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LATE PLEISTOCENE - HOLOCENE TRANSGRESSIVE SEDIMENTATION IN DELTAIC AND NON - DELTAIC AREAS OF THE NORTHEASTERN BERING EPICONTINENTAL SHELF[1]

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ABSTRACT

Nelson, C.H. 1982 Late Pleistocene - Holocene transgressive sedimentation in deltaic and non - deltaic areas of the north-eastern Bering epicontinental shelf. In: C.H. Nelson & S.D. Nio (eds): The northeastern Bering shelf: new perspectives of epicontinental shelf processes and depositional products – Geol. Mijnbouw 61: 005-018.

The distribution of late Pleistocene and Holocene surface sediments on the northern Bering Seafloor is patchy and dependent upon locations of seafloor bedrock and pre-late Pleistocene glacial debris, late Holocene river sediment influx, and modern strong bottom currents. Seafloor vibracores and high-resolution profiles record two different sedimentary environments in the northern Bering shelf: late Pleistocene-Holocene shoreline transgression (<16.000 years BP) in Chirikov Basin, and Holocene deposition from the Yukon River in Norton Sound.

Lag gravels remain exposed on the margins of Chirikov Basin where the transgression of the late Pleistocene-Holecene shoreline reworked pre-Quaternary bedrock and Pleistocene glacial moraines. In central Chirikov Basin, the transgressive deposits cover Pleistocene limnic peaty mud of emergent shelf deposition. In places, a few centimeter thick basal transgressive facies of pebbly medium of fine sand is left above which is a widespread sheet of thin (< 1m) inner-shelf fine-sand facies. Water circulation patterns have inhibited deposition of Holocene Yukon River silt over trangressive sand and lag gravels of Chirikov Basin.

About 10,000 BP, a rapid marine transgression caused the deposition of a basal nearshore facies of thick storm-sand layers in marine silt over the Pleistocene freshwater peaty mud of Norton Sound. This has been covered by an offshore bioturbated silt.

A younger progradation of thick storm-sand layers and Holocene brackish-water silt (up to 14 m) in southern Norton Sound has been deposited since a shift of the active Yukon Delta into its present position about 2,500 BP.

INTRODUCTION

The epicontinental shelf in northeastern Bering Sea is much like the North Sea shelf because of its strong currents (CACCHIONE & DRAKE, 1979) and numerous insular and peninsular constrictions. During shoreline transgression of the late Pleistocene ($\geqslant$ 10,000 years BP)[3] to Holocene ($\leqslant$ 10,000 years BP), different transgressive sedimentary facies developed on the northern Bering shelf in the non-detaic region of Chirikov Basin to the west and the prodeltaic area of Norton Sound to the east (Fig. 1). This paper addresses the processes and products of these two types of transgressive sedimentation on the Bering epicontinental shelf region so that they can be compared with similar deposits in other areas, like the North Sea, and with deposits of similar facies in ancient analogs.

The extremely thin trangressive sandy facies of the Chirikov Basin are compared with the thick, muddy sequence of Holocene deposits in Norton Sound. The variable lithology, sedimentary processes, and sedimentary history of these facies during the late Pleistocene and Holocene time provide one of the few examples of modern sedimentation on broad epicontinental shelves. The varying sediment distribution patterns and processes of northeastern Bering shelf can be contrasted with the gradational patterns of epicontinental shelf sedimentation in the southeastern Bering Sea. These highly variable sediment facies patterns on Bering shelf provide new insights for the interpretation of similar ancient shelf deposits that make up a significant portion of the geologic record.

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[1] Manuscript received: 1981-10-21.
Manuscript accepted: 1982-01-08.

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[3] For consistent stratigraphic nomenclature, deposits 10.000 years BP and younger are defined as Holocene in this paper (see Hopkins, 1975).

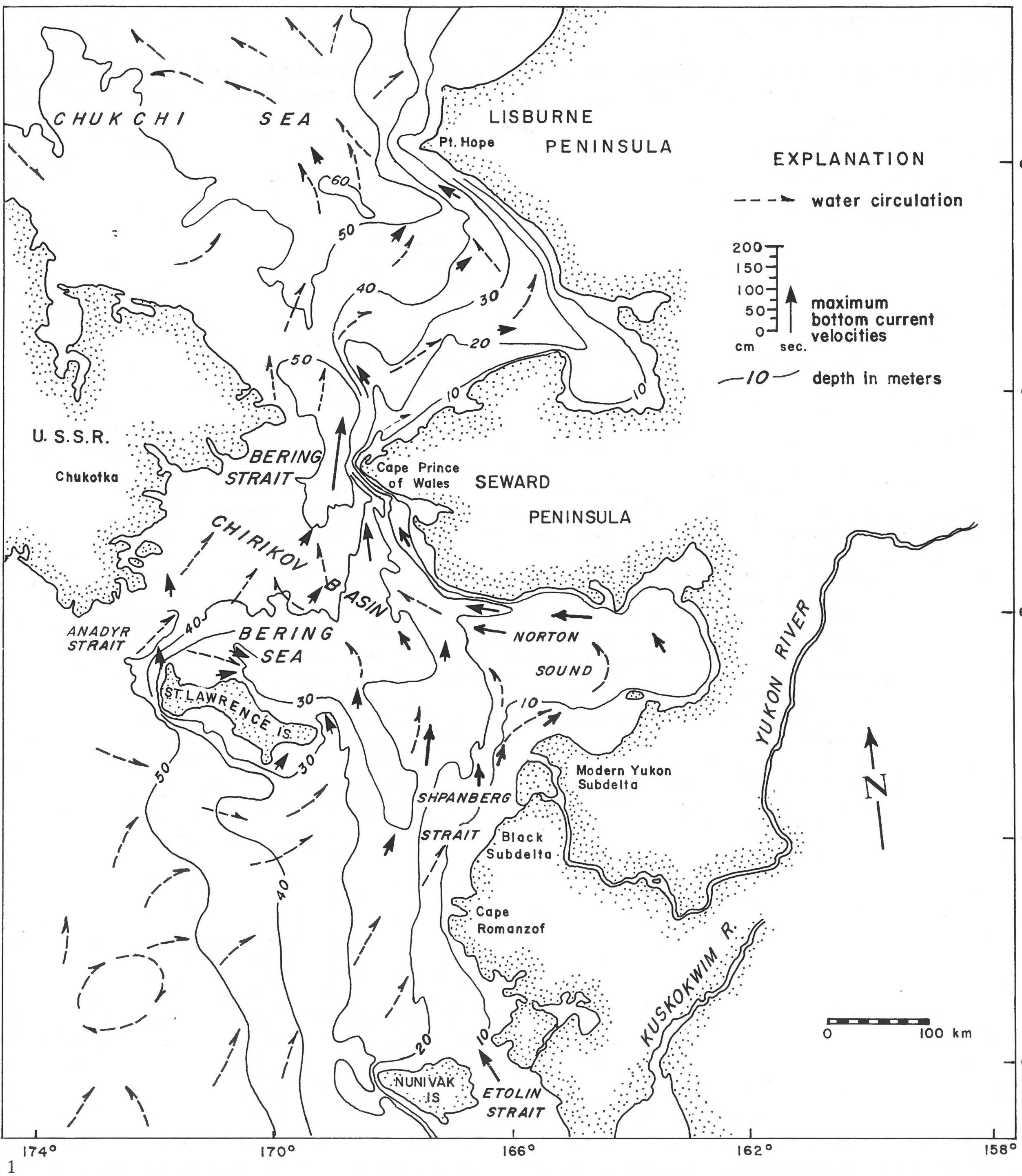


Fig. 1
Northeastern Bering Sea and southern Chukchi Sea, showing water circulation, maximum measured bottomcurrent velocities, and bathymetry. Modified from Nelson & Creager (1977) including new long-term *in situ* current measurements from Cacchione & Drake (1979) and R. Muench (written commun., NOAA-PMEL, Seattle, Wash., 1979).

METHODS

This study of late Pleistocene and Holocene history of sedimentation on the northeastern Bering shelf summarizes a decade of marine geologic research by the U.S. Geological Survey in this region. The findings in this paper are based on box cores and vibracores up to 6 m into the seafloor and on more than 10,000 km of tracklines covered by high-resolution sparker, Uniboom, and 3.5 kHz continuous seismic profiling systems. (Fig. 2).

Nearly 50 vibracores and 250 box cores have been described (NELSON ET AL. in press; HOWARD & NELSON, 1982, this volume) from lithologic analyses, X-ray radiography and epoxy peels. Samples also have been analyzed for texture, microfauna, and radiocarbon dates (see also MCDOUGALL, 1982, this volume).

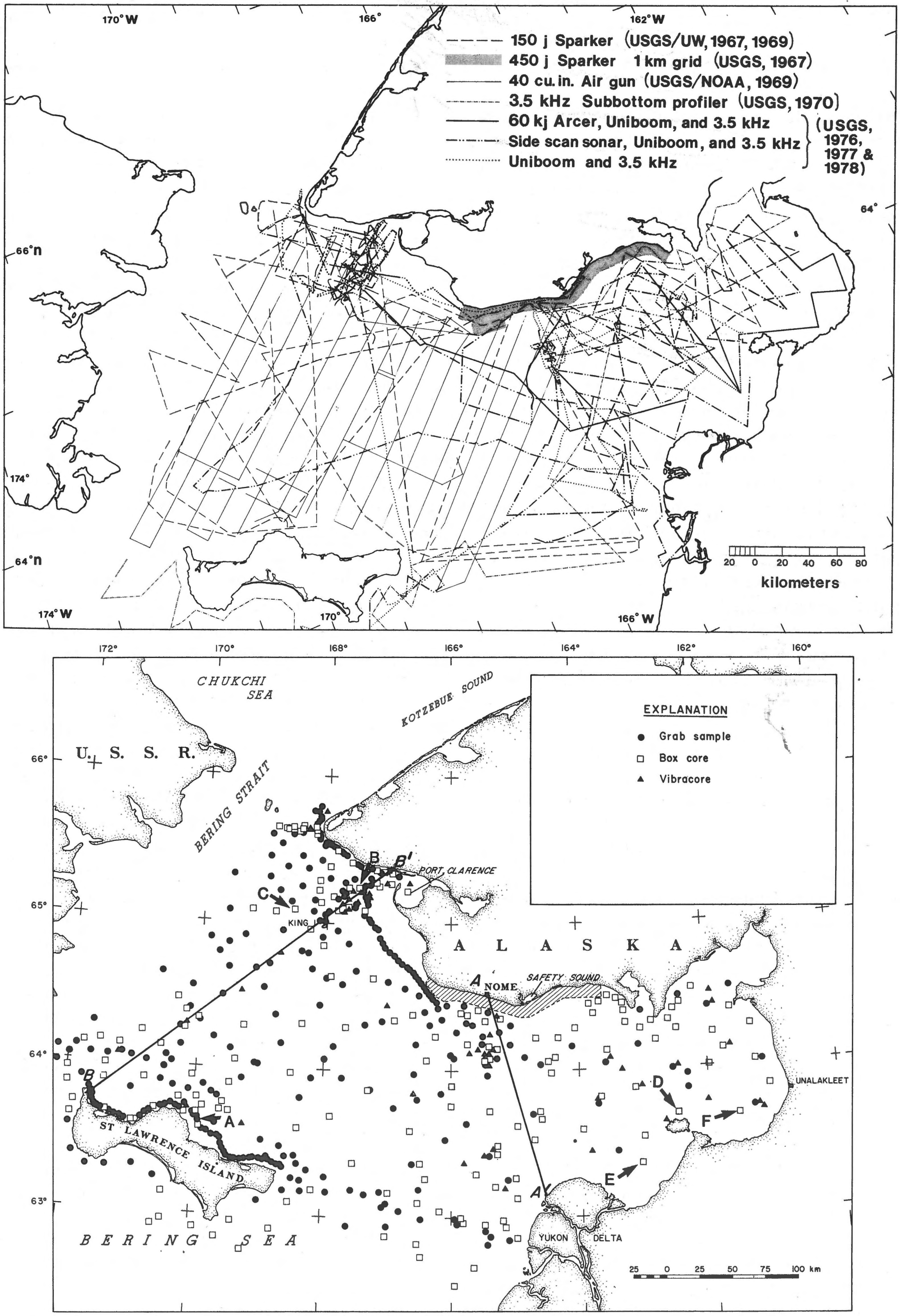


Fig. 2
Location of geophysical tracklines and sampling stations for U.S. Geological Survey research in northern Bering Sea between 1967 and 1978. Lines A-A' and B-B' show locations of cross-sections shown in figure 3. Single letters A-F show station locations of core photographs in figure 5.

OCEANOGRAPHIC SETTING

The northeastern Bering Sea is a shallow epicontinental shelf area (< 60m deep) that can be divided into two provinces, Chirikov Basin and Norton Sound (Fig. 1). The shallower eastern half of the area, the Norton Sound embayment, is generally less than 20m deep (Fig. 1). The very shallow prograding Yukon Delta wedge in southern Norton Sound is an important morphologic feature of Norton Sound; its topography influences wave and storm surge processes in this region. The western region, Chirikov Basin, is surrounded by continental land masses on the northwest and northeast, and the large St. Lawrence Island on the south that constrict and reinforce the strong geostrophic current flow (Fig. 1).

Sedimentary processes on the northeastern Bering shelf are dominated by the strong northward geostrophic current (Fig. 1) and only the north part of Norton Sound is dominated by tidal currents (CACCHIONE & DRAKE, 1979). Bottom currents are intensified along the eastern Bering Sea margin wherever land projects westward to constrict the northward geostrophic flow (Fig. 1). Even more important is the increase in geostrophic current speeds, which have been observed to double, during moderate storms (CACCHIONE & DRAKE, 1979; SCHUMACHER & TRIPP, 1979).

As in the North Sea, storm surge set-up along Alaskan coast results in storm-related currents that cause major sedimentation events (NELSON, 1980).

GEOLOGIC BACKGROUND

Past eustatic sea level changes influence distribution of the present Holocene and late Pleistocene shelf deposits in all of Chirikov Basin and shoreline areas of Norton Sound (NELSON & HOPKINS, 1972; MCMANUS ET AL. 1977).

The most important influence, the last sea level transgression, began in northeastern Bering shelf about 12,000 to 13,000 years ago in straits where the water was deepest (HOPKINS, 1973). At first a narrow seaway developed from Anadyr Strait to Bering Strait (HOPKINS, 1979) and then from Shpanberg Strait to Bering Strait (KNEBEL & CREAGER, 1973a; NELSON & CREAGER, 1977). The narrow seaways expanded to fill out the deeper western area of Chirikov Basin until about 10,000 years ago.

During shoreline transgression in Chirikov Basin a number of stillstand features were created. For example, ancient shorelines remain as large submerged sand ridges between King Island and Port Clarence (Figs. 2 and 3, B-B′), (see NELSON ET AL., 1982, this vol.), and recognizable ancient strandlines occur in numerous other locations, particulary off Nome (NELSON & HOPKINS, 1972; HOPKINS, 1973).

The entire Norton Sound region remained emergent until about 10,000 years ago. General sea level fluctuations determined elsewhere (FIELD ET AL., 1979) and specific radiocarbon dates in Norton Sound (Fig. 3, A-A′; NELSON & CREAGER, 1977) show that from 10,000 to 9,500 years B.P., the shoreline rapidly transgressed eastward over Norton Sound, and buried tundra peat deposits.

The transgressing shoreline planed over a number of previous alluvial, glacial, and bedrock exposures. Bedrock remains exposed on the seafloor in regions near insular and penisular granitic stocks and volcanic outdrops, such as near Cape Prince of Wales, King Island, and off northern St. Lawrence Island (Fig. 4) (NELSON & HOPKINS, 1972). Another extensive area of seafloor bedrock occurs north of a major fault scarp (JOHNSON & HOLMES, 1978) along the subsurface channel west of Port Clarence (Fig. 4) to the Cape Prince of Wales shoreline, and is perhaps correlative with Precembrian to Paleozoic limestone of the adjacent shoreline area (NELSON & HOPKINS, 1972)

Numerous subsurface alluvial channels covered by the transgressive deposits have been mapped in the Norton Sound region where the most detailed grid of seismic profiles is present (Fig. 4). In Chirikov Basin the limited grid of seismic profiles (Fig. 2) does not permit detailed mapping of the subsurface channels, but major subsurface channels are known to exist west of Port Clarence, extending toward Bering Strait, and in the sea valley extending south from King Island (HOPKINS ET AL., 1976) (Fig. 4).

Early and middle Pleistocene continental glaciation extending off (U.S.S.R.-Chukotka) to the central part of Northeastern Bering Sea, and local valley glaciation offshore from Seward Peninsula have been determined both by seismic profiling and by sediment sampling (GRIM & MCMANUS, 1970; NELSON & HOPKINS, 1972; TAGG & GREENE, 1973; HOPKINS, 1975, 1979). The glacial moraines appear in the subsurface of seismic profiles in the central part of Chirikov Basin and emerge on the seafloor surface toward land as gravel ridges. (Figs. 4 and 5A). Complete sequences of moraines and outwash were documented in the nearshore areas off Nome from detailed profiling (TAGG & GREENE, 1973) and drill holes as deep as 75m below the seafloor (NELSON & HOPKINS, 1972).

The other major geologic event that significantly influenced the distribution of late Pleistocene and Holocene deposits is the change in position of the active Yukon Delta lobe on the Bering shelf. About 16,000 years ago, the Yukon River apparently crossed the present Bering shelf in the vicinity of Cape Romanzof and deposited a deltaic sequence south of St. Lawrence Island (KNEBEL & CREAGER, 1973a). As sea level rose in the early Holocene, various active lobes developed far south of Norton Sound in the Black subdelta and Cape Romanzof regions (Fig. 1) (NELSON & CREAGER, 1977). The present active delta lobe first developed in southern Norton Sound after 2,500 years BP as shown by dating of onshore delta deposits (DUPRÉ, 1982, this volume) and of offshore change from marine to brackish-water fauna (see core C in Fig. 3, A-A′) (MCDOUGALL, 1982, this volume). Since then the Yukon River has prograded significantly into Norton Sound and altered biological activity and attendent bioturbation patterns (NELSON ET AL., 1981; HOWARD & NELSON, 1982, this volume).

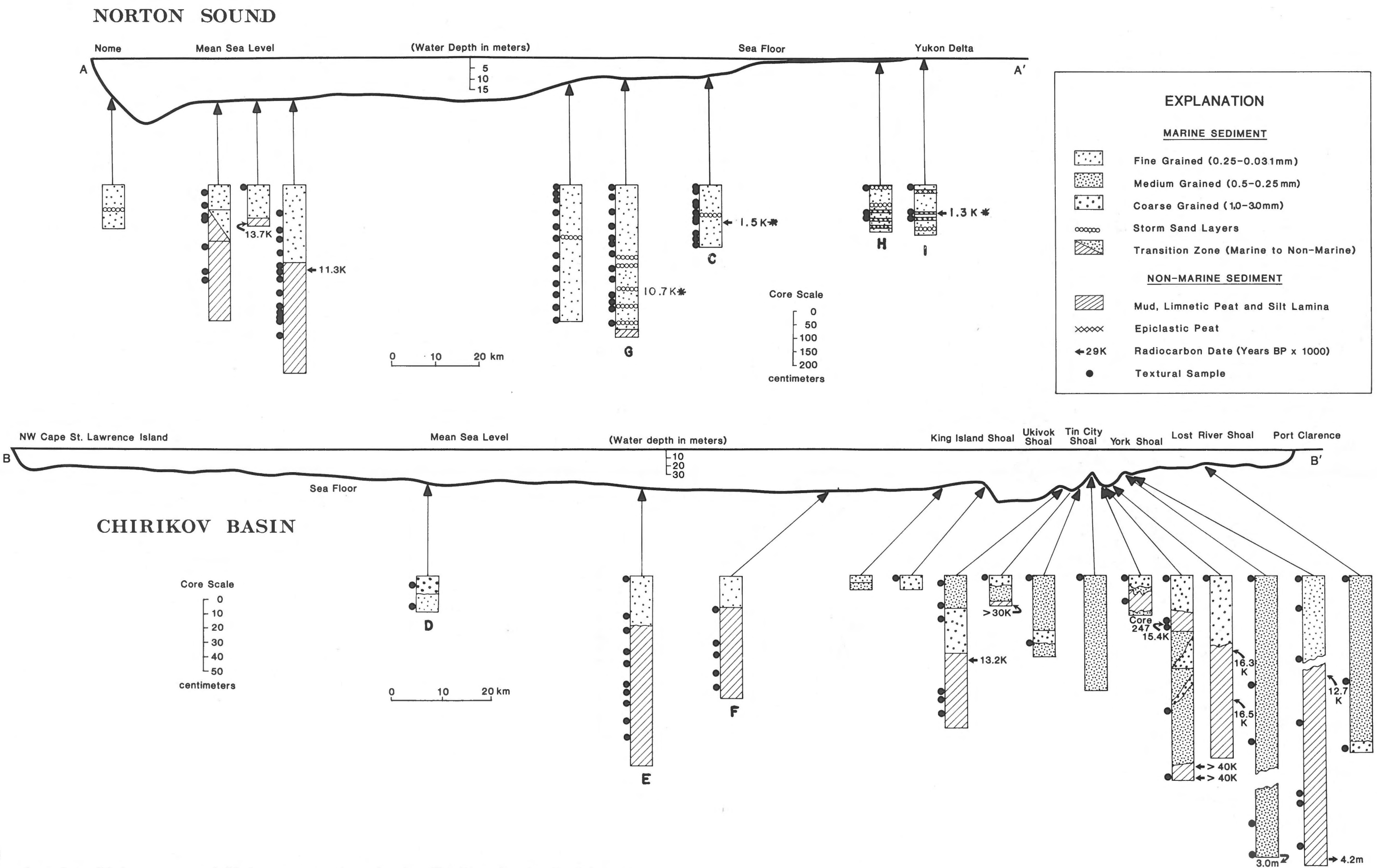


Fig. 3
Near-surface late Pleistocene and Holocene stratigraphy in Chirikov Basin (B-B') and Norton Sound (A-A') (see figure 2 for locations). Corrected dates with stars are calculated by the method shown in figure 5D. In profile A-A' the date of 1500 years BP in core C approximately dates freshwater influx of the modern Yukon delta lobe. In profile B-B' the region of sand ridges in northeast Chirikov Basin extends from King Island shoal to Port Clarence.

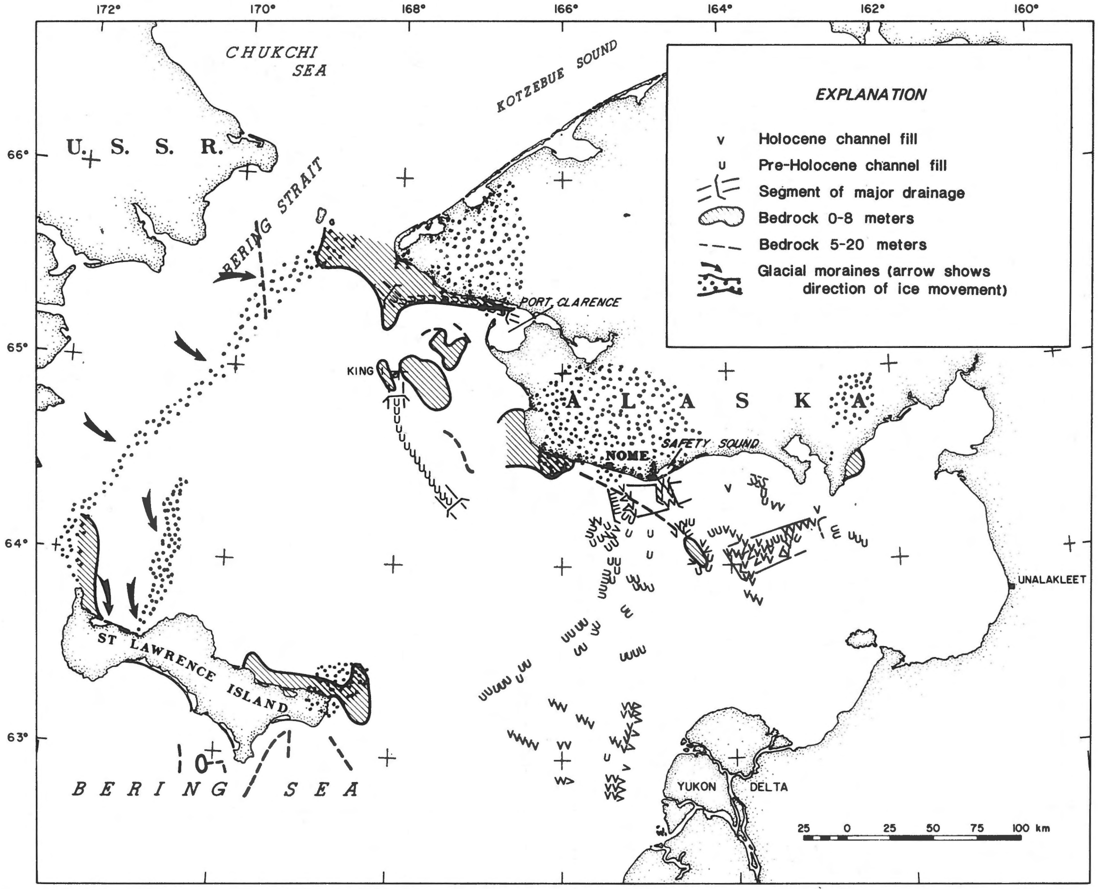


Fig. 4A
Elements of pre-transgressive geologic history in northeastern Bering Sea showing locations of seafloor and near-surface bedrock outcrops, glacial moraines, and alluvial channels. Details of subsurface channels are incomplete, particularly in Chirikov Basin, because of insufficient geophysical trackline coverage.
Information on glacial moraines is based on Nelson & Hopkins (1972) and on bedrock outcrops and subsurface channels is modified from Devin Thor (written communication, 1979).

LATE PLEISTOCENE TRANSGRESSIVE SEDIMANTATION IN CHIRIKOV BASIN

Transgressive Deposits

The late Pleistocene to Holocene shoreline transgression deposited only a thin (< 1 m) sequence of transgressive deposits throughout Chirikov Basin. On some locations near the shoreline, only a thin gravel lag is found over bedrock outcrops of glacial deposits (Fig. 3, B-B′, core D; Figs. 4 and 5B). In other nearshore areas, the typical sequence is late Pleistocene freshwater peaty silt overlain by transgressive sand (Fig. 3, B-B′ and Fig. 5B). The Pleistocene peaty silt occurs near the seafloor in troughs between sand ridges where strong bottom currents have either prevented deposition or have scoured through the transgressive sand into the peaty mud (Fig. 3, B-B′; King Is. Shoal to Port Clarence). The determination of very old radiocarbon dates from peaty mud in some trough locations suggests that significant scour has taken place there.

A typical trough sequence is fine sand above medium-grained sand overlying the peaty freshwater silt (Fig. 3, B-B′). An example of a complete regressive to transgressive cycle in northeastern Chirikov Basin is found in Core No. 247, taken between Tin City and York Shoal (Fig. 3, B-B′ and Fig. 5B). At the very base is a thin layer of coarse-grained regressive sand that contains a relict fauna typical of cold, brackish water of regressive cycles (P. Valentine, U.S. Geological Survey Woods Hole, 1976, written commun.). This is overlain by a 20 cm thick sequence of freshwater mud (MCDOUGALL , 1982, this volume) which is cut into by sand-filled burrows of marine clams. Above is medium sand showing good trough cross-lamination that in turn is overlain by flat-laminated to massive fine sand (Fig. 5B).

The different transgressive gravel and sand facies on the present seafloor surface exhibit an areal pattern related to underlying older deposits (Figs. 4 A and B). The thin gravel lags are found close to the present shoreline over bedrock or are coincident with emergent seafloor moraines that project into central Chirikov Basin south from Cape Prince of Wales and north from St. Lawrence Island (Fig. 3, B-B′, Core D; Figs. 4 A and 5 A). Offshore from the bedrock gravel lag of

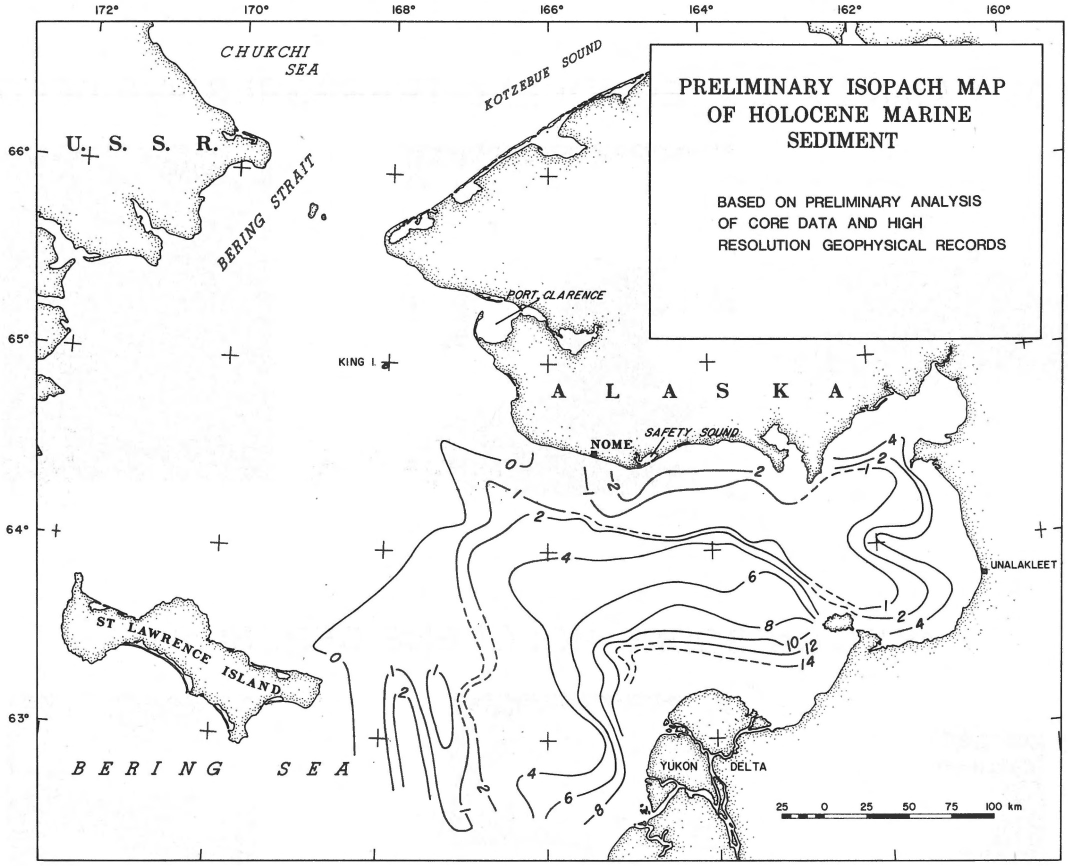


Fig. 4B
Thickness of Holocene sediment based on seismic profiles (modified from Nelson & Creager, 1977) (Devin Thor, written communication, 1979).

Seward Peninsula, medium-grained sand fringes the northeastern edge of Chirikov Basin (Fig. 6). The surface of central and southern Chirikov Basin is covered by fine sand that overlies the medium sand or late Pleistocene freshwater muds (Figs. 3, B-B′, and 5, B and C).

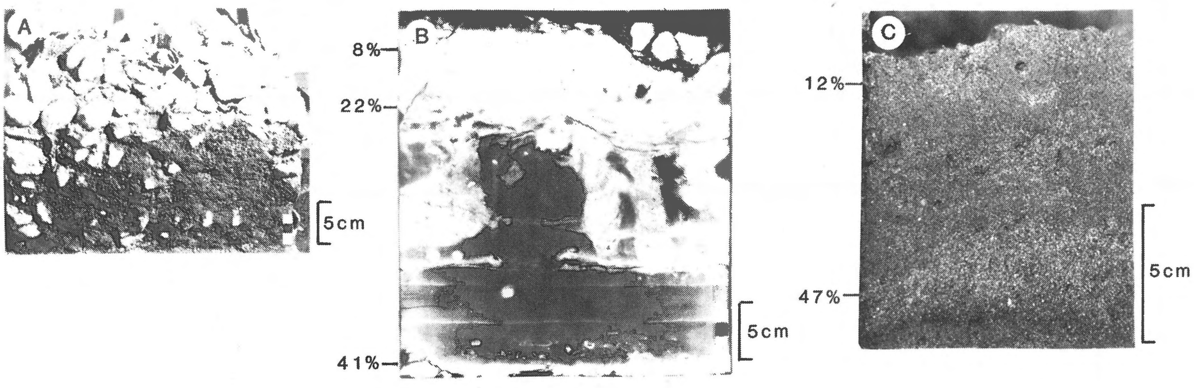
Transgressive History

The oldest deposits in Chirikov Basin are the gravel lags that occur over bedrock and pre-late Pleistocene glacial deposits (Fig. 6). These lags developed as the late Pleistocene shoreline transgressed across the seafloor and reworked bedrock or glacial deposits, removed fine-grained sediment and left a gravel lag deposit over their surface (NELSON & HOPKINS, 1972). Although the source material remains the same in places, the lags are much better rounded, contain higher percentages of quartz, and exhibit modes of medium- to coarse-grained sand (NELSON ET AL., 1969). All these characteristics plus morphologic evidence of shorelines in seismic profiles (TAGG & GREENE, 1973) indicate late Pleistocene-Holocene stillstands of the strand line at these particular present water depths of minus 10-12 m, 20-24 m, 30m and 38 m; NELSON & HOPKINS, 1972; HOPKINS, 1973).

At locations where topographic elevations of bedrock and glacial morains were not present, late Pleistocene tundra and freshwater silt with occasional alluvial deposits developed (Figs. 3, B-B′ and 4 A). As the shoreline transgressed over the freshwater peaty mud of continental deposits a basal coarse to medium-grained sand, only a few centimeters thick, was deposited and remains uncovered along the northern margin of Chirikov Basin (Fig. 6). A fine-grained, inner shelf sand (NELSON ET AL., 1969) was laid down offshore from the shoreline as it transgressed; this generally overlies the basal coarser sand facies and forms a blanket deposit now covering most of the surface of central and southern Chirikov Basin (Fig. 6).

The few vibracores from central Chirikov Basin suggest that innershelf sand facies is no more than a few tens of centimeters thick (Fig. 3, B-B’, cores E and F). The mineralogy and texture of this sand contain no evidence of derivation from the Yukon River sediment source. (MCMANUS ET AL., 1974). Thus, the sediment entering this region from the Yukon River during the Holocene has bypassed northward with the geostrophic flow (Fig. 1) to deposit in southern Chukchi Sea (NELSON & CREAGER, 1977). No Holocene sediment is found in Chirikov Basin, except for that temporarily ponded in the troughs between sand ridges (Fig. 3, B-B’).

CHIRIKOV BASIN LATE PLEISTOCENE TRANSGRESSIVE DEPOSITS



NORTON SOUND HOLOCENE DEPOSITS

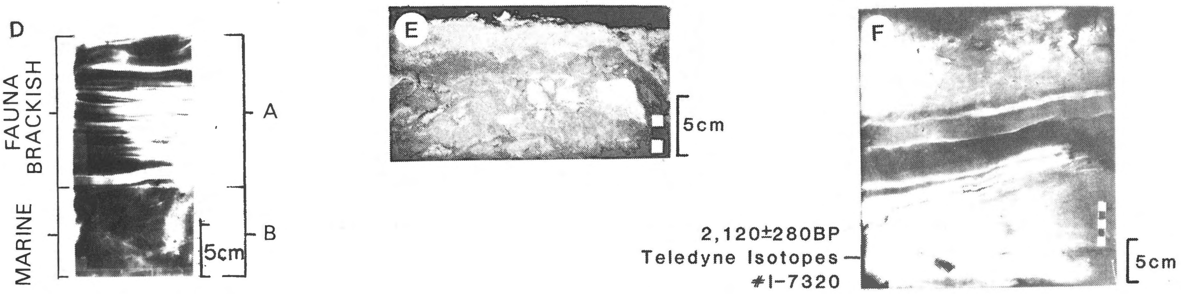


Fig. 5
Internal sedimentary features of late Pleistocene and Holocene deposits in northeastern Bering Shelf. Numbers to the left in B and C show percent of gravel and coarse to medium sand in transgressive and regressive sand layers. See figure 2 for core locations.

A. Transgressive lag gravel over glacial till shown in a box core slab face. 41 m water depth.

B. Box core no. 247 radiograph showing cross-laminated transgressive fine-grained inner shelf sand overlying limnic clays with freshwater ostracodes (P. Valentine, written commun., U.S.G.S. Woods Hole, Mass., 1971). Note deep pelecypod burrowing into freshwater mud after the marine transgression. 36 m water depth.

C. Box core slab showing transgressive inner shelf fine sand overlying basal transgressive medium to fine sand. 48 m water depth.

D. Radiograph of cross-laminated and wavy bedded sand layers (light colored) in late Holocene Yukon silt (<5,000 years old), based on bulk sample radiocarbon dates (corrected for surface sample age), underlain by bioturbated older Yukon silt (>5,000 years old) (after Nelson & Creager, 1977). Located 75 km from the Yukon Delta in 16 m water depth.

E. Box core slab face showing a surface and a deeper bioturbated sand layer (light colored) in Yukon silt. 30 km from the modern Yukon subdelta, 11 m water depth.

F. Radiograph showing shell and pebble storm lag layers, near the surface and base of the core, in addition to a series of thin sand layers (light colored) and parallel and lenticular bedding in the center of the core. Radiocarbon date at the core bottom is based on a piece of wood. Located 110 km from the Yukon Delta in 14 m water depth.

HOLOCENE SEDIMENTATION IN NORTON SOUND

Holocene Deposits

As in much of Chirikov Basin, freshwater late Pleistocene silt and interbedded peat or peaty mud is the oldest stratigraphic unit observed in Norton Sound (Fig. 3, A-A'). Overlying the freshwater peaty mud is marine sandy silt with interbedded very fine sand layers in the southern Norton Sound region and deeper parts of the Holocene section in central Norton Sound. Above this sequence in central Norton Sound and throughout the northern area is bioturbated sandy silt derived from the Yukon River (MCMANUS ET AL., 1977) (Howard & Nelson, 1982, this volume).

From onshore to offshore, the interbedded sand beds become finer grained, thinner, contain a smaller percentage of graded sand layers, and exhibit less complete sequences of vertical sedimentary structures (NELSON, 1980) (Fig. 5E and F). Nearshore, the graded sand layers make up 50 - 100% of the total sedimentary section; they range from 10 to 20 cm in thickness and have a mean grain size of about 0.25 mm in the coarsest part of the layer (Fig. 5E see also Figure 4G of (NELSON ET AL., 1982, this volume). At the outer extremity of the distribution of interbedded sand layers, usually 60 to 75 km from the Yukon Delta shoreline, the graded sands are generally 1-2 cm thick, make up less than 35 percent of the total section, and have mean grain sizes of .038 mm or less (Fig. 5F).

The surficial Holocene deposits in Norton Sound vary from fine-grained sand surrounding the delta and through along northern Norton Sound to very fine sand and coarse silt in central and eastern Norton Sound (Fig. 6 and Figure 3 of HOWARD & NELSON, 1982, this volume). Not only is sediment coarser in the northern trough, but the mineralogy also shows a mixed derivation from Seward Peninsula and Yukon River sources (MCMANUS ET AL., 1974). Bioturbated mud is present in the surface of most of Norton Sound (Fig. 5F), except surrounding the modern Yukon Delta where fine to very fine sand layers may be present at the surface (Fig. 5E), (NELSON, 1980; HOWARD & NELSON, 1982, this volume).

Holocene Transgressive and Deltaic History

In contrast to the thin transgressive sequence of sand deposited in Chirikov Basin, Norton Sound contains a thin to thick blanket of Holocene silt and interbedded sand layers derived from the Yukon River. Thick sections (4-14 m) of Holocene sediment have been deposited in southern Norton Sound because of progradation of the Yukon Delta; only 2 m or less of bioturbated mud has been deposited in the more distal areas of northern and eastern Norton Sound (Fig. 4B).

Although late Pleistocene alluvial deposits are shown in seismic profiles to cut the freshwater silt, these deposits have not been identified in cores. The bathymetric trough in northern Norton Sound is an exception that appears to be an area of nondeposition through the Holocene because of tidal current flushing of the trough (Figs. 1 and 6) (CACCHIONE & DRAKE, 1979). Coarser texture than Yukon derived deposits (Fig. 6) and a mineralogic origin from Seward Peninsula (Fig. 6) (MCMANUS ET AL., 1974) suggest that Holocene transgressive sand remains unburied in the tidal trough. Elsewhere, in Norton Sound, Yukon derived silt with a marine fauna has been deposited directly over late Pleistocene freshwater silt, and basal transgressive sand is not found as it is in Chirikov Basin (Fig. 3, A-A').

Thick nearshore sand layers at depth (Fig. 3, A-A', core G) in central Norton Sound, however, suggest that the transgressive shoreline was close to this location early in Holocene time. As the shoreline transgressed, deposition of the interbedded nearshore sandlayers ceased, resulting in sedimentation of the upper sequence of offshore massive silt without

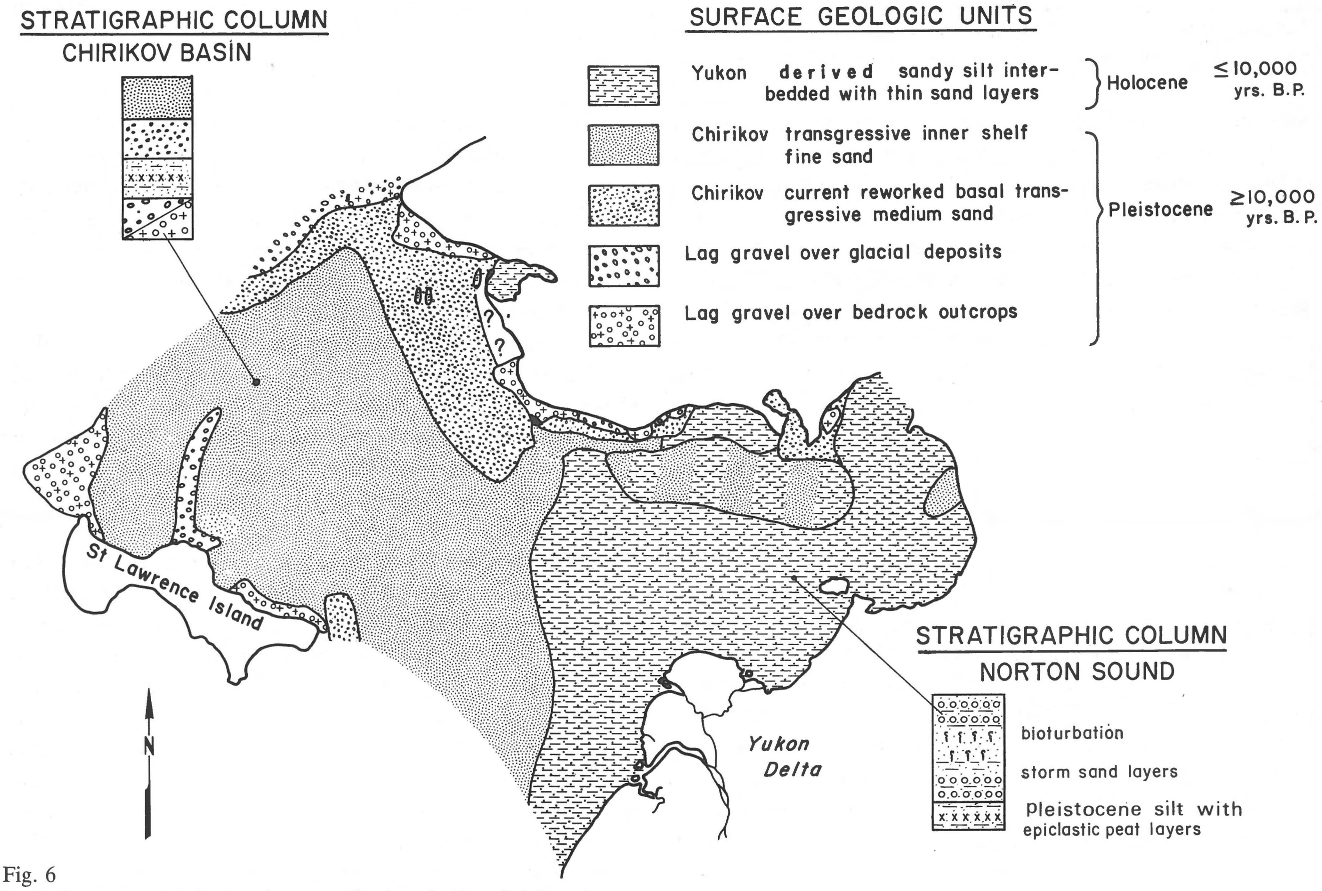


Fig. 6
Preliminary map of the northeastern Bering shelf surficial geology.

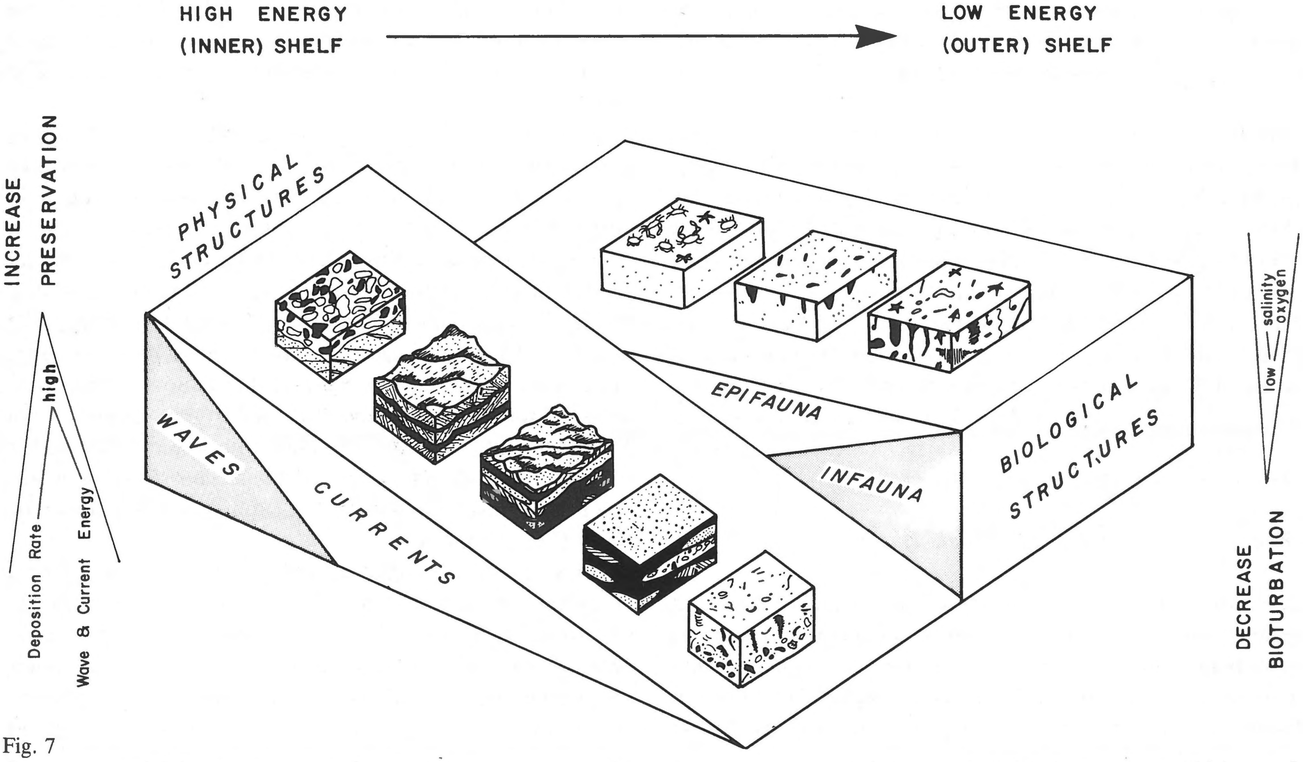


Fig. 7
Conceptual model showing importance of physical structures versus biological structures in epicontinental shelf deltaic sequences. Thickness of wedge depicts relative intensity of process from lower salinity and higher energy to higher salinity and lower energy shelf environments offshore. Relative thickness of storm sand sequences from inshore to offshore also is shown. Area of thick storm sands and physical structures shifts seaward with influx of a prograding delta lobe and low-salinity water.

interbedded sand layers (Fig. 3, A-A', core G; and Fig. 7).

Transgression of the shoreline is observed in the lower Holocene stratigraphy of central Norton Sound: in contrast, migration of the active Yukon Delta lobe from the Cape Romanzof region (KNEBEL & CREAGER, 1973 a; (DUPRÉ, 1982, this volume) into southern Norton Sound and progradation of brackish-water delta deposits is evident in the upper Holocene stratigraphy of the Sound. When the delta shifted to its present position about 2500 BP (Fig. 3, A-A', core C) (DUPRÉ, 1982, this volume), influx of low-salinity water into southern Norton Sound caused a change in fauna (see (MCDOUGALL, 1982, this volume) and fluctuation in the rate of bioturbation, so that well-bioturbated mud was locally overlain by unbioturbated sequences of sand and interbedded mud (Fig. 3, A-A', core C; and Fig. 5D) (NELSON & CREAGER, 1977). Progradation of the active delta wedge with its unbioturbated sequences of thick sand layers interbedded in silt is shown in all upper Holocene sequences surrounding the Delta (Fig. 3, A-A', cores C.H.I.; Fig. 5, D-F; and Fig. 7) (HOWARD & NELSON, 1982, this volume; NELSON ET AL., 1981). The vertically and horizontally graded sand layers in the near-surface sediment off the Yukon Delta appear to be prograding sand sheets deposited by currents (CACCHIONE & DRAKE, 1979; (SCHUMACHER & TRIPP, 1979) associated with large-scale storm surges that occur in Norton Sound (NELSON, 1980; NELSON & CREAGER, 1977).

Resuspension and removal of large quantities of Yukon derived sediment from Norton Sound by storm-related currents has been significant throughout the Holocene depositional history (Fig. 8). In previous studies (NELSON & CREAGER, 1977) the estimated discharge of Yukon River sediment for the Holocene has been compared with the isopach thickness of Holocene sediment in Norton Sound (Fig. 4B); about half of the estimated sediment introduced into Norton Sound is missing, but can be accounted for in a 10-m-thick blanket of Holocene mud found in the southern Chukchi Sea (Fig. 9).

Effects of the extensive storm resuspension of sediment are also shown by the old radiocarbon dates yielded by modern surface mud (Figs. 5D and 3, A-A, core I) and the pebble and shell lag layers that are found within the bioturbated mud (Fig. 5F). The lag layers are produced by storm-wave and current reworking of sediment. This concentrates the coarser fragments from the resuspended mud which is removed and advected out of northeastern Bering to be deposited in the Chukchi Sea by the northward geostrophic currents. New evidence for this resuspension process has recently been acquired in central Norton Sound by *in situ* sediment dynamic and current meter probes (GEOPROBE) that show a several hundred percent increase in suspended sediment transport during a moderate storm event (CACCHIONE & DRAKE, 1979; (CACCHIONE ET AL., 1982, this volume).

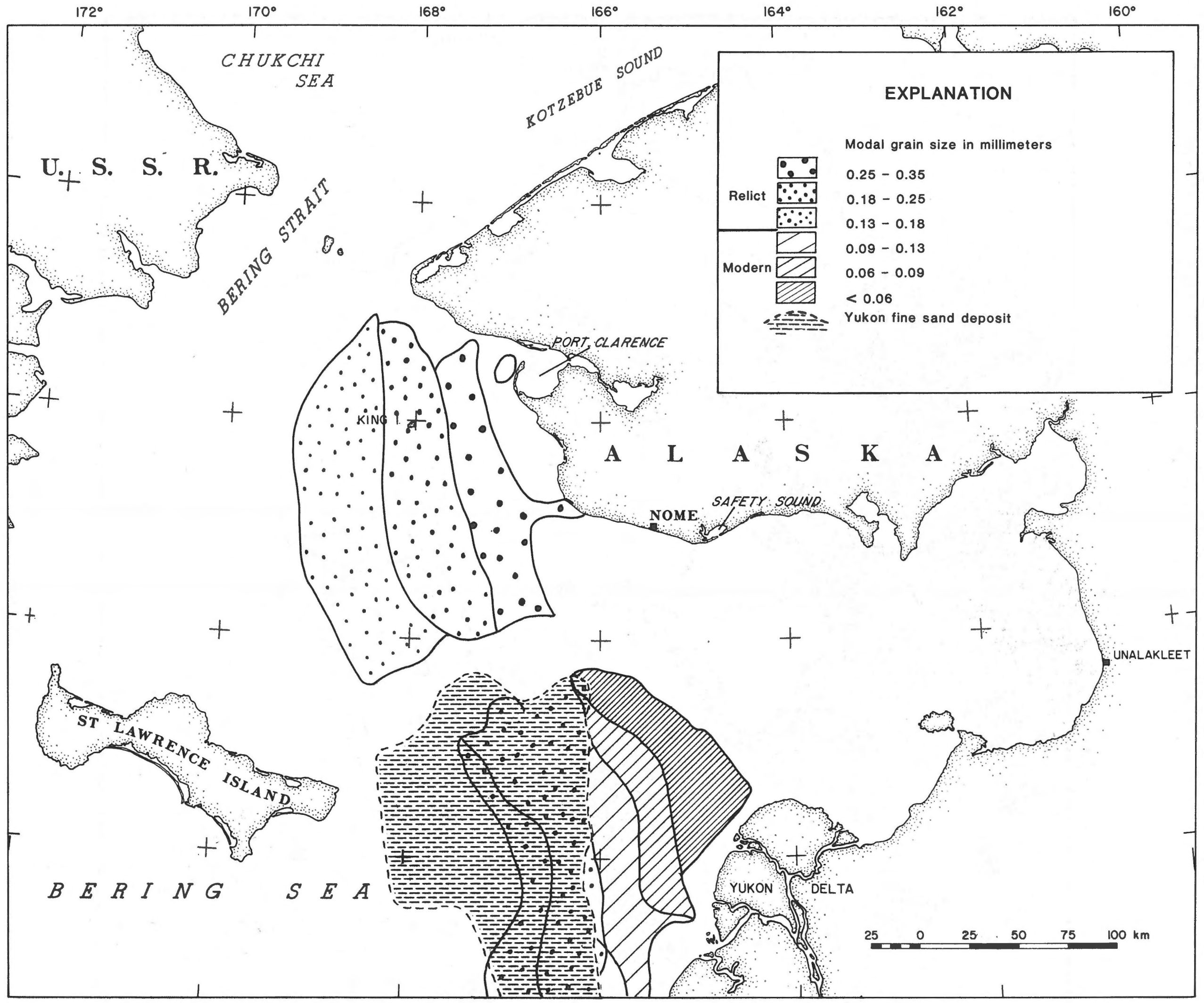


Fig. 8
Transgressive sediment facies patterns based on grain-size modes (from McManus et al., 1977).

GEOLOGIC SIGNIFICANCE OF BERING SHELF FACIES PATTERNS

Comparison of the Chirikov Basin and Norton Sound regions shows that strong currents have influenced late Pleistocene and Holocene deposition in both regions. The strong currents in the northeastern area and lack of sediment input into central and southwestern Chirikov Basin (DRAKE ET AL., 1980; (CACCHIONE & DRAKE, 1979) have resulted in a transgessive sand sequence that has no Holocene mud over it. Instead, on the northeastern margin of Chirikov Basin, non-deposition and/or scour have taken place. Thus, in nearshore areas, where maximum geostrophic current shear occurs (Fig. 1), the basal coarse-sand facies remains exposed on the seafloor without a cover of transgressive inner shelf find sand; farther inshore only bedrock outcrops with gravel lags are present (Figs. 6 and 8). Topographic elevations projecting upward into currents in this region (1) retain relict gravel lags over glacial or bedrock outcrops or (2) contain basal transgressive sand that is reworked into large-scale mobile bedforms (see Figs. 4, C and H; and Figure 5 of NELSON ET AL., 1982, this vol.).

Offshore from the inshore bands of gravel and basal transgressive sand facies in northeast Chirikov Basin (Fig. 8), a parallel band of transgressive inner shelf occurs where the geostrophic current flow becomes considerably weaker to the west (Fig. 1). Thus the surface sediment patterns of increasing coarseness inshore (Fig. 8) parallel those of increasingly stronger geostrophic current flow toward the northeast side of Chirikov Basin (Fig. 1).

The shore-parallel facies patterns in these areas also could suggest equilibrium with offshore to inshore gradients of

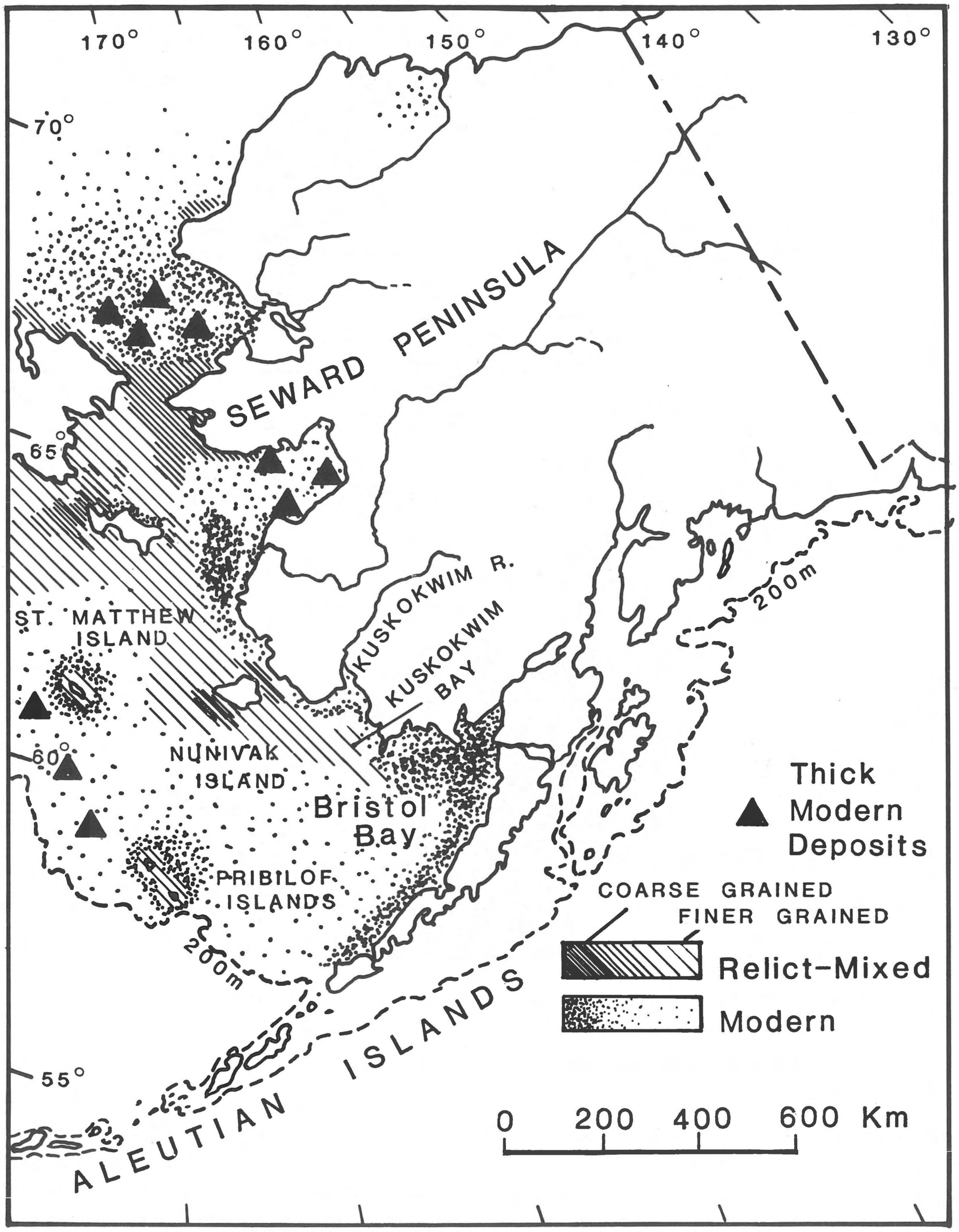


Figure 9.
Generalized late Pleistocene and Holocene deposits of the eastern Bering Shelf, Alaska. Compiled from Gardner et al., (in press); McManus et al., (1977); Nelson and Creager, (1977); Knebel and Creager, (1973b); Nelson and Hopkins, (1972); Sharma et al., (1970).

increasing wave energy. St. Lawrence Island, however, limits the fetch and shelters the northeast Chirikov basin margin from waves. This, in addition to an inshore mud blanket parallel to the Port Clarence coastline where the coarsest wave generated facies should be (Fig. 8), eliminates wave energy as a possible cause of the shore-parallel transgressive facies in northeastern Chirikov Basin.

The region west of the modern Yukon Delta in Shpanberg Strait is another area of strong geostrophic current shear that has important implications for the facies distribution (Fig. 1). The southwest distributary discharges most of the Yukon River sediment load at this location, and parallel banding of sediment facies patterns occurs offshore. Here, fine-grained deposits are found closer to shore near the sediment source and become progressively coarser toward the center of the strait (Fig. 8). MCMANUS ET AL., (1974) suggested that the central part of the strait is underlain by an older transgressive sand deposited in the narrow early Holocene seaway in this region. Therefore, sediments become increasingly coarser grained offshore where current erosion and lower suspended sediment content (DRAKE ET AL., 1980) prevent prograding of modern fine sand and silt deposits over the coarse-grained, older transgressive sand.

Comparison of surface sediment facies patterns in the current-dominated region of northeastern Bering Sea with those in the east central Bering shelf shows the following:

Just south of St. Lawrence Island, an inner shelf fine sand facies like that in Chirikov Basin is present (Figs. 8, 9) (KNEBEL & CREAGER, 1973 a, b; KNEBEL ET AL., 1973). Progressively to the south, and toward the edge of the shelf, surface sediment becomes finer grained, and a prograding mud blanket beginning in the mid-central shelf area extends toward the edge of the continental shelf; exceptions are areas where islands are surrounded by coarse-grained relict deposits (Fig. 9).

Studies of SHARMA ET AL. (1972) and GARDNER ET AL. (in press) show that from the Bristol Bay shoreline out toward the shelf edge of southeastern Bering Sea, deposits become increasingly fine grained. In contrast to the northern Bering shelf, where deposition has been completely dominated by strong bottom current regimes, a classic wave-graded pattern of sediment size distribution has developed on the epicontinental shelf in southern Bering Sea (Fig. 9).

The extreme variance of Holocene sedimentation patterns in the eastern Bering epicontinental shelf from north to south has important implications for studies of facies gradations in ancient analogs. Epicontinental shelf deposits may in one part of a shelf be wave graded from the shoreline out; they may in another part show similar offshore gradations that are in equilibrium with offshore current regimes rather than wave regimes in nearby areas (Fig. 9). Sediment input from a major river source may reverse the typical facies patterns of coarser sand inshore to finer sand offshore, in transgressive sequences from two adjacent regions of an epicontinental shelf like Chirikov Basin and Norton Sound (Fig. 8).

Introduction of a prodelta sequence into an epicontinental shelf with strong geostrophic flow causes unexpected stratigraphic sequences as well as facies gradations. Contrary to stratigraphic concepts, prograding prodelta deposits may be extremely thin on a broad shelf close to a major river source, yet thick, significant amounts of prodeltaic river sediment may deposit hundreds of kilometers from the source.

Large quantities of Yukon derived sediment introduced into Norton Sound are removed and displaced by currents from storms and related geostrophic circulation to create a major depocenter hundreds of kilometers from the source in Southern Chukchi Sea (Fig. 9) (NELSON & CREAGER, 1977).

Because of the influence of deltaic sedimentation, geostrophic current systems and topography, areas of transgressive (Chirikov Basin) and regressive (Norton Sound) shelf deposits may develop and coexist in the same general shelf region during rising sea levels. In a broad epicontinental shelf area like Chirikov Basin there is no prograding delta and a low quantity of suspended sediment in the western area; the rapid shoreline transgression and strong geostrophic currents result in thin late Pleistocene and Holocene transgressive basal and inner shelf sands without deposition of an overlying offshore mud sequence (Figs. 3 and 6). In inshore regions with strongest currents only thin basal transgressive lags may occur because finer grained offshore facies have been stripped off (Fig. 6).

In contrast to thin transgressive sand sequences of Chirikov Basin, in southern Norton Sound a thick sequence consisting of transgressive mud and interbedded nearshore storm sands is covered by offshore bioturbated mud. This is overlain by a regressive sequence of thicker storm sands in mud deposited by the prograding delta in the late Holocene (Figs. 3 and 6).

ACKNOWLEDGMENTS

I thank Devin Thor and Kristin McDougall for contributing background information on seismic stratigraphy and biostratigraphy, respectively. Bob Muench kindly provided new bottom current information from NOAA long-term *in situ* current stations. I am also indebted to Meyer Rubin and Steven Robinson for the radiocarbon dates from the U.S. Geological Survey Radiocarbon Laboratories. Beneficial review comments were made by Monty Hampton and Les Magoon. Mathew Larsen assisted in compilation of data and figures and Tau Rho Alpha drew the three dimensional drawing of Figure 7.

The cruises were supported jointly by the U.S. Geological Survey and by the Bureau of Land Management through interagency agreement with the National Oceanic and Atmospheric Administration, under which a multiyear program responding to needs of petroleum development of the Alaska continental shelf is managed by the Outer Continental Shelf Environmental Assessment Program (OCSEAP) Office.

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