

SURFACE AND SHALLOW SUBSURFACE SEDIMENT REGIME
OF THE NEARSHORE INNER CONTINENTAL SHELF,
NAGS HEAD AND WILMINGTON AREAS, NORTH CAROLINA

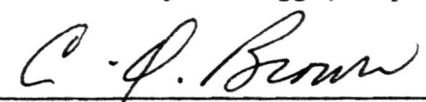
by

Daniel R. Pearson

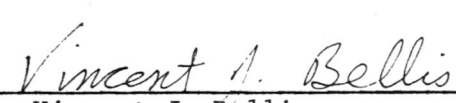
APPROVED BY:

THESIS COMMITTEE

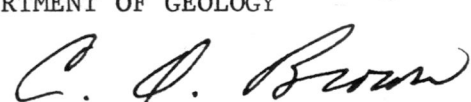

Dr. Stanley R. Riggs, Supervising Professor


Dr. C. Q. Brown


Dr. Scott W. Snyder


Dr. Vincent J. Bellis

CHAIRMAN OF THE DEPARTMENT OF GEOLOGY


Dr. C. Q. Brown

DEAN OF THE GRADUATE SCHOOL


Dr. Joseph G. Boyette

SURFACE AND SHALLOW SUBSURFACE SEDIMENT REGIME
OF THE NEARSHORE INNER CONTINENTAL SHELF,
NAGS HEAD AND WILMINGTON AREAS, NORTH CAROLINA

A Thesis

Presented to

the Graduate Faculty of the Department of Geology
East Carolina University

In Partial Fulfillment
of the Requirements for the Degree
Master of Science in Geology

by

Daniel R. Pearson

November, 1979

NOCAR
GC
383
P42
1979

A B S T R A C T

In order to characterize the sediments and geologic processes operating within the nearshore inner continental shelf off Dare and New Hanover Counties, North Carolina, 39 sample stations were occupied along 6 three nautical mile sample traverses run perpendicular to shore. The following samples and information were collected and analyzed from the nearshore shelf of the two study areas: 1) 43 surface samples, 2) 25 hand-core samples, 3) 32 vibracores, 4) approximately 100 nautical miles of seismic profiles, and 5) diver observations from each of the sample stations.

The Nags Head nearshore inner continental shelf is characterized by a thin modern shoreface sediment wedge overlying an eroding sequence of Pleistocene sedimentary units. Distribution of the modern surface sediment is a direct function of the bottom topography, water depth, distance offshore, and the proximity of relict strata. In profile the Nags Head nearshore shelf is characterized by a steep shoreface, which planes out into a major topographic low trough which is oriented oblique to the shore. Seaward of the low trough is a major topographic high shoal complex. Each topographic environment has a distinct sedimentary facies type associated with it. Variations in each of these specific topographic-facies types may result from the presence of relict stratigraphic units. In contrast, the surface sediment distribution pattern on the Wilmington nearshore inner continental shelf is more complex. This complexity arises from the abundance and activities of benthic organisms and extensive exposures of Pleistocene and Tertiary

sediment and rock strata on the Wilmington nearshore shelf. Thus, the resulting surface sediment distribution pattern is largely a function of the distribution and type of relict strata which is exposed and actively being eroded. In general, distinct sedimentary facies found on the Wilmington nearshore shelf are limited to facies corresponding to well defined topographic highs and topographic lows.

Seaward of the lower shoreface the nearshore shelf of both areas consists of a thin veneer of modern sediments overlying relict strata. Thickness of the modern sediment sheet varies according to bottom topography, being thinnest or absent in the major topographic lows. Thus, some topographic lows are floored with relict strata. In addition, the topographic lows commonly serve as traps where thin deposits of lag gravels and modern muds accumulate. Black organic-rich muds were commonly observed in the topographic lows. These muds were found in topographic lows within water depths as shallow as 28 ft (8.5 m) located 0.2 nautical miles offshore. Topographic highs consist of actively mobile modern sands responding to wave induced bottom currents which are focused on the highs. The modern sediment sheet is thicker where the topographic highs are located.

Major relict fluvial-estuarine channels occur in the subsurface on the nearshore continental shelf off both study areas. These channels are thought to be products of the ancestral Albemarle-Roanoke River system in Dare County and the ancestral Cape Fear River system in New Hanover County.

A C K N O W L E D G E M E N T

I would like to extend my appreciation to the following persons for lending assistance resulting in the completion of this thesis. A much appreciated thanks is due to the field research team consisting of Scott Hardaway, George Wood, Dr. Al Hine, and Dr. Vincent Bellis; the laboratory assistants, Deborah Landy and Sarah Lauria; and to Penny Austin and Jane Whitley for editorial and typing expertise. In addition, special appreciation is extended to the thesis committee consisting of Dr. Michael P. O'Connor, Dr. Scott Snyder, and Dr. Vincent Bellis. And to a very dynamic Dr. Stan Riggs who assisted in all phases of the thesis project, providing guidance and assistance, I extend with utmost respect, a very special thanks.

This project was funded through the Institute of Coastal and Marine Resources at East Carolina University as part of a larger research project to evaluate the feasibility of an ocean outfall wastewater disposal system for North Carolina. The project was funded by the Coastal Plains Regional Commission and Department of Administration, State of North Carolina. I would like to express thanks to Dr. William Queen, Director of the Institute of Marine and Coastal Resources, East Carolina University, for his financial support.

CONTENTS

	Page
Abstract	iii
Acknowledgment.....	v
Introduction.....	1
Location of study areas.....	1
Regional geologic setting.....	1
Nags Head area.....	6
Wilmington area.....	7
Objectives of study.....	8
Investigation Procedures.....	9
Field phase.....	9
Laboratory phase.....	11
Surface sediment regime - Nags Head area.....	14
Sedimentary facies.....	14
Sediment descriptions of sample stations.....	15
Avalon Pier traverse.....	16
Nags Head Pier traverse.....	20
Jennettes Pier traverse.....	22
Correlations between sediment and bottom topography.....	24
Relationships between facies, bottom topography, and physical processes.....	35
Topographic highs.....	39
Topographic lows.....	40
Surface sediment distribution.....	42
Stratigraphic correlation - Nags Head area.....	49
Avalon Pier traverse.....	51
Nags Head Pier traverse.....	58
Jennettes Pier traverse.....	64
Surface sediment regime - Wilmington area.....	71
Sediment descriptions of sample stations.....	72
Wrightsville Beach traverse.....	72
Carolina Beach traverse.....	75
Kure Beach traverse.....	76
Correlation between sediments and bottom topography.....	78
Relationships between sediment type and bottom topography....	83
Surface sediment distribution.....	84
Stratigraphic correlation - Wilmington area.....	90
Wrightsville Beach traverse.....	90
Carolina Beach Pier traverse.....	99
Kure Beach Pier traverse.....	104

	Page
Summary and conclusions.....	111
References cited.....	115
Appendix.....	118

TABLES

<u>Table</u>	Page
1. Statistical sediment parameters grouped according to topographic environments, Nags Head study area.....	28
2. Shoreface gradients along the Nags Head sample traverses...	46
3. Lithologic divisions of vibracores from the Nags Head study area.....	50
4. Lithologic divisions of vibracores from the Wilmington study area.....	91
A1. Sample station information for the Nags Head study area.....	119
A2. Sample station information for the Wilmington study area.....	120

ILLUSTRATIONS

<u>Figure</u>	Page
1. General location map.....	2
2. Location map of the Nags Head study area.....	3
3. Location map of the Wilmington study area.....	4
4. Stratigraphic cross-section of Eastern North Carolina.....	5
5. Cross-sectional profiles illustrating bottom topography and station location along the Nags Head sample traverses.....	17
6. Schematic evolution and detachment of a nearshore shoal from the shoreface.....	18
7. Plots of sorting versus bottom topography for the Nags Head sample traverses.....	26

<u>Figure</u>	Page
8. Composite plot of sorting versus distance offshore for the Nags Head sample stations.....	27
9. Plots of mud versus bottom topography for the Nags Head sample traverses.....	29
10. Plots of s-clay versus bottom topography for the Nags Head sample traverses.....	30
11. Plots of organic material versus bottom topography for the Nags Head sample traverses.....	32
12. Plots of skewness versus bottom topography for the Nags Head sample traverses.....	33
13. Plots of mean and mode grain size versus bottom topography for the Nags Head sample traverses.....	34
14a. Mechanics of wave induced bottom orbital velocity currents.....	37
14b. Initiation of motion in bottom sediments due to wave induced bottom orbital velocity currents.....	37
15. Distance offshore at which waves of different periods begin to appreciably interact with the sea floor, Nags Head study area.....	38
16. Schematic relationship between topographic low and topographic high shoal complex.....	39
17. Surface sediment distribution along the Nags Head sample traverses.....	43
18. Generalized surface sediment distribution map for the Nags Head study area.....	45
19. Lithic descriptions of vibracores NA-2, 3, and 4 from the Avalon Pier sample traverse.....	52
20. Lithic descriptions of vibracores NA-5 and 6 from the Avalon Pier sample traverse.....	53
21. Cross correlation of the Avalon Pier core sections.....	54
22. Stratigraphic cross section of the Avalon Pier sample traverse.....	55
23. Seismic trace of ancestral Kitty Hawk Bay fluvio-estuarine channel.....	57
24. Lithic descriptions of vibracores NN-1, 2, and 3 from the Nags Head Pier sample traverse.....	59

<u>Figure</u>	<u>Page</u>
25. Lithic descriptions of vibracores NN-4, 5, and 6 from the Nags Head Pier sample traverse.....	60
26. Cross correlation of the Nags Head Pier core sections.....	61
27. Stratigraphic cross section of the Nags Head Pier sample traverse.....	62
28. Lithic description of vibracores NJ-1, 2, and 4 from the Jennettes Pier sample traverse.....	65
29. Lithic descriptions of vibracores NJ-5, 6, and 7 from the Jennettes Pier sample traverse.....	66
30. Cross correlation of the Jennettes Pier core sections.....	67
31. Stratigraphic cross section of the Jennettes Pier sample traverse.....	68
32. Cross-sectional profiles illustrating bottom topography and station location along the Wilmington sample traverse.....	73
33. Plots of sorting versus bottom topography for the Wilmington sample traverses.....	79
34. Plots of mud versus bottom topography for the Wilmington sample traverses.....	80
35. Correlation plots of s-clay and organic material versus bottom topography for the Wrightsville Beach sample traverse.....	81
36. Plots of gravel versus bottom topography for the Wilmington sample traverses.....	82
37. Surface sediment distribution along the Wilmington sample traverses.....	85
38. Weight percent grain size distributions of surface samples WW-1 through WW-6, Wrightsville Beach sample traverse.....	86
39. Lithic descriptions of vibracores WW-1, 2, and 4 from the Wrightsville Beach sample traverse.....	92
40. Lithic descriptions of vibracores WW-5 and 6 from the Wrightsville Beach sample traverse.....	93
41. Cross correlation of the Wrightsville Beach core sections.....	94

<u>Figure</u>	Page
42. Stratigraphic cross section of the Wrightsville Beach sample traverse.....	95
43. Seismic reflectors depicting a rock surface located offshore along Wrightsville Beach.....	98
44. Lithic descriptions of vibracores WC-1, 3, and 5 from the Carolina Beach Pier sample traverse.....	100
45. Lithic descriptions of vibracores WC-6 and 7 from the Carolina Beach Pier sample traverse.....	101
46. Cross correlation of the Carolina Beach Pier core sections.....	102
47. Stratigraphic cross section of the Carolina Beach Pier sample traverse.....	103
48. Lithic description of vibracores WK-1, 3, and 4 from the Kure Beach Pier sample traverse.....	105
49. Lithic description of vibracores WK-5 and 6 from the Kure Beach Pier sample traverse.....	106
50. Cross correlation of the Kure Beach Pier core sections.....	107
51. Stratigraphic cross section of the Kure Beach Pier sample traverse.....	108

I N T R O D U C T I O N

The North Carolina coastal zone is characterized by three major cape shoal structures and adjacent cusped embayments (Figure 1). These are, from north to south, Hatteras Embayment, Cape Hatteras, Raleigh Bay, Cape Lookout, Onslow Bay, Cape Fear, and Long Bay. Portions of the nearshore inner continental shelf of two of these cusped embayments, Hatteras Embayment and Onslow Bay, are the subject of this investigation. The different orientation of these two embayments results in distinctly different hydraulic energy regimes acting within each. In addition, each area has a different regional geologic setting that is reflected in a different geomorphology, sedimentology, and geologic history.

L O C A T I O N O F S T U D Y A R E A S

The study areas are located on the nearshore inner continental shelf off Dare and New Hanover Counties, North Carolina (Figure 1). Both areas extend seaward from the surf zone to approximately 3 nautical miles (n.m.) offshore. The Nags Head study area, Dare County, extends from Avalon Beach Pier southward to Jennettes Pier (Figure 2). The Wilmington study area, New Hanover County, extends from the municipal water tank at Wrightsville Beach southward to Kure Beach Pier (Figure 3).

R E G I O N A L G E O L O G I C S E T T I N G

Surface sediments of the North Carolina Coastal Plain generally consist of blanket deposits of marine and estuarine sands and clays

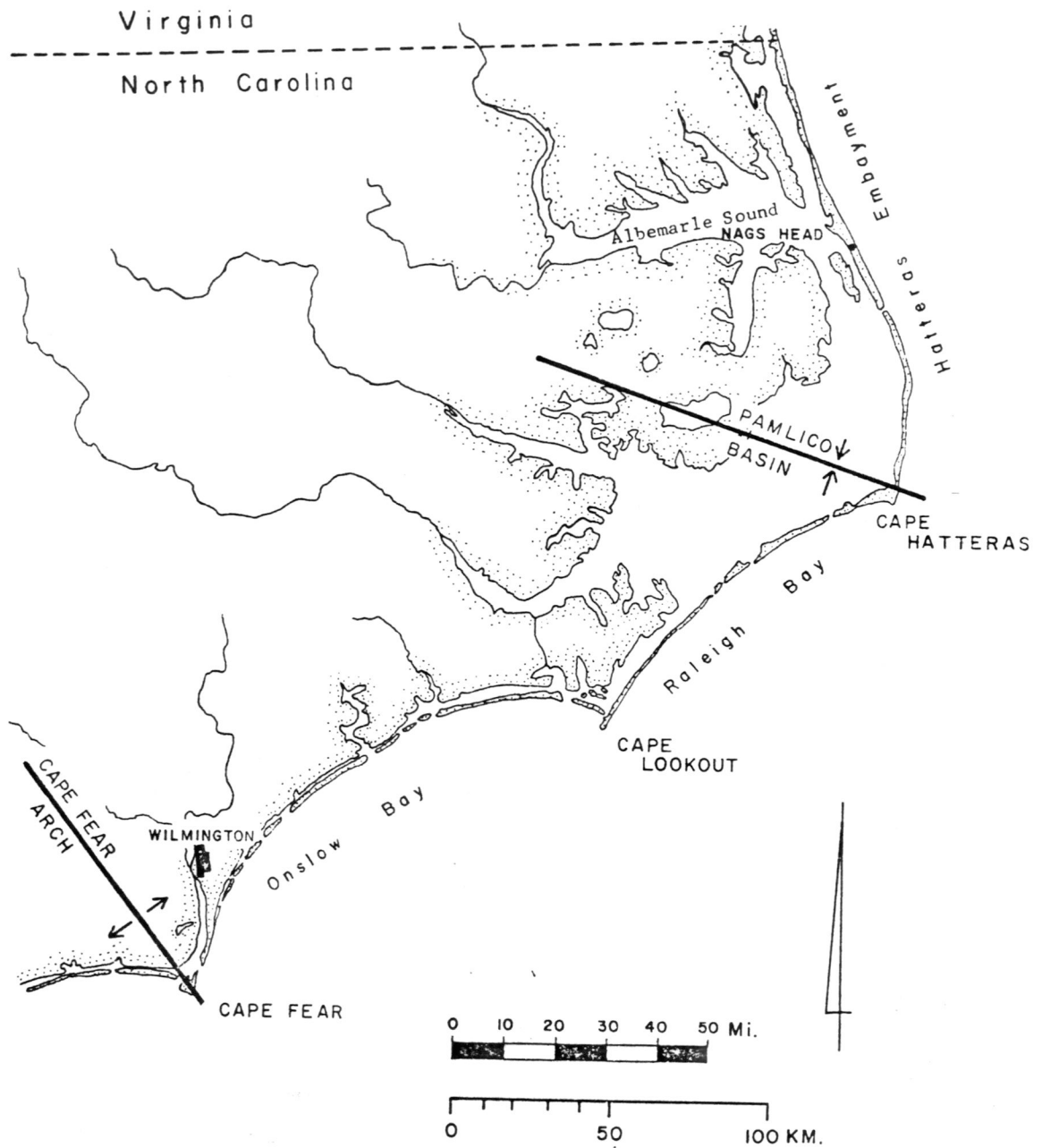


Figure 1. General location map.

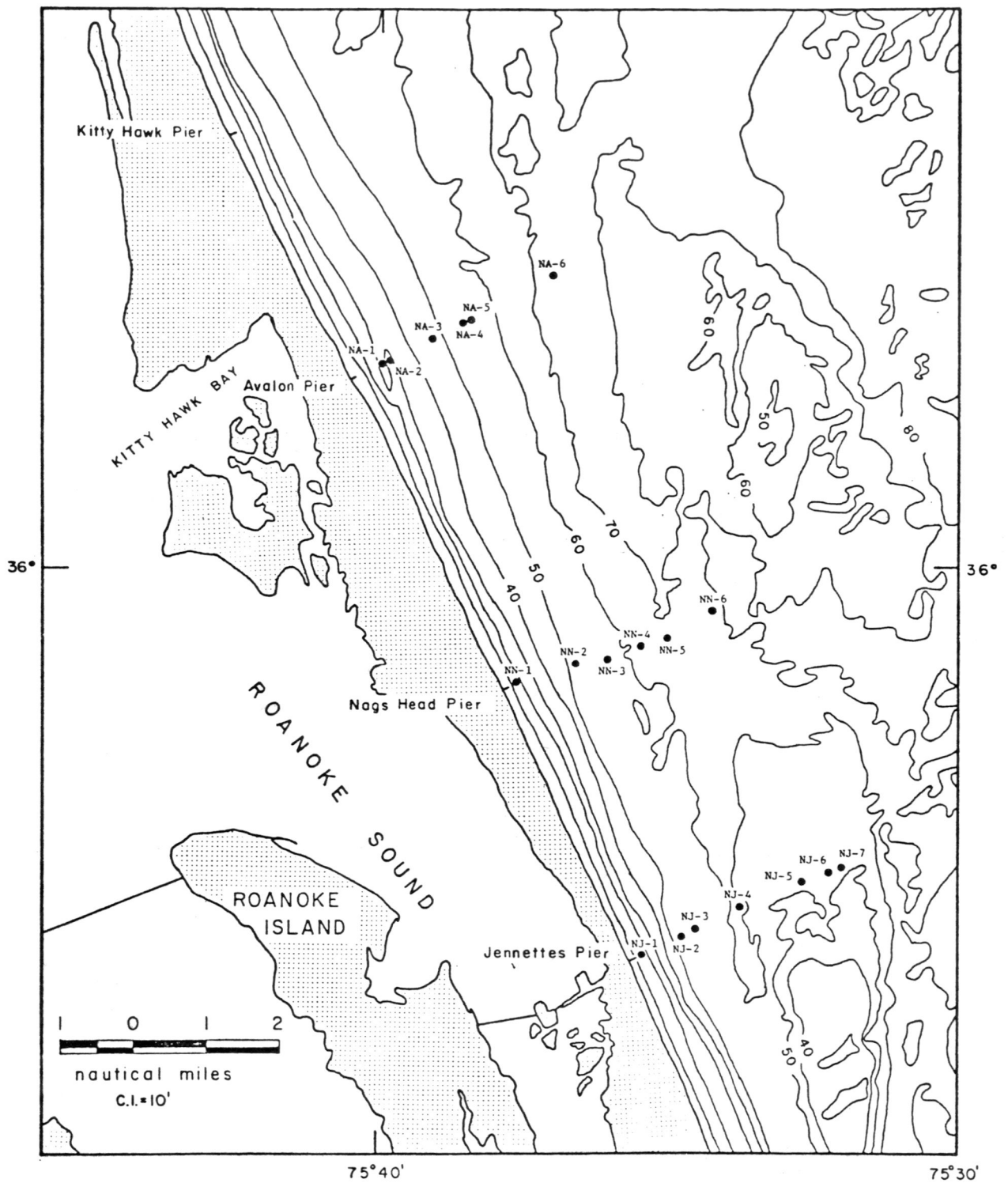


Figure 2. Location of the Nags Head study area (bathymetry modified after Swift, 1973a).

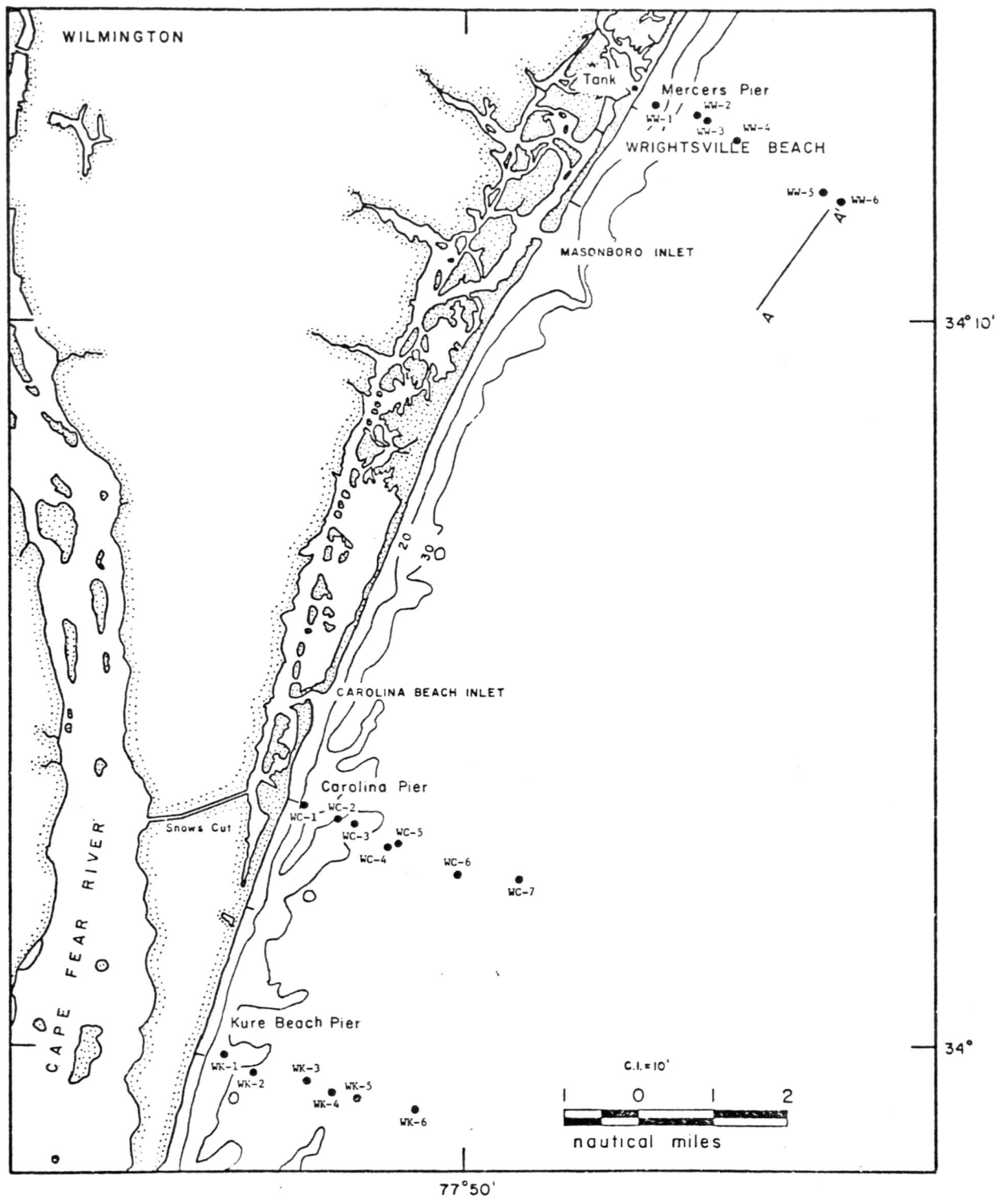


Figure 3. Location of the Wilmington study area. (A to A' marks the location of a seismic profile.)

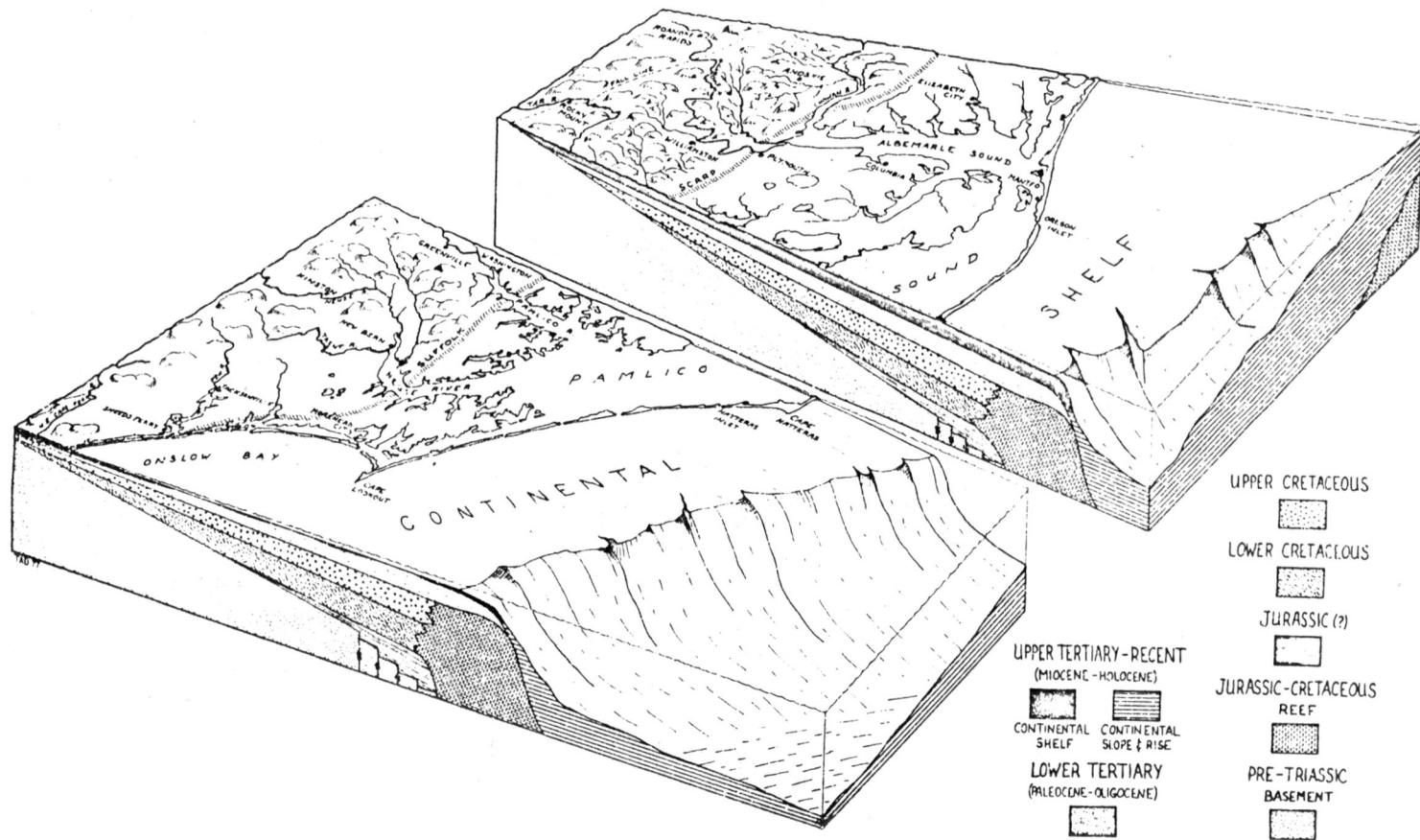


Figure 4. Stratigraphic cross section of Eastern North Carolina (from Riggs, 1979).

deposited during marine transgressions of the Pleistocene. This thin sequence of Pleistocene sediments overlies a more extensive seaward thickening wedge of Cretaceous and Tertiary terrigenous and carbonate deposits (Figure 4). Crystalline rocks of the Paleozoic, in turn, underlie the Cretaceous and Tertiary deposits. According to Richards (1950), the morphology of the basement rock defines a series of northwest to southeast trending arches and embayments, which occur from Maryland to Florida. Depth to the basement rock near the Wilmington study area is roughly 470 ft (143 m), while the depth at Cape Hatteras is 9,980 ft (3,042 m) (Brown et al, 1972). Thus, the Wilmington study area is situated on the Cape Fear Arch which, according to Hicks (1972) and Balazs (1974), has been rising at a rate of 5 to 6.5 mm per year between 1932 and 1963 (Figure 1). In contrast, the Nags Head area and the Hatteras Embayment are situated in a structural low, known as the Pamlico Basin. According to Hicks (1972) and Balazs (1974), the Pamlico Basin has been subsiding at a rate of 5 mm per year between 1932 and 1963.

Nags Head Area

Riggs (1979) describes the Hatteras Embayment as being characterized by a narrow and steep shelf containing a thick section of Upper Tertiary to Recent sediments. Mixon and Pilkey (1976) point out that several Piedmont rivers, which carry relatively high sediment loads, discharge into the Albemarle and Pamlico Sounds, and ultimately onto the nearshore shelf of the Hatteras Embayment. In addition, the Nags Head coastal area faces east-northeast and receives the direct impact of the high energy winter storms.

The sediment distribution on the inner continental shelf of the Hatteras Embayment has been investigated by various authors (Sheppard,

1932; Swift et al, 1971; Swift et al, 1973a; Swift et al, 1973b; and Sears, 1973). Sheppard describes the northern North Carolina inner continental shelf as consisting of patches of sand of varying grain size. He attributes the heterogeneity of grain sizes to glacio-eustatic sea level changes in the past.

The works of Swift et al (1973a) have shown that the sediment distribution on the inner continental shelf follows a systematic pattern according to topography. The sediment distribution of the shoreface, seaward of the surf zone, consists of a series of isobath-parallel bands of varying grain size. The sediments in these bands are characterized by fine to very fine sand and muddy sand. The sand fraction becomes finer and better sorted in a seaward direction, being best sorted at a depth of approximately 10 meters. Seaward of the shoreface the inner continental shelf is characterized by a subdued ridge and swale topography with the ridges rising up to 10 meters above the adjacent troughs (Swift et al, 1973b). Swift's work suggests a north-south banding of grain sizes which parallel the ridge and swale topography. The nearshore and seaward flanks of the troughs contain fine sand while the troughs contain the coarsest sand as a lag deposit. Smaller order topographic features, sand waves, are superimposed on the ridges and oriented obliquely to the shore. The sand waves reach 2 to 6 meters in relief and are spaced 0.2 to 1.2 km from crest to crest.

Wilmington Area

Onslow Bay is characterized by a shallow broad shelf of Lower Tertiary to Quaternary rock covered with a minor modern sediment blanket of variable thickness (Riggs, 1979). The most extensive outcrops are of

Eocene and Oligocene rocks with less extensive Miocene and Quaternary exposures. The continental shelf of Onslow Bay has experienced a low rate of terrigenous sediment input because only sediment-poor Coastal Plain rivers empty into the embayment (Mixon and Pilkey, 1976). In contrast to the Hatteras Embayment, Onslow Bay is a south-southeast facing coastal system which is shielded from the full effects of major winter storms and their associated swells and winds from the north, northeast, and northwest. This results in a relatively low energy regime for Onslow Bay (Pearson, 1977).

Studies of Southern Onslow Bay include those of Riggs (1979), Riggs and Freas (1967), Moorefield (1977), and Meisburger (1979). According to Riggs and Freas (1967), the inner continental shelf is marked by a ridge and swale topography with rock outcrops being more abundant farther offshore. Sediment distribution maps of the Fort Fisher area of Onslow Bay (Moorefield, 1977) show coquina rock outcrops and coarse sand to mud in the nearshore area with the muds being trapped in a topographic low. Meisburger (1979) conducted a large scale sediment sampling, coring, and seismic profiling survey of the inner continental shelf of Onslow Bay and Long Bay looking for beach replenishment sand. He found that the pattern of surface sediments is complex and variable. Accordingly, he expresses the need for more detailed studies to determine the sediment pattern on this portion of the inner continental shelf.

OBJECTIVES OF STUDY

Riggs (1979) summarized the status of the geologic studies within the inner continental shelf of North Carolina. The lack of geological information on the North Carolina nearshore inner continental shelf

demonstrated the need for and became the basis of the present investigation.

The main objective of the study was to investigate in detail the sedimentological regime of two portions of the nearshore inner continental shelf of Onslow Bay and the Hatteras Embayment. More specifically, the investigation emphasized the following sub-objectives for the two study areas:

1. Determine the textural character and distribution of surface sediments seaward of the surf zone to a distance of approximately three nautical miles offshore.
2. Examine the textural character of subsurface sediments to:
 - a. determine the thickness of the modern sediment sheet over relict sediments; and
 - b. determine if a relationship exists between sediment type and topography.
3. Examine seismic data to aid in determining relict stratigraphic units.

INVESTIGATION PROCEDURES

Field Phase

The field phase of the investigation was conducted from the 34 ft R/V NITRO, provided by the Department of Geology, East Carolina University, Greenville, North Carolina. The vessel was manned by a crew of four who conducted the field research from July 22 to August 25, 1978.

1. Seismic Procedures:

The initial phase of the study entailed running seismic profiles parallel and perpendicular to shore to a distance of

approximately 3 n.m. offshore at each of the study areas. The perpendicular seismic runs coincide with the sample traverses discussed in the section on sampling procedures. Seismic profiles were obtained with a high resolution EG&G uniboom seismic sub-bottom profiler, in cooperation with Dr. Al Hine from the University of North Carolina Marine Science Center, Morehead City, North Carolina.

2. Sampling Procedures:

- a. Three sampling traverses were selected within each of the study areas (Figures 2 and 3). The traverses were run perpendicular to shore from a known reference point and each extended 3 n.m. offshore.

- 1) Nags Head Area:

The three traverses are located off Avalon Pier, Nags Head Pier, and Jennettes Pier, each of which are approximately 5 n.m. apart.

- 2) Wilmington Area:

The three traverses are located off Kure Beach Pier, Carolina Beach Pier, and off the main water tank at Wrightsville Beach.

- b. Sample stations were selected according to the bottom topography along the sample traverses. A Ray-Jefferson model 621 continuous recording fathometer and seismic tapes were used to determine bottom topography. Stations were located at each major change in topography or at intervals of 0.5 n.m., whichever came first. The location of each sample station was determined with a continuous tracking Simrad model 123 LORAN-C.

- c. At each station the following samples were taken:
- 1) A shipek bottom sampler was used to obtain a surface grab sample.
 - 2) A vertical core section was taken by a diver operated pneumatic vibracorer with a plastic lined 4 in by 8 ft core barrel. The core samples were stored in the plastic liners and frozen until lab analyses were begun.
 - 3) A separate observation dive was conducted to;
 - a) examine and describe the sedimentary environment at the sampling location;
 - b) collect samples that vary from the previously collected shipek samples; and
 - c) collect a 9 cm hand-core of the upper-most sediment surface for geochemical analyses. (Due to a change in procedures these samples were not collected from the Kure Beach and Carolina Beach traverses.)

Laboratory Phase

1. Shipek sample analyses:
 - a. Each shipek sample was desalted, wet-sieved, and dry-seived using standard laboratory methods (Folk, 1968). Any samples containing over 5% mud were pipetted to analyze the fine fraction. Standard descriptive parameters, such as mean, skewness, standard deviation, mode, and kurtosis, were determined for each sample.
 - b. Statistical grain-size parameters are presented in Tables A1 and A2 in the Appendix. Descriptive sediment names were

assigned using Folk's terminology, with the following modifications:

- 1) Specification of mode diameter rather than median diameter is used in describing the sand and gravel component of the samples.
- 2) Gravel samples containing less than 1% gravel are designated as very slightly gravelly. Gravel samples containing less than 5%, but greater than 1% gravel, are designated as slightly gravelly.

2. Vibracore analyses:

- a. Each core was split and examined using a binocular microscope.
- b. The lithologic character of the core was recorded in a core log and is presented graphically.
- c. The lithology of the core was compared to the topography to see if a relationship exists between topographic features and grain parameters.

3. Seismic analyses:

- a. Seismic traces for each sampling traverse were examined for subsurface structures.
- b. The seismic profiles were graphically reduced and used along with fathometer profiles to construct cross sectional profiles.
- c. The seismic profiles were studied in conjunction with the vibracores to aid in discerning relict stratigraphic units.

4. Surface hand-core analyses:

Percent clay and organic content in the top 3 cm of the surface handcores were analyzed under the direction of Dr. John Bray,

Department of Surgery, School of Medicine, East Carolina University, Greenville, North Carolina. The percent clay from the hand-core samples (% s-clay) represents the clay contents found in the top 3 cm of the surface sediments. This percentage of clay will differ from the percent clay analyzed from the shipek samples. Therefore, to avoid confusion the percent clay from the surface 3 cm hand-core samples will be designated as % s-clay. As pointed out in the sampling procedures, hand-core samples were not collected at all sample stations.

S U R F A C E S E D I M E N T R E G I M E -

N A G S H E A D A R E A

SEDIMENTARY FACIES

Based on lithic character and statistical grain parameters, the surface sediments on the nearshore shelf in the Nags Head area have been classified into five sedimentary facies. A close relationship exists between bottom topography, water depth, distance offshore, and proximity of relict stratigraphic units, to the lithic character and descriptive statistical parameters of the sediments. Thus, the lithofacies reflect specific sedimentary environments which are defined primarily by bottom topography. Relationships between sediment type and proximity to relict strata will be considered in a later section concerning subsurface data.

The five surface sediment facies types are as follows.

- A. Shoreface Sands: This facies type represents deposits associated with shoreface environments. These facies are characterized by uniform, clean, light colored, well sorted, fine sands with low percentages of mud, clay, and s-clay, with an actively rippled surface.
- B. Lower Shoreface - Topographic Plain Sands: This facies type represents deposits associated with deeper shoreface or topographically flat environments. These facies are characterized by either slightly dark to dark, moderately well sorted to moderately sorted fine to very fine sands, or fine to very fine muddy sands with a moderately rippled surface. In

addition, these sediments have low percentages of clay, s-clay, and organic matter.

- C. Topographic High Sands: This facies type represents deposits associated with minor, low amplitude topographic highs. These facies are characterized by either clean moderately well sorted fine sands or slightly granular fine sands with low percentages of mud, clay, and s-clay, with an actively rippled surface.
- D. Topographic High Shoal Sands: This facies type represents deposits associated with major, broad topographically high offshore shoal complexes. These facies are characterized by iron stained orange, well to moderately sorted, very slightly granular to slightly granular medium sands, with an actively rippled surface.
- E. Topographic Low Sands and Muds: This facies type represents deposits associated with topographic low environments. These facies are characterized by bimodal deposits of poorly sorted to very poorly sorted, gravelly muddy very fine to coarse sands, with relative high percentages of mud, clay, and s-clay. The muds occur as black organic-rich patchy or sheet-like deposits consisting of relatively high clay to silt ratios. Sedimentary structures consist of mega ripples of coarse sediments, with muds accumulating in the troughs of the mega ripples.

SEDIMENT DESCRIPTIONS OF SAMPLE STATIONS

The following is a general description of the surface sediments and sedimentary environments at each sample station. Descriptions will include surface sediment characteristics, sedimentary structures, and bottom topography. These descriptions, along with an understanding

of the close relationship which exists between sedimentary facies and bottom topography, are used as a basis for interpretation of a schematic sediment distribution map for each sample traverse. Lateral correlation between the individual sediment distribution maps for each sample traverse are used to construct a general sediment distribution map for the Nags Head study area.

Avalon Pier Traverse

The northern most sample traverse consists of 6 sample stations and extends seaward for 3.08 n.m. from Avalon Pier (Figure 5). The profile reveals a uniformly sloping bottom with a gradient of 6:1000 out to a depth of 60 ft (18.2 m). Beyond this depth, the slope is less than 6:1000, with a minor low amplitude topographic low and high occurring as small deviations from the uniformly sloping bottom.

Station NA-1 is located in a topographic low 0.47 n.m. offshore in 36 ft (11 m) of water. A topographic high is located immediately seaward of the low station. The sediments are poorly sorted, granular, very coarse sands, with 25% gravel. Patchy deposits of dark organic-rich mud were observed with maximum accumulations of 18 cm. Analysis of the mud yielded a very poorly sorted, slightly granular very fine sandy mud, with 4.6% gravel and 53.4% mud (of which 15.5% is clay). Accordingly, the sediments are classified as a type E topographic low facies.

Sedimentary structures include gravelly mega ripples, with 1 to 2 m wavelengths, oriented parallel to shore. Secondary sand ripples, with 0.5 to 1 m wavelengths, were oriented perpendicular to and superimposed on the mega ripples. Approximately 50 m to the west, the gravel was overlain by muds. Further west, as well as east, the gravelly muds graded to fine sands.

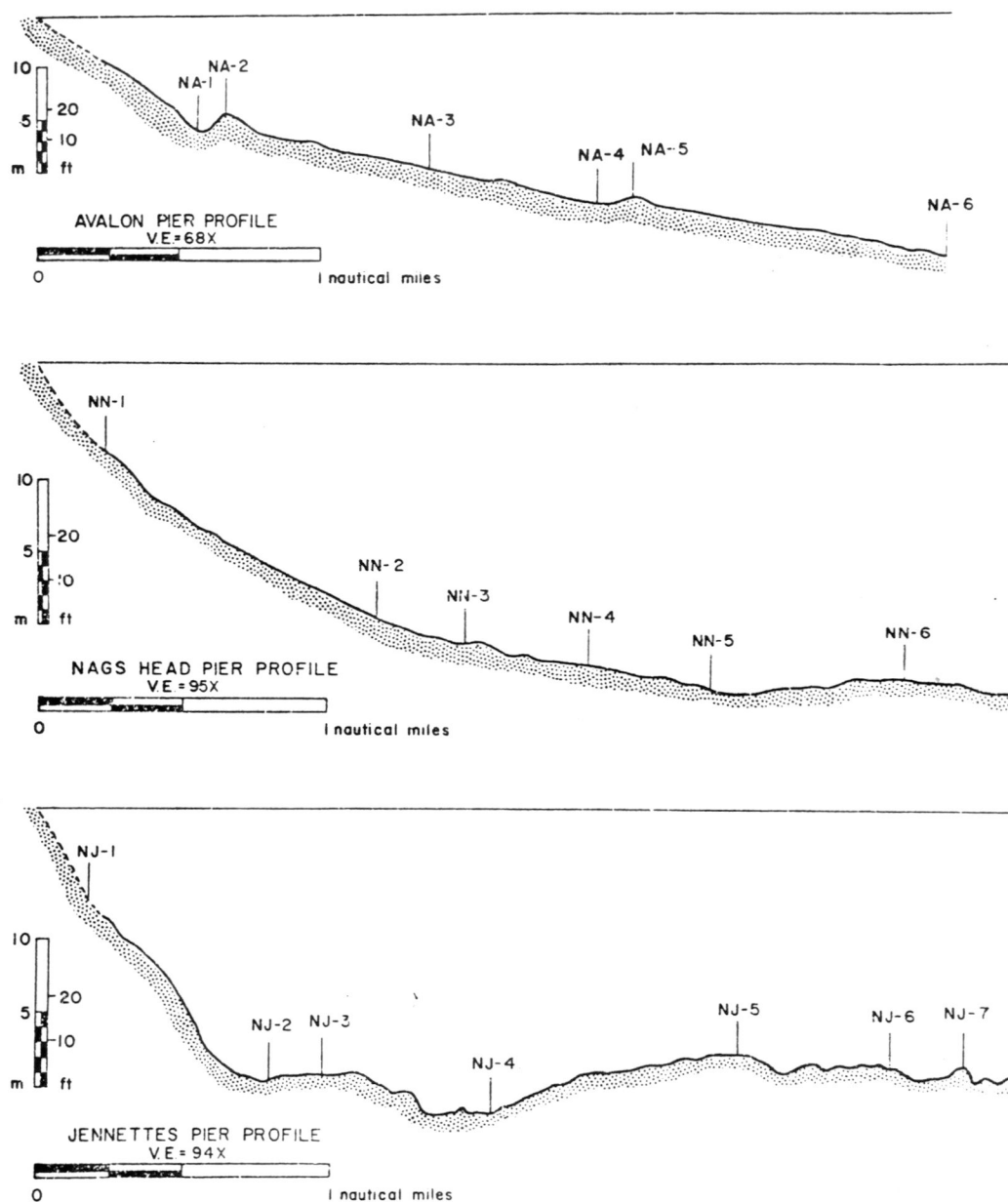


Figure 5. Cross-sectional profiles illustrating bottom topography and station location along the Nags Head sample traverses.

Station NA-2 is situated on a topographic high located 0.54 n.m. offshore in 28 ft (8.5 m) of water. The relationship of the topographic high to the shoreface is not clearly understood, although it may be connected to the shoreface south of station NA-2 (Figure 2). If so, the high may represent an embryonic shoal in the "initiation" or "growth" stage of development (Figure 6), as pointed out by Duane et al (1972).

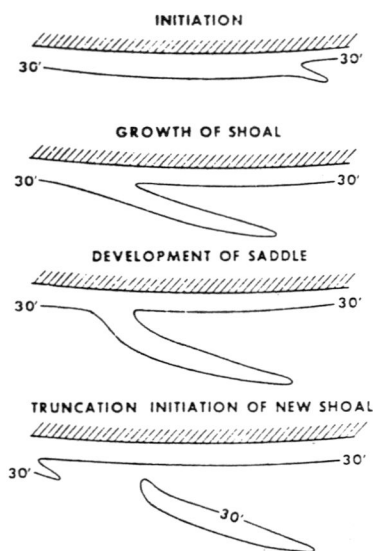


Figure 6. Schematic evolution and detachment of a nearshore shoal from the shoreface (from Duane et al, 1972).

Surface sediments are moderately well sorted, very slightly gravelly fine sands containing 0.2% shell gravel, 0.4% mud, and 0.9% s-clay. The sediments are classified as a type C topographic high facies, exhibiting a marked decrease in mud and s-clay content while being better sorted.

The bottom is marked by an active rippled surface. The ripples have 30 cm wavelengths, 10 cm wave heights, and are oriented parallel to shore, with smaller secondary ripples in the troughs, oriented 45° to the larger ripples. The active ripples attest to the onshore-offshore and longshore current activity at this station.

Station NA-3 lies 1.25 n.m. offshore on a topographic plain in 52 ft (16 m) of water. Surface sediments are moderately sorted, slightly gravelly fine sands, with 1.9% shell gravel, 4.7% mud, and 2.9% s-clay. This sediment is classified as a type B topographic plain facies. The bottom is characterized by active ripples which are oriented parallel to the beach, with 25 cm wavelengths and 2 to 5 cm wave heights.

Station NA-4 lies in a minor topographic low located 1.68 n.m. offshore in 61 ft (18.6 m) of water. Sediments are poorly sorted, very slightly gravelly, muddy very fine sands, with 0.1% shell gravel, 44.1% mud (of which 4.6% is clay), and 15.3% s-clay. The sediments show a marked decrease in sorting while an increase in percent mud, percent s-clay, and percent organics. Thus, they are classified as a type E topographic low facies.

Accumulations of mud were observed in patches 15 to 20 cm in thickness. In addition, small ripples were observed which had 10 to 15 cm wavelengths and 2 to 5 cm wave heights.

Station NA-5, located on a minor topographic high, occurs 1.85 n.m. offshore in 58 ft (17.7 m) of water. Surface sediments are characterized by moderately well sorted, fine sands with 3.4% mud and 1.0% s-clay. A considerable decrease in the mud and clay content, relative to adjacent topographic low stations, indicates the presence of the type C topographic high facies. The presence of ripples, with 20 cm wavelengths and 7 to 10 cm wave heights, were observed and testify to the more active environment of the topographic high.

Station NA-6 marks the middle of a broad and deep topographic low located 3.08 n.m. offshore in 74 ft (22.6 m) of water (Figure 2).

Surface sediments are poorly sorted, muddy very fine sands with 45.1% mud (of which 14.3% is clay), 7.2% s-clay, and 2.7% organics. Thus, the sediments are classified as a type E topographic low facies.

The bottom was observed to have a dense layer of suspended sediments over 23 cm of soft, black organic-rich mud, which overlies a firm, very fine sand surface. Two distinct layers of mud were observed. A 10 cm layer of very easily disturbed soft mud covered a 13 cm layer of somewhat compacted, dewatered mud. Current flow structures were not observed in the bottom sediments at this station.

Nags Head Pier Traverse

The Nags Head Pier sample traverse is located 4.82 n.m. south of Avalon Pier. The traverse consists of 6 sample stations, with the outer most station located 3.02 n.m offshore (Figure 5). The profile reveals a moderately sloping bottom with a gradient of 8:1000 to a depth of 60 ft (18.2 m). Beyond the 60 foot depth, the gradient decreases to 3:1000 until a broad topographic low is encountered which rises seaward onto a topographic high shoal.

Station NN-1 is located 0.20 n.m. offshore in 18 ft (5.5 m) of water. Surface sediments are well sorted fine sands with 0.3% mud and 5.0% s-clay. The bottom contains ripples which have 10 cm wavelengths. The sediments are characteristic of a type A shoreface facies.

Station NN-2 is on a topographic plain located 1.04 n.m. offshore in 55 ft (16.8 m) of water. The sediment is characterized by a moderately well sorted, muddy very fine sand with 18.3% mud (of which 0.7% is clay) and 4.1% s-clay. The relatively high percentage of mud (18.3%) is indicative of a topographic low, but analysis of the mud fraction reveals that 83% of it is coarser than 50 ϕ . Thus, the ratio

of clay to silt is only .04. This low ratio is not typical of muds from topographic lows, which are characterized by much higher clay to silt ratios and are also usually bimodal. Accordingly, the sediment is classified as a type B topographic plain facies. Bottom sedimentary structures consist of ripples aligned parallel to shore with 7 to 15 cm wavelengths and 2 to 5 cm wave heights.

Station NN-3 is located 1.45 n.m. offshore in 63 ft (19.2 m) of water and is characterized by moderately well sorted, muddy very fine sands with 23.1% mud (of which 0.9% is clay) and 3.9% s-clay. Again, analysis reveals that 88.7% of the mud fraction is coarser than 50, resulting in a clay to silt ratio of .04, which is not characteristic of muds from topographic lows. Therefore, the station is classified as a type B topographic plain facies. Small ripples with 5 to 10 cm wavelengths and 1 to 2 cm wave heights were observed to be oriented parallel to the beach, which indicates lower bottom current activity.

Station NN-4 is on a topographic plain located 1.90 n.m. offshore in 64 ft (19.5 m) of water. Sediments consisted of moderately sorted, slightly gravelly medium sands with 1.7% gravel, 1.3% mud, and 2.5% s-clay. The textural character and distinctive orange color of the sediment is similar to the type of sediments found on topographic high shoals. Thus, the station is classified as a type D topographic high shoal facies. Further discussion concerning the presence of the shoal sediment apron will follow in a later section considering subsurface information. No sedimentary structures were noted at the station.

Station NN-5 lies in a broad topographic low located 2.30 n.m. offshore in 74 ft (22.6 m) of water. Surface sediments consist of poorly sorted, pebbly coarse sands with 9.8% gravel, 1.8% mud, and 7.5% s-clay. The relatively high s-clay content is characteristic of

a topographic low. The low percentage of mud from the shipek sample results from the discontinuous nature of the mud observed in the low. Sedimentary structures consist of large ripples with 1 m wavelengths and undulating crests. The sediment is classified as a type E topographic low facies with a considerable amount of type D topographic high shoal facies sediment.

Station NN-6 is located on a broad, low amplitude, topographic high shoal, 3.02 n.m. offshore in 66 ft (20.1 m) of water. Surface sediments are characterized by well sorted, very slightly granular medium sands with 0.2% gravel, 0.3% mud, and 0.5% s-clay. The small percentage of mud and s-clay indicates the more active environment of the topographic high shoal. The sediments are classified as a type D topographic high shoal facies. Surface sedimentary structures consist of large 1 to 1.3 m wavelength ripples. Superimposed on the large ripples are secondary ripples with 15 to 20 cm wavelengths and 2 cm wave heights.

Jennettes Pier Traverse

The southernmost sample traverse was run off of Jennettes Pier, 4.13 n.m. south of Nags Head Pier. Seven sample stations were occupied along the traverse, which extends 3.15 n.m. offshore (Figure 5). The Jennettes Pier profile shows a shoreface that slopes more steeply than the gentle and moderate slopes of the Avalon and Nags Head Pier profiles, respectively. A gradient of 13:1000 exists from the shore to a depth of 60 ft (18.3 m). At this point, the profile levels out into a topographic plain that is bounded on its seaward side by a broad and deep topographic low. Seaward of the low is a major topographic high shoal.

Station NJ-1 is located on the shoreface 0.22 n.m. offshore in 16 ft (4.9 m) of water. Sediment sample analysis yields a well sorted fine sand with 0.2% mud and 0.8% s-clay, thus fitting the classification of a type A shoreface facies. Ripples with 10 to 15 cm wavelengths and 2 to 5 cm wave heights were observed.

Station NJ-2 is located 0.82 n.m. offshore in 60 ft (18.3 m) of water. The station is in a poorly defined topographic low at the base of the steep shoreface slope. Surface sediments consist of moderately sorted, gravelly medium sands, with 5.4% gravel, 2.5% mud, and 1.3% s-clay. The poorly defined nature of the topographic low is reflected by the moderate sorting, although the higher content of mud and s-clay, relative to adjacent stations, are indicative of the topographic low. Bottom sedimentary structures consist of small ripples with 2 to 6 cm wavelengths and 1 cm wave heights. Accordingly, the surface sediments are loosely classified as a type E topographic low facies.

Station NJ-3 is located on the landward flank of a poorly defined minor topographic high 0.98 n.m. offshore in 60 ft (18.3 m) of water. Sediments consist of poorly sorted, iron stained orange, pebbly coarse sands, with 17.1% gravel, 0.3% mud, and 1.1% s-clay. Although the poor sorting, resulting from a high percentage of gravel, is not indicative of a topographic high, the sediments have low percentages of mud and s-clay, which are characteristic of topographic highs. Accordingly, the sediment is classified as a coarse sand version of a type D topographic high shoal facies. Sedimentary structures consist of 15 to 20 cm wavelength ripples.

Station NJ-4 is located in a major topographic low 1.81 n.m. offshore in 73 ft (22.3 m) of water. Surface sediments are very poorly

sorted, pebbly, muddy fine sands that contain 4.9% gravel, 16.4% mud (of which 6.7% is clay), and 7.5% s-clay. The high percentages of mud and clay reflect the trapping nature of the topographic low.

Accordingly, the sediments are classified as a type E topographic low facies. The station is characterized by a very irregular bottom. Clay escarpments, 1 to 1.5 m depressions, and accumulations of dewatered, black, organic-rich muds up to 13 cm in thickness were observed.

Detailed bottom observations were limited due to low visibility resulting from the suspended sediment in the water.

Stations NJ-5, 6, and 7 are located on a topographic high shoal complex, 2.60, 2.95, and 3.14 n.m. offshore in water depths of 56 ft (17.1 m), 58 ft (17.7 m), and 55 ft (16.8 m), respectively. Surface sediments consist of moderately sorted, slightly granular medium sands for stations NJ-5 and 6, and poorly sorted, pebbly medium sand for station NJ-7. Mud content ranges from 0.2% to 0.5% with s-clays ranging from 0.6% to 1.0%. This attests to the active winnowing action on the topographic high. Poor sorting of station NJ-7 sediments results from the high percentage of gravel. The sediments are classified as type D topographic high shoal facies because of their orange color, grain size, low percentage of fines, and low sorting. Surface sedimentary structures include an actively rippled bottom with 45 cm wavelength and 10 cm wave height ripples. Located in the troughs of the larger ripples, are ripples with 8 cm wavelengths and 1 cm wave heights.

CORRELATIONS BETWEEN SEDIMENTS AND BOTTOM TOPOGRAPHY

Bottom currents acting on shelf sediments create discrete sediment environments, each of which are characterized by sediments with distinct statistical parameters. In turn, physical sedimentary

processes, particularly wave induced bottom currents, are affected by the geometry of the bottom topography. Therefore, the sediment parameters should be expected to reflect the different bottom topographies. This is demonstrated by plotting the sediment parameters against topographic profiles for each profile section. The plots demonstrate that a number of statistical sediment parameters are reliable indicators of bottom topography and vice versa.

Figure 7 reveals a strong relationship between sorting and bottom topography. Thus, sorting values generally reflect the actual bottom topography. Figure 8 represents a composite plot of sorting versus distance offshore for all the sample stations. Clustering, by connecting sorting values for the topographic high and low stations, clearly delineates the difference between the topographic low and high sedimentary environments.

Sorting values for each topographic environment are given in Table 1. Dominant and mean sorting values show that shoreface environments are characterized by well sorted sediments, topographic high and topographic plain environments exhibit moderate to moderately well sorted sediments, while topographic lows are characterized by poorly to very poorly sorted sediments. Sorting for station NJ-2, a topographic low, deviates from this scheme. This is thought to result from the subtle topography at the station. Additional deviations from the above scheme occur at topographic high stations NJ-3 and NJ-7. These are attributed to the relative high percentages of gravel in the sediments from these stations.

An examination of percent mud from shipek samples, presence of mud by diver observation, and percent s-clay, reveal a strong relationship between the bottom topography and mud deposition (Figures 9 and 10). Relationships between topography and mud deposition, suggest that

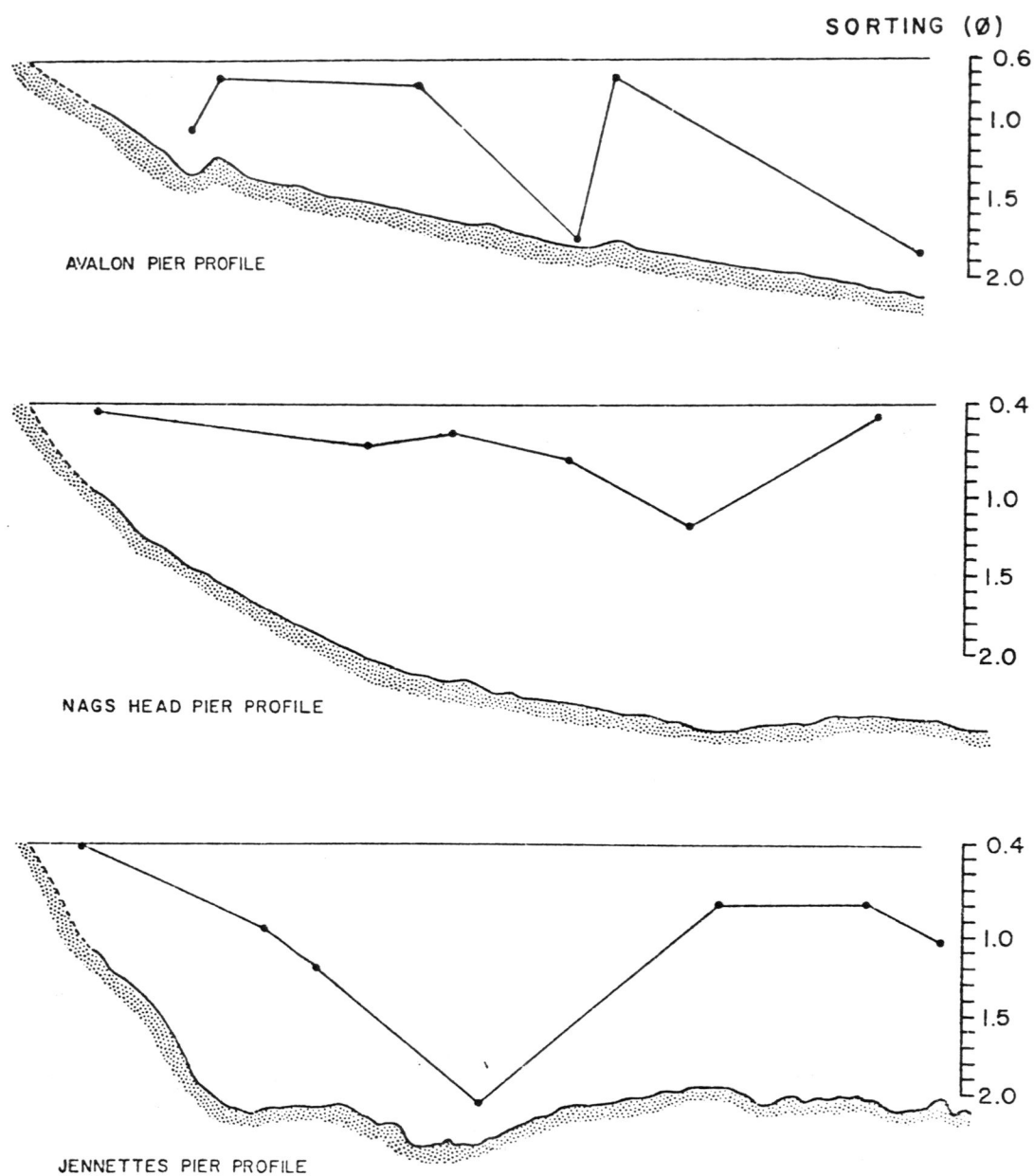


Figure 7. Plots of sorting versus bottom topography for the Nags Head sample traverses.

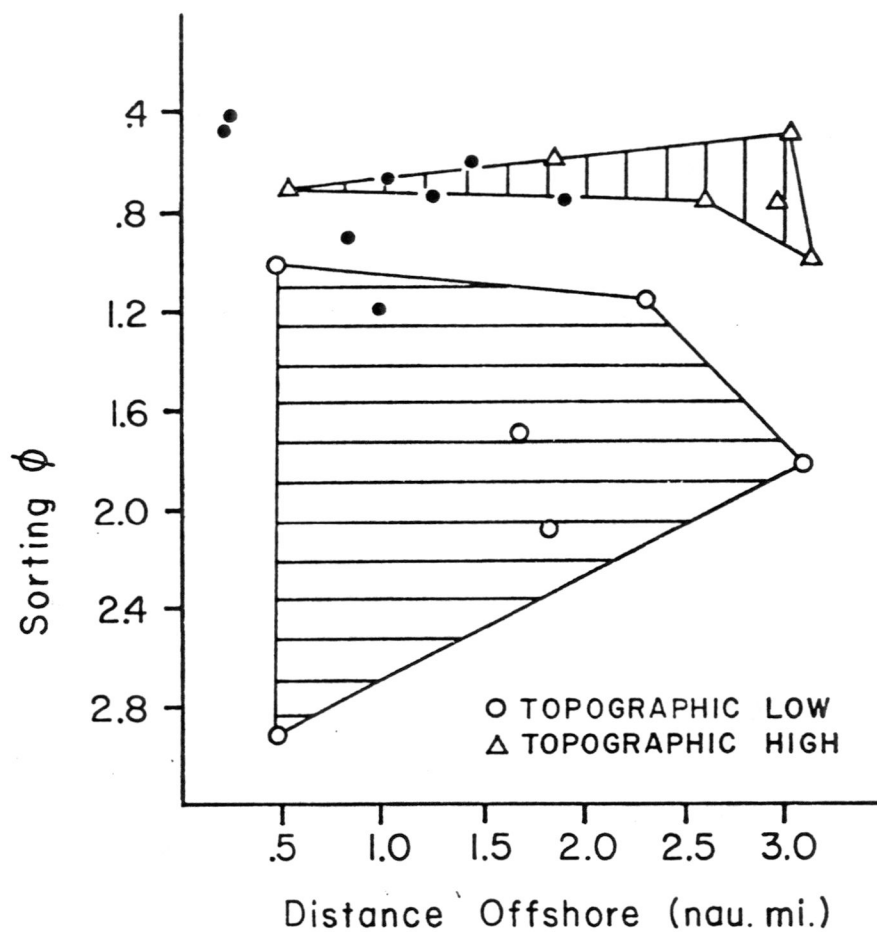


Figure 8. Composite plot of sorting versus distance offshore, Nags Head sample stations. Sorting values for the well defined topographic high and low environments can be separated into two groups. The topographic highs are characterized by better sorting values, while the topographic lows are characterized by poor sorting values.

SAMPLE TRAVERSE	SAMPLE STATION	TOPOGRAPHIC ENVIRONMENTS																			
		SHOREFACE A*					TOPOGRAPHIC HIGH C&D*					TOPOGRAPHIC PLAIN B*					TOPOGRAPHIC LOW E*				
		Sort	Mud	S-clay	Organ	Skew	Sort	Mud	S-clay	Organ	Skew	Sort	Mud	S-clay	Organ	Skew	Sort	Mud	S-clay	Organ	Skew
Avalon Pier	NA-1																2.93	53.4%			+ .29
	NA-2						0.71	0.4%	0.9%	0.4%	-.16										
	NA-3											0.75	4.7%	2.9%	1.2%	-.11					
	NA-4																1.75	44.1%	15.3%	3.6%	+ .51
	NA-5						0.59	3.4%	1.0%	0.6%	+ .07										
	NA-6																1.83	45.1%	7.2%	2.7%	+ .74
Nags Head Pier	NN-1	0.45	0.3%	5.0%	0.4%	-.19															
	NN-2											0.67	18.3%	4.1%	1.4%	-.13					
	NN-3											0.59	23.1%	3.9%	1.0%	+ .37					
	NN-4											0.75	1.3%	2.5%	0.7%	-.14					
	NN-5																1.16	1.8%	7.4%	1.7%	-.19
	NN-6	0.48	0.3%	0.5%	0.4%	-.03															
Jennettes Pier	NJ-1	0.42	0.2%	0.8%	0.4%	-.12															
	NJ-2																0.93	2.5%	1.3%	0.5%	-.18
	NJ-3						1.20	0.3%	1.1%	1.1%	-.38										
	NJ-4																2.07	16.4%	7.5%	0.8%	+ .27
	NJ-5						0.77	0.2%	1.0%	0.5%	-.31										
	NJ-6						0.77	0.3%	0.6%	0.4%	-.44										
	NJ-7						1.02	0.5%	0.7%	0.4%	-.25										
MEAN		0.44	0.3%	2.9%	0.4%	-.16	0.79	0.8%	0.8%	0.5%	-.21	0.69	11.9%	3.4%	1.1%	-.01	1.78	27.2%	7.7%	1.9%	+ .24

Sort = Sorting (ϕ), Mud = % Mud from shipek sample, S-clay = % clay from surface 9cm sample, Organ = % Organic material from surface 9cm sample, Skew = Skewness, * indicates corresponding sedimentary facies type.

Table 1. Statistical sediment parameters of surface sediment samples grouped according to topographic environments, Nags Head study area.

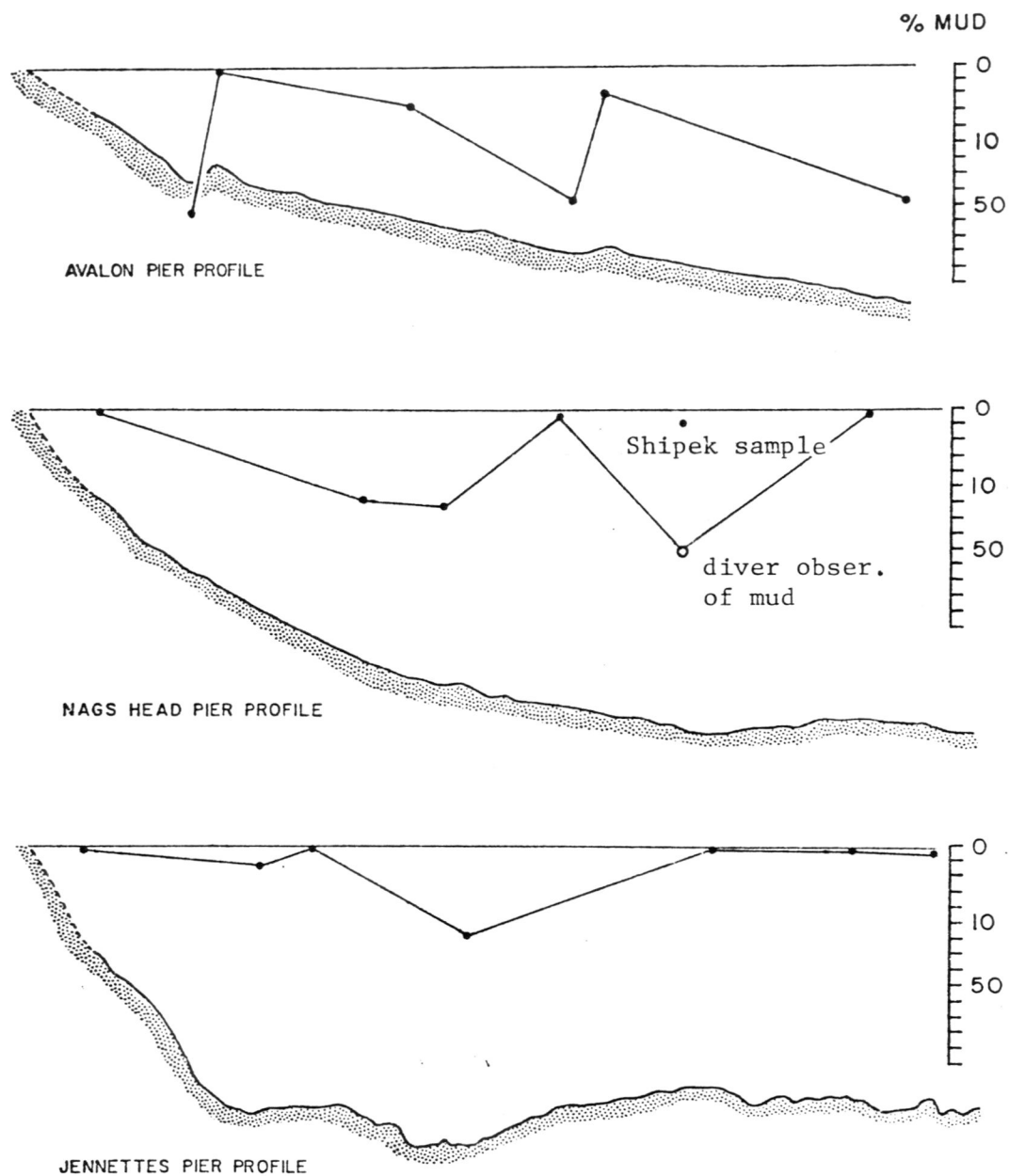


Figure 9. Plots of mud versus bottom topography for the Nags Head sample traverses.

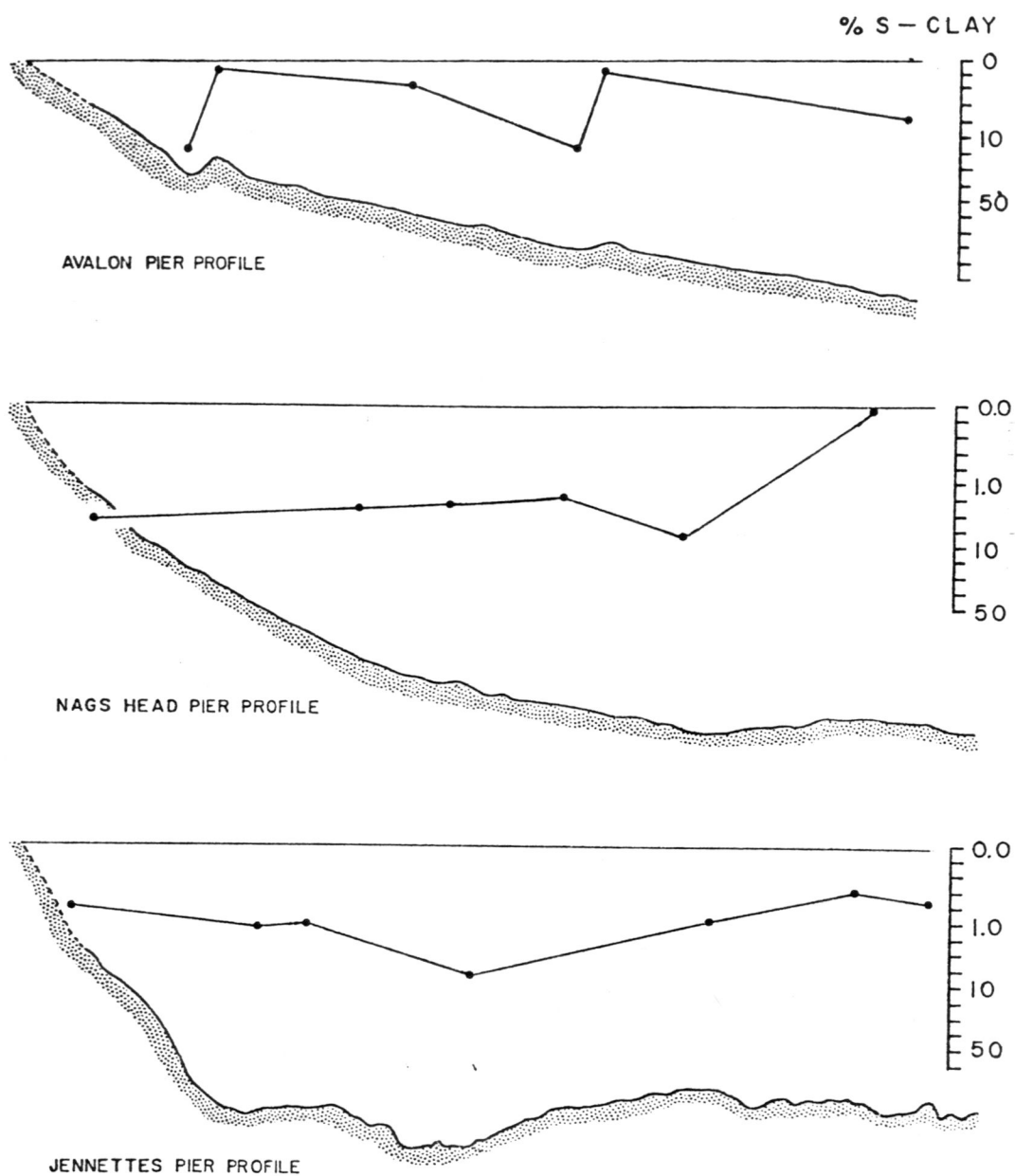


Figure 10. Plots of s-clay versus bottom topography for the Nags Head sample traverses.

percentages of mud increase within topographic lows and with increasing depths. Major topographic lows serve as traps for mud accumulations, whereas the topographic highs have relatively lower percentages of mud.

Anomalously high percentages of mud encountered at topographic plain stations NN-2 and 3 can be accounted for by examining the clay to silt ratios of the mud fraction (Table A1). Of the 18.3% mud for NN-2, 15.2% or 83% of the 18.3% is coarser than 5 ϕ . Of the 23.1% mud for NN-3, 18.3% or 79% of the 23.1% is coarser than 5 ϕ (coarse silt). Accordingly, these sediments are typical of topographic plain stations, with decreasing grain sizes resulting from increasing depths. This interpretation is further supported by their moderately well sorted sediments which are not indicative of topographic low sediments.

Although individual and mean values of sorting for the topographic plains and highs are similar, a notable difference in percent mud and percent s-clay separate the two environments (Table 1). Mean values of 0.8% s-clay and 0.8% mud are characteristic of the clean, winnowed topographic high environment. In contrast, the topographic plain environment is characterized by mean values of 3.4% s-clay and 11.9% mud.

Plots of percent organics versus topography demonstrate a direct relationship between the two variables (Figure 11). Although the Jennettes Pier traverse shows a weak correlation, the Avalon and Nags Head traverses clearly demonstrate a strong correlation. The mean percentage of organics reveals a clear delineation between the different topographic sedimentary environments (Table 1). Shoreface and topographic high environments (0.4% and 0.5% organics, respectively) have lower relative percentages of organics than topographic plain and topographic environments (1.1% and 1.9%, respectively).

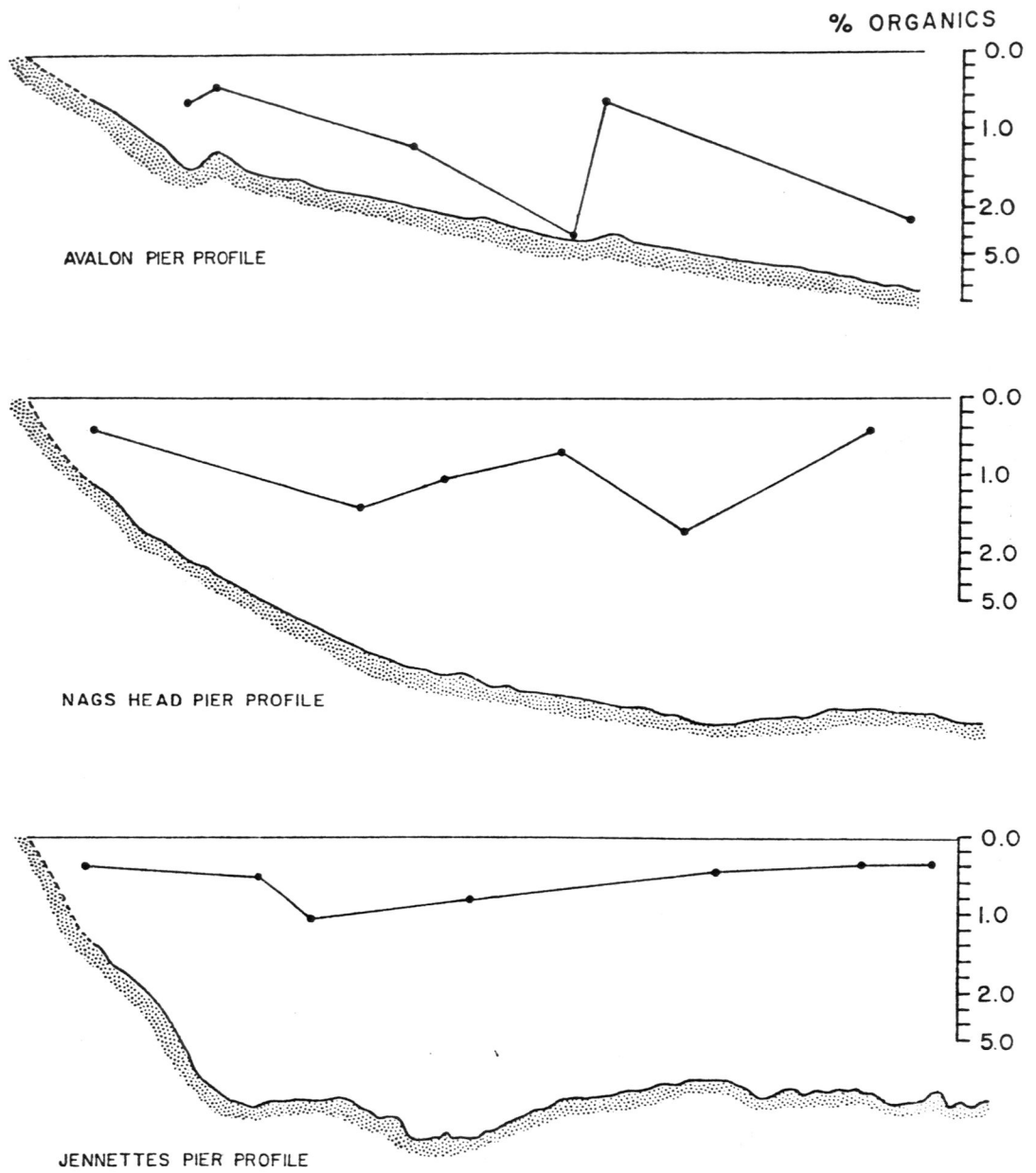


Figure 11. Plots of organic material versus bottom topography for the Nags Head sample traverses.

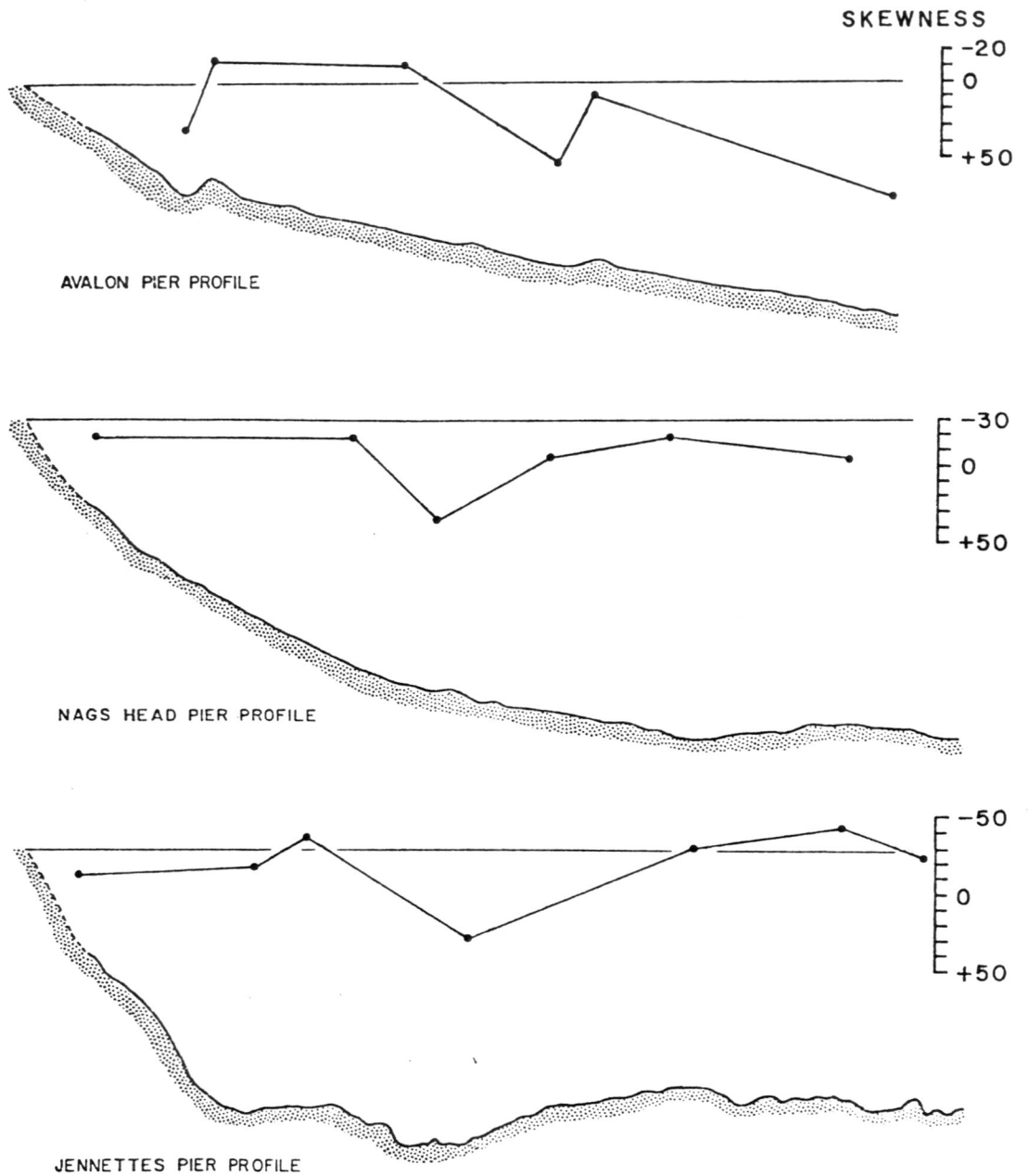


Figure 12. Plots of skewness versus bottom topography for the Nags Head sample traverses.

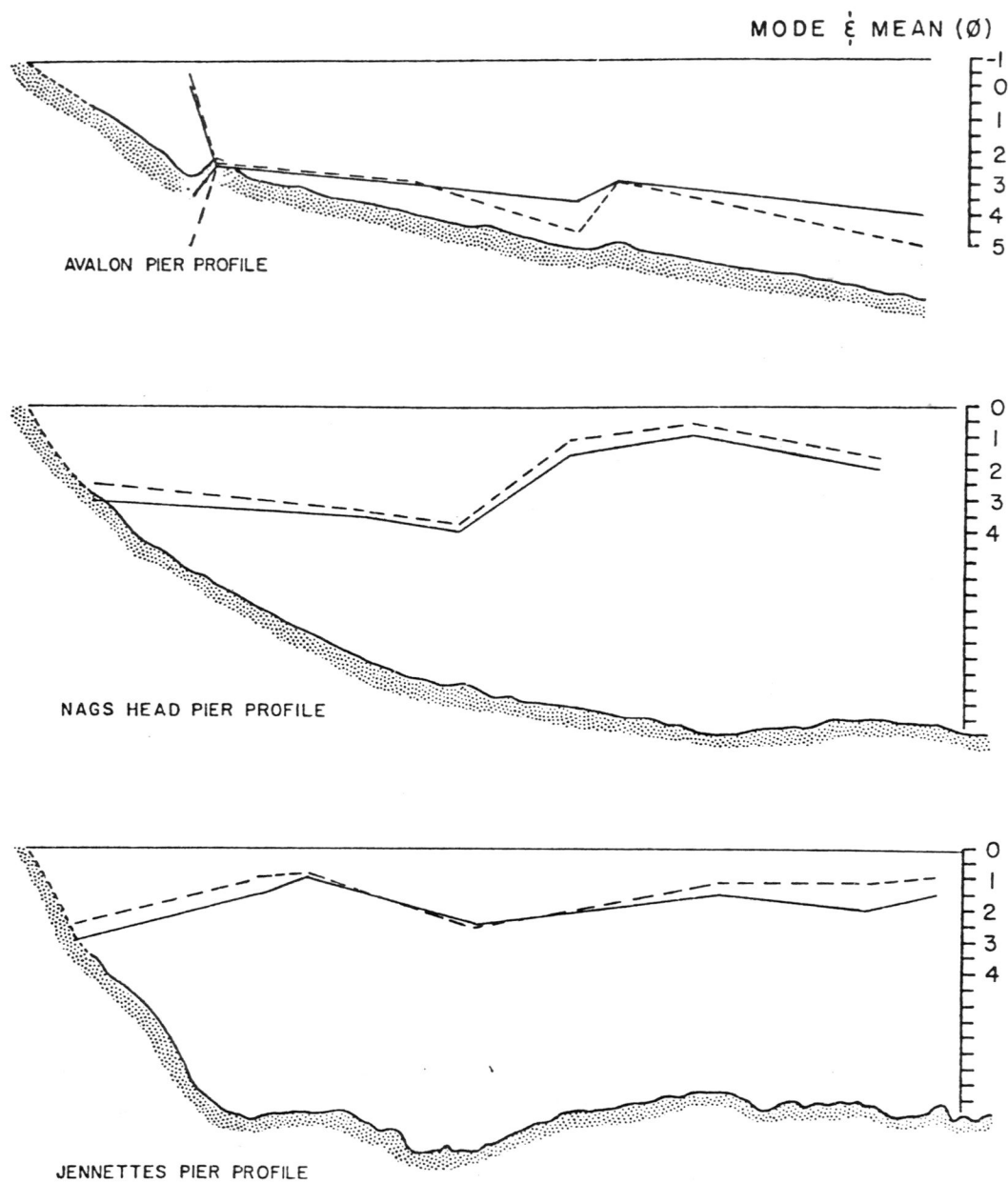


Figure 13. Plots of mean and mode grain size versus bottom topography for the Nags Head sample traverses.

Comparisons of skewness versus topography reveal a strong correlation between these parameters for the Avalon and Jennettes Pier traverses (Figure 12). Mean values of skewness suggest that the topographic low environments trap an excess of fine sediments, while winnowing of the fines from the topographic high environments results in an absence of fines (Table 1).

Although not as strong as previous correlations, examination of mean and mode grain size versus topography demonstrates that a general relationship does exist (Figure 13). A general decrease in grain size, as depth increases, is noticeable with the Avalon Pier traverse and to a lesser degree with the first 3 stations of the Nags Head Pier traverse. Deviations in grain size reduction associated with increasing depths, occurs when topographic highs and/or particular relict stratigraphic units are encountered. This may result in increased grain sizes.

RELATIONSHIPS BETWEEN FACIES, BOTTOM TOPOGRAPHY, AND PHYSICAL PROCESSES

Distinctive sedimentary facies, such as those described earlier, exist and result largely from the transport and deposition of sediments by various ocean currents. Such currents include wave induced fluid motion currents, meteorologically generated currents, and currents due to density differences of fluids (Weggel, 1972). Teleki (1972) outlines the complexity of sediment motion in the marine environment and concludes that no adequate theory for the mechanics of turbulent flow exists at this time. Therefore, the following discussion will deal mainly with qualitative generalities concerning wave induced bottom orbital velocity currents (WIBOVCS).

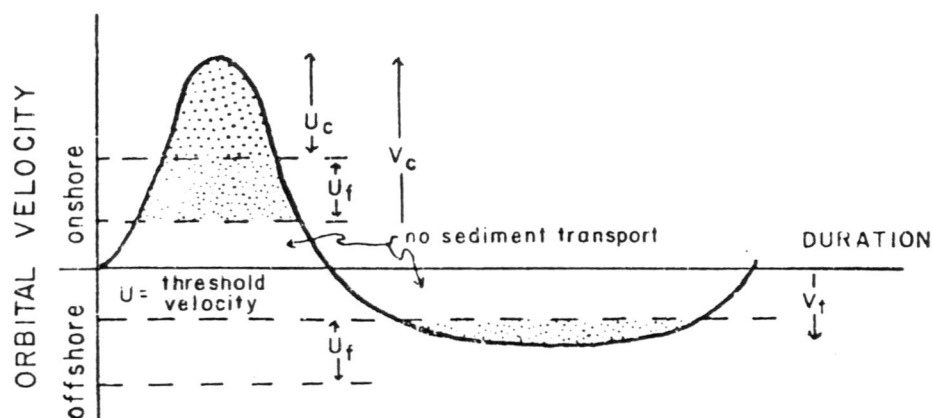
Komar (1976) points out that WIBOVCS are important in sediment transport and as agents controlling sediment facies on the continental

shelf. Accordingly, a brief discussion concerning WIBOVCS is necessary to understand the distribution, character, and geometry of the sediment facies.

Of particular importance is the onshore-offshore movement of sediments resulting from WIBOVCS. Bottom water particle velocities associated with the crests and troughs of shoaling waves is demonstrated in Figure 14a. Komar (1976) and Silvester (1974) found that wave crests possess a high velocity-low duration current directed shoreward, while wave troughs possess a low velocity-high duration current directed seaward. The differing current velocities and directions associated with crests and troughs cause sediments of different sizes to be transported selectively in opposite directions simultaneously. The size of the sediment being transported is a function of the bottom orbital velocity associated with waves. Bottom orbital velocities increase as waves enter shallower depths. Thus, topographic highs experience greater velocities due to their shallow depths.

Another important process of sediment transport results from coupling of unidirectional bottom currents with wave induced bottom turbulence (Weggel, 1972). The unidirectional currents, regardless of velocity, will transport sediments that are already in suspension due to wave induced turbulence.

The work of Goldsmith et al (1974) and Weggel (1972) suggests that water depths within the study area are well within the threshold range for sediment disturbance and transport by WIBOVCS. Weggel's work demonstrates that bottom velocities resulting from 10 foot waves in 80 feet of water are capable of moving sediments greater than 5 mm in diameter (Figure 14b). In addition, work by Goldsmith et al (1974) demonstrates that waves with periods of 6 seconds or greater interact



V_c = velocity of crest orbital

V_t = velocity of trough orbital

U_f = velocity for fine sediment transport

 U_c = velocity for coarse sediment transport

Figure 14a. Mechanics of wave induced bottom orbital velocity currents (from Pearson, 1977; modified after Komar, 1976 and Silvester, 1974). Upon entering shoaling waters, a high velocity - low duration bottom current is directed shoreward below wave crests. A low velocity - high duration bottom current is directed seaward below wave troughs.

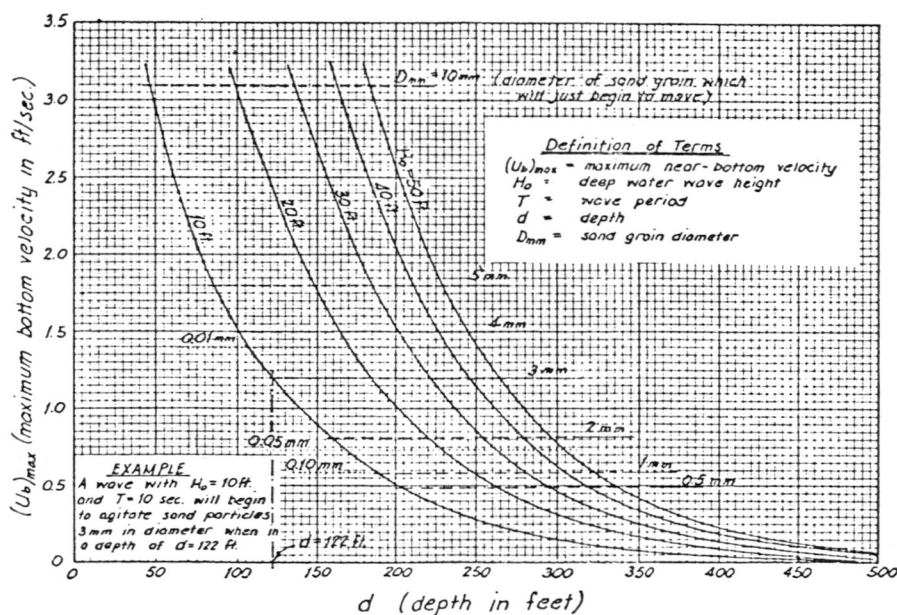


Figure 14b. Initiation of motion in bottom sediments due to wave induced bottom orbital velocity currents (from Weggel, 1972).

significantly with the sea bottom within the study area. Significant bottom disturbance resulting from waves with 6 second periods begins to occur approximately 1 n.m. offshore in the Nags Head area (Figure 15). According to the U. S. Naval Weather Service Command (1970), waves with periods of 6 seconds or greater occur within the Cape Hatteras area 49.4% of the time.

Thus, the work of various authors suggest that sediments within the nearshore inner continental shelf are actively and frequently disturbed by wave induced bottom currents. This, in turn, results in active sediment facies in which topographic features, both lows and highs, are actively created and modified during both low and high energy wave conditions.

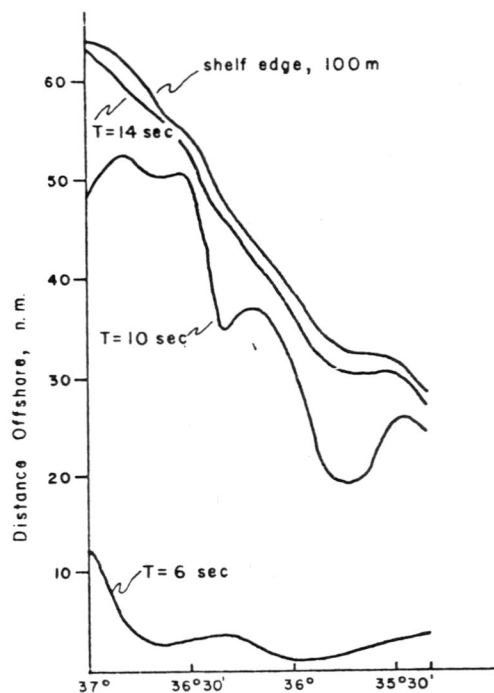


Figure 15. Distance offshore at which waves of different periods begin to appreciably interact with the sea floor, for the Nags Head study area (modified after Goldsmith et al, 1974).

Topographic Highs

Because topographic highs are shallower than adjacent areas, they experience greater exposure to WIBOVCS. This results in greater winnowing and mobility of the topographical high sediments. This creates moderately sorted, uniform sedimentary environments with actively rippled sediment surfaces (Figure 16).

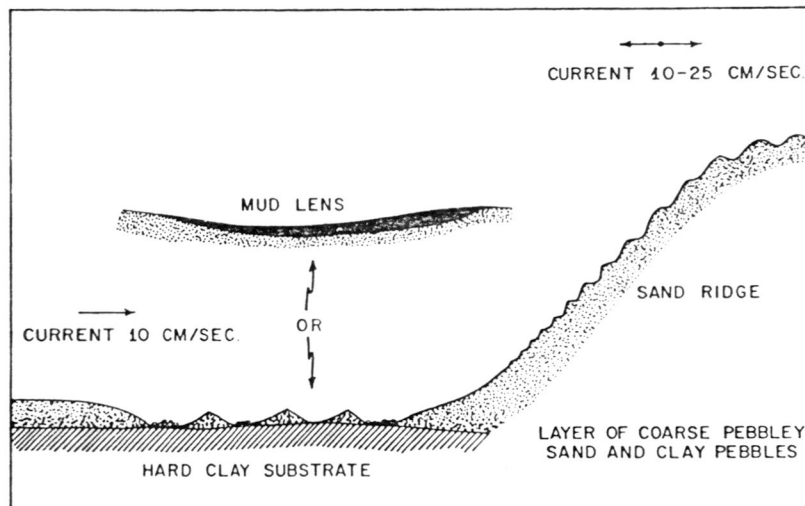


Figure 16. Schematic relationship between topographic low and topographic high shoal complex (from Duane et al, 1972). Topographic highs experience greater winnowing due to the greater frequency and magnitude of WIBOVCS, relative to topographic lows. The above relationship exists at station NJ-4 and NJ-5.

The minor, small amplitude topographic highs may represent mobile sand waves that are in hydraulic disequilibrium with their environment. During extremely high energy wave conditions, the sediments of the minor topographic highs (sand waves) are thought to be transported offshore by WIBOVCS associated with wave troughs. However, during lower wave activity, the sand waves migrate progressively shoreward. The shoreward migration results from WIBOVCS, associated with crests of low energy waves, reaching threshold velocities capable of transporting the sand wave sediments shoreward. Simultaneous sediment

transport in an offshore direction is prevented since WIBOVs, associated with the low energy wave troughs, do not reach threshold velocities capable of sediment transport.

Although operating less frequently, in deeper water, and over a longer time period, this process is probably similar to the migration of sand bars in the surf zone. Shallow nearshore bars result from sediments being transported offshore during high energy periods. During low energy periods the bars migrate shoreward, eventually welding to the strand line.

Active migration of the sand waves is suggested by subsurface evidence which indicates a sand wave has migrated over and filled a minor topographic low. Pelletal muds and clays similar to those deposited in surficial topographic lows are found in a core taken from a low amplitude high. This suggests that the high has migrated shoreward, filling the topographic low.

Active shifting of sands on the major broad topographic high shoals is evidenced by the moderate sorting and uniform, clean nature of the shoal sediments. Vibracores from the shoals also contain layers of marine pelletal muds and clays, suggesting migration of the shoal sands resulting in burial of the pelletal clays which accumulated in minor low troughs on the topographic high shoal complex.

Topographic Lows

The geometry of the bottom controls the deposition of muds on the nearshore inner continental shelf. Topographic lows, due to their greater depths, are concluded to inhibit the magnitude and frequency of wave induced bottom currents and allow deposition of mud, even in shallow water (Figure 16). McCave (1971) reports similar relationships

between bottom geometries and mud deposition on deeper continental shelf areas. Origin of the muds deposited in topographic lows in my study area are assumed to be derived from suspended estuarine discharges, organic pelletal detritus, and/or reworked relict muds.

Coarse lag gravels trapped with mud deposits in the topographic lows create a very poorly sorted bimodal sediment facies. The lag gravels represent either 1) sediments migrating shoreward from offshore sources by the action of WIBOVs from wave crests and/or 2) gravels eroded from relict units cropping out in the topographic lows. In either case, the low depressions serve as basins and provide a confining trap for the gravel. Muds occur as blanket-like to patchy blanket-like deposits characterized by relatively high percentages of fecal pellets, organic matter, clays, and water content. They exhibit a distinctive black color with an offensive hydrogen sulfide odor characteristic of reducing environments. The muds overlies sediments of an entirely different character, suggesting these muds are ephemeral in nature. Similar ephemeral organic-rich muds are reported accumulating on the nearshore inner continental shelf areas of Nags Head (Swift, 1973a) and Fort Fisher, (Moorefield, 1978) North Carolina.

The dark organic-rich muds were observed to be easily disturbed by divers. The presence of such muds in the topographic lows attest to the absence of WIBOVs with sufficient velocity to disturb them, thus the lows provide a shelter for mud deposition. A more resistant dewatered type of mud resembling cold gravy was observed in the topographic lows at depths greater than 70 ft (21.2 m). The deeper, dewatered muds are thought to be less ephemeral in nature than the muds deposited in shallower depths, being activated only during less frequent high energy periods. Although the muds are thought to be

ephemeral, McCave (1972) points out that in only a few hours, nearshore mud deposits may be sufficiently compacted to withstand critical erosion shear stress resulting from WIBOVCS during storm conditions.

Based upon sedimentological findings and diver observations, the following sediment facies-topography relationships were found to exist.

1. As distance from shore and depth increase, the sediments become finer grained and somewhat less well sorted as long as the topography remains planar. Deviations in grain size and sorting may result from changes in topography and/or upon encountering relict strata. Sedimentary facies A, B, and E correspond to the above relationships. Examples occur at stations: NA-3, 6 and NN-1, 2, 3.
2. Where the bottom is topographically high the sediments are moderately to moderately well sorted and of uniform grain size; and consequently, they exhibit better sorting with lower percentages of mud than adjacent shoreward environments. Sedimentary facies C and D correspond to the above relationship. Examples occur at stations: NA-2, 5; and NJ-3, 5, 6, 7.
3. Where there is a low in the bottom topography bounded by a seaward high, the low will act as a shelter or shadow zone from WIBOVCS. Thus, the low basin or trough provide a trap for deposition of muds and lag gravels. Sedimentary facies E corresponds to the above relationship. Examples occur at stations: NA-1, 4, 6; NN-5; and NJ-4.

SURFACE SEDIMENT DISTRIBUTION

Individual surface sediment distribution profiles were constructed for each sample traverse (Figure 17). These were based on interpre-

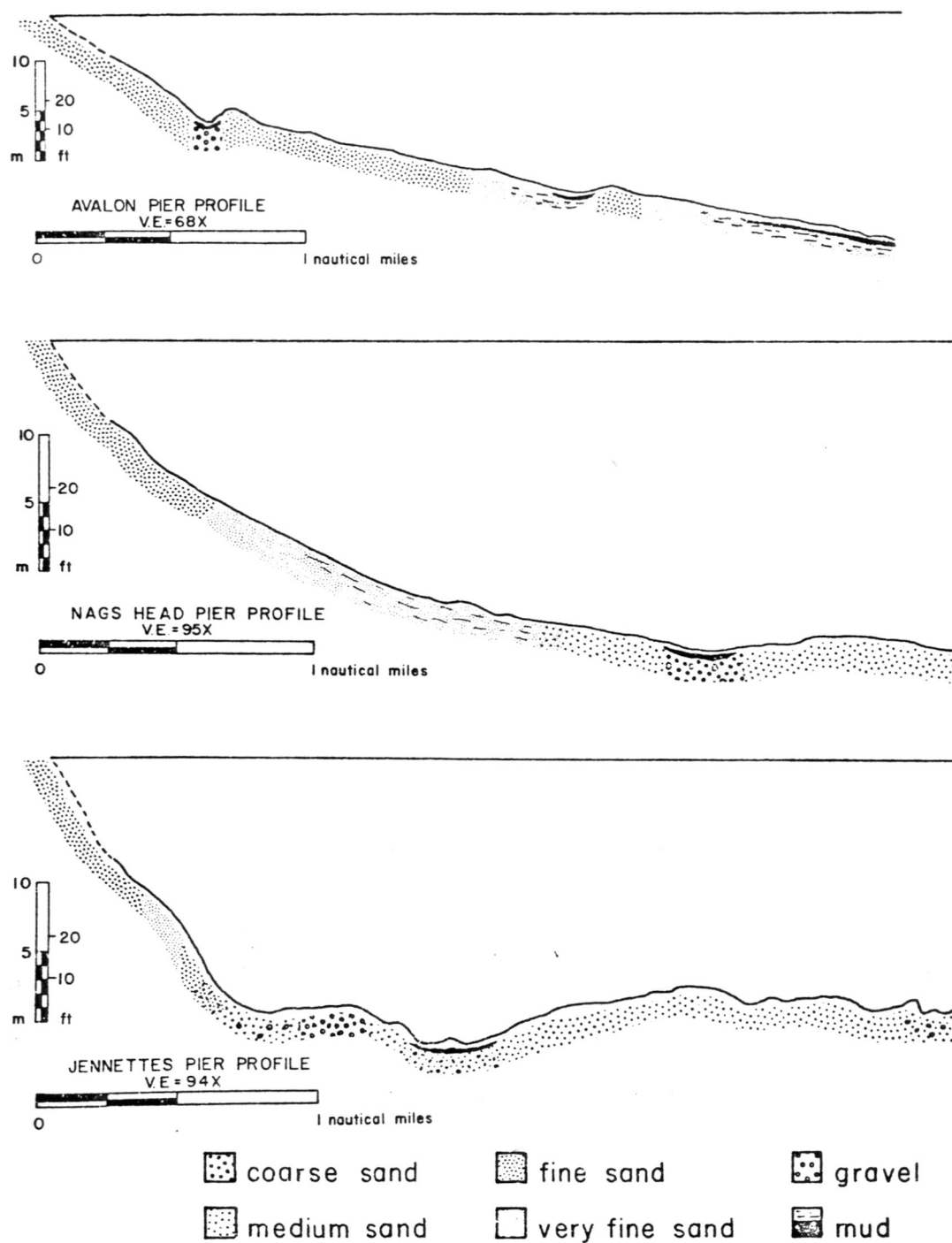


Figure 17. Surface sediment distribution along the Nags Head sample traverses.

tation of sediment descriptions and relationships between bottom topography and statistical parameters of sediment samples.

Knowledge about the direct relationships between bottom topography and sediment types allows us to construct a fairly realistic surface sediment distribution map for the Nags Head area (Figure 18). Major factors controlling the distribution of the surface sediments were found to be slope of the bottom profile, water depth, distance offshore, proximity to shoal complexes and relict beds, and topographic geometry of the bottom (Figure 2).

It should be noted that the sediment distribution map is very generalized. Minor irregularities in the surface sediments are expected because of the general nature of the bathymetric map and low number of surface sediment samples used to construct the distribution map.

In examining the distribution of surface sediments, reference should be made to Table A1 for analyses of individual sediment samples. Examination of the surface sediment distribution along the Avalon Pier traverse reveals a transition from shoreface sands to progressively finer and muddier sediment in an offshore direction. Deviations from this seaward transition occur where topographic lows and highs are encountered (Figures 17 and 18). Due to a considerable change in the gradient of the Avalon Pier profile, the fining scheme is best demonstrated seaward of NA-2 where the gradient is uniformly 3:1000, as opposed to the 13:1000 gradient shoreward of NA-2.

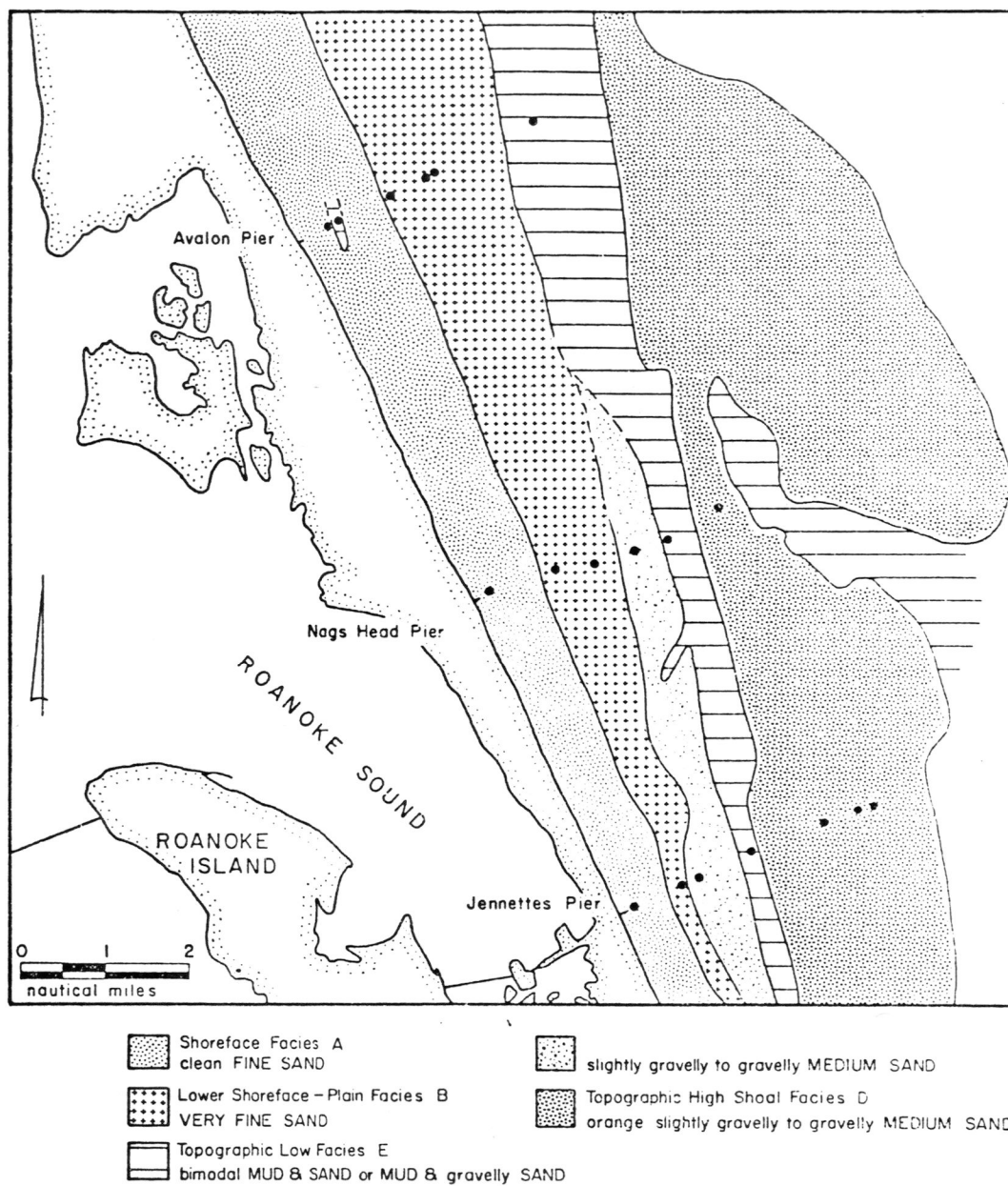


Figure 18. Generalized surface sediment distribution map for the Nags Head study area (refer to Figure 2).

	Avalon Pier Traverse	Nags Head Pier Traverse	Jennettes Pier Traverse
Shoreface Gradient 0 to 60' (18.3 m) depth	6:1000	8:1000	13:1000
Distance offshore to 60' (18.3 m) depth	1.68nm	1.40nm	0.75nm

Table 2. Shoreface gradients for the Nags Head traverses.

An overall gradient for each profile, computed from the distance offshore to the 60 ft (18.3 m) depth can be seen in Table 2. The Avalon Pier profile, having a relatively gentle gradient of 6:1000, encounters the 60 ft depth 1.68 n.m. offshore (station NA-4). Since grain size is a function of depth, fining of the shoreface sediments occurs from 0 to 1.68 n.m. offshore for the Avalon Pier profile. If a similar scheme of fining grain sizes attributed to increasing depth is assumed for the Nags Head and Jennettes Pier profiles, an equivalent seaward decrease in grain size should be encountered between 0 to 1.40 n.m. offshore for the Nags Head profile and between 0 to 0.75 n.m. offshore for the Jennettes Pier profile. Thus, the decrease in grain size depicted in Figure 18 takes place closer to shore and within a progressively narrower lateral distance as you go from the Avalon Pier traverse to the Jennettes Pier traverse. This decreasing grain size scheme is evidenced by samples from stations NN-1, 2, and 3 along the Nags Head Pier traverse, and is assumed to occur along the Jennettes Pier traverse.

A major topographic low trough bounded by a major seaward high shoal creates a trap for gravel and/or mud deposition (Figure 2). The low trough is aligned oblique to the shoreline such that it is located 3.08 n.m. offshore at the Avalon Pier traverse, 2.30 n.m. offshore at the Nags Head traverse, and 1.81 n.m. offshore at the Jennettes Pier

traverse. Accordingly, the bimodal topographic low mud and sand or gravelly sand facies occurs closer to shore in the southern portion of the study area. The occurrence of coarse sand and gravel as a lag deposit in the low trough at stations NJ-4 and NN-5, as well as stations immediately shoreward of the trough, NJ-2 and 3 and NN-4, are thought to be associated with the adjacent shallower seaward shoal complex and/or they may result from in situ lag deposits from the erosion of relict units cropping out at these stations due to the steeper shoreface slope.

A topographic high shoal complex also trends oblique to the shoreline, being further offshore and in deeper water at the Avalon Pier traverse (Figure 2). Lower WIBOV activity is thought to impair the winnowing of the deeper shoals, preventing concentration of the coarse sediment fraction, which may explain the absence or lower abundance of gravels found along the shoal and low trough off Avalon Pier. In addition, the absence of coarse sediments off Avalon Pier may result from the lack of gravel in underlying relict stratigraphic units which act as a sediment source. This is suggested by examination of a 80 ft (24.2 m) land drill hole located at Mann's Point on the sound side of the barrier island, northwest of Nags Head Pier. According to the drill information obtained by Riggs and O'Connor,¹ the stratigraphic units are devoid of coarse grained sediments. If the relict stratigraphic units cropping out offshore along the Avalon Pier profile correlate with the relict units encountered at the land drill hole, the absence of coarse sediments seaward of NA-2 may be accounted for.

¹Unpublished information from Riggs, S. R. and O'Connor, M. P., 1970-1975, UNC Sea Grant Program Project, entitled "Recent Sediments of Eastern North Carolina Estuaries and their Relationship to Plio-Pleistocene Mineral Deposits."

In conclusion the following relationships are made based on surface sedimentological data which is portrayed by the sediment distribution map.

1. Increases in depth in conjunction with distance offshore result in finer grained sediments as long as the bottom profile forms a planar surface.
2. Topographic lows are conducive to mud deposition with or without lag gravels.
3. Topographic highs are comprised of winnowed sediments of uniform grain size, with larger grain sizes occurring on the major shallower shoal complexes.

S T R A T I G R A P H I C C O R R E L A T I O N -
N A G S H E A D A R E A

Lithologic units in the vibracore samples are broken down into two major stratigraphic types (Table 3). Type one is interpreted as the modern sediment sheet, defined as sediments which are a product of present processes and environments, and type two being the modern-relict sediments defined as sediments which are a product of an earlier and different environment. The term modern-relict is used because of difficulty in discerning whether the sediments are modern, undisturbed relict, or relict being actively modified by modern processes. Subdivisions within the modern and modern-relict stratigraphic types are based on distinct lithologic variations in the sedimentary units.

The modern units consist of clean sands and gravels along with some mud deposits. In contrast, the relict units consist of dense clays and dirty or muddy sands and gravels, which do not represent sediments that have been actively winnowed by wave action. The presence of estuarine bivalves suggests that these relict units may be estuarine or lagoonal deposits. Lithologic evidence of dirty coarse gravels and seismic evidence of subsurface channels further suggest that some of the relict units may represent fluvial deposits. The thickness of the modern barrier sands and the depth of the relict stratigraphic units at the shoreward end of the sample traverses was extrapolated from unpublished drill information from Riggs and O'Connor.²

Lithic descriptions of the vibracores sampled along each of the traverses are presented in Figures 19, 20, 24, 25, 28, and 29. Cross

²Ibid.

TYPE OF STRATIGRAPHIC UNIT	LITHOLOGIC DESCRIPTION
1. Modern Sediment Sheet	1A. light orange clean fine to medium sand 1B. orange poorly sorted slightly gravelly or gravelly medium to coarse sand 1C. gray clean very fine to fine sands with slight very fine shell material 1D. orange clean gravelly fine to coarse sand 1E. dark organic-rich high water content mud
2. Modern - Relict Sediments	2A. gray clean slightly shelly very fine to fine sand 2B. gray slightly shelly slightly muddy very fine to fine sand 2C. gray sandy mud 2D. gray coarse to very coarse sand 2E. dark gray mud or clay 2F. dirty to clean gravelly coarse sand with very abraided shell material 2G. gray clean fine to medium sand with abraided shell material 2H. dark gray very shelly sandy mud with very abundant whole <u>Mulinia</u> shells 2I. brown silty mud to muddy sand with abundant <u>Mulinia</u> shells

Table 3. Lithologic divisions of vibracores from the Nags Head nearshore inner continental shelf.

correlation between the core sections is illustrated in Figures 21, 26, and 30. Correlation lines attempt to delineate the modern and modern-relict stratigraphic units. From the vibracore data, seismic information and land drill hole information, a general stratigraphic cross section was constructed for each of the sampling traverses (Figures 22, 27, and 31).

AVALON PIER TRAVERSE

Two major stratigraphic units are recognized along the Avalon Pier traverse (Figure 22). A modern shoreface sediment wedge pinches out in a seaward direction, forming a thin blanket over relict strata. The lithic character of the upper modern stratigraphic unit changes in a lateral direction in accordance with changes in depth and topography. Clean well sorted fine upper shoreface sands gradually give way to very fine and muddy very fine sand in an offshore direction, as evidenced by the core samples.

The contact between the relict and modern stratigraphic units below the upper shoreface sediment wedge is assumed to be a surface which is not experiencing active erosion by modern day processes. As the modern shoreface sediment wedge thins in a seaward direction, the relict units nearly crop out. At this point, the contact between the relict and modern units appears to be an erosional surface below a thin modern sediment sheet. It further appears that the modern sediment sheet is periodically stripped away during extreme high energy periods, exposing the relict units which may experience erosion. By this mechanism, relict sediments could be eroded and introduced into the modern sediment regime.

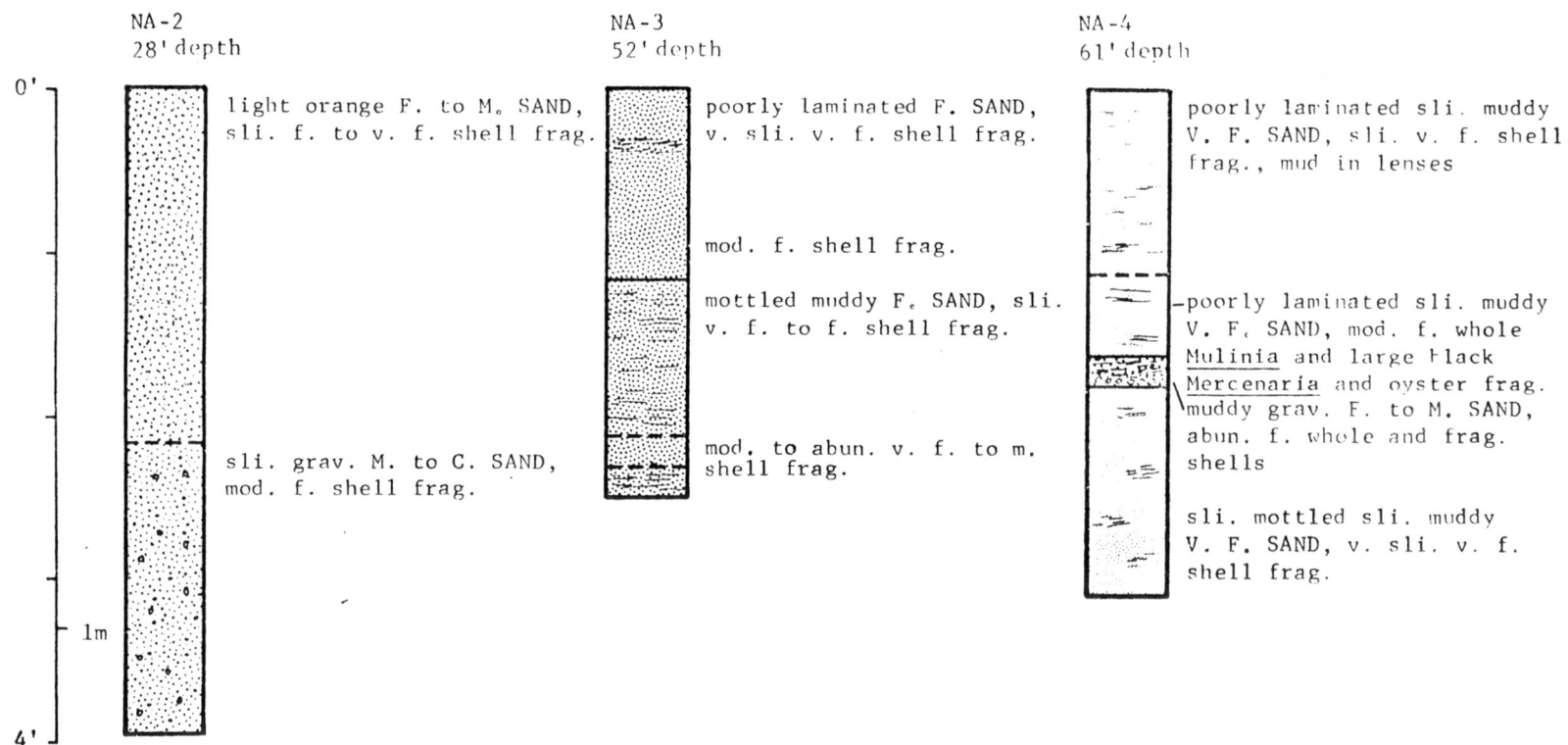


Figure 19. Lithic descriptions of vibracores NA-2, 3, and 4 from the Avalon Pier sample traverse.

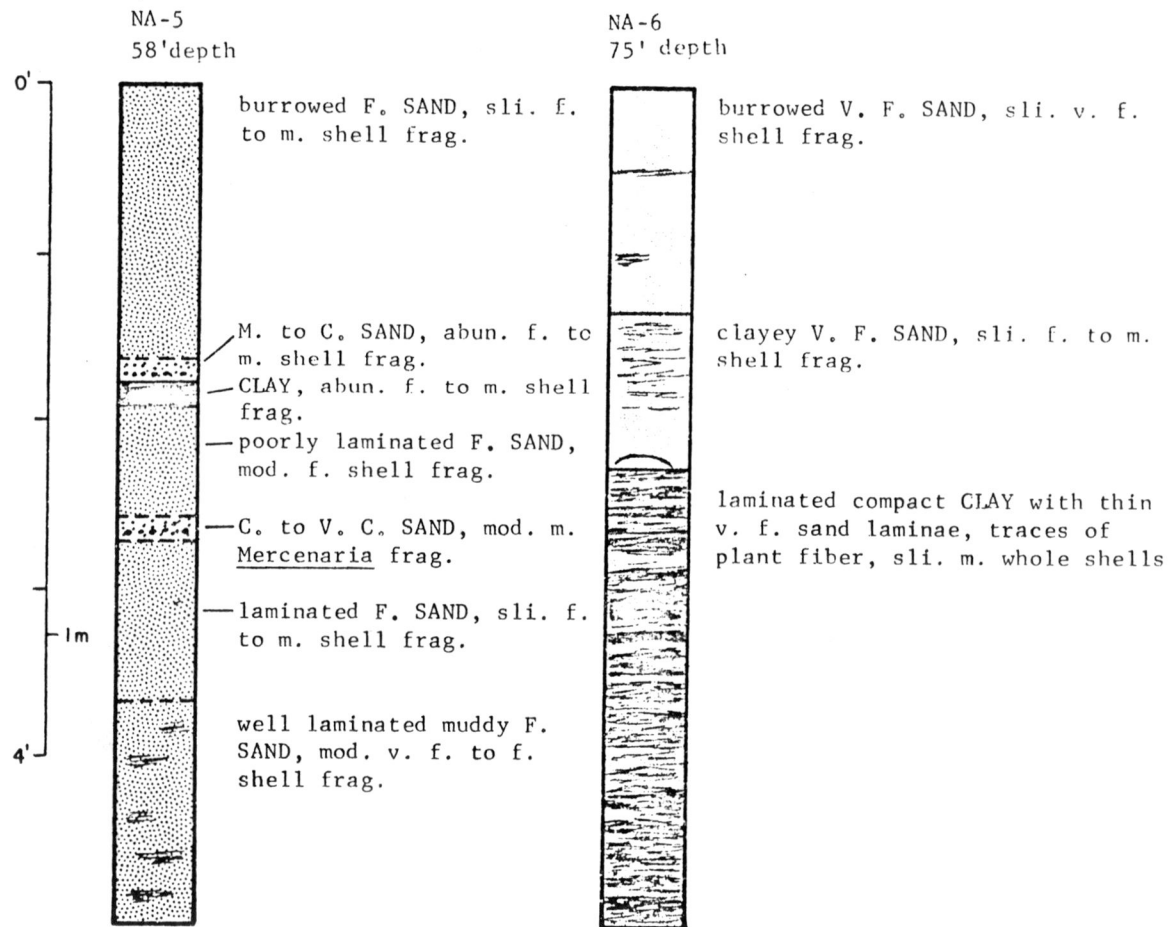


Figure 20. Lithic descriptions of vibracores NA-5 and NA-6 from the Avalon Pier sample traverse.

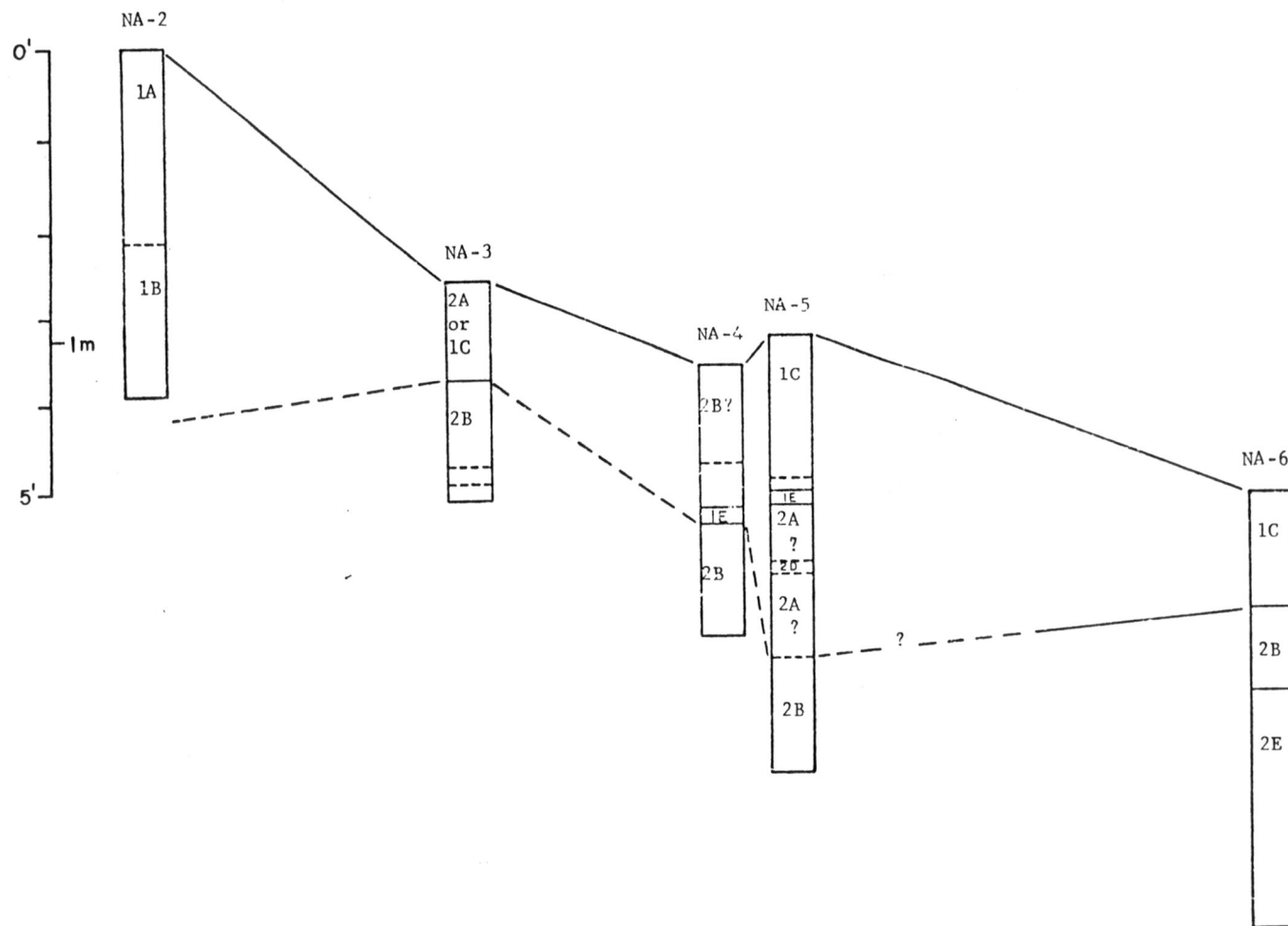


Figure 21. Cross correlation of the Avalon Pier core sections.

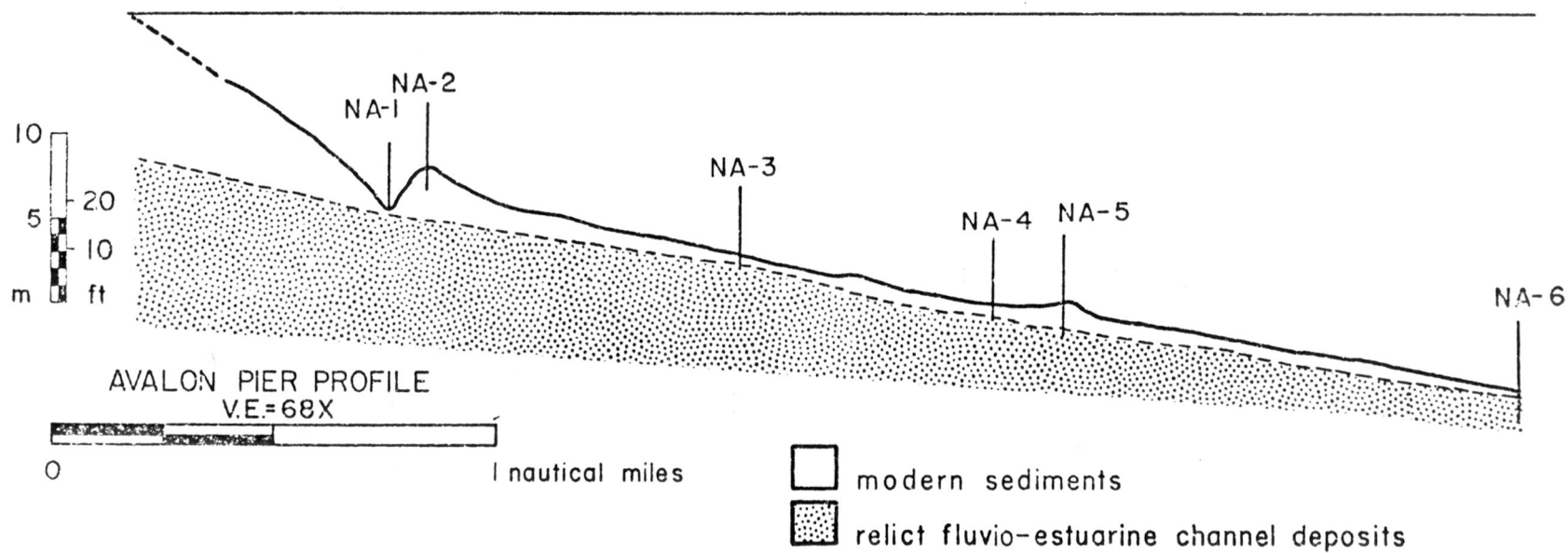


Figure 22. Stratigraphic cross section of the Avalon Pier sample traverse.

The underlying relict strata are interpreted to be fluvio-estuarine channel deposits on the basis of subsurface seismic and vibracore data. Existence of a fluvio-estuarine channel is suggested by strong seismic reflectors marking a major channel located seaward of Kitty Hawk Bay, approximately 1.5 n.m. offshore (Figure 23). The top 2.2 ft (0.7 m) of the NA-6 core is characterized by very fine sand and clayey very fine sand. Below 2.2 ft (0.7 m) the core consists of dense clays with thin laminae of very fine sands containing traces of very fine plant fiber. The upper units are interpreted as the top of the relict unit which has been reworked by modern processes. The lower unit represents an undisturbed relict channel fill, as suggested by the fluvio-estuarine channel picked up by seismic reflectors and by the thin laminae of dense clay and plant fibers.

In addition, the existence of a relict fluvio-estuarine channel is also suggested by evidence of relict beach ridges located on the barrier island north of Kitty Hawk Bay. The ridges are similar in morphology and orientation to modern and relict beach ridges associated with fluvio-estuarine outlets in Nayarit, Mexico (Pearson, 1978; and Curray, 1969). This suggests that at one time a major fluvio-estuarine outlet was located at Kitty Hawk Bay. Although the beach ridges indicate a fluvio-estuarine outlet existed at one time, it is not clear how or if the outlet was associated with the relict channel evidenced by the seismic data.

Clean winnowed sediments found in core samples NA-2 and 5 on topographic high stations demonstrate the active nature of the topographic high environments. Sediments in the NA-2 core are characterized by clean fine to medium sands overlying clean gravelly medium to coarse sand. The upper 1.6 ft (0.5 m) of the NA-5 core consists of clean fine

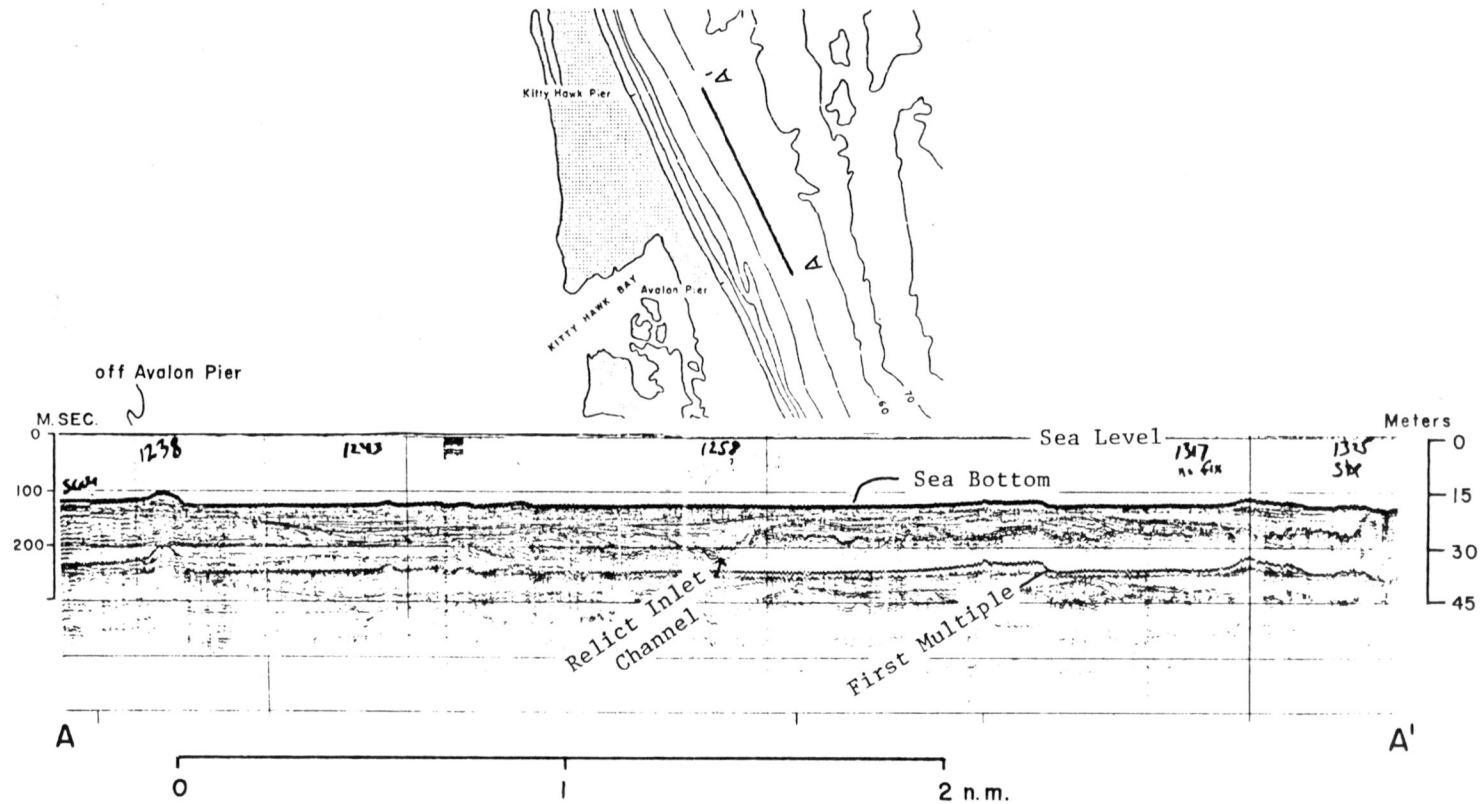


Figure 23. Seismic trace of ancestral Kitty Hawk Bay fluvio-estuarine channel. The bottom of the relict channel has a gentle gradient to the south, 1238, whereas the northern bank exhibits a sharp gradient, 1325. The 3.7 nautical mile wide channel is believed to be associated with the ancestral Albemarle fluvial system (Figure 2). Within the fluvial channel are one or more relict inlet channels. A distinct inlet channel can be seen below 1258. This channel, as is suggested by the cut and fill nature of the seismic reflectors, has migrated from 1243 to a position below 1258. It is suggested that the fluvial channel formed during a lower stand in sea level, followed by a sea level rise and subsequent filling of the channel.

sand. In contrast, the upper portions of cores from adjacent seaward and shoreward stations consist of slightly muddy very fine sand. The differences arise from active winnowing of the NA-5 sediments due to WIBOVC activity being focused on the topographic high station. A pelletal mud unit occurs below the upper winnowed sediments in the NA-5 core and is thought to represent a buried modern topographic low mud facies. Burial of the topographic low mud probably resulted from the migration of the low amplitude topographic high sand wave covering the shoreward topographic low environment where pelletal muds were observed to be accumulating.

NAGS HEAD PIER TRAVERSE

Two major stratigraphic units are discernable along the Nags Head traverse (Figure 27). A modern shoreface sand wedge overlies relict strata of estuarine-lagoon or inlet channel deposits. The shoreface sands pinch out in a seaward direction giving way to the underlying eroded surface of relict strata. The erosional contact between the modern and relict units is suggested by seismic reflectors. Near parallel reflectors within the relict strata are truncated by a strong seaward dipping reflector. This reflector is interpreted as marking the erosional contact between the modern and relict units. In addition, the modern shoreface sands become finer in a seaward direction as is discerned in core samples NA-1, 2, and 3.

Seismic data suggest that an eroded relict surface appears to come close to cropping out near NN-3. This is where possibly relict strata is first encountered in the core samples. The top 2.7 ft (0.8 m) of the NN-3 core consists of uniform sediments which overlie a thin pebbly clay unit. The clay unit shows evidence of being deposited in a

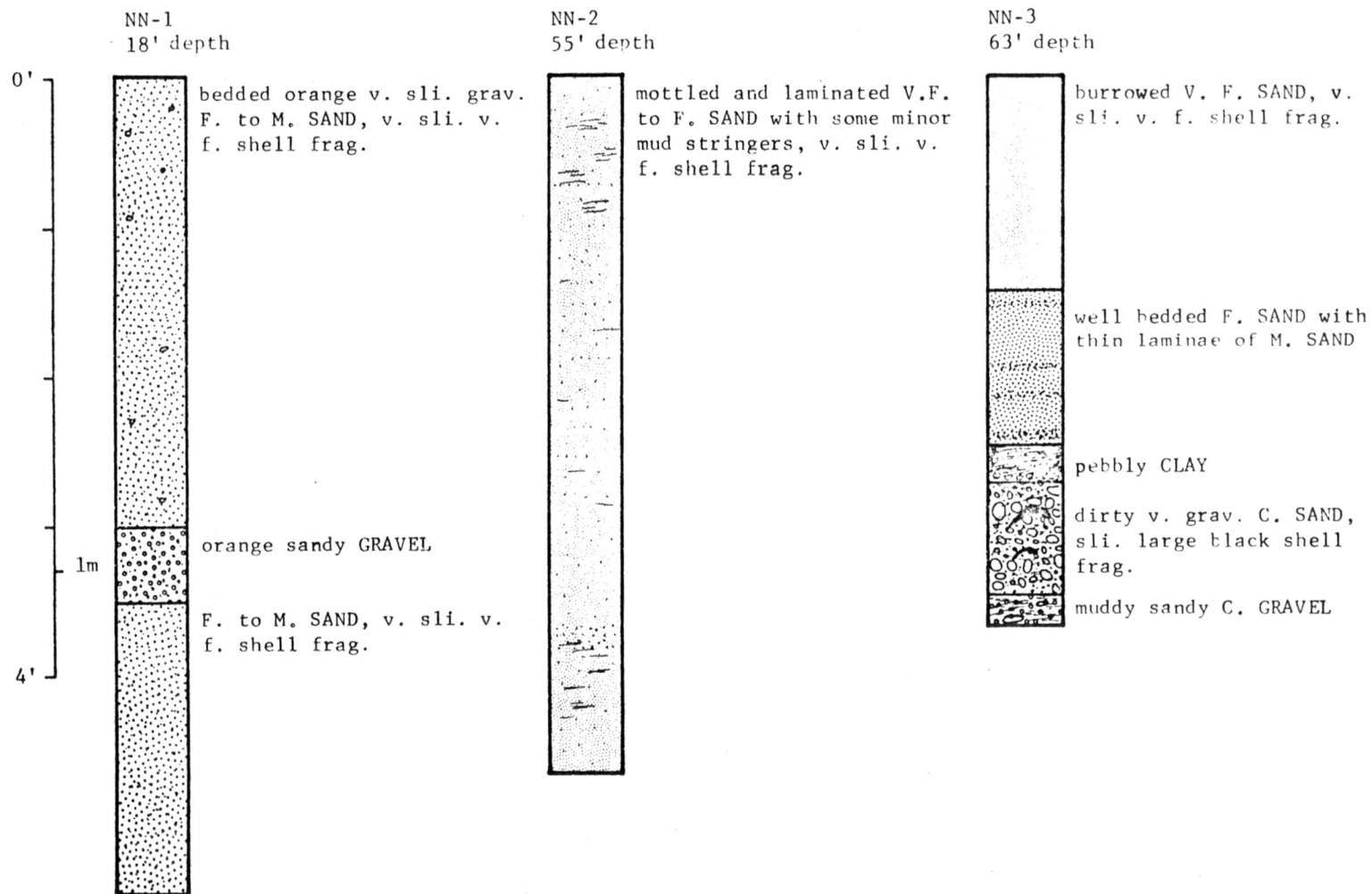


Figure 24. Lithic descriptions of vibracores NN-1, 2, and 3 from the Nags Head Pier sample traverse.

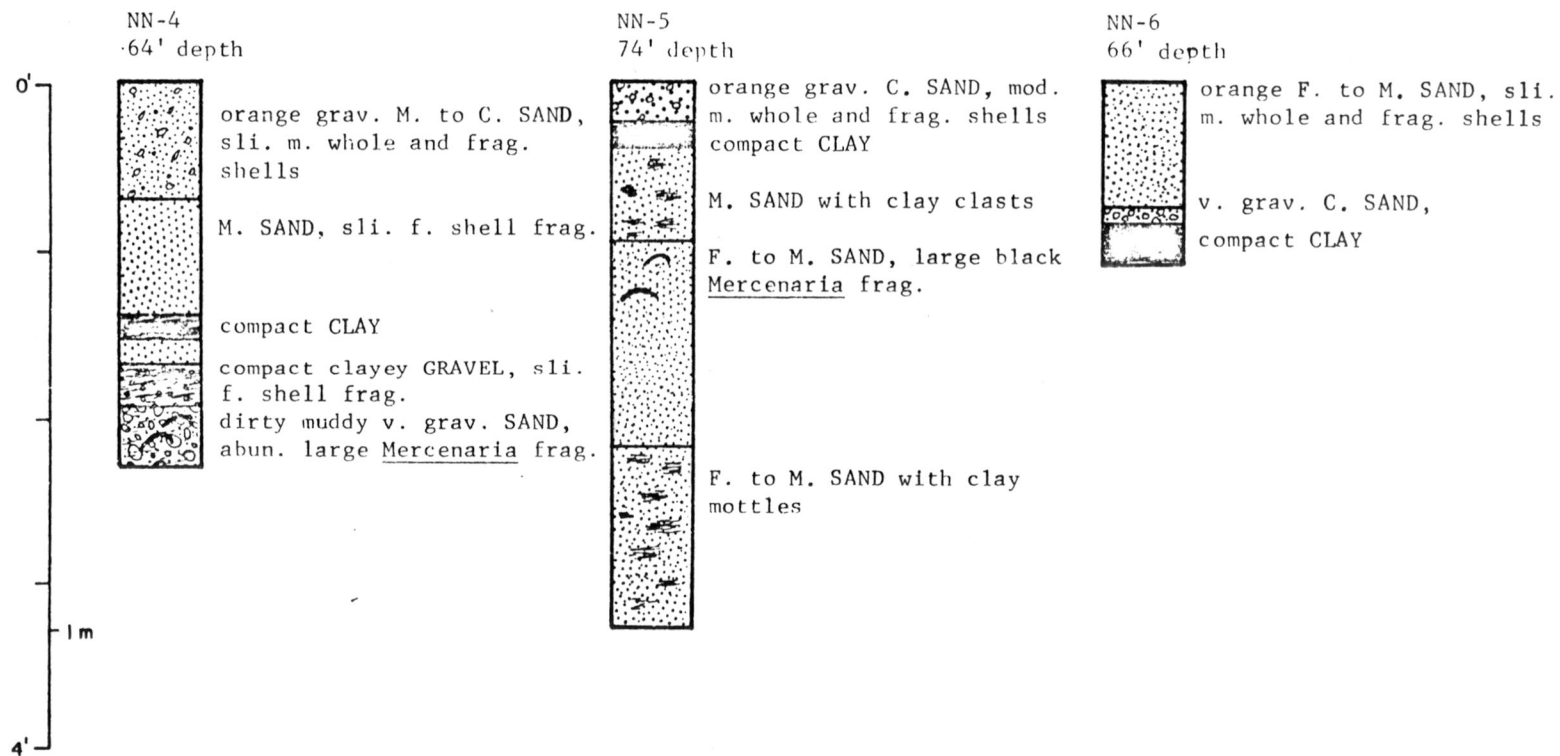


Figure 25. Lithic descriptions of vibracores NN-4, 5, and 6 from the Nags Head Pier sample traverse.

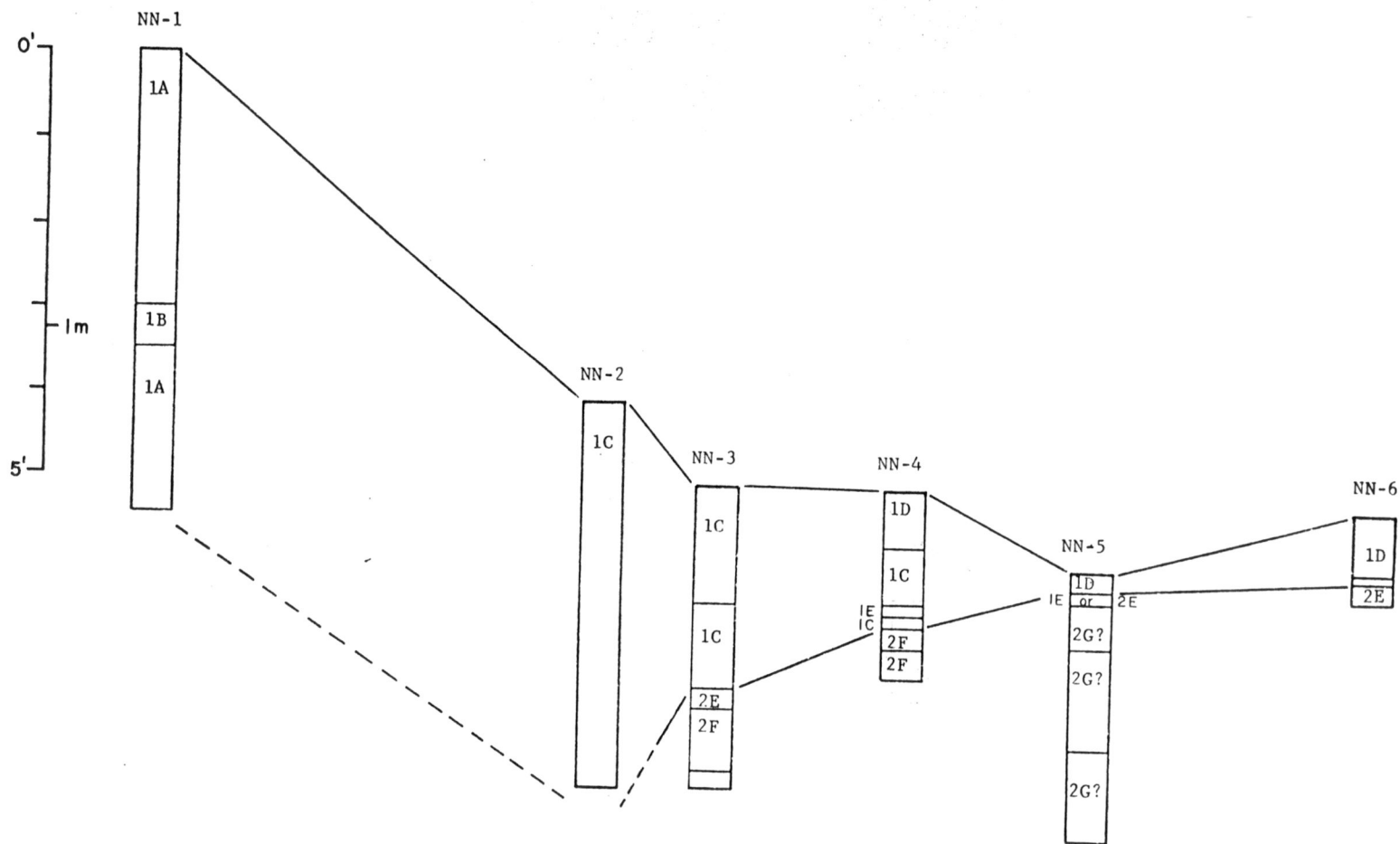


Figure 26. Cross correlation of the Nags Head Pier core sections.

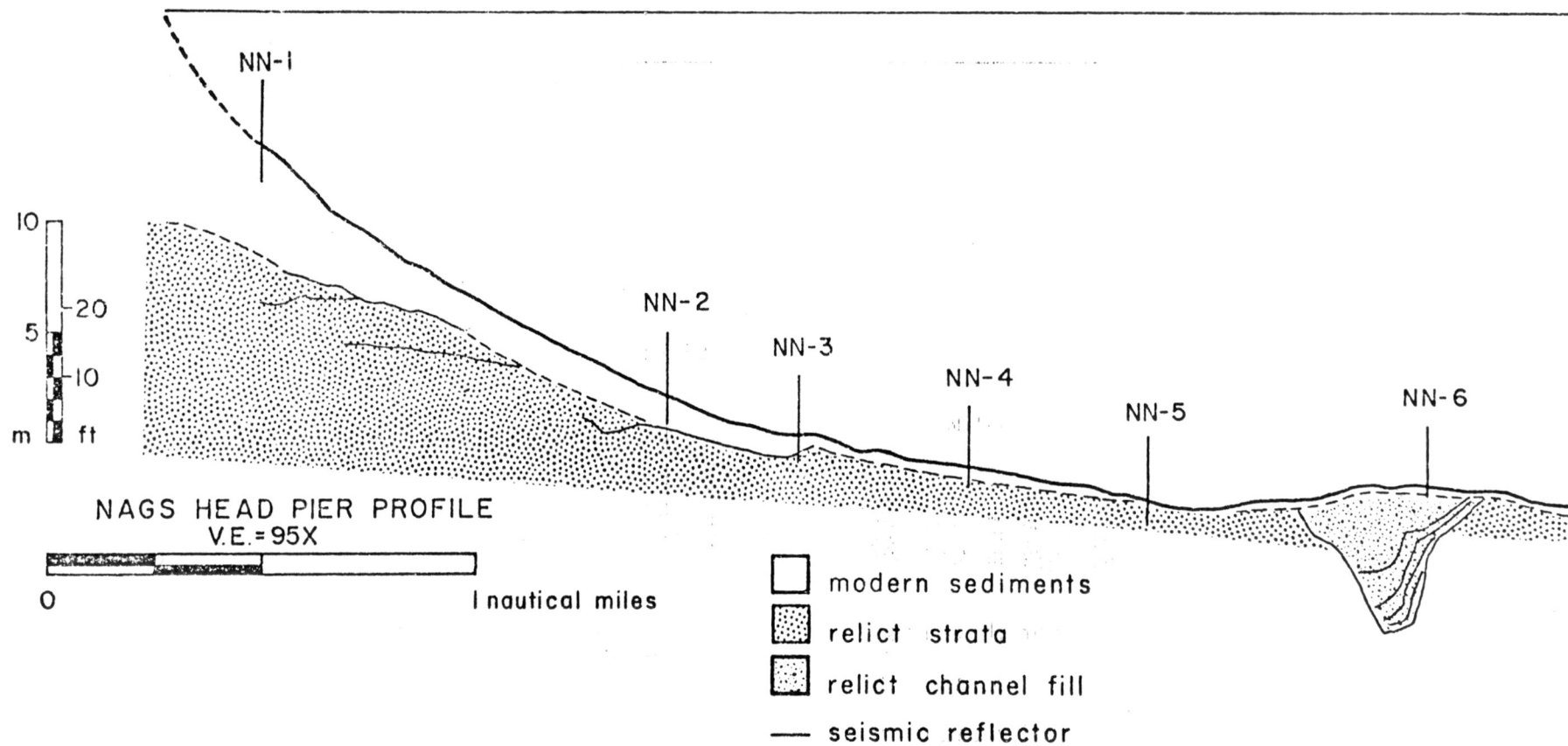


Figure 27. Stratigraphic cross section of the Nags Head Pier sample traverse.

graded sequence with a gravel base, suggesting that it has been reworked from lower relict units, or that it represents a modern mud deposited with lag gravels that were later covered by lower shoreface sands.

A dark, very poorly sorted, dirty, very gravelly coarse sand is encountered below the gravelly clay, the top of which coincides with a strong seismic reflector which almost crops out at NN-3. This unit is interpreted as being relict. The lithic character of the relict unit resembles a relict fluvial muddy gravel encountered at the base of Roanoke Island in land cores by Riggs and O'Connor.³ The coarse nature of the NN-3 sediments suggest that the unit may be an in situ lag deposit resulting from reworking of the relict strata. In addition, the unit may coincide with a basal transgressive muddy gravel encountered between 45 to 50 ft (13.7 to 15.2 m) below the surface in land drill holes CS85 and CS97, which are located 0.1 n.m. landward of and approximately 0.8 n.m. north of Jenettes Pier, respectively (Riggs and O'Connor).⁴

A relict dirty gravelly sand is again encountered 1.9 ft (0.6 m) below the surface in the NN-4 core. Overlying the relict unit is a gravelly clay similar to the NN-3 core and the sequence is therefore interpreted likewise.

Core sample NN-5 consists of 0.2 ft (0.1 m) of modern orange shoal sands overlying units of dense clay and fine to medium sand with clay clasts. It is not readily discernable whether the stratigraphic units below the modern shoal sand are modern or relict, although they are believed to be relict due to the occurrence of the dense clay.

³Ibid.

⁴Ibid.

The NN-6 core consists of 0.7 ft (0.2 m) of modern orange shoal sands which overlie a dense uniform clay. Seismic tracers delineate a relict channel at station NN-6, suggesting that the dense clay may represent a relict channel deposit.

JENNETTES PIER TRAVERSE

Two major stratigraphic units are discernable along the Jennettes Pier traverse (Figure 31). A modern shoreface barrier sand wedge pinches out at the lower shoreface near station NJ-2. Here it becomes a thin sediment blanket covering the eroded surface of relict strata.

The relict units consist of at least 3 subunits. The upper unit is an estuarine-lagoonal muddy sand, underlain by a dirty lag deposit of black abraded coarse shell fragments and coarse quartz pebbles, which is underlain by a distinct estuarine-lagoonal muddy very fine sand and clay unit characterized by a high abundance of whole Mulinia lateralis and Nucula proxima. Seismic reflectors are thought to mark the eroded surface of the relict units below NJ-1. This marks the contact between the modern and relict stratigraphic units. Near outcropping of a seismic reflector at NJ-2 delineates the thin modern sediment blanket overlying relict stratigraphic units. The same seismic reflector is detectable below NJ-1, where it is thought to coincide with the top of the distinct relict Mulinia clay bed, encountered at 50 ft (15.2 m) below mean sea level, in land drill hole CS95, which is located 1.4 n.m. west of Jennettes Pier (Riggs and O'Connor).⁵ Therefore, the reflector is believed to mark the surface of the Mulinia bed below NJ-1, NJ-2, and again between NJ-3 and 4 where it crops out.

⁵Ibid.

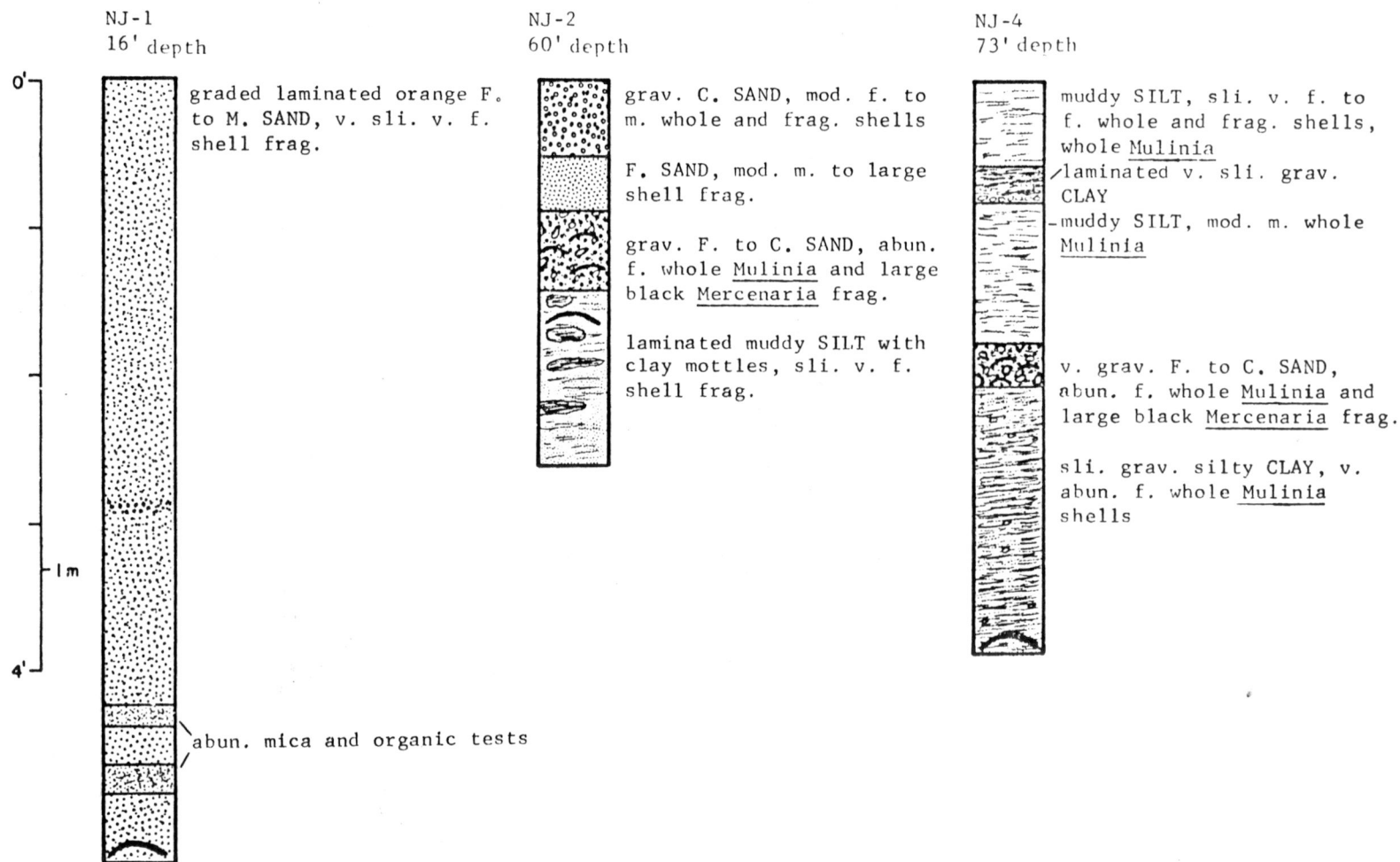


Figure 28. Lithic descriptions of vibracores NJ-1, 2, and 4 from the Jennettes Pier sample traverse.

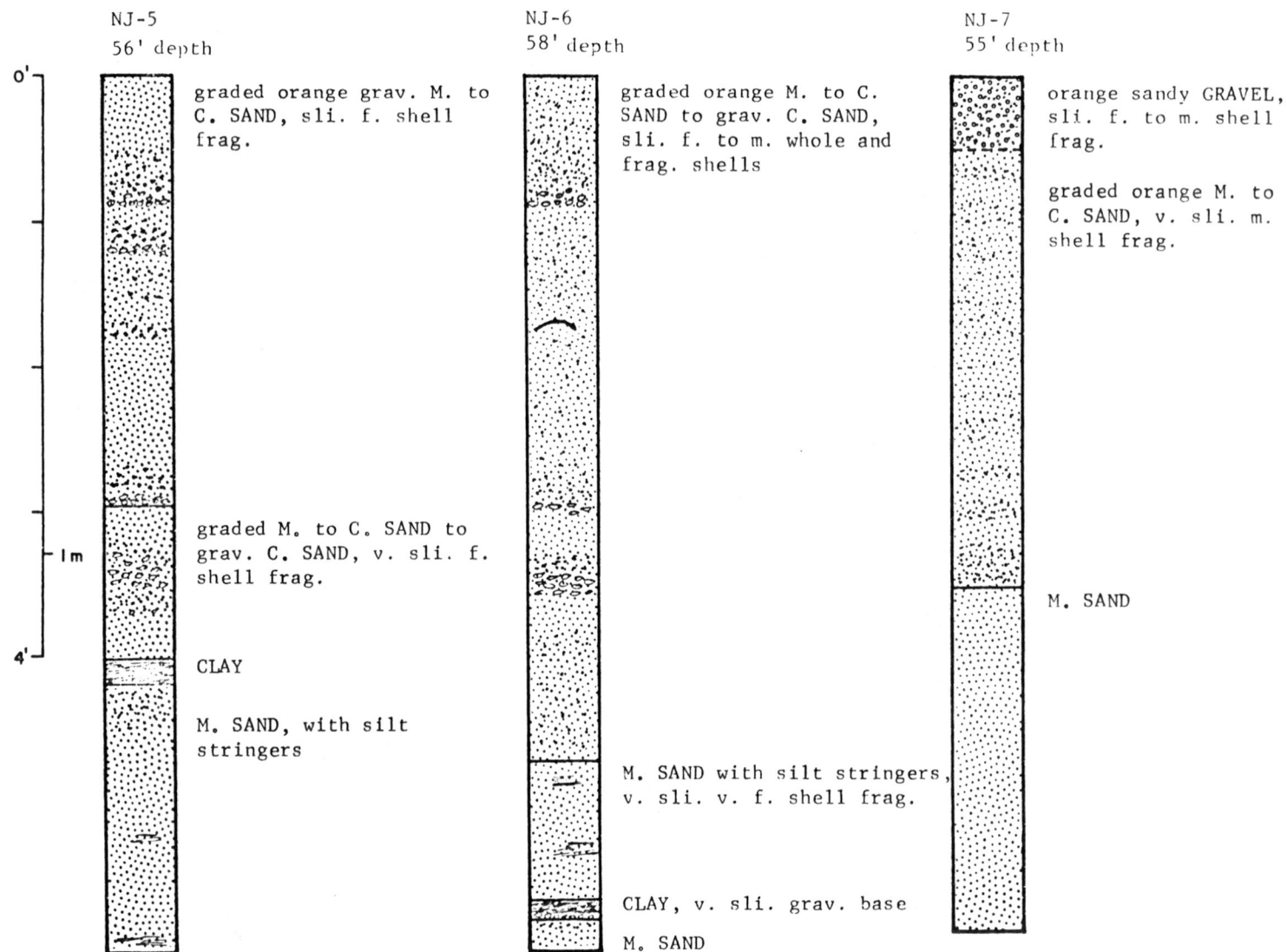


Figure 29. Lithic descriptions of vibracores 5, 6, and 7 from the Jennettes Pier sample traverse.

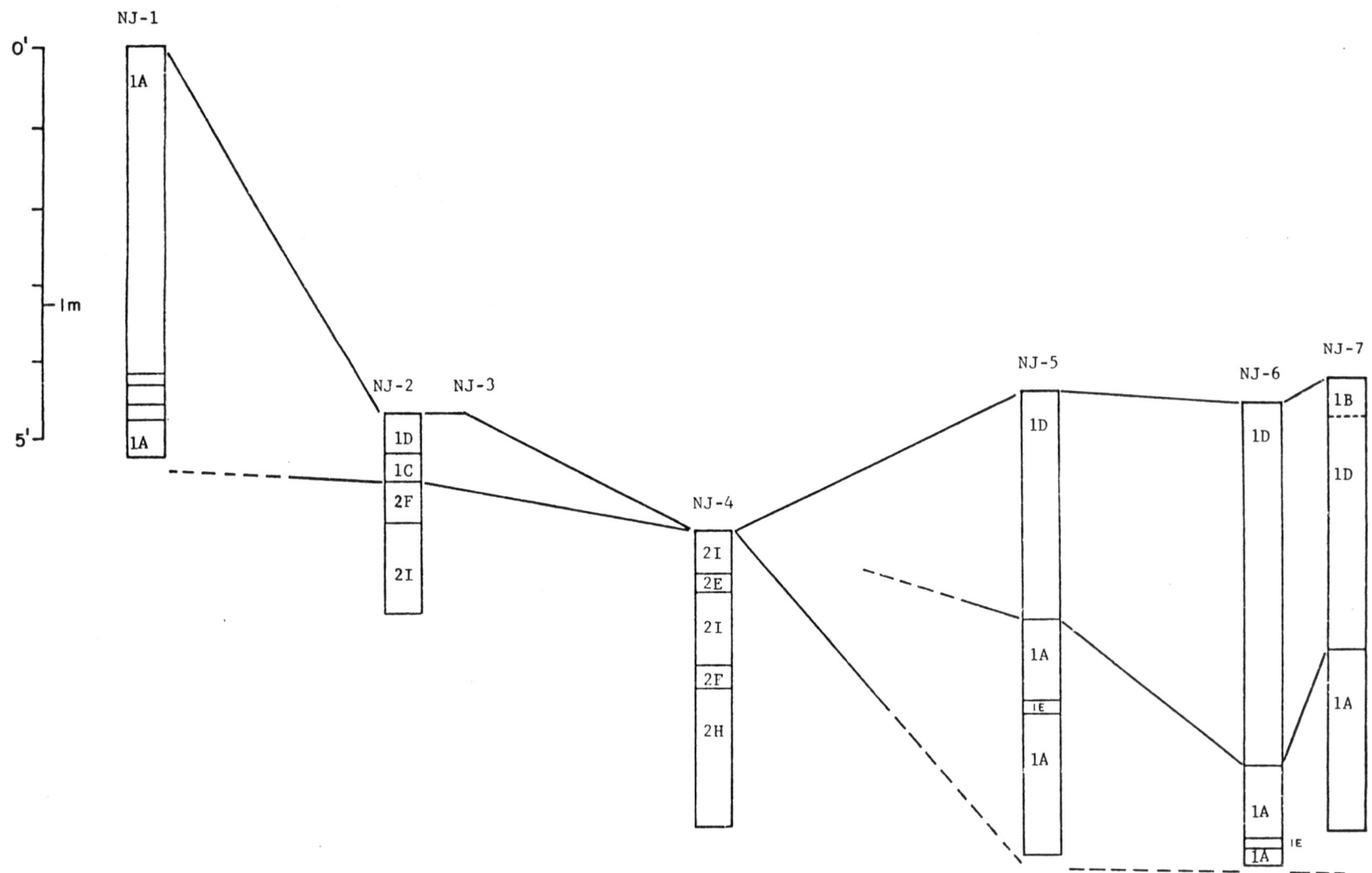


Figure 30. Cross correlation of the Jennettes Pier core sections.

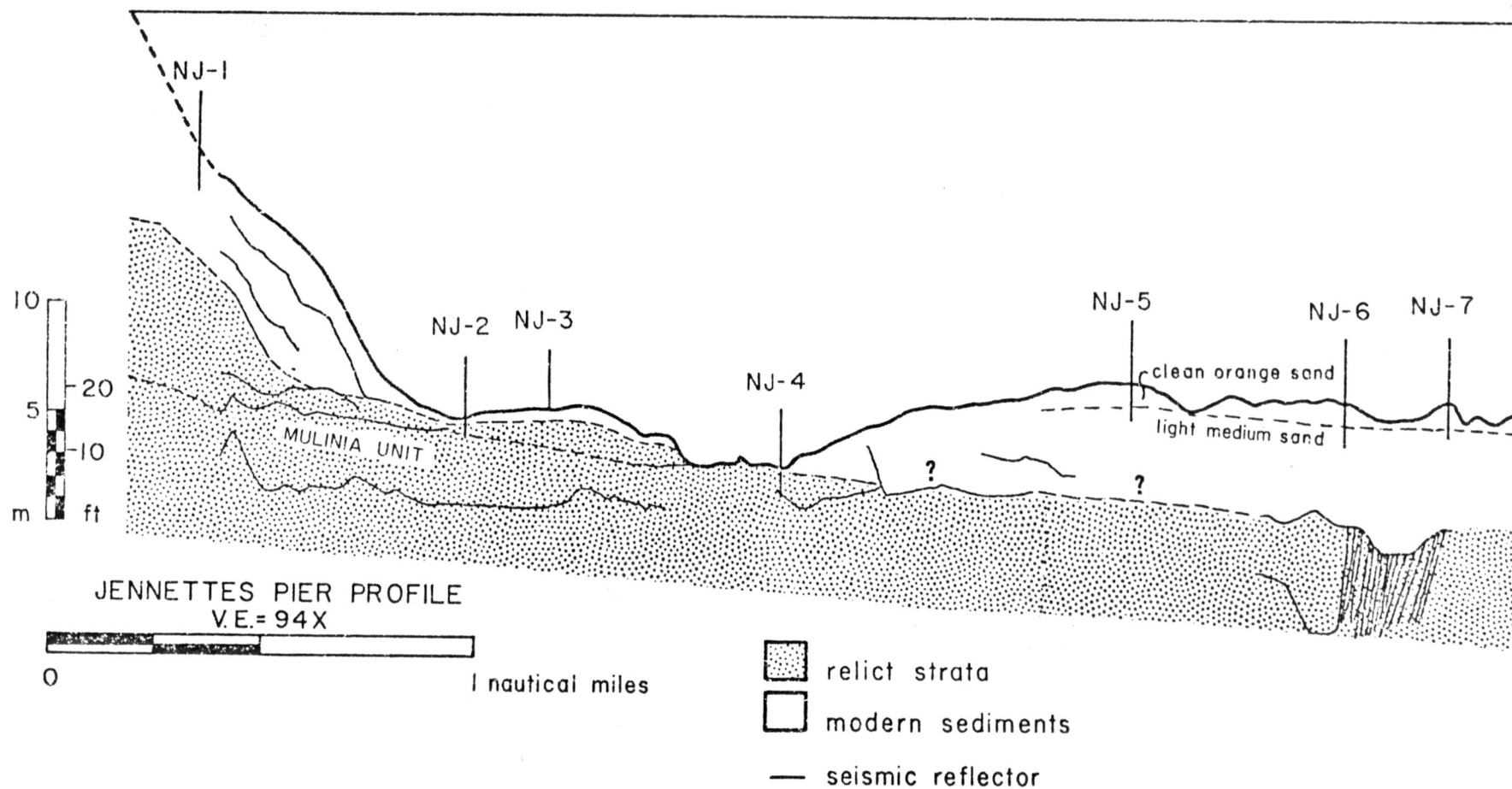


Figure 31. Stratigraphic cross section of the Jennettes Pier sample traverse.

The upper 0.9 ft (0.3 m) of the NJ-2 core is interpreted as modern sediments below which is a very gravelly fine to coarse sand unit with whole Mulinia lateralis and large black abraded shell fragments. This unit, similar to units in NN-3 and 4, represents either an undisturbed relict basal lag gravel or a lag deposit resulting from the reworking of relict strata by modern processes. Below the gravel unit is a dark laminated muddy silt with clay mottles and whole Mulinia lateralis shells, which represents either the surface or reworked surface of the relict estuarine-lagoonal Mulinia unit.

The upper 1.7 ft (0.5 m) of the NJ-4 core resembles the lower unit of the NJ-2 core and is interpreted as such. A 0.3 ft (0.1 m) unit of dense clay with a pebble base within the upper 1.7 ft (0.5 m) of NJ-4 suggests that the unit is a modern mud deposited among reworked sediments from the underlying relict Mulinia unit. The lower stratigraphic unit of NJ-4 is a slightly gravelly silty clay with a high density of whole Mulinia lateralis and Nuclea proxima shells. Both of these molluscs live in restricted marine-estuarine environments. According to Riggs (per communication, 1979), the Mulinia bed represents a major mappable relict stratigraphic unit which underlies the Nags Head area. Comparison of the Mulinia unit from land core CS76, drilled at the north end of Roanoke Island,⁶ with the offshore Mulinia unit from NJ-4 supports correlation between the units. As previously stated, seismic reflectors suggest that the relict Mulinia unit outcrops west of NJ-4. According to diver observations, the bottom at station NJ-4 is very irregular with clay escarpments and depressions. Thus, this suggests that the station may mark the exposed surface of the relict Mulinia stratigraphic unit.

⁶Ibid.

Vibracores from NJ-5, 6, and 7 represent modern shoal sands, consisting of graded sequences of clean orange gravelly medium to coarse sand which overlie light well sorted slightly gravelly medium sands. A pelletal clay unit is encountered in the lighter sand unit of NJ-5 and 6. The mud is thought to be modern, having been deposited in a minor topographic low on the topographic high shoal complex and later buried by active migration of the shoal sands.

Although relict strata was not encountered in the shallow cores taken on the shoal complex, the relict strata is interpreted to be approximately 15 ft (4.6 m) below the modern sediment surface as suggested by scanty seismic data in addition to work by Sears (1976) and Swift (1973). A schematic illustration of the shoal sands overlying a relict clay substrate is presented in Figure 16 (Duane et al, 1972). The figure depicts the situation observed at NJ-4, where the relict clay substrate was found outcropping in a topographic low. Seaward of the low, the relict substrate is covered by shoal sands (NJ-5, 6, and 7; Figure 31). It should also be noted that the coarse gravelly shell unit found in the NJ-2 core coincides with and may be representative of the coarse pebbly sand layer illustrated in Figure 16.

S U R F A C E S E D I M E N T R E G I M E -
W I L M I N G T O N A R E A

Due in part to the rising of the Cape Fear Arch, which has been active at least since the Tertiary, and minimal terrigenous sediment input by Coastal Plain rivers emptying into Onslow Bay, the Wilmington nearshore inner continental shelf is characterized by a unique sediment package. This unique sediment package is mostly comprised of sediments derived from an internal source within the nearshore inner continental shelf. Sediment input from this internal source results from: 1) the reworking by modern day processes of relict shells, rock fragments, sands, and clays; and, 2) from the introduction of "new" sediments resulting from the increased activity of benthic organisms on rock substrates.

Organisms play a major role in the production of modern sediments on the Wilmington nearshore shelf in two different ways. First, the shelf is characterized by abundant Lower Tertiary to Quaternary rock outcrops which are covered with a relatively thin and scattered sediment blanket (Riggs, 1979). These rock substrates provide hardgrounds which are characterized by diverse and large populations of benthic organisms. This results in an increased input of calcium carbonate shell material to the sediment regime. Second, the rock exposures are extensively bored and corroded by the benthic epi- and infauna, thus contributing abundant rock fragments to the total sediment regime (Crowson and Riggs, 1976). Shell and rock fragments were found to make up approximately 15-20% of the surface sediments, with some surface sediment samples consisting of greater than 45% shell and rock

fragments. Gravel and very coarse sands in 17 of 19 surface samples examined consist of approximately 80-100% shell and rock fragments.

Consequently, the abundant exposures of rock substrates of varied lithologies, plus the continuous reworking of the thin modern-relict sediment sheet overlying the rock strata, results in a complex surface sediment regime for the Wilmington nearshore shelf. These sediments, although modified by the hydraulic regime, result in complex sediment facies which reflect the proximity and type of rock located on the nearshore shelf. Accordingly, distinct sediment facies outlined for and found on the Nags Head nearshore shelf, with the exception of topographic low and topographic high facies, are not as readily discernable on the Wilmington nearshore shelf. Although the complexity of sedimentary facies on the Wilmington shelf prevents categorization of facies types, facies are recognizable along the Wrightsville Beach traverse. This results from the offshore transport and hydraulic sorting of sediments from numerous beach nourishment projects along Wrightsville Beach.

SEDIMENT DESCRIPTIONS OF SAMPLE STATIONS

Wrightsville Beach Traverse

The northernmost sample traverse extends seaward for 3.05 n.m. from the municipal water tank, 0.23 n.m. north of Mercer's Pier, at Wrightsville Beach. Six sample stations were occupied along the traverse (Figures 3 and 32).

Station WW-1 represents a shoreface station, located 0.25 n.m. offshore in 22 ft (5.7 m) of water. Surface sediments are well sorted, very slightly granular fine sands containing 1.3% gravel, 1.1% mud, and 1.2% s-clay. The sediments represent a type A shoreface facies.

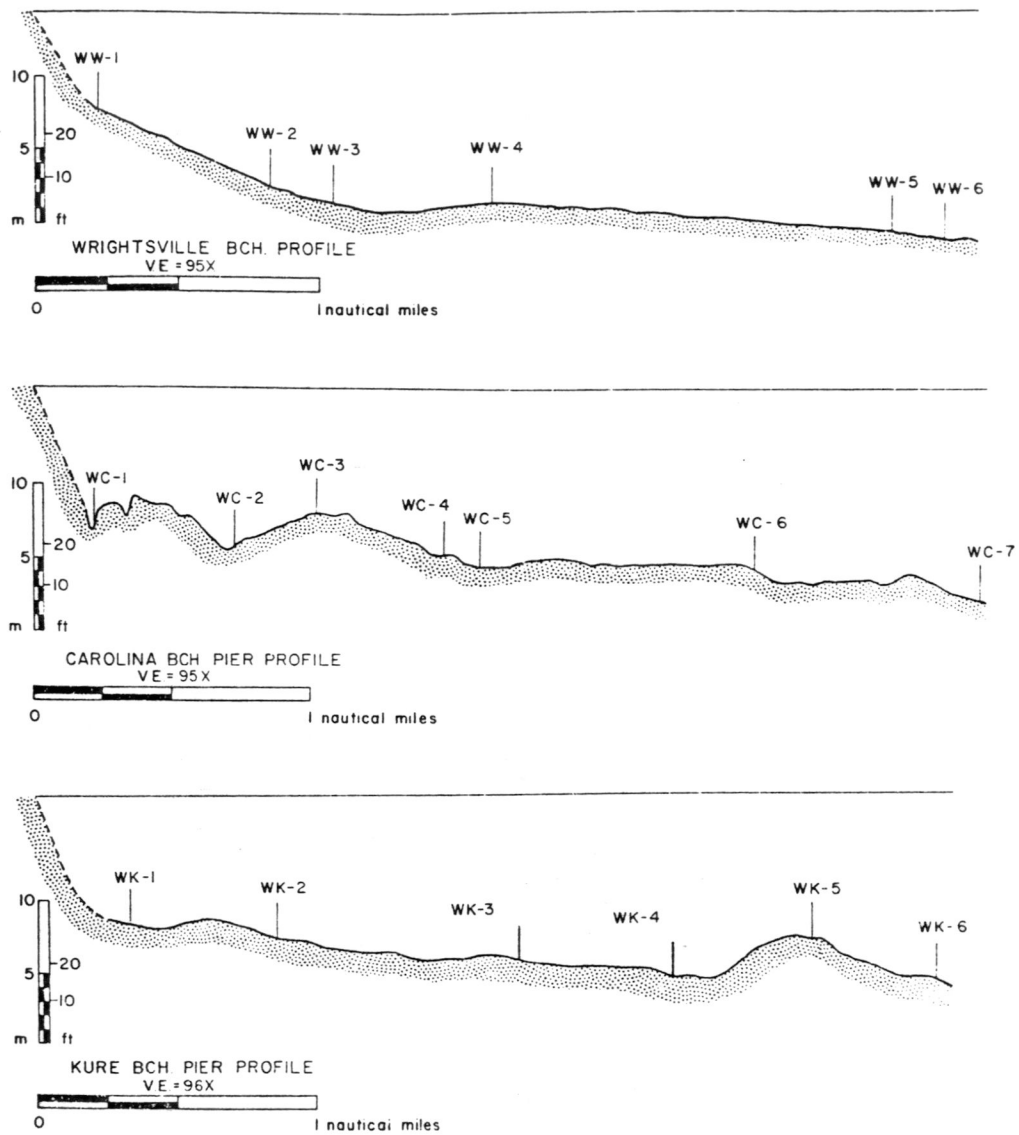


Figure 32. Cross-sectional profiles illustrating bottom topography and station location along the Wilmington sample traverses.

Station WW-2 lies on a topographic plain 0.87 n.m. offshore in 37 ft (11.3 m) of water. Sediments are moderately well sorted, slightly granular medium sands with 1.1% gravel, 1.8% mud, and 1.5% s-clay. They represent a type B lower shoreface or topographic plain facies.

Station WW-3 is located on the west flank of a broad and gentle topographic low, 0.98 n.m. offshore in 43 ft (13.1 m) of water. Surface sediments are poorly sorted, granular very fine sands that contain 7.0% gravel, 6.8% mud, and 4.0% s-clay. Significant increases in percentages of mud, s-clay, organics, and gravel relative to adjacent stations delineate the presence of a type E topographic low facies. The gravel consists of rounded mold and cast sandy limestone, rock fragments, and lesser amounts of phosphate and quartz granules and pebbles. Divers observed that the bottom was covered with the sandy limestone fragments which became more extensive below the upper 0.5 ft (0.2 m) of surface sediments. Here the rock contained abundant bore holes filled with clay. The recovery of several shells of Arcopis adamsi, a mollusc which lives attached to rock, suggests the presence of a hard rock surface.

Station WW-4 is situated on a gentle and broad topographic high, located 1.47 n.m. offshore in 44 ft (13.4 m) of water. The sediments are moderately well sorted, slightly granular fine sands with 1.3% gravel, 1.3% mud, and 1.3% s-clay. Slight decreases in percent mud and s-clay relative to adjacent stations are characteristic of the type C topographic high facies.

Stations WW-5 and WW-6 are located on a topographic plain 2.79 and 3.05 n.m. offshore in 51 ft (15.5 m) and 54 ft (16.5 m) of water,

respectively. Surface sediments of station WW-5 are well sorted, very slightly granular very fine sands containing 0.3% gravel, 2.1% mud, and 2.3% s-clay. Station WW-6 sediments are well sorted, very slightly gravelly fine sands that contain 0.3% gravel, 2.7% mud, and 2.9% s-clay. Both stations experience a slight increase in percent mud and s-clay relative to the shoreward topographic high station. Consequently, sediments from both stations are classified as type B deeper topographic plain facies.

Carolina Beach Pier Traverse

The Carolina Beach Pier traverse is located 10.75 n.m. south of the Wrightsville Beach sampling traverse and consists of 7 sample stations, with the seawardmost station located 3.29 n.m. offshore (Figure 32).

Station WC-1 is located in a well defined, narrow topographic low 0.20 n.m. offshore in 28 ft (8.5 m) of water. Analyses of two samples, collected from different depths in the topographic low, demonstrate the bimodal character of the sediments. Sample WC-1 was collected on the flank of the low trough. The sediments are moderately sorted, slightly granular medium sands with the gravel and coarse sand fraction being iron-stained orange. Sample WC-1-23, collected in the middle of the low trough, is characterized by a poorly sorted mud containing 93.2% mud (of which 27.1% is clay, and 14.4% is organic matter). According to diver observations, the mud consists of a very easily disturbed black deposit, 38 cm in thickness, overlying a surface of medium sand. Accordingly, the sediments are classified as a type E topographic low facies. This station demonstrates the ability of topographic lows to accumulate mud in the shallow nearshore area.

Station WC-2 is located in a topographic low 0.72 n.m. offshore in 33 ft (10.1 m) of water. Surface sediments are poorly sorted, granular coarse sands containing 10.7% gravel and 1.5% mud. Divers observed a coquina rock fragment and clay clasts 8 cm below the sediment surface.

Station WC-3 is located on a topographic high 0.96 n.m. offshore in 26 ft (7.9 m) of water. The surface sediments are moderately sorted, slightly granular fine sands with 3.8% gravel and 1.3% mud. Shell fragments were found by the divers to become very abundant 0.5 ft (0.2 m) below the sediment surface.

Station WC-4 is situated on the seaward flank of a topographic high, 1.49 n.m. offshore in 41 ft (12.5 m) of water. Surface sediments are moderately well sorted, fine sands that contain 0.6% gravel and 0.6% mud.

Station WC-5 is situated in a slight topographic low 1.61 n.m. offshore in 43 ft (13.1 m) of water. Surface sediments are poorly sorted, granular fine sands with 6.3% gravel, 1.9% mud, and 1.8% organics.

Station WC-6 is located 2.50 n.m. offshore in 43 ft (13.1 m) of water. The sediments are poorly sorted, granular fine sands containing 6.1% gravel, 1.3% mud, and 1.0% organics.

Station WC-7 is located 3.30 n.m. offshore in 47 ft (14.3 m) of water. Surface sediments are moderately well sorted, granular fine sands with 1.5% gravel, 0.9% mud, and 1.0% organics.

Kure Beach Pier Traverse

The southernmost sample traverse was run off of Kure Beach Pier, 3.70 n.m. south of Carolina Beach Pier. Six sample stations were

occupied, with the seawardmost being located 3.05 n.m. offshore (Figure 32).

Station WK-1 is located 0.37 n.m. offshore in 27 ft (8.2 m) of water. Surface sediments are moderately sorted, slightly granular medium sands containing 3.6% gravel and 1.1% mud.

Station WK-2 is located 0.82 n.m. offshore in 33 ft (10.1 m) of water. Surface sediments are poorly sorted, granular fine sands with 7.0% gravel and 2.4% mud. Abundant large Mercenaria and less abundant Busycon shell fragments were observed covering the bottom. A diver-collected sample consists of approximately 90% shell fragments which are very highly abraded and extensively bored.

Station WK-3 is located 1.50 n.m. offshore in 38 ft (11.6 m) of water. The sediments are poorly sorted, granular coarse sands containing 6.9% gravel and 2.4% mud. Large coquina rock fragments and very abundant large, whole, black stained Mercenaria shells covered the bottom. The presence of the coquina fragments suggests that rock may crop out near the station.

Station WK-4 is located 1.93 n.m. offshore in 41 ft (12.5 m) of water. Surface sediments are poorly sorted, granular very coarse sands that contain 8.1% gravel and 1.7% mud.

Station WK-5 is situated on a well defined topographic high 2.26 n.m. offshore in 34 ft (10.4 m) of water. Surface sediments are moderately well sorted, slightly granular fine sands containing 1.8% gravel and 0.5% mud. A significant decrease in mud and an increase in sorting characterize the station as a type C topographic high sediment facies.

Station WK-6 is located 3.05 n.m. offshore in 44 ft (12.6 m) of water. Surface sediments are poorly sorted, granular fine sands containing 7.7% gravel and 0.9% mud.

CORRELATIONS BETWEEN SEDIMENTS AND BOTTOM TOPOGRAPHY

Plots of statistical sediment parameters against topographic profiles reveal that certain general relationships exist. Most notable relationships are exhibited by well defined topographic highs and lows, while statistical grain parameters associated with the topographic plain stations varied considerably due to the complex sediment regime of the Wilmington nearshore shelf.

Examination of Figure 33, illustrating a plot of sorting versus topography, reveals that considerable increases in sorting are detectable on the topographic highs, while decreased sorting occurs in the well defined topographic lows.

Plotting the percentages of mud from shipek samples against topography also reveals a general correlation (Figure 34). Although only low percentages of mud were detected, obvious increases occur within topographic lows while decreasing percentages occur on topographic highs. The most significant occurrence of mud was found at station WC-1. Black organic-rich muds, similar to the type of muds in the Nags Head area, were observed in the low trough at the station. Accumulation of 38 cm of the organic-rich mud, consisting of 93.2% mud (of which 27.1% is clay and 14.4% is organic matter) was found collecting in the low trough.

A close correlation exists between percentages of both s-clay and organic matter versus topography for the Wrightsville Beach traverse (Figure 35). Because of the sampling procedures, similar data is not available for the Carolina and Kure Beach traverses. Noticeable decreases in s-clay and organic matter occur on the upper shoreface and broad topographic high of the Wrightsville Beach sample traverse, while increases occur in the topographic low.

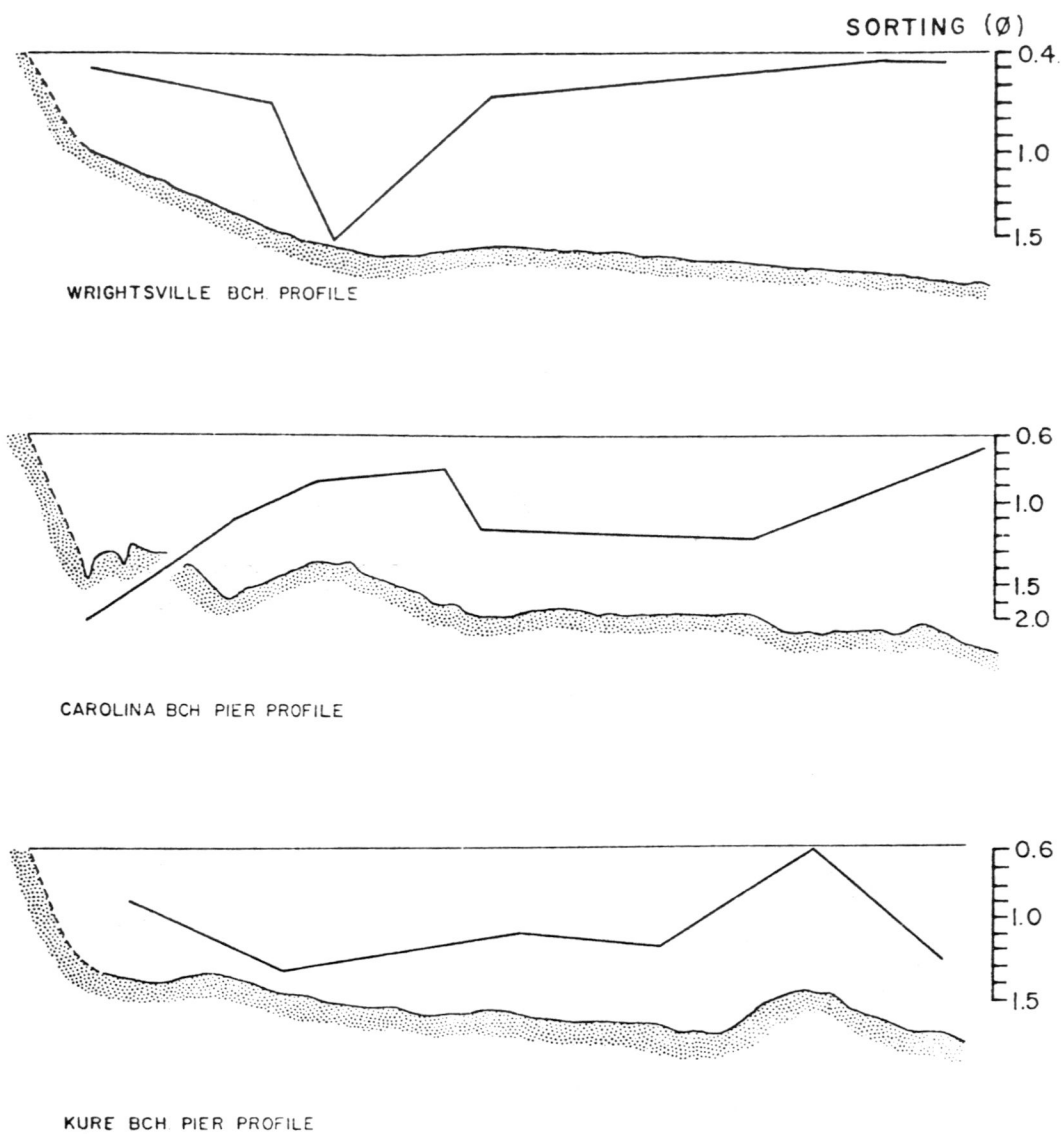


Figure 33. Plots of sorting versus bottom topography for the Wilmington sample traverses.

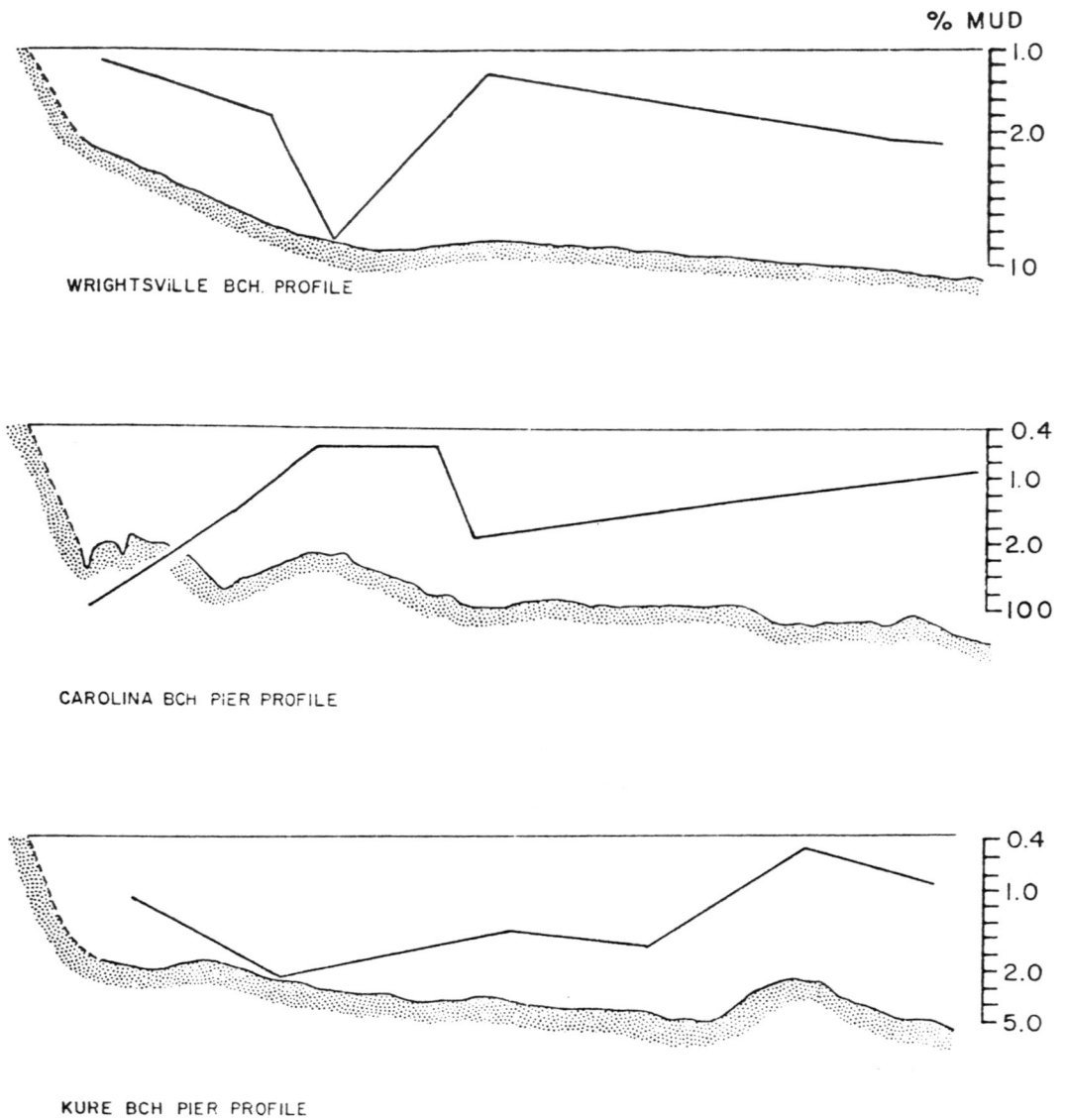


Figure 34. Plots of mud versus bottom topography for the Wilmington sample traverses.

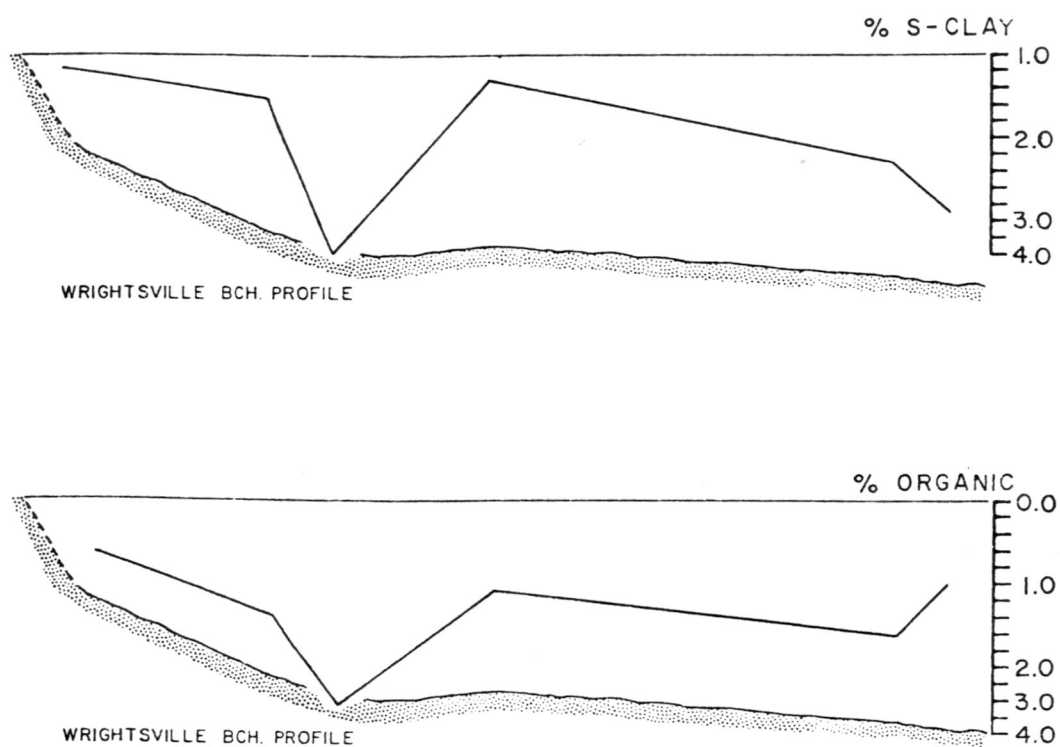


Figure 35. Plots of s-clay and organic material versus bottom topography for the Wrightsville Beach sample traverse.

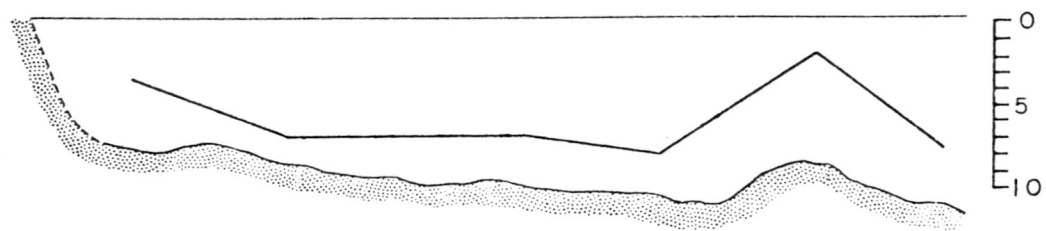
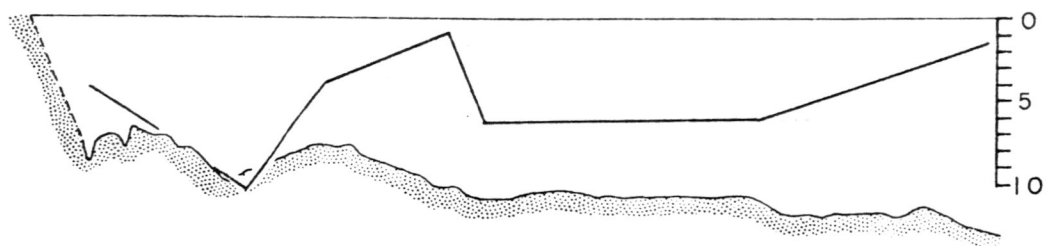
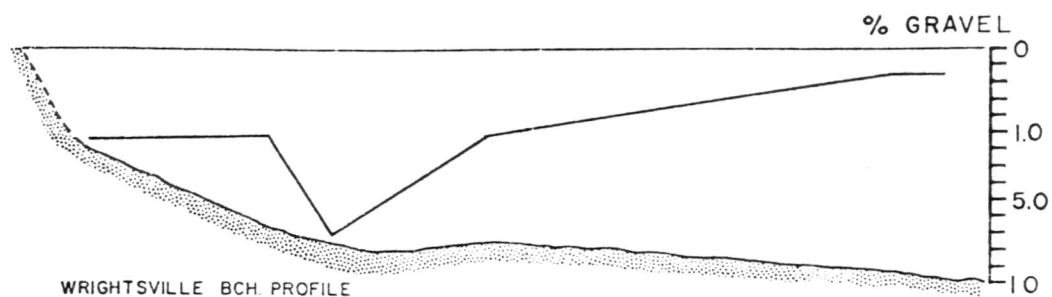


Figure 36. Plots of gravel versus bottom topography for the Wilmington sample traverses.

Figure 36 depicts a general correlation between percent gravel and bottom topography. The concentration of gravel increases into the topographic lows, while there is a relative decrease on the topographic highs.

RELATIONSHIPS BETWEEN SEDIMENT TYPE AND BOTTOM TOPOGRAPHY

Knowledge of the bottom topography in conjunction with diver observations and analyses of surface sediments allows determination of generalized relationships between sediment types and bottom topographies. Although the complex history of sedimentation and occurrence of rocks within the study area make categorization of sedimentary facies difficult, the following general sediment-topography relationships are recognized.

Topographic lows have higher percentages of muds and coarse sediments than do other topographic environments. Although major mud deposition was observed at only one topographic low sample station, minor increases in percent mud occurred wherever topographic lows were encountered.

Increases in percentage of gravel also coincide with the topographic low areas. Consequently, the sediments in the topographic lows are poorly sorted and bimodal. This unique pattern of poorly sorted and bimodal sediments results from reduced hydraulic sorting in the topographic lows. Gravels are deposited in the topographic lows during high energy periods. During and after deposition of the gravels, the lows act as gravitational basins or traps, resulting in accumulation of the coarse sediments. During normal or lower energy conditions, the lows experience wave induced bottom orbital velocity currents

(WIBOVCS) of a lesser frequency and magnitude than other topographic environments. This is due to 1) topographic highs seaward of the topographic lows buffer waves and create a shadow zone of weaker or nonexistent WIBOVCS in the topographic low areas and 2) the greater depths of the topographic lows cause WIBOVCS to be weaker or nonexistent. Thus, deposition of mud occurs due to the absence of, or lesser WIBOVCS activity. This results in muds being deposited over coarser sediments which creates a poorly sorted bimodal deposit in the topographic lows.

Well defined topographic highs are found to consist of moderately to moderately well sorted fine sands with lower percentages of gravel and mud relative to adjacent topographic environments. Where gravel is encountered on the topographic highs, it usually consists entirely of shell fragments rather than the mixed shell, rock fragment, and quartz gravels found in the lows.

Subtle variations in bottom morphology are not characterized by discrete sediment-topography relationships. Rather, they are characterized by considerable variations in the sediments due to the interaction of two important factors. First, the complex sediment-rock relationship of the Wilmington nearshore shelf results in continuous input of "new sediments" derived from the rocks. Secondly, the hydraulic regime is not able to efficiently sort the sediment due to the continuous input of these "new sediments."

SURFACE SEDIMENT DISTRIBUTION

The distribution of surface sediments for the Wilmington nearshore shelf is presented in Figure 37. Lateral correlation between the three sample traverses is not attempted due to the distance between the

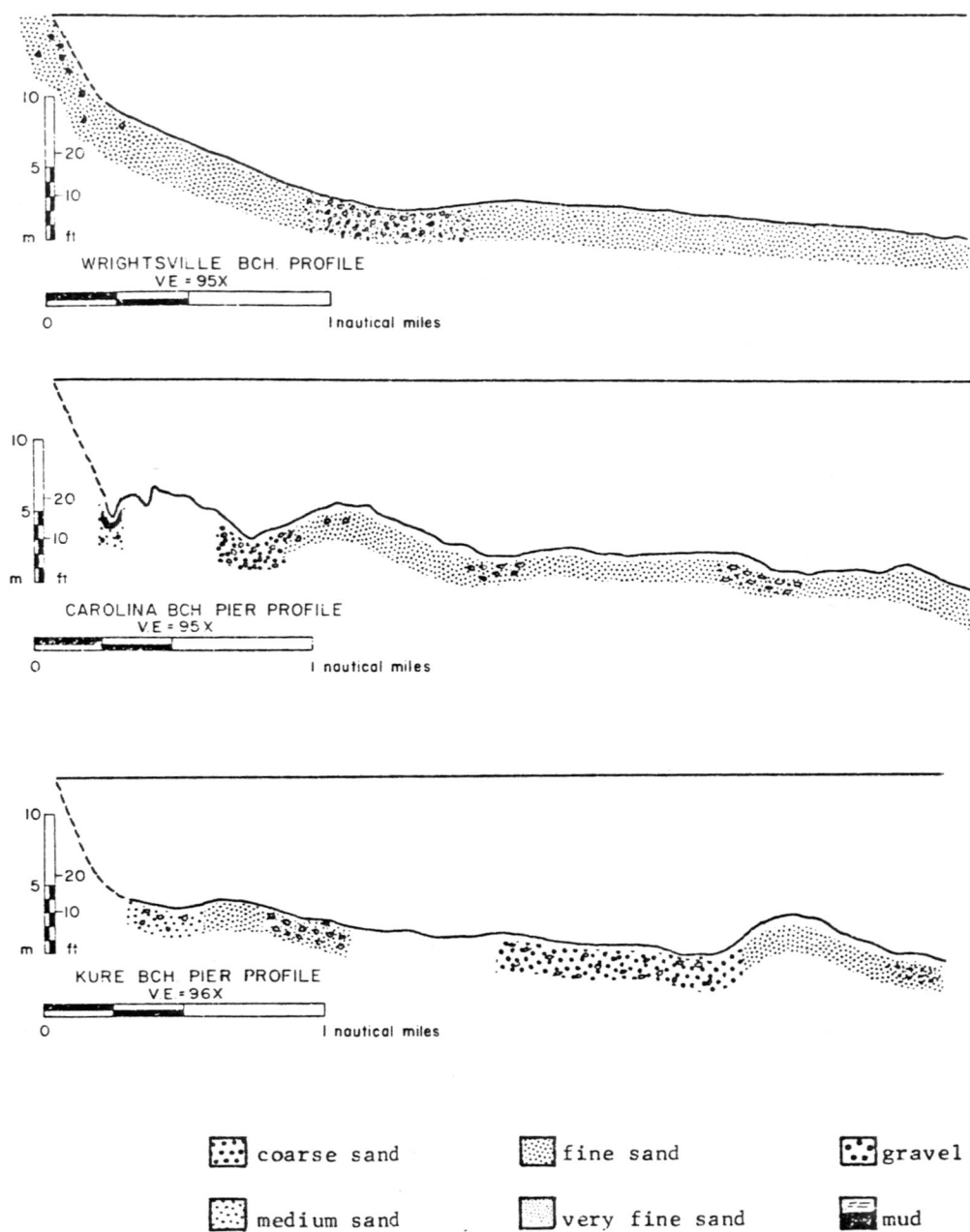


Figure 37. Surface sediment distribution along the Wilmington sample traverses.

individual traverses and the complexity of the sediment regime in the study area.

Consistency among the sediments along the Wrightsville Beach traverse allows interpretation of the sediment distribution along the entire traverse. With the exception of sandy limestone rock fragments at station WW-3, the sediment samples at each of the Wrightsville Beach sample stations are noticeably similar. Similarities among the sediment samples is demonstrated in Figure 38, which shows a composite plot of the grain size distribution for each of the surface samples collected along the Wrightsville Beach traverse.

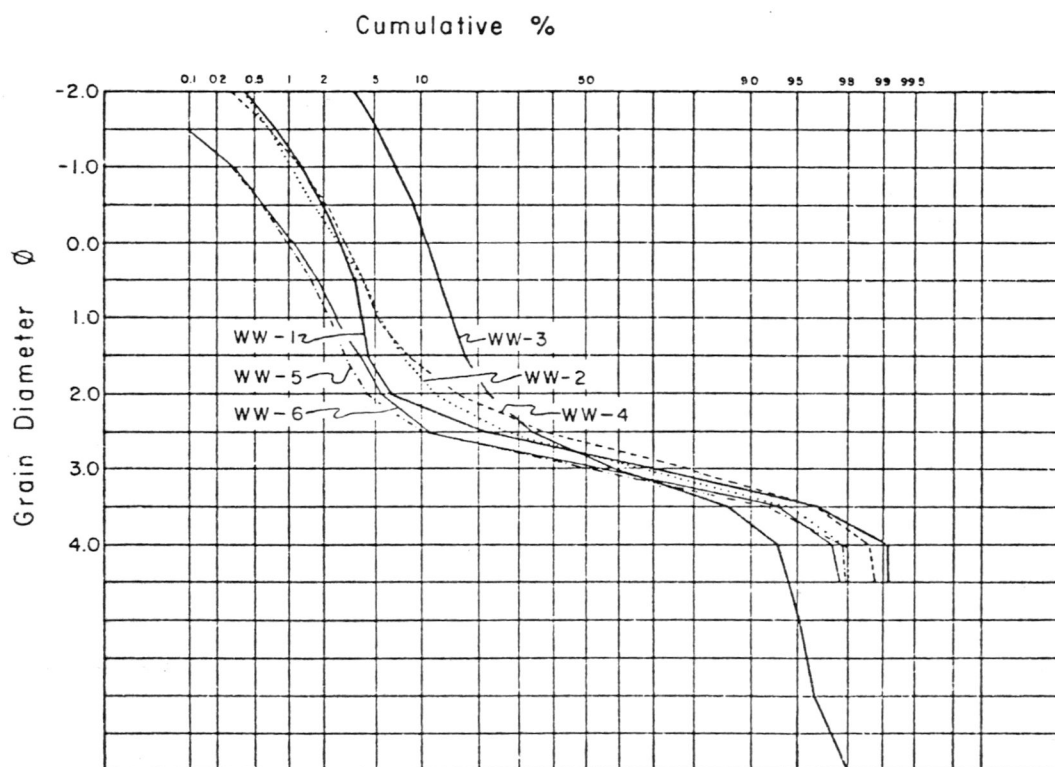


Figure 38. Weight percent grain size distributions of surface samples from stations WW-1 through WW-6, Wrightsville Beach sample traverse.

Each sample, with the exception of WW-3, is characterized by moderately well to well sorted slightly granular fine to very fine sands that contain 0.3 to 1.3% gravel, 1.1 to 2.7% mud, 1.2 to 2.9%

s-clay, and 0.6 to 1.6% organic matter. Sorting values range from 0.43 to 0.68 ϕ , mean grain sizes range from 2.59 to 2.99 ϕ , mode percentages from 42-45%, kurtosis values range from 1.35 to 1.69, while all samples are nearly fine skewed. Further examination of the sediments reveals a slight gray to black staining of the shell fragments and sand grains in the samples.

The uniformity of the samples suggests that they have been derived from a common source. One possible source could result from the erosion of lithologically homogeneous relict stratigraphic units, thus contributing similar sediments to the modern regime. This source is not likely, because experience indicates that uniformity in relict stratigraphic units or in surface sediments is atypical of Onslow Bay. A second and more probable source is thought to result from erosion of the artificial berm constructed along 2.7 mi (4.3 km) of Wrightsville Beach. Evidence supporting this as the sediment source includes the black stained appearance of the dredge spoil, the occurrence of oyster shells, and the fine to very fine grain size of the dredge spoil used to construct the berm. The spoil for the artificial berm was dredged from an estuarine source and resembles the sediments examined along the offshore traverse.

According to Cleary et al (1977), approximately 4,860,000 cubic yards (3,717,900 m³) of fill material was pumped on the beach from 1965 to 1970. Since then, the northern half of the Wrightsville renourishment berm has been severely scarped or totally removed by erosion. With no sediment losses to the berm resulting from washover, it is hypothesized that the dredged sediments of the artificial berm have been transported offshore. This hypothesis is supported by the action of two mechanisms operating on the beach, both of which

result in the offshore transport of sediments. First, hydraulic sorting by wave activity results in very fine grained sediments being transported offshore. Secondly, the vertically escarped artificial berm creates a seawall or bulkhead, resulting in offshore transport of beach sediments.

Offshore transport of the artificial berm sediments is further evidenced by subsurface data. A 4.8 ft (1.5 m) core, taken at station WW-1, consists of 3.3 ft (1.0 m) of gray to black fine sand overlying 1.5 ft (0.5 m) of light cream colored, slightly gravelly fine sand, with the contact between the two units being very abrupt and distinct. The light cream color is indicative of well oxidized surface environments, whereas the gray-black stained sands reflect sediments from a reducing environment. Light oxidized sediments commonly occur over darker reduced sediments, the darker sediments being blackened in response to chemical conditions associated with anoxic or reducing environments. The occurrence of the gray-black sediments over the light oxidized sediments suggests that the upper sediments could have been transported from the artificial berm which is constructed of reduced gray-black fine grain estuarine sands.

It is estimated that most of the northernmost 1.4 mi (2.3 km) of the artificial berm has been totally eroded. The southern 1.3 mi (2.1 km) of the berm have experienced less or no erosion due to the protection afforded by sand deposition north of the jetty at Masonboro Inlet. It is estimated that 3,187,000 cubic yards of sediment have been eroded from Wrightsville Beach since 1965. This volume of sediment could cover an area of 9 sq mi (23 sq km) with a layer of sediment 4.1 in (10.4 cm) in thickness. Thus, it appears that the volume of sand eroded from the artificial berm could feasibly supply enough sediment

to the offshore area to account for the uppermost layer of surface sediments along the Wrightsville Beach sample traverse. In addition, 1,200,000 cubic yards ($918,000 \text{ m}^3$) of estuarine sediments were placed on the beach between 1939 and 1960. This increases the feasibility that the offshore sediments have been derived from an artificial source. Therefore, it appears there has been a continuous source of fine sediments available to blanket the nearshore shelf off Wrightsville Beach during the past 40 years.

STRATIGRAPHIC CORRELATION - WILMINGTON AREA

Lithologic units in the vibracore samples are broken down into 5 major stratigraphic types (Table 4). Type one is interpreted to be the modern sediment sheet, type two to be modern-relict strata, and types three through five to be relict stratigraphic units. The modern-relict interpretation results from difficulty in discerning whether the sedimentary units are modern or relict.

In general, the modern units are characterized by very clean light colored sands and dark, organic-rich, high water content mud. The modern-relict units are characterized by gray muddy sands. The three relict stratigraphic units include the following lithologies: muddy olive green sands, clean sands and dense gray organic clays of fluvial-estuarine origin, and calcareous rock units. Several types of calcareous rock fragments occur in the study area and include 1) a coquina; 2) a chalky, sandy calcareous, slightly mold and cast, semi-indurated mud; 3) a gray mold and cast, dense, micritic limestone; and 4) a light tan, fossiliferous, sandy limestone.

Lithologic descriptions of the vibracores sampled along each of the traverses are presented in Figures 39, 40, 44, 45, 48, and 49 with cross correlations between the core sections illustrated in Figures 41, 46, and 50.

Wrightsville Beach Traverse

A modern shoreface sediment wedge, represented by core number WW-1, thins seaward to a thin sediment sheet overlying relict strata (Figure

TYPE OF STRATIGRAPHIC UNIT	LITHOLOGIC DESCRIPTION
1. Modern Sediment Sheet	1A. gray very clean slightly shelly fine sand 1B. light orange very clean slightly gravelly and shelly fine sand 1C. light orange very clean very shelly fine to medium sand 1D. light orange very clean very shelly fine to medium sand with slight amounts of fibrous organic matter 1E. dark organic-rich high water content mud
2. Modern - Relict Sediments	2A. gray very fine slightly shelly muddy fine to very fine sand 2B. gray fine to coarse very shelly muddy fine to coarse sand 2C. gray fine to coarse very shelly and gravelly muddy fine to coarse sand 2D. clean coarse sand to gravel 2E. gray dirty gravelly sandy mud
3. Relict Olive Green Sands	3A. olive green burrowed slightly muddy fine sand
4. Relict Fluvial-Estuarine Sediments	4A. gray clean compact clay 4B. gray very sandy clay or clayey sand with some organic matter 4C. white very clean medium sand with or without organic matter and graded beds
5. Rock and/or Rock Fragments	5A. coquina 5B. chalky sandy calcareous mud with some slight molds and casts 5C. light tan fossiliferous sandy limestone pebbles 5D. gray mold and cast micritic limestone

Table 4. Lithologic divisions of vibracores from the Wilmington nearshore inner continental shelf.

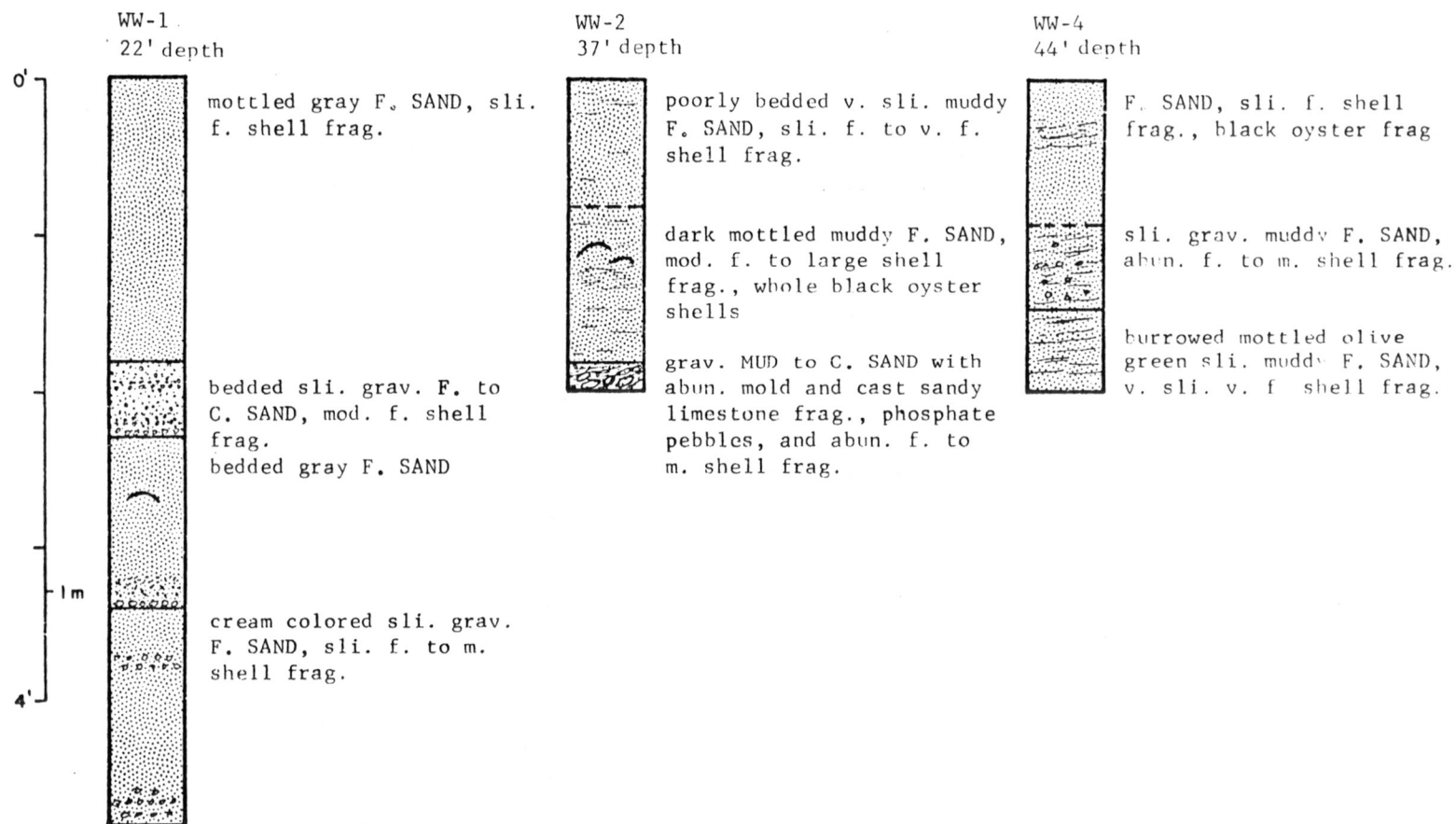


Figure 39. Lithic descriptions of vibracores WW-1, 2, and 4 from the Wrightsville Beach sample traverse.

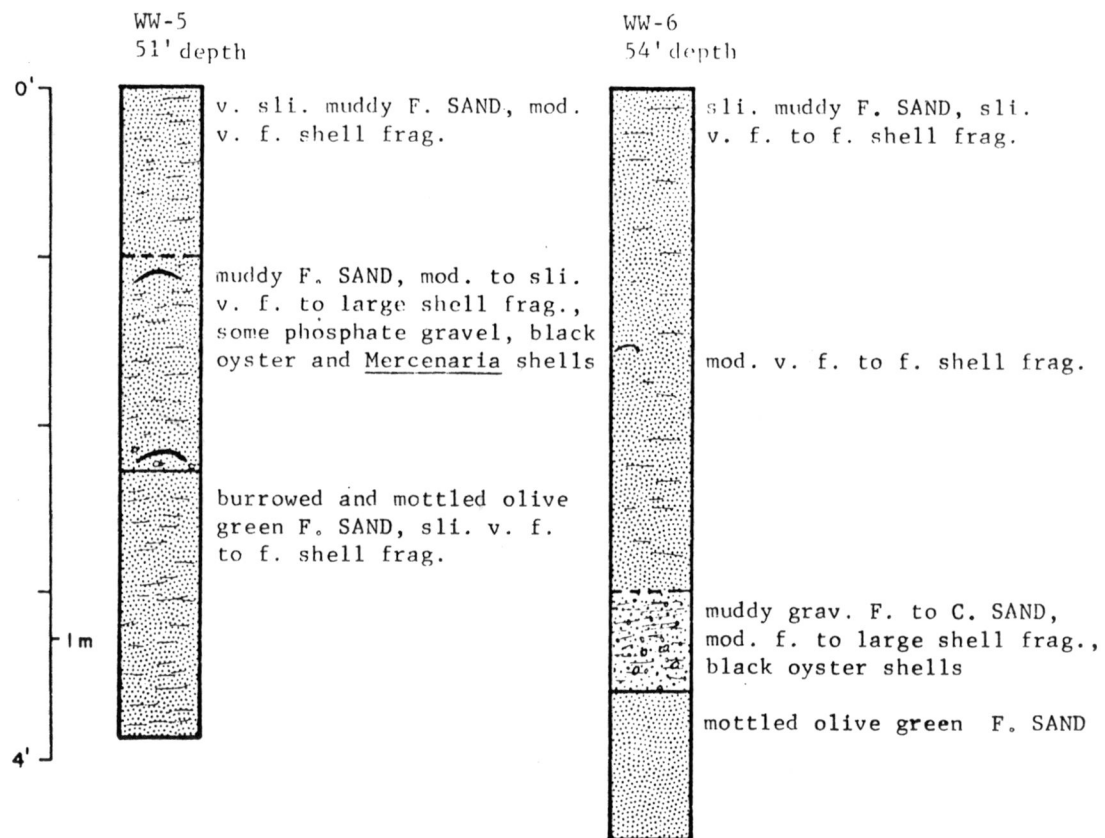


Figure 40. Lithic descriptions of vibracores WW-5, 6, and 7 from the Wrightsville Beach sample traverse.

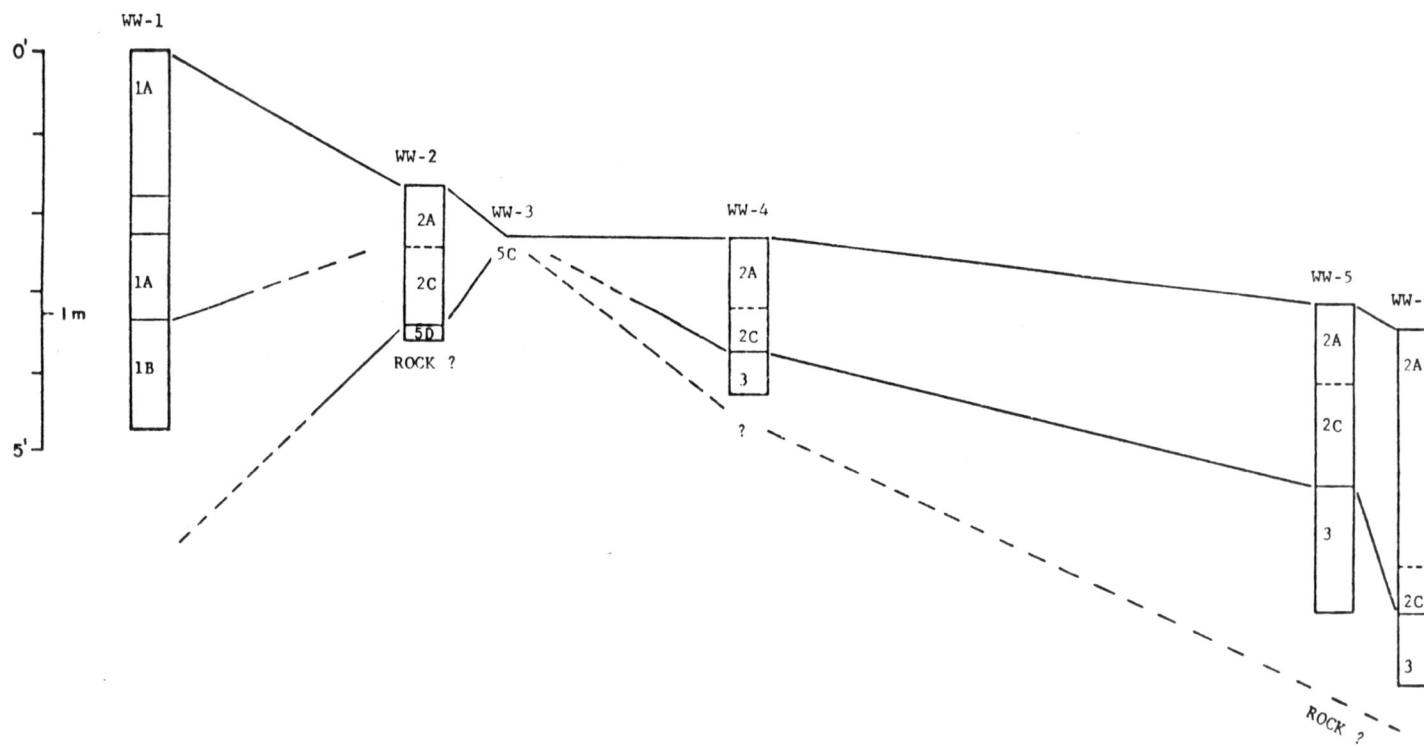


Figure 41. Cross correlation of the Wrightsville Beach core sections.

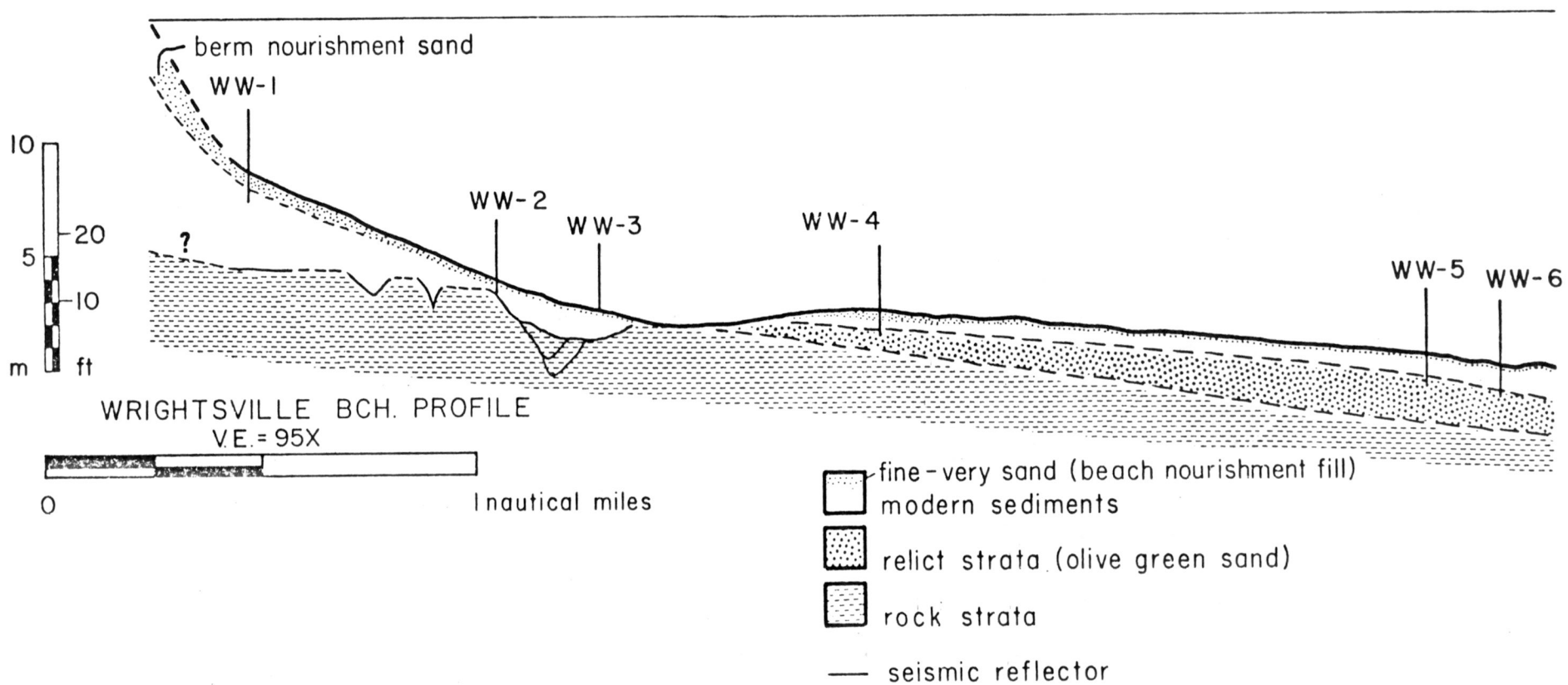


Figure 42. Stratigraphic cross section of the Wrightsville Beach sample traverse.

42). Distinguishing between the modern and modern-relict sand units proves to be difficult, although the uppermost surface sediments are interpreted to be modern sediments derived from the artificial berm constructed along Wrightsville Beach. Black to gray fine sands, characteristic of the artificial berm, are detectable in the WW-1 core where they overlie light cream colored, well oxidized, slightly gravelly sands.

Drill log information from a municipal water well at the shoreward end of the Wrightsville Beach traverse, indicates that a relict rock unit(s) occurs approximately 32 ft (9.8 m) below mean sea level. This coincides with a seismic reflector below station WW-1. Although the depth to the rock unit has been established, the thickness of the modern active sediment wedge on top of the relict units is not known. Logs of 5 water wells located on Wrightsville Beach report rock at approximately 30 ft (9.1 m) to 37 ft (11.3 m) below mean sea level. Three additional well logs report rock strata located 18 ft (5.5 m), 80 ft (24.4 m), and 124 ft (37.8 m) below mean sea level, which indicates the rock unit has an irregular surface, is absent in places, or represents multiple rock units. According to the well logs, the rock unit(s) is described as lime rock, coquina rock, soft shell rock, Castle Hayne rock, and soft lime rock, which suggests the unit is variable in character, represents multiple rock strata, and/or the descriptive names assigned by local drillers vary for the same rock.

Existence of the rock strata along the sample traverse is evidenced by vibracore data at station WW-2 and dive information and samples from station WW-3. The lower 1.8 ft (0.5 m) to 2.2 ft (0.7 m) of the core sample from station WW-2 consists of large quartz pebbles, phosphate

granules, and indurated, gray, mold and cast, micritic limestone rock fragments. Thus, the bottom of the core is interpreted as representing a rock surface overlain by a thin sediment sheet. In addition, the rock surface coincides roughly with a seismic reflector at station WW-2. Station WW-3 is the approximate location where the same seismic reflector (?) from WW-2, approaches the seafloor. At WW-3, surface sediments consist of abundant rounded, mold and cast, sandy limestone fragments with less abundant quartz and phosphate gravels. Diver observations report the sandy limestone fragments increase in abundance with depth. Further evidence of hard rock is suggested by the presence of Arcopis adamsi, a rock attaching marine bivalve found in the sediments at station WW-3.

A modern-relict stratigraphic unit of slightly muddy fine sand overlies a distinct olive green, slightly muddy sand at stations WW-4, 5, and 6. Similar "greenish gray silty sand" and "green sandy clay marl" is reported 37 ft (11.3 m), 38 ft (11.6 m), and 46 ft (14.0 m) below mean sea level in bore holes located along the north Masonboro Inlet jetty.⁷ These holes are 2.15 n.m. south of the Wrightsville Beach sample traverse. The bore holes are located at the landward end of the jetty, 0.25 n.m. and 0.45 n.m. offshore along the jetty, respectively. The "green" fine sand was not reported elsewhere in the drill logs, thus, this unit appears to represent a distinct lithology which is thought to correlate with the distinct olive green sand units at stations WW-4, 5, and 6. Accordingly, the unit is interpreted as a relict stratigraphic unit.

⁷Bore holes BR-1, B-1, and B-2, U. S. Army Corps of Engineers, Wilmington District, N. C.

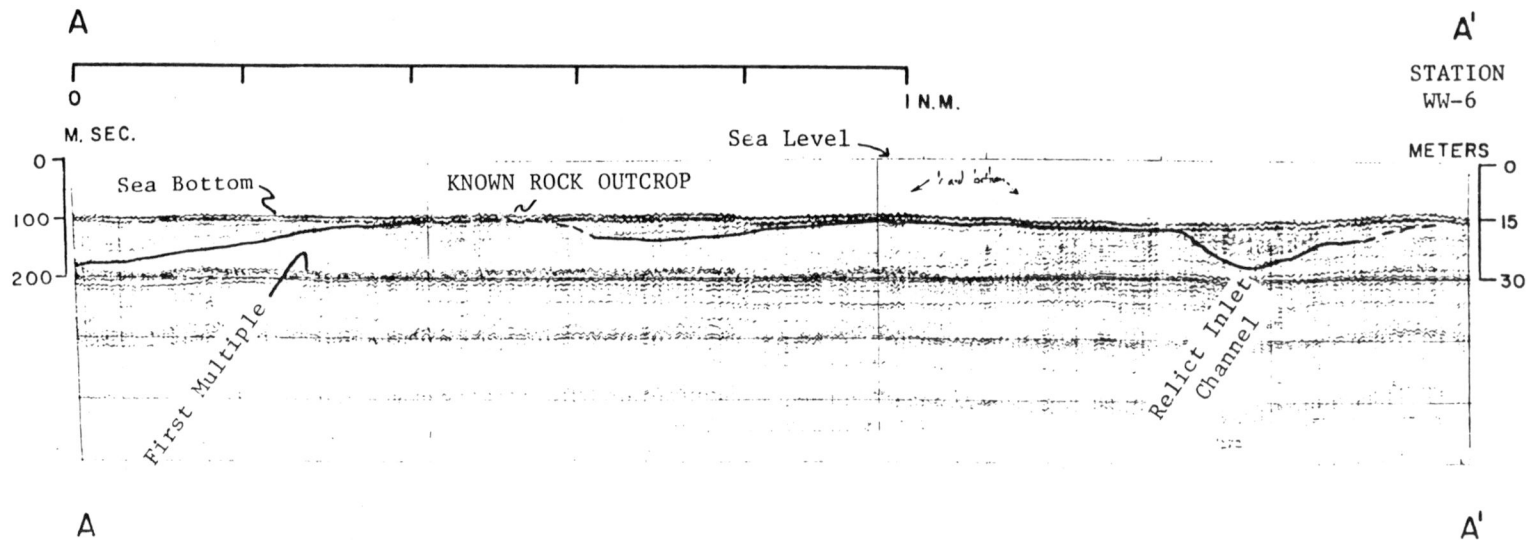


Figure 43. Seismic profile depicting a rock surface located 3 nautical miles offshore along Wrightsville Beach. Refer to Figure 3 for the location of the seismic trace. The rock surface approaches the sea floor and coincides with a known rock outcrop approximately 1.2 nautical miles south-southwest of station WW-6. Accordingly, it is believed to mark a rock surface. This suggests that rock strata may be located a short distance below A', which coincides with the location of station WW-6.

It is thought that the olive green sand unit may overlie the limestone rock unit encountered at station WW-3. According to personal communication with Riggs (1979), the olive green sand unit may derive its distinct color either from fine glauconitic sediments and/or the combination of magnesium rich clays and calcium carbonate mud, both of which are common in the North Carolina Tertiary. Also, the presence of the "clay marl" in the bore hole log⁸ suggests that a carbonate mud has been encountered. In addition, seismic data and the known existence of rocks cropping out in 47 ft (14.3 m) of water approximately 1.1 n.m. south-southwest of station WW-6 indicate that the rock unit is located at a shallow depth below station WW-6 (Figure 43).

Carolina Beach Traverse

Core data from the Carolina Beach sample traverse indicates the sedimentary units along the traverse consist of modern or modern-relict strata (Figure 47). A core 1.7 ft (0.5 m) in length from station WC-1 consists of modern organic-rich, high water content mud deposited on a sand unit in a topographic low. A possible source of the mud could be from the Cape Fear River, as suggested by examination of aerial photographs. Photographs taken during ebb tide show a very dark sediment plume flushing through Carolina Inlet. The plume can be traced to Snows Cut which connects the Cape Fear River with Myrtle Grove Sound.

Coring at station WC-2 was not successful due to the presence of abundant coarse shell debris.

Core WC-3 and the upper 3.4 ft (1.0 m) of core WC-5 contain clean sands which are interpreted to be modern. Dirty gray fine to coarse

⁸Ibid.

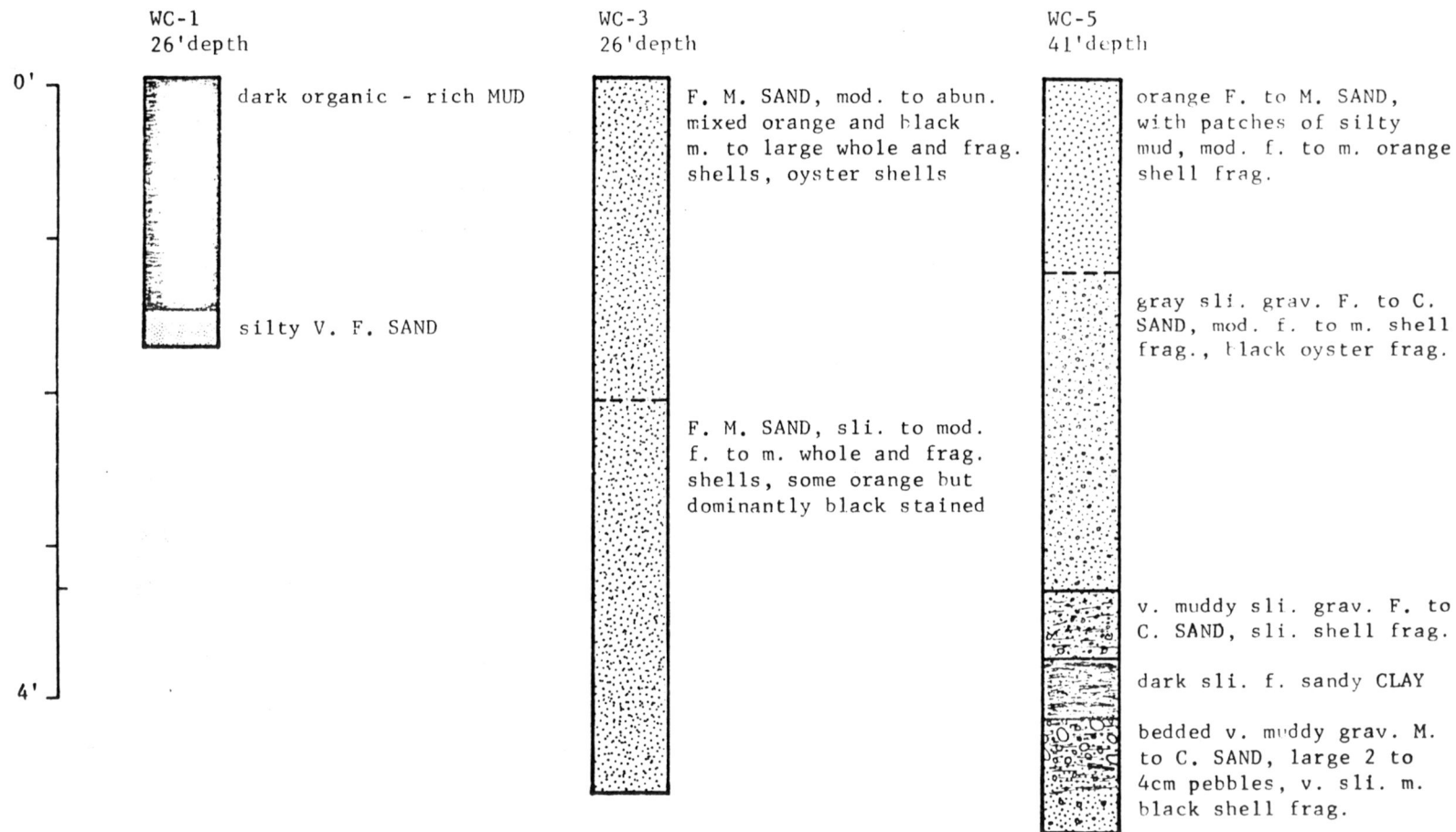


Figure 44. Lithic descriptions of vibracores WC-1, 3, and 5 from the Carolina Beach Pier sample traverse.

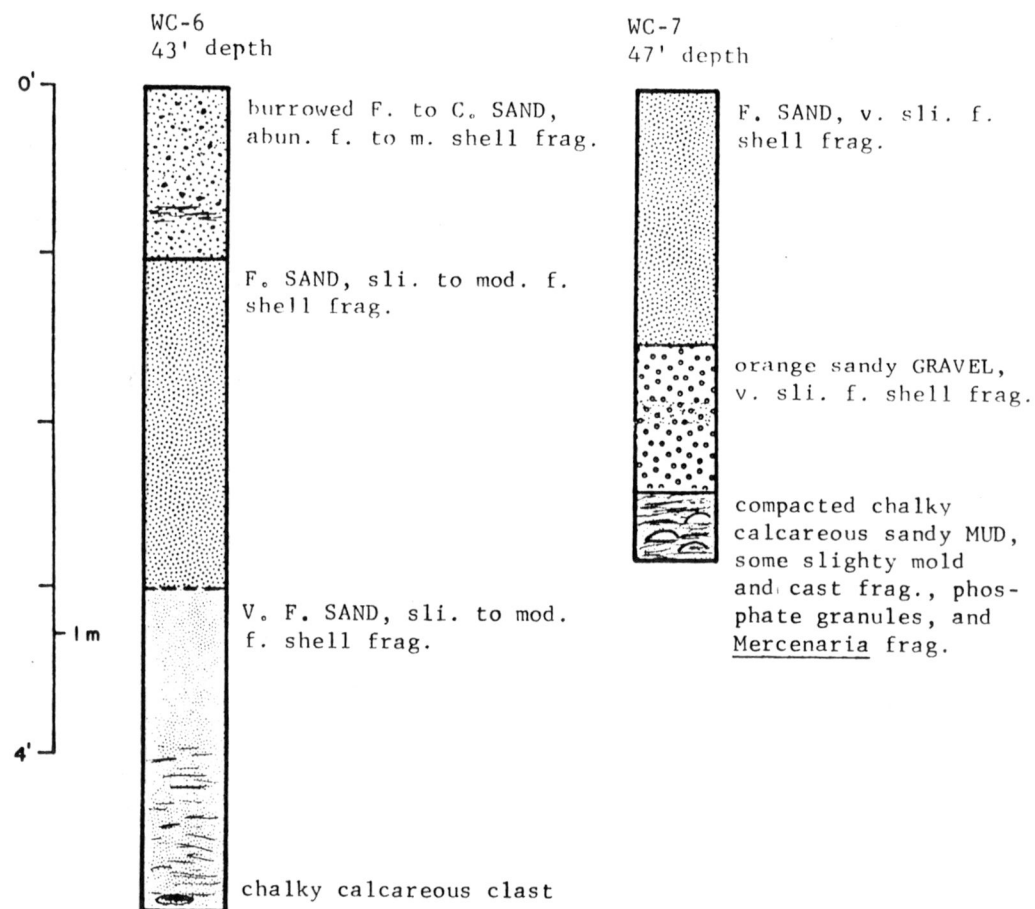


Figure 45. Lithic descriptions of vibracores WC-6 and 7 from the Carolina Beach Pier sample traverse.

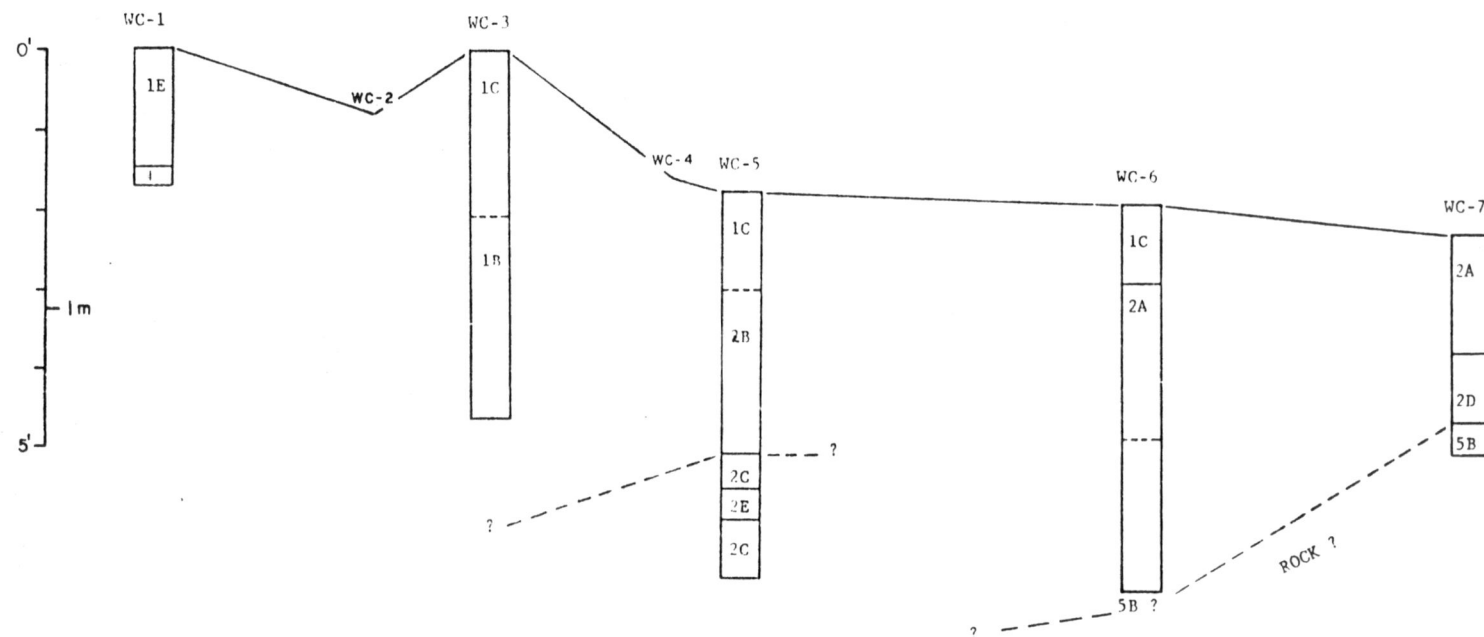


Figure 46. Cross correlation of the Carolina Beach Pier core sections.

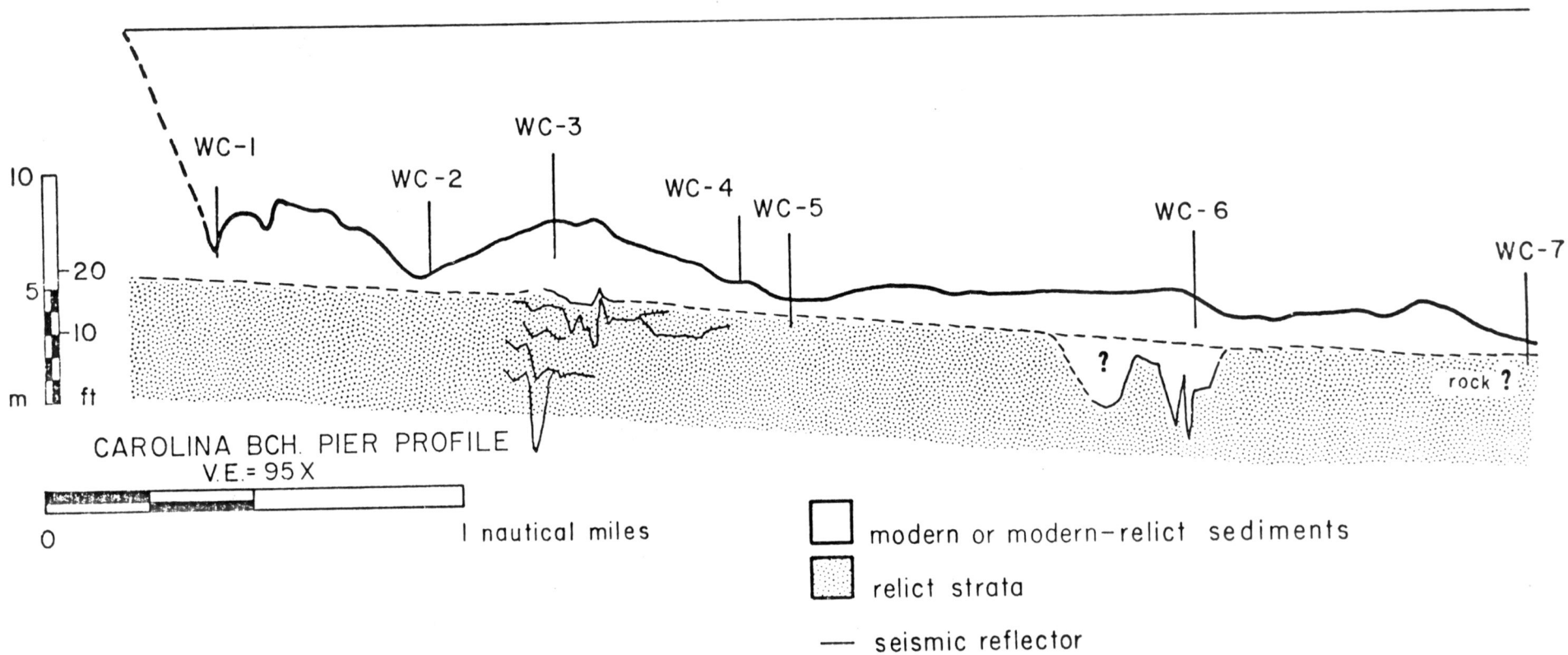


Figure 47. Stratigraphic cross section of the Carolina Beach Pier sample traverse.

sands; dark sandy clay; and dirty, muddy, gravelly medium to coarse sand in the WC-5 core consists of quartz granules and pebbles up to 4.5 cm in diameter and is overlain by a mud unit. This suggests that the lower units in the WC-5 core may represent a modern topographic low mud and lag gravel deposit. The mud and gravel deposit is overlain by sands that were probably deposited as the low was filled. An alternate interpretation is that the muds may represent a relict channel fill.

Modern active sands are found to overlie a modern-relict fine sand unit in the WC-6 core. A small cream colored, chalky, calcareous clast was found in the bottom of the modern-relict fine sand unit. This suggests that limestone may be located a short distance below the bottom of the core.

The core at station WC-7 contains 2.2 ft (0.7 m) of modern sands and sandy gravels. These overlie a compacted, light, chalky, calcareous sandy mud which contains phosphate gravels, a few molds and casts, and shell fragments covered with bryozoans. This is all suggestive of a limestone rock surface. If a limestone unit does exist below the surface, as suggested by cores at stations WC-6 and 7, then it may be represented by irregular seismic reflectors recorded approximately 10.8 ft (3.3 m), 6.2 ft (1.9 m), and 12.3 ft (3.8 m) below stations WC-3, 4, and 6, respectively.

Kure Beach Traverse

Three major stratigraphic units, shown in Figure 51, are interpreted to occur along the Kure Beach stratigraphic cross section. Active modern sands and modern-relict muddy sands were found to overlie relict fluvial-estuarine deposits. Abundant coquina rock fragments

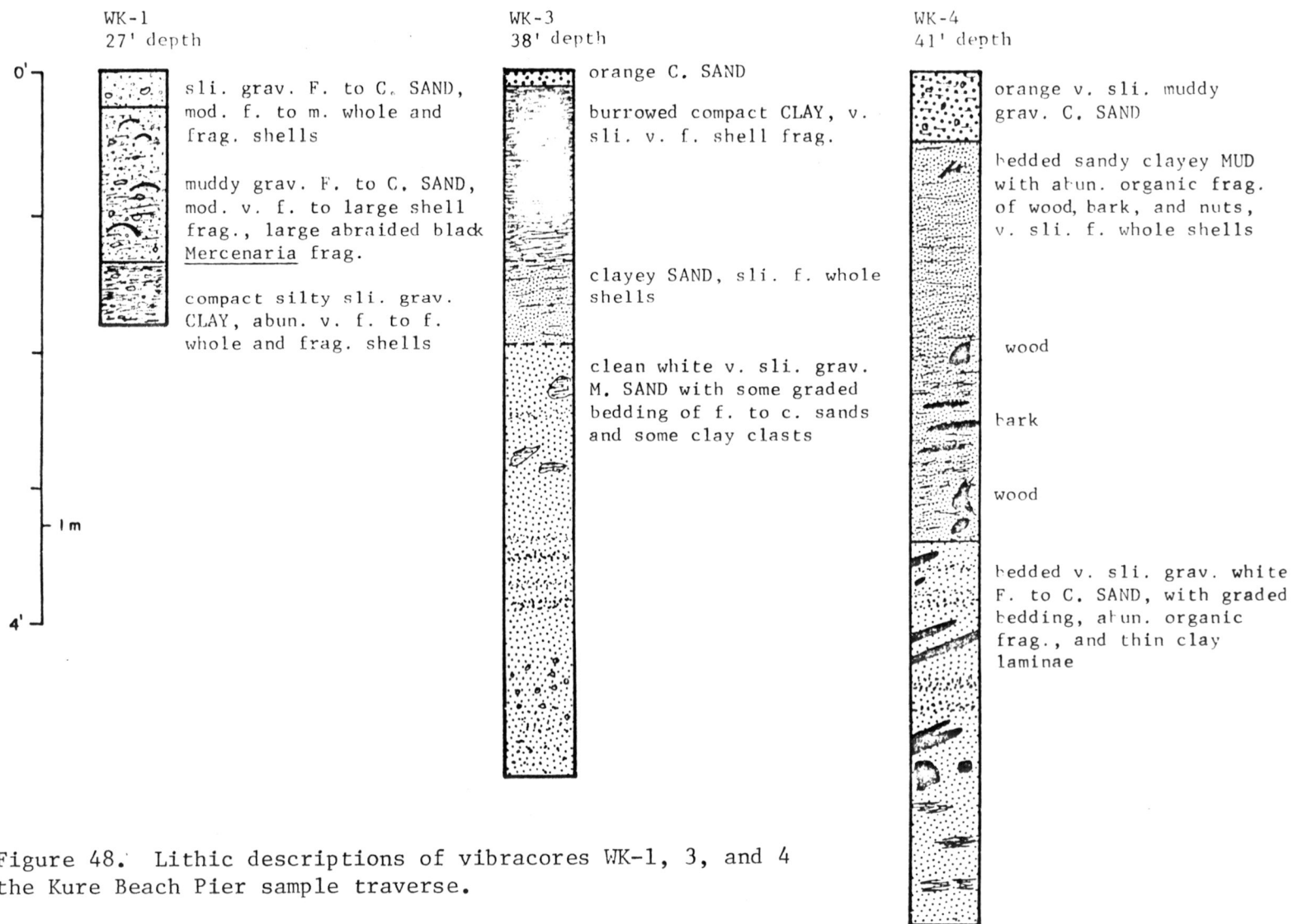


Figure 48. Lithic descriptions of vibracores WK-1, 3, and 4 from the Kure Beach Pier sample traverse.

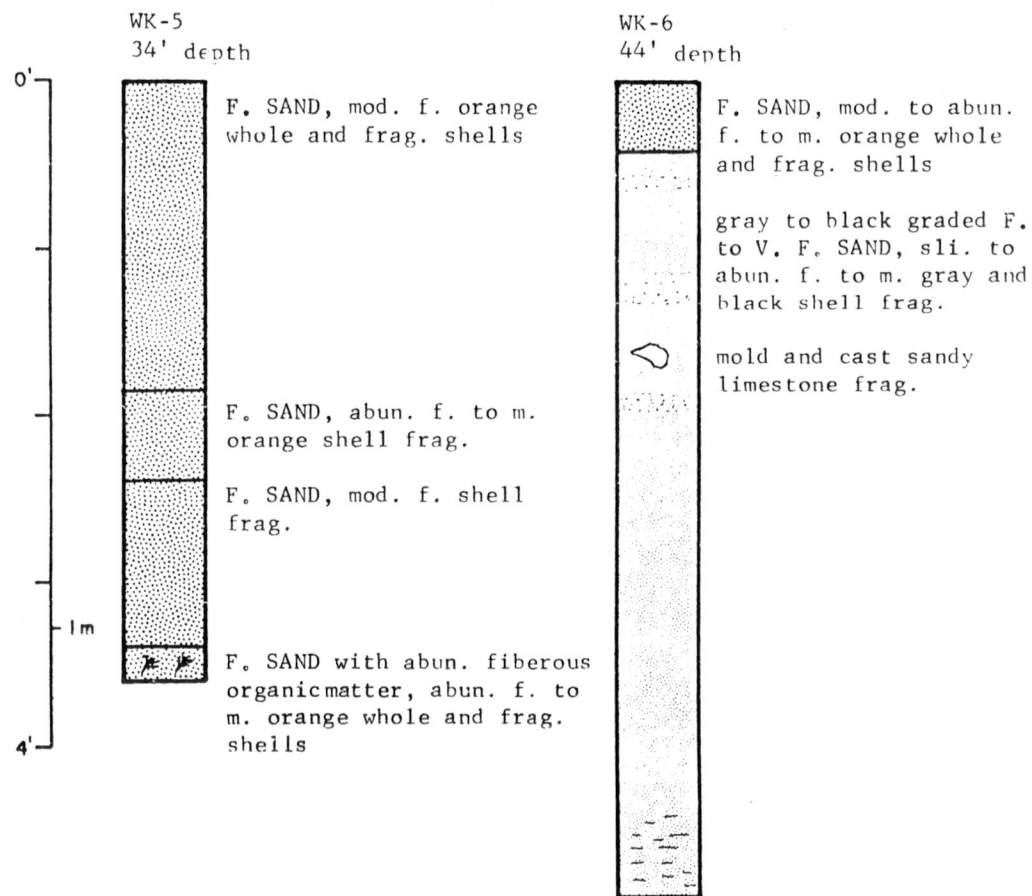


Figure 49. Lithic descriptions of vibracores 5 and 6 from the Kure Beach Pier sample traverse.

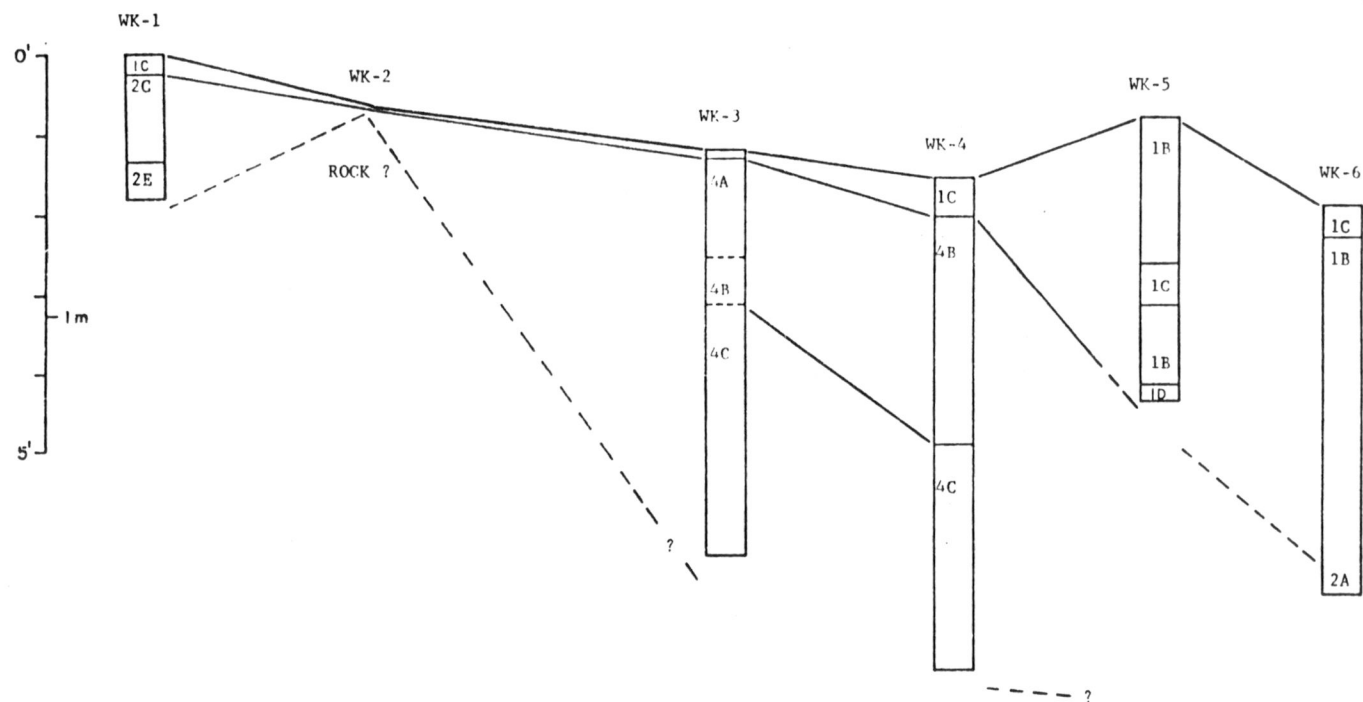


Figure 50. Cross correlation of the Kure Beach Pier core sections.

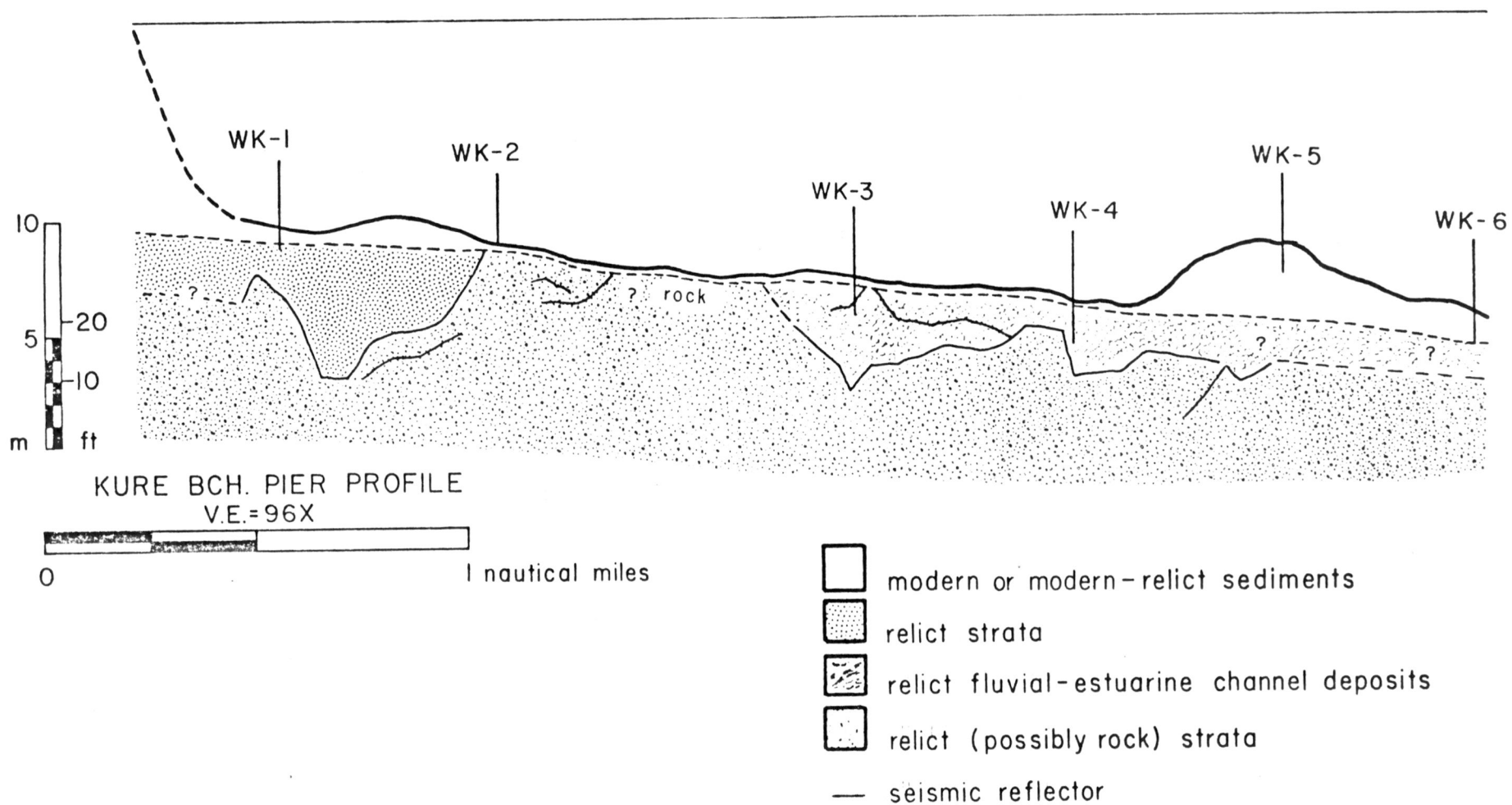


Figure 51. Stratigraphic cross section of the Kure Beach Pier sample traverse.

suggest the occurrence of a shallow subsurface rock unit which may crop out along or near the traverse.

The upper 0.25 ft (.01 m) of the WK-1 core consists of active clean modern sediments. The lower 1.60 ft (0.5 m) of the core is interpreted as modern-relict sediments which consist of dirty, muddy, gravelly sands with very abundant and large, whole and fragmental Mercenaria bivalves. Seismic reflectors below station WK-1 suggest that the modern-relict unit may represent a channel deposit.

The seismic reflector recorded below station WK-1 almost crops out near station WK-2. Here the surface sediments are dominantly abraded shell debris with very abundant, whole, large Mercenaria bivalves. It is thought that the prolific surface shell material at station WK-2 may represent reworked channel deposits similar to the subsurface modern-relict strata at station WK-1. In addition, it is suggested that the seismic reflectors which almost crop out between stations WK-2 and WK-3 may mark a rock surface upon which the channel fill is deposited. The presence of the rock surface is suggested by the occurrence of abundant coquina rock fragments, up to 0.5 m in diameter, collected at station WK-3. Although the rock unit may not actually crop out along the sample traverse, additional seismic traces run across the traverse and parallel to shore indicate a rock surface cropping out, or nearly so, immediately north and south of the Kure Beach traverse.

Cores taken at stations WK-3 and WK-4 are interpreted as relict estuarine-fluvial channel deposits. Channel geometry is suggested by seismic reflectors recorded below stations WK-3 and WK-4. The WK-3 core consists of a very thin surface layer of modern iron-stained orange

coarse sand which overlies 1.9 ft (0.6 m) of tight, clean, gray clay. This grades downward to a mottled, clean, white medium to coarse sand. Graded bedding and some clay clasts are found in the lower clean white sand unit.

The WK-4 core consists of 0.5 ft (0.2 m) of modern iron-stained orange gravelly coarse sand which overlies a 2.9 ft (0.9 m) section of sandy, clayey mud. The sandy, clayey mud contains numerous organic fragments of wood, bark, and whole tree nuts. Below this unit is 2.9 ft (0.9 m) of slightly gravelly, fine to coarse, white sand which exhibits graded-bedding, clay laminae, and abundant organic fragments of bark, wood, and whole tree nuts. Consequently, the stratigraphic units of the WK-3 and WK-4 cores are interpreted to be fluvial deposits where shells are absent, and possibly estuarine deposits where slight amounts of small bivalves occur. The stratigraphic units are believed to represent relict flood plain and/or channel deposits of an ancestral Cape Fear River.

Stratigraphic units in core samples from stations WK-5 and 6 are interpreted as modern active sediment units. The active nature of the topographic high at station WK-5 is reflected by the clean fine sands throughout the core. WK-6, which occurs on the seaward flank of the high, contains a slightly muddy, very fine sand at the bottom of the core. This is interpreted to be a modern-relict unit which underlies the active sand body. The relict interpretation of the basal unit as relict is based on the muddy nature of the sediments.

SUMMARY AND CONCLUSIONS

1. The surface sedimentological regime of the Nags Head nearshore inner continental shelf consists of distinct mappable sedimentary facies. These facies denote specific sedimentary environments which are a direct function of the bottom topography, distance offshore, water depth, and proximity of relict Pleistocene and Holocene strata. Relationships between these parameters and the facies types include the following:
 - a. Sediments generally become finer grained and more poorly sorted as distance from shore and water depth increase along the regional planar topographic surfaces of the shoreface and nearshore shelf. Deviations from this trend in grain size and sorting occur as the topography changes from a planar surface and/or where relict strata crop out.
 - b. Sediments associated with topographic highs are clean, moderately to moderately well sorted sands. Consequently, these sediments are better sorted and have lower percentages of mud than the sediments from adjacent topographic environments.
 - c. Topographic lows which are bounded by a seaward topographic high, are shadowed by the high from wave induced bottom orbital velocity currents. Thus, the low basin or trough provides a low energy shelter where mud is deposited. Under high energy conditions the low serves as a trap where lag gravels are deposited. This results in a poorly sorted bimodal sedimentary facies, which is characteristic of the topographic low environments. Maximum accumulation of up to 38 cm of black organic-rich mud was observed in a topographic low 0.20 n.m. offshore in 28 ft (8.5 m) of water. Although frequently

observed in topographic low environments, these muds are suggested to be ephemeral deposits present during seasonal low energy periods.

2. A major relict fluvio-estuarine channel associated with the ancestral Albemarle-Roanoke River drainage system was found to be located seaward of Kitty Hawk Bay. Vibracore and seismic data from the Avalon Pier traverse give evidence of an extensive channel sequence with infilled Holocene sediments.
3. A major mappable relict stratigraphic unit containing an abundant concentration of Mulinia was encountered offshore in a topographic low along the Jennettes Pier traverse. This unit is known from previous investigations to underlie much of the Nags Head area and has been dated as Pleistocene in age.
4. The surface sedimentological regime of the Wilmington nearshore inner continental shelf is comprised of a complex sediment package. The complexity is due to the following:
 - a. abundant exposures of Pleistocene and Tertiary sediment and rock substrate of highly variable composition; and
 - b. abundance and prolific boring activities of benthic organisms upon the relict hardgrounds contributing new sediment to the modern sediment regime.

Consequently, distinct sedimentary facies are not as readily discernable on the Wilmington nearshore shelf as they are on the Nags Head nearshore shelf. Although the Wilmington nearshore sediment regime is complex, distinct sediment facies do occur on well defined topographic highs and in well defined topographic lows. These resulting sediment facies are similar to the topographic high and low facies on the Nags Head nearshore shelf.

5. Much of the uppermost sediments along the Wrightsville Beach traverse are thought to result from the seaward movement of fine grained sands derived from the erosion of a man-made berm constructed along Wrightsville Beach.
6. Surface sediment samples, along with seismic and vibracore information, suggest the presence of an extensive limestone rock unit at a shallow depth below the sediment surface on the inner continental shelf along the Wrightsville Beach traverse. This rock unit is known to crop out approximately 1.2 nautical miles south-southwest of the seaward end of the Wrightsville Beach traverse.
7. Seismic profiling suggests, and vibracore samples demonstrate, the presence of an ancestral Cape Fear fluvial-estuarine channel and associated sediment deposits approximately 1.5 nautical miles offshore from Kure Beach Pier. The channel is filled with fluvial-estuarine sediments which are probably Holocene in age.
8. On the basis of shallow subsurface vibracore and sub-bottom seismic profiling information, the modern shoreface sediment wedge in both areas thins in a seaward direction forming a thin sediment sheet overlying relict strata at the lower shoreface and inner shelf area. The modern sediment sheet is thinnest or absent in major topographic lows. In contrast, the topographic highs usually consist of a thicker, actively mobile modern sediment sheet.
9. According to diver observations, sediment samples collected with shipboard samplers do not necessarily indicate the variation in sediments found at specific sea floor locations. This is especially true in the topographic low environments. Here the shipboard

samplers may not retain mud deposits and/or may not retrieve patchy mud deposits that commonly occur in the topographic lows.

REFERENCES CITED

- Balazs, E. I., 1974, Vertical crustal movements of the Middle Atlantic Coastal Plain as indicated by precise leveling: Rockville, Md., Nat. Geod. Survey, U. S. Dept. of Commerce, 19 p.
- Brown, P. M., Miller, J. A., and Swain, F. M., 1972, Structural and stratigraphic framework, and spatial distribution of permeability of the Atlantic Coastal Plain, North Carolina to New York: U. S. Geol. Survey Prof. Paper 796, 79 p.
- Cleary, W. J., and Hosier, P. E., 1977, New Hanover Banks: then and now: Raleigh, Univ. of N. C. Sea Grant Pub. UNC-SG-77-14, 62 p.
- Crowson, R. A., and Riggs, S. R., 1976, Nearshore rock exposures and their relationship to modern shelf sedimentation: Geol. Soc. America Abstracts with Programs, v. 8, no. 2, p. 156-157.
- Curray, J. R., Emmel, F. J., and Crampton, P. J. S., 1969, Holocene history of a strand plain, lagoonal coast, Nayarit, Mexico: in Lagoonas Costeras, Un Simposio, Mem. Simp. Intern. Lagunas Costeras, UNAM-UNESCO, Nov. 28-30, 1967. Mexico, D. F., p. 63-100.
- Duane, D. B., Field, M. E., Meisburger, E. P., Swift, D. J. P., and Williams, S. J., 1972, Linear shoals on the Atlantic Inner Continental Shelf, Florida to Long Island, in Swift, Duane, and Pilkey, eds., Shelf sediment transport: process and pattern: Stroudsburg, Pa., Dowden, Hutchinson, and Ross, Inc., p. 447-498.
- Folk, R. L., 1968, Petrology of sedimentary rocks: Austin, Texas, Hemphill's, 70 p.
- Goldsmith, V., Morris, W. D., Burne, R. J., and Whitlock, C. H., 1974, Wave climate model of the Mid-Atlantic Shelf and shoreline (Virginian Sea); Washington, D. C., Spec. Pub. no. 358, Scientific and Technical Information Office, NASA, 146 p.
- Hicks, S. D., 1972, Vertical crustal movements from sea level measurements along the east coast of the United States: Jour. Geophys. Research, v. 77, p. 5930-5934.
- Komar, P. D., 1976, Nearshore currents and sediment transport, and the resulting beach configuration, in Stanley, D. and Swift, D., eds., Marine sediment transport and environment management: New York, John Wiley and Sons, p. 241-254.
- McCave, I. N., 1972, Transport and escape of fine-grained sediment from shelf areas, in Swift, Duane, and Pilkey, eds., Shelf sediment transport: process and pattern: Stroudsburg, Pa., Dowden, Hutchinson, and Ross, Inc., p. 225-248.

- McCave, I. N., 1971, Wave effectiveness at the sea bed and its relationship to bed-forms and deposition of mud: *Jour. Sed. Petrology*, v. 41, p. 89-96.
- Meisburger, E. P., 1979, Reconnaissance geology of the inner continental shelf, Cape Fear Region, North Carolina: Fort Belvoir, Va., U. S. Army Corps of Engin. Coastal Engineering Research Center, Tech. Report No. 79-3, 135 p.
- Mixon, R. B. and Pilkey, O. H., 1976, Reconnaissance geology of the submerged and emerged Coastal Plain province, Cape Lookout area, North Carolina: U. S. Geol. Survey Prof. Paper No. 859, 45 p.
- Moorefield, T., 1978, Geologic processes and history of the Fort Fisher Coastal Area, North Carolina (M.S. thesis): Greenville, N. C., East Carolina Univ., 100 p.
- Pearson, D. R., 1978, Beach ridge genesis West Mexico Coastal Plain (unpub. paper): Buffalo, Dept. of Geology, State Univ. N. Y., 24 p.
- Pearson, D. R., 1977, Sand storms storage - a review of barrier island beach mechanics (unpub. paper): Greenville, N. C., Dept. of Geology, East Carolina Univ., 59 p.
- Richards, H. G., 1950, Geology of the coastal plain of North Carolina: *Amer. Philos. Soc. Trans.*, v. 40, part 1, p. 1-64.
- Riggs, S. R., 1979, A geologic profile of the North Carolina Coastal-Inner Shelf system, *in* Langfelder, J., ed., Ocean outfall wastewater disposal feasibility and planning: Raleigh, Dept. of Marine Sciences and Engineering, N. C. State Univ., p. 90-113.
- Riggs, S. R., and Freas, D. H., 1967, Submerged shoreline features on the shelf near Cape Fear, North Carolina: *Geol. Soc. America Spec. Paper* 115, p. 50-51.
- Sears, P. C., 1973, Evolution of Platt Shoals, Northern North Carolina shelf - inferences from areal geology (M.S. thesis): Norfolk, Va., Institute of Oceanography, Old Dominion Univ., 58 p.
- Sheppard, F. P., 1932, Sediments of the continental shelves: *Geol. Soc. America Bull.* 43, p. 1017-1040.
- Silvester, R., 1974, Coastal Engineering Vol. 1: Amsterdam, N. Y., Elsevier Scientific Pub. Co., 453 p.
- Swift, D. J. P., Shideler, C. L., Holliday, B. W., McHone, J. F., and Sears, P., 1973a, Distribution and genesis of Virginia-Northern North Carolina inner shelf sands (unpub. paper): Norfolk, Va., Institute of Oceanography, Old Dominion Univ., 56 p.
- Swift, D. J. P., Duane, D. B., and McKinney, T. F., 1973b, Ridge and swale topography of the Middle Atlantic Bight, North America: secular response to the holocene hydraulic regime: *Marine Geology* v. 15, no. 4, p. 227-247.

- Swift, D. J. P., Sanford, R. B., Dill, C. E., and Avignone, N. F., 1971, Textural differentiation on the shoreface during erosional retreat of an unconsolidated coast, Cape Henry to Cape Hatteras, western North Atlantic shelf: *Sedimentology*, v. 16, p. 221-250.
- Teleki, P. G., 1972, Wave boundary layers and their relation to sediment transport, in Swift, Duane, and Pilkey, eds., *Shelf sediment transport: process and pattern*: Stroudsburg, Pa., Dowden, Hutchinson, and Ross, Inc., p. 21-59.
- U. S. Naval Weather Service Command, 1970, Summary of synoptic meteorological observations, North America Coastal Marine Areas, Vol. 3: Springfield, Va., Federal Clearinghouse for Scientific and Technical Information, 472 p.
- Weggel, J. R., 1972, An introduction to oceanic water motions and their relation to sediment transport, in *Shelf sediment transport: process and pattern*: Stroudsburg, Pa., Swift, Duane, and Pilkey, eds., Dowden, Hutchinson, and Ross, Inc., p. 1-20.

A P P E N D I X

STATION NUMBER	LORAN COORDINATES	DEPTH (FEET)	BOTTOM TOPOGRAPHY *	DISTANCE OFFSHORE N.M.	SORTING (ϕ)	SKWNESS	KURTOSIS	MEAN (ϕ)	MODE (ϕ)	MODE %	% GRAVEL	% MUD	% CLAY SHIPEK SAMPLE	% S-CLAY (top 3 cm)	% ORGANICS (top 3cm)	FOLK NAME	DIVE OBSERV., CM. OF MUD
NA-1	71299.7 x 56075.3	36	L	0.47	1.02	+ .01	1.15	-0.42	0.0	21	25.0	0.5				gran. V. COARSE SAND	18
NA-1-D	71299.7 x 56075.3	36	L	0.47	2.93	+ .29	1.57	5.03	3.5	17	4.6	53.4	15.5			sli. gran. v. fine sandy MUD	18
NA-2	71299.6 x 56074.4	28	H	0.54	0.71	- .16	1.20	2.29	2.5	32	0.2	0.4		0.9	0.4	v. sli. gran. FINE SAND	
NA-3	71298.0 x 56066.5	52	P	1.25	0.75	- .11	2.35	2.81	3.0	49	1.9	4.7	0.7	2.9	1.2	sli. gran. FINE SAND	
NA-4	71297.2 x 56061.6	61	L	1.68	1.75	+ .51	1.00	4.45	3.5	25	0.1	44.1	4.6	15.3	3.6	v. sli. gran. muddy V. FINE SAND	20
NA-5	71296.7 x 56059.7	58	H	1.85	0.59	+ .07	1.09	2.88	3.0	36	0.0	3.4		1.0	0.6	FINE SAND	
NA-6	71294.8 x 56045.9	75	L	3.08	1.83	+ .74	1.06	5.02	4.0	38	0.0	45.1	14.3	7.2	2.7	muddy V. FINE SAND	23
NN-1	71332.9 x 54100.3	18		0.20	0.45	- .19	1.33	2.59	3.0	52	0.0	0.3		5.0	0.4	FINE SAND	
NN-2	71331.9 x 54091.6	55	P	1.04	0.67	- .13	1.14	3.44	3.5	32	0.0	18.3	0.7	4.1	1.4	muddy V. FINE SAND	
NN-3	71331.9 x 54087.2	63	P	1.45	0.59	+ .37	1.24	3.79	4.0	37	0.0	23.1	0.9	3.9	1.0	muddy V. FINE SAND	
NN-4	71331.1 x 54082.5	64		1.90	0.75	- .14	1.13	1.21	1.5	27	1.7	1.3		2.5	0.7	sli. gran. MEDIUM SAND	
NN-5	71330.5 x 54077.9	74	L	2.30	1.16	- .19	1.26	0.55	1.0	20	9.8	1.8		7.4	1.7	pebbly COARSE SAND	6
NN-6	71328.9 x 54069.8	66	H	3.02	0.48	- .03	1.09	1.67	2.0	44	0.2	0.3		0.5	0.4	v. sli. gran. MEDIUM SAND	
NJ-1	missed reading	16		0.22	0.42	- .12	1.18	2.57	3.0	48	0.0	0.2		0.8	0.4	FINE SAND	
NJ-2	71359.9 x 54113.1	60	SL	0.82	0.93	- .18	1.57	1.02	1.5	29	5.4	2.5		1.3	0.5	gran. MEDIUM SAND	
NJ-3	71359.4 x 54111.7	60	SH	0.98	1.20	- .38	1.03	0.84	1.0	21	17.1	0.3		1.1	1.1	pebbly COARSE SAND	
NJ-4	71358.4 x 54103.4	73	L	1.81	2.07	+ .27	3.25	2.60	2.5	28	4.9	16.4	6.7	7.5	0.8	pebbly muddy FINE SAND	13
NJ-5	71356.0 x 54093.0	56	H	2.60	0.77	- .31	1.16	1.20	1.5	28	2.6	0.2		1.0	0.5	sli. gran. MEDIUM SAND	
NJ-6	71355.7 x 54089.5	58	H	2.95	0.77	- .44	1.10	1.22	2.0	28	1.2	0.3		0.6	0.4	sli. gran. MEDIUM SAND	
NJ-7	71356.0 x 54087.8	55	H	3.14	1.02	- .25	1.21	1.00	1.5	22	6.5	0.5		0.7	0.4	pebbly MEDIUM SAND	

Table A1. Sample station information for the Nags Head study area.

STATION NUMBER	LORAN COORDINATES	DEPTH (FEET)	BOTTOM TOPOGRAPHY *	DISTANCE OFFSHORE N.M.	SORTING (ϕ)	SKEWNESS	KURTOSIS	MEAN (ϕ)	MODE (ϕ)	MODE %	% GRAVEL	% MUD	% CLAY SHIEK SAMPLE	% S-CLAY (top 3cm)	% ORGANICS (top 3cm)	FOLK NAME
WW-1	55944.1 x 72050.6	22		0.25	0.47	- .17	1.47	2.78	3.0	45	1.3	1.1		1.2	0.6	sli. gran. FINE SAND
WW-2	55941.4 x 72052.5	37		0.82	0.68	- .31	1.69	2.72	3.0	42	1.1	1.8		1.5	1.4	sli. gran. FINE SAND
WW-3	55941.1 x 72053.3	43	L	0.98	1.52	- .41	2.33	2.50	3.5	28	7.0	6.8	0.7	4.0	3.3	gran. V. FINE SAND
WW-4	55940.5 x 72056.1	44	SH	1.47	0.65	- .28	1.45	2.59	3.0	43	1.3	1.3		1.3	1.1	sli. gran. FINE SAND
WW-5	55937.5 x 72062.2	51	P	2.79	0.43	- .08	1.35	2.99	3.5	42	0.3	2.1		2.3	1.6	v. sli. gran. V. FINE SAND
WW-6	55937.0 x 72063.1	54	P	3.05	0.46	- .12	1.51	2.97	3.0	44	0.3	2.7		2.9	1.0	v. sli. gran. V. FINE SAND
WC-1	16379.4 x 56066.1	26	L	0.20	0.88	- .10	1.33	1.30	1.5	28	4.0	0.7				sli. gran. MEDIUM SAND
WC-1-D	16379.3 x 56065.9	28	L	0.21	1.92	+ .14	1.57	7.16	7.0	34	0.0	93.2	27.1			MUD
WC-2	16376.1 x 56062.3	33	L	0.72	1.08	+ .07	1.18	0.23	0.5	23	10.7	1.5				gran. COARSE SAND
WC-3	16373.9 x 56058.9	26	H	0.96	0.86	- .42	1.75	1.96	2.5	36	3.8	0.6				sli. gran. FINE SAND
WC-4	16370.5 x 56056.8	41		1.49	0.68	- .27	1.14	2.03	2.5	35	0.6	0.6				v. sli. gran. FINE SAND
WC-5	16370.4 x 56055.8	43		1.61	1.15	- .43	1.73	1.88	2.5	29	6.3	1.9				gran. FINE SAND
WC-6	16363.2 x 56049.0	44		2.50	1.21	- .19	1.10	1.34	2.5	17	6.1	1.3				gran. FINE SAND
WC-7	16359.5 x 56041.1	47		3.29	0.67	- .38	1.98	2.63	3.0	47	1.5	0.9				sli. gran. FINE SAND
WK-1	72118.8 x 16344.2	27		0.37	0.89	- .16	1.59	1.54	2.0	30	3.6	1.1				sli. gran. MEDIUM SAND
WK-2	72119.9 x 16341.8	33		0.82	1.31	- .57	1.53	2.05	3.0	35	7.0	2.4				gran. MEDIUM SAND
WK-3	56067.5 x 16340.0	38		1.50	1.06	- .08	1.45	0.91	1.0	24	6.9	1.5				gran. COARSE SAND
WK-4	56064.5 x 16337.8	41		1.93	1.17	+ .38	1.04	0.24	0.0	25	3.1	1.7				gran. V. COARSE SAND
WK-5	56062.8 x 16336.9	34	H	2.26	0.60	- .29	1.24	2.20	2.5	36	1.8	0.5				sli. gran. FINE SAND
WK-6	56057.0 x 16333.5	44		3.05	1.26	- .95	2.00	2.15	3.0	41	7.7	0.9				gran. FINE SAND

Table A2. Sample station information for the Wilmington study area.