FORAMINIFERAL DISTRIBUTION IN TWO NOVA SCOTIA MARSHES

B. DEONARINE
Atlantic Geoscience Centre, Geological Survey of Canada
Bedford Institute of Oceanography, Dartmouth, Nova Scotia, Canada, B2Y 4A2

Thirty sediment samples from marshes at Peggy's Cove and Clementsport, Nova Scotia, were examined and nine benthonic foraminifera species identified. Agglutinated tests form 98% of the total Foraminiferal population. Trochammina macrescens *is the dominant form in upper marsh environments. This species is gradually replaced by* Miliammina fusca *as lower marsh conditions are developed.* M. fusca *comprises 97% of the total population in the lower marsh environments sampled in this study.*

INTRODUCTION

Marshes are marginal marine environments separating marine and continental areas. They are relatively widespread especially along low relief coastlines and are usually well developed in estuaries and lagoons. Their landward and seaward boundaries are controlled by tidal amplitude. Marshes included in this study were not sampled quantitatively but qualitative results can be compared directly to more detailed information from nearby marshes (Scott and Medioli 1980a).

The foraminiferal assemblages in two marshes located near Peggy's Cove and Clementsport were identified and compared (Figs. 1, 2, and 3). Unweighted pair-group cluster analysis (Sokal and Sneath 1963) was used for the analysis. The total foraminiferal percentages in sample pairs were compared using the Jaccard Coefficient of Association (S_j) following the method used by Schafer and Scott (1976). The diversity index of foraminifera was calculated using the Shannon-Weaver information function (H) where $H = \Sigma_{i=1}^{N} p_i \ln p_i$ and p_i is the percentage of value of the i^{th} species; N is the total number of species in the sample.

This diversity index is a function of both the number of species and the equality of species abundance in each sample.

PREVIOUS STUDIES OF MARSH ENVIRONMENT

Studies of the distribution of salt marsh foraminifera have increased substantially since 1950. Phleger investigated marshes in several areas of the world between 1950 and 1970. His studies (Phleger 1970) suggested that foraminiferal distribution data could be used to estimate tidal regime, current velocities, and water exchange in these environments. Work carried out before 1950 included that of Cushman and Bronnimann (1948) who described some new genera and species of foraminifera from inshore mud in mangrove swamps of the west coast of the Republic of Trinidad and Tobago. Recent marsh studies include that of Steineck and Bergstein (1979). Their data, they believe, support the view that shallow-water foraminifers inhabit a 'living zone' extending 10 cm or more below the sediment surface.

Chapman (1960), MacDonald (1969), and Redfield (1972), among others, have described the vertical plant zonation in marsh environments. MacDonald (1969), using molluscs in his quantitative studies of salt marsh faunas from the North American Pacific coast, showed a distribution relationship between faunal and floral zones of West Coast salt marshes. The use of molluscs, however is comparatively unreliable in showing this relationship because their shells are calcareous and are easily

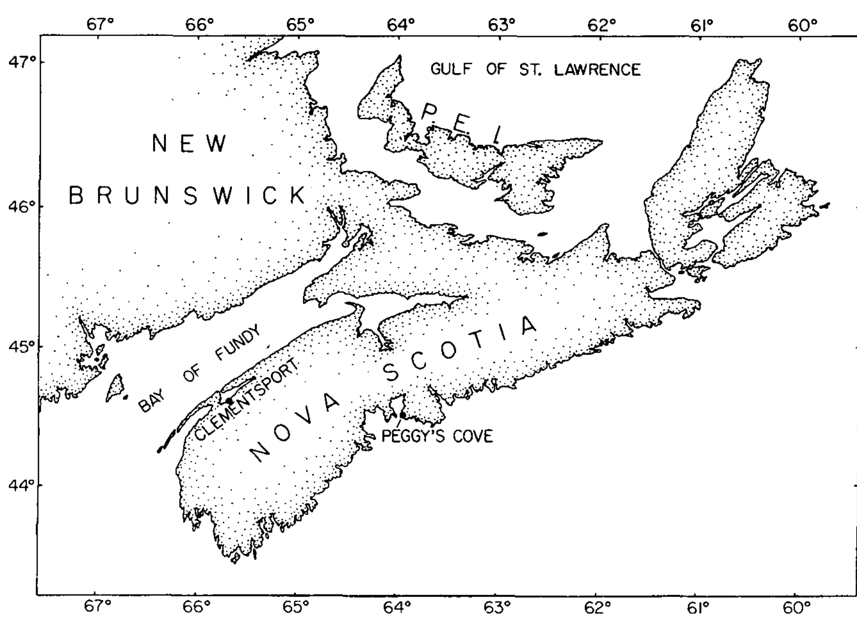

FIG. 1 Map of Nova Scotia with study sites.

TABLE 1.

Foraminiferal species distributions in relative percent and diversity in marshes of Peggy's Cove and Clementsport

	LOWER MARSH								MIDDLE MARSH							
Station	CLEM 1B	CLEM 9A	CLEM 9B	CLEM 2B	CLEM 1A	CLEM 2A	PEGG 1A	Mean %	PEGG 2A	PEGG 3A	PEGG 2B	PEGG 1B	PEGG 3B	PEGG 4A	PEGG 4B	Mean %
Total	96	776	526	305	122	536	201		75	199	96	120	215	186	143	
Diversity	0.06	0.05	0.07	0.11	0.10	0.05	0.64		1.09	0.86	0.88	0.84	1.24	0.91	0.77	
Miliammina fusca	99.0	99.2	99.8	98.0	98.4	99.2	78.6	97.4	61.3	70.4	71.9	72.5	46.1	36.3	14.7	51.3
Trochammina macrescens	1.0	0.5	0.8	1.0		0.2	0.5	0.6	2.7		1.0		0.9		4.2	1.1
Tiphotrocha comprimata		0.3	0.4	1.0	0.8	0.6		0.4								
Eggerella advena					0.8		1.0	0.1	1.3	0.5		0.8		0.5	0.7	0.5
Trochammina inflata									22.7	20.1	10.4	7.1	27.4	55.9	76.9	33.6
Haplophragmoides bonplandi																
Cribrononion williamsoni							18.4	1.4	1.3	7.0	2.1	18.0	20.0			7.9
Cibicides lobatulus												0.8				0.1
Jadammina polystoma							1.5	0.1	10.7	2.0	14.6	0.8	5.6	7.0	3.5	5.5

dissolved in low-pH marsh sediment. Scott (1976) demonstrated a relationship between flora and foraminiferal assemblages with sediment surface elevation in Southern California marshes, Scott (1977) and Scott and Medioli (1978, 1980a) have since illustrated the marsh foraminifera-sea level relationship for several locations in the Maritime Provinces.

Comparison of these published data with the results of this study confirm the association between foraminifera and flora in the Peggy's Cove and Clementsport marshes.

METHOD

Surficial samples were collected at low tide using a stainless steel corer (Scott 1977), and replicate samples of 10 cm^3 (10 cm^2 x 1 cm) were obtained. To separate plants and other coarse materials from the foraminifera specimens the samples were wet-sieved through a 0.5 mm screen over a 0.062 mm screen. Samples were then fixed in 10% buffered formalin and stained with Rose Bengal. After washing, the foraminiferal samples were stored in denatured ethanol.

To obtain the total population, specimens were counted wet in a 5-cm square tray that was divided into 12 equal areas. Micrographs of species discussed in this paper were taken using the Cambridge Stereoscan 180 scanning microscope.

MARSH ENVIRONMENTS

Marsh areas, as distinct from intertidal mud flats, are covered with characteristic vegetation and occur between mean sea level to higher high water (Chapman 1960). They can usually be subdivided into three vertical zones as a result of the duration and amplitude of tidal flooding in relation to elevation above mean sea level (Mac Donald 1969; Hinde 1954; Scott and Medioli 1978, 1980a).

In Nova Scotia (Fig. 1) the typical upper marsh zone is usually inhabited by *Spartina patens*, *Scirpus* spp., and *Solidago sempervirens*, all of which are present in the upper marsh at Clementsport (Fig. 3). The Peggy's Cove upper marsh (Fig. 2) supports *Distichlis* spp. and *Scirpus* spp. populations. *Spartina patens* which is common in middle marsh areas is also present in the middle marsh at Peggy's Cove (Fig. 2). However, this species was not present at Clementsport. Lower marsh zones are often dominated by *Spartina alterniflora* and this species has been observed in this environment at Peggy's Cove and Clementsport (Figs. 2 and 3).

TABLE 1. continued

UPPER MARSH																		
CLEM 5A	CLEM 5B	CLEM 8A	CLEM 6B	CLEM 8B	CLEM 7A	CLEM 7B	CLEM 3A	CLEM 4B	CLEM 4A	CLEM 6A	CLEM 3B	PEGG 5A	PEGG 5B	PEGG 6A	PEGG 6B	Mean %	Total Population	Relative % of Total Population
211	147	223	291	58	453	180	200	208	374	99	117	11	27	146	150			
0.96	0.93	0.99	0.83	0.95	1.10	1.07	1.14	1.12	1.24	0.83	1.33	1.24	0.97	0.00	0.00			
9.9	8.9	14.8	3.8	25.9	36.4	23.3	23.0	26.4	20.0	52.6	21.4	27.3	55.6			19.7	3595	55.4
53.6	57.1	51.6	69.4	58.6	29.8	35.0	46.5	42.3	46.8	43.4	20.5	45.4	29.6	100.0	100.0	51.1	1503	23.2
36.0	33.3	33.6	23.7	15.5	33.8	41.7	28.0	30.3	23.8	4.0	45.3					26.6	782	12.0
																	8	0.1
0.5	0.7		3.1				2.5	1.0	9.4		11.1	9.1	14.8			2.4	419	6.4
											1.7					0.1	2	-
																	119	1.8
																	1	-
												18.2				0.1	62	1.0

In addition to the vertical topographic gradient, marsh environments are subject to other physical gradients of parameters such as salinity, temperature, and pH which control the distribution of faunal and floral assemblages (Phleger and Bradshaw 1966).

SPECIES AND ABUNDANCE

Although samples were stained with Rose Bengal (to detect living specimens) only total assemblages are reported here. It has been shown (Scott and Medioli 1980b) that over a three-year period total assemblages were the most reliable indicators of marine conditions in a Nova Scotian marsh, while living populations were irregular, both spatially and temporally.

Agglutinated tests form 98% of the total foraminiferal population at Peggy's Cove and Clementsport (Table 1). *Miliammina fusca* comprises 55% of the total and is abundant in all assemblages. *Trochammina macrescens* accounts for 23% of the total population. A monospecific assemblage of *T. macrescens* occurs at stations PEGG 6A and PEGG 6B. *Tiphotrocha comprimata* represents 12% and *Trochammina inflata* 6% of the overall population. The other species are less than 2% including the calcareous species, *Cribrononion williamsoni* and *Cibicides lobatulus*.

RESULTS

The cluster analysis suggested three thanatotypes in the Peggy's Cove marsh and two in Clementsport (Fig. 5). Peggy's Cove and Clementsport (Fig. 4) have three of six species common in the upper marsh (*N. fusca*, *T. macrescens* and *T. inflata*). In the lower marsh they have two of six species common (*T. macrescens* and *E. advena*). The middle marsh at Peggy's Cove which is not observed at Clementsport contains two calcareous of a total of seven species present (*C. williamsoni* and *C. lobatulus*).

In the upper marsh thanatotope at Peggy's Cove and Clementsport (Fig. 5), six species were identified. *Trochammina macrescens* (51%) is the dominant species with *Tiphotrocha comprimata* comprising 26% and *Miliammina fusca* 19% of the total population. The other species comprise less than 3% of the total population. This thanatotope corresponds with marsh zone IB of Scott and Medioli 1978).

In the middle marsh thanantotope at Peggy's Cove seven species were identified. *Miliammina fusca* comprises 51% of the total population; *Trochammina inflata* 33%, *Cribrononion williamsoni* 7%, *Jadammina polystoma* 5%; the other species proportions are below 2%. This thanatotope corresponds with marsh zone IIA of Scott and Medioli (1978).

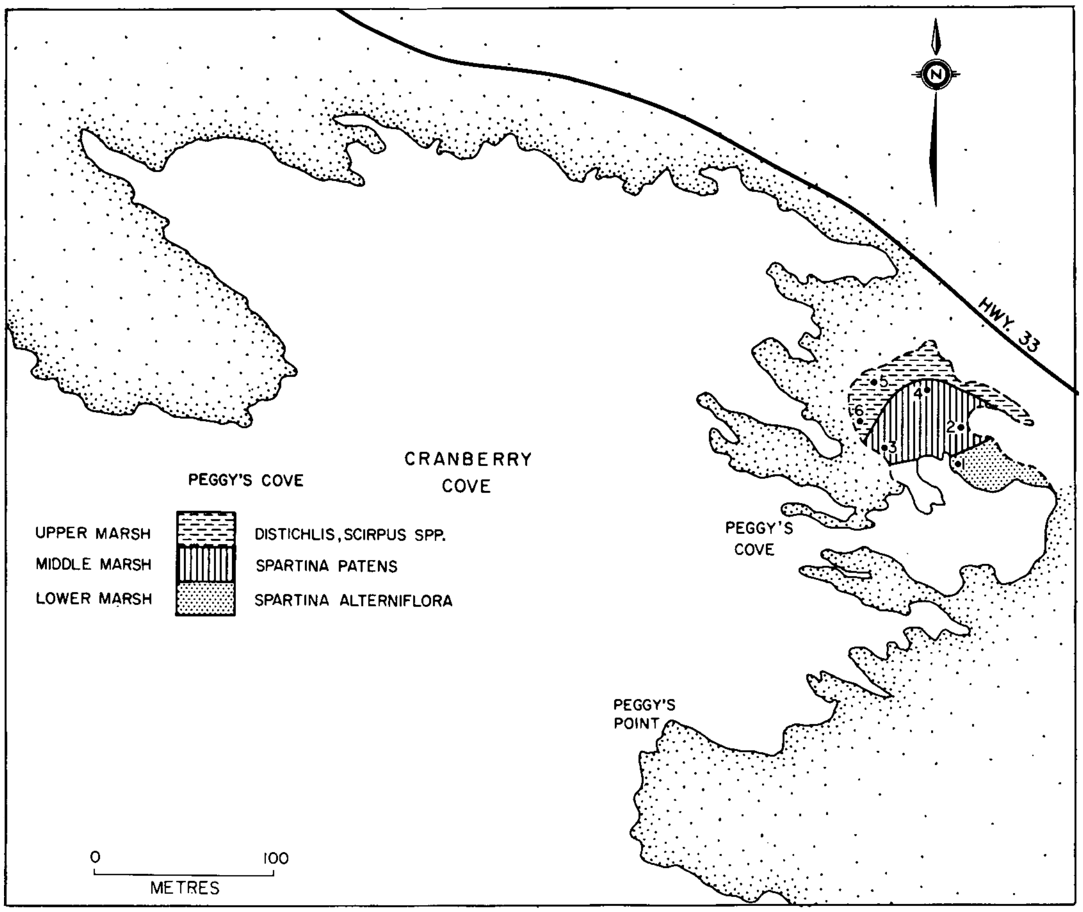

FIG. 2 Peggy's Cove.

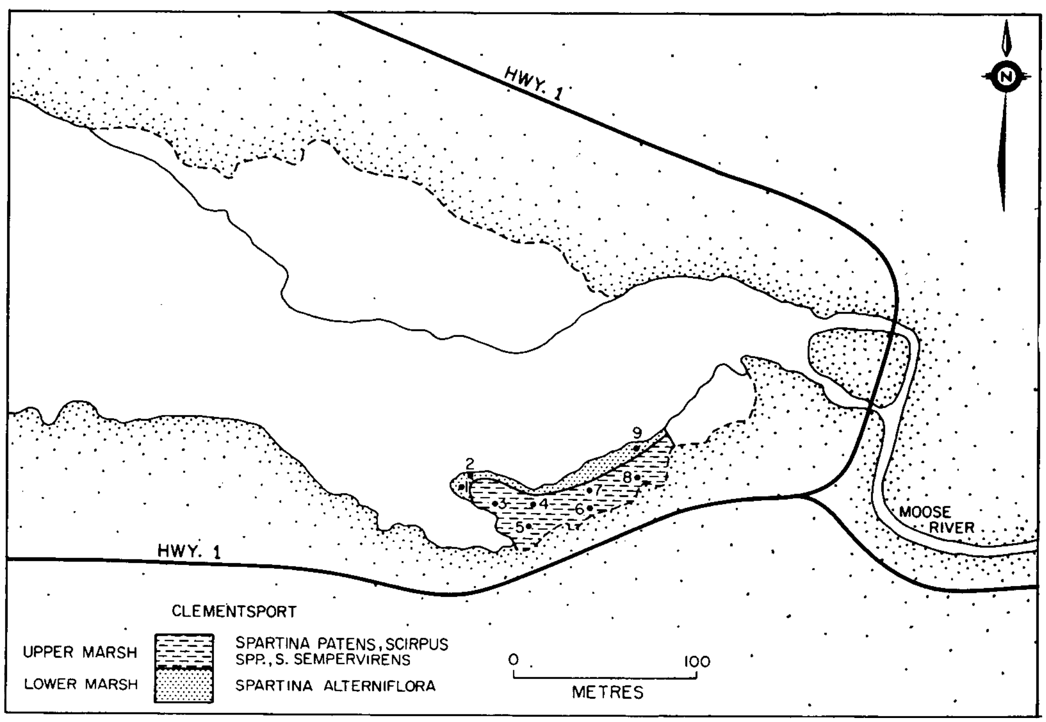

FIG. 3 Clementsport.

	PEGGY'S COVE		CLEMENTSPORT	
MARSH	VEGETATION	FORAMINIFERA	VEGETATION	FORAMINIFERA
UPPER MARSH	*Distichlis* *Scirpus*	*M. fusca* *T. macrescens* *T. inflata*	*Spartina patens* *Scirpus* spp. *S. sempervirens*	*M. fusca* *T. macrescens* *T. inflata* *T. comprimata* *H. bonplandi*
MIDDLE MARSH	*S. patens*	*M. fusca* *T. macrescens* *T. inflata* *E. advena* *J. polystoma* *C. williamsoni* *C. lobatulus*		
LOWER MARSH	*S. alterniflora*	*M. fusca* *T. macrescens* *E. advena* *J. polystoma* *C. williamsoni*	*S. alterniflora*	*M. fusca* *T. macrescens* *T. comprimata* *E. advena*

FIG. 4 Summary of Peggy's Cove and Clementsport marsh data.

In the lower marsh thanatotopes at Peggy's Cove and Clementsport, six species were identified. *Miliammina fusca* accounts for 97% of the total population followed by *Cribrononion williamsoni* the next highest at 1%. This environment corresponds with marsh zone IIB of Scott and Medioli (1978).

Relatively high diversity (1.33) and a high frequency of single species occurrences characterize the upper marsh thanatotope at Peggy's Cove and Clementsport (Table 1). In 14 of the 16 stations in the upper marsh the diversity ranges from 0.83 to 1.33. The other two monospecific stations (PEGG 6A and PEGG 6B) are located in the uppermost part of the upper marsh. *T. macrescens* is the only species found there and is also abundant at most other stations in the upper marsh thanatotope. This assemblage corresponds with zone IA Scott and Medioli (1978). Middle marsh diversity ranges from 0.77 to 1.24 and the lower marsh diversity ranges from 0.05 to 0.64. The dominant species in these two environments is *M. fusca*.

CONCLUSIONS

1. The cluster analysis method resolves three major thanatotopes for the two marshes at a similarity index level of 0.49.
2. The more important indicator species in each of the thanatotopes are usually part of a ubiquitous association. These include *T. carescens* and *T. comprimata* in the upper marsh, *M. fusca* and *T. inflata* in the middle marsh and *M. fusca* in the lower marsh.
3. The foraminiferal thanatotopes subdivide the marshes into zones that are comparable aerially with their floral distributions. The main floral species in the upper marshes, *Distichlis* and *Scirpus* at Peggy's Cove and *Solidago sempervirens* and *Scirpus* spp at Clementsport are associated with *T. macrescens*. In the middle marsh thanatotope, *T. inflata* and *M. fusca* are the most abundant species in Peggy's Cove where *S. patens* is common. *M. fusca* is associated with *S. alterniflora*, the grass which predominates in the lower marsh thanatotope at both Peggy's Cove and Clementsport.
4. Population diversity appears to decrease from the upper marsh to the lower marsh except at Stations PEGG 6A and PEGG 6B, the area where the characteristic monospecific zone IA was encountered (Scott and Medioli 1978). The diversities observed in all zones compare favorably with those of Scott and Medioli (1980a) except that they recorded more species in low marsh areas. The middle marsh is a transition area where some species either reach their upper or lower limit of distribution within the marsh gradient. Hence, diversity here could be expected to be higher. However, the apparent lower diversities in the low marsh may be the result of inadequate sampling (seven samples total in low marsh versus sixteen in the upper marsh).
5. The upper marsh foraminiferal assemblage comprises 100% agglutinated species. Foraminiferal assemblages in the middle and lower marshes are also dominant in agglutinated species, but include a small percentage of the calcareous form *C. williamsoni*. In general, absence of calcareous species can probably be attributed to low pH levels and low salinities that prevail in the upper marsh sediment.
6. The Clementsport marsh is characterized by a distinct upper and lower marsh assemblage. Peggy's Cove shows an upper, middle, and lower marsh assemblage. The middle marsh thanatotope in Peggy's Cove is represented by *M. fusca*, *T. macrescens*, *T. inflata*, *E. advena*, *J. polystoma*, *C. williamsoni* and *C. lobatulus*. This assemblage was not evident in Clementsport but may have been missed due to an in-

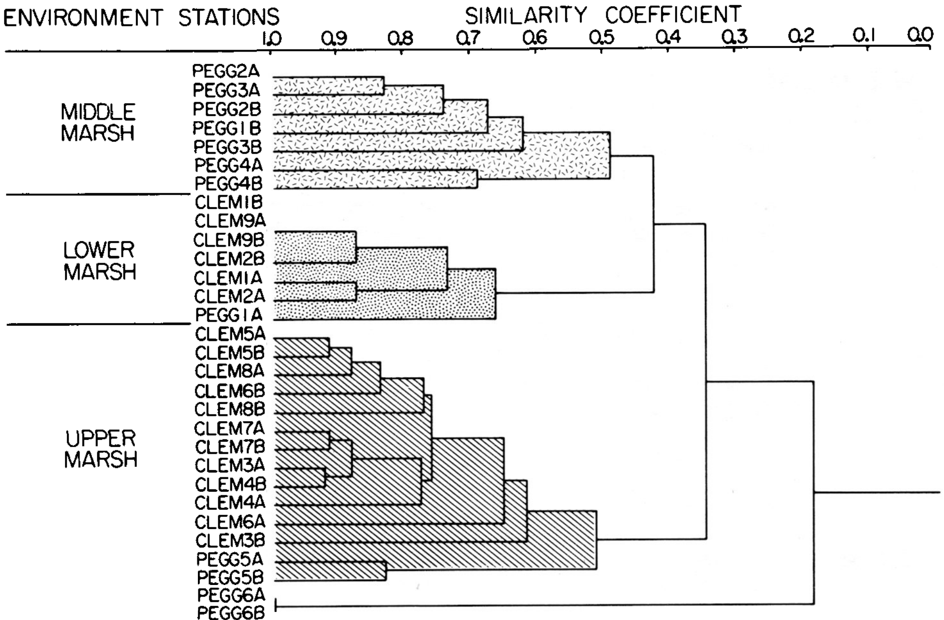

FIG. 5 Dendrogram showing similarity of stations and three main clusters used to identify major assemblages in Peggy's Cove and Clementsport.

sufficient number of sampling stations.

7. *Trochammina macrescens* comprises the total population at stations PEGG 6A and PEGG 6B of the upper marsh at Peggy's Cove. This assemblage has been shown to occur only in the upper 5 cm of the tidal range in Nova Scotia by Scott (1977) and Scott and Medioli (1978, 1980a). A combination of elevation (i.e. exposure) and lowered salinities probably influences the development of this species to the complete exclusion of other marsh forms.

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APPENDIX

Systematic Taxonomy

Species are listed below in alphabetical order. Refer to Plates 1 and 2 for micrographs of the species. The original and subsequent references are also listed below for each of the nine species identified.

CIBICIDES LOBATULUS (Walker and Jacob), Plate 1, Figures 8, 9

Nautilus lobatulus Walker and Jacob in Kanmacher, 1798, p. 642, pl. 14, fig. 36.
Cibicides lobatula (Walker and Jacob). Cushman, 1931, p. 118, pl. 21, fig. 3a-c.
Cibicides lobatulus (Walker and Jacob). Norvang, 1945, p. 49, pl. 6, fig. 26a.

CRIBRONONION WILLIAMSONI (Haynes), Plate 1, Figures 10, 11

Polystomella umbilicatula Williamson, 1858, p. 42-44, fig. 81-82.
Elphidium umbilicatulum (Williamson). Levy *et al.*, 1969, p. 96, pl. 1, fig. 62, b, pl. 2, fig. 1, 2.
Elphidium williamsoni Haynes, 1973, p. 207-209 pl. 24, fig. 7: pl. 25 fig. 6 & 9, pl. 27, fig. 1-3.

EGGERELLA ADVENA (Cushman), Plate 1, Figure 4.

Verneuilina advena Cushman, 1921, p. 141.
Eggerella advena (Cushman). Cushman, 1937, p. 51, pl. 5, fig. 12-15.

HAPLOPHRAGMOIDES BONPLANDI Todd and Bronnimann, plate 2, Figures 9, 10
Haplophragmoides bonplandi Todd and Bronnimann, 1957, pl. 23, pl. 2, fig. 2; Scott *et al.*, 1977, p. 1579, pl. 3, fig. 5, 6.

JADAMMINA POLYSTOMA Bartenstein and Brand, Plate 1, Figures 5, 6, 7

Jadammina polystoma Bartenstein and Brand, 1928, p. 381, fig. 1a-c, 2a-l, 3.

MILIAMMINA FUSCA (Brady), Plate 1, Figures 1, 2, 3

Quinqueloculins fusca Brady, 1870, p. 47, pl. 11, fig. 2, 3.
Miliammia fusca (Brady). Phleger and Walton, 1950, p. 280, pl. 1, fig. 19a, b.

TIPHOTORCHA COMPRIMATA (Cushman and Bronnimann) emend. Saunders, 1957, Plate 2, Figures 7, 8.

Trochammina comprimata Cushman and Bronnimann, 1948a, p. 41, pl. 8, fig. 1-3.
Tiphotrocha comprimata (Cushman and Bronnimann). Saunders, 1957, p. 11.

TROCHAMMINA INFLATA (Montagu), Plate 2, Figures 1, 2, 3.

Nautilus inflatus Montagu, 1808, p. 81, pl. 18, fig. 3.
Trochammina inflata (Montagu). Parker and Jones, 1859, p. 347.

TROCHAMMINA MACRESCENS Brady, Plate 2, Figures 5, 5, 6

Trochammina inflata (Montagu) var. *macrescens* Brady, 1870, p. 290, pl. 11, fig. 6, 7.
Jadammina macrescens (Brady). Murray, 1971b, p. 41, pl. 13, fig. 1-5.

PLATE 1

(Scanning Electron Micrographs)

Figures 1-2.	*Miliammina fusca* (Brady)	
	1. side view (four chamber side), x 94	
	2. side view (three chamber side), x 140	
	3. aperture view, x 225	
Figure 4.	*Eggerella advena* (Cushman)	
	4. side view, x 244	
Figures 5-7.	*Jadammina polystoma* Bartenstein and Brady	
	5. ventral view, x 162	
	6. aperture view, x 150	
	7. dorsal view, x 280	
Figures 8-9.	*Cibicides lobatulus* (Walker and Jacob)	
	8. dorsal side, x 112	
	9. ventral sixe, x 134	
Figures 10, 11.	*Cribrononion williamsoni* (Haynes)	
	10. aperture view, x 180	
	11. side view, x 112	

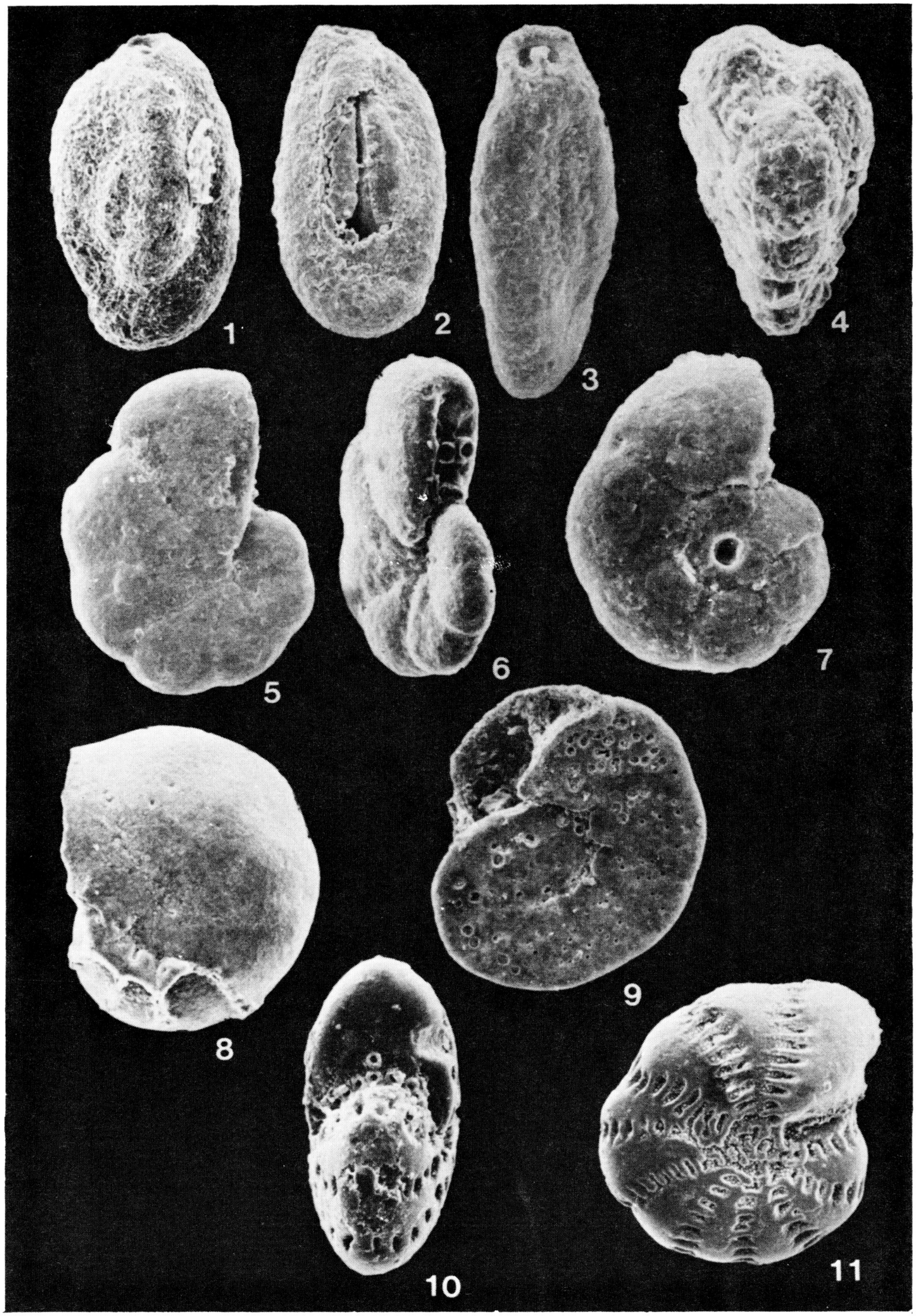
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PLATE 2

(Scanning Electron Micrographs)

Figures 1-3. *Trochammina inflata* (Montagu)

1. dorsal view, x 105
2. aperture view, x 98
3. ventral view, x 118

Figures 4-6. *Trochammina macrescens* Brady

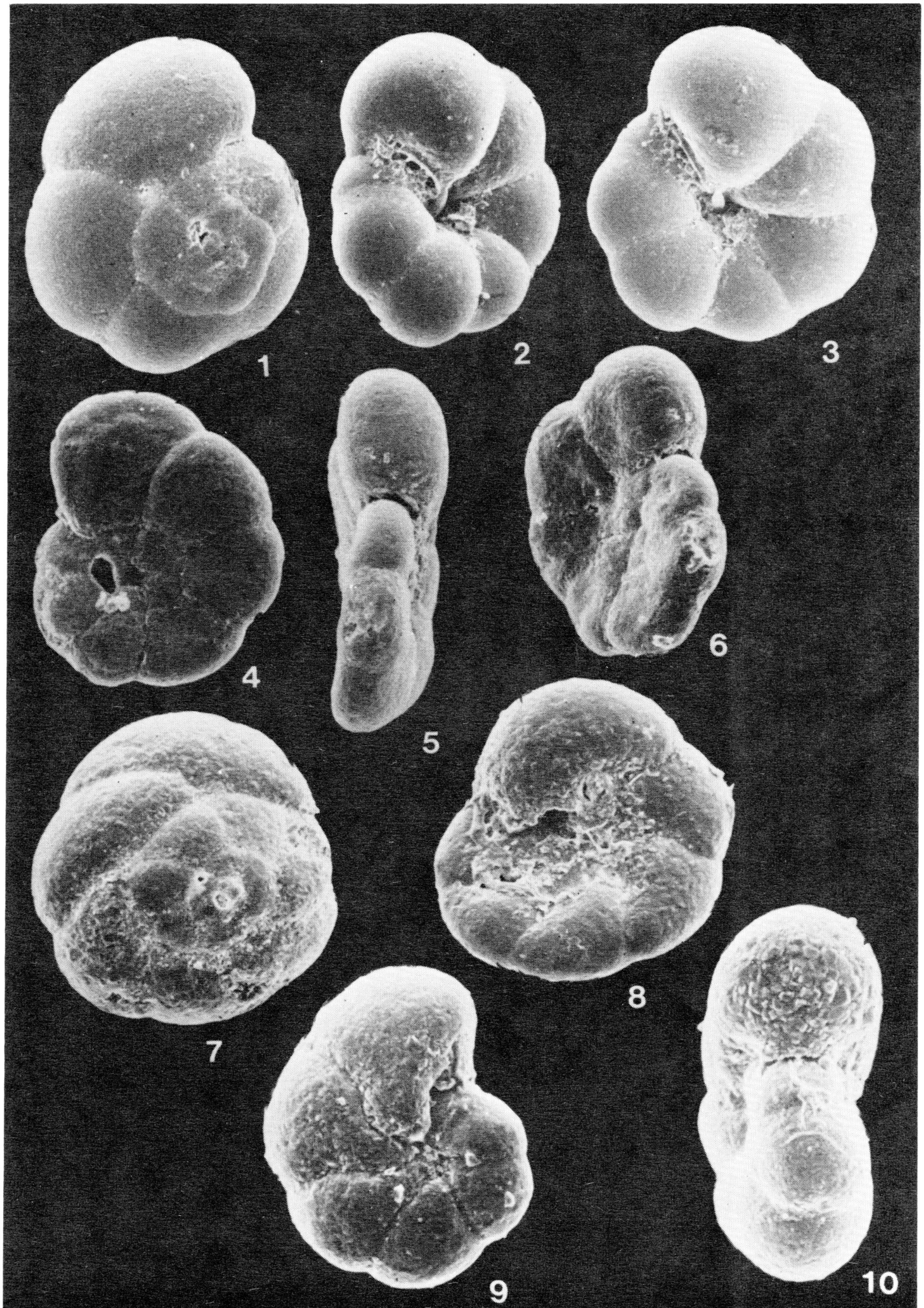
4. dorsal view, x 176
5. aperture view, x 162
6. ventral view, x 131

Figures 7-8. *Tiphotrocha comprimata* (Cushman and Bronnimann) emend. Saunders, 1957

7. dorsal view, x 112
8. ventreal view, x 160

Figures 9-10. *Haplophragmoides bonplandi* Todd and Bronnimann

9. side view, x 186
10. ventral view, x 232.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