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DISTRIBUTION OF FORAMINIFERA IN CHALEUR BAY, GULF OF ST. LAWRENCE

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CONTENTS

Tables

Illustrations

DISTRIBUTION OF FORAMINIFERA IN CHALEUR BAY, GULF OF ST. LAWRENCE

Abstract

The total population of foraminifera in the Chaleur Bay-Restigouche estuary system reflects the observed bathymetry, water mass characteristics and general circulation pattern. The increase in arenaceous species below 16 m in the bay probably defines the lower limit of the seasonally-influenced and highly perturbed shallow bay environment. Dense living and total populations are indicative of ecotones in the bay near zones characterized by high primary production rates where food material is readily available. The highest species diversity occurs at intermediate depths (40-70 m) in comparatively stable environmental conditions. These conditions are superimposed on regional (north-south) changes in substrate type and in water mass characteristics. Using cluster analyses (Q-mode) of a total percentage data matrix it is possible to define shallow upper estuarine, nearshore bay-lower estuarine, and deep offshore bay biotopes.

Résumé

On a observé une corrélation entre la population globale de foraminifères de la baie des Chaleurs et de l'estuaire de la rivière Restigouche, et la bathymétrie, les caractéristiques de la masse d'eau, et la configuration générale de la circulation des eaux. Au-dessus de 16 m, l'augmentation du nombre des espèces arénacées correspond probablement à la limite inférieure des milieux d'eau peu profonde soumis à l'influence des saisons et à des perturbations importantes. La forte densité des populations globales et des populations vivantes indique l'existence d'écotones dans la baie, près de zones caractérisées par une forte production primaire et une grande abondance d'éléments nutritifs. On observe la plus grande diversité d'espèces aux profondeurs intermédiaires (40-70 m) dans un milieu relativement stable. En plus de cette situation, on observe des variations régionales (nord-sud) du type de substrat et des caractéristiques de la masse d'eau. A l'aide d'analyses par grappes (mode Q) d'une matrice de données relatives au pourcentage total, il est possible de définir dans la baie des biotopes peu profonds à l'amont de l'estuaire, des biotopes littoraux à l'aval, et des biotopes profonds au large.

INTRODUCTION

For the past several years the distribution of benthonic foraminifera in the Restigouche estuary under a variety of natural and artificial (polluted) conditions has been investigated (Schafer, 1973; Schafer and Frape, 1974; Schafer and (Frape) Cole, 1974). The study described here is based on data from more than 300 samples collected over a four-year period in the lower part of the Restigouche estuary and in Chaleur Bay (Fig. 1). The Restigouche River-Chaleur Bay system is located on the south side of Gaspé Peninsula and is one of several large estuaries opening into the Gulf of St. Lawrence. The aim of this report is to relate the observed distribution patterns to known physical and chemical parameters and to establish the extent of major foraminiferal biotopes (includes living plus empty specimens) within this estuarine-marginal marine environment.

Methods and Equipment

Most sediment samples were collected using a 15x15 cm Eckman dredge. In the deeper parts of the bay east of Grande Anse a 21x21 cm Shipek sampler was used. Collections were made in the western part of the bay with a 14-m Cape Island type fishing vessel and stations were located by triangulation using a horizontal sextant. In the eastern part of the bay the Bedford Institute of Oceanography research vessel **CSS Dawson** was used and station locations were established in 1972 using calibrated Decca and radar, and in 1973 using the Del Norte Trisponder navigation system. Details of other instrumentation used can be found in Schafer et al., 1972, and Schafer et al., 1974.

A 2-cm-thick surface sediment layer was removed from an undisturbed part of each sample and transferred to a plastic vial. Between 30 and 40 cm^3 of material was usually collected in each instance. The samples were preserved with a 5% solution of formalin buffered with $CaCl_2$ and 'Harleco' 9883 buffered salt mixture (final pH = 8.0). In the laboratory the samples were placed in graduated cylinders to determine their wet volume and then washed through a 230 mesh (0.063 mm) sieve. The sediment fraction larger than 0.063 mm was dried and added to a 10:4 solution of bromoform and acetone (Gibson and Walker, 1967), which separated the foraminifera by flotation. The separation took place in about one minute after which the float was washed into filter paper, rinsed with acetone and dried. All counts were made using a Wild M5 microscope.

Foraminiferal data were processed using a cluster anlaysis method described by Parks (1970) which objectively classifies related samples into groups which can usually be mapped. The clustering technique used is based on a sample-by-sample (Q mode) comparison of the similarity of species occurrence and relative abundance using the simple distance function (D) where

$$D_{1,2} = \left[\sum_{i=1}^{M} (X_{i1} - X_{i2})^2 / M \right]^{1/2}$$

M is the number of species and X equals the normalized (transformed to range from 0 to 1) value of the relative abundance of each species. The resulting matrix of D values will range from 0.0 (shortest distance equals closest similarity) to 1.0 (longest distance equals greatest dissimilarity). Clusters of related samples were determined from this matrix using the Unweighted Pair-Group method (for details see Parks, 1966; Sokal and Sneath, 1963) and the resulting groups were represented in an easily interpreted dendrogram. This graphical representation is simply a two-dimensional hierarchial diagram on which the 'natural breaks' between groups can usually be easily discerned. However, some caution must be used in interpretation because the dendrogram forces samples into hierarchial groups even though these may not really exist in nature. Previous studies have demonstrated that, among the various clustering

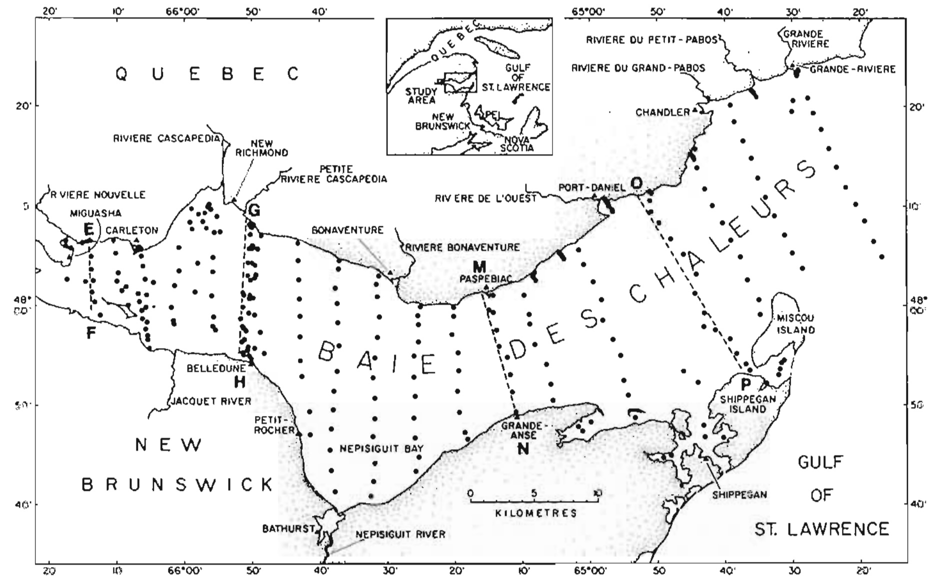
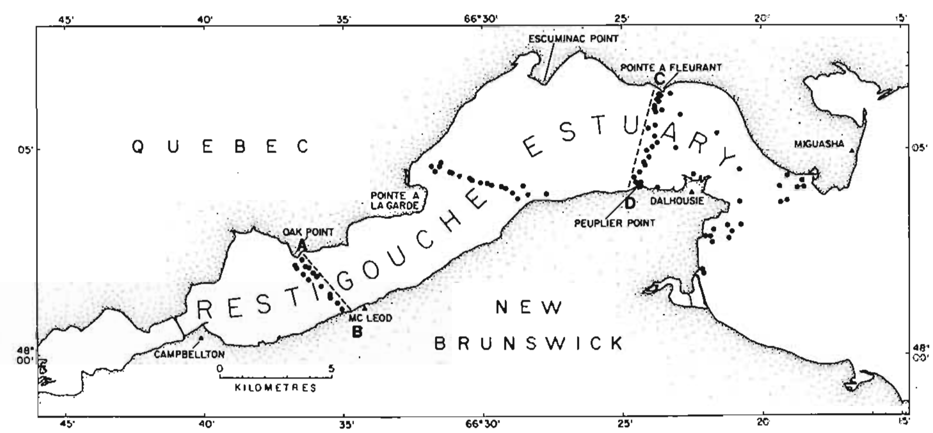


Figure 1.

Location of sampling stations in the Restigouche estuary and major tributaries emptying into the Restigouche estuary-Chaleur Bay system. The location of faunal profiles is also shown (see Figs. 4 and 5).



techniques, the Unweighted Pair-Group method gives, both analytically and empirically (Brooks, 1973), the highest fidelity between dendrogram representations and the original pairwise similarity matrix.

Physical Setting

Physiography and Bathymetry

Water depths in the bay deepen gradually east of Dalhousie, New Brunswick, and reach maximum values east of Chandler, Quebec, where the bay opens into the Gulf of St. Lawrence (Fig. 2). The bathymetry of Chaleur Bay, especially east of Bonaventure, Quebec, is controlled by the morphology of the Chaleur Trough which delineates the preglacial drainage system in this area (Loring and Nota, 1966, 1973). Near Dalhousie the ancient Restigouche River channel forms the western end of the Trough. The old channel is very narrow at this locality and is further characterized by relatively steeply sloping walls and a present floor depth greater than 24 m. East of Dalhousie the channel is partially filled by postglacial marine sediments at several locations (Schafer, 1976). Tributaries to the main channel are the ancient Jacquet and Nepisquit rivers (not shown on Fig. 2) in New Brunswick and the Cascapedia and Bonaventure rivers in Quebec. East of Bonaventure the main channel of the ancient Restigouche River follows the north side of the bay. South of Port Daniel, Quebec, a mid-bay topographic high reaches about 8 m above the main channel floor and divides it into two smaller channels both of which are about 80 m deep. East of Port Daniel the northernmost channel deepens to 96 m, and continues into the Gulf of St. Lawrence. Water depths within the bay are all less than 100 m.

Circulation

The surface circulation in the bay is westerly-oriented and enters the bay along the north shore while an easterly flow leaves along the south shore (Tremblay, 1943). According to Legendre and Watt (1970) the waters of the Quebec shore, flowing in the opposite direction to those on the New Brunswick shore, generate a cyclonic gyre in the intermediate region of the bay which is centred near Port Daniel, Quebec. This cyclonic eddy corresponds to a zone of comparatively high primary production rates. According to Steven (1971) the central part of the bay can be included within the "area of maximum sustained primary production." This area is identified with the main Gaspé current system which flows around Gaspé Peninsula and into Chaleur Bay. The high level of production is generated by the rich nutrient supply carried by the current system from the St. Lawrence estuary to the north. The production levels are sustained throughout the summer months even when surface waters are well stratified and are reflected in underlying sediments by comparatively

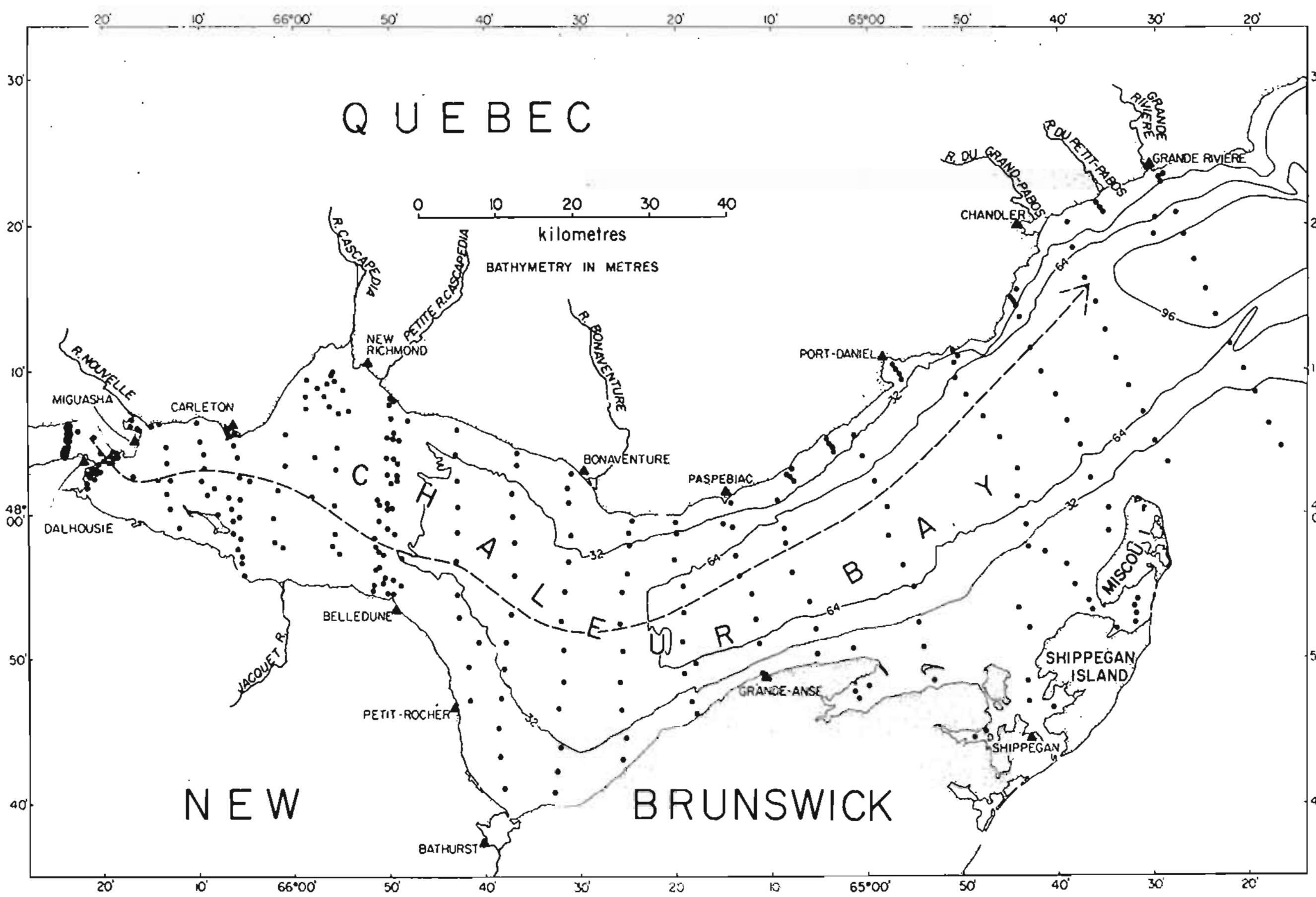


Figure 2. Station locations, bathymetry and axis of the ancient Restigouche River channel in Chaleur Bay.

high concentrations of methane, organic carbon, extractable organic matter, and plant pigments, and by a more diverse (probably less reworked) foraminiferal assemblage (Rashid et al., 1975).

Temperature and Salinity

Bottom water temperatures range from near 0 to 19°C and salinities from 11 to 32‰. Mean values for various parts of the estuary are summarized in Table 1. Maximum lateral variation in summer bottom water temperature in the 40- to 70-m depth interval reflects the circulation pattern described earlier. Thus, at a depth of about 45 m on the north shore off Bonaventure, temperature values are near 0°C while at a comparable depth off Grande Anse they might reach 11°C during the summer season. The seasonal and spatial variability of temperature and salinity decreases generally with depth throughout the bay and both parameters are relatively constant between water depths of 80 to 90 m. The surface water layer responds to seasonal temperature changes to a depth of about 50 m on the south side of the bay but only to about 30 m on the north side because of the continued influx of comparatively cold Gaspé current water.

Bottom Sediments

Surface sediment textures range from gravelly sand to silty clays (textural description after Shepard, 1954). The silty clay facies is present below an average depth of 70 m in central Chaleur Bay east of Bonaventure (Fig. 3). This facies widens eastward and terminates near the mouth of the bay. A clayey silt facies occurs immediately west of the silty clay and again in the western part of Chaleur Bay between Dalhousie, and New Richmond. East of Bonaventure this facies is confined between the 60 to 72 m isobaths. West of New Richmond the clayey silts are dominant at much shallower depths, usually between 8 and 32 m. The two 'patches' of clayey silt are joined by a somewhat coarser sand-silt-clay facies that has been deposited along the central axis of the bay, and which is rather extensively distributed between Belledune and Bonaventure at water depths of 32 to 60 m. The deep-water silty clay and the sand-silt-clay facies are comparable to the "sandy pelite" and the "very sandy pelite" described by Loring and Nota (1973). Only three bottom areas of the bay appear to be characterized by sand facies. One of these is near Bonaventure at a water depth of 16 to 40 m, the second occupies a relatively shallow environment (8 to 24 m) near Petit Rocher, and a third lies northwest of Miscou Island at a depth of about 32 m. Sandy silt facies occur along the coastline west of Belledune and north of Petit Rocher as well as at the mouth of the Cascapedia River near New Richmond. Much of the remainder of the bay is covered by deposits of gravelly sand. These relatively coarse sediments extend offshore into the deeper parts of the bay between Bathurst and Bonaventure. There is also an isolated occurrence of this material south of Port Daniel on the crest of the mid-bay topographic high at a water depth of 72 m.

The mean pH of bottom sediment ranges from 6.4 to 7.2 (Table 1). Between Campbellton and Dalhousie winter values are slightly lower and may reflect a decrease in sediment mixing because of ice cover which would permit a concentration of the acidic byproducts of decaying organic detritus derived from adjacent marshes.

Table 1

Mean values (upper number in each box) of bottom water temperature, salinity, and of sediment pH at various depth intervals and times in Chaleur Bay. The standard deviation is shown below the mean value in each case

AREA	DEPTH METRES	TEMP. °C SUM.	TEMP. °C WINT.	SAL. ‰ SUM.	SAL. ‰ WINT.	SED. pH SUM.	SED. pH WINT.
CAMPBELLTON TO DALHOUSIE	>1-5	13.5 1.3	6.1 3.0		20.0 9.1	7.0 0.3	7.1 0.2
	5.1-10	12.1 0.8	3.6 0.9		26.7 4.8	7.3 0.3	7.0 0.3
	10.1-15	10.8 1.0	2.0 2.7		29.4 0.5	7.2 0.2	7.0 0.3
MIGUASHA TO BELLEDUNE	>1-5	9.6 3.4	4.3 1.6	26.8 1.8	24.9 1.0	6.7 0.2	6.5 0.3
	5.1-10	10.1 3.8	4.7 1.4	26.2 0.8	25.5 2.6	7.1 0.2	6.9 0.2
	10.1-15		4.7 1.1		27.8 0.7		7.0 0.2
	15.1-20	9.9 3.5	4.7 0.8	27.4 1.2	28.5 1.5	7.0 0.1	7.1 0.3
	20.1-25		4.7 1.5		28.9 1.4		7.2 0.1
	25.1-30	9.5 1.1	4.5 0.6	28.8 0.1		7.0 0.1	7.1 0.1
NEW RICHMOND TO GRANDE ANSE	>1-5	12.9 1.3				6.5 0.1	
	5.1-10	12.8 2.1		26.7 0.6		6.8 0.2	
	10.1-20	12.8 2.4				6.8 0.2	
	20.1-30	10.6 4.1				6.8 0.2	
	30.1-40	12.1 3.0				6.7 0.2	
	40.1-50	10.7 6.2		31.7 0.3		6.8 0.2	
	50.1-60	2.0 5.1		31.9 0.1		7.0 0.3	
	60.1-70	3.9 6.8		32.1 0.1		6.8 0.4	
	70.1-80	0.4 0.2		32.2 0.1			
GRANDE ANSE TO GRANDE RIVIERE	>1-5	13.2 2.7		25.0 0.7		6.6 0.9	
	5.1-10	10.3 3.2		25.9 0.4		6.4 0.8	
	10.1-20	8.1 3.2		26.4 1.3			
	20.1-30	3.9 1.2		28.0 0.7			
	30.1-40	2.0 0.1		28.8 0.1			
	40.1-50	1.7 0.2		29.4 0.1			
	50.1-60	2.0 0.1		29.7 0.1			
	60.1-70	2.1 0.1		29.9			
	70.1-80	2.2 0.2		30.2 0.2			
	80.1-90	2.3 0		30.4 0.1			

There are several indications that the gravelly sands have been reworked by waves and that they comprise material derived from underlying sediments (Schafer, 1977). For example, they extend bayward into waters as deep as 40 m near Bathurst while sediments to the east and west of this area are relatively fine at comparable depths. They also tend to be very poorly sorted (classification after Folk and Ward, 1957), the sorting coefficients being usually greater than 4ϕ. This feature may be related to both the inherent textural characteristics of the material and to mixing of modern and older sediments during sampling operations. Grab samples from this area often include modern coarse sediments and an older glaciomarine material which is characterized by its relatively high content of clay-sized particles compared to deeper offshore deposits of modern sediment. Observations by divers at a depth of 13 m in central Nepisiquit Bay also indicate that the bottom in this area is composed of two differing sediment types including a "clean fine gravel and sand layer overlying fairly firm brown mud" (Eaton, 1975). Echogram records and sediment textures observed in cores indicate that recent sediments comprise a relatively thin veneer in many parts of the bay, and that in shallow bay environments these sediments have been reworked and mixed with older glaciomarine deposits.

Suspended Sediments

Near Dalhousie the mean suspended particulate matter (SPM) concentration during the spring season is 12.5 mg/l, while between Dalhousie and Belledune, the mean SPM drops to 5.8. East of Belledune the mean SPM in surface water is only 3.9 representing a 60 per cent decrease in concentration (Cranston et al., 1974). Much of this material should reach the bottom in the central and eastern part of the bay but it is only evident in large quantities in the area delimited by the Clayey silt and silty clay sediments (Fig. 3). Reddy (1968) noted that near Belledune rip currents are an important mechanism for transporting the suspended fines from comparatively shallow water environments into the main current circulation offshore. Their deposition in offshore areas, however, is dependent on a combination of water depth and the intensity of circulation and reworking processes (Schafer, 1977).

KEY FORAMINIFERA SPECIES

The relative importance of species throughout the entire bay was initially approximated by ranking their frequency of occurrence in the total number of bottom sediment samples (Table 2). These data are somewhat biased, however, because a greater number of samples was collected in the western part of the bay and in comparatively shallow water environments. The table nevertheless distinguishes between ubiquitous and restricted forms. Comparison of mean percentage abundance ($\bar{A}$) versus frequency data confirms this observation and demonstrates that the more numerically abundant species (i.e., $\bar{A} \geq 1\%$) are also the most widely distributed. The correlation coefficient for $\bar{A}$ and frequency is 0.82 for the abundant species as defined above and 0.60 for the rare forms. Both values are significant at the 99.9 per cent level of probability.

Comparison with data from other areas shows the cool temperate to Arctic affinity of the Chaleur Bay assemblage. About 53 per cent of the bay species are found in Long Island Sound, New York (Parker, 1952; Schafer, 1968; Buzas, 1965), 64 per cent in the western Arctic (Vilks, 1969), 72 per cent in Hudson Bay (Leslie, 1965), 87 per cent in Mahone Bay, Nova Scotia (Bartlett, 1964), and 97 per cent in the Miramichi estuary (Bartlett, 1966; Tapley, 1969; Scott et al., in press). Eighteen species are present in at least one third of all samples collected in the bay and most of the numerically abundant forms observed in the bay are included in this group.

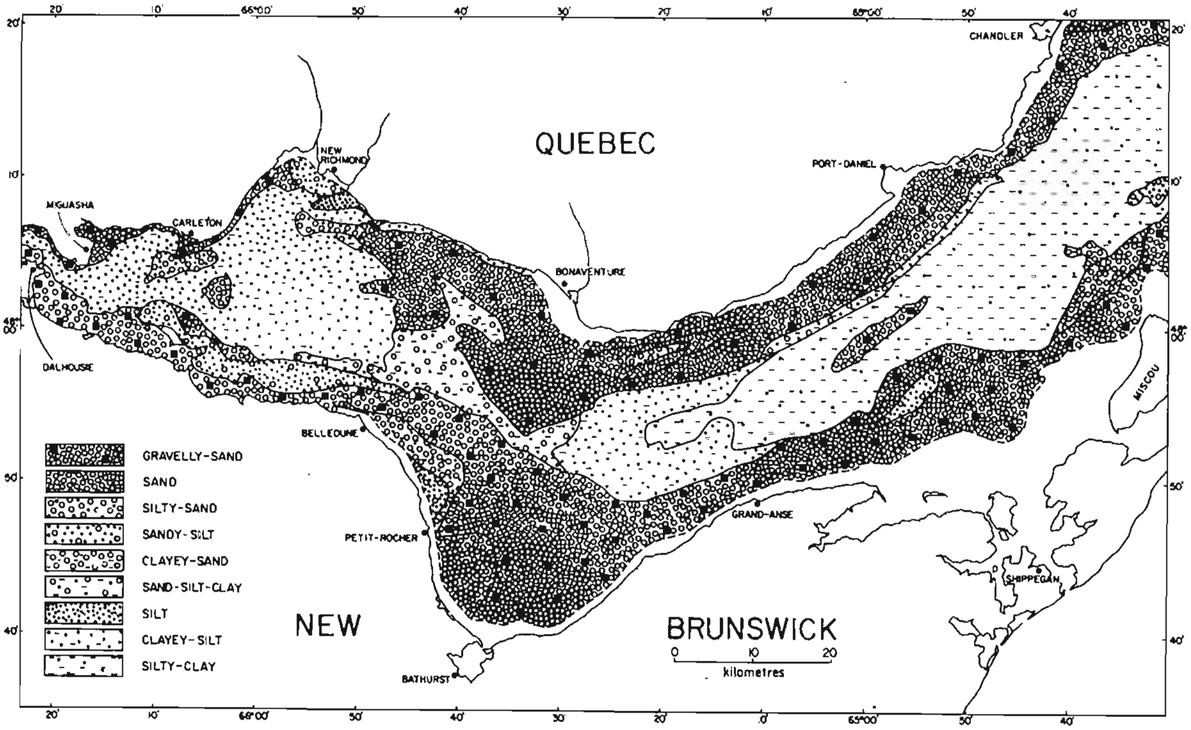


Figure 3. Distribution of sediment types in Chaleur Bay.

Sixty per cent of the fauna is composed of arenaceous types that reflect both the cool temperate to sub-Arctic conditions as well as the estuarine influence within the bay.

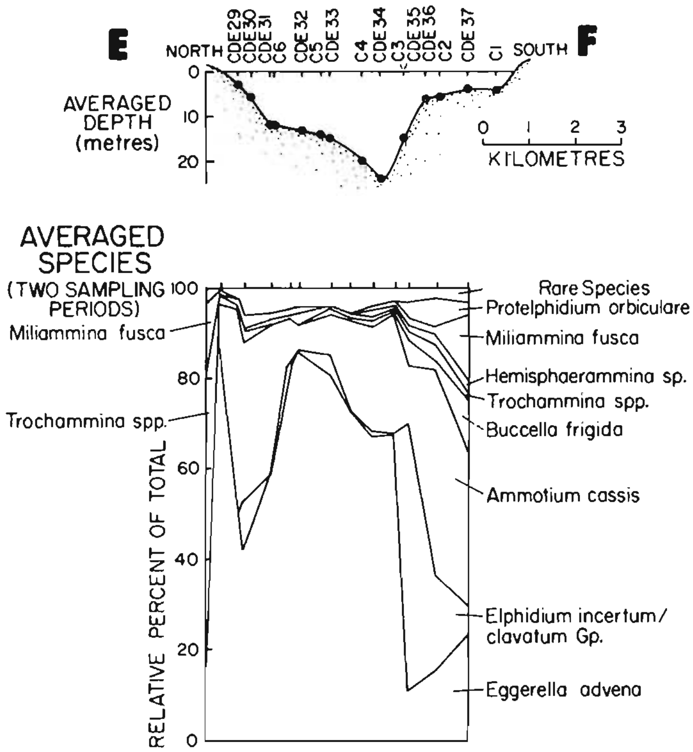
In the relatively estuarine western end of the bay **Eggerella advena** and Ammotium **cassis** are the dominant species. At many stations in this area **E. advena** and **A. cassis** combined represent more than 90 per cent of the total population, particularly in water depths greater than 10 m (Fig. 4A). At shallower water depths in this area calcareous elements such as **Elphidium incertum/clavatum** Gp., **Protelphidium orbiculare, Buccella frigida,** and the arenaceous form **Miliammina fusca** become more common. West of Dalhousie, near McLeod and Peuplier Point, New Brunswick, the proportion of **A. cassis** and **M. fusca** to other species shows a distinct increase especially at water depths less than 10 m. In this upper estuarine environment **E. advena** is confined primarily to the deeper offshore channel environments (10 to 15 m) where salinities are comparatively high (Figs. 4B and 5A). Further details of foraminiferal distributions in this part of the estuary will be given in a separate report. Moving eastward from Dalhousie to a section of the bay near Belledune, **Eggerella advena** is replaced, but to a lesser degree than **Ammotium cassis**, by other more marine arenaceous forms such as **Reophax arctica**, Spiroplectammina **biformis** and **Ammobaculities** salsus (Fig. 5B). Eastward, near Grande Anse, the calcareous species **Pateoris hauerinoides** and **Elphidium margaretaceum** are prominent in water less than 20 m deep (Fig. 6A). On the north shore in this area of the bay these forms are replaced at comparable depths by **Elphidium incertum/clavatum** Gp. At intermediate depths (40 to 70 m) **Cassidella complanata** and **Reophax fusiformis** show a pronounced increase in abundance, especially on the south side of the bay. **Islandiella** sp., **E. advena** and **Reophax scottii** show a similar trend within the same depth range on the north side of the bay. The deeper offshore areas here (> 50 m) are characterized by **Textularia torquata, Spiroplectammina biformis** and **Reophax arctica.**

At the eastern end of the bay near Miscou, New Brunswick, a shelf less than 20 m deep is well developed on the south side of the bay. This shallow, open marine environment is dominated by calcareous forms such as **Elphidium** spp., **Protelphidium orbiculare** and **Elphidium incertum/clavatum** Gp. (Fig. 6B). The very shallow subtidal assemblages in this area are dominated by **Miliammina fusca.** Similar assemblages occupy much of the shallow upper estuary west of Dalhousie, at depths usually less than 5 m. The basic calcareous composition of the assemblage along the southeastern shore of the bay is indicative of the comparatively warm bottom water and high salinity conditions that prevail in this area during the summer months. In relatively colder bottom environments on the north side of the bay **Glomospira gordialis, Glabratella wrightii, Trochammina** spp., and **Eggerella advena** replace the **Elphidium** assemblage in the shallow nearshore zone. In deeper environments on the north shore of the bay (i.e., > 50m), **Islandiella** sp., **Adercotryma glomeratum** and **Reophax arctica** are among the most prominent species. The relatively large numbers of **E. incertum/clavatum** Gp. in this deeper part of the bay are not typical and may be related to the relatively high organic production reported in this area (Steven, 1971). Downslope transport is probably not significant since several other easily transportable nearshore species are observed to decrease uniformly with distance offshore. The arenaceous forms **Reophax arctica, R. scottii** and **R. fusiformis** show a pronounced increase in relative abundance at intermediate depths (i.e., 30 to 70 m) in this area.

Table 2

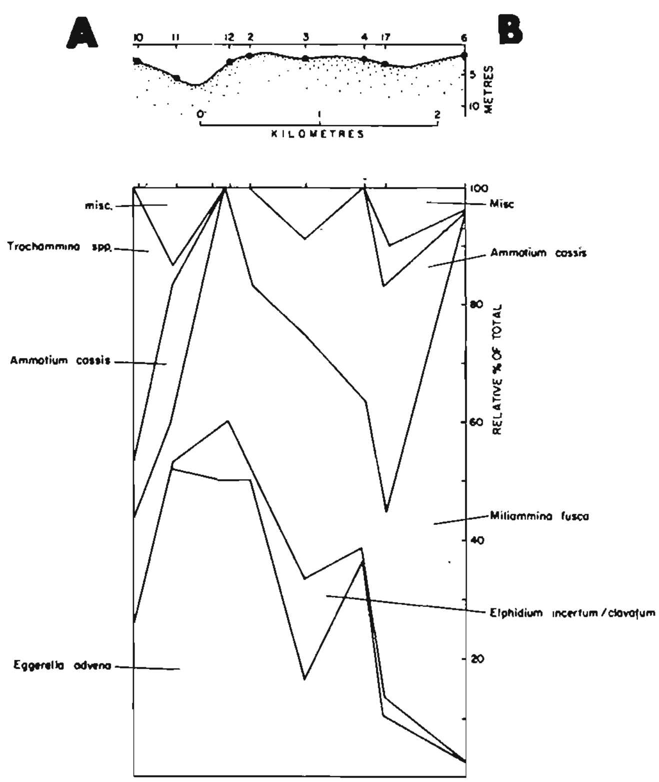
Ranked Frequency of Total Species Counts at Stations in Chaleur Bay

SPECIES	F	SPECIES	F	SPECIES	F	SPECIES F $\leq$ 1.0%
Eggerella advena	91.1	Elphidium bartletti	12.5	Lagena gracillima	3.0	Astacolus hyalacrulus
Elphidium incertum/		Trochammina macrescens	11.9	Oolina borealis	3.0	Bulimina marginata
Clavatum Gp.	88.1	Buliminella elegantissima	11.6	Quinqueloculina arctica	3.0	Cyclogyra foliacea
Buccella frigida	78.9	Trifarina fluens	10.4	Reophax pilulifera	3.0	Fissurina cucurbitasem
Ammotium cassis	67.6	Trochammina squamata	10.4	Gordiospira arctica	2.7	Fissurina serrata
Protelphidium orbiculare	61.9	Glomospira gordialis	9.8	Oolina melo	2.7	Glandulina laevigata
Reophax arctica	58.0	Islandiella norcrossi	9.2	Scutuloris tegminis	2.7	Hyperammina elongat
R. fusiformis	57.1	Nonionella atlantica	9.2	Spirillina vivipara	2.7	Lagena meridionalis
R. scottii	56.5	Hyperammina subnodosa	8.9	Cibicides pseudoungerianus	2.4	Lagena parri
Spiroplectammina biformis	55.9	Buccella inusitata	8.0	Dentalina baggi	2.4	Laryngosigma hyalasci
Miliammina fusca	47.3	Cyclogyra involvens	8.0	Parafissurina himatiostoma	2.4	Nodosaria emphysaocy
Textularia torquata	44.9	Reophax nodulosa	7.7	Fissurina marginata	2.1	Oolina caudigera
Hemisphaerammina sp.	42.6	Elphidiella arctica	7.4	Lagena laevis	1.8	Oolina hexagona
Nonionellina labradorica	35.1	Patellina corrugata	7.4	Protoschista findens	1.8	Oolina squamosa
Cassidella complanata	34.8	Fissurina lucida	6.8	Lagena mollis	1.5	Reophax gracilis
Islandiella teretis	33.0	Glabratella wrightii	6.8	Triloculina trihedra	1.5	Trifarina angulosa
Ammodiscus catinus	31.3	Rosalina floridana	6.8	Bulimina exilis	1.2	Triloculina trigonula
Trochammina ochracea	31.0	Robertinoides charlottensis	6.5	Dentalina frobisherensis	1.2	
Cribrostomoides crassimargo	29.8	Ammobaculites dilitatus	5.4	Esosyrinx curta	1.2	
Elphidium subarcticum	29.2	Lagena semilineata	5.4	Lagena flatulenta	1.2	
Saccammina atlantica	29.2	Textularia earlandi	5.4	Miliolinella chukchiensis	1.2	
Ammobaculites salsus	28.6	Epistominella takanagayii	5.1			
Recurvoides turbinatus	27.1	Astrononion stellatum	5.1			
Islandiella islandica	24.7	Eoeponidella pulchella	4.8	THECAMOEBINA		
Hippocrepina indivisa	24.4	Pseudopolymorphina novangliae	4.8	Difflugia capreolata	3.0	
Elphidium frigidum	23.2	Bathysiphon filiformis	4.5	Difflugia oblonga	2.4	
Adercotryma glomeratum	22.3	Quinqueloculina stalkeri	4.5			
Cibicides lobatulus	21.7	Ammonia beccarii	3.6			
Elphidium margaritaceum	21.7	Dentalina ittai	3.6			
Trochammina lobata	21.4	Elphidium excavatum	3.6			
Bolivina pseudopunctata	19.6	Nonionella auricula	3.6			
Reophax nana	19.6	Pyrgo williamsoni	3.6			
Pateoris hauerinoides	18.8	Triloculina oblonga	3.6			
Cribrostomoides jeffreysi	17.6	Pontigulasia compressa	3.3			
Quinqueloculina seminulum	17.3	Saccammina sphaerica	3.3			
Trochammina inflata	17.0	Globobulimina auriculata	3.0			
Ammomarginulina fluvialis	13.4	Hippocrepinella hirudinea	3.0			
Quinqueloculina agglutinata	12.8	Lagena apiopleura	3.0			



4A

(A) near Carleton, Que.

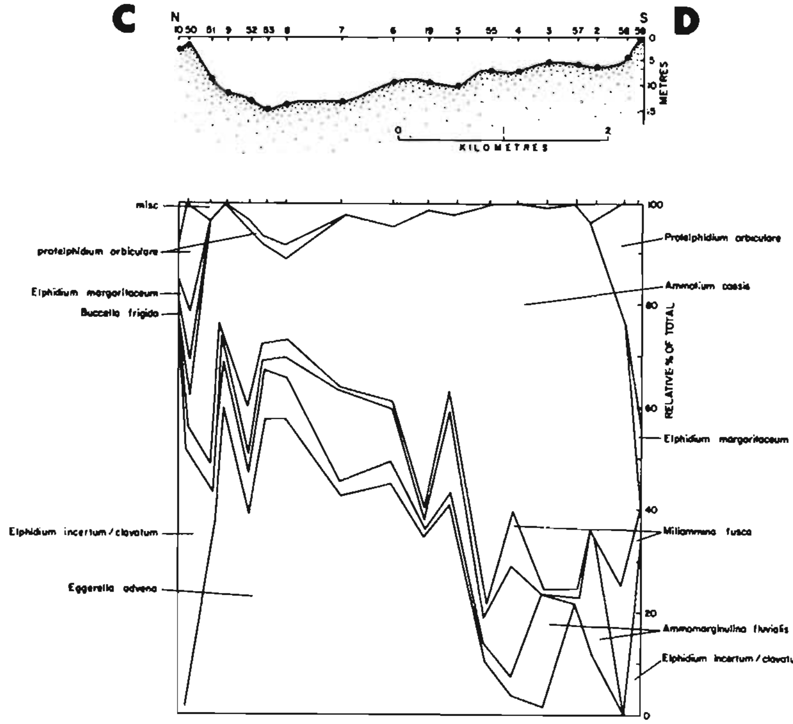


4B

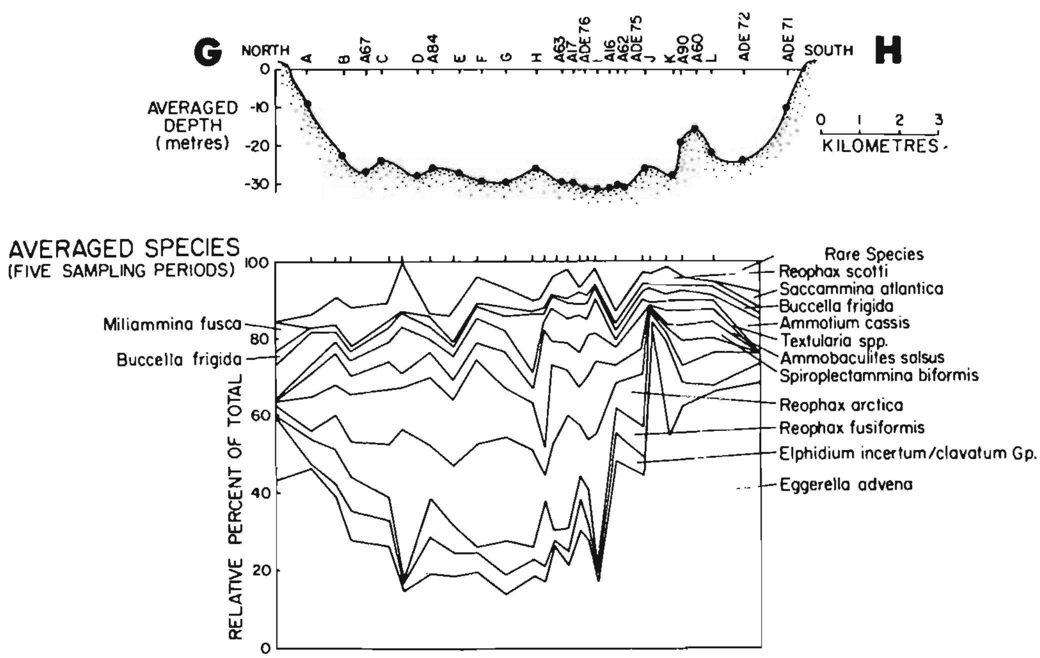
(B) near McLeod, N.B.

Figure 4.

Profiles of major species abundance in western Chaleur Bay.



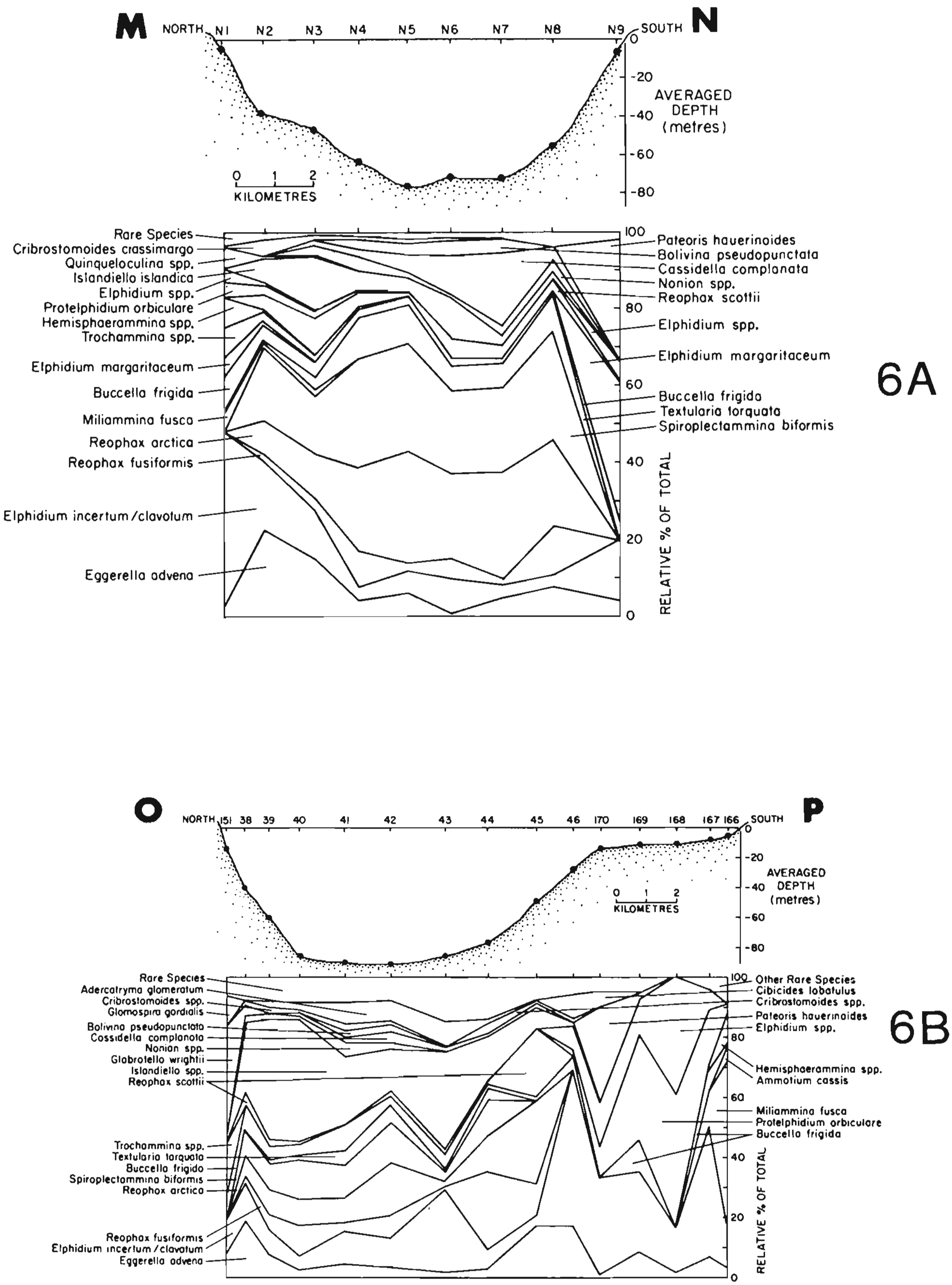
5A



5B

(A) near Dalhousie, N.B.
(B) near Belledune, N.B.

Figure 5. Profiles of major species abundance in western Chaleur Bay.



(A) near Grande Anse, N.B.
(B) near Miscou, N.B.

Figure 6. Profiles of major species abundance in central and eastern Chaleur Bay.

REGIONAL DISTRIBUTION OF THE TOTAL POPULATION

It is evident that the foraminiferal population in this estuary-bay system is dominated by arenaceous species. West of longitude 65°10'W, and typically at water depths greater than 16 m, the relative abundance of arenaceous forms is generally more than 75 per cent of the total population (Fig. 7). East of this arenaceous species dominate in the southern half of the bay. At depths less than 16 m and especially adjacent to Shippigan, New Brunswick they are replaced by a nearshore calcareous assemblage. This comparatively shallow part of the bay is noted for its high summer bottom water temperatures compared to those noted in most other nearshore areas of the bay (e.g., 15 to 19°C by middle June). In the easternmost part of the bay, north of the dominantly arenaceous facies, a deep, open gulf calcareous assemblage, dominated by species of **Islandiella**, has established itself. South of Chandler, Quebec, the change from dominantly calcareous to dominantly arenaceous total populations with increasing water depth transgresses known sediment facies boundaries and appears instead to be related to the general bottom water temperatures. In these deep areas of the bay the water has a relatively constant temperature and high salinity (2.0 to 2.3°C and 28 to 31 ‰) throughout the year. This stable oceanographic condition supports the deep gulf fauna within the eastern part of the bay.

Total population data (number of specimens per cubic centimetre of wet sediment) have been mapped to assess the influence of the reported high primary productivity zone in the middle part of the bay on the size of the foraminiferal population (Fig. 8). Generally, population densities are highest at intermediate depths in the offshore environments of the bay between longitude 65°10'W and 65°50'W. This part of the

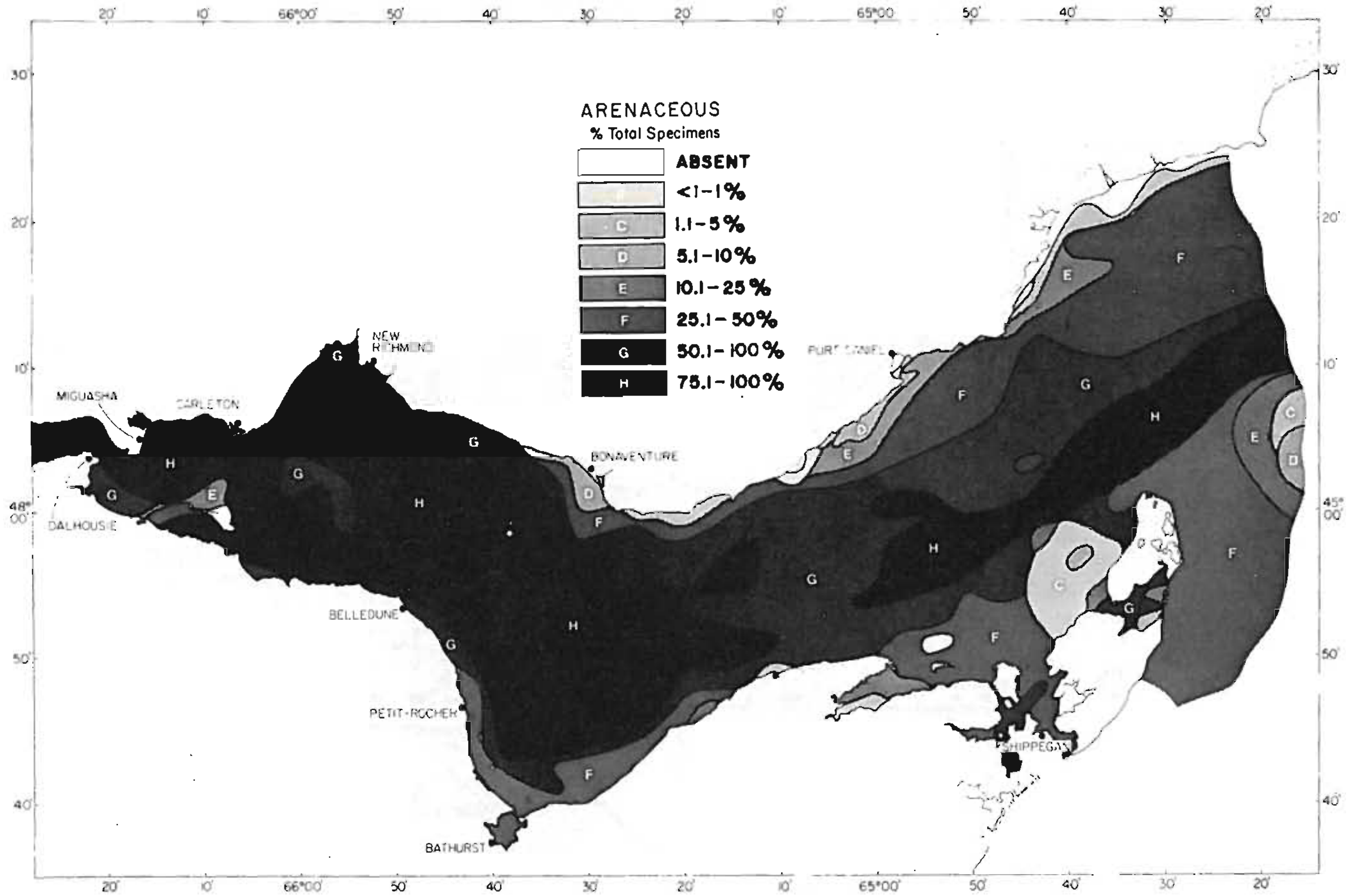


Figure 7. Arenaceous specimens as percentage of the total population.

bay is characterized by gravelly sands that are presently being reworked by wave turbulence (Schafer, 1977). The development of these relatively high population densities on the periphery of the high productivity zone, despite the resuspension and redistribution processes operating here, may thus reflect the availability of abundant food material, and the presence of a suitable sediment substrate for maintaining dense populations. The comparatively high density fields on the north side of the bay may be indicative of the predominant westerly direction of tidal currents carrying nutrients into this area. In other adjacent areas of the bay there is a general direct correlation between sediment grain size and population density especially with regard to the silty clay facies that has been deposited in relatively deep water east of 65°10'W.

Living population densities show a similar relationship with respect to the location of the primary productivity gyre and to the zone of sediment reworking (Fig. 9). The highest living population densities are located in the central one third of the bay between Bathurst and Bonaventure. This area is essentially an ecotone separating estuarine and more open marine communities and, as such, the high values noted are not surprising. In other analogous environments large living populations are often associated with similar transitional zones (e.g., Murray, 1973, p. 42; Nichols and Norton, 1969; Arnal, 1961; Bartlett, 1964). The paucity of living specimens in the eastern part of the bay (east of 64°00'W) is somewhat surprising since this area is characterized by sediments that are comparatively rich in organic carbon. According to Loring and Nota (1973) high concentrations of organic matter (2 to 5 per cent) usually occur in the deep water pelites on the floors of the troughs throughout the Gulf of St. Lawrence, and highest concentrations (3 to 5 per cent) are characteristic of the most central and deepest parts of the troughs. Although these general statements agree with the mapped organic carbon concentrations in the Chaleur Trough (op. cit., p. 80) the observed levels are apparently well above those required by the foraminifera, as evidenced by the observed low living population densities. Areas of the bay east of 65°50'W that are inhabited by relatively dense living populations are comparatively shallow and are characterized by coarse sediments that have a relatively low organic carbon content ranging from 1 to 2 per cent.

In the upper bay environment west of 65°50'W between Dalhousie and Belledune mean organic carbon concentrations range between 1.83 and 1.32 per cent respectively (Cranston et al., 1974). In this area the living population is moderately dense at intermediate water depths (10 to 15 m). Sparse populations are associated with the comparatively fine clayey silt sediment facies northwest of Belledune, and with texturally similar sediments that have been deposited in the ancient Restigouche River channel near Dalhousie. In this upper bay environment there is also a correlation between high organic carbon concentrations and the occurrence of relatively fine sediment that parallels the relationship reported by Loring and Nota (1973) in eastern Chaleur Bay and in other offshore areas of the Gulf of St. Lawrence. Although the correlation between sediment texture, organic carbon and living population densities is not as pronounced in the western part of the bay, compared to areas east of 65°10'W, relatively high living population densities in the upper bay are usually associated with sediments in which the silt plus clay-sized particles comprise between 10 and 35 per cent and in which the organic carbon concentration is less than 2.5 per cent. The nitrogen content of sediments

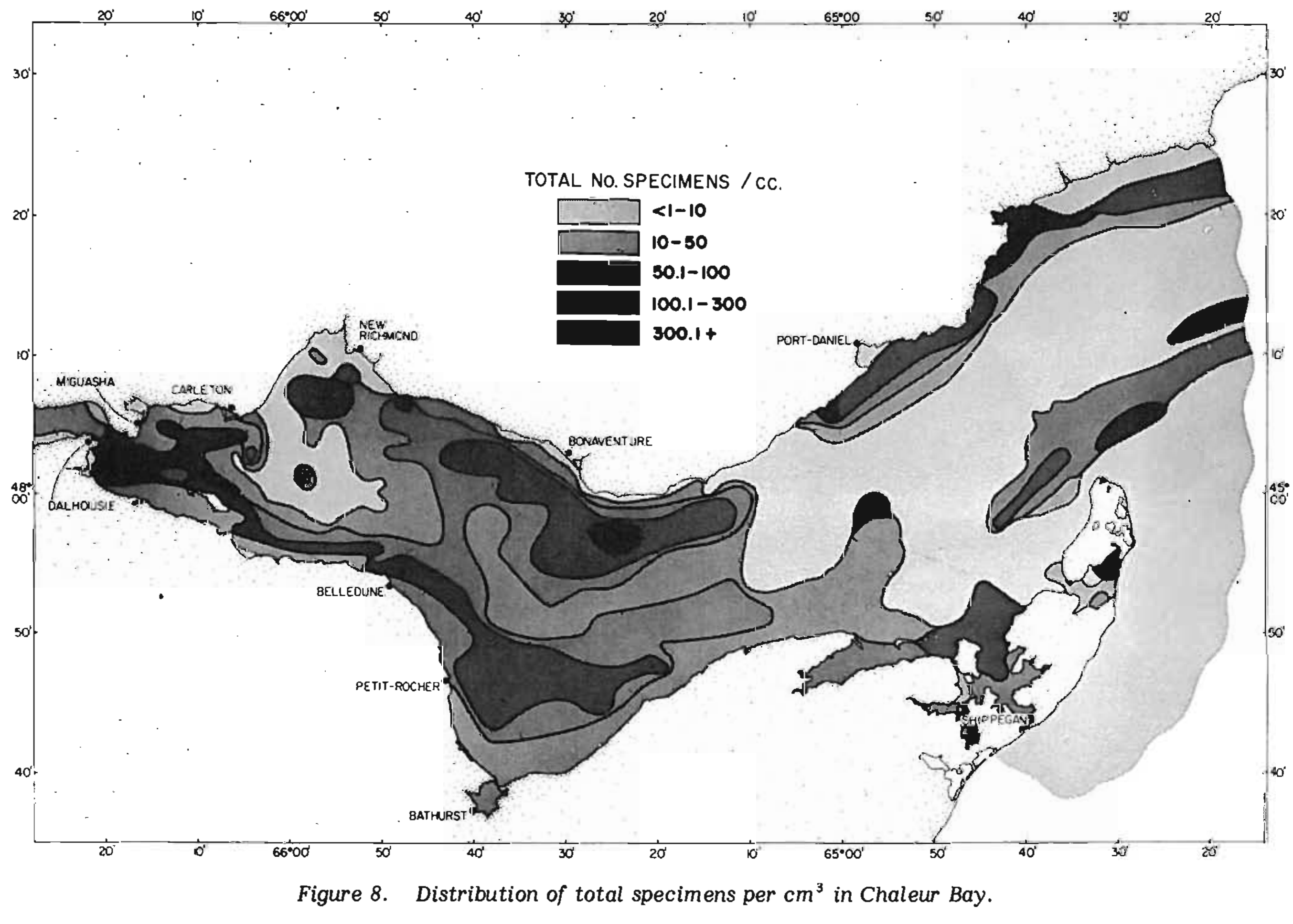


Figure 8. Distribution of total specimens per cm³ in Chaleur Bay.

measured near Bonaventure, Bathurst and Dalhousie is 3.0, 2.6, and 1.4 mgN/gm respectively (Pocklington, 1975) and also suggests that the area of highest benthic productivity is confined to the central one third of the bay where sediment organic carbon values are relatively low. At other locations in the bay in which the concentration of terrestrial organic matter is very high (e.g., near pulp mill outfalls) living population densities are usually low, especially when coarse organic matter exceeds 25 per cent by weight (Schafer and Cole, 1974).

The total species number decreases significantly in most nearshore environments throughout the study area especially near the mouths of major rivers such as the Restigouche in the western part of the bay and near the Cascapedia, Bonaventure and Nepisquit in central Chaleur Bay. Highest numbers are confined to intermediate depths (Fig. 10) and are probably indicative of transitional environments where niche diversity is high but where physical perturbations are reduced in both frequency and intensity (i.e., 40 to 70 m). It is evident again, however, that the highest number of species is found within the gravelly sand facies where sediment reworking processes are relatively intense compared to both the shallow nearshore and the deeper offshore areas. The deepest, and most oceanographically stable, eastern part of the bay supports fewer species than would be expected based on generally accepted ecological principles and on observations of benthonic foraminifera diversity in highly stable shelf and slope environments (e.g., Buzas and Gibson, 1968). Conversely, the low total species number in the western part of the bay is probably related to the regional influence of estuarine processes. A plot of the mean total species number ($\bar{S}$) as a function of depth is shown in Figure 11. It is evident that the 50 to 80 m depth interval supports a higher minimum number of species and that the range of species per sample is small compared to shallower and deeper environments. This relationship correlates generally with relatively high mean standard deviation values of summer bottom water temperatures ($\overline{SD}_{T,S}$) at this depth interval. The high $\overline{SD}_{T,S}$ delimit an offshore depth interval in the bay that is characterized by the highest regional (north-south) variation and is, in fact, indicative of the general circulation pattern described earlier. Minimum species per sample and mean species ($\bar{S}$) are therefore higher because of the overlap of populations associated with these distinctive areas on each side of the bay. Despite this north-south change in certain components of the environment at this depth interval, the distribution of species is relatively uniform and diverse.

The compound diversity (in the sense of Berger and Parker, 1970) of total populations was estimated using Margalef's index (Margalef, 1968) where

$$D_C = -\sum_{r=1}^{S} P_i \log_2 P_i$$

and P_i is the percentage of the i^{th} species in a sample. The index considers both the numbers and kinds of organisms present in a community. Comparatively high values are confined to the central part of the bay east of Belledune (Fig. 12) and appear to reflect a change to more marine conditions and the position of the gyre described by Legendre and Watt (1970). In the western part of the bay the estuarine influence, and the concomitant water depth decrease, is reflected by the extension of comparatively low D_C fields into the offshore areas.

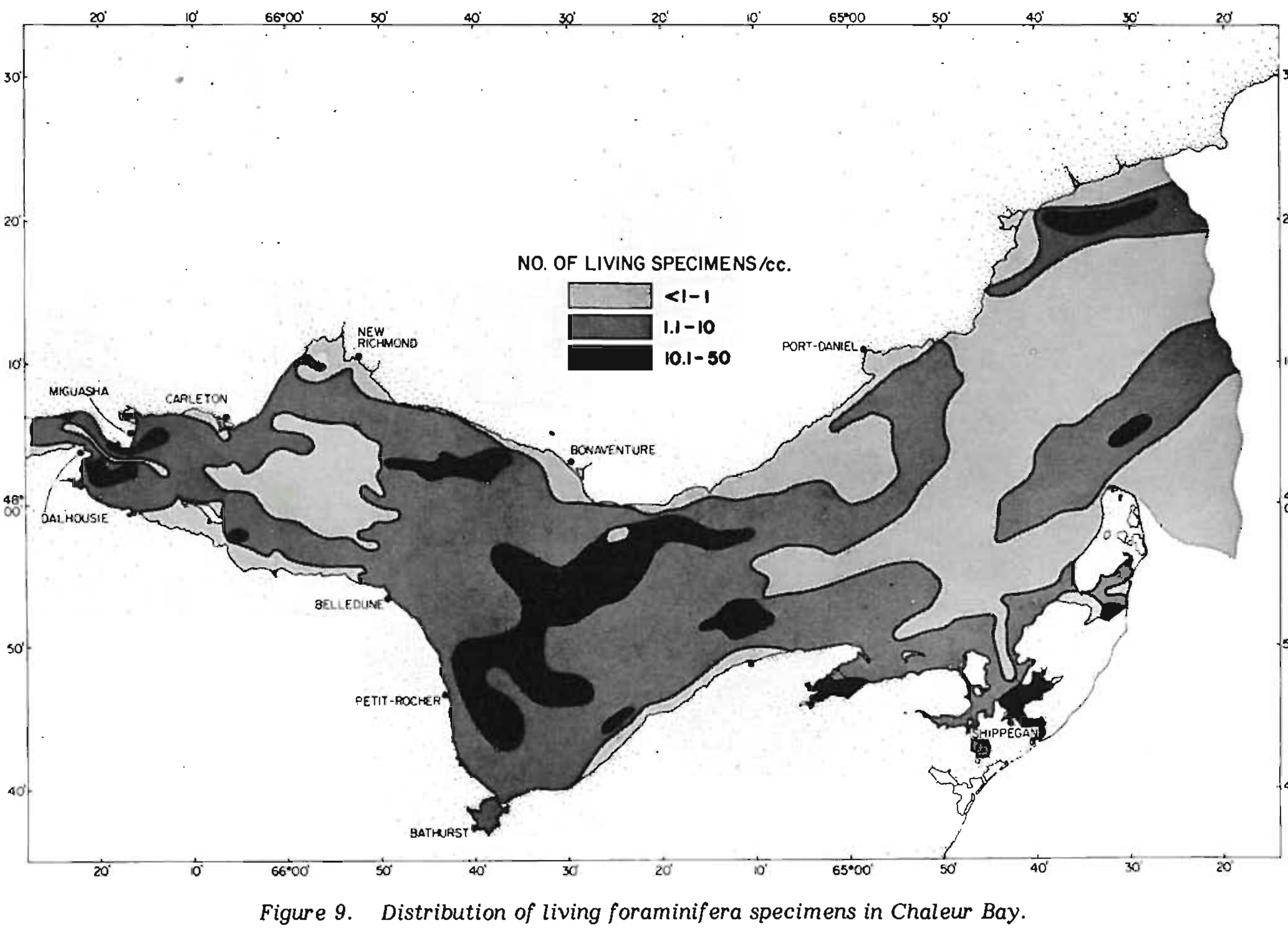


Figure 9. Distribution of living foraminifera specimens in Chaleur Bay.

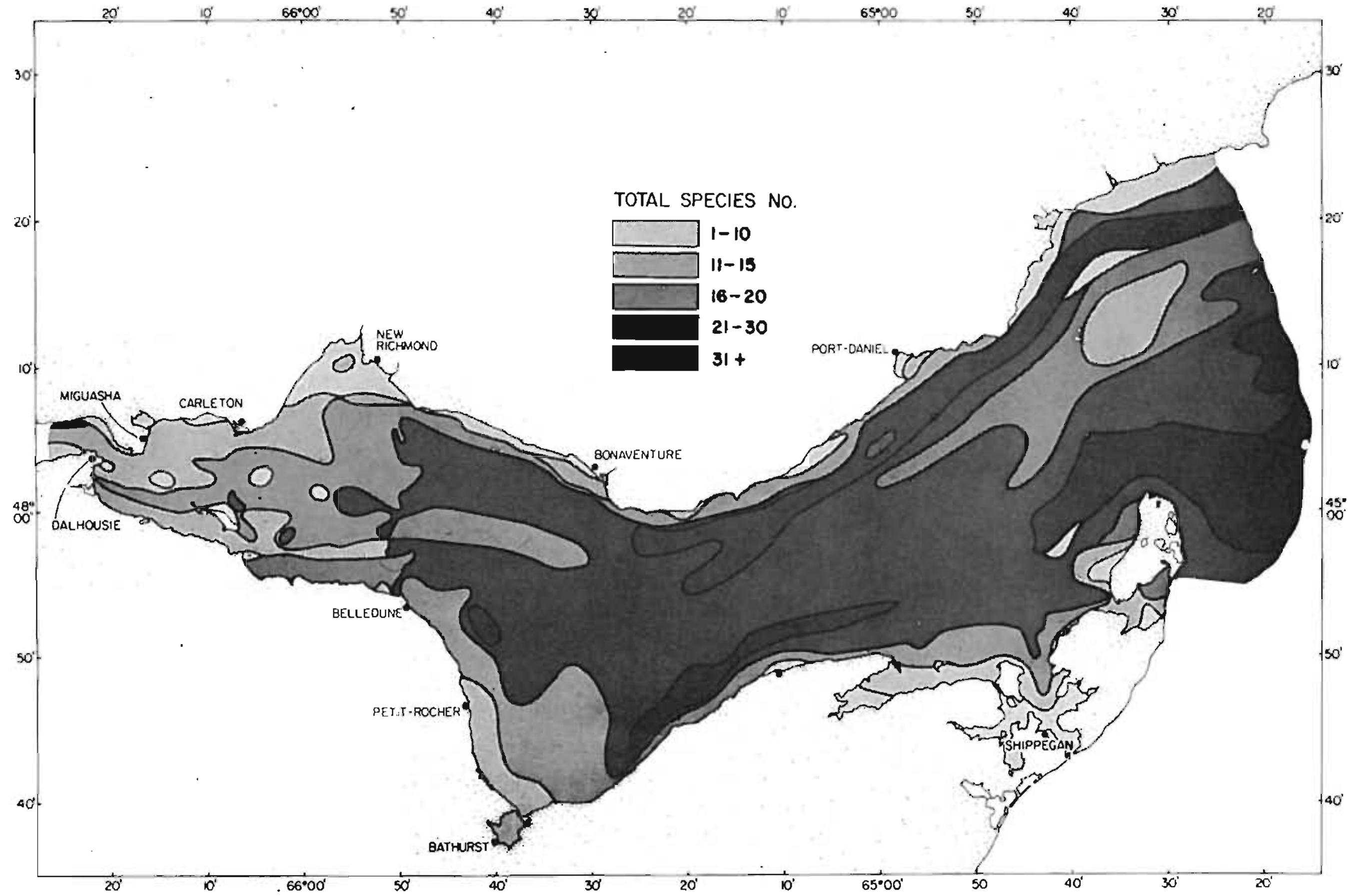


Figure 10. Distribution of total species in Chaleur Bay.

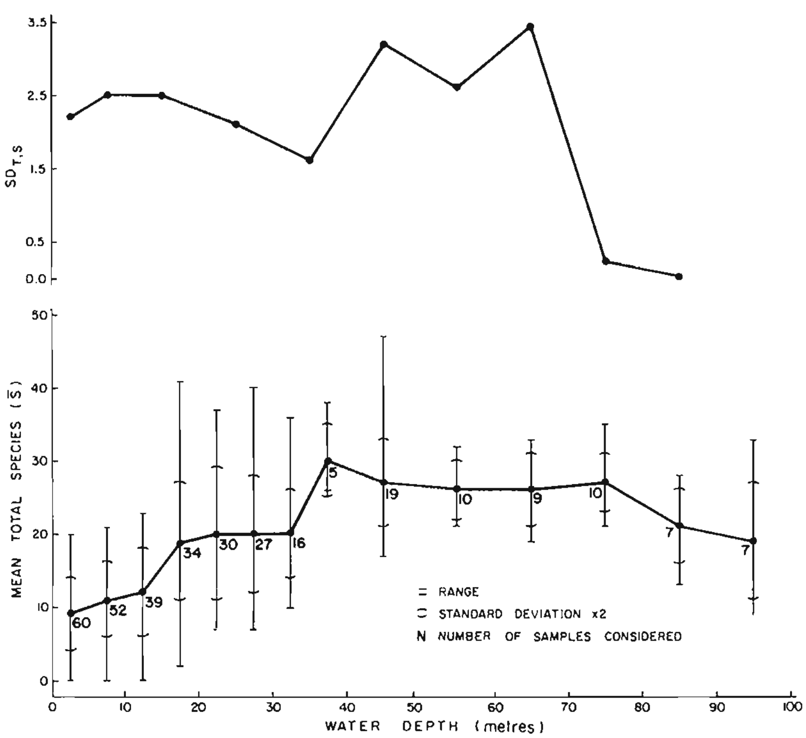


Figure 11.

Mean total species as a function of depth and regional variability of summer bottom water temperature.

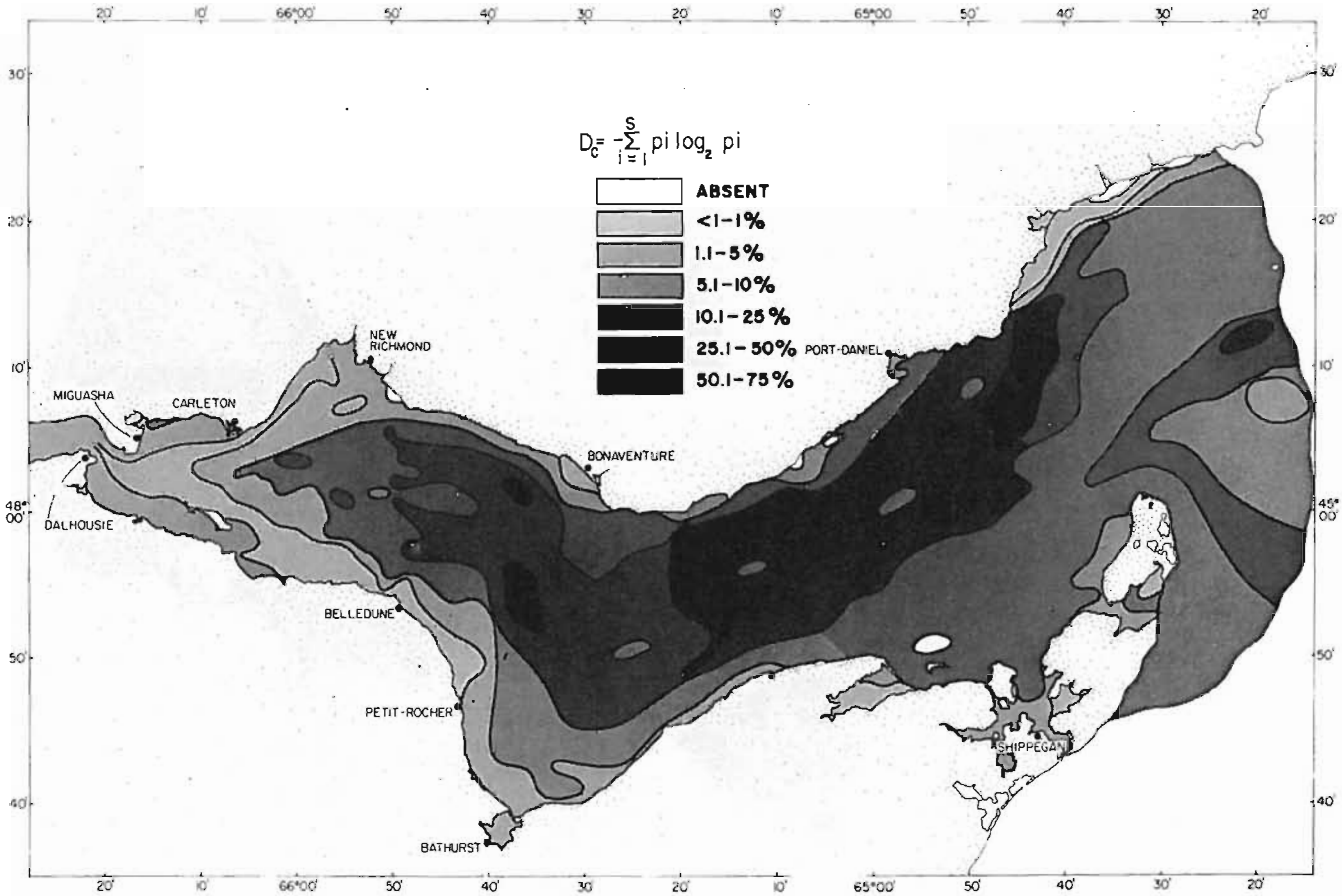


Figure 12. Compound diversity of the total population in Chaleur Bay.

REGIONAL DISTRIBUTION OF KEY SPECIES

The predominant counterclockwise circulation, the inflow of high volumes of fresh water into the bay, and the development of relatively extensive shallow shelf environments adjacent to the southern shore of the bay, has influenced the regional distribution of several important indicator species including **Eggerella advena, Protelphidium orbiculare,** Elphidium **incertum/clavatum** Gp., **Reophax arctica, Ammotium cassis,** and species of the genus **Islandiella.**

The total population distribution of **Islandiella** species (**I. teretis, islandica** and **norcrossi**) outlines those parts of the bay that are constantly exposed to open gulf bottom water which penetrates into the eastern part of the bay up to Carleton, Quebec (Fig. 13). The relatively intense inflow of this water along the north shore of the bay is evidenced by high total percentages of **Islandiella** between 56 and 80 m depth south of Port Daniel. This water mass is probably related to the "warm (4-6°C) water layer" reported by Loring and Nota (1973). However, it appears to occur first at about 80 m in the eastern part of the bay, a depth which is 20 m shallower than reported by Lauzier (1960) in the Laurentian Channel to the north. At comparable depths along the southern side of the Chaleur Trough the abundance of **Islandiella** spp. is usually less than 15 per cent indicating the restriction of this deep water mass to the north side of the bay.

In the adjacent Gulf of St. Lawrence, **Islandiella** is prominent at water depths of 50 to 300 m (Cole, in prep.). The environment at these depths is characterized generally as one of "active depositon of deepwater pelites" that typically contain moderate amounts (2-3 per cent) of "organic carbon matter" (Loring and Nota, 1973).

Protelphidium orbiculare is usually associated with comparatively warm water subtidal environments in the bay (Fig. 14). Consequently, this species is most abundant in the Shippegan area where conditions are comparable to the warm bay and lagoonal environments that occur throughout much of the New Brunswick and Prince Edward Island coastlines in the southern Gulf of St. Lawrence (Tapley, 1969). The species is absent from the central part of eastern Chaleur Bay and appears to be confined to waters less than 70 m deep. It is thus excluded from the deep "warm water" mass noted earlier. In the Gulf the mean relative abundance of this species decreases to about 2 per cent at a depth of 50 m. It is most prominent at depths less than 10 m and is associated primarily with "offshore areas of active reworking" and "areas of essentially nondeposition with local reworking" (Loring and Nota, 1973). The sediments deposited in these environments usually contain less than 1 per cent "organic carbon matter."

The distribution of **Reophax arctica** is less restricted than **Islandiella** spp. (Fig. 15). Highest percentage values are confined to intermediate depths in the bay and may be related to the intermediate cold water layer reported by Lauzier (1960) in the St. Lawrence estuary. In the summer this layer occurs at a depth of about 100 m in the St. Lawrence estuary but appears to be about 20 m shallower in Chaleur Bay which may be indicative of upwelling processes associated with the high productivity zone.

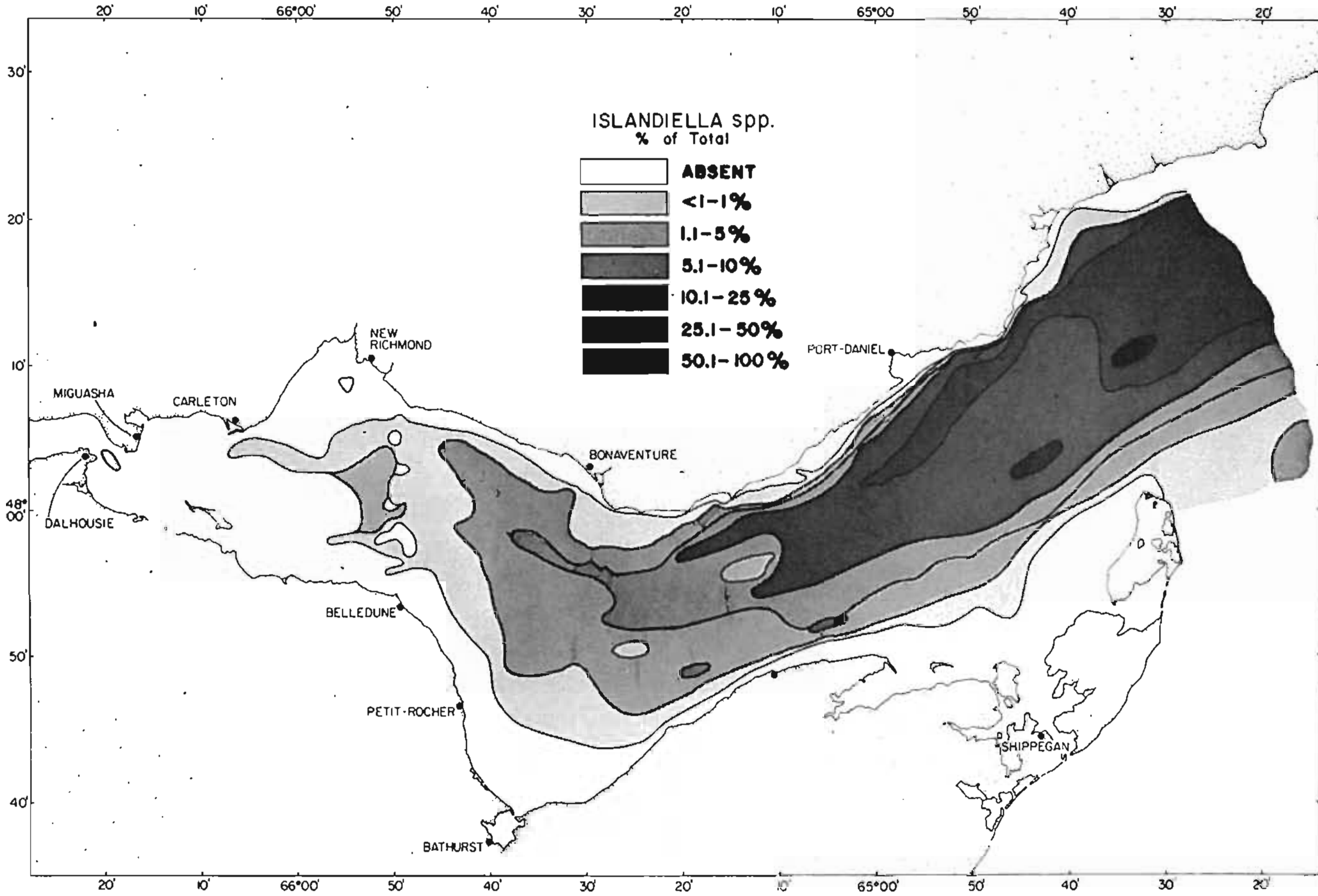


Figure 13. Distribution of total **Islandiella** species in Chaleur Bay.

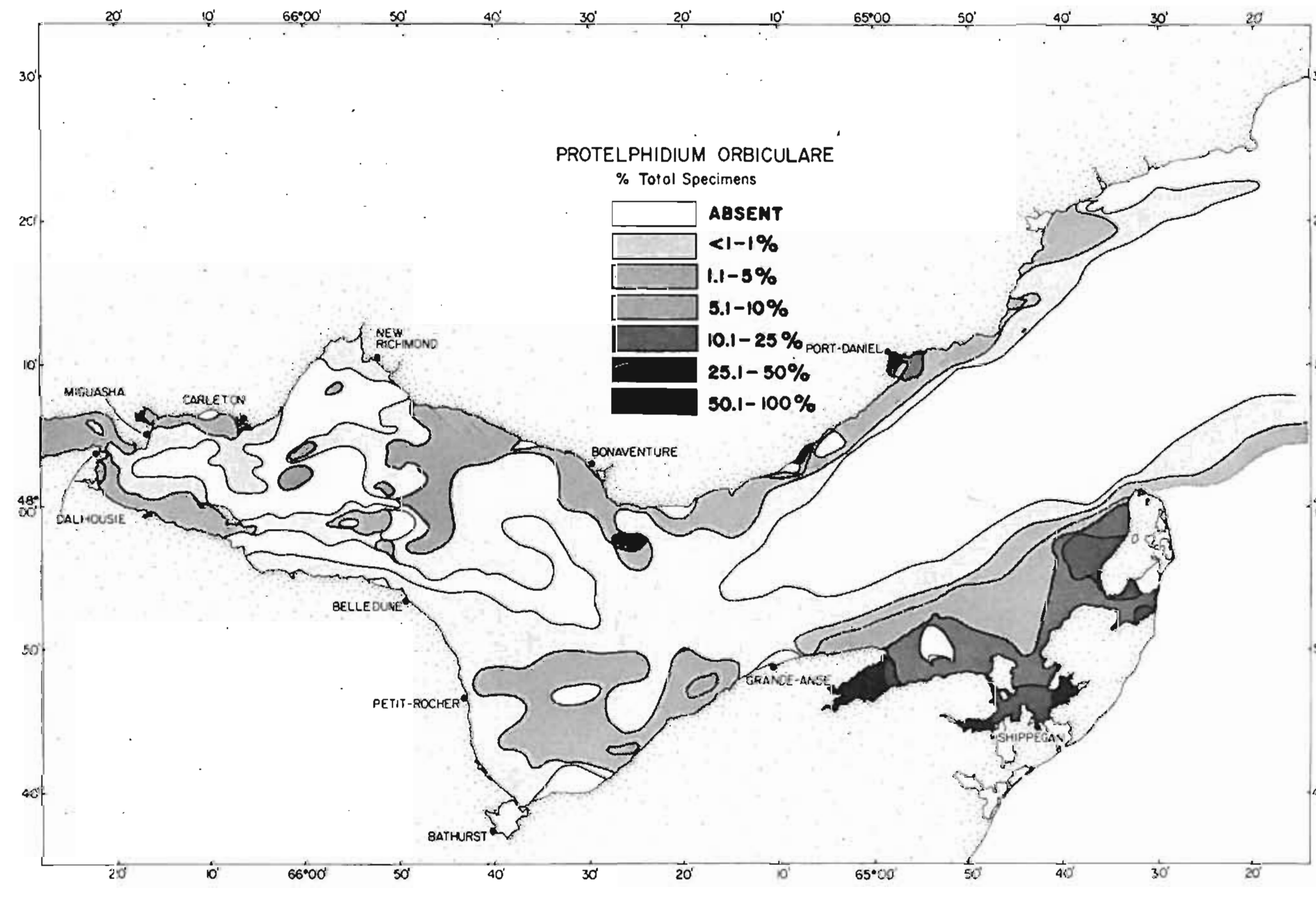


Figure 14. Distribution of total specimens of **Protelphidium orbiculare** in Chaleur Bay.

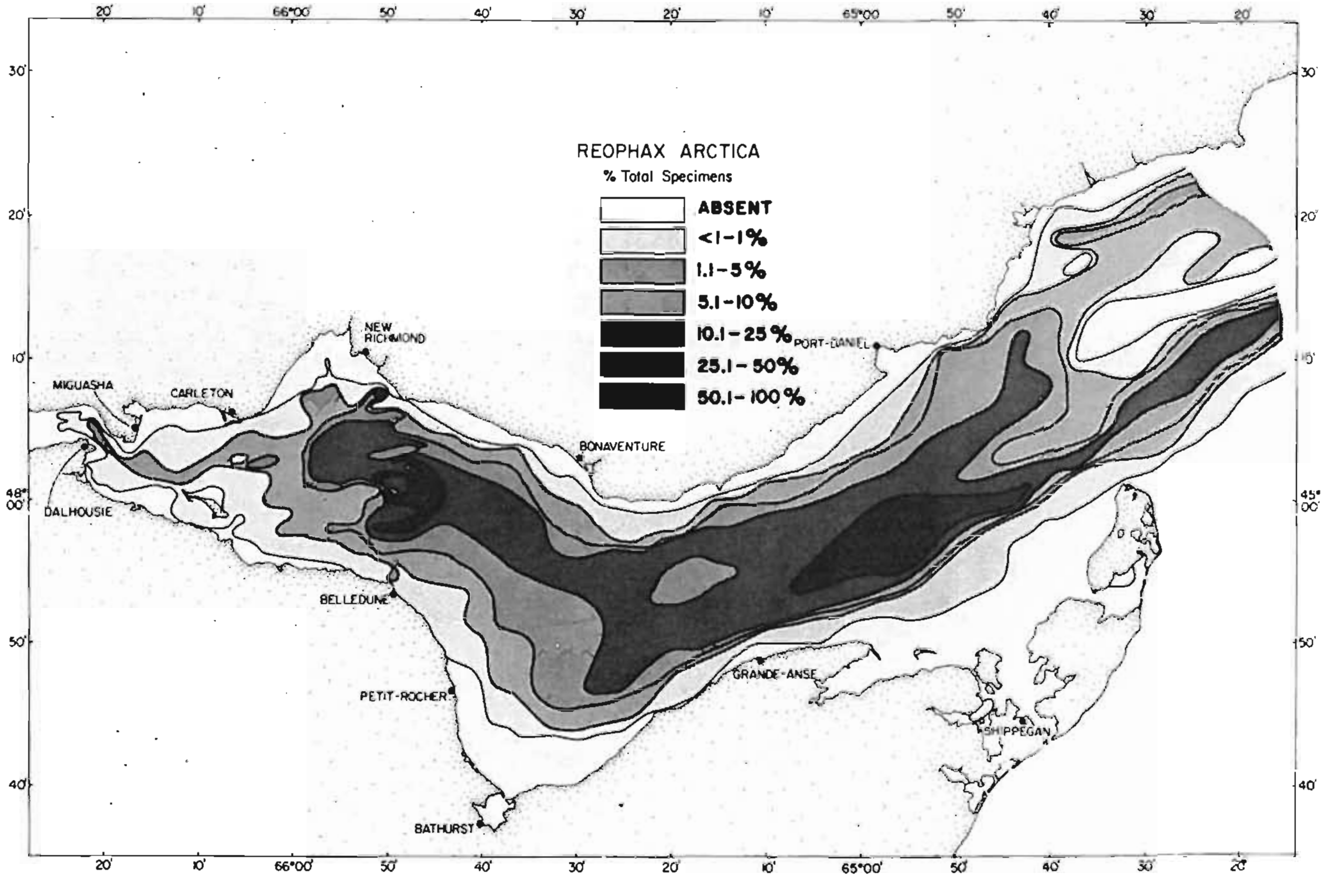


*Figure 15. Distribution of total specimens of **Reophax arctica** in Chaleur Bay.*

Although this shoaling effect cannot account for the westward penetration of **R. arctica** to depths of less than 32 m in the bay, it is interesting to note that the abundance of this form decreases significantly in the eastern part of the bay that is continuously occupied by the comparatively warm bottom layer. The highest percentages of this species are associated with distinctly differing sediment facies (i.e., gravelly sand near Shippegan and clayey silt north of Belledune) which is also indicative of other dominating distribution-controlling factors. The extension of the 1 to 5 per cent abundance field of **R. arctica** west to Dalhousie suggests a minimum mean salinity tolerance of about 27‰ for this species.

R. arctica shows a distinctive preference for water depths of 50 to 100 m in the Gulf of St. Lawrence. The mean total percentage at this interval is about 10 per cent compared to 4 per cent in the 10- to 50-m interval and 0.6 in the 100- to 300-m interval. Thus its distribution conforms remarkably well to the three-layer water mass system described earlier. The high mean abundance values noted for the Gulf of St. Lawrence are associated with offshore areas of active reworking and sediment redistribution that fall within the cold intermediate water layer.

The total specimen distribution of **Eggerella advena** is almost the reciprocal of **Islandiella** spp. Its distribution describes the limits of the upper bay estuarine environment and, except for a relatively small anomalous area near 64°30'W, 45°05'N, its abundance fields denote the counter-clockwise circulation pattern described earlier and the influence of brackish water discharge in the western part of the bay (Fig. 16). The distribution of living **E. advena** is highest in the shallow parts of the bay west of Bathurst (i.e., <30 m) and again in the shallow shelf environment north of Shippegan and Miscou islands. Comparison of living and total distributions may be indicative of offshore test transport and/or adult specimen mobility. This observation is based on the absence of the living form of this comparatively abundant species in the offshore areas of eastern Chaleur Bay (Fig. 17). Leslie (1965) noted a similar living to total distribution relationship in Hudson Bay. In the Gulf of St. Lawrence the highest mean total percentage of this species occurs in the 10- to 50-m depth interval and secondly in the 0- to 10-m interval. There is a marked decrease in the 50- to 100-m interval (50 to 23 per cent) and again in the 100- to 300-m interval (23 to 1 per cent). The species tends to inhabit nearshore and coastal areas of active reworking and non-deposition in the Gulf of St. Lawrence, although this is not always the case in western Chaleur Bay. In the latter area the 50.0 to 100 per cent abundance fields of both the living and total populations transgress the central comparatively quiescent part of the bay that is characterized by relatively fine deposits of clayey silt. According to Bartlett (1964) this species is probably depth-dependent in St. Margaret's and Mahone bays, Nova Scotia (<50 m). In both of these, high frequencies were recorded from various substrates (silt, sand, pebble, and macerated shells) that are indicative of both sediment reworking and comparatively low energy depositional processes. In Hudson Bay the living depth range of this form is 26 to 102 m and the highest percentage value was recorded in 47 m of water (Leslie, 1965). The substrate at stations in Hudson Bay containing abundant living **E. advena** has a high percentage of sand (average 50 per cent) and the suggested optimum substrate is a well sorted, fine grained sand. Oxygen content is usually high at stations in Hudson Bay that are characterized by either coarse or fine grained sediments so that this parameter may be a major limiting factor for this species.

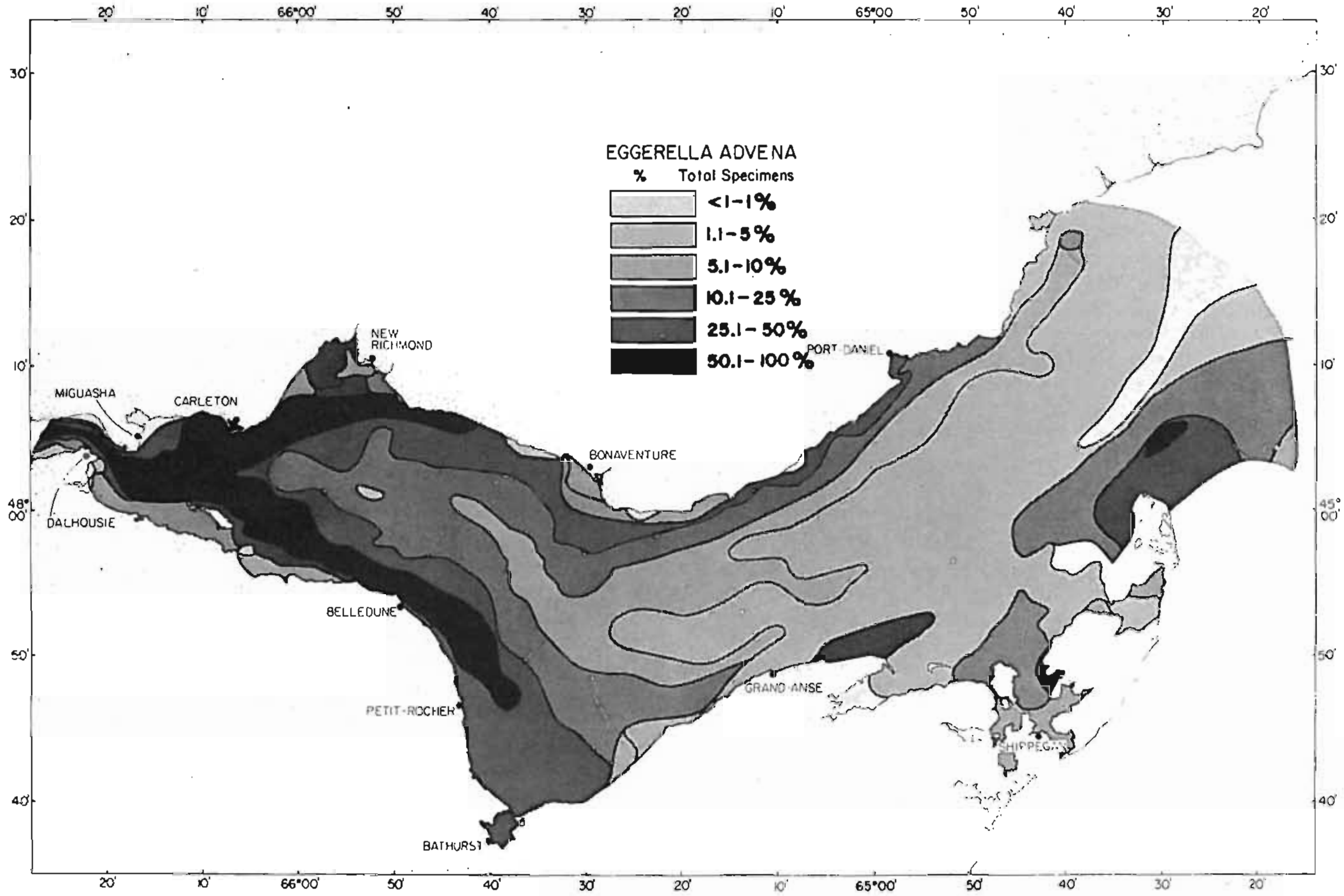


Figure 16. Distribution of total specimens of **Eggerella advena** in Chaleur Bay.

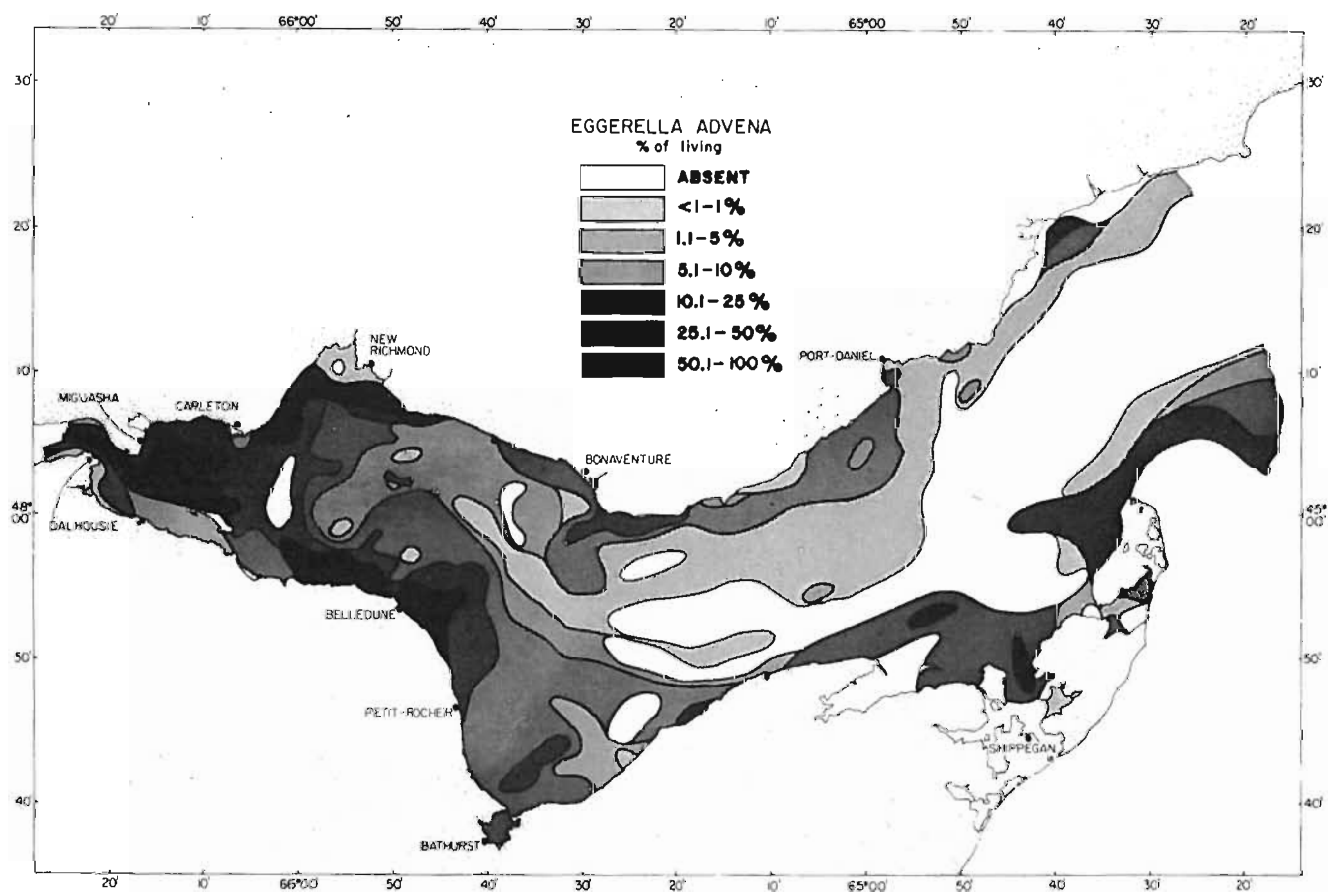


Figure 17. Distribution of living specimens of **Eggerella advena** in Chaleur Bay.

Elphidium incertum/clavatum Gp. is primarily a shallow bay species complex that is particularly abundant along the south shore of the bay between Petit-Rocher and Miscou Island and at comparable depths on the north shore (<32 m) between New Richmond and Port Daniel (Fig. 18). The complex is also relatively abundant in mid-bay environments where it is usually associated with comparatively fine sediments (i.e. clayey silt). This distribution pattern is somewhat analogous to that noted for **E. advena** and may be indicative of offshore transport processes. Leslie (1965) also noted that the relatively restricted distribution of living specimens in Hudson Bay is indicative of considerable offshore transport of the total population of this species. If this is the case, then major areas of deposition of resuspended nearshore material are indicated by high total percentage fields in the central parts of Chaleur Bay north of Grande Anse and south of New Richmond. It is interesting to note that these areas lie adjacent to a zone of sediment reworking (Schafer, 1977) which is delimited in part by the comparatively extensive gravelly sand facies between Bonaventure and Bathurst (Fig. 3).

In the Gulf of St. Lawrence the highest mean total percentage of the **E. incertum/clavatum** species group occurs in less than 10 m of water. Except for anomalously high values recorded for the Laurentian and Chaleur troughs south of Anticosti Island, the mean total percentage drops from 48 per cent in the 0- to 10-m intervals to 10 per cent in the 10- to 50-m depth interval throughout most of the remaining areas of the gulf. Total percentage values range from 5 to 25 per cent in areas of "essentially non-deposition with local reworking and formation of lag deposits" (Loring and Nota, 1973). Leslie (1965) found that **Elphidium incertum** occurs both living and dead in the shallowest and deepest stations sampled in Hudson Bay (26 to 230 m) and that this species is one of the most prolific forms observed in that area. He concluded that depth is not an important factor in the distribution of this species within the bay and that this form may be more substrate-dependent, preferring finer sediments that have relatively higher concentrations of calcium carbonate and organic carbon. Although this relationship was also suggested for this species group at several locally polluted sites in Chaleur Bay (Schafer, 1973), there is evidence from field experiments of the comparatively high transport susceptibility of this group (Schafer, 1976).

Ammotium cassis is an important shallow water estuarine indicator species in Chaleur Bay (Fig. 19). Total percentages are highest in the western part of the bay and in several shallow embayments near Shippegan. Its restricted distribution in offshore bay environments is probably related to its relatively large size (1.5 to 1.8 mm compared to 0.7 and 0.6 mm for **E. advena** and **E. incertum/clavatum** Gp. respectively; Loeblich and Tappan, 1953). In the Gulf of St. Lawrence **A. cassis** is more abundant in the 0- to 10-m depth interval by a factor of 20 compared to deeper environments. Its distribution is restricted to the southern gulf and especially to the Northumberland Strait area. It is an important indicator species of a lower estuarine 'transitional' biotope that has been identified by Scott et al. (in press) in the Miramichi estuary south of Chaleur Bay. In the Miramichi, this form appears to have increased in proportion to the total population observed ten years earlier by Bartlett (1966) because of a decrease in tidal exchange between Inner Miramichi Bay and Northumberland Strait. As such, the species appears to be primarily salinity-dependent. Bartlett (1964) indicated that **A. cassis** is most abundant at the mouth of estuaries in St. Margaret's and Mahone bays in southeast Nova Scotia. He also found that the large size of this species did not permit transportation of this form much beyond its actual living habitat.

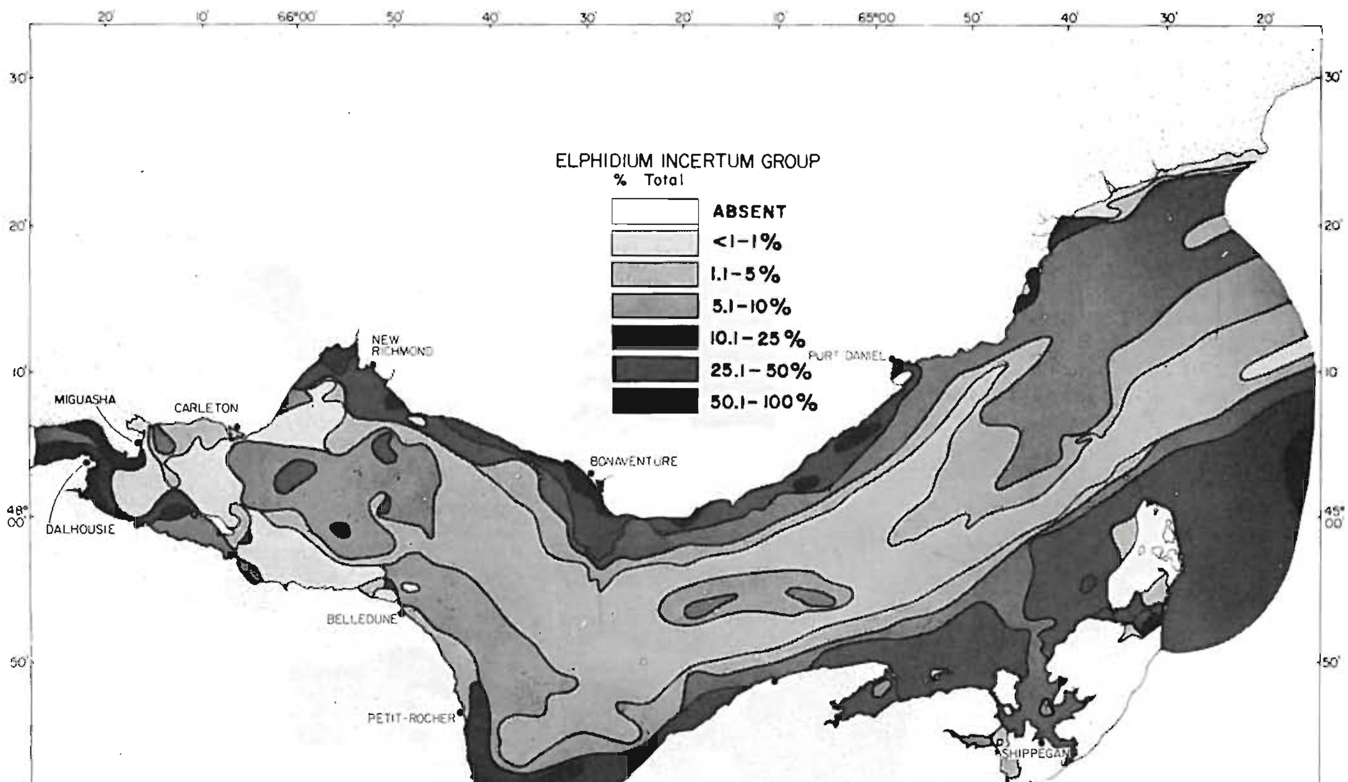


Figure 18. Distribution of total specimens of ***Elphidium incertum/clavatum*** *Gp. in Chaleur Bay.*

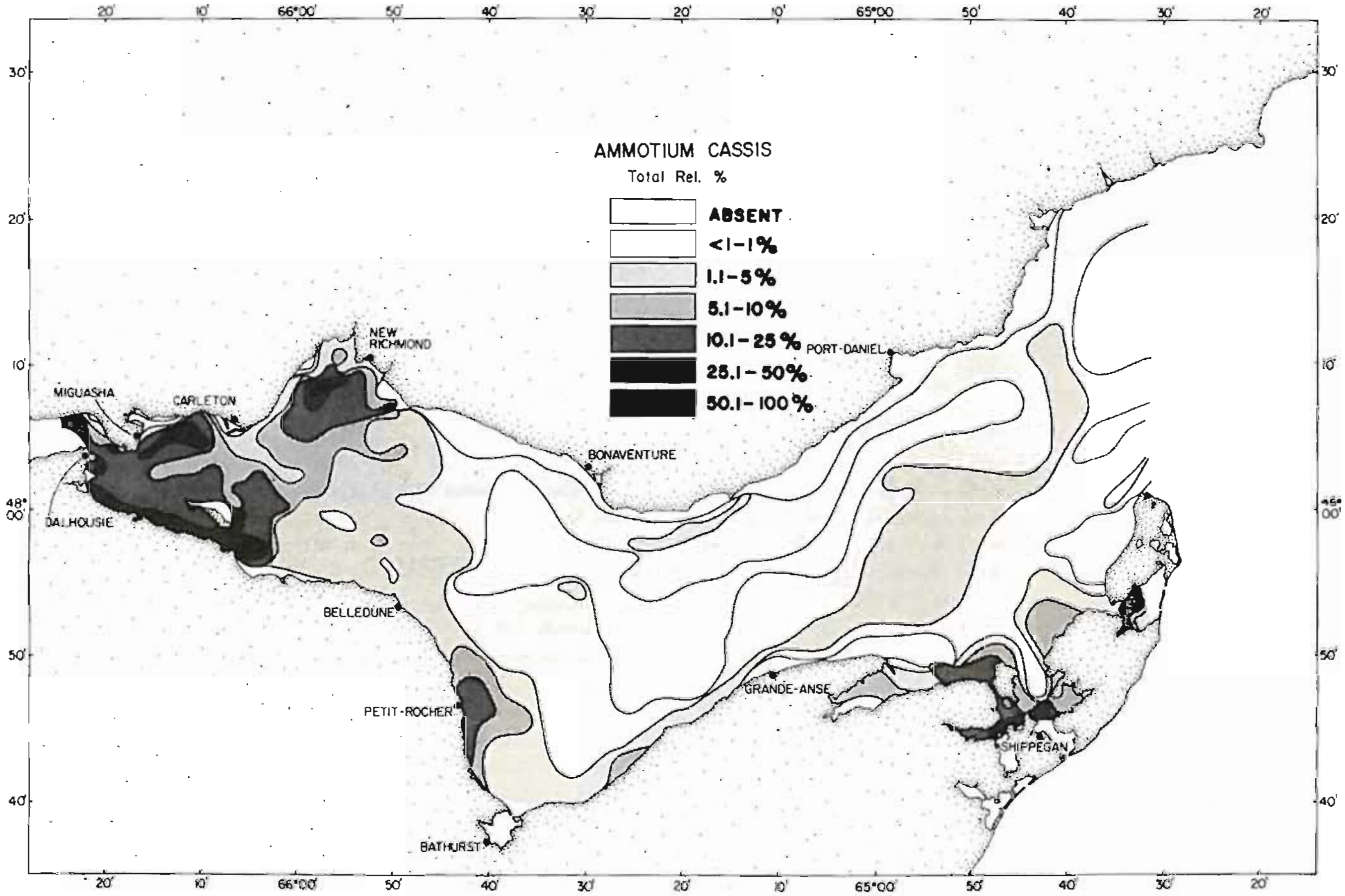


*Figure 19. Distribution of total specimens of **Ammotium cassis** in Chaleur Bay.*

FORAMINIFERAL BIOTOPES IN CHALEUR BAY

Two biotope models have been developed for Chaleur Bay using the cluster analysis method described by Parks (1966). The term biotope is used here in the broad sense to define distributions that reflect primarily ecological influences but which, in fact, may also be controlled by contemporary sedimentary and diagenetic processes. The cluster method sorts the samples using the simple distance function defined earlier in this paper. In the first analysis the total population counts of all species were used to define the biotopes and four related cluster groups were defined at the D = 0.15 level (Table 3). The groups are characterized in terms of their respective species components using Constancy (C) and Biostratigraphic Fidelity (BF) values (Hazel, 1970), which give quantitative estimates of the species frequency and proportion in each of the groups. Constancy is the percentage of all samples included in a particular cluster group in which a species occurs and is thus indicative of the extent of the species areal distribution within the biotope. Biostratigraphic Fidelity (alternatively the term Biogeographic Fidelity can be used here because the thanatotopes based on total population values are considered to be approximate representations of Chaleur Bay biotopes) relates the percentage of occurrences of species j in a cluster group i (P_i) to the sum of the per cent occurrences of species j in all other groups (i = 1, 2, 3 . . . p) within the limits of the problem. Thus,

$$BF_{j,i} = \frac{P_{i,j}}{\sum_{i=1}^{p} P_j} \times 10$$

The degree of restriction of a species to a particular biotope is expressed as a number ranging from one to ten where ten is indicative of a species that is totally confined to a particular biotope (indicator species).

Biotope 1 reflects a nearshore marine to offshore estuarine environment (Fig. 20). Dominant species within this biotope in terms of relative abundance (BF) and within biotope occurrences (C) include the arenaceous species **Ammobaculities salsus** and **Ammotium cassis** and the calcareous forms **Elphidium frigidum** and **Protelphidium orbiculare.** Biotope 3 is closely associated with 1 but is particularly indicative of relatively shallow estuarine conditions. The occurrence of biotope 3 assemblages in the offshore area of western Chaleur Bay probably reflects seaward transport of several species by natural processes and/or dredging disposal practices. These displaced(?) assemblages are deposited in the relatively deep (24 m) extension of the Chaleur Bay Trough. In the nearshore estuarine environment delimited by biotope 3, the aforementioned biotope 1 species decrease in dominance in all instances except for **A. cassis**. Biotope 1 species are replaced (in terms of relatively increased proportions of the total population) by the arenaceous species **Ammomarginulina fluvialis, Hemisphaerammina** sp., **Trochammina inflata**, and **Miliammina fusca**. The calcareous form **Elphidium margaritaceum** also increases slightly in abundance in the relatively shallow nearshore biotope 3 environment. Biotopes 2 and 4 reflect deeper and/or relatively marine conditions compared to 1 and 3. Biotope 4 is associated with coarse nearshore sediment facies ranging in particle size from gravelly sands to silty sands. Biotope 2 sediments, on

Table 3

Biogeographic Fidelity (BF) and Constance (C), of the Total Foraminiferal Population in Four Cluster Groups

CLUSTER GROUP	1	2	3	4
NO. OF STATIONS/GROUP	142 stns.	64 stns.	116 stns.	13 stns.
	BF (C)	BF (C)	BF (C)	BF (C)
Adercotryma glomeratum	1.3(18)	4.7(66)	0.1(1)	3.9(54)
Ammobaculites dilitatus	3.1(5)	1.0(2)	5.9(9)	-
A. salsus	3.5(38)	3.2(36)	1.2(14)	2.1(23)
Ammodiscus catinus	2.8(33)	3.8(44)	2.1(25)	1.3(15)
Ammomarginulina fluvialis	3.6(13)	0.4(2)	6.0(23)	-
Ammonia beccarii	4.7(5)	2.9(3)	2.4(3)	-
Ammotium cassis	3.0(75)	2.2(55)	3.0(75)	1.8(46)
Astacolus hyalacrulus	-	-	-	10.0(8)
Astrononion stellatum	1.1(4)	6.4(20)	-	2.4(8)
Bathysiphon filiformis	0.4(2)	1.9(9)	0.2(1)	7.6(38)
Bolivina pseudopunctata	1.6(16)	5.5(58)	-	2.9(31)
Buccella frigida	2.3(79)	2.9(100)	1.9(65)	2.9(100)
B. inusitata	1.9(6)	4.7(16)	1.0(3)	2.3(8)
Bulimina exilis	1.3(1)	8.7(5)	-	-
B. marginata	-	10.0(3)	-	-
Buliminella elegantissima	2.2(11)	3.6(19)	1.3(7)	2.9(15)
Cassidella complanata	2.3(40)	4.3(75)	0.3(5)	3.1(54)
Cibicides lobatulus	2.0(25)	2.9(36)	0.8(10)	4.3(54)
C. pseudoungerianus	4.1(3)	2.3(2)	3.7(3)	-
Cribrostomoides crassimargo	1.7(31)	4.1(73)	0.3(5)	3.9(69)
C. jeffreysi	2.1(18)	4.0(33)	1.1(9)	2.8(23)
Cyclogyra foliacea	-	-	-	10.0(8)
C. involvens	4.0(14)	3.7(13)	-	2.3(8)
Dentalina baggi	0.3(1)	6.0(13)	-	3.7(8)
D. frobisherensis	-	3.8(5)	-	6.2(8)
D. ittai	5.1(6)	4.2(5)	0.8(1)	-
Eggerella advena	2.6(96)	2.4(91)	2.4(88)	2.7(100)
Elphidiella arctica	4.7(11)	4.6(11)	0.7(2)	-
Elphidium bartletti	2.6(16)	3.5(22)	0.3(2)	3.7(23)
E. excavatum	7.9(6)	-	2.1(2)	-
E. frigidum	3.4(28)	2.4(20)	2.3(19)	1.8(15)
E. incertum/clavatum Gp.	2.5(92)	2.7(100)	2.1(76)	2.7(100)
E. margaritaceum	2.6(21)	1.6(13)	3.0(24)	2.9(23)
E. subarcticum	2.7(35)	2.8(36)	1.5(19)	3.0(38)
Eoeponidella pulchella	1.1(4)	3.9(13)	0.3(1)	4.8(15)
Epistominella takanagayii	1.1(4)	4.3(14)	-	4.7(15)
Esosyrinx curta	4.8(1)	5.2(2)	-	-
Fissurina cucurbitasema	0.9(1)	-	-	9.2(8)
F. lucida	1.9(8)	1.9(8)	0.6(3)	5.6(23)
F. marginata	2.9(3)	6.3(6)	0.9(1)	-
F. serrata	-	-	-	10.0(8)
Glabratella wrightii	2.6(8)	3.1(9)	1.7(5)	2.6(8)
Glandulina laevigata	-	1.7(2)	-	8.3(8)
Globobulimina auriculata	0.3(1)	6.0(13)	-	3.7(8)
Glomospira gordialis	0.7(5)	1.9(13)	1.7(11)	5.8(38)
Gordiospira arctica	2.9(3)	6.3(6)	0.9(1)	-
Hemisphaerammina bradyi	2.7(39)	1.7(25)	4.0(57)	1.6(23)
Hippocrepina indivisa	1.8(24)	2.9(39)	0.9(12)	4.5(62)
Hippocrepinella hirudinea	2.6(4)	2.8(5)	-	4.6(8)
Hyperammina elongata	-	-	-	10.0(8)
H. subnodosa	0.7(4)	4.2(25)	-	5.1(31)
Islandiella islandica	1.7(23)	5.3(72)	0.1(1)	2.9(38)
I. norcrossi	4.0(13)	5.4(17)	0.5(2)	-
I. teretis	1.7(32)	4.3(80)	0.3(5)	3.7(69)
Lagena apiopleura	1.1(3)	3.0(8)	-	5.9(15)
L. flatulenta	10.0(1)	-	-	-
L. gracillima	2.0(4)	3.6(6)	-	4.4(8)
L. laevis	0.4(1)	1.6(3)	-	8.0(15)
L. meridionalis	-	-	-	10.0(8)
L. mollis	-	4.5(6)	-	5.5(8)
L. nebulosa	5.8(2)	4.2(2)	-	-

CLUSTER GROUP	1	2	3	4
NO. OF STATIONS/GROUP	142 stns.	64 stns.	116 stns.	13 stns.
	BF (C)	BF (C)	BF (C)	BF (C)
L. parri	-	10.0(2)	-	-
L. semilineata	2.8(7)	4.3(11)	-	3.0(8)
Laryngosigma hyalascidia	-	2.9(3)	-	7.1(8)
Miliammina fusca	3.2(49)	1.5(23)	4.3(65)	1.0(15)
Miliolinella chukchiensis	1.3(1)	1.5(2)	-	7.2(8)
M. subrotunda	-	2.9(3)	-	7.1(8)
Nodosaria emphysaocyta	-	10.0(2)	-	-
Nonion sp.	-	10.0(2)	-	-
Nonionella atlantica	3.0(10)	6.5(22)	0.5(2)	-
N. auricula	0.8(2)	3.9(11)	-	5.4(16)
Nonionellina labradorica	2.3(40)	4.1(73)	0.2(3)	3.4(62)
Oolina borealis	0.9(2)	2.5(6)	0.4(1)	6.3(15)
O. caudigera	10.0(1)	-	-	-
O. hexagona	-	-	-	10.0(8)
O. melo	3.6(4)	6.4(6)	-	-
O. squamosa	3.1(1)	6.9(2)	-	-
Parafissurina himatiostoma	3.6(4)	6.4(6)	-	-
Patellina corrugata	2.6(10)	2.9(11)	0.5(2)	4.1(15)
Pateoris hauerinoides	1.9(23)	2.2(27)	0.6(8)	5.2(62)
Pontigulasia compressa	5.0(4)	-	5.0(4)	-
Protelphidium orbiculare	3.0(71)	2.6(61)	2.2(53)	2.3(54)
Protoschista findens	1.7(2)	1.3(2)	0.7(1)	6.3(8)
Pseudopolymorphina novangliae	0.5(2)	3.5(14)	0.2(1)	5.8(23)
Pyrgo williamsoni	1.0(4)	2.3(8)	-	6.7(23)
Quinqueloculina agglutinata	1.7(14)	2.4(20)	0.5(4)	5.4(46)
Q. arctica	1.2(4)	3.7(11)	-	5.2(15)
Q. seminulum	1.4(16)	3.0(34)	1.0(12)	4.7(54)
Q. stalkeri	0.6(3)	2.5(11)	-	6.9(31)
Recurvoides turbinatus	1.6(24)	4.5(67)	0.4(6)	3.6(54)
Reophax arctica	2.1(57)	3.2(88)	1.7(46)	3.1(85)
R. fusiformis	2.2(58)	3.4(91)	1.2(32)	3.2(85)
R. gracilis	-	10.0(3)	-	-
R. nana	3.1(24)	5.7(44)	0.2(2)	1.0(8)
R. nodulosa	1.9(7)	1.2(5)	2.9(11)	4.0(15)
R. cf. R. nodulosa	0.7(1)	9.3(9)	-	-
R. pilulifera	4.0(4)	2.9(3)	3.1(3)	-
R. scottii	2.3(60)	3.4(89)	1.3(34)	3.0(77)
Robertinoides charlottensis	0.8(4)	5.5(23)	-	3.6(15)
Rosalina floridana	2.5(7)	4.4(13)	0.3(1)	2.7(8)
Saccammina atlantica	2.2(33)	2.8(42)	1.0(14)	4.1(62)
S. sphaerica	1.1(4)	1.5(5)	-	7.4(23)
Scutuloris tegminis	1.7(3)	3.7(6)	-	4.6(8)
S. cf. S. tegminis	-	3.8(5)	-	6.2(8)
Spirillina vivipara	1.2(3)	2.1(5)	-	6.7(15)
Spiroplectammina biformis	2.3(60)	3.4(88)	1.3(35)	3.0(77)
Textularia earlandi	1.3(5)	3.7(13)	0.5(2)	4.6(15)
T. torquata	2.3(50)	3.7(81)	0.8(17)	3.2(69)
Trifarina angulosa	-	10.0(2)	-	-
T. fluens	1.0(8)	4.0(31)	-	5.0(38)
Triloculina oblonga	1.3(4)	2.9(8)	-	5.8(15)
T. trigonula	-	10.0(2)	-	-
T. trihedra	-	2.3(5)	-	7.7(15)
Trochammina inflata	3.1(14)	1.0(5)	5.8(26)	-
T. lobata	2.4(25)	2.1(22)	1.8(19)	3.7(38)
T. macrescens	3.7(13)	1.8(6)	4.5(15)	-
T. ochracea	1.8(30)	2.2(36)	1.4(24)	4.6(77)
T. squamata	4.0(13)	3.2(11)	2.8(9)	-
Difflugia capreolata	4.1(4)	-	5.9(5)	-
D. oblonga	4.6(3)	-	5.4(3)	-
Planktonic Species	2.0(2)	-	0.8(1)	7.2(8)
NUMBER OF SPECIES/GROUP	101	107	68	87

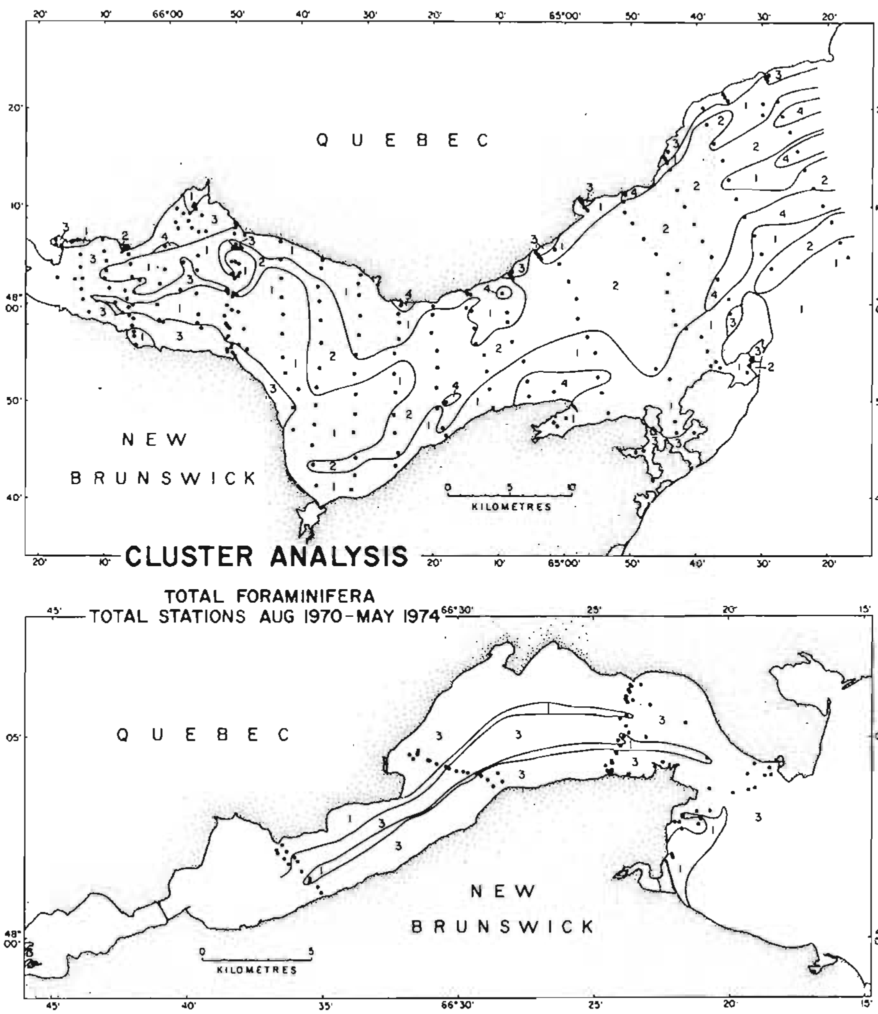


Figure 20. Distribution of major biotopes in Chaleur Bay using all (121) species.

the other hand, are usually combinations of silt- and clay-sized particles. Biotope 2 indicator species are characterized by their relatively high abundance compared to biotope 4, and are mostly calcareous types such as **Bolivina pseudopunctata, Islandiella islandica, Nonionella atlantica**, and a number of other very rare forms (e.g., **A. hyalcrulus, C. foliacea, F. cucurbitasema, F. serrata, H. elongata, L. meridionalis**, and **O. hexagona**). In biotope 4, calcareous species such as **Cibicides lobatulus, Pateoris hauerinoides, Pyrgo williamsoni, Glomospira gordialis**, and **Hippocrepina indivisa** become prominent compared to their observed abundance in biotope 2.

It is evident from Table 2 that the computer clustering procedure is dependent, in part, on the occurrence of rare species within each biotope. While the biotopes derived from these data certainly reflect the present day environmental regime, it is also useful to examine models that may be more useful for paleoecological interpretations. A second biotope model was computed for this purpose using 30 species all of which were present in at least 20 per cent of the samples collected in the bay. In this model the biotopes are defined to a greater degree on the basis of the relative abundance of ubiquitous species which could be expected to occur with greater frequency in older sediments. Six cluster groups were identified at the D = 0.12 level (Fig. 21). Biotope 5 compares favourably with the areal extent of the silty clay sediment facies and is somewhat more restricted compared to the biotope 2 in the total species model. Biotope 2 in the 30-species model correlates generally with the occurrence of clayey silt sediments in the western part of the bay and is somewhat analogous to biotope 1 in the total species model.

Biotope 1 (30 species) reflects nearshore estuarine conditions and comparatively coarse sediments such as gravelly sand and silty sand. It is associated with biotope 4 which is indicative of subtidal nearshore environments characterized by very coarse pebble- to cobble-sized sediments with attached species of marine algae.

In the 30-species model the prominent biotope 1 estuarine indicator species are **Elphidium frigidum, E. margaritaceum, Miliammina fusca**, and **Hemisphaerammina** sp. All of these species are absent in the shallow water marine biotope 4 where the most prominent indicator form is **Cibicides lobatulus** (Table 4). This species also occurs in biotope 6 which is located within the silty clay sediment facies. However, in this instance, other species such as **Cribrostomoides crassimargo, Islandiella islandica** and **Recurvoides turbinatus** reflect the relatively deep offshore environmental characteristics that prevail in this part of the Bay.

Table 4

Biogeographic Fidelity and Constancy of Well Represented (F ≥ 20%) Foraminifera Species in Six Cluster Groups

CLUSTER GROUP NO. OF STATIONS/GROUP	1 191 stns. BF (C)	2 64 stns. BF (C)	3 40 stns. BF (C)	4 4 stns. BF (C)	5 34 stns. BF (C)	6 2 stns. BF (C)
Adercotryma glomeratum	0.2(3)	1.1(19)	3.6(63)	-	5.2(91)	-
Ammobaculites salsus	0.7(12)	3.5(58)	3.3(55)	-	2.5(41)	-
Ammodiscus catinus	1.6(25)	3.0(45)	3.5(53)	-	1.9(29)	-
Ammotium cassis	2.6(73)	3.0(83)	2.1(60)	-	2.3(65)	-
Bolivina pseudopunctata	0.1(1)	0.6(13)	3.2(65)	-	3.6(74)	3.3(50)
Buccella frigida	1.4(71)	1.6(83)	1.9(98)	1.4(75)	1.9(97)	1.9(100)
Cassidella complanata	0.3(9)	1.7(55)	2.4(80)	-	2.7(88)	3.0(100)
Cibicides lobatulus	0.9(21)	1.1(27)	0.8(20)	2.1(50)	1.0(24)	4.1(100)
Cribrostomoides crassimargo	0.2(8)	1.2(41)	2.9(98)	-	2.6(88)	3.0(100)
Eggerella advena	2.3(92)	2.4(97)	2.4(98)	0.6(25)	2.4(97)	-
Elphidium frigidum	5.4(32)	3.4(20)	1.2(8)	-	-	-
E. incertum/clavatum Gp.	1.5(82)	1.7(92)	1.8(98)	1.4(75)	1.8(100)	1.8(100)
E. margaritaceum	5.5(30)	3.1(17)	1.4(8)	-	-	-
E. subarcticum	2.4(30)	2.0(25)	1.4(8)	2.0(25)	1.2(15)	-
Hemisphaerammina bradyi	4.1(54)	2.7(36)	2.1(28)	-	1.1(15)	-
Hippocrepina indivisa	0.9(13)	2.4(34)	3.0(43)	-	3.7(53)	-
Islandiella islandica	0.3(9)	1.0(27)	2.4(65)	-	2.5(68)	3.7(100)
I. teretis	0.3(9)	1.1(39)	2.4(85)	0.7(25)	2.7(94)	2.8(100)
Miliammina fusca	4.5(64)	2.9(42)	1.4(20)	-	1.2(18)	-
Nonionellina labradorica	0.2(6)	1.9(59)	2.8(88)	0.8(25)	2.8(88)	1.6(50)
Protelphidium orbiculare	2.2(62)	2.8(80)	2.4(70)	1.7(50)	0.9(26)	-
Recurvoides turbinatus	0.3(9)	1.1(30)	1.9(53)	-	3.2(88)	3.6(100)
Reophax arctica	1.2(43)	2.1(77)	2.7(95)	-	2.6(94)	1.4(50)
R. fusiformis	0.9(33)	2.3(83)	2.7(98)	-	2.8(100)	1.4(50)
R. scottii	1.0(36)	2.4(84)	2.8(98)	-	2.4(85)	1.4(50)
Saccammina atlantica	1.2(18)	3.0(47)	2.7(43)	-	3.2(50)	-
Spiroplectammina biformis	0.8(35)	1.9(78)	2.4(98)	-	2.4(100)	2.4(100)
Textularia torquata	0.7(20)	2.5(69)	3.5(98)	-	3.3(91)	-
Trochammina lobata	2.3(21)	3.2(30)	3.0(28)	-	1.6(15)	-
T. ochracea	2.1(29)	2.1(30)	3.1(43)	-	2.8(38)	-
NUMBER OF SPECIES/GROUP	30	30	30	8	28	13

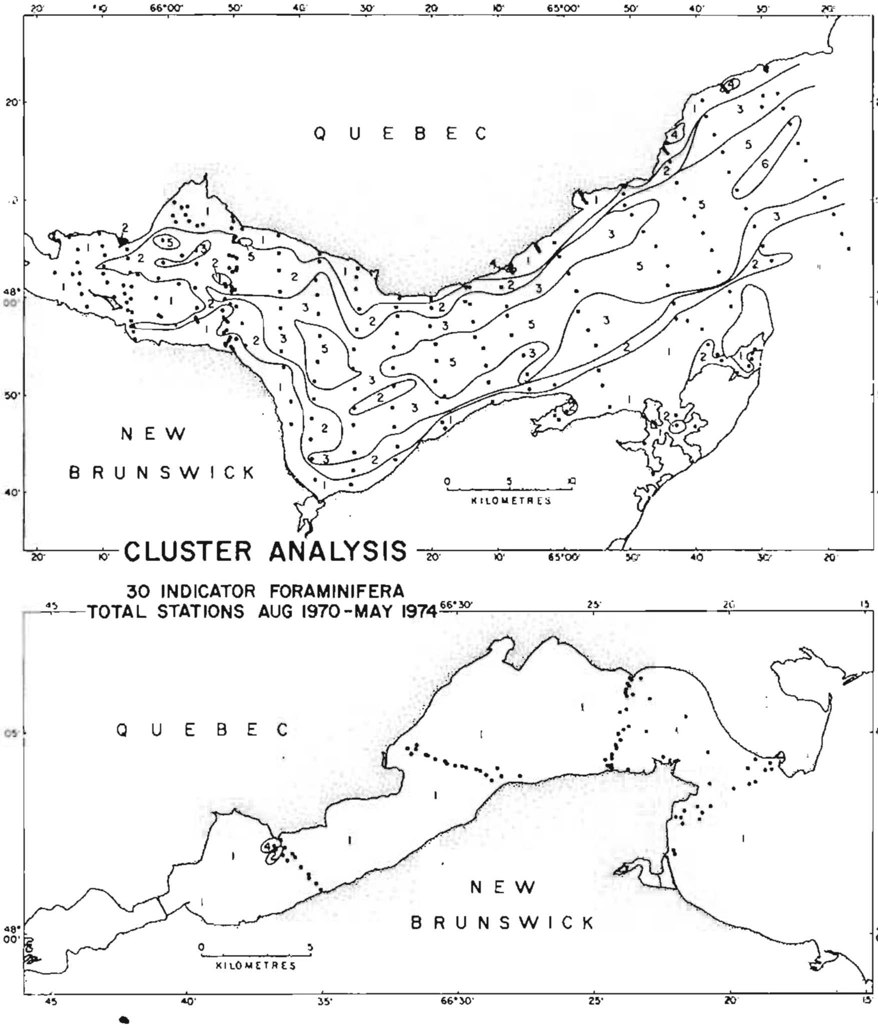


Figure 21.

Distribution of major biotopes in Chaleur Bay using the 30 most abundant species.

Comparatively high percentages of **Adercotryma glomeratum** and **Recurvoides turbinatus** are potentially among the best biotope 5 indicators. However, **A. glomeratum** does not occur in the cores (11 samples) as reported by Rashid et al. (1975) and is found in only one of 67 samples reported by Mageau (1974). **R. turbinatus** similarly occurs in only 6 of Mageau's 67 samples and 3 of Rashid's samples so that the usefulness of these species as indicators must be restricted to analyses of contemporary environments.

At intermediate water depths (biotopes 3 and 2) in Chaleur Bay only **Ammodiscus catinus** shows a relatively restricted occurrence. However, its occurrence in the above cited core sample data is the same as **A. glomeratum** and thus it cannot be considered in quantitative paleoecological interpretations in this area.

A UTILITARIAN PALEOECOLOGICAL MODEL

Quantitative biotope models that can be used to interpret contemporary environmental processes are not necessarily applicable for paleoecological interpretations because of drastic changes in the species composition of fossil assemblages. Some changes in assemblage composition begin immediately at the sediment-water interface (e.g., ingestion by large invertebrates; Mageau and Walker, 1975) while others are related to post-depositional physical and chemical processes (Brodniewicz, 1965). In Chaleur Bay about nine species are well represented in both recent sediments and in samples of Holocene material (Rashid et al., 1975; Mageau, 1974; Schafer, unpublished data). They include **A. cassis, R. arctica, E. advena, E. incertum/clavatum** Gp., **I. islandica, I. norcrossi, I. teretis, P. orbiculare,** and **B. pseudopunctata.** These forms contribute comparatively little to the observed heterotrophic distribution pattern of nearshore bay faunas (Schafer and Cole, 1976). These overdispersed or 'patchy' patterns are due primarily to the occurrence of rare forms and may, in certain instances, be an artifact of the sampling procedure. The nine-species model thus represents not only the most realistic version for quantitative paleoecological interpretations, but also the one which reflects the highest possible resolution obtainable from the paleontological signal under the comparatively variable conditions that prevail in this nearshore environment. The model has again been generated using the same Q-mode clustering technique and three major biotopes are event at the D = 0.2 level. These biotopes are indicative of transitional-estuarine, shallow bay and deep bay environments (Table 5).

In the transitional-estuarine biotope the high relative abundance of **E. advena** and **A. cassis** relative to all other species noted is the major diagnostic feature. As this biotope gives way to a more open marine shallow to intermediate depth bay environment, the proportion of these two arenaceous forms decreases and calcareous species of the genus **Elphidium** and **Islandiella teretis** increase in number.

Table 5

Biogeographic Fidelity and Constancy of Reliable
Paleoecological Indicator Species in Three Cluster Groups

CLUSTER GROUP NO. OF STATIONS GROUP	1 82			2 233			3 16			
	BF	(C)	$\bar{A}$	BF	(C)	$\bar{A}$	BF	(C)	$\bar{A}$	F
Eggerella advena	3.75	(100)	60	3.43	(91)	14	2.82	(75)	3	91
Elphidium incertum/clavatum Gp.	2.92	(79)	6	3.40	(92)	18	3.68	(100)	13	88
Ammotium cassis	4.88	(98)	16	3.24	(65)	7	1.88	(38)	<1	68
Protelphidium orbiculare	3.22	(48)	1	4.66	(69)	7	2.12	(31)	1	62
Reophax arctica	3.69	(76)	1	2.65	(54)	6	3.66	(75)	6	58
Islandiella teretis	0.64	(9)	<1	2.80	(37)	3	6.56	(88)	22	33
I. islandica	0.41	(5)	<1	2.32	(28)	<1	7.27	(88)	6	25
Bolivina pseudopunctata	0.14	(1)	<1	2.56	(22)	<1	7.30	(63)	2	20
Islandiella norcrossi	0.93	(2)	<1	4.28	(11)	<1	4.79	(13)	1	9
GENERAL ENVIRONMENT	TRANS.-ESTUARINE			SHALLOW BAY			DEEP BAY			

The arenaceous species **Reophax arctica** also shows a pronounced increase in per cent of the total fauna. In the deep bay biotope the proportion of **E. advena, A. cassis, E. incertum/clavatum** Gp., and **P. orbiculare** decreases while that of **I. teretis, I. islandica** and **B. pseudopunctata** increases. In terms of BF values, the most prominent and reliable indicator forms are **A. cassis** (transitional estuarine), **P. orbiculare** (shallow bay-open marine), and **I. teretis** (deep bay-gulf).

The removal of easily transportable species such as **E. incertum/clavatum** Gp. and **E. advena** from this model resulted in a significant breakdown in the geographic continuity of the major biotopes in a subsequent cluster analysis. This effect may be indicative of the importance of postmortem allochthonous processes in controlling the species proportionality of present day nearshore assemblages. The nine-species model is nevertheless a reliable paleoecological indicator of the three major subenvironments that have been identified in the Chaleur Bay-Restigouche estuary system using more complex (total species) data matrices. It can be applied with greatest confidence to the quantitative interpretation of Holocene paleoecologic events in this area.

CONCLUSIONS

1. Bathymetry, water mass characteristics, and the general circulation pattern appear to be the major factors governing foraminifera and sediment distribution patterns in Chaleur Bay. No single water mass parameter is probably as important as the degree of inherent variability of each mass in determining the observed foraminiferal distribution patterns.
2. Arenaceous species are dominant in Chaleur Bay especially at water depths greater than 16 m. This water depth probably defines the lower limit of the seasonally-influenced and comparatively highly perturbed shallow bay environment. Ecologically, it may also be indicative of the lower limit of algal zones and of coarse sediment substrates that are preferred by some nearshore calcareous forms.
3. Dense living and total populations are indicative of ecotones in open bay environments. In the relatively estuarine upper bay areas, high population densities are associated with comparatively coarse sediments containing moderate amounts of organic carbon (i.e., <2.5 per cent.
4. The highest species numbers occur at intermediate depths (i.e., 40 to 70 m). Here, niche diversity is high because of a north-south change in substrate and water mass characteristics. This change occurs at depths where physical perturbations are of relatively low amplitude, a condition which may preserve the regionally high level of environmental heterogeneity.
5. The regional distribution pattern of several dominant species such as **E. advena, Islandiella** spp., and **R. arctica** reflects the three-layer water mass system and the basic counterclockwise circulation pattern in the bay. Other dominant forms such as **E. incertum/clavatum** Gp. appear to be indicative of resuspension and offshore transport processes.
6. Cluster analysis of total species percentages defines three major biotopes in Chaleur Bay including shallow upper estuarine, nearshore bay-lower estuarine, and deep offshore bay (<100 m). Analysis of a nine-species matrix, including forms that are usually abundant in Holocene sediments, also reflects the three major biotopes. Their pattern is, however, somewhat less continuous in the deeper parts of the bay compared to the 30 species biotope equivalent. Removal of the easily transported species from the nine-species matrix results in a significant breakdown in the regional continuity of all biotopes and may be indicative of the over-all allochtonous character of the most abundant members of total population (**E. advena** and **E. incertum/clavatum** Gp.).

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PLATE 1

1.	**Pontigulasia compressa** (Carter) G.S.C. no. 54238	Stn. G-1	x 228
2.	**Difflugia oblonga** Ehrenberg G.S.C. no. 54239	Stn. G-1	x 198
3.	**Difflugia capreolata** Pénard G.S.C. no. 54240	Stn. G-3	x 245
4.	**Dendrophrya arborescens** (Norman) G.S.C. no. 54241 = **Psammatodendron arborescens** Norman	Stn. 74013-16	x 43
5.	**Hemisphaerammina bradyi** Loeblich & Tappan G.S.C. no. 54242	Stn. A-75	x 138
6.	**Ammopemphix** sp. G.S.C. no. 54243	Stn. A-10	x 184
7.	**Technitella legumen** Norman G.S.C. no. 54244	Stn. 74013-10	x 58
8.	**Hippocrepina indivisa** Parker G.S.C. no. 54245	Stn. 74013-14	x 255
9.	**Hyperammina subnodosa** Brady G.S.C. no. 54246	Stn. J-11	x 156
10.	**Hyperammina elongata** Brady G.S.C. no. 54247	Stn. 74013-22	x 51


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PLATE 2

1.	**Ammodiscus catinus** Höglund G.S.C. no. 54248	Stn. A-82	x 389
2.	**Glomospira gordialis** (Jones & Parker) G.S.C. no. 54249	Stn. A-8	x 279
3.	**Saccammina atlantica** (Cushman) G.S.C. no. 54250	Stn. 74013-50	x 272
4.	**Reophax nana** Rhumbler G.S.C. no. 54251	Stn. R-3	x 227
5.	**Reophax arctica** Brady G.S.C. no. 54252	Stn. 74013-71	x 166
6.	**Reophax nodulosa** Brady G.S.C. no. 54253	Stn. R-4	x 202
7.	**Reophax scottii** Chaster G.S.C. no. 54254	Stn. P-14	x 191
8.	**Reophax dentaliniformis** Brady G.S.C. no. 54255	Stn. Q-53	x 58
9.	**Reophax fusiformis** (Williamson) G.S.C. no. 54256	Stn. A-65	x 69
10.	**Adercotryma glomerata** (Brady) G.S.C. no. 54257	Stn. I-9	x 263

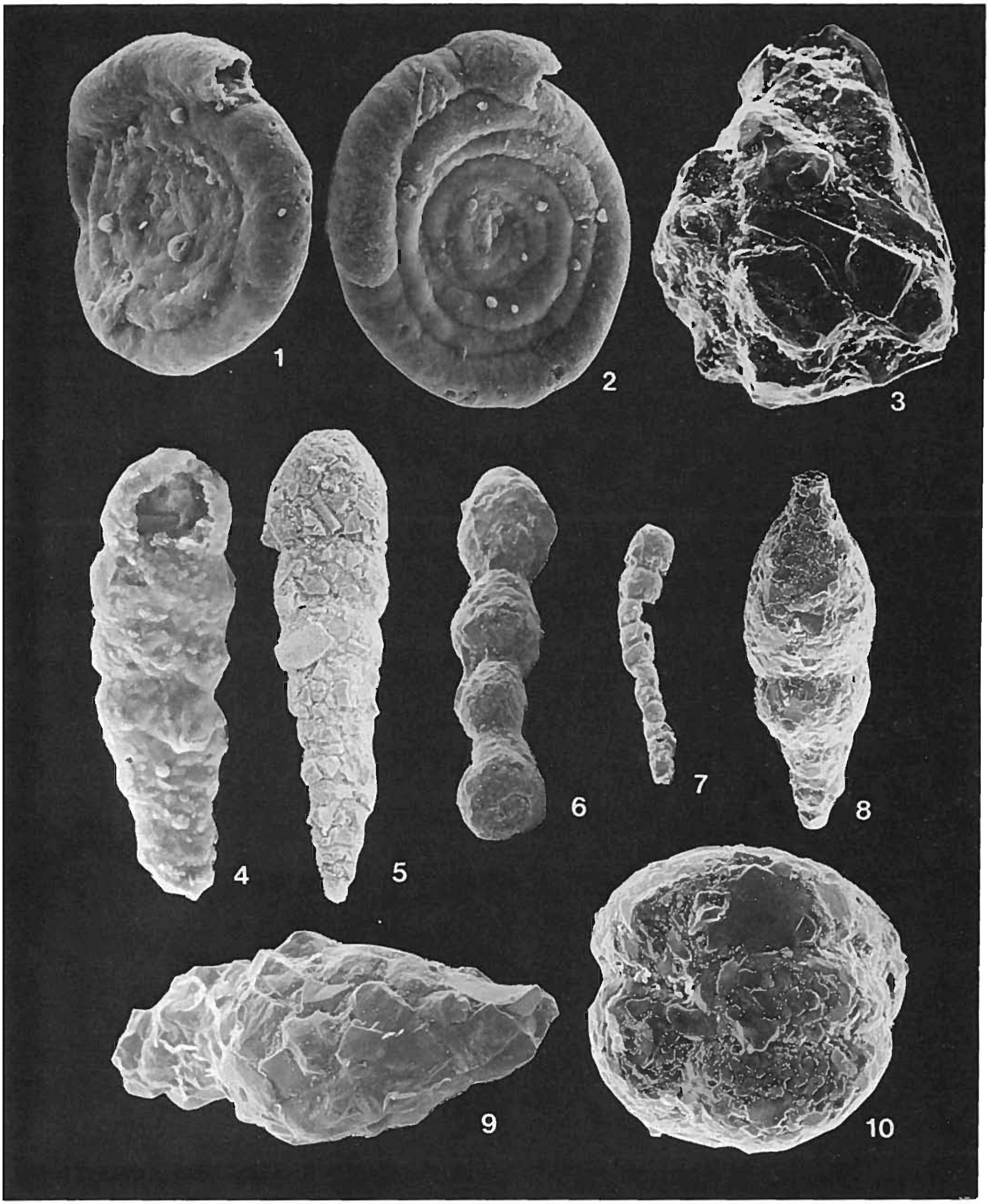
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PLATE 3

1.	**Eggerella advena** (Cushman) G.S.C. no. 54258	Stn. R-54	x 161
2.	**Spiroplectammina biformis** (Parker & Jones) G.S.C. no. 54259	Stn. G-2	x 177
3.	**Textularia torquata** F. Parker G.S.C. no. 54260	Stn. A-14	x 219
4.	**Textularia earlandi** Phleger G.S.C. no. 54261	Stn. A-15	x 224
5.	**Protoschista findens** (Parker) G.S.C. no. 54262	Stn. 74013-47	x 545
6.	**Ammomarginulina fluvialis** (F. Parker) G.S.C. no. 54263	Stn. S-6	x 102
7.	**Ammotium cassis** (Parker) G.S.C. no. 54264	Stn. S-5	x 42
8.	**Ammotium cassis** (Parker) var. **inflatus** Stschedrina = **Ammobaculites salsus** Cushman & Bronnimann-Schafer & Cole, G.S.C. no. 54265, 1974, 1976	Stn. A-79	x 53
9.	**Ammobaculites dilitatus** Cushman & Bronnimann G.S.C. no. 54266	Stn. C-1	x 97

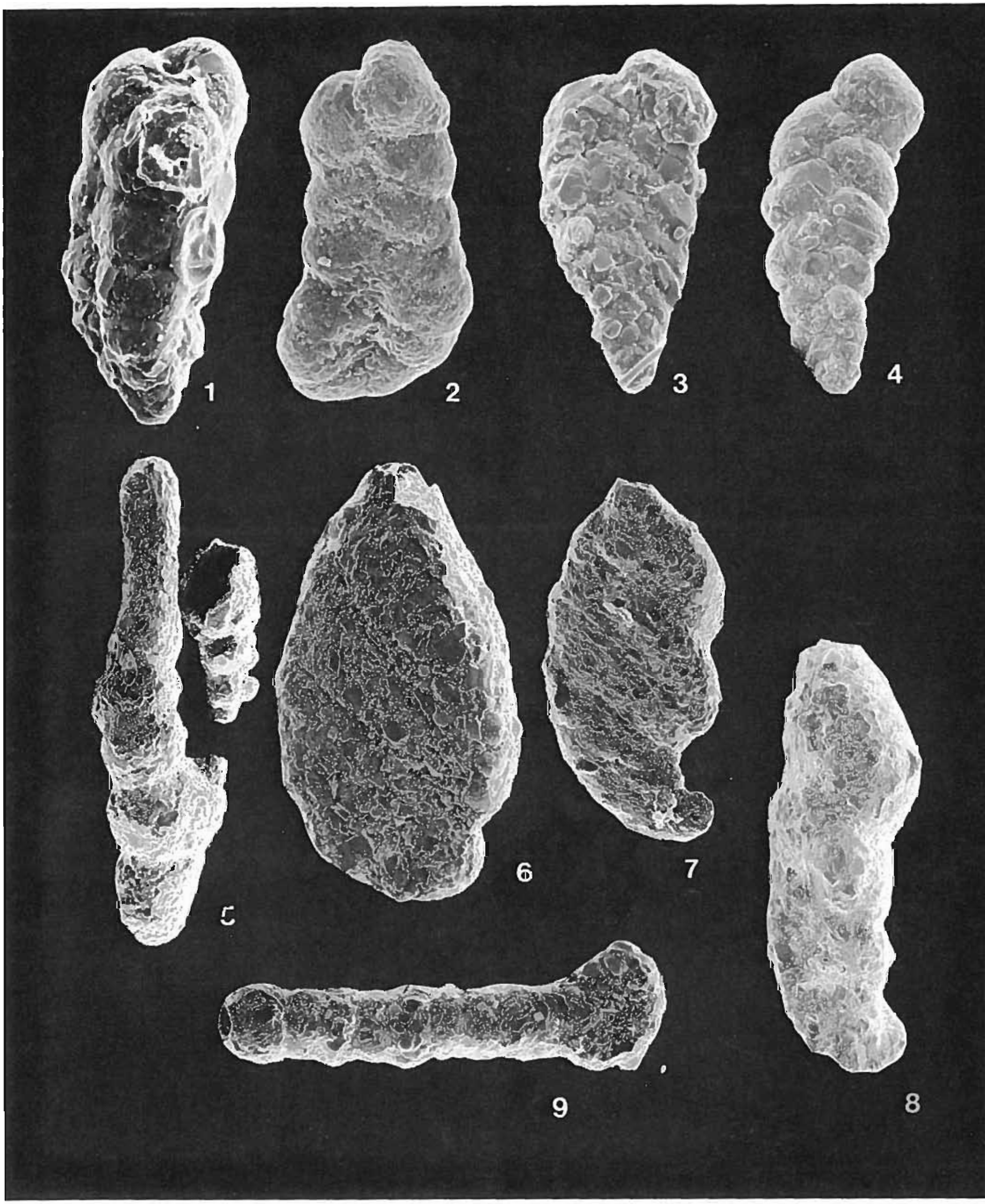
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PLATE 4

1a.	**Cribrostomoides jeffreysi** (Williamson) G.S.C. no. 54267	Stn. I-6	x 266
1b.	**Cribrostomoides jeffreysi** (Williamson) G.S.C. no. 54268	Stn. I-9	x 179
2a.	**Cribrostomoides crassimargo** (Norman) G.S.C. no. 54269	Stn. 74013-14	x 72
2b.	**Cribrostomoides crassimargo** (Norman) G.S.C. no. 54270	Stn. 74013-14	x 65
3.	**Trochammina macrescens** Brady G.S.C. no. 54271	Stn. Q-1	x 156
4a.	**Trochammina ochracea** (Williamson) G.S.C. no. 54272	Stn. G-2	x 219
4b.	**Trochammina ochracea** (Williamson) G.S.C. no. 54273	Stn. P-10	x 482
5.	**Trochammina lobata** Cushman G.S.C. no. 54274	Stn. G-8	x 175

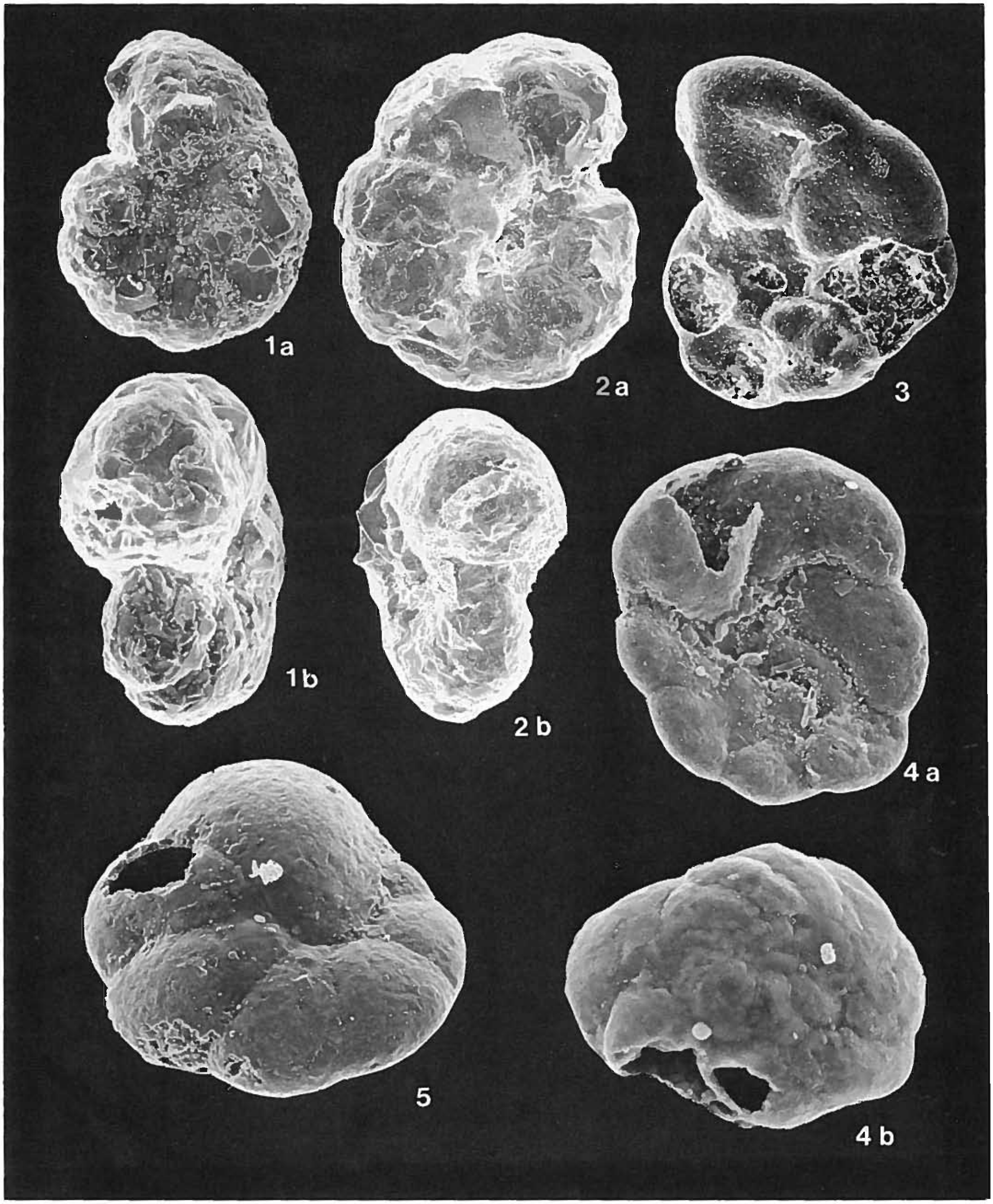
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PLATE 5

1.	**Trochammina squamata** Jones & Parker G.S.C. no. 54275	Stn. C-1	x 303
2.	**Trochammina inflata** (Montagu) G.S.C. no. 54276	Stn. G-4	x 179
3a.	**Fissurina cucurbitasema** Loeblich & Tappan G.S.C. no. 54277	Stn. 74013-54	x 209
3b.	**Fissurina cucurbitasema** Loeblich & Tappan G.S.C. no. 54278	Stn. 74013-13	x 204
4.	**Parafissurina himatiostoma** Loeblich & Tappan G.S.C. no. 54279	Stn. K-4	x 506
5.	**Fissurina marginata** (Montagu) G.S.C. no. 54280	Stn. K-4	x 188

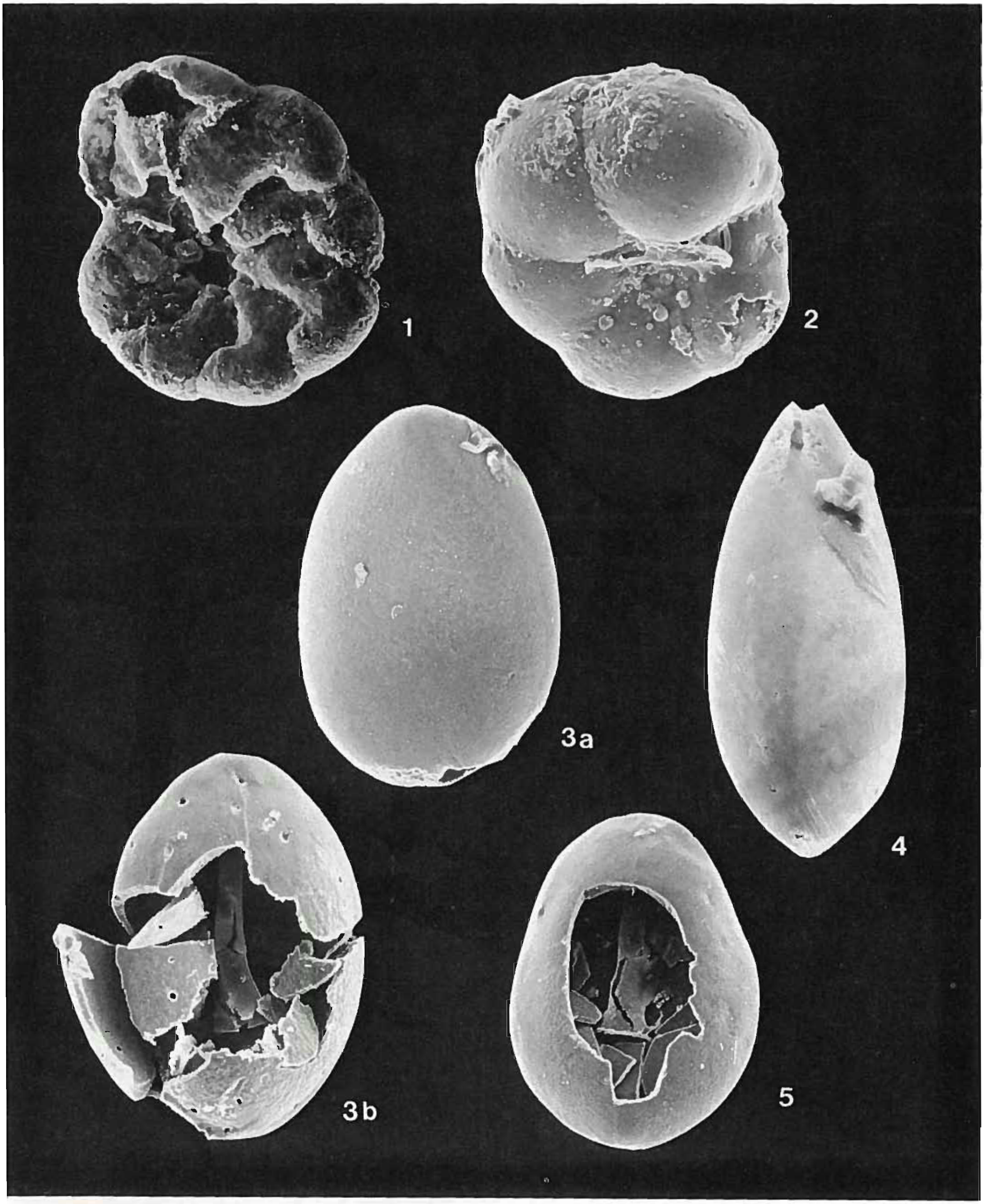
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PLATE 6

1.	**Dentalina ittai** Loeblich & Tappan G.S.C. no. 54281	Stn. B-4	x 66
2.	**Dentalina baggi** Galloway & Wissler G.S.C. no. 54282	Stn. 74013-14	x 35
3.	**Oolina hexagona** (Williamson) G.S.C. no. 54283	Stn. 74013-35	x 230
4.	**Oolina caudigera** (Wiesner) G.S.C. no. 54284	Stn. 74013-27	x 257
5.	**Oolina melo** d'Orbigny G.S.C. no. 54285	Stn. 74013-18	x 233
6.	**Oolina borealis** Loeblich & Tappan G.S.C. no. 54286	Stn. M-9	x 105
7.	**Lagena apiopleura** Loeblich & Tappan G.S.C. no. 54289	Stn. 74013-16	x 303
8.	**Lagena gracillima** (Seguenza) G.S.C. no. 54290	Stn. I-8	x 201
9.	**Lagena semilineata** Wright G.S.C. no. 54291	Stn. A-27	x 187
10.	**Lagena laevis** (Montagu) G.S.C. no. 54292	Stn. A-54	x 130

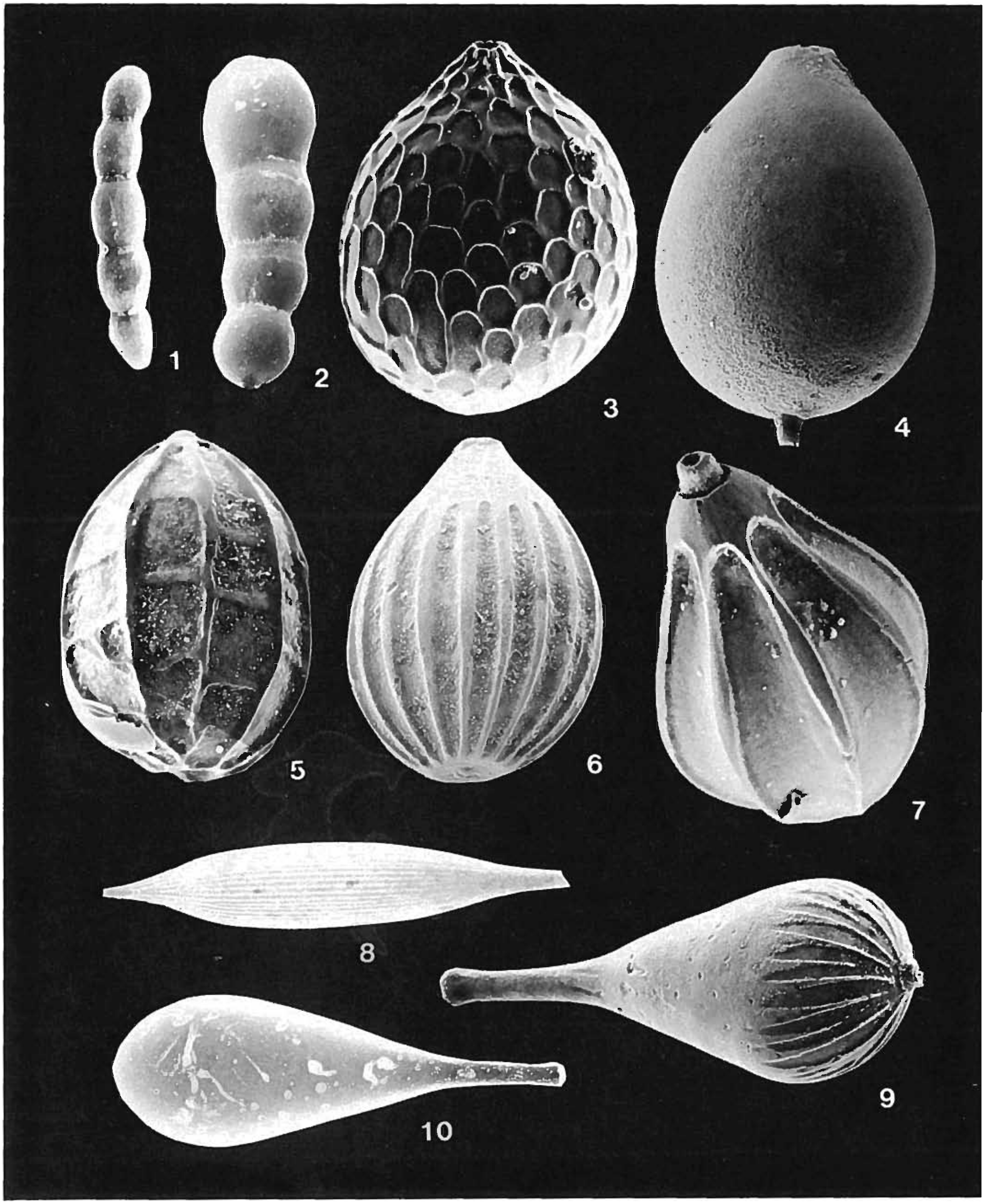
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PLATE 7

1.	**Robertinoides charlottensis** (Cushman) G.S.C. no. 54293	Stn. A-82	x 110
2.	**Trifarina angulosa** (Williamson) G.S.C. no. 54294	Stn. 74013-33	x 200
3.	**Trifarina fluens** (Todd) G.S.C. no. 54295	Stn. J-8	x 181
4a.	**Patellina corrugata** Williamson G.S.C. no. 54296	Stn. 74013-18	x 259
4b.	**Patellina corrugata** Williamson G.S.C. no. 54297	Stn. A-66	x 389
5.	**Spirillina vivipara** Ehrenberg G.S.C. no. 54298	Stn. 74013-18	x 335
6a.	**Cyclogyra involvens** (Reuss) G.S.C. no. 54299	Stn. 74013-18	x 661
6b.	**Cyclogyra involvens** (Reuss) G.S.C. no. 54300	Stn. I-10	x 319

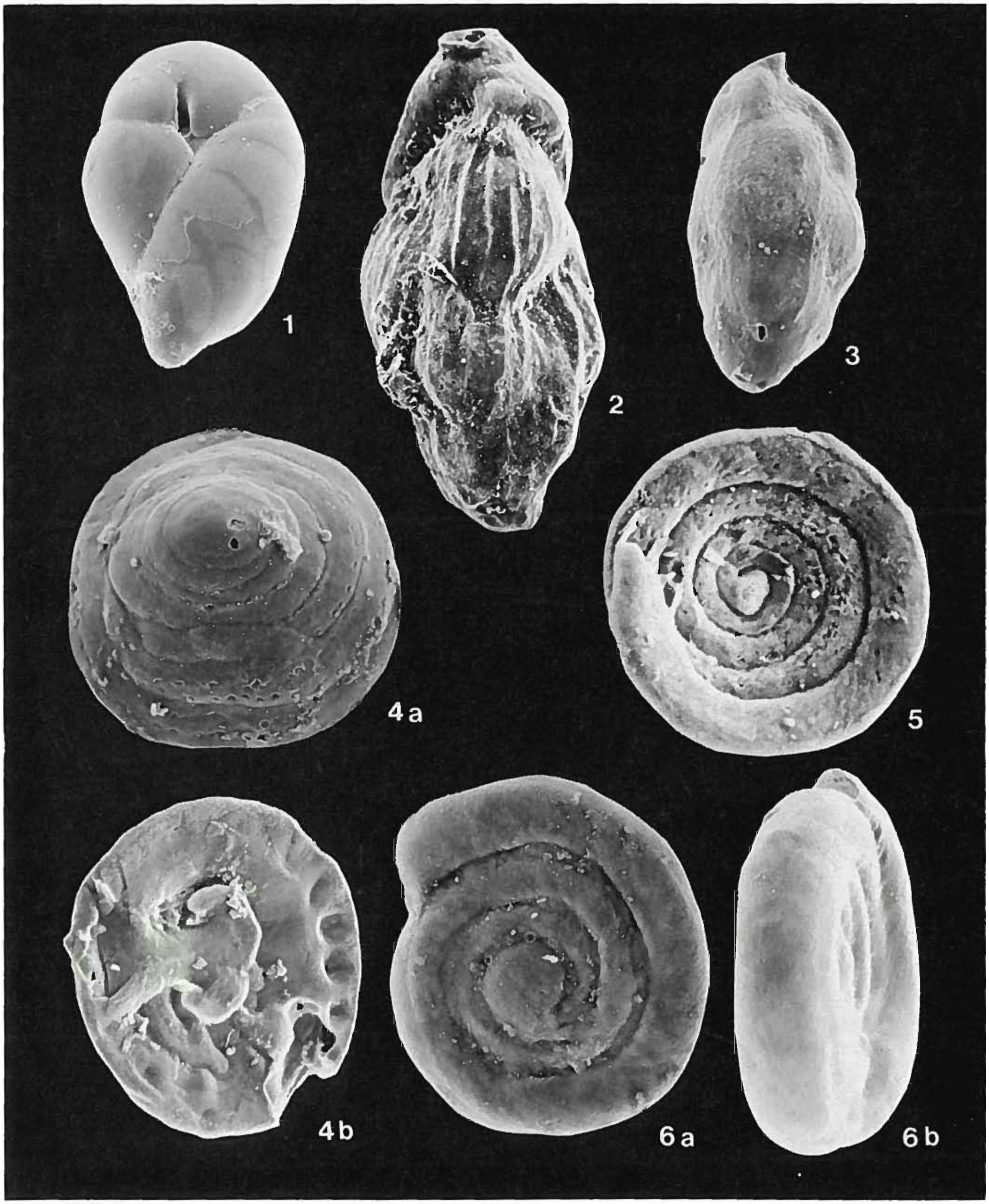
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PLATE 8

1a.	**Buccella frigida** (Cushman) G.S.C. no. 54301	Stn. 74013-72	x 147
1b.	**Buccella frigida** (Cushman) G.S.C. no. 54302	Stn. C-1	x 166
2.	**Buccella inusitata** Anderson G.S.C. no. 54303	Stn. C-2	x 122
3a.	**Epistominella takayanagii** Iwasa G.S.C. no. 54304	Stn. 74013-12	x 350
3b.	**Epistominella takayanagii** Iwasa G.S.C. no. 54305	Stn. 74013-12	x 312
4.	**Rosalina floridana** (Cushman) G.S.C. no. 54306	Stn. K-2A	x 126
5.	**Glabratella wrightii** (Brady) G.S.C. no. 54307	Stn. 74013-142	x 191
6.	**Ammonia beccarii** (Linné) G.S.C. no. 54308	Stn. G-2	x 208

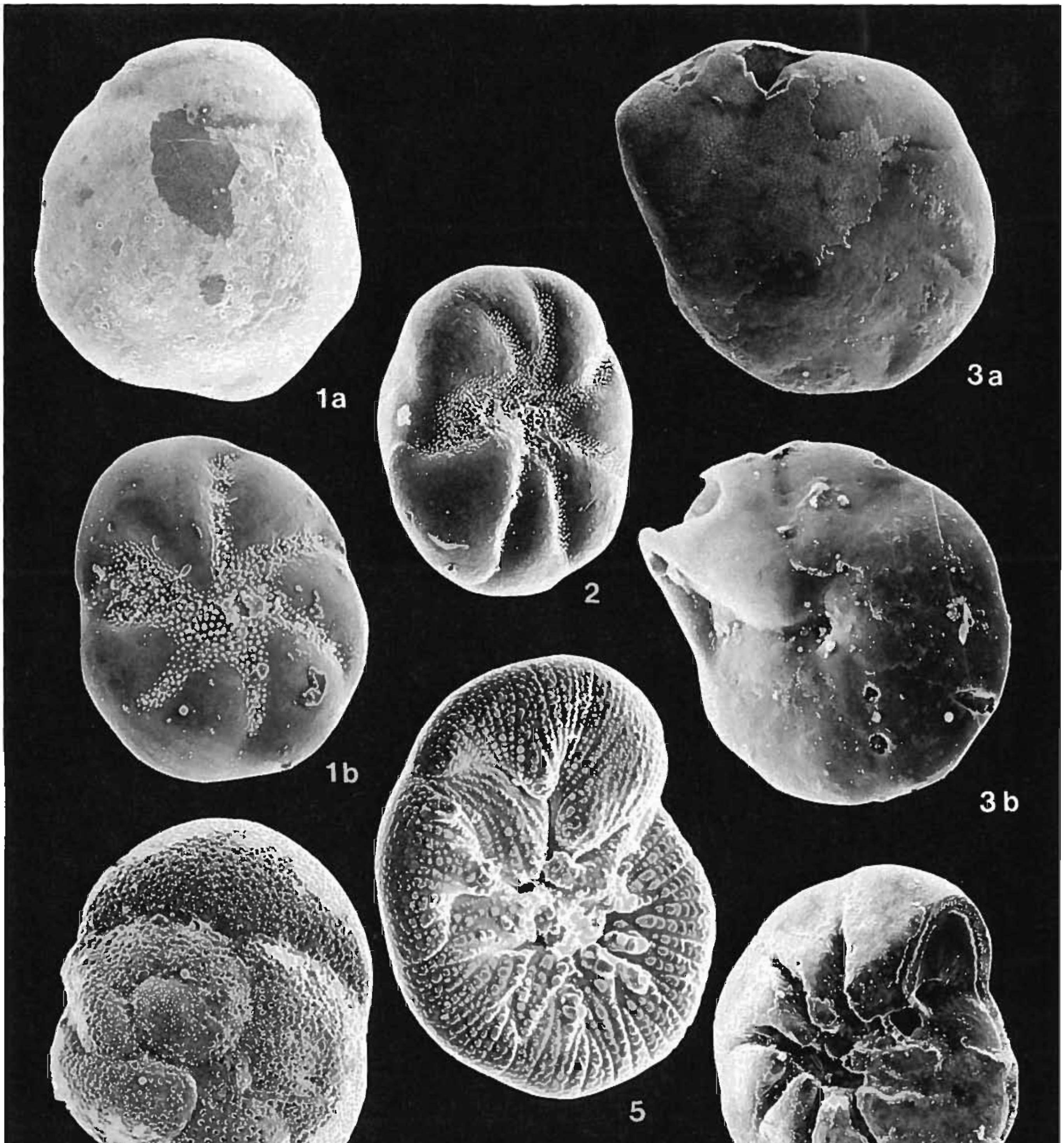
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PLATE 9

1a.	**Cibicides lobatulus** (Walker & Jacob) G.S.C. no. 54309	Stn. 74013-143	x 140
1b.	**Cibicides lobatulus** (Walker & Jacob) G.S.C. no. 54310	Stn. 74013-143	x 169
2.	**Astrononion gallowayi** Loeblich & Tappan G.S.C. no. 54311	Stn. J-6	x 153
3.	**Nonion** sp. G.S.C. no. 54312	Stn. 74013-29	x 113
4.	**Nonionellina labradorica** (Dawson) G.S.C. no. 54313	Stn. B-26	x 135
5.	**Nonionella atlantica** Cushman G.S.C. no. 54314	Stn. I-2	x 109
6.	**Elphidiella arctica** (Parker & Jones) G.S.C. no. 54315	Stn. 74013-147	x 77
7.	**Elphidium excavatum** (Terquem) var. G.S.C. no. 54316	Stn. R-56	x 102

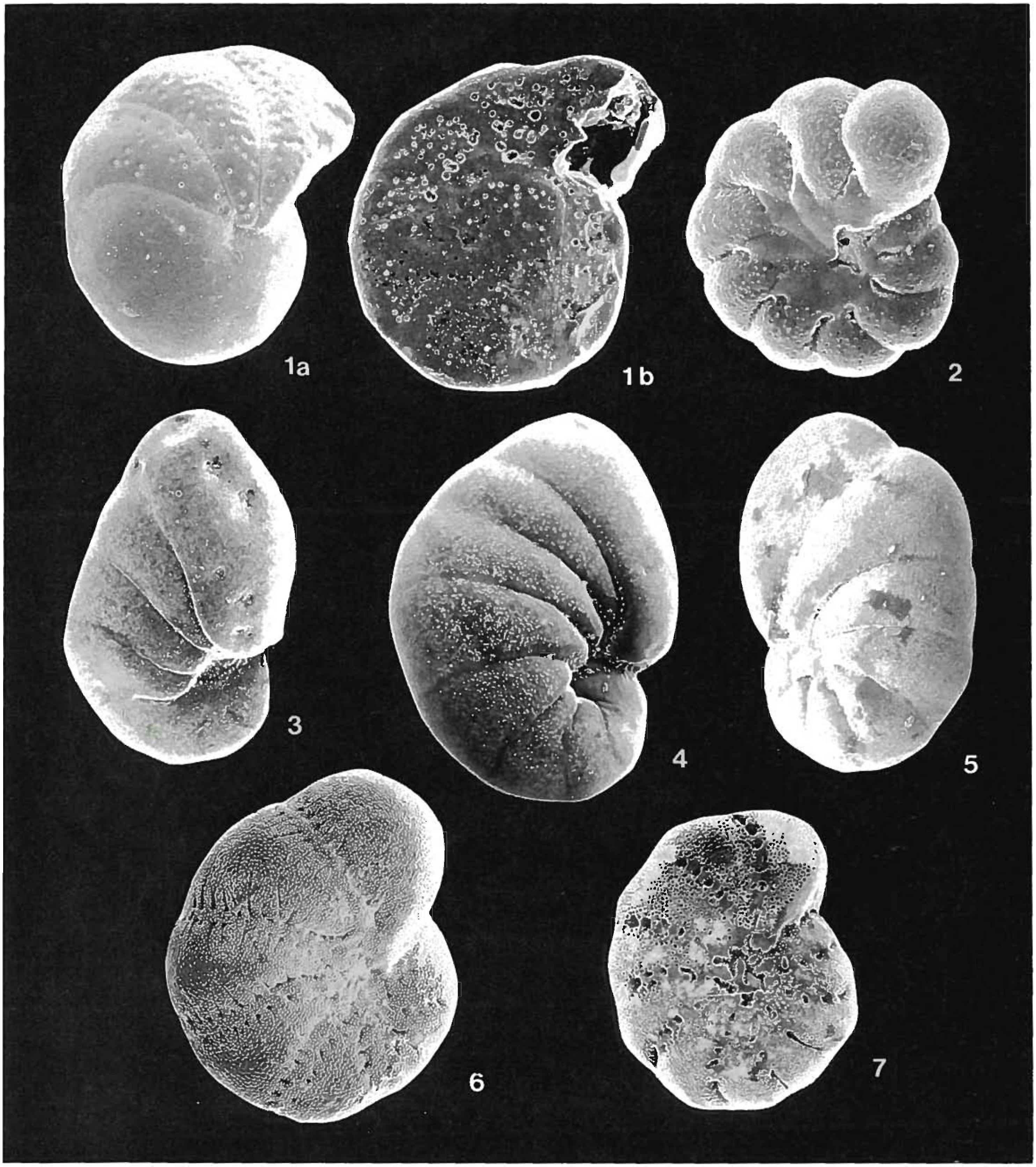
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PLATE 10

1.	**Elphidium subarcticum** Cushman G.S.C. no. 54317	Stn. 74013-08	x 117
2a.	**Elphidium frigidum** Cushman G.S.C. no. 54318	Stn. 74013-08	x 154
2b.	**Elphidium frigidum** Cushman G.S.C. no. 54319	Stn. 74013-08	x 136
3.	**Elphidium margaritaceum** Cushman G.S.C. no. 54320	Stn. T-8	x 182
4.	**Elphidium bartletti** Cushman G.S.C. no. 54321	Stn. A-16	x 120
5.	**Protelphidium orbiculare** (Brady) G.S.C. no. 54322	Stn. C-2	x 118
6.	**Islandiella islandica** (Nørvang) G.S.C. no. 54323	Stn. 74013-14	x 134
7.	**Islandiella teretis** (Tappan) G.S.C. no. 54324	Stn. 74013-14	x 205

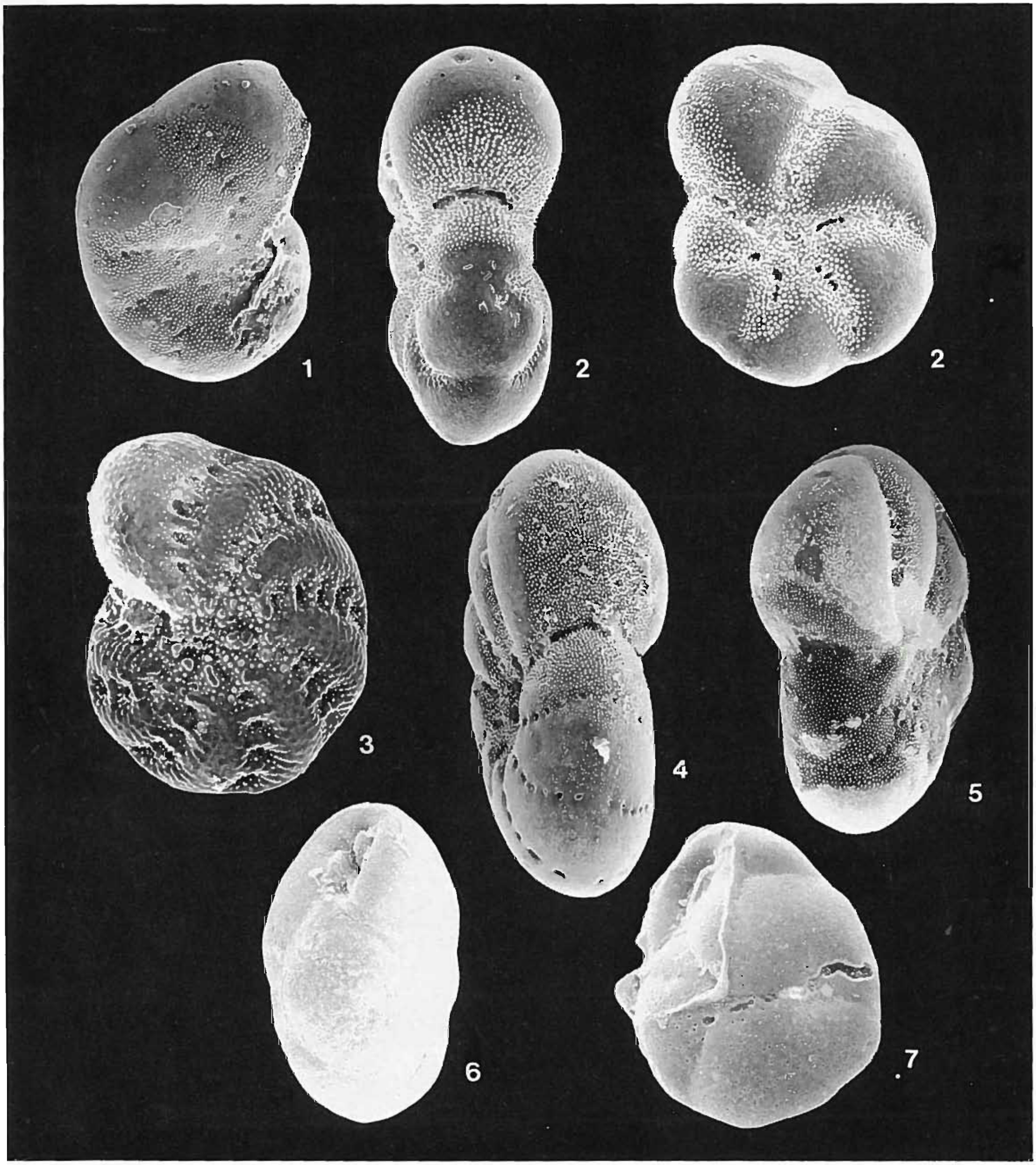
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PLATE 11

1.	**Globobulimina auriculata** (Bailey) **gullmarensis** Höglund G.S.C. no. 54325	Stn. 74013-12	x 66
2.	**Pseudopolymorphina novangliae** (Cushman) G.S.C. no. 54326	Stn. J-2	x 55
3.	**Miliolinella subrotunda** (Montagu) G.S.C. no. 54327	Stn. A-82	x 182
4a.	**Miliolinella chukchiensis** Loeblich & Tappan G.S.C. no. 54328	Stn. K-4	x 330
4b.	**Miliolinella chukchiensis** Loeblich & Tappan G.S.C. no. 54329	Stn. M-2	x 187
5.	**Pateoris hauerinoides** (Rhumbler) G.S.C. no. 54330	Stn. S-50	x 218
6a.	**Quinqueloculina arctica** Cushman G.S.C. no. 54331	Stn. M-6	x 41
6b.	**Quinqueloculina arctica** Cushman G.S.C. no. 54332	Stn. 74013-69	x 146

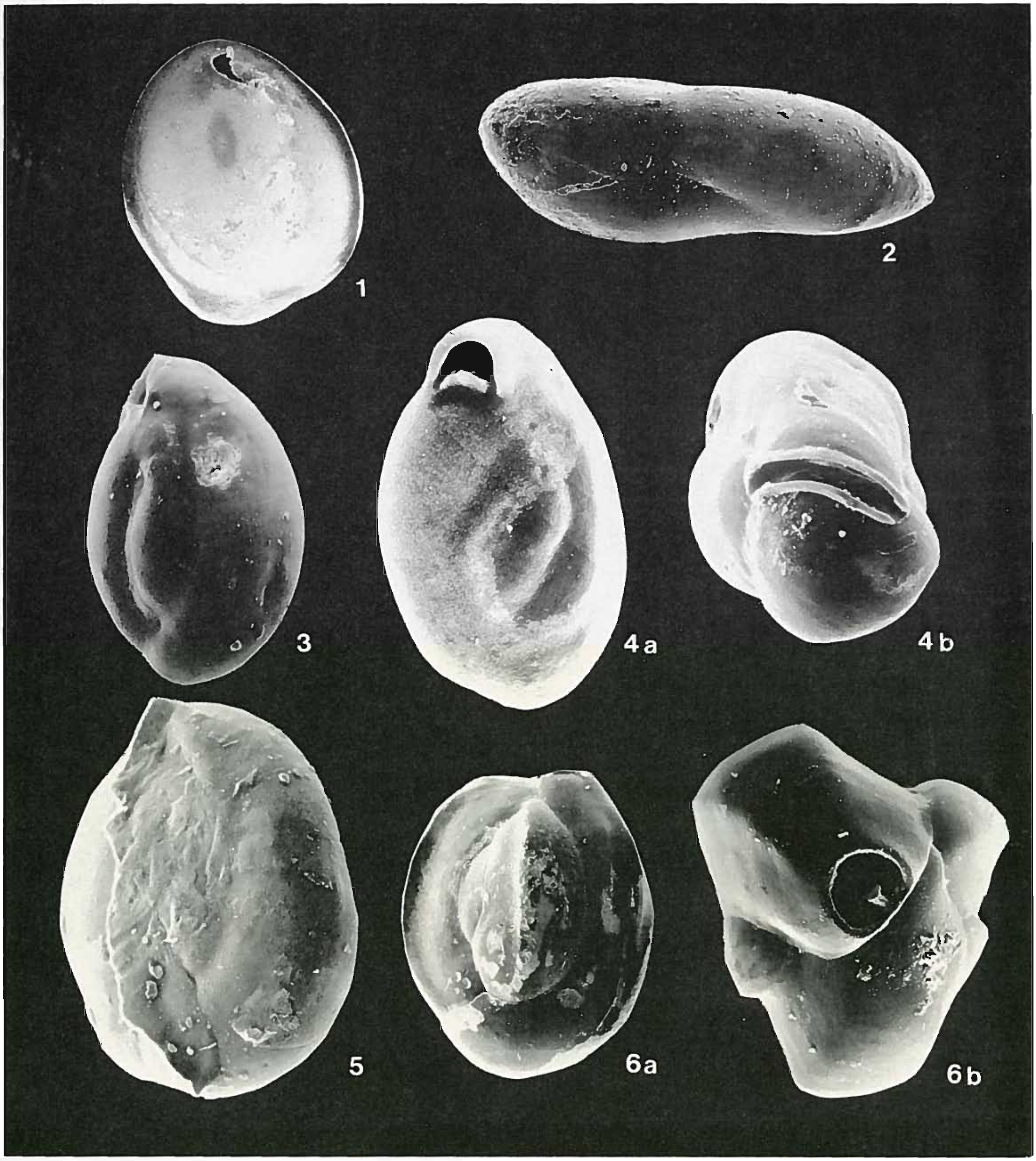
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PLATE 12

1.	**Quinqueloculina stalkeri** Loeblich & Tappan G.S.C. no. 54333	Stn. M-6	x 316
2.	**Miliammina fusca** (Brady) G.S.C. no. 54334	Stn. G-3	x 110
3.	**Quinqueloculina agglutinata** Cushman G.S.C. no. 54335	Stn. G-5	x 92
4.	**Quinqueloculina seminulum** (Linné) G.S.C. no. 54336	Stn. Q-57	x 104
5.	**Triloculina trigonula** (Lamarck) G.S.C. no. 54337	Stn. 74013-19	x 172
6.	**Triloculina oblonga** (Montagu) G.S.C. no. 54338	Stn. 74013-38	x 208
7.	**Triloculina trihedra** Loeblich & Tappan G.S.C. no. 54339	Stn. 74013-24	x 121

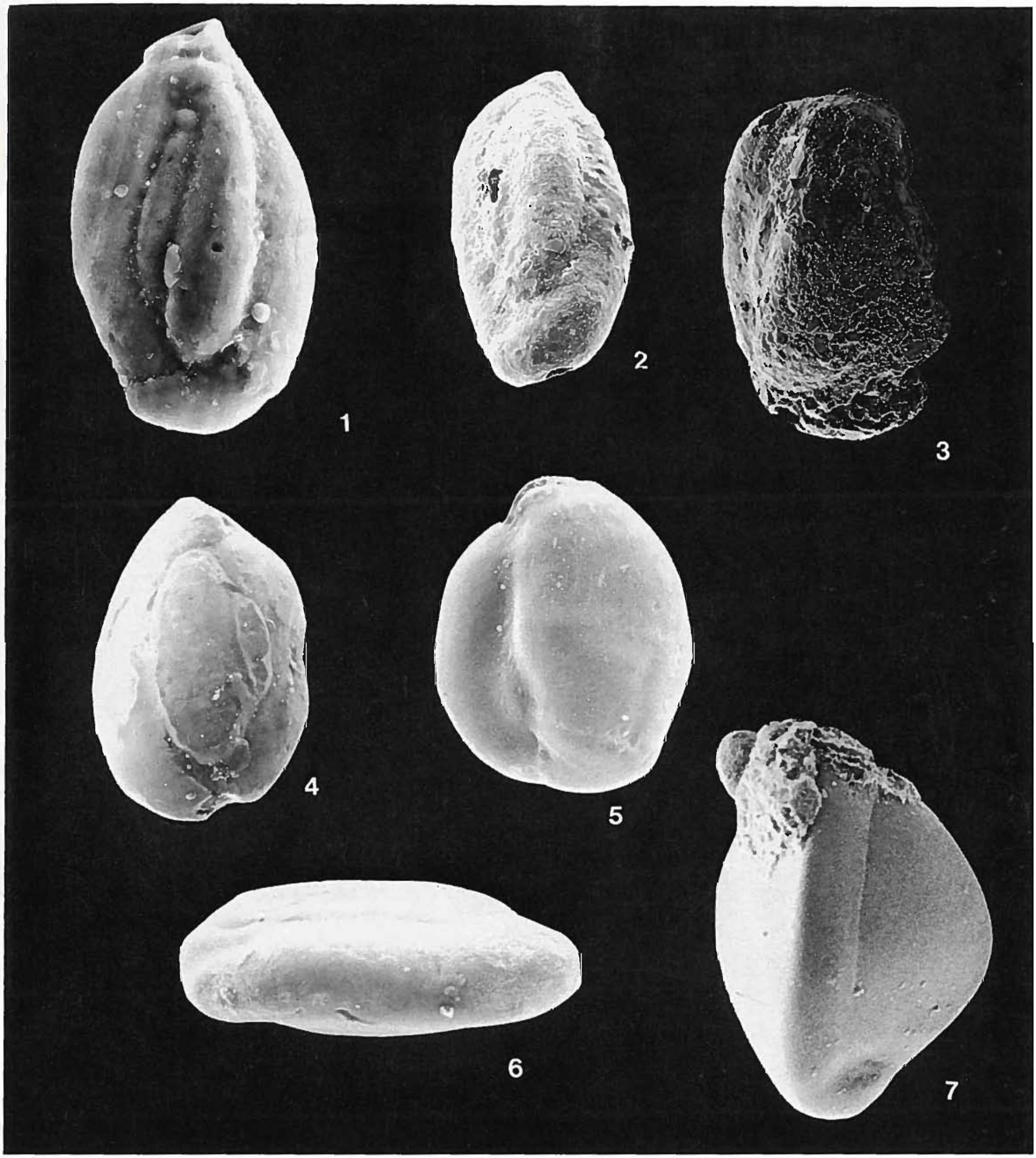
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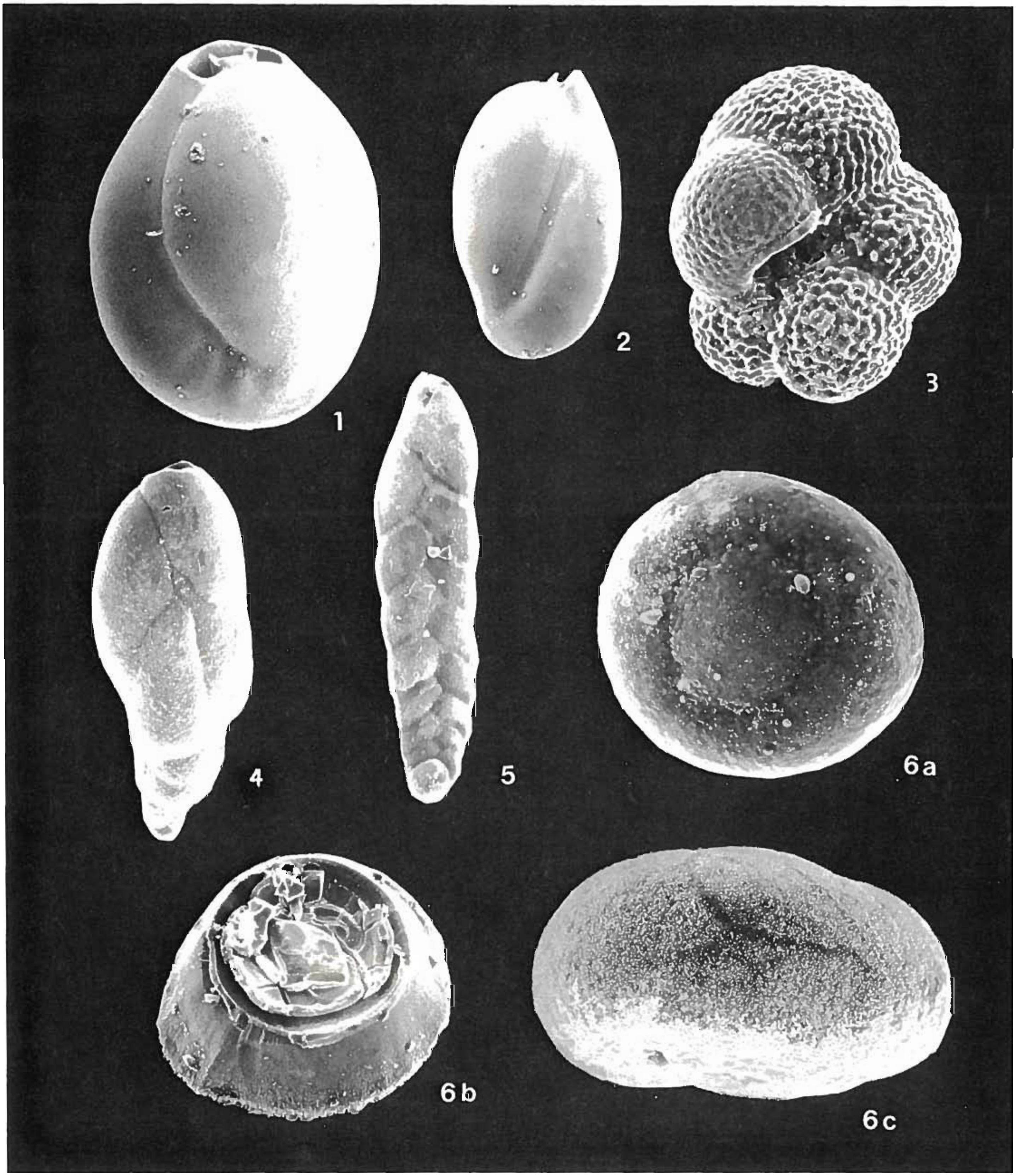
PLATE 13

1.	**Pyrgo subsphaerica** (d'Orbigny) G.S.C. no. 54340	Stn. 74013-42	x 109
2.	**Pyrgo williamsoni** (Silvestri) G.S.C. no. 54341	Stn. I-4	x 103
3.	Planktonic typical of area G.S.C. no. 54342	Stn. 74013-55	x 212
4.	**Cassidella complanata** (Egger) G.S.C. no. 54343	Stn. 74013-12	x 195
5.	**Bolivina pseudopunctata** Höglund G.S.C. no. 54344	Stn. I-2	x 188
6a.	Cold water indicator – top view G.S.C. no. 54345	Stn. B-1	x 238
6b.	Cold water indicator – interior G.S.C. no. 54346	Stn. C-2	x 230
6c.	Cold water indicator – side view G.S.C. no. 54347	Stn. B-1	x 475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