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Charles F. Stehman

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Reports

Planktonic Foraminifera in Baffin Bay, Davis Strait and the Labrador Sea*

CHARLES F. STEHMAN
Department of Geology, Dalhousie University, Halifax, N. S.

Introduction

In the summer of 1970, the Canadian Scientific Ship DAWSON spent eight weeks on a geological cruise into the waters of Baffin Bay, Davis Strait, and the Labrador Sea. Though it was not the primary objective of the cruise, sediment samples and plankton net tows of sufficient number were taken to make possible some conclusions concerning the distribution of planktonic foraminifera in these areas. Planktonic foraminifera are of interest to both the geologist and the oceanographer, for, as Bé and Hamlin (1967), Jones (1964) and others have shown, they have excellent potential for use as paleo-oceanographic indicators. Information will be given here concerning the taxonomic distribution abundances and also the species form variation of planktonic foraminifera in 22 sediment and 30 net tow samples, taken in the above-mentioned areas. Where data have been available, some attempts have been made to correlate paleontological data with oceanographic observations.

As far as the author is aware, this is the first comprehensive work done on planktonic foraminifera from this area; however, other studies of foraminifera in polar waters have been made. Planktonic foraminifera from sediments of Arctic waters have been described by Parker and Jones (1865), Loeblich and Tappan (1953), Vilks (1969), Brady (1884), but these studies were concerned primarily with benthonic rather than planktonic foraminifera. Certain northern polar forms of planktonic foraminifera have been studied (Bé, 1960), but little information was given about distribution patterns.

In southern polar waters, studies by Bé (1969), Boltovskoy (1969), and Kennett (1968) have dealt with the distribution of planktonic foraminifera more thoroughly, and to date have presented the greatest amount of information on planktonic foraminifera in higher latitudes. During the present study, the work of Kennett (1968) on variation in form of the species *Globigerina pachyderma* has proven particularly interesting in relation to similar observations in northern waters.

Sample Localities

Stations from which planktonic foraminifera were sampled from their biocoenose and thantocoenose are shown on Figure 1. The squares indicate net tows, while triangles indicate bottom samples. At many stations both bottom samples and net tows were taken; these are indicated by circles. It is only proper to point out the lack of samples from a large area of Baffin Bay and along Baffin Island. This was due to ice, which prevented the ship from entering that general area.

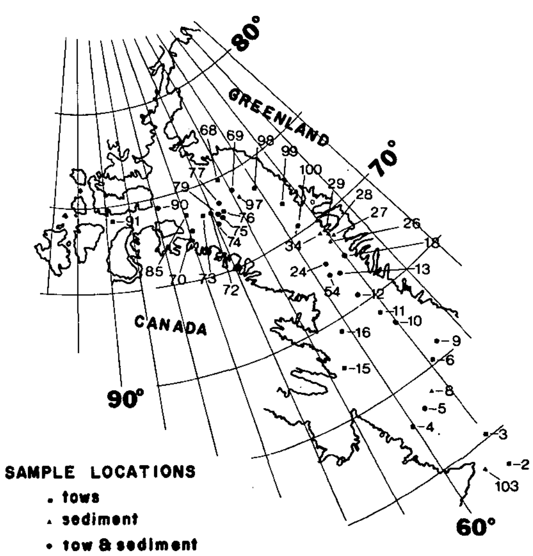

Figure 1 – Location of plankton tow and bottom sample stations.

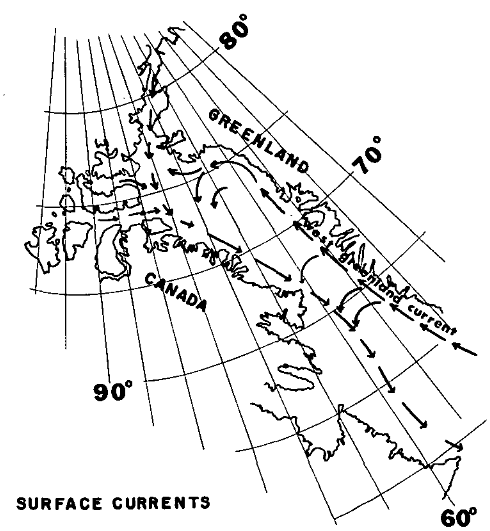

Figure 2 – Surface circulation in area of study.

* Manuscript received June 30, 1972.

Procedures

Planktonic foraminifera were collected for study by two means: 1) grabs and cores of bottom sediments, and 2) plankton net tows through the water column. The bottom samples were stored and brought to the laboratory, where they were washed for micropaleontological studies of both planktonic and benthonic foraminifera, the latter not being dealt with in this paper. However, it is worth noting that the benthic foraminifera greatly outnumbered the planktonics in all bottom samples.

Plankton collections were made with a 200-mesh nytex plankton net with a 75-cm diameter. All collections consisted of vertical tows to 200 metres. The volumes of water filtered in each tow were measured with an Ogawa Seki T.S. flow meter suspended in the centre of the net opening. Collections were preserved in a 15% formaldehyde solution buffered with hexamethylene tetramine.

In the laboratory, the plankton samples were ashed and the residue washed to a concentrate of hard parts from foraminifera, diatoms, pteropods and radiolarians (Sachs et al, 1964). The plankton and bottom sample concentrates were split to a fraction containing about 200 to 300 foraminifera which were then examined microscopically. Where the samples did not contain 200 specimens, counts were still made and the data used. Such statistically poor samples are indicated in the data that follow.

Hydrology

The oceanographic information collected concurrently with the planktonic foraminiferal tows was insufficient to allow any conclusive statements concerning relationships between foraminiferal data and hydrology. Few studies have been conducted in this area, especially on a year round basis because of ice, and thus some significant problems remain unsolved. The most tenable information on the hydrology can be found in papers by Killerich (1933), Dunbar (1951), and Collin and Dunbar (1964). This information, especially concerning Baffin Bay, is briefly summarized here as it will be useful in discussion of data presented later.

Essentially three water types come into play in Baffin Bay: 1) Polar water derived from the Arctic Ocean via Lancaster, Jones and Smith sounds. This water is quite cold (-1.7 to -0.2°C) and ranges from 32 to 34 $^{o}/oo$ saline; 2) West Greenland current water from the North Atlantic which in places is comparatively warm (+1 to 7°C) and has a salinity between 32.5 and 35$^{o}/oo$; and 3) Baffin Bay water which is a combination of the first two types, and can be found with various salinities and temperatures depending on where it is located (Dunbar, 1951). The interaction of these water types is controlled mainly by the currents that drive type 1 and type 2 into the area. The West Greenland current following the coast of Greenland and the Arctic water running down the coast of Baffin Island (the Canadian Current) develop a somewhat predictable circulation pattern shown in Figure 2 (from Dunbar, 1951). Mixing of these two currents and their respective water types in Baffin Bay presents a noticeable effect especially in northern Baffin Bay where relatively unaltered West Greenland and Arctic water produce oceanographic conditions that differ considerably from the rest of the Bay.

Killerich (1933) as translated in Dunbar (1951) describes a situation of extensive vertical mixing or circulation in northern parts which is responsible for a lack of water stratification in much of the area, and for open (ice free) water most of the year. His hypothesis to explain this remains to be proven or disproven. It states that the West Greenland current water travelling to the northern extremity of Baffin Bay cools and sinks to a depth of 250 to 300 metres. In the northern part of the Bay, encounter with denser Arctic water brings about an interchange of position of these two water types and thus sets up vertical circulation. The resulting lack of stratification and year-round ice free water could conceivably have some influence on the biota living in this area and, in any case, it is commonly accepted by investigators of planktonic foraminifera that highest densities of these organisms occur in areas of upwelling or water mass confluence where two water masses come in contact. A similar situation may occur in the northern part of Davis Strait (the vicinity of stations 13, 18, 24, 54 - see Fig. 1). West Greenland current water that has entered Davis Strait from the Labrador Sea cools and sinks until it is confronted with a shallow bottom sill in the area mentioned, which forces the current flow upwards.

The northern area of mixing considered by Killerich (1933) is actually north of any samples taken in this study, but Dunbar (1951) has suggested that similar phenomena may occur in a more southerly region west of Lancaster Sound and Pond Inlet, an area from which samples for the present study have been obtained.

Results

A. Total planktonic foraminiferal fauna abundance:

Density of living planktonic foraminifera populations was measured by the use of flow meter

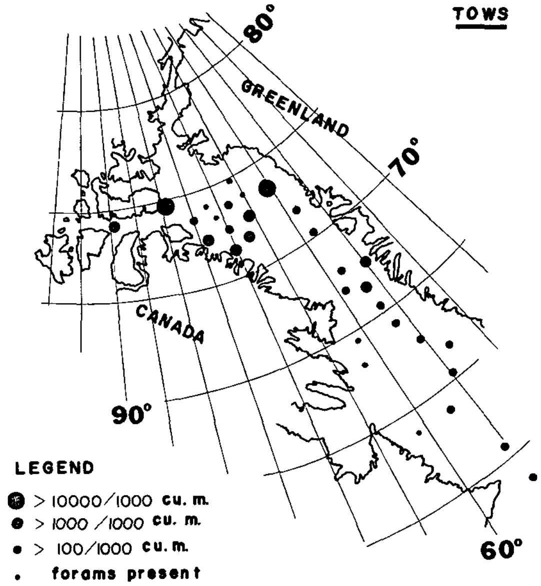

Figure 3 – Density of living planktonic foraminifera at stations in Baffin Bay, given in number of individual/1000 curic metres of water.

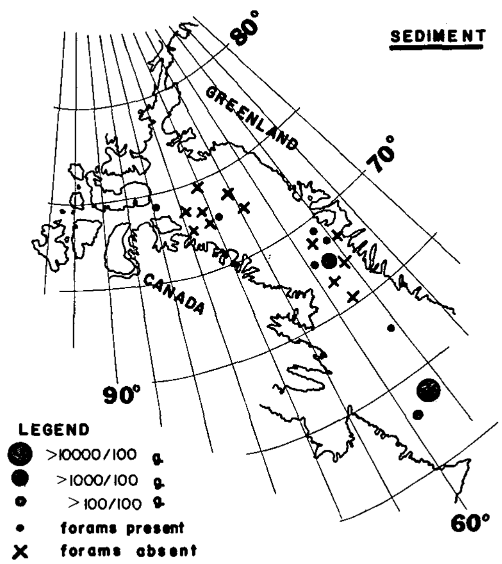

Figure 4 – Density of planktonic foraminiferal tests in sediment samples from study area given in number of individuals/gram of sediment.

data and foraminiferal counts of ashed samples. The densities are given in Figure 3 as the number of planktonic foraminifera of all species present in 1000 cu.m. of sea water. Figure 4 represents the planktonic foraminifera density in the thanatocenose, or sediment, and is derived from a count of the number of individuals per 100 grams of unwashed sediment.

Dealing first with the live material, one finds that for a majority of the stations the faunal density is an order of magnitude less than that for stations in the temperate waters of the Atlantic taken by Bé and Hamlin (1967) and others. This was expected since Vilks (1970) had noted considerable reduction in faunal density in the northern waters of the Canadian Arctic. Daylight and non-daylight stations in the same region showed little appreciable variation; however, due to the northern latitude of the study area and the time of year, most net tows were taken in some daylight.

As shown in Figure 3 there is some variation in the population of planktonic foraminifera at different localities in the study area. If one had not studied the foraminifera in this area an obvious hypothesis might state that with increasing latitude and increasing distance from the Atlantic Ocean numbers of planktonic foraminifera would decrease. This relationship does not exist, at least for the data collected in this study. Areas of highest density are in the northern part of Baffin Bay (1000 to 10,000 individuals per 1000 cubic metres of water), and a second area of high density is found south of Disko Island in the Davis Strait area (1000 or more individuals per 1000 cubic metres of water).

Nothing can be positively concluded about the ecology of planktonic foraminifera in the study area because, as mentioned before, insufficient oceanographic data were collected concurrently with the plankton tows. Even with this information conclusions based on it might be questionable, for the distribution patterns are quite possibly the result of year-round factors. In view of the oceanographic work that has been done in the area (discussed previously) it could be hypothesized, however, that the observed distribution of planktonic foraminifera is controlled by the occurrence of relatively unaltered West Greenland current water which in this particular situation is surfacing at the sill of Davis Strait, then sinking again and resurfacing at the northern extremity of the Bay. Either the upwelling of water or the confluence of different water types or both could be responsible for the observed density distributions.

With respect to foraminiferal remains in the sediment, data are sparse, and at times very unreliable as will be seen. The values given in Figure 4 are sometimes based on a count of only 20 to 30 specimens in a kilogram of mud. In a few cases, however, large numbers of specimens were recovered from the sediments, though generally, areas of high density did not correspond to the high density net tows. The majority of the sediment density values are generally low and are most likely affected by loss of foraminiferal specimens to solution or possibly by current transport removal as discussed by Vilks (1970). It is conceivable that tests are being lost to transport removal as discussed by Vilks (1971), but the writer prefers to explain the apparent defficiency as the result of carbonate solution because of a selective solution displayed by the species *Globigerina bulloides* at various geographical locations. Examination of Tables 2 and 3 shows that at stations 10 and 24 numerous specimens of this species were found in the water column, but none was found in the sediment directly below. Specimens of the other species *Globigerina pachyderma*, however, were relatively abundant. Thus selective solution has been discussed elsewhere by Bé (1960).

A hypothetical prediction of the numbers that should be found in the sediment has been constructed to clarify this: 1000 individuals/1000 cubic metres of water = 1 individual/cubic metre or 200 individuals in a column of water 1m x 1m x 200m deep. Assuming an annual turnover of the entire standing crop, then 200 individuals/square metre of sediment should be deposited yearly. Assuming sedimentation rates in Baffin Bay to be in the order of 10 cm/1000 years, (this value supports a current model for sedimentation in Baffin Bay constructed by J. Johnson, 1971) about 2 specimens/cc of sediment or more; thus there is a considerable deficiency in many samples.

The problem of solution could be researched more extensively than was done in this study, for the cause of foraminiferal absence was not satisfactorily established. It can be positively said that no significant relationship exists between preservation (densities) and bathymetry. This is demonstrated in Table 1. Chemical and physical oceanography for the deep water at sample stations is unknown, and no studies of the chemistry of the sediment itself have been conducted, a factor which could easily be responsible for dissolution of calcite.

Table 1 - Bottom Populations and Bathymetry at Sediment Sample Locations

Station	Bathymetry	Population density (individuals/100 grams of sediment)
05	2160	305
08	3000	31642
10	1514	11
12	648	0
18	43	0
24	380	23
26	220	800
27	750	0
28	175	7
29	121	40
34	177	0
54	1054	0
69	1730	0
70	705	0
73	890	0
74	1950	0
75	2185	4
77	2107	0
79	1002	0
90	702	22
97	1937	0
103	3005	24576

From the preceding model and consideration of the data in Figures 2 and 3, it can be deduced that a significant percentage of foraminifera living in the water column never reach the sediment, and that planktonic foraminifera may not be a reliable tool for determining sedimentation rates or paleo-productivities in the study area.

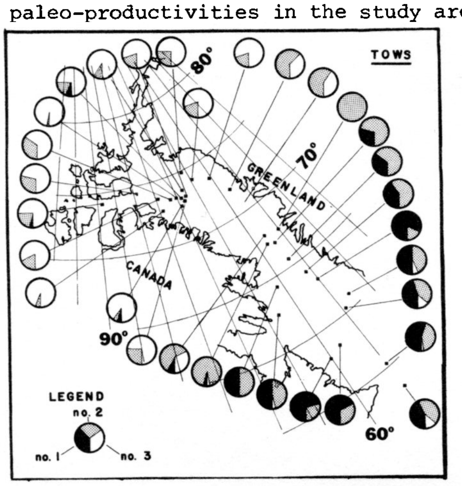

Figure 5 – Distribution of Globigerina pachyderma form variations in tow samples.

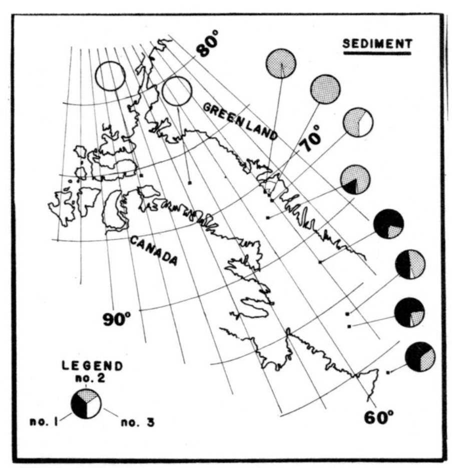

Figure 6 – Distribution of Globigerina pachyderma form variations in sediment samples.

B. Taxonomic distribution:

Only two species of planktonic foraminifera were found - *Globigerina bulloides* d'Orbigny and *Globigerina pachyderma* (Ehrenberg, see Fig. 7). Tables 2 and 3 show the percentage of each of the two species found in the plankton tows and bottom samples in the study area respectively.

Table 2 - % of *G. pachyderma*, *G. bulloides* and overall foraminiferal abundance in tows

Station	*G. bulloides*	*G. pachyderma*	based on	Abundance/1000 cu.m.
2	75	25	300 +	460
3	81	19	300 +	381
4	26	74	22	22
5	39	61	300 +	870
6	34	66	300 +	575
9	35	65	300 +	511
10	34	66	300 +	620
11	30	70	300 +	690
12	42	58	300 +	479
13	35	65	300 +	4244
15	40	60	100 +	100
16	25	75	38	38
18	66	34	300 +	7085
24	29	71	300 +	835
54	20	80	300 +	820
68	00	100	60	60
69	0	100	93	93
70	0	100	300 +	5628
72	0	100	300 +	420
73	0	100	130	130
74	0	100	300 +	8011
75	0	100	300 +	4100
76	0	100	300 +	6116
77	0	100	85	85
79	0	100	165	165
85	0	100	300 +	250
90	0	100	300 +	24000
91	0	100	300 +	5360
98	0	100	300 +	11000
99	0	100	300 +	206
100	0	100	300 +	368

Table 3 - % of *G. pachyderma* and *G. bulloides* in sediment

Station	*G. bulloides* %	*G. pachyderma* %	based on
05	1	99	152
08	3	97	444
10	0	100	20
12	no planktonic foraminifera present		
18	no planktonic foraminifera present		
24	0	100	25
26	1	99	171
27	no planktonic foraminifera present		
28	0	100	22
29	0	100	30
34	no planktonic foraminifera present		
54	no planktonic foraminifera present		
70	no planktonic foraminifera present		
74	no planktonic foraminifera present		
75	0	100	40
77	no planktonic foraminifera present		
79	no planktonic foraminifera present		
83	no planktonic foraminifera present		
90	0	100	98
97	no planktonic foraminifera present		
103	4	96	412

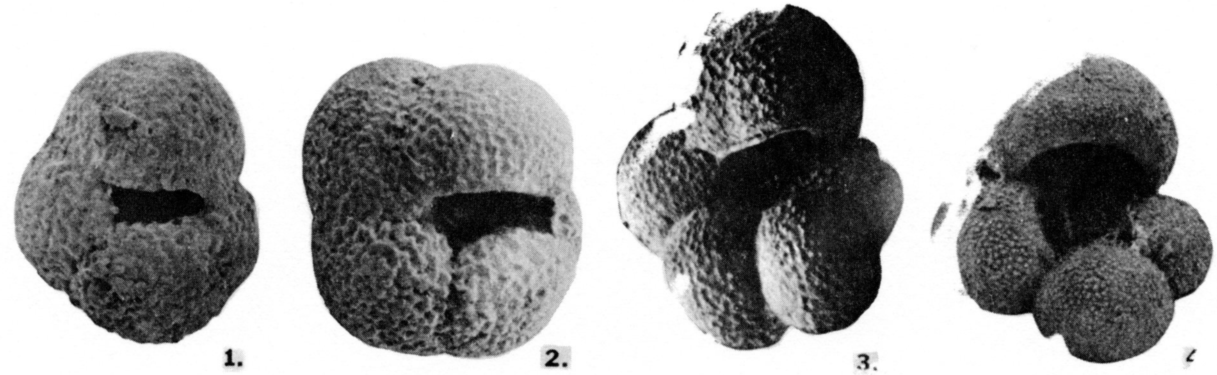

Figure 7 – 1. Globigerina pachyderma form 1
2. Globigerina pachyderma form 2
3. Globigerina pachyderma form 3
4. Globigerina bulloides

Approx. 100X

Also shown in the two tables is the number of specimens from which the data are drawn, which in many cases is not a very significant number. Both tables show clearly that *G. bulloides* quickly diminishes in number with increasing latitude and is almost nonexistent north of the Davis Strait. No distinction has been made in any of the data for left and right coiling forms of *G. pachyderma*, as it was assumed that all specimens were of the left-coiling polar variety. At first glance, this lack of faunal diversity was unexciting and discouraging, but a closer look at the form variants of the species *G. pachyderma* revealed a faunal variation that is indeed worth noting. Kennett (1968) has shown variation in form of this species corresponding to changes in latitude in the South Pacific Ocean. A similar type of variation was present in this study in both plankton and sediment samples. The three distinctive forms of *G. pachyderma* are shown in Figure 7, along with a representative specimen of *G. bulloides* from the study area. These forms, numbered 1, 2, and 3 for convenience, are characterized as follows: in No. 1, by a compactness with small aperture and heavy calcification which masks any pore structure at high magnifications; in form No. 2, a quadrate or square appearance of the classic *G. pachyderma* form, and in No. 3, the appearance of five chambers on the dorsal side, an arched sinuous lip around the aperture, and much less calcification. Figures 5 and 6 give data on the distribution of these various forms in the summer waters and sediments, respectively: the relative percentages of each form at each station (for the *G. pachyderma* population only) is also shown. Looking first at the plankton samples, a general pattern can be discerned with form No. 1, which occurs in highest concentrations in the southernmost part of the study area. Form No. 2 is more nearly universal, but diminishes somewhat with increasing latitude. Form No. 3 is quite predominant in the northern part of the survey area, but is also found in several southern stations. In the sediment samples, the same pattern of change with latitude is not quite so clearly defined, for there is a much more widespread distribution of form No. 3 with noticeable increases in the Western Labrador Sea area.

The distributional pattern of the sub-species forms found in the plankton samples, and somewhat more weakly in the sediment samples, is not exactly like that of Kennett (1968); rather it is somewhat an inverse with respect to latitude. Therefore latitude is not the controlling factor. The distribution of species form No. 3 is interesting with respect to the movement of the West Greenland current within the study area. It is conceivable that this sub-specific form is reacting to the presence of the West Greenland current or essentially the type of water it carries. Its presence in the most southern stations of the study area would indicate that the West Greenland current water had not sunk to too great a depth in these localities. In the southern stations along the Greenland coast where this species form is absent, it is proposed that the West Greenland current was below the water column sampled by the plankton net. On the western side of the southern area, West Greenland current water may not be present at all. In the northern area West Greenland current water would have been traversed in every sampling, thus giving higher counts of this species form.

The presence of species forms No. 1 and No. 2 would have a more subtle meaning in view of the above hypothesis, but their occurrence is probably related to the presence or absence of certain water types or certain amounts of mixing thereof.

Summary

Total planktonic foraminiferal densities in the study area are somewhat lower than in the temperate North Atlantic, as was expected, and a comparison of plankton tow and bottom density data seems to indicate that a considerable number of foraminiferal tests are not being preserved in the sediments of the study area after death.

Distribution of planktonic foraminifera in the water of the study area showed considerable variation from station to station. The cause of this variation cannot be definitely established, but it is proposed that it is a function of the position of various water masses in the study area.

Taxonomically the area studied is very uniform and unexciting, containing only two species of planktonic foraminifera: *Globigerina bulloides* and *Globigerina pachyderma*. Distribution patterns, based primarily on the form variants of the species *G. pachyderma* in the sediment and in the summer water mass, are fairly well defined and show a considerable similarity. These form-variant distributions present a potential paleo-oceanographic tool for further studies of Arctic sediments.

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