Meddelelser om Grønland

Meteoritic iron, telluric iron and wrought iron in Greenland

Vagn Fabritius Buchwald and Gert Mosdal

Man & Society
9 · 1985

Meddelelser om Grønland

The series *Meddelelser om Grønland* was started in 1879 and has since then published results from all fields of research in Greenland. In 1979 it was split into three separate series:

Man & Society
Bioscience
Geoscience

The series should be registered as *Meddelelser om Grønland, Man & Society (Bioscience, Geoscience)* followed by the number of the paper. Example: *Meddr Grønland, Man & Soc. 1,* 1979.

The new series are issued by Kommissionen for videnskabelige Undersøgelser i Grønland (The Commission for Scientific Research in Greenland).

Correspondence
All correspondence and manuscripts should be sent to:

The Secretary
Kommissionen for videnskabelige Undersøgelser i Grønland
Øster Voldgade 10
DK-1350 Copenhagen K.

Questions concerning subscription to any or all of the series should be directed to the agent.

Agent
Nyt Nordisk Forlag – Arnold Busck A/S, Købmagergade 49, DK-1150 Copenhagen K. Tlf. +45.1.111103.

Meddelelser om Grønland, Man & Society

Meddelelser om Grønland, Man & Society invites papers that contribute significantly to studies in Greenland concerning human beings (such as anthropology, archaeology, arts, economics, education, ethnology, history, law, linguistics, medicine, psychology, religion, social sciences). Papers dealing with borderline subjects as for instance exploitation of natural resources and environmental research may be referred to one of the series *Bioscience, Geoscience* or *Man & Society* according to what is considered appropriate from an editorial point of view. Papers primarily concerned with other areas in the Arctic or Atlantic region may be accepted provided the observations are considered important in a Greenland context.

Instructions to authors. – See page 3 of cover.

Meteoritic iron, telluric iron and wrought iron in Greenland

Vagn Fabritius Buchwald and Gert Mosdal

MEDDELELSER OM GRØNLAND, MAN & SOCIETY 9 · 1985

Contents

Accepted April 1985
ISSN 0106-1062
ISBN 87-17-05239-4
Printed in Denmark by AiO Print Ltd., Odense

Meteoritic iron, telluric iron and wrought iron in Greenland

VAGN FABRITIUS BUCHWALD and GERT MOSDAL

Buchwald, Vagn Fabritius & Mosdal, Gert. 1985. Meteoritic iron, telluric iron and wrought iron in Greenland. Meddr Gønland, Man & Soc. 9: 49 pp, Copenhagen 1985-12-31.

Seventyfour iron objects have been randomly selected from the Greenland archaeological material accumulated in Copenhagen since about 1850. The objects comprise knives, ulos and harpoon blades from most of West Greenland but also include several unworked fragments and some "hammerstones". The objects have been subjected to microscopic and X-ray microanalytic studies to determine their origin and mode of fabrication. The objects fall into three distinct groups. North of the Melville Bugt a majority of the tools have been produced from small fragments of the Cape York iron meteorite shower, that fell near Savigsivik more than 2000 years ago. Some of the meteoritic iron was carried across Smith Sund and as far as Hudson Bay, while transport south along the Greenland coast apparently was more sporadic. In the Disko Bugt area half of the objects may be traced to the occurrences of basalt with pea-sized iron inclusions, while the other half has been made of wrought iron. In the south all ten objects were produced from wrought iron. Some of the wrought iron tools originate from Norse settlements and have apparently been carried as far north as 76°–77° by Norse ships as early as the 12th century. Other wrought iron tools have been introduced by whalers, probably mainly of Dutch, Spanish and British origin, after about 1575 A.D. Some tools may have been manufactured from iron nails, and fittings from wrecked ships. No signs of indigenous iron production have been detected.

V. F. Buchwald, Department of Metallurgy, Building 204, Technical University of Denmark, 2800 Lyngby, Denmark. G. Mosdal, Thomas Laubsgade 28, 2100 Copenhagen Ø, Denmark.

In the past one hundred years Danish archaeologists have systematically examined a significant number of Eskimo settlements on the west coast of Greenland. Many artefacts have been retrieved, restored, dated, and studied in detail. On a few occasions, implements with iron parts or with the corroded remnants of iron, have been collected, but usually have not generated more than a superficial interest. A few have been cursorily examined, while most have been stored for future work.

In the course of a systematic study of meteoritic iron (Buchwald & Munck 1965) it was noticed that out of four examined Eskimo tools from the Melville Bugt region three were equipped with blades of meteoritic iron. This is very remarkable because well documented finds of tools or weapons based upon meteoritic material are extremely rare (Buchwald 1975, Appendix 5–6). On the other hand, the fourth implement, a harpoon head, was made of wrought iron. The archaeological dating, about 1100 A.D., clearly placed this material before any Nordic settlement in the region, so the question about its origin raised additional problems.

The possibility of a systematic examination of a large number of Eskimo tools with remains of iron came, when in 1979 it was decided to reorganize part of the collections of the National Museum of Denmark in order to select material for exhibition in the new museum, Kalaallit Nunaata Katersugaasivia, at Nûk (Godthåb). A total of 74 samples were selected from various parts of West Greenland in order to i) detect the origin of the iron, ii) study the technology of the production of the tools, and iii) evaluate the mechanical properties of the finished implements.

Such artefacts which had been exposed to conservation by annealing techniques after the method of Rosenberg (1917) were excluded from the present study, because it is known that annealing in a significant way changes the structure and the mechanical properties of iron (Buchwald 1976).

The selection of samples and presentation of data

The examined material has been collected or excavated between about 1850 and 1979. In Table 1 the origin of the samples is given, while in Table 2 locations, references and the approximate archaeological datings are presented.

It is appropriate already at this place to give our excuses for rendering locations in Greenland in the traditional spelling, for example Nûgdlît not Nuulliit, Igdlorssuit not Illorsuit. There are two main reasons i) al-

Table 1. List of archaeologists and collectors, responsible for the more important specimens, with sample identification. Present repository is the National Museum, Copenhagen.

Lb 560, Lb 561	Samuel Kleinschmidt (1814–86), Moravian missionary, collecting about 1850–86.
1881-602,-605,-608	K. J. V. Steenstrup (1842–1913), expeditions to Disko Bugt and Ūmánaq, 1879.
L12–	Therkel Mathiassen (1892–1967), excavations at Utorqait, Manîtsoq, July 1930.
L6–	The same, excavations at Igdlorssuit, Disko Bugt, August 1933.
L3-1-12018	Erik Holtved (1899–1981), excavations in Inglefield Land and Thule, 1935–37.
L3-12032-15000	The same, excavations at Nûgdlît, Thule district, and Thule, 1946–47.
L2–	Japetus Steenstrup (1813–97), collected in the Disko Bugt-Ūmánaq district in the late 19th century.

most all the pertinent map sheets are still using the old spelling, and ii) most of the artefacts examined have been published under the old names, have been catalogued in the museum collections under these names, and some have reappeared in later archaeological publications with these names attached. We are afraid that introducing the new ortography on this occasion would be too early and could generate some confusion.

Table 2 contains, beside locations etc., in the last two columns some of the results of this work, i.e. identification as to the nature of the iron and references to photomacrographs and photomicrographs. It was felt that it was convenient already at this place to incorporate these data as a useful survey of all the examined samples. The relevant analytical and microstructural data will be found in the following tables and in the text.

The samples from the Manîtsoq (Sukkertoppen) district, which were collected by Samuel Kleinschmidt, are without any details as to the circumstances of finding.

Table. 2. List of all specimens examined in this report.

Nr.	Type	Location	Approx. latitude	Date, A.D.	Reference	Material	Figures
L3–528	Knife	Inuarfigssuaq, house 2, midden	79°	700– 900	4,6	M	10
L3–662	Adze	Inuarfigssuaq, house 2, midden	79°	900–1200(?)	4,6	M	11
L3–2474	Chain mail	Ruin Ø, Inglefield Land	79°	1200–1300	4	W	37
L3–3604	Harpoon blade	Thule, house 8	76½°	1200–1300	4,6	W	
L3–9918	Fragment	Thule, Comer's midden, layer 7	76½°	1200–1300	4: 305	M	19, 20
L3–12004	Ulo	Inuarfigssuaq, house 4, midden	79°	700– 900	4,6	M	7, 8, 9
L3–12152	Knife	Nûgdlît, house 10	77°	900–1200	5	M	6
L3–12167	Corr.blade	Nûgdlît, house 10	77°	900–1200	5	M	
L3–12237	Corr.blade	Nûgdlît, house 13A	77°	900–1200	5	M	
L3–12238	Fragment	Nûgdlît, house 13A	77°	900–1200	5	M	
L3–12292	Fragment	Nûgdlît, house 13B	77°	900–1200	5	M	
L3–12466	Corr.blade	Nûgdlît, house 20	77°	900–1200	5	M	
L3–12480	Fragment	Nûgdlît, house 20	77°	900–1200	5	M	24
L3–12481	Corr.blade	Nûgdlît, house 20	77°	900–1200	5	M	
L3–12536	Corr.blade	Nûgdlît, house 22	77°	900–1200	5	M	
L3–12572	Knife	Nûgdlît, house 23	77°	900–1200	5	W	
L3–12573	Corr.blade	Nûgdlît, house 23	77°	900–1200	5	M	
L3–12605	Corr.blade	Nûgdlît, house 24A	77°	900–1200	5	M	
L3–12631	Fragment	Nûgdlît, house 24A	77°	900–1200	5	M	15, 16
L3–12672	Fragment	Nûgdlît, house 24B	77°	900–1200	5	M	17
L3–12673	Corr.blade	Nûgdlît, house 24B	77°	900–1200	5	W	
L3–12686	Fragment	Nûgdlît, house 25	77°	900–1200	5	M	67
L3–12782	Corr.blade	Nûgdlît, house 26	77°	900–1200	5	M	
L3–12880	Corr.blade, ulo	Nûgdlît, house 28	77°	900–1200	5	M	12, 13
L3–12881	Corr.blade	Nûgdlît, house 28	77°	900–1200	5	M	
L3–12882	Corr.blade	Nûgdlît, house 28	77°	900–1200	5	M	
L3–12883	Corr.blade	Nûgdlît, house 28	77°	900–1200	5	M	
L3–13032 I	Fragment	Nûgdlît, house 30	77°	900–1200	5	M	
L3–13032 IV	Corr.blade	Nûgdlît, house 30	77°	900–1200	5	M	
L3–13032 VI	Fragment	Nûgdlît, house 30	77°	900–1200	5	M	18, 25, 68
L3–13069	Corr.blade	Nûgdlît, house 31	77°	900–1200	5	M	
L3–13070 II	Corr.blade	Nûgdlît, house 31	77°	900–1200	5	M	14
L3–13133	Fragments	Nûgdlît, house 32	77°	900–1200	5	M	
L3–13134 IV	Corr. blade	Nûgdlît, house 32	77°	900–1200	5	M	
L3–14106	Fragment	Thule, Comer's midden, layer 6	76½°	1200–1300	5	M	22, 23
Northumberland	Met. Stone	Island in Smith Sund	77½°	?	9: 416	M	21
Akpohon	Met. Stone	Ellesmere Island ancient site	79°	?	9: 425	M	
1881–602	Iron basalt	Eqaluit, Ūmánaq district	70½°		1, 2	T	28
1881–605	Iron basalt	Eqaluit, Ūmánaq district	70½°		1, 2	T	
1881–608	Iron basalt	Eqaluit, Ūmánaq district	70½°		1, 2	T	
3927	Ulo	Ūmánaq district	70°	Before 1650		W	41

Nr.	Type	Location	Approx. latitude	Date, A.D.	Reference	Material	Figures
L 2855	Ulo	Ūmánaq district	70°	Before 1650		T	
L 2856	Ulo	Ūmánaq district	70°	About 1650		W	3, 4, 5
L 7154	Iron basalt	'Karnarkarsuak', Ūmánaq dist.	70°			T	
L 7210	Harpoon blade	Eqaluit, Ūmánaq district	70½°	Before 1650		T	
L 7218	Knife	Ūmánaq district	70°	Before 1650		T	
L 8356	Knife	Ūmánaq district	70°	1650–1750		W	42, 43, 44, 65, 66
Lb 560	Harpoon blade	Manîtsoq district	65°	1650–1750		W	53
Lb 561	Harpoon blade	Manîtsoq district	65°	1650–1750		W	54
Lc 277	Ulo	Ūmánaq district	70°	Before 1650	3	T	30, 31
Lc 297	Arrow blade	Ūmánaq district	70°	After 1650		W	45
Lc 750	Ulo	Eqaluit, Ūmánaq district	70½°	Before 1650		T	
Lc 752	Ulo	Eqaluit, Ūmánaq district	70½°	Before 1650		T	
Lc 755	Knife	Eqaluit, Ūmánaq district	70½°	Before 1650		T	33
Lc 800	Knife	Ūmánaq district	70°	Before 1650		T	34
L2–425	Harpoon blade	Ūmánaq district	70°	1650–1750		W	46
L2–426	Harpoon blade	Ūmánaq district	70°	1650–1750		W	47
L2–621	Knife	Ūmánaq district	70°	Before 1650		T	32
L2–959	Knife	Ūmánaq district	70°	Before 1650		T	
Geol. Mus. 1984: 864	Ulo	Qaersut, Ūmánaq district	70½°	Before 1650		T	35, 36
L6–3155	Knife	Igdlorssuit, Disko Bugt	70°	1300–1500	7	W	
L6–3308	Knife	Igdlorssuit, Disko Bugt	70°	1700–1800	7	W	48, 49
L6–3316	Knife	Igdlorssuit, Disko Bugt	70°	1700–1800	7	W	50, 51
L6–3479	Nail	Igdlorssuit, Disko Bugt	70°	1700–1800	7	W	52
L12–292	Knife	Utorqait, Kangâmiut area	66°	1650–1700	8	W	57
L12–439	Adze	Utorqait, Kangâmiut area	66°	1600–1650	8	W	56
L12–463	Knife	Utorqait, Kangâmiut area	66°	1600–1650	8	W	58, 59
L12–644	Knife	Utorqait, Kangâmiut area	66°	1650–1700	8	W	60
L12–686	Ulo	Utorqait, Kangâmiut area	66°	1650–1700	8	W	61, 62
L12–814	Harpoon blade	Utorqait, Kangâmiut area	66°	1500–1650	8	W	55
L12–820	Harpoon blade	Utorqait, Kangâmiut area	66°	1500–1650	8	W	
Vienna A217	Harpoon blade	"Sowallick", Melville Bugt	76°	Acq. 1818	9: Fig. 494	W	40
1924.13	Harpoon blade	Anoritôq, Inglefield Land	78½°	1800–1900		W	39
Crowned F	Ulo	West Greenland (Nûk)?	64°	1800–1850?		W	63

References: 1 Steenstrup 1882, 2 Lorenzen 1882, 3 Steenstrup 1872, 4 Holtved 1944, 5 Holtved 1954, 6 Buchwald & Munck 1965, 7 Mathiassen 1934, 8 Mathiassen 1931, 9 Buchwald 1975.
Material: M meteoritic iron, T telluric iron, W wrought iron.

They were probably acquired at the time because they were remarkable and well worked, in short: beautiful souvenirs.

The three specimens from Steenstrups 1879-expedition come from an old grave at Eqaluit, near Ikerasak in the Ūmánaq district. It is remarkable that this grave contained a piece of basalt with native iron of a type which may be considered as the raw material for several of the implements that are studied in this work.

The requirements of modern archaeological research have been fulfilled by Therkel Mathiassen (1931; 1934) and Erik Holtved (1944; 1954), who were actively excavating in the second quarter of this century. In their reports all background information as to circumstances of finding and discussions of the archaeological settings may be found. Individual specimens are treated in context with all the other excavated specimens, of bone, schist, soapstone etc.

Besides the significant number of specimens from these excavations several individual samples from a variety of locations have been incorporated into the present study. The samples were retrieved from the store rooms of the Department of Ethnography, the National Museum of Denmark, by a systematic going over the collections by Mrs. Gerda Møller. Part of these specimens, mainly those numbered L-, Lc- and L2-, have apparently not been discussed in the literature earlier.

In addition a few samples from other sources have been included: a harpoon blade (A 217) from the Museum of Natural History in Vienna; a hammerstone (Akpohon) from the American Museum of Natural History in New York; a hammerstone (Northumberland) and ulo (1984: 864) and a harpoon blade (1924: 13) from the Geological Museum in Copenhagen; and an ulo (Crowned F) in private possession. We are grateful to all who have helped in putting these items at our disposal for the analytical and metallurgical work.

Finally we wish to thank curator Jørgen Meldgaard of the National Museum of Denmark, who has critically examined the datings of most of the objects and in a number of cases revised them, in accordance with the results of recent C-14 datings.

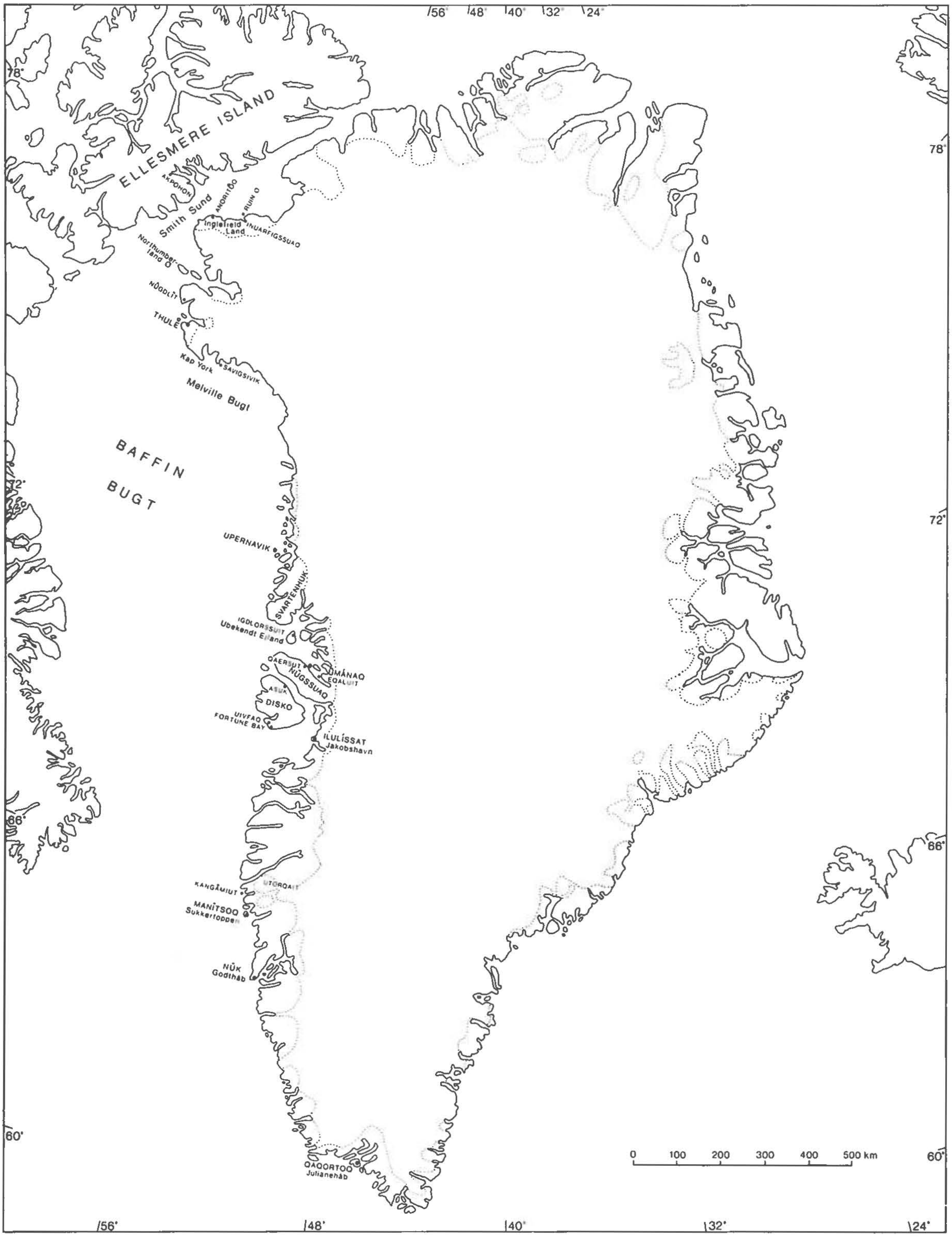


Fig. 1. The locations discussed in the text marked on a map of Greenland.

Sample preparation – requirements and limitations

It is characteristic of the examined iron objects of this study that the iron was examined before any preservative method had been applied. The iron is therefore corroded to varying degrees. Sometimes the corrosion products have partly destroyed the bone part and thus made it very difficult to separate the iron insert from the bone part. However, in order for the conservator to make a meaningful conservation it is normally required to prepare the different materials separately (Schmidt 1979). It was therefore decided to cooperate very closely with the conservation laboratory, so that the following operations could be carried out: i) retrieval, verification and macrophotography, ii) separation, if necessary; weighing and macrophotography, iii) cutting of a minute fragment for metallographic and microanalytical examination, iv) conservation, and v) reassembling and finishing, usually with the result that the scar from the examination was fully eliminated.

From the tables it will be seen that the metallic part of the samples ranges from 50 milligrams to kilogram size. The smaller specimens were often in a severely corroded state, so all that was left usually were minute metallic specks a few square millimetres in area. This, however, sufficed for both a metallographic and an analytical examination.

Some of the larger specimens were so unique in either shape or location that it turned out to be imperative to use either nondestructive methods or to remove only minute fragments from places where it could not be seen after the final conservation. The nondestructive methods included X-ray radiography and semiquantitative scanning electron microscopy on lightly filed surfaces. Another gentle method was superficial electropolishing (Knuth-Winterfeldt 1952) where a spot of a few square millimetres could be brought to a metallographic finish and, after the examination, by the conservator could be restored to its initial colour and texture.

For the ideal examination the sample should be cut both lengthwise and crosswise in order to reveal textural and chemical variations across the full section. Usually, however, much less material was available, typical areas for the microscopical examination being of the order of 10×2 mm. This, however, was found in all cases to suffice for a full classification as to structure, texture, state of corrosion, hardness, microprobe analysis and unambiguous identification as to origin. As it turned out, the crucial question whether the material was telluric iron, meteoritic iron, or wrought iron, could be answered by application of these methods in combination.

During the study additional questions arose, such as, is it possible to identify the specific meteorites that were used in working the tools? Is it possible to distinguish between wrought iron made about 900 A.D. and for example about 1600 A.D. and thus verify the archaeological datings? Is it possible to identify the sources of wrought iron? These questions will be discussed below. However, it can already here be noted that our methods presently appear to be insufficient to provide unambiguous answers.

As stated above, it will normally be necessary to separate iron and shaft for individual conservation. Where the decomposition of the iron is so severe that the corrosion products have split the organic material, there are no problems associated with the separation. However, in such cases where the corrosion attack is limited, the corrosion products unfortunately fix the two parts very firmly. Add to this the fact that the Eskimo craftsman often secured the iron blade to the shaft with a small pin, and it will be understood that each artefact requires careful deliberation before actual handling. It was found that a small homebuilt tool, a saw constructed from a capillary copper tube in which was squeezed a piece of a jeweller's saw blade (Fig. 2) could be very efficient in penetrating into the delicate openings which had to be cleaned before separation. For the most careful work the set of the saw was reduced by grinding.

To illustrate the procedure, a woman's knife, a so-called ulo, of wrought iron and dated to about 1650 A.D., is shown in Fig. 3–4 before and after separation of the iron blade from the shaft. In Fig. 5 the four brass-wedges that secured the blade are shown. The operation was tedious, but lenient towards the unique material.

In a case like this, the sample for our examination could be removed from that part of the blade which, af-

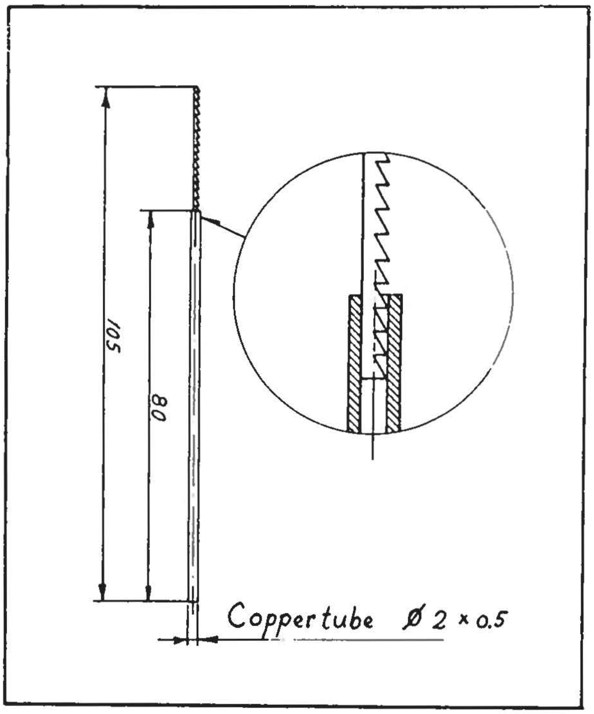


Fig. 2. Sketch of miniature saw for preparation. A fragment of a jig-saw blade is fastened in a coppertube. Dimensions in mm.

Fig. 3. Ulo, L 2856, with blade of wrought iron. In the centre a rivet consisting of four brass pins. Scale in mm.

Fig. 4. The ulo of Fig. 3. disassembled. Scale in mm.

Fig. 5. The brass pins from Fig. 3. Scale in mm.

ter restoration, is again hidden in the shaft. In other cases material had to be removed from visible locations, however, usually in a way so that the tool could be rebuilt to the original shape by the conservator.

It was, for instance, from a museum viewpoint decidedly to be preferred to remove a wedge by incision or sawing from one side only, instead of taking a full section through the tool. In the last case no one would later know exactly how much material had been removed, and the restoration would, moreover, be more difficult. But, of course, from the viewpoint of the metallurgist full cross sections in more than one place would have given the most information.

The cutting was performed without lubricant with a jeweller's saw, or, when the sample had a shape and firmness fit for mounting in a vice, with a mechanical saw. In the last case the best method was cutting with a rotating diamond saw, in this case Buehler Isomet, in which a low-speed disc, impregnated with diamond grit cuts its way, lubricated with kerosene or various brands of lubricants, suited for iron and rusted iron and steel. Two diamond wheels were used, either a 100 mm diameter wheel with a blade thickness of 0.3 mm, or a 75 mm diameter wheel with a blade thickness of 0.15 mm. The widths of the cuts were, respectively, about 0.5 and 0.2 mm, when using a speed of 200 rpm. The cutting by diamond wheel was slow in most cases.

Samples that were only weakly cohesive due to severe corrosion were usually mounted in a cold-curing resin (Struers Epofix) for stabilisation during cutting.

After cutting the lubricant was removed by washing with kerosene and alcohol. After drying in a stream of warm air (e.g. application of a hair-drying apparatus), the sample was set in cold-curing resin and impregnated in a small vacuum box. For this operation a thick-walled glass-desiccator with water-jet pumping was sufficient. The vacuum impregnation served to fill pores and crevices, and to bind any loose particles that otherwise might become loose under the following grinding and polishing operations and thereby scratch the finished surface.

Grinding took place on rotating, horizontal wheels with emery papers of increasing fineness, from 80, through 220, 300, 500 to 1000 (Knuth Rotor, Struers, Copenhagen). During grinding, a copious stream of water served to remove the dust and cool the sample. For the smaller samples the coarser grits were usually omitted and grinding took place with only 1000 emery paper.

Polishing was carried out on horizontal discs with cloths impregnated with diamonds (Struers DP-9 and DP-U2). The grain sizes were 7, 3 and 1 μm.

The samples were studied as polished for defects, pores, slag distribution and corrosion products. Finally, the samples were etched in dilute nitric acid dissolved in ethyl alcohol, usually the 2% HNO_3-concentration, called Nital.

The hardness test

An important characteristic of iron and steel is the indentation hardness. The hardness number is on the order of 80–100 for unalloyed, annealed iron, but 700–900 for fully hardened steel. Between these limits the hardnesses of most iron and alloys of iron are to be found. There is a vast background information on hardness and its variation, and it is safe to say that a hardness determination combined with a structural examination and a chemical analysis will usually fully characterize any sample.

Resistance to plastic indentation was in this study determined by a Vickers hardness test, in which a small diamond, in the shape of a pyramid, is pressed into the surface by a standard load, whereupon the size of indentation produced by it is measured. The hardness number HV is defined as the load of the indenter (kilopond) divided by the projected area of contact between the pyramid and the material (mm^2). In the present study the load was chosen as 100 g (0.1 kp) and the size of the indentations were therefore rather small and had to be measured on a microscope. The entire microhardness test was carried out on a special test machine, the Leitz Durimet.

The tensile strength is to a good approximation about one third of the hardness of iron and steel, expressed in kp/mm^2. If, for example, the Vickers hardness is 150 (kp/mm^2), the tensile strength is about 50 kp/mm^2. This is a quite useful indication of the strength of the material; however, it must be remembered that any defect, such as slag alignment, or textural variation along a sample will not be disclosed by the hardness determination, which is a "spot test" as compared to the tensile test that averages over a considerable volume of the material. To improve somewhat on the limitations of the hardness test one usually makes three to ten indentations and calculates the average hardness number. On the other hand, the microhardness test is unique in being able to detect any gradient present, for example in a carburised and hardened surface or in a knife that is only partially cold-worked.

The hardness test is standardized and more information may be found in, e.g. Andersen (1984) and Danish Standard nr. 10411.

Chemical composition

The bulk chemical composition was not determined, firstly because of the rather limited quantity of material available, secondly because of the heterogeneity of most of the samples. For identification it is, in fact, more important to determine the composition and variation of the individual phases and components than to determine the bulk composition. On severely corroded material it is, because of the deep and complex penetration of the corrosive attack, usually impossible to extract sufficient sound material for a bulk analysis, whereas an X-ray microprobe examination can always be carried out. Moreover, the microprobe can assist in identifying phases that are present as small inclusions, but nevertheless are of diagnostic value, such as taenite (see Appendix), which is unique to iron of meteoritic origin.

The X-ray analytical microprobe was an Applied Research Laboratories instrument. Eight chemically analyzed, annealed Fe-Ni alloys ranging from 2 to 40% Ni were used as calibration standards. Calibration curves permitted accurate interpolation. Corrections for drift, background, and counting system dead-time were also made. The data were taken using fixed time counting, usually 10 sec, the acceleration voltage was 25–30 KV, and the specimen current 0.2 μA. The probe diameter was 1–2 μm.

In addition to the Fe-Ni standards, a series of pure metals (Fe, Ni, Mn, Cu, Cr) was used as well as two Fe-P alloys (0.2 and 0.4% P) and three Fe-Si alloys (0.04, 0.17 and 0.33% Si).

Several analyses were, in addition, confirmed on a scanning electron microscope with energy-dispersive analytical equipment (Philips SEM-EDAX).

The structure, composition and hardness of the Greenland material

While the entire material is presented in Tables 1–2 with information on locations, age, museum numbers etc., the following presentation will be broken down into three divisions, according to the origin of the iron objects. For the sake of clearness the meteoritic iron will be treated separately from the telluric iron and from the wrought iron, and each division will start with a brief introduction and references to earlier work.

Meteoritic iron

General background

It is now known that meteoritic iron always contains at least 5 wt.% nickel (bulk), that it is rich in inclusions, such as schreibersite, $(Fe, Ni)_3P$, chromite, $FeCr_2O_4$, troilite FeS, and sometimes in addition contains cohenite, $(Fe, Ni)_3C$ and graphite, C (Buchwald 1975, see also Appendix). Furthermore, the fresh iron meteorite will be enveloped in a paper-thin, black fusion crust, under which is found a heat-affected zone (HAZ) with steep structural and hardness gradients. The meteoritic matrix usually consists of major portions of the phase kamacite, which is a body-centered cubic ferrite with 5–7.5% Ni in solid solution, and of minor portions of the phase taenite, which for the present study can be perceived as a face-centered cubic austenite with 30–50% Ni in solid solution. Kamacite and taenite may be intergrown in a variety of intricate patterns, called plessite, all of which are diagnostic of meteoritic iron and never met with in telluric or wrought iron.

It is on basis of such characteristics seldom difficult to identify an unknown sample as meteoritic iron. However, if the sample is corroded, or heat-treated, or severely cold-worked, one or more of the traits disappear and the identification in such cases may require a careful study.

The origin of iron samples found in Greenland was in the 19th century very controversial (Buchwald 1964). The state of confusion may be illustrated by the catalogue of Buchner (1863: 154) who states that meteoritic iron occurs in Baffin Bay (i.e. Kap York), Niaqornaq, Fortunebay (both in the Disko district) and in the Davis Strait. Today we only recognize the Cape York occurrence as of meteoritic origin. Prominent scientists, such as Nordenskiöld, Brezina and J. Steenstrup, maintained that all iron from Greenland was of meteoritic origin. When K.J.V. Steenstrup finally proved that the widespread iron in the basalt of Disko was of native, or telluric, origin, most scientists accepted this conclusion, but in addition believed that also the Cape York iron was of similar nature (Steenstrup 1882; Wülfing 1897: 404–405).

The problem was caused partly by the difficulty in making a precise analytical determination of the nickel content, partly by the incomplete knowledge and geological mapping of Greenland. Brande analyzed in 1818 some fragments of iron, exchanged by Captain John Ross with the Polar Eskimos from the Kap York district (Chladni 1819: 344). Although Brande only found about 3% nickel, he, Wollaston and Sabine rightly concluded that the fragments must be of meteoritic origin. It lasted, however, 80 years before the source of the material was finally identified by Peary (1898), who also correctly showed that the nickel content was not 3, but rather 8%. However, the matter was again confused when Coghlan (1956: 178) described an Eskimo knife from Cape York and reported an erroneous analysis with 11.83% Ni and traces only of cobalt and copper.

Lorenzen (1882) analyzed a number of Eskimo tools and found in one knife 7.76% Ni and 0.56% Co. This is a remarkable analysis for the period and in perfect agreement with the analyses that have been performed in the last twenty years (Buchwald 1975: 417). While Lorenzen required about 3 g, out of the 6 g knife, for his analysis, similar analyses would today require about 0.5 g; less will not do for a bulk analysis because of the heterogeneity of the material. The microprobe analyses may on the other hand be carried out on the same material which is used for the structural examination and for the hardness test, and it may thus be said to be non-destructive. It does, however, require a polished surface, and if this surface is not representative of the entire specimen, the result may of course be misleading. The small polished samples are usually kept in desiccators, and the collection thus built may become a very valuable reference collection.

Iron meteorites occur only at one place in Greenland, in the Kap York district between Meteoritø and Wolstenholme Fjord (Buchwald 1975: 410–425; 1191–1195). At least nine specimens, ranging from 290 g to 31 t in weight, have been found and removed to museum collections in New York and Copenhagen. While individual specimens have acquired their own names, such as Ahnighito, Woman, Dog, Agpalilik, Savik and Thule, it is certain that all samples come from one main body which split in the atmosphere and scattered large and small fragments over an area of at least 125×20 km. The meteorite, which is called Cape York, has probably fallen more than 2000 years ago, judging from the present state of corrosion, but unfortunately all attempts at an accurate determination of the date of fall have so far been defied.

The main body may have had a mass above 200 t. When it split, many fragments disappeared in the waters of the Melville Bugt and in the Inland Ice, and others, no doubt, lie in remote places, waiting to be found. However, a large number of fragments evidently landed on ice free islands, peninsulas and valleys, and it is the authors' opinion that the Eskimos started with collecting whatever they found of a suitable, handy size, say 10–1000 g, while they later, in addition started to work the unwieldy masses in the Savigsivik area. The polar explorers Kane (Buchner 1863), Hayes (1862) and Peary (1898) all reported that the Eskimos knew how to exploit the iron fragments, and one of the authors (V.F.B.) has visited the places in the Melville Bugt where the large blocks were located and can testify to the activity of the Eskimos, noting the surprising number of basaltic boulders that the Eskimos carried to the

Table 3. The chemical composition of individual, large fragments of the Cape York iron meteorite. Data from Buchwald (1975) and Esbensen et al. (1982)

	Weight kg	Ni %	Cu %	P %	Co %	As ppm	Ga ppm	Ir ppm	Au ppm
Savik II	7.8	7.54	0.018	0.15	0.50	4.11	18.8	5.13	0.57
Savik I	3,402	7.46	0.017	0.15	0.50	4.11	19.0	5.10	0.57
Ahnighito	30,880	7.55	0.017	0.20	0.49	5.20	19.2	4.86	0.60
Woman	3,000	7.65	0.017	0.19	0.50	5.30	19.6	4.65	0.68
Dog	407	7.89	0.016	0.17	0.50	5.37	19.6	4.42	0.75
Agpalilik	20,140	8.25	0.017	0.21	0.51	8.00	19.6	2.68	0.97
Thule	48.6	8.52	0.020	0.24	0.52	8.42	19.7	2.68	1.03

Other elements, such as carbon, manganese, silicon and chromium have also been determined. Each of these is below 0.01%.

place as hammer stones. In one place alone, around the 3 t Woman block, the number of basaltic hammer stones, ranging from 1 to 10 kg, may be estimated to 10 000. No doubt, the Eskimos have travelled for countless generations to the distant place in order to renew their stock of iron for implements (Fig. 27).

Individual specimens of the Cape York shower show some variation in composition (Table 3); however, the structural variation is small, being that of a medium octahedrite. There is a typical Widmanstätten structure with an average kamacite bandwidth of 1.0–1.3 mm. A loose fragment will thus be accepted as a part of the Cape York shower if its analysis falls within the reported range, and the structure is compliant with the structures of the examined masses. The best studied are those of Agpalilik, Thule and Savik, and extensive information with photomicrographs and hardness tests can be found in Buchwald (1975).

Samples of meteoritic origin

The meteoritic samples may be divided into three categories. Some samples are still fixed in their tool, whether a knife, an ulo or a harpoon point, others have been found as loose, flattened fragments, intended for use as blades or actually used and later separated (by corrosion perhaps) from the handles. In Table 2 these have been identified with the phrase "corroded blade". Finally the third category is composed of raw iron meteorite fragments of various shapes and sizes and not

Table 4. *Meteoritic iron.* Knife blades, ulo blades and remains of cutting tools, difficult to identify. Dimensions, electron microprobe analyses of the kamacite phase, and Vickers hardness (100 g). Ordered after registration number.

Type	Number L3–	Dimensions mm	Weight g	Ni %	P %	HV 100	Remarks, Figures
Knife	528	30×10×1	1	+		–	Holtved 1944: 241, 303
Adze	662	50×20×7	10	~7.2	~0.1	250–300	
Ulo	12004	65×23×1	4	~7.2		–	Stamp motive
Knife	12152	68×23×3	10			254–297	
Blade	12167	15×15×3	1			–	Severely corroded
Blade	12237	40×20×0.5	3			281–302	
Blade	12481	20×13×3	3			266–317	
Blade	12536	23×12×3	1			216–274	Severely corroded
Blade	12573	37×20×1	3.5			266–339	Compare L3–12572, p. 28
Knife	12605	48×29×2	7	~7.2	0.38	254–283	With a hole for a pin
Blade	12782	33×17×2	2			299–319	
Ulo	12880	69×21×2.5	10.3			243–268	
Blade	12881	32×28×3	5			274–281	
Blade	12882	32×21×2	5			245–317	
Blade	12883	30×17×4	2			–	Severely corroded
Blade	13032IV	28×15×1	2			287–314	
Ulo?	13069	48×28×1	5	7.1	0.18	272–281	With a hole for a pin
Blade	13070 II	27×17×4	3			294–314	
Blade	13134 IV	20×15×1	1			266–339	
Knife	Sermermiut, Ilulíssat		6.1	7.76	0.56Co	–	Lorenzen 1882: 26; Table 7

Table 5. *Meteoritic iron.* Unworked, more or less shock-deformed fragments of Cape York meteoritic iron found in house ruins, middens and graves. The microhardness values are the range of 5 indentations at 100 g load.

Location and number	Approx. latitude	Dimensions mm	Weight g	HV 100	Museum
Akpohon, Ellesmere Island, Canada	79°	98×97×46	1660	225–285	AMNH New York
Northumberland, Smith Sund	77½°	60×50×30	292	281–314	Geol. Mus. Copenhagen
L3–9918 Thule, Comer's midden	76½°	55×44×15	78	194–247	Natl. Mus. Copenhagen
L3–14106 Thule, Comer's midden	76½°	110×105×15	711	198–212	Natl. Mus. Copenhagen
L3–12238 Nûgdlît, house 13A	77°	34×15× 3	4	253–281	Natl. Mus. Copenhagen
L3–12292 Nûgdlît, house 13B	77°	21×15× 5	2	262–281	Natl. Mus. Copenhagen
L3–12466 I Nûgdlît, house 20	77°	31×23× 6	6	279–294	Natl. Mus. Copenhagen
L3–12466 II Nûgdlît, house 20	77°	23×11× 7	3		Natl. Mus. Copenhagen
L3–12480 Nûgdlît, house 20	77°	40×13× 5	5	272–322	Natl. Mus. Copenhagen
L3–12631 Nûgdlît, house 24A	77°	20×20× 9	12.5	202–258	Natl. Mus. Copenhagen
L3–12672 Nûgdlît, house 24B	77°	41×22×11	21	251–306	Natl. Mus. Copenhagen
L3–12686 Nûgdlît, house 25	77°	30×22× 2	4	276–302	Natl. Mus. Copenhagen
L3–13032 I Nûgdlît, house 30	77°	26×21×11	14		Natl. Mus. Copenhagen
L3–13032 VI Nûgdlît, house 30	77°	24×13× 7	5	235–249	Natl. Mus. Copenhagen
L3–13133 Nûgdlît, house 32	77°	85×58× 4	63	264–327	Natl. Mus. Copenhagen

worked to any significant extent. In Table 2 these are identified with the phrase "fragments".

Due to the corroded nature of the excavated specimens there are a few cases where it is a little doubtful, whether a particular sample should be referred to one or the other category, but the general picture is clear. In the following, typical or special samples have been selected for presentation, while information on the remaining samples can be found in Tables 4–5.

L3–12152 is a knife (Fig. 6) from Nûgdlît, a site located 150 km NW of the Cape York fall area. The archaeological dating is 900–1200, and the general background has been discussed by Holtved (1954), who excavated a considerable number of house ruins, but only found very little iron.

Two metallographic sections show that the knife blade has been produced from a fragment of the Cape York meteorite by cold-working. The metallic matrix has been severely kneaded and the Vickers hardness has correspondingly increased from about 220 to 272±15. Mineral inclusions, such as schreibersite, have been sheared and partly lost their identity. The taenite lamellae and the plessite fields have been folded and distorted. All components show, however, that heat was not applied; the hammering and kneading was performed at ambient temperature, and no recrystallization or hardening in the sense of heating followed by a water-quench took place.

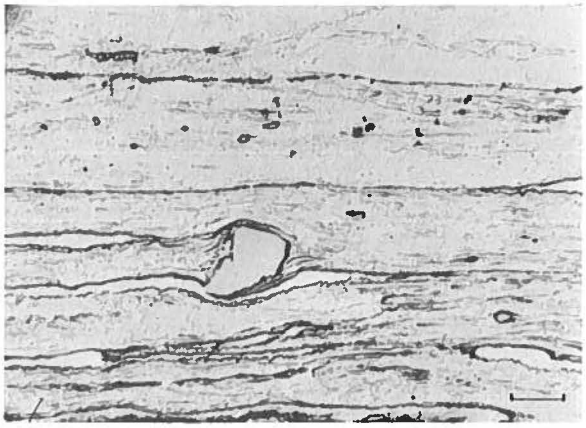


Fig. 6. A polished and etched section through the meteoritic iron knife L3–12152. Cold-worked kamacite and taenite and, in the center, a distorted rhabdite crystal. Scale bar 10 μm.

L3–12004 is an ulo from Inuarfigssuaq in Inglefield Land, about 300 km north of Kap York. The ulo has previously been discussed and pictured by Holtved (1944) and Buchwald & Munck (1965). Fig. 7 shows the entire, well-preserved tool: an iron blade 65×25×0.6 mm has been set in a walrus tusk handle. It was found with other Dorset specimens in a midden in front of house 4. In view of the unique material no cutting has taken place. Instead a small area of 5×5 mm was cleaned for loose rust and scales, electropolished and lightly etched in Nital. The structure was that of severely cold-worked meteoritic iron from Cape York, and the structural details were similar to those reported for the previous sample (Fig. 8). On the scanning electron microprobe the kamacite phase was found to contain 7.2±0.2 Ni, the same as that of Cape York.

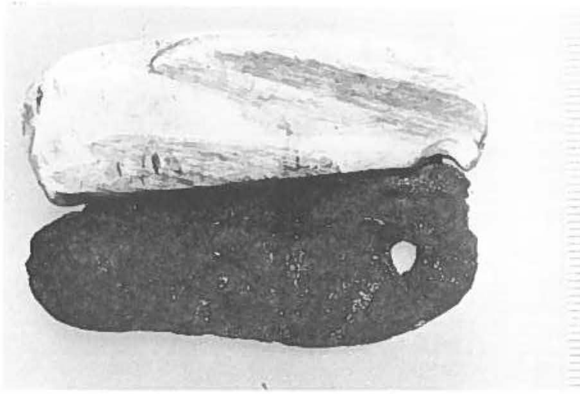


Fig. 7. Ulo of meteoritic iron from Inuarfigssuaq, Inglefield Land, L3–12004. Scale in mm.

When the "Commission for Scientific Research in Greenland" in 1978 celebrated its centenary, it was decided to issue a commemorative stamp. The ulo L3–12004 was chosen as the chief motive and it was situated on the background of a typical Widmanstätten structure from a Cape York iron meteorite from which it was made.

In collaboration with the artist Jens Rosing and the engraver Cz. Slania various combinations were examined and finally the design shown in Fig. 9 was selected as a symbol of the Commission's equal dedication to archaeology, geology and ethnology.

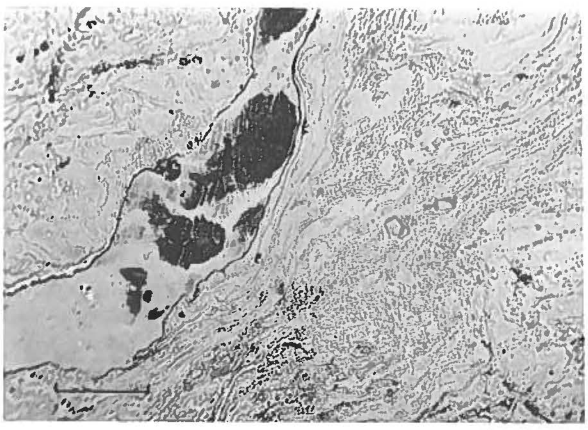


Fig. 8. Microstructure of the ulo L3–12004. The kamacite is severely distorted and the small rhabdites are sheared. The cloudy taenite lamella is bent. Scale bar 40 μm.

Fig. 9. Stamp emission of 1978, for letter first class, celebrating the centenary of the "Commission for Scientific Research in Greenland". The ulo, L3–12004, is placed on top of a polished and etched plate of the Cape York iron meteorite.

L3–528 is a small knife (Fig. 10) from Inuarfigssuaq, from midden B II at house 2. A small and corroded iron blade, 30×8×0.5 mm, has been set in a handle of antler. The flat handle is almost rectangular in section. The spectrographic analysis of the blade was positive for nickel (Holtved 1944: 303). Due to the feebleness of the material, it was decided here not to remove a sample for examination. The old spectrographic determination by M. P. Mogensen at Paul Bergsøe & Søn, no doubt, can be relied upon.

L3–662 may be perceived as an adze or a scraper (Fig. 11), where a massive iron blade, originally measuring about 55×20×5–10 mm, has been inserted into a handle of antler. The handle is decorated by lines incised in a trapezoid pattern and roughened on both sides, probably in order to provide a better grip for the user. The adze was excavated from house 4 at Inuarfigssuaq and may belong to either the Dorset or the Thule culture (Holtved 1944). Although the iron is now severely corroded it was possible to polish and etch a few mm^2 on the tool without removing material. Metallographic examination showed clearly that L3–662 had been produced from a Cape York meteorite fragment that had been shaped by cold-work. Especially the taenite lamellae that by Nital etching became stained in bluish-brownish colours were in this case diagnostic. The hardness could not be measured, but was estimated as 275±25.

L3–12880 is a blade from an ulo; the handle has not been preserved. The blade measures 69×21×2.5 mm (max.) and weighs 10.3 g (Fig. 12). It comes from house 28 at Nûgdlît and is probably from 900–1200 (Holtved 1954; as corrected by Meldgaard, pers. comm.). The small section shows the structure of heavily cold-worked, meteoritic iron (Fig. 13). The grain boundaries of kamacite and taenite are parallel and elongated into a ropy texture in which numerous rhabdite crystals are incorporated. The larger schreibersite crystals have become dislocated and individual fragments rotated so that they fit into the metal lattice. The comb plessite is distorted and compressed from the process of hammering. The microhardness is 257±10.

Like L3–12004 this sample represents the ultimate in Eskimo technology. From a small meteorite fragment a surprisingly large blade, ductile and hard, of excellent quality for a cutting tool has been produced.

L3–13069 is a 5 g rusted remnant of some tool, possibly an ulo. The hole for fastening to the shaft with a small nail may still be seen. It comes from Nûgdlît and is of early Thule age (Meldgaard, pers. comm.). The material extracted for examination was mainly rust, but in the centre of the fragment small specks of uncorroded iron could be identified. It was cold-worked kamacite with a hardness of 277±15; in addition cloudy taenite lamellae were identified. Microprobe analysis gave 7.1±0.1% Ni which confirmed that the sample had been produced from a Cape York iron meteorite fragment by hammering.

L3–12237 is a 3 g flattened and rusty flake. The texture is similar to the previous flake; all the typical meteoritic phases and minerals have by intensive hammering been

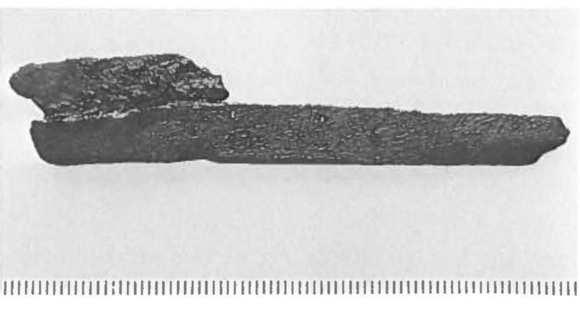


Fig. 10. A small knife, L3–528, from Inuarfigssuaq, Inglefield Land. The iron blade of meteoritic iron is severely corroded. Scale in mm.

Fig. 11. An adze, L3–662, from Inuarfigssuaq, Inglefield Land. The blade of meteoritic iron is severely corroded. Total length 50 mm.

Fig. 12. Ulo blade, L3–12880, made from meteoritic iron. It is in shape and size rather similar to L3–12004, shown in Fig. 7.

worked into parallel textures, where crushed minerals have been aligned along the ductile kamacite – and taenite lamellae. The hardness is 319±20, near the maximum which this material will attain through workhardening.

L3–13070 II is another 3 g flattened and rusty flake. The 12×1.5 mm section revealed cold-worked textures very similar to the previous ones, and the hardness was also similar, HV 305±15 (Fig. 14). In this fragment are inclusions of troilite and daubreelite, sulfides which are present in the bulk meteoritic iron, but are rarely seen in the Eskimo tools. The reason is partly the irregular occurrence of troilite and daubreelite, partly that these minerals provide weak zones of cohesion, so that the meteoritic iron usually will split along these zones, whereby the minerals themselves are lost.

The remaining numbers identified "corr. blade" in Table 2 are similar to those just described. There are small variations in the textures, state of corrosion and exterior shape, but common to all are the flattened shape and limited size, which probably indicate their purpose, i.e. small, sharp, cutting edges for knives such as Fig. 29 or similar tools.

L3–12631 (Table 5) is an irregular fragment of 12.5 g that evidently never was worked by the Eskimos (Fig. 15). The 20×8 mm polished section discloses the typical structure of the Cape York meteorite with kamacite, taenite, plessite, schreibersite, rhabdite and carlsbergite. In the kamacite are Neumann bands and deformation bands and the hardness is correspondingly high, HV 233±15. The cold-deformation is rather slight, but it is variable, and very different from the parallel, heavily worked textures found in the finished tools. Nevertheless, some cold-work has taken place, but this is of cosmic origin and may be associated with the violent event when the meteorite parent body hit the atmosphere and broke up into numerous fragments. From other similar cases, such as the iron meteorites Campo del Cielo, Chupaderos, Gibeon and Trenton (Buchwald 1975), we know that individual fragments of a large, shower-producing meteorite will be distorted and cold-worked to varying degrees. Shear zones will penetrate the material, fan out and disappear, the metallic matrix will locally increase significantly in hardness, and inclusions will break and become dislocated. No doubt, L3–12631 is a small such fragment from the Cape York shower, collected at some time or other and intended for use, but never actually employed. – Fig. 16 shows a cloudy taenite area surrounded by kamacite, with indications of the microprobe analytical procedure.

L3–12672 (Table 5) is a similar irregular fragment of 21 g (Fig. 17). It is slightly more influenced by the violent

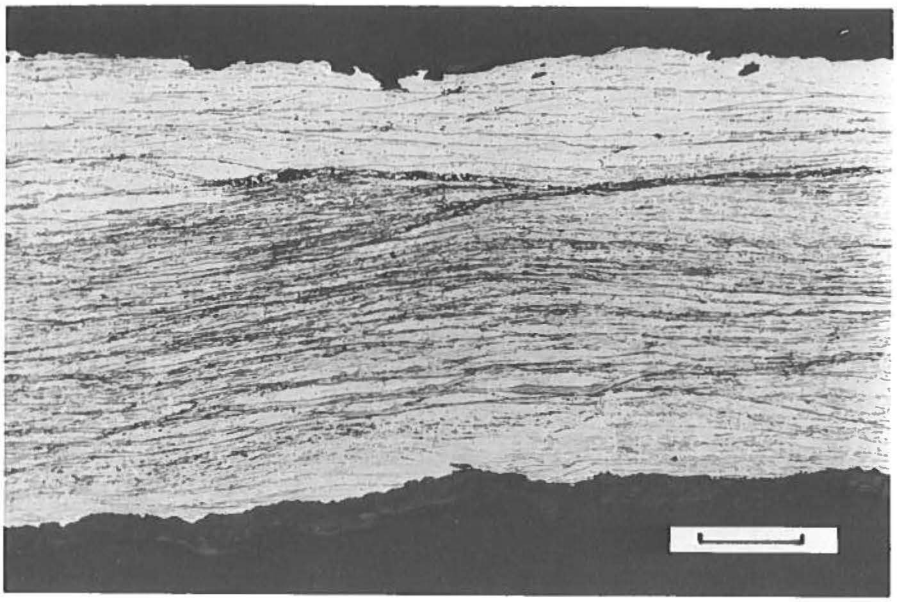


Fig. 13. Cross-section of the ulo blade, Fig. 12. Heavy cold-work has created a ropy texture of elongated kamacite- and taenite-grains. Scale bar 200 μm.

Fig. 14. Cross-section through a meteoritic iron flake. L3–13070 II. Cold worked kamacite and, in the middle, kneaded and microfolded taenite. Scale bar 25 μm.

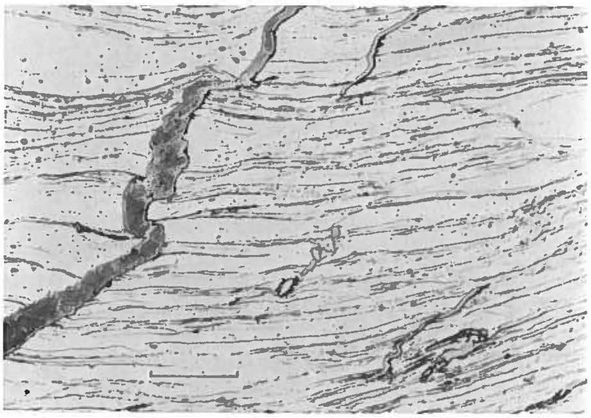


Fig. 15. Cross-section through the meteoritic fragment L3–12631. Distorted kamacite, taenite and rhabdites. Scale bar 100 μm.

event, that split the meteorite, and the hardness reaches a peak of HV 306. At one end, the structural elements are heavily faulted and indicate the place of necking, i.e. the location where the fragment in the process was torn from another piece.

L3–12466 I is a 6 g flattened and rusty fragment. The 13×3 mm section discloses well-preserved metallic parts. All kamacite and taenite have been extended parallel to the exterior flat sides by extensive cold-work. Locally, many irregularities in the cold-kneaded texture are apparent, for example in connection with inclusions of schreibersite and rhabdite, that are torn and dislocated. The hardness, HV 286±15, is in line with the violent deformation.

L3–9918 (Table 5) is a rather large, wedge-shaped fragment of 76.4 g, measuring 55×44×15 mm (Fig. 19). It was excavated from Comer's midden in Thule and is probably from the 13th century (Holtved 1944). During the long contact with decaying bone and animal remains, the normal reddish-brown rust has become supplemented by a light bluish-green mineral, the same vivianite as identified in L3–14106, p. 16.

The exterior, flat, wedge-shaped surfaces are shear-faces from the violent event when the sample separated from the main body at the atmospheric disruption. There are no signs of hammering or working by the Eskimos.

The thick end of the sample was polished and etched. The structure shows macroscopically the normal Widmanstätten development of kamacite and taenite, but microscopically all elements are altered due to heating: the kamacite is now a serrated α_2 structure and the taenite etches white and sends thorny projections into the surrounding kamacite (Fig. 20). The interfaces between schreibersite and the corrosion products constitute a 1 μm wide creamcoloured reaction zone, formed at high temperature. The low temperature corrosion products have been altered to a lace-like mixture of metallic beads and high-temperature oxides. The hardness of the α_2 matrix is 220±25.

In order to explain the structural observations it must be assumed that the sample after having been released by the atmospheric explosion was exposed to a long period of terrestrial corrosion. It was then found and at some poorly understood occasion – a fire? – reheated to about 800°C and again cooled. It was not forged, and it was never used as a tool. Finally it was discarded and during hundred of years in the midden new corrosion products formed, notably the blue vivianite in the crust.

Three fragments, Akpohon, Northumberland, and L3–14106 (Table 5) deserve special mention. *Akpohon* was secured in 1914 by W. E. Ekblaw, of the Crocker Land Expedition, from an Eskimo (Wissler 1918). The 1660 g specimen had been found near an ancient igloo site at Eskimopolis at the eastern end of Knud Peninsula, Ellesmere Island (Hovey 1918). The structural examination (Buchwald 1975: 425) disclosed that Akpohon is not an individual iron meteorite from Canada, but rather a transported fragment of the Cape York shower. The macro- and microstructure is identical to that of the large Cape York blocks. However, Akpohon shows local variation in cold-work (HV 225–285), such as may be expected when a small fragment is torn apart during the atmospheric disruption The main mass, now 1473 g, is in the American Museum of Natural History, New York.

Northumberland is a rounded fragment of 292 g, measuring 6×6×3 cm. It was obtained by Knud Rasmussen in 1928 from an Eskimo on Northumberland Ø, which is 250 km northwest of the Cape York fall (Buchwald & Munck 1965). The sample which is presently in the Geological Museum, Copenhagen, is uncut, but the metal-

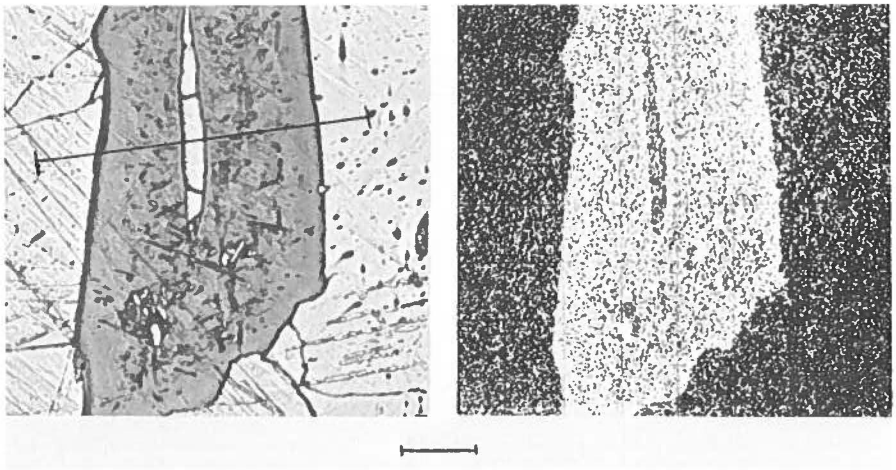


Fig. 16. Cross-section through the meteoritic fragment L3–12631. A plessite field in kamacite, to the left as seen in the microscope, to the right an X-ray microprobe exposure showing high nickel concentration (white) in plessite, and low in kamacite. Scale bar 50 µm.

lographical examination of a small polished and etched surface-area confirms that it belongs to the Cape York shower (Fig. 21). Evidently it was transported with the purpose of using it for a hammer or, possibly, for some other use. It shows distorted Neumann bands and locally slightly twisted structural elements. In concordance herewith the hardness is high, 300± 15.

L3–14106 is the largest meteoritic fragment found in any Eskimo site in Greenland. It is a flat, angular piece, measuring 110×105×15 mm, and it weighs 711 g (Fig. 22). It was excavated by Holtved (1954) from Comer's midden, layer 6, at Thule, and it may be dated to the 12th or 13th century. Its surface is covered by rust-scales that vary in colour from normal reddish-brown to light bluish-green.

The exterior, flat shape is conditioned by the Widmanstätten structure of the meteorite: cleavage has taken place along two parallel $\{111\}_\gamma$ planes, situated 12–15 mm apart. There are no indications that the sample has been hammered by the Eskimos. The shape is rather the result of spallation from the main body of the meteorite when it split in the atmosphere.

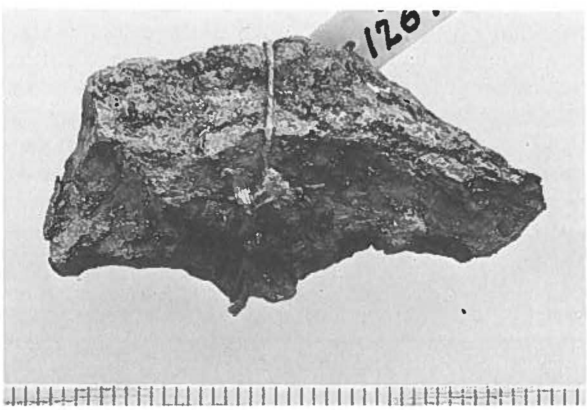


Fig. 17. An irregular fragment of the Cape York iron meteorite shower, secured by the Eskimos, but never worked. Nûgdlît, Steensby Land. L3–12672; 21 g. Scale in mm.

The cross section shows a normal, only slightly deformed Widmanstätten structure, Fig. 23. However, all structural elements have been severely altered by heat: the kamacite is transformed into a fine-grained mixture of serrated α_2 grains with tiny particles of austenite and phosphides. The taenite has lost its brownish stain and appears creamy-white, with thorns protruding into the surrounding α_2 matrix. The schreibersite is surrounded by 1–2 µm wide creamy reaction zones, and the corrosion products inside the fissures have assumed spheroidal shapes. Finally, all exterior and interior, corroded surfaces have transformed into a lace-like network of metal and high-temperature oxides. The hardness of the α_2 phase is 200±10, that of the taenite 325±25.

All the evidence points to some reheating by the Eskimos. The relatively low hardness and anomalous appearance of the structural elements suggest that a peak temperature of 750–850°C was reached and held for about an hour. Longer holding times would have erased the delicate taenite lamellae by diffusion. Temperatures above 950–1000°C would have radically changed the schreibersite inclusions and melted them (Buchwald 1975: 40).

The light bluish-green mineral, which partly covers the corroded surface, was subjected to X-ray diffraction analyses (copper tube) in order to verify the hypothesis that it was vivianite. The diffractogram showed all the typical lines and intensities as recorded in the ASTM-mineral file, so the identification is unambiguous. It appears that vivianite, the monoclinic iron phosphate $Fe_3(PO_4)_2$, $8H_2O$, has formed by the slow interaction of the meteorite with decaying bones and other organic material of the midden.

The two large fragments *L3–9918* and *L3–14106* are in most structural respects very similar and it appears that they must have been exposed to the same sequence

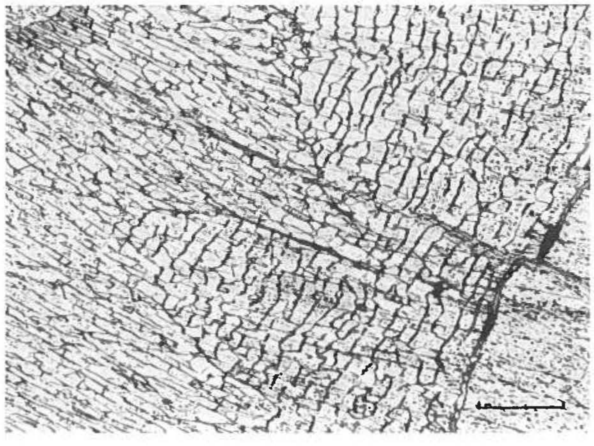


Fig. 18. Section through net plessite in the meteoritic fragment L3–13032 VI. Relatively undistorted structure. Scale bar 0.5 mm.

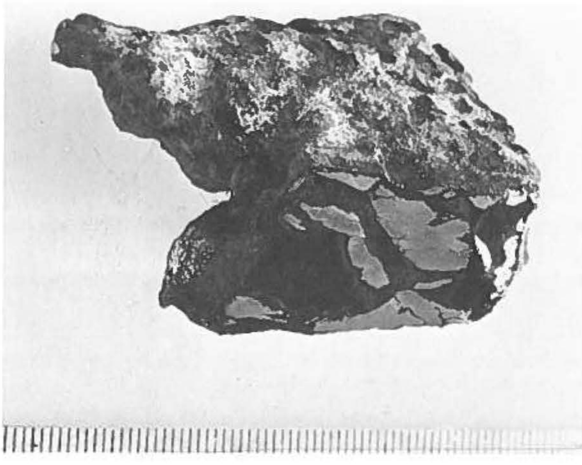


Fig. 19. The irregular, wedge-shaped iron meteorite fragment, L3–9918, of 76 g. Polished and etched on one face: Grey is metal, black corrosion products. Scale in mm.

of events, spallation, corrosion, artificial heating and renewed corrosion. The reason for the reheating event is not clear; it could have been an accidental fire, but hardly an exposure to the less intensive normal oil-lamp fire.

The rest of the fragments in Table 5 resemble *L3–12631* and *L3–12672* or present small variations over the same theme (Figs 24–25, 67–68). It appears that the fragments have their natural size from the atmospheric disruption, or possibly have been slightly reduced by terrestrial corrosion. So far, it has not been possible to identify samples that have been removed from the big meteorites Woman and Savik, although it is known that the Eskimos often visited these monsters and struggled with them. The surface of the 3 t Woman is marred by the numerous attempts of hammering.

The problem of working meteoritic iron

Many authorities have held it for impossible to work meteoritic iron, and there is some truth in this statement because iron meteorites are very different in composition and structure. Without going into too much detail, let it be stated here that there may be distinguished about 12 different main types, socalled genetic chemical groups, known by their Roman Symbols IA, IB, IIA, IIB etc. Of these, groups IA, IIA, IIIA, and IVA are the most common when judged by the frequency of recovered fragments (Buchwald 1975: 60–61). The meteorites of group IA, such as Canyon Diablo, Toluca and Campo del Cielo, are very difficult to exploit because of their significant number of non-metallic inclusions. When the finder attempts to cold-work or to forge

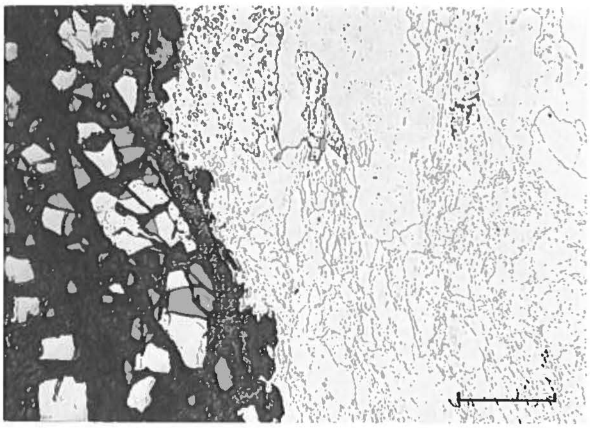


Fig. 20. Section through the meteoritic fragment L3–9918. To the right reheated kamacite, to the left schreibersite fragments in reheated corrosion products. Scale bar 40 µm.

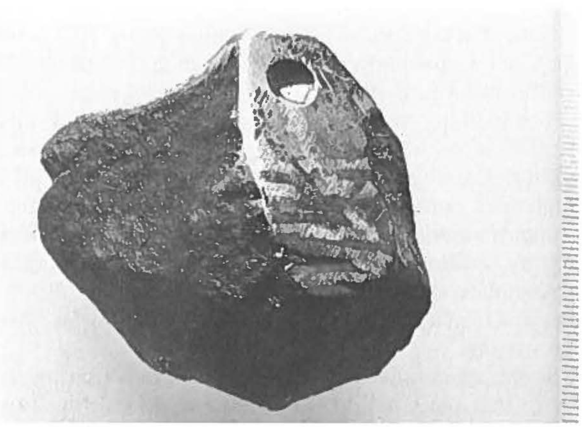


Fig. 21. The iron meteorite fragment called Northumberland. A 292 g mass belonging to the Cape York shower. Polished and etched on one face. Hole after drilling for analytical sample. Scale to the right in mm.

Fig. 22. A large, flat meteoritic spallation fragment, excavated from Comer's midden, Thule. The bright spots are bluish-green crusts of the iron phosphate mineral, vivianite. L3–14106; 711 g. Scale in mm.

such a meteorite, the material will split along the brittle, and/or low-melting minerals. Such meteorites have, however, been found in use as pounding stones or anvils, but have very rarely been used as forged tools or weapons (Buchwald 1975: 162–166).

On the other hand, meteorites of group IIA, IIIA and IVA are relatively poor in inclusions, and numerous examples are known of their exploiting. Chesterville, a group IIA iron, was in the 19th century converted into nails and other building items in a South Carolina blacksmithy. Gibeon, a group IVA iron, was in the 18th century forged into assagais and other weapons by the natives of Namibia; and Toubil River, a IIIA iron found in a gold mine near Krasnojarsk, was as late as 1891 forged by a Russian blacksmith (Buchwald 1975: 450; 584; 1225).

Cape York belongs to the common group IIIA and may, not surprisingly, be subjected to cold-working as well as forging. During the present investigation, signs of hot-working or forging were never observed. It appears that the Eskimos never applied forging methods, perhaps because of their very restricted access to adequate fuel, perhaps also by the lack of knowledge of the proper methods. The situation is similar with respect to pottery. Although there are many natural occurrences of adequate clay in Greenland, the production of pottery in a furnace was never attempted, probably for similar reasons.

Some experiments are reported in the following to prove that the Cape York material lends itself well to cold-work. The material was cut from the large Agpalilik fragment, which is in the Geological Museum of Copenhagen and now is one of the best studied of all iron meteorites. For comparison a normal structural steel, St 42-B, was used, Table 6. Both the meteoritic iron and the steel was given the shape of "axes", Fig. 26, by cold-hammering with a 2.2 kg hammer on a normal anvil. A smaller hammer, of 1 kg, soon turned out to be rather inadequate. The material had at the start rectangular shapes with dimensions 61×25×4–5 mm, and hammering was continued until one edge was so thin that further hammering would have split the sample. The temperature never exceeded about ca 50°C.

The finished "axe" was cut lengthwise for structural examination and for microhardness testing (HV 100 g). The wedge shape of the axe was good for this kind of work. At one end no reduction in thickness had taken place, but at the opposite end the thickness had been reduced as much as the material would allow. For an evaluation of the degree of cold-work the approximate expression

$$D = \frac{t_0 - t}{t_0}$$

was used. D is the degree of reduction in percent – it can approach but never reach 100%. t_0 is the thickness at start, and t the variable thickness along the wedge.

Table 6 shows that the modern steel, which is homogeneous even on a microscale, takes hardening in an orderly way, the hardness increasing proportionally with the reduction in thickness. At about 90% reduction in thickness – the edge is then about 0.5 mm thick – it is no longer possible to cold-work the material: the hammer rebounds as from an anvil, or the steel cracks open.

The Cape York material behaves in the same way. It starts, however, at a higher hardness value, because the natural nickel alloy in itself is harder than steel, and because the cosmic story of collisions and attritions has inflicted some cold-work on it already. Experiments in this department have shown that the Cape York material as annealed, i.e. in its softest form, has a hardness

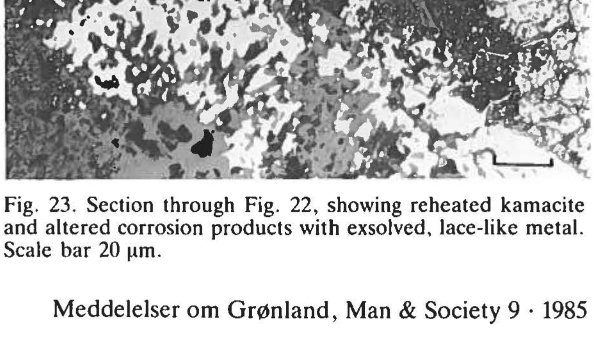


Fig. 23. Section through Fig. 22, showing reheated kamacite and altered corrosion products with exsolved, lace-like metal. Scale bar 20 μm.

of HV 155±5. The apparent lack of proportionality between cold-work and hardness in Cape York is partly due to the heterogeneity of the meteorite, being composed of the very different phases kamacite and taenite, and partly due to the coarsely crystalline structure, individual kamacite crystals easily attaining mm-size.

From the experiments it may be concluded that both mild steel and meteoritic iron by simple cold-work in the fashion that the Eskimos would be able to achieve may reduce the material to 60–90% of the original thickness and thereby increase the hardness to at least twice that of the annealed state.

The final shape may, of course, have been improved upon by grinding and polishing, but the state of corrosion has always prevented us from proving that this method has been in use.

In a comparison of hardness and microstructure it was found that the Eskimo material for the same hardness, often had a more complicated, kneaded structure than our test specimens. Otherwise the meteoritic features were identical. There may be two reasons for this. First, most of the material that the Eskimos used was already severely distorted from the atmospheric disruption, and secondly, the hammers and anvils of the Eskimos consisted of natural, rough blocks of basalt (greenstone) (Fig. 27) while our experiments were carried out on a smooth anvil with a smooth steel hammer.

Table 6. The hardness of steel and meteoritic iron as a function of degree of cold-work, D%.

Steel St 42-B		Cape York, Agpalilik	
D%	HV 100 g	D%	HV 100 g
0	143	0	230–250
5	179	1	230
9	204	13	246
12	197	28	254
15	198	37	266
28	216	44	254
38	231	52	285
49	237	60	305
61	245	67	288
70	250	75	283
88	283	88	292
		92	333
Annealed	120	Annealed	155

Telluric iron

General background

When loose boulders of iron, ranging from 10.5 kg (Forchhammer 1854) to 25 t (Nordenskiöld 1871), were reported from Disko and the adjacent bay area, it was taken for granted that the material was of meteoritic origin. This was only natural, for since 1819 when Captain John Ross had published his "discovery" of the Polar Eskimos and brought back various tools made from me-

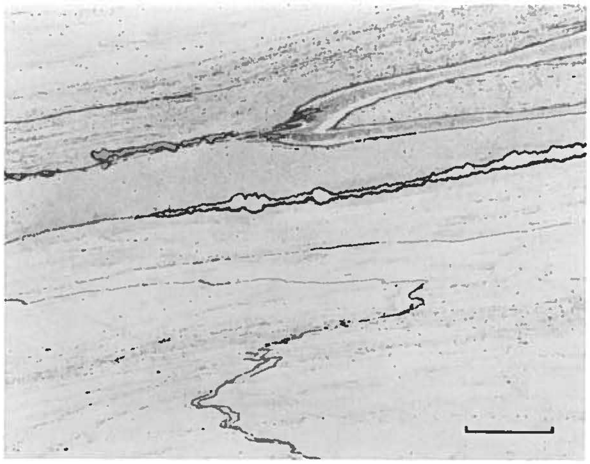


Fig. 24. Section through a shock-deformed meteoritic fragment, L3-12480. Faulted taenite lamellae and irregular, sheared schreibersite crystals. Scale bar 50 µm.

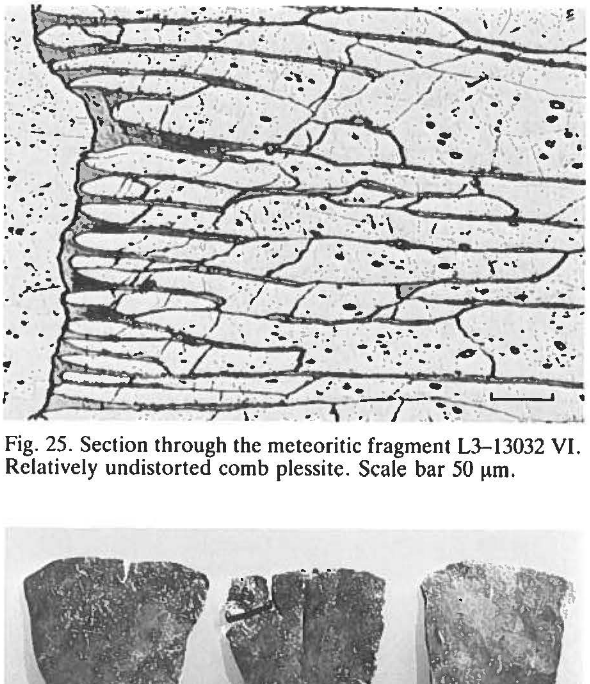


Fig. 25. Section through the meteoritic fragment L3-13032 VI. Relatively undistorted comb plessite. Scale bar 50 µm.

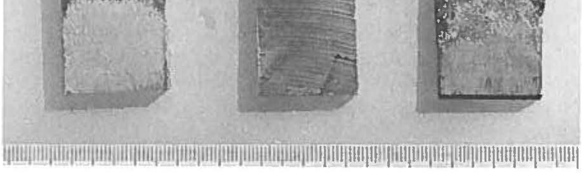


Fig. 26. Three 'axes' produced by cold-working steel 42-B (left and right) and a slab of the Cape York iron meteorite (centre). The hammering was continued until fracture occurred. Scale in mm.

2*

teoritic iron, many scientists and ship crews had been on their alert in order to detect the meteoritic sources from where the Eskimos had their raw material.

The new material from the Disko area was, however, slightly different from the few slivers of meteoritic iron, reported in the Melville Bugt tools. This was not noticed in the beginning. It appeared that the two types of material had in common a significant nickel content and a coarse-grained Widmanstätten structure, enough similarities to pronounce all finds meteoritic. Japetus Steenstrup (1872), for example, studied a number of knives and ulos from the Disko area and concluded that the tools had been produced from iron meteorites found on Disko and in the Vaigat. His, or rather professor Johnstrup's check of the nickel content gave about 3% (Table 7). Today we know that this is too low for meteoritic iron, and – assuming that the analysis is correct – this alone is sufficient to conclude that the material under dispute is of telluric origin.

K. J. V. Steenstrup (1875; 1882) was the first to arrive at the correct conclusion that the new-found iron was telluric. He identified outcrops at Asuk at the north coast of Disko as an iron bearing basalt, and he showed that the Widmanstätten pattern might occur in iron grains included in basalt from Mellemfjord. Lawrence Smith (1879) a specialist on meteorites, supported Steenstrup's conclusions, and Lorenzen (1882), evidently a very competent analyst, presented a number of important analyses on the various natural occurrences and on a few Eskimo tools (Table 7).

Although Nordenskiöld for a long time maintained that what he had found was of meteoritic origin, he had in fact found something that was still more unique and

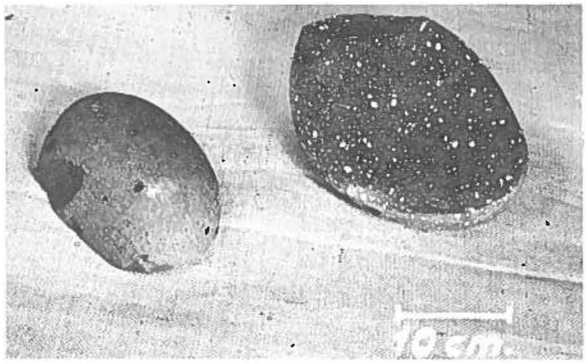


Fig. 27. Two basalt boulders which were transported by the Eskimos more than 50 km in order to be used as hammerstones on the Cape York iron meteorites, 1.8 and 5,4 kg. (Buchwald 1975).

valuable. For a century, geologists and mineralogists have now worked in the field and in the laboratory with the extraordinary Disko province and yet there are many problems to be solved. For reviews of the historic development the reader may be referred to, e.g., Sjögren (1916), Löfquist & Benedicks (1940), Buchwald (1964), Fundal (1972) and Noe-Nygaard (1980). For reviews of the geology and mineralogy similarly Phalen (1904), Vaasjoki (1964), Melson & Switzer (1966), Pauly (1969), Pedersen (1975, 1977, 1979), Clarke & Pedersen (1976), and Ulff-Møller (1938).

For the purpose of this treatment the geological background may be summarized by quoting Clarke & Pedersen (1976: 364): "The tertiary volcanic province of

Table 7. Old bulk analyses of telluric iron and Eskimo knives from West Greenland.

Location	Analyst	Mass, g	Ni %	C %	Type	Reference
A. Samples collected in situ on Disko and Nûgssuaq						
Asuk	Lorenzen		0.34	0.96	II	Lorenzen 1882
Jernpynten	Lorenzen		0.45	0.87	II	Lorenzen 1882
Qaersut, Nûgssuaq	A. Uchiyama		3.5	0.13	II	Urey 1952: 78; Phalen 1904
Mellemfjord	S. M. Jørgensen		2.69		II	K. J. V. Steenstrup 1882
Mellemfjord	Lorenzen		2.55	0.28	II	Lorenzen 1882
Uivfaq	Lindström		1.24–2.48		I	Nordenskjöld 1871
Uivfaq	Lorenzen		1.39–1.82	1.2 –1.7	I	Lorenzen 1882
Uivfaq	Blix		1.76–1.87	3.48–3.92	I	Löfquist & Benedicks 1940
Uivfaq	Høeg		2.24	2.68	I	Pauly 1969
B. Samples from loose boulders of uncertain origin						
		Mass, g				
Eqaluit, Nûgssuaq	Lorenzen	<100	2.85	trace	II	Lorenzen 1882
Fiskenæsset, Nûk	Lorenzen	153	2.73	0.20	II	Lorenzen 1882
Fortunebay, Disko (Rudolph)	Lorenzen	11844	2.54	2.40	I	Lorenzen 1882
Niaqornaq, Ilulíssat (Rink)	Forchhammer	10500	1.56	1.69	I	Forchhammer 1854
Niaqornaq, Ilulíssat (Rink)	Lawrence Smith	10500	2.88	1.74	I	Smith 1879
Niaqornaq, Ilulíssat (Rink)	Lorenzen	10500	1.92	3.11	I	Lorenzen 1882
C. Eskimo knives						
Disko, unspecified	Johnstrup		3		II	Jap. Steenstrup 1872
Hunde Ejland	Lorenzen	3.1	0.23 Ni+Co		II	Lorenzen 1882
Sermermiut, Ilulíssat	Lorenzen	6.1	7.76		Met.	Lorenzen 1882

West Greenland is geographically divisible into four main areas, namely Svartenhuk Halvø, Ubekendt Ejland, Nûgssuaq and Disko. The areal extent of the province including recently discovered offshore extensions, is roughly 55.000 km^2 and has maximum onshore dimensions of 125 km in width by 370 km in north-south length. This volcanic area has already become widely known for its occurrences of native iron bearing basalts and the production of enormous volumes of picrites and olivine basalts".

In the present paper we will limit ourselves to the telluric iron (= native iron) occurrences, which are an extremely small and, so far, economically insignificant part of the eruptive basalt sheets. It is only locally that there are outcrops with iron concentrations, but some of these must have been known by the Eskimos. It is, however, at present not possible to say which ones have been exploited. (See Note p. 47).

The telluric iron may roughly be divided into two categories, white nickel cast iron and malleable nickel iron. The principal difference is not so much in the nickel content, but rather in the carbon content, bulk carbon being 1.7–4% in the cast iron, but below 0.2% in the malleable iron. In the first category fall the prominent, large blocks discovered 1870 at Uivfaq by the Finnish-Swedish scientist A. E. Nordenskiöld (Nordenskiöld 1871) and transported to the Fenno-Scandinavian capitals in 1871. The huge 25 t block is now outside the Riksmuseum at Frascati, Stockholm, the 6.6 t block is outside the Geological Museum, Copenhagen (Hintze 1918), and the 3 t block is in the Kaisaniemi Park, Helsinki (Buchwald 1975: fig. 499). A slightly smaller block of 765 kg, secured in 1884 by the Fylla expedition, is also in front of the Geological Museum in Copenhagen (Hintze 1918). The large Swedish block is the best studied, since Löfquist and Benedicks (1940) let a 24 mm thick and 188 cm long core diamond-drill through the entire block.

In the second category fall the disseminated iron grains, that by now have been identified in many places in the tertiary iron basalt of Disko. The grains are usually 1–5 mm in diameter, and are sometimes isolated from each other by intervening basalt, sometimes sin-

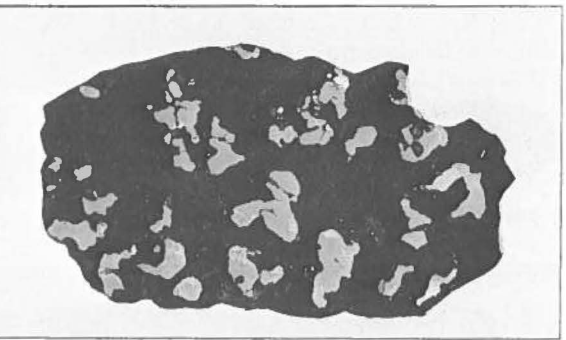


Fig. 28. Typical iron basalt with pea-sized iron inclusions (white). Eqaluit, Umánaq, 1881–602. Longest dimension 32 mm.

tered together in more massive aggregates with ilmenite, cohenite, troilite and pearlite as minor accessories (Ulff-Møller 1983). The typical texture is shown in Fig. 28 and analytical data are presented in Table 8. If this type of material, basalt with pea-sized iron inclusions, is crushed between other stones, the iron peas will be released, and may be cold-worked to flat, coin-sized fragments (Lorenzen 1882: 24) that may be inserted into the groove of a harpoon shaft, an ulo or a knife. If several fragments of the same size are inserted in a groove, slightly overlapping each other as the tiles of a roof, and the last one is secured by a small rivet, one has an excellent tool with properties like a cross between a knife and a saw (Fig. 29).

Table 7 summarizes early bulk analyses of the various occurrences. For the purpose of this paper the cast iron material has been identified with a Roman I, while the malleable type has been identified with a Roman II. The present investigation supports the opinion already expressed by Forchhammer (1854) and Lorenzen (1882) that only the material of type II could be exploited by the Eskimos. Because of its relatively low carbon content, usually well below 0.7% C in bulk, type II can be cold-worked and attain significant deformation hardening. The more nickel and the more carbon, up to about 0.7%, there is in the material, the greater final hardness in the cold-worked tool.

Table 8. Selected analyses on mm-sized iron grains in Disko iron-bearing basalts. Electron microprobe analyses (%), the first three from Pedersen (1981), the following seven from Ulff-Møller (1983).

Location	Fe	Co	Ni	Cu	Si	P	S	C	Reference
Maligat formation, Disko; dacite		0.15	1.36	0.06		0.25			GGU 176486;
Maligat formation, Disko; dacite		0.13	0.43	0.09		0.06			GGU 176466
Maligat formation, Disko; dacite		0.05	0.22	0.05		n.d.			
Hanekammen, andesit; pearlite part	99.30	0.17	0.62	0.08	0.01	0.10	<0.001	~0.7	GGU 264397;
Hanekammen, andesit; ferrite part	98.56	0.25	1.52	0.31	0.02	0.04	0.01	~0	
Hanekammen, basalt; pearlite part	96.88	0.29	1.40	0.10	0.03	0.15	0.02	~0.7	GGU 264355
Hanekammen, basalt; ferrite part	97.97	0.33	1.70	0.14	0.01	0.17	0.02	~0	
Hanekammen, basalt; pearlite part	97.45	0.32	1.44	0.14	0.01	0.04	0.02	~0.7	GGU 264389
Hanekammen, basalt; ferrite part	98.22	0.33	1.58	0.16	<0.01	0.03	0.01	~0	
Hanekammen, basalt; cementite	93.85	0.17	0.45	<0.02	<0.01	<0.01	0.02	6.7	

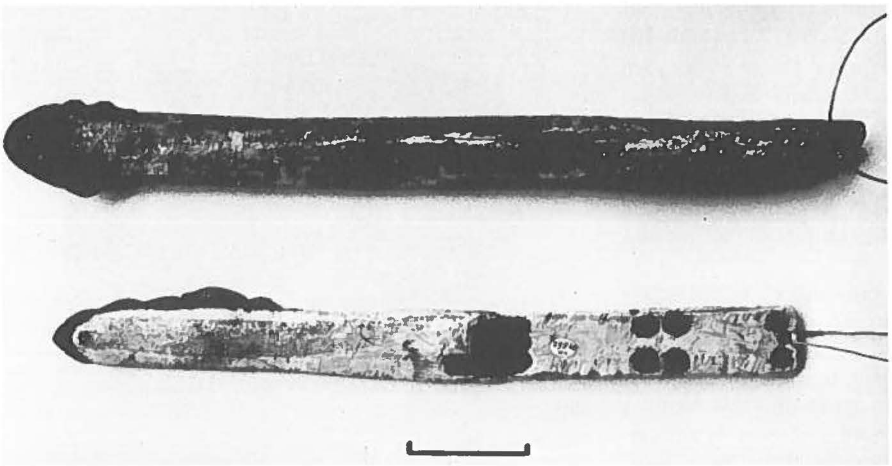


Fig. 29. Two knives acquired from the Eskimos by Captain Ross and now in the British Museum, nos 87561 and 87562. Cape York meteorite fragments have been cold-hammered and inserted into grooves in the bone or antler handles. Brit.Mus. negative CG 17 (Buchwald 1975). Scale bar 5 cm.

Type I, on the other side, will behave like a strong, unwieldy material when cold-hammered. It is not malleable and will break into irregular pieces if forcefully handled. Its bulk specific gravity is 6.5–7.6, and it consists mainly of pearlite and the extremely hard carbide, cementite or cohenite (HV 1000–1300). Besides there are some troilite and silicate inclusions. Even when worked with modern tools, type I presents formidable problems, but it will be found that cutting with rotating, watercooled carborundum wheels normally gives the best results. The subsequent grinding and polishing will only present minor problems, except that the best polished specimen ensues if the sample has first been impregnated in vacuum to prevent loose grains and corrosion products from scratching the polished surface.

Type I is best represented by the four very large boulders, mentioned above, but smaller specimens from other locations are also known and have been discussed by Pauly (1969), Fundal (1972) and Ulff-Møller (1983). The very first boulders of telluric iron, that were reported, were of type I, Rink's piece of 21 pounds found 1848 at Niaqornaq (Forchhammer 1854), and Rudolph's piece of 11.8 kg found 1852 at Fortunebay (Lorenzen 1882), Table 7.

In the last few years both type I and type II material, and material rich in pyrrhotite, has been reinvestigated. Since the Eskimo tools have only been produced from type II material we will limit ourselves to present a selection (Table 8) of the best data available, all obtained by electron microprobe analyses on individual grains and phases and therefore comparable to our results which will be presented in the following paragraphs.

Samples of telluric iron from Eskimo settlements

As was the case in North Greenland where the meteoritic *raw* material has been identified in Eskimo sites, see e.g. L3–9918 and L3–12631, also the telluric raw material, basalt with inclusions of iron has been excavated from settlements in central West Greenland. K. J. V. Steenstrup (1882) thus reported the find of 9 fragments of basalt with metallic iron from a grave at Eqaluit near Ũmánaq. Lorenzen (1882) and Fundal (1972) studied the material and rightly concluded that it might have served as the starting point for the production of small chips or blades.

Another find, L 7154, comes from a grave at "Karnarkasuak" and consists of two fragments, 81 and 19 g, that contains 70 vol.% of iron in the shape of stellate or amoeboid mm-sized inclusions, that in many places have coalesced to larger aggregates. It appears, how-

Table 9. Fragments of basalt with telluric iron, excavated in Eskimo graves. Electron microprobe analyses (%) and Vickers hardness (100 g) of the non-silicates. Carbon estimated from the structures.

		Ni	Cu	Si	P	S	Mn	C	HV 100
1881–605	ferrite	2.00	0.08	0.01	0.06	0.015	<0.02	~0	130± 5
	cementite	0.75	0.02	0.01	0.005	0.014	<0.02	6.7	1100±75
	troilite	0.005	0.02	0.01	0.018	~36	<0.02	~0	325±25
1881–608	ferrite	2.75	0.05	0.01	0.018	0.015	<0.02	~0	129± 4
	troilite	0.20	0.07	0.01	0.015	~36	<0.02	~0	325±25
L 7154	ferrite, grain A	3.15	0.25	0.01	0.034		0.02	~0	152± 5
	ferrite, grain B	3.7			0.030			~0	175± 8
	cementite	1.30	0.35		0.010			6.7	1100

Table 10. Tools produced from the pea-sized inclusions of telluric iron in basalt. Microprobe analyses (%) and Vickers hardness (100 g) of the distorted ferrite. Carbon, as estimated from the structure, is in all cases below 0.2%.

	Weight, g	Ni	Cu	Si	P	S	Mn	As	HV 100
Ulo, L 2855	0.1	1.90	0.05	0.01	0.018	0.014	0.02		186±15
Harpoon point L 7210*	<0.1	3.7							198±10
Knife, L 7218	0.09	3.95	0.15	0.01	0.04		<0.02	<0.02	210±20
Ulo Lc 277	0.16	3.20	0.15	0.01	0.028		<0.02	<0.02	230±25
Ulo Lc 750	0.3	1.75	0.06		0.075	0.015			215±15
Ulo Lc 752	0.05	2.1	0.05		0.032	0.014			195± 8
Knife Lc 755*	0.05	2							195±10
Knife Lc 800	0.05	2.00	0.10	0.005	0.065		<0.02	<0.02	210±25
Knife L2-621	0.08	2.15	0.15	0.013	0.045		<0.02	<0.02	230±10
Knife L2-959	0.08	2.15	0.10	0.010	0.030		<0.02	<0.02	225±30
Ulo Geol. Mus. 1984: 864	0.1	3.90	0.06	0.010	0.018	0.015	0.02		225±15

* These two samples were severely corroded and transformed into rust cakes with a few remnants of metal.

ever, that the relatively high proportion of cementite- and troilite-inclusions in this specimen would have prevented the Eskimos from using it for flakes. For the present examination it became necessary to use a carborundum disc for cutting.

We have examined the non-silicate inclusions of three of these fragments, typical for the range of all, *1881–605* (a fragment of 14.5 g), *1881–608* (11 g) and *L 7154* (81 g), Table 9. It is characteristic that the individual ferrite grains are about 1 mm in size and may vary somewhat in composition, even within the same stone, or within one and the same grain from edge to centre. The ferrite is nevertheless rather pure nickel-ferrite, with hardnesses in the range 125–180, without Neumann bands and other distortions. The ferrite grains meet along lobed grain boundaries, dotted with 5–25 μm wide cementite lamellae of extreme hardness, above 1000 HV, and some troilite. When worked, it is these inclusions that will determine to what extent the operation succeeds. In the beginning the cementite will yield a little and become distorted, but finally a rupture will start from here, or still earlier from the troilite inclusions. As noted above, Lorenzen (1882) nevertheless succeeded in cold-hammering pea-sized inclusions into coin-sized flakes.

The number of *tools* examined by us is rather small, 11, and all derive from excavations north and northeast of the island of Disko (Table 10). It would have been interesting to extend our study to material from sites on Disko and east and south of Disko, but such material has so far not been available for examination. The 11 tools with cutting edges of iron are five ulos, five knives and one harpoon point, and almost all have from the archaeological context been dated to before 1650 A.D.

Lc 277 is an ulo, mentioned and pictured by Steenstrup (1872, pl. 26), who, however, believed it was made from meteoritic iron (Figs 30–31). It is a beautiful tool and remarkable by the holes in the shaft. One of the small flakes that constitute the cutting edge is analyzed in Table 10, from where it is seen that the material has all the characteristics of telluric iron. The structure is that of heavily distorted nickel-ferrite and the hardness has correspondingly increased to 230±25, probably from initial values about 150 HV. The nickel content of the ferrite is 3.2%, and in the ferrite there are numerous dislocated

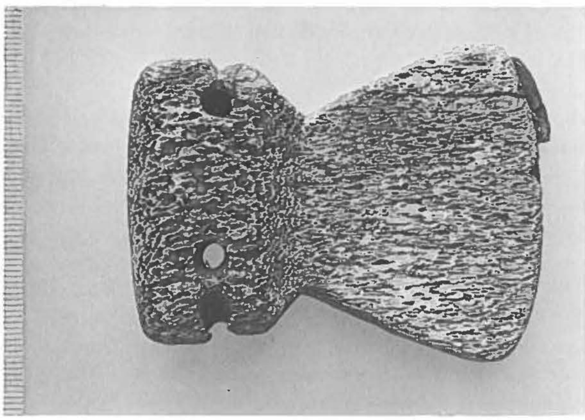


Fig. 30. Ulo, Lc 277, of telluric iron, Ũmánaq district. Only two of, perhaps, nine iron flakes now remain. Scale in mm.

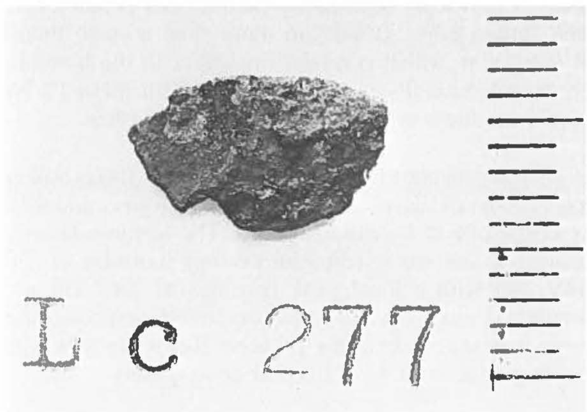


Fig. 31. One of the two remaining flakes of the ulo in Fig. 30 removed for examination. Scale in mm.

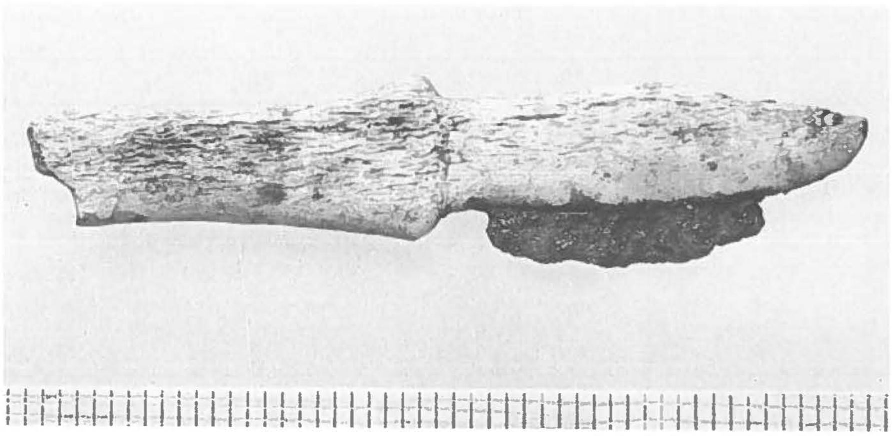


Fig. 33. Knife, Lc 755, with inserted flakes of telluric iron. Eqaluit, Ūmánaq district. Scale in mm.

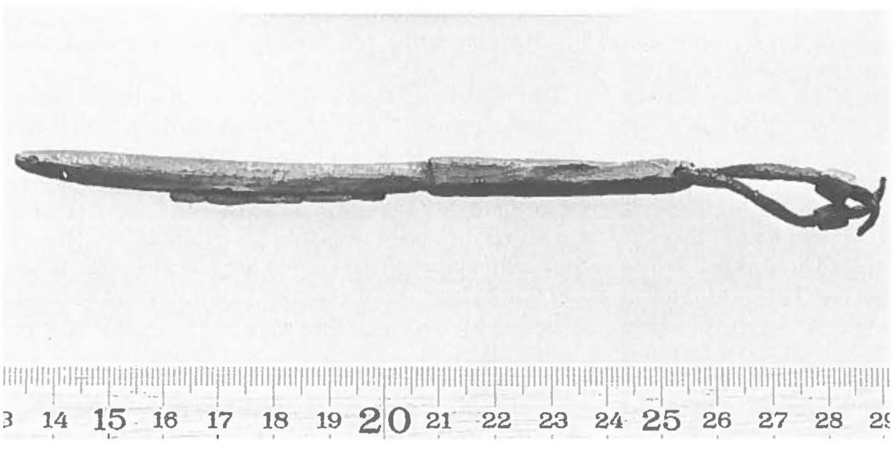


Fig. 34. Knife, Lc 800, with inserted flakes of telluric iron. Ūmánaq district.

and brecciated cementite particles. There is no evidence of heating or forging, the forming of the flakes took place by cold-hammering only, possibly assisted by some grinding and polishing. The flake was fastened and secured to the shaft by a wedge.

Lc 755 is a knife from Eqaluit in the Ūmánaq district. Fig. 33 shows the shaft and what has been preserved of the cutting edge, in fact no more than a small flake, 3×4×1 mm, which is now a rust cake. In the limonite scattered remnants of distorted ferrite with about 2% Ni and a hardness of 195 HV can be distinguished.

Lc 800 is a slender knife, Fig. 34, with five flakes still in place. One of these, 7.3×3.4×0.5 mm in size, and with a weight of 0.054 g was examined. The ferrite is heavily distorted and has reached an average hardness of 210 HV, but with a local peak hardness of 250. The cementite crystals have become brecciated, and corrosion now penetrates along the fissures. But when new, the cutting edge must have been of good quality.

The knives, *L 7218, L2–621* and *L2–959,* present variations over the same theme. The flakes range in size from 8×4×0.7 mm to 10×4.5×1 mm and in weight from 0.08 to 0.1 g (Fig. 32). The flakes may have been slightly larger, before corrosion set in, but it is felt that the preserved flakes rather truly reflect the original size. The nickel content ranges from 2.0 to 4.0%, and the hardness from 185 to 260 HV. All have been cold-worked in order to form the flakes. Simultaneously they have acquired the hardness; from initial values of 130–150 HV they have attained peak hardnesses above 230 HV.

A single harpoon point, or rather the weathered remnant of a point, *L 7210*, was examined. The ferrite contains about 3.7% Ni and is rich in sliplines and deformation bands, with a corresponding hardness of 198±10 HV.

The ulos, *L 2855, Lc 750, Lc 752* and *Geol.Mus. 1984: 864* (Table 10) are of the same general construction as Lc 277: In a bone, antler or ivory handle a number of iron flakes are wedged into a narrow groove. The individual flakes usually measure about 10×6×1.5 mm, and 1/3 to 2/3 is buried in the groove (Figs 35–36). Lc 750 has the largest flakes, they reach 13×8×1.5 mm in size.

The mass of the individual flake is small, 0.05–0.3 g, and has probably rarely exceeded 0.5 g, taking the corrosive attack into consideration.

Wrought iron

General background

There are numerous large and small deposits of iron ore in Greenland (Nielsen 1976), e.g. on the Thule peninsula and at Isua near Nûk (Godthåb), thus in both north and south. While it is certain, that the Eskimos never exploited any ore or undertook any smelting operations, it is an open question whether the Norsemen did. Nielsen (1930) examined slags from the Norse ruins at Østerbygden and Vesterbygden and concluded that they were similar to medieval slags from Denmark and Iceland, slags which supposedly had originated in a bloomery process, i.e. in a primitive hearth or low furnace used for the reduction of bog ore to iron.

The evidence which Nielsen (1930) presents is, however, not convincing seen in the light of recent research on the smelting process. It rather appears that the very small slag fragments which he examined were the by-products of forging operations in a blacksmithy. If iron smelting had taken place at least some slags of larger, massive types, similar to what has been described from medieval Norway (Hauge 1946) should have been discovered. Hauge excavated and discussed no less than 103 pits for iron making, many of them stone-rimmed, and associated with these he identified slag lumps ranging up to 200 kg in size, usually with some clay-lining from the pit baked in. Hauge's study is particularly relevant, because it concerns the same medieval epoch, a similar nature, climate and bog ore, and no doubt well illustrates the iron production methods and results that

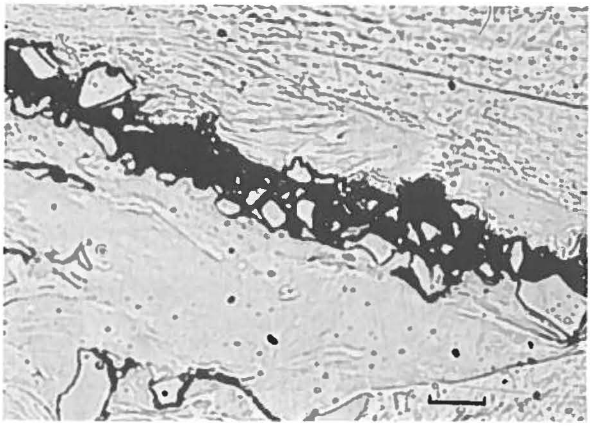


Fig. 32. Section through a single blade from the knife L2–621, Ūmánaq district. Distorted nickel ferrite and a fissure filled with cementite fragments. Scale bar 10 μm.

the Norsemen in Greenland would be familiar with from their home-country. Iron slags from iron smelting are very durable and would survive as well in Greenland as in Norway, so when they have not been found it is probably because they have never been there.

Nørlund (1967: 68) quoted Nielsen's examinations, but was realistic in assessing the importance of Greenlandic iron production: "It is probable, though, that the iron production in Greenland has been very limited, and that there often has been a shortage of iron. Interesting is the note in the Icelandic Annals from 1189, that in this year a ship with 13 sailors arrived from Greenland to Bredefjord on Iceland, and the ship was mainly held together by wooden pegs and cords of baleen. Slightly older is the report that a group of Norsemen on the east coast of Greenland found a ship wreck, that

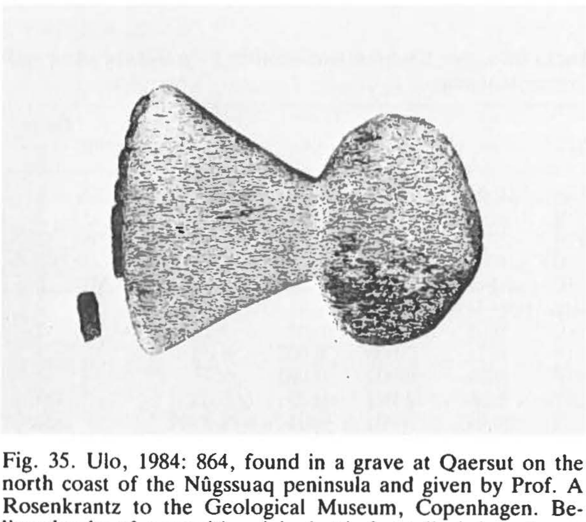


Fig. 35. Ulo, 1984: 864, found in a grave at Qaersut on the north coast of the Nûgssuaq peninsula and given by Prof. A Rosenkrantz to the Geological Museum, Copenhagen. Believed to be of meteoritic origin, but in fact telluric iron. Longest dimension 7 cm.

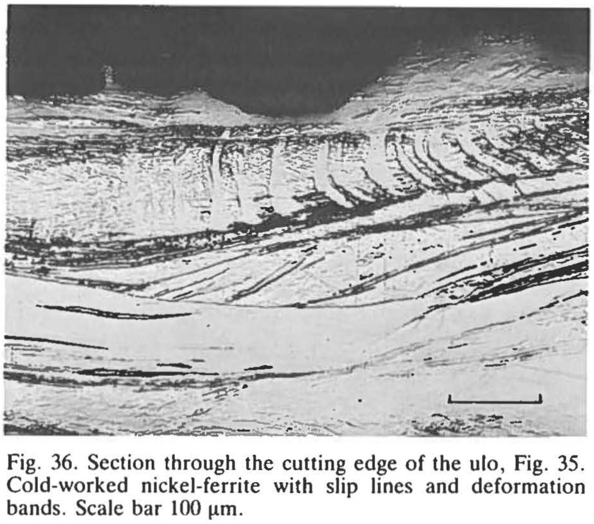


Fig. 36. Section through the cutting edge of the ulo, Fig. 35. Cold-worked nickel-ferrite with slip lines and deformation bands. Scale bar 100 μm.

they unfortunately could not take along; then they burned it, but carefully removed all the iron nails".

Nørlund (1967: 69) continued his discussion stating "What has prevented the production of iron is, no doubt, the limited technical knowledge and the restricted access to fuel. Around the forge of the bishop there were thick layers of burned and charred animal bones, evidently having been used as fuel for the forge. By the smelting of iron it has been difficult to succeed without access to charcoal, but few items were so expensive as charcoal in Greenland. After a few centuries of felling, very little has probably been left of the old forest, and the new grew only slowly".

The smelting of iron was in medieval times a rather uneconomic process. It is not exactly known how much fuel was required to produce 1 kg of iron, and it depended much upon the quality and the dryness of the ore, and on the technique used. The shape and running of the furnace were crucial for the yield of reduced iron from any given charge of ore. In the old German bloomery process (Rennfeuer) Beck (1890,1: 779) estimated that the production of 1 kg iron required from 5 to 6 kg charcoal. In the medieval blast furnace (Stückofen) the ratio had improved considerably to about 3 or 4 kg charcoal per kg iron bloom (Luppe) (Ibid. p. 816).

Recently a very interesting document has been found in the National Archives, Riksarkivet, in Oslo, a manuscript from 1670 rich in observations and calculations regarding the European manufacture of iron (Fritz 1981). The examination of the bloomery process near Bilbao, the socalled Catalan hearth process, provides us with valuable information as to the ancient manufacture of iron. On page 12–15 of the manuscript it is stated that 3 quintals ore and 3 charges charcoal are required to produce 1 quintal iron, and that further 25% charcoal is needed to forge the iron into bars. Although the old measures are somewhat uncertain, variable as they were from place to place, the following recalculation may be performed with some caution:

3 quintals = 3 Zentner (Hematite, limonite)	= 150 kg ore plus
3 charges = 3 horseloads each of 87 kg	= 261 kg charcoal
give 1 quintal = 1 Zentner	= 50 kg iron
The finery process requires further about	= 65 kg charcoal,

from which we see that 1 kg iron has required, from its extraction from ore to a forged iron bar, 6.5 kg charcoal. The iron bars were exported from Bilbao and were strongly competitive to the Swedish iron bars exported via Stockholm and Norrköping in the seventeenth century.

It is probably safe to conclude that in the medieval times it required between 5 and 8 kg charcoal to produce one kilogram of finished wrought iron. Whether or not it would have been possible in Greenland to produce suitable wood in such quantities, e.g. from driftwood and low birch-forest, it is not easy for us to determine. Considering, however, the general deficiency of wood, the absence of charcoal pits, the absence of furnaces and hearths, and the absence of anvils, we are very sceptical with respect to the manufacturing of iron in Greenland.

Wrought iron came with the Norsemen A.D. 985, and they introduced the same variety of items as we know from Norway, Iceland and Denmark, i.e. nails, fish hooks, sickles, arrow blades, swords, spear blades, axes, knives, chain mail, and perhaps, helmets, horseshoes, anchors and chains. Whether semi-finished products, such as iron bars and spade iron, were also imported, we do not know, but one would think it would be rather limited, because that again would require an-

Table 11. Selected analyses of iron objects from Scandinavia, ordered after age. Electron microprobe (1–7) and chemical and spectrographical analyses (8–13). Vickers hardness (100 g) stated where available.

Object	Approx. date A.D.	Ni	Cu	Si	P*	S	Mn	C*	HV 100	Reference
1. Axe, Sdr. Onsild	975	0.02		0.01	<0.05		0.02	0–1.3	140–325	1
2. Knife, Aggersborg A3–760 D2	975	<0.01		<0.01	0.03		<0.01	<0.02	133–155	2
3. same, adjacent lamella	–	0.18		<0.01	0.30		<0.01	<0.02	172–206	2
4. Horseshoe D 6828	1200			<0.02	0.07		<0.02	0–0.2	141–221	2
5. Horseshoe D 1070	1350			<0.02	0.04–0.17		0.05	<0.02	165–203	2
6. Horseshoe D 1189	1450			0.014	0.03–0.64		<0.02	0–0.75	126–396	2
7. Horseshoe 12148	1600			<0.02	0.04		<0.02	0–0.7	124–247	2
8. Bar iron, Læsø, 48	1650	0.01	0.09	0.03	0.31	0.006	0.007	0.02		3
9. Bar iron, Læsø, 45	1650	0.001	0.006	0.06	0.08	0.002	0.002	0.25		3
10. Bar iron, Svartå	1700	0.001	0.008	<0.05	0.06	0.007	<0.02	0–0.2		3
11. Window frame, Norrberg	1770			0.03	0.042	0.004	0.01	0.04–0.47		4
12. Siemens-Martin, DDS	1960	0.02	0.15	<0.05	0.019	0.051	0.33	0.08		5
13. Electrosteel, DDS	1975	0.08	0.4	0.2	0.025	0.025	0.3	0.06		5

* P and C may in the pre-industrial-age objects vary considerably from lamella to lamella.
References: 1 Buchwald 1976, 2 Buchwald unpublished, 3 Björkenstam 1975, 4 Molander 1982, 5 Det Danske Staalvalseværk, (The Danish Steelworks), pers. comm.

vils, forges, and first of all plenty of fuel: As stated above, at least 1 kg charcoal per kg iron to be manufactured.

In Table 11 a number of typical iron objects from Scandinavia have been assembled with their modern analyses, which may be compared to the analyses that will be presented in the following paragraphs. The objects of Table 11 represent a very long period of about 1000 years, but there has been no systematic change in the analytical composition in most of the period, the first eleven analyses. Unfortunately, it thus appears to be very difficult with the present knowledge to date any object on basis of its analysis. With the advent of the Bessemer-, Siemens-Martin-, and electrosteel-processes after 1860 the picture has changed somewhat, most modern steel having been through several melting processes at high temperatures (1600–1700°) which have influenced the final composition of the steel. Modern steels are thus relatively rich in manganese and silicon, with the two elements increasing from rimmed through semi-killed to killed steels. Besides, most steel produced in Denmark has in the last generation been based upon recycling of scrap, which has led to a slow, but definite, accumulation of copper and nickel in the final product, compare the last analyses from the Danish Steelworks with the older analyses.

Samples of wrought iron

Chain mail from Ruin Ø, L3–2474.
About 1200 A.D.

In house 4 on Ruin Ø two objects of Norse origin were found, a comb and an irregular nugget of rust which was judged to be composed of rusted links of chain mail (Holtved 1944, plate 44). The nugget measures about 40×35×15 mm and weighs 18 g. The individual, circular links are about 12 mm in outer and 6 mm in inner diameter (Fig. 37). The links are flattened and in cross section typically 3 mm wide and 2 mm high. They are in an advanced state of corrosion. The nugget hardly responds to a pocket magnet at all, and no metal could be found in the fracture when the nugget was split into pieces of 16.7 and 1.3 g. On this background the metallographic analysis had to be abandoned, but there can be no doubt that the determination as chain mail of wrought iron is correct.

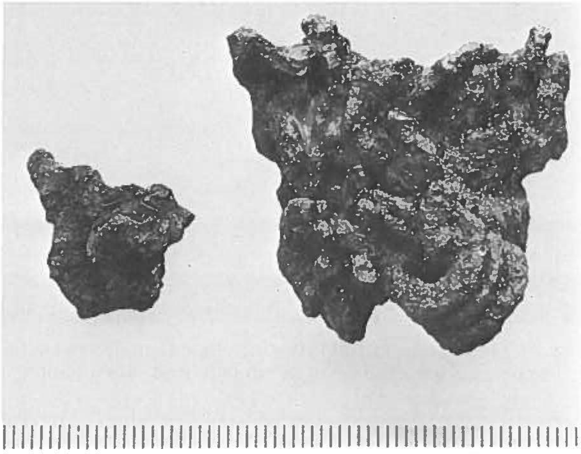


Fig. 37. Chain mail from Ruin Ø, 79°N. Rusted fragments of wrought iron. Scale in mm.

Harpoon from Thule, house 8. L3–3604.
1200–1300 A.D.

The harpoon is a socalled thin toggle-harpoon with blade and closed socket and is typical for the Thule culture (Holtved 1944: 189). The blade and the rivet are preserved, but rather severely corroded. The original size of the blade may have been about 25×19×2 mm with a mass of 2–3 g. A metallographic examination of a small polished and etched area of the surface disclosed an annealed structure of rather large (~ 100 µm), polyhedric ferrite grains with few impurities. This type of structure is well known from medieval wrought iron of Norse origin (Fig. 38) and is, for example, rather similar to the samples L6–3479 and Lb 561, to be discussed below.

Harpoon point. Anoritôq, Inglefield Land. 1924: 13.
After 1500 A.D. probably 19th century

The harpoon is undescribed. It was donated to the Geological Museum in January 1924 by Dr. Lauge Koch who assumed that it was of meteoritic iron and told that it was found in a grave at Anoritôq (Fig. 39). There is no further information attached to the object. There can be little doubt, however, that Anoritôq is the ancient site at Kap Inglefield, Inglefield Land, which Lauge Koch visited several times on the Bicentenary Jubilee Expedition north of Greenland (Koch 1927). The

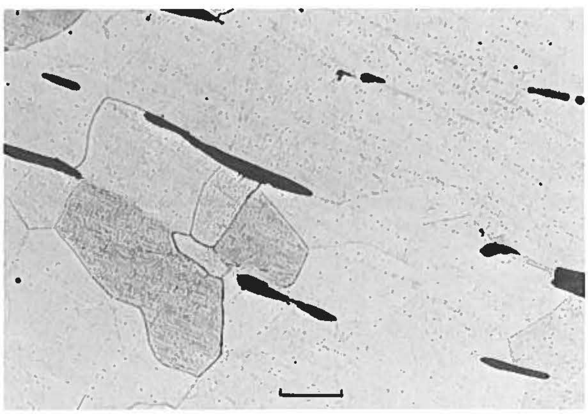


Fig. 38. Typical wrought, carbon-poor iron. Large equiaxed ferrite grains and parallel slag inclusions (black) that indicate the forging direction. Scale bar 50 µm.

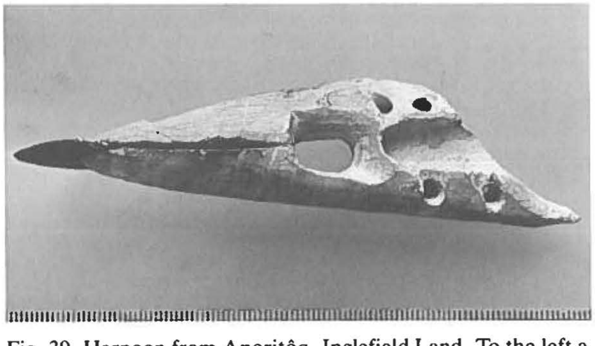


Fig. 39. Harpoon from Anoritôq, Inglefield Land. To the left a triangular, cold-worked point of wrought iron. Scale in mm.

grave has not been identified and the tool has not been dated, but we assume on typological basis that it is after 1500 A.D.

The harpoon head is of a type similar to specimens found in the youngest layers of "Comer's midden" at Thule, where they have been dated to the 19th century (Holtved 1944: 190 and plate 4, no. 22). The open shaft socket in our specimen is possibly the result of repair of a broken closed socket.

It is of antler, while the blade is of iron, measuring 25×21×1.5 mm and with an estimated weight of 3 g. The blade is squeezed into a long, narrow slit in the antler, and no nail hole is present.

The small section that was analyzed on the electron microprobe (Table 12) is of pure iron. All elements analyzed were near the detection limit of the probe, and the harpoon blade is thus the purest iron of all samples examined in this study. The structure is ferritic, with grains 20–500 μm across, and an estimated carbon content below 0.04%. After hot-forging, the blade has been cold-worked 30–50%, whereby all ferrite grains have become elongated and have attained hardnesses in the range 124–179.

In another publication Koch (1925: 261) briefly reported the finding of an ancient knife at Cass Fjord, Washington Land (80°N, 64°W): "an old rib-bone in which a number of meteoritic iron flakes were inserted. It was an old knife which he (Talilenguak) had found at the house ruins, that Knud Rasmussen had discovered at the mouth of Cass Fjord four years ago". Unfortunately, it has not been possible in this study to relocate this object, evidently the northernmost of all knives with edges of iron.

Knife from Nûgdlît, Thule district, L3–12572.
900–1200 A.D.

The knife blade, which measures 81×17×3 mm, is a very significant piece of wrought iron from so early a period (Table 12). It is rich in slags, which are elongated in the forging direction, but the metallic coherence is, nevertheless, good. The knife blade is rather pure iron, having less than 0.1% C and a ferritic, equiaxial structure with grain sizes of the order 50–100 μm. The only significant element present is phosphorus which varies from lamella to lamella and is the reason for the varying, but high hardness, and for the ghost structure in the ferrite. No cold-work has taken place. It must be concluded that the knife blade was manufactured somewhere else by forging, and then was used without alteration by the Eskimos. It is interesting to note that in the same house ruin, nr. 23, the small knife blade of meteoritic iron, L3–12573 (Table 4) was also found.

Harpoon blade (?). Nûgdlît, Thule district, L3–12673.
900–1200 A.D.

The corroded stump, which measures 25×22×3 mm, may come from either an original knife or a harpoon. There is a hole for securing the blade to the shaft. There are but few slags, elongated in the forging direction, and the structure consists mainly of slightly elongated ferrite grains, except in one lamella where there is some pearlite, suggesting a carbon range from 0 to 0.1%. The hardness ranges from 150 to 200 due to some cold-work after the final forging.

Harpoon head from "Sowallick", Vienna A 217

In the Museum of Natural History of Vienna there is a harpoon head labelled "Sowallick, Greenland". In a shaft of walrus tooth a triangular iron blade, measuring 38×28×1 mm, is inserted (Fig. 40). The iron has always been assumed to be of meteoritic origin (Brezina, 1896; Buchwald, 1975: fig. 494), and to derive from John Ross's expedition in search of the Northwest Passage in 1818.

By the kind assistance of dr. Alfred Kracher in Vienna, the harpoon point was in 1979 reexamined and qualitatively tested for nickel in an electron microprobe. To our surprise there was no nickel signal and the structure appeared to be that of cold-worked, wrought iron. The records at the Museum, however, confirmed its acquisition, indirectly, from John Ross, and in Partsch (1843: 135) the full story is given: the harpoon head was acquired by John Ross (1819, chapter 6) when he bartered with Eskimos near Bushnan Island. The iron came from a place called Sowallick and it was later acquired by the ardent collector Mr. Heuland at a public sale in London. From Heuland it came to the collector Heath, and finally, in 1838, it was purchased by Herr Pötsche for the Vienna collection. There is thus no doubt about the provenience. With respect to the type, the Vienna sample is rather similar to the Thule harpoon heads of toggle type with closed socket, described by Holtved (1944: 188, plate 4). Like the Vienna specimen, which has a 3 g iron point, also many of the Thule harpoon heads are equipped with iron points.

It is quite interesting that the Polar Eskimos, among

Table 12. Eskimo tools produced from various sorts of imported wrought iron. Roughly ordered from north to south after location of find. Microprobe analyses and Vickers hardness (100 g). Carbon as estimated from the structure.

Type	Number	Weight g	Ni %	Cu%	Si%	P%**	Mn%	As%	C%**	HV 100 range
Chain mail	L3–2474*	18								
Harpoon blade	L3–3604	2							<0.05	
Harpoon blade	1924: 13	3	<0.01	<0.02	0.01	0.02	<0.02	<0.02	<0.04	124–179
Knife blade	L3–12572	11	0.01	0.015	0.01	0.27	<0.02	<0.02	<0.1	195–274
Harpoon blade?	L3–12673	3							0–0.1	147–199
Harpoon blade	Vienna A217	3	<0.01						<0.1	
Ulo	3927	4.5	0.01	<0.02		0.03			0–0.5	165–279
Ulo	L 2856	12.5	0.015			0.9			0–0.2	222–360
Knife	L 8356	19	<0.01	<0.01	0.01	0.2–0.4	<0.02	<0.02	0–0.4	151–413
Arrow blade	Lc 297	3.5	0.015	0.016	0.01	0.1–0.35	<0.02	<0.02	0–0.1	205–327
Harpoon blade	L2–425	2.5	<0.01	<0.01		0.23	<0.02	<0.02	<0.04	192–221
Harpoon blade	L2–426	2.5	0.03	0.08	<0.06	0.21	<0.02	<0.02	0–0.2	213–292
Knife	L6–3155	10	<0.01	<0.01	<0.01	0–0.06	<0.02	<0.02	0–0.1	200–390
Knife	L6–3308	34	0.05	<0.02	0.01	0.14	0.02	<0.02	<0.05	185–206
Knife	L6–3316	29	0.01	0.0–0.5	0.01	0–0.3	0–0.4	<0.02	0–0.5	190–627
Nail?	L6–3479	3.5	0.01			0.25			<0.05	123–153
Harpoon blade	Lb 560	5.8	<0.01	0.57	<0.01	0.06	<0.02	0.09	0–0.1	203–218
Harpoon blade	Lb 561	3.6	<0.01	<0.01		0.14	<0.02	<0.02	0–0.04	160–185
Harpoon blade	L12–814	5	<0.01	<0.01	0.01	0.05	<0.02	<0.02	0–0.3	209–348
Harpon blade?	L12–820*	9							0–0.2	243–283
Adze	L12–439	329	0.01	0.015	0.01	0.11	<0.02	<0.02	0–0.2	148–205
Knife	L12–292	38.5	0.01			0.15			0–0.15	222–276
Knife	L12–463	3.5	0.01	<0.02	0.02	0.22	0.02	<0.02	<0.1	242–297
Knife	L12–644	9	0.01			0.25			<0.05	225–258
Ulo	L12–686*	31.5							0–0.15	205–254
Ulo marked	F crown	80							0–0.4	197–351

* Severely corroded. ** Phosphorus and carbon usually vary from lamella to lamella, compare Table 13.

their definite meteoritic iron tools, also were in possession of wrought iron in 1818, at a time when these "Arctic Highlanders" (Ross 1819) were entirely unknown to the outside world. The possibility is that some daring whaleboat has ventured right up in the Melville Bugt in the 18th century and bartered in the usual way. If this is the case, the meeting has gone entirely unreported. The more distant probability, that the iron should have survived at least 400 years from the Norse connections, appears less likely.

There seems, however, to be yet a third possibility. When Ross acquired the tools in 1818 he had them examined immediately on board the HMS Isabella: "The knives had by this time been examined by the armourer, who thought they were made from pieces of iron hoop, or from flattened nails. We, therefore, asked if any plank or wreck had formerly been driven on their shore; to which they replied, that a piece of wood with some nails had come on shore, and been picked up. We, therefore, concluded that the knives which they had left with us had been formed from this iron, and consequently made no further enquiries" (Ross 1819, chapter 5).

It now remains to reexamine the important collection of knives, ulos and harpoon heads that Captain John Ross acquired in the Melville Bugt in 1818, the bulk of which is now in the British Museum, for example the beautiful knives nr. 87561 and 87562 (Fig. 29). Contrary to the general opinion that all iron objects are of meteoritic origin it now appears that wrought iron also has played its role.

Ulo from the Ūmánaq district, nr. 3927.
Before 1650 A.D.

The ulo has one large blade, measuring 44×20×1.7 mm (Fig. 41). Our sample was taken from the back, the part hidden in the handle. When cut the sample disbanded into two pieces, no doubt because corrosion had penetrated along the slag lines separating two parallel lamellae. One lamella is low in carbon, <0.02%, the

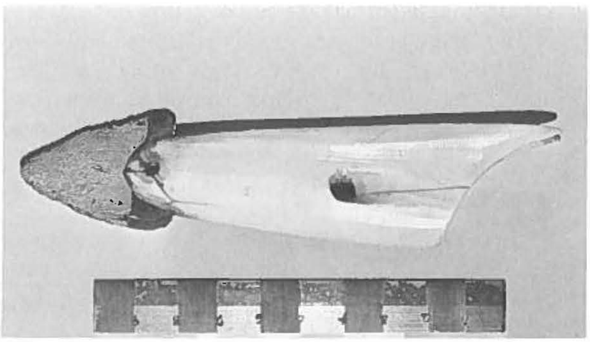


Fig. 40. Harpoon, A 217 in Vienna. Acquired by John Ross in 1818 at "Sowallick", i.e. Savigsivik, in the Melville Bugt. Wrought iron. Scale bar in cm.

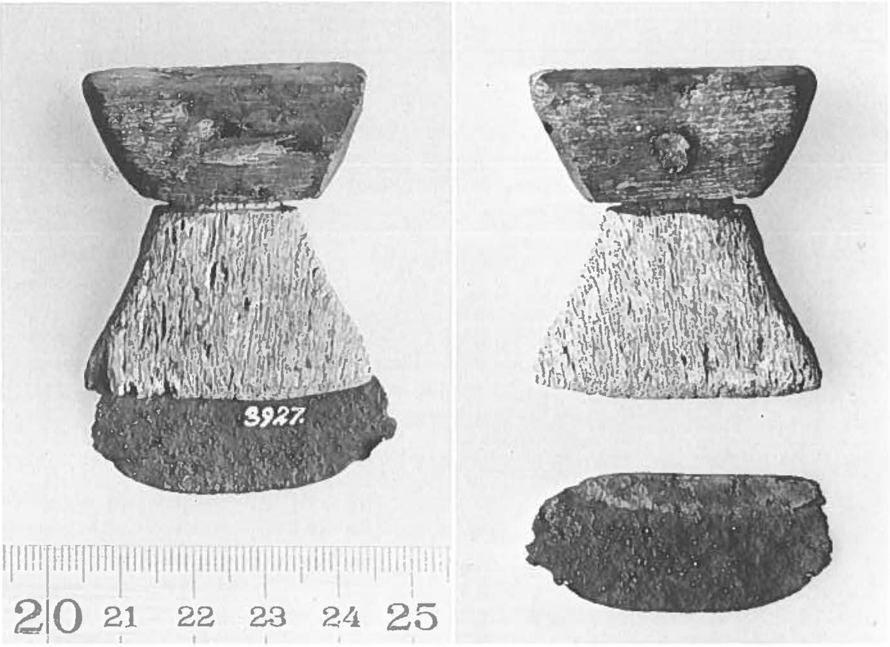


Fig. 41. Ulo, nr. 3927, from the Ūmánaq district. Wrought iron blade. Before and after separation.

other high, about 0.5% C. Ni, Cu and P are low in both lamellae, Table 12. After manufacturing by forging, the ferrite and the ferrite-pearlite have been significantly cold-worked. Because of this and because of the varying carbon content the hardness ranges from 165 to 279.

Ulo from the Ūmánaq district, L 2856.
About 1650 A.D.

This beautiful ulo (Figs 3–5) has one large blade, 54×51×1.5 mm in size. It is nailed to the handle with four brass pins of varying lengths. A section through the blade shows that it is composed of four or five parallel lamellae, that are different in structure and composition, due to variation in carbon and phosphorus. The two exterior lamellae have little carbon, but up to 0.9% P (!), and a ferrite grain size of 200–400 µm. In the grains are minute particles of exsolved iron phosphides, Fe_3P. The ferrite grains are slightly elongated and show sliplines, in accordance with the high hardness of 280–360. The central lamellae have less phosphorus, but about 0.2% C, ghost structure and a ferrite grain size of 20–50 µm with some pearlite colonies at the grain corners. The hardness is lower, 220–235, mainly because the phosphorus content is lower.

The pin examined, 0.2 g, is rather pure, ductile brass, with 72% Cu, 28% Zn and lead, sulfur, tin and arsenic just around the detection limit of the microprobe, i.e. lower than 0.02%. The hardness is 180±20.

Is it possible that some smith onboard a whaler has manufactured the blade, and perhaps the entire ulo, at the request of an Eskimo? Perhaps the smith reshaped a saddler's knife, a tool that must have been a standard item on board sailing ships.

Knife from the Ūmánaq district, L 8356.
After 1650 A.D.

The blade (Fig. 42) measures 120×24×6.5 mm and is well preserved. Only sections from the tang was taken in order not to damage the blade. The sections show at least four lamellae with different carbon- and phosphorus contents, and separated by lines of slags. The sample happens to include a part where one of the lamellae shows a clear 180° bend and therefore doubles up, with the result that all structural elements are repeated in an inverted order (Figs 43–44).

The exterior lamellae have been carburized, to 0.4% C or perhaps more, but since corrosion has removed the original surface it is difficult to determine the initial maximum value. Phosphorus varies from 0.15 to 0.4%, and there is local segregation into 20 µm ferrite grains with low and high phosphorus contents (about 0.25 and 0.5%; to be studied further), Figs 65–66. These observations lead to the following scenario for the production of the knife: after forging to shape it was briefly held at about 1000°C. Then it was waterquenched, and finally it was annealed at about 300°C. All in all a procedure which will lead to a high-quality product. The hardness range is from 410 (tempered martensite), via 190 (0.4% P-ferrite) to 150 (0.2% P-ferrite).

The shape and structure of the blade suggest that a knife of European origin simply was inserted into a bone handle without much further ado.

Fig. 42. Knife, L 8356, from the Ũmánaq district. Wrought iron blade.

Arrow blade from the Ũmánaq district, Lc 297. After 1650 A.D.

The arrow, Fig. 45, is very similar to the arrow blade, examined by J. Steenstrup (1872) and figured on his plate 25. The present arrow blade, measuring 39×21×1.7 mm, is definitely wrought iron, while Steenstrup assumed his to be of meteoritic iron, which however, is very doubtful. In Lc 297 three different ferritic lamellae may be distinguished, each about 0.3 mm thick and separated by elongated, phosphorus-rich slags. The lamellae have, respectively, 0.13, 0.30 and 0.35% P, and the structure is that of distorted, elongated ferrite grains suggesting forging followed by cold-work. Due to phosphorus there are large patches of the socalled ghost structure. The carbon content appears to be low, <0.1%, and the rather high hardness, 205–327, is due to the combined effect of phosphorus and cold-work.

The arrow blade was assembled with the shaft with an iron nail, which was not examined.

Harpoon head from the Ũmánaq district, L2–425. After 1650 A.D.

The harpoon blade measures 27×17.5×2.1 mm and is fastened to the bone with a round iron nail, 2 mm in diameter and 9.5 mm long (Fig. 46). The section shows a rather pure phosphorus-rich ferrite of large grain size, 100–400 µm. The grains are elongated from forging and recrystallization, and there are numerous Neumann bands from a late overhammering. The hardness, 192–

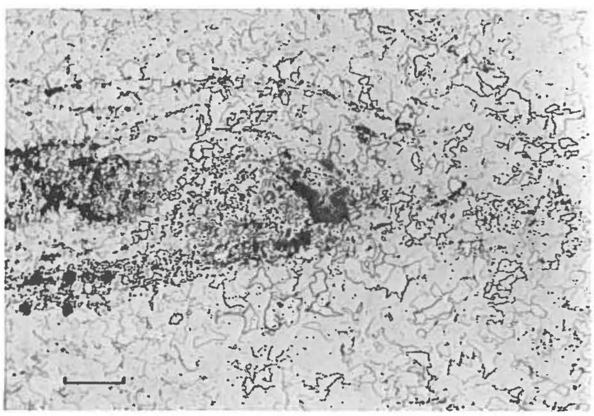


Fig. 43. Section through the knife blade, Fig. 42. the structural elements are curved suggesting folding of the iron lamellae during forging. To the left five square, dark hardness indentations that indicate the area analyzed in the electron microprobe. Scale bar 200 µm.

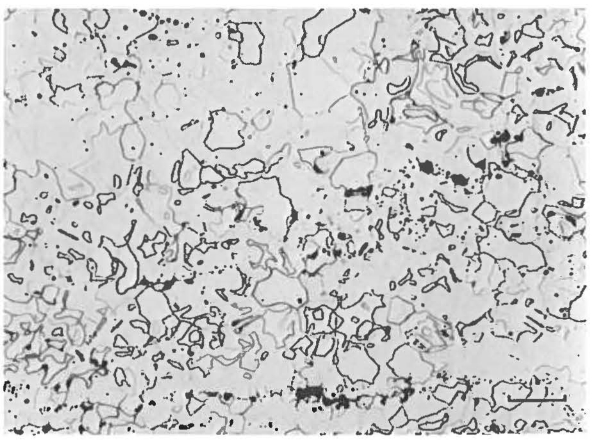


Fig. 44. Section through the knife blade, Fig. 42. The confusing structural details, that here have been termed ghost structure, are due to substantial quantities of phosphorus (0.2–0.5%) in solid solution in the ferrite. Scale bar 70 µm.

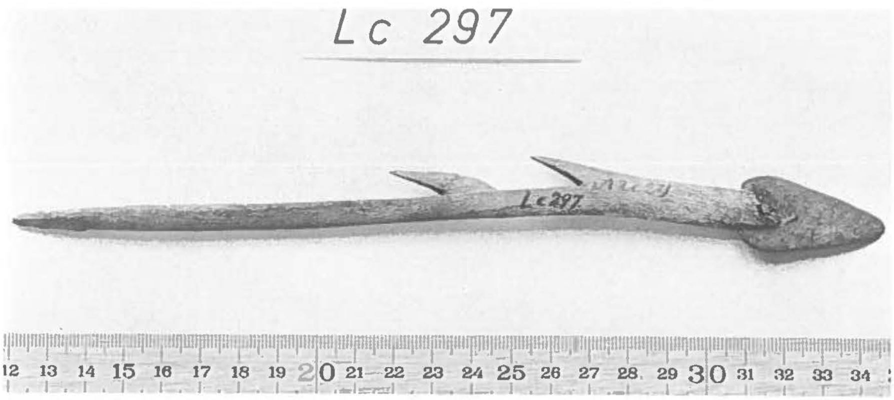


Fig. 45. Arrow blade, Lc 297, from the Ūmánaq district. Wrought iron blade.

221 HV, is due to the combined effect of phosphorus in solid solution and slight cold-working. The carbon content is probably below 0.04%.

Harpoon head from the Ūmánaq district, L2–426. After 1650 A.D.

The harpoon blade, measuring 31×17×1.1 mm (Fig. 47) is similar to the previous one, and it is also fastened to the bone with a round iron nail, 1.9 mm in diameter and 8 mm long. The nail has been flattened in both ends by hammering. A section through the blade shows two lamellae, the widest having large, equiaxial ferrite grains, about 100 µm across, the other having a ferrite grain size of 10–20 µm with some pearlite. Carbon ranges from 0 to 0.2%; phosphorus was only measured in the coarse ferrite part, where it was 0.21%. The hardness range is rather high, 213–292, caused by the combined effect of carbon, phosphorus and slight coldwork.

Knife from Igdlorssuit, L6–3155. 1300–1500 A.D.

The knife blade, measuring 78×16×3 mm, was excavated in house no. 8, where it was found together with other things of Norse origin, particularly a bronze cooking pot, which dates from 1300–1500 A.D. (Mathiassen 1934: 156). A cross- and a lengthwise section through the knife show an almost pure and slag-free ferrite with grain sizes from 25 µm to 1 mm, caused by grain growth around 800°C. Late cold-working has introduced many Neumann bands, and the hardness is therefore 200–245. Locally, there are patches, up to 50 µm across, of low-carbon martensite with a hardness of 400±20. The structure shows that the smith has tried to harden the knife by quenching it in water from a high temperature. He has, however, not succeeded i) because the bulk carbon content was below 0.1%, ii) because the temperature was about 800°, which is too low for this composition.

Knife from Igdlorssuit, L6–3308. 1700–1800 A.D.

The large blade, Fig. 48, measuring 78×16×3 mm, is of rather recent date, according to the wealth of European objects, such as glass and faience beads, with which it was found (Mathiassen 1934: 160). The section shows elongated ferrite grains, about 100 µm across, without cementite or pearlite, putting the carbon content below 0.05% (Table 12). Patches of ghost structure may be as-

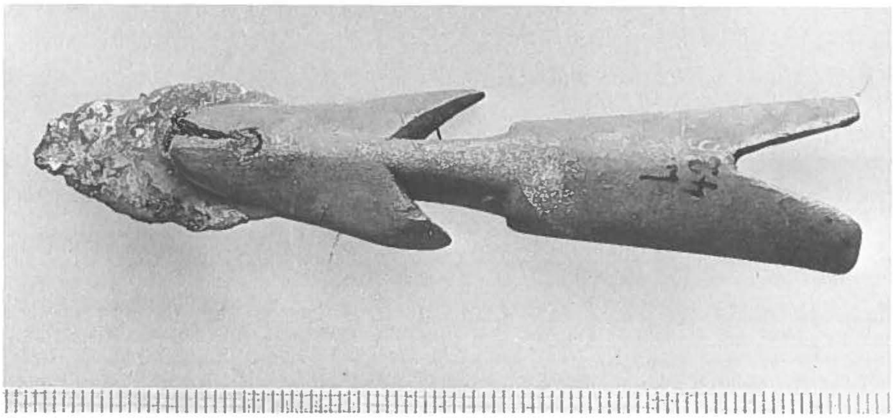
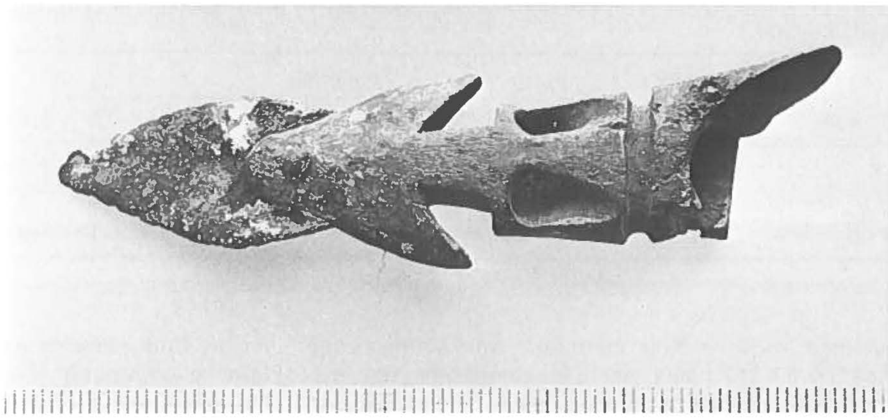


Fig. 46. Harpoon, L2–425, from the Ūmánaq district. Wrought iron blade. Scale in mm.

Fig. 47. Harpoon, L2–426, from the Ūmánaq district. Wrought iron blade. Scale in mm.



cribed to a local high phosphorus content, while the hardness of 185–206 HV, is due to the combined effect of phosphorus and cold-work. The cold-work is revealed by Neumann bands, slip lines and distorted ferrite grains in various places (Fig. 49). There are few slags. The knife has been of low quality, because the carbon-poor iron is unsuited for hardening. Whatever qualities the knife may have had have been due to some phosphorus in solid solution, conferring a certain hardness.

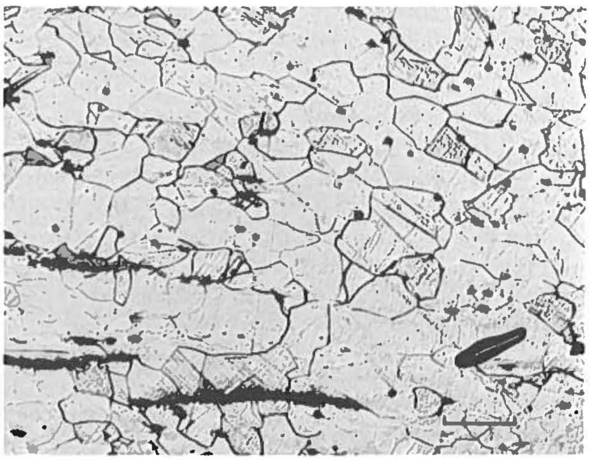


Fig. 49. Section through the knife blade, Fig. 48. Slightly cold-worked, equiaxed ferrite grains and elongated slags. Scale bar 100 μm.

Knife with tang, Igdlorssuit. L6–3316.
1700–1800 A.D.

Like the previous one, this large knife (Fig. 50) measuring 140×26×10 mm including the tang, is of relatively recent date. The blade is forged from three lamellae, which are very different in composition, but of about equal width, 0.5 mm, where the section has been taken, (Table 13).

This knife represents a typical case for the heterogeneity of ancient iron objects. The three lamellae may in the microscope clearly be distinguished by their structure and microhardness. A thin transition layer between B and C is also well-developed (Fig. 51). When tested with the electron microprobe it turns out, that A – besides much carbon – contains significant quantities of copper and manganese, which is rather unusual for Norse objects, while B and C are rich in phosphorus. C is, in addition, rich in finely disseminated iron-silicon slags, which is the reason for the strong silicon signal; there is just as little silicon in the metallic matrix as in the other lamellae. The knife is correctly hardened, from about 950°C, and tempered, now exhibiting fine-

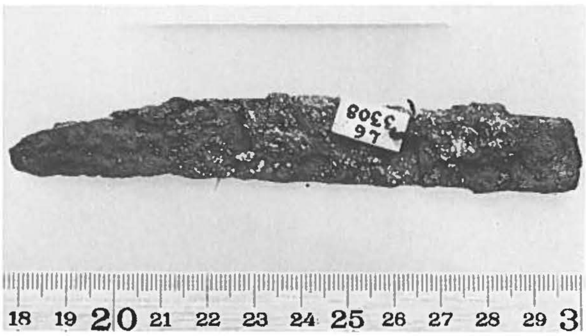


Fig. 48. Knife, L6–3308, from Igdlorssuit, Disko Bugt. Wrought iron.

Fig. 50. Knife, L6–3316, from Igdlorssuit, Disko Bugt. Wrought iron. Scale in mm.

Table 13. Heterogeneity of ancient iron objects as illustrated by the composition and structure of three adjacent lamellae in the knife L6–3316.

Lamella	Width mm	Percentage Ni	Co	Cu	Si	P	Mn	As	C	Structure	HV
A	0.5	0.01	<0.01	0.35	0.01	0.01	0.3	<0.02	0.5	temp. martensite	440–627
B	0.4	0.01	<0.01	0.01	0.01	0.20	<0.02	<0.02	0.1	ferrite/ghost	230±20
B/C	0.1	0.01	<0.01	0.01	0.05	0.08	<0.02	<0.02	0.3	temp. martensite	320
C	0.5	0.01	<0.01	0.01	(0.4)	0.30	<0.02	<0.02	0.1	ferrite/ghost	230±20

grained, brown-etching martensite with hardnesses in the 500–600 HV range, where the composition was optimal. In other parts of the knife, the carbon content was inadequate for martensite formation. However, the phosphorus content resulted in a ghost structure with a hardness of about 230 HV, which is quite good.

Nail? Igdlorssuit, L6–3479. 1700–1800 A.D.

The sample, 48×9×5 mm, resembles a flat nail, Fig. 52. The section shows polyhedric ferrite grains, 25–50 μm across, with a hardness of 123–153 HV. There is little carbon, but up to 0.25% P, particularly in the two exterior lamellae where there is a faint ghost structure. The sample is forged and normalized with no subsequent cold-working.

Harpoon head. Manîtsoq (Sukkertoppen) district, Lb 560. 1650–1750 A.D.

The blade measures 37×25×2 mm and is fastened to the shaft with an iron nail, 3 mm in diameter and 11.5 mm long (Fig. 53). The section shows a carbon-poor, ferritic structure with equiaxial grains 10–50 μm across. The analysis which was checked and rechecked on the electron microprobe is unusual in showing no less than 0.4–0.6% copper and 0.09% arsenic in solid solution in the ferrite. Both elements are usually found at a 5–20 times lower concentration level in wrought iron. The blade has been used as acquired from the whalers (?), with only a little, superficial subsequent cold-working.

Harpoon head. Manîtsoq district, Lb 561. 1650–1750 A.D.

The blade measures 34×18×2 mm and is fastened to the shaft with an iron nail, 2.4 mm in diameter and 11 mm long (Fig. 54). The section shows a homogeneous, carbon-poor, ferritic structure of coarse, somewhat elongated grains, typically 200×400 μm in size. There is only a slight cold-work, evidenced by a few Neumann bands, and the hardness is correspondingly low, 160–185 HV. The sample is very simple in its analysis in contrast to the previous one, of similar size and location, and it is a typical wrought iron with rather few slags. Due to the phosphorus content there is a faint ghost structure.

Harpoon head from Kangâmiut, L 12–814. 1500–1650 A.D.

The harpoon blade, measuring 44×24×3 mm, is rather corroded (Fig. 55), but a metallic cross-section could be taken in the part that had previously been hidden in the

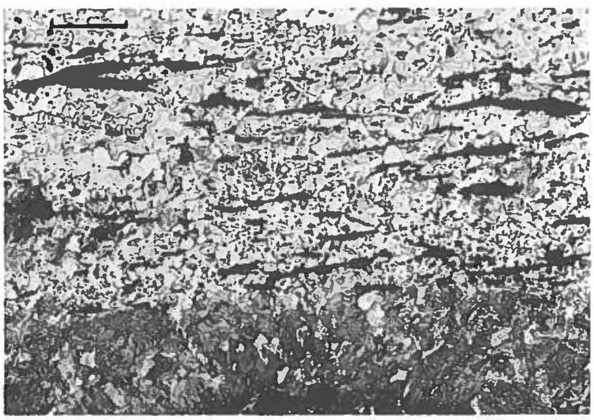


Fig. 51. Section through the knife, Fig. 50. Part of lamella C with ferrite and slags, and, below, the transition zone B/C of tempered martensite. Compare Table 13. Scale bar 50 μm.

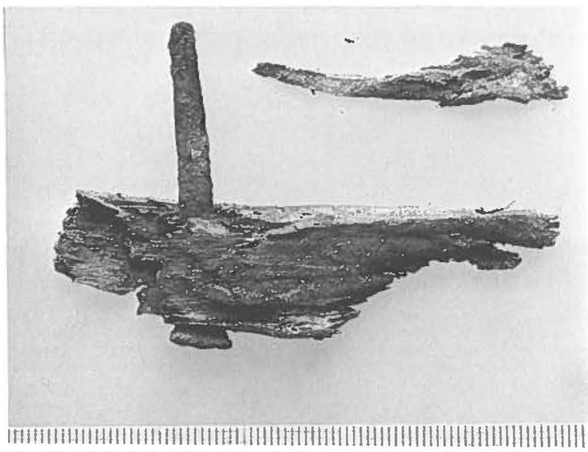
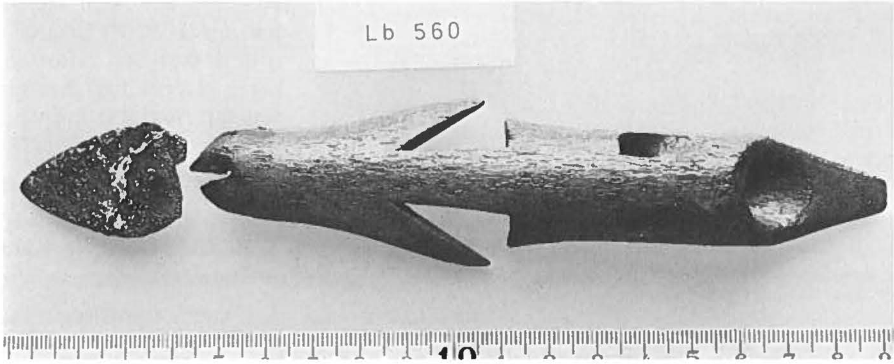


Fig. 52. Nail, L6–3479, from Igdlorssuit, Disko Bugt. Wrought iron. Scale in mm.

Fig. 53. Harpoon, Lb 560, from Manîtsoq district. Wrought iron blade.



shaft. The blade is composed of two lamellae, separated by a few slag lines. One lamella is carbon-poor (<0.05%) and shows elongated, lancet-like ferrite grains with a hardness of 209–230. The other is carbon-rich (~ 0.3%) and shows much narrower ferrite grains (~ 3 μm wide) of the same, ropy texture, but interspersed rather homogeneously with 1μm cementite particles. The structure is that of a forged and recrystallized/annealed ferritic iron, that finally has been cold-worked to a significant extent. The last action can be associated with the Eskimo that shaped the iron blade for his harpoon blade.

Harpoon blade (?). Kangâmiut, L 12–820.
1500–1650 A.D.

The blade, 38×37×3 mm, is corroded and it is difficult to determine its original application. The section shows a much distorted ferrite structure with a grain size of 5–20 μm. The iron which contains less than 0.04% C, has been water-quenched whereby austenite has transformed to serrated ferrite; a later thorough cold-working has distorted the grains and increased the hardness to 243–283 HV. The little slag that remains from the forging process has been severely broken and kneaded during the subsequent cold-work.

Adze from Utorqait, Kangâmiut. L 12–439.
1600–1650 A.D.

The adze blade, which is the most massive iron object in the present survey, measures 113×47×41 mm and weighs 329 g (Fig. 56). It was discussed and pictured by Mathiassen (1931: 110 & fig. 42) who concluded that it had been introduced by whalers in the first half of the 17th century.

A cross-section of the cutting edge shows a ferritic to ferritic-pearlitic structure with hardnesses from 148 to 205. The ferrite is rather coarse, 100 μm, and rich in cementite in grain boundaries. The ferrite-pearlite is developed as a coarse Widmanstätten structure, suggesting air cooling of a coarse-grained austenite with about 0.25% C. Centrally is a continuous line of single-phased slags, indicating that this part of the adze is forge-welded from two individual pieces. The iron is very pure, the only essential components being a little carbon and a little phosphorus (Table 12). Hardening of the tool was not attempted, and also would have led to a poor result, due to the low C-content.

Knife from Utorqait, Kangâmiut. L12–292.
1650–1700 A.D.

The knife which probably was introduced to the settlement by whalers (Mathiassen 1931: 11, 63, 120), measures 153×19×6 mm and weighs 38.5 g (Fig. 57).

Fig. 54. Harpoon, Lb 561, from Manîtsoq district. Wrought iron blade.

Fig. 55. Cross-section of harpoon blade, L12–814, from Kangâmiut. Elongated, lancet-like ferrite grains. Heavy crust of limonitic corrosion products. Scale bar 200 μm.

Fig. 56. Adze, L12–439, from Utorqait, Kangâmiut. Wrought iron. Scale in mm.

The cross-section shows that it was forge-welded from three lamellae, now being 0.5 mm wide each at the location of the section. The two exterior ones are low in carbon (~ 0.05%) and ferritic, the central one slightly richer (~ 0.15%) and now ferritic pearlitic. A late cold-working has distorted the structure, so that all elements are now elongated and kneaded. The ferrite therefore has a hardness of 225 and the ferrite-pearlite 270. These medium hardnesses are quite good, but of course inferior to what can be obtained in a carburized and hardened knife, compare e.g. L 6–3316.

Knife from Utorqait, Kangâmiut. L 12–463.
1600–1650 A.D.

According to Mathiassen (1931: 26) this knife was found in the same, collapsed house, no. 23, as the adze, discussed above. It is a fragment of a blade measuring 36×8.5×4 mm and weighing 3.5 g, Fig. 58. The cross section shows that the blade is composed of two lamellae, separated by a line of slags and, furthermore, now severely corroded along this line, Fig. 59. The two lamellae are of the same composition, Table 12, with about 0.22% P and very little carbon, silicon and manganese. However, in one of the lamellae there are numerous slag particles that under the electron microprobe can be shown to be rich in silicon and manganese.

Due to hot-working around 975°C the two-phase structure has been kneaded and the phosphorus-rich part (~ 0.5% P) has assumed the shape of elongated, wormy particles. After cooling additional working has taken place so that the present hardness is 270±20. Presumably, both the hot-working and cold-working action were due to the original owners, the whalers, or their resort home country.

Knife from Utorqait, Kangâmiut. L 12–644.
1650–1700 A.D.

The knife, consisting of an iron blade and a handle of antler, was found in the late layers of midden B and dated to the second half of the 17th century (Mathiassen 1931: 28 and plate 7, no. 6). The blade measures 80×15×3 mm and weighs 9 g (Fig. 60). Our two specimens were sawn from the tang. They are very similar to the knife, L 12–463, both in structure and composition (Table 12). The knife has been forged at about 975°, when it separated into two phases on a microscale. Both the phosphorus-poor (0.2% P) austenite and the phosphorus-rich (0.4% P) ferrite were stretched and kneaded by the operation. On cooling the austenite transformed to ferrite. A slight, late cold-working served to increase the hardness to 240±15, and the ferrite grains became elongated and filled with deformation bands. Again, the knife blade was probably made and finished elsewhere. The Eskimos mounted it in a handle of antler.

Ulo from Utorqait, Kangâmiut. L 12–686.
1650–1700 A.D.

The large ulo, which has an iron blade and a handle of antler, was found in the same midden layer as the knife, L 12–644 (Mathiassen 1931: 28 and plate 7, no. 9). The blade measures 86×70×2.5 mm and weighs 31.5 g (Fig. 61). The section, from the tang, is unfortunately very corroded and could not be analyzed. However, the blade is composed of two lamellae, one is a very fine-grained (~ 10 µm) ferritic-pearlitic, equiaxed structure with about 0.15% C, the other is a slightly coarser (~ 30 µm) ferrite with less than 0.05% C and an estimated phosphorus content of 0.2%. The blade was forged at about 900° and cooled in air. Since neither the slags, nor

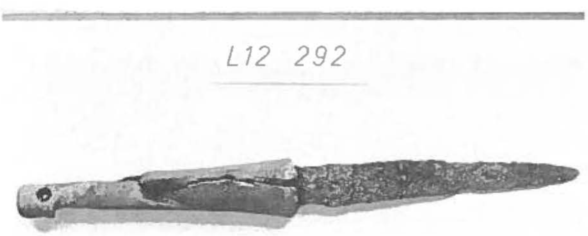


Fig. 57. Knife L12–292, from Utorqait, Kangâmiut. Blade of wrought iron. Scale in mm.

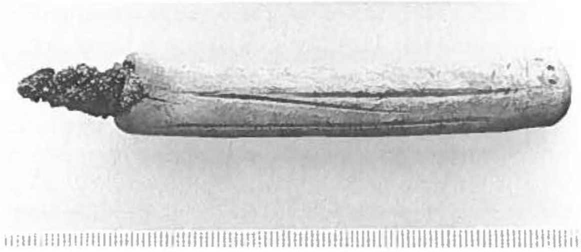


Fig. 58. Knife, L12–463, from Utorqait, Kangâmiut. Corroded blade of wrought iron. Scale in mm.

the metallic components have been deformed, only limited cold-work has taken place. The hardness ranges from 205 to 254, due to the carbon and phosphorus-variation and the slight cold-work.

The blade may originally have been forged into the shape sketched in Fig. 62; later use and grinding have altered it to the present shape. It is not clear whether the European smith had an ulo in mind when he produced the rather unique blade, but he may have started from a saddler's knife.

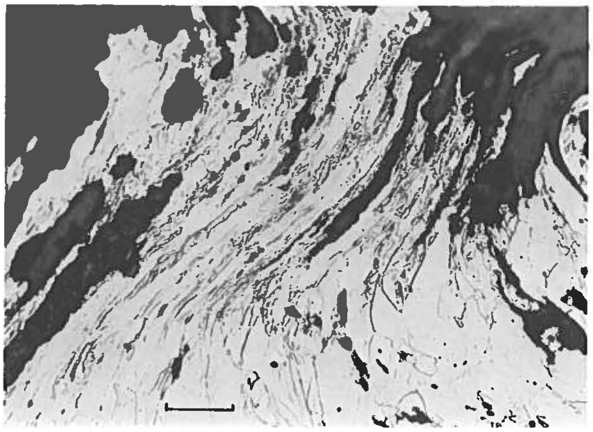


Fig. 59. Section through the knife blade, Fig. 58. Cold-worked ferrite and corrosion penetrating deeply into the iron blade. Scale bar 50 μm.

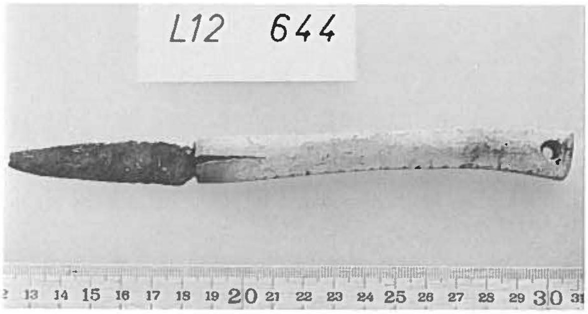


Fig. 60. Knife, L12–644, from Utorqait, Kangâmiut. Wrought iron blade.

Ulo. Private collection. 19th century

This ulo blade is a rather modern tool, with a prominent tang and a curved cutting edge, ground from only one side. It measures overall 115×100×2–3 mm and weighs 80 g. The sections taken from the tang present a more homogeneous appearance than the specimens previously examined. Nevertheless, also this tool has been fabricated from lamellae, three in the sections, of different composition. One is fine-grained (10 μm) ferritic-pearlitic with about 0.25% C, one is more coarse-grained (~ 50 μm) ferritic-pearlitic with some Widmanstätten structure and about 0.3% C, and the third one is ferritic (~ 50 μm) with a little grain-boundary pearlite, suggesting about 0.1% C. The slags are rather few, they are extended in the forging direction and broken. All structural elements are slightly elongated, suggesting 10–20% cold-work. The microhardness is correspondingly 215±15 in the ferritic parts and 330±20 in the pearlitic parts.

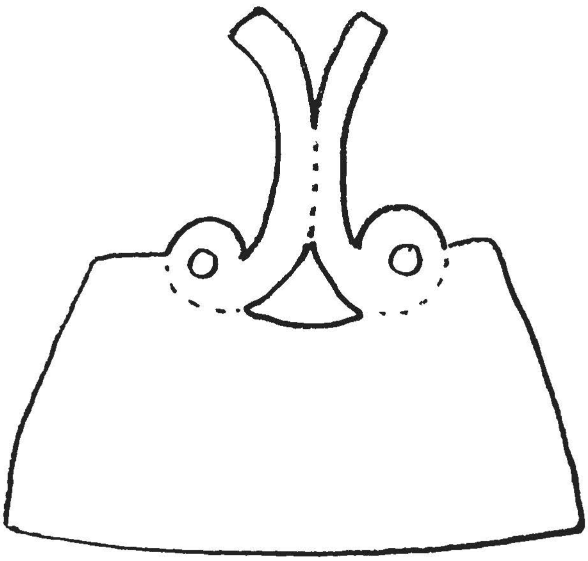


Fig. 62. Ulo, L12–686. Sketch of the forged iron blade as it may have appeared before it was worn and inserted in the ulo, Fig. 61.

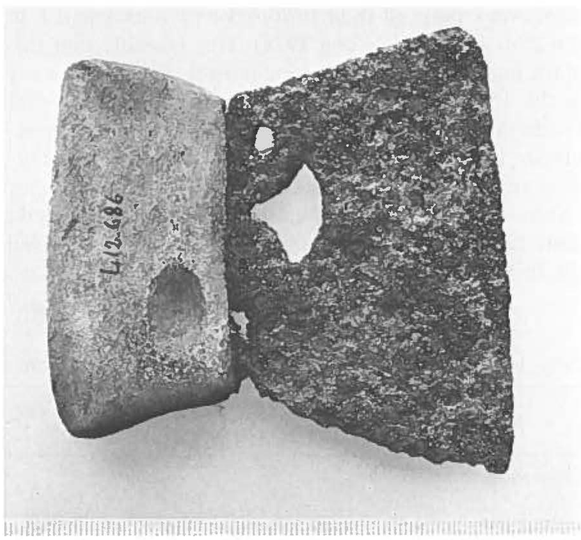


Fig. 61. Ulo, L12–686, from Utorqait, Kangâmiut. Blade of wrought iron. Scale in mm.

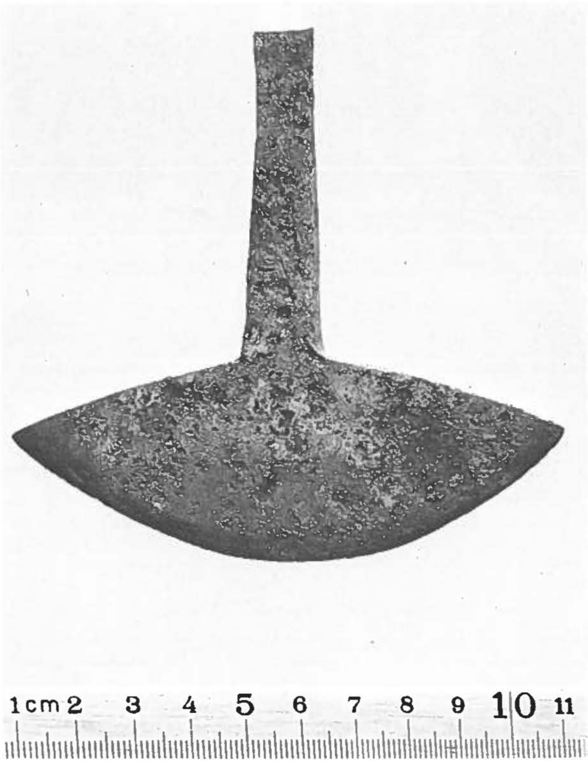


Fig. 63. Ulo, marked crowned F, of rather modern origin. Wrought iron.

The blade has probably been little used and has passed directly from the owner to a private collector. Unfortunately, all details as to origin have been lost. On the blade, however, there is a stamped mark, a crowned F, see Fig. 63. It is known that Anker Heegaard in Frederiksværk marked their products with a crowned F in the 20th century (Kisling 1978). It is possible that this mark has been used for a long period, perhaps already in the 18th century. From 1800 to 1856 we know that Frederiksværk had a production of sword- and knife-blades, and it is not unlikely that they also had minor orders from the Royal Greenland Trade Company for knives and ulos to Greenland. The crowned F would then stand for King Frederik 5 (1746–66) who founded the factory at Frederiksværk. In 1857 Anker Heegaard purchased the plant from the State and it appears that the crowned F continued to be used by the new owners.

Discussion

The method

In starting the present project there was some scepticism whether it would prove feasible to distinguish between the various sources of iron. However, as the project progressed it became increasingly clear that there were systematic differences in the composition, structure and hardness between tools made from meteoritic iron, telluric iron and wrought iron. The most important facts have for diagnostic purposes been collected in Table 14. Essential is the nickel content. All meteoritic iron contains more than 5% nickel (bulk), and due to this high nickel content there will usually be taenite inclusions, that are of distinctive diagnostic value, because taenite is easy to recognize and unknown from telluric iron and wrought iron. The same is true for the phosphides (schreibersite and rhabdite) in meteoritic iron.

Wrought iron, on the other hand, is poor in nickel. It may or may not contain carbon and phosphorus, and it will accordingly vary very widely in hardness, especially if it has been exposed to a hardening operation, when the hardness may increase to above 900 HV. The highest hardness observed in this study was 627 HV, attained in the knife L6–3316. Diagnostic for wrought iron are the aligned slags which may occur in large concentration, but sometimes are very scarce, probably because they have been squeezed out by repeated forging at high temperatures.

The telluric iron objects are intermediate with respect to nickel and carbon, and usually display a rather pure ferritic structure with few inclusions. Since the type of native iron that could be used by the Eskimos only occurred as disseminated, pea-sized iron inclusions in basalt (Table 8) it was very limited how large a tool could be produced. We therefore find that tools with telluric iron bits are small, the metallic part not exceeding 0.5 g in this study, corresponding to an original iron globule no more than 5 mm across.

Many of the samples have been severely attacked by corrosion during up to 1000 years of exposure to terrestrial ground water. The meteoritic fragments have

Table 14. Characteristics of the three types of iron that were used by the Eskimos.

	Ni-range %	Co-range %	P-range %	C-range %	Hardness range	Phosphides	Taenite	Slags	Maximum size g
Meteoritic iron	>5	>0.4	0.1–0.3	<0.1	175–350	+	+	–	10
Telluric iron	1–4	0.1–0.4	<0.08	<0.2	125–250	–	–	–	1
Wrought iron	<0.2	<0.01	0–0.5	0–1	100–900	–	–	+	1 000

Table 15. Summary showing the provenience of the iron objects examined in this study.

District		Total	Of which Meteoritic	Telluric	Wrought iron Before 1500	After 1500 A.D.
Thule, north of 76°N		39	33	0	4	2
Disko, 69–71°N		25	0	15	1	9
Manîtsoq, south of 66°N		10	0	0	0	10
	Total	74	33	15	5	21

furthermore been exposed many thousands of years (?), before they were found by the Eskimos. It appears that corrosion has attacked all types of iron with about equal rate, the precise location, soil-type and -porosity being of more importance than the difference in chemical composition of the tools. In this connection it is interesting to note that even fully rusted items may sometimes be identified as to structure and composition. For this identification a high-quality, polished section should be examined under the microscope: small (~ 1–5 μm) specks of yet undissolved cementite, pearlite and slags from forging will suggest that the original tool was made from wrought iron (Buchwald 1976), while similar tiny particles of phosphides and taenite will point to a meteoritic origin (Buchwald 1975).

In the present study such fully corroded fragments were, however, excluded from the survey in order to present a clear-cut picture. Also, all tools that had been preserved for museum purposes by some heat-treatment method were excluded, because all structural elements and the hardness presumably would have been altered in an unpredictable way, making it impossible to fit the item into our survey.

It should also be noted that the present selection of some seventy objects of iron is a random sampling from the north, the middle and the south of West Greenland. We know that more tools with iron parts are stored in the collections, e.g. in those carried home by Holtved (1944, plates 3–5 and 44), we believe, however, that our selection is unbiased and in a fair way represents the types presently known from Greenland.

Some sources of iron were, however, deliberately not touched upon on this occasion. The iron tools and weapons excavated from *Norse* ruins in Østerbygden and Vesterbygden will be the subject of a future study. Here we have limited ourselves to iron from Eskimo sites. Similarly, the highly interesting collection of all sorts of iron implements, excavated by Gulløv & Kapel (1979) and illustrating what Danish-Norwegian colonists thought necessary for the establishment of Haabets Colonie in 1721, has not been examined. It apparently represents a very valuable and all-round display of iron objects of the early 18th century.

Distribution of iron

Table 15 summarizes our results. The total number of tools and fragments examined is 70. In addition, four pieces of iron basalt excavated from graves in the Ũmānaq district were studied. While North and middle Greenland is rather well-covered the South is somewhat weaker represented. This is due to the fact that from the beginning we have put more emphasis upon the areas where we supposed that meteoritic and telluric iron sources had supplemented the wrought iron import, and we therefore specifically searched the collection at the National Museum of Denmark for tools from these areas.

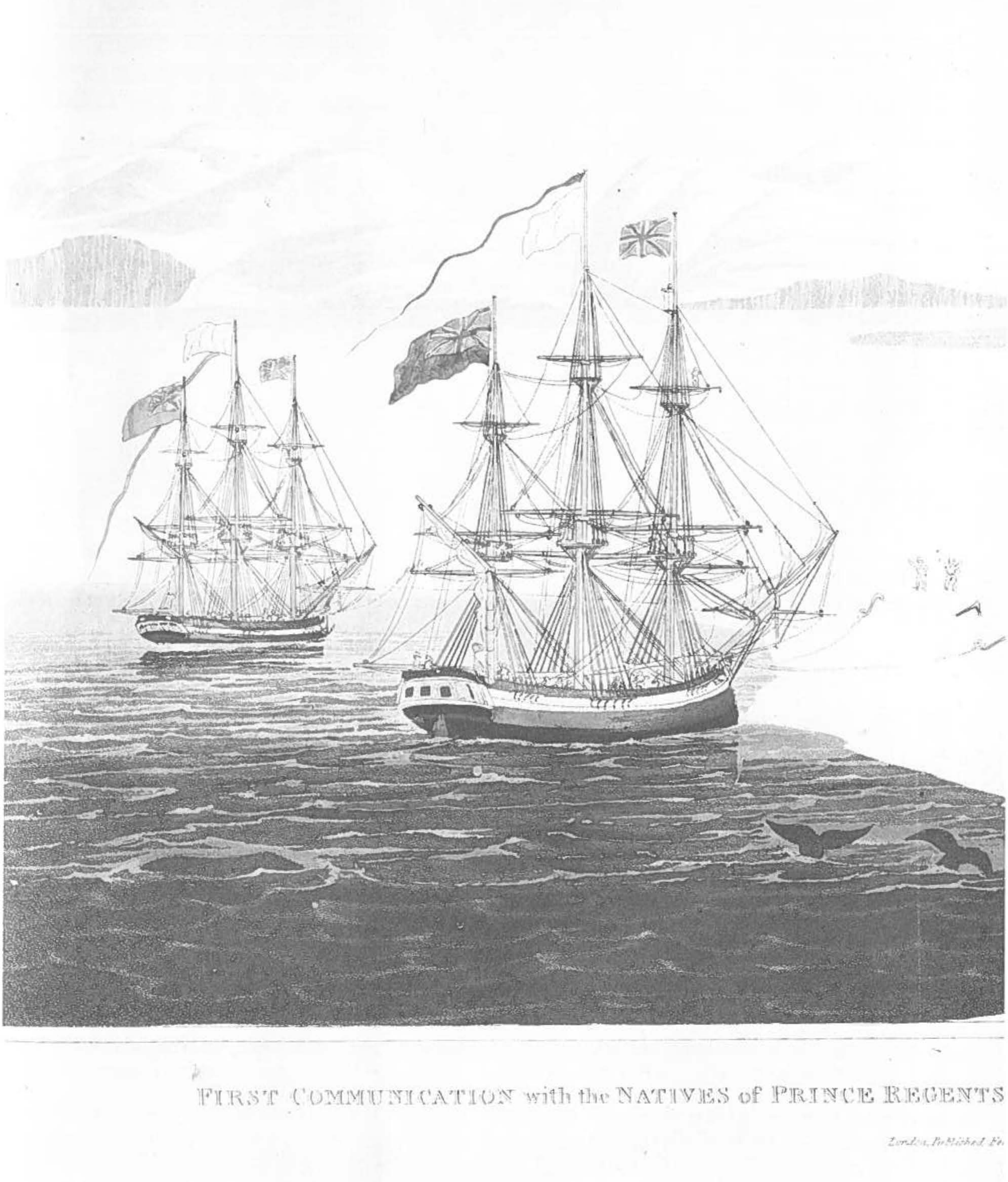
Out of 39 fragments coming from north of the Melville Bugt, 33 are of meteoritic origin. The Eskimos evidently combed the Kap York area for meteorites and picked up whatever was small and could be transported. Fragments of 1–10 g size they beat into cutting edges for various purposes, while larger fragments were used as hammer stones, such as Northumberland and Akpohon. It is remarkable that the Eskimos were able to produce tools as large as L3–12880 and L3–12004 (Table 4) from the iron flakes. On the other hand, such sizes that could be attained from wrought iron, was never achieved.

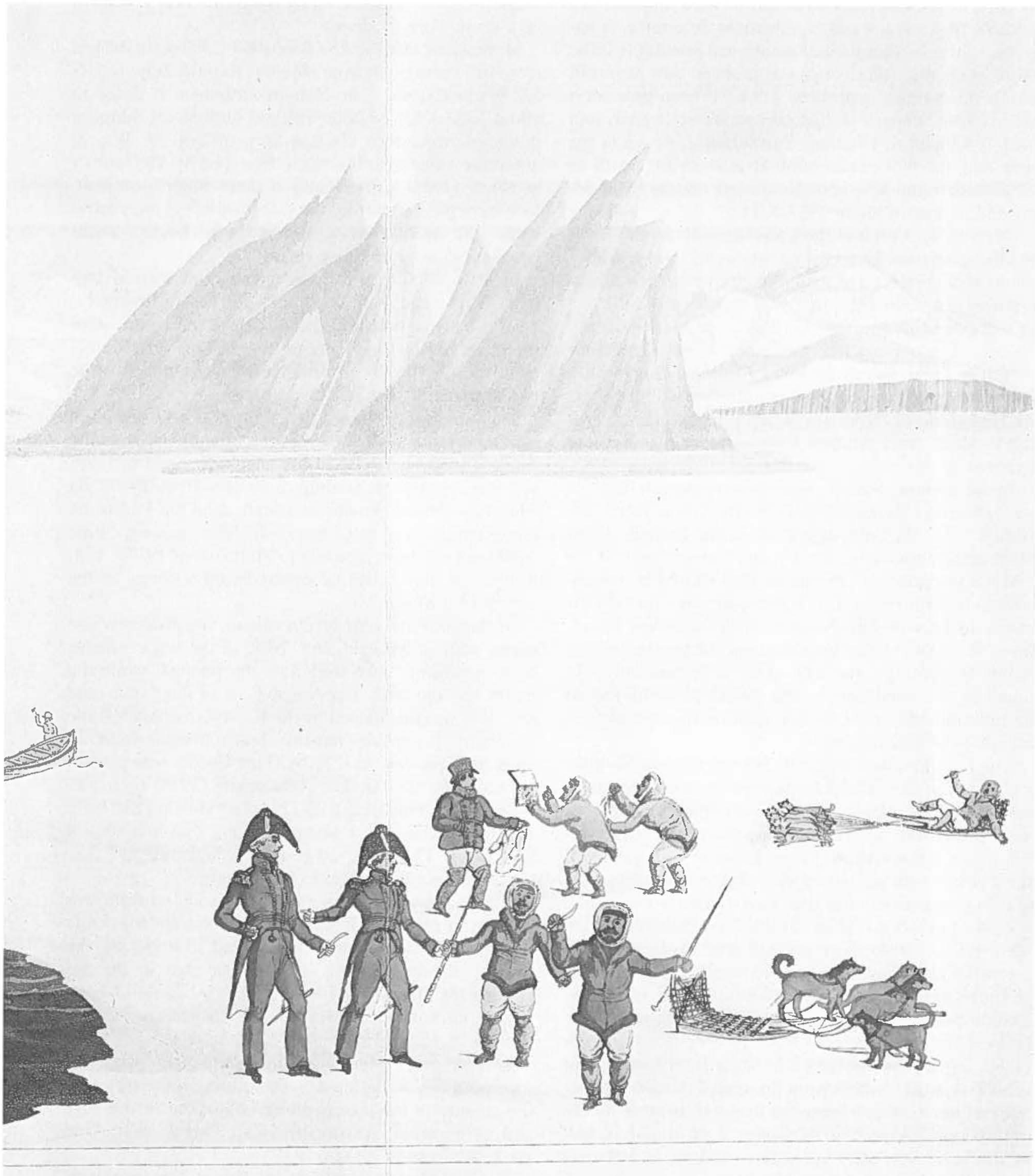
In the north four wrought iron samples are dated before 1500 A.D. and thus in one way or the other must be associated with the Norsemen. This connection has long been noted. For example, Holtved (1944) reported several objects of Norse origin from Thule, Inuarfigssuaq and Ruin Ø, among these a leg of a bronze cooking pot, a comb of bone, and chess-men of bone and walrus ivory.

It is remarkable that no telluric iron found its way up north of the Melville Bugt. It may be a hint that the contact with the Polar Eskimos was with the Norsemen directly and not via some intermediate Eskimo sites in the Disko Bugt area. Had this been the case one would have expected them to carry along some of their tools or raw material, basalt with iron grains, to trade up north.

Whether this contact took place by the Polar Eskimos travelling south on their sledges in spring and autumn,

Fig. 64. H.M.S. "Isabella" and "Alexander" secured by ice anchors to the ice about six miles south of Bushnan Island, East of Kap York. Captains Ross and Sabine trade shirts, necklaces and mirrors for narwhal tusks and implements with cutting edges of (meteoritic) iron. The sledge in the foreground is now in the British Museum. The West Greenlandic interpreter Zachaeus made this water colour of the situation (Ross 1819; Laursen 1955; Buchwald 1975: Fig. 492).





as Drawn by IOHN SACKHEOUSE and Presented to CAP^T. ROSS, Aug^t. 10.1818.

n Murray, Albemarle Street.

or the Norsemen travelled north in their ships in the summer time, we are not competent to determine. It appears, however, that the last mentioned possibility is the more likely one, since ships can proceed that far north in a good summer, and there will have been time for a safe return, while a sledge trip to Vesterbygden and back is difficult to visualize. Furthermore, we know for sure that the Norsemen came at least as far north as 72°55′ where the Kingigtorssuaq runic message was deposited in a cairn about 1333 A.D.

The contact with and the knowledge about the Polar Eskimos apparently vanished when the Norse settlements disappeared. For many hundred years the northernmost people in the world lived isolated from the rest of Greenland by the vast ice barrier of Melville Bugt. There are no reports that Frobisher, Davis, Lindenow or Baffin knew about the Polar Eskimos. But in 1818 John Ross made the surprising re-discovery of the "Arctic Highlanders" (Ross 1819), who themselves according to Ross, were without knowledge of the southern tribes (Fig. 64).

In the present study we identified a harpoon blade of wrought iron (Vienna nr. A 217) which came from "Sowallick", i.e. the Savigsivik area, in the Melville Bugt. As discussed above, p. 29, it is quite surprising that the "Arctic Highlanders" as late as 1818 should be in possession of wrought iron. It is recommended that the archives in London and Amsterdam be searched for reports of possible visits by whalers in the century before Ross. In addition, the important collections brought home by Ross and now in The British Museum should be reexamined in order to see whether the iron objects are all of meteoritic origin.

The 21 randomly selected tools from the *middle of the west coast of Greenland* turned out to comprise about equal parts of telluric iron and wrought iron objects. The telluric iron occurrences have thus been significant for the local population. Since, however, the quality of the finished tool was never very high and the bits were always very restricted in size, the telluric iron remained a local commodity. When the whalers appeared on the scene late in the 16th century and afterwards, the interest in the telluric iron must have waned considerably.

There were no tools of meteoritic origin in our selection from the mid west coast. However, meteoritic iron can not have been entirely unknown, for Lorenzen (1882: 26) reported a 6 g knife blade from Sermermiut (Tables 4 and 7), which from his analytical data and the size can have been nothing else than a transported piece of the Cape York meteorite shower. Unfortunately, half of the knife was used up in the analysis, and the repository of the rest is unknown today.

While we thus so far have only one documented case that Cape York meteoritic iron was traded down the west coast, there are many examples that it was carried across Smith Sund and into Ellesmere Island. A prominent witness is the 1.7 kg Akpohon fragment, which was excavated in 1914 in a ruin site at 79° N in Ellesmere Island (Table 5) and shown by Buchwald (1975: 425) to be a Cape York fragment.

Mathiassen (1927a: 25) described a harpoon with a meteoritic iron point from Naujan, Repulse Bay, (66° N 85° W) in Canada. The Naujan settlement is dated to about 1200 A.D. Another Eskimo settlement, Silumiut in the northwestern Hudson Bay (64° N 90° W), of about the same age, has been described by McCartney & Mack (1973) who identified three objects of iron. Two were produced from the Cape York iron meteorite, while the third was a rather large blade, about 60×30×1.5 mm, of Norse origin.

In 1976 McCartney (pers. comm.) excavated two large Thule age sites on Somerset Island, Northwest Territories, and both copper and iron objects were identified. Of 13 iron fragments, 10 could be proven to come from the Cape York iron meteorite strewnfield, while two apparently were of Norse origin.

There is thus no doubt that there was a rather good contact around 1200 A.D. between the Eskimos of the Thule district and those of the northwest coast of Hudson Bay. A possible trading route runs from Thule via Ellesmere Island, Somerset Island, Boothia Peninsula and Repulse Bay to Chesterfield Inlet, a route some 2400 km long, but according to Mathiassen (1927b: 128) no greater than it can be covered with a sledge in the course of a winter.

In the *southern part of Greenland*, the Eskimos had access only to wrought iron. Nine of the ten examples have apparently been traded by the whalers, while the tenth, the ulo with a crowned F, is of later date and probably was introduced by the Royal Greenland Trade Company. It appears that the Danish Mission immediately after its start in 1721 by Hans Egede, was providing tools for the Eskimos. Ostermann (1938) reported, for example, that already in 1724 the following had been sold to the Eskimos: 1 pair of scissors, 2 knife blades, 4 files, 1 ax, 17 knives, 10 forks, 16 "uglemikker" (i.e. ulos), 35 swordblades and 1 band knife.

It is impressive that the traders already so soon was ready to provide the Eskimos with such a specific knife type as the ulo, at that time called uglemik by the Danes. The explanation seems to be that in the beginning the ulos to the Eskimos were fabricated by minor modifications of traditional sailmakers' knives (Gulløv & Kapel 1973; 1979: 125).

With respect to the rather indefinite term "whalers" we would like to digress briefly to bring some notes on the activity in the waters along Greenland in the 16th and 17th century (Scoresby 1820; Pingel 1845; Gad 1967; McCartney 1984).

In 1578 Martin Frobisher landed on the southwest coast and noted that the local population possessed some tools with metal edges. In 1585–87 John Davis landed on various parts of West Greenland, even as far north as Upernavik, and he reported that he had met whaling ships probably from the province of Biscay. In 1605 Christian IV outfitted three ships under Godske

Lindenow and with the pilot James Hall. They landed in Southwest Greenland and kidnapped four Eskimos, one of whom was killed before the ships returned home (Gad 1967: 266). In 1606 and 1607 Lindenow and Hall again visited Greenland, and in 1612 James Hall went alone, this time exploring for the English King. He was killed at Sisimiut (Holsteinsborg) on account of his previous kidnappings. In 1616 William Baffin penetrated as far north as Smith Sund.

The explorers brought news of the many whales and about 1650 it was not unusual that hundreds of ships from England, Scotland, Holland, Biscay, Denmark and Norway met in Baffin Bay. The catch was about 1000 whales a season.

The Danish-Norwegian participation in this industry was rather restricted, however, as may be gathered from this quotation from Dalgaard (1962): "Only during the height of the whaling in the mid-1630's is any interest evident in the wider circles of Copenhagen and Bergen society; later in the century, when there was free access, hardly any. The most likely explanation is that Danish or Norwegian whaling under free conditions was normally quite unable to compete with the Dutch, the strength of which lay in the very structure of Dutch society and economic life, with its much larger circle of small capitalists, its tradition of investment in fishing and trade, its low rates of interest etc."

It is reported many times that there was an extended trade with the Eskimos who could provide the ships with furs of polar bear, seal and fox, with unicorns (the teeth of the narwhal), and walrus ivory, when the ships landed for leisure and fresh water supplies. In exchange the Eskimos received, according to one source (Pingel 1845: 674, 677, 717), hooks and eyes, mirrors, iron nails, needles and knives.

Especially the Dutch sailors were very active and also found time to draw up a number of charts of the coast, from which names as Sukkertoppen (Zuikerbrood), Vaigat (i.e. the blow hole) and Svartenhuk (Zwarte Hoek) still survive.

When, therefore, in the preceding discussion of the origin of the Greenland wrought iron objects we have often mentioned the possibility of imported iron, this hypothesis is strongly supported by numerous historic sources.

Technology

All items have been meticulously checked for the method of production and there has been no case where it can be said that the Eskimos applied heating in order to shape the iron. Whenever there are indications of forging, hardening and recrystallization, the actions must be referred to the previous owners, be it the Norsemen, whalers or, lately, the Royal Greenland Trade Company. The Eskimos took over whatever blades and pieces of iron they could lay their hands on, and finished them by cold-hammering, drilling and, probably, some grinding. Evidence of grinding could, however, not be found in this investigation because the samples were in an advanced state of corrosion.

The intricate problems associated with the many tools of iron from the Disko Bugt region seem to have found their solution with the present study. In no case were tools fabricated from the cast iron-type of telluric iron (Type I of Table 7). They were either made from Type II (Tables 7–10) or they were made from wrought iron (Table 12), imported from Europe. If telluric, the bits had been thoroughly cold-worked to hardnesses of about 200 HV which is quite satisfactory for a number of purposes. If wrought iron, the metal was used as received and mounted anew, or it was divided and cold-worked according to the purpose. Therefore the hardness range met with in this study, 124–627 HV, is very large and indicates on the one hand the initial hardness attained by the smith who originally produced the item, on the other hand the additional hardness which the object acquired when the Eskimos sometimes cold-hammered the traded material. In no case has any metallurgical operation, such as forge-welding, annealing, soldering and riveting, been observed. The Eskimo technique was primitive and akin to what had been learned from working the native copper deposits of the Coppermine River-Coronation Gulf-Bathurst Inlet area in Canada.

When a number of tools, particularly from the Disko Bugt area, are furnished with very small bits of iron, it is simply because, as discussed above, the globules of native iron in the iron basalt are disappointingly small. The opinion expressed by Kaalund (1979: 90) that the small flakes constituting the cutting edge of an ulo had attained their present size and shape by wear, is hardly tenable.

It is a well known method in metallurgy to impart hardness and strength by cold-working. The process is often termed work-hardening, implying a significant hardness increase upon working, i.e. rolling, hammering, bending and drawing. In an earlier section some experiments were reported to demonstrate the significance of work-hardening, and it was shown, Table 6, that the hardness could easily be increased to twice the initial value of the annealed state. In this respect, meteoritic iron would acquire the highest final hardness, about 350, because it is rich in nickel, an element that in itself adds to the effect by introducing socalled solid-solution hardening.

Hardness and strength are roughly synonymous, so the harder knife has also been the stronger knife, provided the iron was massive and coherent. However, the work-hardening process itself introduces zones of weakness, because if carried to the extreme by beating, the material will often split lengthwise, the crack being initiated by inclusions, especially the omnipresent slags. In addition, corrosion would have easy lines of attack along these same zones. In the present examination we have seen many examples of this behaviour. For example, the ulo from Nûgdlît, L3–12880 (Table 4), which

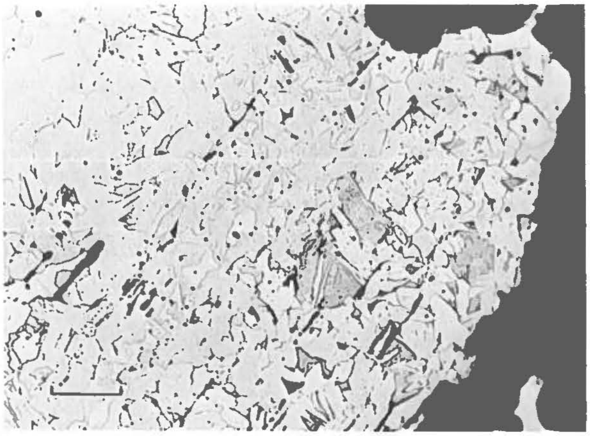


Fig. 65. Section through typical wrought iron with variation in the carbon and phosphorus content. Ferritic zones to the left alternate with ghost structures in the middle and Widmanstätten ferrite-pearlite to the right. Knife L 8356. Scale bar 50 μm.

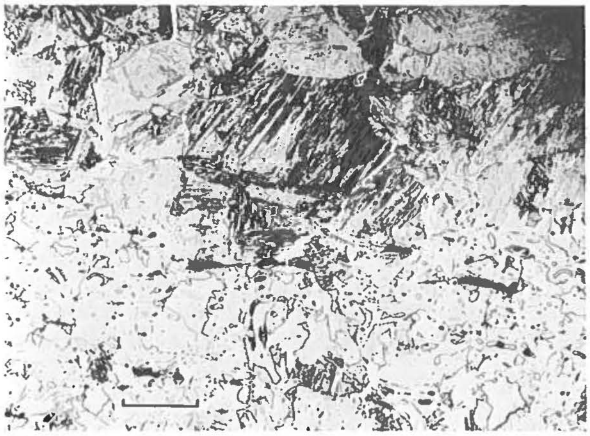


Fig. 66. Section through wrought iron. At the surface the carbon content and the cooling rate have been sufficient for martensite to form (above). Deeper inside there is a phosphorus-rich ghost structure. Knife L 8356. Scale bar 100 μm.

consisted of a rather large blade, was partially split into two parallel lamellae, each of which was only 1 mm thick, but cold-worked to spring characteristics. The ulo, nr. 3927 (Table 12), behaved in a similar way. This inherent weakness of cold-worked iron has sometimes limited the use of the tools; on the other hand, whenever the iron was cleverly handled, excellent tools were produced, like L3–12004, L3–12573 (Table 4), Lc 297 and L12–814 (Table 12).

The hardness alone is not sufficient for the evaluation of the wear resistance of a knife. For example is it better to impart wear resistance by alloying the iron with carbon – which makes steel – or with phosphorus and nickel, than by increasing the hardness by cold-working. A modern pocket knife will be of eutectoid or slightly hypereutectoid steel, i.e. iron with 0.7–1.0% carbon, and it will be hardened and tempered to a hardness range of 650–800 HV. This superb quality was rarely accessible to the Eskimos. Only in one instance, L6–3316 (Table 12), there is some indication that high hardness and wear resistance were reached due to proper hardening of steel by the initial owner. In all other cases, both hardness and wear resistance were rather inferior, and may even have been unsatisfactory for the tough job of working bone and antler. On the other hand, work in flesh, sinews and fur would present few problems.

In two cases only, reheating by the Eskimos may be proven. In both cases it concerns irregular fragments of meteoritic iron of not insignificant size, L3–9918 of 76 g and L3–14106 of 711 g size (Table 5). Both fragments were excavated from Comer's midden in Thule into which they were thrown for unknown reasons 700–800 years ago. From metallographical observations it is certain that the pieces have been at a red heat for some time, but it is at the same time clear that they have not been forged. Also McCartney & Mack (1973) noted that one of their samples of meteoritic iron had been reheated to above 800°, but this was a piece (nr. 1411) in the shape of a projectile point, thin and elongated, and it could have been forged. However, the evidence was insufficient, and we are inclined to support McCartney & Mack's conclusions that the heating was accidental, and that smithing techniques were unknown to the Eskimos.

It is remarkable how heterogeneous most wrought iron tools are, Figs. 65–66. When sections are macro-etched with Nital or Oberhoffer's reagent one may easily distinguish between dark-stained and bright parts, that alternate in an irregular way. It is the most distinct mark of ancient iron objects that they vary considerably along their length and width, both in chemical composition, structure and technological properties. First with the introduction of large-scale melting and refining operations in the second half of the 19th century more homogeneous iron and steel products became common. Steel of the 20th century that has been produced in a Bessemer furnace, a Siemens-Martin furnace, an oxygen-blown furnace or an electric furnace and then been forged into for example a heavy anchor or rolled into railway rails or boiler plates, these steels are uncomparably much more homogeneous and slag-free than the old steels, and the mechanical properties may be guaranteed to be constant from end to end of even a kilometre-long wire or profile.

The ancient iron of Table 11 and 12, on the other hand, vary in chemical composition from cm to cm and are rich in slags. The analytical chemical data as presented in our Tables and in other publications therefore expresses truly only the composition where the section was taken. Furthermore, the classical chemical analyses based upon solution of say 1 g of shavings will be somewhat different from our analytical values that are electron microprobe analyses of the metallic phases only. The differences are usually especially distinct with reference to the silicon and manganese values. Our probe analyses show the metal matrix to be very pure with usually less than 0.02% Si og Mn in solid solution. The higher values reported from classical analyses are due to incorporation of varying portions of the omnipresent slags that usually consist of iron silicates and iron manganese silicates.

From a technical point of view it is the trio iron-carbon-phosphorus that determines the quality of all ancient iron. These elements should therefore always be analyzed for. It is possible to produce a strong and hard iron object on basis of iron-phosphorus alone; however the object will be somewhat brittle at normal temperatures, and still more so at the low temperatures of the Arctic. It is better to work on basis of iron and carbon – and that indeed is what modern technology does, phosphorus being banned to values less than 0.04%. The iron-carbon alloys may by proper handling be transformed into superb hardened and tempered steel objects, which fare better at low temperatures than iron-phosphorus alloys. However, as we have proven here a large number of ancient iron objects are composites, with alternating layers or segments of Fe-C, Fe-P and Fe-C-P alloys. In the present material we did not detect any systematic pattern, for example from steeling the cutting edge or squeezing a high carbon martensitic steel between tough, ferritic exterior lamellae. Rather, the objects showed a haphazard sequence of the various structural elements, suggesting that none of the tools examined belonged to the production of a cunning craftsman. It would, however, be unjust to the smith if we did not make two reservations: firstly, many objects were in a bad state of corrosion and may have lost their better parts, and, secondly, in the cases where we were limited to examining the tang rather than the knife blade, it would be understandable that the iron we saw was not of superior quality. Typical examples of the heterogeneity were discussed in connection with the knives L 8356 and L6–3316, and the ulo L 2856.

Meteoritic iron

Although we know of more than 500 different iron meteorite events in the whole world, only 32 of these can be dated. These 32 falls took place between 1751 and 1968. Evidently, the fall of an iron meteorite is an extremely rare event.

From the general state of corrosion and the location of Cape York it can be deduced that the fall took place long ago, in the order of hundreds to thousands of years (Buchwald 1975). Unfortunately, all attempts to date the fall more precisely have until now failed. The more significant are therefore the archaeological data that allow us to conclude that the fall was accessible already to the Eskimos of the Dorset culture, i.e. in the 8th to 10th century. The hammerstones accumulated around Woman and Savik I show that the Eskimos travelled to the site generation after generation and collected iron fragments. While it is normally assumed that they acquired their fragments by working the big meteorites, the present data allow us to conclude that the majority of the tools was produced from small fragments, released when the meteorite split in the atmosphere.

Whenever the fragments were irregular they must have presented great problems to the Eskimos who had no anvils, no tongs and no steel hammers. We therefore find a number of irregular fragments, such as L3–9918, L3–12631 and others (Table 5) that were duly collected and taken home, but were never applied in a tool because of the associated difficulties in cold-hammering.

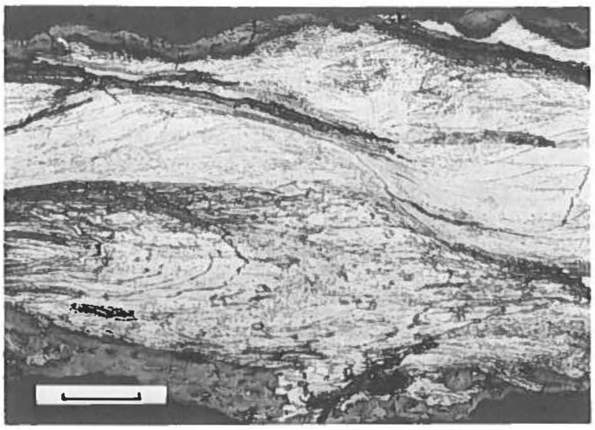


Fig. 67. Section through irregular explosion fragment from the Cape York iron meteorite shower, L3–12686. Heterogeneous cold-work divides the fragment into several lenticular segments. Scale bar 0.5 mm.

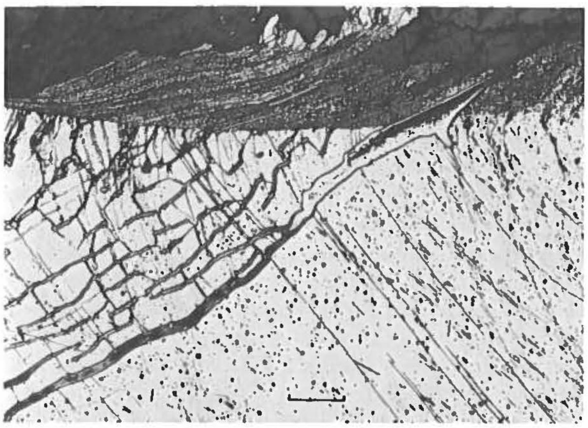


Fig. 68. Section through irregular explosion fragment from the Cape York iron meteorite shower, L3–13032 VI. Below, relatively undistorted kamacite and comb plessite. Above, dark-etching, heavily sheared and partly recrystallized kamacite, caused by irregular shock-wawes. Scale bar 100 µm.

This multitude of surviving fragments which is here recognized for the first time is important to the meteoritic science because they serve to illustrate the violence with which the meteorite exploded, Fig. 67–68. Many of them are severely torn and kneaded and may be compared to fragments from a detonating shell. They are extremely hard, much harder than the large Cape York blocks, because the shearing forces acting in the few seconds of break-up work-hardened the material. It is known that some meteorites, like Gibeon and Imilac (Buchwald 1975), broke up so violently that small fragments attained red heat and recrystallized or underwent phase transformations. Such features have been searched for between the Cape York fragments, but so far not identified. Nevertheless, the Cape York event that scattered fragments from Thule to Savigsivik, i.e. a distance of about 125 km, must have been violent and left a lasting impression on such people who happened to witness the fall. That no such account was alive when Ross (1819) first met the Polar Eskimos and heard about the "Iron Mountain" may perhaps be taken to indicate that the fall took place centuries before the present Eskimos arrived to the Thule district more than thousand years ago.

Can we trace the origin from analytical data?

The meteoritic iron shows a very narrow range in analyses (Table 3) which is exactly the reason why we feel confident that all fragments so far identified belong to the same Cape York shower. Other iron meteorites will usually deviate significantly in most elements, first and most important in nickel, phosphorus, iridium and germanium.

The telluric iron will display more variation (Table 7–10), but is still confined within limits that are utterly characteristic to the deposits of the Disko Bugt area.

We are very less fortunate when it comes to the wrought iron (Table 11–12). There are apparently no easy clue that could associate a certain tool with its source, such as a typical bog ore or hematite deposit. Usually, the concentration of nickel, cobalt, copper, silicon, manganese, sulfur and arsenic are low and vary in a random way. The variation in carbon and phosphorus is very significant and from a technological point of view important because the level of these elements determines the hardness, strength and wear resistance of the tools in question. Carbon and phosphorus are, however, of little value when it comes to tracing the origin of the material, for both are common to a long variety of deposits all over Europe (and Greenland), and furthermore may be introduced or eliminated during the actual production processes of extraction, smelting, forging and carburizing.

In the disappointing picture of insignificant variation two samples appear slightly different: The knife L6–3316 has one lamella rich in copper and manganese, while the harpoon blade Lb 560 is rich in copper and, in addition, shows a slight increase in arsenic above the general low concentration.

While there is reason to believe that all other iron tools could have been produced from any of a number of bog iron occurrences in Denmark, Norway, Sweden and Iceland, the two with copper contents in the order of 0.5% may have had a more distant origin, perhaps in the Basque province, where the Catalan bloomery process was applied to local hematite and limonite ores. Or, perhaps the tools are so late, especially L6–3316, that they could have been produced by converting cast iron to wrought iron by a finery process. Future research may be able to solve some of these problems, especially when full analyses of iron ore, slag and finished product from the same ore have been systematically acquired for a number of ore types and process methods.

In the wrought iron are numerous particles of glassy and glassy crystalline slags, originating from the smelting and forging operations. The few that were analyzed in this study were iron silicates and iron manganese silicates. It is possible that systematic analysis of many slags could help in solving the problems of ultimate origin.

One must, however, bear in mind that the idea of recycling scrap is far from new. Iron was in medieval times an expensive commodity and any used item would have been reused. The cunning craftsman would be able to forge new plowshares out of worn, and might use steel from a worn sword to steel a knife edge, in short new items might soon be a mixture of iron and steel from many sources and ages. As late as in the 1940's the blacksmith at Hellum, North Jutland, would forge new horseshoes out of discarded old ones. And where, then, is the idea that we should be able to trace the origin of the object to a specific ore, locality and date?

Conclusions

1. The iron objects from West Greenland fall into three distinct groups, meteoritic iron, telluric iron and wrought iron.
2. Meteoritic iron objects were produced from minute explosion fragments of the Cape York shower, an iron meteorite strewnfield stretching from Savigsivik in the Melville Bugt 125 km northwest to the Thule (Dundas) area.
3. Meteoritic iron objects were traded across Smith Sund and at least 2500 km into Canada where the farthest identified locality so far is Silumiut at the northwestern coast of Hudson Bay. It appears that the trade south along the Greenland coast was much more restricted, only one knife having been identified at Ilulíssat (Jakobshavn).
4. The telluric iron is of significantly varying quality. Only the carbon-poor quality, here called Type II, could by used for tools. Other types were not duct-

ile enough, but could be used for hammerstones.

5. The tools of telluric iron are restricted to the Disko Bugt area where they constitute about 50% of all examined objects. The tool bits are very small, because the starting point was small globules of telluric iron in basalt, and no welding or riveting of metal to metal was ever carried out.
6. Meteoritic iron and telluric iron were cold-hammered into objects of suitable shape and size. Sometimes a hole was drilled for the insertion of a rivet. The tools were probably finished by grinding.
7. No forging or heat-treatment were carried out. The very few cases where a tool or a fragment have been exposed to red heat, it seems that the action was unintentional.
8. Wrought iron has been identified as far north as 79°, and as far back in time as the Thule culture at about 1100 A.D.
9. Wrought iron disappears from the settlements north of the Melville Bugt approximately when the Norse colonies in South Greenland succumb. Perhaps the trade up north of the Melville Bugt was dependent on Norse ships and not on Eskimo sledges.
10. All wrought iron has been imported to Greenland, first by the Norsemen, then by the whalers, and finally by the various Greenland trade companies. Driftwood with nails, hoops and fittings from wrecked ships may also have played a role.
11. The Eskimos used the wrought iron as it came, or they shaped it by cold-hammering to their purpose.
12. Large objects are always of wrought iron, or perhaps cast iron, which has not been included in this study. Meteoritic iron objects do not exceed about 7×2.5 cm and 10 g mass, while telluric iron objects do not exceed 1×1 cm and 0.5 g mass.
13. The wrought iron is, as is contemporary European wrought iron, extremely heterogeneous in composition and structure. One should be careful and state whether analytical results have been derived from classical chemical methods or from electron microprobe or similar instrumental studies.
14. The wrought iron objects are of average standard and mechanical properties. No top-quality knife or tool has been identified in the material.
15. The flakiness, or lamination, which is the result of cold-hammering operations, has sometimes limited the value of the tool. Hardness alone is an insufficient criterion for the wear resistance of a knife.
16. It is highly improbable that there was ever produced iron in Greenland from local ores. The very limited access to fuel and charcoal no doubt prevented any attempt of building a furnace. As far as we are informed no charcoal pit or furnace site, anvil or pottery kiln have ever been recorded in Greenland.
17. Although corrosion had severely attacked many objects, meteoritic iron as well as telluric and wrought iron, sufficient metal was usually present inside the rust cakes that the object could be fully identified. Sometimes the rust truly preserved a fossil structure of the original structural elements, enough for identification as to type.
18. In many wrought iron objects a more or less diffuse microstructure, termed ghost structure, was noted. It could be shown that it is due to phosphorus that at yellow heat (950–1000°) redistributed itself in phosphorus-poor and phosphorus-rich grains. Work in progress shows that the ghost structure, previously unnoticed, is common in medieval and pre-Bessemer iron and steel.
19. Two of the meteoritic objects, L3–9918 and L3–14106, have thin, greenish-blue incrustations of the rather rare iron phosphate, vivianite. The mineral formation took place during the extended corrosion contact between the meteorites and the decaying bones of the midden.

Acknowledgements

The authors would like to thank R. Norbach Nielsen for invaluable help with the electron microprobe analyses, T. Kjer for critically reading the manuscript and Eva Larsen for typing it. S. Karup-Møller assisted in identifying the vivianite, and Aage Jensen, the Danish Steelworks, provided analytical data on modern steels. Edith Johannsen and Annelise Steffensen were most helpful in polishing and photographing the tiny metallographical sections. Finally, we wish to thank Gerda Møller and Jørgen Nordqvist, Department of Conservation, and Jørgen Meldgaard, Department of Ethnography, all of the National Museum of Denmark, without whose interest and help the present work could not have been accomplished.

Note added in proof

In August 1985 Finn Ulff-Møller (pers. comm.) visited a site called Saviarqat on the north coast of the Nûgssuaq peninsula, about 20 km west of the well-known iron basalt locality Qaersut (Table 7). Already Steenstrup (1882: 123) suspected, on basis of the name, Savik meaning knife, that the Eskimos might have collected useful material at Saviarqat, but he was not able to find the place on account of fog and bad weather. Ulff-Møller identified the locality and took samples, that prove that the iron basalt is of type II and thus may have been one of the important sources for telluric iron in the Eskimo tools.

Literature

Andersen, K. Offer 1984. Metallurgi for Ingeniører. 5. edition Akademisk Forlag, København. 642 pp.
Beck, Ludwig 1890. Die Geschichte des Eisens in technischer und kulturgeschichtlicher Beziehung. Braunschweig. Vol. 1–5.

Björkenstam, Nils 1975. Läsöskeppets järnlast. En studie i 1600-tallets metallurgi och bearbetningsteknik. Jernkontorets Forskning, Serie H, Nr. 11, 69 pp.
Bobé, L. 1936. Diplomatarium Groenlandicum 1492–1814. Aktstykker og breve til oplysning om Grønlands besejling, kolonisation og missionering. Meddr Grønland 55: 3.
Brezina, A. 1896. Die Meteoritensammlung des K. K. Naturhistorischen Hofmuseums. Annalen des K. K. Naturhistorischen Hofmuseums. Wien. 10: 297, 299.
Buchner, Otto 1863. Die Meteoriten in Sammlungen. Leipzig. 202 pp.
Buchwald, V. F. 1964. Meteorit- og jernfund i Grønland. Naturens Verden, Februar: 33–64.
– 1975. Handbook of iron meteorites. Their history, distribution, composition and structure. University of California Press, Berkeley. Vol. 1–3: 1418 pp.
– 1976. En metallografisk undersøgelse af en vikingetidsøkse fra Sønder Onsild. Aarbøger for nordisk Oldkyndighed og Historie, 96–123.
– 1982. On the use of iron by the Eskimos of Greenland. Meteoritics 17: 188 (abstract).
– & Munck, Sole 1965. Catalogue of Meteorites in the Mineralogical Museum of the University, Copenhagen. Analecta Geologica 1: 81 pp.
Chladni, E. F. F. 1819. Über Feuermeteore und über die mit denselben herabgefallenen Massen. Wien. 434 pp.
Clarke, D. B. & A. K. Pedersen 1976. Tertiary volcanic province of West Greenland. In Geology of Greenland, ed. A. Escher & W. S. Watt, Geological Survey of Greenland: 364–385.
Coghlan, H. H. 1956. Notes on Prehistoric and Early Iron in the Old World. Oxford University Press. 220 pp.
Dalgaard, Sune 1962. Dansk-norsk hvalfangst 1615–1660. Gad, Copenhagen. 463 pp.
Esbensen, K. H., V. F. Buchwald, D. J. Malvin & J. T. Wasson 1982. Systematic compositional variations in the Cape York meteorite. Geochimica et Cosmochimica Acta, 46: 1913–1920.
Forchhammer, J. G. 1854. Meteorjern fra det nordlige Grønland. Oversigt over Kgl. Danske Vidensk. Selsk. Forhandlinger 1854, nr. 1, for Januar: 1–4.
Fritz, Martin (red.) 1981. Svenskt och utländskt järn på 1600-talets europamarknad. Med Hammare ock Fackla, 28: 1–171.
Fundal, Erling 1972. Det vestgrønlandske jern – geologiens arbejdsfelt og eskimoens værktøj. Grønland, No. 4: 97–110.
Gad, Finn 1967. Grønlands Historie. I. Nyt Nordisk Forlag. København. 461 pp.
Gulløv, H. C. & H. C. Kapel 1973. Grønland 1721. Kolonialisation og kulturmøde. Nationalmuseets Arbejdsmark. København: 15–30.
– 1979. Haabets Colonie 1721–1728. A historical-archaeological investigation of the Danish-Norvegian colonization of Greenland. The National Museum. Ethnographical Series, Vol. 16. Copenhagen. 245 pp.
Hauge, T. Dannevig 1946. Blesterbruk og myrjern. Studier i den gamle jernvinna i det østenfjelske Norge. Universitetets Oldsaksamlings Skrifter. Oslo. 221 pp.
Hayes, I. I. 1862. On a meteorite from Savisavik. Proceedings of the Academy of Natural Science, Philadelphia, page 520.
Hintze, V. 1918. Større sten udstillede i Universitetets Mineralogiske og Geologiske Museums Gaard i København. Pamphlet, 30 pp.
Holtved, Erik 1944. Archaeological investigations in the Thule district. Meddr Grønland 141 (1): 1–308.
– 1954. Archaeological investigations in the Thule district. Meddr Grønland 146 (3): 1–135.
Hovey, E. O. 1918. The use of meteoric iron by the Polar Eskimo. Anthropological Papers of the American Museum of Natural History. 22: 164–166.
Kaalund, Bodil 1979. Grønlands kunst. København. 223 pp.
Kisling, H. M. 1978. Industrien og dens pionerer i Danmark. København. 226 pp.
Knuth-Winterfeldt, E. 1952. Korttidsmetoder til metallografisk elektropolering ved stuetemperatur. Disputats. København. 115 pp.
Koch, Lauge 1925. Nord om Grønland. København. 279 pp.
– 1927. Report on the Danish Bicentenary Jubilee Expedition North of Greenland 1920–23. Meddr Grønland 70: 1–232.
Laursen, Dan 1955. Grønlændere i forskningens tjeneste: Hans Zakæus. Grønland: 397–400.
Lorenzen, Joh. 1882. Kemisk undersøgelse af det metalliske jern fra Grønland. Meddr Grønland 4: 1–40.
Löfquist, H. & C. Benedicks 1940. Det stora Nordenskiöldska järnblocket från Ovifak. Kungl. Svenska Vetensk. Akad. Handl. 19: No. 3: 1–96.
Mathiassen, Therkel 1927a. Archaeology of the Central Eskimos. Report of the Fifth Thule Expedition, 1921–24. Vol. IV.
– 1927b. The Thule culture and its position within the Eskimo culture. Report of the Fifth Thule Expedition, 1921–24. Vol. IV.
– 1931. Ancient Eskimo settlements in the Kangamiut area. Meddr Grønland 91 (1): 1–149.
– 1934. Contributions to the archaeology of Disko Bay. Meddr Grønland 93 (2): 1–192.
McCartney, Allen P. 1984. History of native whaling in the Arctic and Subarctic. In Arctic Whaling, Proc. Internatl. Symposium February 1983, Groningen.
– & D. J. Mack 1973. Iron utilization by Thule Eskimos of Central Canada. American Antiquity 38: 328–39.
Melson, W. G. & G. Switzer 1966. Plagioclase-spinel-graphite xenoliths in metallic iron-bearing basalts. American Mineralogist 51: 664–76.
Molander, Bo 1982. Kyrkfönstren som gav et unikt kors. Jernkontorets Annaler 166: nr. 3, 18–19.
Nielsen, Bjarne Leth 1976. Economic minerals. In Geology of Greenland, editors A. Escher and W. S. Watt, The Geological Survey of Greenland: 460–486.
Nielsen, Niels 1930. Evidence on the extraction of iron in Greenland by the Norsemen. Meddr Grønland, 76: 193–213.
Noe-Nygaard, Arne 1980. A. E. Nordenskiöld og Grønland. Societas Scientiarum Fennica. Årsbok 58 B; No. 3a: 1–9.
Nordenskiöld, A. E. 1871. Redogörelse för en ekspedition til Grønland 1870. Öfvers. Vetensk. Akad. Förh. 27: 973–1082.
– 1885. Den andra Dicksonska ekspeditionen till Grønland ... utförd år 1883. Stockholm. 546 pp.
Nørlund, Poul 1967. De gamle nordbobygder ved verdens ende. Nationalmuseet. København. 152 pp.
Ostermann, H. 1938. Fra arkivernes gemmer. Det Grønlandske Selskabs Aarsskrift. København: 125–160.
Partsch, P. 1843. Die Meteoriten oder vom Himmel gefallenen Stein- und Eisenmassen. Wien. 162 pp.
Pauly, H. 1969. White cast iron with cohenite, schreibersite and sulphides from tertiary basalts on Disko, Greenland. Meddr. Dansk Geol. Foren. 19: 8–26.
Peary, R. E. 1898. Northward over the Great Ice. London. Vol. 2. 625 pp.
Pedersen, Asger Ken 1975. New investigations of the native iron bearing volcanic rocks of Disko, central West Greenland. Rapp. Grønlands geol. Unders. 75: 48–51.
– 1977. Tertiary volcanic geology of the Mellemfjord area, south-west Disko. Rapp. Grønlands geol. Unders. 81: 33–49.
– 1979. Basaltic glass with high-temperature equilibrated immiscible sulphide bodies with native iron from Disko. Contrib. Mineral. Petrol. 69: 397–407.
– 1981. Armalcolite-bearing Fe-Ti oxide assemblages with native iron from Disko. Contrib. Mineral. Petrol. 77: 307–324.
Phalen, W. C. 1904. Notes on the rocks of Nugsuaks Peninsula and its environs, Greenland. Smithsonian Miscellaneous Collections, 45: 183–212.
Pingel, C. 1845. Om de vigtigste reiser, som i nyere tider ere foretagne fra Danmark og Norge, for igjen at opsøge det tabte Grønland og at undersøge det gjenfundne. Part

XXXIII in Grønlands historiske Mindesmærker, Vol. 3: 625–794. Reprint edition, Copenhagen 1976.
Rosenberg, G. A. 1917. Antiquités en fer et en bronze ... et leur conservation. Gyldendal, København. 92 pp.
Ross, John 1819. A voyage of discovery ... exploring Baffin's Bay and ... a North-West passage. London.
Schmidt, Ole 1979. Konserveringen af kunstkammergenstandene, Det Indianske Kammer. Nationalmuseet, København.
Scoresby, William 1820. An account of the Arctic regions with a history and description of the northern Whale-fishery. Vol. 2. David & Charles Reprints. 1969. 574 pp.
Sjögren, H. 1916. Om Ovifakjärnet och andra telluriska basaltjärn. Kungl Sv. Vetensk. Akad. Årsbok. Uppsala: 255–290.
Smith, J. Lawrence 1879. Sur le fer natif du Groenland et sur la dolerite qui le renferme. Ann. des chim et des phys. 16: 452–505.
Steenstrup, Japetus 1872. Sur l'emploi de fer météorique par des esquimaux du Groenland. Compte Rendu du Congrés Internat. d'Anthropologie & d'Archeologie préhistoriques. 6[me] Session, Bruxelles: 242–250.
Steenstrup, K. J. V. 1875. Om de nordenskiöldske jernmasser og om forekomsten af gediegent jern i basalt. Videnskabelige Meddelelser fra Dansk naturhistorisk forening, Copenhagen, 7: 284–306.
– 1882. Om forekomsten af nikkeljern med Widmanstättenske figurer i basalten i Nord-Grønland. Meddr Grønland 4(3): 114–132.
Ulff-Møller, Finn 1983. Tellurisk jern fra subvulkanske intrusioner på Disko, Grønland. Licentiatafhandling. Geologisk Museum, Københavns Universitet.
Urey, H. C. 1952. The planets. Their origin and development. Yale Univ. Press. 245 pp.
Vaasjoki, O. 1964. On basalt with native iron in Disko. Comptes Rendus Soc. Geol. Finlande, 37: 85–98.
Wissler, Clark 1918. Archaeology of the Polar Eskimo. Anthropological Papers of the American Museum of Natural History, New York. Vol. 22, Part III.
Wülfing, E. A. 1897. Die Meteoriten in Sammlungen und ihre Litteratur. Tübingen. 460 pp.

Appendix

α_2, alpha-2 structure. An unequilibrated structure in carbon-poor iron nickel alloys. Related to martensite, and, like that, caused by rapid cooling from temperatures in the austenite region. Harder than equilibrated ferrite, but much softer than martensite.

Austenite. The stable form of pure iron above 910°C. With increased carbon- or nickel-content the austenite stability field expands to lower temperatures.

Carlsbergite. The chromium nitride mineral CrN. It occurs as minute plates in the kamacite of the Cape York meteorites.

Cementite. The iron carbide, Fe_3C. Common in steel, either as disseminated inclusions, when bulk carbon content is low, or as a part of pearlite when the bulk carbon content increases above ~ 0.1%. Also present in the Disko telluric iron.

Eutectoid. Iron-carbon alloys with 0.7% carbon have eutectoid composition. When they are heated above 721° they are fully austenitic. When slowly cooled below 721° they transform to pearlite, but if cooled rapidly they transform to martensite of superb hardness, 900–1000 HV.

Ferrite. The stable form of pure iron below 910°C. Ferrite can only dissolve 0.01–0.02% carbon; what is in excess is exsolved as cementite. Ferrite can, however, dissolve essential amounts of manganese, copper, silicon and nickel, and by so doing it increases its own hardness.

Ghost structure. A term introduced to cover the unequilibrated, two-phase structure that is typical of phosphorus containing iron that has been heat-treated at 900–1100°. According to temperature, duration and subsequent cooling rate the structure appears more or less diffuse and indistinct-confusing, wherefore the word ghost structure was introduced.

Hypereutectoid. Iron-carbon alloys with 0.7–1.7% carbon have hypereutectoid composition. They usually consist of pearlite and excess cementite.

Kamacite. The mineral name for ferrite. Kamacite will have 5–7.5% nickel in solid solution if in an iron meteorite, but 0.5–4% if in telluric iron from the Disko district.

Martensite. When iron with 0.3–1.2% carbon is heated into the austenite field (721–1000°C) and then quenched in water, the resulting structure is martensitic. This is too hard and brittle for general use, wherefore the object is normally tempered, i.e. reheated to 200–700°C for a short time.

Nital. An etching reagent for steel and iron alloys, composed of 2% nitric acid in ethyl alcohol. General purpose: grain boundaries, pearlite, martensite etc.

Oberhoffer. An etching reagent for steel and iron alloys, especially to reveal the location of phosphorus-rich parts. Composition: 0.5 g $SnCl_2$, 1 g $CuCl_2$, 30 g $FeCl_3$, 42 ml conc. HCl, 500 ml distilled water, 500 ml ethyl alcohol.

Pearlite. A common structure in steel, consisting of the two phases, ferrite and cementite in intimate, lamellar intergrowths.

Plessite. A structure in meteorites composed of kamacite and taenite in net-like, comb-like or similar very fine intergrowths.

Rhabdite. The iron-nickel-phosphide mineral $(Fe,Ni)_3P$, usually occurring as prismatic inclusions in iron meteorites. Contains 20–45 % nickel.

Schreibersite. The iron-nickel-phosphide mineral $(Fe, Ni)_3P$, usually occurring as irregular inclusions in iron meteorites. Contains 10–30% nickel.

Taenite. The mineral name for nickel-rich austenite. Due to very high nickel content (30–50%) the taenite is stable in meteorites at ambient temperature and even at very low temperatures.

Vivianite. The iron phosphate mineral $Fe_3(PO_4)_2, 8H_2O$. Here identified as soft, earthy, bluish crusts on iron meteorites exposed to decaying bones.

Meddelelser om Grønland, Man & Society

Aasivissuit – The Great Summer Camp Archaeological, ethnographical and zoo-archaeological studies of a caribou-hunting site in West Greenland

Grønnow, Bjarne, Meldgaard, Morten and Nielsen, Jørn Berglund, 1983. Aasivissuit – The Great Summer Camp. Archaeological, ethnographical and zoo-archaeological studies of a caribou-hunting site in West Greenland. Meddr Grønland, Man & Sic. 5: 96 pp, Copenhagen 1983–12–22.

An interdisciplinary analysis of an archaeological source material from the caribou-hunting site Aasivissuit in central inland West Greenland is presented. Subsistence changes over the years are the subject of ethnographichal, archaeological and zoo-archaeological investigations.

The following maina points are treated:
1. Resource dynamics: The inland game – the caribou population – undergoes drastic changes in the course of time.
2. The ethnography of caribou-hunting: Ethnographical description of the caribou hunt and of life in the inland area based on hitherto largely unpublished ethnographical material.
3. Hunting structures: Cairn systems, shooting-hides. meat caches, etc., document the extent of the Aasivissuit site catchment area and the hunting activities carried out there – *i.a.* large-scale battues.
4. Occupation phases: Excavations in the stratified ossiferous midden deposits reveal 6 occupation phases of varying duration and intensity at Aasivissuit. The phases represent different segments of the period from about 200 B.C. to the present, the neo-Eskimo layers from the 18th–19th centuries in particular holding much information.
5. The game: Osteological analyses of the comprehensive bone material show total dominance of caribou (selective late summer and autumn hunting of bucks and young animals) and that the excavation covers an area where coarse butchering took place.

Subsistence changes (changes in hunting forms and exploitation of game) and the discontinuity of inland occupation can be documented ethnographically, arcaeologically and zoo-archaeologically. The changes are seen as a function of resource fluctuations and socio-historical changes.

Bjarne Grønnow, Forhistorisk Arkæologisk Institut, University of Copenhagen, Vandkunsten 5[1], DK-1467 København K, Morten Meldgaard, Zoologisk Museum, 1. afd., University of Copenhagen, Universitetsparken 15, DK-2100 København Ø, Jørn Berglund Nielsen, Institut for Eskimologi, University of Copenhagen, Fiolstræde 10, DK-1171 København K.

Man & Society 5 · 1983
Export price Dkr. 145.25
ISBN 87-17-05121-5

Concentrations of mercury, selenium and lead in blood samples from mothers and their newborn babies in four Greenlandic hunting districts

Hansen, J. C., Christensen, R. B., Allermand, H., Albøge, K. & Rasmussen, R. 1984. Concentrations of mercury, selenium and lead in blood samples from mothers and their newborn babies in four Greenlandic hunting districts. Meddr Grønland, Man & Soc. 6: 19 pp, Copenhagen 1984–11–23.

Earlier investigations carried out in Greenland have shown high exposure levels of mercury and lead to be present. The levels of mercury and lead are found not to be of immediate risk to adults, but both elements are able to pass the placental barrier and thereby influence foetal development. As the foetus must be regarded as most sensitive to environmental toxicants it was found necessary to carry out a follow-up investigation in order to elucidate foetal exposure.

This investigation was started in the fall of 1981 and continued until the end of 1982. Samples of venous blood were collected from women giving birth, and the foetal exposure was evaluated on the basis of samples of cord blood. Samples were taken at the local hospitals in the four districts of Upernavik, Umanak, Scoresbysund, and Angmagssalik. In total, 98 sample pairs were collected: 14 from Upernavik, 36 from Umanak, 17 from Scoresbysund, and 31 from Angmagssalik. At the time of sampling a questionnaire was filled out with information on the age of the mother, length of pregnancy, weight of child, smoking and eating habits of the mother.

All samples were analysed for mercury and lead contents. Furthermore, the selenium concentration was analysed, as in animal experiments this trace element has been shown to alleviate toxic effects of mercury and probably of lead, too.

The high exposure level of mercury in Greenland was confirmed in this study, too. A close correlation was found between the blood of mothers and children. The children's blood contains more mercury than that of the mothers, approximately 80% more. The highest concentration seen in a newborn baby was 177 µg/l, which is close to values found to have caused mercury intoxication during the Minamata episode in Japan.

Selenium concentrations were found to be correlated between mothers and children, but in a non-linear way. The concentration level was found to exceed that of mercury on a molar basis. This might constitute a protective effect, and explain that neither in Greenland nor in other places where marine food is an important part of the total diet, has mercury intoxication been found, except in cases such as the Minamata area in Japan, where a local mercury pollution was present. Still, the high concentration in babies must give rise to concern.

No correlation was found between mercury and selenium concentrations on an individual basis, neither in mothers nor in children. This indicates that the two elements pass the placental barrier independent of each other.

As seen in other investigations, lead was also shown to pass the placental barrier, and a significant correlation was found between the blood of mothers and of children, the mean concentration being approximately the same. The mean concentration level in mothers was a little lower than should have been expected from earlier investigations. This is probably due to the fact that the blood lead level decreases during pregnancy. As shown in earlier studies from Greenland, the blood lead level was found to be on the same level as that found in European industrial areas.

The present information on heavy metal exposure in Greenlandic hunting districts should be subjected to a closer evaluation as regards the influence on the health condition in the Greenlandic population now and in the future. Such material will be highly relevant to the understanding of the significance of the global pollution by heavy metals.

Jens C. Hansen, Institute of Hygiene, University of Aarhus, Universitetsparken, DK-8000 Århus, René B. Christensen, DK-3961 Umanak, Henrik Allermand, Langåsen 35, DK-4450 Jyderup, Kurt Albøge, DK-3913 Angmagssalik, Rolf Rasmussen, DK-3980 Scoresbysund.

Man & Society 6 · 1984

Export price Dkr. 38.00

ISBN 87-17-05225-4

Kalaallit inngerutaannik nipilersortar-nerannillu immikkoortiterineq

Klassifikation af traditionel grønlandsk musik

Classification of traditional Greenland music

Hauser, M. and Petersen, H. C. 1985. Kalaallit inngerutaannik nipilersortarnerannillu immikkoortiterineq. Klassifikation af traditionel grønlandsk musik. Classification of traditional Greenland music. Meddr Grønland, Man & Soc. 7: 50 pp, Copenhagen 1985-08-02.

This classification of traditional Greenland music is based on a copious source material and on the authors' dealing with the subject for many years. The classification includes eleven main groups and their subdivisions into various categories. Ten of the groups deal with traditional Greenland music, and one group concerns acquired Euro-American music. The most religious-ritual groups and categories have been placed first. For each category brief information is given about usage and performance. The introduction brings a survey of the history of traditional Greenland music, and its past and present importance to the society. An elaborate bibliography has been included. The classification is presented trilingually, in Greenlandic, Danish, and English.

Michael Hauser, Haraldsborgvej 35, DK-4000 Roskilde.
H. C. Petersen, Ilisimatusarfik/The Inuit Institute, Box 279, DK-3900 Nuuk/Godthåb.

Man & Society 7 · 1985
Export price Dkr. 114.35
ISBN 87-17-05227-0

Disease pattern in Upernavik in relation to housing conditions and social group

Bjerregaard, Peter and Bjerregaard, Beth 1985. Disease pattern in Upernavik in relation to housing conditions and social group. Meddr Grønland, Man & Soc. 8: 18 pp. Copenhagen 1985-10-23.

From April 1979 to March 1980 all 2673 contacts between the 836 inhabitants of Upernavik town, West Greenland, and the local medical officers were recorded together with information on social conditions and housing standard. Housing conditions included size of house, space per inhabitant, heating, and water supply; pronounced differences were observed between Greenlanders and Danes of Upernavik and between different social groups of Greenlanders.

In comparison with general practice in Denmark the following disorders were less frequently registered in Upernavik: Infectious children's diseases, cancer, diabetes, minor mental disorders, high blood pressure, coronary artery disease and urinary infections. On the contrary, gonorrhea, chronic otitis, impetigo and accidents were more frequently encountered in Upernavik.

Danes of Upernavik had a low rate of admissions to hospital compared with Greenlanders of corresponding social group, and low incidences and contact rates for all diseases.

In Greenlanders of Upernavik the rate of admissions to hospital for all causes, as well as contact rates for skin and respiratory infections, were highest in the lowest housing standard and social groups and in the smallest households.

Contact rates for all causes together and for accidents were similar in the socio-economic subgroups.

Peter Bjerregaard and Beth Bjerregaard, The Danish Institute for Clinical Epidemiology, 25, Svanemøllevej, DK-2100 Copenhagen Ø.

Man & Society 8 · 1985
Export price Dkr. 38.70
ISBN 87-17-05231-9

Instructions to authors

Manuscripts will be forwarded to referees for evaluation. Authors will be notified as quickly as possible about acceptance, rejection, or desired alterations. The final decision rests with the editor. Authors receive two page proofs. Prompt return to the editor is requested.

Alterations against the ms. will be charged to the author(s). Twenty five offprints are supplied free. Order form, quoting price, for additional copies accompanies 2nd proof. Manuscripts (including illustrations) are not returned to the author(s) after printing unless especially requested.

Manuscript

General. – Manuscripts corresponding to less than 16 printed pages (of 6100 type units), incl. illustrations, are not accepted. Two copies of the ms. (original and one good quality copy), each complete with illustrations should be sent to the Secretary.

All Greenland place names in text and illustrations must be those authorized. Therefore sketch-maps with all the required names should be forwarded to the Secretary for checking before the ms. is submitted.

Language. – Manuscripts should be in English (preferred language), French, or German. When appropriate, the language of the ms. must be revised before submission.

Title. – Titles should be kept as short as possible and with emphasis on words useful for indexing and information retrieval.

Abstract. – An English abstract should accompany the ms. It should be short, outline main features, and stress novel information and conclusions.

Typescript. – Page 1 should contain: (1) title, (2) name(s) of author(s), (3) abstract, and (4) author's full postal address(es). Large mss. should be accompanied by a Table of Contents, typed on separate sheet(s). The text should start on p. 2. Consult a recent issue of the series for general lay-out.

Double space throughout and leave a 4 cm left margin. Footnotes should be avoided. Desired position of illustrations and tables should be indicated with pencil in left margin.

Underlining should only be used in generic and species names. The use of italics in other connections is indicated by wavy line in pencil under appropriate words. The editor undertakes all other type selection.

Use three or fewer grades of headings, but do not underline. Avoid long headings.

References. – Reference to figures and tables in the text should have this form: Fig. 1; Figs 2–4, Table 3. Bibliographic references in the text are given as: Shergold (1975: 16) and (Jago & Daily 1974b).

In the list of references the following usage is adopted:

Journal: Macpherson, A. H. 1965. The origin of diversity in mammals of the Canadian arctic tundra. – System. Zool. 14: 153–173.

Book: Marsden, W. 1964. The lemming year. – Chatto & Windus, London: xxx pp.

Chapter (part): Wolfe, J. A. & Hopkins, D. M. 1967. Climatic changes recorded by Tertiary landfloras in northwestern North America. – In: Hatai, K. (ed.), Tertiary correlations and climatic changes in the Pacific. – 11th Pacific Sci. Congr. Tokyo 1966, Symp.: 67–76.

Title of journals should be abbreviated according to the last (4th) edition of the World List of Scientific Periodicals (1960) and supplementary lists issued by BUCOP (British Union-Catalogue of Periodicals). If in doubt, give the title in full.

Meddelelser om Grønland, Man & Society should be registered under *Meddelelser om Grønland.* Example (with authorized abbreviations): *Meddr Grønland, Man & Soc. 1,* 1979.

Illustrations

General. – Submit two copies of each graph, map, photograph, etc., all marked with number and author's name. Normally all illustrations will be placed within the text; this also applies to composite figures.

All figures (incl. line drawings) must be submitted as glossy photographic prints suitable for direct reproduction, i.e. having the format of the final figure. Do not submit original artwork. Where appropriate the scale should be indicated in the caption or in the illustration.

The size of the smallest letters in illustrations should not be less than 1.5 mm. Intricate tables are sometimes more easily reproduced from line drawings than by type-setting.

Colour plates may be included at the author's expense, but the editor should be consulted before such illustrations are submitted.

Size. – The width of figures must be that of a column (77 mm), 1½ column (120 mm) or of a page (160 mm). Remember to allow space for captions below full page figures. Maximum height of figures (incl. captions) is 217 mm. Horizontal figures are preferred.

If at all possible, fold-out figures and tables should be avoided.

Caption. – Captions (two copies) to figures should be typed on separate sheets.

Meddelelser om Grønland

Bioscience
Geoscience
Man & Society

Published by
The Commission
for Scientific
Research
in Greenland

AiO Print Ltd., Odense, Denmark