Fauna and flora

ROLF W. FEYLING-HANSSEN and SVEND FUNDER

Foraminiferal assemblages

(R.W. Feyling-Hanssen)

A total of 51 species of benthonic foraminifera occur in the 16 investigated samples from the Thule area. Approximately 20 of these are common in at least a few of the samples. Of these 20 species only 10 are very frequent in one or more of the samples (Fig. 11). The most important are *Islandiella helenae, Astrononion gallowayi, Cassidulina reniforme, Islandiella norcrossi, Elphidium excavatum, Elphidium subarcticum, Elphidium albiumbilicatum,* and *Nonion orbiculare*. Planktonic foraminifera, represented by two specimens of *Globigerina pachyderma*, occur only in one sample.

In order to obtain a clearer picture of the palaeoenvironments of the Quaternary in the Thule district, it would be of interest to compare these Quaternary assemblages with arctic foraminiferal faunas of the present day. Such assemblages have been studied by Aksu (1985) from Baffin Bay between Baffin Island and the west coast of Greenland. However, Aksu's results are not comparable with the present Thule faunas due to the very deep water (minimum 900 m) in his study area.

Phleger (1952) has described recent foraminiferal assemblages from six bottom samples in the Thule district. These were all taken at 31 m depth, and the benthonic foraminiferal populations contained a high frequency of agglutinated specimens. This contrasts with the fossil assemblages dealt with in the present investigation, in which no agglutinated foraminifera occur.

Other investigations of recent foraminifera of arctic shelf waters show that many arenaceous species and specimens occur in the assemblages (e.g. Cushman 1948, Loeblich & Tappan 1953). Vilks (1964, 1969) found that the recent foraminiferal populations of the Canadian Arctic are dominated by arenaceous forms, and Schafer & Cole (1985) published similar observations from the eastern Baffin Island shelf.

Quaternary arctic assemblages, on the other hand, contain few if any arenaceous foraminifera (cf. Gudina 1966, 1969; Feyling-Hanssen 1976, 1980, 1985).

Environmental conditions could hardly be responsible for these differences. Rather, the underrepresentation of agglutinated foraminifera in fossil assemblages has probably resulted from *post-mortem* destruction of their delicate tests in the sediment. Nagy (in Elverhøi *et al.* 1980), for example, has argued that the decreasing frequency of the arenaceous *Spiroplectammina biformis* downwards in Spitsbergen cores is a function of the solution of wall cement combined with increasing pressure in the sediment. In particular, it is probable that serious decimation of the arenaceous tests takes place in permanently frozen sediment bodies or during freezing and thawing in outcrops. If, as an experiment, the arenaceous specimens of the richest of Phleger's recent Thule assemblage; (sample OP15) are ignored, the resulting faunal composition would be as follows, (names changed to present taxonomic usage):

Islandiella helenae	60%
Astrononion gallowayi	15%
Elphidium excavatum	7%
Buccella frigida	4%
Nonion labradoricum	4%
Elphidium subarcticum	4%
Lagenidae	1%
Stainforthia fusiformis	1%
Cibicides lobatulus	1%
Angulogerina fluens	1%
Cassidulina reniforme	1%
Nonion barleeanum	< 1%

This faunal composition compares well with the fossil *Islandiella helenae* assemblages in the youngest samples from the area. The resulting Sanders (1960) similarity index for the above assemblage and that of sample no. 010 (unit S7) is high (78%).

The foraminiferal assemblages of the Quaternary samples from Thule are inner shelf faunas indicating arctic marine climatic conditions. A few subarctic species do however occur in the assemblages. These species are known in the arctic today, but they are not confined to the arctic, and they may not have occurred there during glacial periods of the past.

Different views exist on which foraminiferal taxa should be considered as indicating subarctic, or warmer, as opposed to the arctic conditions (cf. Gudina & Evserov 1973, Feyling-Hanssen 1980). In the present study a very limited number of species have been grouped under the heading subarctic (Fig. 11) viz. *Buccella calida, Rosalina vilardeboana, Epistominella vitrea, Gavelinopsis praegeri, Cibicides lobatulus, Nonionella auricula, Nonion barleeanum,* and *Elphidium incertum*. The presence of one or more of these taxa in significant numbers in a fossil assemblage is probably a definite indication of ameliorated conditions, and they are used here as an index of warming.

Another palaeoenvironmental parameter is the faunal diversity index of Walton (1964), which is defined as "the number of ranked species in a counted assemblage whose cumulative percentage accounts for 95% of the

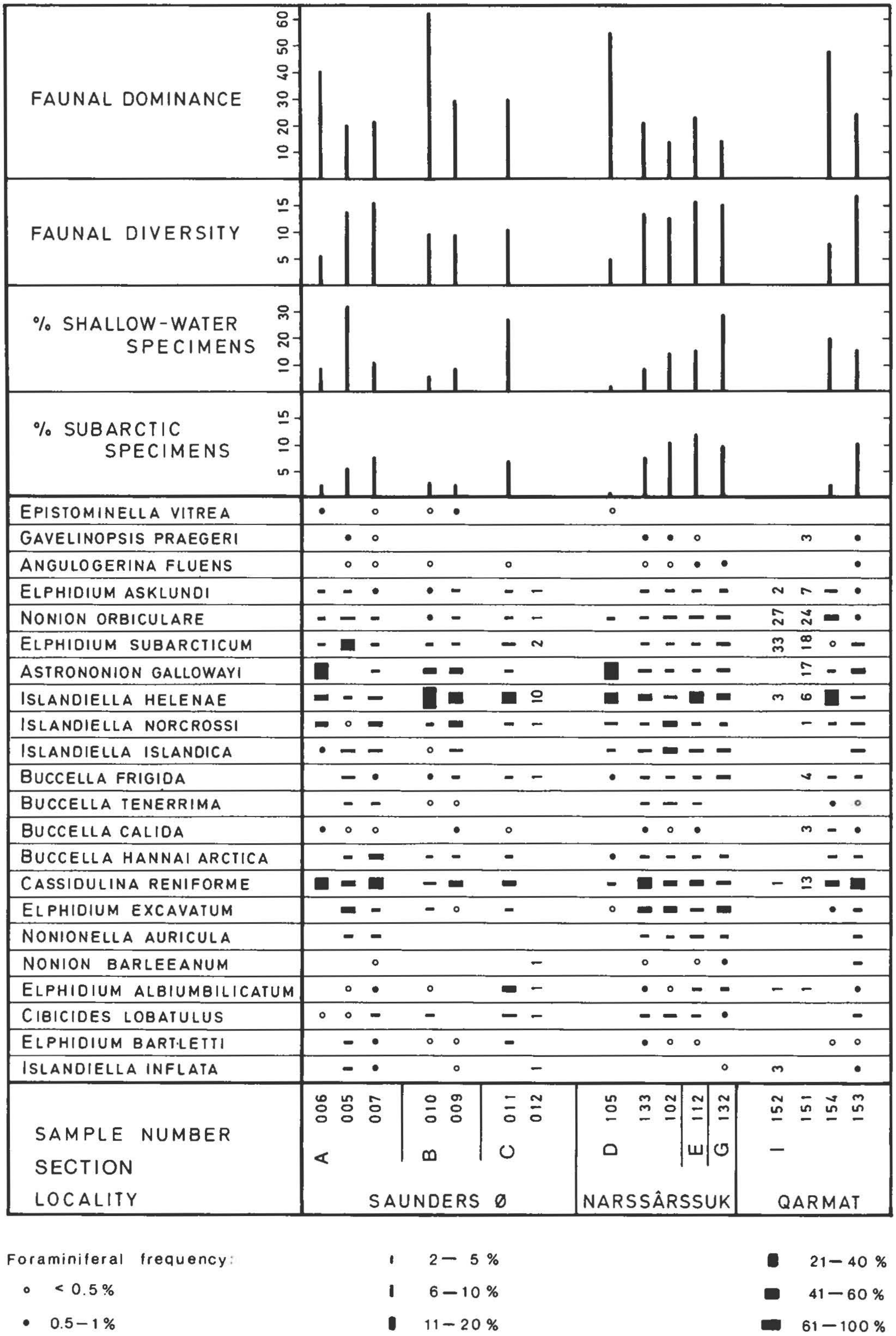
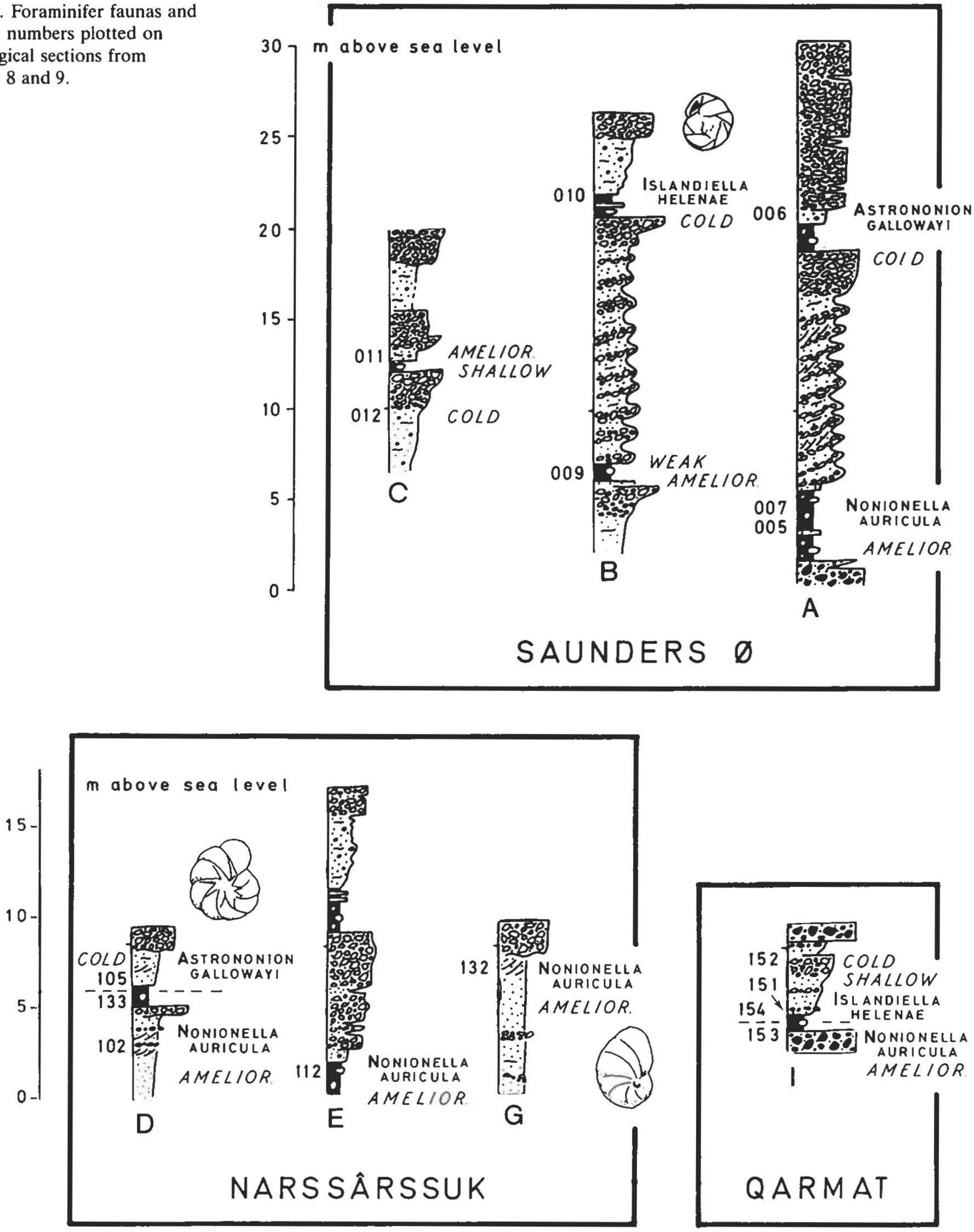


Fig. 11. Foraminifer range-chart for the sections on Saunders Ø and at Narssârssuk and Qarmat. Sample numbers and foraminiferal assemblages are indicated for each section.

Fig. 12. Foraminifer faunas and sample numbers plotted on lithological sections from Figs 4, 8 and 9.



total assemblage". High diversity would, in general, indicate stable and favourable environmental conditions, whereas low diversity would reflect unstable and severe conditions. A third indicator is the faunal dominance index, which is smply the percentage of the most frequent species in a counted assemblage. High faunal dominance would in general indicate extreme environmental conditions, and would normally occur together with low faunal diversity (Fig. 11).

The *Nonionella auricula* assemblage

Fossil assemblages reflecting arctic but ameliorated conditions occur in the lower part of the Saunders Ø sequence (samples 007 and 005, unit S2), in the lower part of the Narssârssuk sequence (sample 112, unit N1), as well as in its upper parts (samples 102, 132, unit N5), possibly reworked in unit N6 (sample 133), and reworked in till at Qarmat (sample 153, unit Q1).

In addition to their ameliorated character (high diversity, low dominance), these assemblages are characterised by the presence of *Nonionella auricula*, which is absent in high-arctic fossil assemblages from the Thule area. The samples in question have been grouped as the *Nonionella auricula* assemblage. The faunal composition of sample 007 from Saunders Ø is typical for this assemblage (Table 1). Another fauna of the same assemblage but from shallower water (sample 132, at Narssârssuk) contains the same percentage of *Nonionella auricula* but fewer *Cassidulina reniforme* (10%) and more *Elphidium excavatum* (13%). Shallow-water species are more frequent, e.g. *Nonion orbiculare* (9%), *Elphidium subarcticum* (9%), *E. albiumbilicatum* (5%), and *E. asklundi* (4%). Shallow-water specimens account for 28% of this assemblage.

Nonionella auricula was originally described from off Plymouth, England (Heron-Allen & Earland 1930), but it also occurs in the present day Arctic, e. g. off Point Barrow, Alaska, at depths from 21 m to 223 m (Loeblich & Tappan 1953). Gudina & Evserov (1973) considered it to be an arctic-boreal species. It has been recorded from interstadial Weichselian layers in southwestern Norway (Feyling-Hanssen 1971, Mangerud *et al.* 1981, Sejrup 1987), and has also been found in early Eemian or pre-Eemian deposits in Norway (Mangerud *et al.* 1981). Other records include the Upper Pliocene of eastern Baffin Island (Feyling-Hanssen 1980).

Most of the samples from the Thule area containing the *Nonionella auricula* assemblage originate from units of shell-bearing diamicton deposited in deep water; only samples 102 and 132 are from sandy deposits indicating shallower water.

Table 1. Foraminifer-frequencies in sample 007, unit S2, weight 100 g.

Species	Percentage
Cassidulina reniforme Nørvang	22
Islandiella norcrossi (Cushman)	18
Buccella hannai arctica Voloshinova	12
Islandiella helenae Feyling-Hanssen & Buzas	9
Islandiella islandica (Nørvang)	8
Elphidium subarcticum Cushman	5
Nonionella auricula Heron-Allen & Earland	5
Nonion orbuculare (Brady)	4
Elphidium excavatum (Terquem)	4
Buccella tenerrima (Bandy)	2
Cibicides lobatulus (Walker & Jacob)	2
Astrononion gallowayi Loeblich & Tappan	2
Bucella frigida (Cushman)	1
Elphidium bartletti Cushman	1
Elphidium albiumbilicatum (Weiss)	1
Islandiella inflata (Gudina)	1
Nonion labradoricum (Dawson)	1
Elphidium asklundi Brotzen	1

Thirteen other species, each accounting for less than 1% of the counted assemblage.
Counted: 494 specimens = ⅟₁₅ of the sample.
Six additional species in the uncounted part of the sample.
Number of species: 37.
Number of specimens/100 g sediment: 1850.
Faunal diversity: 16. Faunal dominance: 22.
Subarctic specimens: 8%.
Shallow-water specimens: 11%.

Table 2. Foraminifer frequency in sample 006, unit S4, weight 100 g.

Species	Percentage
Astrononion gallowayi Loeblich & Tappan	41
Cassidulina reniforme Nørvang	21
Islandiella norcrossi (Cushman)	13
Islandiella helenae Feyling-Hanssen & Buzas	12
Elphidium subarcticum Cushman	5
Nonion orbiculare (Brady)	3
Buccella calida (Cushman & Cole)	1
Islandiella islandica (Nørvang)	1
Epistominella vitrea Parker	1

(One specimen of the planktonic *Globigerina pachyderma* Ehrenberg has been observed).
Three other species, each accounting for less than 1% of the counted assemblage.
Counted: 378 specimens = ⁷⁄₁₀₀ of the sample.
Number of species: 12.
Number of specimens/100 g sediment: 4850.
Faunal diversity: 6. Faunal dominance: 41.
Subarctic specimens: 3%.
Shallow-water specimens: 9%.

Table 3. Foraminifer frequency in sample 010, unit S7, (Holocene), weight 100 g.

Species	Percentage
Islandiella helenae Feyling-Hanssen & Buzas	63
Astrononion gallowayi Loeblich & Tappan	11
Cassidulina reniforme Nørvang	7
Buccella hannai arctica Voloshinova	4
Islandiella norcrossi Cushman	2
Cibicides lobatulus (Walker & Jacob)	2
Elphidium excavatum (Terquem)	2
Elphidium subarcticum Cushman	2
Elphidium asklundi Brotzen	1
Buccella frigida (Cushman)	1
Nonion orbiculare (Brady)	1

Nine other species, each accounting for less than 1% of the counted assemblage.
Counted: 366 specimens = ⅟₁₅ of the sample.
One additional species in the uncounted part of the sample.
Number of species: 21.
Number of specimens/100 g sediment: 1370.
Faunal diversity: 10. Faunal dominance: 63.
Subarctic specimens: 3%.
Shallow-water specimens: 6%.

Sample 132 and also sample 005 contain considerable numbers of shallow-water foraminifera.

The distinctly ameliorated *Nonionella auricula* assemblage is similar, to assemblages in sections of the Qivituq Peninsula on the northeast coast of Baffin Island (Feyling-Hanssen 1980), where they overlie layers with strongly ameliorated foraminiferal assemblages, probably representing oxygen isotope stage 5e, the Eemian. *Nonionella auricula*-bearing deposits have also been found in North Sea boring 2501, directly overlying an Eemian sand unit (Feyling-Hanssen 1981).

The *Astrononion gallowayi* assemblage

An assemblage dominated by *Astrononion gallowayi* occurs in unit S4 on Saunders Ø (sample 006. Table 2), while unit N6 from Narssârssuk carries an assemblage with a similar faunal composition (sample 105). Furthermore this foraminifer is encountered in fewer numbers in nearly all the other investigated samples. *Astrononion gallowayi* is an arctic species which is known to occur in some abundance in the vicinity of calving glaciers (Nagy 1965). It would appear sometimes to occur in increasing amounts, associated with indications of somewhat ameliorated environmetal conditions, of which calving or melting ice may be a result (Feyling-Hanssen 1980, Feyling-Hanssen & Ulleberg 1984).

The *Astrononion gallowayi* assemblage of the Thule area may, nevertheless, reflect high-arctic conditions (faunal dominance high, diversity low, few subarctic specimens), and the low content of shallow-water specimens indicates a sublittoral environment. The lower parts of units S4 and N6 are therefore interpreted as ice proximal and deposited during the Narssârssuk and Wolsteholme Fjord stades respectively, an interpretation that is compatible with lithological and stratigraphical observations.

The *Islandiella helenae* assemblage

A third type of assemblage had *Islandiella helenae* as its dominant species. This *Islandiella helenae* assemblage occurs in the Early Holocene of Saunders Ø (sample 010, unit S7, Table 3), and in unit Q2 of Qarmat (sample 154, Figs 11 and 12). At both localities it reflects high-arctic conditions and at Qarmat also a littoral environment (less than 20 m depth). The assemblage in sample 010 in particular resembles recent faunas in East Greenland fjords, and, as illustrated on p.19, the recent fauna of the Thule area when the arenaceous component is ignored.

Other assemblages

The assemblage in sample 009, unit S4, is also dominated by *Islandiella helenae*, but not to the same extent as the two above-mentioned assemblages. *Astrononion gallowayi* and *Islandiella norcrossi* are also important, and *Islandiella islandica* is common. This assemblage reflects arctic conditions but probably not high-arctic. Its content of subarctic specimens is low, only 3%, but the faunal diversity index is 10 and the dominance only 30%.

Slightly ameliorated conditions were also observed in an assemblage from the Early Holocene unit S7 on Saunders Ø. This is a shallow-water sample with 7% subarctic specimens, a faunal diversity index of 11, and a dominance of 30.

Three of the samples from the area contain less than 100 foraminifers in 100 g sediment, whereas most have between 200 and 5000, and a single sample, 009 from unit S4, contain 12 000. The absence of planktonic foraminifera may be explained by the fact that deposition occurred in a nearshore environment that was effected by the influx of meltwater, which must have caused somewhat reduced salinities.

Conclusions

The investigation has led to the distinction of four different assemblage types in the Quaternary sediments of the Thule area: the subarctic *Nonionella auricula* assemblage, the high-arctic *Astrononion gallowayi* assemblage, the high-arctic *Islandiella helenae* assemblage, and an ameliorated assemblage with *I. helenae* as the dominant species, which has only been registered in a single sample. As discussed in the following section the environmental implications are in close agreement with those obtained from other faunal and floral evidence. Especially important is the recognition of the cold water *Astrononion gallowayi* assemblage, correlated with the two periods of glacier advance known from glacial deposits in the interior parts of the region.

Molluscs, barnacles and other marine and terrestrial fauna and flora

(S. Funder)

Blake (1973, 1975, 1977) demonstrated that pre-Holocene sediments on Saunders Ø and elsewhere in northern Baffin Bay contain the subarctic molluscs *Mytilus edulis* and *Chlamys islandica* outside their present limits, and used this to correlate the sediments with the Sangamonian (Blake 1973: 56, although revised by Blake 1987: 26).

One purpose of the NORDQUA 86 work was to obtain a more detailed knowledge of the faunas, and relate them to regional oceanographic changes. The new results show that besides the two species mentioned above, the subarctic barnacles *Balanus balanoides* and *B. crenatus* also occurred, as well as remains of a few thermophilous terrestrial organisms, and that subarctic organisms lived in the area during at least two phases of the last interglacial/glacial cycle.

This section gives a brief survey of the present-day oceanography and fauna in Baffin Bay and a description of the subfossil marine faunas, with emphasis on the subarctic species and their environmental implications.

Present fauna and oceanography

Early observations on marine faunas in the Thule district have been summarised by Posselt & Jensen (1898), Stephensen (1913) and Thorson (1951). Detailed studies have been made by Vibe (1939, 1950) and Theisen (1973), and in August 1968 extensive dredging was carried out by J. Just and C. Vibe, especially in the area between Saunders Ø and Narssârssuk (e.g. Just 1980). The molluscs from this work have been identified by K. Ockelmann, and have been made available to me at The Zoological Museum, Copenhagen.

The Baffin Bay distribution of the four species mentioned above is given in Fig. 13, and the results show that while *Balanus balanoides* is absent, *Mytilus edulis*, *Chlamys islandica* and *Balanus crenatus* have their Baffin Bay northern limits in the Thule area. However they occur sparsely, and the area is apparently critical for them. Thus only two populations of *Mytilus* are known, at Thule and at Siorapaluk, 150 km to the north (Vibe 1950). Theisen (1973) found that both populations consisted only of old individuals that for some time had not been able to reproduce. *Balanus crenatus* is known from Etah 200 km to the north of Thule, and from Cape Herschel on the Canadian side of Smith Sound. Like *Mytilus*, this species is restricted to rock crevices in a narrow zone at low water mark, where the animals, protected from abrasion by ice, may take advantage of high temperatures in the surface water, thus underlining the critical situation for them (Vibe 1950).

Chlamys islandica lives at greater depth, and in the 1968 dredging at Thule a few adult individuals of *Chlamys* were found at 30 and 50 m at two localities, between Saunders Ø and Narssârssuk, and in Murchison Sund 150 km to the north. Empty shells have been dredged at Siorapaluk (Vibe 1950), and at Narssârssuk, and were found on the beach of Wolstenholme Fjord (1968 collections). The observations show that also this species is sparse in the area.

For all the three species mentioned the populations in the Thule district appear to be disjunct from their main areas which have their northern limit at Upernavik, 400 km to the south. This area also marks the northern limit for *Balanus balanoides*, but Petersen (1962, 1966) noted that its populations here may be sustained by larvae brought up from the south. He also showed that its distribution has apparently varied considerably during this century, in harmony with the known changes in extent of the West Greenland Current along the coast.

On the Canadian side of Baffin Bay *Mytilus* has a disjunct occurrence at Pond Inlet, northern Baffin island, while its main area of distribution begins 800 km to the south. The occurrence at Pond Inlet may be conditioned by insolation and local warming in this sheltered area (e.g. Ellis 1960). The population has lived here for at least a millenium (Blake 1987: 23), and is considered a relict from a continuous distribution along the Baffin Island coasts that was severed 3000 years ago (Andrews *et al.* 1981).

The summer surface circulation in Baffin Bay is shown in Fig. 14. The exchange with adjacent oceans is afforded by the West Greenland Current moving northwards along the Greenland coast, and the Labrador Current carrying cold polar water from the Arctic Ocean south along the Canadian coasts.

The West Greenland Current contains a mixture of cold polar and underlying warm Atlantic water. However, the relative proportion of the two components varies, and in periods the warm Atlantic water is known to invade even shallow depths, to the great benefit of the Greenland fishing industry (Jensen 1939).

The greater part of the water in the West Greenland Current is deflected into central and eastern Baffin Bay, and some occurs as surface water in Cumberland Sound and Frobisher Bay on the Canadian side (Kramp 1963, Ellis 1955). However, small amounts have been traced in coastal shallow water as far north as the Thule district and even eastern Ellesmere Island (Aarkrog *et al.* 1987). Since the water spends some time in transit one effect is that it prolongs summer warmth at high northern latitudes (e.g. Smidt 1979).

From Figs 13 and 14 there appears to be a causal relationship between the occurrence of subarctic water masses in Baffin Bay and the distribution of the four species mentioned. This has been pointed out already by Madsen (1936, 1940), while Dunbar (1968) defined his important marine subarctic zone as the area where polar and Atlantic water masses mix, with its northern limit marked by the northernmost penetration of warm Atlantic water.

In summary, there is a large amount of evidence to show that the distribution of the four species in Baffin Bay is associated with the occurrence of warm subarctic Atlantic water, and consequently especially *Mytilus* and *Chlamys* have often been used as palaeooceanographic indicators for this type of water in Baffin Bay (e.g. Andrews *et al.* 1981, Funder & Símonarson 1984, Funder 1984, 1989, Kelly 1985, 1986). Marine oceanographic and biological studies show that the Thule area today marks the northernmost extension for the conveyance of Atlantic water in the West Greenland Current, and the fossil occurrence of subarctic species in this area is therefore interpreted as reflecting a palaeooceanographic regime similar to the present one, or with deeper penetration of The West Greenland Current.

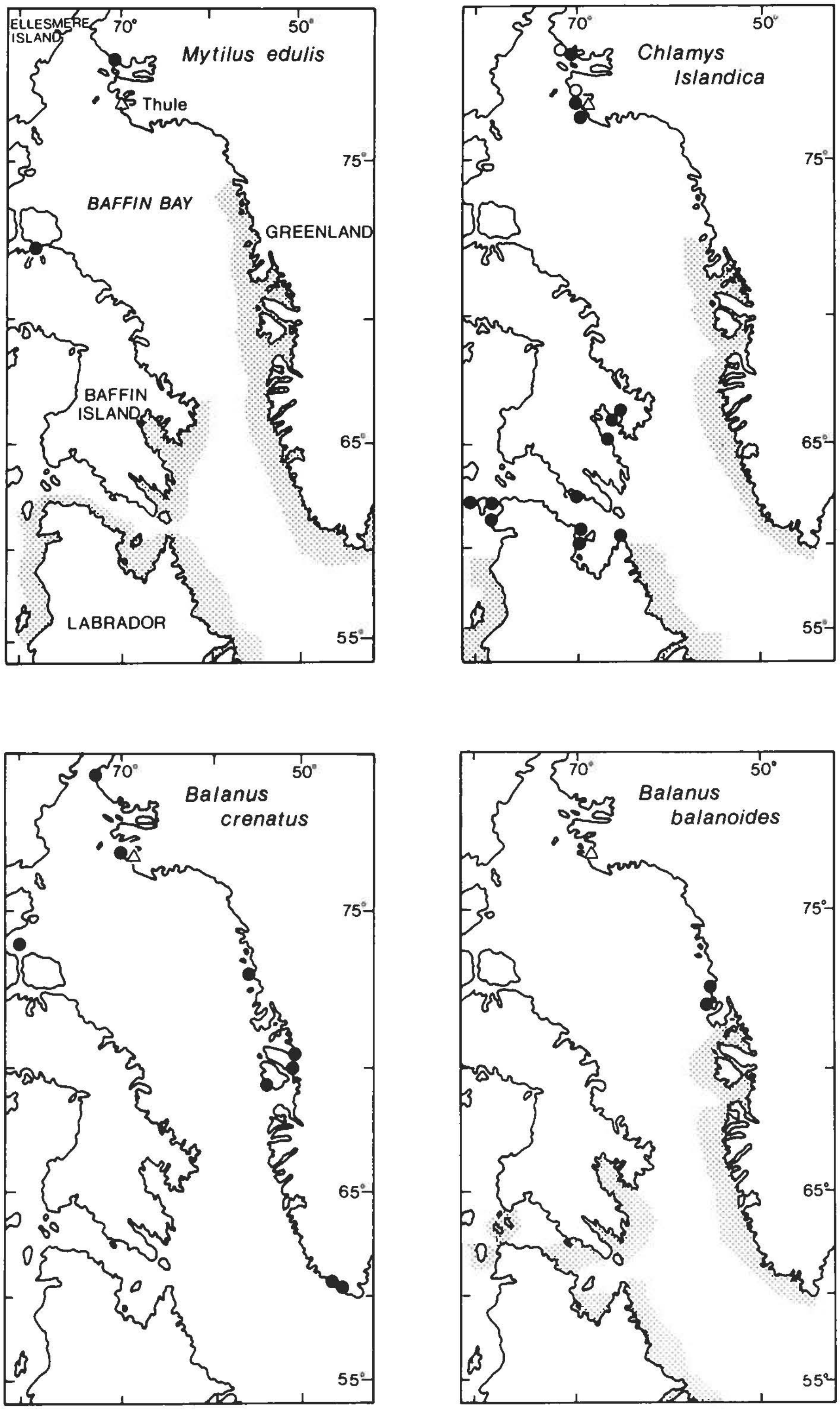


Fig. 13. Present distribution of some marine subarctic species in Baffin Bay. Shading shows continuous distribution, black dots are isolated northern occurrences, open dots are empty shells. (sources: Posselt & Jensen 1898, Stephensen 1936, Vibe 1950, Barnes 1957, Petersen 1962, Theisen 1973, Lubinsky 1980, Dale 1985).

Table 4. Pre-Holocene marine flora and fauna from the Thule aminozone. (Location of samples in sections appear from Figs 4, 8, 9).

	Saunders Ø											
Sample No. (sectionwise-upwards)	005	007	006	009	008	012	101	102	112	119	110	113
Section	A	A	A	B	B	C	D	D	E	E	E	E
Unit	S2	S2	S4	S4	S4	S5a/2?	N5	N5	N1	N1	N4	N4
Type (1)	sd	sd	sd	sd	sd	sd	sd	sd	sd	pk	pk	sd,pk
State (2)	is,x	is,x	is,x	is	is,x	x	x	x	is,x	x	is,x	is
BIVALVIA												
Portlandia sp.	–	–	–	–	–	–	–	–	–	–	1	–
Nuculana pernula Costigera	2	1	–	–	–	–	–	–	–	–	1	–
Modiolaria nigra (Gray)	–	–	–	–	–	–	–	–	3	–	–	–
Mytilus edulis Linne	–	–	–	–	–	f	–	–	–	–	–	–
Chlamys islandica (Møller)	r	–	–	–	–	2	–	r	r	1	r	–
Palliolum greenlandicum (Sowerby)	–	–	–	–	–	–	–	–	2	–	–	–
Astarte sp.	–	–	r	–	–	–	–	–	r	–	–	–
Axinopsida orbiculata Sars	–	–	–	–	–	–	–	–	–	–	–	–
Clinocardium ciliatum (Fabricius)	–	–	–	–	–	–	–	1	1	–	–	–
Serripes groenlandicus (Chemnitz)	–	–	r	–	–	–	–	–	–	–	r	–
Macoma calcarea (Chemnitz)	2	–	r	c	–	–	–	3	1	–	–	c
Hiatella arctica (Linne)	r	r	f	c	r	c	–	c	c	r	c	f
Mya truncata Linne	f	c	f	c	r	c	–	c	f	c	c	f
GASTROPODA (3)												
Buccinum cf *hydrophanum* Hancock	–	–	–	–	–	–	–	–	1	–	–	–
Buccinum sp. (?*belcheri* Reeve)	–	–	–	–	–	–	–	–	–	–	–	–
CIRRIPEDIA												
Balanus balanoides Linne	–	–	–	–	–	–	–	–	–	–	–	–
Balanus cf. *balanoides*	–	–	–	–	–	–	–	–	–	–	–	–
Balanus balanus (Linne)	1	r	c	–	–	r	–	r	c	–	2	2
Balanus crenatus Bruguiere	1	–	r	–	–	r	–	r	–	–	r	–
Balanus sp.	c	c	c	–	–	–	–	c	f	r	–	r
ECHINODERMATA												
Strongylocentrotus droebachensis (Møller)	–	–	+	–	–	–	–	–	+	–	+	+
POLYCHAETAE												
Sprirorbis sp.	–	–	–	–	–	–	–	–	–	–	–	–
BRYOZOA (4)												
Myriapora coarctata (M. Sars)	–	–	–	–	–	–	–	r	r	–	–	–
Myriapora subgracilis (d'Orbigny)	–	–	–	–	–	–	–	r	–	–	–	–
Celleporina surcularis (Packard)	–	–	–	–	–	–	–	–	r	–	–	–
Celleporina ventricosa (Lorenz)	–	–	–	–	–	–	–	–	r	–	–	–
ALGAE (5)												
Sphacelaria arctica Harvey	–	–	–	–	–	–	–	–	–	–	–	–
FORAMINIFER ASSEMBLAGES (from Fig. 10)												
Monionella auricula ass.	+	+					+	+	+			
Islandiella helenae ass.				+								
Astrononion gallowayi ass.			+									
TL age, ka (from Table 9)	136	119	114	113	89	69						
Total alle:Ile, x' (from Table 10)		.036	.021	.049		.041		.027	.030			

Frequencies: f: frequent, c: common, r: rare, 1–3: very rare, number of fragments, +: frequency unspecified, ?: identification doubtful.
(1): sd: bulk sediment, pk: shells picked from section
(2): is: *in situ*, x: fragmented shells
Identification other than the author: (3): L. A. Símonarson, University of Reykjavik; (4): Karen Bille Hansen, Zoological Museum, Copenhagen; (5): P. M. Pedersen, Botanical Institute, Copenhagen.

Narssarsûk														Qarmat						
117 E N5	115 E N5	134 E N5	125 F N2	126 F N2	129 F N4	128 F N4	127 F N4	130 G N5	132 G N5	131 G N5	181 K	182 K	183 K	142 I Q1	143 I Q2	144 I Q2	151 I Q3	145 I Q3	146 I Q3	147 I Q3
sd is	pk is	sd is	pk x	pk x	sd x	sd x	pk x	pk is	sd is	sd is	pk x	pk x	pk x	pk x	sd,pk is	sd is	sd x	sd is,x	pk x	pk is
–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
–	–	–	–	–	–	–	–	+	f	1	–	–	–	–	–	–	?	–	–	c
–	–	r	–	–	2	r	1	–	–	–	–	–	–	1	–	–	?	–	–	–
–	–	2	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
–	–	2	–	–	–	–	–	–	–	–	–	–	–	?	–	–	–	–	–	–
–	–	–	–	–	–	–	–	–	r	–	–	–	–	–	–	–	–	–	–	1
–	–	–	–	–	1	–	–	–	–	–	+	–	–	–	r	–	–	–	–	–
–	c	–	–	–	–	–	–	+	c	–	–	1	–	–	–	–	r	2	2	f
r	3	–	–	–	1	–	–	–	c	–	–	–	–	3	–	–	c	c	c	f
f	f	–	r	f	c	c	f	+	c	1	–	c	r	r	c	c	c	r	c	f
r	f	c	–	c	c	c	c	f	c	1	+	c	r	c	c	f	c	c	c	f
–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1
–	–	–	–	–	–	–	–	–	–	r	–	–	–	–	–	–	–	–	r	f
–	–	–	–	–	–	–	–	–	1	a	–	–	–	–	–	–	–	–	–	c
–	–	r	–	–	c	3	–	–	–	–	–	–	–	1	–	–	r	–	–	3
–	–	–	–	–	–	1	–	1	1	–	–	–	–	1	–	–	+	–	–	r
–	–	c	–	–	c	–	–	–	–	–	–	–	–	c	–	–	–	–	–	–
+	+	–	–	–	+	+	–	–	+	–	–	–	–	+	+	+	+	–	–	+
–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
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–	–	–	–	–	–	–	–	–	+	+	–	–	–	–	–	–	–	–	–	–
									+					+						
															+					
															86		80			80
				.032	.026			.035					.058	.037	.025					.025

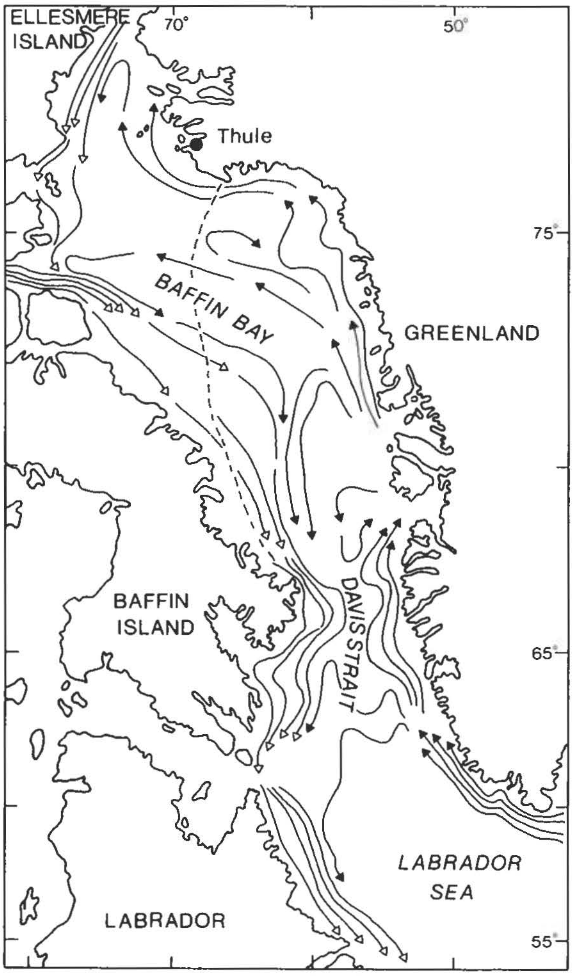

Fig. 14. Summer surface circulation in Baffin Bay, simplified from Kramp (1963) and Jacobs *et al.* (1985). Stippled line is northern boundary for marine subarctic zone from Dunbar (1968). Black and white arrows are warm and cold water.

Material

Faunal analysis has been carried out on 70 samples from 5 localities. The samples generally consist of 3 kg bulk sediment, but some are smaller and comprise shells picked out from the sections. 54 samples are considered pre-Holocene in age, and out of these 29 are from the youngest pre-Holocene marine episode, the Qarmat interstade, while only 2 are from the older Saunders Ø interstade. However, rather well preserved faunas occur in some samples of till and glacially reworked sediment from the Narssârssuk stade, and are – on the basis of their amino acid ratios – interpreted to be derived from the underlying Saunders Ø interstade (units N1-N3 and Q1, Table 4). Hence different stratigraphic levels are variously represented, and this must kept in mind in the environmental interpretation.

Besides shells from bivalves and barnacles, needles and plate fragments from sea urchins occur frequently. Less frequent are fragments of gastropods, bryozoans and marine algae which have been identified by L.A. Símonarson, Karen Bille Johansen and Poul Møller Pedersen. A few samples contain washed-out remains of terrestrial flora and fauna. Moss remains in these samples have been identified by G.S. Mogensen, angiosperm leaves and seeds by O. Bennike, and a single well preserved beetle fragment by J. Böcher (1989).

Lists of the identified pre-Holocene and Holocene marine species are given in Tables 4 and 5, and remains of terrestrial flora and fauna are listed in Table 6.

The shell material varies from highly fragmented in coarse grained sediments to well preserved with articulated shells in silt sediments. From field observations the latter have generally been interpreted to be *in situ*, while the fragmented faunas, living in a high energy environment, have been displaced after death. The faunas have a heavy bias towards species with robust shells, and are dominated by forms that are very widespread in northern waters (e.g. *Mya truncata*, *Hiatella arctica*, *Macoma calcarea*). Apart from the subarctic species mentioned above there are few ecological indicators. Especially noteworthy is the rarity of arctic forms in the pre-Holocene faunas. Thus, while *Portlandia arctica* is rather common in the Holocene faunas, it is absent from the older ones. The only arctic representative in the pre-Holocene samples is *Palliolum greenlandicum* which, however, is known as a bathyal form in southern areas (Thorson 1951). The environmental interpretation of the faunas therefore relies mainly on the presence or absence of subarctic fauna elements, and some notes on their occurrence in the material, and in the Baffin Bay region are given below, and discussed in a later section. Event names are shown on Fig. 24.

Mytilus edulis. – This species has been found in 11 pre-Holocene samples from all three pre-Holocene localities, and in three Holocene samples. The pre-Holocene material is highly fragmented, and only unit N5 (sample 132) contains fairly intact shells. In some samples the fragments are extremely abundant; this is the case for unit S5a where they are a distinct component of the gravel sediment, as noted also by Blake (1975: 436). On the other hand, in the samples from unit Q3, they are both tiny and rare.

Mytilus occurs at all three localities only in the littoral sediments of the younger pre-Holocene units, best preserved and most frequent in unit N5. However, amino acid ratios from unit S5a indicate that the worn shell fragments here may be eroded from older sediments equivalent to unit S2 from the Saunders Ø interstade, and thus would be 50 000 years older than the gravel in which they are embedded.

Mytilus edulis therefore occurred in the area during the Qarmat interstade, whereas its presence during the earlier Saunders Ø interstade rests on circumstantial evidence. Its apparent rarity in the latter, however, should be viewed in the light of the very sparse sample material, and lack of littoral sediments from these units.

In the Baffin Bay region pre-Holocene *Mytilus edulis* has been observed on Coburg Island, where it was referred to the Sangamonian (Blake 1973, 1977). In western Greenland it occurs in the Early Quaternary Pátorfik Formation and in the Laksebugt aminozone referred to the stage 6/5 boundary (Funder & Símonarson 1984). It has also been observed at Svartenhuk, and referred to the Kaffehavn interglaciation correlated with isotopic stage 5e (Kelly 1986). On Baffin Island *Mytilus* is known from the early Quaternary Cape Christian Member, but is conspicuously absent from younger pre-Holocene sediments, including the Kogalu aminozone (Andrews *et al.* 1981, Miller 1985).

Although *Mytilus* is rare in the area at present, it occurs frequently in the raised Holocene deposits, and apparently immigrated in the Early Holocene. Thus the C-14 date of 9200 yrs BP for a sample from Wolstenholme Fjord containing *Mytilus* (sample 021, Table 5) shows that the West Greenland Current was functioning as at present at this early stage. This is in agreement with a date of 8500 yrs BP obtained earlier on whale bones found in association with *Mytilus* (Krinsley 1963). Along the coast of Baffin Island it was more frequent at 8400 yrs BP than it is now (Andrews *et al.* 1981).

Table 5. Holocene marine faunas and ages. (Location in sections appear from Figs 4, 8, 9).

Sample No. Section Unit	010 B S6	011 C S6	013 surf.	133 D N6	104 D N6	135 H N6	138 H N7	021(1)	161 J	172 J
BIVALVIA										
Nucula tenuis Reeve	–	–	–	–	–	–	–	r	–	–
Nuculana pernula Costigera	–	–	–	–	–	–	–	r	–	–
Nuculana minuta (O. F. Møller)	–	–	–	–	–	2	r	r	–	–
Portlandia arctica (Gray)	+	–	–	–	–	–	–	–	–	–
Mytilus edulis Linne	–	–	–	–	–	–	–	r	–	–
Chlamys islandica (Møller)	–	–	1	3	1	–	–	r	–	–
Palliolum greenlandicum (Sowerby)	–	–	–	1	–	–	–	–	–	–
Astarte sp.	–	–	–	r	–	–	–	–	–	–
Axinopsida orbiculata Sars	–	–	–	–	–	–		c	–	–
Clinocardium ciliatum (Fabricius)	–	–	–	–	3	–	–	c	s	–
Serripes groenlandicus (Chemnitz)	–	–	–	–	–	–	–	r	–	–
Macoma calcarea (Chemnitz)	–	–	–	–	3	r	f	c	–	–
Hiatella arctica (Linne)	c	–	+	r	f	f	f	f	–	s
Mya truncata Linne	c	c	+	c	f	f	f	f	a	s
GASTROPODA										
Acmaea testudinalis (O. F. Møller)	–	–	–	–	–	–	–	1	–	–
?*Colus togatus* (Mörch)	–	–	–	–	–	–	–	1	–	–
?*Buccinum undatum* Linne	–	–	–	–	–	–	1	–	–	–
CIRRIPEDIA										
Balanus balanus (Linne)	c	1	–	–	r	f	f	–	–	–
Balanus crenatus Bruguiere	+	r	1	1	–	–	3	f	–	–
ECHINODERMATA										
Strongylocentrotus droebachensis (Møller)	+	+	–	–	+	–	+	+	–	–
BRYOZOA (2)										
Celleporina surcularis (Packard)	–	–	–	r	–	–	–	–	–	–
Nonionella auricula ass. *Islandiella helenae* ass. *Astrononion gallowayi* ass.	+	+								
C-14 age, ka (See appendix)	8.2	8.0 (3)	8.8			8.7		9.2	9.0	7.0
TL age, ka (from Table 9)	14	36								
Total aIle:Ile, x' (from Table 10)	.014		.013&.023		.016					

Frequencies: f: frequent, c: common, r: rare, 1–3: very rare, number of fragments, +: frequency not specified.
(1): 1 m above sea-level in coast cliff on north shore of Wolstenholme Fjord, near Salisbury Gletscher.
(2): Identified by Karen Bille Hansen, Zoological Museum, Copenhagen.
(3): Sample GSC-2079, Blake (1975).

Chlamys islandica. – This species occurs in 16 pre-Holocene samples and in one Holocene sample. Like *Mytilus* it occurs at all three localities where pre-Holocene sediments are known, and only as fragments. However, in agreement with its sublittoral habitat, it occurs mainly in fine-grained deep-water sediment. Generally the samples contain only 2–5 fragments, and only in units N4 and N5 (samples 128 and 102) are they rather frequent. A few fragments are found in one of the two samples from the Saunders Ø interstade (unit S2), and may correlate with those found in glacially reworked sediments of the Narssârssuk stade (units N1-N3).

Chlamys occurs together with *Mytilus* on Carey Øer and Coburg Island (Bake 1977), and – probably reworked – in Olrik Fjord where the Olrik Fjord aminozone is tentatively correlated with isotopic stage 5e (Weidick 1978, Kelly 1986). In West Greenland it is known from the Early Quaternary Pátorfik Formation and also from Mudderbugt and Eqalugsugssuit in northern Melville Bugt. These deposits were grouped in the Meteorbugt marine event, considered to be older than isotopic stage 5 (Kelly 1986).

On Baffin Island *Chlamys* is known from all marine episodes since the Cape Christian Member, and it occurs in deposits on Clyde Foreland and Broughton Island which are referred to the Kogalu aminozone (isotopic stage 5), and most abundantly in its upper part (Andrews *et al.* 1981).

In the Holocene, *Chlamys* apparently occurred in the Thule region as early as 9200 yrs BP (sample 021, Table 3). Around southern Baffin Island where the species is now absent, it occurred already at 9700 yrs BP (Andrews *et al.* 1981).

Balanus balanoides. – This barnacle has been identified in three pre Holocene samples, one from Narssârssuk (unit N5) and two from Qarmat (unit Q3). The species, which is very rare in the fossil record (e.g. Feyling-Hanssen 1953), has been identified from its compartment plates, using the characters noted by Broch (1924) and comparison with type material from Greenland. Certain identification of the delicate plates can only be made on well preserved material and plates lacking some diagnostics are referred to *B.* cf. *balanoides*. The richest material is from Qarmat where 10–15 well preserved plates occur in samples 150 and 152.

B. balanoides is thus known only from the youngest pre-Holocene units, i.e. the Qarmat interstade; this is not surprising since it is an intertidal species, and shallow water deposits are known only from this marine episode.

B. balanoides is not known from other pre-Holocene depos-

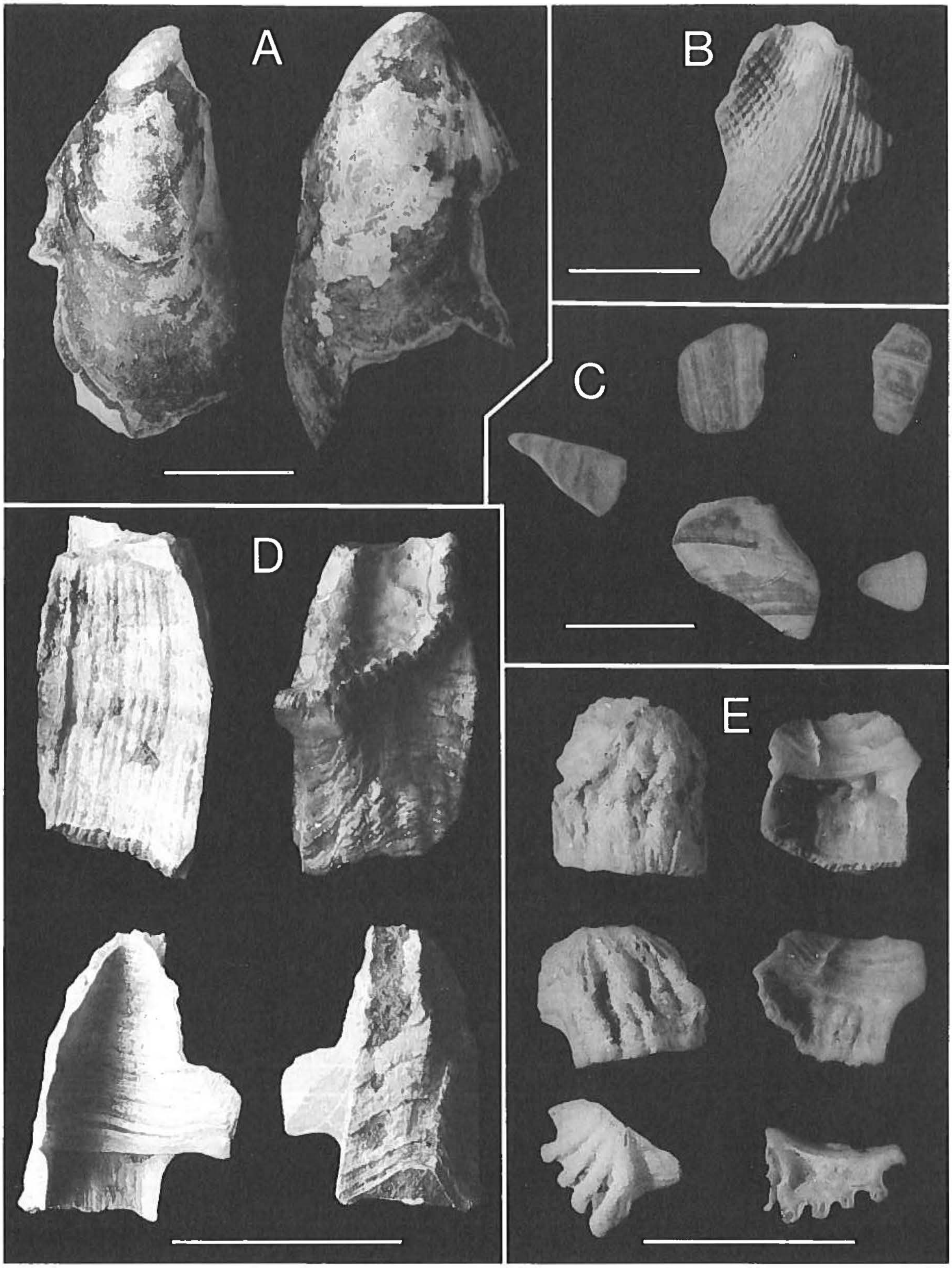

Fig. 15. Pre-Holocene subarctic species from Thule. A: *Mytilus edulis*, B: *Chlamys islandica*, C: *Mytilus edulis*, worn fragments from unit S5a. D: *Balanus crenatus*, inner (left) and outer (right) side of compartment plates, E: *Balanus balanoides*, outer (left) and inner (right) side of compartment plates. White bar is 1 cm.

Table 6. Pre-Holocene terrestrial flora and fauna. (Location of samples in sections appears from Figs 4, 8, 9).

Sample No.	101	113	114	132	131
Section	D	E	E	G	G
Unit	Nx	N4	N5	N5	N5
ANGIOSPERMAE 1)					
Dryas integrifolia M. Vahl	–	–	–	–	+
Menyanthes trifoliata L.	–	–	–	–	+
Carex spp.	–	–	–	–	+
Salix sp.	–	–	–	–	+
Potentilla sp.	–	–	–	–	+
Eriophorum sp.	–	–	–	–	?
Empetrum sp.	–	–	–	–	?
BRYOPHYTA 2)					
Scorpidium scorpioides (Hedw.) Limpr.	+	+	+	–	+
Pogonatum dentatum	–	+	–	–	–
Pohlia cruda	–	+	–	–	–
Pohlia nutans	–	+	–	–	–
Ditrichum flexicaule (Schwaegr.) Hampe	–	+	–	–	–
Ditrichum cf. *flexicaule*	+	–	–	–	–
Bryum spp.	+	+	+	–	–
Rhacomitrium sp.	+	+	–	–	–
Drepanocladus cf. *exannulatus* Warnst.	–	–	+	–	–
Drepanocladus sp.	+	+	–	–	–
Distichium sp.	+	–	–	–	+
COLEOPTERA 3)					
Amara alpina Paycull	–	–	–	+	–

Identification: 1) O. Bennike, Geological Museum, Copenhagen; 2) G. S. Mogensen, Botanical Museum, Copenhagen; 3) J. Böcher, Zoological Museum, Copenhagen.

Balanus crenatus. – This species occurs infrequently in the pre-Holocene samples from Saunders Ø (unit S2), Narssârssuk (units N4) and Qarmat (units Q1 and Q3). It occurs equally infrequently in the Holocene samples.

its in the Baffin Bay region, and also its Holocene history is virtually unknown.

The species thus appears both in the Saunders Ø and Qarmat interstades.

B. crenatus was observed in the Early Quaternary Pâtorfik Formation (Símonarson 1981), and in the Kogalu aminozone deposits (isotopic stage 5) on Broughton Island (Andrews et *al.* 1981). Its occurrence in sample 021 (Table 5) indicates an Early Holocene immigration to the Thule area together with *Mytilus* and *Chlamys*.

Terrestrial flora and fauna

The shallow water sediments from unit N5 at Narssârssuk contain scattered washed out remains of the terrestrial flora and fauna, as shown in Table 6. The list is interesting because it contains the first unambiguous evidence of Greenland's terrestrial flora and fauna during the last ice age.

Although the identified taxa generally belong to species and genera that are widespread in the area today there are two exceptions: a single seed of *Menyanthes trifoliata*, identified by O. Bennike, and a well preserved pronotum of the beetle *Amara alpina*, identified by J. Böcher (1989). *Menyanthes* has its present northern limit in Greenland in the interior Disko Bugt region, 800 km to the south of Thule, and shows that summer temperatures during the Qarmat interstade were significantly higher than at present. *Amara alpina* is absent from Greenland, and apparently was not able to reach the country during the Holocene, although it occurs as far north as Devon Island in the Baffin Bay region (Böcher 1989). It is interesting to note that this species has also been identified in peat from nearby Ellesmere Island, although its C-14 age here, 31 100 yrs BP, would indicate a considerably younger age

	Mytilus edulis	*Chlamys islandica*	*Balanus balanoides*	*B. crenatus*	*Menyanthes trifoliata*	*Nonionella auricula* ass. (warm)	*Islandiella helenae* ass. (interm.)	*Astrononion gallowayi* (cold)	Number of analysed samples
HOLOCENE	+	+	–	+	–	–	+	–	21
QARMAT INTERSTADE	+	+	+	+	+	+	+	+	29
NARSSÅRSSUK STADE	–	–	–	–	–	–	+	–	5
SAUNDERS Ø INTERSTADE	+*	+	–	+	–	+	–	–	2 (6*)

* Reworked into younger glacial sediment

Fig. 16. Distribution of subarctic and cold water fauna in Thule aminozone deposits.

(GSC-3364, Blake 1982), if this age is accepted without reservation.

Conclusions

From the description above and Fig. 16 it appears that subarctic species are more abundant in the sediments related to the Qarmat interstade than in older or younger sediments. This is especially conspicuous when the record is compared to that from the Holocene. The presence of *Balanus balanoides*, a sensitive indicator of warm Atlantic water, reflects a West Greenland Current that was stronger and had a larger warm water component than is known from the Holocene, while the occurrence of *Menyanthes trifoliata* shows that summers on land were warmer.

When comparing this record with that of the earlier Saunders Ø interstade it should be kept in mind that the material from the latter is often glacially reworked, while the few *in situ* samples belong to a deep water facies where the littoral *Mytilus* and *Balanus balanoides* would not occur. However, the presence of *Chlamys*, *Balanus crenatus*, and the ameliorated *Nonionella auricula* foraminifer assemblage (see discussion by Feyling-Hanssen above), indicates that warm Atlantic water reached Thule also during this phase, and that marine conditions were similar to the present or warmer. That *Mytilus* may have occurred also during the Saunders Ø interstade is indicated by the circumstantial evidence from unit S5a.

A conspicuous feature of the faunas is the lack of arctic species. The only indication of colder than present conditions comes from the *Astrononion gallowayi* foraminifer assemblage recorded by Feyling-Hanssen (above).