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HOLOCENE SEDIMENTATION IN THE SHALLOW NEARSHORE ZONE OFF NAUSET INLET, CAPE COD, MASSACHUSETTS[1]

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ABSTRACT

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Present conditions and sedimentary evolution of the shallow offshore region near Nauset Inlet on Cape Cod, Massachusetts were clarified using high-resolution seismic-reflection profiles, sidescan-sonar records, surface grab samples and current meter measurements. The study area contains three provinces: (1) a nearshore province (shallower than 18 m) with a relatively steep slope (0.6°) and a cover of medium sand; (2) a northern offshore province covered with coarse sand, gravel, and boulders, interpreted to be glacial drift; and (3) a southern offshore province with a gentle seaward-dipping slope (0.3°) and a surface sediment of coarse sand. The glacial drift exposed in the northern offshore province can be traced southward under the coarse sand province. The overlying fill is comprised of either outwash sediment derived from the Pleistocene South Channel ice lobe to the east or Holocene-aged marine sediments eroded from seacliffs to the north. Latest Holocene sediment appears to be limited to the zone shoreward of 18 m where the medium sand occurs.

Near-bottom mean flows (measured over two winter months in 10 m water depth) average 6 cm sec^{-1} to the south. Mean flows exceeded 20 cm sec^{-1} approx. 23% of the time. Ninety percent of the flows exceeding 20 cm sec^{-1} were directed to the south, reflecting the dominant atmospheric forcing during these winter months. Waves had an average variance of 650 cm^2 with variance exceeding 5000 cm^2, 3% of the time, indicating moderate wave activity.

Present processes are actively reshaping the nearshore province, which is characterized by many east to northeast-trending shore-oblique channels that do not extend seaward of the 18-m contour. Coarse sand in the floors of these channels suggests they may be erosional features, and the presence of megaripples oriented perpendicular to the channel axes indicates active transport in these channels. Megaripple orientation and the current and wave regime of the study area support a rip-current origin for these channels.

INTRODUCTION

The zone extending from just seaward of the surf zone to depths of about 25 m often is neglected in studies of nearshore sediment transport and beach

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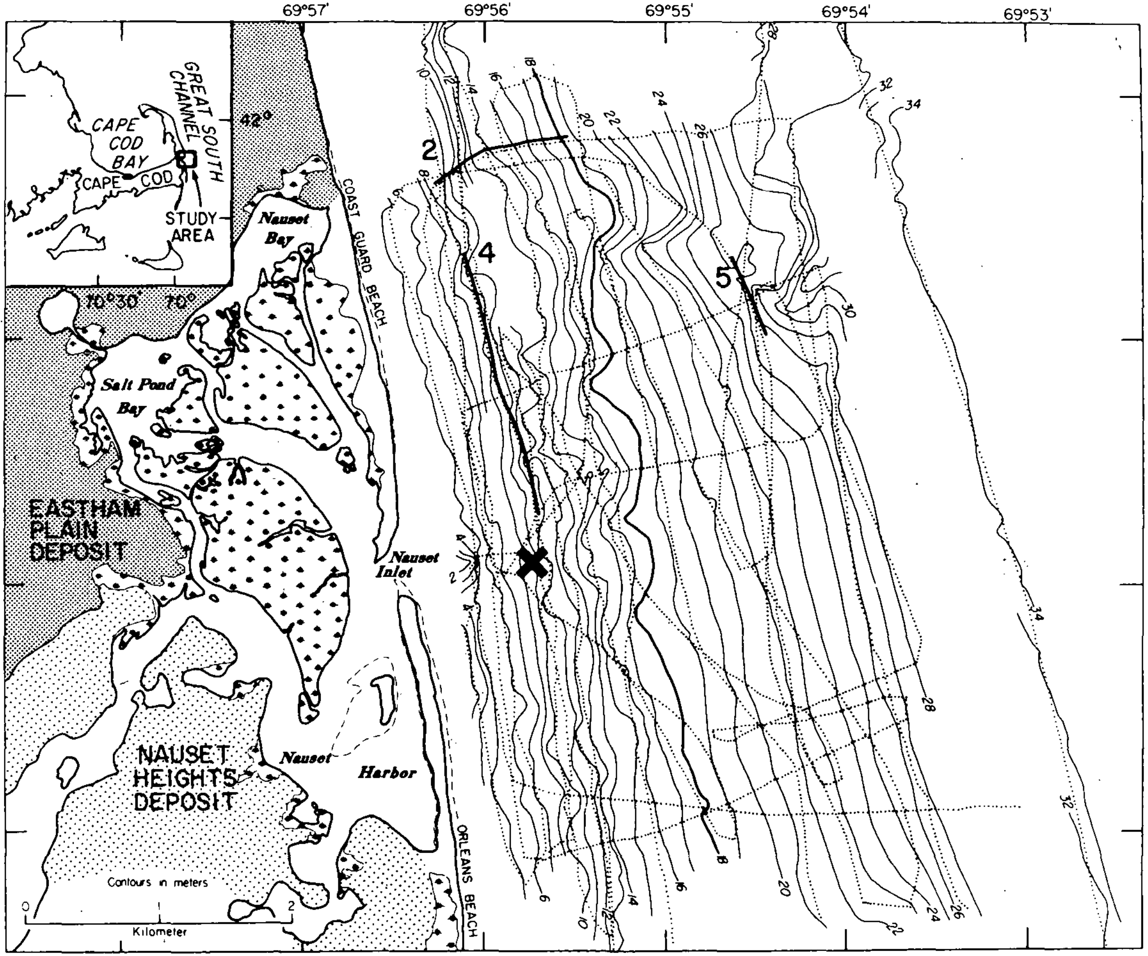
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CAPE COD BAY
CAPE COD
GREAT SOUTH CHANNEL
42°
STUDY AREA
70°30'
70°
Nauset Bay
COAST GUARD BEACH
Salt Pond Bay
EASTHAM PLAIN DEPOSIT
Nauset Inlet
NAUSET HEIGHTS DEPOSIT
Nauset
Harbor
ORLEANS BEACH
Contours in meters
Kilometer
2
4
5

development. This offshore region, however, profoundly influences processes active shoreward of the breaker zone, both by exchanging sediment with the beach and by modifying the waves incident on the beach. In an effort to define paths of active sediment transport in the nearshore zone off Nauset Inlet and the adjacent barrier beaches on Cape Cod, Massachusetts (Fig.1), sea-floor morphology (including bed-form geometry), surface sediment texture, shallow subbottom characteristics, and wave and current activity were measured during the fall of 1979 in water depths ranging from 3 to 40 m. Objectives of the study included evaluating the existence of active onshore or offshore sediment transport; the presence and effects of offshore morphology (such as bars and channels) on beach and inlet processes; and patterns of local sedimentation since late Wisconsinan glacial retreat.

The glacial history of the Nauset region has been established onshore but has not been completely extended offshore. Two major ice lobes occupied the Nauset area in the late Wisconsinan Stage: the Cape Cod Bay lobe to the northwest and the South Channel lobe to the east (Oldale, 1976). Inference based on the relative ages of the drift deposits on Cape Cod suggests that the Cape Cod Bay lobe retreated before the South Channel lobe. The retreat of the Cape Cod Bay lobe and continued damming to the east by the South Channel lobe created a proglacial lake in Cape Cod Bay confirmed by lake deposits along the northern side of Cape Cod (Oldale et al., 1971). In the initial stages of this lake, two known outlets were the Monument—Scusset River Valley, and the Whites Brook River—Parkers River Outlet (Oldale et al., 1971). The Nauset region is a third topographic low in the glacial drift along the Cape Cod Bay shore, and perhaps it also was an outlet to the lake (Oldale et al., 1971).

The study area lies seaward of a topographic low presently occupied by marshland which is bounded to the north, west, and south by glacial deposits and to the east by a barrier beach system (Fig.1). South of the marsh lie the Nauset Heights deposits, which are ice-contact sediments from the South Channel lobe (Oldale et al., 1971). North and west of the marsh are the younger Eastham plain deposits (thought to be the youngest drift on Cape Cod) which represent glacial drift laid down by the retreating South Channel lobe. Scarps bordering the marshland may be fossil sea cliffs (not ice-contact slopes), cut before Nauset spit was well-developed (R.N. Oldale, pers. commun.).

The shallow nearshore region off eastern Cape Cod has been studied extensively in the past, with emphasis on beach processes. Zeigler (1954, 1960) and Zeigler et al. (1964) examined active processes within the surf zone. Studies of the beach proper (summarized by Leatherman, 1979) have all been limited by a lack of information on the role of the offshore morphology

Fig.1. Bathymetric map with tracklines superimposed. Geologic units shown on shore taken from Oldale et al. (1971). Inset shows location of study area. Thick, numbered segments along tracklines indicate profile locations for later figures (track segments are referred to by figure numbers). *X* indicates pressure sensor-current meter location.

on nearshore sedimentation. Dillon et al. (1979) initiated a brief geophysical survey of the shallow nearshore region east of Nauset Inlet in order to examine offshore morphology; the present effort is an extension of their work.

METHODS

High-resolution seismic-reflection records were collected along 150 km of trackline aboard the R/V "Neecho", utilizing a 200 kHz Raytheon[1] echo-sounder, an EG&G Uniboom, and an Edo Western 100 kHz sidescan sonar (Fig.1). Twenty-seven bulk surface sediment samples of the upper 5 cm of the sea bottom were obtained using a spring-loaded BM-54 underway sediment sampler (U.S. Water Resources Council, 1966). Navigation was performed by both a Motorola Mini-Ranger III system and Loran-C. The Mini-Ranger data were used except when the instrument malfunctioned; at these times Loran-C data were used. Where the two navigation types overlapped Loran-C measurements were compared to Mini-Ranger results in order to determine a relative Loran-C offset for the Nauset Inlet region. The Loran-C had a root-mean square positional error of approx. 100 m with respect to the Mini-Ranger locations, which themselves should have had a root-mean square error of only 5 to 10 m.

Echo-sounder data were corrected for predicted tide, transducer depth, and variations in the recorder stylus speed (due perhaps to voltage variations). These corrections reduced the trackline crossing errors from roughly 1.5 m to less than 0.5 m.

Sediment samples were analyzed using a rapid sediment analyzer (Schlee, 1966). Multiple analyses of subsamples from the same bulk sample were run to obtain a representative mean sample size and to evaluate the reproducibility of the results. Graphic moments were calculated after Inman (1952).

Wave, tide, and mean flow data were collected in January and February of 1981 using a Sea Data directional wave gage (Aubrey, 1981). This gage employs a precision pressure sensor and Marsh-McBirney two-axis electromagnetic current meter to determine directional characteristics of surface gravity waves. Quantities calculated from this gage include estimates of the full directional wave spectrum, mean flows, tidal flows, and sea surface elevation.

The gage was deployed in 10 m water depth directly off the inlet (Fig.1). The current meter was mounted 0.6 m off the bottom; the pressure sensor was located 1.6 m off the bottom.

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[1] Use of trade names in this report is for descriptive purposes only and does not constitute endorsement by the U.S. Geological Survey.

RESULTS

Bathymetry

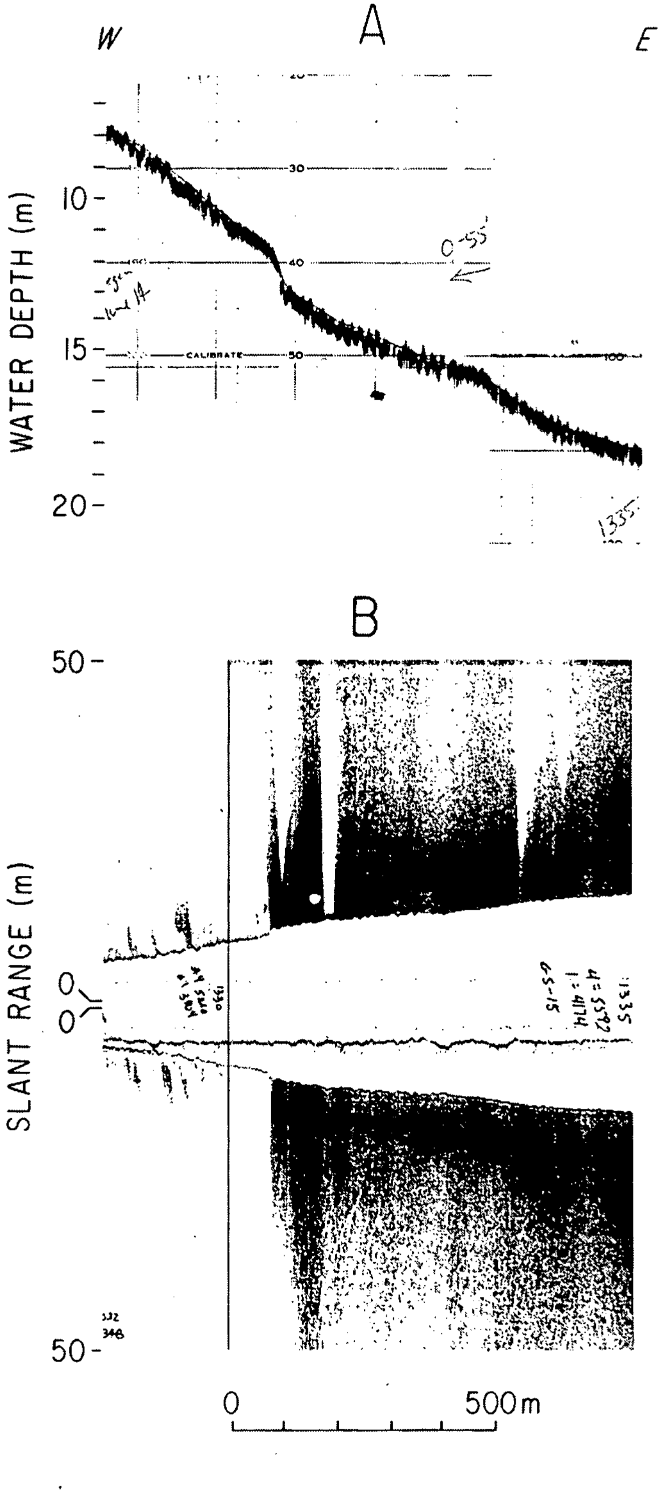
The study area can be divided into three geomorphic provinces based on bathymetry: a shallow nearshore province and two offshore provinces. The nearshore province extends from the shoreward limit of the survey (3 m) seaward to approx. the 18-m contour and has a regional slope of 0.6°. A scarp with 1—1.5-m relief commonly marks the boundary between the nearshore and the two offshore provinces (Fig.2). Echo-sounding profiles and sonographs (Fig.4) show that the nearshore province is heavily channelled, resulting in undulating contours on the bathymetric map (Fig.1). Channel size varies from too small to resolve on echo-sounding profiles (identified only on the sonographs), to features with 1—3 m relief and as much as 200 m width (Fig.3). In profile they are V-shaped and, when asymmetrical, their north side is steeper (Fig.4A). Only small channels were found shoreward of 8 m, generally occurring in clusters, whereas larger channels are present between 8 m and 18 m. Some of the large offshore channels are seaward continuations of clusters of small nearshore channels whereas others are not associated with smaller channels (Fig.3). Sonographs show that the channels are discontinuous, with east to northeast orientations nearly perpendicular to the shoreline.

Seaward of the 18 m contour, two offshore provinces were identified, separated by an east-trending valley (Figs.3 and 5). North of the valley the sea-floor is irregular; to the south it is smooth. Both areas share a gentle eastward slope of approx. 0.3°, half the bottom slope shoreward of the 18 m contour.

Texture

Surface sediment texture was established by grab samples and has been interpolated between sampling points using the acoustic signature from the sonographs (Figs.3 and 6). Sediment distribution coincides with the three geomorphic provinces. Surface sediments of the nearshore province, except in the channels, consist of medium sand with a weak (light) signature on the sonographs (Fig.4). Channel floors have an acoustically dark signature on the sonographs that suggests that they are floored by coarse material, an observation supported by one grab sample collected from a channel (Fig.6). The dark channel floors have a sharp contact with the adjacent sea-floor along their northern sides but sometimes have a gradual transition along their southern sides (Fig.4B). Some channel floors have megaripples whose crests are transverse to the channel axes suggesting either onshore or offshore movement, whereas other channel floors are featureless (within the resolution of the instrumentation).

Textural differences distinguish the two offshore provinces from each other and from the nearshore province (Fig.3). The southern province has a featureless surface of coarse sand giving a strong (dark) uniform acoustic


A
W
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WATER DEPTH (m)
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SLANT RANGE (m)
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signature on the sonographs. Surface sediments of the northern offshore province are coarser with scattered boulders (Fig.5C). Coarse sand, gravel, and boulders suggest that the sediments within this province are probably glacial drift, which has been partially buried in the area shoreward of the 18-m isobath by Recent medium sand, leaving only a few boulders exposed. The valley between the northern and southern offshore provinces has some patches of medium sand (Fig.5). The sonographs suggest that these patches of medium sand have positive relief over the surrounding valley floor.

Subsurface geology

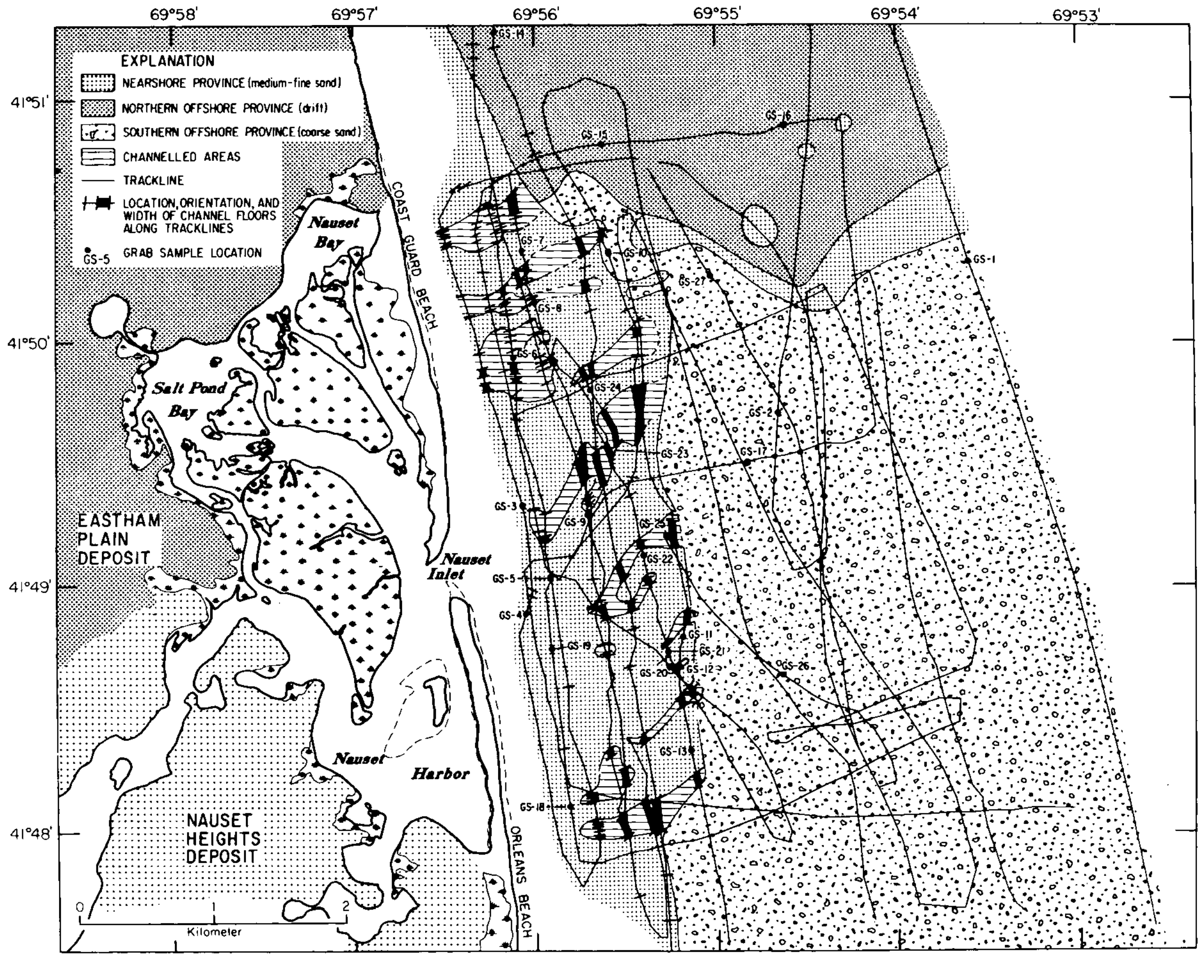
An acoustic reflector defines a broad, buried depression extending seaward from the marshy lowland bordering the study area (Fig.7). This reflector, which separates depression fill from underlying acoustically massive material, shoals both to the north and south, and is exposed at the sea-floor in the northern offshore province (Fig.5) where the presence of boulders and coarse sediment suggest this reflector marks the top of the glacial drift. Channels cutting this reflector define valleys formed prior to the depression being filled (Fig.7). Material filling the depression is acoustically diverse, in some areas lacking internal reflectors and in others having many irregular discontinuous horizons. Profiles across the northeastern part of the depression commonly show foreset bedding dipping to the south or west. The absence of unconformities or changes in the acoustic character of the depression fill seaward of 18 m, suggest that the sedimentation processes which filled the depression were constant through time, and that these sediments or a reworked product of them presently comprise the surface sediments of the southern offshore province. The medium sand of the nearshore province is too thin to be resolved on Uniboom profiles, but the scarp commonly observed along its seaward edge (Fig.2) suggests this deposit is less than 2 m thick. The scarp suggests these medium sands have built out over the two offshore provinces (also supported by the presence of boulders protruding through the nearshore sediments shoreward of the northern offshore province) making these sediments the youngest in the study area.

Waves and currents

The study area has a moderate wave climate, with wave variances $\langle\eta^2\rangle$ averaging 650 cm^2 over the winter measurement period (January and February, 1981). $\langle\eta^2\rangle$ is an indication of wave energy, where wave energy (E) is related to the water density (ρ), gravitational acceleration (g), and variance as:

$$E = \rho g \langle\eta^2\rangle$$

Fig. 2. A. Echo-sounder record of scarp separating finer nearshore sediments and coarser offshore sediments. B. Sidescan record of abrupt contact between finer nearshore sediments (less reflective) and coarser offshore sediments (highly reflective). See Fig.1 for location of profile.



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EXPLANATION
NEARSHORE PROVINCE (medium-fine sand)
NORTHERN OFFSHORE PROVINCE (drift)
SOUTHERN OFFSHORE PROVINCE (coarse sand)
CHANNELLED AREAS
TRACKLINE
LOCATION, ORIENTATION, AND WIDTH OF CHANNEL FLOORS ALONG TRACKLINES
GS-5 GRAB SAMPLE LOCATION
Nauset Bay
Salt Pond Bay
COAST GUARD BEACH
EASTHAM PLAIN DEPOSIT
Nauset Inlet
Nauset Harbor
NAUSET HEIGHTS DEPOSIT
ORLEANS BEACH
0
1
2
Kilometer
GS-1
GS-2
GS-3
GS-4
GS-5
GS-6
GS-7
GS-8
GS-9
GS-10
GS-11
GS-12
GS-13
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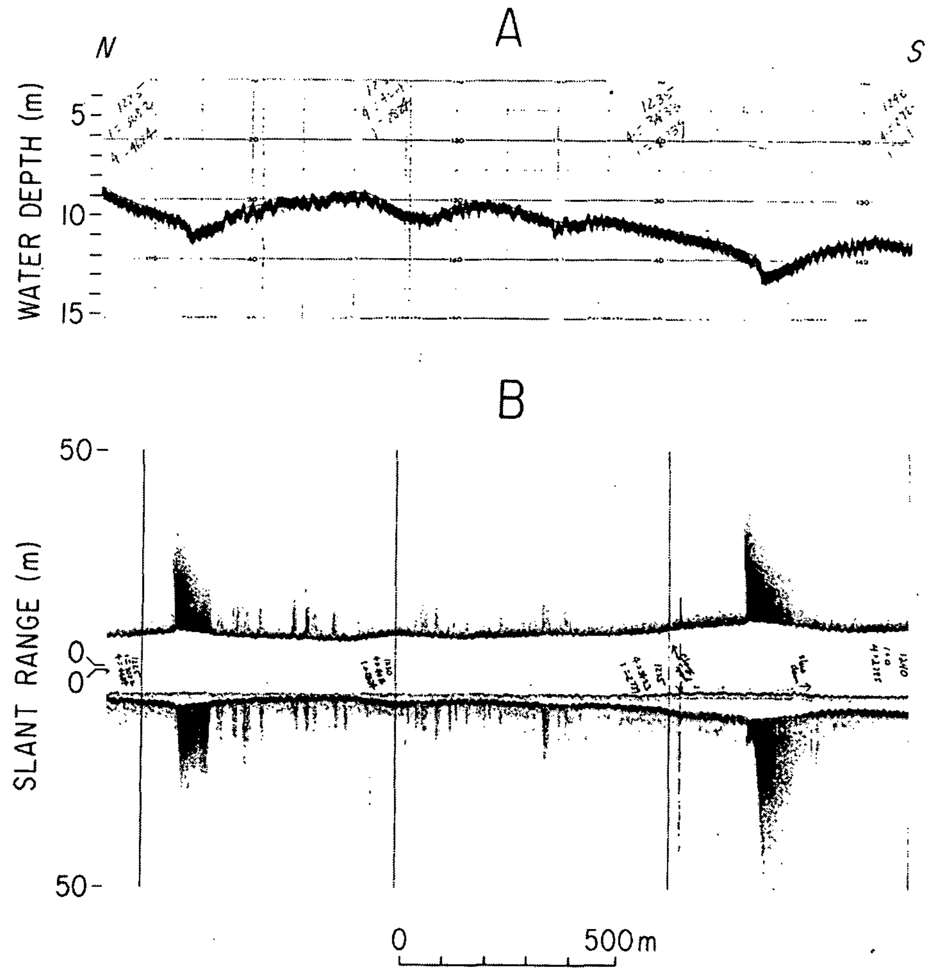

Fig. 4. A. Longshore echo-sounder record run parallel to shoreline across channels. Note asymmetry of the channel profiles. B. Sidescan record showing the coarse sediment (more highly reflective) in the channel floors. See Fig. 1 for location of profile.

Maximum wave variance measured during winter storm activity was 6000 cm^2 (corresponding to a significant wave height of over 3 m), with waves exceeding 5000 cm^2 about 3% of the time.

During the two-month winter period, mean flows averaged 6 cm/sec to the south. Flows averaged over 30-min intervals (sampled at 1 Hz) exceeded 20 cm/sec 23% of the time, while flows exceeded 30 cm/sec about 3% of the

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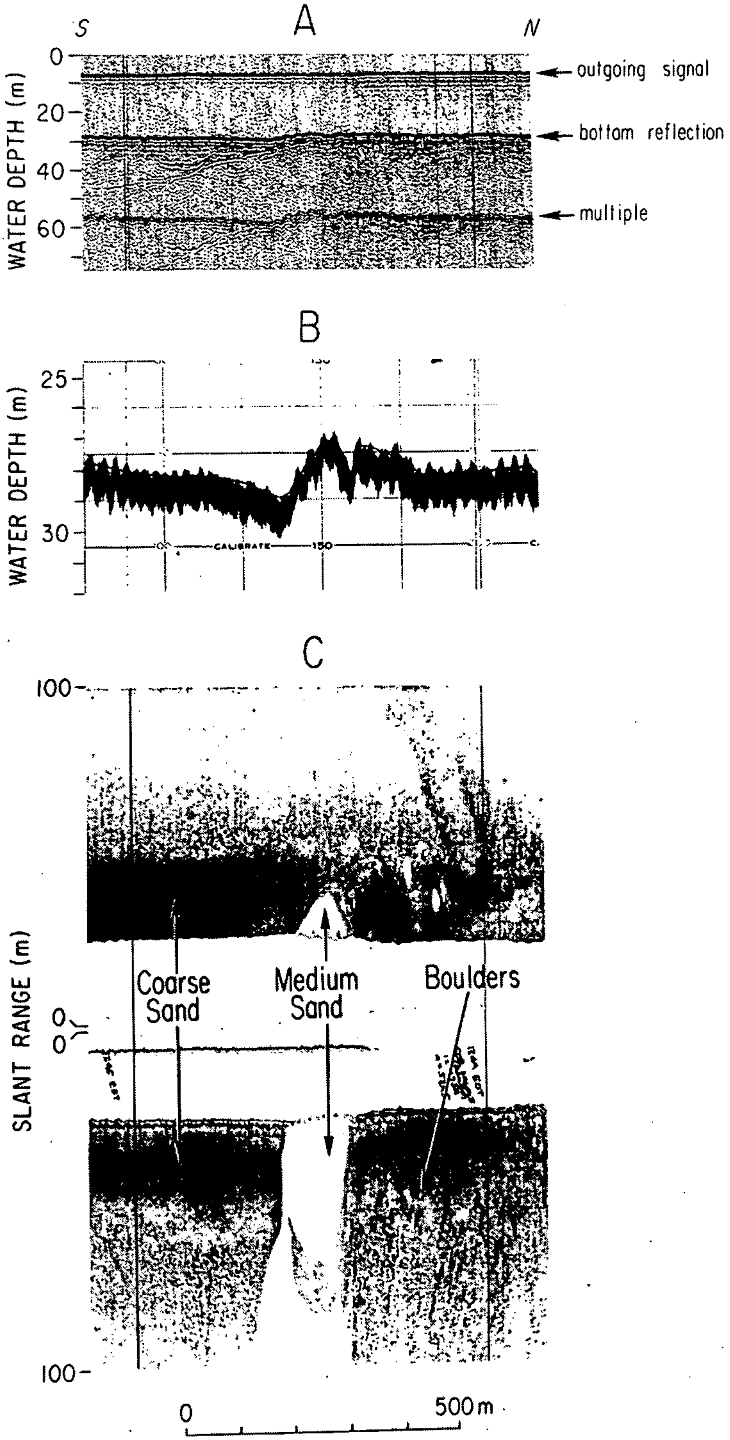
Fig. 3. Sea-floor texture and morphology inferred from sidescan sonographs. Textural information from grab samples used to confirm the sonograph interpretation is summarized in Fig. 6. Heavy lines along tracklines indicate width of coarse channel floors; light lines roughly normal to tracklines indicate orientation of the channels.


A
S
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WATER DEPTH (m)
0
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outgoing signal
bottom reflection
multiple
B
WATER DEPTH (m)
25
30
CALIBRATE
150
C
SLANT RANGE (m)
100
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0
100
Coarse Sand
Medium Sand
Boulders
0
500 m

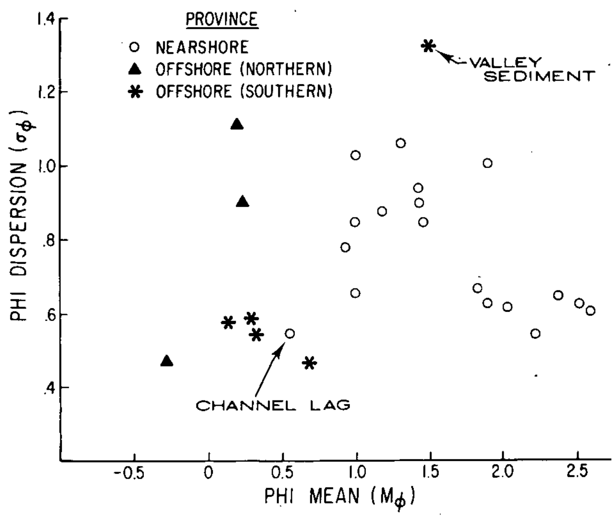


Fig.6. Plot of mean sediment diameter (in phi units) versus sediment dispersion coefficient (in phi units).

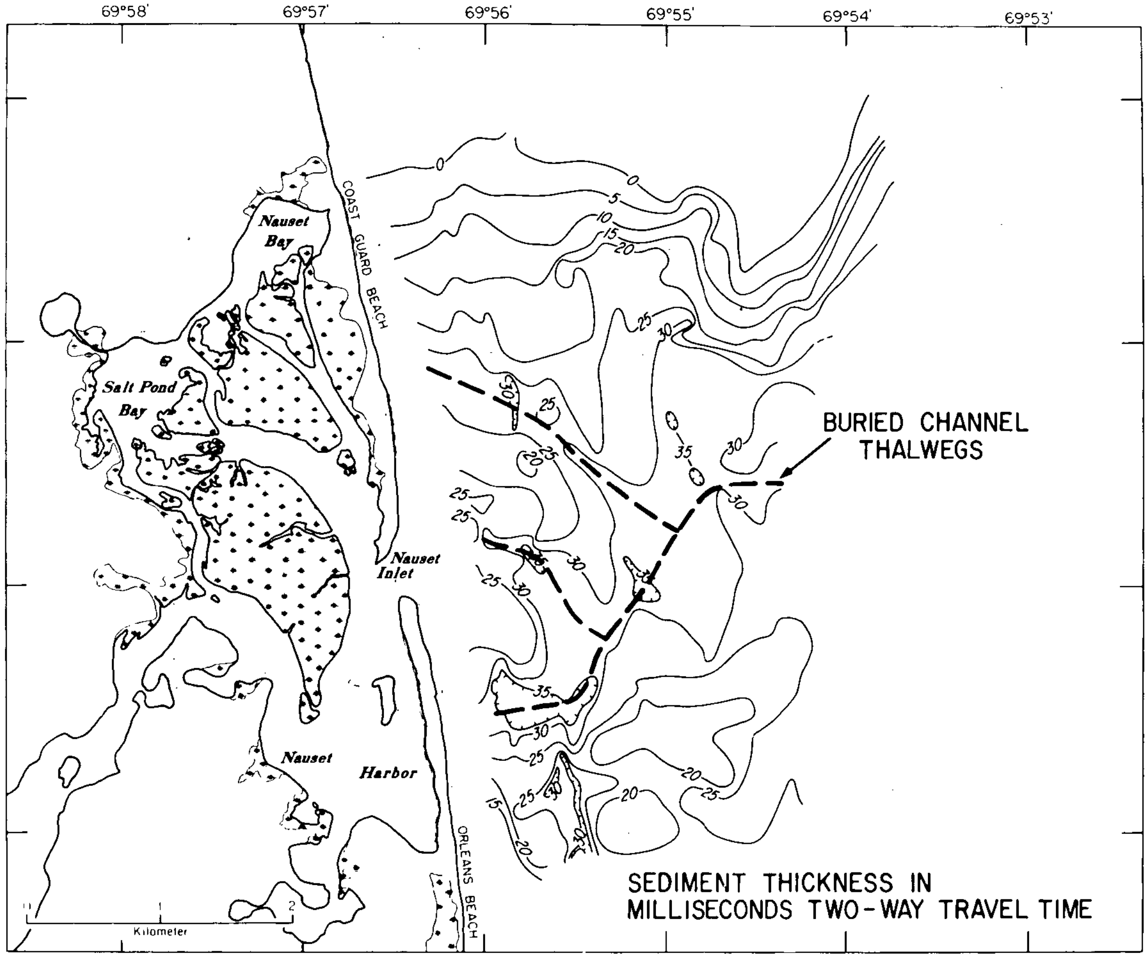
time. Most of the high velocity events represent atmospherically-forced flows superimposed on tidal flows; because of the dominant wind patterns in the winter, these high-velocity net flows were generally towards the south.

The tides off Nauset beach are predominantly semi-diurnal, with an M2 (semidiurnal) amplitude of 1.04 m, a K1 (diurnal) amplitude of 0.13 m, and combined (N2 + S2) of 0.36 m. Total tidal amplitude is 1.92 m, placing the Nauset region intermediate between a microtidal and mesotidal environment. Tidal flows are constrained to be parallel to the coast; flows to the south are generally larger and more frequent due to superimposed mean currents to the south (Table I).

DISCUSSION

The location and width of the buried depression mapped on the seismic-reflection profiles indicate that it is a seaward extension of the depression filled by Nauset Marsh (Fig.7). This seaward extension of the depression supports Oldale's (1979) suggestion that a protrusion of the South Channel ice lobe occupied this region while outwash was deposited to the north and west of the ice, probably the Eastham plain deposit. As the glacier retreated the depression left by the ice was first channeled, perhaps by discharge from the lake in Cape Cod Bay, then filled either by outwash or more recent

Fig.5. A. Uniboom profile showing exposed drift to the north passing below sediment fill to the south. B. Echo-sounder profile showing the shallow valley which separates the two offshore provinces. C. Sidescan sonograph across the boundary between the two offshore provinces showing coarse sand to the south (left), boulders and rough sea-floor to the north, and probable medium sand fill in the valley separating the two provinces. See Fig.1 for profile location.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41°48'
Nauset Bay
Salt Pond Bay
COAST GUARD BEACH
Nauset Inlet
Nauset Harbor
ORLEANS BEACH
Kilometer
0
1
2
BURIED CHANNEL THALWEGS
SEDIMENT THICKNESS IN MILLISECONDS TWO-WAY TRAVEL TIME

TABLE I

Current statistics

Velocity	% of deployment time velocity is exceeded	% of the time velocity is exceeded that flow is to south
>20 cm sec^{-1}	23%	90%
>30 cm sec^{-1}	3%	100%

Holocene marine sediments. Foreset beds dipping to the west and south within the depression fill support a fluvial or deltaic environment with a source to the northeast, consistent with the South Channel lobe as the source for outwash sediments. Alternatively the depression may have been filled later, during the Holocene transgression, with sediment derived from the rapidly eroding seacliffs to the north. Assuming the present erosion rate of about 1 meter per year for the seacliffs (U.S. Army Corps of Engineers, 1969), ample sediment would have been available from this source to completely fill in the depression. During the postglacial sea-level transgression, the migration of the shore zone across this area would have planed off preexisting topography, creating a well-defined, smooth unconformity upon which subsequent sediments would have accumulated. This surface has been identified in nearby Vineyard Sound and Rhode Island Sound (O'Hara and Oldale, 1980), and its absence on the seismic records in this area suggests that, seaward of the 18 m contour, the unconformity is either at the sea-floor or so close to the surface it cannot be resolved on the seismic profiles. The presence of some buried channels with their walls truncated at the sea-floor further supports the suggestion that the present sea-floor is an erosional surface. The coarse surface sediment of the offshore provinces is interpreted to be a reworked or lag deposit from this fill.

Latest Holocene sedimentation appears to be limited mostly to the nearshore province, shallower than 18 m water depth, where the medium textured sand occurs. The medium sand lens is too thin to be resolved on the Uniboom profiles; however, the scarp along parts of its seaward edge (Fig.2) suggests it is less than 2 m thick. Its textural similarity to sediment comprising Coast Guard Beach (Schalk, 1938) suggests it is a seaward continuation of the present barrier spit system overlying the coarser reworked sediments. The barrier beach may have been formed only in the past 6000 or 7000 years, when sea level was above the present 18-m contour.

Present sand movement appears to be most intense in the nearshore province. Sonographs show that seaward of 18 m the sea-floor is smooth and featureless with only scattered trawl marks. Exceptions to the monotony of the offshore provinces are patches of sand (with an acoustic signature charac-

Fig.7. Isopach map of the sediment filling the depression (above the drift surface) underlying the study area. Contours are in milliseconds, two-way travel time. Heavy dashed lines show axes of channels cut in the underlying drift surface.

teristic of medium sands) on the drift and the extensive area of medium sand in the valley separating the two offshore provinces (Fig.5). Medium sand at these greater depths may be winnowed from the drift and be transported in patches southward, becoming trapped in the valley along the south side of the drift. When this valley fills, the medium sand should be transported onto the coarse sand to the south as well. This net southward drift is supported by mean current flow observations. The valley at the boundary between the two offshore provinces may represent a conduit for introducing finer nearshore sediments into the offshore; however, this process must be episodic as the medium sand in the valley presently is separated from the nearshore province by an area of coarse sand (Fig.3). Lack of information on the current regime within the valley prevents confirmation of this on/offshore flow.

A more uniform medium sand cover shoreward of the 18-m isobath indicates a greater medium sand supply to this area. The only interruptions to the medium sand cover of the nearshore province are channels scattered throughout the nearshore province and some boulders at the northern end of the study area. The boulders lie shoreward of the northern offshore province, representing a shoreward extension of the drift which has been mostly buried by the more recent nearshore medium sand (Fig.3).

The channels are the most striking features of the nearshore province. These channels were postulated by Dillon et al. (1979), to be continuous, to trend northeasterly, and perhaps to be caused by rip currents. The present investigation noted a range in length scales for these channels (Fig.3), many of which appear discontinuous on sidescan records. Channels become more numerous and narrower towards shore, with many of them obliterated on their shoreward end (Fig.3). This shoreward termination of the channels probably represents infilling by active longshore transport of beach material in this zone of high wave energy and consequent large, longshore transport rates, estimated to be about 250,000 m^3/yr (U.S. Army Corps of Engineers, 1969). All channels terminate in a seaward direction at a depth of 18 m or less (Fig.3), which corresponds to the contact between the coarse offshore sediments and the finer nearshore sediments. The seaward termination of these channels may reflect one of four conditions: (1) maximum depth of bedload transport by rip currents under wave conditions characteristic of outer Cape Cod; (2) reduction in slope limiting offshore transport; (3) higher threshold of motion for coarser sediment found in the offshore provinces; and (4) or a zone of more active longshore sediment movement at depths greater than 18 m, thereby infilling the channels soon after their formation. More active longshore transport seaward of 18 m is ruled out because near-bottom wave activity increases progressively shorewards, the opposite effect of what is required by the hypothesis, and the persistance of trawl marks in the southern offshore province indicates that mean and tidal flows are not strong enough by themselves to rapidly fill in the channels. A higher threshold of motion for coarser sediment is probably a contributing, not a controlling, factor. In fact, differences in grain size probably reflect different sediment sources, not different processes.

Support for a change in sea-floor gradient is confirmed by the change in slope at 18 m. The mean bottom slope from 3 to 18 m is 0.6°, while from 18 to 26 m, the slope is 0.3°. This reduction in slope has two effects: it reduces the downslope gravitational force available for transporting sediment offshore, and also requires an increased expenditure of power to maintain sand in suspension. The slope change at 18 m is in part a result of a prograding sediment wedge formed by offshore transport; the resultant slope change in turn will influence that offshore transport by the two mechanisms stated above.

The final explanation for the channel termination is that the channelized flows (driven by wave-forced rip currents) lose their jet-like nature by the 18 m depth contour through turbulent mixing and entrainment. This process, combined with the effects of the slope change, is our preferred explanation for rip-current termination (although no current meter data are available to verify this hypothesis).

Implicit in our discussion of nearshore channels is the assumption of a direct relationship between channels and rip currents. Alternative mechanisms for producing these channels may be coastal "jets", suggested by Swift and Freeland (1978), which are shore-intensified large-scale coastal currents responding to shelf wind forcing. However, because coastal jets typically have maximum velocities close to the surface, several kilometers offshore, with little near-bottom motion close to shore (Csanady, 1981), they are considered improbable mechanisms for creating these channels. Rip-current generation of these channels is supported by a number of direct observations. Aerial photographs at Nauset Inlet spanning forty years document intense rip-current activity (Aubrey, 1980). Orientation of megaripples perpendicular to channel axes suggests at least moderate axial flows. Finally, the wave climate off Nauset is as intense as other locations (for example, southern California) where rip current activity has been documented.

Active sediment transport is now occurring in some of these channels, evidenced by megaripples (oriented perpendicular to channel axes) on the south sides of the channels. The north sides of the channels are often steeper than the south slopes, and the ripples are confined to the south slopes. The steep north channel sides may result from a slow net southwards longshore drift of material in this region, which fills in the rip channels from the north. Current meter data support this hypothesis. This net mean-flow field may therefore modify but not generate these channels.

SUMMARY

Holocene sedimentation patterns off Nauset Inlet, Cape Cod, Massachusetts, have been clarified during a combined shallow geophysical and surface sediment sampling investigation. The coastal region east of the barrier beaches adjoining Nauset Inlet can be divided into three geomorphic provinces. The shallow nearshore province is floored by medium sand with a bottom slope of 0.6°; it extends from the shoreline to water depths of 18 m. The offshore

region (deeper than 18 m) is divided into two provinces by an east-trending valley. North of the valley, glacial drift composed of coarse sand, gravel, and boulders is exposed at the sea-floor. South of the valley, the sea-floor, composed of coarse sand, slopes gently to the east at 0.3°. This southern offshore province and the shallow nearshore province are both underlain by an acoustic reflector interpreted to be the glacial-drift surface, which crops out in the northern offshore province. This drift surface was channeled and subsequently filled to form the present-day sea-floor. Foreset beds within the depression fill dipping to the west and south support a source to the east (outwash from the retreating South Channel lobe). Alternatively, eroding sea-cliffs bordering the study area may have contributed reworked outwash sediments to fill the glacial depression. After the depression was filled, the area was smoothed by the transgression of the shoreline, and on top of this unconformity the medium sands of the nearshore province have been deposited.

Active on/offshore sediment transport is now occurring in the study area. Numerous channels limited to the nearshore province are floored by mega-ripples, oriented perpendicular to channel axes, suggesting on/offshore bed-load sand movement perhaps caused by rip currents. The channels terminate near the 18 m contour, where a 1 to 2 m scarp in many places separates coarse offshore sediments from finer nearshore sediments. This scarp represents the offshore limit of the most recent Holocene sedimentation. The shoreward ends of these channels are terminated by active longshore sand transport in the surf zone. Another indication of offshore transport may be the medium sand exposed along the east-trending valley separating the two offshore provinces, texturally similar to that found inshore.

No offshore morphologic features (such as discontinuous longshore bars) exist; thus, offshore controls as an explanation for the rhythmic features often seen along the outer Cape beaches (Aubrey, 1980) are absent.

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