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MICROFAUNAL ANALYSIS OF LATE QUATERNARY DEPOSITS OF THE NORTHERN BERING SEA[1]

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ABSTRACT

McDougall, K. 1982 Microfaunal analysis of late Quaternary deposits of the northern Bering Sea. In: C. H. Nelson & S. D. Nio (eds): The northeastern Bering shelf: new perspectives of epicontinental shelf processes and depositional products –Geol. Mijnbouw 61: 019-027.

Holocene microfaunal associations and distribution patterns define three inner-shelf (<20m) biofacies in Norton Sound, northern Bering Sea. The first biofacies is composed of typical bay faunas dominated by the species *Eggerella advena, Buccella frigida, Ammotium cassis,* and *Reophax dentaliformis.* The second biofacies contains bay to inner-shelf faunas indicative of deeper, more marine waters; such inner-shelf species as *Reophax arctica, R. fusiformis, Spiroplectammina biformis,* and *Textularia torquata* dominate. The third biofacies, common in deltaic areas with high sedimentation rates and freshwater input, is characterized by abundant *Elphidium orbiculare* and *E. clavatum.* The distribution of other microfaunal groups (diatoms, ostracods, tintinnids, and fragments of larger invertebrates and plants) corresponds to current and sedimentary patterns.

These Holocene facies relations are the basis for interpreting early Holocene and late Pleistocene environmental conditions in the northeastern Bering Sea area. Within older deposits the sequence of biofacies can be used to interpret the Holocene transgressive cycle in Norton Sound. Norton Sound cores provide evidence of two marine transgressions and a varying river input.

INTRODUCTION

Shpanberg Strait, northers Bering Sea, was breached by marine waters about 11,800 B.P., when sea level rose to —30m. This event separated Saint Lawrence Island from the Alaskan mainland and marked the beginning of the Holocene transgression in Norton basin (HOPKINS, 1973). The rising sea level and warming climate brought about a sequence of physical and biologic changes that transformed the basin from a tundra-covered plain containing peat bogs to a shallow sea. This transformation is recorded in a thin veneer of Holocene sedimentary deposits in Norton Sound.

Holocene and older transgressive-regressive cycles in the Bering Sea have been studied by MCMANUS ET AL (1969), HOPKINS (1972, 1973), NELSON & HOPKINS (1972), KNEBEL & CREAGER (1973), HERMAN (1974), MCMANUS ET AL. (1974,

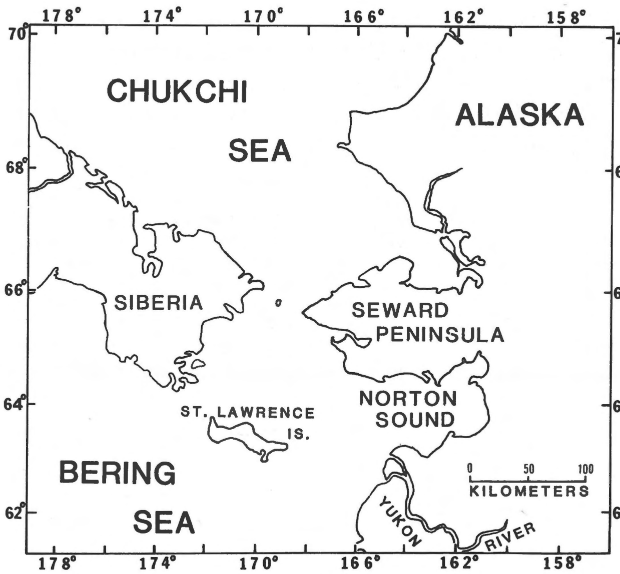

Fig. 1
Index map of study area in northern Bering Sea and southern Chukchi Sea.

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1977), COACHMAN ET AL. (1975), HOPKINS ET AL. (1976), CACCHIONE ET AL. (1977), NELSON & CREAGER (1977), AND NELSON (1982, this volume). Few of these studies have considered the biologic changes and faunal distributions that reflect these cycles. In particular, data on foraminifers, which are sensitive ecologic indicators, have not been previously reported for the northeastern Bering Sea.

Holocene foraminiferal studies along the west coast of Alaska considered the ecologic relations of inner-shelf (<20 m) assemblages of the southern Bering Sea (Anderson, 1963) and the Chukchi Sea (Cooper, 1964). Fossil foraminiferal studies include the work by R. J. Echols (in KNEBEL ET AL., 1974) south of Saint Lawrence Island and that of BELJAEVA (1960) and KUMMER & CREAGHER (1971) in the Gulf of Anadyr. These works recognized inner-shelf assemblages, using criteria formulated during Holocene studies to interpret the paleoenvironment. Faunas from depths of less than 20 m were not identified. Because Norton Sound is mostly shallower than 20 m (MCMANUS ET AL)., 1977), foraminiferal assemblages and faunas representing the Holocene transgression could only be considered as representative of the inner neritic biofacies of earlier workers. Microfaunal analysis limited by this conceptual framework would provide little or no further information on the Holocene transgression. This investigation was conducted to determine what biofacies, if any, could be recognized in the shallow marine waters of Norton Sound, what physical parameters might be related to any of the biofacies found, and which of these biofacies relations might be useful in interpreting the paleoecology of the Holocene transgression.

Norton Sound is a shallow epicontinental shelf sea bounded on the southwest by the Yukon Delta and on the north by Seward Peninsula, Alaska (Fig. 1). Water depths are commonly less than 20 m (MCMANUS ET AL., 1977). Warmer (6°-9°C, average summer temperature), less saline (≤31‰) Alaskan coastal water fills Norton Sound and, circulating in a counterclockwise direction, moves generally northward (ANDERSON, 1963; COACHMAN ET AL., 1975; MCMANUS ET AL., 1977). Runoff from the Yukon River carries sand, silt, and low-salinity water into Norton Sound, where little of the sediment actually accumulates beyond the modern prodelta (NELSON & CREAGER, 1977). Strong storm surges frequently resuspend the sediment and periodically disrupt the substrate (Nelson, 1982, this volume).

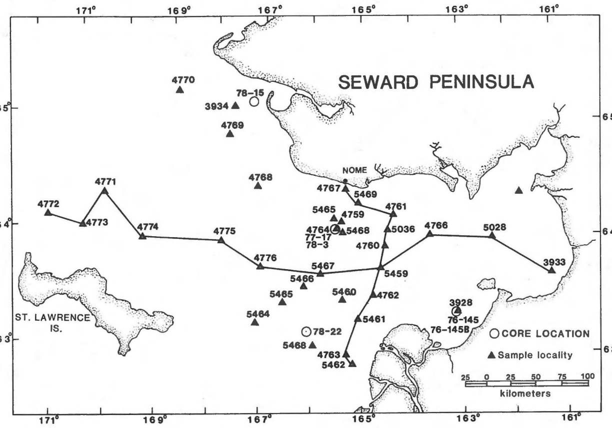


Fig. 2
Locations of surface samples (▲) and cores (O). East-west and north-south lines indicate cross sections in figures 6 and 7.

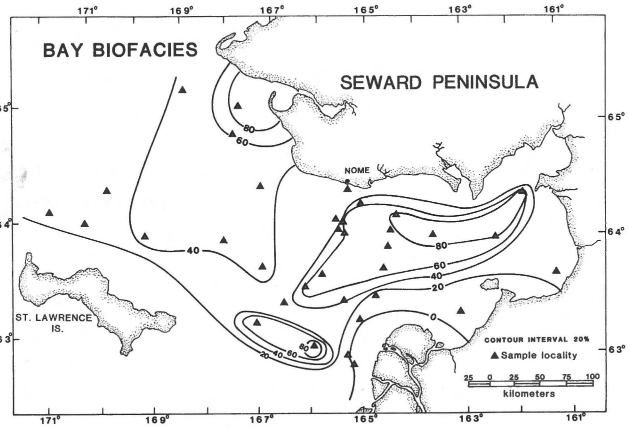


Fig. 3
Distribution of bay biofacies in Norton Sound. Percentage of indicative bay specimens in each sample is contoured to show distribution pattern.

From an analysis of 35 stained surface samples from Norton Sound, three foraminiferal biofacies can be recognized: bay, bay/inner-shelf, and delta. The bay biofacies is associated with slightly higher salinities, lower water temperatures, and fine sand. The bay/inner-shelf biofacies is associated with cool water temperatures, normal salinity, and greater depths. The delta biofacies is associated with shallow water depths, low salinity, warmer water temperatures, and sandy substrates (HOWARD & NELSON, 1982, this volume). Other microfaunal and microfloral groups (diatoms, ostracods, tintinnids, and fragments of larger invertebrates and plants) are also associated with specific environmental conditions in Norton Sound. Fossil assemblages interpreted as representing the Holocene transgression contain many of the species presently living in Norton Sound. These assemblages indicate a progressive change in Norton Sound from a tundra-covered plain to a shallow sea. Foraminiferal assemblages from earlier transgressive-regressive cycles are not included in this discussion.

HOLOCENE MICROFAUNAS

During 1976 and 1977 surface (box cores) and subsurface (vibracores and piston cores) samples were taken from Norton Sound, northern Bering Sea (Fig. 2). Of the surface samples, 35 form the basis of the Holocene surface-study. These samples were collected form the top 1 to 2 cm of the box cores and were stained with rose bengal solution onboard the RV Sea Sounder. Subsequent laboratory processing of both surface and subsurface samples included soaking samples in water and wet sieving through a 63-mesh (250μ) screen. From the dried residues, 300 organic specimens (foraminifers, diatoms, ostracods, tintinnids, and fragments of larger invertebrates and plants) and, where possible, 300 foraminiferal specimens were counted and identified. These microfaunal data (total assemblages) were subjected to both visual statistical (cluster and factor) analysis.

Benthic foraminiferal species constitute one of the major microfaunal groups in the Holocene surface samples. In all, 53 foraminiferal species were recorded; although deversity ranges from 1 to 7 species, most assemblages are dominated by 3 or 4 species. Bij cluster and factor analysis these assemblages were separated into three groups, identified here as the bay, the bay/inner-shelf, and the delta biofacies (Figs. 3-5).

The bay biofacies

The bay biofacies is characterized by *Eggerella advena, Buccella frigida, Ammotium cassis,* and *Reophax dentaliformis. E. advena* is the most abundant, and makes up 10 to 80 percent of the faunas. Stained specimens were difficult to recognize because most of the tests are yellow to brown and thus obscure the red stain. Living specimens, however, were noted in samples south of Nome, Alaska, and west of Port Clarence (an embayment northwest of Nome). *Buccella frigida* and *Ammotium cassis,* the next most abundant species, range in abundance from 1 to 35 percent. *A. cassis* is more abundant in areas where the bay assemblages make up less than 40 percent of the faunas and the sedimentary material is coarser; no living specimens were recognized. *B. frigida,* which is more evenly distributed, increases in abundance in the central parts of Norton Sound and in the bay/inner-shelf assemblages; living specimens are present in both the bay and bay/inner-shelf biofacies.

Faunas dominated by the bay biofacies are most abundant in the northeastern and central parts of Norton Sound as well

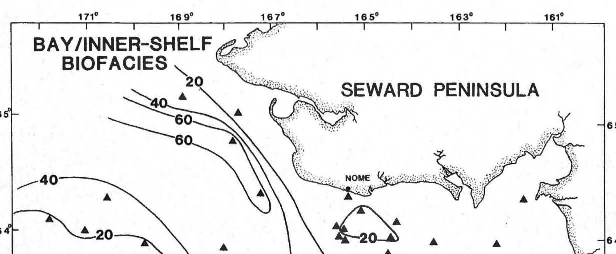


Fig. 4
Distribution of bay/inner-shelf biofacies in Norton Sound. Percentage of indicative bay/inner-shelf specimens in each sample is contoured to show distribution pattern.

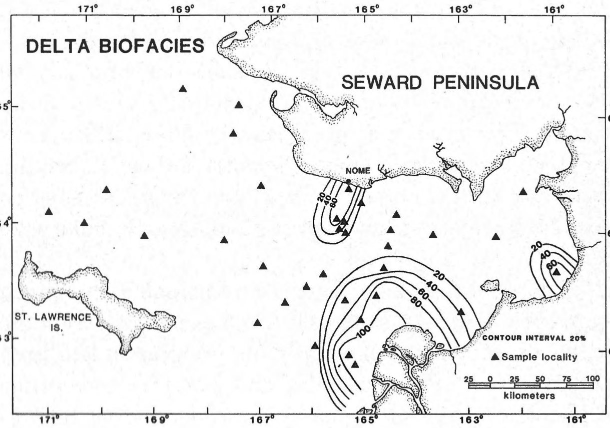


Fig. 5
Distribution of delta biofacies in Norton Sound. Percentage of indicative delta specimens in each sample is contoured to show distribution patters.

as around Port Clarence. These faunas are absent in samples from off the Yukon delta and Cape Rodney, northwest of Nome (Fig. 3). This distribution correlates with water depths between 10 and 30 m (HOPKINS ET AL., 1976; MCMANUS ET AL., 1977) salinities of 29 to 31.5‰ (COACHMAN ET AL., 1975), and temperatures below 12°C (average summer temperature). The substrate in these areas is a fine sand derived from the Yukon River or Seward Peninsula (MCMANUS ET AL., 1977).

The bay/inner-shelf biofacies

The bay/inner-shelf biofacies is characterized by *Spiroplectammina biformis, Textularia torquata, Reophax arctica,* and *R. fusiformis. R. arctica* and *R. fusiformis,* the most common of the four diagnostic species, together average more than 20 percent of the bay/inner-shelf biofacies; *Spiroplectammina biformis* and *Textularia torquata* are less common and occur more sporadically. Inner-shelf species that occur infrequently in association with this biofacies are *Cassidulina islandica, Buliminella elegantissima,* and *Nonionella auricula.*

The bay/inner-shelf biofacies makes up about 20 percent of the species in the depression in Norton Sound, southeast of Nome; higher percentages of the assemblages are found in the western part of Norton Sound (Fig. 4). Species diagnostic of this biofacies frequently occur in association with the species characteristic of the bay biofacies. Little to no overlap with the delta biofacies is evident. Water depths are generally 20 m or greater, summer water temperatures are below 12°C, and salinities are 29‰ or higher (COACHMAN ET AL., 1975). The substrate is composed of several sedimentary types in these areas and fine sand predominates (MCMANUS ET AL., 1974).

The delta biofacies

The delta biofacies is characterized by *Elphidium clavatum* and *E. orbiculare;* these two species together constitute more than 50 percent of the delta faunas. Four other species of

Elphidium were identified in the Norton Sound assemblages: *E. albiumbilicatum, E. bartletti, E. incertum,* and *E. frigidum.* These other species do not occur frequently or abundantly but could be included as species characteristic of the delta biofacies. They occur most frequently in the outer fringes of the delta biofacies areas where the delta and bay faunas are mixed. *E. frigidum* occurs principally in the bay/inner-shelf assemblages and thus cannot be used as diagnostic of the delta biofacies.

Specimens of *Elphidium* were the most commonly stained group; the rose bengal stain colored all chambers except the last (living) chamber. Apparently the protoplasm had been withdrawn from the last chamber and therefore none of the specimens are believed to have been alive at the time of collection.

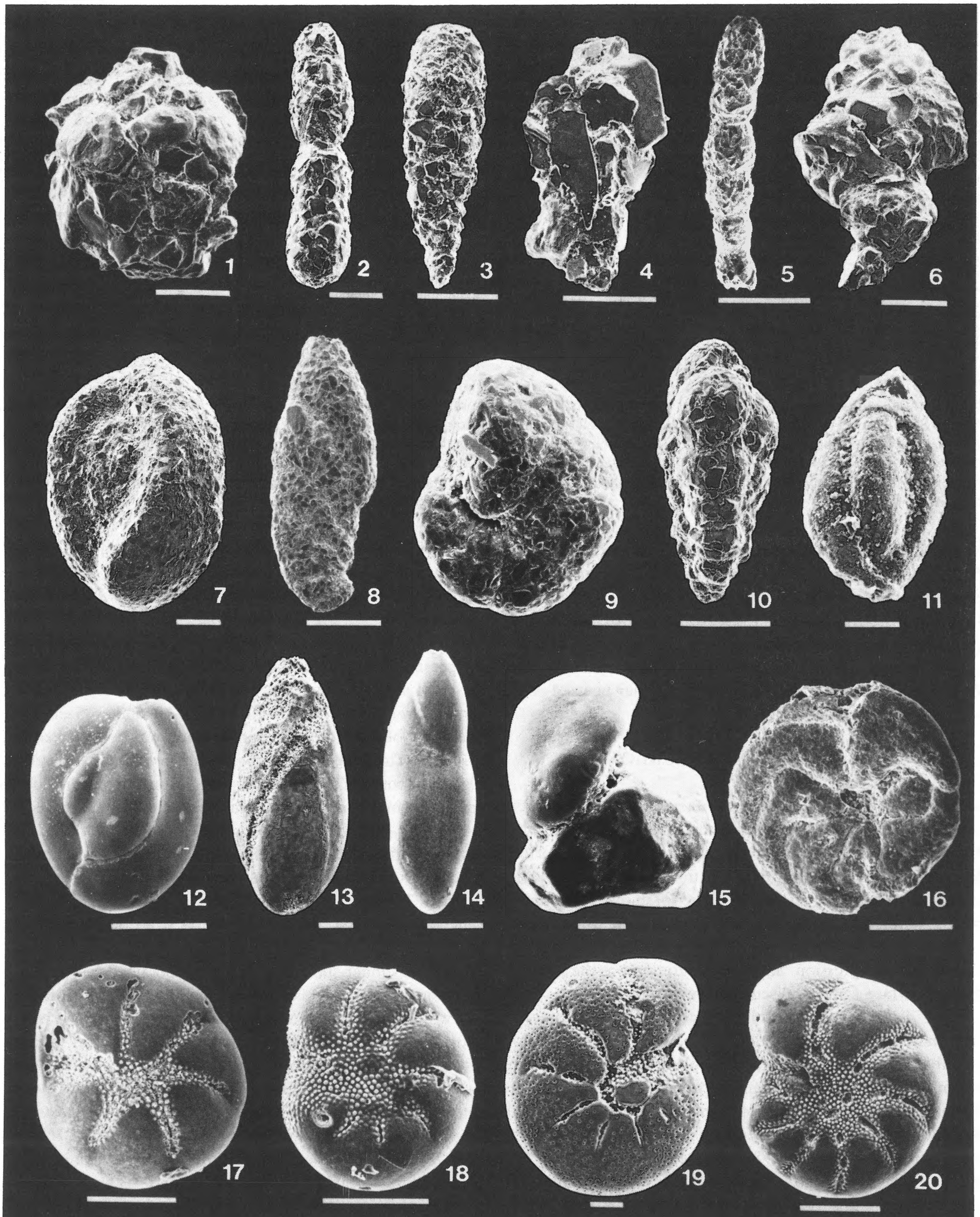
Faunas dominated by the delta biofacies are concentrated around the Yukon delta, the southeastern part of Norton Sound, and in an area immediately south of Nome, Alaska (Fig. 5). This distribution correlates with the shallowest water depths (<10 m) to about 20 m, warmer water temperatures (to 12°C average summer temperature; COACHMAN ET al., 1975), and lower salinities (≤29‰). The substrate is dominated by Yukon silt and fine sand (MCMANUS ET AL., 1974).

The interrelation of the three biofacies is evident in two transects of surface samples across Norton Sound. Most faunal assemblages contain species from all three biofacies. Species diagnostic of each biofacies are present in every assemblage except those directly affected by the Yukon River (samples Mf4763, Mf5461, Mf5462). The bay/inner-shelf biofacies exists principally in the deeper waters and only where the delta species make up less than 50 percent of the assemblage (Figs. 6, 7).

The three biofacies recognized here refine the inner-shelf sublittoral biotopes recognized in the southern Bering Sea and the faunal assemblages recognized in the Chukchi Sea. The deltaic biotope of ANDERSON (1963) and the delta biofacies of this study are equivalent. Both the delta biofacies and biotope are dominated by species of *Elphidium* and controlled largely by salinity. No clearly deltaic assemblage was recognized in the Chukchi Sea. The bay and bay/inner-shelf biofacies of this study resemble the inner shelf biotope of ANDERSON (1963) of which they may be subdivisions. The transitional biotope of ANDERSON (1963) was not recognized in the Norton Sound surface samples but was recognized in the subsurface samples; this biotope contains abundant occurrence of *Buccella frigida* and *Buliminella elegantissima* and is therefore unlike the bay or bay/inner-shelf biofacies of this study. The group II and group III faunal assemblages in the Chukchi Sea (COOPER, 1964) resemble the bay and bay/inner-shelf biofacies in Norton Sound, although Cooper's groups are not so cleary defined or restricted.

Other faunal and floral groups recognized are plant fragments, larger invertebrate fragments, ostracods, diatoms, and tintinnids. Plant fragments were present in every sample and very high abundances were observed in samples from near the Yukon Delta. Larger invertebrates include worm tubes, crustaceans, and mollusks, present throughout Norton Sound and generally the only living (stained) component of the assemblages. Ostracods were considered separately from the other invertebrates; this faunal group is concentrated in the eastern part of Norton Sound, where they make up as much as one-fourth of the faunas (Fig. 8). Elsewhere in Norton Sound, ostracods were only minor components (<5%). Larger diatoms, which occur in the foraminiferal residues, are present throughout and increase in abundance form east to west as the water becomes deeper and more normal marine (Fig. 8). Smear slides contained oceanic, neritic marine, benthic marine, and freshwater diatoms; no particular pattern has yet been recognized. Tintinnids *(Tintinnopsis fimbriata)* are minor members of all assemblages,

Plate 1 (facing page)
1. *Psammosphaera fusca* Schulze, sample Mf3928, 0-1 cm. Bar equals 100 μm.
2. *Protoschista findens* (Parker), sample Mf3928, 0-1 cm. Bar equals 100 μm.
3. *Reophax arctica* Brady, sample Mf3934, 0-1 cm. Bar equals 100 μm.
4. *Reophax curtus* Cushman, sample Mf5036, 0.1 cm. Bar equals 100 μm.
5. *Reophax scotti* Chaster, sample Mf3934, 0-1 cm. Bar equals 100 μm.
6. *Reophax subfusiformis* Earland, sample Mf3934, 0-1 cm. Bar equals 300 mm.
7. *Millammina fusca* (Brady), sample Mf3934, 0-1 cm. Bar equals 300 mm.
8. *Ammotium cassis* (Parker), sample Mf3934, 0-1 cm. Bar equals 300 μm.
9. *Trochammina nitida* Brady, sample Mf5028, 0-1 cm. Bar equals 30 μm.
10. *Eggerella advena* (Cushman), sample Mf3934, 0-1 cm. Bar equals 100 mm.
11. *Quinqueloculina* sp., sample Mf5036, 0-1 cm. Bar equals 30 μm.
12. *Quinqueloculina subrotunda* (Montagu), sample Mf3934, 0-1 cm. Bar equals 100 mm.
13. *Guttulina lactea* (Walker & Jacob), sample Mf3928, 0-1 cm. Bar equals 30 μm.
14. *Guttulina austriaca* d'Orbigny, sample Mf3934, 0-1 cm. Bar equals 100 μm.
15. *Discorbis baccata* (Heron-Allen & Earland), sample Mf3928, 0-1 cm. Bar equals μm.
16. *Neoconbrina* sp., sample Mf3934, 0-1 cm. Bar equals 100 μm.
17. *Buccella frigida* (Cushman), sample Mf3934, 0-1 cm. Bar equals 100 μm.
18. *Elphidium bartletti* Cushman, sample Mf3934, 0-1 cm. Bar equals 100 μm.
19. *Elphidium clavatum* Cushman, sample Mf5028, 0-1 cm. Bar equals 30 μm.
20. *Elphidium albiumbilicatum* (Weiss), sample Mf3934, 0-1 cm. Bar equals 100 μm.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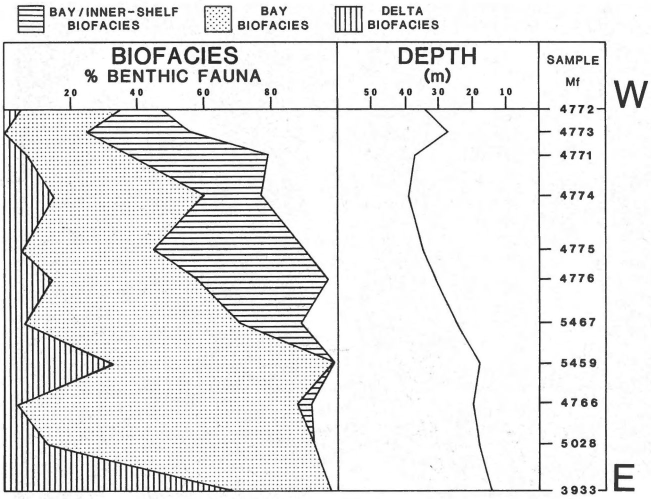

Fig. 6
Foraminiferal composition and depth. West to east transect through Norton Sound shows that the percentage of bay/inner-shelf species in surface samples decreases as the water depths decrease, whereas the percentage of the bay and delta species increases. The unpatterned area represents those species not associated with any of the three recognized biofacies.

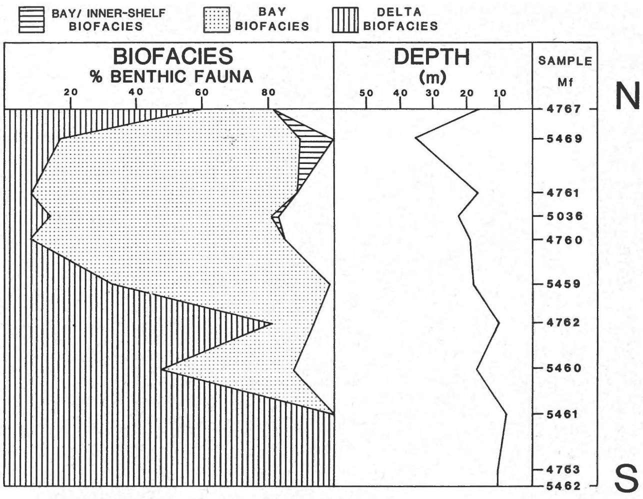

Fig. 7
Foraminiferal composition and depth. North to south transect through Norton Sound shows that bay/inner-shelf species occur only in the deeper northern part of Norton Sound and that the percentage of delta species increases rapidly near the Yukon River. Only a small percentage of foraminiferal faunas is not associated with one of the recognized biofacies.

except in a few samples from the extreme eastern part of Norton Sound (Fig. 8), where tintinnids make up as much as one-fifth of the organic remains. Abundant tintinnids are also found in the depression south of Nome, a distribution that probably reflects the current pattern and transport of fine-grained sediment. ECHOLS & FOWLER (1973) reported this same species in the Chukchi Sea and note that it may be used as an indicator of Yukon River sediment.

HOLOCENE TRANSGRESSION

Refinement of the shallow-water biofacies serves as a basis for interpreting environmental changes during the Holocene transgression. Five cores from different parts of Norton Sound were selected for study. In these cores the biologic changes, particularly in the benthic foraminiferal faunas, were examined and related to paleoenvironmental conditions to provide a clearer picture of the transition taking place during the transgression. Sample preparation was the same as for the surface samples discussed previously.

Core 78-22 (Fig. 9) was collected northwest of the present Yukon delta (lat. 63.21° N., long. 165.50° W.) in an area now dominated by the bay biofacies. Subsurface samples were taken at about 50-cm intervals between —2 and —513 cm. Faunal analyses indicate a progression from an interval dominated by plant fragments, assumed to represent a nonmarine environment (—513 cm), to one dominated by the delta biofacies (—450 to —250 cm). The benthic foraminiferal assemblages in this fossiliferous interval also contained a few species of the bay biofacies and the transitional biotope of ANDERSON (1963). Samples between —250 and —50 cm were dominated by plant fragments. One specimen of *Eggerella advena* occured at —200 cm, and several diatoms were present in the sample at —250 cm. The sample at —2cm was, as expected, dominated by bay species and included rare delta species.

Core 76-145 – including 76-145B – (Fig. 10) was northeast of the present Yukon delta (lat. 63.22° N., long 163.07° W.; Fig. 2), in an area dominated by the delta biofacies. Subsurface samples were at —3, —9, —10, —15, —20, and —85 cm; the beginning of the Holocene transgression was not reached in this core. The lowest sample (—85 cm) contained an assemblage composed of 60 percent bay species and 40 percent delta species. Plants were the only organic remains in the samples at —20 and —15 cm. The higher samples (—10, —9, and —3 cm) were all dominated by deltaic species, which make up the modern Norton Sound faunas in this area.

Cores 78-3 and 77-17 (Fig. 11) were south of Nome, Alaska (lat. 64.05° N., long. 165.29° W., Fig. 2), in an area dominated by the bay biofacies. Assemblages containing as much as 20 percent bay/inner-shelf biofacies were obtained just east of these sites, and assemblages dominated by the delta biofacies just west of the sites. Information from core 77-17 was used to supplement the unsampled part of core 78-3. Samples in core 78-3 were taken at approximately 50-cm intervals between —100 and —550 cm; core 77-17 was sampled at 50-cm intervals from —5 to —130 cm. The Holocene transgression begins above the plant-dominated assemblages at —30 cm in core 78-3 (C. H. Nelson, oral commun., 1980). The benthic foraminiferal assemblages between —5 and —300 cm in these cores are dominated by species indicative of the bay biofacies. Evidence of an initial delta fauna was not found in these cores. A minor number of bay/inner-shelf species appeared at —5 cm. Delta species also appear as minor components in the

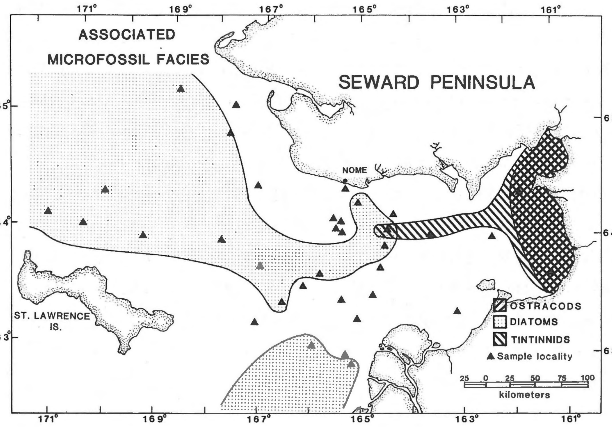

Fig. 8
Distribution of associated microfossil groups. Ostracods and tintinnids were common in the eastern part of Norton Sound, whereas diatoms were common in samples from the western part.

assemblages at —50 and —5 cm. No plant-fragment-dominant interval was evident in the upper part of the core.

Core 78-15 (Fig. 12) was west of Port Clarence (lat 65.14° N., long 167.25° W.; (Fig. 2), in an area now dominated by bay and bay/inner-shelf species. The Holocene transgression begins above the peat at —144 cm (C. H. Nelson, oral commun., 1980). The upper part of the core was sampled at —130, —80, —30, and —3 cm. Benthic foraminifers at —130 cm represent the delta biofacies. The delta assemblage is overlain by plant dominated intervals at —80 and —30 cm. The shallowest sample resembles the modern fauna in this area: 17 percent delta biofacies. 67 percent bay biofacies, and 15 percent bay/inner-shelf biofacies.

PALEOENVIRONMENTAL INTERPRETATION OF THE HOLOCENE TRANSGRESSION

Biofacies analysis of these five cores indicates changes in the biologic and physical conditions of Norton Sound. Two benthic assemblages are recognized in the cores examined. The lower benthic foraminiferal faunas indicate patterns that differ from the modern pattern; the upper benthic foraminiferal faunas resemble modern faunas and represent similar biofacies patterns. The two assemblages are separated by several plant-fragment-rich intervals in all cores but one.

When the Shpanberg Strait was breached, marine waters encroached from the south. The initial benthic foraminiferal faunas indicate very shallow water depths (<10 m) and low salinities; these initial faunas were observed only in the western cores (78-22, 78-15). The next fauna to appear is dominated by species of the bay biofacies. Environmental changes included increased water depths and increased salinities. The presence of bay/innershelf and transitional species in several lower samples suggest that transgressive water depths reached the present level or that salinities increased to 31‰.

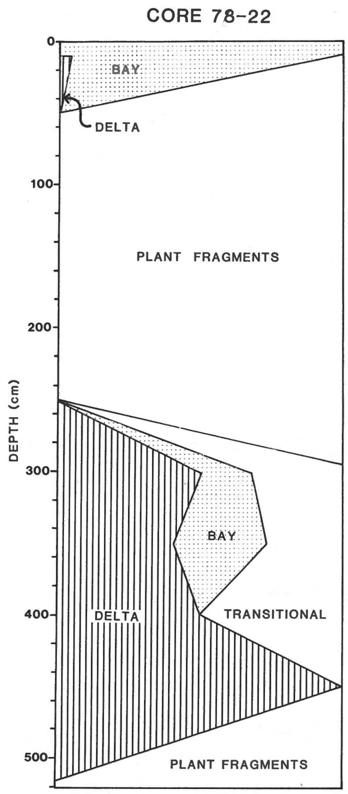

Fig. 9
Faunal composition of core 78-22. The foraminifera assemblages in the lower part of the core are dominated by delta species bay species and species representing transitional biotope of Anderson (1963) are also present. Above the interval of plant fragments, benthic foraminiferal species of the bay biofacies predominate.

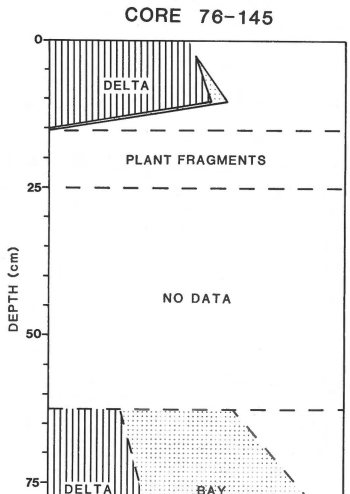

Fig. 10
Faunal compostion of core 76-145 (including core 76-145B). The foraminiferal assemblages in the lower part of the core contain nearly equal proportions of delta and bay species. Above the interval of plant fragments, delta species predominate.

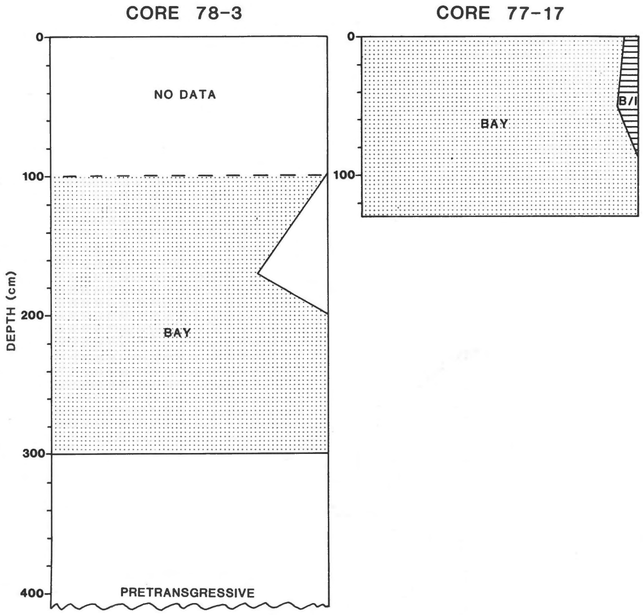

Fig. 11
Faunal composition of cores 78-3 and 77-17. Benthic foraminiferal species characteristic of the bay biofacies predominate throughout.

In cores 78-22, 76-145, and 78-15, an interval barren of benthic foraminifers and dominated by plant fragments separates the lower from the upper assemblages and abruptly alters the benthic foraminiferal assemblages. This change in faunas may indicate the time at which the Yukon River began actively to influence the water quality and sedimentation in Norton Sound (NELSON, 1982, this volume). The upper benthic foraminiferal assemblages and biofacies patterns resemble modern assemblages and patterns. The modern foraminiferal assemblage is strongly influenced by the Yukon Rivers.

CONCLUSIONS

Three biofacies can be recognized in the shallow waters of Norton Sound: bay, bay/inner-shelf, and delta. The faunal species and the distribution of the biofacies are influenced by such physical factors as salinity, water temperature, and sedimentation. These modern biofacies are useful in interpreting the paleoenvironmental conditions in Norton Sound since the Holocene transgression began. As sea level rose Norton Sound was first occupied by low-salinity waters that became progressively more marine and deeper. Then water quality or sediment regime changed, possibly because of changes in the Yukon River discharge and formation of the modern lobe about 2,500 B.P. (Nelson, 1982, this volume). Above the level of this change, benthic foraminiferal assemblages have the same distribution and interrelations as the modern faunas.

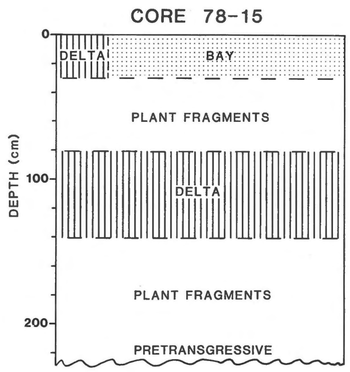

Fig. 12
Faunal composition of core 78-15. Benthic foraminiferal species characteristic of the delta biofacies predominate in assemblages below the plant-fragment-dominated interval, whereas bay species predominate above.

ACKNOWLEDGMENTS

C. H. Nelson directed the surface and subsurface sampling of Norton Sound. J. A. Barron examined the smear slides for floral groups. M. G. Murphy and Jonathan Schneider prepared the samples and figures.

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