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ENVIRONMENTAL ASSOCIATIONS OF BAFFIN ISLAND FJORD AGGLUTINATED FORAMINIFERA

by

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With 8 figures and 5 tables

ZUSAMMENFASSUNG

Artenhäufigkeiten von benthonischen Foraminiferenarten und Thecamöbenpopulationen wurden in einer Serie von 63 Van Veen-Greiferproben studiert. Sie wurden in zehn Fjorden entlang der Ostküste der Baffin Insel (Kanada) gesammelt. Sie enthielten durchschnittlich 75% agglutinierter Taxa. Die Gesamtzahl der Individuen pro Kubikzentimeter Naßsediment betrug 111 Exemplare mit rund 91% agglutinierter Formen. *Textularia earlandi* ist in fünf Fjorden dominant, *Spiroplectammina biformis* und *Tochammina nana* in vier anderen und *Reophax arctica* in einem. *Reophax arctica* und *S. biformis* zeigen eine relativ hohe, inverse Korrelation zu den Bodenwassertemperaturen. Die Temperaturparameter können jedoch nicht gänzlich vom offensichtlichen Einfluß des Substrates auf die Verteilung dieser beiden Arten und anderer agglutinierter Formen getrennt werden. Ursachen für diese Situation sind: 1) Bathymetrische Temperaturveränderungen der jahreszeitlichen Wasserschichtung in der arktischen Umgebung, die sich über mehrere stabile Substrattypen erstrecken können; 2) eine mögliche jahreszeitliche Migration einzelner Arten in seichteres Wasser. Diese Migration könnte durch eine Veränderung der Ernährungsgewohnheiten während des langen Intervalls mit Eisbedeckung im Winter verursacht werden oder könnte Nährstofferfordernisse vor der Reproduktion reflektieren.

ABSTRACT

The species counts of benthic foraminifera plus thecamoebian populations studied in a suite of 63 Van Veen grab samples collected in 10 east coast Baffin Island fjords during September 1982, averaged 75% agglutinated taxa. The total number of specimens per cubic centimeter of wet sediment averaged 111 individuals of which about 91% were agglutinated. *Textularia earlandi* is the dominant species in five of the fjords, *Spiroplectammina biformis* and *Trochammina nana* in four of the others, and *Reophax arctica* in one. *R. arctica* and *S. biformis* show a relatively high inverse correlation to bottom water temperature. However, the temperature parameter cannot be completely isolated from an apparent substrate influence on the distribution pattern of these two species, as well as on that of some other agglutinated forms. Among the reasons proposed for this situation are: (1) the bathymetric temperature variation of the seasonal water layer in arctic environments which can extend over a number of stable substrate types and (2) possible seasonal migrations of species into shallow water. This migration could be driven by a change of feeding habits during the long interval of winter sea ice cover, or may reflect a response to pre-reproduction nutrition requirements.

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INTRODUCTION

Agglutinated species dominate the foraminiferal population in many nearshore arctic marine settings (e.g. Schafer and Cole 1986; Vilks 1969; Iqbal 1973). However, the study of species-environment relationships in these areas has lagged behind research on calcareous species because of the apparently poor preservation potential of modern agglutinated forms in oxidized and bioturbated sediments (Vilks *et al.* 1985; Vilks 1969). Although the destruction of agglutinated tests is frequently evidenced even in the upper 0.5 m of sediment in cores raised from low sedimentation deep-sea environments (e.g. Douglas *et al.* 1980), they are often preserved to a greater degree in high deposition rate fjord and bay environments (e.g. Schafer *et al.* 1980; Rashid *et al.* 1975), where they are useful in defining sediment sources and depositional patterns.

This study presents observations on the paraecology and distribution of modern agglutinated species in ten east coast Baffin Island fjords (figure 1). At these localities, 36 taxa have mean total percentages $\geq 0.1\%$. The nine most abundant species have mean total percentages $\geq 3\%$ and coefficients of variation which are usually $\leq 100\%$ (i.e. comparatively homogeneously distributed species). These nine species have been used in this study to illustrate species-environment relationships that have applications in paleoecologic studies of pre-Recent fjord environments.

METHODOLOGY

Sediments were collected using a Van Veen grab sampler usually in water depths $\geq$ 100 m (appendix I). A portion of the grab surface (upper 1-3 cm) was preserved in the field with buffered formalin solution (final pH = 8.3). In the laboratory, the preserved subsample was stained with Sudan Black B (Walker *et al.* 1974). The total foraminifera population (living specimens and empty tests) was isolated and concentrated using a 63 micron sieve and heavy liquid techniques (Gibson and Walker 1967). Specimen counting was carried out on total populations with a binocular microscope and results were converted to relative percentages of species.

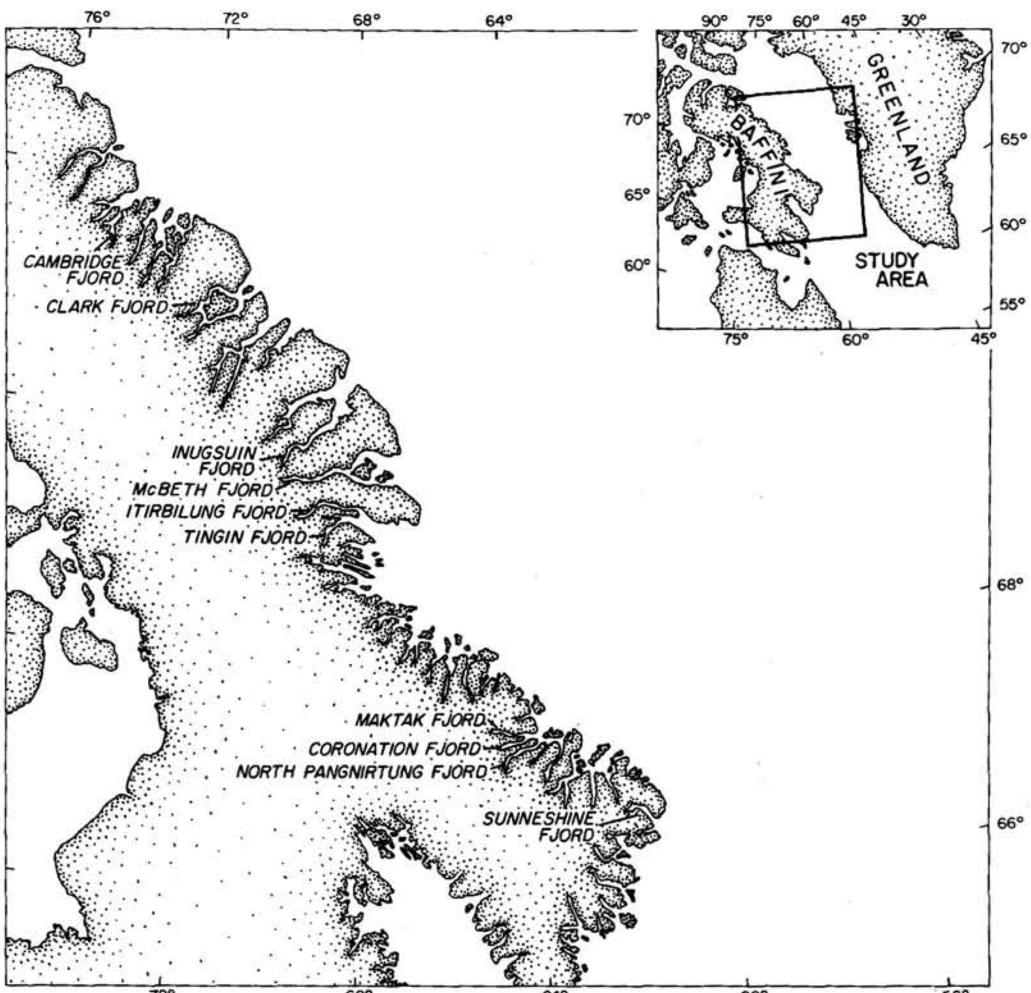

Fig. 1.
Location of fjords on the northeast coast of Baffin Island that were surveyed for this study.

These data were evaluated using R-mode factor analysis (Nie *et al.* 1975). Foraminiferal data referred to in this paper are tabulated in Clattenburg *et al.* (1983).

ENVIRONMENTAL SETTING

The ten fjords range in length from about 25 km to 100 km (table 1). Drainage basin areas vary by about a factor of six from a low of 564 km^2 for McBeth (Gilbert and MacLean 1983). Sills are from less than 100 m to more than 439 m deep and some fjords (e.g. McBeth and Cambridge) have several sills that divide them into distinct submarine basins. The depth of these basins ranges up to at least 800 m.

The fjords are covered by sea ice for up to 10 months each year and Alpine glaciers reach tidewater at the head of Coronation Fjord, or through side entry valleys in several of the other systems. Watermass properties are influenced by both cold arctic water (Canada Current) and relatively warm "Atlantic" water. Bottom water temperatures and salinities at the time of the survey were in the range of 1.3°C to (-) 1.5°C and 34.5‰ to 33.0‰ respectively (figure 2). The influence of Atlantic water is evident especially in the deeper parts of basins in Tingin, Clark and Cambridge fjords where bottom waters are warmer than 0°C below depths of 300m to 500m (Trites *et al.* 1983)

Suspended particulate matter (SPM) concentrations in surface waters can be in excess of 5.0 mg ℓ^{-1} near the edge of a tidewater glacier but are normally in the order of 1.0 mg ℓ^{-1}. Suspended sediments in the fjords have a modal grain size of about 15 microns (Asprey *et al.* 1983). The annual input of SPM per fjord shows a general inverse relationship to the fjord-averaged percent organic carbon in surface sediment (Syvitski, unpublished data).

Surface water primary production is typically 80-90 mg C M^3D^{-1} and bacterial biomass averages about 0.65 mg C M^3 (Albright and Stroh 1983). Most bottom sediments are more than 85% silt plus clay-size particles that have a modal total carbon and organic carbon content of about 1.3% and 0.7%

Table 1.
Morphological and geological characteristic of Baffin Island fjords (data from GILBERT & MACLEAN, 1983).

Fjord [Length in km]	Maximum Depth (m)	Drainage Basin Area (km 2)	Area Elevation Ratio (km /m)	Glacier Cover (%)	Sill Depth (m)	Tidal Prism (m^3x10^6)	Sediment Volume (m x10) Thickness [m]
Sunneshine [36]	215?	564	0.31	16	64	300	(?) [?]
North Panguirtung [48]	479	2064	1.05	35	None	155	(0.42) [40]
Coronation [41]	606	1128	0.60	70	None	142	(1.06) [130]
Maktak [26]	585	1132	0.60	47	None	65	(0.45) [70]
Tingin [47]	523	1228	0.83	37	180?	119	(2.10) [130]
Ititbilung [55]	435	2184	1.28	32	249	89	(3.60) [200]
McBeth [93]	563	3584	2.05	26	249	196	(7.67) [97]
Inugsuin [98]	633	2192	1.28	24	121	240	(1.83) [110]
Clark [67]	552	1324	0.81	40	108	57	(2.17) [200]
Cambridge [61]	708	1992	1.42	12	439	140	(6.55) [290]

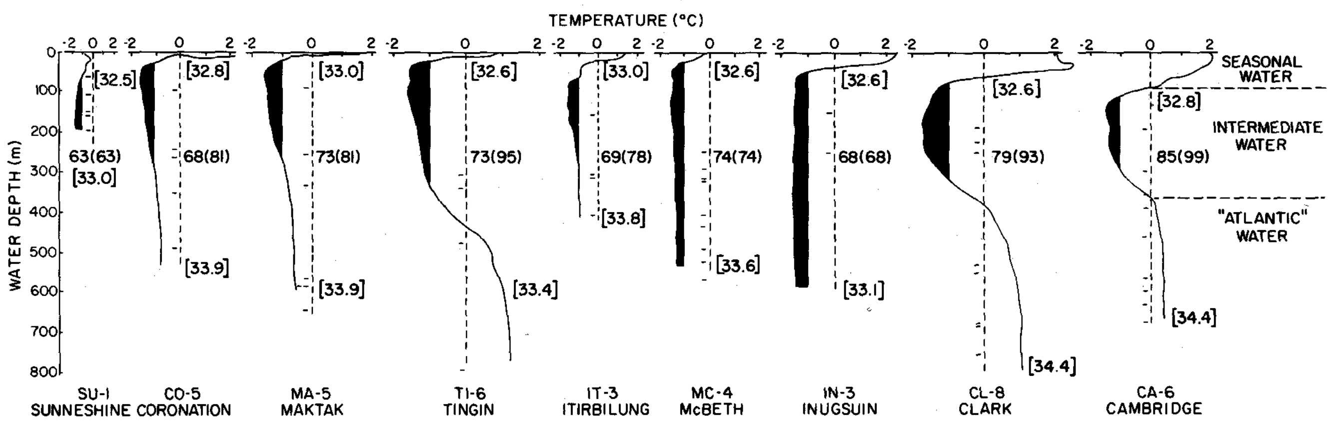

Fig. 2.
Water temperature profiles for representative stations.
Percentages of arenaceous species number averaged for each fjord (table 2) is shown to the right of the 0°C axis. The dashes shown to the left of the 0°C axis indicate the water depth from which the grab samples were collected (see Appendix I). In parenthesis is the arenaceous species number percentage observed in the cold intermediate water layer of each fjord. Darkened areas of water temperature profiles are ≤−1.0°C. Salinities at the top of the ≤−1.0°C layer and about 1 m above the bottom are shown in brackets to the right of the 0°C axis.

respectively (Clattenburg *et al.* 1983). Modal algal and bacterial biomass in surficial sediments is about 45 mg C M^3 and 38 mg C M^3 respectively. In Coronation, Itirbilung and McBeth fjords, surface sediment organic carbon percentages increase down fjord (Farrow *et al.* 1986).

RESULTS

General Characteristics of the Total Population: Between one and three thecamoebian species were observed in the samples; these forms are poorly represented in Maktak, Tingin and Itirbilung fjords.

Table 2.
Summary of foraminiferal assemblage characteristics.
Planktonic foraminifera are shown as upper to middle fjord occurrences (U) or middle to lower fjord occurrences (L). SD is the standard deviation of the various mean values.

FJORD [NO. OF SAMPLES]	SAMPLE DEPTH RANGE [M] MEAN DEPTH (M)	TOTAL SPECIES FORAM.	TOTAL SPECIES THEC.	DOMINANT SPECIES	AREN. SPECIES %	TOTAL N/CC	PLANK. FORAM
Sunneshine [5]	[67-215] (143)	54	2	R. arctica S. biformis	63	177	L
North Pangnirtung [3]	[80-347] (253)	31	2	TR. nana TE. earlandi	84	60	
Coronation [6]	[90-495] (294)	44	3	S. biformis TR. nana	68	50	U
Maktak [7]	[90-670] (440)	52	1	S. biformis TR. nana	73	75	L
Tingin [4]	[302-800] (484)	56	1	TE. earlandi TR. nana	73	124	U
Ititbilung [4]	[167-417] (302)	52	1	TE. earlandi A. glomerata	69	137	U
McBeth [9]	[250-572] (405)	42	2	TE. earlandi TR. nana/ A. glomerata	74	99	
Inugsuin [8]	[160-570] (385)	56	2	S. biformis R. arctica	68	124	
Clark [7]	[192-755] (486)	73	3	TE. earlandi TR. nana	79	124	U
Cambridge [10]	[366-681] (473)	79	3	TE. earlandi TR. nana	85	140	L
	Mean	= 54		Mean	= 74	111	
	SD	= 14.0		SD	= 7.2	39.6	

The most ubiquitous taxon is *Pontigulasia compressa* (see Clattenburg *et al.* 1983). Planktonic foraminifera tests of the arctic species *Neogloboquadrina pachyderma* were noted in Tingin, Itirbilung and Clark.

Benthic foraminifera and thecamoebians (fresh water protozoans) were studied in all of the grab samples (appendix I). The average total number of foraminifera species in the 10 fjords is 54 with a remarkably low standard deviation (SD) of only 14 (table 2). Seventy-five percent of these, on average, are agglutinated forms. The absolute total number of foraminifera in terms of number of tests per cubic centimeter of wet sediment (N/CC) averages 111 individuals (SD = 39.6), of which about an average of 91% are agglutinated specimens. The N/CC is highest in Sunneshine fjord. This fjord is the shallowest and the southernmost surveyed in this study. It is characterized by the highest fjord-averaged sedimentary organic carbon, and by one of the lowest annual inputs of suspended sediment (Syvitski, unpublished data).

Total foraminiferal assemblage in the east coast Baffin fjords is predominantly agglutinated (figure 2). *Textularia earlandi* is the dominant species in five fjords located north of latitude 68°N; it is of secondary importance south of this latitude in North Pangnirtung. *Spiroplectammina biformis* and *Trochammina nana* dominate in four fjords situated south of latitude 70°N. *T. nana* is an important secondary taxon in six of the fjords. It is replaced by *S.biformis* in Sunneshine where *Reophax arctica* is the dominant species and, respectively, by *Adercotryma glomerata* and *R. arctica* in Itirbilung and Inugsuin.

Paraecological Relationships:
In general, correlation coefficients of environmental variables and total population percentages of the most abundant species are low. Those having a significance level (P) of at least 5% are described below. Total agglutinated species percentages correlate positively with percent silt ($r = 0.31$; $P = 0.05$) and water depth ($r = 0.33$; $P = 0.05$) and inversely with percent thecamoebians ($r = -0.27$; $P = 0.05$). Living agglutinated population percentages show a weak relationship to water depth ($r = 0.26$; $P = 0.05$) and an inverse relationship to percent thecamoebians ($r = -0.26$; $P = 0.05$) and to percent gravel ($r = -0.38$; $P = 0.05$). Among the nine most abundant species in the total population, *Recurvoides turbinatus* shows a direct association with total agglutinated species percentage ($r = 0.37$; $P = 0.05$) and to the concentration of suspended particulate matter in bottom water ($r = 0.27$; $P = 0.05$). Total populations of *Trochammina nana* and *Saccammina atlantica* are inversely related to percent sand ($r = -0.32$ and -0.31; $P = 0.05$) and *S. atlantica* is positively associated to distance measured from fjord heads ($r = 0.39$; $P = 0.05$). *Trochammina nana* total percentages show an inverse relationship to bottom

Table 3.
Mean, standard deviation (SD), coefficient of variation (CV) of physical variables, and of total percentages for the nine most abundant arenaceous foraminifera species.

	MEAN	SD	CV(%)
Gravel (%)	1.0	5.0	500
Sand (%)	18.0	18.0	100
Silt (%)	44.0	10.0	22
Clay (%)	37.0	17.0	46
Bottom Water SPM (mg/l)	1.0	0.8	80
Bottom Water Salinity (‰)	32.0	7.2	23
Bottom Water Temp. (°C)	- 0.8	0.8	100
Bottom Water Oxygen (ml/l)	5.5	1.4	25
Water Depth (m)	388.0	184.0	47
Textularia earlandi (%)	17.9	14.0	78
Spiroplectammina biformis (%)	10.7	11.0	102
Trochammina nana (%)	9.3	7.4	79
Adercotryma glomerata (%)	8.4	7.2	86
Reophax arctica (%)	7.8	6.3	80
Textularia torquata (%)	6.6	5.5	83
Reophax fusiformis (%)	4.7	3.2	68
Saccammina atlantica (%)	4.7	4.4	93
Recurvoides turbinatus (%)	3.2	3.2	100

water oxygen concentration (r = -0.38; P = 0.05) and are positively correlated to percent clay and water depth (r = 0.45 and 0.31; P = 0.05).Both *Reophax arctica* and *S. biformis* total percentages show a comparatively strong inverse relationship to bottom water temperature (r = -0.54 and -0.53; P =

Table 4.
Summary of factor characteristics for nine comparatively abundant agglutinated species.

FACTOR [% VARIANCE]	VARIABLE	LOADING
1. Deep Lower Fjord Warm Water (0.5° C) Basin [13.6%]	Bottom water temperature	0.65
	SPM-bottom water	-0.23
	Reophax arctica	-0.34
	Spiroplectammina biformis	-0.23
	Adercotryma glomerata	-0.21
	Textularia earlandi	-0.19
2. Intermediate water depths and silty substrates [11.0%]	% Gravel	-0.58
	Water depth	0.26
	% Silt	0.27
	Recurvoides turbinatus	0.43
	Reophax arctica	0.31
	Textularia torquata	0.23
	Adercotryma glomerata	0.22
3. Intermediate to Shallow Depth - Inner Fjord Basin [9.3%)	Bottom water salinity	0.88
	Bottom water oxygen	0.79
	% Silt	0.28
	% Clay	-0.43
	Spiroplectammina biformis	0.22
	% Thecamoebians	-0.85
	Trochammina nana	-0.35
	T. earlandi	0.10
4. Lower Fjord Intermediate Basin Depth, Fine Substrate [6.7%]	Water depth	0.48
	Dist. from head of fjord (km)	0.43
	% Clay	0.24
	Saccammina atlantica	0.71
	Reophax fusiformis	0.56
	Adercotryma glomerata	0.48
	Trochammina nana	0.46
	Spiroplectammina biformis	-0.61
	Textularia earlandi	-0.22
5. Shallow Sill [5.3%]	% Gravel	0.61
	% Sand	0.64
	% Planktonic specimens	0.48
	Saccammina atlantica	-0.20
	Textularia earlandi	-0.24
6. Middle to Lower Fjord Intermediate Depth [4.9%]	Bottom water temperature	-0.32
	Distance from head of fjord	0.43
	Reophax arctica	0.66
	Textularia torquata	0.54
	Spiroplectammina biformis	0.27
	Trochammina nana	-0.44
	Textularia earlandi	-0.77

0.05). These correlations point to the physical setting of deep fjord basins as the favored habitats for the relatively dominant agglutinated species.

Textularia earlandi, Spiroplectammina biformis and *Trochammina nana* are the three most abundant taxa in the study area (table 3). Their coefficients of variation suggest comparatively uniform distribution patterns within the depth interval represented by the samples (table 2). *T. earlandi* is most abundant (>50%) near the head of Itirbilung and McBeth fjords and in the basins of Cambridge, Clark, McBeth, Tingin, and Coronation (figure 3A, B), but is under-represented in Inugsuin and Sunneshine. The latter two fjords are distinguished by below average agglutinated species number and percent hinterland glacier covers, and by above average tidal prisms.

Spiroplectammina biformis shows an inverse relationship to *T. earlandi*. *S. biformis* is well represented in Inugsuin and Sunneshine; it is about equal in abundance to *T. earlandi* in Clark, and is under-represented in the other fjords (figure 4A, B). The abundance distribution of *Trochammina nana* is comparable generally to *T. earlandi* and tends to be highest in the deep offshore basins that are found in the central reaches of most fjords (figure 5A, B).

R-mode common factor analysis of nine environmental variables and 36 species having mean total percentage abundances ≥0.1% indicated that only 51% of the total variance was included in the first six factors. Tentative species-environment associations are described below for the nine comparatively abundant species listed in table 3 based on their varimax rotated factor loadings (table 4).

Factor 1 describes a deep basin warm water environment that occurs where lower fjord to inner shelf basins are flushed by bottom water of Atlantic origin (e.g. Cambridge fjord). Bottom water temperatures in these areas are usually above 0°C and range up to 0.5°C (Trites *et al.* 1983). Many of the nine most abundant agglutinated species are negatively loaded on this factor.

Factor 2 describes a high total agglutinated species percentage setting that is characterized by intermediate water depths and silty substrates. *Recurvoides turbinatus* has a high loading on this factor. Except for Sunneshine, *R. turbinatus* and *Reophax arctica* tend to be comparatively abundant in middle fjord basin environments. *R. turbinatus* is also relatively abundant in basins located in the upper part of Cambridge, McBeth and Inugsuin fjords and *R. arctica* is relatively abundant in the upper reaches of Sunneshine fjord. At Sunneshine station SU-01, *R. artica* appears to be responding to both temperature and substrate. Bottom water temperature at SU-01 is lower than -1.5°C in September. The correlation of bottom water temperature and *R. arctica* percentage in the 63 sample suite is strongly inverse ($r = -0.54$; $P = 0.05$). The high percentages of *R. arctica* observed at the heads of Inugsuin, Cambridge and McBeth (average per cent *R. arctica* = 14.2 versus 16.7% at Sunneshine) are associated with an average silt percentage of 46.0 that is essentially similar to the 50.1% value observed at Sunneshine station SU-01.

Factor 3 is negatively loaded on thecamoebians and positively loaded on bottom water salinity, bottom water dissolved oxygen and per cent silt; it is negatively loaded on clay size particles. These conditions are most analogous to those observed at shallow to intermediate depths in middle fjord basins. *Spiroplectammina biformis* is the indicator species for this environment. In general, its abundance is highest in the upper basins of Cambridge, Clark, Inugsuin, Maktak and Coronation fjords. These settings are often marked

Table 5.
Relationship between agglutinated species number percentage, the 8-fjord average, and textural and environmental variables.
Standard deviations for % clay and % arenaceous specimen mean are shown in paranthesis.

LOCATIONS	% HINTERLAND GLACIER COVER	TIDAL PRISM M-3X10-6	% CLAY	% AREN.SP.	% AREN. SPECIMENS
8-fjord average	37	120	39.4 (17.1)	76	91.6 (8.3)
Inugsuin Fjord	24	240	31.8 (11.8)	68	93.1 (10.4)
Sunneshine Fjord	16	300	18.8 (18.3)	63	80.3 (28.6).

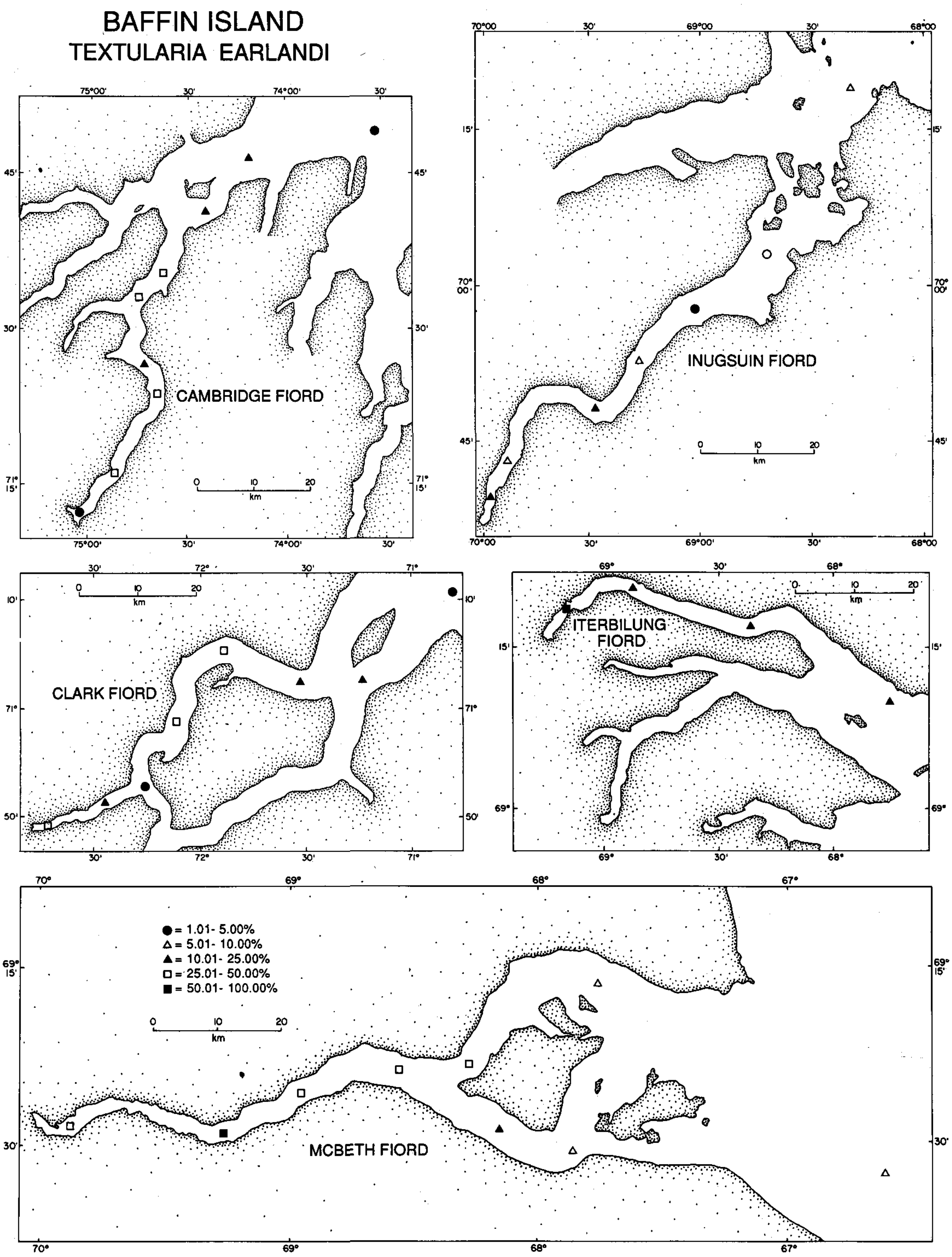

Fig. 3.
Distribution of *Textularia earlandi* total population percentages in ten Baffin Island fjords.

by increased percentages of *T. earlandi* and reduced numbers of *Trochammina nana*.

Factor 4 describes a lower fjord, intermediate depth (50-450 m) clayey substrate basin environment but with colder bottom water temperatures than are associated with the Factor 1 environment. The Factor 4 environment is comparable to conditions that are also described by Factor 6 loadings. Factor 4 is negatively loaded on bottom water temperature and on water depth, suggesting conditions associated with the intermediate depth cold water layer (≤ -1.0°C and 50-200 m) that is indicative of the water column structure of many fjords along this part of the coast. *Saccammina atlantica* has a relatively high positive loading on this factor.

Factor 5 reflects a distinctive shallow sill setting. It is positively loaded on per cent gravel, per cent sand and on per cent calcareous planktonic specimens.

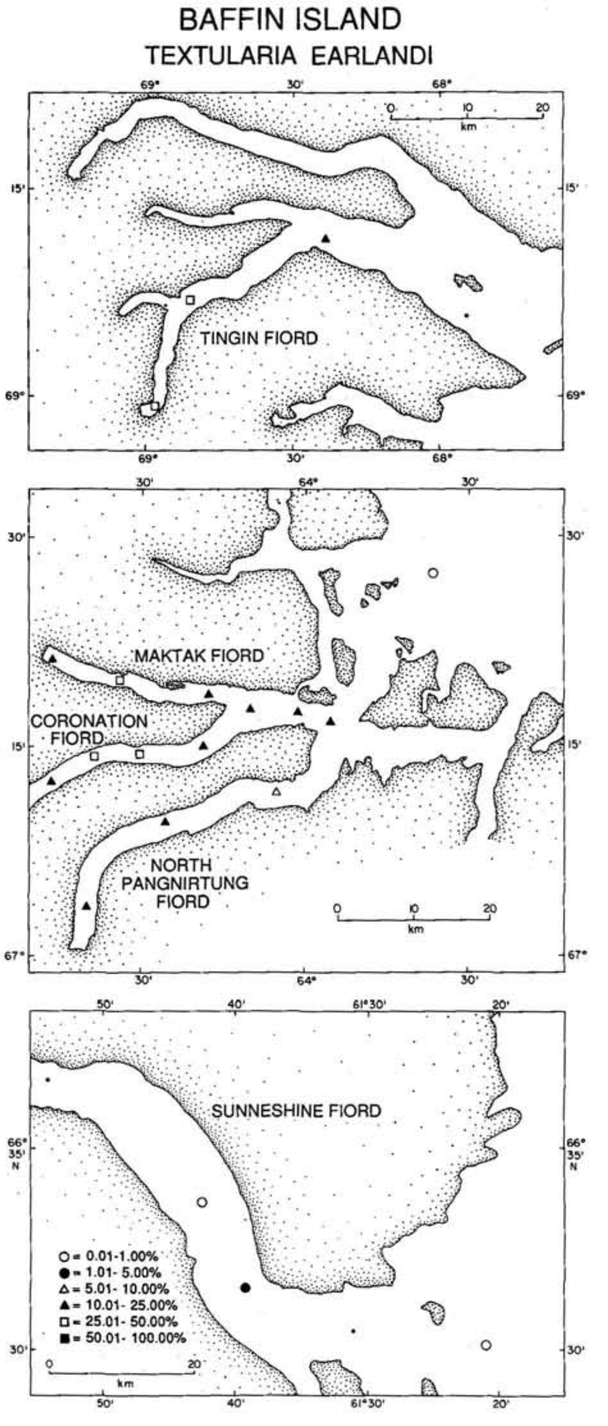

Fig. 3 (continued).

The associated agglutinated assemblage is distinguished by its reduced percentages of intermediate depth fjord basin species such as *Saccammina atlantica* and *T. earlandi*.

DISCUSSION

In many of the arctic fjords discussed here, agglutinated foraminifera appear to be related to cold water temperatures, with highest population densities occurring in environments exposed throughout the year to less than -1.0°C water. This intermediate depth watermass lies below the seasonal layer and above the comparatively warm and saline "Atlantic" water (figure 2). Water temperatures $\leq$ -1.0° C are confined to the upper 150 m of the water column in several western arctic channel environments. Within this depth interval of the channels, agglutinated forms such as *Spiroplectammina biformis*, *Cribrostomoides crassimargo*, *Textularia torquata* and *Trochammina nana* are relatively abundant (Vilks 1969). These distributions are consistent with those observed by Iqbal (1973) who described a nearshore fine-grained substrate thanatotope in M'Clure Strait (western arctic) that was marked by large numbers of *C. crassimargo*, *Textularia earlandi* and by species of *Trochammina*. *Trochammina nana* was one of four prominent agglutinated species in the 230-505 m depth interval of the Strait which is characterized by comparatively warm (0.0° C to + 1.0° C) temperatures. *T. nana* distributions follow a similar pattern in several of the Baffin fjord basin environments having relatively higher abundances in waters that are warmer than -1.0°C in Coronation, Maktak and Cambridge fjords (figure 5A,B).

In the western half of Baffin Bay, agglutinated foraminifera such as *Adercotryma glomerata*, *Spiroplectammina biformis*, *Textularia torquata* and *Trochammina nana* are prominent members of an intermediate depth (150-400 m) association (Hume 1972). One unique difference between the Baffin fjord basin and Baffin Bay assemblages is the occurrence of large numbers of *Eggerella advena* in the shallow seasonal layer between 20 and 170 m depth in Baffin Bay (Hume 1972). In the Bering Sea (Anderson 1963) and Hudson Bay (Leslie 1965), the species appears to thrive in comparatively sandy substrates.

In the relatively temperate setting of the Gulf of St. Lawrence, Rodriguez (1980) identified an agglutinated foraminifera association (his Association No. 3) that is dominated by *Adercotryma glomerata*, and that occurs within a comparatively cold intermediate depth (70-150 m) watermass off the south shore of Anticosti Island. This cold watermass is also reflected by a significant increase in agglutinated species diversity between the 50 and 200 m isobaths (Rodriguez 1980, figure 1.16). This relationship is comparable to the association in Baffin fjord environments of poorly represented forms such as *Recurvoides turbinatus* (mean abundance = 3.2%) with relatively dense agglutinated populations that may denote an intra-specific rather than an environmental association.

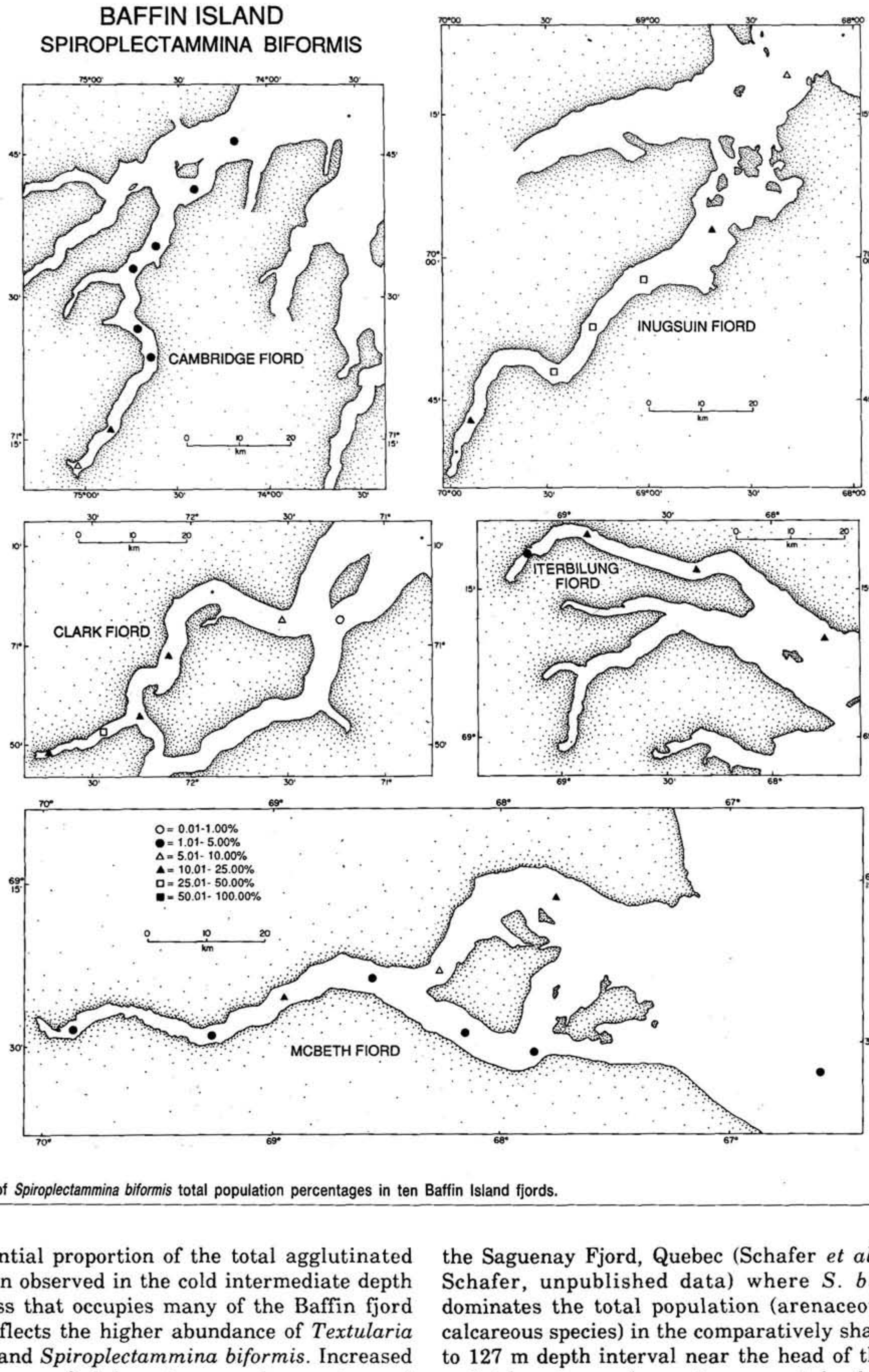

Fig. 4.
Distribution of *Spiroplectammina biformis* total population percentages in ten Baffin Island fjords.

A substantial proportion of the total agglutinated population observed in the cold intermediate depth watermass that occupies many of the Baffin fjord basins reflects the higher abundance of *Textularia earlandi* and *Spiroplectammina biformis*. Increased percentages of *Adercotryma glomerata* and *Trochammina nana* are evident below the cold intermediate layer especially in Coronation and Maktak fjords (figures 6 and 7). This general distribution stands in contrast to that observed in the Saguenay Fjord, Quebec (Schafer *et al.* 1980; Schafer, unpublished data) where *S. biformis* dominates the total population (arenaceous plus calcareous species) in the comparatively shallow 87 to 127 m depth interval near the head of the fjord and *Adercotryma glomerata* occurs at depths below 127 m in association with increased percentages of *C. crassimargo* and *Reophax fusiformis*. The *S. biformis, A. glomerata* transition in the Saguenay Fjord appears to be unrelated to water temperature

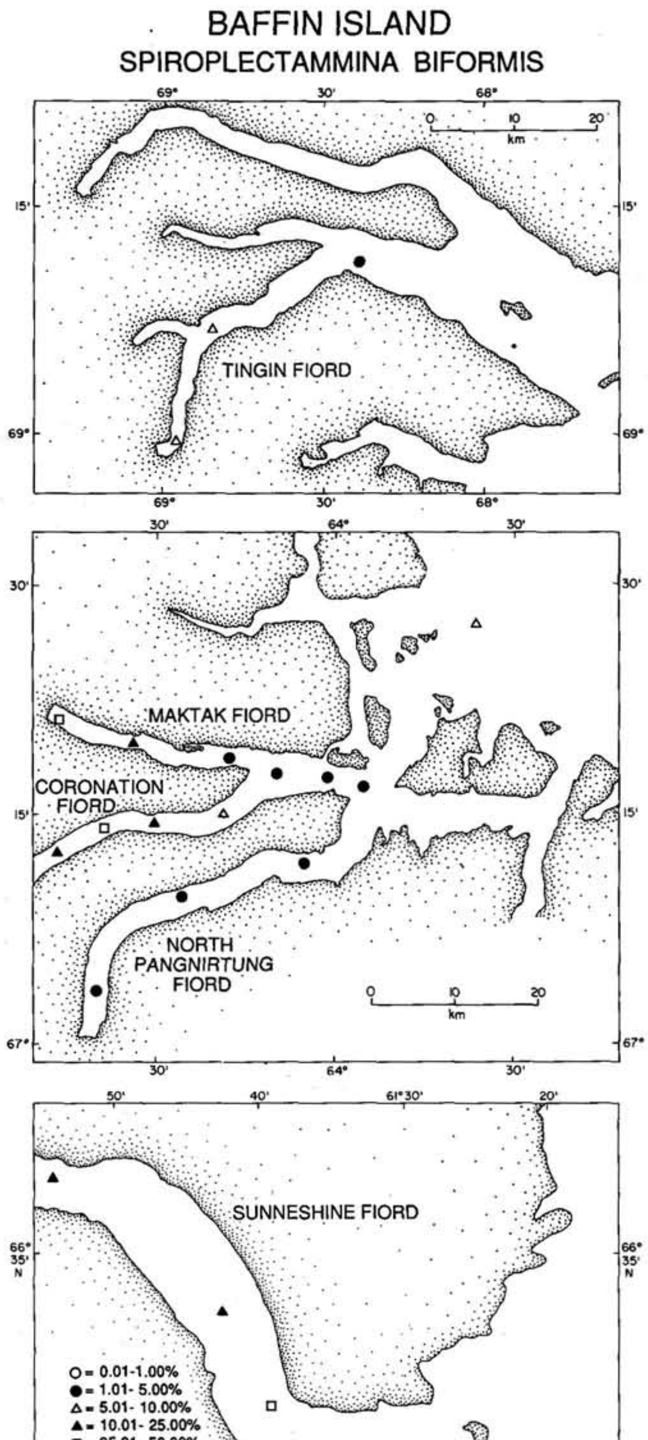

Fig. 4 (continued).

and may be associated instead with SPM and substrate changes that characterize the estuarine gradient in this part of the fjord. It is interesting to speculate on the reason for the well developed *S. biformis* - *A. glomerata* depth relationship in Coronation and Maktak fjords. These fjords have the highest hinterland glacier cover of the 10 fjords surveyed (table 1). The runoff of glacier meltwater into the head of these two fjords is considerably higher (≈40%) than that noted for the eight other fjords surveyed (Syvitski, personal communication). This condition may influence the spatial and temporal character of the estuarine gradient in these two systems in a way that tends to approach those developed under the more temperate conditions found in the Saguenay Fjord.

Previous studies have often suggested that neither sedimentary characteristics, temperature nor salinity are mutually exclusive in controlling the distribution of agglutinated species (e.g. Kennett 1968; Corliss 1979 a,b; Anderson 1963; Iqbal 1973). In contrast, Hofker (1972) concluded that bottom water temperature was the key factor controlling the overall occurrence of agglutinated species while Leslie (1965) indicated that water depth and substrate were of major importance as limiting factors in Hudson Bay. Lindenberg and Auras (1984) reported that clay content correlated directly with the occurrence of agglutinated species on the Antarctic slope but noted that deep-sea faunal composition is controlled primarily "by the overall situation of an oceanic area rather than by depth of oceanographic factors like temperature or salinity." Nevertheless, it is interesting to note that their two study areas are also marked by the presence and absence of cold Antarctic slope water which is the dominant watermass in the clay-enriched area. In shallow Antarctic waters, Mullineaux and Delaca (1984) found living *Trochammina* specimens in abundant numbers on both bivalve surfaces and in bottom sediment although there seemed to be a slightly greater preference for soft sediments as opposed to hard substrates.

The relationship of the total number of agglutinated species in Inugsuin and Sunneshine fjords to an average total species number observed in the eight other fjords investigated in this study suggests a direct relationship between per cent clay and the number of agglutinated species (table 5). Percent clay, in turn, appears to be inversely associated with the size of the tidal prism and directly related to the percentage of the respective fjord hinterland covered by glaciers. These relationships could imply that tidal currents disperse (i.e. dilute) clay size particles derived from the melting of glaciers over wider areas of some fjord basins thereby enlarging the preferred habitat of some agglutinated species.

The strongest correlations in the Baffin fjords data set are inverse relationships between water temperature and agglutinated species percentages that reflect the increase in abundance of these forms in the relatively cold (≤ -1.0°C) intermediate depth water layer that was observed in the majority of fjords surveyed. Evaluation of this relationship for the species *Reophax arctica* and *Spiroplectammina biformis* suggests some interesting possibilities.

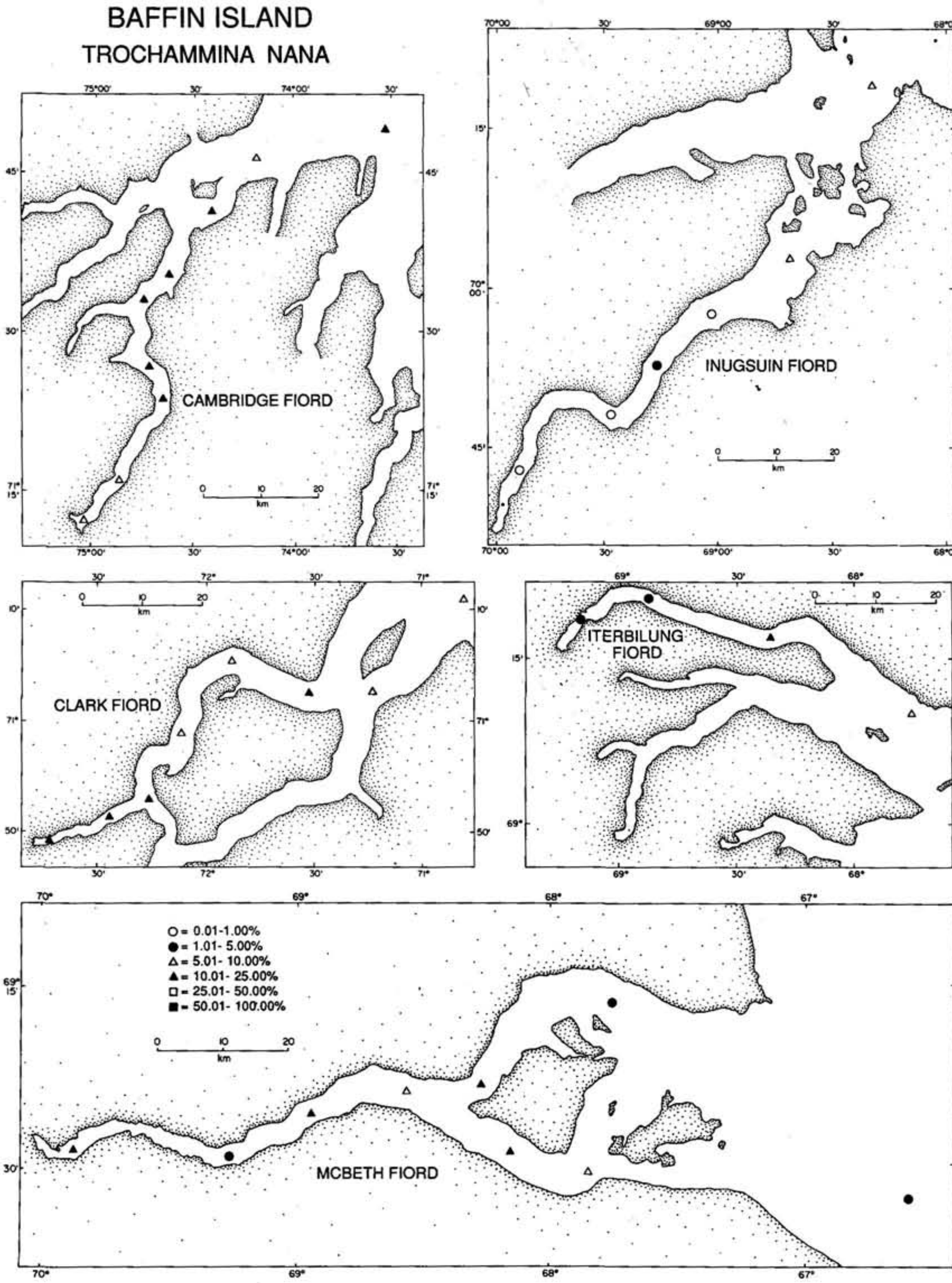

Fig. 5.
Distribution of *Trochammina nana* total population percentages in ten Baffin Island fjords.

High percentages of both species are confined typically to water temperatures of ≤ -1.0°C (figures 8 and 9). Given their apparent preference for very cold water and, to a lesser extent, for fine sediment substrates, their rare occurrence in shallow + 0°C water in association with comparatively coarse sediments, as determined during the September 1982 survey, may be the result of a migration phenomenon that could have taken place during the preceding fall and winter. At that time, specimens could have moved up into the seasonal water layer following a decrease in its temperature to below zero values. The impetus for this migration might be related to food supply since organic detritus is considerably more abundant in the photic zone of these shallow nearshore environments (i.e. the upper 10 m - 20 m). This proposed seasonal feeding habit may indicate a relationship between nutrition requirements, intraspecific competition (e.g. Muller 1975), and the timing of reproduction which is

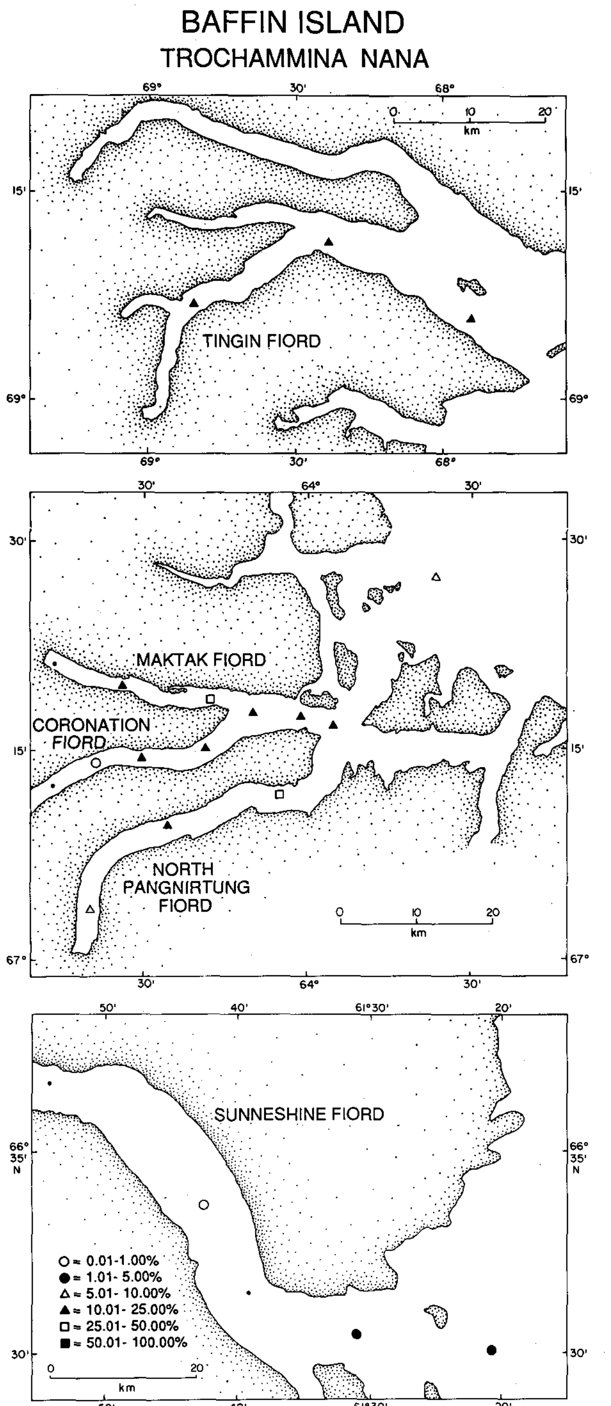

Fig. 5 (continued).

presumed to occur during the following spring and summer. On the other hand. shallow water occurrences of *R. arctica* and *S. biformis* could include allochthonous specimens derived from raised pre-recent coastal deposits that are now being eroded (e.g. Leslie 1965). They may also represent tests abandoned during the annual reproduction cycle, or those specimens that were unable to migrate to deeper water following the breakup of sea ice and the rewarming of the seasonal layer. Migration to deeper water during the spring/summer season might reflect a natural response of agglutinated foraminifera to the predation habits of larger indigenous shallow water organisms (e.g. Brand and Lipps 1982).

SUMMARY

On average, about 75% of the total number of foraminifera species observed in the surface sediments of 10 Baffin Island fjords are agglutinated types that represent 91% of the total specimen population. The three most abundant species are *Textularia earlandi*, *Spiroplectammina biformis* and *Trochammina nana*. Correlations of species percentages to environmental variables indicate a comparatively strong inverse relationship for several species in regard to fjord bottom water temperature. An artifact of this association appears to be the inverse relationship of many agglutinated species with respect to comparatively coarse (*i.e.* sandy) substrates that are found in the fjords mostly in nearshore shallow waters and in offshore sill environments.

Because of the direct effect of winter climate on sea ice formation (and indirectly on light penetration) and on the temperature of the seasonal shallow water layer, some species may migrate to shallower depths as part of a winter feeding strategy that transcends the influence of fine substrate texture which apparently exerts a significant control on distributions during the warmer ice free seasons. In the Baffin fjords, this hypothesis may be exemplified by the percentage abundance distributions of species such as *Reophax arctica* and *Spiroplectammina biformis* with respect to bottom water temperature during the early autumn season.

FAUNAL REFERENCE LIST

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Recurvoides turbinatus (Brady) Loeblich and Tappan, 1953. Smithsonian Misc. Coll. v. 121, No. 7, p. 21, plate 1, figures 19-20.

Reophax arctica (Brady) Loeblich and Tappan, 1953. Smithsonian Misc. Coll. v. 121, No. 7, p. 21, plate 1, figures 19-20.

Reophax fusiformis (Williamson) Parker, F., 1952. Bull. Mus. Comp. Zool., v. 106, No. 9, p. 395, plate 1, figures 11-19.

Saccammina atlantica (Cushman) Parker, F., 1952. Bull. Mus. Comp. Zool., v. 106, No. 10, p. 454, plate 1, figures 1-2.

Spiroplectammina biformis (Parker and Jones) Loeblich and Tappan, 1953. Smithsonian Misc. Coll., v. 121, No. 7, p. 34, plate 4, figures 1-6.

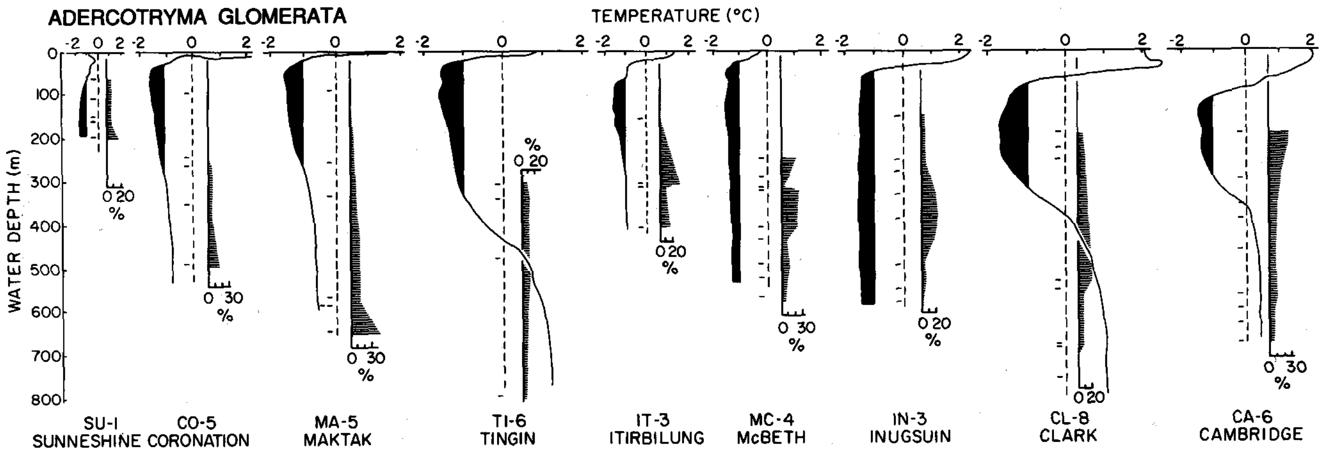

Fig. 6.
Bathymetric distribution of *Adercotryma glomerata* total population percentages in relation to water temperature variations observed in the Baffin Island fjords.

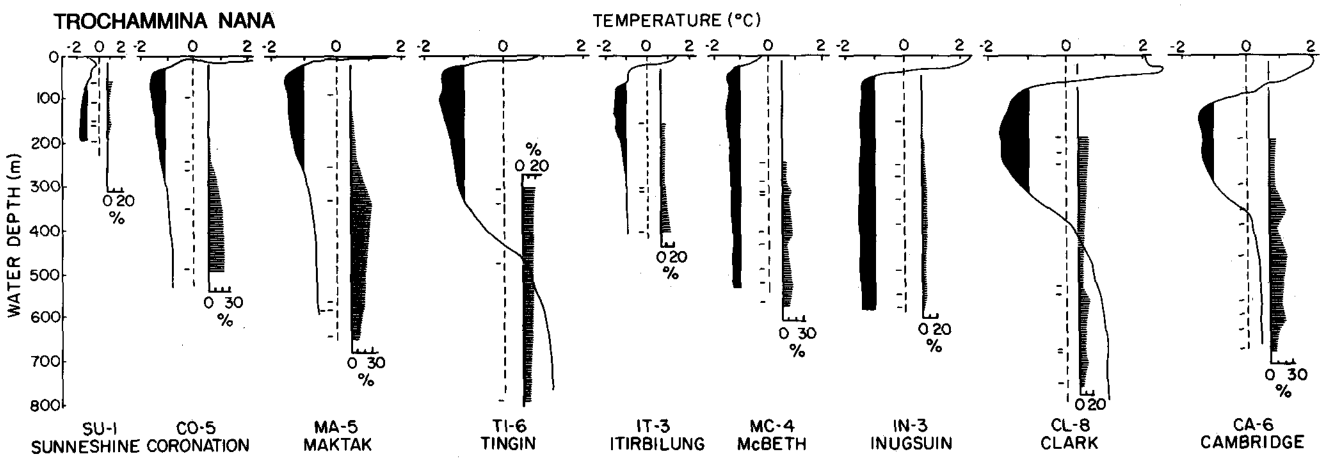

Fig. 7.
Bathymetric distribution of *Trochammina nanna* total populations in relation to water temperature variations observed in the Baffin Island fjords.

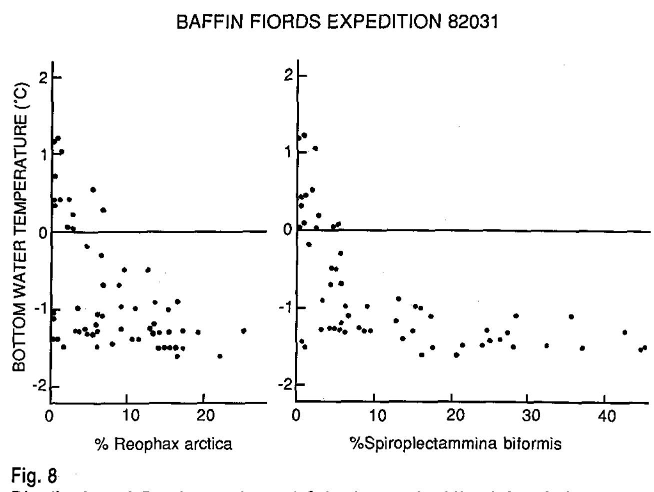

Fig. 8
Distribution of *Reophax arctica* and *Spiroplectammina biformis* in relation to water temperature in the Baffin Island fjords.

Textularia earlandi Phleger Feyling-Hanssen, 1964. Norges Geol. Unders. NR 225, p. 238, plate 3, figures 9-10.

Textularia torquata F. Parker Loeblich and Tappan, 1953. Smithsonian Misc. Coll., v. 121, No. 7, p. 25, plate 2, figures 19-21.

Trochammina nana (Brady) Loeblich and Tappan, 1953. Smithsonian Misc. Coll. v. 121, No. 7, p. 50, plate 8, figure 5.

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Appendix I.
Summary of station locations and water depths.

Station	Latitude(N)	Longitude(W)	Depth(m)
MCBETH			
MC-1	69°31.9'	69°47.5'	329
MC-3	69°31.4'	69°16.0'	440
MC-4	69°34.7'	68°57.0'	530
MC-5	69°36.8'	69°35.0'	572
MC-6	69°31.7'	68°09.4'	415
MC-7	69°37.5'	68°16.0'	497
MC-8	69°44.0'	67°44.0'	290
MC-9	69°30.0'	67°51.0'	326
MC-11	69°29.5'	66°39.0'	250
INUGSUIN			
IN-1	69°40.8'	69°43.5'	160
IN-2	69°42.9'	69°54.0'	280
IN-3	69°48.8'	69°33.0'	557
IN-4	69°53.0'	69°17.3'	585
IN-5	69°58.5'	69°02.0'	503
IN-6	70°03.8'	68°41.4'	267
IN-7	70°19.1'	68°19.2'	338
IN-8	70°23.1'	68°03.6'	391
CLARK			
CL-1	70°49.6'	72°37.0'	192
CL-2	70°50.0'	72°27.0'	234
CL-3	70°52.8'	72°15.7'	256
CL-4	70°58.5'	72°07.3'	530
CL-5	71°05.5'	71°53.0'	683
CL-6	71°02.7'	71°31.0'	552
CL-7	71°02.6'	71°13.7'	685
CL-8	71°10.9'	70°49.2'	755
CAMBRIDGE			
CA-1	71°12.5'	75°00.0'	196
CA-2	71°16.6'	74°52.0'	316
CA-3	71°23.6'	74°40.0'	366
CA-4	71°26.5'	74°43.7'	476
CA-5	71°33.0'	74°45.7'	575
CA-6	71°34.9'	74°40.0'	640
CA-7	71°41.3'	74°25.2'	398
CA-8	71°46.9'	74°12.3'	681
CA-9	71°48.8'	73°31.0'	610

Appendix I (continued).

Station	Latitude(N)	Longitude(W)	Depth(m)
SUNNESHINE			
SU-1	66°36.9'	61°53.8'	215
SU-5	66°33.3'	61°42.6'	155
SU-6	66°30.7'	61°39.2'	117
SU-7	66°29.3'	61°31.0'	67
SU-8	66°33.1'	61°11.8'	160
CORONATION			
CO-1	67°12.5'	64°46.5'	98
CO-2	67°14.1'	64°38.0'	248
CO-3	67°14.5'	64°30.0'	269
CO-4	67°15.2'	64°18.2'	356
CO-5	67°17.8'	64 09.0'	497
MAKTAK			
MA-1	67°21.3'	64°46.5'	90
MA-2	67°19.7'	64°33.6'	257
MA-4	67°18.9'	64°17.0'	333
MA-5	67°17.5'	64°01.0'	585
MA-5A	67 16.8'	63°55.0'	575
MA-6A	67°27.4'	63°35.4'	658
MA-7	67°34.8'	63°34.6'	585
NORTH PANGNIRTUNG			
NP-1	67°03.5'	64°40.0'	80
NP-2	67°09.5'	64°25.0'	347
NP-3	67°11.6'	64°05.0'	333
TINGIN			
TI-1A	69°05.4'	68°54.0'	302
TI-2	69°07.0'	68°50.5'	347
TI-3	69°11.5'	68°23.5'	487
TI-6	68°48.9'	66°05.4'	800
ITIRBILUNG			
IT-1	69°18.5'	69°10.0'	167
IT-2	69°20.5'	68°53.0'	320
IT-3	69°16.9'	68°22.0'	417
IT-4	69°10.0'	67°45.0'	303