exist. However, the possibility that the two cups with Greenlanders were transferred

Fig. 2a-d. The Eskimo in enamelled copper.

Fig. 3. Tankard. Around 1660. Walrus tusk mounted in silver. Height 15.4 cm.

from the 'Kunstkammer' in the 17th century cannot be completely ruled out. A third cup with a Greenlandic motif is to be found at Rosenborg today, just as it appeared in the 1696 inventory. It is made of walrus tusk, and stands on three silver gilt feet in the shape of walruses and with an engraved walrus on the silver cover.[4)] This cup can with a high degree of certainty be identified in the 'Kunstkammer' inventory of 1673 (Liisberg 1897: 165).

The second cup has a total height of 19.6 cm.[5)] It has the shape of a tankard with a handle and a hinged lid. The flat base is made of pieces of narwhal tusk, and the cylindrical cuppa of seventeen panels, grooved at the edges, and joined by shafts, which in this case are also made of tusk. It is held together by a footring and a mouthring of silver gilt. The slightly curved lid is made of seventeen panels and tongues, constructed in the same manner as the cuppa, and held together by a ring and a circular central plate, both in silver gilt. The footring stands on three kneeling, silver gilt unicorns. The S-curved, silver gilt handle runs from the footring to the hinge, on which, as a thumb-piece, sits a 4.1 cm high Eskimo figure in silver gilt. In this case, too, it is a male figure with a narwhal tusk in his right hand, his left hand resting on the head of a seal which lies curled-up behind his back. He is also wearing a female costume. The central piece on the lid is engraved with two standing figures, a woman and a man. The man holds a bow and a spear in his right hand, and in his left, a harpoon with a bladder. In this case the costumes are rendered correctly (see Fig. 7).

Fig. 4. Tankard. Around 1660. Narwhal tusk mounted in silver gilt. Height 19.6 cm.

From these descriptions some facts emerge, which will be dealt with in the following. One of the cups is dated 1663 and is directly connected with the King. The fine execution and the precious materials are common to both cups. Unicorn horns were at the time prime collector's items among princely collectors, and were thus just as costly as gold. Both cups show the thematic combination of Eskimos and unicorns.

The first problem to be dealt with is the date of the tankard. Axel Garboe, who published material on the cups in 1915, and gave a useful list of the literature on the subject (Garboe 1915: 39, 109), dated the tankard on stylistic grounds to 1620–30. Eugen v. Philippowich, who mentioned the cups in his book on ivory, dates them both to around 1660 (Philippowich 1982: 119). This is more reasonable, since prior to this time there were no Eskimos in Denmark or anywhere else from which to model figures as naturalistic as these two.[6] Furthermore, it is possible to establish a 'terminus post quem' for the creation of the tankard. It is a well-known fact that four Eskimos were brought back with the Greenland Expedition of 1654. The famous full-length portrait of these four, the man 'Jhiob', and the women 'Gabelou', 'Gunelle', and 'Sigjo', is dated 'Bergen, den 28. september Anno 1654', and is today in the National Museum, but was originally in the 'Kunstkammer'.[7] The connection between this painting, the expedition, and the two cups is obvious. The engraving on the lid of the tankard is a copy of Jhiob and Gunelle in the Bergen painting. They are standing in the same positions, only reversed, as is common with engravings, and the way in which the man is holding his weapons is revealing. Jhiob died *en route* to Copenhagen whereas the three women were sent to the Danish Court, then residing in Flensborg, and later to Gottorp to meet Adam Olearius (Meldgaard 1980: 4). In his account of this event (Olearius 1656; Scheffel 1987), Olearius published an engraving from which the engraving on the tankard is directly copied. Consequently the tankard cannot have been made prior to Olearius's book, which appeared in 1656.

It follows that both cups may be closely contemporary, and since both (and the portrait) are so obviously connected with Frederik III and his 'Kunstkammer', founded in 1652, it seems reasonable to ask whether they were made by the same artist, and, if so, by whom?

As already mentioned, unicorns were considered truely Royal beasts, and their horns were eagerly sought after by most collectors for princely and private 'Kunstkammers'. Few felt inclined to believe Ole Worm when in 1638 he published the finds of the Danish expedition of 1636 to Greenland, namely, a cranium and a tusk, which proved that the unicorn was in fact the Arctic narwhal (Schepelern 1971: 278–279). As we have already seen, unicorns were alive and kicking for many years to come. The Rosenborg collection still holds several unicorn horns and a substantial number of objects made of this material, mostly datable to around 1660: first and foremost, the Royal Anointment Throne from the late 1660s, and also a miniature ship and several cups which can be dated because they were mentioned by their maker, Jacob Jensen Nordmand, in his autobiography (Suhm 1784: 134–158; Liisberg 1893: 245–284). The reason so many objects could be produced for the King at that time is undoubtedly that a large amount of the costly horn was brought back from Greenland by David Dannel. During his return voyage in 1653 he "weighed the unicorn they had obtained, consisting of 8 complete horns, a small young one, all 9 complete to their points and weighing in all 88½ pounds. The longest was 4 Zealand ells, less than a hand's width. Furthermore 6 horns with their points broken off, weighing 65 pounds. All other small pieces and half horns weighed in all 190 pounds, and consequently all they had traded of this article 343 pounds." (Erichsen 1787: 35).

Jacob Jensen Nordmand undoubtedly made use of this hoarded treasure in his work for the King. His career was as unusual as the fact that he, a seventeenth century artisan, wrote an autobiography. He was born in Norway around 1614, joined the Navy, and later

Fig. 5a-d. The Eskimo as thumb-piece on the tankard. Silver gilt.

Fig. 6. The four Eskimos captured in 1654. From Adam Olearius, 1656.

spent three years in Holland becoming a trained gunsmith. The years 1634–39 were spent with Prince Johann Moritz of Nassau in Brazil, and although he does not mention it, he may well have acquired many of his skills at the Prince's Brazilian court. Back in his native country he also learned to stock guns, and eventually, in 1648 he came to Copenhagen to spend the rest of his life in Denmark. He died in 1695. During the 1650s and 1660s he was employed at Rosenborg, at the 'Kunstkammer', and at the Royal Armoury.

Besides being, so to speak, a professional supplier of 'Kunstkammer' objects, he also taught three generations of the Royal family the noble art of ivory turning.

Among the many objects he describes, made of many different materials, he mentions a cup, which, he says, was made in the year 1662. The text, which for reasons of interpretation must first be given in the original, runs as follows: "Den 28. Octob: giorde jeg hans Mayest: et runt beger af Enhjørning, paa 2 potter af 28 stycher med bund og laag paa, ethuert styche bleff med guld infattet oc saa siden henskichet till Guld=Smiden, huilchen skulle det indhefte." (Suhm 1784: 154). In translation: On the 28th October I made for his Majesty a round beaker of unicorn, holding 2 pots, consisting of 28 pieces with base and cover, each piece mounted in gold and then sent to the goldsmith, who was to *'indhefte'* it. As will be discussed below, the word 'indhefte' creates difficulties as to whether Nordmand made the figure or not.

The cup described, with a cover made of 28 pieces of narwhal tusk mounted in gold, does, however, makes the identification a strong possibility. No other preserved cup fits the description. The contents of two pots is acceptably close to the two litres the cup actually holds. The year 1663, with which the cup is dated, as opposed to Nordmand's date of October 1662, can be explained by his simply having forgotten the precise year.

What is more mystifying, however, is the fact that he does not mention the cup's most important feature, namely the Eskimo. And why doesn't Nordmand, who never hid his light under a bushel, boast of the exquisite enamelling of the figure or of the gold bands? No other works of his show enamelling, and he does not once refer to his having acquired this very specialized skill.

How, then, is the last sentence in his description to be interpreted? Why does he send the cup to the goldsmith to be *'indheftet'*, and what is the meaning of the word? What immediately comes to mind is merely the assembling of the prefabricated elements. But if this is the case, it is hard to understand why he did not do it himself, or why he found it necessary to mention it at all. The Dictionary of the Danish Language explains the word as either 'to fasten' or 'to sew'. The Dictionary of Older Danish interprets it as to fasten, ironically quoting only Jacob Jensen Nordmand for this interpretation. Dictionaries of Norwegian, modern or older, have the same denotation. Modern philologists have no alternative explanation, and modern goldsmiths have no recollection of any other version within their craft.[8)]

This leaves the case open to speculation. It seems fairly certain that Jacob Jensen actually made the cup and its fittings. Strictly speaking, the text "each piece mounted in gold" does not necessarily include more than the gold tongues. If this is the case, then the unknown goldsmith made the bands and the figure with their enamelling; the word *'indhefte'* then standing for far more than it suggests. This would make the reference to the goldsmith more understandable, and at the same time account for the difference in dates.

The next question is whether it was a Copenhagen or a Hamburg goldsmith that did the finishing work on the cup. An entry in the autobiography, undated, but after 1657, when Nordmand was given command of the armoury, informs us that he went to Hamburg for the King to have "cups of unicorn, of rhinoceros, and of other rare materials mounted (*'indfattet'*) in gold by the goldsmiths." (Suhm 1784: 156). This, of course, makes Hamburg a possibility, but not a very convincing one. The figure is so naturalistic and so accurate in the rendering of detail that the artist must have had direct access to the costume and the weapons. And this was only possible in Copenhagen.

As mentioned above, the man Jhiob died before reaching Denmark, but the three women lived on in Copenhagen at least until around 1660 (Meldgaard 1980: 4). Although the three women, according to Adam Olearius (Olearius 1656), were given European dress upon their arrival in Flensburg, there is every reason to believe that on occasions they were made to wear their native costume. This may be the reason why the artist, who made the figure of the Eskimo for the cup, made the mistake of dressing a male Greenlander in female costume. The same mistake occurs in the case of the Eskimo on the tankard. This is all the more strange since the artist would have been better informed if he had only read the very page from which he took his model for the engraving on the lid of the tankard. Olearius writes that "the hood of the men sits flat on top of the head while that of the women extends almost half an ell above the head because of their hair arrangement. The female coat has a long point hanging from it in front and at the back, extending all the way to the knees, something the men do not have. The trousers reach to the knees, some even further below; those of the women end above the knees, barely covering the buttocks. They are entirely naked between the rim of the trousers and the upper edge of the boots, a distance of about the width of one hand." (Scheffel 1987: 708). This mistake seems to link the two cups closely together. No evidence, however, can be obtained as to who made the tankard. Jacob Jensen does not mention anything identifiably similar, but it is possible that he created both cups for the King. The similarity in conception, in construction, in execution, and in date makes this attribution defensible.

It seems hard to understand today what unites such heterogeneous themes as Eskimo, Unicorn, Drinking Vessel, Cabinet of Curiosities, and King. The first two themes are related through the rediscovery of Greenland in the late 16th and the early 17th centuries. Before this, unicorns were legendary and mythical creatures, believed to be horse-like animals with a one-horned forehead, living in remote parts of the earth. They were fierce and wild, and according to medieval legend, could only be tamed by pure virgins, in whose laps they would quietly lie down, horn and all. Tales of how they looked and where they lived were varied and numerous, going back to classical authors, and they were even mentioned, it was believed, in the Bible. Tangible evidence - apart from the beast's horn - had never been found. In the 16th century, rumours that marine unicorns lived in the Arctic oceans began to penetrate Europe's learned circles. As one among several, Olaus Magnus mentioned this fact as early as 1555 (Magnus 1555:743-44). On his second voyage in 1577 Martin Frobisher found the carcass of a 'fish', which he had described and depicted, and whose tusk he brought back as a present to his Queen. "This horne", he wrote, "is to be seene and reserved as a Jewel, by the Queens maiesties commaundement, in hir Wardrop of Robes." (Stefansson 1938). This is the first official entry of the Marine Unicorn into Royal circles.

Among Danish scientists the unicorn was a much debated topic. In 1628 Caspar Bartholin published his book 'De Unicornu'. It is illustrative of the state of the debate that he found it necessary to defend the existence of the old unicorn. "He who denies this", he wrote, "shows ignorance of classical authors and of the Holy Book. As long as there are unknown regions of the world, there is hope of finding a complete unicorn." As a matter of interests, this conviction can be found as late as 1862 in a paper by an English traveller (W. B. Baikie 1862).

Ole Worm was the first to carry out serious scientific research on material evidence. In 1636 the Greenland expedition had brought back not only tusks, but also a cranium of the narwhal. In a reminiscing letter to Isaac de la Peyrère, dated 12th April 1645, Worm recalls the situation (Schepelern 1968: 99). During a visit to the Chancellor Niels Friis, Worm had reproached the travellers to Greenland for only bringing back the horns, never any other part of the animal, so that the old question could finally be solved. Friis told Worm to be patient and then showed him not only a horn, but also a cranium with a piece of the same horn still in its place. Worm was overjoyed. He saw at once that the skull was that of a whale, and that the 'horn' was indeed a tusk growing from the left side of the upper jaw. He was given permission to borrow it in order to study it more closely. He called friends and students to his house, had the skull measured and drawn, and in 1638 he published his results (Worm 1638). In the debate which followed, he always maintained one fact, which shows his good common sense. In his experience, he said, horns always grow from the exterior of the skull, never, as in this case from a hollow in the cranium. He did not deny the existence of the old unicorn, but could only say that what he had seen, or heard of from travelling students and learned colleagues, were tusks – of the narwhal.

This is the background for the two themes: Greenlanders and Unicorns. The two cups can be seen as minor monuments to newly-acquired knowledge in an age when the world was being discovered by courageous travellers and clear-minded scholars.

The Drinking Vessel theme springs from a different notion, which is meaningless today, but which at that time was an established fact. Unicorn's horn was believed to have a purifying effect on poisoned liquids. Ground horn, or just a small piece of horn attached to the inside of a cup, was considered effective, if one was unable to afford a cup made entirely from the precious material.

In 1636, when Worm had first seen the narwhal, he took part in an experiment in which pigeons and kittens were given poisoned food, with and without powder from the tusk. The result, wrote Worm, was not entirely unsatisfactory. Faint praise, admittedly, but enough for him to remain positive towards the powers of the tusk. Later, in Schleswig, Olearius experimented with two dogs, which were given corrosive sublimate, one of them with an addition of ground tusk dissolved in milk. One dog died at once, the other to his delight survived until later in the night. What Olearius did not – and could not – know was that milk is an effective antidote to corrosive sublimate.

Jacob Jensen Nordmand made quite a number of drinking vessels, still at Rosenborg, for Frederik III. He also made a still-existing miniature model of a boat. In the stern, he informs us, was a piece of iron, so that with the help of a magnet the King could sail it in his wine-cups. This sounds like a perfect toy for people of a playful disposition; but, although Nordmand does not mention it, it was a far more serious business: a protection against being poisoned.

In consequence it can be said that the connection between unicorn/narwhal and drink was quite natural at the time. Rhinoceros horn was known to hold similar powers, and was thus also made into drinking vessels. This even goes for serpentine stone. The Swedish general Wrangel, for example, had a complete set of dining utensils in serpentine, intended for use on his military campaigns. Few of these objects, however, show traces of having been put to practical everyday use. It seems much more probable that they were normally kept in cupboards to be taken out only on special occasions, during visits by foreign potentates perhaps, to give prestige to the owner. Rather they were considered precious and rare man-made 'artificialia', filled with the wonders of nature. As such they were true 'Kunstkammer' objects, fit for a King.

Cabinets of Curiosities must not be seen as the mere haphazard accumulations of objects that modern rationalists would have us believe. According to their time-bound rules, they had rational as well as educational value. Each item was meant to make the visitor – prince or scholar – ponder the marvels of a surrounding world. Each 'Kunstkammer' was a universe in miniature, meant to illustrate Man's skill and Nature's boundless wonder. A mirror, in short, reflecting God the Almighty. Thus, the larger and more varied a 'Kunstkammer' collection was, the more it glorified the King who owned it.

Seen from this point of view, the two Eskimo cups were ingenious 'Kunstkammer' objects. Not just ethnographical pieces to be placed in the 'Indian Cabinet', not just pieces of raw material to be placed in the 'Cabinet of Naturalia', nor even just precious man-made objects to be placed in the 'Cabinet of Artificialia', but all of these at once – a miniature world in their own right. And in addition to this, they pay homage to a King who was Sovereign of a people in such distant regions as Greenland.

Finally, one feature requires comment. This is the three unicorns which form the feet of the tankard.

When Greenland is so much emphasized in the cup, and when Ole Worm's scholarly results were well-known facts by the 1660s, why place the mythical beast there rather than the marine unicorn?

Mere conservatism is, of course, a possible explanation. On the other hand, there is no doubt that the Danish King had very definite economic and political interests in keeping the old unicorn alive. All three expeditions to Greenland during the reign of Christian IV and Frederik III brought back unicorn horns. If trade with Greenland became permanent, the King

Fig. 7. Central piece on the lid of the tankard. Silver gilt. Originally copied from Olearius.

would find himself in the position of being sole supplier of a costly raw material to the courts of Europe, equivalent, for instance, to Saxony's serpentine stone and Pommerania's amber. And politically, horns could serve as ambassadorial gifts of such splendour that they might pave the road to success. Thus Worm's insisting that the horn was a narwhal's tusk cannot have met with approval at court. No wonder that Christian IV's son-in-law Corfitz Ulfeldt severely criticized Worm.[9] In 1647 Ulfeldt went on a diplomatic mission to France and succesfully negotiated a treaty. He brought with him as his main gift a unicorn's horn, which, he insisted, was the major reason for the favourable reception the French gave him. As we have seen, Frederik III did his best to maintain the unicorn in its former position, but he was fighting a losing battle. Seen in this light, the presence of two Eskimos on the cups are a concession to the progress of science, and the unicorns a perpetuation of the myth.

Thus the two Eskimos were not placed on the cups as mere artistic flights of fancy. They were an important part of both cups' calculated iconography. [10]

Acknowledgements

I wish to thank Paulette Møller for her invaluable help in revising the manuscript, and John Lee who has taken the photographs.

Notes

1. Rosenborg, Mus. No. 5–320.
2. The 1696 inventory, p. 56, No. 16. This inventory only exists in an incomplete version, published in Copenhagen in 1775.
3. These inventories, as yet unpublished, are kept at Rosenborg.
4. Rosenborg, Mus. No. 7–55.
5. Rosenborg, Mus. No. 7–57. The 1696 inventory (p. 57, No. 20) describes the tankard as follows: 'A Unicorn's Jug mounted in Silver, gilt, on the Lid a Plate with two Greenlanders, it stands on two (sic!) Unicorns, and on the Handle stands (sic!) a Greenlander with the same Fish.'
6. Stylistically, the tankard cannot be dated to 1605, when Goske Lindenov brought back Eskimos from his expedition (Gad 1967: 266).
7. It should be mentioned that at least two further paintings existed in the 17th century. They are listed among Carl Gustav Wrangel's paintings as '3 Grönländische Persohn' (No. 281) and '4 Grönländer' (No. 317). It seems reasonable to suggest that Wrangel brought them back to his manor Skokloster in 1659 after his looting of Danish castles in the Swedish-Danish war. They are no longer at Skokloster, and – if they still exist – there is no knowledge of their present whereabouts. I am indebted to mag. art. Charlotte Christensen for this information, deriving from Povl Eller's notes on the Skokloster paintings (Det Nationalhistoriske Museum, Frederiksborg Castle).
8. I am indebted to Professor S. Hjorth, Copenhagen University and the firm Kgl. Hofjuveler A. Michelsen for help in this matter.
9. The discussion between Ulfeldt and Worm is mentioned in the correspondence between Worm and de la Peyrére from 1645 (Schepelern 1968).
10. The enamelled Eskimo's downward-pointing finger is an iconographical feature which I can only mention in passing because I have found no interpretation of it. It appeared after restoration in the Bergen painting, and it can be seen in some of the copies, including that of Olearius. It is also to be found in other contemporary paintings. A possibility is that it was meant to represent the heathen pointing towards hell as the future home for his unbaptized soul.

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Anthropology of the Qilakitsoq Eskimos

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Balslev Jørgensen, J. 1989. Anthropology of the Qilakitsoq Eskimos. – Meddr Grønland, Man & Soc. 12: 56–57. Copenhagen 1990–01–26.

The anthropological examination showed two children aged six months and 4-4½ years respectively, and six adult women aged 18-22 years, 20-25 years, about 30 years, 40-50 years, about 60 years, and about 50 years respectively. The physical type of the mummies corresponds with the general impression of physical types of Eskimos from the 16th-17th century.

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The most important features of the finds from Qilakitsoq are the extremely well-preserved clothing and the mummification of the soft tissues. For this reason the clothing of the best-preserved mummies has not been touched, and the soft tissues have not been removed from some of the other mummies. Accordingly, no in-depth removed from some of the other mummies. Accordingly, no in-depth anthropological scrutiny of the bones has been performed.

From a purely anthropological point of view the finds, consisting of only eight individuals, are not of paramount importance; the group is too small. The following article describes the anthropological observations of the various mummies. The sex and age of the mummies was determined by anthropological methods. The determinations were modified by the results obtained from X-ray and odontological examinations.

Mummy No. 1: Child, six months old. Sex cannot be determined anthropologically.

Mummy No. 2: Child, 4–4½ years old.

Mummy No. 3: Relatively large mummy with rather big head and small hands. Sex cannot be determined by anthropological investigations, it could be male. Age: adulta. X-ray revealed some pathological findings. Stature has been calculated at 165 cm.

Mummy No. 4: Small and delicate body. Valuted frontal bone without superciliary prominence. Sex is female. Age: adulta. Stature calculated at 145 cm.

Mummy No. 5: Medium-size body with hair showing slight balding and eyebrows, no beard present. Stature could not be measured. Small hands and feet, pelvis of female type, slight superciliary prominence, weak mastoid processus. Sex accordingly female. The suture has at least partly closed. Age: matura (40–50 years). Stature calculated at 158 cm.

Mummy No. 6: Small body. Perpendicular frontal bone with slight superciliary prominence. Small hands; sex female. Odontologically, the age has been estimated at about 50 years. Stature calculated at 153 cm.

Mummy No. 7: Small delicate body with hair and eyebrows, but without beard. Small hands and feet. The stature is medium, the frontal bone perpendicular without superciliary prominence. The sex is female. The spheno-basilar synchrondrosis is closed. The odontological estimation of age is given as 18–20 years.

Mummy No. 8: Small crouched body with hair and eyebrows, but without beard. Stature approximately 150 cm. The head is below medium size with vaulted frontal bone without superciliary prominence. The lower jaw is angular, teeth small. The pelvis is female with broad (1 cm) and deep preauricular sulci. The sex in undoubtedly female. The spheno-basilar synchrondrosis is closed, the age accordingly over 20 years. The age has been estimated at 50 years on the basis of odontological examinations. Given the length of the long bones the stature can be calculated at 150 cm. Heavy pathological changes in cranial base and slighter changes in the lumbar part of the backbone.

The six adults were 18–22 years, 20–25 years, about 30 years, 40–50 years, about 60 years, and about 50 years old respectively. The represent all age groups but it is remarkable that three of the eight mummies were fifty years of age or older at the time of death. This indicates that survival conditions in the environment were better than might have been expected.

All six adults seem to have been women. The anthropological investigation of mummy No. 3 was not unequivocal, and from an anthropological point of view this could be a male, which also might be indicated by the stature of 165 cm against the stature of about 150 cm of all the other adults. The tattooing on the face, the absence of a beard in spite of well-preserved hair and

Measurement of the long bones.

	Mummy I/3	Mummy I/4	Mummy I/5	Mummy II/6	Mummy II/7	Mummy II/8
Femur, length (M1)	(44)	(37–38)	40	((40))		(37)
Femur, trochanteric L. (M5)					35	34
Tibia, length (M1)	(37)	(30)	33	31–32	30	31
Humerus, length (M1)					27	
Ulna, length (M1)				21–22	21	22

eyebrows, and the clothing, are on the other hand very clear signs indicating female sex.

As mentioned above, the stature of mummy No. 3 was 165 cm, whereas the others were 145, 158, 153, 148 and 150 cm respectively. This stature of about 150 cm closely matches the results of investigations of female skeletons from the Thule culture from about 1400 AD, and the stature of 153 cm for skeletal materials from the seventeenth century (Balslev Jørgensen & Vesely 1974). Thus stature must have remained constant at least until the period of colonization. It is interesting that examinations of older present-day women in the Thule area and in Upernavik show statures of 151 and 149 cm (Gilberg *et al.* 1975; Balslev Jørgensen *et al.* 1976).

There is nothing outstanding about the physical type of the mummies. It corresponds very well with the general impression of physical types of Eskimos from the 16–17th century. The odontological, X-ray and pathological tests will provide further information about the general type of these peoples.

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X-ray Examination of the Eskimo Mummies from Qilakitsoq

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Eiken, M. 1989. X-ray Examination of the Eskimo Mummies from Qilakitsoq. – Meddr Grønland, Man & Soc. 12: 58–68. Copenhagen 1990–01–26.

Eight mummified Greenlandic Eskimos, two of which were children, underwent a thorough X-ray examination, which preceded the other comprehensive scientific examinations. The two children were identified as males while all the adult mummies proved to be females. In one of the older adult mummies extensive destruction was demonstrated in the base of the skull, presumably the result of a nasopharyngeal cancer. In the same mummy a pseudoarthrosis of the left clavicle was found. Another, a younger woman, was supposed to have a calculus in the right kidney. One of the children, a four-year-old boy, seems to have suffered from Down's syndrome and a disorder of the left hip, probably Legg-Calvé-Perthes disease.

In two of the older mummies a few compression fractures of thoracic or lumbar vertebral bodies were observed, as well as degenerative osteoarthrosis and other signs of advanced age.

As for the remainder, only slight degenerative osteoarthrosis was demonstrated, as well as a few congenital anomalies which were probably of no clinical importance. Neither fractures nor bone diseases, whether of older or more recent date, could be demonstrated.

The frontal sinuses were missing in all the mummies and in four of the adult mummies, Harris lines were observed, particularly in the distal femoral metaphyses.

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In the autumn of 1972 Greenlandic Eskimo hunters found two graves with a total of eight mummified corpses, not far from an earlier settlement, Qilakitsoq. Six years later, when a preliminary dating had proved them to be about 500 years old, they were brought to Copenhagen for further examination. The first step in the extensive scientific investigations was to carry out an X-ray examination of each mummy, including its clothing and skin wrappings. X-ray examinations of both natural and embalmed mummies have become increasingly frequent over the past twenty years because they may be carried out without damaging the specimens; in fact, if necessary the mummy is not touched at all.

X-ray examination has been widely used in the study of Egyptian mummies in museums throughout the world. Among the more comprehensive publications should be mentioned Cuenca 1978, Isherwood *et al.* 1979, Harris & Wente 1980, and Christensen 1969.

Although Denmark's "import" of embalmed Egyptian mummies is not particularly great, Danish peat bogs, as well as those of other, mostly Northern European countries, have yielded a number of corpses of people who lived nearly 2000 years ago. Some of these "bog people" are astonishingly well-preserved and a few of the Danish finds have been X-rayed (Krebs & Ratjen 1956). X-ray examinations of Eskimo mummies from Greenland have not previously been carried out, but the Laboratory of Physical Anthropology at Copenhagen University has a very large number of Eskimo skeletons, mostly from Greenland, which have contributed to our knowledge of these people (Jørgensen 1953).

Material and Methods

Upon arrival in Denmark, the eight Greenlandic mummies were in varying states of preservation, but their general condition was surprisingly good. All of them were clad in skin clothes; several were also wrapped in large skins, which, like the clothes, were as stiff as cardboard. Almost all the mummies had extremely flexed hip and knee joints, and the heads of some were bent sharply forward or to the side. This to some extent hampered X-ray examination, or resulted in an inconveniently long distance between the object photographed and the X-ray film. However, the mummies were quite robust and could be placed in various positions without being damaged.

The X-ray examination contributed to the determination of age and sex. Radiological age determination is most accurate in the case of children and young people up to eighteen or twenty years of age. Because of the characteristic development of the bones, evaluation of the ossification of epiphyses and the degree of fusion of epiphyses with metaphyses can pinpoint the age of the individual with a precision ranging from two to three months of age for infants to about one year for 18–20 year-olds, assuming that the development and maturation of bones has remained relatively constant over the intervening 500 years.

Except for the two children, all the mummies proved to be fully-grown individuals. In adults, radiological age determination is far less reliable, because we know little about the aging proces in Greenlandic Eskimos today and even less about those of 500 years ago. Therefore the following estimated age is based both on the radiological evaluation and on the joint efforts of experts in different fields.

The X-ray equipment used for the examinations was the Diagnost 85 by Massiot/Philips, which allowed for continuous fluoroscopic control during the radiographic survey. A focus-film distance of 150 cm and a 0.6 mm focal spot was normally used. Supplementary tomographic examinations were carried out on a Stratomatic U by CGR.

In the following the mummies will be identified by the official numbering, where the Roman figure refers to the grave and the Arabic figure to the mummy.

Results

Grave I, Mummy No. 1

General: A child (Fig. 1) whose age, judging from the development of the teeth and bones, was about six months at the time of death. It was clad in skin clothes with a hood and was extremely well preserved. Although the X-rays did not reveal the sex, the clothing was typical for a boy. No amulets were seen.

Skull: At the back of the head there was a small crack, involving both the bones corresponding to the hindmost part of the sagittal suture and the overlying skin, and thus evidently of postmortal origin. In the posterior skull groove a small triangular bone was revealed and identified as a dislocated basilar part of the occipital bone (Figs. 2–3). This small bone has its own developmental centre of ossification and in a six-month-old child is normally in cartilaginous connection with the adjacent bones. In its present position it was turned almost 180° backwards. In continuation of this there was a slightly radiopaque intracranial density stretching upwards towards the upper occipital region, probably representing the shrunken brain.

Trunchus and extremities: No skeletal changes were seen.

Comment: Normal child.

Fig. 1. Mummy No. 1, a six-month-old child.

Fig. 2. Lateral view of the skull of mummy No. 1. The dislocated pars basilaris of the occipital bone is marked by two arrows.

Fig. 3. Mummy No. 1. In the AP view the shape of the dislocated pars basilaris is clearly outlined in the occipital region.

Grave I, Mummy No. 2

General: A child with a development of teeth and bones corresponding to an age between 4 and 4½ years at death. Its sex could not be determined from the X-ray examination, but when the clothes were later removed, it proved to be a boy. As in the previous case this child was dressed in skin clothes with a hood but was rather poorly preserved. X-ray examination was carried out before and after removal of various parts of the spine and extremities for special examination. The first radiological survey (at the University Hospital Rigshospitalet) revealed an accumulation of 7–8 teeth, projected level with the lower end of the sternum. They later proved to originate from the child itself, and were found underneath the clothes on the back of the child. Four other detached teeth were observed: one at the left side of the chest, two near the upper thoracic aperture and one just behind the left angle of the jaw. There were no amulets.

Skull: Apparently normal in shape and size, corresponding to those of the adult mummies (Fig. 4). The mouth was fixed in a wide open position. The bones of the calvaria appeared undercalcified, with a pronounced fine honeycomb structure of the diploic bone. There were no visible remnants of brain tissue. Some of the cervical vertebrae were detached and dislocated, but no abnormalities could be seen.

Trunk: The vertebral bodies of the spine looked undercalcified. Furthermore, it was noteworthy that all cartilage corresponding to the articulations between the bones in the spine, as well as in the extremities, appeared more shrunken in the case of this child than in the adults. Otherwise there were no changes in the chest or the abdomen.

Upper extremities: No skeletal changes were observed in the upper limbs. However, it should be mentioned that a generalized rarefaction of bones is difficult to identify ratiologically in the extremities.

Pelvis and lower extremities: The shape of the pelvis was abnormal, with both ilia flaring laterally and the acetabular slopes flattened (Fig. 5), as is characteristic in children suffering from mongolism (Down's syndrome). The acetabular angle measured by the method of Caffey & Ross (1958), was 4–5° and the iliac angle 32–34° (Fig. 6) (normal values being about 15° and 55° respectively). The lower extremities were widely spread at the hips and with flexed knees – the "frog position". The epiphyseal ossification centre of the left femoral head was sligthly flattened and sclerosed (Fig. 7). There were no structural changes of the femoral neck or of the adjacent acetabular roof, and the right femoral head was normal. An early stage of left-sided Legg-Calvé-Perthes disease is the most probable explanation, with a healed pyogenic arthritis as a less likely diagnostic possibility. Legg-Calvé-Perthes disease is thought to be due to avascular necrosis of the femoral head in childhood. It mainly occurs in boys between the ages of three and twelve, and is not uncommon among Eskimos, although the incidence is not known (Goff 1954).

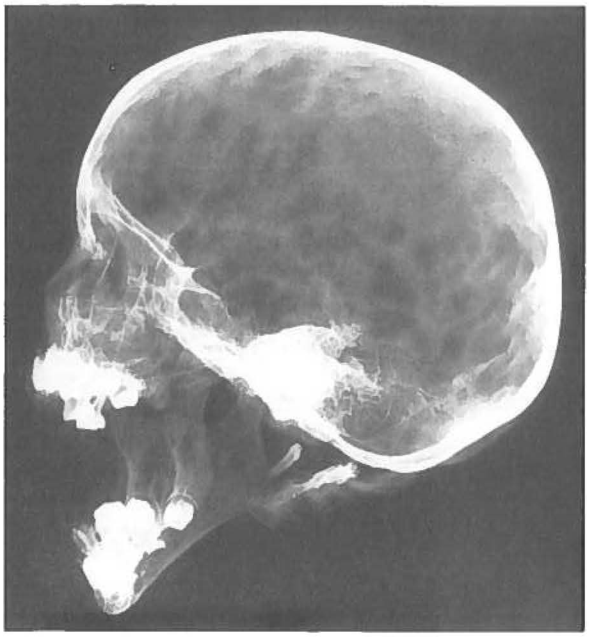


Fig. 4. Lateral view of the skull of mummy No. 2.

Fig. 5. Pelvis of mummy No. 2 with horizontal position of the acetabuli and flaring of the iliac wings.

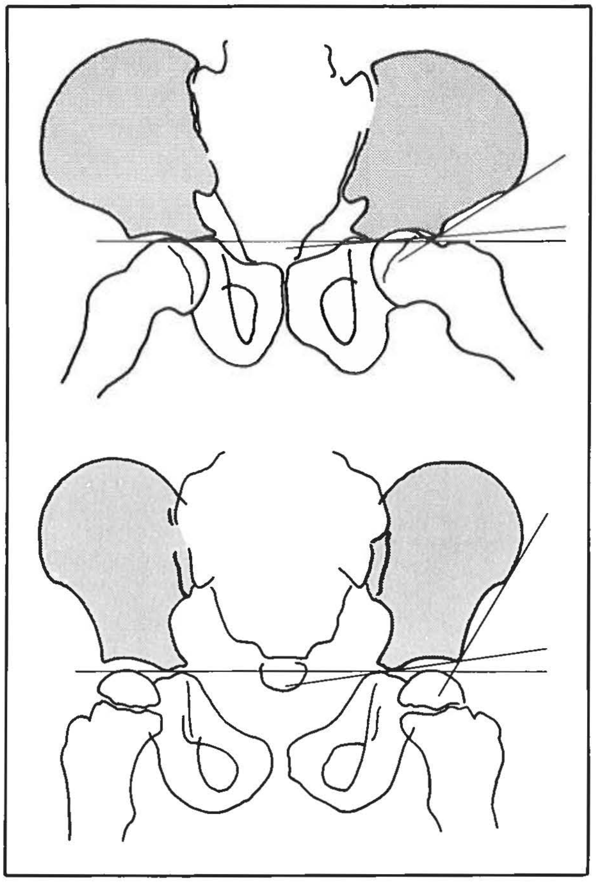


Fig. 6. Pelvis of mummy No. 2 (upper tracing), compared with that of a normal, 4½-year-old-child (lower tracing). The acetabular and iliac angles are marked on the left side.

On the whole there was a generalized rarefaction of the pelvic bones with increased translucency and a coarsening of trabeculae in the spongiosa.

Comment: The rarefaction of bones indicates that this child had been sick and probably immobilized for some time, perhaps because of pain in the left hip, but probably also because of the presence of Down's syndrome. The "frog position" of the lower limbs is remarkable, as the usual position is adducted legs with flexion of the hips and knees.

Grave I, Mummy No. 3

General: Well-preserved mummy of young adult, judged to be a woman between 20 and 25 years of age. The X-ray examination was carried out with the mummy clad in skin clothes.

Furthermore, it was wrapped in a large, stiff skin, containing a number of small fragments of rock. To the right of the head were two loose teeth, an incisor and a bicuspid. No radiopaque amulets were seen.

Skull: The head was bent strongly forward. In the right upper jaw the lateral incisor and the first bicuspid were missing and the corresponding alveoli were open.

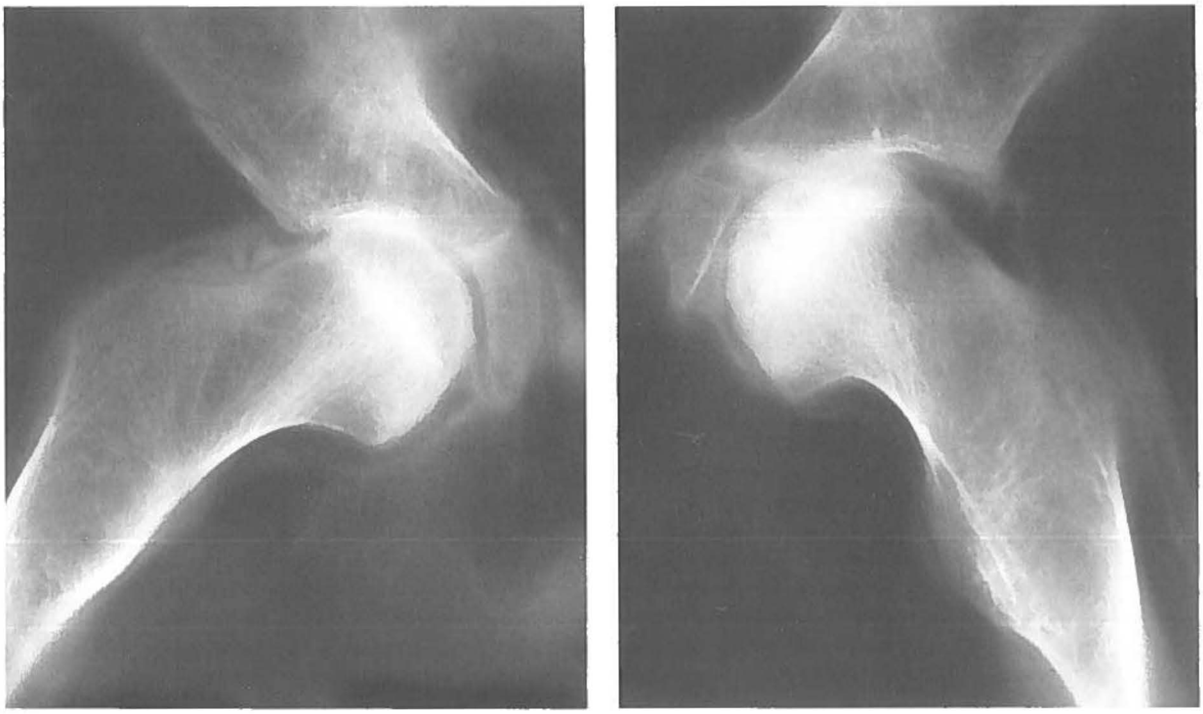
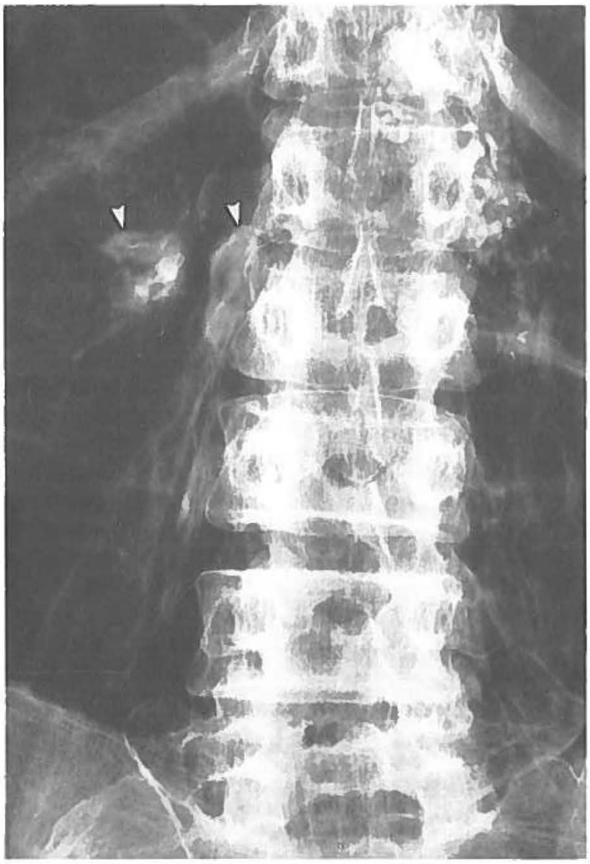


Fig. 7. Tomography of the right (a) and left (b) femoral head. The left epiphysis in slightly flattened and sclerosed.



It is probable that the missing teeth were those found in the skin wrapping. Otherwise the dentition was complete. There was a post-mortem subluxation of the right temporo-maxillary articulation. There were no visible remnants of brain tissue.

Trunk: Along the margins of the lumbar vertebral bodies a slight bony proliferation was observed, of the type called "lipping". Otherwise there were no skeletal changes. The pelvis was gynaecoid in shape. In both halves of the chest homogenous radiopaque shadows were revealed, probably remnants of lung tissue, without calcifications. To the right of the two uppermost lumbar vertebrae there were two distinct calcium shadows, one of them oval, the other irregularly curved and with a structure similar to bone tissue, both measuring a few centimetres in size (Fig. 8). Judging by their position, they might well be kidney stones. The two calcifications were removed by a minor operation, through the skin clothes and the back of the mummy. Subsequent analysis indicated that the oval one consisted mainly of magnesium ammonium phosphate (struvite), which is a frequent composition of urinary calculi. It had probably been situated in the renal pelvis,

Fig. 8. To the right of the second lumbar vertebra two abnormal calcifications are seen (arrows). The lateral one proved to be a piece of bone, probably from a seal, the other one had a chemical composition consistent with urinary stone (mummy No. 3).

but examination of the surrounding mummified soft tissue did not help to determine the position more precisely. The other piece proved to be bone tissue, apparently a fragment of the temporal bone of a seal or polar bear. It was probably swallowed with food and was on its way through the gastrointestinal canal.

Extremities: Both arms were flexed at the elbow joint and the hands placed above the upper chest. The legs were close together, slightly flexed at the hips and knees. No bone changes were demonstrated.

Comment: A youngish woman with only very slight degenerative changes of the lumbar spine and a probable stone in the right renal pelvis.

Grave I, Mummy No. 4

General: Well-preserved mummy of youngish woman, probably above thirty years of age. The mummy was dressed in skin clothes and wrapped in a large skin, containing numerous small fragments of rock together with two detached third molars. Most remarkable was a distended abdomen, on account of which she was at first thought to be pregnant. There were no radiopaque amulets.

Skull: The head was bent strongly forward with the mouth opened 10 mm. Both third molars in the lower jaw were missing and the alveoli were open, indicating that the teeth found in the skin wrapping probably originated from the mummy itself. There was no evidence of disease, and no visible remnants of brain.

Trunk: The number of cervical and thoracic vertebrae was normal while the lumbar spine included a sixth supernumerary vertebra with only slight bilateral sacralization of the transverse processes. Only negligible lipping of the bodies of the lumbar vertebrae was present. Otherwise there were no degenerative changes and no evidence of skeletal disease. In the thoracic cage radiopaque material was seen, probably representing the remains of lung tissue and the diaphragm. The pelvic shape was gynaecoid. As mentioned above, the abdomen was distended (Fig. 9). If this were to be ascribed to a pregnancy, it ought to have been at least in the fifth month, given the size. A fetus of this age would contain enough calcium in its bones to allow for radiological detection. However, even a thorough X-ray examination, including tomography and xerography, failed to reveal any fetal parts, and the pregnancy theory had to be dropped.

Extremities: Both arms were flexed at the elbow joint with the hands placed above the chest. The legs were flexed at the hips and knees and kept close together. No disease or malformations were demonstrated.

Comment: Youngish woman with a supernumerary lumbar vertebra but otherwise only very slight degenerative changes of the spine. A distention of the abdomen, which could not be ascribed to pregnancy, was most probably of post-mortem origin although an ovarial cyst is a possibility.

Fig. 9. Lateral view of the distended abdomen of mummy No. 4.

Grave I, Mummy No. 5

General: Fairly well-preserved mummy of a person, about fifty years old, dressed in skin clothes and wrapped in a large additional stiff skin. As with the previous mummies, the skin wrapping contained a number of small stones and gravel. There were no visible amulets.

Skull: Flexed a little forward and to the left with the mouth tightly closed. There was a post-mortem subluxation of both the temporomandibular joints. The two upper central incisors and both lower left incisors were lacking. Two of the corresponding alveoli were entirely closed, while the remaining two were partially so, indicating that two teeth had been lost some time before death. At the back of the oral cavity a single stray tooth and a root fragment were demonstrated. Foremost and in the middle of the hard palate a tooth rudiment was enclosed, a rare phenomenon but one which has been reported earlier in two ancient Greenlandic skulls (Jørgensen 1953).

Tomography of the temporal bones was carried out. The ossicles could not be seen but otherwise the anatomy was normal.

Trunk: All vertebrae of the spine appeared undercalcified with an increased reticular weblike structure of the spongiosa. In the thoracic spine there was a pronounced biconcave collapse of the fourth and fifth vertebral bodies and a slighter collapse of the ninth and tenth vertebral bodies (Fig. 10), all changes which are characteristic of postmenopausal or senile osteoporosis. Another type of deformation was seen in the two lowest

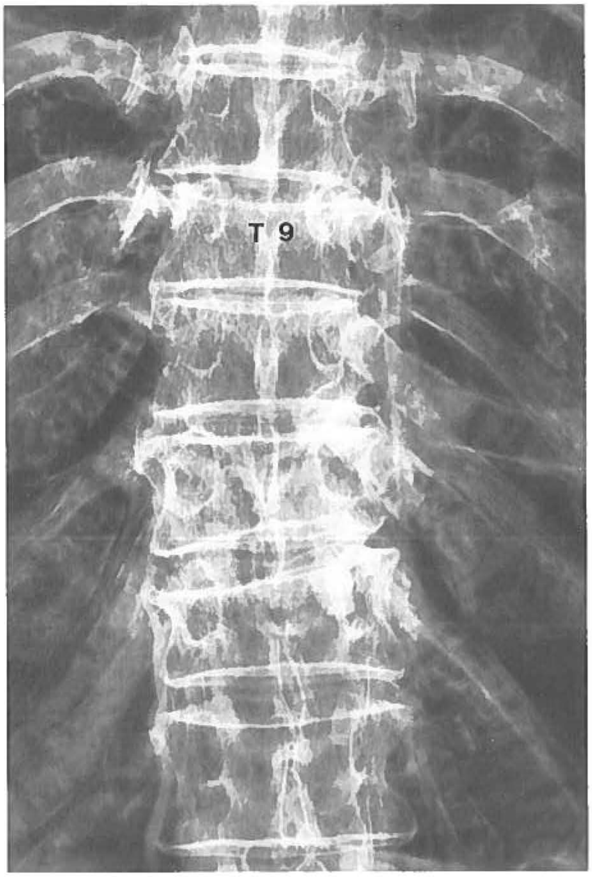


Fig. 10. In mummy No. 5 slight biconcave compressions of the ninth and tenth thoracic vertebral bodies can be seen, with a probable congenital developmental anomaly of the eleventh and twelfth vertebral bodies.

thoracic vertebrae, in that the eleventh vertebral body was lower on the left side than on the right whereas the body of the twelfth vertebra was, in contrast, lower on the right side than on the left, the two thus counterbalancing each another (Fig. 10). This can hardly be due to collapse, but is rather a congenital developmental anomaly. In the lumbar spine a decrease in height of the fourth intervertebral disc was found, with marked bony spur formation on the adjacent vertebral bodies. At the upper anterior margin of the fifth lumbar body a separation of a triangular fragment was seen, caused by a prolapse of the intervertebral disc in youth. Slight degenerative osteophyte formation was seen on the vertebral bodies along the whole lumbar spine. The pelvis was android in shape but the garments, when removed, and the bodily remains, proved to be female. Distinct calcifications of several medium-sized arterial branches were demonstrated in the pelvis. This mummy also had considerable calcification of the rib cartilages, another finding seen mainly among older people, although the age at which they occur may vary greatly.

Extremities: The upper limbs were flexed at the elbow joints and the hands were placed above the abdomen. Slight degenerative osteoarthrosis was present in both acromioclavicular joints and apparently in the distal joints of the second to fourth fingers of both hands, although these were difficult to represent radiographically. The lower limbs were extremely flexed at the hips and knees and turned to the left. Moderate osteoarthrosis was present in the talonavicular joint and the first tarsometatarsal joint of both feet. A post-mortem luxation of some of the toes was present. At the distal end of both femora 3–4 very thin, hardly visible transverse lines were seen. Otherwise the bones of the extremities appeared normal.

Comment: Mummy of an older person, which after the clothes were removed, proved to be a woman, even though the pelvis was android. The osteoporosis of the spine with collapse of multiple vertebral bodies, calcification of the costal cartilages, calcification of pelvic arteries and degenerative osteoarthrosis in the spine and other joints all pointed to a rather advanced age. Minor developmental anomalies were seen, partly as a deformity of the two lower thoracic vertebrae, partly as a supernumerary tooth in the hard palate.

Grave II, Mummy No. 6

General: The mummy which lay uppermost in grave II was a woman, probably about fifty years of age. She was clad in the usual skin clothes and tightly wrapped in a large skin, which entirely surrounded her head and reached down to the middle of the lower limbs. It contained rock fragments, especially in the pelvic region. There were no visible amulets.

Skull: Flexed forward and to the right. The bones of the calvarium were thicker than usual, measuring up to 14 mm.

The sagittal and coronal sutures were closed while the lambdoid suture was still open. There was no special thickening of the skull base. On tomography of the temporal bones the ossicles could not be seen but otherwise the conditions were normal. The mouth was tightly closed, so the teeth had to be examined by tomography. In the upper jaw the crown of the right lateral incisor was lacking, there was hypercementosis of the roots of both third molars and chronic apical parodontitis corresponding to the right lateral and the left central incisor. In the lower jaw the right third and the left second and third molars were missing. Furthermore, both central incisors and the left lateral incisor were missing. There were varying degrees of closure of all the corresponding alveoli and remnants of an apical parodontitis at the alveolus of the right central incisor.

Trunk: Slight spondylosis was seen in the cervical spine. The thoracic spine was normal except for a reduced eleventh disc space with slight osteophytosis on the adjacent vertebral bodies. In the lumbar spine there was disc space narrowing and osteophytosis of L_1 - L_2 and especially of L_4 - L_5. The second vertebral body was wedge-shaped, probably the result of an old compression fracture. The remaining discs and vertebrae were normal with no demonstrable decalcification. The costal cartilages were rather heavily calcified and calcifications of medium-sized arteries in the pelvis were seen.

Extremities: The arms were flexed 130° at the elbows and the hands crossed over the lower end of the sternum. The four ulnar fingers of both hands were extremely flexed and could not be evaluated radiographically. All other bones and joints were normal; in particular there was no demonstrable degenerative osteoarthrosis. The legs were flexed at hips and knees and turned to the left. Apart from a single, very thin transverse line at the distal end of both tibiae, and 2–3 similar lines at the distal end of both femora, no abnormality was demonstrated.

Comment: Middle-aged woman with a poor dental state, an old compression fracture of the second lumbar vertebra, heavy disc narrowing and osteophytosis, especially of L_4 – L_5, and slight spondylosis of the cervical spine. Further, there was calcification of the costal cartilages and of arteries in the pelvis.

Grave II, Mummy No. 7

General: Poorly-preserved mummy of younger woman, probably in her early twenties. She was clad in skin clothes but without additional skin wrapping. There were no amulets.

Skull: The head, along with the four uppermost cervical vertebrae, were almost separated from the rest of the mummy, and were only held in place by dried-out shreds of skin and the hood of the skin garment. These changes undoubtedly occurred after death. The mouth was half-open. Seventeen teeth of the upper and lower jaw were missing, but the corresponding alveoli were all open, indicating that they had been lost post mortem. Several of the remaining teeth were loose, and in the clothes three separate teeth were found, probably originating from the mummy itself. At the lateral angle of the right eye was a 20 mm long fissure in the skin, but X-ray examination of the orbita revealed no bony damage. Tomography showed the temporal bones to be normal, except for the ossicles. In both ears the malleus was demonstrated to be out of place and the right stapes in an almost normal position. The remaining ossicles could not be seen.

Trunk: Normal, apart from a slight wedge shape of the eleventh thoracic vertebral body.

Extremities: The arms were placed along the body with 90° of flexion at the elbow joints and the hands above the upper abdomen.

Post-mortem luxation was present in both shoulder joints. The four ulnar fingers were extremely flexed, and the radiological evaluation of these was difficult. However, neither bony nor articular changes could be demonstrated. The lower limbs were flexed at hips and knees and bent to the right. The toes were flexed. About four very thin transverse lines were observed at the distal end of both femora. No other pathological changes were observed.

Comment: Young woman, poorly preserved. Seventeen teeth were probably lost post-mortem. Further there was post-mortem luxation of the cervical spine and of both shoulder joints. Otherwise there were no skeletal changes apart from a single slightly wedge-shaped thoracic vertebral body.

Grave II, Mummy No. 8

General: A woman, who on general evaluation was determined to be about fifty years of age, although the absence of degenerative changes of the skeleton, especially of the spine, might indicate a younger age. She was in a very poor state of preservation. Clad in skin clothes with a hood but without additional skin wrapping. The back of the clothing had disintegrated and skin and soft tissue of the body had disappeared as far down as the level of the pelvic brim, thus exposing the spine and the posterior parts of the ribs. The left scapula and humerus were entirely detached and without remnant of soft tissue while the remainder of the left arm and accompanying sleeve were preserved.

Skull: The head was held in place only by the skin hood, out of which it could be lifted. The sagittal and coronal sutures were closed while the lambdoid suture was still open. The six uppermost cervical vertebrae were attached to the head, while the seventh lay by itself. All soft parts had disappeared from the lower jaw, which was also loose. In the upper jaw three incisors (1 + 1,2) and the right second premolar were missing, apparently having fallen out post-mortem, as the corresponding alveoli were all open. In contrast, some time before death the woman had lost her lower incisors and the third right molar, as these alveoli had different degrees of closure. A single loose tooth was found in the clothing.

The radiographs taken of the head frontally and in profile showed some changes in the bones at the base of the skull. The poor state of preservation of this mummy proved advantageous to X-ray examination. Since the head was detached from the body, it could be examined more thoroughly than would otherwise have been possible. The examination revealed an extensive destruction of bone, including the part of the base of the skull which forms the roof of the nasopharynx, along with the internal parts of both temporal bones, which contain the inner ear (Fig. 11). There was also destruction of the posterior part of the left eye socket (Fig. 12).

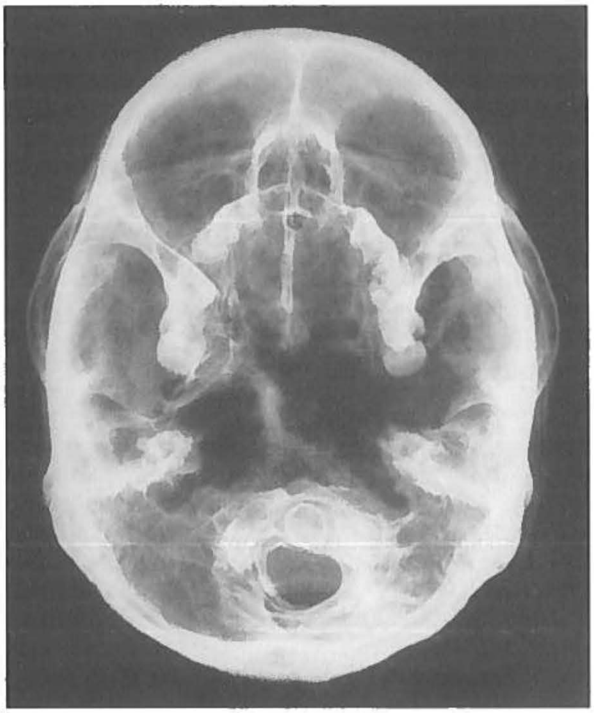


Fig. 11. Base of the skull of mummy No. 8. The extensive destruction of bone is clearly visible as an irregular dark area.

Fig. 12. Mummy No. 8. In the AP view the destruction is seen to comprise the left orbita, particularly the sphenoid bone.

Considering the mummy's poor state of preservation, it was natural to inquire whether the observed destruction of the skull bones might have occured post-mortem. This possibility can be definitely rejected, for all other bones, including the exposed and rather thin ribs, were completely intact. The changes resemble the effect caused by a malignant tumour spreading in a bone. Now, it is well known that nasopharyngeal cancer has an exceptionally high incidens among Greenlandic Eskimos (Nielsen *et al.* 1977) and those of Northern Canada (Schaefer *et al.* 1975; Mallen & Shandro 1974) as it does in certain other peoples of mongoloid stock in Southern China and parts of South East Asia. Thus, it is natural to ascribe the destruction in the base of the skull to such a cancer.

Trunk: Only the innermost two-thirds of the left clavicle was in proper position; the outer third was missing. However, some time after the recovery of the mummies a small bone fragment was found at the bottom of grave II. This proved to be the lateral part of a clavicle. The two bone fragments proved to be compatible, constituting a fractured clavicle. Along the edges of both fracture surfaces, a thickening of the bone was noted. The surfaces themselves were partly sclerosed, and covered with cortical bone. These changes reveal that the fracture of the clavicle had probably occurred at least six months before death, resulting in a fibrous union or pseudoarthrosis (Fig. 13). There were no cancerous changes here as in the skull. Otherwise, the thoracic cage was normal, with only slight calcifications of the costal cartilages. In the spine there was some disorganization of the lower lumbar vertebrae with irregular height of the intervertebral spaces and subluxation of the fourth and fifth vertebra. This was caused by a disintegration of the discs, but on direct examination of the vertebrae no evidence of disease could be seen; in particular, there was no spondylolysis.

Extremities: The right arm was placed along the chest with a flexion at the elbow joint of barely 90° and the hand was placed over the lower abdomen. No abnormalities were demonstrated either in the right arm, or in the loose left arm. The lower extremities were flexed at the hips and knees and turned to the right. At the distal end of both femora, several distinct transverse lines were present, indicating early periods of growth arrest. Such lines were not visible in other long bones. The right fibula was loose. The calcium content otherwise appeared to be normal, and there were no signs of disease.

Comment: Probably a middle-aged woman with extensive destruction of bones of the skull base, most likely caused by a nasopharyngeal carcinoma. Five teeth in the lower jaw were probably lost some time before death, while four teeth in the upper jaw seem to have

Fig. 13. The two parts of the left clavicle of mummy No. 8, placed in the supposed position while alive.

been lost post-mortem. An old fracture of the left clavicle with pseudoarthrosis formation was demonstrated. Apart from lines of growth arrest in the lower end of the femora there were no other degenerative or disease changes of the skeleton.

Discussion

An important question raised by the discovery of eight mummified Greenlandic Eskimos was that of the cause of death - and did they die singly or together? However, a possible cause of death, a presumed nasopharyngeal cancer, was found only in mummy No. 8, and even in this case another event may have brought the life to an end. The development of a pseudoarthrosis of the left clavicle indicates that daily work had to continue in spite of the pain and weakness which the fracture may have caused. Another of the mummies, No. 3, had an abnormal calcification to the right of the upper lumbar vertebrae, of a chemical composition corresponding to urinary stone. Only one of the remaining mummies appear to have been sick, i.e. the 4½-year-old boy, presumed to have suffered from Down's syndrome and probably also from a left-sided Legg-Calvé-Perthes disease. None of these conditions necessarily immobilized the child, but the undoubtedly decreased calcium content of the skeleton indicates a rather prolonged period of reduced physical activity.

From a radiological point of view the remainder of the mummies appear to have been normal healthy individuals, with such different degrees of physiological changes and degenerative osteoarthrosis as are to be expected, considering their ages. Even the presence of a few compression fractures of vertebral bodies among two of the older Eskimos may not be regarded as a surprising finding among a population living under such rough environmental conditions. A few small and probably unimportant congenital anomalies were demonstrated.

Some general findings, which have been mentioned only casually in the survey, should be emphasized.

Skull: X-rays of the skull were always done in strictly lateral and AP standard projections, with a focus-film distance of 150 cm. However, only in two instances, i.e. mummy No. 7 (Fig. 14) and No. 8, could the head be placed directly on the table-top. In the remaining cases the posture of the head and, if present, the stiff skin wrapping caused various degrees of increased distance between the head and the table-top. Thus, exact cephalometric measurements could not be carried out; but on comparison of the AP and lateral radiographs, the shapes of the calvaria of mummies No. 3 to 7 were very much alike, and all were of dolichocephalic type, while the skull of mummy No. 8 was slightly flattened corresponding to the intersection between the lambdoid and sagittal sutures of the cranial vault.

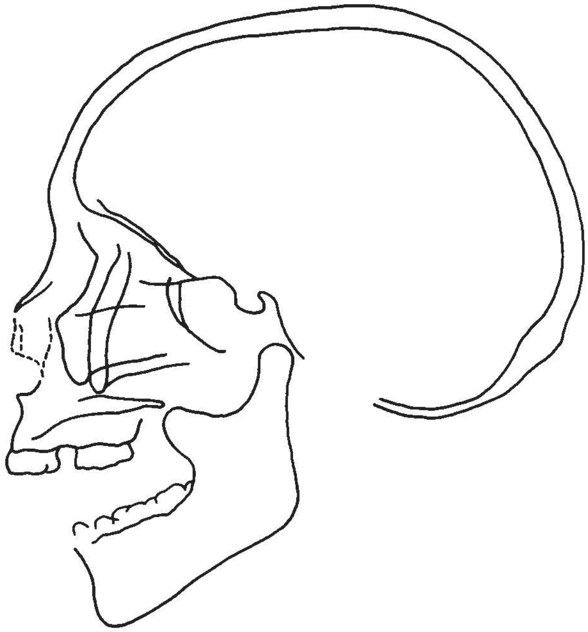


Fig. 14. Tracing of the skull of mummy No. 7. The dolichocephalic shape was characteristic of all the adult mummies.

Sutures: The sagittal and coronal sutures were closed or almost closed in all the adult mummies. The lambdoid suture was also in an advanced state of closure, except for mummy No. 4, where it was still open. In fact we don't know much about the normal time for this closure among Greenlanders, although early closure was assumed as early as Pansch (1874).

Nasal sinuses: The frontal sinuses were totaly absent in all the mummies, while the maxillary and ethmoidal sinuses were well developed. Small or absent frontal sinuses among Eskimos, perhaps due to the climatic conditions, have been described in earlier publications, and recently by Hanson & Owsley (1980).

Transverse lines of increased density (Harris lines) through the metaphyses of the long bones were observed in four of the mummies, Nos. 5, 6, 7 and 8, predominantly at the distal femoral metaphyses. Such lines develop in bones because of a failure of normal removal of calcified cartilage in the zone of provisional calcification during debilitating disease, starvation and probably other types of malnutrition. In mummy No. 8 they were fairly distinct, while in the other three mummies they were negligible. The phenomenon is well known among children and adults of our time, and has been described among earlier human populations of various racial origins, including Eskimos (Lobdell 1984).

Spondylolisthesis and spondylolysis have proved to be surprisingly common diseases among adult present-day Greenlanders (Kalbak *et al.* 1972; Simper 1983). However, no signs of this disease were observed in the present material.

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The Mummies from Qilakitsoq – Paleopathological Aspects

J. P. HART HANSEN

Hart Hansen, J. P. 1989. The Mummies from Qilakitsoq – Palaeopathological Aspects. – Meddr Grønland, Man & Soc. 12: 69–82. Copenhagen 1990-01-26.

The preservation of the eight Eskimo bodies found near Qilakitsosq, dating from around A.D. 1475, is due to mummification. The bodies, their garments and their loose belongings desiccated by a combination of dry air and low temperatures.

The scope of the anthropological, medical and odontological investigations was restricted because the four best-preserved bodies were conserved with the garments *in situ*. Thus, more extensive examination could not be carried out and only noninvasive methods such as X-ray examination were permissible. The remaining four bodies were partly decayed. Only in a single body could internal organs be identified. In this 18–22-year-old woman severe anthracosis was found.

Immunological investigations employing the Western blot technique and immunohistochemistry were negative. Bacteriological investigations showed the presence of *Clostridium perfringens* in an abdominal cavity as the only potentially pathogenic bacteria in the mummies. Most probably the find was made by chance.

It was not possible to establish either the cause or the manner of death for several of the mummies. There are indications that the smallest child, mummy 1, was buried alive, which was not unusual in ancient Greenland when a mother died leaving an infant child. The four-year-old boy, mummy 2, suffered from Down's syndrome and Legg-Calvés-Perthes' disease and thus had a lowered resistance to infections and other disorders. Mummy 8 probably died of a nasopharyngeal carcinoma. In the other mummies the cause of death has not been established with any certainty. Infectious diseases, starvation, hypothermia, drowning, and poisoning have been mentioned in this connection.

Nor was it possible to decide with any certainty if all or any of the bodies had been buried simultaneously or at intervals of decades. Indications of several burials were found in both graves. Only in one case could the time of death (July/August) be established with some certainty.

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Mummified ancient bodies from the Arctic are few. It might be expected that the dry, cold arctic climate would enhance natural mummification, but so far relatively few bodies have been discovered. The special conditions of the circumpolar regions will often make safe burial impossible and the body will disappear because of exposure to the weather and animals.

Naturally mummified Eskimo bodies have, however, been discovered before in Alaska. Thus, a frozen female body dating from about A.D. 400 was found on a beach on St. Lawrence Island in 1970. The body had most probably been washed out of the bankside because of erosion. It was extremely well preserved and examination revealed that she must have succumbed to suffocation after being trapped in a landslide or earthquake (Zimmerman & Smith 1975; Masters & Zimmerman 1978).

Another extraordinaty find was made in Barrow, Alaska, in 1982 when two Eskimo bodies and three skeletons dating from A.D. 1510 (+/÷ 70 years) were discovered. They had been crushed and killed in a winter house by overriding sea ice, and the bodies were frozen. An excellent interdisciplinary investigation was carried out (Newell 1984; Zimmerman & Aufderheide 1984).

In Western Greenland graves with mummified bodies have been encountered from time to time. They all seem to date from a later period than the Qilakitsoq mummies. No radiocarbon dating has been performed. The graves most probably date from the period from the sixteenth century up to the introduction of the Christian burial custom some time in the eighteenth century (Meldgaard 1984).

Two important finds of mummified bodies have been made in rock caves in South Greenland. Inhabitants on the island of Uunartoq north of Nanortalik knew of caves containing many dead bodies (Bak 1971). Local legends say that the bodies were of Eskimos who were not able to flee the settlement of Qerrortut when Norsemen planned to attack at some time in the fourteenth or fifteenth century. They hid in the caves close to the settlement and starved to death. An American anthropologist, Martin Luther, visited the area in 1930 on a study tour financed by the the Association of American Meat-Packers. Luther obtained permission from Copenhagen to open ancient graves and bring back a few skeletons to Harvard University, but he discovered the caves at Uunartoq and removed about fifteen mummified bodies (Hooton 1930). A few af these mummies are still preserved in the Peabody Museum at Harvard University in Boston, U.S.A.

In 1934 the Danish archaeologist Therkel Mathiassen visited the site and found the disturbed remains of stone graves in the caves. Only one grave was found intact. It held three infants, all a few months old (Mathiassen 1936).

Mummified bodies have also been found beneath the Pisissarfik mountain at the settlement of Iffiartarfik in the Kapisillit Fjord in the Nuuk/Godthåb district. In this area Norse and ancient Eskimo ruins have been found. Many graves lie on the mountainside among fallen boulders, and they were investigated in 1945 and 1952 (Meldgaard 1953). The bodies of three adults and seven infants and children were found with well-preserved clothing and garments. The bodies were also well preserved. The find has not been radiocarbon dated but is most probably from the sixteenth or seventeenth century (Meldgaard 1984). An interdisciplinary research project on this find is in preparation.

Artificial mummies are not known from Greenland or other parts of the Eastern Arctic. Artificial mummification has been practiced throughout the world in various periods (Cockburn & Cockburn 1980). As early as 4000 B.C. the Egyptians embalmed their dead. Artificial mummification is also know from Australia, China, South America and North America. It was practiced by the inhabitants along the west coast of Alaska and the Aleutian Islands. A few artificially mummified bodies from the Aleutian Islands have been subjected to investigations (Zimmerman *et al.* 1971; Zimmerman *et al.* 1981). The purpose of artificial mummification was to achieve immortality. It is likely that naturally mummified bodies provided the model.

Mummification

The preservation of the bodies, their clothing and their belongings in the two graves at Qilakitsoq is a result of the particular local conditions. The deceased humans as well as their belongings were desiccated; they were mummified by a combination of low temperature and dry air.

The annual mean temperature at the site is well below freezing point. The climate is arctic. The fluctuations may, however, be considerable with temperatures below –40° C in the winter and up to +15° C in the summer. The temperature in the graves, however, can hardly ever have reached more than +5° C. The graves faced north and the overhanging rock protected the capstones on the graves from direct sunlight. Probably there were no more than a few hours each year of direct sunshine on the stones.

The projecting rock also sheltered the graves from direct snow and rain so that only minimal amounts of water came into contact with the bodies. Any water and moisture was drained off through the stones at the bottom of the graves. In addition air could pass between the stones around the bodies thus enhancing evaporation and the desiccation process. The air in the area is very dry with low humidity.

This is a process of natural mummification which has taken place, stopping normal post-mortem decomposition. Immediately after death, when the cessation of breathing and circulation stops the nourishment of the organs and tissues, the processes of decomposition start (Camps *et al.* 1976). Factors such as low temperature and desiccation can stop or delay these processes, which otherwise gradually lead to the disappearance of the soft tissues of the body. A deceased adult buried in well-drained soil in Denmark, for example, normally becomes a skeleton in about ten years; for a child, it takes about half the time. Some parts of the body are particularly resistant to decomposition, i.e. the bones, teeth, cartilage, hair, nails, and crystalline lenses.

The processes of decomposition are complicated. Decomposition is primarily real putrefaction with decomposition of organic material due to bacterial activity. Bacteria from the intestines and the respiratory passages spread through the dead body, first along the circulatory system. Blood is an excellent nutritive medium for bacteria. Later, bacteria from the environment and soil may join in. Decomposition is also due to autolysis, caused by the enzymes of the dead body. These are bound to the cells during life but escape after death.

The decomposition of a dead body can take different periods of time. Temperature is a very significant factor. Thus, a dead body decomposes rapidly when the temperature of the environment is high, as in the Tropics, or when the deceased has had fever. Low temperatures delay or completely stop decomposition, which is minimal at temperatures below +4° C. It is the complicated chemical processes of decomposition which are slowed down or stopped by low temperatures.

Water is necessary for the processes. The growth of bacteria and to a lesser degree of fungal organisms depends upon the presence of water. As water freezes into ice crystals it is not available for the processes. If water disappears because of freezing or desiccation bacterial growth and thus putrification are hindered. Alternating periods of freezing and thawing have a particularly desiccating effect. The cell membranes are destroyed so that the water of the cell is released and can evaporate.

Mummification by desiccation is not characteristic of cold regions alone. In fact, the drying process is rather favoured by high temperatures, dry air, and draughts which enhance evaporation. Mummification is normally rare in temperate climates. It may, however, be encountered in certain parts of the body such as the hands, which have a relatively large surface and therefore dry easily. Finds of mummified infants are also known. These infants may have been born clandestinely, done away with, and hidden in a warm, dry attic. In warm and dry desert regions it is not unusual to find mummified bodies in the sand, sometimes more than one thousand years old (e.g. in Nubia). These desert people have died in the open and rapidly dried up because of the high temperature and low humidity of the air. These bodies are preserved for an unlimited length of time.

The bodies

A detailed description of the eight mummified bodies can be pieced together from the papers in this volume, particularly the papers on the anthropological (Balslev Jørgensen 1989), radiological (Eiken 1989), dermatological (Kromann *et al.* 1989) and odontological (Pedersen & Jakobsen 1989) investigations.

The scope of the investigations was, however, restricted because the four best preserved bodies (mummies nos. 1, 3, 4 and 6) were restored with the garments *in situ* so they could be exhibited in the Greenland Museum in the capital Nuuk/Godthåb. This meant that only non-invasive methods could be employed in the investigation of these bodies. Hairs from the heads were sampled and small specimens of mummified tissue and bone were, however, removed for various analyses through a small opening made in the garments in the back in all of them, except mummmy 1 (the six-month-old child).

Due the extreme degree of preservation and its small size, this mummy was left untouched. It was decided that more extensive investigations than X-rays might damage the body without any change of giving new information. Hence, the sex of the child was not determined. Small details in the making of the hood of the skin jacket indicate, however, that the child was a boy (Rosing 1979).

The four remaining mummies (Nos. 2, 5, 7 and 8) were accessible for more thorough investigations after their garments had been removed for conservation. None of these bodies were suitable for exhibition because of extensive decay and destruction. The soft tissues of the bodies had disappeared in some places and some were partly skeletonized. From all of the bodies material could be sampled for investigations.

Only in mummy 7 could internal organs be identified.

Figure 1. Mummy 1. The beautifully preserved body of a six-month-old child. Photo: John Lee, National Museum, Copenhagen.

In the other three bodies the mummified internal structures appeared as uncharacteristic brittle material. In mummy 7 the thoracic wall and part of the abdominal wall had to be removed with an electric saw because of the very hard consistency of the mummified tissue. In the thoracic cavity the desiccated heart and two shrunken lungs could immediately be identified. In the abdominal cavity part of the transverse and descending colon could be seen on the front side of the spine. On the left side a small structure was registered at the normal position of the spleen and on the right side a small shrunken liver below the diaphragm with a small structure looking like the gall bladder. White mould was encountered on all internal as well as external surfaces (Svejgaard *et al.* 1989). Eight mummified flies were also found, some of them embedded in mould. They were determined to be representatives of *Trichocera sp.* and *Neoleria prominens* (Lyneborg 1984).

Figure 2. Mummy 1. Photo: John Lee, National Museum, Copenhagen.

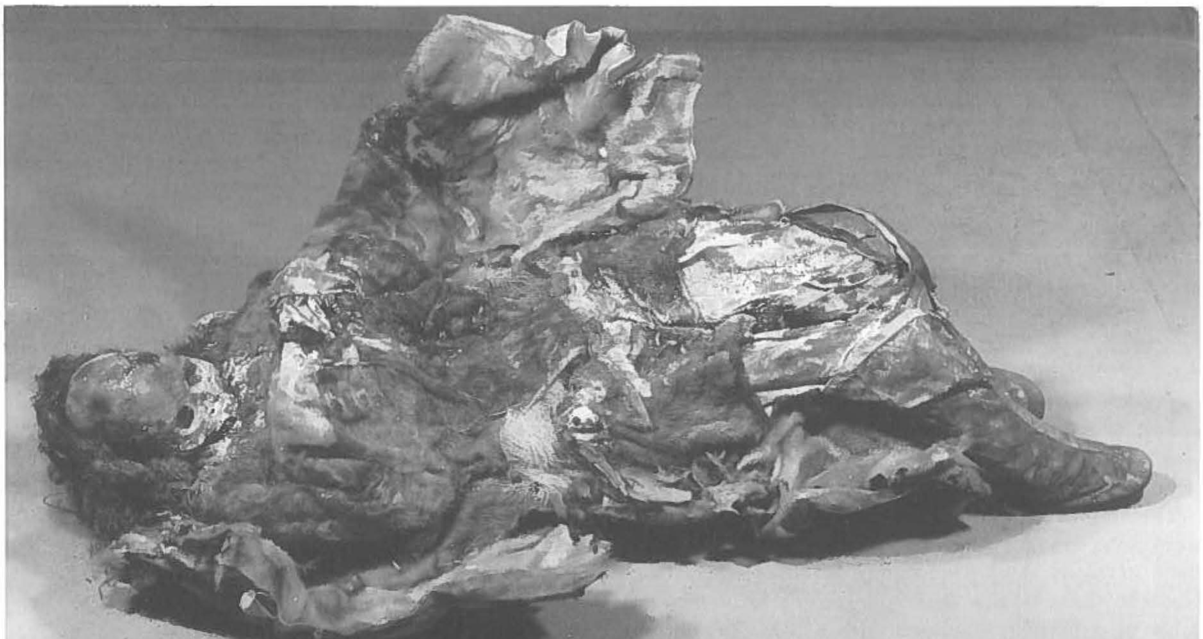

Figure 3. Mummy 3 before conservation. Photo: John Lee, National Museum, Copenhagen.

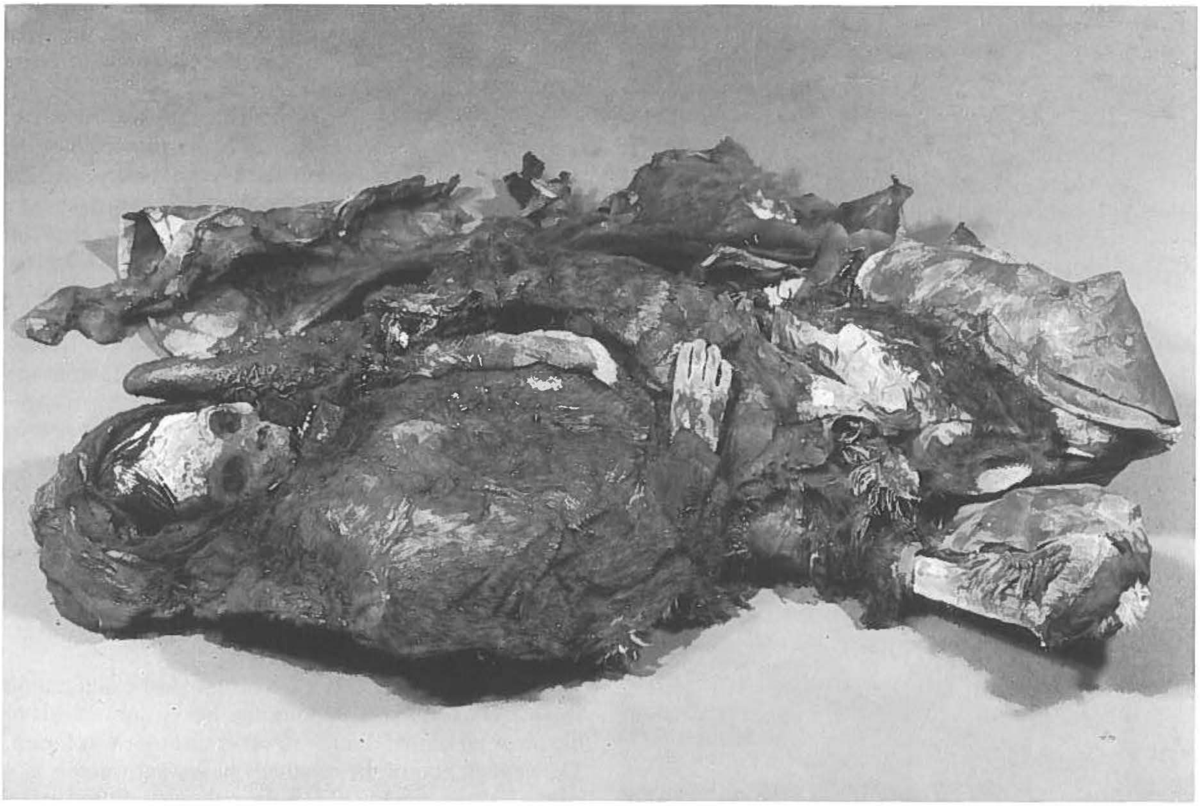

Figure 4. Mummy 7, a young woman of 18 – 22. This body was poorly preserved in comparison with the other mummies. Photo: John Lee, National Museum, Copenhagen.

Figure 5. Mummy 8, a woman of about fifty when she died of a malignant tumour in her nasopharynx. Photo: John Lee, National Museum, Copenhagen.

Figure 6. The mummified right lung from mummy 7 after being removed from the thoracic cavity. Photo: Gentofte Hospital.

The two lungs and the heart could easily be removed from the thoracic cavity. It was not possible, however, to remove the abdominal content without using a saw. The abdominal cavity was therefor rehydrated using the original solution of Ruffer according to Zimmerman *et al.* 1971. This procedure made the organs soft and easily removable.

The isolated liver measured 22 × 17 × 2,5 cm. The surface and the cut internal surfaces were without macroscopical changes. The gall bladder was well defined with a wall measuring few mm. The gall bladder itself measured 4 × 2 × 2 cm. No concrements were encountered.

The transverse colon was easy to identify with both flexures. Fat was seen in the retroperitoneal space. The descending colon and the sigmoideum were also discovered. During the removal several faecal lumps appeared with discernible hairs (Lorentzen & Rørdam 1989; Fredskild 1989). After the removal of the colon the small intestine could be identified. The wall was as thin as paper. No content was encountered. The ventricle could be identified too, with a paper thin wall without mucosal relief or any content.

The lungs and the heart were placed in the rehydrating solution of Ruffer. After 24 hours the consistency had changed. The tissues were now soft and permitted the use of knife and scissors without doing any damage to the structures. The rehydrating fluid was strongly dark-brown coloured. After rehydration the heart measured 10 × 7.5 × 2 cm. The pericardium was normal. It was possible to inspect the cavities and valves of the heart and no abnormalities could be registered. In particular, no atherosclerotic changes could be seen in the ascending part of the aorta. The openings of the coronary arteries were easy to locate. Other internal organs could not be identified, neither kidneys, other urinary or sexual organs.

Histological investigations

Tissue samples were taken for histological examination (Myhre *et al.* 1989). Beside rather heavy anthracosis of the lungs no sign of disease or other disorder was found. The explanation of the relatively heavy anthracosis in a young woman aged 18–22 living in the unpolluted arctic air is the fact that it was the duty of the Eskimo woman to tend the lamps and cooking fires (Kleivan 1984). In so doing she inhaled particles of soot. There were no signs of tuberculosis, a disease which in recent generations has ravaged the Greenlandic population (Stein *et al.* 1968).

Immunological investigations

Even if HLA-typing of the mummies turned out to be successful (Hansen 1989) it was not possible to demonstrate antibodies in eluant from mummy skin and muscle tissue using Western blot technique (Shand & Høiby 1987). This was in agreement with the findings of immunohistochemical investigations, which were negative after application of a wide range of stained antibodies to sections of paraffin-embedded tissue.

The following antibodies were applied (Pallesen 1987). The relevant antigen is mentioned in brackets: UCHL-1 (T-cell antigen), LN 3 (HLA-DR antigen), MAC387 (macrophage antigen), Muramidase (polyclonal antibody), Alpha-1-anti-chymotrypsin (polyclonal antibody), CAM5.2 (cytokeratin), AE1 (cytokeratin), Anti-vementin (vementin), Anti-desmin (desmin), Anti-myoglobin (polyclonal antibody), E29 (epithelial membrane antigen), Anti-S-100 protein (polyclonal antibody), and F8/86/3 (factor 8-related antigen).

Figure 7. Section from the root of a lung showing cartilage from the air passages, collapsed alveoli and heavy deposits of inhaled soot (anthracosis). Periodic acid-Schiff (PAS). x 25. Photo: Gentofte Hospital.

Bacteriological investigations

These investigations were carried out by Sebbesen & Thomsen 1984. Material was secured from most of the bodies (skin, heart, lungs, liver, ileum, and colon). Tissue samples measuring approximately 2 × 2 ×2 cm were isolated after impressions had been made of the surface with Rodac plates (5 per cent blood agar). Part of the tissue specimens was homogenized with sterile sand and mortar and suspended in serum broth. It was not possible to sterilize the surface of the tissue samples before homogenization without damaging possible viable germs in the tissue.

For cultivation of the serum broths a semiquantitative technique was used, and the serum broth dilutions were spread on agar plates and 5 per cent blood agar plates for aerobic cultivation. For anaerobic cultivation serum broth dilutions were spread on chocolate agar plates.

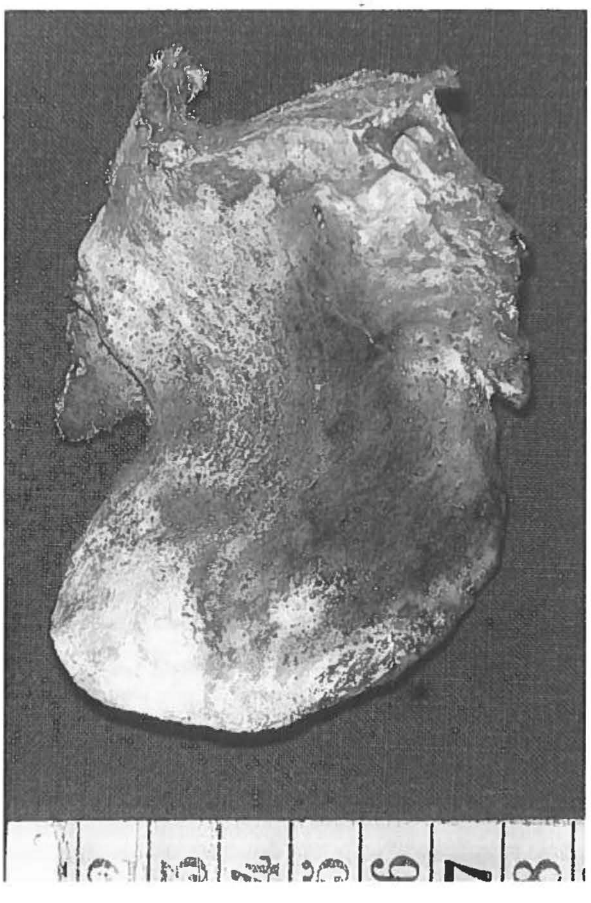

Figure 8. The mummified heart from mummy 7. Both auricles can be seen. Examination after rehydration showed normal conditions. Photo: Gentofte Hospital.

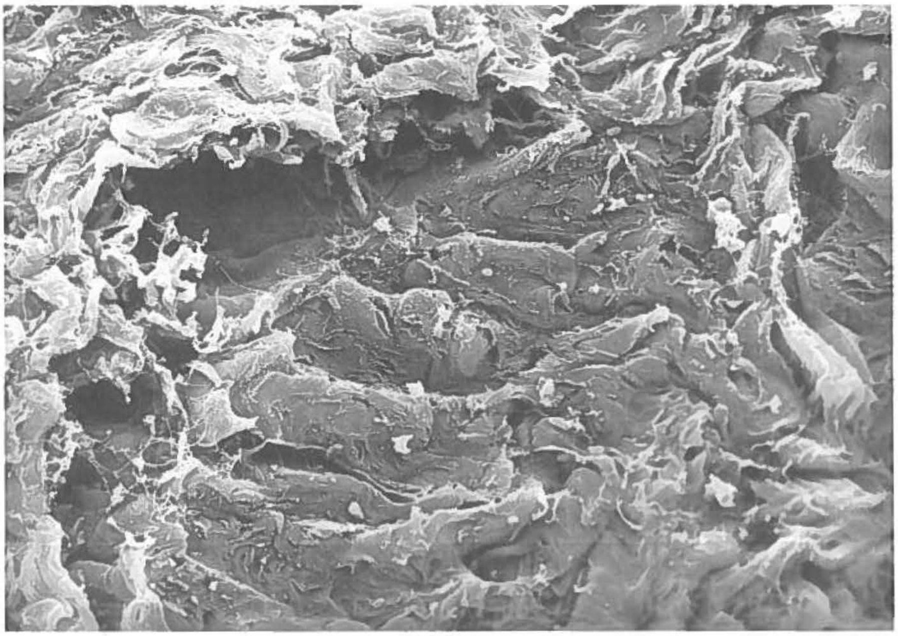

Figure 9. Scanning electron micrograph of the aorta seen from the lumen. The smooth lining of flat cells (endothelium) which in vivo lines the inside of the artery have disappeared and bared the deeper structures of the vessel wall, mainly collagen and elastic fibrils. Magnification 2.000 x. The examination and photo by Bo Hainau, MD, Herlev Hospital, Copenhagen.

Aerobic cultivation was done at 22° C in normal atmosphere and 37° C in 10 per cent carbon dioxide atmosphere. Anaerobic cultivation was done at 37° C in anaerobic jars containing an atmosphere of 70 per cent nitrogen, 20 per cent hydrogen and 10 per cent carbon dioxide. Examination of the plates was carried out after 48 hours and the plates were observed for a period of fourteen days. The morphology of the colonies was described, the bacteria were examined by Gram staining, and movement, spores and suspected pathogenic bacteria were identified.

The results were that up to ten different bacteria were cultured in some of the samples, all of them gram-positive and not different from those found in common soil. Most of the bacteria were found on the surface as well as in the tissue, indicating contamination from the

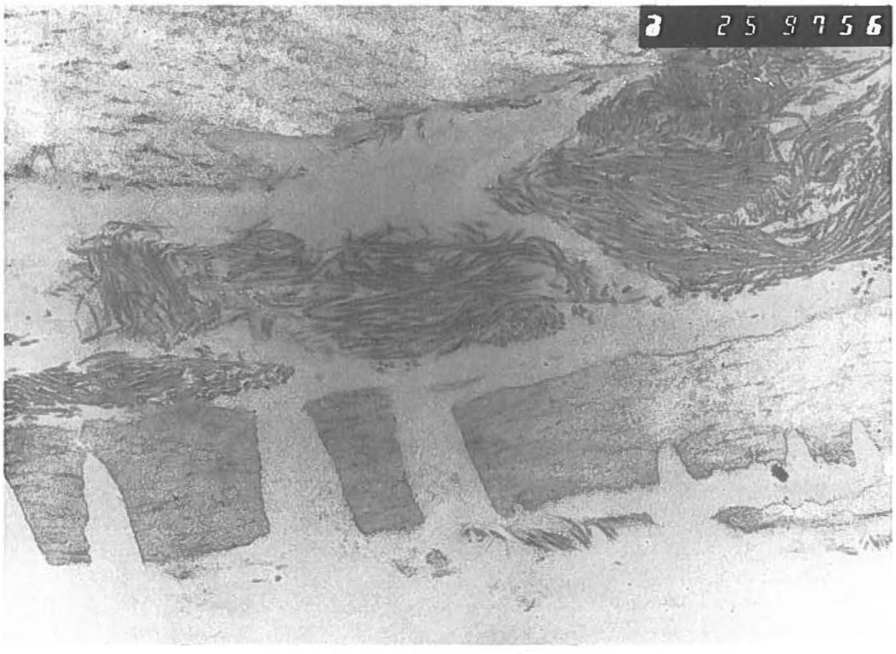

Figure 10. Transmission electron micrograph of the aorta. The slender cross-striated fibrils are collagen. The thick fibre exhibits the striation parallel to the long axis which is typical of elastin. The sequestration of the fibre is probably due to the process of mummification. Magnification 25,000 x. The examination and photo by Bo Hainau, MD, Herlev Hospital, Copenhagen.

Figure 11. Skin specimen with tattooing. The epidermis has disappeared. In the dermis deposits of black soot can be seen. The tatooings of the Qilakitsoq mummies were made by the so-called sewing technique. A thread made of caribou sinew was blackened with soot. With a needle the thread was drawn beneath the skin through dermis. The tattooer pressed the thumb on the spot to press in the pigment. Periodic acid-Schiff (PAS). x 100. Photo: Gentofte Hospital.

surroundings. In tissue taken from the pelvic cavity growth of *Clostridium perfringens* was found. This bacterium was not found on the surface.

In conclusion, *Clostridium perfringens* was the only potential pathogenic bacterium found. *Clostridium perfringens* is commonly found today in faeces from humans and animals and in soil contaminated with faeces. In poorly oxygenated tissue these bacteria can cause gas gangrene, which in former times was fatal. The importance of this finding is difficult to evaluate. Most probably, it was a chance finding. Gas gangrene does not seem to have been recorded in Greenland in historic times.

Cause of death

It has not been possible to establish either the cause or the manner of death for several of the mummies. This is partly because thorough internal investigation was not permissible in the cases of the best preserved mummies, which had to be fit for museum exhibition. These bodies would have provided the best possibilities for identification of structures and possible pathological changes.

In some of the cases there are, however, firm indications of the cause of death. In other cases it is only possible to conjecture. Many likely causes could not be put to the test because access to internal examination was limited. In some cases the organs were poorly preserved. When considering the possible causes of death, one must keep in mind that the individuals may have died on the same occasion from the same cause, or at different times for different reasons, perhaps at intervals of several years.

Mummy 1, the smallest child, showed no sign of disease or trauma under external examination and X-ray. The child may have been killed by being buried alive with its deceased mother (Meldgaard 1953). This procedure was in fact not unusual in ancient Greenland. In the small, isolated arctic communities it was not always possible to save a child whose mother had died. Instead of letting the child die gradually of hunger because no other woman could be found to nurse it, the father would kill the child. Often it was suffocated and buried with the mother so they could travel together to the Land of the Dead. In other cases the child was buried alive with the dead mother.

In the present case the child was found on top of the other four bodies in grave I. The lower four bodies were completely covered by hides and the child was placed upon these without any covering itself. This indicates that the child was placed into the grave as the last act before the grave was covered with stones.

In *mummy 2*, a boy of about four, the roentgenological examination offers certain indications of the cause of death (Eiken 1989). Most probably this child suffered from Legg-Calvés-Perthes' disease, which must have caused pain and difficulty in walking normally. Moreover, the shape of the pelvis indicates that the child suffered from Down's syndrome. This syndrome is well known also in Eskimos. Most probably the boy had great need for support and was only able to limp or perhaps just crawl around. His mental development was probably poor in relation to his age. Rarefaction of his bones indicates that he was disabled and probably immobilized for some time. Surprisingly, however, the boots of the boy showed that they were normally worn. The soles were even repaired below the heels. This seems to contradict the above. But explanation may be that the child was given the boots of another child after death. This supposition is supported by the fact that the right and left boot were on the wrong feet. No signs of rickets were found.

A disabled child like this boy must have had great difficulty surviving in ancient Greenland. Resistance to contagious diseases and hunger will have been poor. Children suffering from Down's syndrome also have a higher death rate than normal children as a result of congenital heart diseases and blood cancer. No internal malformations or diseases could be discovered in the boy. The poor state of preservation of the body has, however, limited the extent of the investigations.

It is also well known that in ancient Greenland children and also adult invalids were sometimes killed, either violently by strangulation or drowning, or by exposure, given the limited resources of the small communities (Mylius-Erichsen 1905, Hansêraq 1933). However, it was not possible to find any sign of strangulation or other violence in the boy, and death from exposure, cold or thirst cannot be proven. Thus, the boy may have died a natural death as a result of congenital or acquired disease and general low resistance. It can not, however, be ruled out that he was killed in one or another way.

The custom of killing disabled and sick persons when provisions and resources were low was not regarded as evil but rather as an act of compassion. This is analogous to the behaviour of many old and disabled persons who left their homes and settlements on their own initiative and sought death in order not to be a burden to their families, particularly during periods of hunger (Egede 1939).

The findings made during examination of *mummy 3* included a kidney stone (Hueg 1983) and a bone fragment from the temporal bone of either a seal or a polar bear (Møhl 1983), probably located in the gastrointestinal canal (duodenum). The kidney stone may have caused a malfunction of the kidney. The bone fragment must have been taken in with the food and was following the natural route through the body when death occured. However, it is not possible to exclude the possibility that the fragment may have torn a hole somewhere in the gastrointestinal canal or caused volvulus by lodging in the intestinal passage. Both are possible causes of death.

Mummy 4 had a distended abdomen. This immediately gave rise to speculations that she was pregnant at the time of death. Roentgenological examination however ruled out this possibility. The distension of the abdomen was most likely caused by post-mortem intestinal gas production. An ovarial cyst is however a possibility, though such a cyst very rarely causes death.

In *mummy 5* the hair of the scalp was sparse, resembling the physiological type of baldness in men (Kromann et al. 1989). Baldness is infrequently seen in females, and physiological baldness is rare in Inuit, even in men. The baldness may have been caused by a virilizing tumour of the ovary, and the possibility cannot altogether be excluded that such a tumour may have been of some importance for the occurence of death. Small areas of baldness can be seen in Inuit women in the temples, caused by the widespread habit of arranging the hair with a very tightly knotted top. This type of baldness has been given the name *alopecia arctica s. Groenlandica*. The same type of baldness can be seen today in girls wearing their hair with an excessively tight ponytail.

In *mummies 6* and *7* no changes were observed of relevance to the cause of death. In *mummy 8*, however, a woman of about fifty, extensive destruction of the base of the skull was observed in roentgenological examination (Eiken 1989). This destruction was most probably caused by a malignant tumour spreading in the bone. The changes are identical to those which can be seen in patients with nasopharyngeal carcinoma. This cancer type is particularly frequent among people of Inuit origin in Greenland, Alaska and Canada (Højgaard Nielsen *et al.* 1977). It is also frequent in certain regions of China and North Africa, although it is rare in Europe. In fact, the current incidence is about 25 times greater in Greenlanders than in Danes. Presumably, a nasopharyngeal carcinoma was the cause of death in this woman. This malignant disorder must have caused distressing symptoms during the last period of the woman's life, with blindness and pain. The marks of cuts in her left thumbnail indicate, however, that the woman was able to work to the very end (Kromann *et al.* 1989).

With regard to the establishment of the cause of death it must be taken into consideration that 500 years have elapsed since the death of the people from Qilakitsoq. The disease pattern in Greenland has changed profoundly during this period, particularly during this century. Many serious infectious diseases have been nearly eradicated. Nonetheless, the disease pattern in Greenland today still differs considerably from that of industrialized countries like Denmark (Harvald 1982). For example, the cancer pattern in Greenland differs markedly, with relatively high rates of certain types of cancer, as for example nasopharyngeal and oesophageal cancer, salivary gland cancer, cervical cancer and lung cancer in women, and relatively low rates of other types such as breast cancer, uterine cancer and prostate cancer (Højgaard Nielsen 1986). No doubt both hereditary and environmental conditions play a role for the occurence of cancer and a number of other diseases.

The Inuit have lived in relative isolation for thousands of years. This isolation was only really broken by World War II with the increasing strategic importance of the Arctic and growing exploitation of natural resources. The admixture of non-Inuit genes in the gene pool is constantly increasing and living conditions and the environment are undergoing radical changes. The proportion of European genes in West Greenland today is at least 25–30 per cent (Kissmeyer *et al.* 1971). These changes in heredity and environment are also reflected in the disease pattern.

One characteristic feature of the unique Inuit disease pattern is that coronary thrombosis and both the juvenile and mature form of diabetes are rare (Dyerberg & Bang 1982; Sagild *et al.* 1966). In recent years coronary disease is diagnosed six times more frequently in Danes than in Greenlanders. This is probably because the thrombocytes of Inuit blood have a low ability to aggregate (Bang & Dyerberg 1981). For centuries Greenlanders have been known to bleed easily. Today there is a relatively high rate of cerebral haemorrhages, prolonged bleeding in connection with childbirth and a pronounced tendency to nosebleeding. The occurence of atherosclerosis *per se* in Inuit has not been conclusively investigated. It has been postulated that Inuit do not have atherosclerosis to the same degree as Europeans, for example, and this has been attributed to the traditional hunter's diet. Atherosclerosis has, however, also been found in ancient Inuit bodies (Zimmerman & Smith 1975; Zimmerman & Aufderheide 1984).

The bones of Inuit are relatively deficient in calcium. This fact is well known from investigations of Inuit skeletons up to 1500 years old from the entire Arctic – Greenland, Canada, Alaska and the USSR – as well as of living persons (Thompson *et al.* 1982; Mazess 1974; Mazess & Mather 1975). The absolute blood calcium content in Greenlanders is lower than in Danes (Jeppesen & Harvald 1983) but the content of vitamin D, which is essential for the formation and development of bone tissue, seems to be sufficient in Eskimos living on a traditional diet (von Westarp *et al.* 1982). As a result of the sufficient vitamin D content rickets is not found in Greenlanders, whereas the low calcium content of the blood tend to rarify the bones with an increased risk of fractures. In several of the mummies the skeleton was rarified (Eiken 1989), and small compression fractures of the lumbar vertebral bodies were encountered. Greenlanders who have moved to Denmark show a higher calcium level in the blood, probably due to calcium-rich dairy products. In this context the increased occurrence of lactase insufficiency in Grenlanders has to be kept in mind (Gudmand-Høyer *et al.* 1973).

Among the possible causes of death, infectious diseases are important. For centuries Greenland has been virgin country for many infectious organisms (Bertelsen 1943). Given the secluded location of Greenland and the small, scattered settlements with little contact with the outside world infectious diseases often had a devastating effect. An infectious organism responsible for influenza or measles, for example, brought into the country from the outside by whalers or explorers, for whom it may have been harmless, could spread in the community, killing the greater part of the population in a short time. Many epidemics are on record from historical times, i.e. diseases like smallpox and typhoid fever. Serious epidemics of measles and hepatitis are known from recent decades, and tuberculosis is still remembered as the great killer in the first half of this century (Skinhøj *et al.* 1977; Stein *et al.* 1968). It has not proved feasible to apply any method to material from the mummies which could prove or disprove with reasonable certainty whether infection was the cause of death.

Life in ancient Greenland was harsh, at least at times. The dark period of the year, often with low temperatures, was a threat if provisions had not been stocked during the period of the year with abundant hunting. Families and whole commuinities could be wiped out by starvation, and during such periods of hunger individuals were more at risk from cold and exposure than normally.

Death from starvation, cold and exposure is difficult to trace in anthropological material like this. However, it is unlikely that the mummies died of starvation, at least not all of them. The intestinal content, which could be examined in mummy 7 (Lorentzen & Rørdam 1989), showed that this person had a varied and abundant diet up to her death. There seems to have been enough food at the time of her death, which also seems to have occurred in the summer period when food is normally available. None of the bodies seemed lean; on the contrary mummy 7 was rather stout. The garments and the loose skins and hides were all without traces of chewing or eating and this also contradicts the theory of death by starvation. When humans or their dogs starved in ancient Greenland pieces of skin were often cooked and chewed by the hungry humans and eaten by the dogs (Janssen 1913: 107; Rosing 1963: 151).

Another possible, and fairly frequent cause of death in Greenland is drowning. So the theory of drowning was put forward immediately after the opening of the graves (Rosing 1979). It was supposed that all eight dead persons had sailed together in an umiak, the traditional Greenlandic skin boat for transporting many people and goods. This type of boat was always rowed by women while the men followed in their kayaks. In the present case the umiak could have been sailing near the settlement of Qilakitsoq when an iceberg in the fjord capsized and raised a huge wave. This may have capsized the boat and thrown the women and children into the sea, where they drowned. The men would have survived the big wave in their more manoeuvrable kayaks. The drowned would either have been taken from the sea or washed ashore, and they might then have been buried together in the rock cleft.

It has not been possible to find firm evidence to support this theory. Even today it can be difficult to find absolute proof of drowning in drowned person.

Since the beginning of this century it has been believed that the occurrence of diatoms in the lungs was a proof of drowning. Diatoms are one-celled plants which can turn inorganic material into organic using solar energy. Diatoms are most often found in natural water, but can also be isolated from earth, and they circulate in the air (Foged 1982). Material from all the mummies except the smallest child (mummy 1) was examined for diatoms and a large-scale investigation was launched (Foged 1982) involving meat from animals and fish and material from Danes who had recently drowned or died from other causes. Diatoms were recovered from all the mummies investigated. Most of the diatoms were of the type found in fresh water, not in sea water, which was surprising considering that most of the diet must have had its origin in the sea (Tauber 1989). The Greenlandic material was compared to Danish material and no difference could be found. Thus the results of the investigation neither supported the theory of drowning as the cause of death for the Qilakitsoq mummies, nor did they indicate that the occurrence of diatoms in tissues from drowned persons could with any certainty be utilized in support of diagnosis of drowning (Foged 1983).

It must also be mentioned that a comparative geological investigation could not demonstrate, in the garments of the mummies, one single grain of some very characteristic minerals which were abundant on the local beach (Ghisler 1989). Thus the bodies can hardly have been landed on the beach. Further, it was stressed by an old hunter from Uummannaq that not one single fragment of the boat was found in the graves (Hart Hansen *et al.* 1985). The hunter emphasized that in cases of fatal boat accidents skin from the doomed boat was used to cover the bodies in the grave. Such boats, umiaks and kayaks, as well as other material and implements responsible for fatal accidents could not be used by living persons according to customs.

Another theoretical cause of death is poisoning. Deadly epidemics and single fatal cases of food poisoning (botulism) are well known from the whole arctic area even to-day (Kern Hansen & Bennike 1982). In Greenland deadly cases of poisoning from eating mussels are on record, but no cases of death from eating poisonous plants are mentioned (Berthelsen 1940).

Did they die simultaneously?

It has not been possible to decide with any certainty if the mummies died and were buried simultaneously or if they died from from different causes and were buried at intervals – perhaps of decades.

In the graves some indications were found that there had been one burial initially in each of the graves, which were later filled up on one or several occasions. Thus in grave I a big flat stone was found standing vertically, most probably placed in its position after the burial of the first woman, as the stone was standing on a heap of hides entombed with the woman. The stone may have been meant to increase the height of the grave for later burials and to ensure that the opening of the grave would not be too big when the covering stones had to be placed. In grave II the bottom woman was difficult to find as she was covered with hides and plants. There were many small stones and the grave seemed nearly filled up with loose skins, hides and stones when the two uppermost bodies were removed.

On initial roentgenological examination of the four-year-old boy (mummy 2) seven deciduous teeth were discovered lying together on the back above the lumbar spine, seemingly under the garments. It was initially believed that the teeth had been placed in a small, partly decayed skin purse resting on the surface of the skin, perhaps as a kind of amulet. Four other teeth were found firmly trapped in the mummified soft tissues at four different parts of the trunk and neck. It was discovered that the teeth were all from the boy himself and that they had fallen out after death, since they all had roots. It was also registered that the garments and the soft tissues of the lower part of the back were partly decayed and that the teeth were in fact located inside the soft tissues below the skin surface, not in a purse.

It is most probable that the different positions of the child's teeth, which must have loosened and fallen out years after death and burial, were caused by movement of the body. All the teeth were firmly trapped in the mummified tissues. This indicates that the teeth reached their final position before mummification was complete. After mummification it would have been impossible for the teeth to relocate. Tissues and the garments must still have been soft and decaying when the teeth moved round the body. Most probably, the child was moved from or in his grave, perhaps in order to have other bodies buried in the same grave, or for burial in another grave with his mother or other relatives. This may have happened long after death, after the loosening of the teeth and before completion of mummification. The total process of mummification may have lasted decades, given the particular conditions of the grave.

It had been envisaged that modern scientific methods could help in deciding if the dead persons had died and were buried simultaneously or perhaps at intervals of decades. Carbon 14 dating is too inaccurate in this context. It was also hoped that longitudinal X-ray-fluorescence-spectrometry on hairs from the heads of the mummies might provide some clues as to the contemporaneity of the bodies. This method can show changes in the concentration of different elements and these concentrations are known to fluctuate depending upon the character of the diet. In the event of identical diet, identical changes would be demonstrable in hairs from the individual mummies. Characteristic patterns could not, however, be demonstrated, and the results neither supported contemporarity or the opposite (Hansen *et al.* 1989).

It was only possible to recover food items from the intestines of one of the mummies (mummy 7) (Lorentzen & Rørdam 1989). The content of the faecal lumps suggested that this person most probably died during the summer (July/August). Had it been possible to collect such material from several of the mummies it would have been possible to compare the food content in order to find out if the individuals had shared the same diet, and whether they could have died at the same time of the year or not.

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Dermatological Examination of the Qilakitsoq Eskimo Mummies

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Kromann, N. P., Mikkelsen, F., Løytved, E. R. & Hart Hansen, J. P. 1989. Dermatological Examination of the Qilakitsoq Eskimo Mummies. – Meddr Grønland, Man & Soc. 12: 83–88. Copenhagen 1990-01-26.

The skin was mainly well preserved with intact surface relief and normal histological appearance. Two small keratotic papillomas on a finger of a young woman were histologically compatible with common warts. In a fifty-year-old woman the hair of the crown was extremely sparse and the breasts were atrophic. A virilizing tumour of the ovary may have been the cause. The fingernails of two women showed marks from work, and in two persons the toenails were thickened, presumably because of insufficient shortening.

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Skin

The four most poorly preserved mummies (2,5,7,8) were all in such a state that their clothing was removed and conserved separately to permit more careful study of the bodies. The skin of these mummies, as well as that of the better preserved ones, was marked by mummification. It was dry and shrunken, dark brown, and hard as wood. To a varying extent there was a white, often crackled layer of mould up to a thickness of a few millimetres. The skin of the abdomen was very dark, as was the front of the thighs in some cases. This was probably due to decay processes in the abdominal cavity after death.

The desiccating effects of the mummification process had stretched the skin enlarging the eye opening, nostrils, and mouth, and sometimes causing cracks. Sockets and mouths were asymmetrical in places.

In the palms of the hands accessible to examination there were no traces of wear or pressure in the form of calloused skin. The natural lines of the skin were preserved to some extent, and in a few cases prints could be made of the fingers, palms, and foot soles. The skin was often loosened or destroyed. All prints showed patterns and lines very similar to modern ones.

In several places there were post-mortem maggot holes in the skin. Some of these holes were extremely enlarged as a result of the mummification of the skin. There was a scattering of empty reddish brown cocoons on the mummies and their clothing. There were also some desiccated mosquitoes and flies, in fact mummified like the humans and therefore well preserved. Some of the insects were found inside the body cavities themselves.

The insects and the cocoons come from four different twowinged families (*Diptera*), namely winter gnats, *Borboridae*, swamp flies and blowflies. The blowfly cocoons come from the deterioration of the corpses during the first summer, for this fly is in fact the means by which carrion is broken down in nature. *Borboridae* cocoons may also possibly stem from the first year after

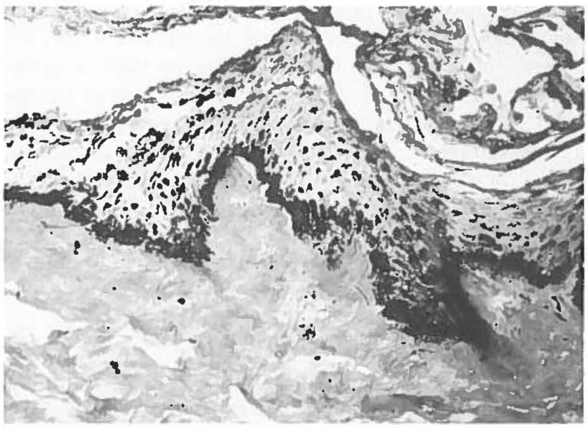


Figure 1. Histological section of mummified skin after rehydration. The horny layer is partly separated during the preparation. The nuclei of epidermis is preserved.

death, for the larvae of these flies live where there is rotten material. In contrast, the winter gnats and swamp flies are not proper carrion fauna. These insects may therefore have arrived at any time after death.

Hair

All the mummies had perfectly preserved, normal eyebrows. However, the eyelashes were missing in some cases because of their precarious position in the thin eyelids.

It was possible to examine the hair on the heads of all the mummies, apart from mummies 1 and 6, whose hair was almost hidden by the parka hoods. None of the mummies showed traces of a coiffure and a topknot could not be identified. Headbands were not found. The children's hair was very thin and wispy. In several places the hair was loose. A common reason for the loss of hair in ancient Greenland was the topknot, once so popular among the women. Constant pulling on the hair destroys the hair follicles at the temples, resulting in baldness here.

Some had lost their hair while alive, whereas the hair of others had become detached after death. One possible cause of hair loss during life is favus, a fungal disease which affects the scalp in particular and which causes cicatricial baldness. This affliction was once widespread in Northwest Greenland, and as late as 1958 there were a number of new cases, especially among families living in turf houses (Lomholt 1959), like those probably inhabited by the Qilakitsoq people.

Hatched nits were found in the hair straws of the adults, but no lice could be localized in the scalps.

Nails

In some cases the fingernails seemed very long. The shrinkage of the skin had caused the nail wall to recede. Accessible nails were scrutinized in the dissecting microscope for signs of change ascribable to work (mummies 5,7,8). Numerous transverse cuts were revealed by this technique on the left thumbnails of two mummies. These marks were probably made when the nail was used as an underlay for cutting thread with an *ulo* (a woman's knife) or cutting holes in the edge of the hides before stretching them. Both are practiced by some few women in East Greenland to day.

Other traces of activity were small chips in the exposed edge of some fingernails, an unevenly worn exposed edge on the nails of the index and middle fingers towards the thumbs, and the wearing down of the superficial, relatively soft layer of the nailplate, exposing the thick, hard layer of the nail with its longitudinal striated structure. This latter change may stem from both mechanical and chemical influence. Warm water and alkaline solutions may have caused scaling of the soft nailplate (Baran 1983). The washing of hides with old urine might explain the result, as old urine is alkaline.

Slightly pronounced transverse grooves in the nailplate were observed in two of the women. These furrows, which are probably caused by inflammation of the nail wall, are frequently seen today among housewives and others who work with their hands submerged in water (Baran 1983).

The toenails could be inspected in four of the mummies (2,5,7,8). They were thickened in two cases – this was probably due to lack of care and insufficient cutting. The thickening of toenails even in young people is a common finding in Greenland today. The thick nails (*onychocauxis*) may also be the result of small footwear. In the same two persons the nails of the big toe were worn into shape by the sole and side wall of the *kamiks*.

Dermatological findings in the individual bodies

No. 1 (Infant, approximately six months old, dressed): Only face and hands were free from the dress. Apart from the eyelids no shrinkage or skin defects were seen. The lips were well preserved. The skin was without any signs of disease. The hair was thin and wispy – as the rule in babies.

No. 2 (Boy, 4–5 years old, undressed): The skin was not cleaned for the cracked layer of white material, which partly consisted of mould. The eye openings and nostrils were unevenly widened. The mouth opening had a large tear in the right side. The external genitals were preserved. As in mummy 1, the hair was thin and sparse. This is fairly common at this age in children with Down's syndrome (Rook & Ebling 1979). Only the toenails could be examined. They were approximately one centimetre long and their free edges were worn into shape by the *kamik* sole. The nailplates had a normal smooth surface but they were rather thick, presumably because of lack of shortening (Fig. 2).

No. 3 (Woman, 20–25 years old, dressed): Only head, hands and thighs could be examined because of the presence of the garments. The skin was cleaned. Face and hands showed no skin abnormalities. The fingernails did not disclose gross abnormalities but they could not be studied in detail with the dissecting microscope. Between the lower edge of the short sealskin trousers and the boots, thirty centimetres of the thighs were naked. Here the skin was folded longitudinally because of the dehydration of the underlying soft tissues, but was otherwise normal. All of the long and strong hair of the crown was loosened and pushed backwards to the neck. The hair follicles were open, thus demonstrating that putrefaction was the cause (Fig. 3).

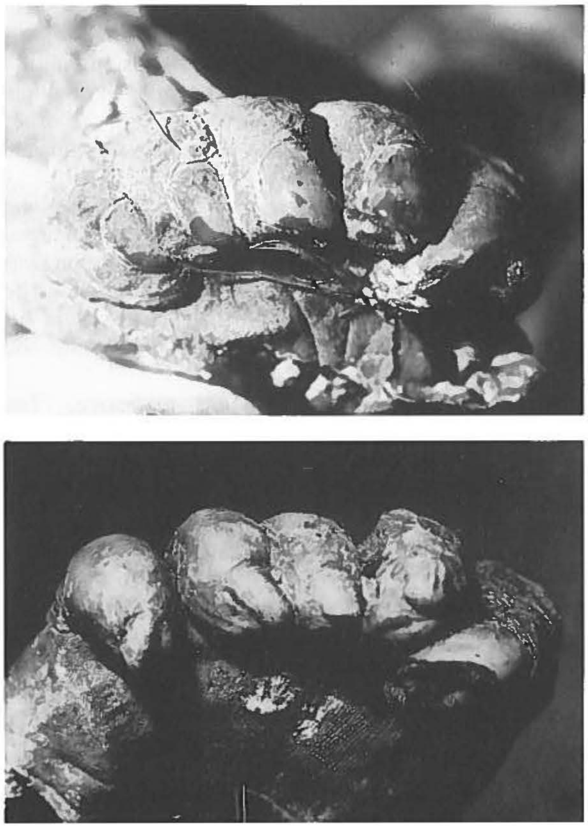


Figure 2. Top: Right forefoot of the 4–5-year-old boy. The skin and nails were not cleaned. Bottom: Right forefoot of the 18–20-year-old woman. In both persons one notices the thickened nails, and in the boy all the nails are worn to the shape of the *kamik*. The nails of the big toes have the characteristic shape of the free edge, like a wide angle.

Figure 3. The head of Mummy No. 3. The hair is displaced and open hair follicles are seen all over the crown. The eyebrows are well preserved. In the left orbit and the right temple maggot holes can be seen.

No. 4 (Woman, approximately thirty years old, dressed): As this body also had to be conserved with the garments *in situ* only the skin of the face and hands could be examined. The skin of the entire face was extremely well preserved, but very wrinkled. This wrinkling was especially obvious on the cheeks. As the woman was rather young, the folding of the skin is presumed to have developed *post mortem*. This was the only mummy whose eye sockets and mouth were not enlarged by the tautening of the skin. The lips of this woman were thus well preserved. Perhaps, like the infant, she had a thicker layer of fat in the subcutaneous layer of the face, as often seen among Eskimos. This layer of fat, combined with the cheekbones, makes the face seem broad. The hair was missing in the left side of the crown and in the temples. Open hair follicles showed the baldness to be a *post mortem* phenomenon.

No. 5. (Woman, approximately forty years old, undressed): Only the face was cleaned. This body was extremely lean and gave an impression of emaciation. Otherwise the skin showed no signs of disease. The

Figure 4. The almost bald crown of mummy No. 5. The hair loss is symmetrical and decreases gradually against front, neck and temples. These connot be post-morten alterations but must be a so-called male-pattern (androgenic) baldness and might well be due to a virilizing tumour.

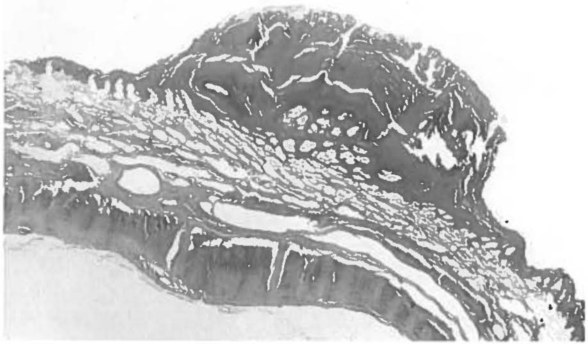


Figure 5. Histological section of a hyperkeratotic papilloma from the right fourth finger of mummy No. 7.

breasts were atrophic. The hair was very thin on the crown but thicker towards the temples and the nape of the neck (Fig. 4). The sparse hairs on the crown resembled the physiological type of baldness in men, although it is rare for women to be bald. Physiological

Figure 6. Hatched nits on the hair of mummy No. 7.

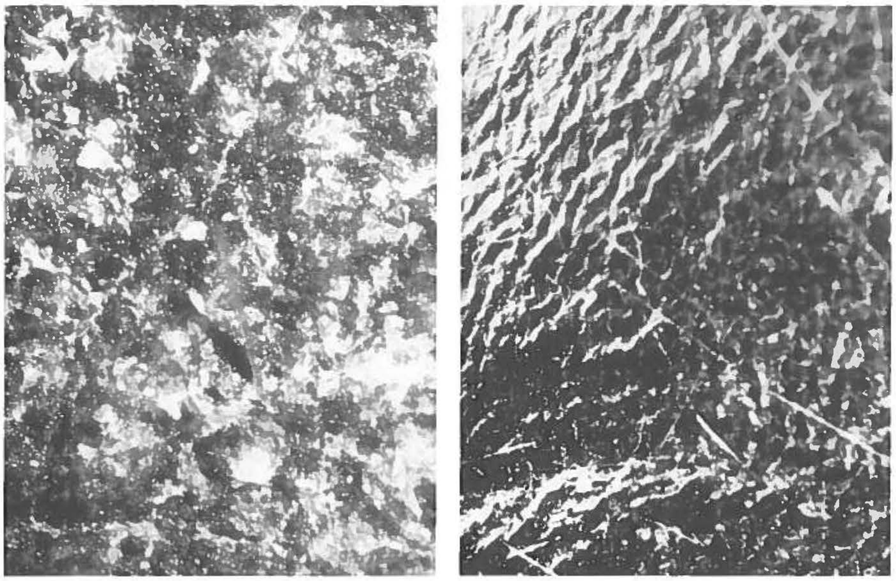
baldness is uncommon among pure Eskimos, even in men. The baldness might be due to a virilizing tumour, most likely of the ovary. Several fingernails and all the toenails were shed. The left thumbnail had a single transverse groove, but no cuts in the nailplate or other signs of work were seen. The toenails were normal without any characteristics.

No. 6 (Woman, about fifty years old, dressed): The face and hands were cleaned. The skin was damaged under the eye sockets and the skin of the chin was drawn downward exposing a part of the jawbone. The hair was covered by the hood of the jacket except for the forelock. The hands were clenched on the chest and thus the nails could not be inspected.

No. 7 (Woman, 18–20 years old, undressed): The face, hands and feet were cleaned. The body and the extremities were covered by a very thick layer of white material with feathers and grass embedded from the underwear and the boots. This young woman had one superficial lesion by the inner corner of the right eye and another one upwards in the abdominal wall. The right eyeball was particularly well preserved with no lesions and X-ray examination of the bone tissue beneath the lesion showed normal conditions without fractures. The lesion in the abdominal wall affected the skin only, as the bottom consisted of muscle tissue. There was nothing to indicate that these lesions occurred while the person was alive. Mummy 7 was the only one of the undressed women to have a relatively large abdomen; it hung down towards the thighs covering the external sexual organs. On the dorsal aspect of the proximal interphalangeal joint of the right fourth digit a three millimetre hemispherical tumour resembling a common wart was seen. On the dorsal side of the distal phalanx of the same finger a two millimetre blue tumour was located. Histologically, both tumours were hyperkeratotic papillomas compatible with common warts (*verruca vulgaris*) but the viral etiology could not be proven, not even by electron microscopy (Fig. 5). Under the left

Figure 7. The left palm of the 18–20-year-old woman. The four ulnar nails are very long. This was the true length in the live person. The cuticle is not retracted (cf. Fig. 9).

Figure 8. Left: Thin atrophic skin from the dorsal wrist of a 50-year-old woman (Stereomicroscopy). Right: Skin from the same region in the 18–20-year-old woman. The normal relief of the skin is preserved.



foot the epidermis was shed except in the foremost part of the sole. Just behind the third toe an approximately one centimetre elevation which disrupted the otherwise well-preserved surface pattern of the sole was situated. Histology revealed only cornification (Fig. 2). The hair of the head was very strong and about fifty centimetres long. It had more nits on the hairs than any of the other mummies (Fig. 6). The four ulnar fingernails on both hands were extremely long (Fig. 7) and as a whole the nails did not carry signs of hard work (cf. mummy No. 8). The fingernails showed in the dissecting microscope: 1) a few knife cuts in the nailplate of the left thumb; 2) scaling of the superficial soft layer of the nail plates (*onychoschizia*). The toenails were thick and clawlike on the four fibular toes on both feet. They were not very long. The distal part was polished where they had

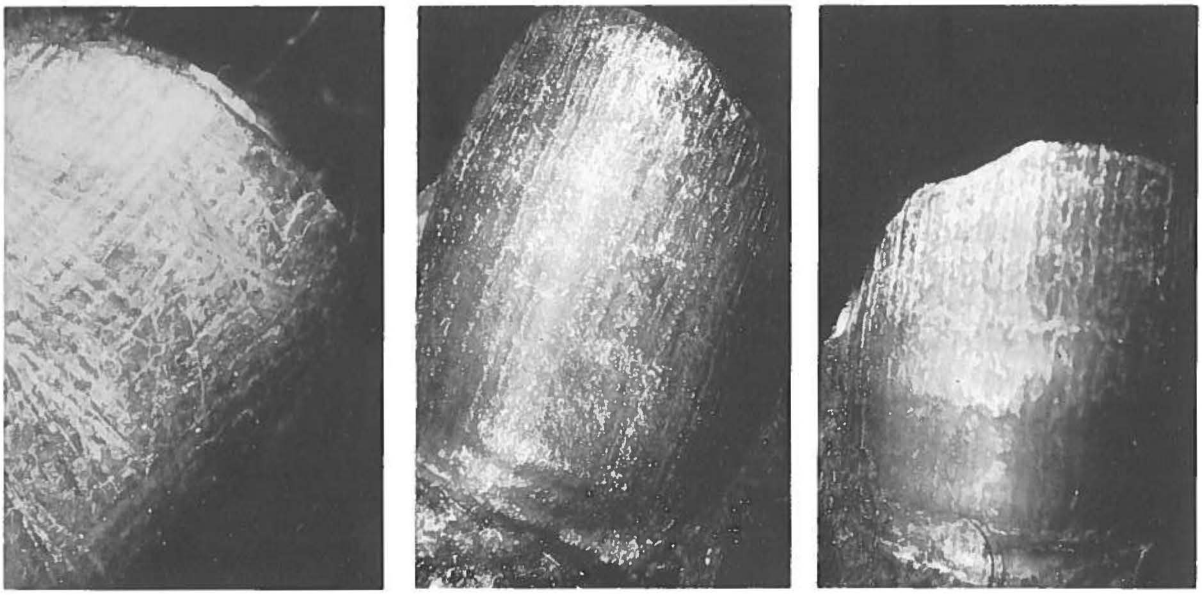


Figure 9. Stereomicroscopic appearance of nails from mummy No. 8. Left: The left thumbnail with countless transverse cuts from a knife. Middle: The nail of the left index finger. The free edge is worn mostly on the radial side Right: Index nail of the right hand. The lesion in the free edge and the shallow transverse grooves may also be due to work. The cuticle has retracted a good millimetre during the drying process. In all of the three photos the longitudinal striation of the nailplate is obvious. The superficial soft and smoot layer have been abraded by mechanical and perhaps chemical action.

rubbed against the interior of the boots (Fig. 2). The nails of the big toes were not thickened. The free edges were worn into shape by the *kamik* bottom.

No. 8 (Woman, approximately fifty years old, undressed): The face, hands and feet were cleaned. The skin of the face had been drawn to the right of the front and to the left in the lower part before the process of drying had finished. This is obvious from the disfiguring of both the nostrils and the tattooing in the front (Fig. 6 in Kromann *et al.*, this volume). Something heavy must have been in direct contact with most of the face, where the colour is dark, because the drying process was delayed and decomposition thus went further. The skin of the dorsal wrist was studied in the dissecting microscope. The wrists are normally exposed to sun, cold and wind because the sleeves are short in women's dresses. As a result the skin was very thin and atrophic, and lacked the original surface relief. In Fig. 8 the skin of the older woman is comparable to that of the youngest, No. 7. The hair was rather short and strong. In the back of the head a pad of bird skin was attached where the head rested on the hood. Examination of the fingernails by the dissecting microscope showed (Fig. 9): 1) the left thumbnail was almost covered by countless cuts from the *ulo* (Woman's knife); 2) the nails of the index and middle fingers on both sides were worn oblique against the midplane; 3) the outermost part of the nails were longitudinally striated, as the superficial layer was worn off; 4) the right index nail was polished; 5) shallow transverse grooves in several nailplates (*Beau*'s lines). The examination of the fingernails of this woman showed many marks caused by work: she must have been busily employed until a few days before she died.

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Head Lice in Mummified Greenlanders from AD 1475

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On initial inspection of the corpses, lice and eggs of lice (nits) were found in the hair of some of the individuals and in a pair of sealskin pants not traceable to any specific individual.

This article briefly describes the results of a light and scanning electron microscopical study of these ectoparasitic findings. The main elements of the morphology have been described previously (Bresciani *et al.* 1983).

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Material and methods

The corpses, six women and two children, were thoroughly examined for parasites while temporarily kept at the National Museum and Gentofte Hospital (both in Copenhagen, Denmark).

A large number of dried-up lice and nits were found in the hairs of five of the corpses and in a pair of sealskin pants. However, the majority of the collected specimens were only fragments; and only three females, two males, a few juveniles, and eggs were in a state of conservation suitable for examination.

The lice materials were slowly rehydrated in a humidity chamber with a gradual increase of the relative humidity over a two-day period. Then they were submerged in distilled water for three days and processed for scanning electron microscopy (SEM) by fixation in 3% glutaraldehyde in 0.1 M cacodylate buffer (pH 7.4), post-fixed in 1% osmium tetraoxyde for 1 hour at 4°C, dehydrated in acetone, and critical-point-dried before gold covering. The material was observed in a JEOL IMS-T20 at 5 or 20 kV. Material for light microscopy was immersed in lactic acid for two days at 50°C before examination.

Results and discussion

As will be evident from Figures 1 and 2, the lice were fairly well preserved, possibly because of the dry, cold conditions of the crevice where they were found. Thus, their morphological characteristics even allowed a taxonomical identification.

The human host may be infested by three kinds of lice, usually designated the head, body and pubic louse. The latter is a very distinct species and of a separate genus, whereas the two former are often regarded either as closely related species (Busvine 1978) or as subspecies of *Pediculus humanus* (Marshall 1981). The two species/subspecies have a vast number of morphological features in common, and their separation is often difficult. However, on the basis of a careful examination of distinguishing characteristics (antennae, paratergites, tibiae of middle legs, etc.), a systematic grouping can be made (Seguy 1944; Brinck 1950; Busvine 1978). The well-preserved structures of our specimens made such examination possible, and all specimens, both from heads and pants, could be regarded as head lice, *Pediculus humanus capitis.* This does not conflict with the localization in the pants, since head lice nowadays may occasionally be found outside the head hairs, e.g. in the pubic region and underwear, whereas body lice, on the other hand, are never found in the head.

In one of the corpses particularly many eggs were found, i.e. eggs on every three or four hairs. In the same mummy the abdomen of a louse was microscopically identified in the intestinal contents, suggesting that lice had been eaten. This habit was (possibly) not uncommon previously among Greenlanders (Fabricius 1780, cit. Hart Hansen *et al.* 1985).

Archaeological findings suggest that the louse had a world-wide distribution in ancient times. Adult lice

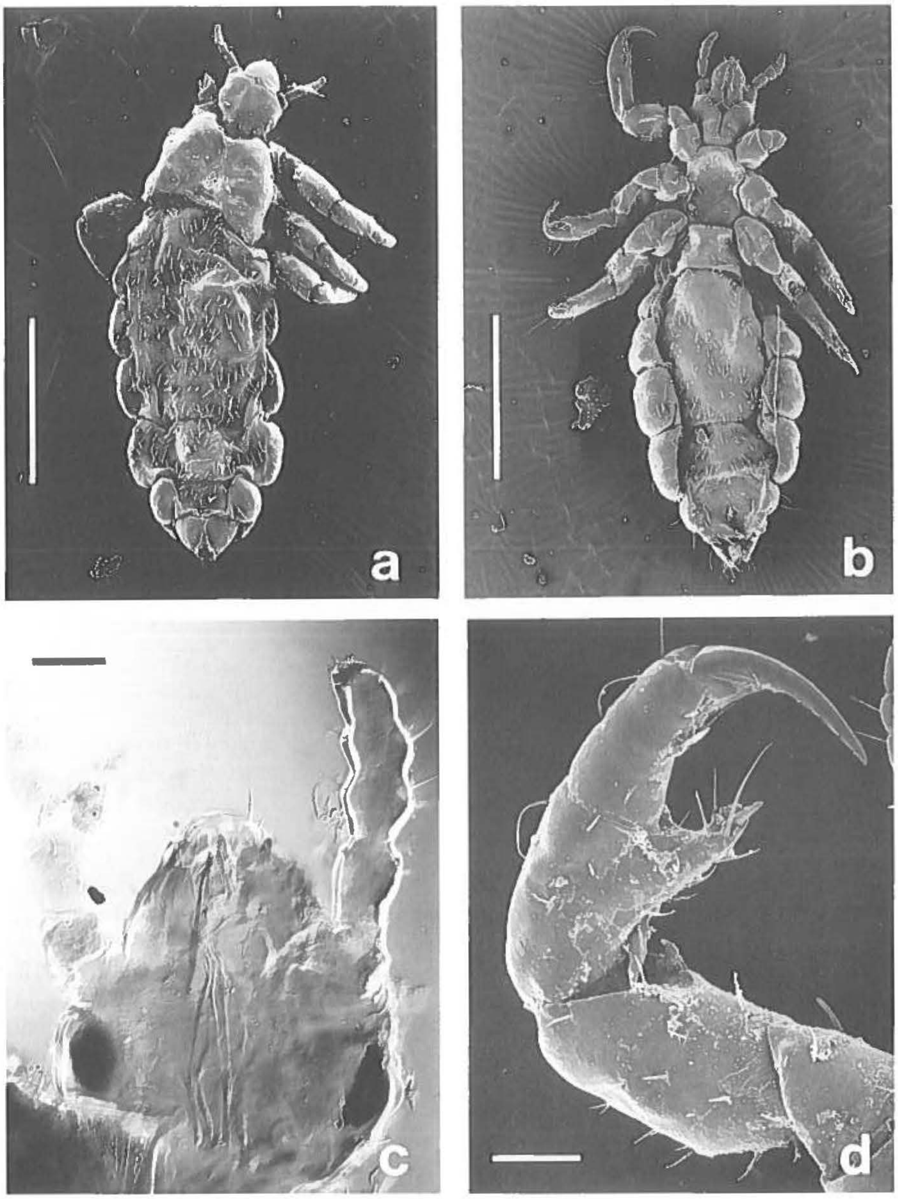
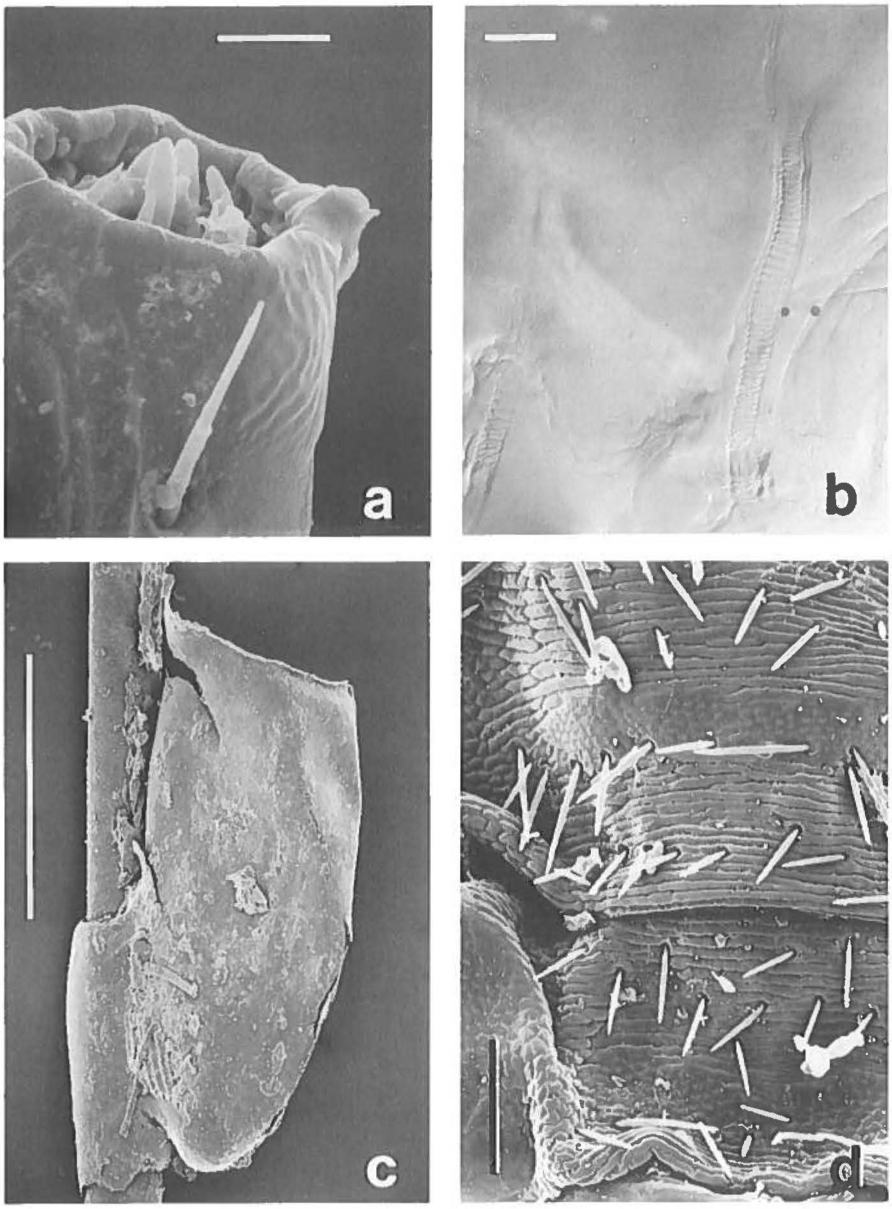


Fig. 1. *Pediculus humanus capitis* de Geer from mummified corpse of an Eskimo. a: dorsal side (♀), b: ventral side (♀), c: head with well-preserved antenna and eye, d: leg I (♂). Bar: 1 mm (a,b) ,100 µm (c,d).

Table 1. Distinguishing characteristics of the head louse and the body louse (after Seguy 1944; Brinck 1950; Busvine 1978).

	Head louse (*P.h.capitis*)	Body louse (*P.h.humanus*)
Length of female	2.6–3.7 mm	3.3–4.2 mm
Antennae	Second last segment almost as long as broad	Second last segment somewhat longer than broad
Tibial length	0.29 mm	0.42 mm
Dorsal hairs on abdomen	Numerous and stout	Few and weak
Paratergites	Broad. Developed also intersegmentally	Narrow. Developed only laterally
Abdominal spiracles	Bud-shaped, diameter above 100 µm	Flat, diameter below 100 µm

Fig. 2. *Pediculus humanus capitis* de Geer from mummified corpse of an Eskimo. a: tip of antenna with sense organ, b: trachea, c: nit (egg) attached to the hair of the host, d: dorsal side of abdomen (♀). Bar 10 μm (a), 20 μm (b), 0.5 mm (c), and 100 μm (d).



have been identified in a pre-Columbian Peruvian mummy (Brothwell & Spearman 1963) and in coproliths from a paleo-Indian site in Utah, USA (Fry 1976). In more northerly regions lice have been identified in Aleutian mummies from about AD 1500–1600 (Horne 1979) and from a Norse settlement in Greenland where a body louse was found in a refuse heap of a farm (Sveinbjörnadóttir & Buckland 1982). The Vikings might have brought the lice with them from their European places of origin, since they had little contact with the Eskimos.

The good preservation of our specimens and the lice specimens from the studies cited may be seen in the light either of very dry or very cold storage conditions, or both, at the excavation sites.

There are a number of well-known diseases which are transmitted by human lice. The most important is exanthematious typhus, caused by micro-organisms belonging to the *Rickettsiae*. This disease was previously quite common in temperate climate with high death rates, especially in crowded households with poor hygienic standards (Harwood & James 1979). The disease may have existed in prehistoric Greenland as well, and the possibility cannot be entirely excluded that it may have contributed in some way to the deaths in Qilakitsoq.

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Collagen and Glycosaminoglycans in Mummified Skin

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Ammitzbøll, T., Møller, R., Møller, G., Kobayasi, T., Hino, H., Asboe-Hansen, G. & Hart Hansen, J. P. 1989. Collagen and Glycosaminoglycans in Mummified Skin. – Meddr Grønland, Man & Soc. 12: 93–99. Copenhagen 1990–01–26.

Two tombs among the rocks at Qilakitsoq, Greenland, contained the 500-year-old bodies of eight Eskimos mummified by a natural drying process. Samples of the human skin and sealskin were analysed for the content of collagen and glycosaminoglycans which are characteristic macromolecules of skin. The skin of the Eskimo mummies was well-preserved. In some respects, the macromolecules of the skin were identical to those of fresh human skin. Well-preserved ancient sealskin had the same biochemical composition as modern skin treated by scraping, washing, stretching and drying in Greenland. The state of preservation could be determined by cellulose acetate electrophoresis of the glycosaminoglycans, because badly preserved skin contained degradation products of glycosaminoglycans. Collagen was better preserved than other components of the skin. The composition of the glycosaminoglycans was different in the skin from the two seal species, ringed seal and harp seal. Such differences may facilitate the general identification of untanned, unhaired skin. Alum tanning removes the glycosaminoglycans from the skin and makes identification impossible.

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The skin of humans and animals is composed of three layers: epidermis, dermis, and subcutaneous adipose tissue (Fig. 1). Epidermis is rich in cells forming the horny layer on top of the skin. Dermis is the thick, tough layer of the skin, which is tanned to leather. Subcutis consists mainly of fat (blubber on seal). Dermis contains fibrous macromolecules forming a network filled up with ground substance and cells. The fibrous protein collagen constitutes about 70% of the dry weight of dermis. Collagen gives toughness and tensile strength to the skin. The ground substance between the collagen fibres consists mainly of water and glycosaminoglycans, a family of water-binding macromolecules. The glycosaminoglycans render the skin soft and flexible.

Analyses of collagen and glycosaminoglycans are part of the investigations performed on patients with certain skin diseases. Some of these analyses were performed

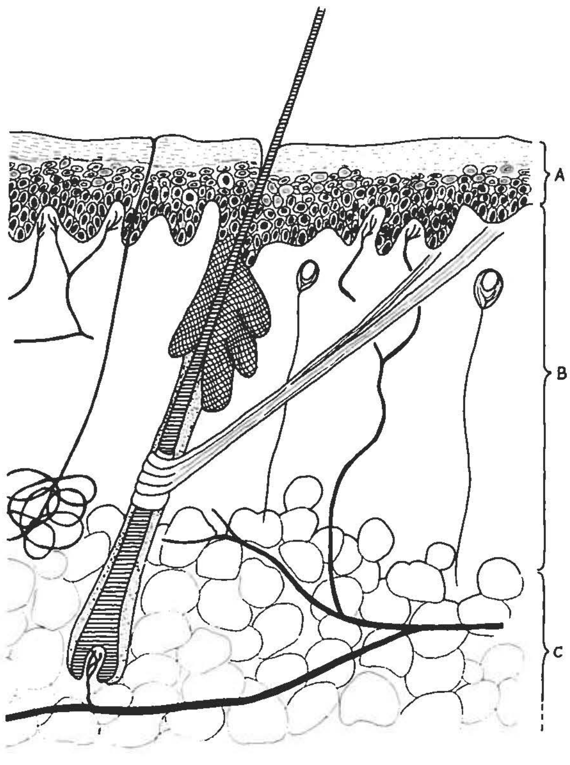


Fig. 1. The skin is composed of three layers: Epidermis (A), dermis (B) and subcutis (C). Dermis consists of cells, collagen and ground substance with glycosaminoglycans. Determinations of collagen and glycosaminoglycans were performed on samples of skin from the 500-year-old Eskimo mummies and sealskin (Gulløv, *del.*).

on samples from the 500-year-old Eskimo mummies and their skin clothes in order to compare the old material from Qilakitsoq with present-day skin.

Material and methods

500-year-old mummies and sealskin

Human skin. From seven of the eight Eskimo mummies, sixteen samples of skin from groin, chest and arm were obtained. The bodies investigated were of a four-year-old boy and six women aged from eighteen to about fifty. The baby was not investigated.

Sealskin. From three ancient skins of ringed seal, fourteen samples were taken, eight of them from well-preserved areas and six from poorly preserved areas. Two samples of well-preserved skin and three samples of badly preserved skin were obtained from two ancient sealskins of harp seal. Furthermore, two samples of alum-tanned sealskins, one of ringed seal ond one of harp seal, were included. The identity of the sealskin (ringed or harp) was established by the colour and marking of the hair.

Kamiks. The 500-year-old eskimo boots, *kamiks,* were made of unhaired sealskin of unknown seal species. The material investigated included samples of two untanned *kamiks* treated with Lederweicher® and samples of 7 alum-tanned (Lutan F) *kamiks.* The treatment with Lederweicher ® or Lutan F was done at the National Museum in order to preserve the items.

Present-day human skin and sealskin

The human control group consisted of 29 age and sex matched Caucasians. Skin specimens from the groin were removed 6-36 h post mortem.

*Sealskin.*The 500-year-old sealskin was compared to fresh, untanned Greenlandic skin of three ringed seals and three harp seals. The modern sealskin were treated in Greenland by scraping, washing, stretching, and air drying. The number of samples were eight from ringed seal and seven from harp seal. The samples from the modern skin were cut from the same anatomical regions as the samples from the ancient skin. A skin of ringed seal was tanned with Lutan F at the National Museum and used in investigation.

Pre-treatment of samples

The samples of sealskin were shaved and defatted in three changes of acetone, subsequently in acetone/ether (1:1) and ether, and then dried in a vacuum dessicator. The samples were weighed before and after the extraction and drying.

Collagen analyses

Collagen is a fibrous protein built of amino acid residues. Hydroxyproline (Hyp) and hydroxylysine (Hyl) are amino acids characteristic of collagen. Proline (Pro) occurs in greater quantities in collagen than in other proteins. The concentrations of Hyp, Hyl and Pro were measured in the samples of skin and fur. The defatted, dried tissue (about 4 mg) was hydrolysed in 2 ml of 6 N HCl at 118°C for 18 h and evaporated to dryness at 60°C at 50 mbar. The residue was dissolved in 5 ml of a 0.046 M citrate – 0.415 M phosphate buffer pH 7.0 and analysed for Hyp, Hyl and Pro in an AutoAnalyzer® equipment (Blumenkrantz & Asboe-Hansen 1977; Blumenkrantz 1980). The results were expressed as nmol amino acid per mg defatted, dried tissue.

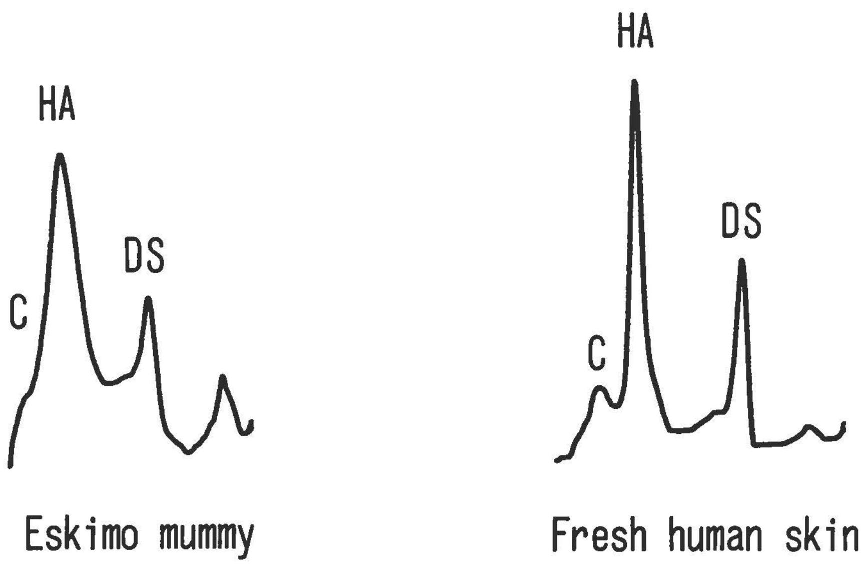
Analyses of glycosaminoglycans

Glycosaminoglycans are a family of macromolecules made of sugar moieties, uronic acid and hexosamine. Typical glycosaminoglycans in skin of humans and animals are chondroitin sulphate (C) hyaluronic acid (HA) and dermatan sulphate (DS) (Fig. 2). The glycosaminoglycans constitute less than 1% of the dry weight of skin. The method of investigation is described in detail elsewhere (Møller *et al.* 1985). The defatted, dried skin (about 10 mg) was cut into small pieces and digested with pronase. The glycosaminoglycans were isolated by precipitation with ethanol and complex formation with cetyltrimethylammoniumbromide. The uronic acid content of the isolated glycosaminoglycans was determined and expressed as nmol uronic acid per mg defatted, dried tissue. Part of the glycosaminoglycans was used for cellulose acetate electrophoresis. The electrophoresis strip was stained with Alcian Blue, which gave the individual bands of glycosaminoglycans a blue colour. The intensity of the blue colour was measured by densitometric scanning of the strips. Each peak on the densitometric curve represents a glycosaminoglycan, C, HA, etc.

Electron microscopy

Small pieces of skin from Eskimo mummies were rehydrated in 0.5 M cacodylate buffer pH 7.4 and then fixed in a solution of glutaraldehyde (2%) in cacodylate buffer, osmicated, dehydrated and embedded in Epon. Ultrathin sections were stained with uranyl acetate and lead citrate, and examined with a Jeol electron microscope 100 CX at 80 kV (Hino *et al.* 1982).

Fig. 2. Glycosaminoglycans isolated from well-preserved skin of Eskimo mummy showed an electrophoretic pattern almost identical to that found in fresh human skin. The curves are densitometric scans of glycosaminoglycans separated on cellulose acetate electrophoresis strips. C: Chondroitin sulphate, HA: hyaluronic acid, DS: Dermatan sulphate.



Statistical evaluation

The Wilcoxon Rank Sum Test for unpaired data was used for the statistical analyses. Biological significance was recognized at $p<0.05$.

Results

Eskimo mummies

The skin of the 500-year-old bodies was stiff and hard as wood and was almost without extractable lipids and water. The acetone/ether extractable fraction was 5% as compared to 75% in fresh human skin.

The concentration of glycosaminoglycans-derived uronic acid in the mummified skin was 4.5 nmol/mg defatted, dried tissue, range 1–10 nmol/mg. This was 56% of that in fresh human skin (8.0 nmol/mg defatted, dried skin, range 5.7–10 nmol/mg). The glycosaminoglycans still present in the 500-year-old human skin were separated by cellulose acetate electrophoresis. The electrophoresis strips were densitometrically scanned (Fig. 2). Each peak of the densitometric scan represents a type of glycosaminoglycan: C = Chondroitin sulphate, HA = Hyaluronic acid, DS = Dermatan sulphate. The relative proportion of the different types of glycosaminoglycans was similar in the mummified skin and in fresh human skin. The broad peaks in the densitogram of glycosaminoglycans from the mummies are due to some degradation of the glycosaminoglycans. The results showed that more than fifty per cent of the glycosaminoglycans were still present in the mummified human skin and could be extracted and identified as such.

Table 1. Collagen content of skin. The concentrations of hydroxyproline, hydroxylysine and proline (nmol/mg defatted, dried skin) are given as mean (range) for skin of Eskimo mummies, 500-year-old sealskin, and control material of recent date.

Number	Species	Number of samples	Hydroxyproline	Hydroxylysine	Proline
7	Eskimo mummy	16	540 (320–700)	31 (21–37)	820 (410–1140)
29	Modern human	29	600 (510–700)	30 (24–37)	960 (840–1100)
3	Ringed seal, 500-year-old				
	well-preserved	8	510 (460–540)	30 (26–34)	770 (720–840)
	poorly preserved	6	640 (560–680)	37 (31–39)	860 (750–910)
3	Modern skin of ringed seal	8	490 (440–590)	29 (25–38)	760 (680–860)
2	Harp seal, 500-year-old				
	well-preserved	2	680 (560–800)	46 (39–53)	1010 (890–1120)
	poorly preserved	3	710 (700–720)	45 (40–49)	990 (950–1010)
3	Modern skin of harp seal	7	640 (590–710)	38 (34–46)	910 (810–1050)

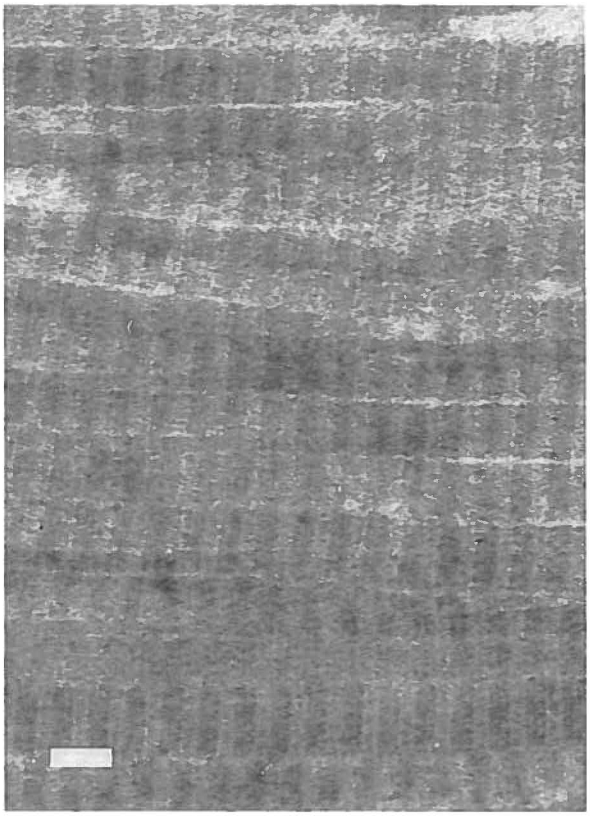


Fig. 3. The ultrastructure of collagen in the dermis from the upper arm of the 500-year-old mummified remains of a 50-year-old Eskimo woman found at Qilakitsoq. The picture is identical to that of fresh human skin. Electron micrograph, X 20,000. Bar equals 100 nm.

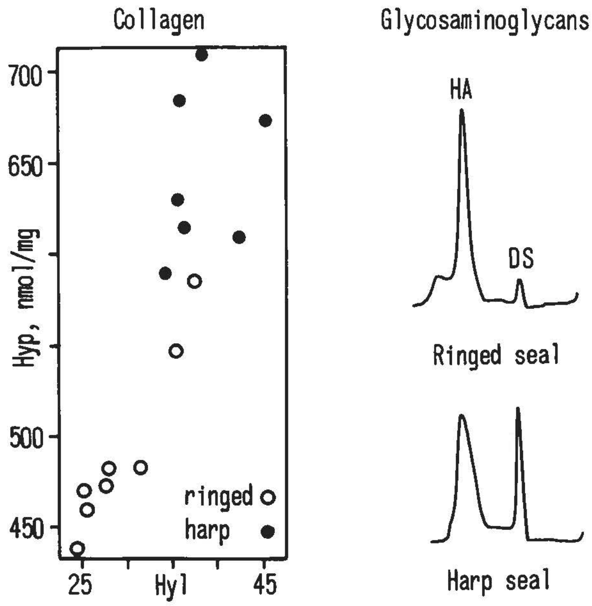


Fig. 4. Analysis of fresh skin showed that the two Greenlandic seal species, ringed seal and harp seal, had significant differences in the dermal content of collagen and glycosaminoglycans. The collagen content was expressed as the concentrations (nmol/mg defatted, dried skin) of the amino acids hydroxylysine (Hyl) and hydroxyproline (Hyp). The glycosaminoglycans were isolated from the skin and separated by cellulose acetate electrophoresis. The curves are densitometric scans of the electrophoresis strips, HA: Hyaluronic acid, DS: Dermatan sulphate.

The collagen content in the 500-year-old human skin was reduced by only 10% as compared to fresh human skin. This is shown by determination of hydroxyproline, hydroxylysine and proline (Table 1). Investigation of mummified skin by electron microscopy (Fig. 3) showed well-preserved collagen fibrils with the characteristic axial periodicity of 67 nm as seen in fresh human skin.

Identification of sealskin from different species

The biochemical analysis of fresh skin and 500-year-old skin showed that the two related Greenlandic seal species, ringed seal and harp seal, had significant differences in the dermal composition of collagen and glycosaminoglycans (Fig. 4). The densitometric scanning of the glycosaminoglycans after cellulose acetate electrophoresis showed two peaks of equal size (hyaluronic acid and dermatan sulphate) in skin of harp seal, whereas skin of ringed seal was dominated by a high hyaluronic acid peak. The ratio of dermatan sulphate to hyaluronic acid was 0.36 (range 0.25–0.55) in harp seal and 0.08 (range 0.01–0.12) in ringed seal. The difference was significant. Skin of harp seal had a higher concentration of collagen (hydroxyproline and hydroxylysine) than was found in skin of ringed seal (Table 1, Fig. 4). Such differences were significant in both modern skin and 500-year-old well-preserved skin from Qilakitsoq.

State of preservation of old skin

Most of the skin clothes and sealskins from Qilakitsoq were well-preserved with light flesh side and intact fur. However, some parts of the skin were dark, hairless and poorly preserved. Unfortunately, the dark, poorly preserved areas of the skin clothes were partly lost during the tanning procedure (Fig. 5). The biochemical investigations showed that the poorly preserved areas were characterized by degraded glycosaminoglycans and the well-preserved skin contained well-preserved glycosaminoglycans.

Fig. 5. The 500-year-old *kamik* illustrates that the poorly preserved areas of the skin clothes were lost during alum tanning at the National Museum.

Fig. 6 illustrates the identical pattern of glycosaminoglycans in modern skin of ringed seal (Fig. 6A) and in 500-year-old skin of ringed seal (Fig. 6B). The results also indicated that the modern and ancient Greenlandic skins have been treated in the same way by scraping, washing and drying. The poorly preserved skin from Qilakitsoq contained degradation products of glycosaminoglycans, which gave an irregular pattern on cellulose acetate electrophoresis (Figs. 6C and 7B).

The concentrations of collagen-derived amino acids were identical in well-preserved ancient sealskin and in modern skin (Table 1). The poorly preserved skin of ringed seal showed a significantly increased concentration of hydroxyproline, hydroxylysine and proline as compared to modern skin. A significantly increased ratio of hydroxyproline to proline was observed in poorly preserved sealskin indicating that collagen (hydroxyproline) was better preserved than other components including proteins (proline) and glycosaminoglycans.

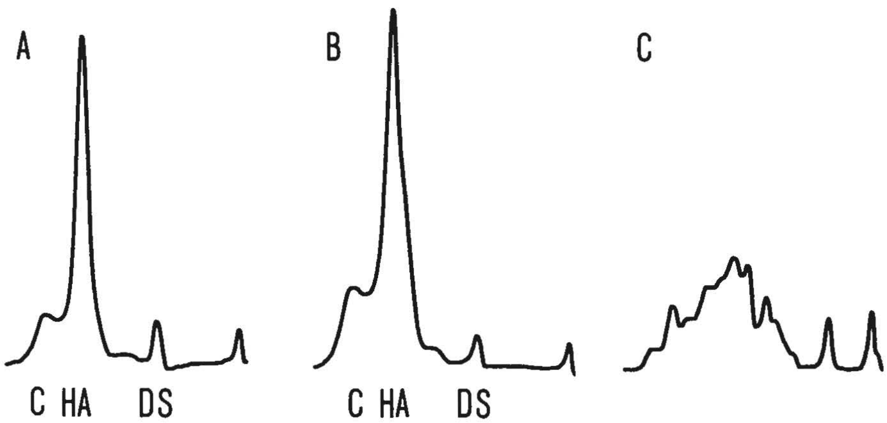
Kamiks

The Greenlandic *kamiks* (boots) were made of unhaired, water-proof sealskin. It is difficult to identify the seal species from which the unhaired skin was taken. Well-preserved samples from two untanned *kamiks* from Qilakitsoq were analysed and the glycosaminoglycans in both revealed two peaks of equal size, hyaluronic acid and dermatan sulphate (Fig. 7A), which showed that the 500-year-old *kamiks* were made of harp seal. Another sample from one of the *kamiks* contained degraded glycosaminoglycans (Fig. 7B) showing that this part of the *kamik* was poorly preserved.

Tanned skin

Most of the *kamiks* were tanned with alum (Lutan F) at the National Museum before the biochemical analyses were performed. The investigation included six tanned *kamiks* (Fig. 7C), two samples of tanned ringed sealskin and one sample of tanned skin of harp seal. All the tanned skin had lost the glycosaminoglycans during the alum tanning. Therefore, it was not possible to identify the seal species from which a tanned skin originates by means of a glycosaminoglycan analysis.

Fig. 6. Densitometric scanning of glycosamionoglycans separated by cellulose acetate electrophoresis. C: Chondroitin sulphate, HA: Hyaluronic acid, DS: Dermatan sulphate. Modern skin of ringed seal (A) had a composition identical to well-preserved 500-year-old skin of ringed seal (B). Poorly preserved skin of ringed seal from Qilakitsoq contained degraded glycosaminoglycans (C).



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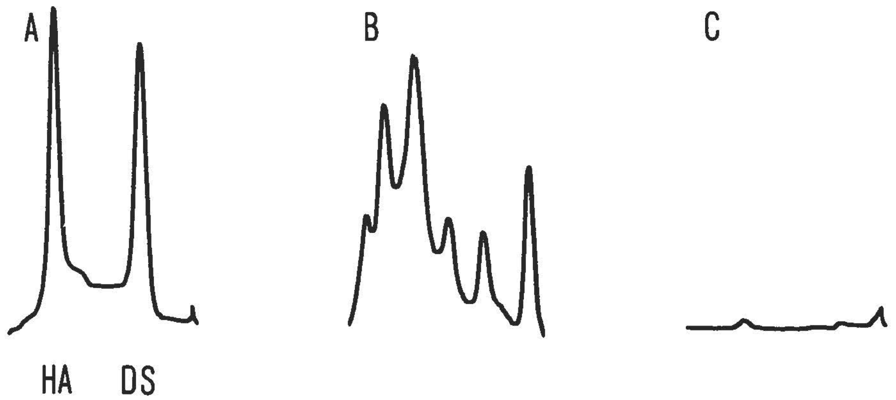

Fig. 7. Glycosaminoglycans were isolated from 500-year-old *kamiks*. Two untanned *kamiks* (A) showed a glycosaminoglycan pattern identical to that of a fresh harp seal (Fig. 4). Another piece of one of the untanned *kamiks* of harp seal contained degraded glycosaminoglycans (B) as an indication of poor preservation. *Kamiks* tanned with Lutan F contained no glycosaminoglycans, as illustrated by cellulose acetate electrophoresis (C), which yielded no peaks of glycosaminoglycans.

Discussion

The dead Eskimos were entombed in two dry clefts and the bodies were dried up before the skin putrefied. The bodies therefore appeared as mummies with a very hard, stiff and shrunken skin. The mummified skin was soluble in hydrochloric acid and could be sufficiently digested by the enzyme pronase. It was thus possible to apply biochemical analyses of dermal macromolecules to the material. Electron microscopy studies revealed intact collagen fibres and, together with the biochemical methods, confirmed the high degree of preservation of the 500-year-old human skin.

It was fascinating to discover that the well-preserved sealskins from Qilakitsoq had the same composition of glycosaminoglycans and collagen as modern Greenlandic skins. These results showed that the ringed seal had not undergone changes of the connective tissue due to environmental or genetic influence during the past 500 years. Since the glycosaminoglycans are sensitive to washing and tanning procedures, the results also indicated that the Eskimos of 500 years ago treated the sealskin in almost the same way as today, i.e. scraping, washing, stretching, and drying. Treatment of fur with fixatives (formaldehyde) or tanning removes the water soluble glycosaminoglycans. Unfavourable storage conditions also decompose the glycosaminoglycans as seen in poorly reserved skin from Qilakitsoq.

The skins of different animal species have characteristic differences in thickness, mechanical properties and the character of the fur. It is novel information that ringed seal and harp seal had differences in the chemical composition of the skin. In particular, the relative proportion of the individual glycosaminoglycans differs in the two seal species. As a result of this discovery, two of the 500-year-old *kamiks* were identified as made of harp seal. This method may perhaps be developed to allow for the general identification of unhaired skin which has not been treated with agents destroying or dissolving the glycosaminoglycans (tanning, fixation etc.).

Previous investigations of archaeological material have been based on collagen, which is the major constituent of connective tissue (skin, bone, etc.). Two Egyptian mummies at the National Museum in Copenhangen contained hydroxyproline (collagen) in the skin, but only 75% of that in fresh human skin (Ammitzbøll *et al.*, unpublished; Hino *et al.* 1982). From fossil bone, hydroxyproline and proline were isolated and used for radiocarbon dating and for stable carbon isotope ratio determinations (Stafford *et al.* 1982). Immunofluorescence studies demonstrated the preservation of Type I and Type III collagen in skin of mummies from Peru (Wick *et al.* 1980). The preservation of the parchments of the Dead Sea Scrolls was studied using X-ray diffraction and racemization analyses on collagen (Weiner *et al.* 1980). These analyses were also applied to material from Qilakitsoq and showed that the collagen fibres in the 500-year-old sealskin and human skin were extremely well-preserved (Traub *et al.*, unpublished). Furthermore, the glycosaminoglycan, chondroitin sulphate, as well as uronic acid and hydroxyproline have been identified in fossil antlers (3,000–130,000 years old) by Scott & Hughes (1981).

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Electron Microscopy of the Skin of a Greenlandic Mummy

TAKASI KOBAYASI, THORKILD AMMITZBØLL & GUSTAV ASBOE-HANSEN

Kobayasi T., Ammitzbøll, T. & Asboe-Hansen, G. 1989. Electron Microscopy of the Skin of a Greenlandic Mummy. – Meddr Grønland, Man & Soc. 12: 100–105. Copenhagen 1990-01-26.

This study was carried out during the archaelogical examination of a Greenlandic mummy by the Danish National Museum.
A nodule on the dorsal surface of the right fourth finger of a 500-year-old mummy from Greenland was studied by electron microscopy. The tissue showed outlines of tissue components such as keratinocytes, melanocytes, vessels, nerves, and histiocytes as well as collagen and elastic fibres.

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In 1972 eight mummified bodies were found under a rock shelter in Qilakitsoq, West Greenland. The bodies had been well preserved by the extremely cold and dry polar weather. The bodies were thought to be from the fifteenth century. Skin from an embalmed mummy from Egypt, about 2000 years old, has been studied by electron microscopy (Hino *et al.* 1982a, 1982b). This study deals with skin of a non-embalmed mummy found in Greenland.

Material and methods

There was a wart-like nodule on the dorsal surface of the fourth middle phalanx in one of the female mummified bodies (no. II/7). The nodule was brownish, round, about 0.5 cm across, and covered with scales. The tissue was immersed and rehydrated in a cacodylate buffer, 0.05 M, pH 7.3, with 7.5% sucrose, for three days in a refrigerator.

The tissue was then cut into slices about 2 mm thick and fixed in 6% glutaraldehyde solution of the same buffer for 48 hours in a refrigerator. The tissue slices were further divided in small blocks, osmicated, dehydrated and embedded in Epon 812. Ultrathin sections were cut by a Reichert ultramicrotome and contrasted by uranyl acetate and lead citrate. A JEOL electron microscope 100 CX was operated at 80 KV for observation.

Findings

The *epidermis* consisted of several layers of horny plates and prickle cell layers. Though the cytoplasm of the epidermal cells appeared dense and homogeneous, some of the cellular components such as cell borders, interdigitations and desmosomes were recognized (Fig. 1). Intercellular spaces were narrow. Desmosomes showed dense thickenings of cell membrane on both sides and an intercellular band with narrow lucent spaces adjacent to the dense cell membrane. Occasionally, the intercellular band showed a faint middle line in the lower Malpighian cells (Fig. 2). Irregularly shaped nuclei contained dense peripheral chromatin and a lucent central area with some dense spots. Nucleoli were not found (Fig. 3). The cytoplasm was diffusely dense without recognizable tonofilament bundles. Faint lucent patterns suggesting some cell organelles such as mitochondira and vesicles were seen (Fig. 2). Keratohyalin granules in dendritic forms and oval melanin granules were seen (Fig. 3). Melanocytes with melanosomes were also found. However, internal structures of the melanosomes were not seen (Fig. 4). Cytoplasm and nuclei of the melanocytes appeared identical to those of the keratinocytes.

Dermo-epidermal junction. Basal lamina was seen to be structureless and of irregular thickness. No semidesmosomes, anchoring filaments nor anchoring fibrils were seen (Fig. 4).

Corium appeared as compact plates of collagen fibrils (Fig. 5). Elastic fibres, vessels, nerves and some cells were also recognized in the corium. Microorganisms were found in the dermis (Fig. 8). The collagen fibrils formed thick bundles without interfibrillar spaces (Fig.

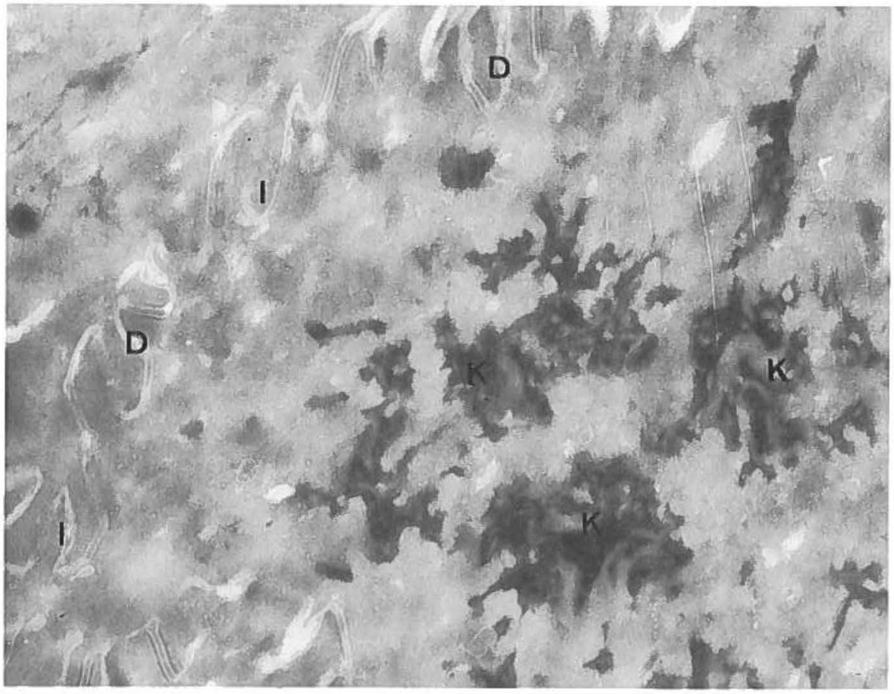

Fig. 1. A keratinocyte of the granular cell layer show keratohyalin granules of dendritic forms (K), desmosomes (D) and interdigitations (I). No tonofilament bundles are visible.
X 30,000.

6).The fibrils showed an axial periodicity of about 66 nm. The fibril diameters seem to be about 70–100 nm with blurred contours. Elastic fibres showed transparent and opaque bands without fibrillar structures (Fig. 6). Vascular endothelium and perivascular cells could be identified by their forms (Fig. 7). Nuclei, dense homogeneous cytoplasm with lucent patterns of cell organelles and interdigitations of cytoplasmic protrusions were seen. Perineurium, endoneurium and Schwann cells were identifiable (Fig. 8). However, their cytoplasmic appearances were similar to those of other cells described above. Axons were not seen. Endoneural col-

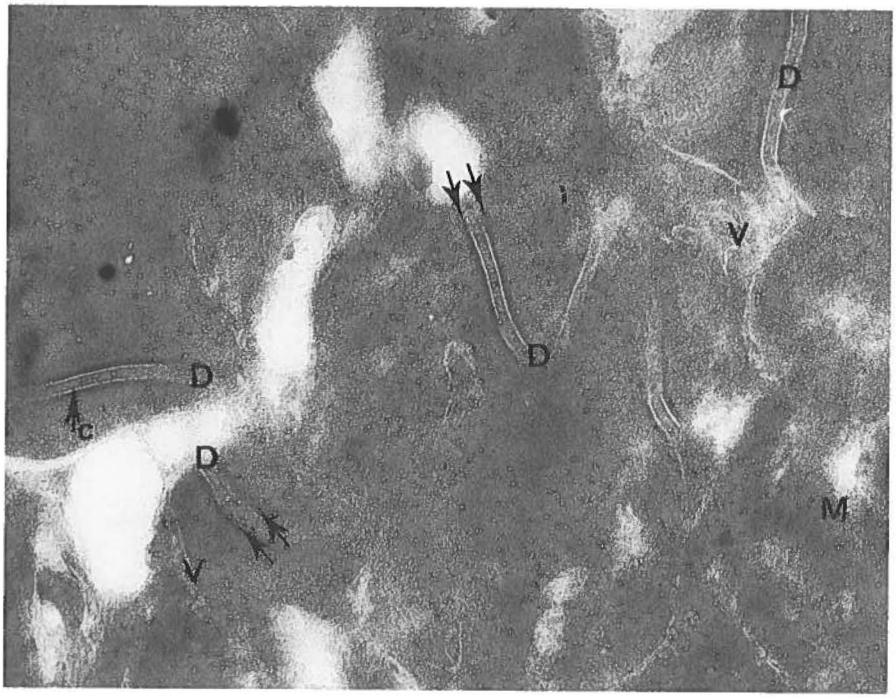

Fig. 2. Desmosomes (D) show dense thickened cell membrane (arrows) and a central band. Arrow c indicates a faint median line. Faint lucent patterns in the cytoplasm are assumed to be mitochondria (M) and vesicles (V).
X 60,000.

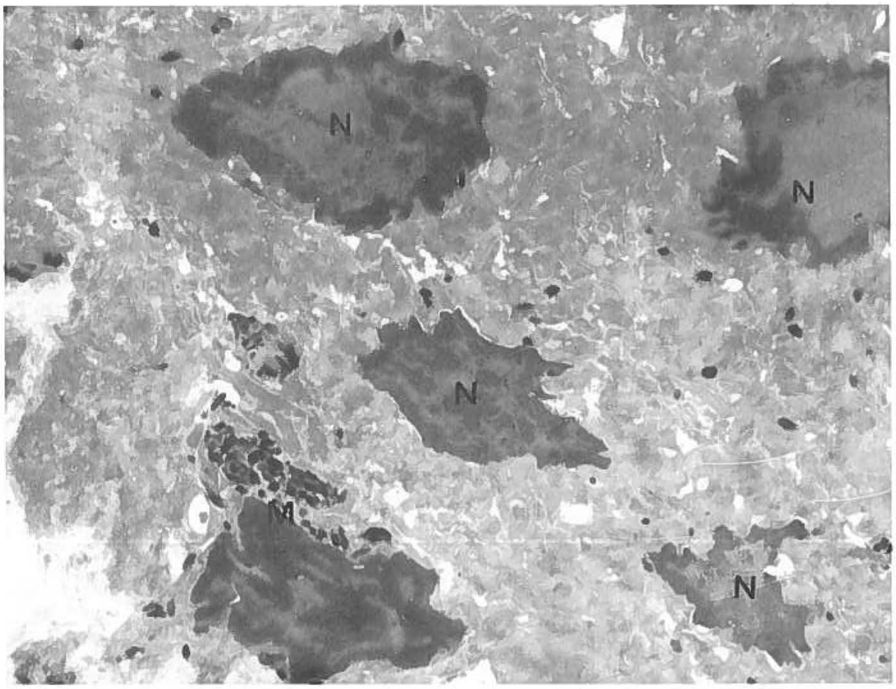

Fig. 3. The lower Malpighian and basal cell layers. Melanocytes (M). Nuclei (N) show dense peripheral chromatin and a lucent centre.
X 7,800.

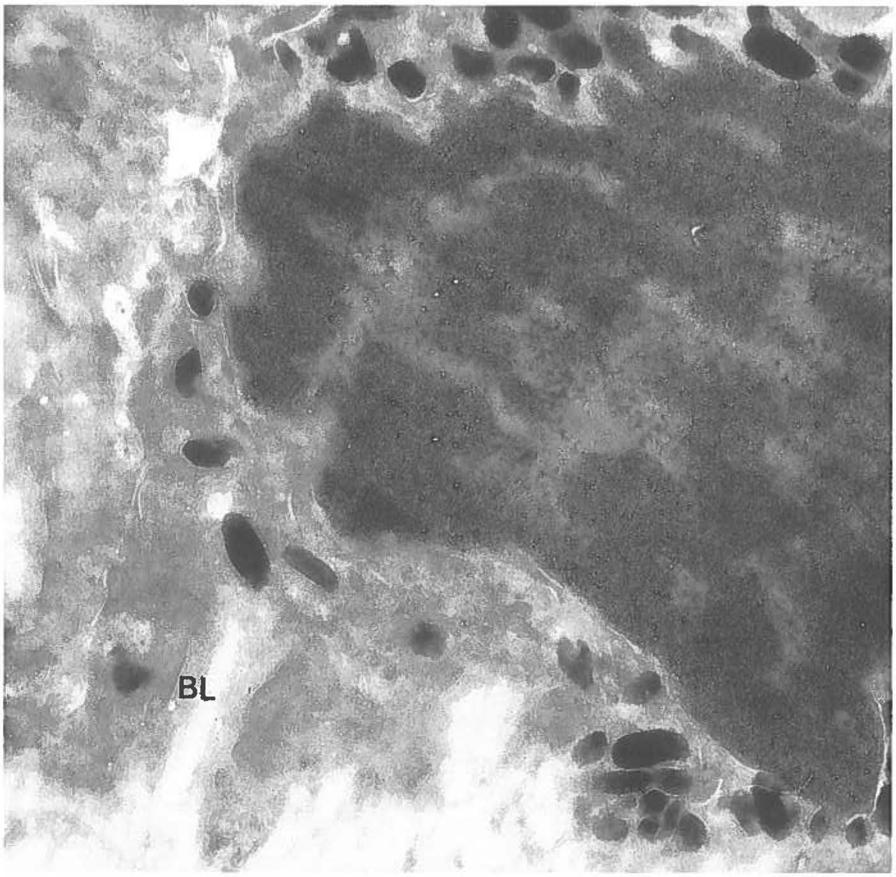

Fig. 4. A melanocyte with numerous melanosomes, appearing dense and without internal structure. Basal lamina (BL) appears as a blurred band.
X 26,400.

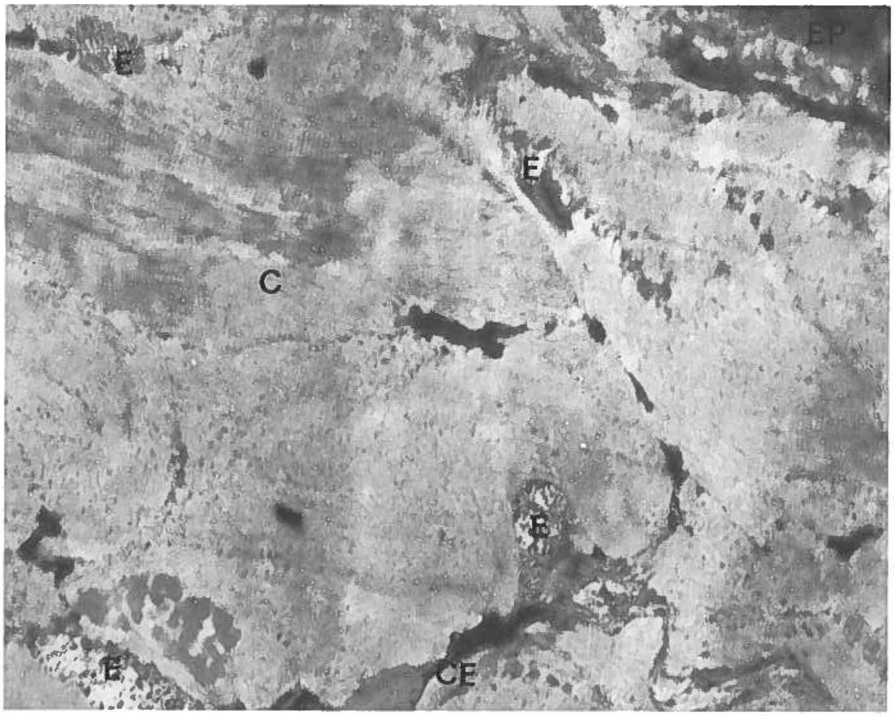

Fig. 5. The dermis consists of compact bundles of collagen fibrils (C) with elastic fibres (E) and cells (CE). Epidermis (EP).
X 15,000.

lagen fibrils were about 30 nm across. Phagocytes with vesicles and large dense granules were found in the corium (Fig. 6).

Comments

Present findings of tissue structures demonstrated that the mummy skin preserved outlines of tissue compo-

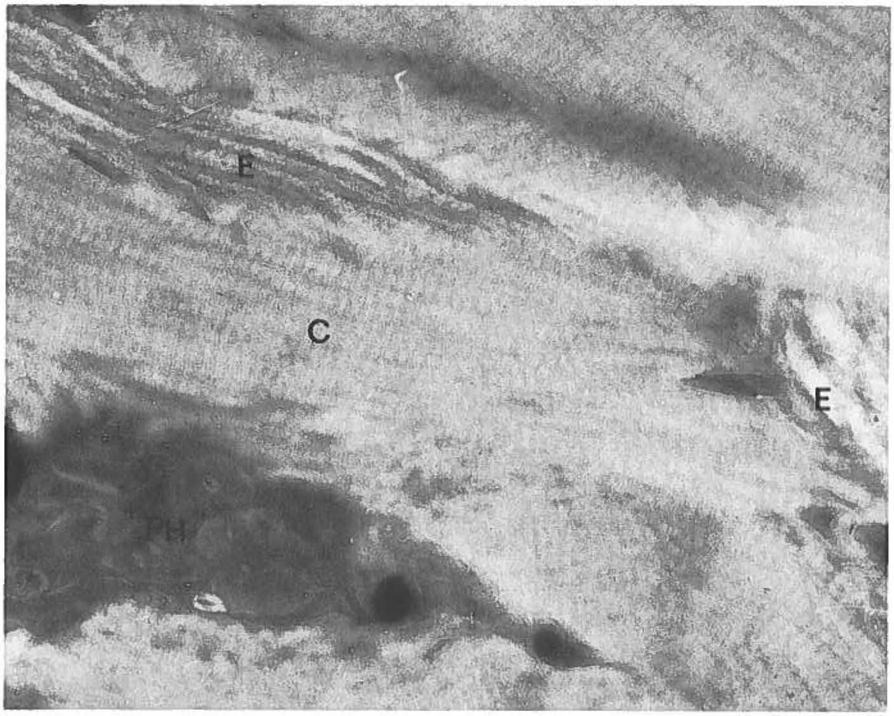

Fig. 6. The collagen fibrils (C) show axial periodicity. Elastic fibres (E) form dense and lucent bands. A phagocyte (PH) shows lucent patterns in its cytoplasm.
X 26,400.

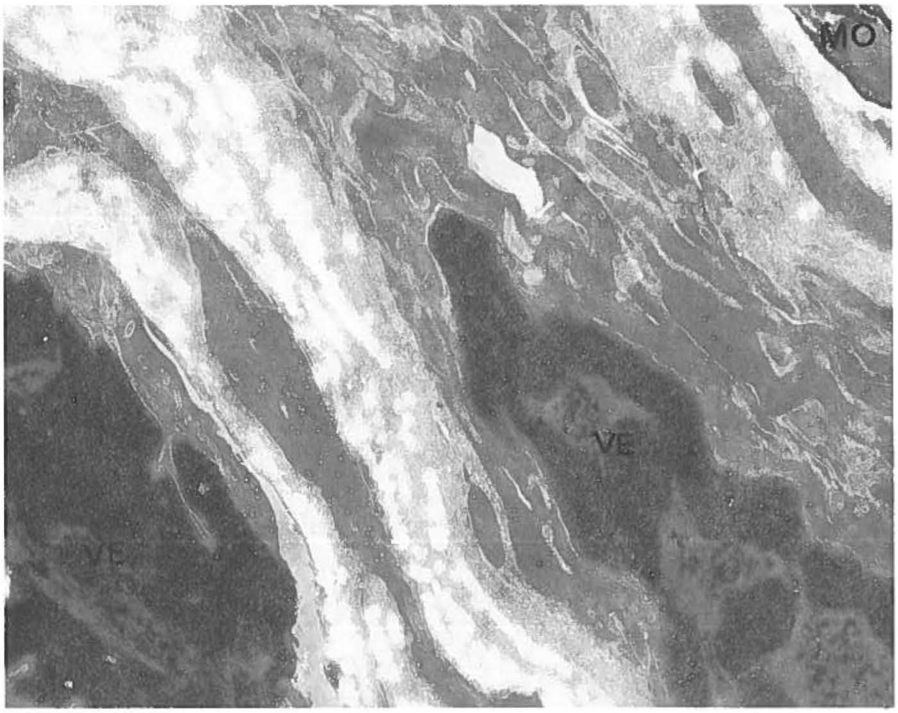

Fig. 7. Vascular endothelial cells (VE) and microorganism (MO). X 26,400.

nents. However, detailed structures of cells and fibres were incompletely demonstrated. Multiple layers of horny plates and keratinocytes with keratohyalin granules led to the presumption that the nodule was callous. Intracytoplasmic, faintly lucent patterns have been noted in an Egyptian mummy in previous papers (Hino *et al.* 1982a, 1982b). Axial periodicity of the collagen fibrils was identical to that of present-day humans and

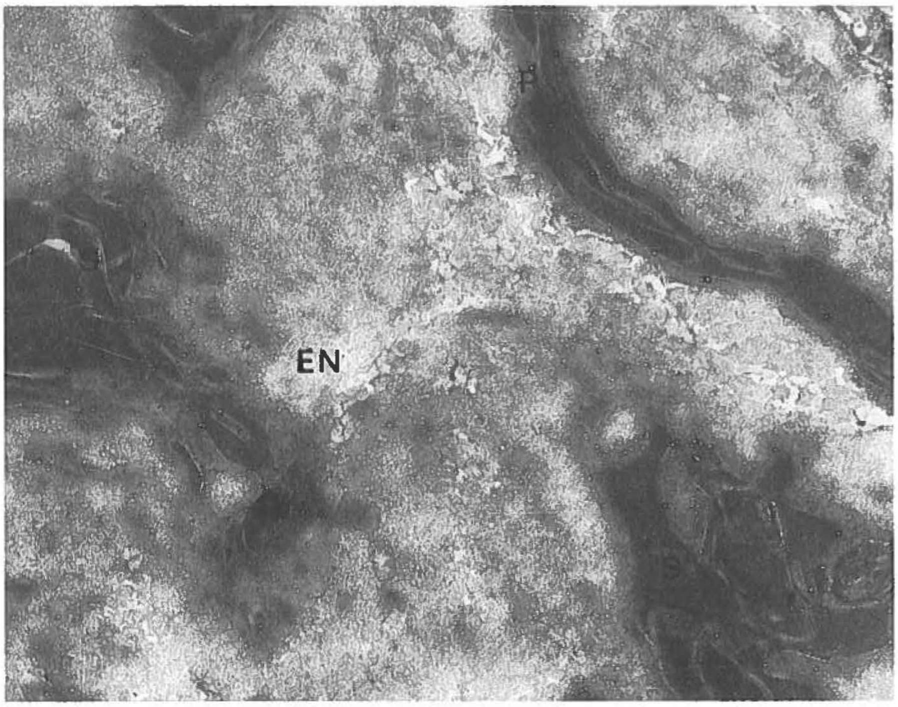

Fig. 8. A nerve shows perineurium (P), Schwann cells (S) and endoneurium (EN). X 30,000.

shows cross bands clearer than the embalmed Egyptian mummy (Hino *et al.* 1982a, 1982b). Microorganisms were also found in the Egyptian mummy under the dermis (Hino *et al.* 1982b)

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Histological Investigations of Mummified Human Tissue from Qilakitsoq

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Myhre, J., Svendstrup, L. & Hart Hansen, J. P. 1989. Histological Investigations of Mummified Human Tissue from Qilakitsoq. – Meddr Grønland, Man & Soc. 12: 106–108. Copenhagen 1990–01–26.

Mummified tissue must be rehydrated prior to processing for histological sections. A comparison is made between different rehydrating solutions. The solution described by Ruffer in 1909 gave the best results with regard to preserved structures.

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Mummified, desiccated tissue is extremely hard and cannot be cut by the microtome unless softened by rehydration. When rehydrated the tissue specimens can be treated like common tissue specimens in the laboratory and cut in a microtome after paraffin wax embedding and properly stained.

The aim of rehydration is to make the tissue come as close as possible to its previous size and structure, with the least possible damage in order to be able to examine the finer structures of the tissues.

Mummified tissue from many previous mummy finds all over the world have been submitted to various procedures for rehydration and technical preparation of specimens. Excellent reviews and guidelines have been given by Sandison (1970), Reyman & Dowd (1980) and Allison & Gerszten (1982). The various methods employed by different authors have not always been described in detail, and comparative studies of technical procedures have not been performed to any great extent. The general impression given by the literature is that many authors have used the solution originally described by Ruffer in 1909 (Ruffer 1921) as well as Sandison's modification (Sandison 1955, 1970) with good results.

In order to find the optimal technical method for rehydration of specimens from the Qilakitsoq mummies a comparison was made between different methods mentioned in the literature.

Material

Specimens from the abdominal wall measuring approximately 18 × 5 mm with a thickness of about 3 mm were used. The specimens were dark brown, very hard and the abdominal layers showed some splitting when cut.

Method

Before rehydration gross evaluation was made by measuring the specimens using a micrometer screw and photographing in two dimensions through a dissecting microscope x 40. This procedure was repeated after rehydration/before fixation and after fixation.

The specimens were suspended in the rehydrating solution (see below) one to 25 parts for 24 hours at room temperature, fixed in 10 per cent buffered formalin for 24 hours, embedded in paraplast and stained (see below) before microscopy. Some paraplast blocks were later re-embedded in plastic (JB-4 from Polysciences Inc.), cut in a rotation microtome using a phosphorus tungsten knife and stained before microscopy.

The rehydrating solutions employed were the following:

1: Ruffer's solution (Zimmerman *et al.* 1971, Zimmerman 1975). Five parts water, 3 parts absolute ethyl alcohol, 2 parts 5 per cent sodium carbonate, saline added to make 0.85 per cent.

2: Sandison's modification of Ruffer's solution (Sandison 1955, Sandison 1970). Three parts 96 per cent ethyl alcohol, 5 parts 1 per cent aqueous formalin, 2 parts 5 per cent sodium carbonate, saline added to make 0.85 per cent.

3: 10 per cent aqueous formalin in 0.85 per cent saline.

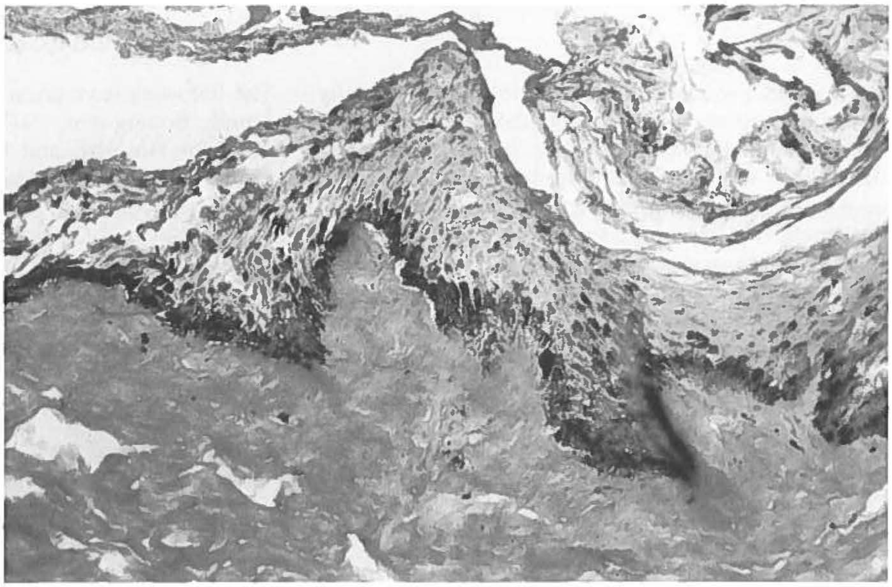
4: 0.2 per cent Comfort in 0.85 per cent saline (Turner & Holton 1981). Comfort is a commercial fabric softener (kindly supplied by Turner).

5: 0.2 per cent Comfort in 5 per cent aqueous formalin.

6: 0.1 per cent Comfort in 0.85 per cent saline.

7: 0.1 per cent Comfort in 5 per cent aqueous formalin.

Figure 1. Skin with preserved nuclei in the epidermal cells. In the basal layer of the epidermis deposits of melanin can be seen showing that the person in question was heavily pigmented. Hematoxylin-eosin. x 250.



8: Bierring's solution (Ry Andersen 1979). Eleven parts 40 per cent aqueous formalin, 71 parts 96 per cent ethyl alcohol, 9 parts pure glycerine, and 9 parts water.

9: Direct fixation in 10 per cent buffered formalin without rehydration.

The following stains were employed. The staining time was increased to obtain satisfactory slides.

1: Hematoxylin-eosin.

2: Periodic acid-Schiff (PAS).

3: Alcian blue-van Gieson.

After comparing the rehydrating solutions, further sections of tissue from the Qilakitsoq mummies were prepared with Ruffer's solution according to Zimmerman *et al.* 1971 and Chapel *et al.* 1981: one third of the rehydrating solution was exchanged with absolute ethyl alcohol every day for three days and the specimens were then cleared in xylen and impregnated and embedded in paraplast. The following supplementary stainings were also employed.

4: Verhoeff's method for elastic fibres.

5: Grocott-Gomori methenamine silver method.

6: Gridley's stain for fungal organisms.

Figure 2. Part of the aortic media showing well preserved elastic fibres. Verhoeff. x 400.

Results

During the process of rehydration specimens rehydrated in solutions 1–7 showed equal swelling and only slight sedimentation. Specimens from solutions 1–2 showed less sediment than those from 3–7. There were no colour changes. All samples floated in the solution. Specimens from solution 8 showed no sediment, did not float and had swelled less than half as much as the previously-mentioned specimens. With regard to cutting in the microtome the technicians described the quality of specimens from solutions 1–2 as good, whereas the other specimens in general were too brittle. Specimens from solutions 3–5 were rather hard, from solution 6 hard as leather.

On histologic examination the slides of the best quality in terms of preserved structures came from specimens rehydrated by using Ruffer's original recipe and formalin fixation as originally described in 1909 (rehydrating solution 1). These slides showed the fewest distortions of the tissue. This procedure was accordingly chosen for the preparation of histologic slides from mummified organs and soft tissues from the Qilakitsoq mummies.

Acknowledgements

The following have given valuable assistance and help: Jannik Boberg-Ans, MD, Wiera Christiansen, MD, Gentofte Hospital, and Chief Technician Karin Nørgaard, Frederiksberg Hospital.

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Histopathological Examinations of Eyes

S. RY ANDERSEN & J. U. PRAUSE

Ry Andersen, S. & Prause J. U. 1989. Histopathological Examinations of Eyes. – Meddr Grønland, Man & Soc. 12: 109–111. Copenhagen 1990-01-26.

Mummified tissue from the upper arm of the six-year-old child was processed according to various rehydration and staining schedules. A 0.2% concentration of the wetting agent "Comfort" in a 0.9% saline was found useful. Staining with Eskelund's combined Alcian blue-van Gieson-elastin and haematoxylin-phloxine-saffron made it possible to distinguish between human and non-human structures. Remnants of the eyelids, sclera, choroid, lens and retina with melanine granules were found in the orbits. These structures revealed no sign of intravital lesions.

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The Eye Pathology Institute in Copenhagen has had the opportunity to investigate the two infant Eskimo mummies from Qilakitsoq.

The investigations were in three parts: 1: A study of fungal contaminants, 2: Investigations of various preparation techniques, and 3: Histopathological examination of remnants of eyes.

1: *The study of fungal contaminants* has been published (Bodenhoff *et al.* 1979).

2: *Preparation techniques.* Pieces of skin, muscle, and bone from the right upper arm of the six-year-old child, which had been kept unfixed at +4°C, were rehydrated in five different solutions (Table 1). The tissues were processed for 24 hrs at room temperature, with constant stirring (rotary mixer, 20r/min). The rehydrated tissues were processed as stated below, and effectiveness of the treatment was considered optimal (+++) when normal anatomical proportions in the tissues were reestablished.

As will be seen from the table, a 0.2% solution of wetting agent "Comfort" in 0.9% saline gave the best results (Turner 1979). However, all solutions containing saline caused some rehydration, in contrast to solutions without saline. Rehydration in solutions without fixatives called for postfixation. Of the solutions tested (Table 1), the 10% buffered formalin provided the best results.

Rehydrated, post-fixed tissues from the arm and orbits were further processed using the routine paraffin technique, but this was carried out by hand with 24 hours between each step.

Table 1. Rehydration, fixation and staining.

Procedure	Reagents	Results
Rehydration	Distilled water	0
	Saline (0.9%)	+
	5% formalin in saline	+
	10% buffered formalin	0
	0.2% Comfort in saline (0.9%)	++
Post-fixation	10% buffered formalin	++
	Sandison's solution, modified*)	+
Staining	Acidic orcein	+
	Alcian blue, 0.2M $MgCl_2$	+
	Alcian blue, 1.0M $MgCl_2$	+
	Benzidin-nitroprusside	+
	Eskelund's Alcian blue-van Gieson-elastin	+++
	Grocott's modification of Gomori's silver methanamine silver nitrate	+
	Haematoxylin-phloxine-saffron	+++
	Iron-haematoxylin	0
	Periodic-acid-Schiff	++

*) = 1.25 vol 40% formalin, 8 vol 96% ethanol, 1/5 vol potassium nitrate, 1 vol glycerin and 1 vol distilled water.

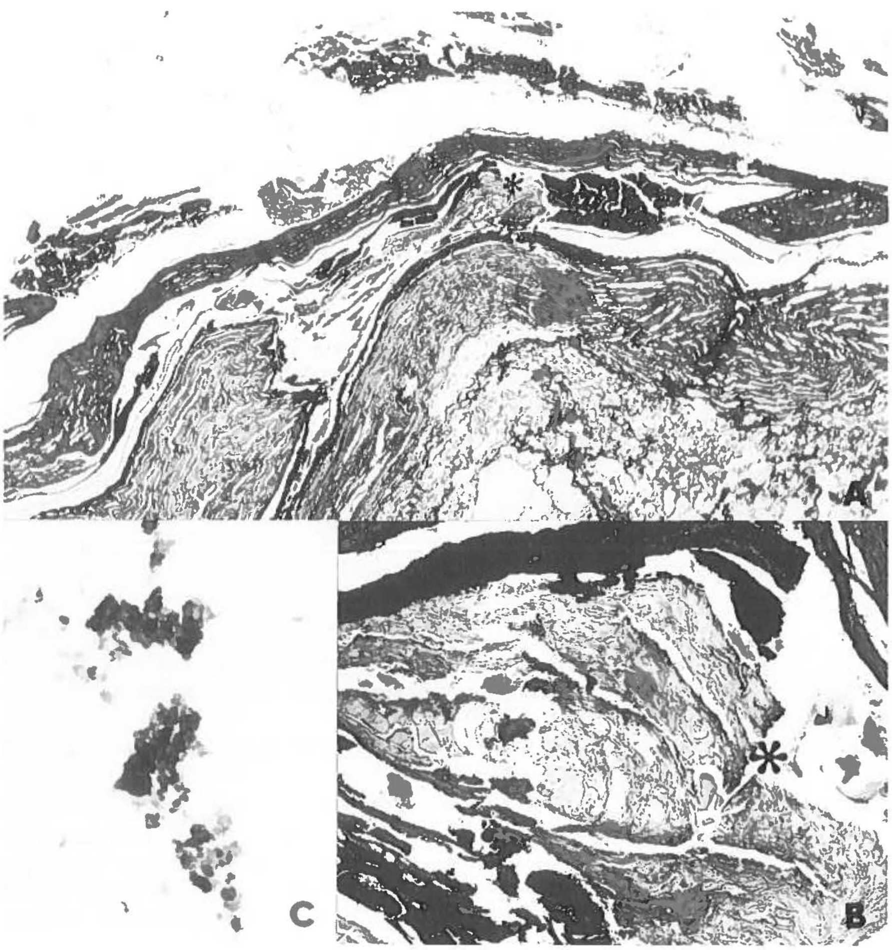

Fig. 1. A. Section of eye tissues from the six-year-old child (Eye Path.Inst.No. 401/78). Choroidal tissue, melanine granules and lens material (asterisk) are to be seen between the two layers of sclera in the collapsed eye. Haematoxylin-phloxine-saffron (x24).

Fig. 1. B. Lens tissue (asterisk) in higher magnification (x140).

Fig. 1 C. Melanine granules of the large retinal size and shape (x560).

A variety of stains was used, with a half, one and two times normal staining times (Table 1). Double staining time was advantageous except with Grocott's modification of Gomori's methanamine-silver nitrate stain, which constantly only gave a faint staining of fungi. In contrast, staining with iron-haematoxylin was always too heavy whatever the staining time.

In line with our earlier experience in preparing tissues from a 2700-year-old human bog body (Andersen & Geertinger 1982), the combined Alcian blue-van Gieson-elastin stain (Eskelund 1957) gave very good results, especially when distinguishing between non-human structures such as fungi and human tissues. Connective tissue was adequately stained with haematoxylinphloxine-saffron.

3: *Histopathological examination* was performed on tissues from both orbital regions of the 6-years-old child.

Macroscopic remnants of the eyelids were identified. They contained skin and connective tissue, but the tear glands were not seen. A totally collapsed eye was seen at the bottom of each orbit with corneae and sclerae readily recognizable.

Microscopy revealed periodic-acid-Schiff-positive fungi both in the skin of the eyelids and in the sclerae. These were classified as *Sporotrix fungorum* and *Torulopsis candida* (Bodenhoff *et al.* 1979).

Choroidal tissue and remnants of lens material could be identified in both eyes between two layers of collapsed sclerae (Fig. 1 A-B). In this region, heaps of brownish-black 3–4 µm melanine granules were also observed (Fig 1 C). Their large size and oval shape indicate that they are of retinal origin, choroidal pigment granules being much smaller and more spherical. No other remnants of the retina or of the optic nerve could be identified microscopically and there were no signs of intravital lesions of the eyes or their surroundings.

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Teeth and Jaws of the Qilakitsoq Mummies

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Pedersen, P. O. & Jakobsen, J. 1989. Teeth and Jaws of the Qilakitsoq Mummies. – Meddr Grønland, Man & Soc. 12: 112–130. Copenhagen 1990-01-26.

In 1972, well-preserved mummies of six adult Eskimo women and two children (an infant of about six months and a boy of 3½–4½ years) were found at Qilakitsoq in the Uummannaq District, Northwest Greenland. Death occurred about 500 years ago.
A multidisciplinary study of these mummies included age estimation, dental anatomy, dental numerical variations, pathology of dental hard tissues and jaw bones, and evidence of temporo-mandibular joint disorders.
Recording of dental conditions, dental radiographic examination, roentgen diffraction analysis, scanning electron microscopy, and chemical analyses were limited to three adults and the oldest child, while the remaining four mummies could only be studied roentgenographically. The results may be summarized as follows.
One adult aged 18–21 had shovel-shaped maxillary incisors. The roots of the anterior teeth were short in mature individuals. One impacted maxillary supernumerary incisor was found, and three third molars were congenitally missing. The loss of teeth post mortem was insignificant but it is noteworthy that no less than eight incisors (and only one molar) were lost ante mortem. Pulp stones, some very large, were seen in many teeth, including those of the young woman. While all teeth were caries-free, traumatic injuries were common. Chipping of the enamel occurred universally and a complete intra-alveolar root fracture was diagnosed radiographically. The occlusal and incisal attrition was very pronounced in the mature women. Due to apposition of tertiary dentine, however, only one tooth displayed pulp exposure. The two mature skulls exhibited transversal grooves in the masticatory surfaces of their incisors, canines and premolars, produced by preparation of animal sinews for sewing. This procedure and other use of the anterior teeth for hide preparation probably accounts for the loss of incisors ante mortem. Fluoride analyses of surface enamel of deciduous and permanent teeth showed the same magnitude of concentration and distribution of this element as found in modern Northwest Greenlanders and in Danish mediaeval skull material.
In all adult dentitions considerable deposits of supragingival calculus were found, while subgingival calculus was only seen opposite two teeth with marginal periodontal bone involvement. The supragingival calculus either forms a rim at some distance from the alveolar margin indicating the course of the gum margin or extends over considerable parts of the facial crown surfaces, even those of anterior teeth. X-ray diffraction analysis of powdered calculus showed it to consist of hydroxyapatite, and samples of calculus examined by means of scanning electron microscopy disclosed a variety of morphological patterns dominated by crystalline structures and numerous mineralized micro-organisms. As was the case in mature East Greenland Eskimos examined by Pedersen in 1937, limbal alveolar bone loss was remarkably slight. However, pronounced bone destruction, probably traumatic in origin, was seen at two teeth. The findings of the dental study of the Qilakitsoq mummies are in agreement with those made in East Greenlanders in 1937 and in Danish collections of Greenland Eskimo skulls. They also offer many points of resemblance to those obtained in skulls of mesolithic hunter-gatherers unearthed at Vedbæk, Denmark, and dating about 7000 years back.

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The discovery in 1972 and the subsequent fate of eight fifteenth-century Eskimo mummies from Qilakitsoq, Uummannaq District, Northwest Greenland, have been described earlier by researchers participating in the multidisciplinary study to which the mummified bodies were eventually subjected. The general report (Hansen, Meldgaard & Nordqvist 1985) contains information on a wide range of findings as well as many aspects of Eskimo life. The present report is largely confined to the authors' studies of the teeth and jaws of the Qilakitsoq mummies though comparison with dental conditions previously found in arctic peoples will occasionally be made. Special attention is drawn to the radiological report by Eiken (1989) on the Qilakitsoq mummies which contains valuable background information relating to our findings.

Material and methods

Dental conditions prevailing in Greenland in the old days were studied previously by Pedersen who in 1936 examined 526 skulls of pre-Danish Eskimos kept in the Laboratory of Biological Anthropology of the University of Copenhagen (Pedersen 1938 and 1947). In 1937 he surveyed dental conditions among 915 natives in Ammassalik/Angmagssalik and Ittoqqortoormiit/Scoresbysund. These Inuit lived traditionally and their lifestyle was little influenced by Europeans before World War II.

The background knowledge thus obtained was a major reason why examination of teeth and jaws proved to be an important step in the investigation of the mummies. The mummy material, however, was particularly suited for studies of the teeth and their surrounding bone because the dry skin had prevented loss of teeth after death and protected the fragile bone margins around their sockets. As a result, very few teeth were lost post mortem. Even teeth with only one short root remained in their proper positions or could be found beneath the dried skin. In contrast, numerous one-rooted teeth are missing from the museum collections of Eskimo skulls because these teeth were lost before or during removal of the skeletons from the graves, in transit or later (Pedersen 1949; Curzon 1976/77).

Dental conditions could be studied closely in only four (Nos. 2, 5, 7, and 8) out of the eight mummies. The mouths of the other mummies were either closed or covered by clothing. In order to preserve the exterior of these mummies and their clothing the dental examination had to be limited to the visible parts of their anterior teeth and to radiological findings.

Inspection of the masticatory apparatus was aided by a magnifying lens. X-ray examination using dental radiographic methods was made of all jaws. Additional examinations included scanning electron microscopy of calculus and worn tooth surfaces, X-ray diffraction analysis of calculus, and fluoride analysis of tooth enamel. Many photos were taken.

Results

Table 1 reviews the material under study, giving for each mummy sex, age at death, number of teeth lost before and after death, congenitally missing teeth and supernumerary teeth.

Some salient dental traits of each mummy are presented in the following individual notes.

Grave I, Mummy No. 1

Teeth and jaws could not be studied directly. The age at death of this infant was estimated to be about six months. The dentition shown in Fig. 1 corresponds to the stage of tooth formation recorded for Finnish children aged six months (Nyström *et al.* 1977; Nyström 1982). One deciduous mandibular central incisor had fallen out but was recovered. The stage of its root formation is that of an average white infant aged six months.

It has been suggested by v. Haven (1882), S. Hansen (1893) and others that primary teeth may erupt earlier in Greenlanders than in whites but no evidence to this effect is available.

Table 1. Sex, age and number of teeth of the Qilakitsoq mummies.

			Number of teeth			
	Sex	Age years	lost ante mortem	lost post mortem	congenitally missing	supernumerary
Mummy 1	M?	½	0	0	0	0
Mummy 2	M	3½–4½	0	1+	0	0
Mummy 3	F	c. 25	0	1	0	0
Mummy 4	F	c. 30	0	0	0	0
Mummy 5	F	c. 45	1	0	0	1++
Mummy 6	F	c. 50	5	0	2	0
Mummy 7	F	18–21	0	11	0	0
Mummy 8	F	c. 50	3	5	1	0

+ deciduous teeth
++ unerupted vestigial upper incisor.

Fig. 1. Mummy No. 1 is an infant aged about 6 months.

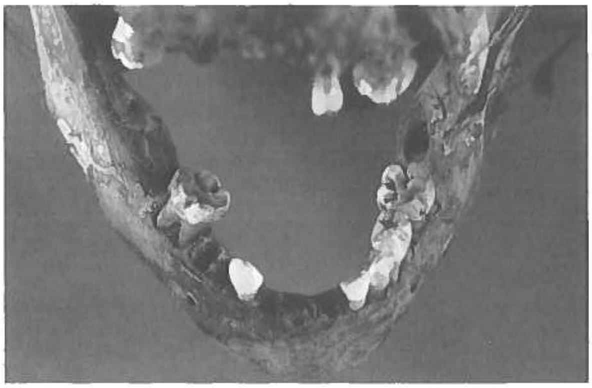

Fig. 3. After removal of the skin the teeth of mummy No. 2 could be examined. Nine loose deciduous teeth are shown in Fig. 4.

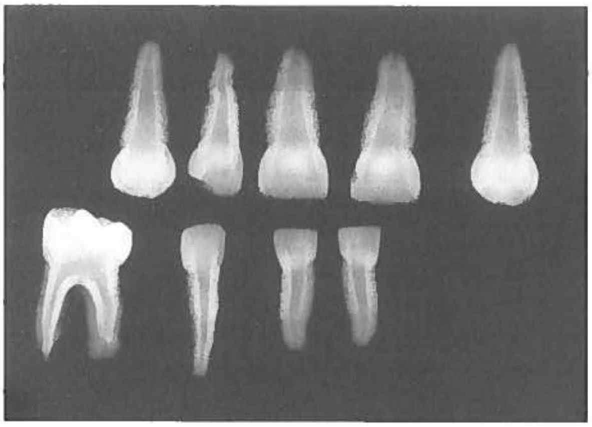

Fig. 4. Nine aberrant deciduous teeth of mummy No. 2. Seven were found in the thorax. The two upper central incisors were located under the skin of the head.

Grave I, Mummy No. 2

The radiological examination of the skeleton of this boy revealed symptoms of Down's syndrome (Eiken 1989) but no such symptoms were found in the development of his jaws, nor were any anomalous teeth encountered. The stage of formation and/or eruption of his teeth, however, may have been influenced, as delays in these processes are known to be associated with Down's syndrome (Roche & Barkla 1964, 1967; Orner 1971). Bearing this in mind we estimate his dental age at death to be within the rather wide range of 3½–4½ years. In any case it is remarkable that there is no sign of formation of second molars (Fig. 2). The more so as Boesen *et al.* (1976) found this tooth to erupt early in Greenlanders.

All deciduous teeth except the upper right first molar were found.Some were located under the skin far away from their natural positions (Fig. 4). When recovered, however, even the remotest ones proved to fit into their proper sockets after removal of the covering dry skin.

The teeth showed slight to moderate occlusal and incisal attrition comparable to that found in 4–5 year old East Greenland Eskimo children in 1937 by Davies and Pedersen (1955). No dental hypoplasia, caries or tooth fractures were present.

Fig. 2. The dentition of mummy No. 2, a boy aged 3½ – 4½. Lower first molar crowns tilted post mortem. No second molars visible.

incisor had an incisal perforation to the pulp cavity, and the left upper central incisor an incisal fracture. Both are likely to have been caused by trauma. There was a minor irregularity of position of the left upper incisors. Mummy No. 4 had no torus mandibularis.

Fig. 5. Mummy No. 3 (20-25-year-old woman). Wide pulp cavities. Two large pulp stones in left central incisor.

Grave I, Mummy No. 3

This is a 20–25 year old woman with a full complement of teeth except for the upper right lateral incisor, which had fallen out after death and was not recovered. The roots of her third molars were fully formed but their crowns were almost unworn and had remarkably wide pulp cavities. Two sizable pulp stones were found in one of the upper central incisors. Moderate chipping of the molar enamel was seen, as were small incisal fractures and multiple facial enamel infractions of the upper incisors. Neither enamel hypoplasia nor caries were found. Dental calculus was abundant but there was practically no marginal periodontal bone loss. Pronounced bilateral mandibular tori were present.

Grave I, Mummy No. 4

Dental examination of this body of a woman aged 25–30 was hampered by technical difficulties and no special dental X-ray examination could be carried out. After recovery of the mandibular third molars, the dental arches were found to be complete and all four third molars had completed their root formation. Attrition of all teeth was slight to moderate. The left lower central

Grave I, Mummy No. 5

This mummy is that of a woman aged 40–50. All teeth except I_1 sup. dxt. were found *in situ* or were picked up in the pharynx. The missing upper incisor was lost some time before death, as evidenced by its healed socket. The X-ray examination disclosed a vestigial supernumerary tooth in the premaxilla above I_1 sup. sin., a phenomenon previously recorded in Greenland Eskimos by Pedersen (1949), Balslev Jørgensen (1953), and Larsen *et al.* (1978). As appears from Figs. 7 and 8 the attrition of the teeth was heavy both occlusally and interproximally. The lower incisors were worn down to their necks and were rounded facio-incisally after loss of all facial enamel while the upper incisors had retained some of theirs. This type of wear distribution is likely to have been caused by pulling hides (predominantly of seal) forward and downward between closed anterior dental arches. The strain on both lower central incisors – or an accident – has caused necrosis of their pulps resulting in periapical osteitis (Fig. 9). In addition to these demands upon the anterior teeth the latter have been subjected to the frequent traumata effected by preparation of sinews for sewing. This activity (described for example by Holm (1888), Steensby (1910), and de Poncins (1942)) resulted in production of transversal grooves in the incisors, as observed in 1937 by Pedersen (1947 and 1952) in East Greenland Eskimo women above the age of 40. When the incisors were lost or extreme wear made then unsuited for sinew preparation the canines (or even premolars) were resorted

Fig. 6. Supernumerary tooth in the premaxilla of mummy No. 5.

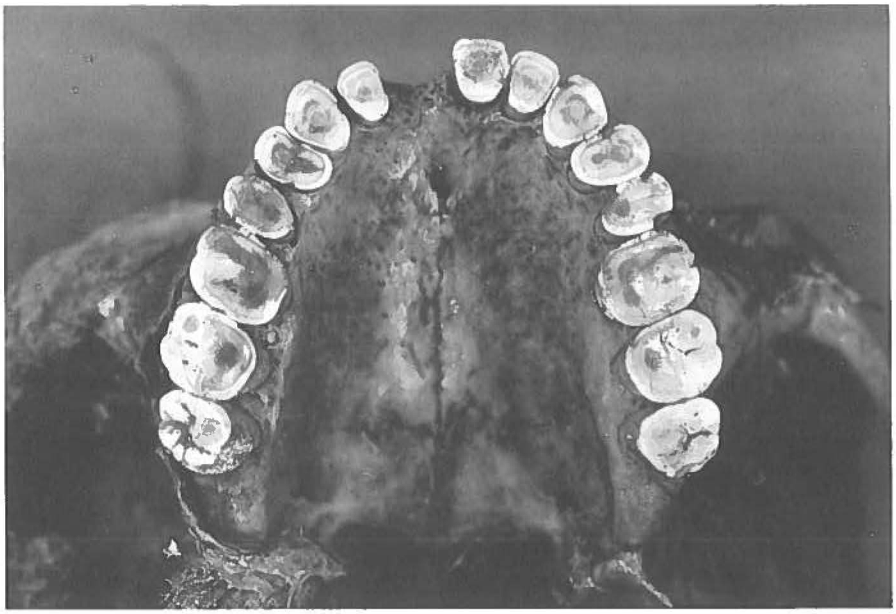

Fig. 7. The maxillary dental arch of mummy No. 5.

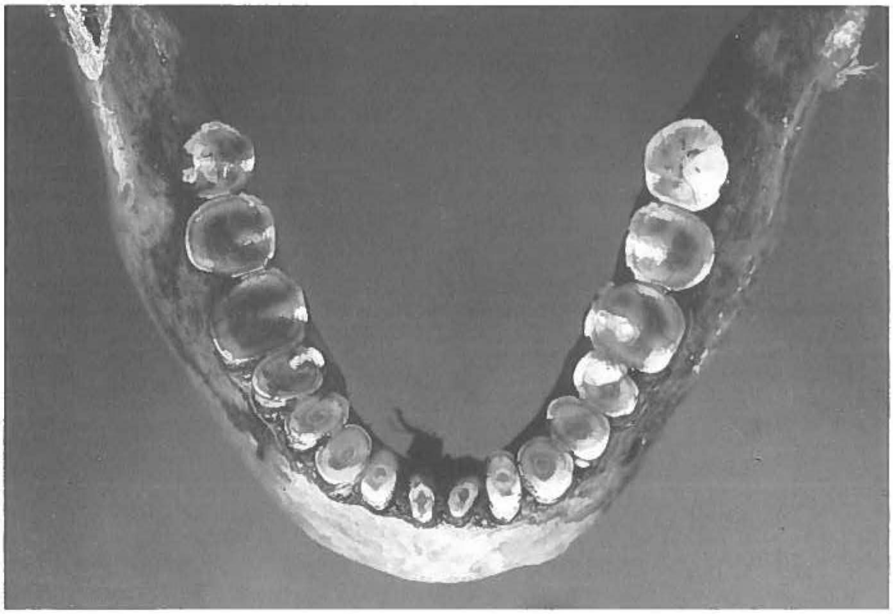

Fig. 8. The mandibular dental arch of mummy No. 5.

Fig. 9. Mandibular central incisors of mummy No. 5 have rounded facio-incisal contours and both exhibit periapical sequelae of pulp necrosis (osteitis).

Fig. 10. Sinew groove in the right mandibular canine of mummy No. 5.

Fig. 12. The coronal part of fractured mandibular premolar of mummy No. 5. Resorption and repair apically (cf. Fig. 11).

to, as is the case with mummy no. 5 (Figs. 10 and 38). Further consequences of the heavy demands on the dentition of this "elderly" woman are the widespread chipping of the enamel margins and the remarkable intra-alveolar fracture of the root of P_1 inf. dxt. close to the apex of a tooth without defects of its crown (Fig. 11). This root fracture is of long standing as evidenced by resorption and subsequent cementoid repair (Fig. 12). Finally, sequelae of trauma are found in the marginal periodontal bone. Mesially to I_1 sup. sin. there is a rather deep bony pocket, and buccally to M_1 sup. dxt. the entire wall of the socket is lost, exposing the buccal roots now covered with islands of calculus (Fig. 13). Figs. 14, 15 and 16 show that abundant supragingival calculus was present on the crowns of all teeth in the form of a rim or wall indicating the course of the free margin of the gum tissue at about two millimetres distance from the alveolar margin. The marginal bone loss is slight to moderate along and between all teeth.

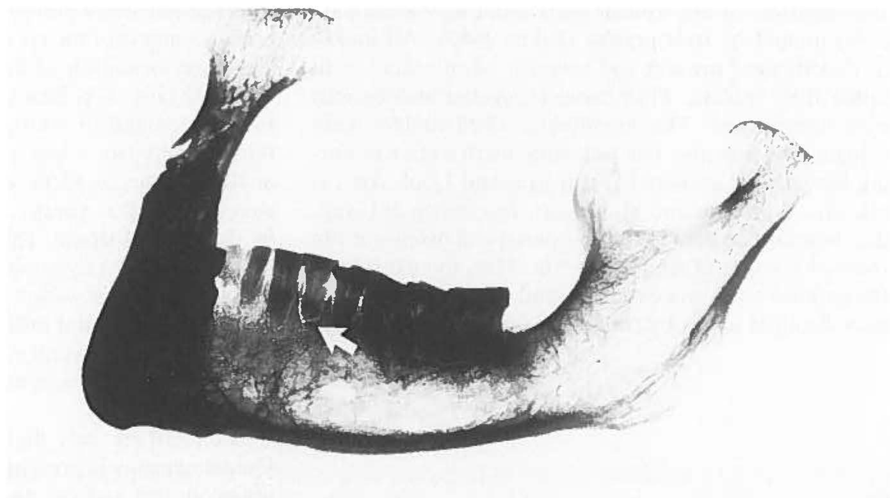

Fig. 11. Inveterate intra-alveolar root fracture of otherwise intact P_1 inf. dxt. in mummy no. 5.

Fig. 13. Breakdown of buccal alveolar wall at M_1 sup. dxt. of mummy No. 5. Supragingival calculus on all teeth. Subgingival calculus on M_1.

Fig. 15. Abundant lingual calculus in mummy No. 5.

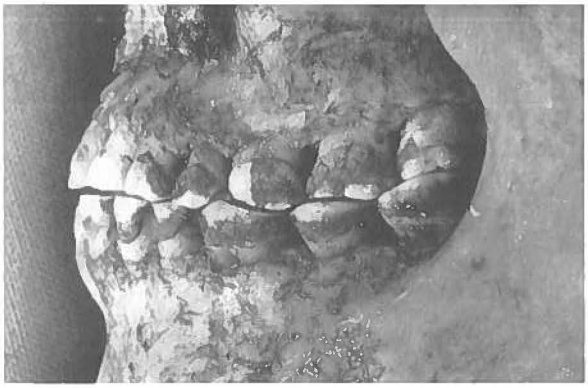

Fig. 14. Abundant buccal calculus in mummy No. 5. Normal occlusion.

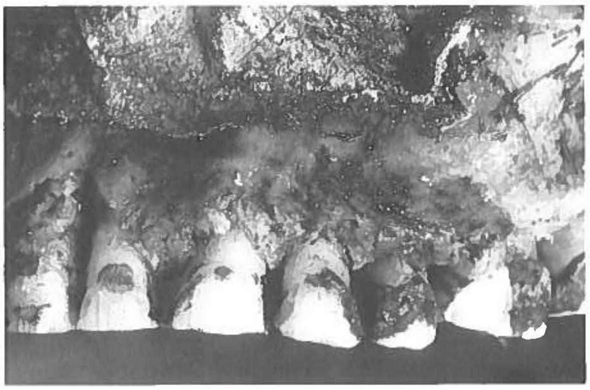

Fig. 16. Supragingival calculus on upper anterior teeth of mummy No. 5.

Grave II, Mummy No. 6

The dentition of this woman aged about fifty could only be examined by tomography (Eiken 1989). All maxillary teeth were present and severely worn except both upper third molars, which were elongated and showed hypercementoses. The mandibular third molars were congenitally missing. The following teeth were lost during life (healed sockets): I_2 sup. sin. and I_1 inf. dxt., I_1 inf. sin., I_2 inf. sin. and M_2 inf. sin. The crown of I_2 sup. dxt. was broken off. There was periapical osteitis at the roots of I_2 sup. dxt. and I_1 sup. sin. Thus the damage to the anterior teeth was extensive and would seem to have been brought about by traumata. Caries was absent.

Grave II, Mummy No. 7

This woman died when she was 18–21 years old and thus is the youngest of the six adult women from Qilakitsoq. The root formation of her third molars was not quite complete (Fig. 17). Dental radiographs taken in 1937 in East Greenland of young Eskimo women corroborate that mummy No. 7 was about 18 years or slightly older at death. Eleven teeth were lost post mortem. None were lost intra vitam. The upper incisors showed marked shovel-shape. The enamel was of perfect structure except for a hypoplastic depression in the parts of the upper incisors which were mineralized at age four (Fig. 18). The dental radiographs revealed a number of pulp stones and several sclerotic areas in the jaw bones which are as yet unexplained. Fig. 19 shows this phenomenon.

The teeth are only slightly worn and caries is absent. Dental calculus is present on the buccal surfaces of the upper molars and on most teeth in the form of a rim

Fig. 17. Left mandibular molars of mummy No. 7 – aged 18–21 – showing incomplete closure of apical foramen af M_3 and large pulp stones in M_1 and M_2.

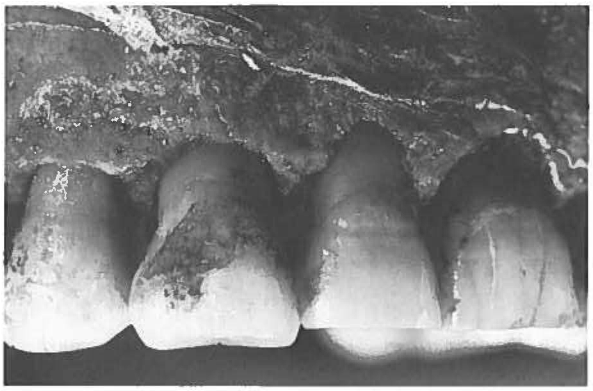

Fig. 18. Maxillary anterior teeth of mummy No. 7 showing facial calculus on C sup. dxt., enamel hypoplasia in I_2 and cracks in I_1.

Fig. 19. Sclerotic bone around P_2 sup. dxt. and large pulp stones in M_1 and M_2. Mummy No. 7 aged 18–21.

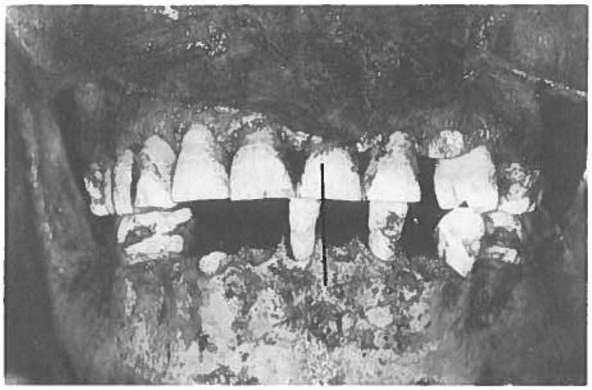

Fig. 20. Deviation of mandibular arch midline towards the left in mummy No. 7..

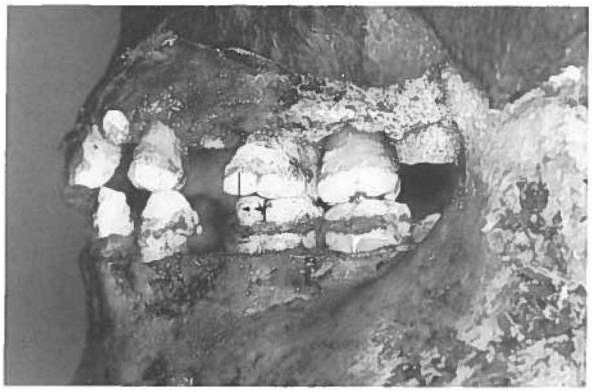

Fig. 21. Distal occlusion of left molars in mummy No. 7, cf. Fig. 20.

Fig. 22. Abnormal shape of right mandibular condyle in mummy No. 7.

along the alveolar margin. Fig. 18 shows a facial "cake" of porous calculus which was present on all upper anterior teeth until it was removed from some of them in order to disclose any enamel defects. This type of facial calculus was seen on upper anterior teeth in many East Greenlanders in 1937.

This woman differs from the others by having an abnormal bite with a skew to the left and backwards

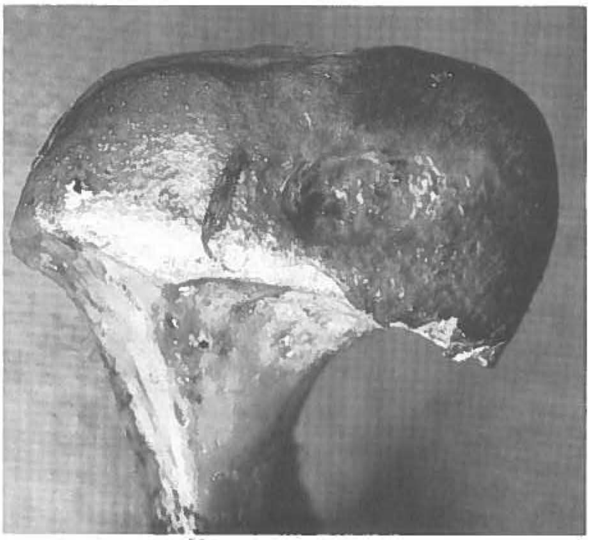

Fig. 23. Right mandibular condyle shows abnormal shape with median projection. Mummy No. 7.

(Figs. 20 and 21). She had marked pathological changes in her right mandibular condyle, and the articular disk was thickened. These changes are probably due to an earlier injury such as a fall or a blow. The shape of the condyle shows that a certain amount of rebuilding of the temporo-mandibular joint had taken place (Figs. 22 and 23). This might have been the consequence of some slight damage to the joint occurring between the ages of six and ten. At that stage, pains in the joint can alter the normal movement to such an extent that abnormal occlusion develops, as has been described by Collin Rasmussen (1984). This would cause later pathological changes such as those evident in the right TM-joint of mummy no. 7.

Grave II, Mummy No. 8

When she died this woman was about fifty years of age. She had lost three incisors ante mortem, viz. I_1 inf. dxt., I_1 inf. sin., and I_2 sup. sin. M_3 inf. sin. was congenitally absent. The upper central incisors have had very short roots, as evidenced by their empty, shallow sockets. They may have been resorbed, cf. Pedersen (1949, plates 26–28). Except for M_3 sup. dxt. (no opposing tooth) the 23 remaining teeth were strongly worn and exhibited a great deal of chipping of the enamel (Fig. 26). The occlusal plane is helicoidal (Fig. 27). Abundant supragingival calculus was present on the palatal and buccal surfaces of the upper molars and on the occlusal surface of M_3 sup. sin. (no antagonist) (Fig. 28). A rim of supragingival calculus was also seen on the buccal surfaces of the mandibular teeth while there was almost none on their lingual surfaces. Considering the age at death the marginal alveolar bone loss was moderate though interproximally it was somewhat more pronounced between the molars (Fig. 29).

Pulp stones were found in several teeth. Tori mandibulares of moderate size were present.

Discussion

Estimation of individual age

To estimate the age at death of the mummies, studies of dental conditions, X-ray examination of the skeletons and histomorphological studies of bone, as well as gen-

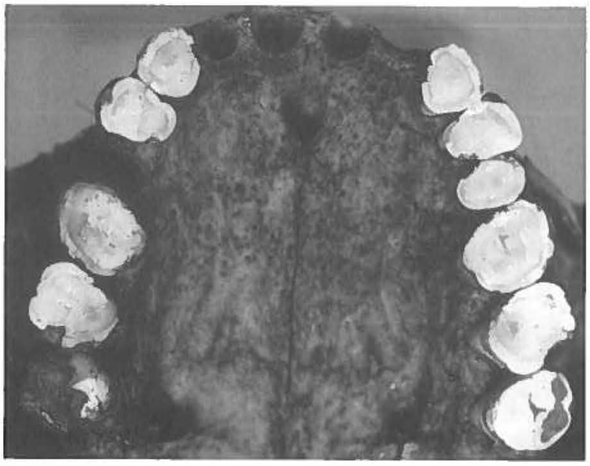

Fig. 24. Maxillary dental arch of mummy No. 8. One incisor lost ante mortem. Extensive chipping of enamel.

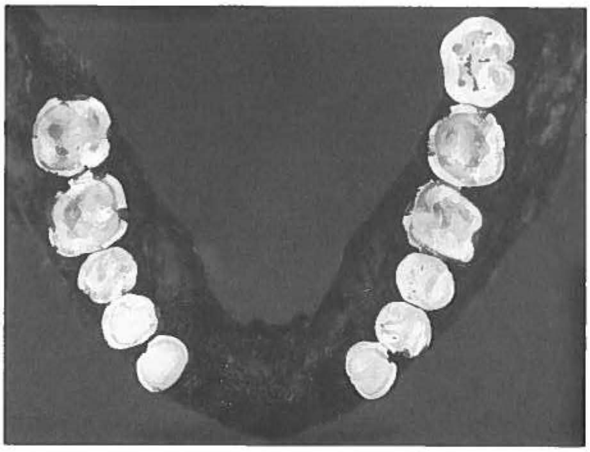

Fig. 25. Mandibular dental arch of mummy No. 8. Both central incisors lost ante mortem. Chipping of enamel. Tori mandibulares.

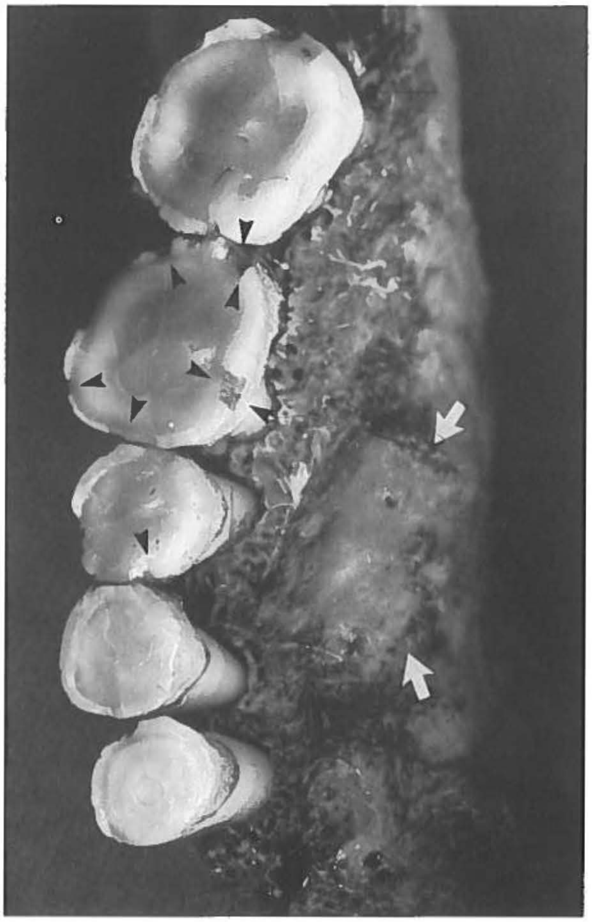

Fig. 26. Attrition and chipping (arrows) in mandible of mummy No. 8. Torus mandibularis (arrows).

Fig. 28. Abundant palatal and occlusal calculus formation on right upper molars of mummy No. 8. M_3 had no opposing molar.

Fig. 29. Right mandibular molars and premolars of mummy No. 8. Alveolar bone loss though moderate includes furcation involvement.

eral anthropological criteria were employed. Dental age estimation is optimal in the case of the three youngest individuals, namely the two children (Nos. 1 and 2) and No. 7 whose wisdom teeth were not completely formed (Fig. 17).

Fig. 27. Left mandibular teeth of mummy No. 8. Helicoidal shape of occlusal plane. Sinew furrow on masticatory surface of P_1. Calsulus rim and moderate marginal bone loss around molars.

Loss of teeth

The radiological examination of the mummies led to the recovery of several teeth located far away from their proper positions. Many of mummy 2's deciduous teeth lay firmly enclosed in the mummified tissues of the back underneath the clothing, which had partly disintegrated. Obviously these teeth had fallen out post mortem.

When all teeth which had fallen out of the jaws after death were repositioned, tooth loss post mortem amounted to eighteen, limiting the loss of teeth ante mortem to nine. These nine teeth were lost by the three oldest women, viz. Nos. 5, 6, and 8. Eight of them were incisors indicating the heavy demands on women's front teeth to be discussed later.

In 1940 Hrdlička, the renowned anthropologist, published an essay on ritual ablation of front teeth in Siberia and America in which he maintained that many anterior teeth were intentionally removed. Merbs (1968 and 1983) questions Hrdlička's interpretations and submits evidence of traumatic causation of (Sadlermiut) Inuit ante mortem loss of anterior teeth. The present authors share Merbs' views as does Costa (1980b). The female Eskimo dentition is a precious tool, crucial to her social and matrimonial success in life. That she – or her community – would permit her to be deprived of this asset voluntarily would seem absurd.

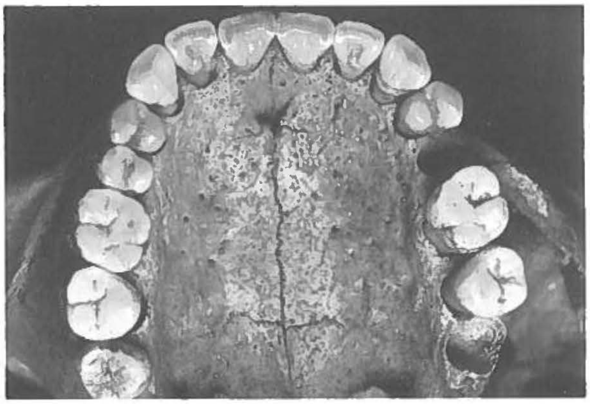

Fig. 30. Shovel-shape of upper incisors of mummy No. 7.

Congenitally missing and supernumerary teeth

The occurrence of congenital absence of teeth was examined and discussed in great detail previously by one of the present authors (Pedersen 1949: 38–59). The most striking feature was shown to be widespread absence of third molars in Greenland Eskimos. In the mummies, however, only three third molars did not develop.

A vestigial supernumerary tooth was found in the premaxilla of mummy No. 5 (Fig. 6). This is a fairly common phenomenon among Greenland Eskimos (Pedersen 1949; Balslev Jørgensen 1953; Larsen *et al.* 1978).

Tooth morphology

Because of heavy attrition, few of the typical dental anatomical features which characterize the Eskimo and indicate his origins among the Mongolian peoples could be identified in the mummies. However, the younger adults, especially mummy No. 7, showed pronounced shovel-shape of the upper incisors (Fig. 30), a typical feature among Greenland Eskimos (Pedersen 1949; Aas 1983). A further difference between Greenland Eskimos and Caucasians is that the Eskimo mandibular first molar frequently has three roots as opposed to the usual two roots in Danish molars (Pedersen 1949). There is, however, no example of three-rooted lower first molars among the six adult mummies. Eskimo teeth have strong and short roots, while the teeth of whites are longer and thinner (Pedersen 1949). In this respect the teeth of the mummies are typical eskimoid as are the gingival enamel margins (see Pedersen and Thyssen 1942) observed in the mummies.

Enamel hypoplasia

Irregular structure and faulty mineralization of the hard tissues of the permanent teeth may be caused by disease, malnutrition or famine during infancy while the teeth develop and calcify, but before they erupt. After eruption of the teeth, the visible result may be enamel hypoplasia, i.e. enamel surface irregularity, a phenomenon seen in mummy No. 7. This young woman exhibited enamel hypoplasia in the parts of the crowns of her front teeth closest to their necks (Fig. 18). This enamel mineralizes between the ages of two and four, viz. the period when breast feeding usually terminated among Greenlanders. Similar depressed areas in the dental enamel have been found in many skull collections in recent years by dental and anthropological workers (*vide* Pindborg 1982 and Goodmann & Armelagos 1985). They occur for instance in Danish mesolithic hunter-gatherers (living about 7000 years ago) excavated at Vedbæk in Denmark during the late 1970s (Albrethsen *et al.* 1976).

Attrition

The most impressive feature of the mummy dentitions is their pronounced to extreme occlusal and interproximal attrition. When the occlusal and incisal wear reaches down below the largest circumference of the crowns the completely worn-down teeth look like pegs at gum level, at some distance from the neighbouring teeth (Fig. 8). The illustrations accompanying this report demonstrate that all degrees of occlusal and interproximal attrition are represented in the adult Qilakitsoq dentitions, largely depending on the age at death of the woman concerned.

For centuries the heavy wear of Eskimo teeth has been noted by arctic travellers, and has been discussed

Fig. 31. Ammassalik woman (1937) scraping blubber off a sealskin with her *ulo*.

Fig. 32. Girl cleaning boot sole sealskin with her *ulo* at East Greenland village 1937.

Fig. 33. Polar Eskimo woman preparing sealskin to be used for boot (*kamik*) soles.

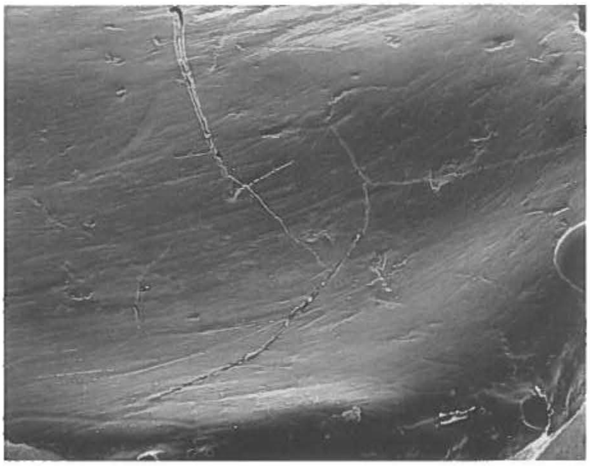

Fig. 34. Cracks and parallel scratches in exposed dentine of M_1 inf. dxt. of mummy No. 5. Direction of scratches is largely lingual-buccal (right-left on fig.). SEM X 20.

intensely by anthropological and odontological workers. Mention of this phenomenon was made as early as 1724 by J. B. Winslow (1724) and 1784 by James Cook (1784). A comprehensive survey of dental attrition in Greenland was published by Davies & Pedersen (1955). They quote a number of early reports and discuss the etiology of the heavy wear of Greenland Eskimo teeth, which seems to be caused both by the chewing of tough food, bruxism, and by the use of the teeth as implements. The latter is especially the case among Eskimo women, who prepare hides with their teeth. Although Eskimo men also had extreme dental attrition (e.g. Steensby 1910), the women ranked first in the use and abuse of their teeth. The women would hold the skin, usually sealskin, with their front teeth as they scraped the blubber off the inner side of the skin (Figs. 31, 32). Skin used, for example, for the soles of *kamiks* (boots) was "rubbed", with the mouth partly closed, down over the lower front teeth (Fig. 33), which were worn and gradually became rounded (Fig. 8). The women also softened the skin before sewing by actually chewing its edges with their front teeth.

Examples of microscopic traces left by chewing activities on exposed molar dentine in the form of numerous fine, parallel scratches are seen in Figs. 34 and 35. This course is similar to that described by Murphy (1964b) in Australians. A closer study of such patterns using a larger material might pay considerable dividends and is on our list of desiderata for future research.

Sinew grooves

The considerable effort involved in preparing threads from sinews for sewing is described by Holm (1888: 65)

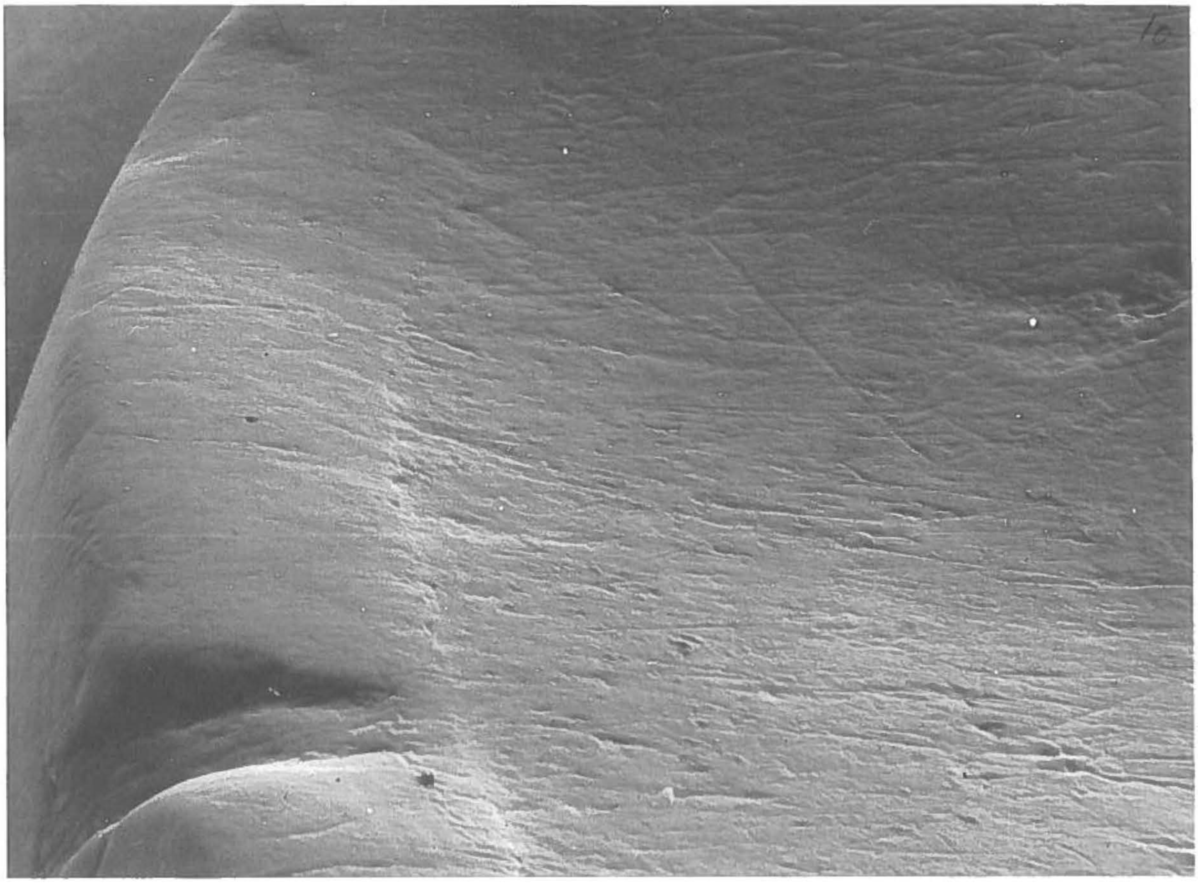

Fig. 35. Occlusal surface of C inf. dxt. of mummy No. 5. Dentine (right) and enamel (left) show parallel scratches. SEM X 250.

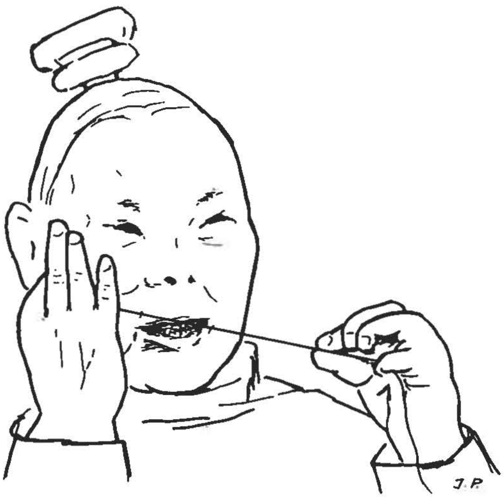

Fig. 36. Sinew thread being rolled against the cheek. Ammassalik 1937.

Fig. 37. Sinew thread being pulled across closed anterior dental arches. Ammassalik 1937.

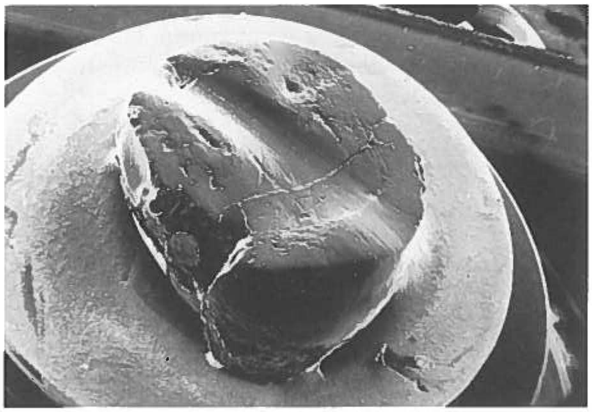

Fig. 38. SEM of sinew groove in C inf. dxt. (same as Fig. 10) of mummy No. 5.

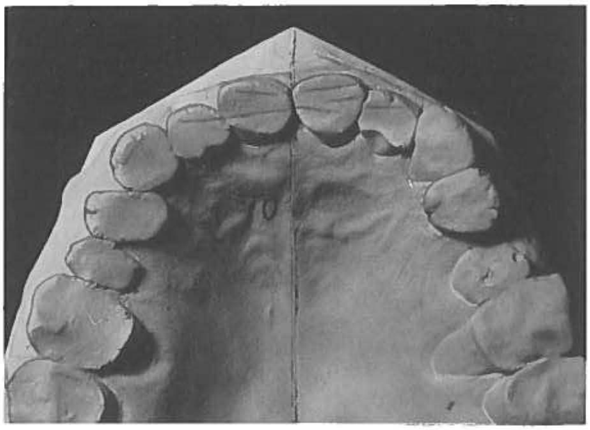

Fig. 39. Sinew grooves in the anterior teeth of 57-year-old East Greenland Eskimo woman examined in 1937. Chipping of enamel of most teeth.

and Steensby (1910: 344) in Greenland natives and by de Poncins (1942: 24) in Canadian Inuit. This activity caused transverse furrows in the "chewing surfaces" of the front teeth. First, thick bunches of tendinous material from animals were split into thin cords with the *ulo* (woman's knife). Next, these cords were alternately rolled against the cheek and drawn across the clenched front teeth (Figs. 36, 37), on which they produced one or more grooves (Figs. 10, 38). The purpose of this latter manoeuvre was to moisten and soften the sinew. Sinew grooves were seen in 1937 in half a dozen women in East Greenland (Fig. 39). They occurred only among "the old ones", meaning women over 40 years of age (Pedersen 1949). The Qilakitsoq women are the first West Greenlanders in whom these furrows have been found. When a woman lost her front teeth, usually as a result of having used them as a third hand for years, the sinew thread had to be prepared with her canines and/or her premolars. One such example occurs in mummy No. 8, who had lost her front teeth long before death. Instead she had used her right lower canine to make the threads. Mummy No. 5 displays furrows in two front teeth – one in the upper jaw, one in the lower. However, furrowing can be most clearly seen on her right lower canine (Figs. 10, 38).

Fractures

Cracks in the enamel of the teeth are also frequently caused by stress factors. The front teeth of several of the mummies show cracks running all the way down the facial surfaces of their crowns. These cracks are particularly numerous in mummy No. 3. The deciduous teeth of mummy No. 2 and the teeth of the mature adults show pronounced chipping of their masticatory surfaces caused by chewing hard foods, by bone fragments and by using the teeth as tools. Chipping of Eskimo dental enamel has been described before by Pedersen (1944, 1949) and has been dealt with by Turner & Cadien (1970), who are widely quoted in the anthropological literature. Effects of trauma are also found in the mesolithic hunters of Vedbæk in Denmark, whose teeth showed many fractures.

In mummy No. 6 the whole crown was broken off from an upper front tooth, and radiographs showed that in mummy No. 5 there was a transversal root fracture of a worn but otherwise intact lower premolar. SEM examination of the fractured root surfaces showed deposits of cementoid repair tissue, indicating that the heavy trauma causing the fracture had occurred quite some time before death.

Resorption

Among the consequences of the extensive use and abuse of the incisors are the shortening of their roots as a result of resorption. This is most evident in the considerably resorbed roots of the anterior teeth of the oldest Qilakitsoq women. Similar observations were made in elderly people in East Greenland in 1937 (Pedersen 1949). Orthodontists have shown that roots can be resorbed by using extensive force during treatment. If too much force is used, the roots may be resorbed and this may remain unnoticed until much later.

Caries

No carious lesions were found in any of the eight people from Qilakitsoq. Similarly there are almost no carious lesions in the large Copenhagen collections from precolonial Greenland, Canada, and Alaska. Less than one percent of these skulls displayed cavities, and then only in very few teeth. Curzon (1976/77) reported identical findings in Eskimo skulls kept in British museums. During the twentieth century, caries has become rampant and widespread among Eskimo populations, and virtually all modern Greenlanders have caries and/or tooth loss from caries. Nowadays, many people over forty are edentulous in Greenland. Despite intensive efforts by Danish health authorities to prevent and treat dental caries, it has been on the increase until recently (Pedersen 1971; Jacobsen & Hansen 1974; Jakobsen 1979; Senderovitz 1981, 1986), the reason being the change from the traditional hunters' diet to a diet of imported food with a high sugar content (Pedersen 1938; Baarregaard 1949; Møller *et al.* 1972). A certain amount of fluorine in food and drinking water protects teeth from caries. However, overconsumption of fluorine is harmful to tooth development giving rise to the condition known as dental fluorosis. The drinking water is low in fluorine almost everywhere in Greenland except for the town of Narssaq in the southern part of West Greenland, and today the prevalence of dental decay is much lower there than elsewhere in Greenland (Jakobsen 1979).

Surface enamel of both deciduous and permanent teeth of the Qilakitsoq mummies has been analysed for fluorine content. It seems to have about the same concentration and distribution as was found among modern Greenlanders in the area.

Pulp calcifications

It is well-known that secondary dentine is deposited on the walls of the pulp cavity during life and that tertiary dentine develops on these walls opposite areas subjected to peripheral damage or irritation. Usually, the heavy occlusal attrition of the teeth does not lead to pulp exposure, because deposition of tertiary dentine keeps pace with the occlusal loss of dentine. In cases with extreme occlusal attrition areas of exposed tertiary dentine appear on the occlusal surface as darker islands because the different structure of tertiary dentine facilitates staining (Figs. 7, 8).

A striking discovery made during the 1937 survey of East Greenlanders was the frequent occurrence of large pulp stones seen in dental radiographs, even those taken of young adult dentitions. Comparative radiographical studies by Andersen & Østergaard (1984) of mandibles of ancient Greenland Eskimos and other ethnic groups established that the Greenlanders had a considerably higher prevalence of pulp stones than had mediaeval Norsemen from Greenland and Danish neolithic people. As a matter of fact, the prevalence in Greenland Eskimo jaws is the highest on record so far. In keeping with this, the radiographs of the mummy dentitions exhibited several sizable pulp stones. The reason why Greenland Eskimos have the highest prevalence of pulp calcifications is not known, but studies in progress of other ethnic groups may contribute to the understanding of this problem.

Calculus

Calculus (tartar) was found on the crowns of all the adults' teeth and on the buccal aspect of the roots of one upper molar exposed by gingival pocket formation. The sharp demarcation of the supragingival calculus deposits at a short distance from the alveolar margins of the jaws indicates the level of the gingival margin when the subject was alive. As calculus formation is slight in museum specimens of Greenlandic skulls, it was surprising to find such widespread and abundant amounts of calculus among the Qilakitsoq women. The skulls in museums probably lost some calculus post mortem as the 1937 survey of the living East Greenlanders revealed widespread calculus, though its location and structure seemed to be somewhat different from those of Danes. This is also the case when closer studies of the calculus of the mummies are made (cf. Figs. 17 and 18). The reason for these differences is not known at the present time.

Samples of supragingival calculus originating from mummy No. 8 were pulverized and subjected to X-ray diffraction analysis. The X-rays showed the presence of hydroxyapatite. No other calcium phosphates and no calcium carbonates were found.

In a further attempt to describe the nature of dental calculus as found in the mummies, scanning electron microscopic studies were carried out. Two of the SEM photos are presented in Figs. 40 and 41. The final interpretation of our results in this area is not yet available. SEM studies of dental calculus have previously been published by American (Baunhammers *et al.* 1973; Lustman *et al.* 1976), Japanese (Shirato *et al.* 1981; Kodaka & Ishida 1984) and Swedish (Friskopp 1984) researchers, and are at present being performed in several laboratories.

Periodontal disease

It is probable that all the older and possibly also the younger adults had chronic inflammation of the gums (gingivitis) at least corresponding to the calculus deposits. However, the loss of alveolar bone material along and between the teeth is horizontal and slight in depth. Deeper disintegration of alveolar bone is seen only in limited areas, for example in mummy No. 5, who had a total loss of bone tissue opposite the buccal aspects of the right upper first molar (Fig. 13). Similar changes are seen approximately at the remaining upper central in-

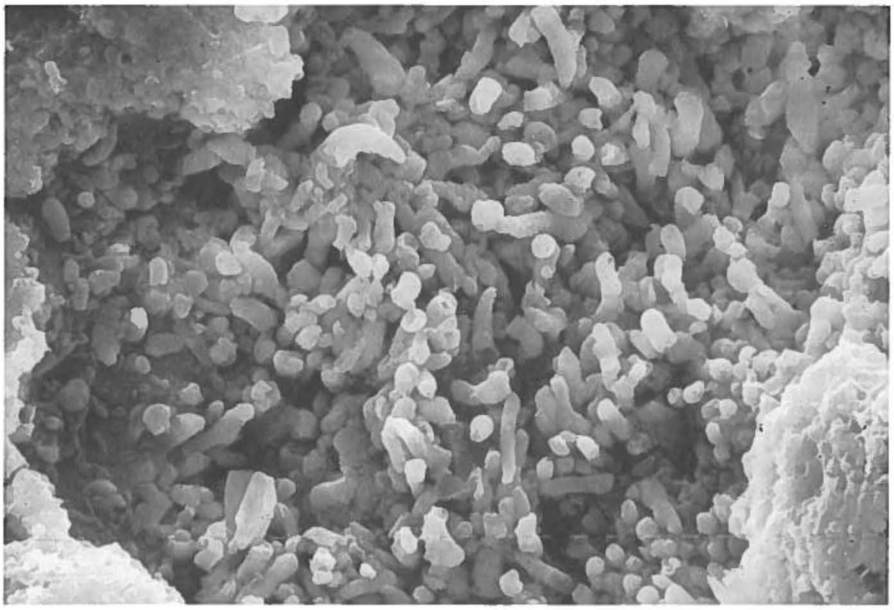

Fig. 40. SEM of supragingival calculus from the innermost layers of deposits on molars of mummy No. 8. Numerous mineralized micro-organisms. X 4,600.

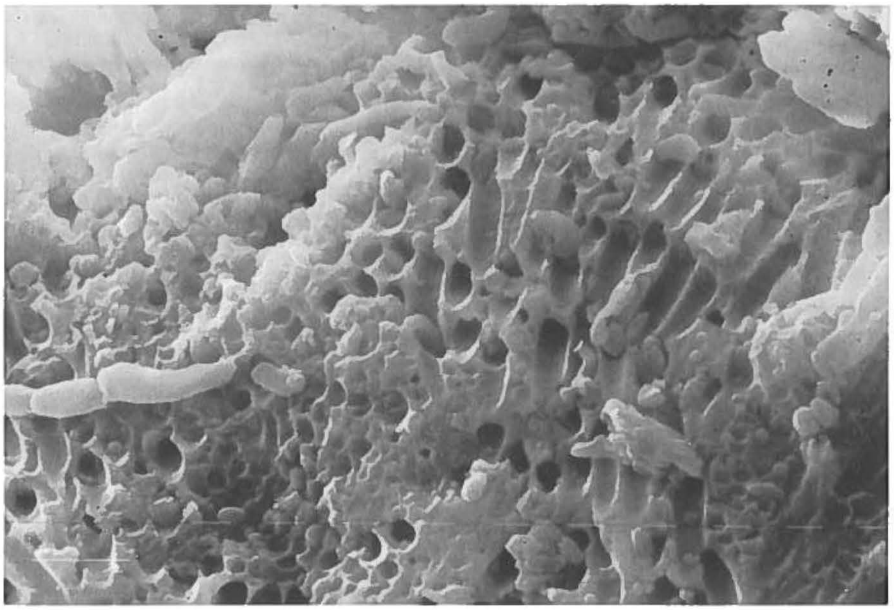

Fig. 41. SEM of surface layer of supragingival calculus shown in Fig. 40. Many lost unmineralized micro-organisms have left impressions in inorganic stroma. X 8,000.

cisor in Fig. 7. In both sites there must have been deep gingival pockets, possibly with pus formation and tenderness. Most probably these changes were initiated by bone splinters or other hard material invading the gingival sulcus.

Occlusion and Temporomandibular Joint

With one exception (mummy No. 4) all the adult mummies exhibited completely regular tooth positions. Their front teeth meet edge-to-edge and the molars show "normal" occlusion (Angle class I). The only exception is mummy No. 7 who had an abnormal bite with a deviation to the left and back of the mandibular teeth (distal occlusion of the left teeth) as shown in Figs. 20 and 21. She had marked changes in the right condyle of her mandible and the articular disc was thickened on that side. These changes are probably due to an earlier injury such as a fall or blow. The shape of the right condyle demonstrated that a certain rebuilding of the temporo-mandibular joint had occurred (Figs. 22, 23). This might have been the consequence of some slight damage to the joint between the age of six and ten. At that stage, pain in the joint can alter the normal movements to such an extent that abnormal bite conditions develop (cf. Collin Rasmussen 1984). This, in turn, would cause later changes such as those found in the right temporo-mandibular joint of mummy No. 7.

Opportunities for close studies of the mummy temporo-mandibular joints were limited. Our findings, however, are in agreement with those published by Knowles (1915) and Ritchie (1923) who studied Canadian Eskimos and reported that their glenoid fossae were remarkably shallow. The mandibular condyles of the mature women at our disposal exhibit considerable amounts of wear and porosities but are too few in number to permit interpretations regarding joint changes as related to dental activities (cf. Merbs 1983).

Jaws

The dental radiographs of mummy No. 7 showed several sclerotic areas in her jaw bones (Fig. 19) for which we can offer no explanation.

Two of the women had bilateral overgrowths on the inner sides of their mandibles opposite the molars, so-called tori mandibulares. Those of mummy No. 8. were moderately developed, while those of mummy No. 3 were larger. A bone projection (torus palatinus) is seen in the midline of the palate in mummy No. 5. Tori mandibulares are notably frequent among Eskimos (Fürst & Hansen 1915; Leigh 1925; Hrdlička 1940; Mayhall & Mayhall 1971). They are probably caused by the special conditions of life in the Arctic, and may have arisen in connection with strongly developed masticatory musculature. Their etiology is, however, still open to discussion and is a favourite subject in arctic anthropological literature (e.g. Sellevold 1980).

In summary, the dental studies of the Qilakitsoq mummies confirmed the importance of the dentition in age estimation. They also demonstrated that the teeth of Eskimo women in the old days were overworked and damaged and in the end might be lost due to lifelong use as tools. The present studies confirm that in ancient Eskimos, calculus can occur without serious damage to the alveolar bone supporting the teeth. They also confirm that Eskimos of the past did not suffer from dental caries.

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Isolation and Eradication of Fungi Contaminating the Mummified Corpses from Qilakitsoq

E. SVEJGAARD, A. STENDERUP & G. MØLLER

Svejgaard, E., Stenderup, A. & Møller, G. 1989. Isolation and Eradication of Fungi Contaminating the Mummified Corpses from Qilakitsoq. – Meddr Grønland, Man & Soc. 12: 131–133. Copenhagen 1990–01–26.

During the period when they were kept at the National Museum, Copenhagen, the mummies demonstrated increasing contamination with fungi, followed by decomposition of the material. The fungi were isolated and identificated as the species *Penicillium*, *Aspergillus* and *Botrytis*. After decontamination with gamma radiation (2–2.5 megarad) the mummies were transported in tight plastic bags to the museum in Nuuk, Greenland. To avoid recontamination they are now displayed in airtight showcases at a suitably low temperature and humidity.

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The mummified corpses from Qilakitsoq were discovered in 1972, but it was not until 1978 that the first, viz. two baby mummies were transferred to the National Museum in Copenhagen for preservation and scientific investigations (Møller 1978). On arrival whitish, dusty patches in the face and on the clothes of the smallest mummy were observed. From these patches *Sporothrix fungorum* was isolated. They were treated and responded well to nystatin (Bodenhoff *et al.* 1979).

Later on, when the remaining adult mummies were transferred to the National Museum, new problems emerged. On the skin of the mummies and in the seal and bird skins from which their clothes were prepared, areas of destruction caused by fungal invasion gradually extended. These areas were characterized by dusty, whitish grey, brown, black and green coatings and pronounced mouldering of the material, which disintegrated when touched (Fig. 1), indicating fungal contamination.

This exuberant fungal growth raised four questions. Were the fungi pathogenic and therefore dangerous to the individuals doing the preservation work? How destructive for the mummies would the fungal growth be in the long term? Which methods would be most appropriate in the decontamination of the mummies? And finally how were the mummies to be kept in future in order to avoid new contamination?

To answer these questions, it was necessary to culture and identify the fungi. It was easy to see the areas of the mummies from which it was most appropriate to take the cultures, the fungal contamination being macroscopically visible in many locations, as mentioned above. Samples were taken under sterile conditions with swabs and scalpels from the eyesockets and sealskins of mummies 1 and 4; from the sealskins of mummies 2 and 6; from the kamiks and bird skins of mummies 1 and 3; and from the eyesocket, back and front of the sealskin of the baby mummy.

The material was inoculated on Petri dishes with Sabouraud dextrose agar 2% with chloramphenicol 0.5 mg/l and incubated at 26°C.

Numerous different fungal colonies appeared on all Petri dishes (Fig. 2). Pure cultures for identification were obtained from the various morphological forms. The following species were isolated: *Penicillium verrucosum* var. *cyclopium* (Westhing); *P. chrysogenum*

Fig. 1. Sealskin contaminated with fungi.

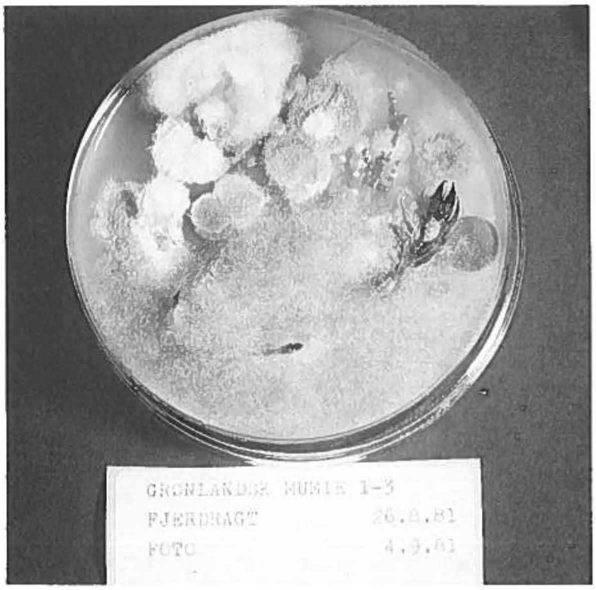

Fig. 2. Primary culture from bird skin.

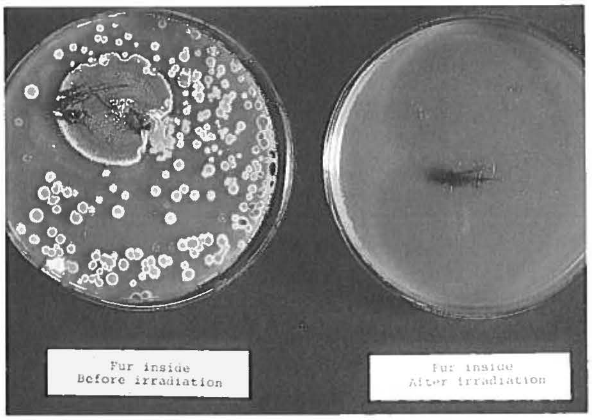

Fig. 3. Irradiation experiment. Positive and negative culture from contaminated fur before and after irradiation.

Thom, *Botrytis cinerarea* Pers. ex Fr. and *Aspergillus versicolor* (Vuill) Tiraboschi. *Sporothrix fungorum* was not rediscovered.

Spores from *Penicillium* and *Aspergillus* may cause allergy and may be pathogenic, especially in immunocompromised individuals, and production of toxins may occur during growth. However, in the present case there was no reason to assume that they would constitute a risk to the staff that was to carry out the preservation. The immediate impression was that the fungi were harmful to clothing and that continuous growth would be destructive, especially in the event of high temperature and humidity. *Botrytis* species have a known destructive effect on plant material at high humidities (Alexopoulos & Mims 1971), while *Penicillium* and *Aspergillus* may under special circumstances attack human skin, and it is well known that they grow well on, and are able to destroy, textiles (Gray 1959).

Decontamination of the mummies was thus necessary. At first, chemicals had to be rejected as in the long view the material might be injured or there might be changes in colour. Antimycotics were not expected to be effective for more than a short period, because their effectiveness is most often restricted to growing fungi. Ethylene oxide is fungicidal and treatment with this medicament is not considered to be injurious to mummies or skins. However, treatment with this was not practically possible, among other things because of the long airing phase after the treatment.

The successfull sterilization of the mummy of Ramses II in 1977 using gamma radiation (Brouqui *et al.* 1978) prompted us to experiment with the efficacy of electron irradiation with 3 megarads of contaminated skin samples. This was done in collaboration with dr. Bährenstein, Risø Research Centre, Roskilde. The material was cultured before and after irradiation and the dosage used proved fungicidal (Fig. 3). Given this, all the mummies were then sterilized with gamma radiation at 2–2.5 megarads at Nunc A/S, Roskilde, which had the necessary capacity. The sterilization was carried out with the mummies sealed in tight-fitting plastic bags which were then transported unopened to Greenland. The last problem was to decide the conditions under which the mummies had to be kept in Greenland with minimal risk of new fungal attacks. To reduce the chance of invasion by contaminating microorganisms, it was suggested that the mummies shoul be displayed in aseptic conditions in air-tight glass cases in which air humidity could be registered by hygrometers. Application of silicagel in the socket was considered sufficient to ensure that the relative air humidity would remain around 50. Finally, a suitably low temperature, preferably not more than 20°C, was recommended. In this way it is hoped that these so well-preserved 500-year-old human remains will be kept in a lasting resting place as safe as the one they had in the crevice.

Acknowledgements

Our thanks are due to Dr. Bährenstein, Risø Research Centre, Roskilde, for her kindness and practical help with the radiation experiment, and Dr. G. A. DeVries, Centraalbureau voor Schimmelcultures, Baarn, the Netherlands, for his kind assistance in definitive identification of some of the fungal cultures.

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Final Preservation of Mummies by Gamma Irradiation

ARNE JOHANSSON

Johansson, A. 1989. Final Preservation of Mummies by Gamma Irradiation. – Meddr Grønland, Man & Soc. 12: 134–136. Copenhagen 1990–01–26.

Final preservation of four mummies was achieved by means of gamma irradiation in a Cobalt 60 plant designed for radiation sterilization of medical products. The radiation dose was between 1.71 and 2.31 megarads.

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At the request of the National Museum in Denmark the final preservation of four Greenlandic mummies was carried out by means of gamma irradiation in the Cobalt 60 plant, Nuncatom, a plant designed for radiation sterilization of medical products.

Given the size of the boxes containing the sealed mummies it was not possible to use the normal procedures for sterilizing medical products. However, owing to the way in which the plant (AECL-Type J6000) was constructed, it was possible to use the excess gamma radiation in an area close to and parallel to the product conveyor system, surrounding the cobalt source (Fig. 1).

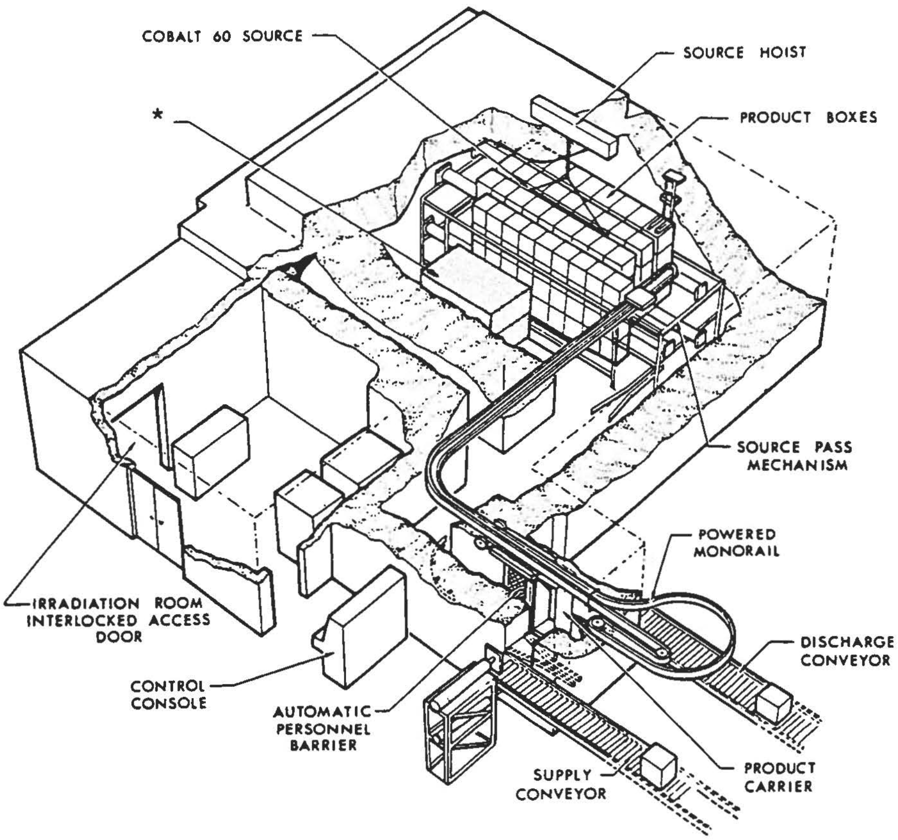

Fig. 1. Cobalt 60 irradiation plant. * The arrow indicates the position of the boxes containing mummies.

Table 1. Sterilizing effect of various doses on pieces of mummy skin

Sample No.	Dose megarads	Weight g	Result of 14 days' incubation
1	0	1.33	Growth
2	0.25	1.81	Growth
3	1.01	2.62	No growth
4	1.75	1.23	No growth
5	1.94	1.71	No growth
6	2.45	1.67	No growth
7	3.33	1.35	No growth

To assess the level of irradiation as well as the uniformity over the desired irradiation area the dose at nine different positions was measured using three Red Perspex 4034 at each position. The result of the dosimetry was dose rates between 39 krad/hour and 47 krad/hour. The above doses were obtained within an area of 170 × 120 cm, enough to cover the boxes containing the mummies.

As the irradiation varies over the required area because of variation in the density of the products in the normal process, the above dose rates were considered to be guidelines only, and it was decided to perform extensive dosimetry during the irradiation of the mummies.

The choice of dose to be applied to the mummies was partly based on results obtained from the gamma irradiation of the mummy of Ramses II (Brouqui *et al.* 1978). The estimated inactivation of various microorganisms was also considered, and test irradiation of various samples of mummy skin, clothing etc. played a substantial part in the decision.

Based on the above considerations and tests it was decided to irradiate the mummies with a dose between 1.8 and 2.5 megarads. As it was impossible to perform any microbiological examination of the mummies before and after the irradiation, it was further decided to perform a simple microbiological test on skin pieces from another mummy found in the same place.

Given the structure of the mummy skin it was not possible to determine the number of microorganisms present in the material, so the piece of skin was divided into seven smaller pieces, weighing from 1.34 to 2.62 g. These pieces were soaked in sterile growth medium (Heart Infusion Broth) and incubated for 14 days. The result of this investigation can be seen from Table 1.

Irradiation procedure

The mummies, hermetically sealed in polyethylene film and packed in shock-resistant cardboard boxes, were taken manually to the irradiation chamber and placed in the desired area. On the basis of the predosimetry, the total irradiation time was calculated at approximately 45 hours. In order to make the irradiation as uniform as possible the boxes were rotated after approximately 20 hours.

To monitor the applied dose a number of dosimeters were taped to the outside of the boxes and measurements of the obtained doses were taken at short intervals. After irradiation the complete set of dosimeters, placed in a pattern corresponding to the profile of the mummies inside the boxes, were measured.

The results obtained can be seen from Figs. 2–5, showing the position of the dosimeters as well as the dose in megarads. All doses indicated are mean values of 2 dosimeters and none of the measurements varied more than 2 per cent from the mean value.

The radiation preservation of the four mummies was of course a minor part of the total conservation process, but in spite of limited experience with the use of gamma irradiation for final preservation, it is a method which should be further elaborated. The clear advantage of the radiation process is the high penetration of the gamma rays, allowing preservation to take place in a sealed environment.

From the experiments with the test material it appears that no damage is done to the material at dose levels up to 2.5 megarads. The radiation degradation of organic material is probably related to the water content of the material, and this is one of the factors which

Fig. 2

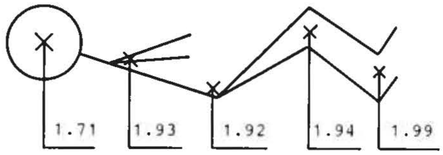

Fig. 3

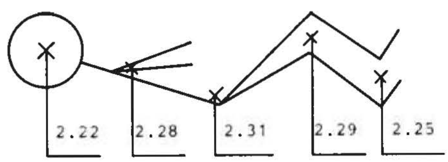

Fig. 4

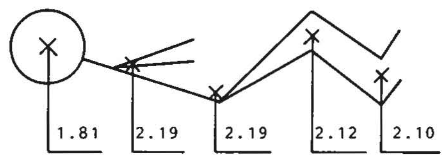

Fig. 5

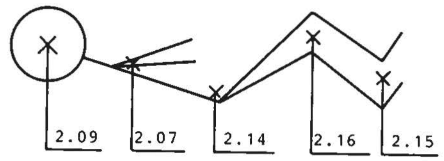

Fig. 2.–5. Location of the dosimeters. Dosimeters were placed outside the boxes containing the mummies in a pattern corresponding to the profile of the mummies. All values indicated are mean doses in megarads.

needs further investigation. The water content of the mummies was approximately 7 per cent, which in organic material is regarded as very low.

Finally, irradiation is one of the most intensively investigated methods for microbial inactivation, allowing accurate determination of the probability of microorganisms surviving the process, provided that the material to be preserved can be microbiologically examined. In the case in question, it was impossible to disintegrate the skin pieces to a degree where all the microorganisms present could be isolated for counting, but further investigations may lead to a solution.

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Age and Diet of the Mummified Eskimos from Qilakitsoq

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Tauber, H. 1989. Age and Diet of the Mummified Eskimos from Qilakitsoq. – Meddr Grønland, Man & Soc. 12: 137–138. Copenhagen 1990–01–26.

By means of C-14 measurements, six samples from the mummies found at Qilakitsoq have been dated to the period AD 1460–1510, with a mean close to AD 1470. Combined C-13 and C-14 analyses of tissue from the four-year-old boy in Grave I suggest that 75 ± 7% of his diet consisted of marine food components, while the remaining 25 % were of terrestrial origin.

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It is known from contemporary drawings and paintings that the characteristic pattern and fashion of the remarkably well-preserved skin garments of the mummies from Qilakitsoq were in use in the 16th and 17th centuries; but it has not been known so far how early this fashion came into existence. It was therefore decided to try a direct dating of the mummies by means of their C-14 content in order to assess their ages and to see if any age differences could be detected between the individual mummies or between the two graves.

Precise datings of tissues from human beings by means of C-14 are only possible if the ratios of marine to terrestrial food components in their diets are known (Tauber 1983). Since these ratios can only be estimated within wide limits, considerable uncertainties in the dating of human tissues from the mummies could be envisaged. It was therefore decided to base the datings on samples of the skins of animals with a well established marine or terrestrial association, like seal and caribou. These samples were taken from the skins that covered the individual mummies, specifically from the topmost and lowermost mummies in each of the two graves. These samples were further supplemented with an additional skin sample from each grave. After thorough pretreatment to purify the skin samples of possible extraneous carbon compounds, the samples were combusted to carbon dioxide, the gas was further purified, and the C-14 content was determined in a gas proportional counter. After a correction for differences in the original C-14 content of marine and terrestrial materials, as monitored by the measured differences in C-13 content, the results given in column 4 of Table 1 were obtained. The ages are expressed in conventional C-14 years with uncertainties ranging from ± 45 to ±65 years.

Due to secular variations in the C-14 content of atmospheric carbon dioxide, and thus of plants and animals, ages calculated directly from the C-14 content of samples need a correction in order to be comparable with solar years, i.e. the usual calendar years. This is done by comparisons with the C-14 content of dendrochronologically dated wood samples. A calibration curve based on such measurements from the long American bristlecone pine chronology was constructed by Clark (1975). The calibrated ages according to this curve are also given in Table 1. After the datings were made, a new and more precise calibration curve, this time based on a dendrochronologically dated sequence of Douglas fir from the northwestern USA, was published by Stuiver (1982). If calibrated in accordance with this new curve the ages of the skin samples deviate only 5–20 years from the previous values.

It may, however, be noted that the more precise calibration curve by Stuiver shows rapid variations in the C-14 content of plant material. As a consequence of these rapid variations an age in conventional C-14 years does not always correspond to a single calendar year. In certain periods a C-14 age may correspond to a whole time interval, all ages within this interval being almost equally probable. This applies to the age of the topmost mummy in Grave II (K-3395). According to the Clark calibration curve the C-14 age of K-3395 corresponds to AD 1510 in calendar years, while the more recent Stuiver curve allows all calendar ages in the time bracket AD 1500–1625, though with slightly higher probability for ages within AD 1500–1520.

As mentioned, the uncertainties in the C-14 ages vary from ± 45 to ± 65 years. When this is taken into consideration no significant difference in age between the individual mummies, or between the two graves, has

Table 1. Measured C-13 values and C-14 ages of samples of seal skin, caribou skin, and one of the mummies from Qilakitsoq.

Sample	Material	$\delta^{13}C$ ‰	Measured ages in years AD		
			^{14}C years	Calendar years	
				Clark	Stuiver
Grave I:					
K-3393	Seal	−14.1	1550 ± 65	1470	1450
K-3019	–	−13.6	1540 ± 50	1465	1450
K-3394	Caribou	−19.7	1570 ± 65	1480	1475
Average				1470	1460
K-3020	Human	−14.8			
Grave II:					
K-3395	Caribou	−19.0	1610 ± 45	1510	(1510)
K-3018	–	−18.8	1530 ± 50	1460	1445
K-3396	Seal	−14.8	1550 ± 45	1470	1450
Average				1480	(1470)

been established. All the mummies may thus originate from a single burial, the most likely age of this event then being close to AD 1470. On the other hand, the C-14 datings do not exclude the possibility of successive burials over a time span of some decades. The C-14 method is not precise enough to distinguish between these alternatives.

The C-14 content of tissue from the four-year-old boy in Grave I (K-3020) was also measured. Although this measurement cannot be used for a meaningful calculation of the age of the boy, in combination with a measurement of the C-13 content in the tissue it allows an estimate of the diet of the boy in terms of marine and terrestrial components.

The stable carbon isotope C-13 makes up about 1 % of the carbon atoms in all living organisms, but the precise content varies slightly depending on whether the carbon compounds ultimately originate from photosynthesis in a terrestrial or a marine environment. If applied to samples from human beings C-13 measurements therefore contain information of the origin of the dietary components (Tauber 1981a, 1981b). The C-13 content is usually measured relative to the international PDB-standard and expressed in $\delta^{13}C$ values, which give the per mille differences from the C-13 content in the standard.

Measured in this way, proteins in bones and skin from marine animals usually have $\delta^{13}C$ values in the range −10 to −17 ‰ (the negative values only indicate that the C-13 content is lower than that of the standard), while proteins of terrestrial animals usually have $\delta^{13}C$ values in the range −18 to −23 ‰. The sample taken from the four-year-old boy had a $\delta^{13}C$ value of −14.8‰, which indicates a predominance of marine food components in the diet.

If it is assumed that the age of the boy is equal to the mean age of the skin samples in the two graves, i.e. AD 1470 in calendar years, the measured C-14 content of this tissue (normalized for isotopic fractionation) allows a more direct calculation of the ratio of marine to terrestrial food components in his diet. This calculation gives the result that 75 ± 7 % of his diet consisted of marine components like seal meat and fish, while the remaining 25 % originated from terrestrial sources, presumably mainly from caribou.

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Investigation of Faeces from a Mummified Eskimo Woman

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Lorentzen, B. & Rørdam, A. M. 1989. Investigation of Faeces from a Mummified Eskimo Woman. – Meddr Grønland, Man & Soc. 12: 139-143. Copenhagen 1990-01-26.

The microscopic analysis of faeces was carried out by a method described in the following. As is usual in the analysis of faeces or stomach contents, the identification of fragments was verified by means of standard comparison material.

Several fragments from cormophytes were identified, *Empetrum sp.*, *Alopecurus sp.*, *Elymus sp.*, *Conifera sp.* and a number of moss species. Furthermore, spores, pollen, fungi, and eggs from a parasite were found. Hairs and feathers of arctic animals were observed.

The examination of the visceral contents has to some extent elucidated the diet of the inhabitants of Greenland 500 years ago, but it did not answer the question at what time of the year this Eskimo woman died.

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Mummy No. 7, determined to be a young woman aged 18–22 years, was in such a good state of preservation that a proper examination was possible after rehydration of the inner organs. The stomach was empty, but in the lower part of the large intestine, some lumps of faeces were found. Half of these were sent to the Department of Pharmacognosy in May 1983 for examination, and the investigation was carried out during the autumn of 1983.

The sample was prepared for microscopy in the conventional way for non-mummified faeces. The sample is stirred up with 96 % v/v ethanol and remains in ethanol for at least 24 hours. The ethanol is removed by means of a suction funnel, and the remanence washed out with ethanol. The ethanol is kept in a bottle for forencis investigation, if necessary. The remanence is degreased with ether. The ether is discarded. The remanence is then divided into two parts. One part, kept in 70 % v/v ethanol, is used directly for microscopic purposes with the following clearing reagents:

1. Water (to find starch)
2. Solution of chloral hydrate 5 + 2 (cold)
3. Solution of chloral hydrate 5 + 2 (boiling)

One drop of glycerol is added to specimens mounted like 2 and 3 to prevent crystallization.

The other part of the remanence is boiled for about fifteen minutes with hydrochloric acid 2 N to eliminate starch. The sediment is kept in 70 % v/v ethanol. If necessary, the sediment can be bleached with sodium hypochlorite before microscopy.

To prepare for microscopy, many small samples were taken from the prepared samples.

In faeces quite a number of uncharacteristic brown particles without cell structure are normally found. These cannot normally be identified; neither could they in this case. One cannot expect to find much animal tissues, as most of this has already been digested before the visceral contents reach the lower part of the large intestine. Only remains of plant tissue with thick walled cells and tissue with particularly resistent cell walls, e.g. hair with silicic acid in the wall, may be found. Therefore, it was very surprising to find a relatively high proportion of plant fragments with many different types of cell tissues.

We had not imagined the possibity of finding well-preserved tissue structure in this 500-year-old faeces lump. A comparatively large quantity of grains of sand in the preparations tells us that the food was polluted by soil. Soil and peat may have come from the peat walls around the cooking area.

For verification, we found it necessary to use standard comparison material for microscopic analysis. In this case, we found it exceptionally important, as we realized that the Eskimo might have consumed food unknown to us. Using such comparison material, received from University departments in Denmark, or belonging to the Department of Pharmacognosy, we could establish that the following was present in the sample:

Fig. 1. *Empetrum nigrum* ssp. *hermaphroditum*. Particle from the faeces showing covering hairs and one glandular hair. Mag. × 250.

Empetrum nigrum L. ssp. *hermaphroditum* (Hagerup) Böch, *Empetraceae,* (Crowberry)

Various fragments of leaves, still exhibiting covering hairs and glandular hairs, were identified as belonging to angiosperms (Fig. 1). These were determined to originate from *Empetrum nigrum,* ssp. *hermaphroditum* (Crowberry). However, we found neither fragments of fruits, nor particles of the stones, although these are so resistant that they normally pass unchanged through the intestinal tract.

Crowberry grows on heaths and in bogs, and is nowadays widespread in the southern part of Greenland. Crowberry is less common in north-west Greenland (Böcher *et al.* 1978).

Cassiope tetragona (L.) D. Don, *Ericaceae,* (White arctic Bell-heather)

Various particles of leaves identified as leaves from White Arctic Bell-heather were found. *Cassiope tetragona* forms heaths in the northern part of Greenland and is nowadays widespread around Qilakitsoq (Böcher *et al.* 1978).

Alopecurus alpinus Sm., *Poaceae,* (Mountain Foxtail)

Fragments of axes of stems with characteristic epidermis and covering trichomes were found. Mountain Foxtail grows in bogs, along riversides, near bird cliffs and around former habitations in north-west Greenland. (Böcher *et al.* 1978: Gassner 1973).

Elymus mollis Trin., *Poaceae* (Downy Lyme-grass)

Fragments of stems with trichomes very similar to the standard comparison material were found. Downy Lyme-grass grows on open, sandy ground on coasts and in river valleys. This species occurs in the southern part of north-west Greenland (Böcher *et al.* 1978).

Conifera sp., (Conifer)

Both conifer pollen and small fragments of conifer wood with the characteristic bordered pits were found. As no *Conifera* species grows in Greenland, it may be suggested that the fragments derive from wind-borne eroded conifer wood or from driftwood collected at the settlement by the inhabitants and used both for making tools and as firewood. A few of these fragments showed traces of carbonisation and may probably derive from burnt driftwood (Fig. 2).

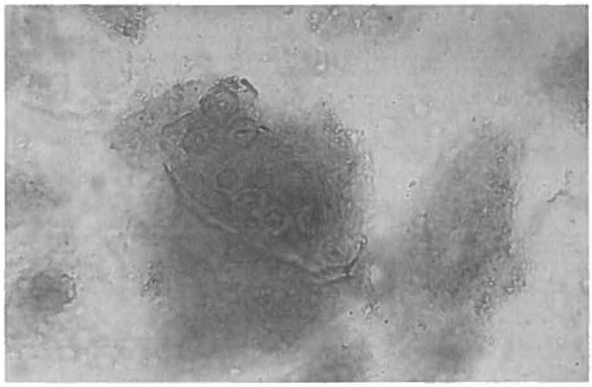

Fig. 2. *Conifer* sp. Particle from the faeces showing fragments with bordered pits.
Mag. × 250.

Several fragments from higher plants were found. The particles consisted of fragments of vascular bundles, but the surrounding tissue was so decomposed that they could not be finally identified. The group of lower plants was plentifully represented, especially by many whole shoots, leaves and leaf fragments from various mosses and bog mosses.

The following mosses have been identified (Andersen *et al.* 1976; Jensen 1923):

Aulacomnium turgidum (Wahlenberg) Schwaegr., *Aulacomniaceae*

Both shoots and fragments of leaves from this moss were found. The plant is common all over Greenland in almost all moist plant communities, like *Betula nana* heath, *Salix-Eriophorum* fen, *Vaccinium* heath, *Carex* fen and bogs, marshes, snowpatches and on soil between cliffs. (Fig. 3).

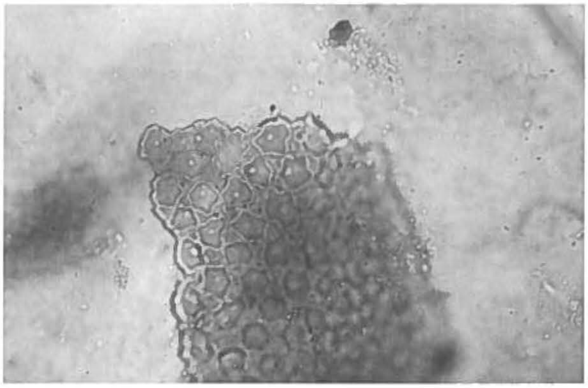

Fig. 3. *Aulacomnium turgidum.* Particle from the faeces. Mag. × 400.

Drepanocladus uncinatus (Hedw.) Warnst., *Amblystegiaceae*

Shoots and fragments of leaves were found. The plant is common all over Greenland, but rare in the far north. It is common in both moist and arid plant communities.

Hypnum sp., *Hypnaceae*

Only small leaves of *Hypnum,* represented by several species in Greenland, were identified.

Dicranum sp., *Dicranaceae*

Fragments of leaves were identified as belonging to this genus. Fragments probably belonging to the genus *Onchophorus* were also found.

Fragments of leaves from other mosses and *Sphagnum* (bog mosses) were found but have not been identified.

Furthermore, spores from *Lycopodium* sp., *Lycopodiaceae* (Club moss), pollen from *Conifer* and other plants, and many hyphae from unidentified fungi were found.

In the faeces sample, a few small particles of striated musculature were also found. They may come from meat or from fish, but cannot be further identified. However, particles from the following animals have been identified (Appleyard 1960; Grassé 1965):

Phoca groenlandica., Phocidae (Harp seal), or other species

Many hairs of different length and width were identified.

Rangifer tarandus, Cervidae (Caribou)

Only short pieces of broken-off hairs were found.

Lepus timidus, Leporidae (Alpine hare)

Some long hairs were found.

Lagopus mutus, Tetraonidae (Ptarmigan) and *Plotus alle, Alcidae,* (Little auk)

Feather and down, which – in the microscope – were quite similar to the standard comparison material, were found.

Acarina, (Mites)

Sugar mites (*Glyciphagus domesticus*) or Orbatid (*Tyroglyphidae*) and moss mite (*Oribatidae*) were identified. More mites – impossible to identify because of their poor condition – were also found (Fig. 4).

Fig. 4. *Oribatidae*. Moss mite from the faeces.
Mag. × 250.

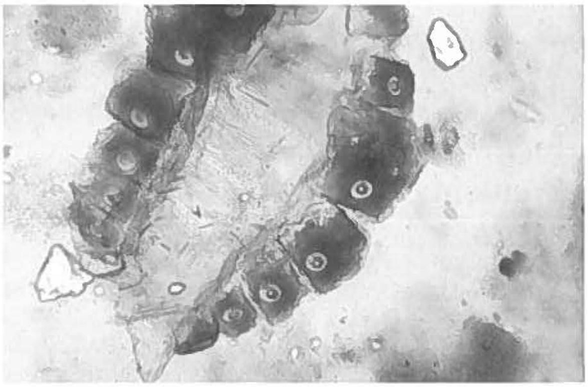

Fig. 5. *Pediculus humanus subsp. capitis*. Part of head louse from the faeces.
Mag. × 100.

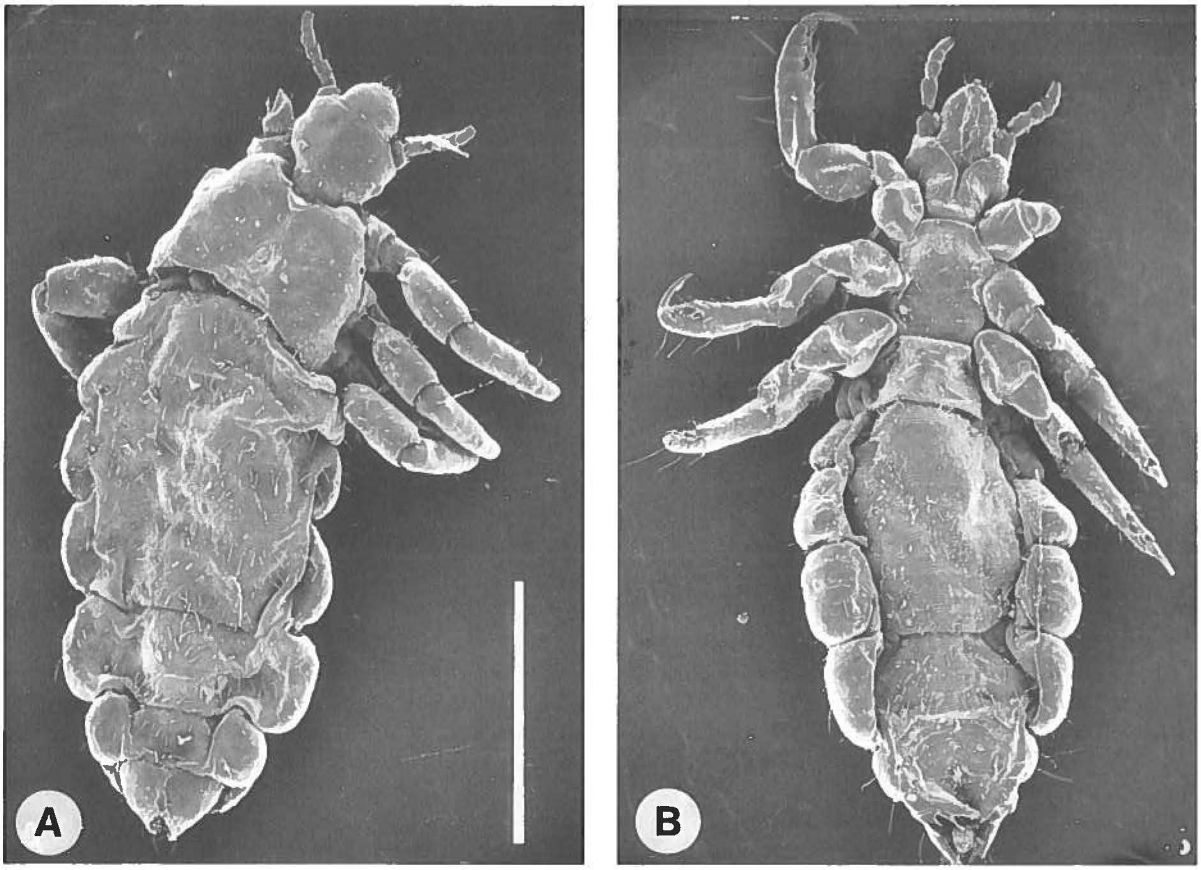

Fig. 6A and B. *Pediculus humanus subsp. capitis* deGeer from a mummified corpse of an Eskimo.
A: dorsal side (♀)
B: ventral side (♀)
Bar A & B 1 mm.

Pediculus humanus capitis. (Louse)

We found both big and smaller parts of lice but none was quite intact. Lice were also found on the hair of five of the Eskimos and in the pants of one of the women (Bresciani *et al.* 1983) (Figs. 5–6).

Enterobius vermicularis, Oxyuridae (Pinworm)

Several almost elliptical bodies measuring 50–75 μm were found. These bodies are probably ova from pinworms (Chandler & Read 1961).

Because of the many fragments of leaves from Crowberry, Mountain Foxtail and various mosses, it is assumed that these plants were part of the food. Furthermore, we suppose that the small particles of striated muscle from animal tissue were also part of the food.

When eating animals, the Eskimos may have eaten the animals' stomach contents as well. However, the identified fragments from plant tissue are in such a good state of preservation that we doubt that they have been exposed twice to the pancreatic juice, first in an animal and then in the gastrointestinal canal of a human being. On the contrary, we suppose that pollen, spores, fungi, mites and fragments from Conifer are impurities.

Hair, feather and down may be present in the intestinal canal because of unhygienic behaviour, or perhaps the Eskimos of those days also stored their food in their distinctive way, preserving whole birds and various plants or parts of plants together in the same bag made of sealskin.

It is not possible – on the basis of this microscopic analysis – to determine whether the Eskimo's last meal was consumed in summer or winter. The relatively high proportion of plant particles could mean that the last meal was enjoyed in the short summertime, when Crowberry, White Artic Bell-heather, Mountain Foxtail and Downy Lyme-grass flourished. Perhaps the Eskimos stored their food until the wintertime, as mentioned above.

Only leaves from *Empetrum nigrum* ssp. *hermaphroditum* were found, no berries or seeds (stones). The stones are very resistant and would undoubtedly have been present in the faeces if eaten. Today, the Eskimos consider Crowberries a delicacy. Therefore, we presume that the Crowberries were not ripe at the time of the woman's death.

Acknowledgements

Jette Levinsky, Botanical Museum, University of Copenhagen, has identified the mosses. Niels Haarløv, The Royal Veterinarian and Agricultural University, Copenhagen, has identified mites and lice. Karen Madsen, The Royal Veterinarian and Agricultural University, Copenhagen, has assisted us in identifying the eggs from pinworms.

Some of the standard comparison material has kindly been made available by various University departments in Denmark.

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Possible Family Relationships Revealed by Determination of HLA-transplantation Antigens

HANNA E. HANSEN

Hansen, H. E. 1989. Possible Family Relationships Revealed by Determination of HLA-transplantation Antigens. – Meddr Grønland, Man & Soc. 12: 144–146. Copenhagen 1990-01-26.

A determination of the transplantation antigens belonging to the HLA-A and HLA-B series was carried out with muscle and skin tissue by means of a microabsorption method. The results indicate that two families have been buried – one in each of the two tombs. No conclusion could be reached on the possibility of an admixture of Caucasian genes.

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The genes of the human histocompatibility system, the HLA system, are situated on the short arm of chromosome No. 6, (Fig. 1). The HLA system is a subject of intense research, because of its overall importance for donor-recipient matching in allotransplantation, and because of the role of the HLA antigens in general immunological recognition. Furthermore, the great polymorphism of the HLA system, and the fact that the antigens are expressed with variable frequencies in different ethnic groups, also makes the system a useful tool in ethnographic studies. (Bauer & Danilovs 1980).

The HLA antigens are structures of glycoproteins with great resemblances to the structure of the gammaglobulins, and they are found on the membranes of most nucleated cells in the body. An HLA determination is usually carried out with live lymphocytes, and the antigens of the HLA-A,-B,-C, and -DR series are all serologically recognizable, the HLA-A,B,C antigens on all lymphocytes, the HLA-DR antigens on B-lymphocytes. (Reviews: Bodmer 1978; Kissmeyer-Nielsen 1981).

The HLA determination of the mummies from Qilakitsoq was attempted because the bodies had been preserved under fairly favourable conditions: they were in fact freeze-dried by nature, and thus the structure of the HLA antigens could be expected to survive inside the larger muscles and in epidermis.

The purpose of the study was mainly to reveal possible family relations, and then to find whether the HLA antigens expressed in those Eskimos were typical of living Eskimo populations. The study involved the antigens of the HLA-A and HLA-B series, and the analyses performed by a microabsorption technique developed in this laboratory for identification purposes (Hansen & Gürtler 1979, 1982).

Below a short description is given of the technique used, with examples of the absorption diagrams, and the combined results of the analyses. Detailed descriptions of the investigations have been published elsewhere (Hansen & Gürtler 1983).

Technique

About fifty different HLA-antisera of well defined specificity and antibody titre were chosen for the experiments. For each absorption aliquots of 150–200 microlitres of centrifuged tissue, previously minced and softened with a balanced salt solution, were mixed with 50 microlitres of specific HLA antiserum. After incubation for one hour at 37°C, the serum was recovered by centrifugation. Titrations of absorbed and unabsorbed se-

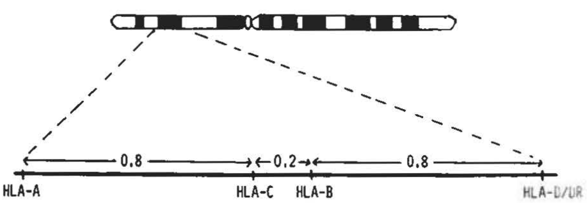
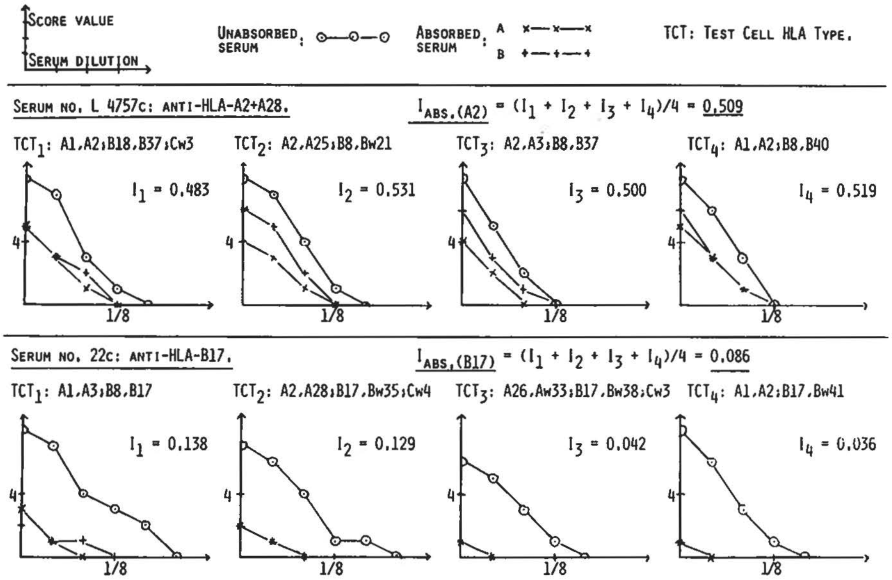


Fig. 1. Chromosome map of the HLA system, 1980.
Here the HLA-A series comprises 17 alleles, HLA-A1, A2, A3, etc., the HLA-B series 33 alleles, HLA-B5, B7, B8 etc. The HLA-C series 8 alleles, HLA-Cw1, Cw2, Cw3 etc. The HLA-D/DR series comprises about 10 defined alleles.
The map distance is given in centimorgans, e.g. a distance of 0.8 cM between the HLA-A and HLA-C locus means that the frequency of recombination between these two loci is 0.8 %. (WHO & IUIS Nomenclature Committee 1980).

Fig. 2 Examples of specific absorption (serum No. 22c) and non-absorption (serum No. L 4757c) from the HLA typing of mummy No. I/4. Reduction of antibody activity in the two reagents is measured by means of test cells from different donors with the appropiate HLA types, and unabsorbed and absorbed sera are tested in the dilutions Undiluted, ½, ¼, ⅛, 1/16, 1/32. It can be seen that serum No. 22c has almost completely lost the ability to kill HLA-B17-positive test cells. The proportion of dead test cells (%) is counted according to the score values (sc):0–5%: sc=0, 6–15%: sc=1, 16–30%: sc=2, 31–45%: sc=3, 46–55%: sc=4, 56–70%: sc=5, 71–85%: sc=6, 86–95%: sc=7, 96–100%: sc=8.
The absorption index, I, was estimated twice for each test cell donor, and was calculated as:

$$I = \frac{\text{area below graph for one absorbed serum sample}}{\text{area below graph for unabsorbed serum sample}}$$

The final index for the reduction of antibody activity in one serum is the average value of the indices obtained by the testing of the duplicate absorptions with the different test cell suspensions. The final Absorption Indes, $I_{abs.}$, for one HLA antigen is obtained as the average value of the indices for two or more antisera defining that antigen.
From Hansen, H. E. & Gürtler, H. 1983. HLA types of mummified Eskimo bodies from the 15th century. Amer. J. Phys. Anthropol. 61: 447–452.



rum were made in Hamax microchambers, and the ability of mummified tissue to remove specific HLA antibody from a given serum was measured by means of the NIH-microcytotoxicity test (Bodmer 1978). Thus, when an antiserum, compared with the unabsorbed serum, had lost the ability to kill specificalty lymphocytes from a donor of the appropriate HLA type, the HLA antibody was retained in the tissue because that mummy was likely to possess the corresponding antigen. Examples are given in Fig. 2.

The reduction of antibody activity in an absorbed serum sample, compared with the antibody activity in the unabsorbed serum, is measured quantitatively by means of the Absorption Index (Hansen & Gürtler 1982), (Fig. 2). The absorption indices from all the antisera used are expressed in one diagram for each mummy. An example is given in Fig. 3.

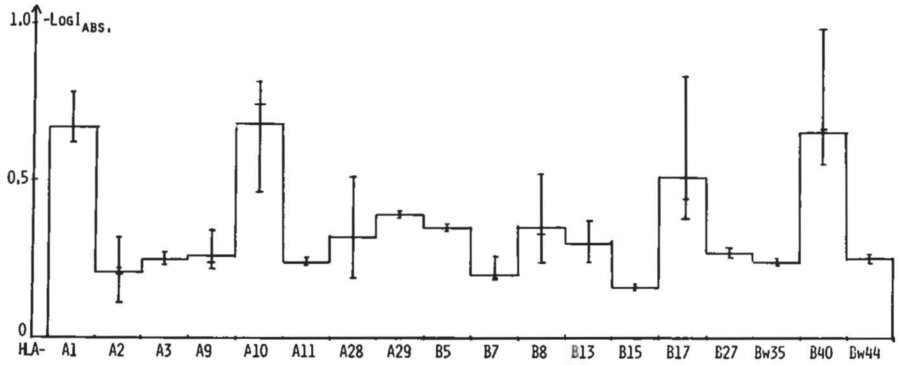


Fig. 3. Results of the HLA typing of mummy No. I/5.
In the diagram the HLA antigens investigated for all the mummies are listed along the X-axis. Along the Y-axis is marked the negative logarithm of the absorption indices for each of the antigens. The use of the negative logarithm makes the HLA types directly evident as the highest columns in the diagram. For each antigen the horizontal line is the negative logarithm of the average value of two or more indices, each of which is shown on the vertical line, that is one value for each of the different HLA antisera defining that antigen.
The HLA types of No. I/5 are: HLA-A1,A10;B17,B40. From Hansen, H. E. & Gürtler, H. 1983. HLA types of mummified Eskimo bodies from the 15th century. – Amer. J. Phys Anthropol. 61: 447–452.

Results and discussion

The tests were done on six adult women and the 4-5-year-old boy. The baby was excluded because of its size, as tissue could not be obtained without molestation. The results of the HLA-determinations were correlated with the placing in the two tombs and with the age at death of each person, as reported by the Danish National Museum (Fig. 4).

The results indicate that one family was buried in each tomb. A possible interpretation of the HLA results is: Tomb I: a grandmother (I/5), two daughters (I/4 & I/3) and one (two) grandchild(ren); Tomb II: two sisters (II/6 & II/8) and a young girl (II/7) who may have been the daughter of either of them. Theoretically the three eldest women, I/5, II/6 and II/8, could be sibs, in which case their parents had the HLA types A1,B17//A28,B5 and A10,B40//A28,B40 respectively, but this cannot be proved. II/6 may have been the mother of I/4 and I/3, but the young woman, II/7, cannot have been the daughter of any of the women in Tomb I, nor can she have been the mother of I/2.

A total of eight different HLA antigens were observed among the seven mummies. HLA-A9, A28, B5, and B40 are frequent among present-day Eskimos, while HLA-A1, A10, B8 and B17 are rare, although they have been observed (Kissmeyer-Nielsen *et al.* 1971; McAlpine *et al.* 1974). The studies of HLA gene frequencies among living Eskimos involve comparatively small population groups, so when a system as polymorph as the HLA system is considered, poor information is obtained about the frequencies of rare alleles. Rare genes may accumulate in isolates and in family clusters, and the HLA genes represented in two random families are due to chance. Thus the presence of four HLA alleles, rare among Eskimos but more frequent among Caucasians (Bauer & Danilova 1980), including Danes (Hansen *et al.* 1979), cannot be considered to indicate Caucasion admixture. These genes might just as well represent the genuine Inuit gene pool around AD 1475.

Age at the time of death	No.	Sex	HLA-type
Tomb I:			
40-50 years	I/5	F	A1,A10;B17,B40
About 30 years	I/4	F	A9,A10;B17,B40
20-25 years	I/3	F	A9,A10;B8,B40
4-5 years	I/2	M	A9,A10;B8,B40
Tomb II:			
About 50 years	II/6	F	A10,A28;B5,B40
40-50 Years	II/8	F	A28;B5,B40
About 18 years	II/7	F	A28;B5

Fig. 4. The results of the HLA determinations of the seven mummies from Qilakitsoq.
The HLA types are correlated with information from the Danish National Museum on the placing in the two graves, and on the age at death of each person. F = female, M = male.

Acknowledgements

The HLA determinations of the mummies from Qilakitsoq are supported by grants from the Danish Medical Research Council. Thanks are due to Mrs. Karen Haagendal and Mrs. Aase Buch Hansen for their excellent technical assistance.

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Bone Mineral Content in Ancient Greenlandic Eskimos

ANDERS GOTFREDSEN, JENS BORG & CLAUS CHRISTIANSEN

Gotfredsen, A., Borg, J. & Christiansen, C. 1989. Bone Mineral Content in Ancient Greenlandic Eskimos. – Meddr Grønland, Man & Soc. 12: 147–150. Copenhagen 1990-01-26.

Bone mineral content (BMC) of the distal forearm was measured by single photon absorptiometry (SPA), and bone mineral density (BMD) of the total arm was measured by dual photon absorptiometry (DPA) in four arms from the archaeological Qilakitsoq Eskimo burial. One arm was within normal Danish range with both SPA and DPA and one arm was subnormal with both methods. One arm from a four-year-old boy which was only measured by SPA was below the lower normal limit, and one arm was inside normal range with SPA, and below with DPA. Although the two methods were not totally in agreement the results indicate the possibility of an increased prevalence of osteopenia in the Qilakitsoq Eskimos.

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Eskimos of Alaska and Canada are subject to an earlier onset and a higher rate of bone loss than US Whites (Mazess & Mather 1974; Mazess & Mather 1975). Children and young adults have values comparable to the white Americans, but after the age of forty both male and female Eskimos have values 10–15% lower (Mazess & Mather 1974; Mazess & Mather 1975). This is supported by some earlier density measurements on bones from an archaeological North American Eskimo population (Mazess & Jones 1972), indicating the absence of a secular explanation of these observations.

We report on measurements of the bone mineral content (BMC) measured by single and dual photon absorptiometry in four arms from ancient Greenlandic Eskimos of the Qilakitsoq archaeological discovery.

Materials and methods

Four arms from the Qilakitsoq find were investigated. Their origins were: a four-year-old boy (I/2), a woman 18–22 years old (II/7), a woman 40–50 years old (I/5), and a woman about 50 years old (II/8). The ages were determined by anthropological methods.

The methods employed in this work for determination of BMC are used routinely in our laboratory for research purposes in studies which aim at the clarification of the calcium metabolism in health and disease. The following two methods were used in the present study.

Single photon absorptiometry (SPA). This method uses a 100 mCi ^{125}I radiation source emitting photons at 27.5 KeV (Christiansen, Rødbro & Jensen 1975). The traditional procedure was modified omitting the water bath in which the forearm of living subjects is usually immersed during measurement. The reason for this was that the air contained in the ancient arms would probably not be replaced by the water and would therefore lead to greater errors in measurement than the absence of the water. Furthermore, the need for a constant thickness of soft tissue/soft tissue equivalent was not so crucial in this study, as the soft tissue remnants were scarce and dried.

Six scans were made on the forearm, starting at the site where the radius and the ulna were 0.8 cm apart and moving proximally in a rectilinear manner, perpendicular to the long axis of the arm (distance between scans = 0.4 cm). BMC was expressed in arbitrary units (dimension: mass per unit length) and was calculated as a mean of six consecutive scans. The method had a long-term reproducibility on healthy subjects of 1%–2% (Christiansen & Rødbro 1977).

BMC by SPA was calculated as the percentage relative to healthy Danes of the same sex and in the same age decade. These normative data have previously been published (Christiansen & Rødbro 1975). The measurement procedure and a computer printout of one scan across the arm are shown in Fig. 1.

Dual photon absorptiometry (DPA). This method is based on the transmission of photons from a radioactive source emitting radiation of two well-defined energy

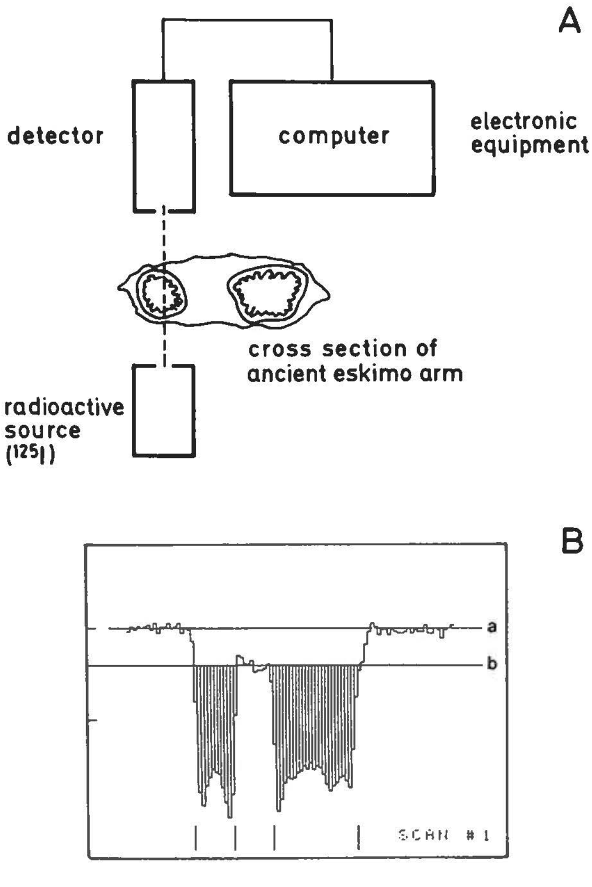

Fig. 1. *A:* BMC measurement procedure (single photon absorptiometry). A schematic cross section of an ancient forearm is shown as well as the radiation source (^{125}I), the detector, and the electronic equipment.
B: A computer printout of the first of the six scans from one of the arms. The profile of the curve expresses the amount of bone mineral. The baseline (*a*) is the beam intensity in air, and the line *b* averages the amount of soft tissues (remains of muscles, connective tissue and skin). The distance from line b to the bone profile curve equals the amount of bone mineral in a particular pixel (one pixel equals the width of a column of the hatching).

levels. We use a 1 Ci ^{153}Gd source with principal photo peaks at 44 and 100 KeV. The DPA scanner at Glostrup Hospital is usually employed as a total body scanner for determination of the body composition in patients and healthy subjects (total body bone mineral, lean body mass, body fat). The apparatus for DPA measurements is shown in Fig. 2. Subjects are scanned in a rectilinear raster pattern with a scan speed of 1 cm per second and longitudinal steps of 2.5 cm. Data are recorded in 0.5 second intervals. The ancient Eskimo arms were measured in the same manner as living subjects.

BMC by DPA is calibrated against dry defatted bones, and is thus expressed in grams dry defatted bone weight, or grams mineral which is 68% of the dry bone value. The precision and accurcy errors of the DPA bone mineral measurements are 1.5% and 2.5% respectively (Gotfredsen *et al.* 1984a, 1984b).

The BMC values of the Eskimo arms measured by DPA were expressed as a bone mineral density (BMD) in grams mineral per cm^2. The measurements were compared to the values of 18 healthy premenopausal and 17

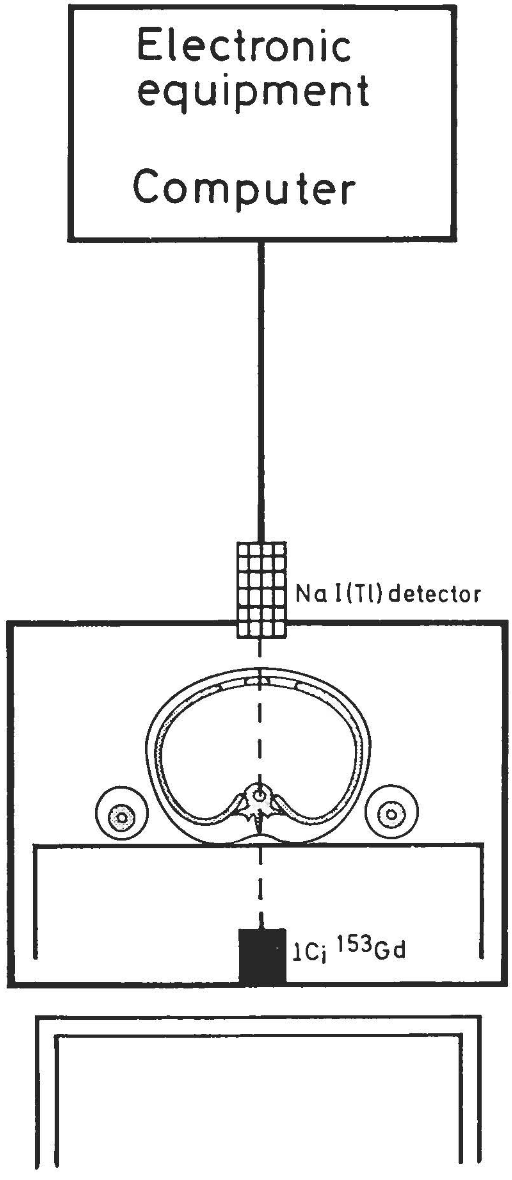

Fig. 2. BMC measurement apparatus (dual photon absorptiometry). A schematic cross section of a subject is seen on the scanner. The radionuclide (^{153}Gd) is placed below the subject and the detector is situated directly opposite, above the subject. During the scanning the subject (or the ancient Eskimo arms) is lying on the couch while source and detector move from side to side, and longitudinally by 2.5 cm steps.

healthy postmenopausal Danish women in which the BMD of the arms had been selected from the total measurement by computer techniques. These healthy women have been described elsewhere (Gotfredsen *et al.* 1986). The BMD by DPA was calculated as the percentage relative to the values of the healthy women.

Results

The result of the bone mineral determination by SPA is given in Fig. 3. The average bone mineral content in the distal forearms in healthy Danes was set at 100%. The normal range was chosen as mean ± 2 standard deviations (hatched area in Fig. 3). If a BMC measurement lies within this area (i.e. 77% – 123%) it is regarded as normal. Two of the Eskimo arms (II/7, 18–22-year-old woman and II/8, 50-year-old woman) had BMC ratings within the Danish normal range (91% and 97%, respectively). Two of the arms fell below the lower limit of normal range (I/2, four-year-old boy and I/5, 40–50-year-old woman) with 71% and 63% respectively.

The arm from the four-year-old boy was not measured by DPA because its dimensions were too small to give a reliable result with this method. BMD measured by DPA for the three arms from the adult women is shown in Fig. 4. The mean BMD of the 35 healthy women is denoted by 100%. The normal range (hatched area) was chosen as mean ± 2 standard deviations (83% – 117%). One of the Eskimo arms (II/7) was close to the normal mean, whereas the other two (II/8 and I/5) were below the lower limit of the normal range.

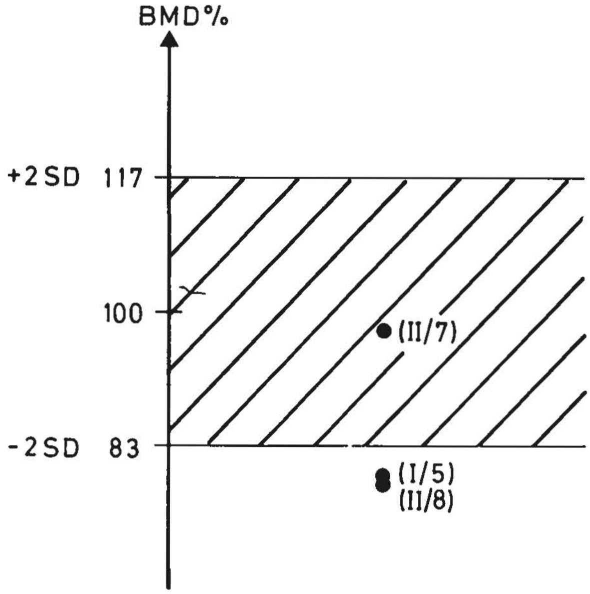

Fig. 4. BMD by dual photon absorptiometry of three ancient Eskimo arms. BMD is given as a percentage of corresponding normal Danish mean. The hatched area is normal mean ± 2 standard deviations.

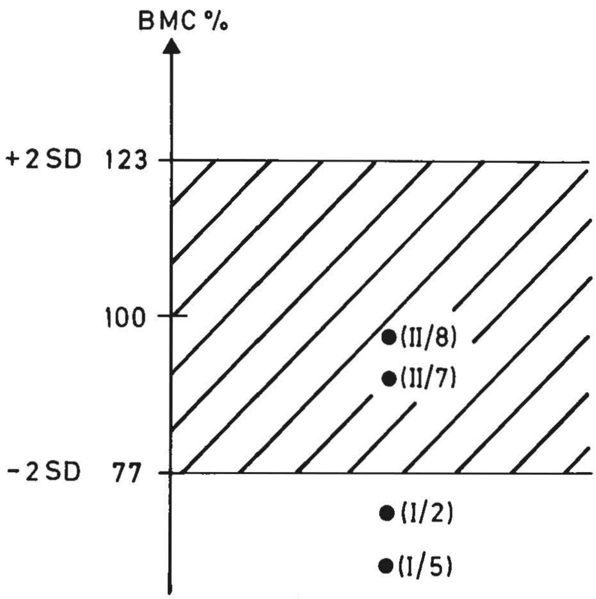

Fig. 3. BMC by single photon absorptiometry of four ancient Eskimo arms. BMC is given as a percentage of corresponding normal Danish mean. The hatched area is normal mean ± 2 standard deviations.

Discussion

The small sample size does not permit us to draw any extensive conclusions. The differences between results with single and dual photon absorptiometry may have several origins. First, the control materials for the two different methods were not the same. Second, the distral forearm BMC by SPA may not be totally indicative of the total arm BMD by DPA. Third, the modification of the ordinary distal forearm SPA measurement to suit the purpose of the present investigation may have introduced some systematic error.

However, one arm (II/7) was consistently inside the normal range with the two methods, and one arm (I/5) was below the normal range with both SPA and DPA. The child arm was below normal range with SPA, and arm No. II/8 was below normal range with DPA. A low bone mineral content (and density) is therefore detectable in ancient Eskimo arms, indicating the presence of osteoporosis.

The reason for early bone loss in Eskimos is not fully explained. The acidic effect on calcium excretion of a diet with high protein (meat) content has been proposed (Mazess & Mather 1974), and serum concentrations of calcium have been found in Greenland Eskimos that were significantly lower than those of subjects living in Denmark (Jeppesen & Harvald 1983).

Acknowledgements

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Estimation of Age at Death and Histomorphometric Analysis of Cortical and Trabecular Bone from Four Greenlandic Mummies

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Thompson, D. D., Cowen, K. S. & Laughlin, S. B. 1989.Estimation of age at death and histomorphometric analysis of cortical and trabecular bone from four Greenlandic mummies. – Meddr Grønland, Man & Soc. 12: 151–155. Copenhagen 1990–01–26.

Iliac crest and femoral bone specimens from four Greenlandic mummies were assessed. Estimated ages at death were calculated, cortical bone mass and bone histological variables from the cortical bone specimens and trabecular bone volume, surface area and diameter from the iliac crest specimens were measured. The cortical bone did not show pathological changes. The trabecular bone variables indicated that one woman was osteoporotic.

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The analysis of mummified remains provides an important link between investigations conducted in skeletal populations and investigations conducted in living populations. The use of the living-dead continuum as a research paradigm has proven valuable in discerning patterns of skeletal aging and osteoporosis among Eskimos (Thompson and Gunness-Hey 1981; Thompson *et al.* 1982). Analysis of skeletons from mummies is especially useful to fill in gaps in information between living and dead skeletal populations; information that is not otherwise obtainable from investigations of living populations or from archeological skeletal populations (Thompson and Cowen 1983). Information excluded from the analysis of archaeological populations ranges from cause of death and soft tissue pathologies to soft tissue composition. Information excluded from the analysis of living populations ranges from the inability to obtain multiple biopsies to a lack of time depth in the analysis. It can be assumed that mummified bone has undergone little post-mortem deterioration and is therefore a good approximation of the condition of the skeleton at the time of death. Additionally, the skeletons of mummies are from periods of time that are often identical with time periods from which archaeological populations are obtained.

For correct interpretation of skeletal data derived from the analysis of mummies, it is desirable to have the same data derived by the same techniques in the living population inhabiting the same geographical region and in the ancestral antecedent populations represented by the skeletons. For example, osteoporosis, a metabolic bone disease, occurs with the world's highest frequency among Eskimos of Alaska, Canada, Greenland, and the USSR (Harper *et al.* 1984; Mazess and Mather 1974, 1975; Thompson *et al.* 1982). This condition is also apparent in Eskimo skeletal populations as old as 1500 BP (Thompson and Gunness-Hey 1981). The site preferred in the diagnosis of metabolic bone diseases, including osteoporosis, is a point on the iliac crest 2 cm posterior and inferior to the anterior superior iliac spine (Merz and Schenk 1970). Age, sex, and disease standards have been established for a host of trabecular bone variables at this site (Byers 1977). Iliac crest biopsies from patients and autopsies where age, sex, etc. are known, and from mummies and archaeological skeletons permit aging and disease patterns to be analyzed across time, between ages and sexes, and between populations.

A second site that is useful in understanding aging and disease patterns and provides complementary data on both processes, utilizes cortical bone instead of trabecular bone. This site at the anterior femoral midshaft permits the analysis of bone mass, bone quality, and of histological features that can be compared with features derived from the iliac crest biopsy from the same skeleton to derive an aging and disease profile from both cortical and trabecular bone. Also derived from the analysis of the femoral bone site is the estimation of age at death determined by the quantification of histological structures following methods described by Thompson (1979).

The purpose of this paper was to assess iliac crest and femoral bone biopsies from four Greenlandic mummies. Estimated ages at death were calculated, cortical bone mass, and bone histological variables from the cortical bone biopsies and trabecular bone volume, surface area and diameter from the iliac crest biopsies were measured. Next, each of the variables is compared with the results obtained from identical analyses in other Greenlandic Eskimo skeletons, in other Eskimo mummies, and finally with living populations.

Materials and methods

Four Greenlandic mumies identified ad I/2, I/5, II/7, II/8 were included in this study. Bone cores 0.4 cm in diameter were taken from one femur from each mummy. Also sampled was a point on the iliac crest from mummies I/2, I/5, II/7, II/8, 2 cm posterior and inferior to the anterior superior iliac spine.

Femoral core analysis

From each intact femoral core removed, cortical thickness (mm) was measured with dental calipers. The endosteal end of the cores was ground to form a cylinder of bone. Bone weight was determined to the nearest 0.0001 gm. Cortical bone density (gm/cm^3) was calculated as the weight of the core divided by the core volume. Next, bone sections 90 microns in thickness were removed from the core with the aid of a low speed saw. The plane of core sectioning was transverse to the longitudinal axis of the femur. With the aid of a semi-automatic, computer-assisted image analyzer, five features were measured in each bone section from each femoral bone core. The variables were: secondary osteon area (mm^2), secondary osteon perimeter (mm), Haversian canal area (mm^2), Haversian canal perimeter (mm), and secondary osteon number per mm^2. Three adjacent periostally-bound fields were analysed in each section and means for each of the five variables across the three fields were computed. Age at death was estimated for each mummy with the use of a regression formula for age estimation generated by Thompson (1979). The formula is y(age)=101.9(x) + 6.7 + 6 years where x is equal to the secondary osteon area times the number of osteons per mm.

Table 1. Greenlandic Mummy Bone Mass Variables

Mummy ID	Cortical Thickness (mm)	Core Weight (gm)	Cortical Bone Density (gm/cm^3)
I/2	1.40	0.0252	1.784
I/5	5.00	0.0977	2.031
II/7	4.25	0.0817	1.993
II/8	3.60	0.0585	2.078

Iliac biopsy analysis

From the iliac crest biopsies removed from the standard clinical biopsy site, sections 80 microns in thickness were taken in a coronal plane. The iliac sections were magnified 44x and using the point counting method the following variables were quantified: trabecular volume, trabecular surface length (mm) and trabecular diameter. Five fields each 4 mm^2 were analyzed and the means for the trabecular variables were computed.

Results

Femoral core analysis

Cortical thickness values and cortical bone density values derived from the analysis of the anterior femoral midshaft cores from each of the mummies are presented in Table 1. The cortical thickness value of 1.40 mm for mummy I/2 suggested a very young age. The other three cortical thickness values fell within the expected Eskimo female range (Thompson and Gunness-Hey 1981). Cortical bone density values (gm/cm^3) indicated no systemic pathological changes in bone composition as they are all within the range for "normal" cortical bone density values. The "normal" range for cortical bone density is 1.75 – 2.05 gm/cm^3 (Thompson 1979).

Table 2 contains mean values for each histological variable obtained across three periosteal fields for each

Table 2. Greenlandic Mummy Cortical Bone Histological Variables

Mummy ID	Secondary Osteon Area (mm^2/mm^2)	Secondary Osteon Perimeter (mm)	Haversian Canal Area (mm^2/mm^2)	Haversian Canal Perimeter (mm)	Secondary Osteon Number (#/mm^2)
I/2	0.0675	0.9271	0.0130	0.3648	5.33
I/5	0.0305	0.6379	0.0047	0.2374	14.00
II/7	0.0543	0.8473	0.0056	0.2651	4.33
II/8	0.0313	0.6521	0.0039	0.2325	13.00

Table 3. Greenlandic Mummy Iliac Crest Trabecular Bone Variables

Mummy ID	Trabecular Bone Volume (%)	Trabecular Surface Length (mm)	Trabecular Diameter (mm)
I/2	13.4	1.998	0.597
I/5	10.1	1.641	0.651
II/7	21.3	2.512	0.472
II/8	17.5	2.212	0.505

Greenlandic mummy. Mummies I/2 and II/7 revealed few but large secondary osteons, compared with mummies I/5 and II/8. This combination of histological features is indicative of very young age. Thus, these individuals must be considered less than twenty years of age. This finding is based upon analysis of individuals less than 20 years of age where the mean secondary osteon perimeter is typically greater than 0.80 mm (Thompson, unpublished results). As individuals age and maximum adult growth is attained (after 20 years of age), secondary osteon size decreases, but in a nonlinear fashion, while the number increases linearly (Thompson 1978). Estimation of age at death by histological methods in young individuals therefore often produces inaccurate results. Because age-estimating regression equations (Thompson 1979) take into consideration the linear age related increase in osteon number and the variation in osteon size, the variable remodelling rates observable in growing bone (both longitudinal and lateral) yield errant age estimate results. The growth rate of each individual less than 20 years will determine how accurately age at death can be estimated. Individuals who have undergone femoral epiphyseal closure earlier in life will undergo earlier adult remodelling of the periosteal femoral midshaft. This pattern of skeletal growth would make it possible to estimate age at death more accurately in this type of skeleton than in a skeleton that experienced growth at a slower rate.

Mean osteon number for each mummy bone section ranged from 4.33 per mm^2 in II/7 to 14 per mm in I/5. Haversian canal area and perimeter are similar in mummies I/5, II/7, and II/8, but considerably larger in I/2 (Table 2). The large Haversian area and perimeter and large secondary osteons in I/2 were further indications of a very young individual. Estimated ages at death for mummies I/5 and II/8 were 51 and 48 years respectively. Mummy II/7 was estimated by the use of histological methods for adults to have been 30 years old.

Iliac biopsy histomorphometry

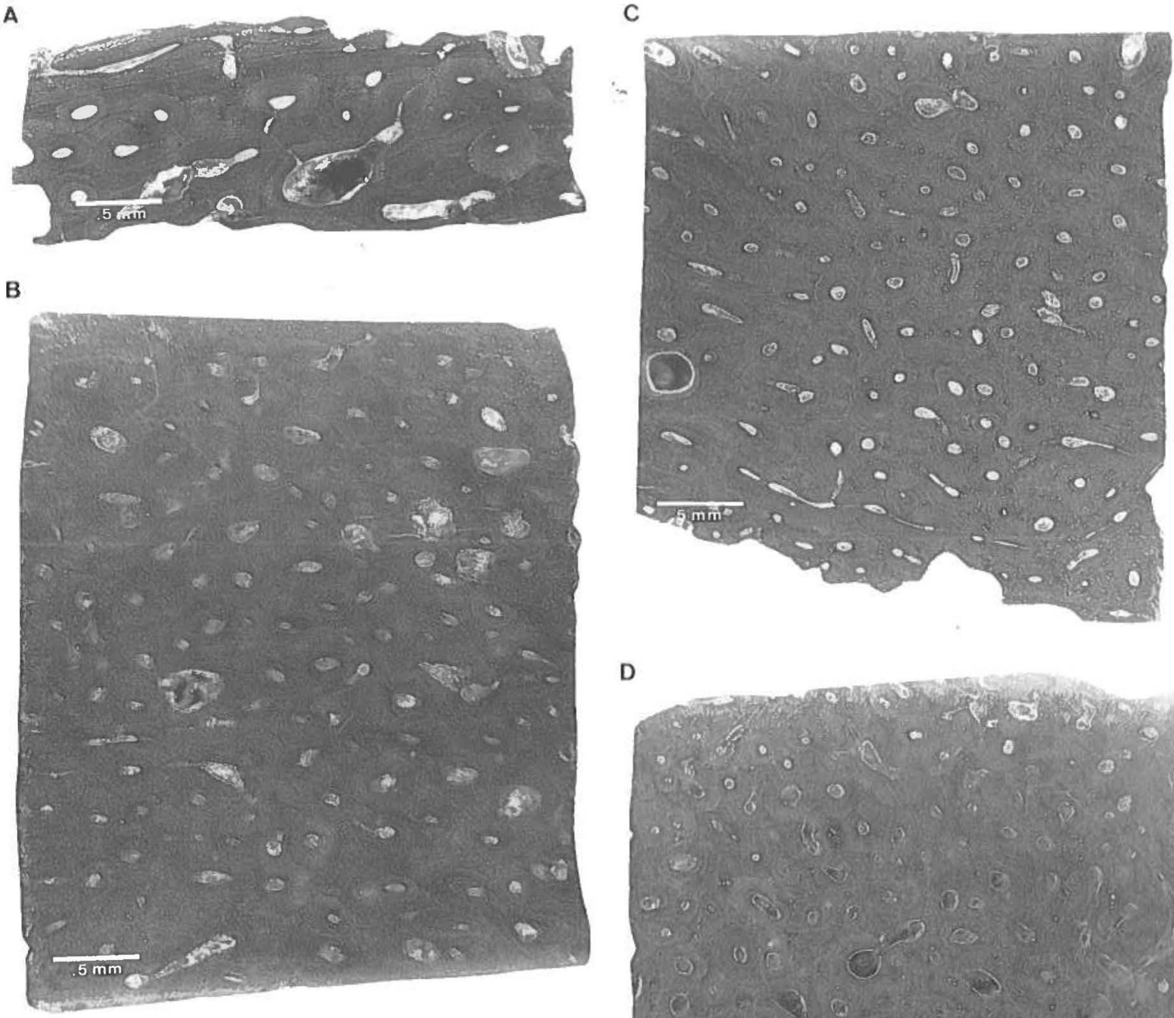
Data from the histomorphometric quantification of the iliac biopsies from mummies I/2, I/5, II/7, and II/8 are presented in Table 3. The trabecular bone values obtained from the analysis of the iliac biopsy from I/2 were expectedly low. Using 16% trabecular volume as the point of discrimination between osteoporotic and nonosteoporotic skeleton (Byers 1977), it is apparent that mummy I25 with a trabecular volume of 10% had clinically defined osteoporosis (Figure 2). Mummies II/7 and II/8 with trabecular volumes of 17.5% and 21% respectively were considered nonosteoporotic. Similarly, mummy I/5 showed the lowest trabecular surface length of the three adult mummies (1.641 mm) compared with 2.512 mm for mummy II/7 and 2.212 mm for mummy II/8.

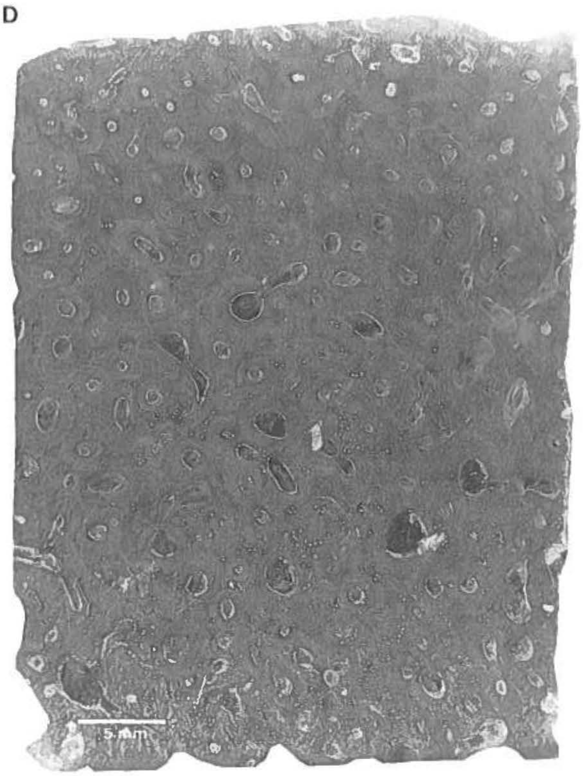
Discussion

From the analysis of cortical and trabecular bone samples taken from standardized sites in four Greenlandic mummies, several important features emerged. First, the femoral cortical thickness values obtained from the analysis of the Greenlandic mummies were virtually identical to those obtained in a large series of Greenlandic Eskimo skeletons (Thompson, unpublished data) and to those obtained from Eskimo skeletons from Canada, Alaska, and the USSR (Thompson and Gunness-Hey 1981). Additionally, cortical thickness values from Eskimos were less than values obtained from US white skeletons of similar ages (Thompson *et al.* 1982). Second, cortical bone density (gm/cm^3) values obtained from cortical bone samples from the Greenlandic mummies were well within the normal ranges of 1.75–2.05 gm/cm^3. Comparable, normal cortical bone densities were obtained for other Greenlandic Eskimo skeletons, for other Eskimo mummies, for other Eskimo skeletons from Canada, Alaska, and the USSR, and for US whites and blacks (Thompson *et al.* 1982). From these data it can be concluded that only under extensive postmortem deteriorative conditions or systemic metabolic bone disease will cortical density values fall outside this range.

Histologically, the cortical bone from the Greenlandic mummies did not show any conditions suggestive of pathological bone remodelling. The areas and perimeters of the secondary osteon and Haversian canals fell within normal ranges. The age at death determination by histological quantification for mummy I/2, a sub-adult, was not performed because standards for this group do not exist. The variability in cortical bone remodelling and modelling rates during growth renders a histological technique of age determination of little use. It is only with the attainment of adult proportions and the cessation of modelling or sculpting of the skeleton that histological techniques become useful.

The quantification of trabecular bone variables in the ilium revealed the oldest mummy, I/5, to have the least amount of trabecular bone and this was considered to





be osteoporotic. The other adult mummies, II/7 and II/8, had normal trabecular volumes for their age and sex. The low trabecular bone quantity in the iliac crest of mummy I/5 did not correspond with the cortical thickness in the femur, where I/5 had the greatest thickness of the three adult mummies. Osteoporosis has been considered to have a variable expression in the human skeleton (Albright and Skinner 1979). In some osteoporotic individuals, only trabecular bone values are lower than normal and in others both cortical and trabecular bone quantities are lower than normal. In the case of I/5, it is probable that the osteoporotic condition was only apparent in trabecular bone. It may be hypothesized that the bone loss experienced by mummy I/5 at the time of her death was recent in its onset and had not yet extended to cortical bone. Several investigations have shown that with advancing age, trabecular bone is lost earlier and more rapidly than cortical bone (Albright and Skinner 1979) and the rate is most rapid

Figure 1. Anterior femoral midshaft sections (90 microns in thickness) from Greenlandic mummies: A) I/2, B) II/7 – estimated by histological methods to have been 30 years of age at death, C) II/8 – estimated by histological methods to have been 48 years of age at death, and D) I/5 – estimated by histological methods to have been 51 years of age at death.

shortly after menopause. Mummy I/5 was estimated to have been 51 years old and thus likely to have have experienced significant normal, post-menopausal, age-related trabecular bone loss which resulted in an osteoporotic skeleton. The relatively young age of mummy I/5 (51 years), yet demonstrating clear signs of osteoporosis, indicates the prevalence of the bone disorder among Eskimos, first identified in the investigation of living Eskimo populations (Mazess and Mather 1974). Also indicated is the existence of this condition in the past, as has been shown by the investigations in Eskimo skeletal populations (Thompson and Gunnes-Hey 1981) and in other Eskimo mummies (Thompson and Cowen 1983).

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Bone Analysis: Silent Testimony of Lead Exposures in the Past

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Modern-day environmental pollution by lead results in considerable adverse health effects. Increased lead exposures are a result of modern technology, and pre-industrial exposures were presumably very low. This possibility may be examined by analysis of mummified human tissues from the past. Bone samples are particularly well suited for this purpose, because the skeleton contains most of the body burden of lead, and because well preserved bone tissue is unlikely to be contaminated post mortem. Trabecular bone from a lumbar vertebral body was taken from each of the mummified bodies from Qilakitsoq, except for the youngest child. The lead concentrations were determined by atomic absorption spectrometry with routine procedures against laboratory contamination. The lead levels varied between 0.12 and 0.30 µg/g dry weight with a median of 0.21 µg/g. Although slightly lower levels may be obtained by using more rigorous clean-laboratory techniques, the results found are similar to minimal levels measured in bone tissue from Nubians of Northern Sudan and Precolumbian Peruvians. Thus, the Qilakitsoq Eskimos lived in a pristine environment low in lead. This result offers an independent indication that modern-day lead exposures are considerably in excess of base-line levels to which humans have originally adapted.

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Chemical information contained within preserved skeletal tissues may be used to provide historical and prehistorical insights into the activities and environmental conditions of past populations. The analytical data derived from skeletal remains can be considered a testimony of previous events. In particular, testimonies provided by these long dead "silent witnesses" may expand our knowledge concerning human lead exposure in different geographical areas over a range of time periods.

Weighty testimonies by such "silent witnesses" especially relate to arguments concerning the relative magnitude of modern-day lead exposure. Patterson (1965) estimated that environmental pollution had increased the human body burden of lead by 100-fold above the "natural" or "unpolluted" level. Publication of this proposal with its significance for low-level lead toxicity initiated a major controversy which has not yet been fully resolved.

Analysis of the skeletal system provides most of our reliable information about past lead exposures. Bone and tooth are frequently the only remaining tissues from ancient burials, and lead is, fortunately, preferentially stored in calcified tissues. However, as these tissues are complex and subject to contamination by exogenous material, caution should be exercised in their use and in data analysis. In addition, lead analysis of calcified tissue is associated with many problems and pitfalls. Based on detailed evaluation, the weight of the evidence provided by these "silent witnesses" should be carefully considered. A few analyses of human calcified tissues from premetallurgical eras have suggested that large increases in lead exposure have occurered since then (Ericsson *et al.* 1979; Grandjean *et al.* 1979) and this chemical testimony therefore supports Patterson's views. In this way chemical information extracted from well-preserved mineralized tissues may be used to answer a contemporary question regarding environmental pollution.

The Qilakitsoq mummies provide an exceptional opportunity to examine Patterson's (1965) hypothesis. The burials took place about 500 years ago, when metallurgy and lead technology was unknown among the Eskimos. The bodies were mummified by the dry and very cold conditions in the cave, and the bone tissues were well protected against any post mortem contamination in the grave. In addition, long-range transport of lead aerosols from European smelting of lead was minimal, as indicated by the very low lead concentrations found in Medieval snow layers from Greenland inland ice (Murozumi *et al.* 1969).

Lead accumulation in the skeleton

Following absorption, lead ions in the blood are efficiently retained in the calcified tissues. Indeed, the skeleton can be likened to a huge ion exchance column with the bone mineral phase serving as the exchange medium. The effectiveness of this scavenging system is such that over 90% of the body burden of lead is located in the skeleton (Barry 1978).

A major factor influencing the bone retention of lead is the metabolic activity of the tissue. Local lead uptake varies due to differences in vascularity of the tissue. Indeed, compared with Haversian bone, active periosteal and sub-epiphyseal bone have very high affinities for lead. However, the lead content of a bone is a function of both the rate of ion uptake and the rate of its release. Compartmental analyses suggest that the average biological half-life for skeletal lead is about ten years, but it varies, of course, with bone type and composition. Thus, the average rate of bone remodelling in adults is about 3.5% per year, but this rate varies from a high of 8% in vertebrae to a low of 1.5% in femurs (ICRP 1975). In agreement with this observation is the finding that cortical bone contains more lead than trabecular bone. Our own studies have shown that temporal bone contained 50% more lead than the vertebral body (Grandjean 1975), and similar results were found by Drasch (1982). Further, because of the very long half-lives of lead in bones, the accumulation of lead may continue throughout the entire life of a human being. When considering bone lead levels, the biological age should therefore be taken into account.

Selection of materials

The main problem in the selection (and preparation) of archaeological samples is the avoidance of post-mortem changes in lead concentration. In our experience, the best specimens are those which have been well preserved in extremely dry environments. Although lead is firmly bound in the calcified tissues, some solid-solution migration and re-crystallization may take place over extended time periods. Migration may occur because the apatite retains its ion exchange characteristics; this property facilitates both lead uptake from the external environment and lead release from the bone. Of course, if exogenous water is unavailable, loss of bone lead would be minimal. In humid conditions, particularly when the soil pH is low, some lead leaching and migration could occur. Unfortunately, the direction and extent of lead transport and migration are difficult to evaluate. Cases of severe lead contamination of bones from a lead coffin have been described by Waldron (1981).

An additional problem which gives rise to abnormally high lead levels is post-mortem contamination of the specimen with dust particles. Exogenous lead-containing particles can adhere to tissue samples and microparticles can become incorporated into the apatite structure. Such particles may arise from the soil and the burial vessel. More recently, anthropogenic lead aerosols have become an atmospheric source of exogenous lead.

Decontamination methods may not completely solve these problems. When sparingly soluble lead salts from soil water become incorporated in bone mineral, the lead ion enters the apatite lattice and undergoes heteroionic exchance with Ca^{2+} or even Mg^{2+}. Thus, the importance of post-mortem contamination of archaeological samples should not be overlooked. Clearly, as environmental lead pollution is ubiquitous, this type of contamination represents a major research obstacle.

When comparing mummified bones to bone samples from present-day autopsies, the possible difference in contents of organic materials should be taken into account. On a dry weight basis, fresh samples contain relatively less lead than do samples without the organic matrix. For femoral bone, Drasch (1982) found a difference of 28%.

Occasionally, tissues other than bone or teeth may be available for chemical analysis. For example, we have examined mummified brain tissue from Sudanese Nubia (Grandjean *et al.* 1977). Unfortunately, postmortem contamination is difficult to remove or exclude, because the tissue may have been permeated by exogenous lead. In addition, lead concentrations cannot be given with reference to dry weight because organic components of the mummified brain have been degraded. For this reason, we chose to express the lead concentration as a function of brain copper. Copper has a long biological half-life and, in contrast to lead, is found in relatively constant amounts in brain. Although the Nubian samples exhibited very low bone lead levels, the lead/copper ratios varied widely but were not significantly different from present-day values. However, a child who exhibited excessive lead concentrations in teeth and bones also had the highest lead/copper ratio found in the Nubian material (Shapiro *et al.* 1980). These results suggest that while the soft tissues may reflect the level of lead exposure, the actual analytical data derived from mummified tissues may be difficult to interpret.

Finally, some comments about lead analysis of hair may be appropriate. While this complex structure is frequently used for toxicological studies, in only a few instances have hair samples from historical and prehistorical times been utilized for lead analyses. The use of this tissue entails some problems similar to those of bone. The most important one is exogenous contamination; indeed, to remove this type of contamination without changing the endogenous lead level is not an easy undertaking (Grandjean 1978). Further, Lockeretz (1973) suggested that the significance of such contamination may increase with time and make interpretation of lead analyses virtually impossible, particularly if the hair was exposed to moisture. Thus, although hair analysis may be utilized as a screening procedure for the measurement of current lead exposure, the use of hair for archaeological sample evaluation has some severe drawbacks.

Calcified tissues are therefore useful for lead analysis for three reasons: 1) most of the body lead burden is retained within these tissues; 2) bones and teeth may be preserved for millenia under dry conditions without major changes in their mineral contents; and 3) surface contamination may be easily removed.

Analytical Procedures

Three critical steps are notable in the measurement of lead in calcified tissues: (1) specimen decontamination, (2) specimen preparation, and (3) sample analysis.

1. Specimen decontamination

A number of specimen cleaning procedures have been described in the litterature. No one method has received universal acceptance. As we have obtained favourable results using an ultrasonic bath to clean hair of surface contamination, we have used this technique to wash bone as previously described (Grandjean *et al.* 1979). More thorough washing techniques have been based on exposure of the tissue to dilute acid (Ericsson *et al.* 1979), but this approach is much more drastic, and extreme care must be exercised in its use. All handling should take place under clean laboratory conditions.

2. Specimen preparation

Frequently, the research worker does not have the luxury of deciding which piece of bone or tooth should be utilized for lead analysis. However, in this study where specimen size was not limiting, the following guidelines were observed. Comparable morphological fragments were selected from the trabecular part of each vertebral body. As in a Japanese study (Ishinishi 1978), interior sections of bone were used to avoid surface contamination. Care was taken to use lead-free surgical scalpel.

3. Sample analysis

Calcified tissues may be dissolved for analysis after ashing the sample in an oven or by wet digestion with acid. Dry ashing may pose a problem because lead is lost from the sample at temperatures above 500°C. Low temperature ashing with excited oxygen is inefficient. Acid digestion is currently the preferred method, and both nitric and perchloric acid may be used. Fresh samples are more easily demineralized with perchloric acid than by nitric acid. However the presence of perchloric acid can produce matrix effects which interfere with flameless atomic absorption detection techniques. In the present study, which was carried out in 1983, concentrated, ultrapure nitric acid was used as previously described (Grandjean *et al.* 1979).

A number of different, sensitive detection methods are available. We have used, with favourable results, atomic absorption spectroscopy (Grandjean *et al.* 1979). The results obtained by this method are reproducible and correlate well with those obtained by anodic stripping voltammetry. All specimens were separated in two subsamples which were both analysed in duplicate on a Perkin-Elmer atomic absorption spectrometer with deuterium background correction and a graphite furnace HGA-76. The coefficient of variation of duplicate results averaged 21%. The IAEA reference material of animal bone was analysed repeatedly in the laboratory with excellent results (Grandjean *et al.* 1984). However, the lead level in this material is about 15-fold above that in the Qilakitsoq mummies and may not be relevant for the analytical quality assurance. On the other hand, repeated assessment of lead concentrations in a commercial hydroxyapatite preparation has shown a coefficient of variation of 27% at an average level of 0.41 μg/g which is closer to the mummy lead levels. However, these determinations were made on 1-mg aliquots of the material. Thus, analytical and biological variations may be relatively large at such low lead concentrations.

The Qilakitsoq testimony

The lead concentrations found are given in Table 1. All results are averages of duplicate analyses of two samples from each mummy. Due to the possibility of minor laboratory contamination, these results should be re-

Table 1. Lead concentrations (μg/g dry weight) in vertebral bodies from the Qilakitsoq mummies.

Identification number	Sex and age (years)	Lead concentration
I/2	♂,3½–4	0.23
I/3	♀,c.25	0.30
I/4	♀,c.30	0.19
I/5	♀,c.45	0.26
II/6	♀,c.50	0.12
II/7	♀,18–22	0.14
II/8	♀,c.50	0.22

Table 2. Lead concentrations (μg/g dry weight) in well preserved bone tissue of adults from preindustrial and contemporary civilizations

Time period	Burial site	Number examined	Bone tissue	Average lead concentration	Source
3300–2900 BC	Sudanese Nubia	9	Temporal	0.6	Grandjean *et al.* 1979
Before 600 AD	Peru	2	Mandible	0.14	Ericsson *et al.* 1979
About 1475 AD	Qilakitsoq	6	Vertebral body	0.21	This study
1977	Copenhagen	17	Temporal	5.5	Grandjean *et al.* 1979

garded as upper limits. The true, *in vivo* lead levels in the Qilakitsoq Eskimos 500 years ago may have been somewhat lower than the results given in Table 1. Additional analyses of bone and tooth samples are now underway in a more sophisticated laboratory with improved contamination control.

From the results obtained so far, no age relationship is apparent. This finding may be surprising, because lead is known to accumulate with age, but the small number of specimens available from Qilakitsoq limits the validity of this apparent lack of correlation.

Other testimonies of past lead exposures

"Silent witnessess" have been examined for lead exposures in several laboratories. Each study of skeletal remains has been carried out with a different method which may make comparison difficult. The types of calcified tissues selected, the age groups examined, the sample cleaning and preparation, and the analytical method are important parameters which may influence the results.

The oldest Nubian and Peruvian samples originate from premetallurgical eras, and the lead levels reflect the magnitude of "natural" or prepollution exposures (Table 2). When compared to present-day levels the analyses show bone ratios of about 0.1 and tooth ratios of 0.01 and below. Both studies (Grandjean *et al.* 1979; Ericsson *et al.* 1979) reveal information which indicates that the bones, despite excellent preservation in a dry environment, were somewhat contaminated, and that tooth lead concentrations may be better indicators of the original exposure levels. Both in Nubia and in Peru the natural tooth lead levels were 1%, or less, of current lead levels in North America.

Bone samples from similar time periods were available from other sources (Grandjean 1975; Drasch *et al.* 1979; Waldron & Wells 1979; Ishinishi *et al.* 1978), but the results are difficult to interpret in detail because the samples were exposed to soil moisture and most likely were somewhat contaminated. However, an increasing lead retention with time as lead technology was introduced was found both in Nubia, Denmark, England and Japan. Medieval samples contained even more lead than present-day controls. A similar pattern was found in Jaworowski's original study (1968) from Poland where excessive lead doses were identified for the 17th-19th centuries. High bone lead levels were prevalent even in the remote Faroe Islands during past centuries (Nielsen *et al.* 1982). Such retention levels were related to the use of pewter, glazed earthenware, lead water pipes, lead-containing drugs and other sources which were common in the past. From the information available, such sources of lead never reached the Qilakitsoq group studied.

In concert, the studies of lead levels in archaeological skeletal samples justify two conclusions: 1) prepollution exposures were lower than 1–10% of present-day exposures in North America and Europe; and 2) with increasing use of lead, exposures increased and have, during some periods, averaged considerably more than today.

Significance of Silent Witnesses

The magnitude of lead exposure levels has been examined by an expert committee under the auspices of the US National Academy of Sciences (1980). On the basis of complex estimates from ecological models and data provided by "silent witnesses", the committee concluded that present-day exposures were 10-to-1,000-fold above those in which Homo sapiens originally adapted. The evidence provided by the chemical testimony of these human ancestors was considered important and in agreement with independent estimates from other sources.

When compared to natural levels, the current lead exposure levels of most industrialized nations are rather excessive. Despite the fact that lead exposures of many contemporary control groups and industrialized populations may well be 100-fold greater than the background level, very little is known of the possible health effects of lead in humans with "habitual" environmental exposures. Environmental lead pollution is not restricted to industrialized countries; airborne lead and other sources of lead intake have probably permeated even the remotest areas of the world. Thus, present-day blood lead levels in Greenland are similar to levels found in Denmark and other countries (Hansen *et al.* 1984). Nevertheless, some population groups have been identified with comparatively low blood lead concentrations. Perhaps by using such populations as controls, we might learn more about the possible effects of lead at low exposure levels.

Governmental monitoring and control of several important uses of lead has resulted in a decrease in the general lead exposure levels. On the other hand, about 10% of the annual lead production is still used for the production of alkyl lead additives for gasoline. The atmospheric lead pollution that results from the lead halides of automobile exhaust also contaminates the food chains. This type of contamination is in sharp contrast with historical times, when excess exposure was caused by a limited number of single sources. Today, environmental lead pollution reaches most people through complex interacting pathways. As might be expected, with the sophistication of modern societies, prevention of lead exposure has not become simpler.

In conclusion, chemical testimonies of lead exposures in the past have been successfully obtained in several laboratories. The examination of "silent witnesses" of past times have contributed significantly to our knowledge of previous lead exposures, and current exposure levels have been put in a new perspective. The Qilakitsoq mummies provide a relatively recent testimony that an almost lead-free environment persisted in Greenland about 500 years ago before the influence of Western civilization.

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Trace Metals in Human and Animal Hair from the 15th Century Graves at Qilakitsoq Compared with Recent Samples

JENS C. HANSEN, T. Y. TORIBARA & ANN G. MUHS

Hansen, J. C., Toribara, T. Y. & Muhs, A. G. 1989. Trace Metals in Human and Animal Hair from the 15th Century Graves at Qilakitsoq Compared with Recent Samples. Meddr. Grønland, Man & Soc. 12: 161–167. Copenhagen 1990-01-26.

Samples from eight Qilakitsoq mummies were analysed by X-ray fluorescence spectrometry, providing a multielement longitudinal analysis along a single strand of hair to obtain concentration profiles. Comparison of the profiles could indicate whether all mummies had died at the same time. No characteristic profiles were found and consequently the question was not answered.

Atomic absorption spectrometry was used to analyse six mummy hair samples, and 22 present day hair samples. In addition nine animal hair samples from the graves and ten present day seal hair samples were analysed.

Quantitative measurements of metals have shown an increase with time for the toxic metals mercury and lead, while cadmium and copper were unchanged, and zinc showed a slight increase. Definite decreases were found for bromine, iron and selenium.

The increase of exposure to toxic metals is assumed to be due to an increase in pollution of the northern hemisphere, while the decrease in essential micronutrients is due to the change in eating habits towards more imported food in the Greenlandic diet.

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Trace metal concentrations in human and animal hair reflect the environment in which the individual has lived. Thus analysis of essential elements can provide information on dietary status, and determination of non-essential elements can give information on exposure level to toxic pollutants.

Hair as an index medium for determining trace metals has aroused increasing interest because hair concentrates most elements, especially heavy metals, to a higher degree than do other tissues or body fluids. Hair samples are easily obtained, transported, stored and, because of its resistance to biological degradation, hair allows comparisons over a wide time range. Such a comparison over a period of 500 years has been possible with the mummies from Qilakitsoq, from which hair samples have been taken, and with animal hair samples collected from the fur wrappings of the bodies.

In the following the results of these investigations are reported and a comparison is made between concentrations found in the older and in more recent hair samples from the district where the graves were found.

The objective of the study was, in the first place, to compare concentrations of toxic elements over a span of time, and secondly to attempt to obtain indices of contemporaneity for the mummies through longitudinal sectional analysis along single hair strands and comparisons between concentration profiles.

Material and methods

Samples were collected at the Danish National Museum, which also provided recent samples of seal hair. The recent human samples originate from a heavy metal survey carried out in 1979 in West Greenland (Hansen 1981).

Two different analytical procedures were used.

1) *Atomic absorption spectrometry.* These analyses were carried out at the Institute of Hygiene, University of Aarhus, Denmark. The analytical procedures are described in detail elsewhere (Hansen 1981; Hansen *et al.* 1983a, 1983b).

By this method six human and nine animal samples

Table 1. Intercomparison: IAEA Powdered Human Hair HH-1

	IAEA			Own results		
	x̄	SD	Range of accepted lab. averages	N	x̄	SD
Cd	0.26	0.13	0.02 – 0.54	5	0.36	0.03
Cu	10.23	3.17	1.89 – 19.05	5	8.93	0.20
Hg	1.70	0.24	1.20 – 2.30	5	2.13	0.05
Pb	2.73	1.40	0.00 – 5.50	5	3.58	0.35

from the graves and 22 human and 10 animal recent samples were analysed. The following elements were determined by this method: mercury, cadmium, lead, copper and selenium.

As reference material IAEA powdered human hair HH–1 was used. The results are compared in Table 1.

2) *Non-destructive X-ray fluorescence spectrometry.* This method, described in detail elsewhere (Toribara *et al.* 1982), provides automatic longitudinal scanning for some 16 elements in consecutive hair segments. The mass (in µg/mm) is determined simultaneously at each point and the absolute concentrations are computed in mg/kg for the elements. The method is non-destructive and results including mass show much reproducible detail. The millimetre by millimetre longitudinal analysis allows recapitulation for previous metal exposure for months or years depending upon the length of the hair strand. This type of analysis was carried out at the Environmental Health Sciences Center, Division of Toxicology, Department of Radiation Biology and Biophysics, The University of Rochester Medical Center.

Only human samples were analysed, eight human (six adults and two children) fifteenth century samples and two recent samples. The following elements were determined: calcium, manganese, iron, copper, zinc, bromine, mercury and lead, as these elements occur in measurable concentrations with reasonable counting times.

A comparison between the two methods for elements determined by both is given in Table 2.

Table 2. Comparison of mean concentrations in identical samples obtained by X-ray and AAS.

Method / Element	15th cent. (N:6)		20th cent. (N:2)	
	X-ray	AAS	X-ray	AAS
Hg	3.2	3.1	14.3	19.9
Pb	n.d.	0.7	44.0	56.9
Cu	8.1	8.8	11.0	16.3

Whether or not hair samples should be washed prior to analysis to remove external contamination is a matter of discussion. Some ions as Na, K, Ca, Mg, Br, Mn, Fe, Cu, Zn and Cd are shown to be removed by washing (Kopito & Shwachman 1975; Salmela *et al.* 1981). Elements which may also be added to hair from solutions similar in composition to sweat are: Zn, Cu, Ag, Fe(3), Cr(4) at pH 5.5, Se(2), Cl, Br, and I at pH 3.5 (Bate & Dyer 1965). Mercury may easily be added to hair, but once incorporated it is almost impossible to remove without altering the hair considerably (Toribara *et al.* 1984).

The samples in this study were not washed before analysis with x-ray spectrometry, while samples analysed by atomic absorption were washed according to the procedure described by Petering *et al.* (1971). The problem, however, may not be that important as good agreement of results was obtained by the two methods (cf. Table 2).

One other precaution concerns the interpretation of the hair level, even after ascertaining that the history show that nothing has occured which would lead one to believe that the concentration has changed, as is the case with the samples here described. A general assumption would be that the hair concentration would be directly proportional to the concentration of the fluid in contact with the root of the hair. This has been shown to the case for methyl mercury (Amin-Zaki *et al.* 1976), while Klevay (1970) could not show such a correlation for zinc. Lead, mercury, copper and probably zinc data provide the most reliable basis for conclusions, while the data on other elements should be interpreted with some caution.

Interpretation of analytical results

Accurate analythical methods measure the actual amount present in the sample. However, the amount present in the hair sample may not be the quantity which was incorporated into the hair at the time of its formation. Once the hair has emerged the concentration of an element at any part of the hair should not change unless external exposure to treatment such as washing, bleaching or exposure to rain or dust from the atmosphere induces it.

Results

Fig. 1 shows concentration profiles of eight elements in hair from one of the mummies compared with those from a recent Greenlander. In all fifteenth century samples no characteristic profiles with peak values were found, so it has not been possible to get indices of whether or not they died at the same time.

Fig. 2 shows an energy spectrum from a one millimetre segment of a single strand of hair taken from a mummified body. The peak corresponding to zinc indicates that the concentration of this metal is slightly lower than those found in normal modern samples. The peaks corresponding to bromine and iron indicate that levels of these elements are definitely elevated compared to modern samples.

Calculated mean values and mass from mummies (six

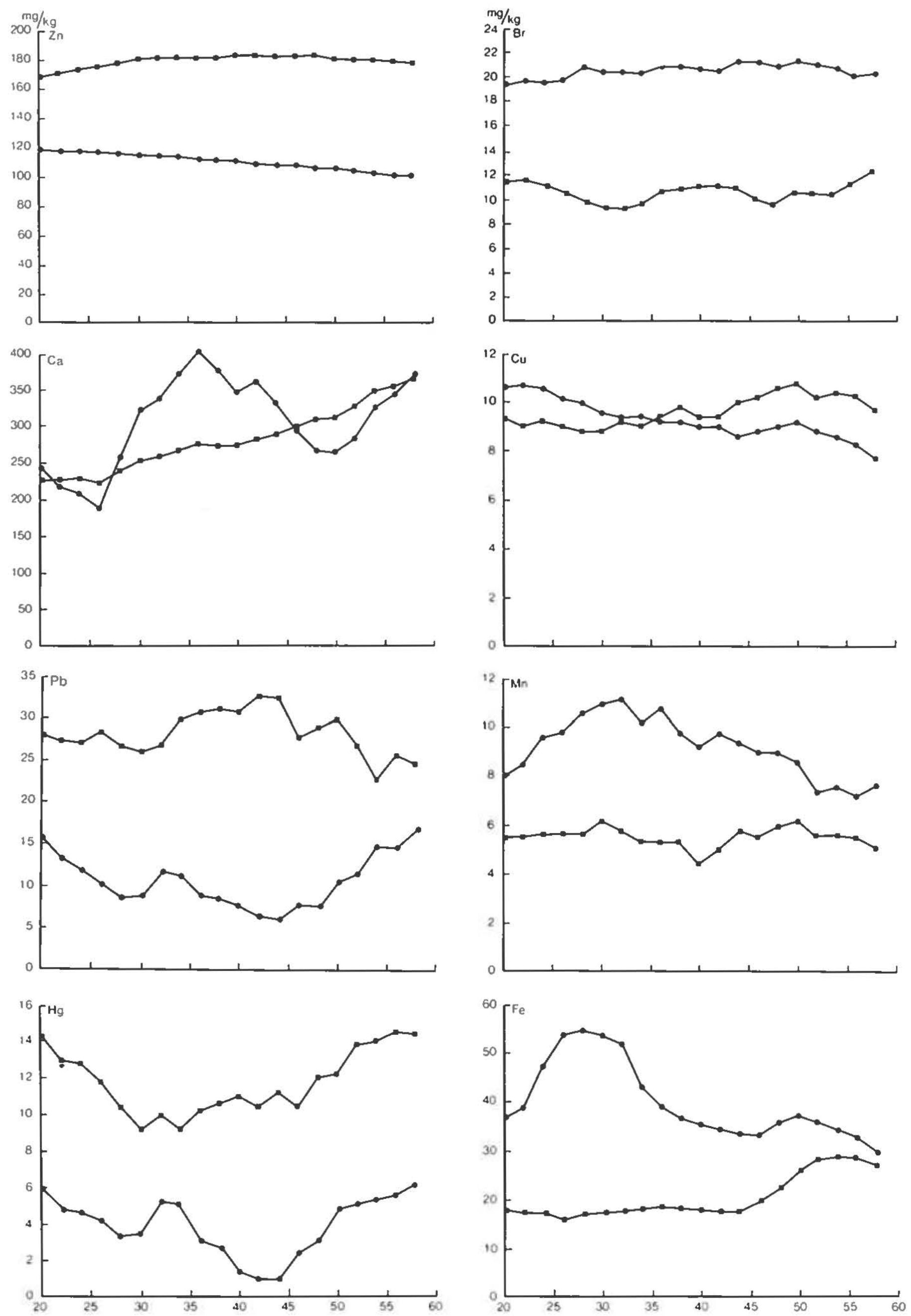


Fig. 1. Longitudinal analysis of a single strand of hair
■–■ Sample from a present-day Greenlander
●–● Sample from a mummified body.

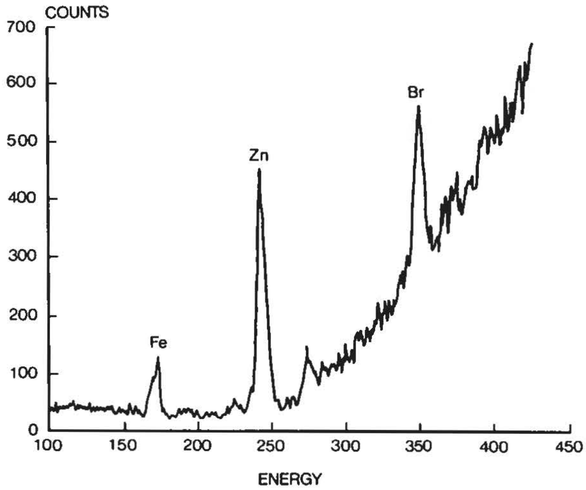


Fig. 2. The energy spectrum from a one millimetre segment of a single strand of hair taken from a mummified body.

adults and two children) and from two recent samples are shown in Table 3. The table also includes for comparison the results of analysis of twenty recent Quebec Inuit samples (Toribara *et al.* 1982). It is seen that children's hair has weights (µg/mm) different from the other groups. For this reason, the results for children's hair have been separated, as the concentrations due to the different hair weight are not necessarily comparable with the concentrations in adults.

No significant difference in hair weight is found between ancient and recent adults, which indicate that no substantial loss has taken place with time.

The results of the atomic absorption analysis are presented in Table 4 and Fig. 3, which, on a logarithmic scale, indicates mean concentrations and the 95% confidence interval.

The figure shows parallel results for mercury and lead concentrations in human and animal samples. Human hair contains more than animal hair reflecting the fact that humans are at a higher level in the food chain.

Table 3. Trace elements concentrations in human hair samples obtained by X-ray fluorescence. Mean and 1 x SD (in brackets) indicated.

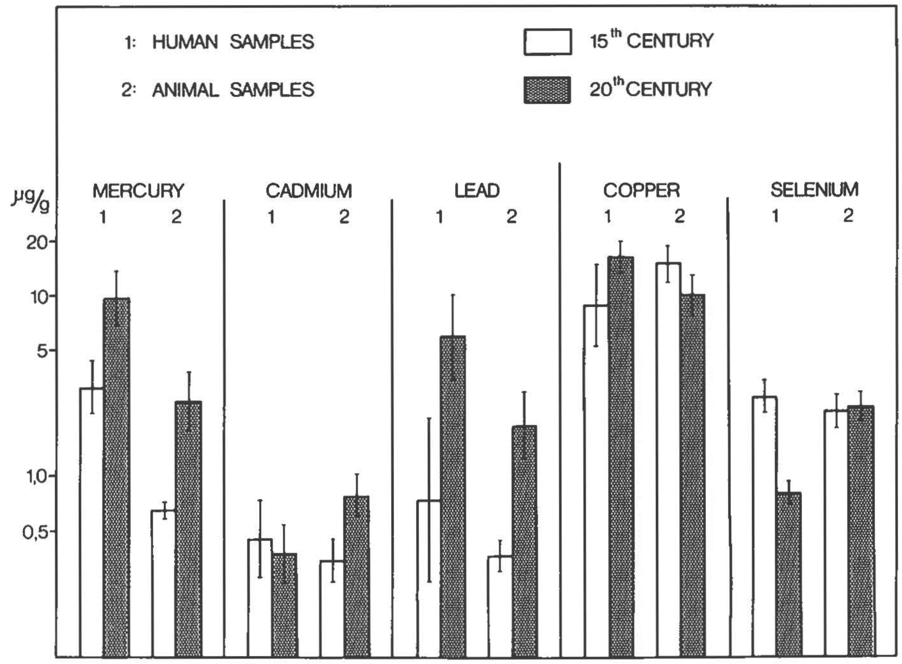
	N	Hair Weight µg/mm	Ca	Pb	Hg	Br	Zn	Cu	Fe
			mg/kg						
15th century samples, Adults	6	5.70 (0.97)	203 (123)	n.d.	3.2 (3.4)	32.9 (10.6)	110 (32)	8.1 (2.4)	123 (94)
15th century samples, Children	2	2.4	1458	24.0	10.0	–	153	18.0	120
Quebec Inuit	20	6.48 (2.55)	224 (103)	8.9 (9.9)	9.93 (14.0)	4.3 (4.5)	171 (43)	14.3 (4.8)	16.9 (7.7)
Recent Greenlandic samples	2	6.20	212	44.0	14.25	17.0	149	11.0	17.5

n.d.: non-detectable concentrations
– : not analysed

Table 4. Trace element concentrations in human and animal hair samples, obtained by atomic absorptionspectrometry. Means and 95% confidence intervals (in brackets) are indicated. Units mg/kg.

Element	Human samples 15th century No.	Mean	Human samples 20th century No.	Mean	Animal samples 15th century No.	Mean	Animal samples 20th century No.	Mean
Hg	6	3.1 (2.3–4.2)	22	9.8 (6.8–13.5)	9	0.6 (0.5–0.7)	10	2.6 (1.8–3.7)
Cd	6	0.5 (0.3–4.2)	22	0.4 (0.3–0.5)	9	0.3 (0.3–0.5)	10	0.8 (0.6–1.0)
Pb	6	0.7 (0.3–2.1)	22	6.0 (3.5–10.3)	9	0.4 (0.3–0.4)	10	1.9 (1.2–1.8)
Cu	6	8.8 (5.3–14.6)	18	16.5 (13.6–19.5)	9	15.1 (12.0–14.6)	8	10.0 (7.7–12.9)
Se	5	2.8 (2.3–3.5)	10	0.8 (0.7–0.9)	9	2.3 (1.9–2.9)	8	2.4 (2.0–3.0)

Fig. 3. Element concentrations in human and animal samples from the 15th and 20th centuries determined by atomic absorption spectrometry. Mean and 95% confidence interval indicated (log scale).



As the two methods have given an identical pattern of information, each element will be commented upon separately in the following, without reference to method.

Discussion of individual elements

Toxic elements

Mercury concentrations in human hair and blood samples from arctic areas have been shown to be much higher than those from industrialized countries. A close relationship between the amount of marine food eaten and blood and hair mercury concentrations has been demonstrated (Hansen 1981; Hansen *el al.* 1983a,b).

The results reported here have shown that mercury has increased significantly with time in human as well as animal hair by factors of 3.2 and 4.3 respectively. The higher factor in animals may be due to the fact that people in the fifteenth century exclusively depended on marine food, while present-day Greenlanders, even those who eat traditional food, will eat supplementary imported food. The increased mercury concentrations cannot be proven to be due to man-made pollution, as variations in natural environmental mercury concentrations have been demonstrated (Petit 1977).

The increase is, however, likely to be a result of man's use of mercury, which has been increasing during historical time. The human hair concentration in ancient samples, compared with present-day Danish mercury hair concentrations is high. In a Danish survey carried out in 1980 a mean of 0.6 µg/g was found (Bach 1980). So even if the exposure in Greenland has increased, it must be realized that in areas with dominantly marine food sources a relatively high mercury exposure is natural.

Cadmium, like mercury, is an environmental pollutant causing great concern. Daily intake in Greenland today through food especially seal liver, exceeds the WHO tolerable weekly (Johansen 1982). The results have shown, however, that in human samples no difference can be observed between old and new samples and that both are within what is regarded as a normal concentration level. This is in agreement with the results from the West Greenland survey 1979 (Hansen 1981), in which it was found that dietary cadmium from marine food was not reflected in hair.

A moderate increase in cadmium is found in animal hair (cf. Table 4), which may mean that seals today are more exposed to cadmium than in earlier times, as industrial use of this element started only in this century.

That no increase is observed in humans may be due to the fact that cadmium is bound in seal liver in a chemical form that is not easily absorbed in the human gastrointestinal tract.

Lead is the toxic element that has been shown to increase most with time in human as well animal samples with factors of 8.3 and 4.1 respectively. Lead has thus increased most in humans, probably because, unlike mercury and cadmium, lead is not likely to be taken up via marine food. Only small concentrations of lead have been found in traditional Greenlandic food (Johansen 1982). The human lead sources in Greenland remain unidentified, however.

Contrary to the results reported here, Toribara *et al.* (1984) demonstrated higher hair lead values in old frozen Barrow bodies than in present day Canadian Inuit. Lead concentrations found in four hair samples taken in 1884 in East Greenland were also a little higher than those found in the same district today (Hansen, unpublished data).

The increase in lead concentrations reported here could support the idea of increasing lead pollution of the northern hemisphere in the historical era, as suggested by Settle and Patterson (1980).

Essential micronutrients

Among the essential elements analysed, copper and calcium showed no time-related differences. This conforms with reports on ancient and recent samples from Canada (Toribara *et al.* 1984). Also in agreement with this study, zinc concentrations tend to be lower in old samples than in recent ones (cf. Table 3). This change is explained by the fact that populations living primarily on fish, especially of the white type, risk zinc deficiency, while varied food, as eaten today is more likely to provide sufficient zinc. If, however, marine mammals are part of the diet, zinc supplements should be sufficient, as these are rich in zinc (Johansen 1982). Thus the difference may not be significant and is probably due to the fact that hair zinc concentrations are influenced by external factors.

Selenium concentrations in modern an ancient animal hair are not different (Table 4 and Fig. 3), indicating that this element, homeostatically regulated in the mammalian body, has not changed in the marine environment during the last 500 years. The decreased concentration in modern human samples compared with old ones can be interpreted as being due to a change in eating habits. People of the fifteenth century presumably depended on marine food alone, which is rich in selenium, while at the present time the diet is mixed with imported (Danish) food items containing lower selenium levels.

Another possible explanation is that the increased mercury intake will bind more selenium because of chemical interaction *in vivo,* with formation of biologically inert complexes leading to a lower uptake in hair. The decline in hair selenium concentrations is, however, most likely an expression of a change in eating habits, as the same decline is observed for iron (cf. Table 3), which is high in the traditional Eskimo diet and low in imported food. In further support of this theory, there is less bromine in modern samples, as this element presumably originates from marine food.

Conclusion

Analysis of hair samples from eight fifteenth-century mummies found in Qilakitsoq has not provided an answer to the question of contemporaneity of the eight bodies. However, comparisons of analytical data on present-day samples from the same district with data from these ancient samples have contributed to our knowledge of the development of heavy metal pollution during the last 500 years. Significant increases in mercury concentrations have been found in both human and animal samples. A relatively high mercury exposure is natural in arctic areas, and related to transport of mercury through the food chains. Lead has also increased significantly with time, while cadmium shows a low and, in general, unchanged concentration level. Unchanged concentrations were also found for cadmium and copper, while zinc showed a minor increase.

Selenium, bromine and iron in human samples were found to be definitely elevated compared with modern samples. This phenomenon is thought to be a reflection of changing eating habits, as ancient Eskimos were totally dependent on local, i.e. marine food, while modern Greenlanders to an increasing degree eat imported food.

The data show that levels of exposure to certain toxic metals such as mercury and lead have significantly increased and that the supply of some essential micronutrients such as selenium and iron has decreased with time. This development is caused partly by increasing pollution and partly by the ongoing change in the cultural pattern in Greenland away from the traditional Eskimo way of life towards the culture of the industrialized societies. These changes, in the long run, may lead to increased health hazards from the environment.

The investigation of the elements in hair has contributed to a better understanding of present-day heavy metal exposure in Greenland.

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The Tattooings of the Qilakitsoq Eskimo Mummies

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Kromann, N. P., Kapel, H., Løytved, E. R. & Hart Hansen, J. P. 1989. The Tattooings of the Qilakitsoq Eskimo Mummies. – Meddr Grønland, Man & Soc. 12: 168–171. Copenhagen 1990-01-26.

The bodies of eight mummies were examined with infrared photography to reveal tattooings. No tattooings were found in the two children nor in a young woman aged 18–20 years. The remaining five women were all tattooed in the face. No such decorations were found elsewhere on the bodies.

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It was presumed that the adult mummies had been tattooed, since historical sources mention tattooing in Greenland as described by Kjellström in his comprehensive work (1979). When the facial skin of the mummies was examined prior to cleaning, no tattoos could be seen. But after cleaning, faint traces of tattoos appeared on the faces. These tattoos must have been distinct when their bearers were alive, but mummification had made the skin very dark and – more important – the translucency of dry skin is slight compared with that of live skin, which has a high moisture content. It was therefore necessary to find a method which could reveal deposits of colour not visible to the naked eye. In the tattooing process, pigment is deposited in the dermis beneath the epidermis.

It was learned that a special photographic technique using infrared light (heat rays) had already been used to reveal the tattoos of a frozen, mummified Eskimo body in Alaska (Smith & Zimmermann 1975). With this method, infrared rays penetrate the skin to a very slight depth. Thus the pigment immediately below the surface of the skin is included in the picture. The exact details of the photographic procedure had not been described earlier; however, in the course of the mummy studies a reliable method has been developed. The technical details are described in the caption of Fig. 1.

As the skin might be damaged by cleaning and conservation processes, all exposed areas of skin were photographed beforehand. Several facial tattoos were thus distinguished wholly or in part. After cleaning, a new set of photographs was made, and facial tattoos were clearly distinguished in five out of the six adult women. The exception was the youngest woman (mummy 7).

No tattoos were found on the bodies or limbs. In particular, none were found at the joints; but it must be noted that several areas were only examined before cleaning. Other areas were covered by clothing. The backs of hands and wrists, where tattoos might be anticipated, were examined with particular care.

The tattoos consisted of elegantly formed, usually

Figure 1. The set-up used during examination for tattooings with infrared photography. Light source: two Osram Theraterm infrared lamps, 220-230 Volt, 250 Watt. Distance from lamps to the subject: approximately 50 centimetres. Film: Kodak High Speed Infrared black and white negative film. Filter: Kodak Wratten Gelatine Filter No. 87 c. Exposure: 1/15 second, focus 11.

Figure 2. Mummy No. 3. Left: The front tattooing, including the dot in the middle, is clearly visible. Right: In the left side of the face the line by the corner of the eye and a few lines on the chin are seen.

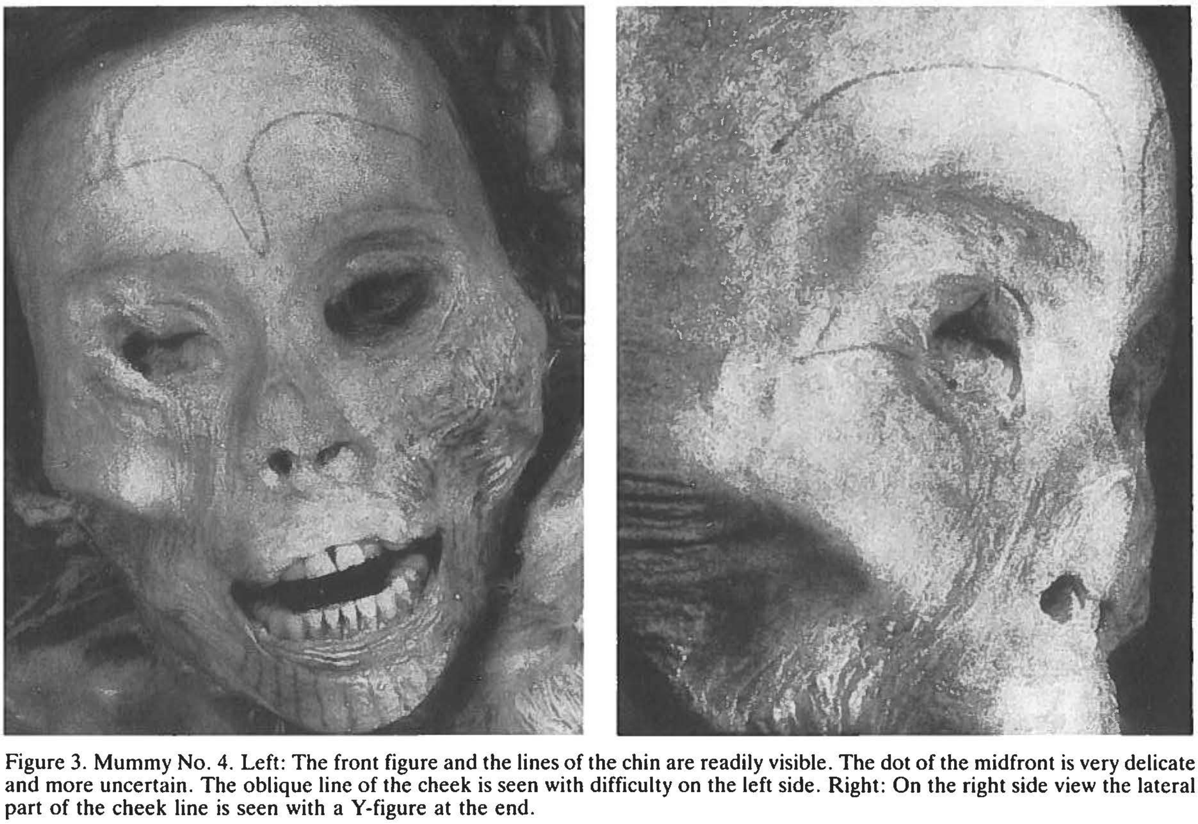

Figure 3. Mummy No. 4. Left: The front figure and the lines of the chin are readily visible. The dot of the midfront is very delicate and more uncertain. The oblique line of the cheek is seen with difficulty on the left side. Right: On the right side view the lateral part of the cheek line is seen with a Y-figure at the end.

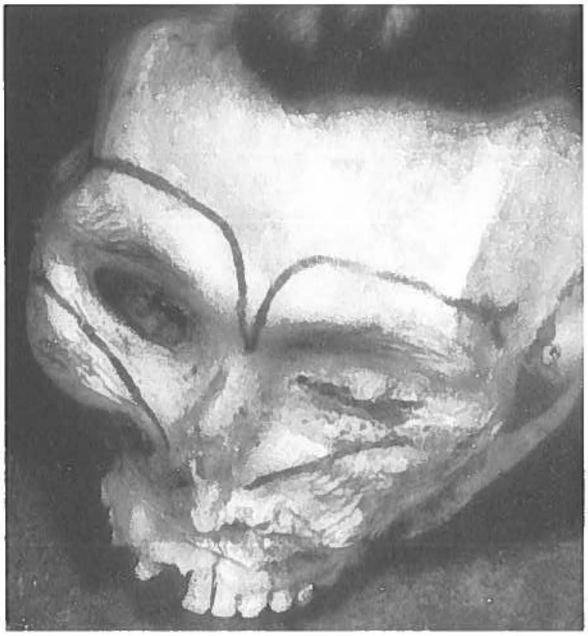

Figure 4. Mummy No. 5. The tattoed figures are very strong.

Figure 5. Mummy No. 6. On the right cheek the lateral part of the tattooing is preserved, on the left side the medial part. On the left cheek a dot is seen on each side of the line. On the right side of the chin, there are a few remaining parallel lines.

fully-drawn lines with no irregularities. In one case, however, there were dotted lines. The width and clarity of the lines was consistent in each individual, and there was in all cases symmetry around the centre line of the face. The colour was black or dark blue. Besides these linear figures there were indistinct dots down the forehead of one, possibly two, of the mummies.

All of the tattooed mummies had lines tattooed in their foreheads. One of them had lines at the outer corner of the eyes, and four were tattooed on their cheeks. Three of them had lines tattooed on the chin. Mummy 8 lacked skin here. The tattoos are depicted diagrammatically in Fig. 7.

The tattooings of the front were similar in design, with small variations. The basic feature was a symmetrical figure with a line on both sides from the temple almost parallel to and one inch above the eyebrow. Near the midline the tattoos bend downward to meet in the area just above the nose (*glabella*). The dot found in the midline of the front of at least one of the women was located about one inch above the bottom of the V-figure (No. 3). In the temples the front tattooing had a Y-shaped split in two cases (Nos. 5 and 8). In one person the front figure included an extra detail, a small T-shaped figure on top of the arch of each side (No. 6). The horizontal line by the outer eye corner was only found in one person (No. 3).

The tattooings of the cheek were very similar in the four women, where they were present (Nos. 4, 5, 6 and 8). The line goes from the nose wing obliquely upwards

Figure 6. Mummy No. 8. The lack of symmetry in the front figure is most probably due to mechanical action on the skin after the burial.

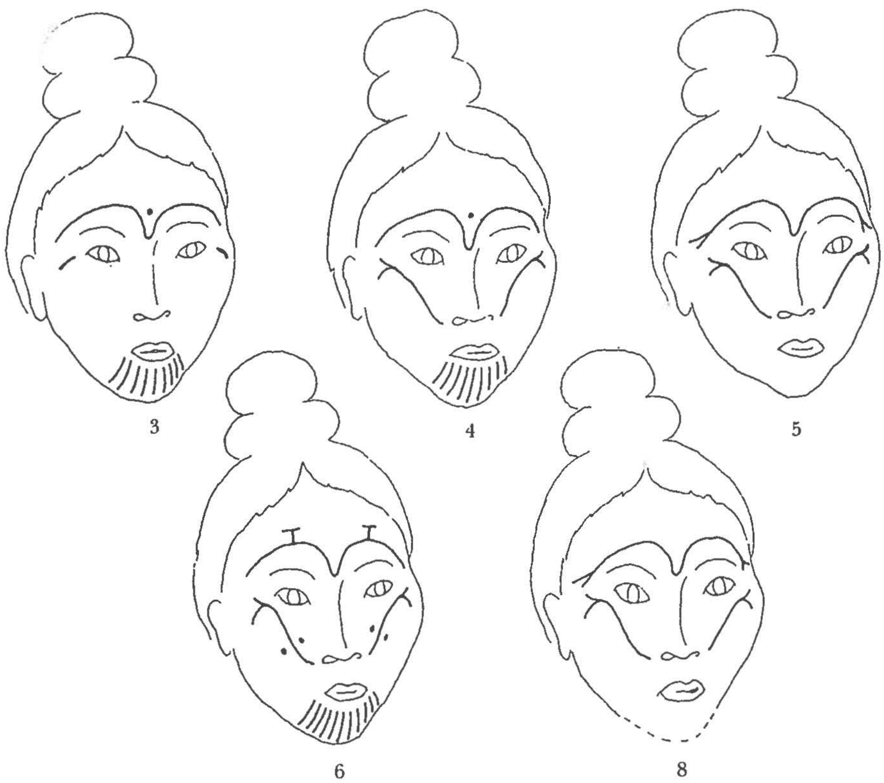

Figure 7. The tattooings depicted diagrammatically. Drawing by H. C. Gulløv.

towards the outer corner of the eye, where it ends in the same Y-shaped figure as some of the front tattooings. In mummy No. 6 only, there was a small dot over and under the capital line of the cheeks. Vertical lines on the chin were found in three of the five tattooed women (Nos. 3, 4 and 6), but in mummy No. 8 no skin was preserved on the lower jaw. If it can be presupposed that No. 8 had been tattooed on the chin, all the five women had different combinations of tattooings in the face.

Remarks on the tattooings of the individual bodies

No. 3: This woman was the only one with the eye corner tattoo and a distinct frontal dot. She was also the only one without the cheek figures. If she had these too they would have interfered with the horizontal line in the temple near the eye.

No. 4: This woman had tattooings in the front and on the cheeks and chin. The oblique line on the cheeks was difficult to see on the infrared photographs, because of the wrinkling of the skin (Fig. 3). There are six distinct lines on the right side of the lower jaw. The lines could not be counted in any of the other mummies.

No. 5: The lines were broader and more distinct in the face of this woman than in the others. She had no striation on the chin.

No. 6: The tattooings of this woman were atypical in several respects. The lines were broken, not fully-drawn as in the others. No other of the five women had the T-figure at the top of the front arches or dots on the cheeks.

No. 8: The figures on both the front and the cheeks were similar to these of No. 5. However, as mentioned above, No. 8 had no skin preserved on the chin.

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Significance of Mineral Grains in Clothing and Skins from the Mummy Graves

MARTIN GHISLER

Ghisler, M. 1989. Significance of Mineral Grains in Clothing and Skins from the Mummy Graves. – Meddr Grønland, Man & Soc. 12: 172–178. Copenhagen 1990-01-26.

A description of the geology and topography around the burial site is given. Mineral grains washed out from the mummies' clothing and other skins were studied under the microscope and compared with the mineralogical composition of the local rocks and the beach sands below the graves.

The significance of 'foreign' minerals lodged in the skins as indicators of the ancient people's wanderings in the Uummannaq area is discussed.

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During the anatomical studies of the mummies from Qilakitsoq a large number of highly reflective fragments were revealed in their clothing by X-ray investigations. In March 1979 the author was asked to study the composition of these fragments and if possible to identify their provenance. This was only possible on the basis of a detailed knowledge of the topography and geology around the graves at Qilakitsoq as well as of the grave and covering stones. Accordingly, the author visited the empty graves at Qilakitsoq and their surroundings for three days in August 1979, drew a sketch map of the site (scale 1:1000), and collected rock samples and sands from the beaches near the graves. A detailed report of the field work is given by Ghisler (1979).

The author received samples of stones, rock fragments and sands collected or washed out from different skins during the conservation process from the Conservation Department of the National Museum in Copenhagen in 1981.

Purpose of investigation

The geological and mineralogical investigations aim if possible to help to elucidate the wanderings of the people from Qilakitsoq and the circumstances of their death.

1. What is the provenance of the mineral grains occurring in the clothing and skins? Are they fragments of the rocks and gravels covering the graves, or weathered particles from the surrounding and overhanging cliffs, or do some of these grains represent material from the areas where the people lived and camped? In other words, is it possible to distinguish between mineral grains of 'local' and 'foreign' origin? Are any such 'foreign' minerals related to certain areas or localities, thus indicating where the people lived and travelled?

2. It has been proposed that the six women and two children capsized and drowned, and all were accordingly buried at the same time (Rosing 1979). If this theory is correct the bodies would have washed ashore. It may be expected that the salvaging of the bodies and the equipment probably took place at one of the beaches below the grave site. Do any of the skins contain mineral grains that are diagnostic for the beach sands?

Geology and topography around the burial site

Qilakitsoq is situated on the north coast of Nuussuaq near the boundary between the Precambrian basement to the east and the Tertiary basalts and the Cretaceous-Tertiary sediments to the west. The bedrock at Qilakitsoq consists mainly of different types of flat-lying grey gneisses, occasionally with minor lenses of black amphibolite. Numerous fissures cut the rock in two directions, one running NW-SE, the other N-S. The area is partly covered by talus with boulders, all of local origin, some up to a hundred tons. A sketch map of the area is given in Fig. 1.

The graves are situated at 20 m above sea level about 50 m from the coast at the northeast side of a steep, 200 m high slope, which continues more gently upwards to a

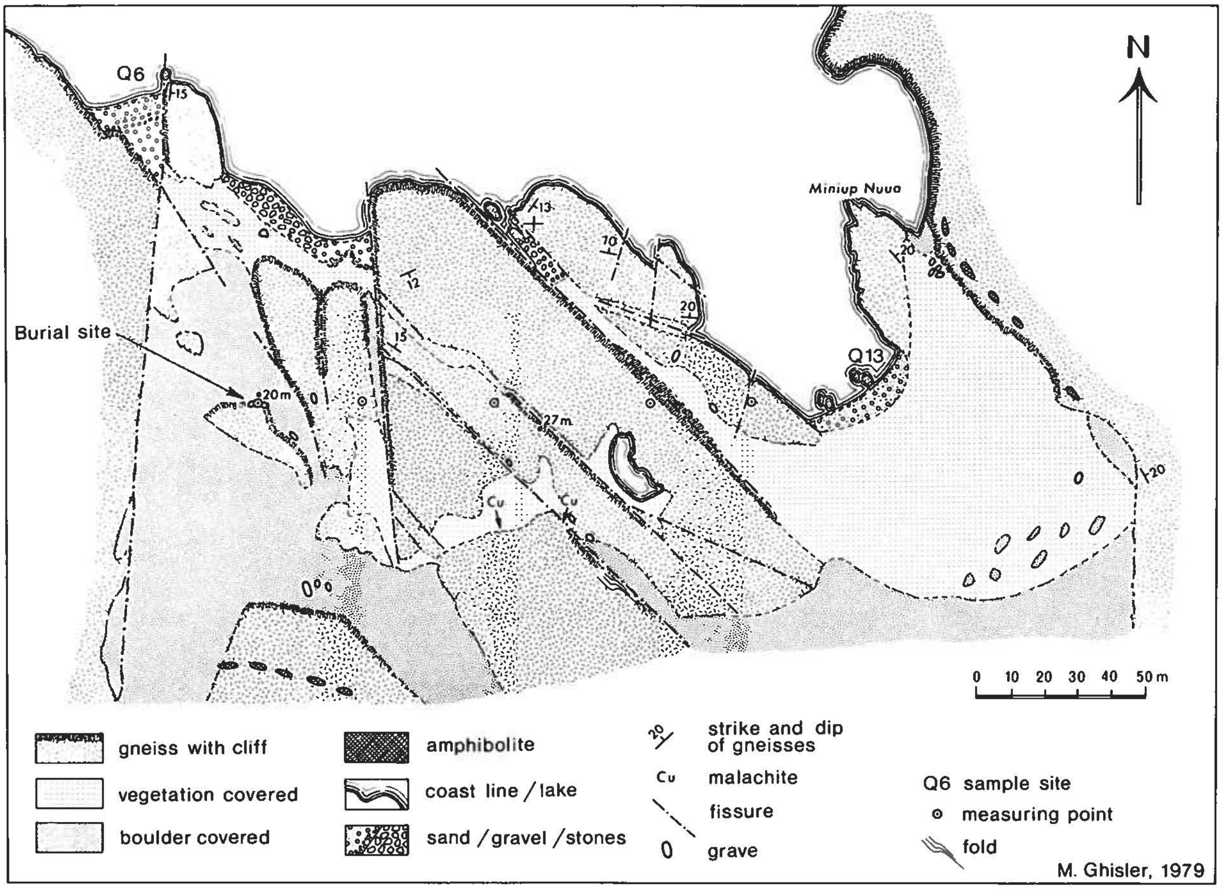

Fig. 1. Sketch map of the geology around the burial site of Qilakitsoq.

plateau at an altitude of 900–1000 m. The burial site is almost always in shadow. Even during the summer the sun does not reach the place until late in the evening (August 12th at 8.45 p.m.).

The graves are sheltered by an overhanging cliff. A rock 2 × 2 × 1.70 m in size is split from the cliff along two zones of weakness: in the roof, a curved layer in the gneiss rich in biotite; to the southwest, one of the regional northwest-southeast fissures. The disrupted block is rotated some thirty degrees leaving a wedge-shaped excavation, at the bottom of which grave I (Fig. 2) is situated. Grave II is situated immediately to the southeast of grave I. A fissure belonging to the north-south oriented system forms the west side of grave II, which is sheltered by a less marked overhang on the east side of the cliff (Fig. 3).

The stones used for building the graves are all of local origin. The largest of them, the covering stones, are up to 75 × 60 cm in size and 10 cm thick. Such rocks are exposed at the nearby coast: they are strongly weathered, banded gneisses (Fig. 4). When the graves were found they were covered with a layer of small stones of both angular and round shape (J. Grønvold, personal communication). The unusual nature of this top layer was the reason the trained eyes of the two Greenlandic hunters discovered the graves. A rounded gneiss pebble from this top layer was found by the author at the grave site. Similar pebbles occur at the triangular beach northwest of the graves (at Q6, Fig. 1).

Mineralogical composition of the covering stones and the bedrock around the graves

The mineralogical composition of the rocks was studied under the microscope, thin sections under transmitted light and polished sections under reflected light. The rock-forming minerals of the gneisses are quartz, plagioclase, green hornblende and brown biotite (Fig. 5), whereas the amphibolites mainly consist of plagioclase and green hornblende. Of special interest for this study is, however, the content of minor components which

Fig. 2. Grave I seen looking east. The grave is placed in the wedge-shaped excavation between the cliff and the main block at which the person is standing.

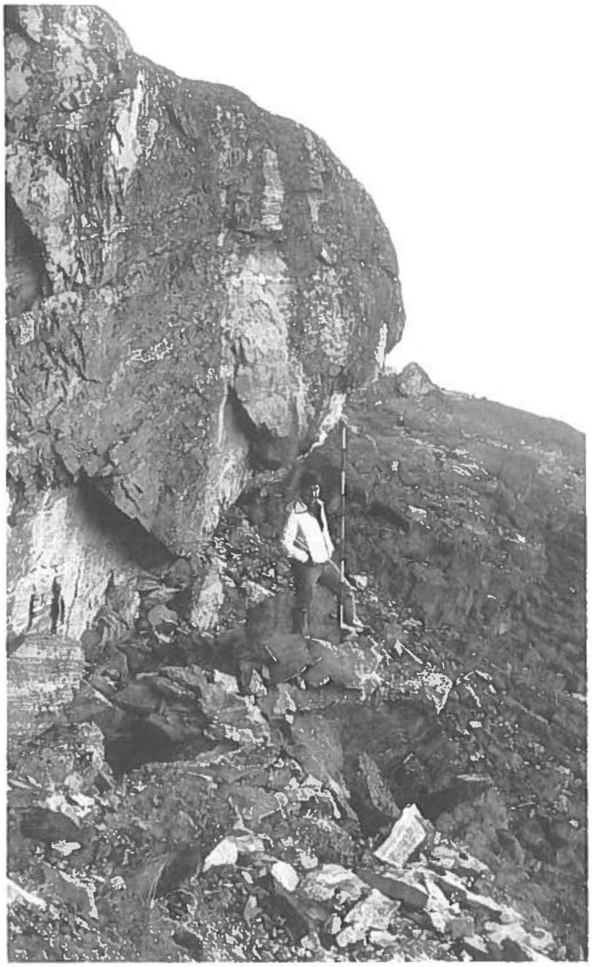

Fig. 3. Grave II at the left side seen looking west. The person is standing at the same place as in Fig. 2

may be of diagnostic importance. The following minerals were identified, listed in alphabetic order: apatite, chalcopyrite, goethite, hematite, ilmenite, magnetite, molybdenite, pyrite, pyrrhotite, rutile, sphene and zircon.

Mineralogical composition of the beach sands

Samples of sand were collected from the main bay (Q13, fig. 1), the beach immediately below the grave site (Q6, Fig. 1), and from two localities 150 m (Q7) and 300 m (Q8) to the northwest, respectively. The samples consist mainly of quartz and feldspar. The heavy minerals (specific gravity above 2.9) were separated out by heavy liquids and studied under the microscope. The heavy minerals form on average 8% of the sands, of which the main portion is green hornblende.

The individual sand grains have a relatively angular shape (Fig. 6). This indicates they have not travelled far – they have only been poorly rounded.

The following minerals were identified in the heavy fractions of the beach sands: andalusite, apatite, chalcopyrite, chromite, diopside, epidote, garnet, goethite, hematite, hypersthene, ilmenite, magnetite, olivine, pyrite, rutile, sphene, titanomagnetite, tremolite and zircon.

The beach sands mainly consist of eroded components from the local rocks. In addition, however, they contain characteristic minerals originating from the basalts occurring in the inner parts of Nuussuaq and along its coast to the northwest. These grains have been transported by means of rivers, glaciers and wind to their present place, after travelling only a few kilometres.

Fig. 4. Schistose gneiss used as covering stones for the graves. At the coast below the burial site.

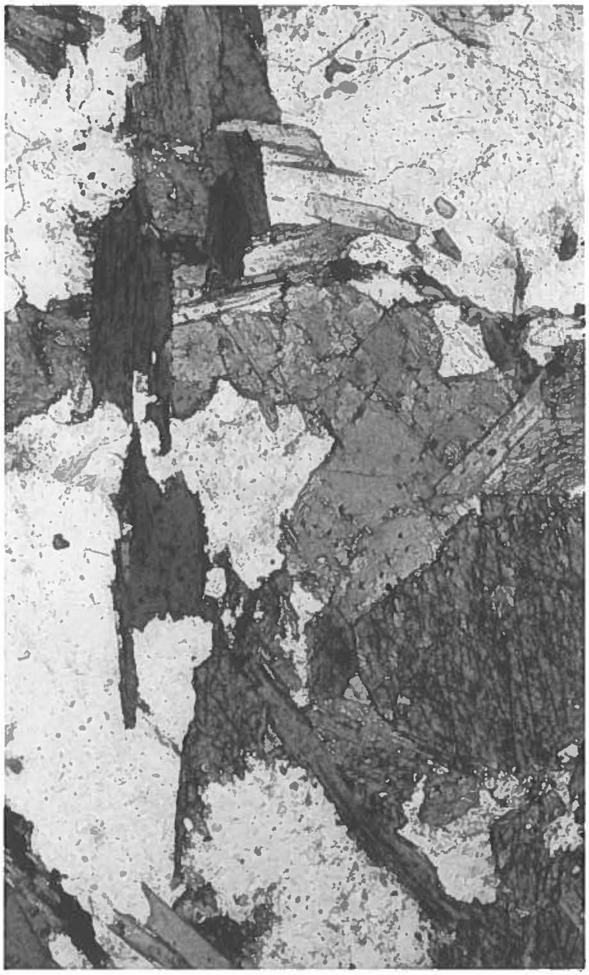

Fig. 5. Microphotograph of gneiss. Transmitted light. Quartz and feldspar (white) are intergrown with hornblende (grey) and biotite (dark grey). Long side of picture 2 mm.

Rock fragments and mineral grains from clothing and skins

A large number of rock fragments (186) ranging in size from 0.5 to 2 cm, enclosed or lodged within skin and clothing from the two graves, were investigated with a hand lens. They all proved to be of local origin. In addition seven samples of sand washed out of the skins were investigated under the microscope, with special emphasis on the study of the heavy mineral components. The content of heavy minerals in the sands washed out from the skins averages 15%.

The most common minerals are quartz, feldspar, hornblende and biotite. The following accessories were identified: apatite, augite, chalcopyrite, chlorite, chromite, diopside, epidote, goethite, hematite, ilmenite, magnetite, pyrite, pyrrhotite, rutile, sphene, white spinel, titanomagnetite, tremolite and zircon. In several cases individual grains from the skins consisted of rock fragments composed of minerals intergrown with typical basaltic structures.

Special attention is drawn to the occurrence of some characteristic structures in the mineral grains found:

1) Exsolution structures of hematite in ilmenite (Fig. 7).

2) Chromite grains, sometimes with a corona of different chemical composition (Fig. 8).

3) Incomplete, skeletal magnetite crystals sometimes altered to hematite (Fig. 9).

4) Magnetite grains surrounded by worm-like intergrowths between magnetite and silicates (Fig. 10).

5) Intense intergrowths between the sulphide minerals pyrite, chalcopyrite and pyrrhotite.

Discussion of results

The mineralogical investigations have shown that most of the mineral grains and rock fragments found in the skins are of local origin. They represent local decomposed rocks and gravel used for the burial. The skins, however, also contained minerals and fragments which belong to geological formations not present near the burial site.

Some of the mineral components found in the beach sands beneath the graves are 'foreign minerals'. Glaciers, rivers and the wind have transported them from the mountains and along the coast. A similar transport of 'foreign' minerals to the graves in the sheltered site under an overhanging cliff is excluded. The possibility of introduction by humans of foreign minerals from the beach is supported by the presence of a rounded pebble from the beach at the burial site.

Fig. 6. Microphotograph of beach sand from site Q6. Transmitted light. Hornblende (black) dominates the sample. Note the angularity of the grains. Long side of picture 2 mm.

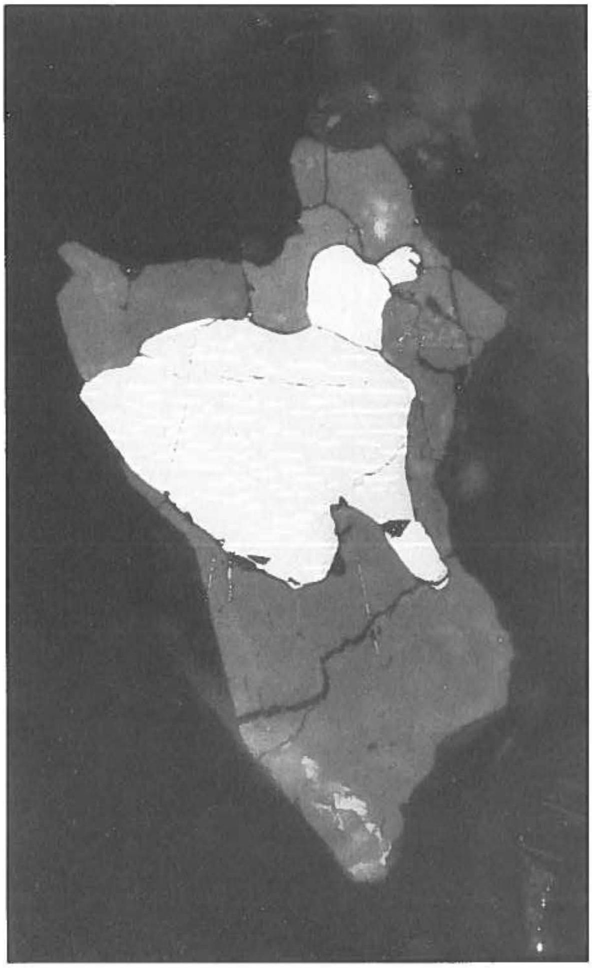

Fig. 7. Microphotograph of ilmenite with regularily arranged inclusions of hematite, surrounded by silicate grains. Reflected light. Longest dimension of picture 0.5 mm. Sand from skin No. 37 between body 7 and 8, grave II.

A comparison between the various foreign minerals occurring in the beach sands and the samples from the graves show that many of the characteristic minerals from the beach are not found in the graves. Thus it is unlikely that sand from the beach has 'polluted' the graves.

A number of selected minerals of importance in the evaluation of the provenance of the mineral components in the skins are listed in Table 1. The minerals occurring in the local rock are also present in the beach sands and the skins. Of those minerals not present in the local bedrock, some are common in the beach sands but

Table 1. Table of the presence of selected minerals in sands from skins, in beach sands and rock samples around the burial site.

Minerals	Sand from skins	'Local' rocks	Beach sands
Hornblende	+	+	+
Sphene	+	+	+
Magnetite	+	+	+
Garnet			+
Olivine			+
Augite			+
Ilmenite	+		+
Skeletal magnetite	+		+
Chromite with corona	+		(+)
Chromite without corona	+		
Skeletal hematite	+		
White spinel	+		
Chalcopyrite with pyrrothite	+		

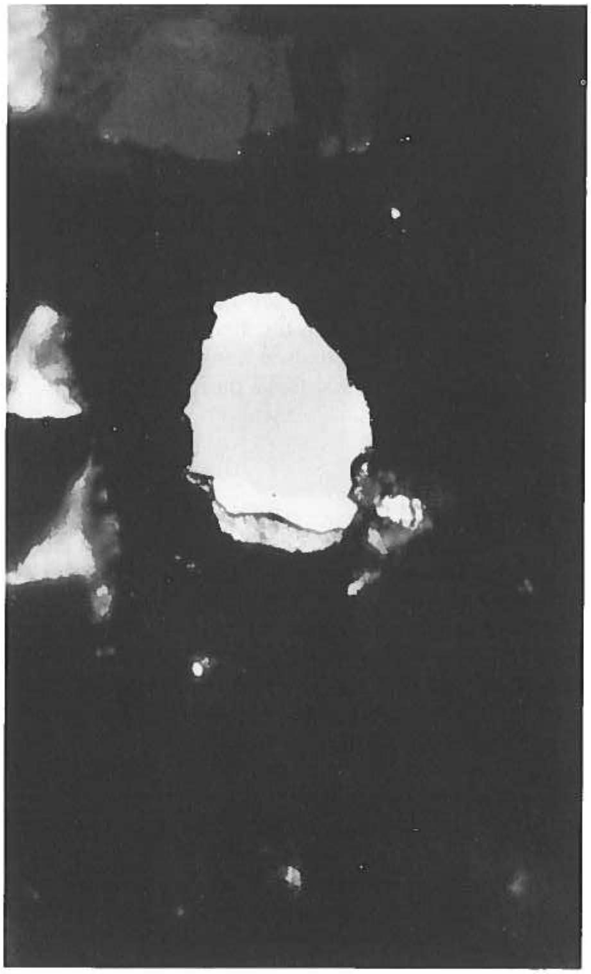

Fig. 8. Microphotograph of chromite grains with a brighter, more iron-rich rim. Reflected light. Longest dimension of picture 0.2 mm. Same sample as Fig. 7.

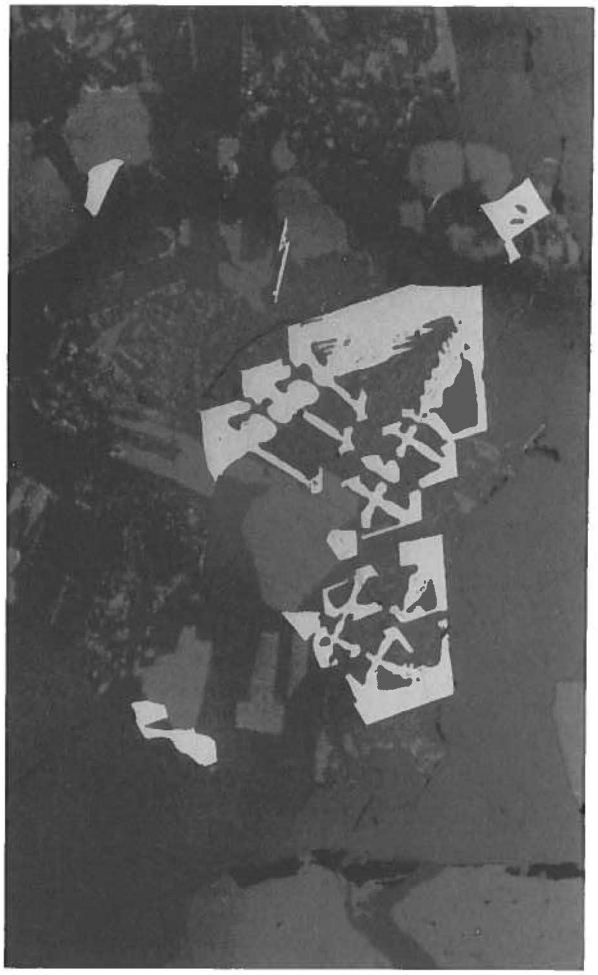

Fig. 9. Microphotograph of incomplete skeletal magnetite. The crystals cooled so fast in the basaltic lava that the grains were never completed. Reflected light. Longest dimension of picture 0.4 mm. Sand mainly from skin No. 28 above body 8, grave II.

are entirely absent from any of the samples from the skins; others are present in both beach sands and in the skins. A few characteristic minerals are only found in samples from the skins.

Heavy minerals are twice as frequent in the samples from the graves as in the beach sands. This suggests that some mineral components in the skins come from areas relatively rich in heavy minerals (e.g. basalt terrains).

Some of the minerals (chromite, skeletal hematite etc.) found in the skins can be clearly related to special basalt types, known to occur to the northwest along the north coast of Nuussuaq (A. K. Pedersen, personal communication). The identification of white spinel in one sample suggests an origin in Uummannaq Storø, some 25 km ENE of Qilakitsoq. This peculiar mineral is only known to occur in connection with amphibolite

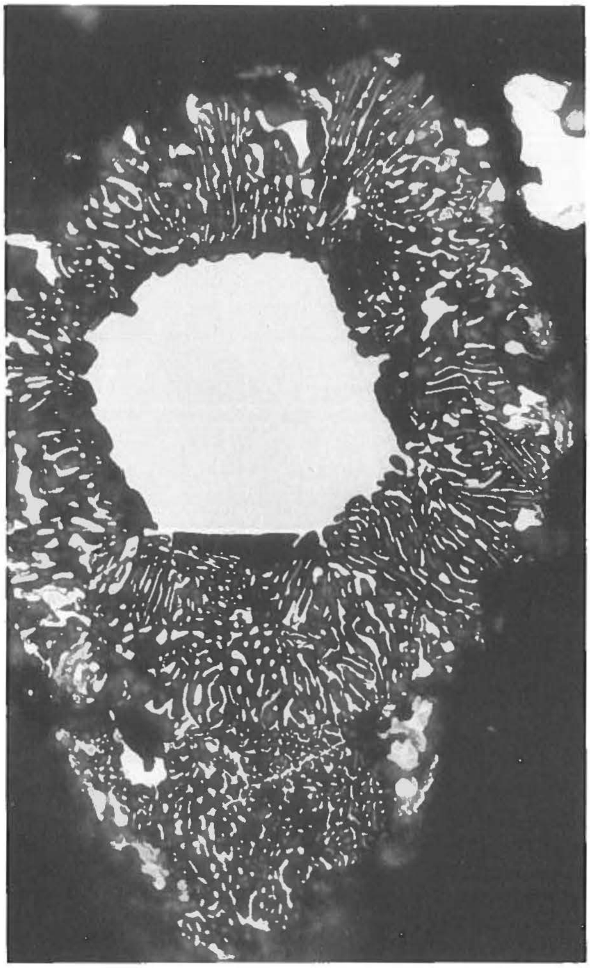

Fig. 10. Microphotograph of a central magnetite grain surrounded by minute silicate-magnetite intergrowths. Typical of basaltic lavas from Nuussuaq. Longest dimension of picture 0.2 mm. Same sample as fig. 7.

layers at two localities in the Uummannaq district (B. Thomsen, personal communication) of which one is a steep mountain slope.

Conclusions

1. Some of the mineral grains lodged in the hairs of clothing and skins found in the graves of Qilakitsoq are definitely of 'foreign' origin.
2. The people of Qilakitsoq obviously travelled and camped on gneissic as well as basaltic terrain in the Uummannaq area. This statement is supported by occurrence of minerals typical of the basalts of western Nuussuaq found in skins and clothing.The presence of white spinel points to the settlement Tupersuatsiaat at Ummannaq Storø as source area.
3. The absence of certain minerals in the skins that are common in the beach sand below the burial site, such as garnet, does not support the theory of capsizing accident. During salvaging of the bodies at the beach some of the most common heavy mineral grains would probably have lodged in the hairs of clothing or skins. The absence of these minerals diagnostic for the beach sand does not however entirely exclude such a theory.

Acknowledgements

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Botanical Investigations of the Mummies

BENT FREDSKILD

Fredskild, B. 1989. Botanical Investigations of the Mummies. – Meddr Grønland, Man & Soc. 12: 179–183. Copenhagen 1990-01-26.

Pollen analysis of a faecal lump shows that the food was contaminated by soil and soot. *Oxyria digyna* had presumably been eaten, as indicated by unripe pollen of this plant. The major part of the grassy soles of the stockings and *kamiks* was made up of *Elymus arenarius* ssp. *mollis* and *Alopecurus alpinus*. The bodies were laid down on a layer of *Cassiope tetragona*. Two independent indices point to, but do not prove, a burial during July-August.

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Pollen analysis

A faecal lump from the intestine of mummy II 7 was processed by standard methods. The result of the analysis is given in Table A. On the assumption that the faeces have not been contaminated between death and the preparation of slides, there are three possible ways in which the pollen, spores and other microscopic remains can have ended up in the intestine: 1) filtering in the nose of inhaled air, followed by swallowing, 2) eating of dirty food, or 3) eating of plant material containing pollen.

The first explanation is unlikely, since no *Cyperaceae* pollen was found. *Cyperaceae,* represented by more than thirty species in this part of Greenland, are wind-pollinated and characterize any arctic sediment containing wind-transported material like mud on the bottom of lakes and ponds (cf. Fredskild 1973: Table 22). Here they usually make up 10–30% of the total pollen. Likewise, moss polsters in plant communities in which Sedges, Cottongrass and other *Cyperaceae* grow, are rich in *Cyperaceae* pollen, whereas polsters in vegetations without plants of this family are very poor or even extremely poor in their pollen (Fredskild 1967: Tables III–XIV). In the same analyses the Rhizopod *Assulina* was found in 13 out of 15 moss polsters. The fruit-bodies of *Microthyrium* occur in humus-rich soil under vegetation.

The frequent pollen of *Cassiope tetragona,* an insect-pollinated plant with drooping flowers, and the occurrence of *Assulina* and *Microthyrium* in connection with the numerous sand grains point to a contamination of the food by soil from a mossy *Cassiope* heath, either directly by contact with the ground during the preparation of the food, by dirty cooking utensils or by soil falling from a turf-and-stone wall, if the meal was prepared in a winter house. *Cassiope* was, and still is, common on the site.

The major part of the *Poaceae* pollen is of *Alopecurus* type. This high-arctic grass, favoured by manured soil, beyond doubt grew luxuriantly at the site, as also indicated by its frequent occurrence as part of the *kamik*-grass.

Charred and uncharred fragments of Conifer wood, transported by air currents from Canada or other forested areas, occur in small quantities in Greenland lake

Table A

Pollen		
	Dwarf-shrubs	
	Betula nana	8
	Cassiope tetragona	44
	Empetrum hermaphroditum	5
	Ericales, indeterminable	17
	Salix arctica/S.glauca	13
	Herbs	
	Artemisia sp.	1
	Campanula gieseckiana/C. uniflora	1
	Cerastium/Stellaria	1
	Juncus/Luzula	1
	Minuartia/Silene	1
	Oxyria digyna	19
	Poaceae	59
	Saxifraga oppositifolia type	1
Spores		
	Huperzia selago	5
	Lycopodium annotinum	4
	Fungi, indeterminable	14
Diverse		
	Assulina	2
	Microthyrium	2
	Fragments of wood, charred, few Conifers	c
	Fragments of wood, uncharred, mainly Conifers	8
	Fragments of moss leaves	4
	Grains of sand, mainly <30μm	cc

sediments and have even been found in the Ice Cap cores (Fredskild & Wagner 1974), but local sources must be responsible for the many fragments in the samples. Driftwood from the Canadian or Siberian taiga has been used by the Eskimos for spears, sledges, handles, kayaks etc. The many charred fragments indicate that the chips and other waste from the woodworking have been used as fuel. It must be borne in mind that the lungs of the woman in question had heavy deposits of soot (Hart Hansen, this volume).

One of the common pollen in the faecal sample does point to the use of plants as food: *Oxyria digyna*. Pollen of this widespread, wind-pollinated plant occur in most Greenland pollen samples as single, well developed grains. However, most of the pollen found in the sample were unripe, and, in one case, still united in the tetrad, indicating that flower buds had been eaten. *Oxyria*, a good source of Vitamins A and C, is most often eaten raw. If this was the case, the woman died in July-August, but as the plant was often also preserved in seal oil by the Eskimos (de Bonneval & Robert-Lamblin 1979; Simmons & Miller 1982) a death during winter can not be excluded.

Macroscopic remains

A total of nineteen samples, partly grass from the *kamiks*, partly plants from the lining of the graves has been determined. Yet clearly every fragment in the (often large) samples could not be put under the microscope. The results are given in Table B, but some of the determinations will be commented on. Nomenclature is in accordance with Böcher *et al.* 1978.

Table B

1. Grave I, mummy 5, layer of grass between *kamiks* and the skin, in which the mummy was wrapped: mainly (?only) *Elymus mollis*, partly "fresh", partly worn, with only the ribs left. Besides, a couple of cakes of worn *Elymus* and sealskin, and one cake, consisting of *Cassiope tetragona*, a bit of moss and grass.
2. Grave II, mummy 6, grass from the underside of skin in which the mummy was wrapped: *Elymus* and a leaf fragment of *Salix arctica/S. glauca*.
3. Grave I, mummy 2, grass inside the stocking: *Elymus*.
4. Grave I, mummy 2, grass between *kamik* and stocking: mainly *Alopecurus alpinus*, some *Elymus*. The grass partly worn, partly "fresh". Furthermore a twig of *Salix arctica/S. glauca* and a flower of *Puccinellia* cf. *vaginata*.
5. Grave I, 1/4–78, grass inside stocking from the entire *kamik: mainly Alopecurus alpinus*, some *Elymus*. A couple of moss fragments: *Calliergon* cf. *sarmentosum* (Wahlenb.) Kindb., *Ditrichum* sp. and *Brachythecium* sp., and also two leaves of *Empetrum*, one leaf of *Vaccinium uliginosum*, one seed of *Cerastium alpinum* ssp. *lanatum*, three seeds of *Draba* sp. and one seed of *Empetrum nigrum* ssp. *hermaphroditum*.
6. Grave I, 1/4–78, grass inside the stocking from the *kamik*, cut short: mainly *Alopecurus*, a couple of *Elymus*. One leaf of *Salix arctica/S. glauca*, one of *Cassiope*, one grass floret, three bits of moss: *Aulacomnium turgidum* (Wahlenb.) Schwaegr., *Dicranum* sp. and *Calliergon* sp.
7. Grave I, 1/4–78, grass between *kamik* and stocking from the entire *kamik:* mainly (?only) *Elymus*.
8. Grave I, 1/4–78, grass between stocking and *kamik* from the *kamik*, cut short: mainly (?only) *Elymus*. One leaf of *Empetrum* and one of *Dryas integrifolia*.
9. 999×30, grass inside stocking: mainly (?only) *Elymus*. One leaf of *Empetrum*, one twig and a couple of leaves of *Cassiope*, two twigs of *Salix arctica/S. glauca*. A couple of moss fragments: *Aulacomnium turgidum*, *Drepanocladus uncinatus* (Hedw.) Warnst., *Hylocomium splendens* (Hedw.) B.S.G., *Polytrichum alpinum* Hedw., *Schistidium* sp.
10. 999×31, grass inside stocking: mainly *Elymus*.
11. 999×31, grass between stocking and *kamik:* mainly (?only) *Elymus*.
12. Grave II, no. 5b, mummy 8, grass inside stocking: mainly (?only) *Elymus*. One leaf of *Cassiope*, one of *Vaccinium uliginosum*, two spikelets of *Elymus* and one lemma, most likely of *Puccinellia* sp.
13. Grave II, no. 5a, mummy 8, grass between stocking and *kamik: Elymus*.
14. Grave II, mummy 8, below the legs: mainly twigs of *Cassiope*, some of *Empetrum*. Further, leaves of *Salix arctica/S. glauca* and of *Vaccinium uliginosum*, some mosses: *Drepanocladus uncinatus*, *Aulacomnium turgidum*, *Racomitrium lanuginosum* (Hedw.) Brid.
15. Grave II, mummy 8, inside the skin wrapping: many twigs of *Cassiope*, some of *Empetrum* and one of *Vaccinium uliginosum*. Only few mosses: *Drepanocladus uncinatus*, *Aulacomnium turgidum*, *Racomitrium lanuginosum*, *Pohlia* cf. *nutans* (Hedw.) Lindb.
16. Grave I, lining from the bottom: seemingly one giant specimen of *Cassiope*, torn up with root, with some soil and a moss cushion of *Kiaeria glacialis* (Berggr.) Hag. and *Polytrichum alpinum* Hedw. still adhering. One of the *Cassiope* twigs with a flower with two anthers still attached to the filament, but without corolla.
17. Grave I, lining from the bottom: mainly (?only) *Elymus*. One leaf of *Salix arctica/S. glauca*, one of *Vaccinium uliginosum*, one twig of *Cassiope*, one seed of *Empetrum*. A couple of mosses: *Hylocomium splendens*, *Drepanocladus uncinatus* and cf. *Kiaeria glacialis*.
18. Grave I, lining from the bottom: *Cassiope*. Besides, a couple of *Elymus* leaves, one of *Vaccinium uliginosum* and a few mosses: *Kiaeria glacialis*, *Aulacomnium turgidum*, *Hylocomium splendens*, *Polytrichum juniperinum* Hedw., *Racomitrium lanuginosum*.
19. Recent collection of "heather" near the graves: almost exclusively *Cassiope*, yet with one twig of *Empetrum* and one of *Pyrola grandiflora*, a couple of *Salix arctica/S. glauca* leaves and a few mosses: *Dicranum elongatum* Schleich., *Hylocomium splendens*, *Pohlia* cf. *nutans*, *Drepanocladus uncinatus*, *Tritomaria quinquedentata* (Hueb.) Buch and *Ptilidium ciliare* (L.) Dum.

Kamik-grass

The *kamik*-grass was found as insoles in the stocking (Fig. 1) or simply lay as an insulating layer between the stocking and the *kamik*. The preferred species in South and West Greenland is *Calamagrostis langsdorffii*, which does not reach Nuussuaq peninsula. Up to the present day Eskimos around Disko Bay have used *Elymus mollis* if they could not get *Calamagrostis* (Porsild 1920). *Elymus*, making up the major part of most of the samples, is common on sandy shores and in riverbeds, and also on manured soil at bird cliffs and inhabited sites, northwards to Fladø (72°15′ N), well north of

Fig. 1. Insole, 17 cm long, made of *Elymus mollis*. Mummy 2.

Fig. 2. Upper side of *Elymus* leaf, 14 x. Grave I, 1/4–78.

Qilakitsoq. This robust grass has long runners and straw more than half a metre high. The leaf is 20–30 cm long, 1 cm broad, flat or slightly convolute, smooth underneath, but with many, 0.2 mm wide ribs, covered with tiny, upright bristles on the upper side, visible also in the samples (Fig. 2). In some of the samples, the grass was worn, leaving nothing but the ribs. Sometimes material like this was mixed with "fresh" material, in-

Fig. 3. *Cassiope tetragona* without corolla. One stamen visible, c. 7 x. Grave I, lining on the bottom.

dicating that a worn sole was not thrown away, but supplemented when necessary.

Only a few fragments of straw were found, in one sample the upper part of the straw with the lower part of the spike axis, in another sample two spikelets. *Elymus* was formerly used for basketry (Birket-Smith 1924; Porsild & Cody 1980) as well as for kamik-grass.

Another grass, *Alopecurus alpinus,* dominates in some of the samples. It is widespread from northernmost Greenland southwards to Holsteinsborg. In natural plant communities it is a small, slender grass, whereas on manured ground it grows robust, with 30–40 cm straw. The leaves are 1 cm broad, with the upper side densely ribbed, carrying scattered, thin, hair-like bristles. On the whole, the leaves do not seem to be as wear-resisting as those of *Elymus.* Only a single straw with spike axis of *Alopecurus* was found, but no spikelets, whereas a single spikelet of a *Puccinellia,* most likely *P. vaginata,* was found. This species is likewise very common at seashores and inhabited sites between Disko Bay and Thule.

Besides many fly maggots, proving that the freeze-drying process in the cave was not too effective, most grass samples contained tiny feathers and down, seemingly intentionally used as part of the soles. Further, leaf fragments of *Salix arctica/S. glauca, Empetrum nigrum* ssp. *hermaphroditum, Vaccinium uliginosum* ssp. *microphyllum, Cassiope tetragona* and *Dryas integrifolia,* as well as seeds of *Empetrum, Cerastium alpinum* and *Draba* sp. were found. The use of *kamik*-grass may have contributed to the spreading of plants. Thus *Elymus mollis* was recently found near an Eskimo site on Ellesmere Island, almost 1000 km to the north of its northern limit (Porsild & Cody 1980). Another likely instance of spreading by man could be the tiny *Chrysosplenium tetrandrum,* widespread in arctic North America, where it grows on soil enriched by animal manure, on ruins of former dwellings, meat caches etc. In Greenland it is only found at a couple of sites at some former Eskimo habitations on Clavering Island on the NE coast.

Lining of the graves

The mummies lay on a lining of plant material, in one case *Elymus mollis,* otherwise of dwarf-shrubs, in most cases *Cassiope tetragona* (Table B). This high-arctic plant is very common on Nuussuaq, preferring snow-protected heaths. It is often used as fuel, and because of its content of resin it can burn, even when wet. The seeds ripen during winter and are dispersed during springtime. The capsules found therefore tell us nothing about the season in which they were gathered. However, sample 16 contained a flower with two anthers still attached to the filament, but without the bell-shaped corolla (Fig. 3). This would indicate picking in July-August, but an investigation of more than 100 sheets in the Greenland Herbarium revealed a couple of anthers in the flowers from the previous year. Another common dwarf-shrub in the samples is *Empetrum nigrum* ssp. *hermaphroditum,* likewise common in the area. It is often used as fuel, and the tasty berries are eaten.

A total of ten phanerogam species was proved. In addition, Jette Lewinsky, Botanical Museum, University of Copenhagen, has determined 12 moss species. All of the plants found are common in the area today.

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Diatoms in Mummies from Qilakitsoq

NIELS FOGED

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Eight mummified Greenlanders were found in 1972. Samples of lung and columna tissue from some of them were investigated for content of diatoms in an attempt, on the basis of diatoms, to state whether they died by drowning. Samples of lung, liver, kidney, columna and femur tissue from four drowned and four non-drowned persons from the year 1981–82 were likewise analysed for diatoms, to permit a comparison between the two groups, and thus by means of diatoms to obtain a basis for the diagnosis: drowned – not drowned. The conclusion of the investigation is that no such diagnosis is possible with the method used here.

Niels Foged, deceased 1988.

Diatoms (kiesel algæ) are single-celled autotrophic plants, that is to say they can use solar energy to form organic products from inorganic matter. They most commonly occur in water (salt, brackish or fresh water), but are also found on land and in the air (troposphere) where they are transported by the wind. The valves can occur as fossils in large geological deposits that are important for many industrial processes.

Living diatoms play an important role in the synthesis of organic material in the sea and freshwater and thus provide food for many kinds of animals (crustaceans, molluscs, worms and many others). Hence they can go further along the food chain and end in the human body, coming either from meat or from the surface of vegetables. Countless diatom cells and valves will also be absorbed into the lungs, as they are found in the air we breathe. They can thus be absorbed by the epithelium of the lungs and can then be circulated via the blood to all the other organs of the body.

The valves are silicon compounds, and practically insoluble in non-alkaline fluids. They will therefore later be discoverable in the organs where they have been deposited. Since diatoms, as has been mentioned, are autotrophic, and thus dependent on light, they cannot live inside the human body.

Revensdorf (1904) used diatoms in the diagnosis of drowning, in as much as he interpreted the presence of vegetable plankton – and in particular diatoms – in the lungs as evidence of drowning. Many investigators have shared this view, and their opinions have had evidential value for forensic verdicts.

Not until 1962 were doubts raised, when Spitz (1963/1964) found diatoms in liver tissue from the body of someone who had not been drowned. Since then opinions have been strongly divided, some research workers still supporting Revensdorf's view, others denying that the presence of diatoms in human organs can have any significance for a diagnosis of drowning.

Geissler and Gerloff (1966), have pronounced on this question. They are biologists and diatomologists, and after studying the bodies of nine people who had been drowned and thirteen who had died from other causes in Berlin, they concluded that diatom analysis cannot provide an adequate diagnosis for forensic use.

As the cause of death of the Greenlanders whose mummified bodies were found in 1972, has not been clarified in most of the cases an attempt is made here to use diatom analysis to find support for Jens Rosing's theory (1979), which assumes that they all died at the same time, drowned at sea near where their bodies were found 500 years later.

For this purpose three samples presumed to be lung tissue were taken from mummies I/2, I/5 and II/8, along with samples of thoracic vertebrae from I/2, I/3, I/4, I/5, II/6, II/7 and II/8. After chemical treatment each sample provided 2–4 microscope slides with circular cover slips (16mm diameter) and in a mounting medium of Hyrax (refractive index ca. 1.65). Diatoms were sought in each slide with a 100× immersion objective and a 10× eyepiece. All valves, whole or fragments were noted. Most of the species found were photographed, and prints with a magnification of 1500× were provided (plated I, II and III).

It must be stressed here that such an analysis can only give a quite erratic and very incomplete indication both of the number and character of the diatoms that are to be found in the subjects examined. Thus it has been necessary to limit the study to few organs and few samples of each. It has only been possible to obtain samples of presumed lung tissue from three of the bodies and vertebral tissue from seven of the eight bodies found. Normally an investigation should cover tissue

Table 1

	I/2		I/3		I/4		I/5		II/6		II/7		II/8	
	taxa	valves	taxa	valves	taxa	valves	taxa	valves	taxa	valves	taxa	valves	taxa	valves
oligohalobe	47	437	8	27	10	18	68	200	27	98	18	84	19	24
unidentified (to genus only)	12		1		4		20		2		3		3	
fragments		18		4		2		52		8		10		15
meso+polyhal.	4	4	6	87	1	1	12	14			1	7	6	15
unindentified (to genus only)	1		2				1						2	
fragments								1						8
Total	51	441	14	114	11	19	80	214	27	98	19	91	25	39
unidentified (to genus only)	13		3		4		21		2		3		5	
fragments		18		4		2		53		8		10		23

Total number for all 7 persons: 126 oligohalobe taxa of which 34 are identified to genus only: 888 valves × 109 fragments. 22 meso- or polyhalobe taxa of which 6 are identified to genus only: 128 valves + 9 fragments.
Together 148 taxa of which 40 are identified to genus only: 1016 valves + 118 fragments.
The figures under taxa indicate the number of identified taxa (taxon means species, or variety, or forma).
Also shown are how many species it has not been possible to identity more precisely than as to genus.
The figures under valves includes all valves found, also when they only are identified as to genus.

from lungs, kidney, liver, thoracic vertebrae and femoral medulla. The diatomaceous valves in these organs will be randomly distributed. When taking samples it is impossible to see if they contain many or few valves or even none at all. The representation of different species must be assumed to vary from one place to another within the body, and we must also assume that the total number of diatomaceous remains grows with age – not regularly, but irreversibly, and varying with environmental factors.

As there are always many airborne diatom valves (Foged 1975) it must be assumed that they are constantly being inhaled. Therefore the valves can initially lodge in lung tissues and enter the bloodstream, whence they can circulate to all parts of the body and can be deposited in all organs.

The number of diatoms that can be absorbed into the body during the process of drowning will be quite small, and as a rule can hardly be distinguished with any certainty from those already present. The greatest chance will be in the lung tissue (possibly also in the alimentary tract). When a body has been immersed in water for some time after drowning it is possible that water containing diatoms could contaminate the body after the time of death, primarily the lungs.

The valve material here appeared, in the main, to be well-preserved whole cells (two conjoined valves), two or more of which sometimes formed colonies (especially small *Fragilaria*-species), besides single valves or valve fragments. Occasionally single valves or valve fragments were more or less damaged (dissolved), which is often the case with airborne valves. Fresh water forms (the oligohalobe) are much more common than the salt water varieties (mesohalobe and polyhalobe). The former are usually more or less elongated, while most of the marine types are disc-shaped.

Table 1 shows how many species and how many valves of freshwater and salt water diatoms were found in each of the seven subjects investigated. Also shown are the number of examples where it has been possible to determine the genus but not the species, and the number of valve fragments observed.

For subject I/3 the salt water species, (mesohalobe and polyhalobe), form the majority (87) of all identified valves (114). For subject II/8 the salt water species constitute a major proportion of both species identified and of the number of valves (respectively 6 out of 25 and 15 out of 39). There are the greatest number of salt water species – 12 – although with only 14 valves, in the species found in subject I/5, with a total of 80 species and 214 valves, so that the proportion of salt water specimens is no higher in this subject than in the others. The proportion of salt to fresh water species does not differ much from the proportion between the two groups found in airborne diatoms as shown, for example, in Foged (1975).

The theory that all seven subjects investigated had died at the same time and in the same coastal water cannot be supported by the current study. There is no greater similarity in the population af diatoms found in the subjects than found in other groups of deceased persons – both drowned and non-drowned – at other times and locations (see Table 2).

A review of the species found reveals that only one, the freshwater variety *Synedra ulna,* was found in six of the subjects, always with only few examples, often only

Table 2

		Not drowned								Drowned							
		L 64/1981		L 65/1981		L 75/1981		L 76/1981		L 79/1981		L 89/1981		L 102/1981		L 51/1982	
	sex – age	male – 53		male – 67		female – 57		male – 67		male – 41		female – 39		male – 25		male – 35	
	occupation	engineer		labourer		–		labourer		radiotech.		teacher		yachtsm.		diver (hobby)	
	cause of death	heart dis.		pneum.		cancer		suicide		drowned		drowned		drowned		drowned	
	locality	–		–		–		–		Ll. Belt		Odense fj.		Gr. Belt		Ll. Belt	
		tax.	valv.	tax.	valv.	tax.	valv.	tax.	valv.	tax.	valv.	tax.	valv.	tax.	valv.	tax.	valv.
Lung	Oligohalobe	20	71	41	192	5	6	4	8	5	13	57	216	–	5	11	26
	meso+polyh.	1	1	2	2	–	–	–	–	–	–	4	5	–	1	1	8
Liver	Oligohalobe	13	52	8	18	5	7	4	8	8	21	27	67	3	5	no sample	
	meso+polyh.	1	2	–	–	–	–	–	–	–	–	1	1	–	–		
Kidney	oligohalobe	23	51	21	37	4	7	7	26	2	19	33	124	3	8	13	31
	meso+polyh.	1	2	1	–	–	–	–	–	–	–	3	3	1	1	–	–
Columna	oligohalobe	12	15	8	8	5	7	2	13	33	200	37	118	1	2	5	11
	meso+polyh.	–	–	–	–	2	3	–	–	–	–	2	2	1	2	–	–
Femur	oligohalobe	no sample		no sample		4	17	8	15	2	5	27	79	15	230	1	1
	meso+polyh.					–	–	–	–	–	–	2	2	–	–	–	–
Total	oligohalobe	49	189	67	255	18	44	21	70	42	258	82	604	20	250	22	69
	meso+polyh.	3	5	3	2	2	3	–	–	–	–	10	13	2	4	2	2
Fragments		34		40		10		14		15		117		8		8	

Table 3. Diatom analysis of organs of 4 deaths from natural causes and 3 cases of drowning:

		lungs	liver	kidneys	columna	femur	total	polyhalobes and mesohalobes	No. of samples
L 64	taxa	22	14	23	12	–	52	3	7
	valves	72	54	53	15	–	194	5	
L 65	taxa	43	8	22	8	–	67	3	7
	valves	197	18	37	8	–	257	4	
L 75	taxa	5	5	4	4	7	20	1	5
	valves	6	7	7	17	10	47	1	
L 76	taxa	4	4	7	2	8	21	–	5
	valves	8	8	26	13	15	70	–	
L 79	taxa	5	8	2	33	2	42	–	5
	valves	13	21	19	200	5	258	–	
L 89	taxa	60	28	35	39	28	92	5	9
	valves	221	68	127	120	81	617	7	
L 102	taxa	1	3	4	2	15	22	–	5
	valves	6	5	9	4	230	254	–	

These analyses do not show significant differences between the diatom content of those who had drowned and those hwo had died from other causes.

fragments. The valves of this species can be very long (here up to 250µm). The freshwater type *Cocconeis placentula* with its variant *euglypta* occurs in five subjects; the brackish water species *Archnanthes brevipes* varian *intermedia* and the fresh water *Achnantes minutissima* and *Cocconeis placentula* in four, the salt water species *Grammatophora marina* in three, while seventeen fresh water species and the two brackish water varieties *Cocconeis scutellum* variant *parva* and *Thalassiosira* sp. were each found in two subjects. The other species occur in one subject only.

Given that all the subjects were coastal dwellers, and presumably derived most of their food from the sea, it is remarkable that more marine diatoms were not found in them, as all animal food must be assumed to contain diatom valves.

In connection with this investigation, and in order to extend my personal basis for solving the present problem, I carried out a parallel study. In this I studied the meat of mammals (pigs, cows and horses) and of fish (cod, plaice, herring, i.e. both predatory fish and plankton eaters), as well as human blood. All these samples revealed diatoms.

Finally, in 1981–82, through the good offices of Professor dr. med. Jørn Simonsen, I obtained from the Institute of Forensic Medicine at Odense University tissue samples from four victims of drowning and from four others who died from other causes. Table 2 shows the results of this study, which involved tissue samples from lungs, liver, kidneys, thoracic vertebræ and femoral medulla from each subject.

As a comparison of Tables 1 and 2 will show, there is no signigicant difference in the populations of diatoms found in the seven Greenland subjects and those found in the eight Danish subjects who lived 500 years later.

Conclusion

The diatom content of tissue samples from drowned subjects and of those from subjects who had died from other causes do not differ sufficiently to provide a reliable opinion on drowning as the cause of death. Thus, diatoms found in the tissue samples from the Greenland mummies cannot enlighten us as to the cause of their deaths.

Appendix

In order to be able to evaluate the diatom content of samples of human tissue from personal experience, in the summer of 1981 I approached Professor dr. med. Jørn Simonsen, of the University Institute of Forensic Medicine at Odense. From the Institute I obtained samples of lung, liver, and kidney tissue and vertebral and femoral medulla from eight people, four of whom had died from drowning, the remaining four from other causes.

Results of the analysis of tissue samples received from

the five organs from the seven subjects so far studied can be summarized as follows:
No. 64/1981 (53-year-old man): 194 whole valves (+34 fragments); in all 52 taxa.
No. 65/1981 (67-year-old man): 257 whole valves (+ a large number of *Fragilaria* valves in girdle view and 140 fragments), in all 67 taxa.
No. 75/1981 (57-year-old woman): 47 whole valves (+ 10 fragments); in all 20 taxa.
No. 76/1981 (67-year-old man): 70 whole valves (+ 14 fragments); in all 21 taxa.

These four subjects all died from other causes than drowning (viz. sudden heart disease, lung infection, suddenly after an operation for cancer, and suicide by hanging).

No. 79/1981 (41-year-old man): 258 valves (+ many *Fragilaria* valves in girdle view); in all 42 taxa.
No. 89/1981 (39-year-old woman): 617 valves (+ 117 fragments); in all 92 taxa.
No 102/1981 (25-year-old man): 230 valves (+ 6 fragments and some few *Fragilaria* valves in girdle view); in all 22 taxa.

These three subjects drowned respectively in the Little Belt, South of Funen, in Odense Fjord, and in the Great Belt. No. 102/1981 drowned on 22nd August, and the body was recovered on 11th September.

The number of valves found varies greatly from one subject to another, and the same is the case in the different organs from the same body, as can be seen in Table 3.

In all seven subjects, apart from a very few polyhalobe and mesohalobe taxa, only oligohalobe species were found. In subject 102/1981, which drifted in the salt water of Great Belt for two and a half weeks, only fresh water diatoms were found (and only 6 valves in the lungs, compared with 230 in the femoral medulla).

A curiosity was the discovery in subject 89/1981 of two valves of *Eunotia sibirica* Cleve in lung samples. This species has not previously been identified in Denmark.

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Note on Plates I–III

The examples illustrated are all taken from the tissue samples used in this study, and show that diatoms can be absorbed into human body whatever their size and shape. Nearly all species have been observed before in recent material from West Greenland. An exception in *Gomphonitzschia ungeri* from Subjects II/6 (four valves) and II/8 (one valve). Outside Africa it is only found, and then only very rarely, in Finnish Lapland. Also *Mastogloia splendida* is new for Greenland, although widespread in all coastal regions, if commonest in warmer seas. It is evident from these two examples that knowledge of the distribution of diatoms is still very imperfect, in that again and again it transpires that species described as rare or perhaps endemic (tied to a particular place, or associated with a limited geographical area), are often found a long way from their point of discovery. Any sample from a given locality will only encompass a few square centimetres, and presumably can only hold a chance selection of the diatom flora there. More and more fresh water diatoms turn out to be cosmopolitans.

The scale shown at the bottom of the plates indicated 10 µm, and is valid for all the figures on the plate apart from the few that show some larges species; these are supplied with a separate scale, also to 10 µm.

1 µm = 1 micron = 1/1000 mm.

Plate I

1. *Actinoptychus adriaticus* Grun. Diam. 62 µm. I/2 (lung).
2. *Cyclotella striata* (Kütz.) Grun. Diam. 15 µm. I/2 (lung).
3. *Cyclotella meneghiniana* Kütz. Diam. 15 µm I/2 (lung).
4. *Cyclotella comta* (Ehr.) Kütz. Diam. 20 µ. II/6 (columna).
5. *Achnanthes minutissima* Kütz. var. *cryptocephala* Grun. 18 × 2 µm. I/2 (lung).
6. *Melosira italica* (Ehr.) Kütz. subspec. *subarctica* Müller. 11 × 7µm. II/6 (columna).
7. *Tabellaria flocculosa* (Roth) Kütz. Breadth 17 µm. I/2 (columna).
8. *Fragilaria capucina* Desmaz. 20 × 4 µm. I/5 (lung).
9. *Fragilaria construens* (Ehr.) Grun. 15 × 7 µm. II/6 (columna).
10. *Fragilaria brevistriata* Grun. 17× 4.8 µm. I/2 (columna).
11. *Tabellaria fenestrata* (Lyngb.) Kütz. 30 × 6 µm. II/7 (columna).
12. *Melosira granulata* (Ehr.) Ralfs. 12 × 8 µm. II/6 (columna).
13. *Eunotia tenella* (Grun). Hust. 16 × 3 µm. I/2 (lung).
14. *Meridion circulare* Agardh. 47 × 7-2 µm. I/2 (columna).
15. *Meridon circulare* Agardh. Length 47 µm. II/7 (columna).
16. *Eunotia rhomboidea* Hust. 19 × 17-8 µm. I/2 (columna).
17. *Eunotia rhomboidea* Hust. 22 × 4 µm. I/2 (columna).
18. *Synedra ulna* (Nitzsch) Ehr. 92 × 9 µm. I/5 (columna).
19. *Eunotia lunaris* (Ehr.) Grun. 46 × 5 µm. II/7 (columna).
20. *Eunotia faba* (Ehr.) Grun. 11 × 4 µm. I/5 (lung).
21. *Achnanthes lanceolata* Bréb. var. *elliptica* Cleve. 10 × 5 µm. II/6 (columna).
22. *Grammatophora marina* (Lyngb.) Kütz. 15 × 10 µ. I/3 (columna).
23. *Eunotia praerupta* Ehr. 25 × 9 µm. I/5 (lung).
24. *Eunotia diodon* Ehr. 25 × 4-4.5 µm. I/2 (lung).
25. *Diatoma elongatum* Agardh. 42 × 3 µm. II/8 (columna).

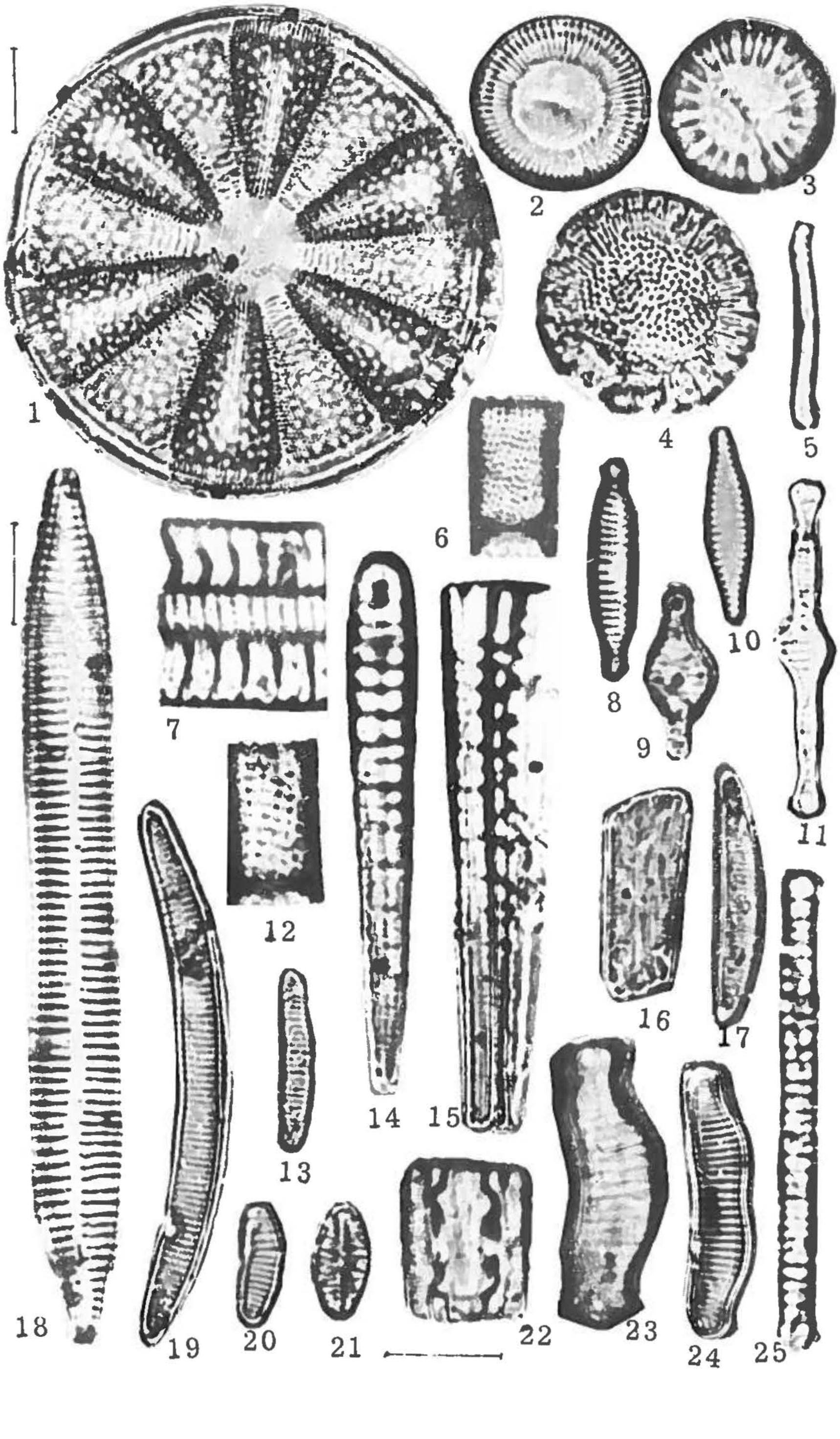
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Plate II

1. *Achnanthes brevipes* Agardh. 58 × 16-17 µm. II/8 (columna).
2. *Achnanthes brevipes* Agardh. 58 × 15-16 µm. II/8 (columna).
3. *Mastogloia splendida* (Greg.) Cleve. 46 × 36 µm. I/5 (lung).
4. *Achnanthes brevipes* Agardh var. *intermedia* (Kütz.) Cleve. 28 × 9 µm. I/3 (columna).
5. *Achnanthes brevipes* Agardh var. *intermedia* (Kütz.) Cleve. 28 × 9 µm. I/3 (columna).
6. *Achnanthes brevipes* Agardh var. *intermedia* (Kütz.) Cleve. 29 × 7 µm. I/3 (columna).
7. *Achnanthes brevipes* Agardh var. *intermedia* (Kütz.) Cleve. 28 × 10 µm. II/8 (columna).
8. *Achnanthes brevipes* Agardh var. *intermedia* (Kütz.) Cleve. 28 × 10 µm. II/8 (columna).
9. *Achnanthes lanceolata* (Bréb.) Grun. 23 × 9 µm. I/4 (columna).
10. *Cocconeis placentula* Ehr. var. *euglypta* (Ehr.) Cleve. 22 × 13 µm. I/5 (lung).
11. *Cocconeis pediculus* Ehr. 18 × 13 µm. I/3 (columna).
12. *Cocconeis placentula* Ehr. 25 × 18 µm. I/5 (lung).
13. *Cocconeis scutellum* Ehr.. 26 × 16 µm. I/5 (lung).
14. *Navicula contenta* Grun. fo. *biceps* Arnott. 13 × 3-4 µm. I/5 (lung).
15. *Mastogloia pumila* (Grun.) Cleve. (?). 23 × 10 µm. II/8 (columna).
16. *Meridion circulare* Agardh. 16 × 8-2 µm, II/7 (columna).
17. *Frustulia vulgaris* Thwaites. 46 × 11 µm. I/5 (lung).

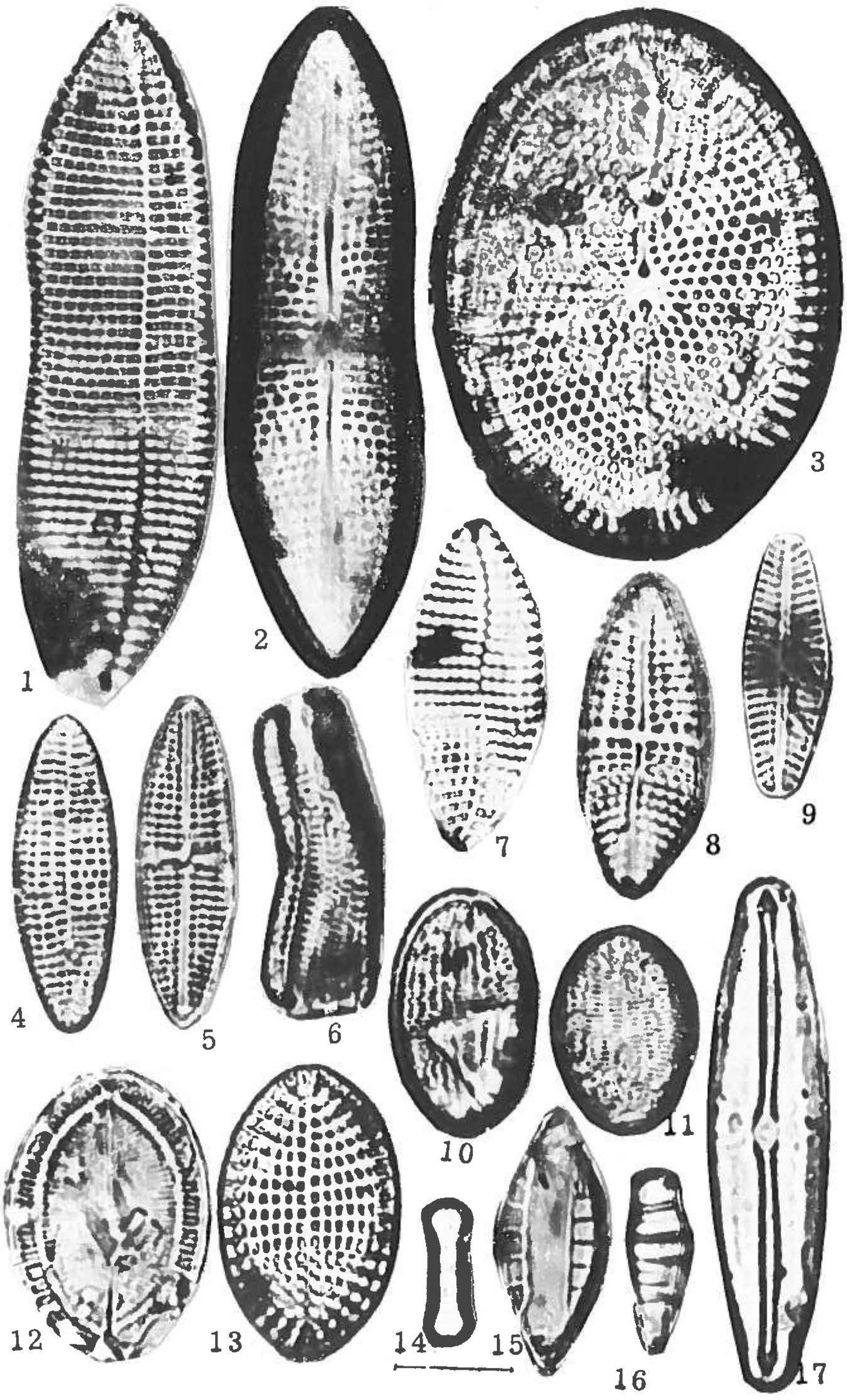
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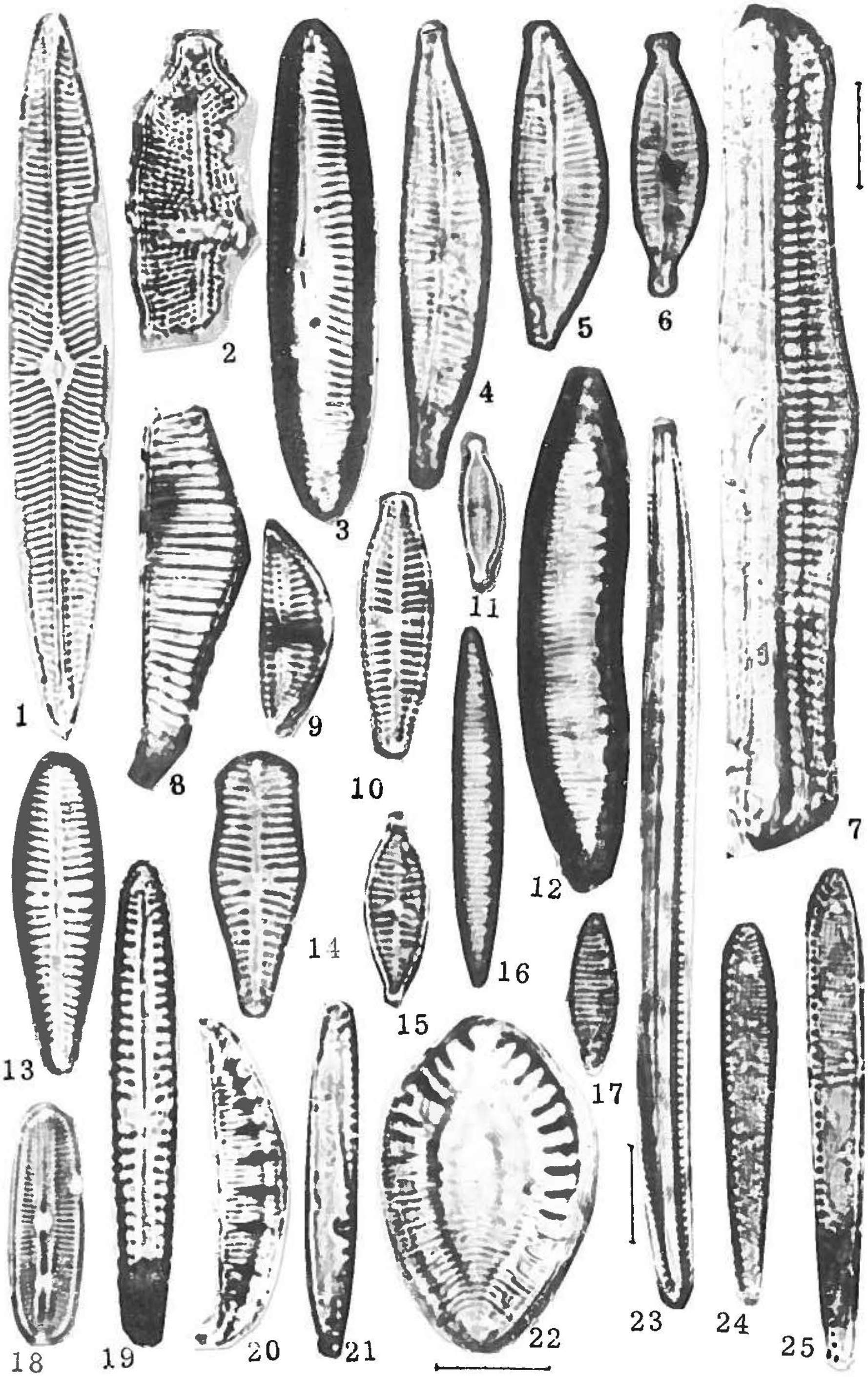
Plate

1. *Navicula radiosa* Kütz. 64 × 9 µm. I/2 (lung).
2. *Navicula charlatii* Perag. (34) × (13) µm. I/5 (lung).
3. *Pinnularia microstauron* (Ehr.) Cleve var. *brebissonii* (Kütz.) Hust. 45 × 11 µm. II/7 (columna).
4. *Cymbella naviculiformis* Auerswald. (?). 40 × 8 µm. I/2 (lung).
5. *Cymbella tumidula* Grun. 29 × 9 µm. I/2 (lung).
6. *Cymbella similis* Krasske. 23 × 7 µm. I/2 (lung).
7. *Rhopalodia gibba* (Ehr.) O. Müller. 86 × 15 µm. I/4 (columna).
8. *Rhopalodia gibba* (Ehr.) O. Müller var. *ventricosa* (Ehr.) Grun. (46) × 15 µm. II/8 (lung).
9. *Cymbella ventricosa* Kütz. 18 × 5 µm. I/5 (lung).
10. *Gomphonema angustatum* (Kütz.) Rabh. var. *producta* Grun. 23 × 6.5 µm. II/7 (columna).
11. *Cymbella microcephala* Grun. 13 × 4 µm. I/2 (lung).
12. *Hantzschia amphioxys* (Ehr.) Grun. 47 × 9 µ. II/6 (columna).
13. *Gomphonema lanceolatum* Ehr. 28 × 8 µm. II/6 (columna).
14. *Gomphonema constrictum* Ehr. 23 × 9 µm. II/8 (lung).
15. *Gomphonema parvulum* Kütz. 15 × 6 µm. II/6 (columna).
16. *Nitzschia amphibia* Grun. 32 × 4 µm. I/5 (lung).
17. *Nitzschia denticula* Grun. 14 × 5 µm. II/8 (lung).
18. *Diploneis ovalis* (Hilse) Cleve var. *oblongella* (Naeg.) Cleve. 21 × 6 µm. I/5 (lung).
19. *Gomphonema intricatum* Kütz. 44 × 5 µm. I/2 (columna).
20. *Rhopalodia gibberula* (Ehr.) O. Müller var. *protracta* Grun. 28 × 6 µm. I/5 (columna).
21. *Nitzschia communis* Rabh. (?). 32 × 4.5 µm. II/8 (columna).
22. *Surirella ovalis* Bréb. 31 × 19 µm. I/2 (columna).
23. *Nitzschia vermicularis* (Kütz.) Grun. 97 × 7 µm. I/5 (lung).
24. *Gomphonitzschia ungeri* Grun. 35 × 5-2 µm. II/6 (columna).
25. *Gomphonitzschia ungeri* Grun. 33 × 5-2.5 µm. II/8 (columna).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