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NEARSHORE ROCK EXPOSURES
AND THEIR RELATIONSHIP
TO MODERN SHELF SEDIMENTATION
ONSLOW BAY, NORTH CAROLINA

A Thesis

Presented to
the Faculty of the Department of Geology
East Carolina University

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

by

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ABSTRACT

The nearshore ocean floor (water depths of fifteen meters or less) in West Onslow Bay, North Carolina reflects a complex relationship between the carbonate rock exposures and the surrounding modern sediments. A limestone containing pelecypod molds and casts, probably the Pollocksville Member of the Belgrade Formation, with extensive interbeds of fossil oyster bioherms (Crassostrea gigantissima) is exposed on approximately 50% of the sea floor around New River Inlet.

Two major kinds of processes are presently acting upon this ancient rock surface to produce the modern topography, sediments and carbonate rock exposures. The dominant constructive processes are controlled by biologic agents which include vermitid gastropod reefs, encrusting algae, corals and sediment trapping bryzoans. The dominant destructive processes are controlled by the mechanical agents of waves and currents and by the biologic agents of boring pelecypods and polychaetes and burrowing crustaceans.

The results of the processes are: 1) highly irregular rock surfaces with steep landward facing scarps (up to 5 meters in relief) subparallel to the beach with large boulders at their base; 2) a series of vermitid gastropod reefs growing along the crest of the scarps in the vicinity of New River Inlet; and 3) the production of a thin blanket of loose sediment that varies

in texture from boulders to mud and is composed dominantly of limestone rock fragments, quartz sand, carbonate mud and a mixed assemblage of modern and fossil shell material. Thus, the modern processes operating on the rock surface result in distinct morphologic features and the production of sediments which have a strong internal heritage.

ACKNOWLEDGMENTS

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My sincere thanks and appreciation go to Drs. Stanley Riggs, Scott Snyder and Donald Neal (thesis committee members from East Carolina University) for their assistance in the planning research and writing of this thesis. Dr. Orrin Pilkey, from Duke University, also provided critical review during the writing of this thesis. Dr. Pei-Lin Tien formerly of East Carolina University aided in some of the laboratory phases of the study. Diana Mills, biologist, was a field assistant aiding in the field and laboratory phase of the study.

Finally, I would like to express my deepest and most loving thanks to Renee Crowson (wife) without whom this thesis would have been meaningless.

INTRODUCTION

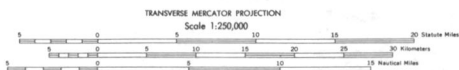
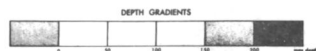
Location of Study Area

This study concerns the nearshore sediment and rock substrates in central Onslow Bay, North Carolina. The fifty four square kilometer study area includes eleven kilometers of shoreline in central Onslow Bay (Figure 1). It extends for approximately five kilometers to the northeast and six kilometers to the southwest from New River Inlet. Water depths range from the surf zone to approximately 12 meters at a distance of 5 kilometers offshore.

Regional Setting

Onslow Bay is a shallow embayment on the southeastern Continental Shelf of North Carolina located between Cape Lookout on the northeast and Cape Fear on the southwest (Figure 1). In the area offshore from Bogue Banks the ocean bottom is characterized by thin discontinuous Quaternary sediments overlying unconsolidated tertiary units (mostly the Yorktown Formation of Pliocene age). To the south and east of this area the substrate of Onslow Bay is characterized by extensive outcrops of Tertiary limestones covered by a thin discontinuous surface layer of Quaternary to modern sediments. The bulk of these surface sediments originated from the disintegration of the Tertiary units.

N.O.S. 0806N-23
CAPE FEAR RIVER TO OCRACOKE INLET



U.S. DEPARTMENT OF COMMERCE
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
NATIONAL OCEAN SURVEY
1972

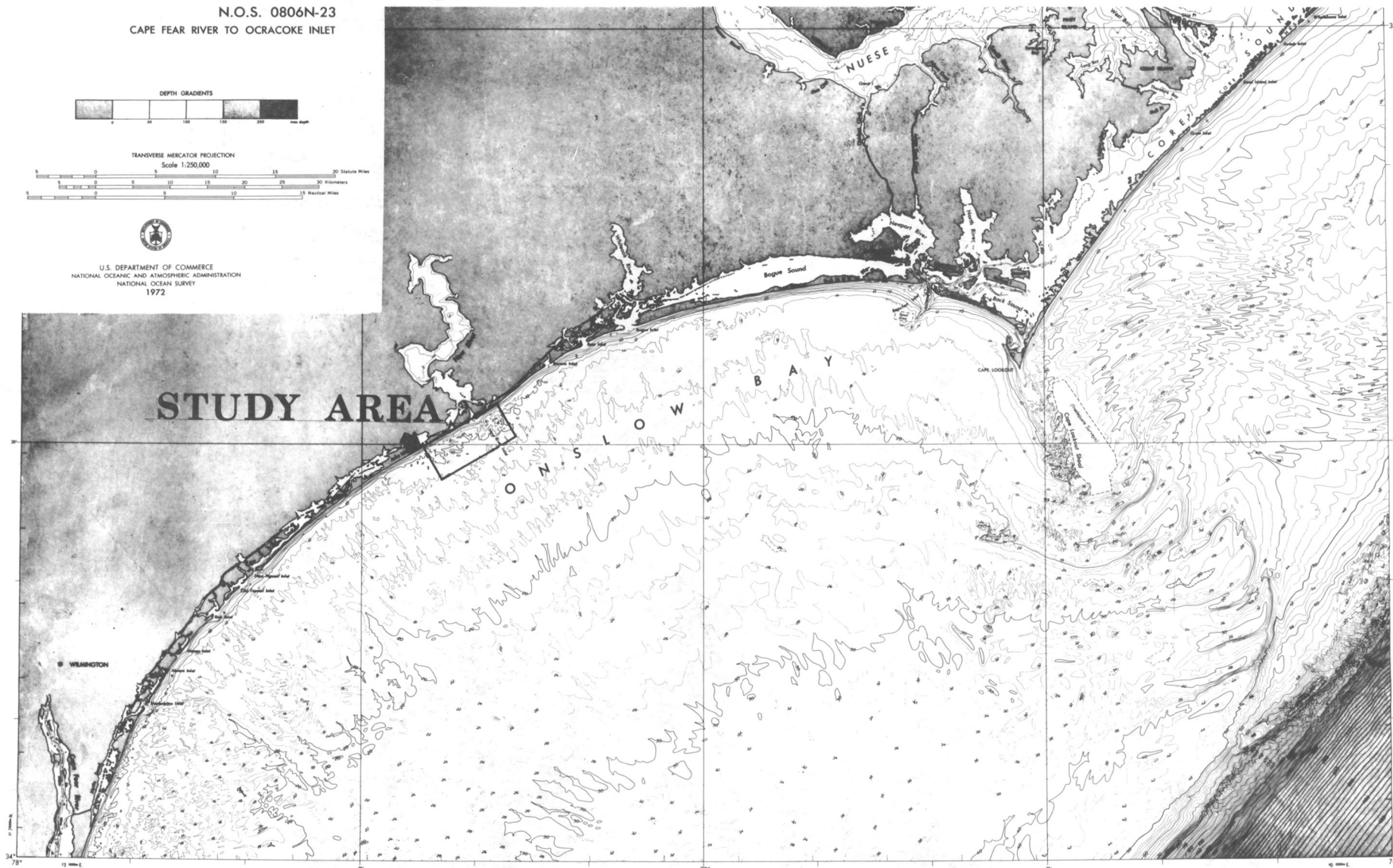


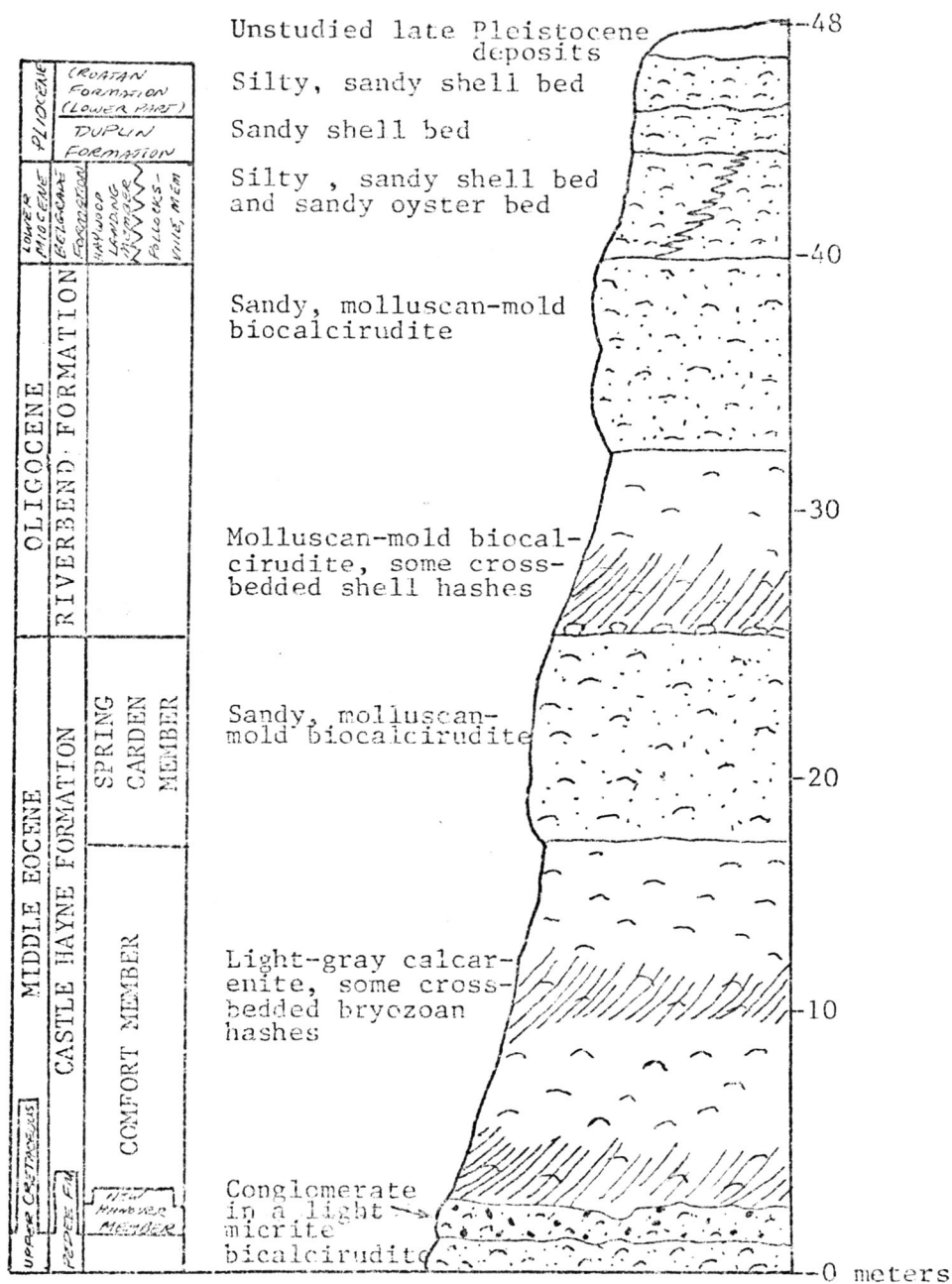
Figure 1. Map showing the location of the study area and the general bathymetric features of Onslow Bay.

In the study area, New River Inlet protrudes seaward forming a small cape feature along the coastline of central Onslow Bay (Figure 1). The cape feature is related to a limestone rock headland exposed on the sea floor in the vicinity of New River Inlet (referred to here as the New River High). Figure 2 is a generalized composite section of the Coastal Plain Tertiary units. These same units extend out onto the Continental Shelf and crop out on the nearshore bottom of the study area.

The Cape Fear and Castle Hayne structural arches bound Onslow Bay Basin to the southwest and north, respectively (Figure 3). These structures largely determine the distribution and geometry of the Tertiary rocks in Onslow Bay.

The coastline in the study area faces south to southeasterly. Consequently these coastal areas do not receive the direct brunt of the dominant winter storms from the northeast which frequent the North Carolina coastline. This southern segment of the North Carolina coast is under the direct influence of a warm tropical ocean current, the Gulf Stream. This results in the growth of tropical and subtropical fauna and flora uncommon to the northern North Carolina Continental Shelf area.

The characteristics of the coastal waters in the study area are quite variable. The water temperature varies from 10°C in the winter to 24°C in the summer. Turbidity of the water varies from less than one meter of visibility on the poorest of days to more than five meters on the best of days.



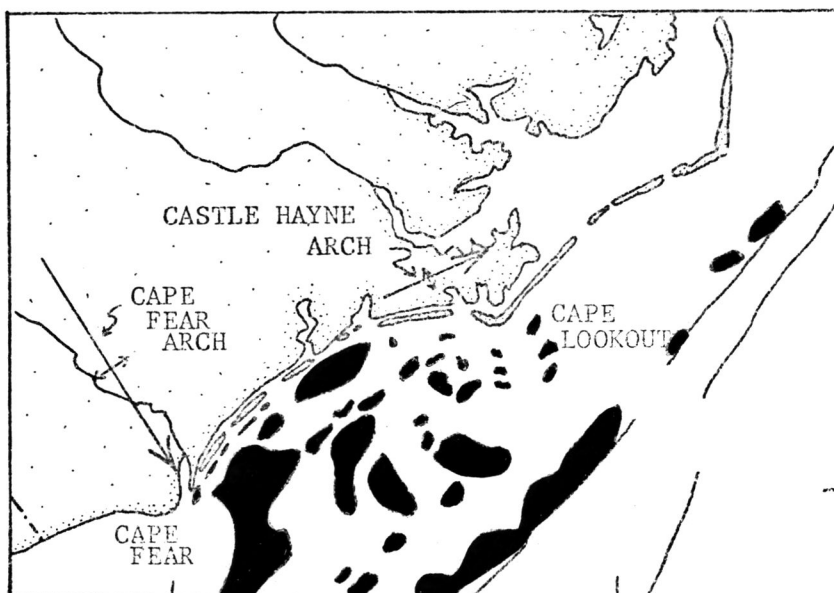


Figure 3. Generalized map of Eastern North Carolina and adjacent Continental Shelf illustrating the basic structural framework and distribution of known seabottom rock outcrops (from Riggs ,1979).

Turbidity is related to sea state, tidal stage, and position relative to New River Inlet. The generally poor visibility experienced during the study prohibited underwater photography.

OBJECTIVES

The study area was selected for the following reasons.

1. The submarine limestone exposures occurring immediately offshore from Onslow and West Onslow Beaches have never been studied in detail from a geologic standpoint.
2. The study area was easily accessible by a small boat operated out of Sneads Ferry (a small fishing port just five minutes by water from the study area) where a low cost field base, equipped with a 14-foot open-bow fiberglass boat, was at my disposal.

The main objectives of the thesis are as follows:

1. To study the submarine geomorphology of the area utilizing National Oceanographic and Atmospheric Administration (NOAA) "smooth sheets" and fathometer profiles of the ocean bottom;
2. To map the surface distribution of sediment and rock surfaces utilizing fathometer profiles and SCUBA diving techniques;
3. To develop an understanding of the biologic and geologic processes operating upon the sediment and rock substrates in the nearshore environment of Onslow Bay.

PROCEDURES

Field Phase

Bathymetry

A Raytheon model DE-725 recording fathometer mounted on the stern of the 14-foot research boat was used to obtain tracings representing approximately 100 kilometers of bottom profiles in the study area. The locations of these profiles are illustrated in figure 4. The profiles were used to identify and map the basic geomorphologic features described in this thesis. The individual fathometer profiles are presented in Appendix I.

Each fathometer profile began and ended at a prominent location shown on a navigation chart. Constant boat speed was maintained within each traverse in order to assure minimum distortion due to variable travel speeds. There was, however, variation in boat speed from one traverse to another. Because each profile was run at different boat speeds none of the horizontal scales of the fathometer traces are the same. Whenever the boat came in line with a known point, a mark indicating its location was made on the chart.

Diving

Standard diving procedures described by Winston et al. (1968, p. 63-80) were employed while utilizing SCUBA diving equipment supplied by the East Carolina University Geology Department.

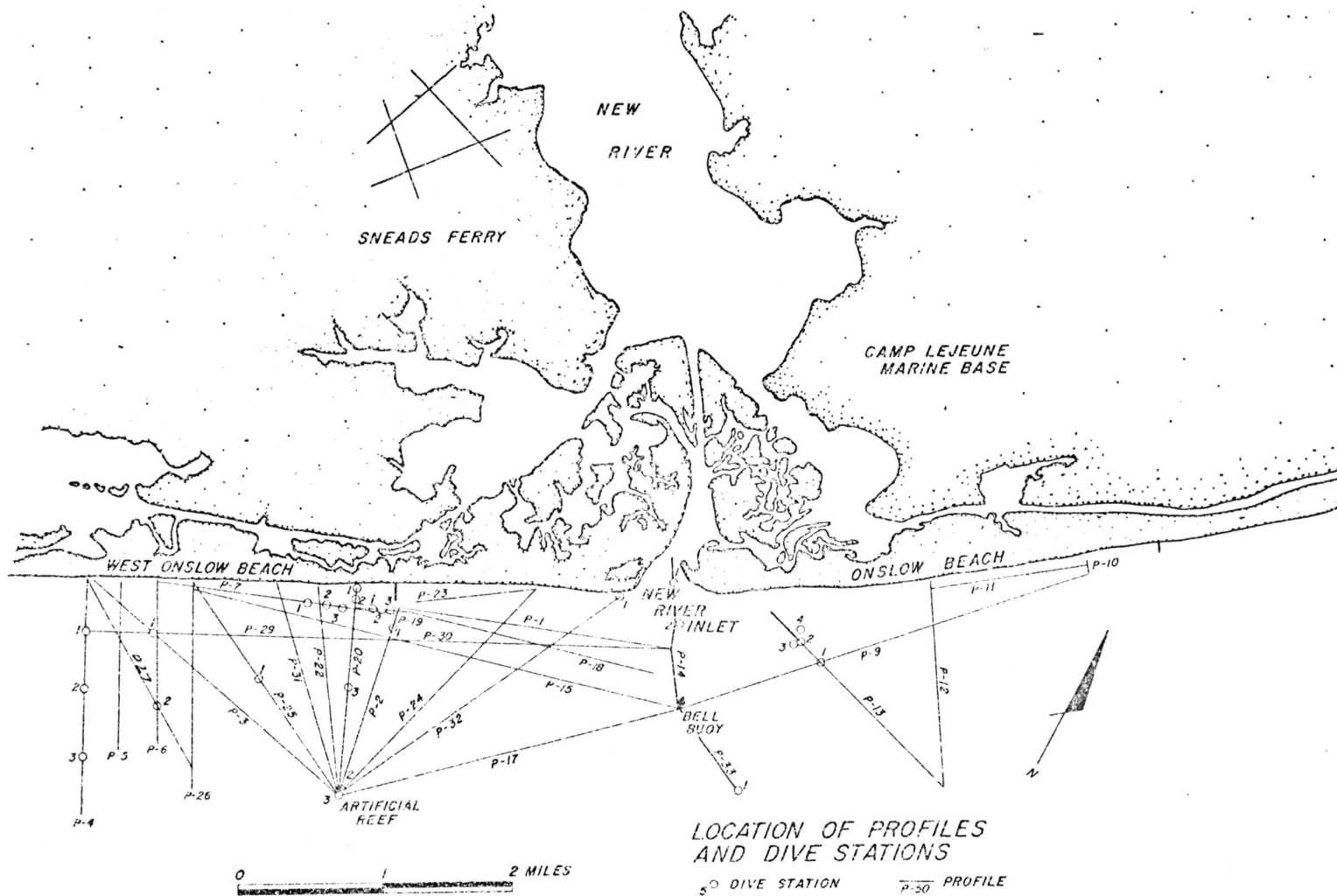


Figure 4. Map showing the location of all fathometer profiles and dive stations. The artificial reef shown on the map was moved south an unknown distance in 1977.

The techniques for bottom description and sample collection employed in the study are described by Riggs and O'Connor (1968, p. 24-27)

Location of Stations and Profiles

The sample stations and profiles were selected from a modified rectangular-radial grid system superimposed over the study area. Accurate location of sample stations, traverses and profiles on the grid were made by triangulation using an astronomical sextant and at least two known positions.

Boating and Navigation

A 14-foot open-bow fiberglass boat equipped with a 40 horsepower outboard motor was used as a research vessel (Figure 5). The study area is well marked with navigation markers so that one's general location relative to safe navigable water can be determined.

Laboratory Phase

Base Map

A detailed base map of the study area was constructed from a photo-mosaic of Topsail Island and Onslow Beaches, and existing navigation charts prepared by NOAA.

Rock and Sediment Description

Standard procedures and methods were used in the descrip-



Figure 5. Photograph of research vessel with thesis supervisor, Stan Riggs, (left) and student, Ron Crowson, (right) at study base in Sneads Ferry, North Carolina.

tion of the rock and sediment samples (Folk, 1968). Most of the samples collected in the field were given brief descriptive names in the field lab.

Smooth Sheet Study

NOAA smooth sheets (H-9426 and H-9427) were utilized in the construction of a detailed bathymetric map of the study area. The hydrographic surveys were made in 1974, and gave great detail with respect to bottom topography. Data was sufficient to construct a bathymetric chart with a three foot contour interval (Figure 11).

Description of Benthic Organisms

Benthic organisms living in or on the sediment and rocks were collected in the field and later identified in the field laboratory. Mr. Francis Belcik, Diana Mills and Dr. Vince Bellis of the Biology Department at East Carolina University assisted in the identification of problematical species.

PREVIOUS INVESTIGATIONS

The rock exposures offshore from New River Inlet have long been known to the sport and commercial fishermen of Eastern North Carolina as excellent fishing locations. The fishermen refer to the exposures as "the black rocks" because of the large black bass fish caught there.

Prior to 1947 the rock exposures within Onslow Bay were thought to be composed of coral formations in the form of living, constructive reefs (Pearse and Williams, 1951). Pearse and Williams studied the biota of the "reefs" in 1947 and found the substrate to be composed of "Trent Marl" (1951, p. 133). They also reported the presence of the following organisms that are of special interest to this study:

1. two species of boring bivalves

Saxicava rugosa

Lithophaga bisulcata (date clam), some specimens of which may have been missidentified and should be placed in the genus Gastrochaena (personal communication from Dr. Scott Snyder).

2. the reef forming sessile gastropod

Vermicularia spirata

3. the reef associated corals

Astrangia astraefiformis

Oculina sp.

The exposures offshore from New River Inlet have never been studied in detail from a geologic standpoint. A few studies have dealt with similar rock exposures elsewhere in Onslow Bay. Cleary and Pilkey (1967) reported large expanses of carbonate rock exposures in Onslow Bay (Figure 6). The rock exposures offshore from New River Inlet were recognized but were not described by Cleary and Pilkey.

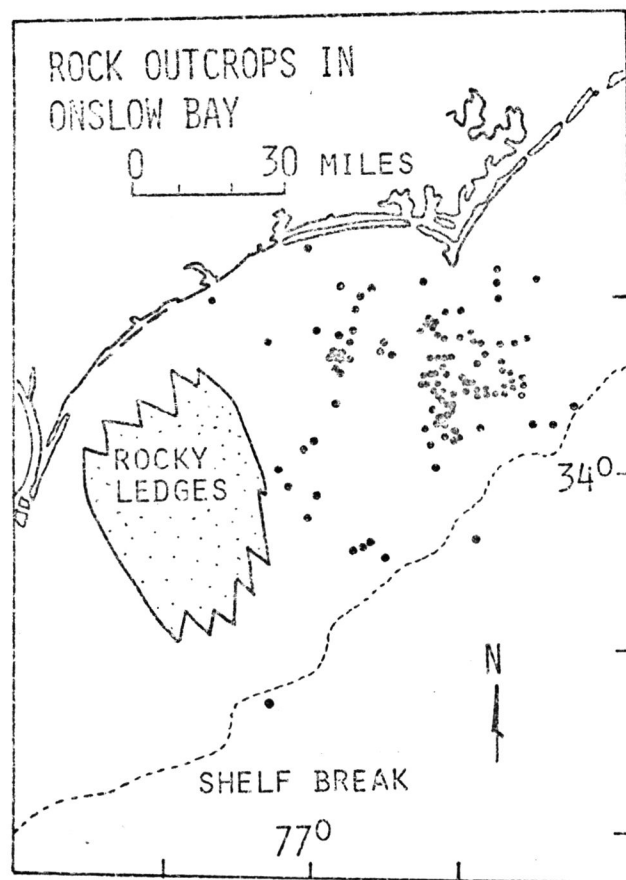


Figure 6. Map showing the distribution of rock outcrops in Onslow Bay identified by Cleary and Pilkey in 1967.

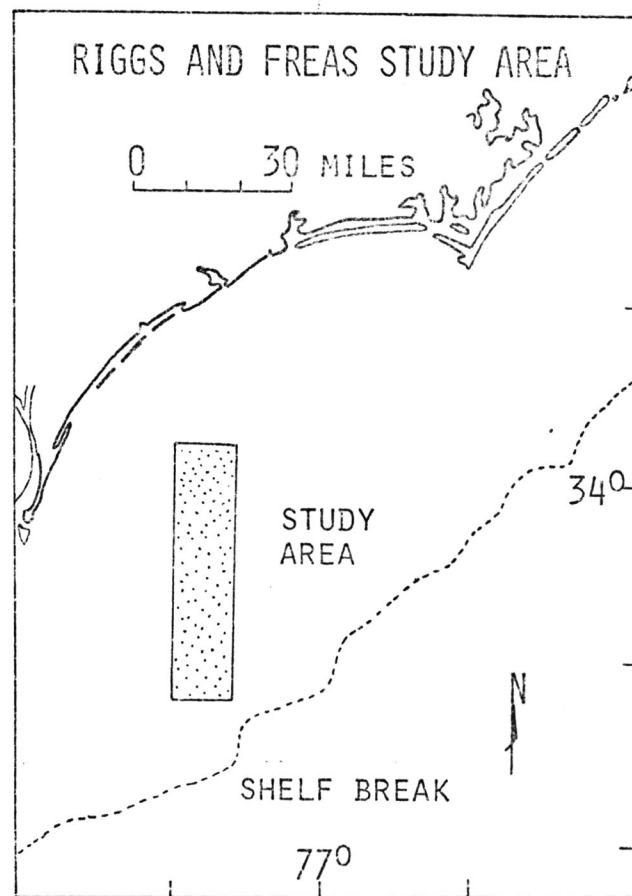


Figure 7. Riggs and Freas (1967) study area. Five zones of distinct bottom types were identified in this area.

Riggs and Freas (1967) described the nature of the rock surfaces exposed 16 kilometers east of Cape Fear's Frying Pan Shoals in the southern end of Onslow Bay (Figure 7). They found the rock surfaces to be highly corroded by organisms and commonly covered by thin layers of phosphatic sands. They related the distribution of sediments and the configuration of the limestone surfaces to submerged Pleistocene shorelines.

Luternauer (1966) described the distribution of phosphorite in Onslow Bay. He noted that the overall phosphate content of the beach sands along Onslow Bay increases to above 5% in the vicinity of New River Inlet. In 1967, Luternauer and Pilkey related the phosphorite grains in Onslow Bay to the possible existence of Miocene phosphorite outcrops in Onslow Bay. They suggested that commercial quantities of phosphate may be present in this area.

Roberts and Pierce (1967) utilized dredge samples to outline an area where the phosphate-bearing Yorktown Formation is sporadically exposed in Onslow Bay. The outcrop extends across a 40 kilometer wide diagonal from Cape Lookout to Cape Fear. They considered the Yorktown to be the main contributor of phosphate to the shelf sediments in Onslow Bay.

Brown et al. (1972) described the structural and stratigraphic framework of the Coastal Plain adjacent to the study area. They pointed out that the Oligocene sediments are characterized by a facies change from a carbonate dominated system east of New River Inlet to a mixed carbonate terrigenous system west of the inlet.

Lawrence (1975) studied the paleoenvironmental setting of the giant fossil oyster Crassostrea gigantissima (Finch) within the study area. He concluded that the giant oyster bioherms were related to a prograding Oligocene delta. The oysters lived marginal to and northeast of the Oligocene delta. In 1975, Lawrence called the oyster unit Oligocene in age. However, Ward, Lawrence and Blackwelder (1978) place this unit in the Lower Miocene as part of the Pollocksville Member of the Belgrade Formation. This major revision introduced the Belgrade Formation as a new stratigraphic unit that includes types lithologies found at Haywood Landing and Belgrade, North Carolina (Figure 8).

In 1979, Baum et. al. proposed yet another stratigraphic name revision. They suggested that the Crassostrea unit found at the Belgrade Quarry and in this thesis study area was younger than the Haywood Landing or Belgrade material, but still included it as part of the Lower Miocene sequence (Figure 8).

Meisburger (1979) studied the geology of the inner continental shelf in the Cape Fear Region, including part of this thesis study area (Figure 9). Meisburger cored four holes within or adjacent to my thesis study area (Figure 10). He reported that the nearshore bottom around New River Inlet contains sparse sediment cover containing abundant microfossils covering common rock outcrops.

AUTHOR SERIES	MILLER 1912	KELLUM 1926	BROWN 1955-1958	SWIFT & HERON 1969. WHEELER & CURRAN 1974	BROWN ET AL. 1972 (# FM. NAMES NOT USED BY AUTHORS)	BAUM ET AL. 1979	WARD ET AL. 1978
LOWER MIOCENE		TRENT FORMATION			UNNAMED MAPPED WITH OLIGOCENE	CRASSOSTREA SILVERDALE FM. BELGRADE FM.	HAYWOOD LANDING MEM. POLLOKS- VILLE MEM.
OLIGOCENE					UNNAMED	TRENT FORMATION	RIVER BEND FORMATION
UPPER EOCENE	CASTLE HAYNE LIMESTONE ? CRASS- OSTREA ?	CRASSOSTREA CASTLE HAYNE LIMESTONE	CASTLE HAYNE LS. INCLUDES CRASSOSTREA	UPPER EOCENE COMPONENT		NEW BERN FORMATION	
MIDDLE EOCENE	TRENT FM. ? IN PART K CARBONATE		MIDDLE EOCENE COMPONENT	CASTLE HAYNE LIMESTONE (AGE NOT SPECIFIED)	# NEW BERN FM. # CASTLE HAYNE LS. # ROCKY PT. MEM.	CASTLE HAYNE LIMESTONE	CASTLE HAYNE LS. SPRING GARDEN MEM. COMFORT MEM. NEW HANOVER MEM.

Figure 8. Chart showing the chronological development of Eocene to Lower Miocene Formation nomenclature from Baum et al. (1979).

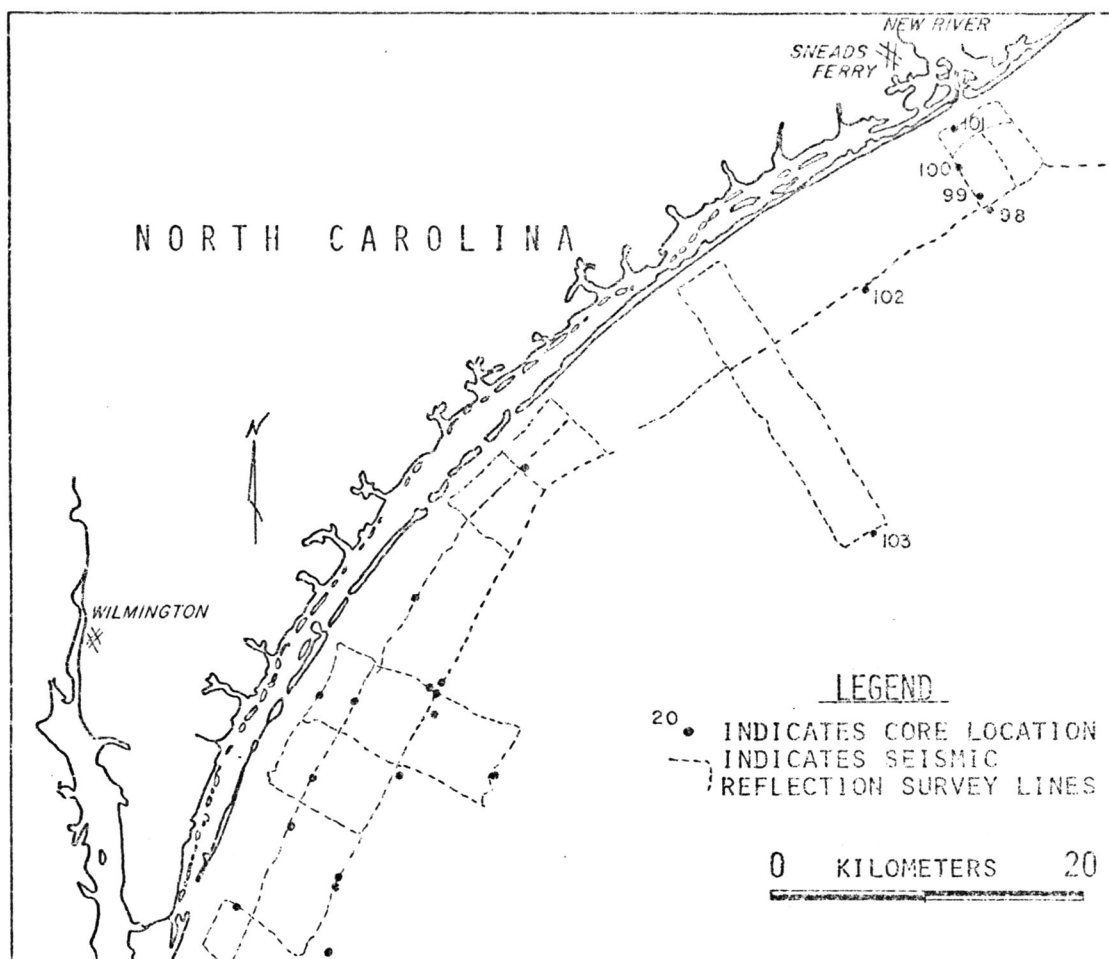


Figure 9. Map showing location of seismic reflection survey lines and core sites in and near the study area (Meisburger, 1979). Logs from core holes 98 thru 103 are presented on figure 10.

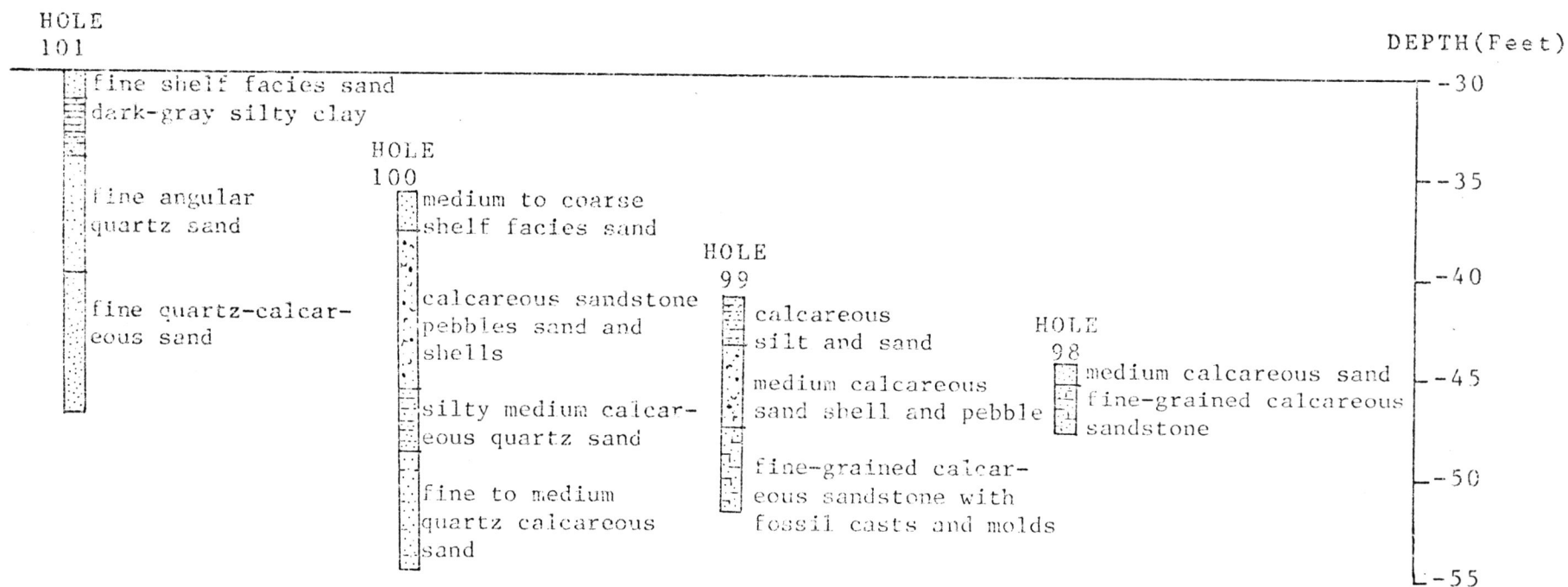


Figure 10. Core holes 98 thru 101 taken offshore from New River Inlet. A moldic calcareous sandstone was intersected in core holes 98 and 99. A bed approximately 2 to 3 meters thick composed of calcareous shells and calcareous sandstone pebbles was intersected in core holes 99 and 100. Core hole data from Meisburger (1979).

RESULTS

Bathymetry and Bottom Types

Regional Bathymetry

Figure 11 is a detailed bathymetric chart of the study area which I compiled from two hydrographic surveys (H-9426 and H-9427) made by NOAA in 1974. The bathymetric chart illustrates several pertinent bathymetric features. A seaward protrusion of the shoreline and the bathymetric contours in the vicinity of New River Inlet is coincident with major rock outcrops east and west of the inlet. Irregular bathymetric contours with a maximum relief of 3 meters over a lateral distance of less than 100 meters indicate a very irregular bottom around New River Inlet. The eastern one third of the map has widely spaced contours indicating a smooth bottom with low relief.

Fathometer Tracings

On the basis of numerous fathometer profiles and dives made along these profiles, four general types of ocean bottom are recognized: 1) sediment surface, 2) rock and sediment surface, 3) undissected rock surface, and 4) dissected rock surface. Figure 12 is an idealized fathometer tracing illustrating typical fathometer patterns for each of the four general ocean bottom types.

The sediment surface bottom type produces fathometer tracings that are smooth and have low relief. The rock and sediment surface produces fathometer tracings that are sharp and indicate an undulatory ocean bottom with less than one meter of relief. The undissected rock surface produces a sharp, clear fathometer tracing indicating a smooth surface perched above the surrounding bottom. The dissected rock surface produces a very irregular fathometer tracing, often indicating up to 5 meters of relief over a distance of only several meters.

Distribution of Bottom Types

The distribution of the four general bottom types is illustrated in Figure 13. In general, the four units are related to the location of New River Inlet and to two major rock outcrop areas east and west of New River Inlet.

The sediment surface occurs as a narrow band, 0.2 to 0.8 kilometers wide, along Onslow and West Onslow Beaches. Sediments are deposited in two distinct depositional environments, 1) the New River ebb tide delta and 2) the nearshore and lower beach face. The New River ebb tide delta is composed of sediments deposited as a result of sediment laden ebb tide flows from New River Inlet. This area extends approximately 2 kilometers east and 4 kilometers west of New River Inlet (Figure 13). The nearshore shelf and lower beach face sediment surface occurs across the entire beach face and extends seaward across the innermost continental shelf until rock outcrops are encountered.

BATHYMETRY

BASED ON 1974 NOAA HYDROGRAPHIC SURVEYS
(H-9426-9427)

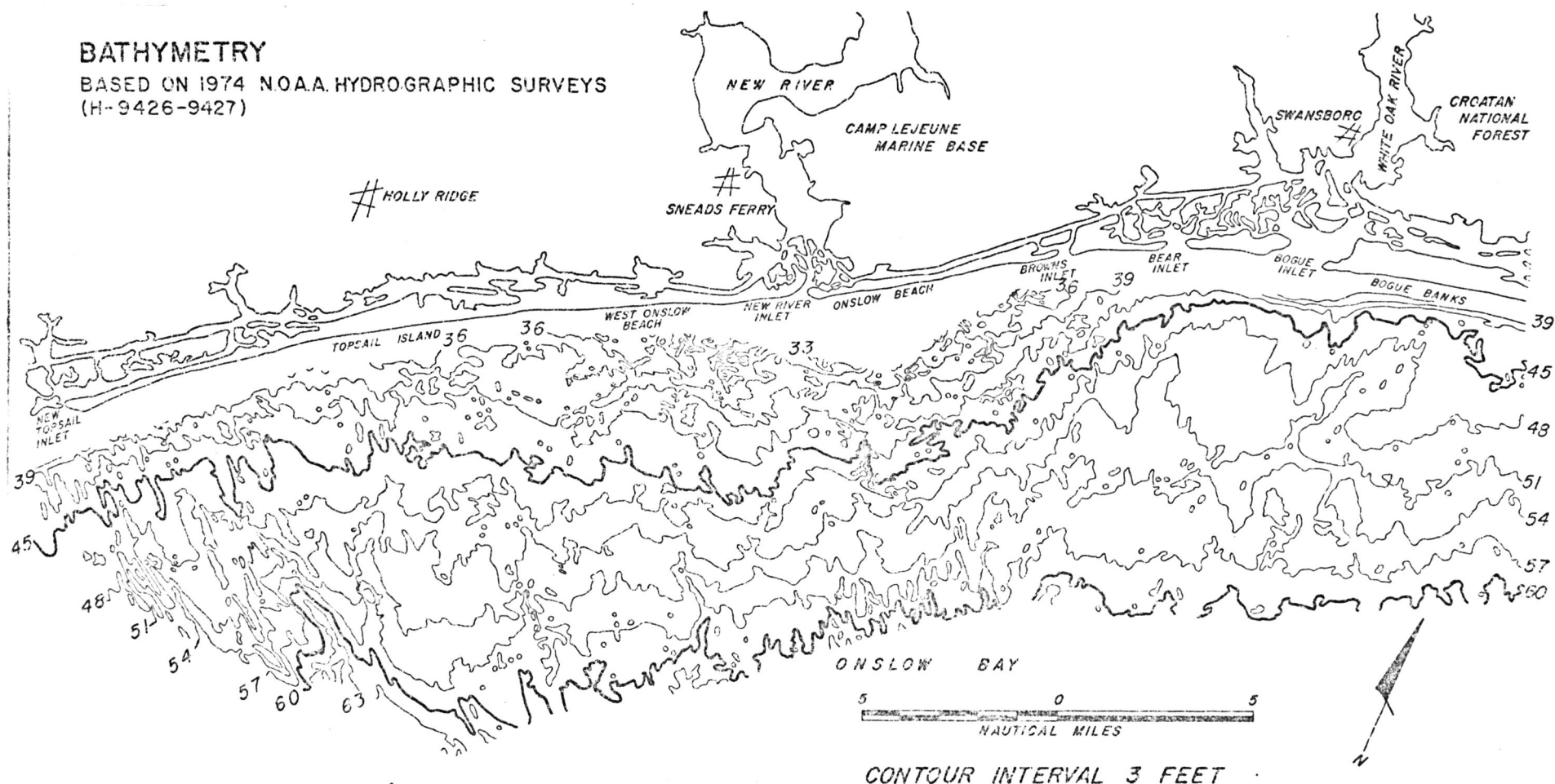


Figure 11. Bathymetric chart of central Onslow Bay, near New River Inlet. Irregular contours in the western one-fourth and in the central portion of the map indicate an irregular rock bottom. The widely spaced contours in the eastern one-third of the map indicate a relatively smooth bottom with a minor channel structure trending from the White Oak River drainage through Bogue Inlet.

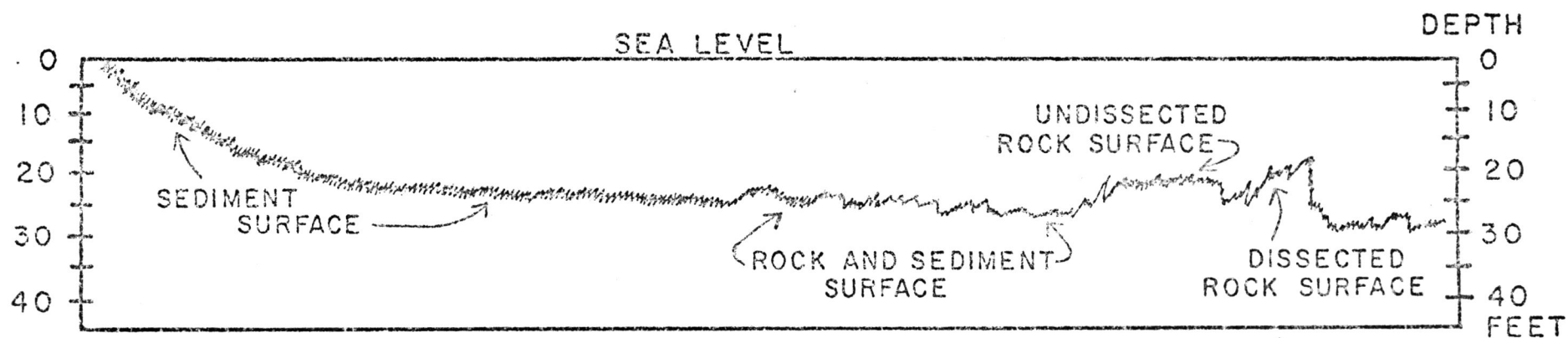


Figure 12. Idealized diagram illustrating the four different ocean bottom types as they appear on fathometer tracings.

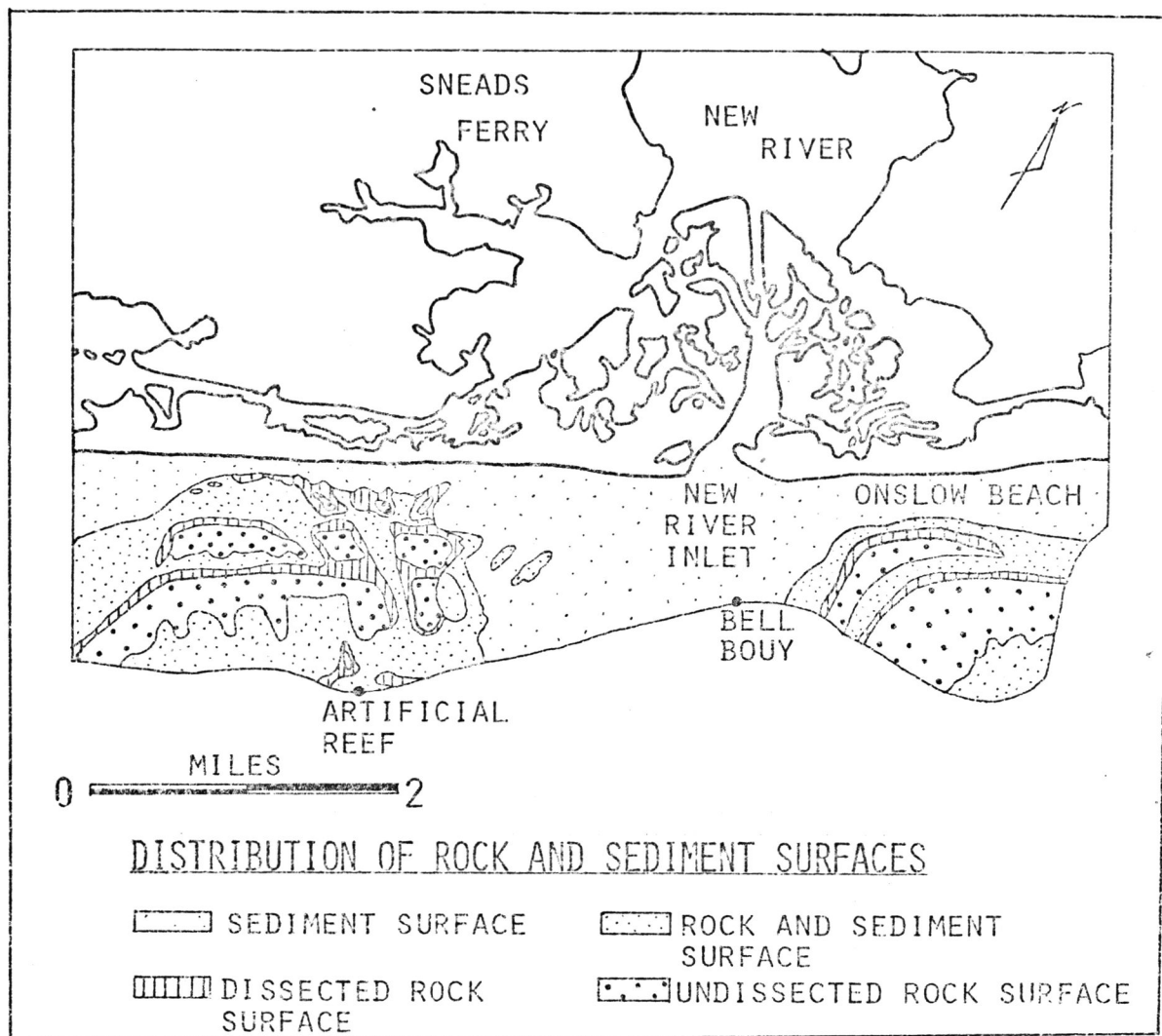


Figure 13. Map showing distribution of rock and sediment surfaces in the study area. Two prominent rock surfaces exist east and west of New River Inlet.

Two areas of major rock outcrops that lie two kilometers east and four kilometers west of New River Inlet are identified in Figure 13. The undissected rock surface makes up the core of each of these outcrops. It is an extensive rock surface exhibiting low relief with minor patches of loose sediment. The undissected rock surface stands in relief (up to 5 meters) above the surrounding ocean bottom and dips two meters per kilometer to the south and southeast (seaward).

Surrounding the exposures of undissected rock is the dissected rock surface. This is a narrow zone around the more shallow rock core where it is actively being eroded. The dissected rock surface is best developed along the shoreward margins of the undissected rock surfaces. Here the rock is extensively undercut, forming scarps up to five meters high with large boulders up to three meters long at the base of the scarps. Figures 14 and 15 illustrate the general nature of two rock scarps east and west of New River Inlet, respectively.

The rock and sediment surface forms a fringe area separating the dissected and undissected rock surfaces from the sediment surface. The rock and sediment surface generally is flat and covered with a thin and scattered veneer of sediment. Minor rock ledges less than 0.5 meter in relief rim small depressions filled with loose sands and gravels. Limestone boulders are present on the surface. The largest and least rounded boulders occur at the base of the small scarps. The limestone boulders become smaller and more rounded as the distance from the scarps increases in the direction of the shoreline.

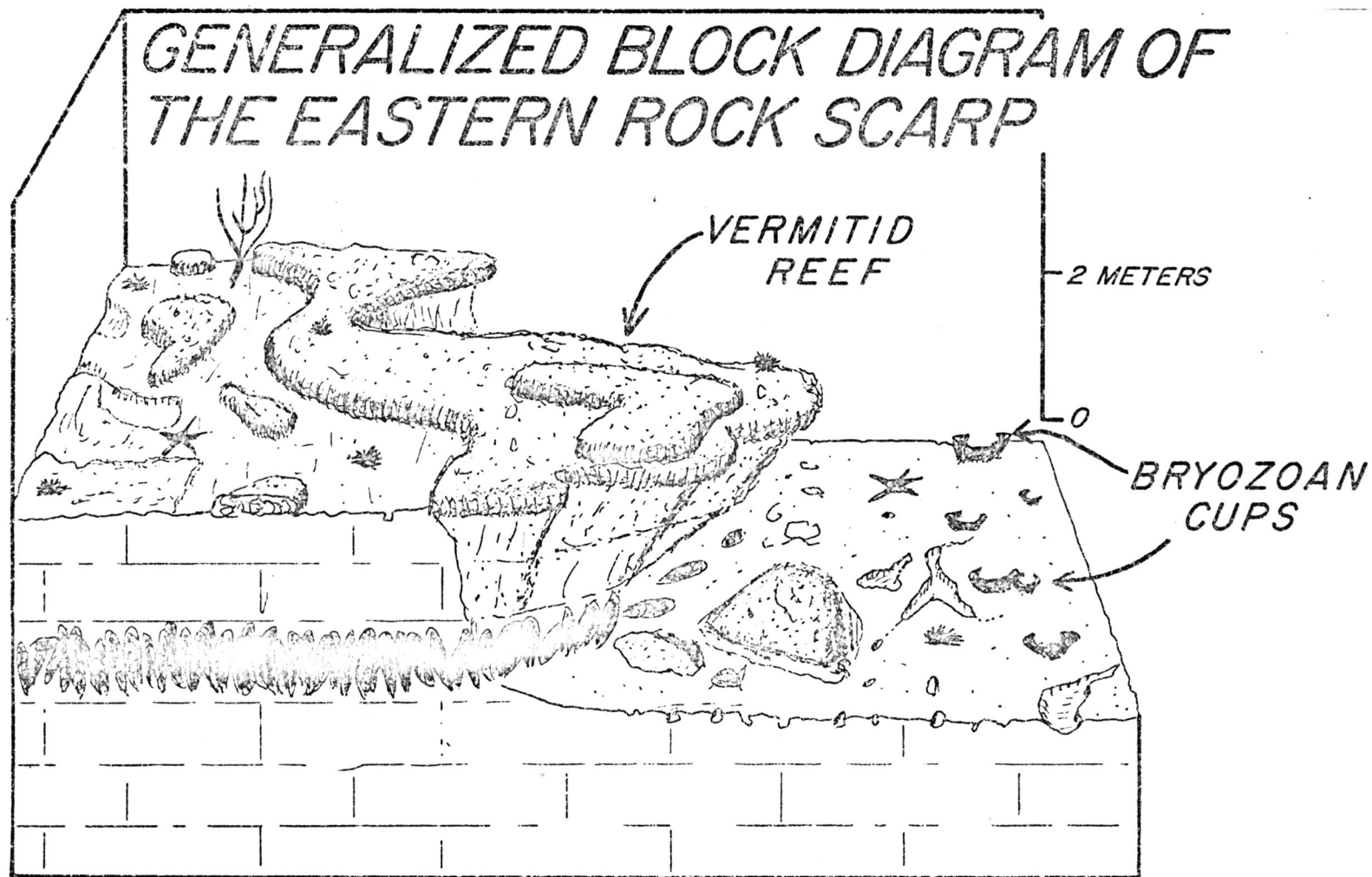


Figure 14. Generalized block diagram of the rock scarp east of New River Inlet. Vermitid gastropod reefs and bryozoan cups are characteristic of the eastern rock area.

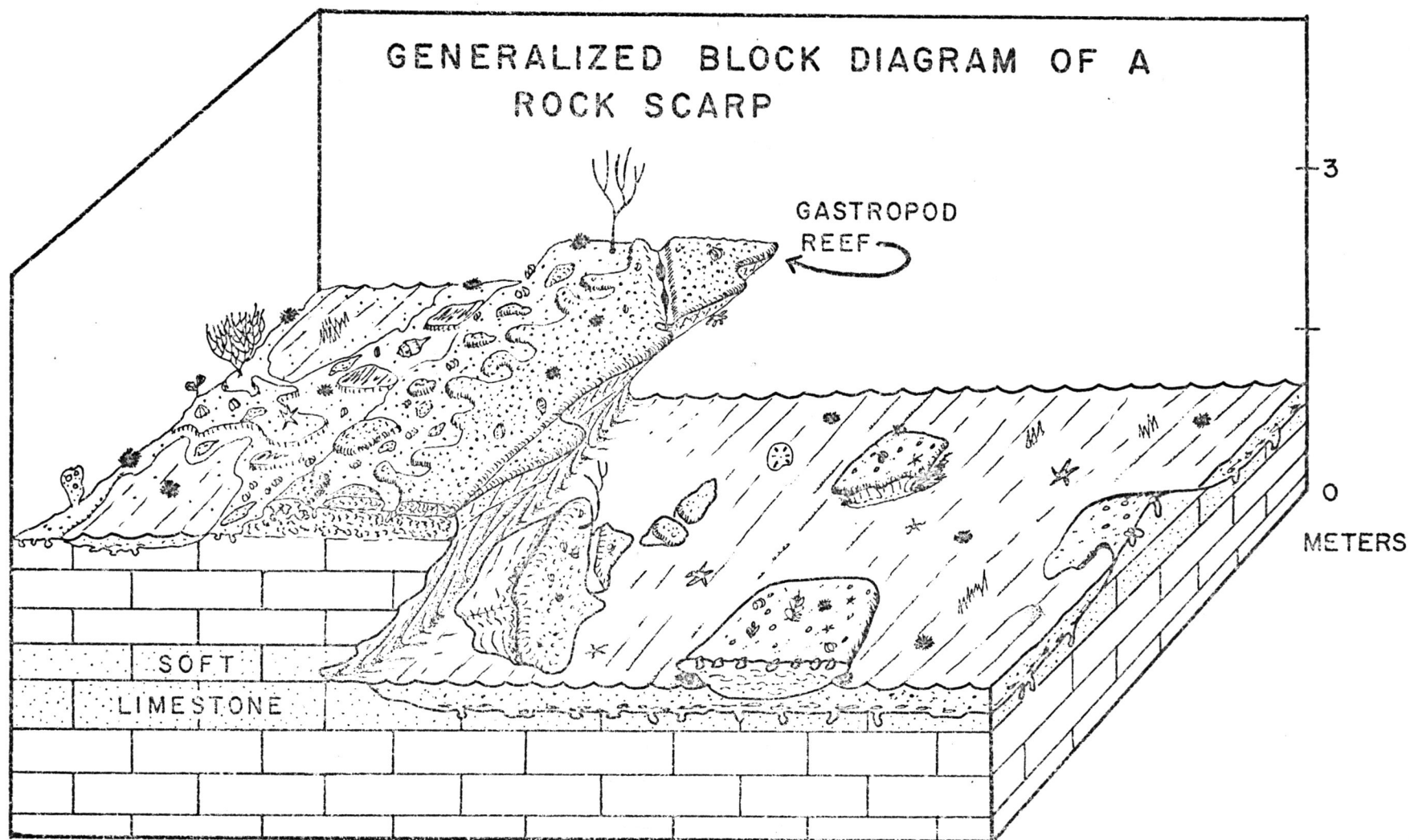


Figure 15. Generalized block diagram of the rock scarp west of New River Inlet. A "soft" limestone or marl commonly is found at the base of most undercut scarp features. Vermitid gastropod growth occurs only along the crest of scarps and large boulders accumulate at the base of the scarps.

Relict Rock

The term "relict rock" is applied to all non-modern rocks cropping out in the study area, and is distinguished from the "modern rock" that is presently being produced by the reef forming vermitid gastropods, bryozoans and calcareous algae. Most of the relict rock found in the study area represents rocks of Tertiary age. Five relict lithologic units have been described in the study area: 1) a pelecypod mold sandy biocalcirudite, 2) a biomicrudite, 3) an argillaceous pelecypod biocalcirudite, 4) an oyster biolithite, and 5) estuarine peats and clays.

The pelecypod mold sandy biocalcirudite is the dominant rock type. It represents more than 50% of the rock found on the sea floor. It is composed mostly of large molds of the pelecypod Mercenaria gardnerae (Kellum) in a medium to fine sandy limestone. The predominant non-carbonate mineral is quartz, which comprises approximately 30% of the total rock. This unit is lithologically similar to the upper part of the River Bend Formation of Ward et. al. (1978) at the Martin Marietta Quarry in Belgrade, North Carolina approximately 50 kilometers (30 miles) north of the study area. Figure 16 illustrates the moldic nature of this sandy limestone which is characteristic of the River Bend Formation.

A biomicrudite occurs as mold fillings within the above biocalcirudite at station P20-3. This rock contains less

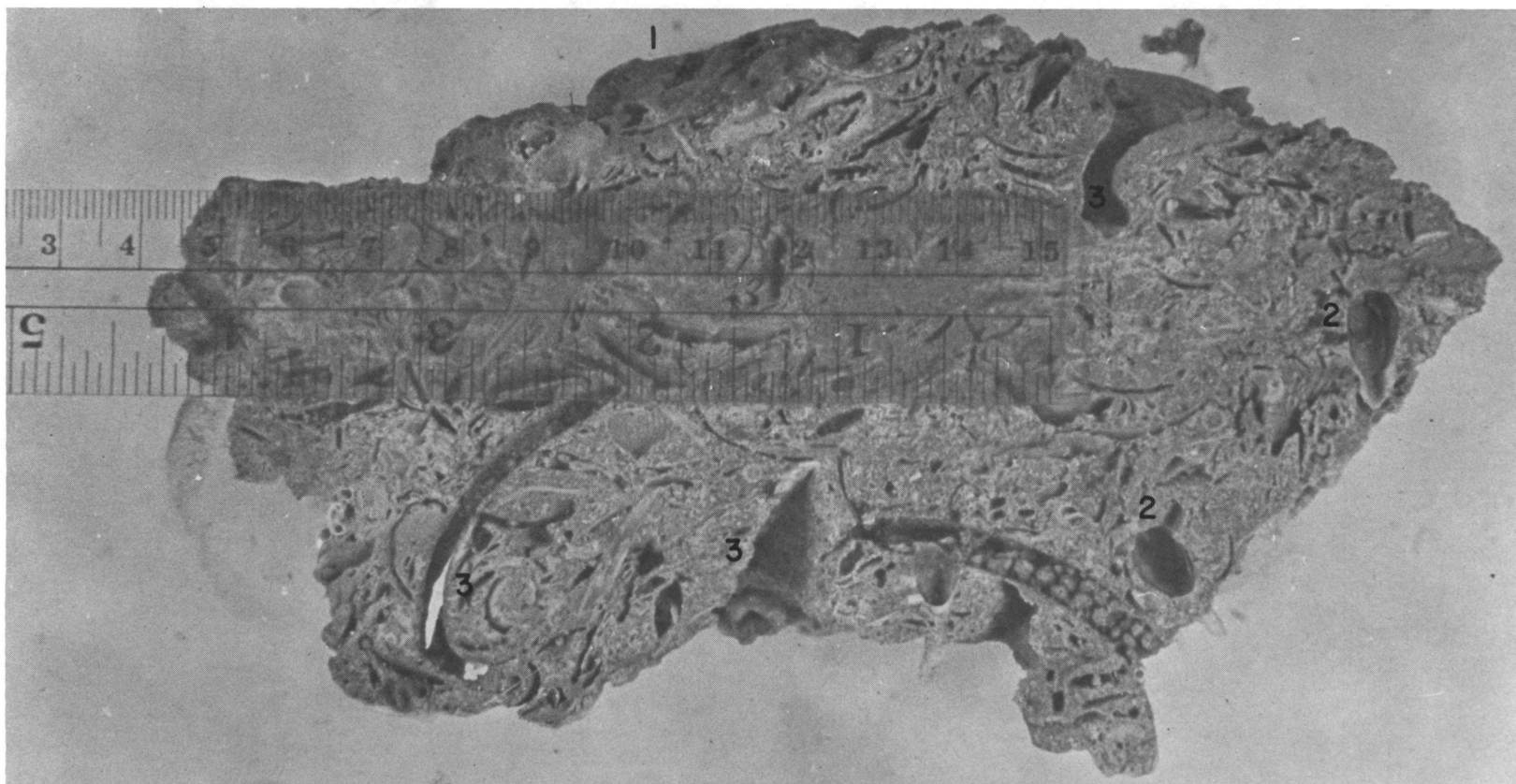


Figure 16. Photograph of a moldic sandy limestone specimen collected at station P2-1. The following numbered features are important to note: 1) dark encrustation of Lithothamnium (calcareous algae), 2) exposed borings of the date clam Lithophaga bisulcata, 3) moldic nature of the rock facilitates growth into the rock by infauna and flora, which accelerates the rate of biocorrosion.

than 5% quartz sand and is composed of fine grained carbonate mud. This unit is not believed to be widely distributed because it was found at only one locality. Meisburger did not report a similar unit in any of his cores in the study area.

An argillaceous pelecypod biocalcirudite occurs at the base of rock scarps in the southeastern one-fourth of the study area (station P4-3). This unit represents an argillaceous facies of the River Bend Formation and stratigraphically underlies the pelecypod mold sandy biocalcirudite described earlier. A similar argillaceous facies is found at the Belgrade Quarry underlying the more arenaceous unit of the River Bend Formation. The rock in outcrop is softer than the overlying pelecypod mold sandy biocalcirudite and thus contributes to the accelerated erosion at the base of the scarps. Many of the scarps with the softer biocalcirudite are extensively undercut forming small "cave like" structures up to 2 meters deep.

The oyster biolithite unit is composed mostly of giant oyster shells up to 40 centimeters long of the fossil Crassostrea gigantissima (Finch). The oyster bioherms, which range up to one meter in thickness, commonly are found at the base of the scarp features east and west of New River Inlet. The greatest concentration of fossil oyster shells occurs in the vicinity of McKee's Pier, ($\frac{1}{2}$ mile) 0.8 kilometers offshore from West Onslow Beach at station P20-3. The oyster shells are found in growth position with the valves paired and aligned vertically. (Figure 14).

The bioherms commonly occur at the base of the numerous shoreward facing scarps. This suggests a possible causal relationship between the occurrence of the bioherms and the erosional processes associated with the prominent shoreward facing scarps.

Estuarine peats and clays associated with the modern beach and marsh sediments crop out in the swash zone at New River Inlet and along Onslow and West Onslow Beaches. The peat unit is composed mostly of compressed roots and plant fragments. In the vicinity of New River Inlet the peat can be traced landward around the inlet to a modern saltwater backbarrier marsh (Figure 17). Most of the peat in the study area occurs as discontinuous outcrops less than one-half meter thick and less than one-hundred meters in lateral extent within the swash zone along Onslow and West Onslow Beaches (Figure 18). Storm erosion of the peat units along the beach produces large boulders more than 70 centimeters in diameter. After storms these peat blocks represent a significant portion of the boulder and cobble sized material in the beach sediments. A clay bed underlies the peat unit and crops out in the vicinity of New River Inlet. The clay is light orange to gray, slightly sandy, and contains numerous vertical limonitic root casts. Because the total thickness of the clay unit is not known and because the clay has only been seen in one outcrop, no statement can be made of its extent and importance in the study area.



Figure 17. Photograph of exposed relict peat bed being eroded from the West Onslow Beach shoreline near station P32-1 at New River Inlet.



Figure 18. Relict peat unit exposed in the swash zone on West Onslow Beach near station P22-1.

Sediments

The composition and distribution of sediments within the study area can be related to 1) the distribution and types of the major rock outcrops, 2) the influences of the New River Inlet, and 3) the location along the shoreface profile. The sediments are described on the basis of their association with the four major bottom types previously described (sediment surface, rock and sediment surface, dissected rock surface, and undissected rock surface).

Sediments on the undissected rock surface are sparse and occur as thin, discontinuous patches which are less than 0.3 meter thick and cover less than 100 square meters in area. The sediments are usually pebbly coarse sands in which the sand fraction is clean, carbonate rich quartz. Urchin spines are the main carbonate constituent in the sand fraction, comprising up to 30% of the sand size grains. The coarse fraction of the sediment is composed almost entirely of whole or broken but unabraded shell material. The undissected rock surface sediments occur along the surface of the two rock cores located to the east and west of New River Inlet (Figure 10).

Sediments on the dissected rock surface are composed of large limestone boulders up to 3 meters in diameter, limestone cobbles and granules, and coarse to medium carbonate rich quartz sands. The large boulders are a result of limestone blocks spalling from undercut rock scarps.

These boulders commonly form rubble piles at the base of the scarps and are generally extensively bored and covered with sessile benthic organisms. In cases where live vermitid gastropod reef growth is present at the top of the dissected rock scarp, the boulders at the base of the scarp have the same prolific vermitid growth on the uppermost surface. The overall size of the boulders and cobbles decreases away from the scarp source.

Sediments on the rock and sediment surface are composed of clean gravelly carbonate rich quartz sands. The gravel component averages approximately 20% of the total sediment and is composed of limestone rock fragments and shell material. The sand size material is composed of about 80% quartz and 20% carbonate rock and shell material. The rock surfaces are generally soft and highly bored by bivalves. Although the rock surfaces are generally covered by sessile fauna and flora, the density and diversity of coverage is much less than observed on the undissected rock surface. The sediment forms thin sediment wedges that coalesce between exposed rock surfaces. The sediments of the rock and sediment surface eventually grade shoreward into the "sediment surface" as the rock surfaces become totally buried beneath the shoreface sediments.

The sediment surface includes 1) the innermost near-shore shelf, lower beach face, and beach environments; and

2) the ebb tide delta and channel fill off of New River Inlet. The nearshore shelf and lower forebeach sediments extend from just below the surf zone out to water depths up to 5 meters. These sediments are characterized by fine to medium, slightly muddy carbonate-rich quartz sands. Occasional granule to boulder size gravel occurs scattered about the surface. The gravel component averages less than 10% of the total sediment and is composed of limestone rock derived from nearshore rock sources and whole and broken shell material. The sand size component of the sediment is composed of mostly quartz sands (90%) with up to 10% carbonate grains composed of broken shells and limestone rock fragments. A study of the mud fraction using X-ray diffraction indicates a calcite composition of more than 50%. Electron photomicrographs of clay-size particles show a preponderance of skeletal material which is acid soluble and thus is probably calcite (Figure 19). The muds are concentrated in the interstices of the coarsest sediments. The presence of mud in gravelly sediments indicates the deposition of mud during low energy conditions and the lack of winnowing by wave action during higher energy levels.

The beach sediments extend from the storm beach to below the surf zone. Sediments deposited in this environment are bimodal in texture. The sediment is composed of limestone and peat boulders, carbonate rich gravels and sands, and little or no mud. The limestone boulders are commonly composed of either peat or limestone similar to that found offshore (Figures 20 and 21).

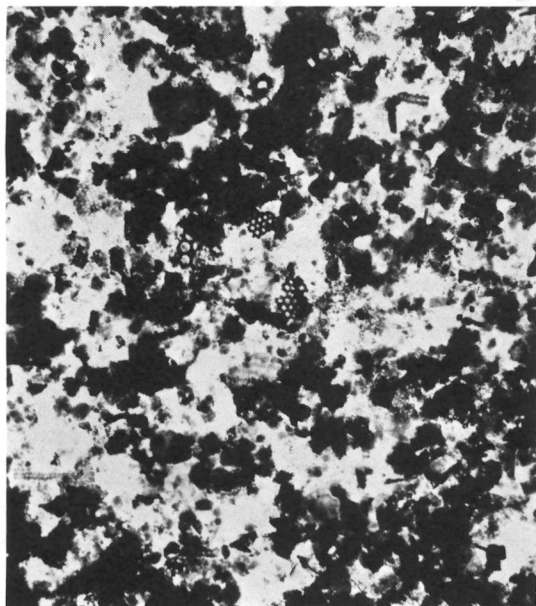


Figure 19. Two photomicrographs of clay-size particles of carbonate mud samples (magnification = 4,200 X). Photograph on the left is of unleached muds and contains abundant skeletal material. Photograph on the right has been treated with a 2-Normal solution of HCl for 2 hours. Note the difference in the quantity of skeletal material before and after treatment.



Figure 20. Photograph of a hand specimen of a highly bored and rounded limestone cobble. The rounded edges of the bore holes indicate the cobble was initially bored by pelecypods and then rounded by mechanical abrasion during transport.



Figure 21. Photograph of a +.30 meter in diameter sandy limestone boulder at the base of an exposed peat unit on West Onslow Beach.

The size and bored and rounded nature of much of the limestone is presented in Figures 20 and 21. Figure 22 illustrates the relative abundance of boulder size material being deposited on Onslow and West Onslow Beaches. The coarse sand and granule component of the beach sediment is composed of more than 80% broken and worn shell hash, rock fragments, and black and brown phosphorite grains. Quartz grains make up less than 20% of the remainder of this sediment fraction. The sand size material is composed of approximately 70% quartz and up to 30% carbonate grains.

Commonly the boulders on the beach contain live biota attached to them that is similar to that found offshore on the main rock outcrop surfaces. After a strong southeasterly storm passed through the study area, I combed the beach and made the following visual estimates. 1) Approximately one-third of the boulder material had live biota attached that was similar to that which occurs on the dissected and undissected rock surfaces. 2) The most common attached forms were Ascenarians, tunicates, and turkey wing clams (Arca sp.). 3) Most of the limestone rocks were the same rock types as those found offshore. 4) Some of the rock boulders consisted of limestone rock types not recognized in the offshore, indicating considerable lithologic variation in the offshore area.

Figure 23 shows the general variations in sediment texture along a theoretical profile from the beach seaward



Figure 22. Photograph looking west on West Onslow Beach. Large peat blocks (1) and limestone boulders (2) have been deposited in the high tide swash zone. Use suntan bottle (3) for scale.

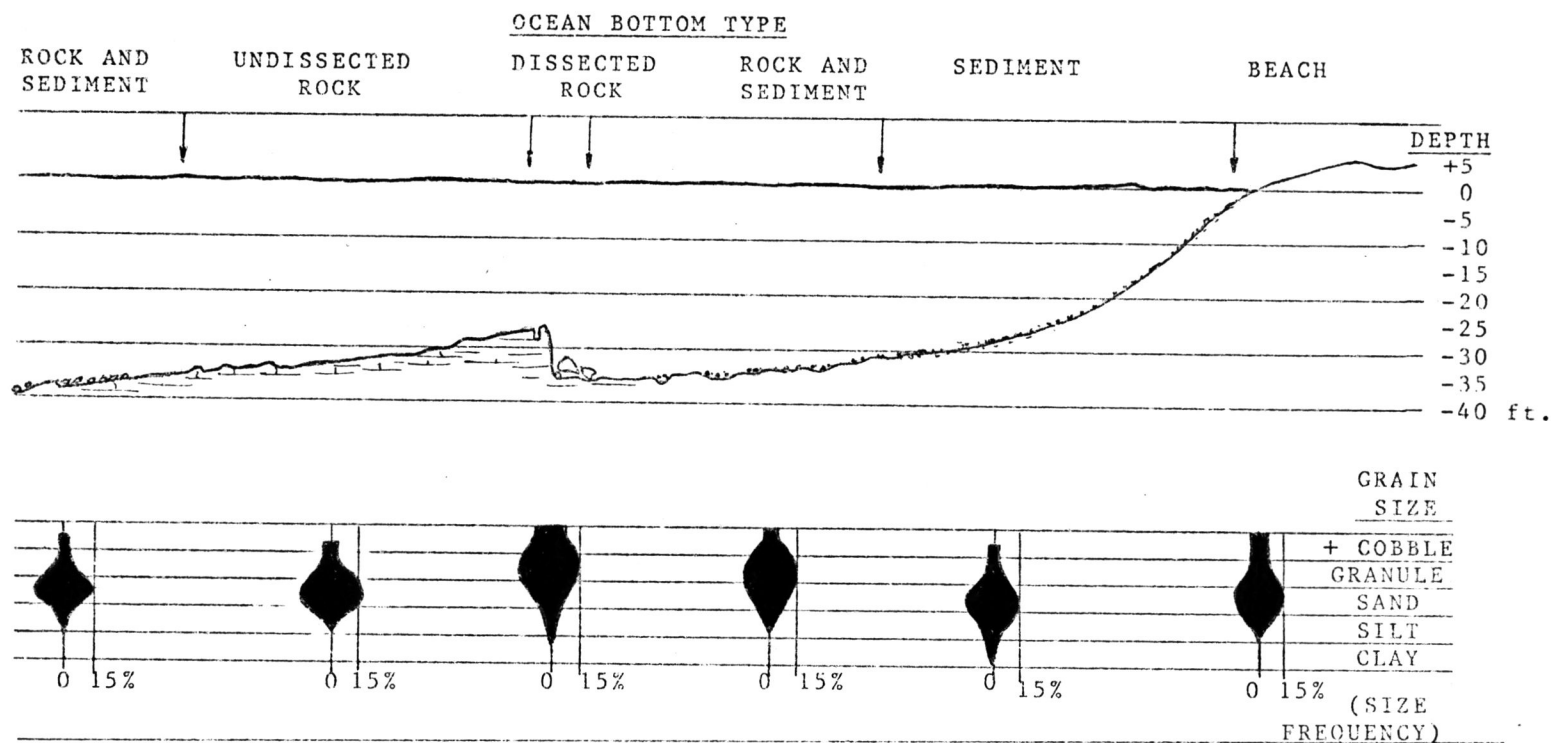


Figure 23. Theoretical diagram showing idealized variations in sediment texture along a profile from the beach seaward to a distance of approximately 5 kilometers. The top line identifies the ocean bottom type along the profile.

to a distance of approximately 5 kilometers. Figure 23 demonstrates the following general conclusions concerning the distribution and texture of the sediments. 1) A general textural fining occurs away from the dissected rock surface in both directions. 2) Gravel size material is common everywhere across the profile. 3) The textural maturity of the gravel sediment increases towards the beach from the major rock outcrops, becoming more rounded and bored away from the source rock outcrops. 4) The finest sediments occur at the base of the lower beach face.

Biota

More than three hundred species of animals and one hundred species of plants have been identified in the study area by previous investigators and during this study. Most of these biota are listed in Appendix III of this report.

During this study the general distribution and occurrence of the most common biota have been related to the four ocean bottom types previously described (sediment surface, rock and sediment surface, dissected rock surface and undissected rock surface). Table 1 illustrates the relative abundance of the most common biota for each of the four ocean bottom types.

The following is a brief description of the major biota and its effect upon the seafloor.

BIOTA

BIOTA TYPE	BOTTOM TYPE			
	SEDIMENT SURFACE	ROCK AND SEDIMENT	UNDISSECTED ROCK	DISSECTED ROCK
PORIFERA	RARE	RARE	PRESENT	ABUNDANT
COELENTERATA				
CORAL	ABSENT	ABSENT	PRESENT	PRESENT
GORGAN.	ABSENT	PRESENT	PRESENT	PRESENT
ANNELIDA				
SABELLID	RARE	RARE	ABSENT	ABSENT
SERPULID	ABSENT	PRESENT	PRESENT	PRESENT
BRYOZOA	RARE	RARE	PRESENT	PRESENT
ARTHROPODA				
SEA SPIDERS	ABSENT	ABSENT	ABSENT	PRESENT
DECAPODS	ABSENT	RARE	PRESENT	PRESENT
BARNICLES	ABSENT	PRESENT	PRESENT	PRESENT
ECHINODERMATA				
BRITTLE STR.	PRESENT	PRESENT	PRESENT	PRESENT
URCHIN	RARE	PRESENT	ABUNDANT	ABUNDANT
SAND DOLLAR	PRESENT	PRESENT	ABSENT	ABSENT
MOLLUSCA				
BIVALVIA				
ARCA sp.	ABSENT	PRESENT	PRESENT	ABUNDANT
LITHOPHAGA	ABSENT	PRESENT	PRESENT	PRESENT
GASTROCHAENA	ABSENT	ABUNDANT	ABUNDANT	ABUNDANT
SAXICAVA	ABSENT	PRESENT	PRESENT	PRESENT
GASTROPODA				
VERMICULARIA	ABSENT	RARE	RARE	ABUNDANT
VAGRANT FORMS	PRESENT	PRESENT	PRESENT	PRESENT
CHORDATA				
TUNICATA	ABSENT	RARE	PRESENT	PRESENT
SEAWEEDS	ABSENT	PRESENT	PRESENT	PRESENT
LITHOTHAMNIA	ABSENT	PRESENT	ABUNDANT	ABUNDANT

Table I. Table showing the relative abundance of the general biota studied on the four different marine bottom types outlined in the thesis.

Sediment Surface Biota

The biota of the sediment surface is characterized by vagrant gastropods, starfish, brittle stars and sand dollars, and burrowing polychaete worms and arthropods. All of these forms were actively bioturbating the bottom sediments. Gastropods actively bulldoze the sediment surface aiding in the winnowing of fine muds from the coarser sediments. Polychaete worms burrow into the sediment and excrete fecal pellets that increase the overall size distribution of the sediment, cohesively binding muds into sand size particles. Arthropods actively burrow into the sediment forming hollow burrows that later become filled with sediment.

Rock and Sediment Biota

The rock and sediment biota is characterized by sea whips, barnacles, sponges, serpulid worms, and common to abundant brittle stars, sea urchins, and the boring clams; Gastrochaena, Lithophaga, and Saxicava. Sea urchins (Arbacia sp.) graze on the thin algal and organic crust covering the rock surfaces. Areas of heavy grazing are characterized by a light tan color that contrasts with the normal brown to red color of the rock surface. Rock-boring clams are the most abundant sessile animal present. Lithophaga bisulcata, Saxicava rugosa and Gastrochaena sp. bore to depth of 10 centimeters below the rock surface (Figures 24 and 25). The boring

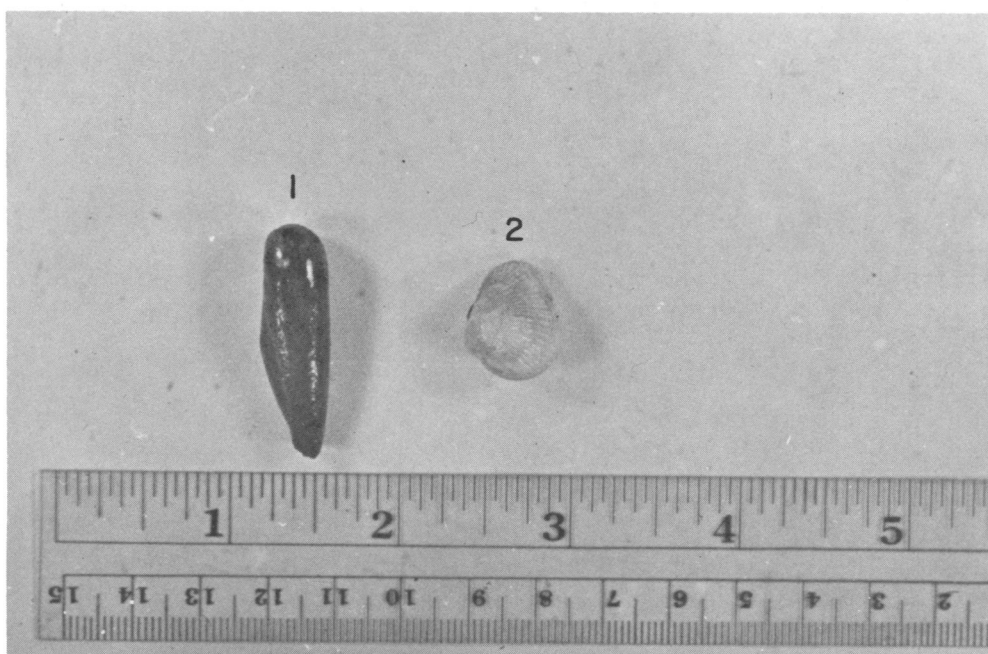


Figure 24. Photograph of two boring pelecypods:
(1) Lithophaga bisulcata (date clam)
(2) Saxicava rugosa

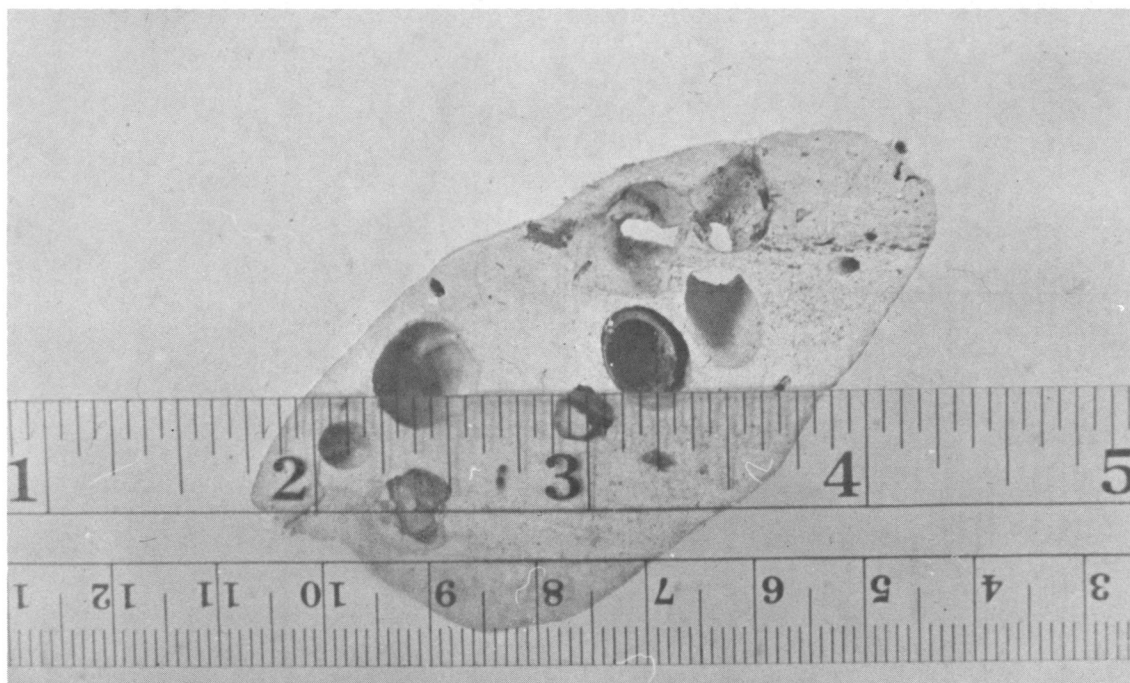


Figure 25. Photograph of thicksection through fine-grained limestone cobble. The cobble has been extensively bored by the "date" clam Lithophagus sp.. The smaller paired holes seen left of the number "3" on the photo is a siphon tube typical of the date clam.

of the clams produces the following results: 1) an increase in porosity and decrease in total rock density, 2) destruction of the general rock fabric and overall rock strength, 3) accelerated chemical weathering by increasing the surface area of the rock exposed to the ocean waters and chemically active organisms, and 4) a resultant increased production of sediment from the disintegration of the rock. Chemically active borers produce a fine white powder which is probably a carbonate rich mud, while mechanical borers produce sediment that is the result of mechanical abrasion of the rock. Rock surfaces that have been or are covered by a thin veneer of sand exhibit a gray to black stained surface with vacant worm tubes and valves of boring clams. Live sponges have been found partially covered but still attached to sediment covered rock surfaces, indicating that the sponge was living before the sediment was deposited over the rock surface.

Undissected Rock Biota

The biota of the undissected rock surface is characterized by common sponges, sea whips and fans, tunicates (sea squirts), encrusting calcareous algae (Lithothamnium sp.), and an abundance of grazing sea urchins, brittle stars, and gastropods. Boring clams are abundant on nearly all rock surfaces which are extensively bored by the previously mentioned species. Figure 26 shows the intensity of benthic growth on a sample of the undissected rock surface.

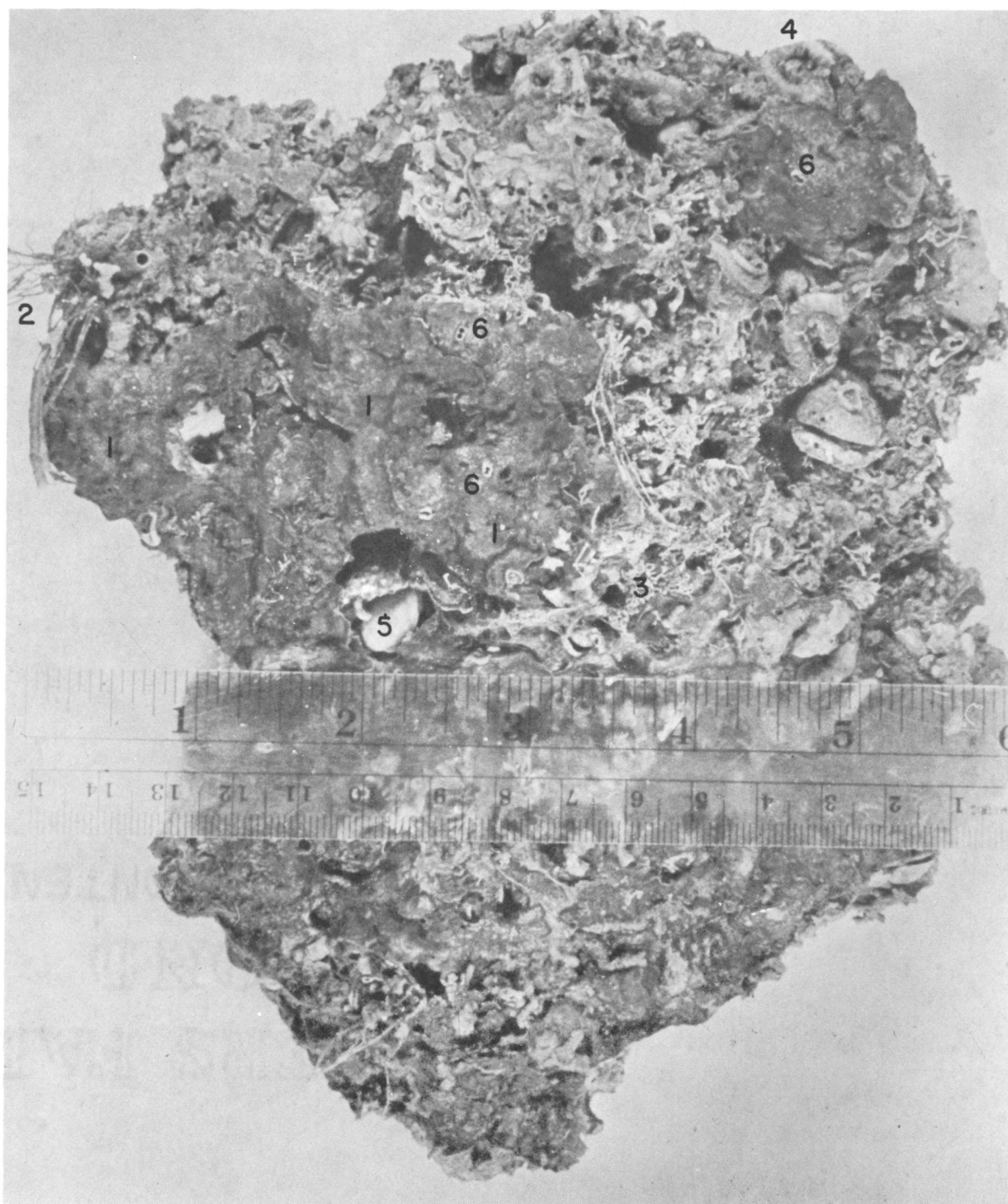


Figure 26. Photograph of heavily encrusted and bored rock boulder collected at station P4-3. Specimen exhibits encrustations of (1) the calcareous algae, Lithothamnium sp., (2) hydrozoans, (3 and 4) two different serpulid worms. The specimen is extensively bored by (5) Saxicava rugosa, and (6) the date clam Lithophaga bisulcata (note the paired siphon holes typical of the date clam).

Dissected Rock Biota

The biota of the dissected rock surface is characterized by corals (Oculina sp. and Astrangia sp.), bryzoans, brittle stars, tunicates (sea squirts) and attached algae. Urchins (Arbacia sp.), turkey wing clams (Arca occidentalis), calcareous algae (Lithothamnium sp.), vermitid gastropods (Vermicularia spirata), and boring clams (Gastrochaena, Lithophaga and Saxicava) are abundant.

Coral growth occurs in protected niches along the margins and undersides of the steep scarps associated with the dissected rock surface. Corals are encrusting in form on the rock surfaces nearest New River Inlet, and become more finger like and less encrusting in form further away from the influence of New River Inlet. Figures 27 and 28 illustrate the two distinguishable coral growth forms.

Vermitid gastropod reef growth is a major biogenic source of modern carbonate rock on the dissected rock surfaces. These gastropod reefs are up to 70 centimeters thick and occur along the rim of the scarps and tops of the largest boulders resting at the base of the scarps. The abundance of the vermitid gastropod reef growth is greatest on the rocks with close proximity to New River Inlet and decreases away from the influence of the inlet. Figure 30 illustrates the tremendous number and size of the gastropods which are intergrown to form the reef rock. The internal structure of the vermitid gastropod reef rock is shown in Figure 31.



Figure 27. Photograph of heavily encrusted fossil oyster shell (Crassostrea gigantissima). The shell has been extensively bored by the boring sponge Cliona (1), encrusted by the coral Astrangia astraefiformis (2) and it contains two species of serpulid sorms (3 and 4) and two species of bivalves Ostrea sp. (5) and Arca occidentalis (6).

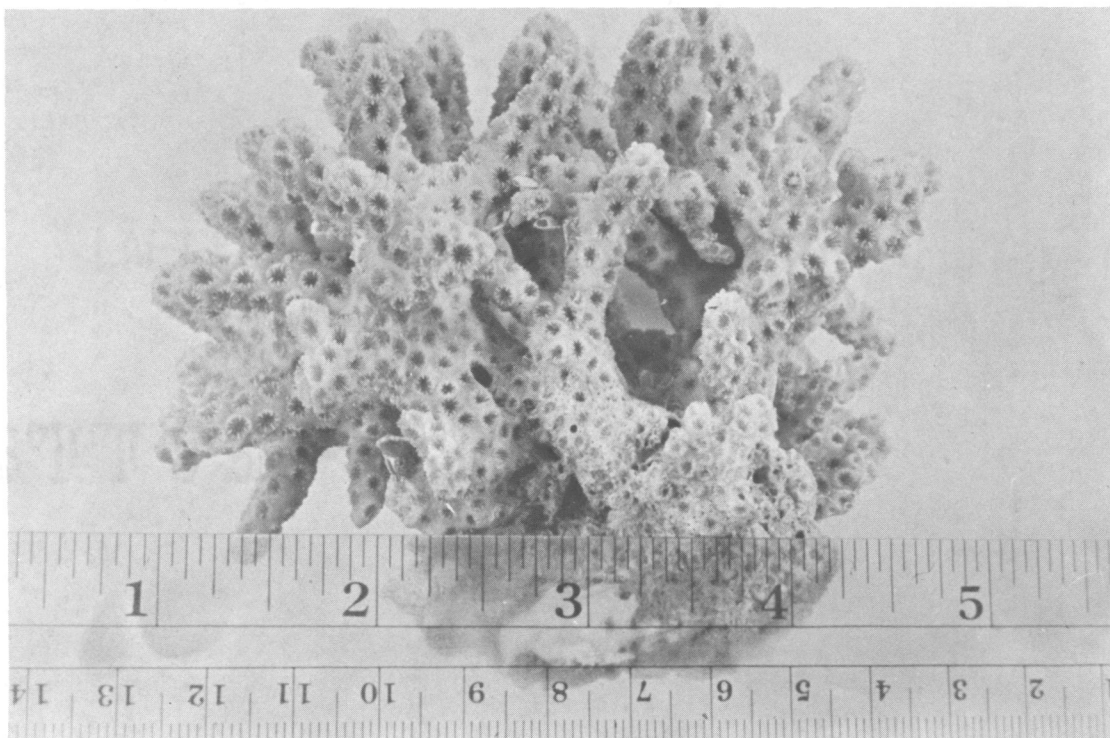


Figure 28 . Photograph of finger coral Oculina sp.
Specimen was light tan during life and faded
to a cream color after death. This specimen
was found growing on the underside of a rock
ledge at station P25-1.

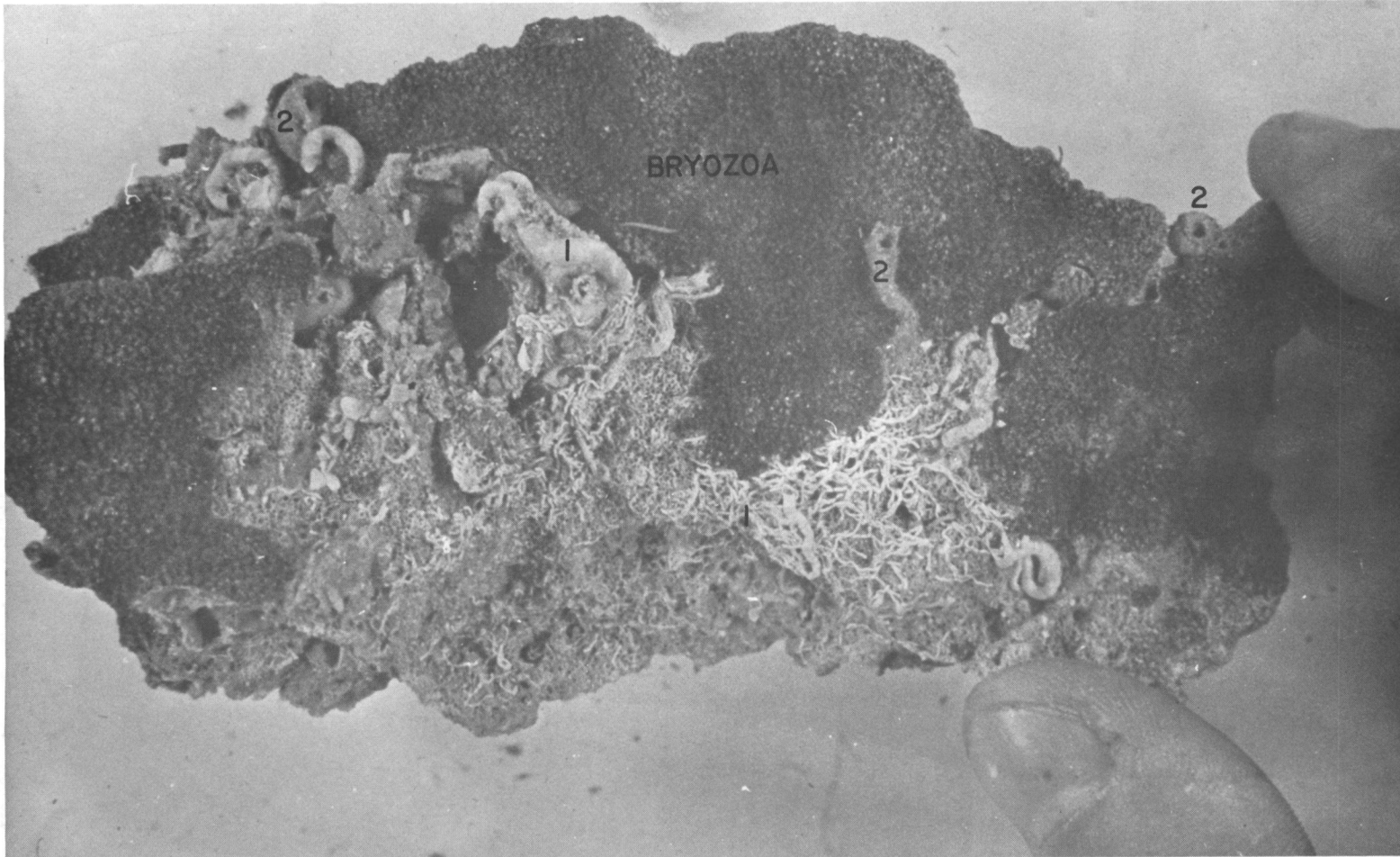


Figure 29. Photograph of bryozoan rock. The bryozoans are bright red when collected but dull very quickly to dark purple upon exposure to direct sunlight and air. Intergrown with the bryozoans are (1) serpulid and (2) sabellid worm tubes. Collectively, these animals form a constructive feature on the rock substrate east of New River Inlet.

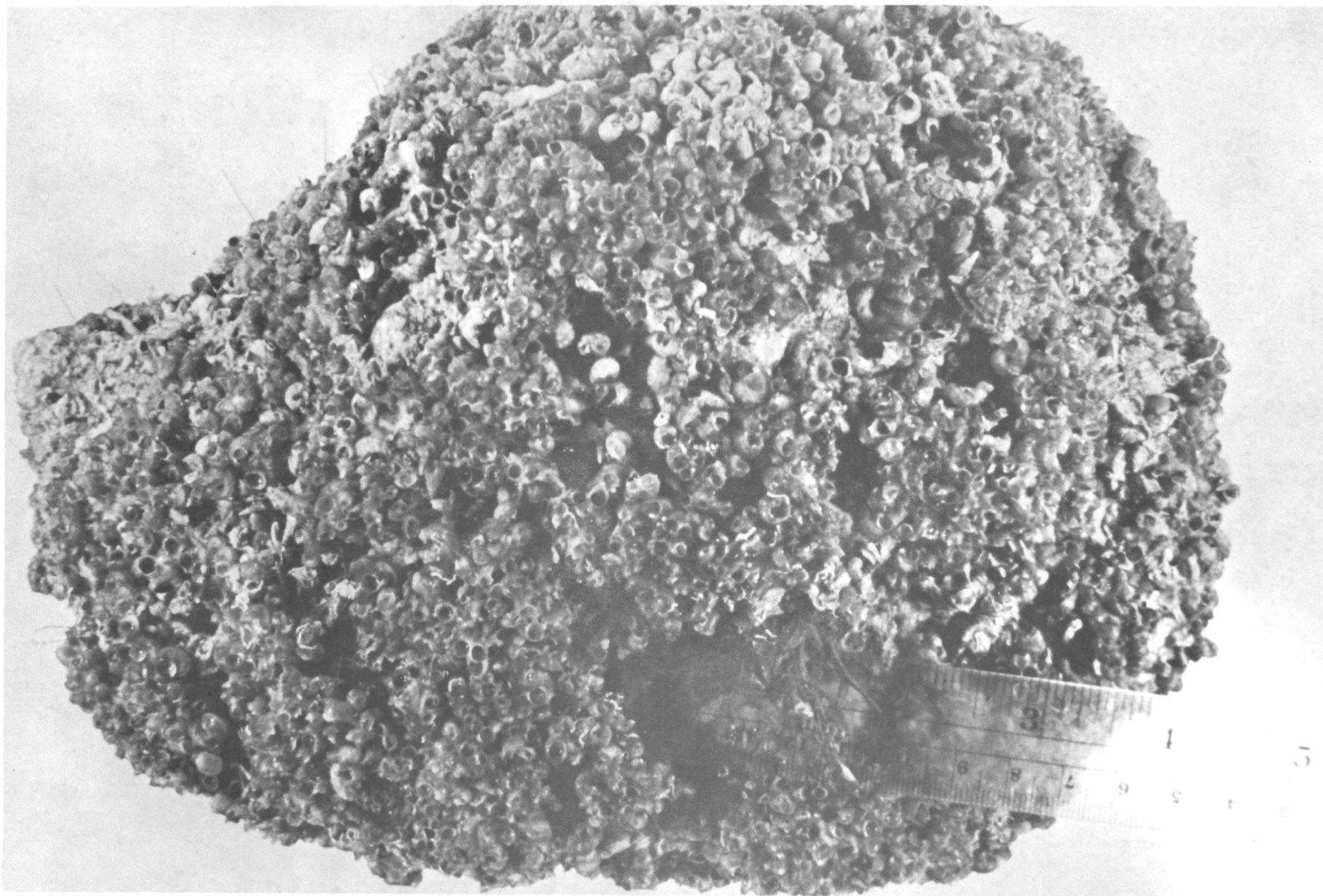


Figure 30. Photograph of large boulder from vermitid gastropod reef. The gastropod individuals are so intergrown that they form a solid mass of limestone.

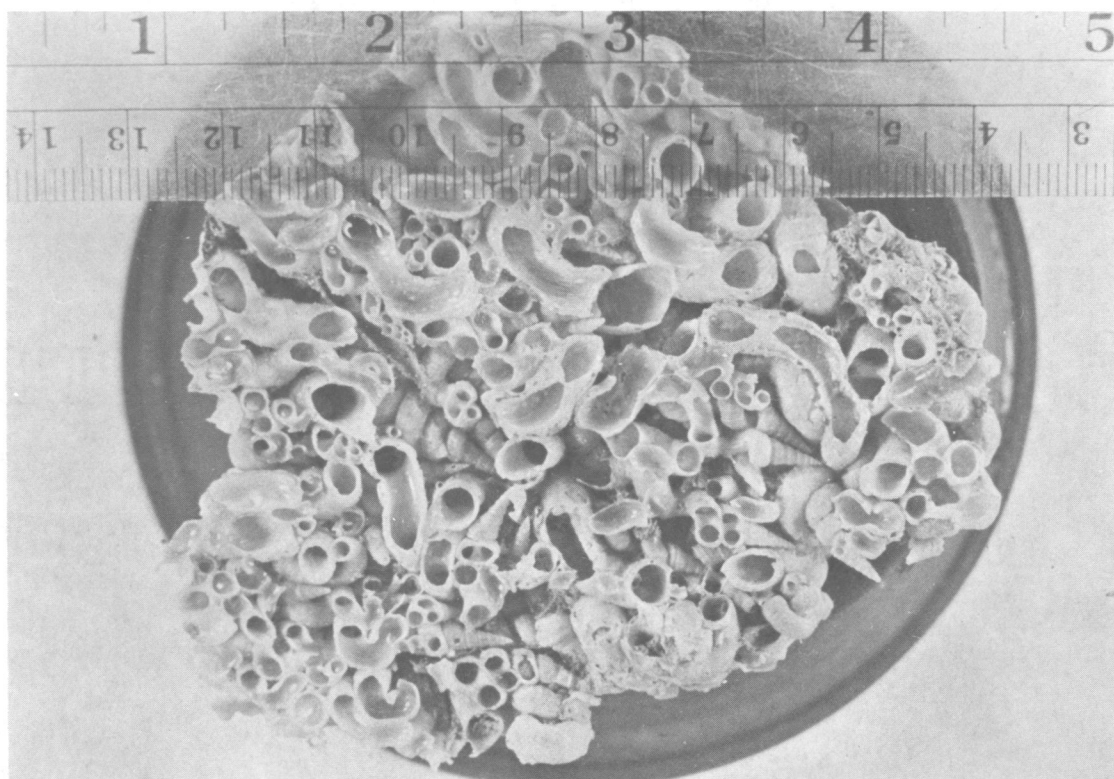


Figure 31. Thick-section across a boulder from a vermitid reef. Boulder is composed of nearly 100% vermitid gastropods. Note that most of the spirals are oriented in the same direction.

Vermittid gastropods are known to form small barrier reefs in the Ten Thousand Island area of southwest Florida (Shier, 1969). In Florida the growth of these reefs is restricted to the intertidal zone, whereas the reefs found in my study area occur in waters greater than 15 feet deep. The Floridian reefs form barriers around small islands and bays, while the reefs in Onslow Bay do not form barriers. The restricted occurrence of vermittid gastropod reefs in Onslow Bay is probably related to the localized nature of a suitable substrate and proper euryhaline waters to foster reef growth. The Floridian gastropod is a different species (Vermetus nigricans Dall) from that found in the study area (Vermicularia spirata Phillippi). The differences in speciation probably have little relationship to differences in the extent and nature of reef development in Onslow Bay and Florida.

Contribution of Biota to Sediments

The biota contribute significant amounts of sediment to the modern sediment regime. The major biologic contributors can be divided into three groups.

1. Allochemical sediment producers. These include all organisms that have hard parts that may be preserved after death. The most conspicuous forms include bivalves (Arca, Chiona), gastropods (Vermicularia, Busycon), the echinoid (Arbacia), the bryzoan (Cheilostomates), and anthozoans (corals and sea fans).

2. Detrital sediment producers. This includes sediment produced by organic erosion of the rock exposures and associated fossil shell material. Important detrital sediment producers are the boring clams (Gastrochaena, Lithophaga and Saxicava), the sponge (Cliona), boring algae, and boring polychaete worms.
3. Sediment cementing organisms. These include organisms that increase the mean size of the sediment by aggregating sand grains into larger particles. Most important among them are encrusting calcareous algae (Lithothamnium sp.), serpulid worms, and sabellid worms. These organisms cement the sediment grains by secreting a carbonate cement. The crustose algae are restricted to the dissected rock surface and the undissected rock surfaces. The serpulid worms cement grains in all of the marine bottom types. Sabellid worms were found cementing sand grains to the outer shell surfaces of gastropods in the lower beach face zone at station P20-1.

GEOLOGIC PROCESSES

In general, the processes acting on the rock exposures in Onslow Bay may be divided into two categories. First are the constructive processes acting to build up the rock surfaces.

These include the activities of gastropods, encrusting calcareous algae, sediment trapping bryozoans, and encrusting corals. Second are those destructive processes acting to reduce the rock surfaces by both physical and biological agents. The physical agents consist of wave and current activity and mechanical abrasion resulting from grain impact. The principle biologic agents of destruction include the activity of boring clams, boring algae, algae rafting during storms, polychaetes and burrowing crustaceans.

Constructive Agents

Vermitid gastropod reef growth contributes most of the modern carbonate that is accumulating along the tops of the dissected rock surfaces. The vermitid gastropod reef growth, accompanied by minor amounts of associated encrusting worms, cover the rock surfaces along the rims of the scarps. This covering protects the rock from erosion and actually causes a build-up of modern carbonate material along the crest of the rock scarps. This build-up continues to exaggerate the undercut scarp and creates an added weight to the scarp margins, ultimately the cliff face will fail and break off forming large boulders. The fresh rock surface exposed because of the break is attacked by the destructive agents and erosion begins again to wear down the new scarp face. The fresh surface on the newly formed boulder is also attacked by the destructive agents and further reduced in size.

Encrusting calcareous algae coat the surfaces of most rock exposures in the study area not containing vermitid gastropod reefs. The thin coating of carbonate material aids in the stabilization of the rock surface and slows the rate of attack by other destructive agents. The calcareous algae commonly act as a binding agent for loose sediment in low areas on the rock surfaces.

Sediment trapping bryozoans were found only in the easternmost rock outcrop area (Figure 10). The bryozoans occur at the base of the dissected rock surfaces. The bryozoans form "cup-like" structures up to 15 centimeters in height and diameter. The cups are cemented to the hard rock substrate by the initial growth of bryozoans. The structure is further fixed to the bottom by concurrent growth of calcareous worm tubes. During the growth of the bryozoan cup and supporting worm tubes, sediment becomes trapped within the fabric of the structure. Bryozoans cups may contain up to 50% sand size rock fragments cemented within the structure.

Encrusting forms of hard corals supply a protective blanket that covers up to 0.05 square meter of the rock surface. In some cases the coral binds fractured or broken rock thus aiding in the stabilization of the rock bottom.

Destructive Agents

Because observations of the bottom in the study area were made during days when the sea state was calm, none of the presumed effects of high wave and current energy were observed. Even though direct documentation is lacking, it

can be concluded that wave and current energy play a major role in the destruction and transport of rock away from the outcrop. Boulders up to 3 meters in diameter were found tens of meters from the outcrops on a relatively flat surface, one must assume that wave and current energy during storms transported the rocks away from the face of the scarps. Observations made along the beach after storms demonstrate an abundance of rock gravel with attached biota similar to that living on the offshore rock surfaces. Thus; it appears safe to conclude that coarse rocks and their associated attached biota are transported shoreward during storms by high energy wave and current activity.

Mechanical abrasion of the rock surface by moving sediment is apparent along the base of scarps as indicated by the following evidence. 1) The base of the scarps are commonly undercut. 2) The lower half-meter of the rock scarps are devoid of any observable attached organisms. 3) Loose sediment is found filling small holes along the base of the rock scarps. Although no major mechanical abrasion was observed on the bottom, the evidence indicates that mechanical abrasion is an important process during high energy bottom conditions.

The effects of boring clams and other boring organisms on the ocean rock bottoms is well documented. Perhaps the one report that best relates the magnitude of the role of boring organisms in the destruction of rock surfaces is by Warne and Marshall (1969). They studied an Eocene age rock

outcrop off the coast of California where numerous organisms were actively eroding the rock surfaces at a rate up to 10 centimeters per year. Boring clams are the most abundant and most destructive of all the boring organisms found within the study area. On rock surfaces where boring clams are abundant approximately one-half of the rock surface has been excavated to a depth of 10 centimeters. This boring action not only produces sediment but also weakens the total rock framework making it more easily eroded by other destructive agents.

My observations of boring organisms in Onslow Bay (based upon depth of penetration of clam boring and the estimated age of the clam that produced the boring) made during this study indicate a similar magnitude of biocorrosion as obtained by Warne and Marshall (1969).

Other biota contribute to the destruction of the rock surface and the ultimate generation of sediment. Another process includes the rafting of rock material that has been worked loose from the bottom during a storm by attached semi-bouyant biota such as various algae with large air bladders and sea fans with large surface areas.

Process-Response Model

The result of the constructive and destructive agents upon the rock surface is depicted in the process-response model in Figure 32. The geologic processes can be summarized as follows.

PROCESS-RESPONSE MODEL

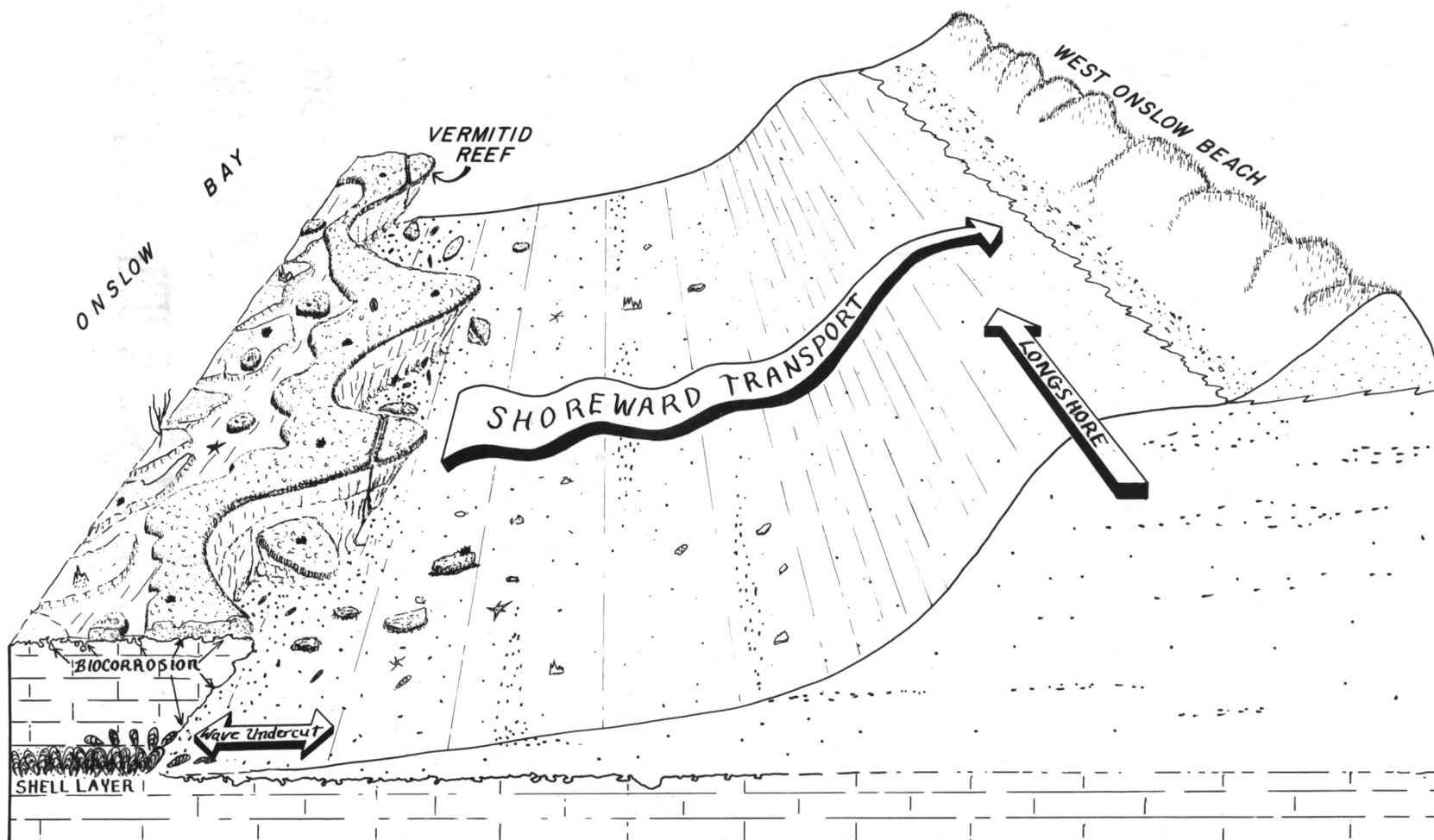


Figure 32. Process - response model for the thesis study area.

1. The constructive vermitid gastropod reef growth and other sessile forms build up an organic overhanging rim along the crest of the rock scarps.
2. The exposed rock surfaces and scarp faces are attacked by boring organisms which produce fine sediment, increase the exposed surface area of the rock, and ultimately result in the weakening of the total rock fabric.
3. Wave and current action during high energy storm events causes mechanical abrasion, scouring, and undercutting of the rock face. The added weight of the overhanging organic accumulation on the rim of the scarp increases the instability of the rock face.
4. Undercutting of the rock scarp is accelerated where the base of the rock face is composed of softer material. This situation exists whenever interbeds of the fossil oyster bioherms of Crassostrea gigantissima and/or less consolidated material occurs at the base.
5. During high energy storm conditions, the now unstable rock face breaks off from the rock outcrop. This exposes a fresh rock surface to begin the process again.
6. The destructive processes continue to erode and reduce the overall size of the boulders, creating smaller gravels, sands, and lime muds in the process.

7. Sediments produced from the destruction of the rock are transported away from the rock face by wave and current action during high energy storm events. The movement of large boulders away from the face is slower than the transport of smaller sediment grains. This results in a crude textural fining in the size of sediment away from the rock faces.
8. The coarser sediments created through the above processes are ultimately transported up the beach face. In the process they become mixed with terrigenous sediments entering the study area via longshore currents or from New River Inlet.

CONCLUSIONS

The nearshore ocean floor in the study area consists of four distinct bottom types: sediment surface, rock and sediment surface, dissected rock surface, and undissected rock surface. The configuration and distribution of these bottom types is strongly related to the constructive and destructive processes acting on two major areas of outcropping rock east and west of New River Inlet. A process-response model explains the configuration and distribution of the rock surfaces and the associated sediments and includes the following points.

- 1) Vermitid gastropod reefs are the main constructive agent actually forming modern rock along the edges of the rock scarps.
- 2) Destructive processes far outweigh the effects of constructive processes; the net result is a gradual erosion of the rock surfaces and the generation of numerous shoreward facing rock scarps. There is a net sediment movement away from the rock surfaces. The coarser sediment moves up the beach face during periods of high energy storms. The shoreward transport of sediment produces a textural fining of the coarse fraction of the sediment as larger sized material is reduced in size by the same destructive processes that liberated it from the rock surface.

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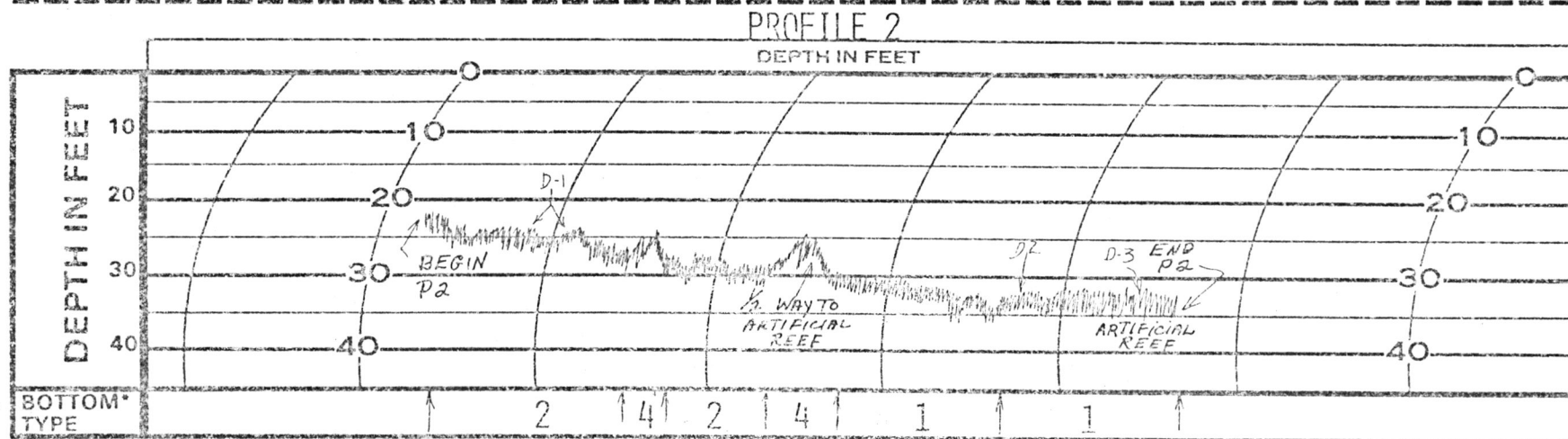
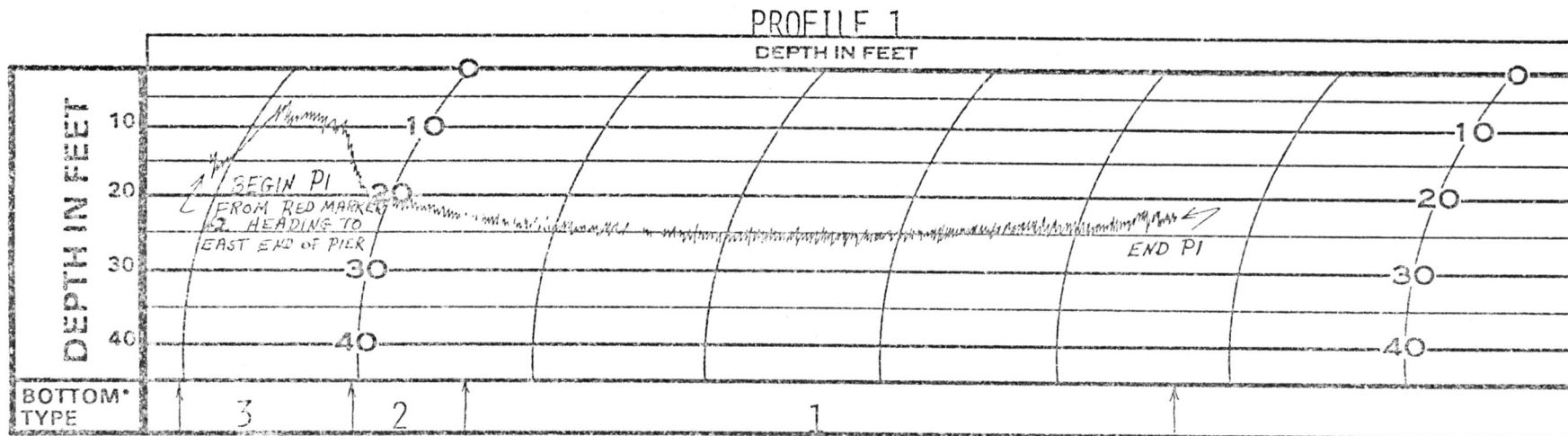
APPENDIX I

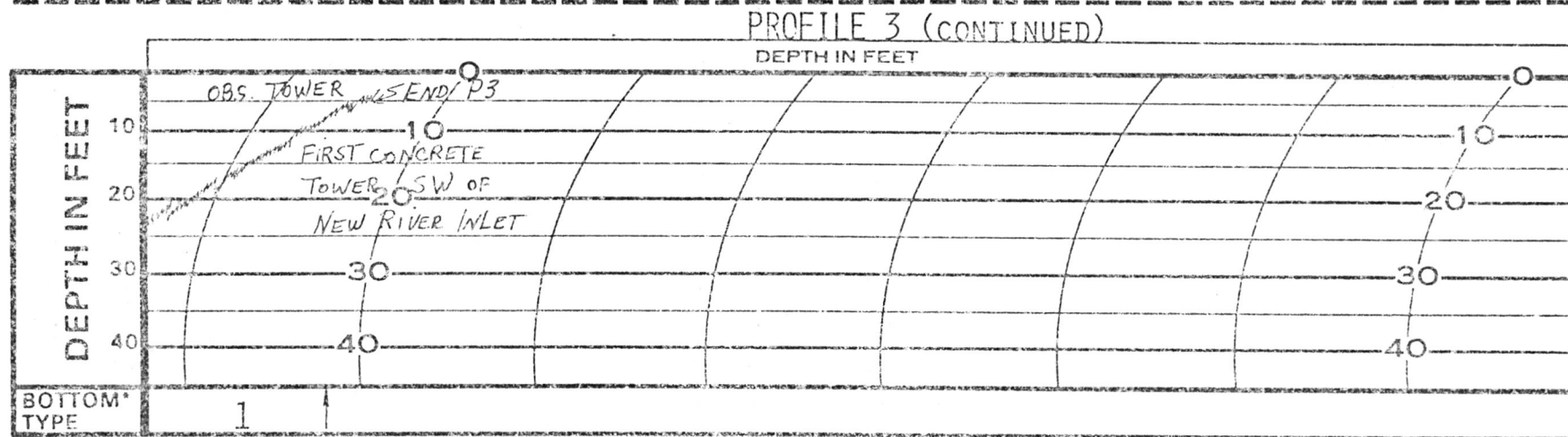
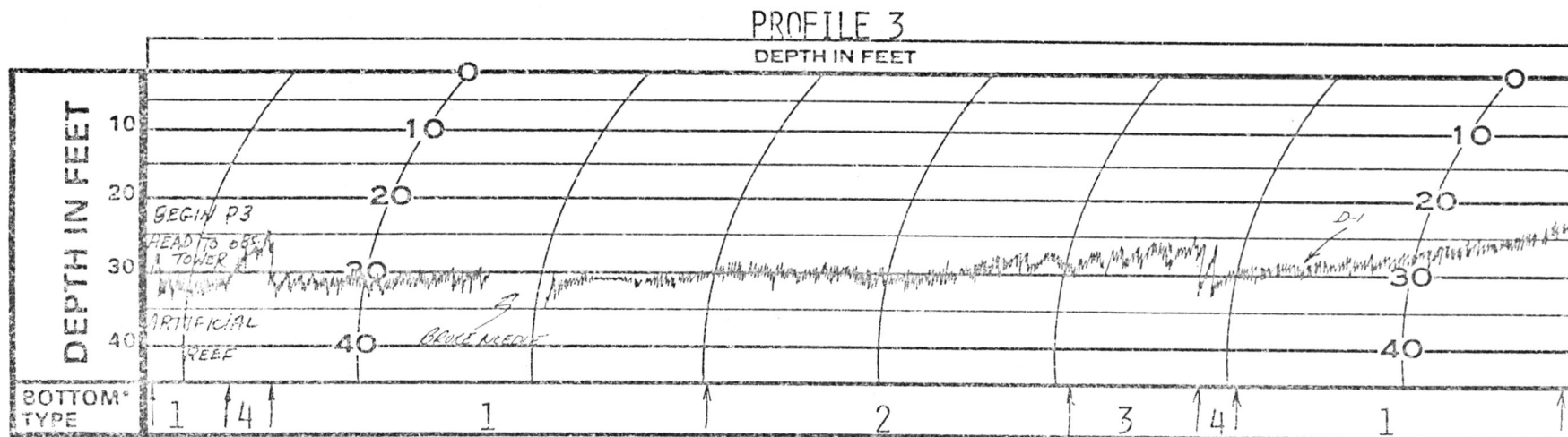
TRACINGS OF FATHOMETER PROFILES FROM THE STUDY AREA

KEY

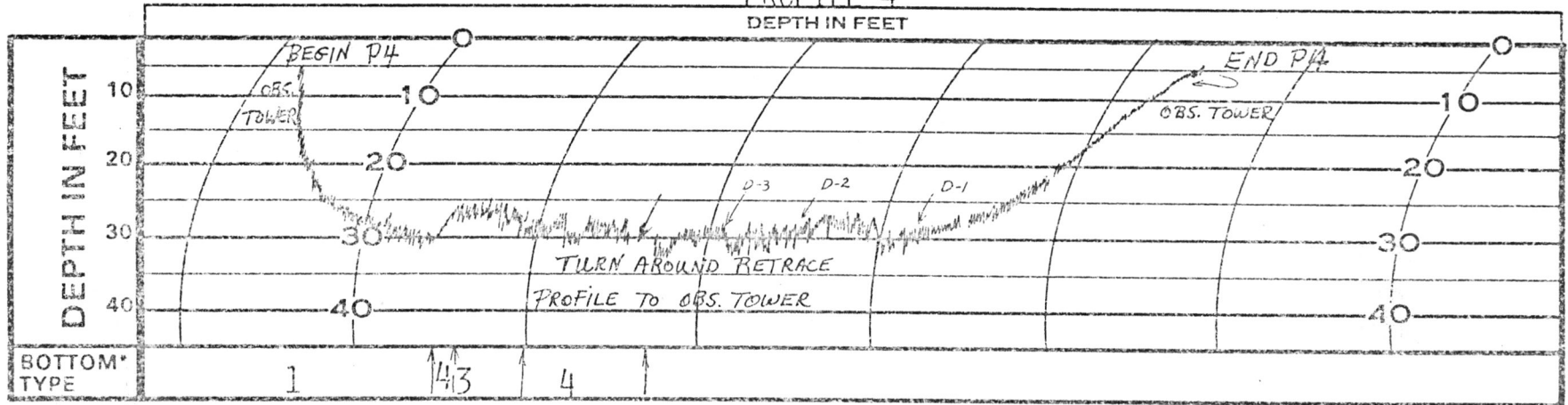
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SEDIMENT SURFACE -----	1
ROCK AND SEDIMENT SURFACE -----	2
UNDISSECTED ROCK SURFACE -----	3
DISSECTED ROCK SURFACE -----	4

Please note that due to the poor quality of copies made from the original fathometer profiles, hand tracings of the originals were selected for thesis publication. See Figure 4 for the location of the following fathometer tracings.

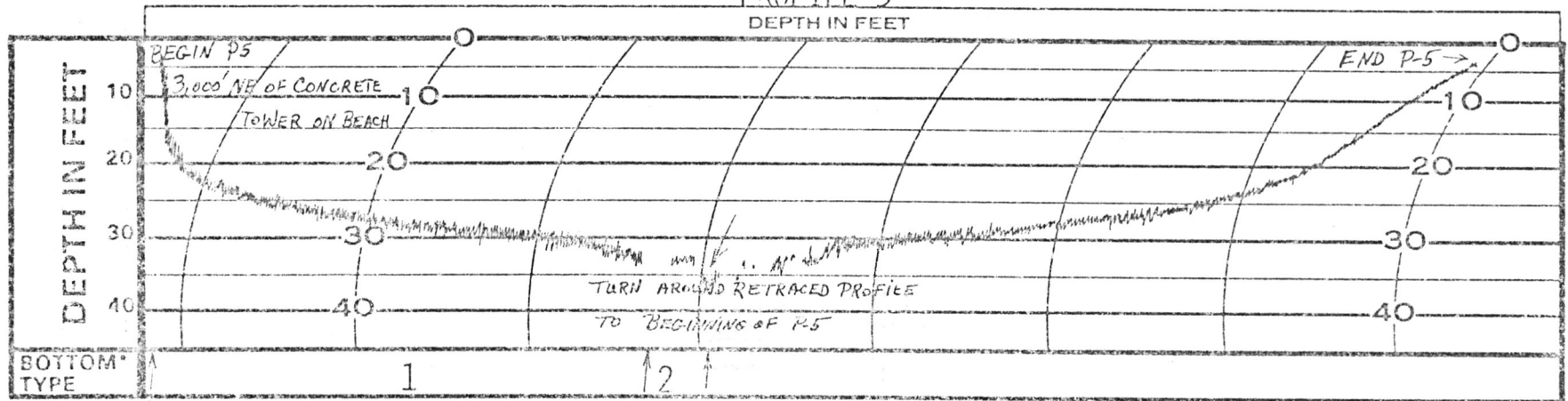


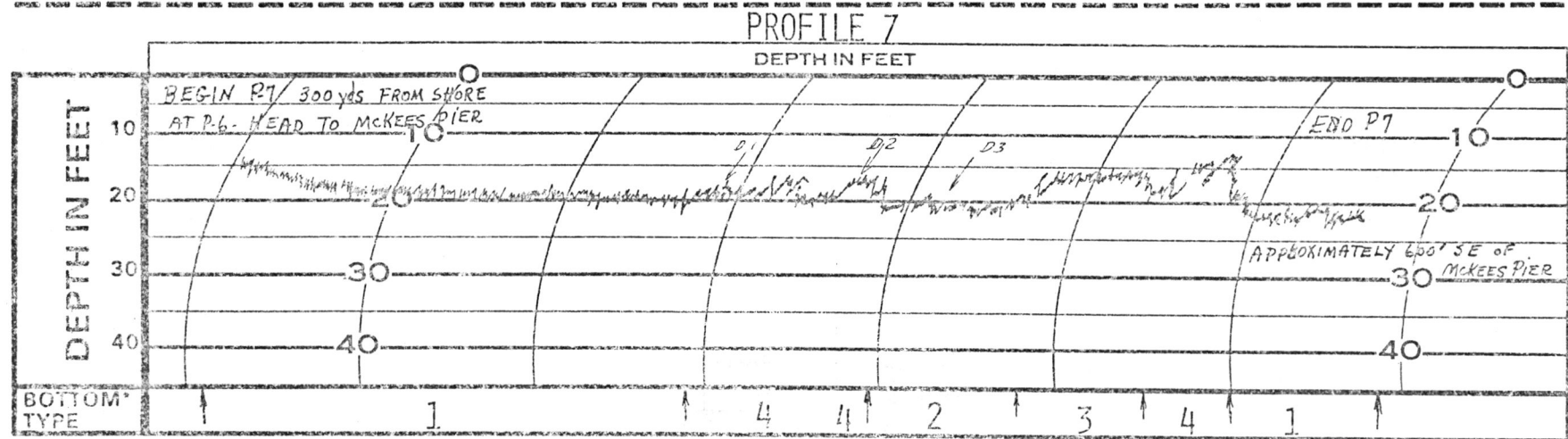
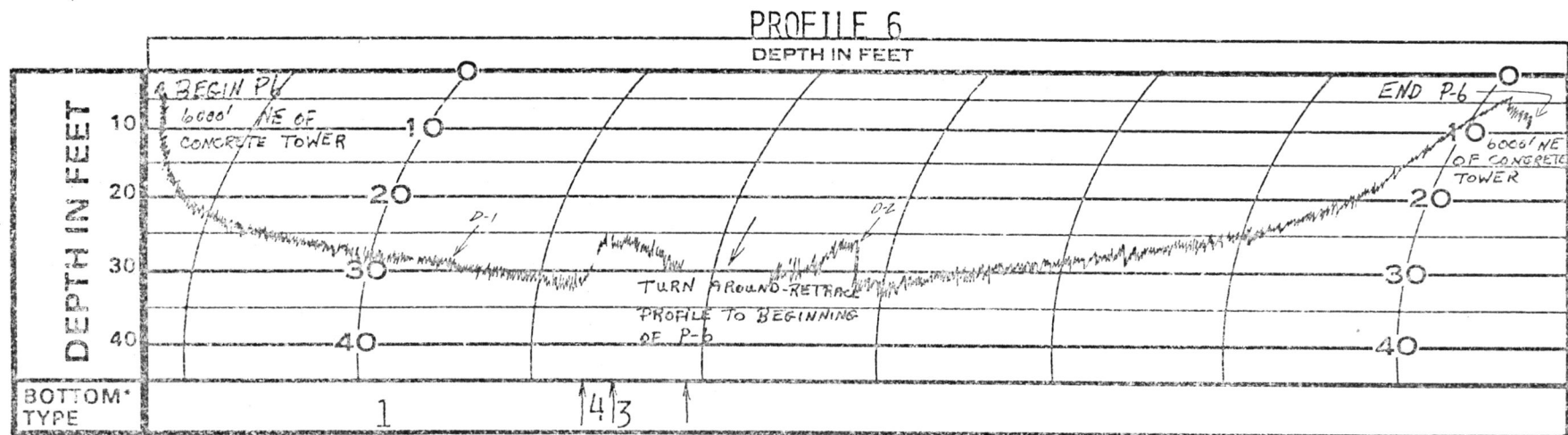


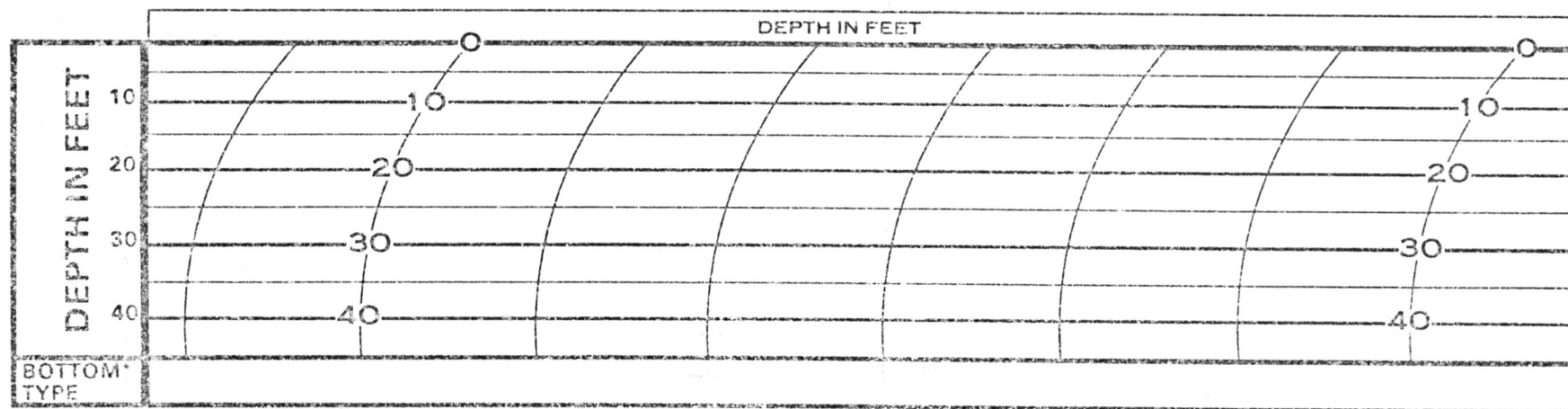
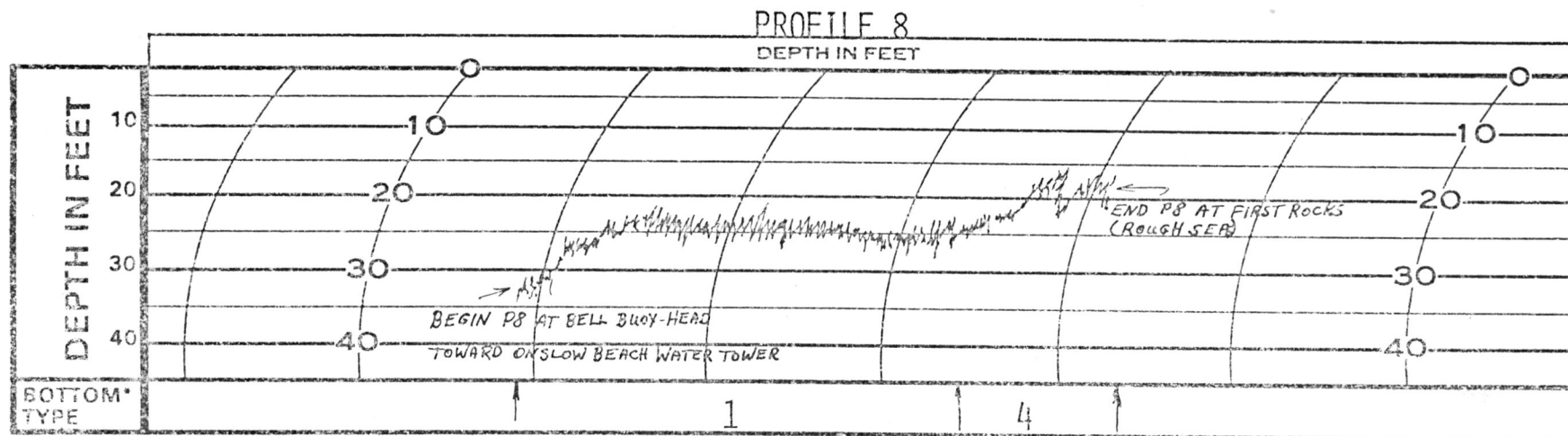
PROFILE 4 DEPTH IN FEET



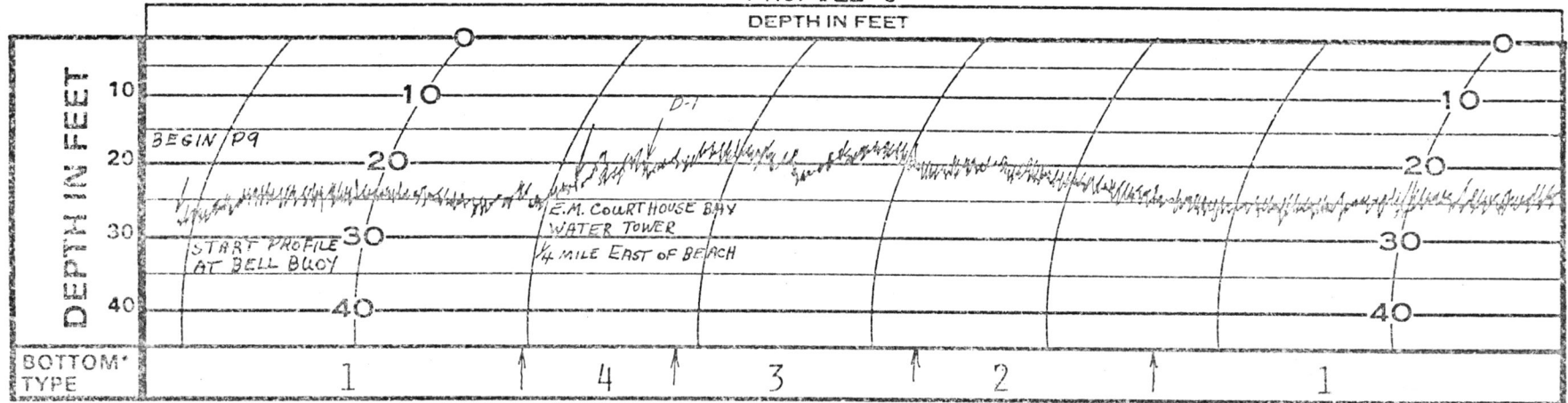
PROFILE 5 DEPTH IN FEET



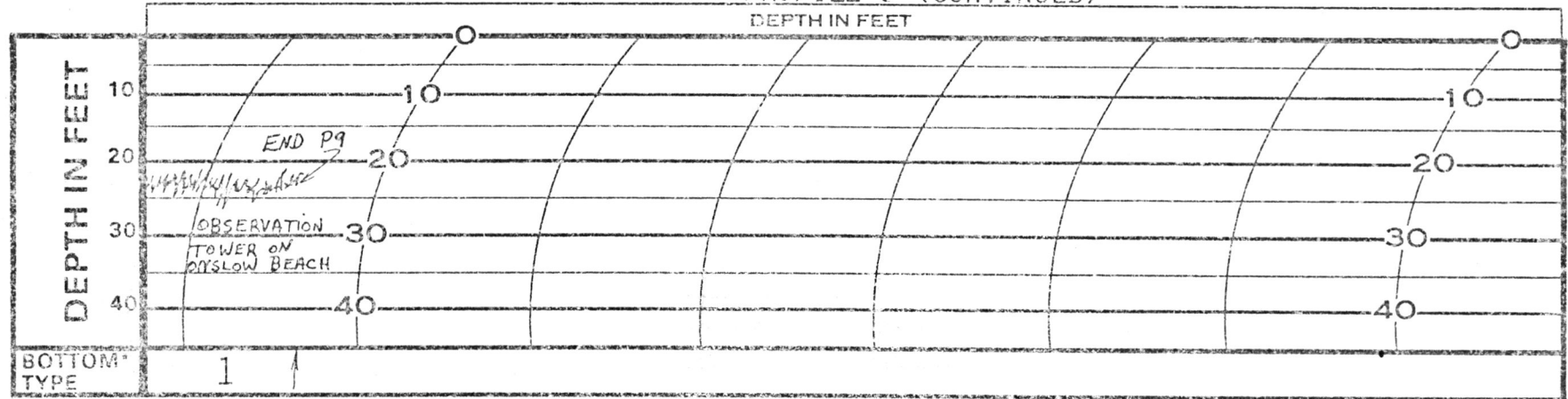


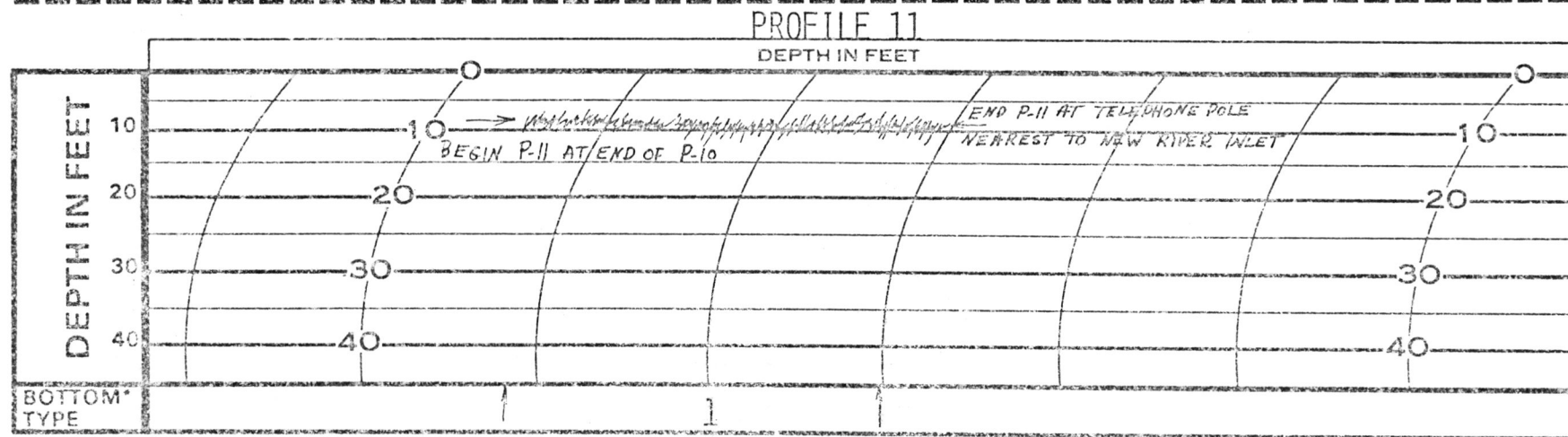
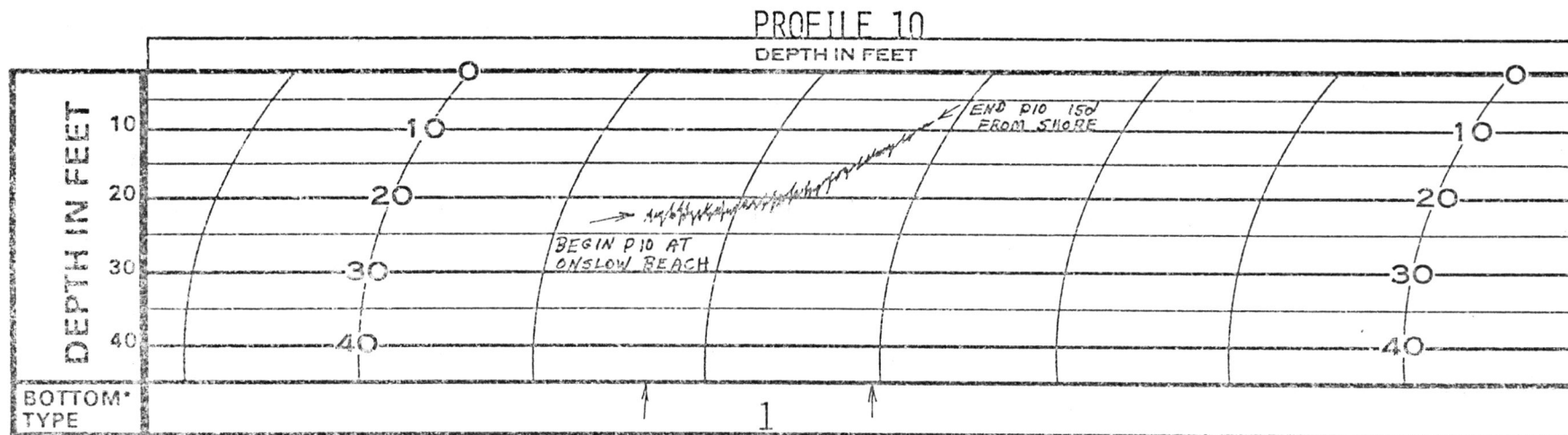


PROFILE 9

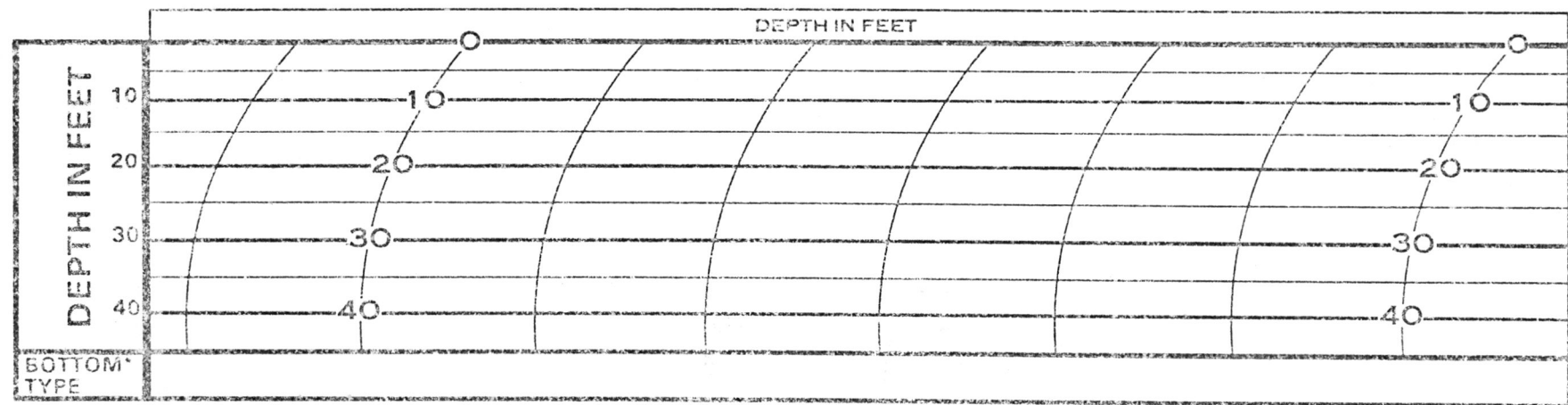
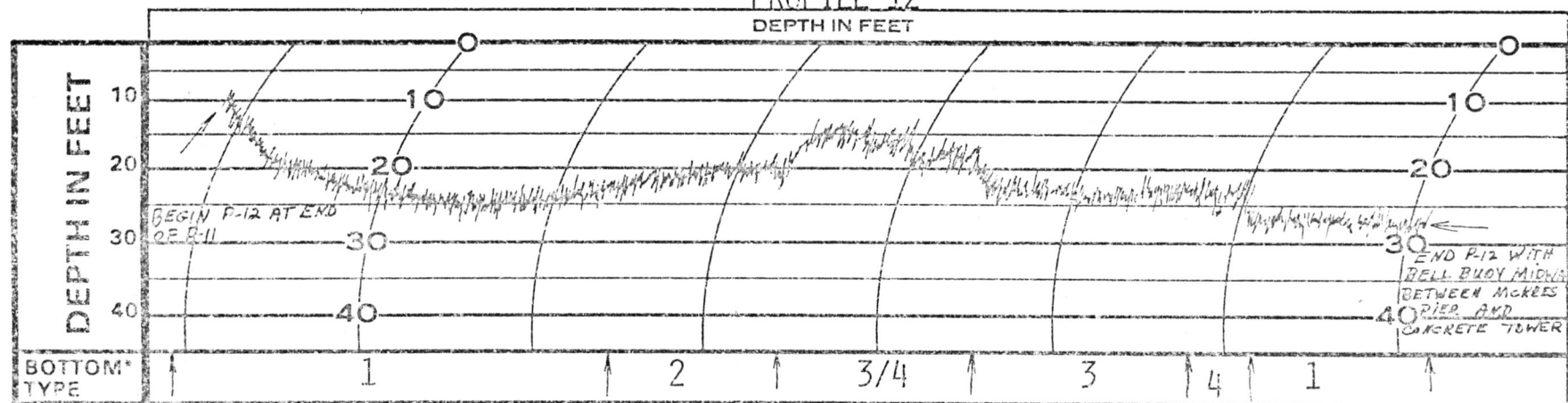


PROFILE 9 (CONTINUED)



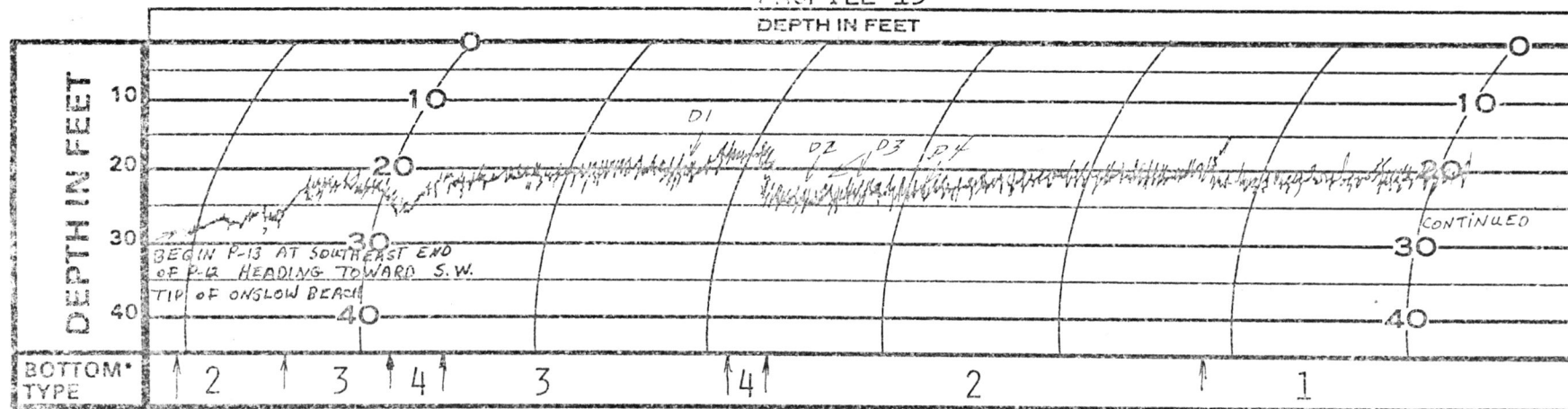


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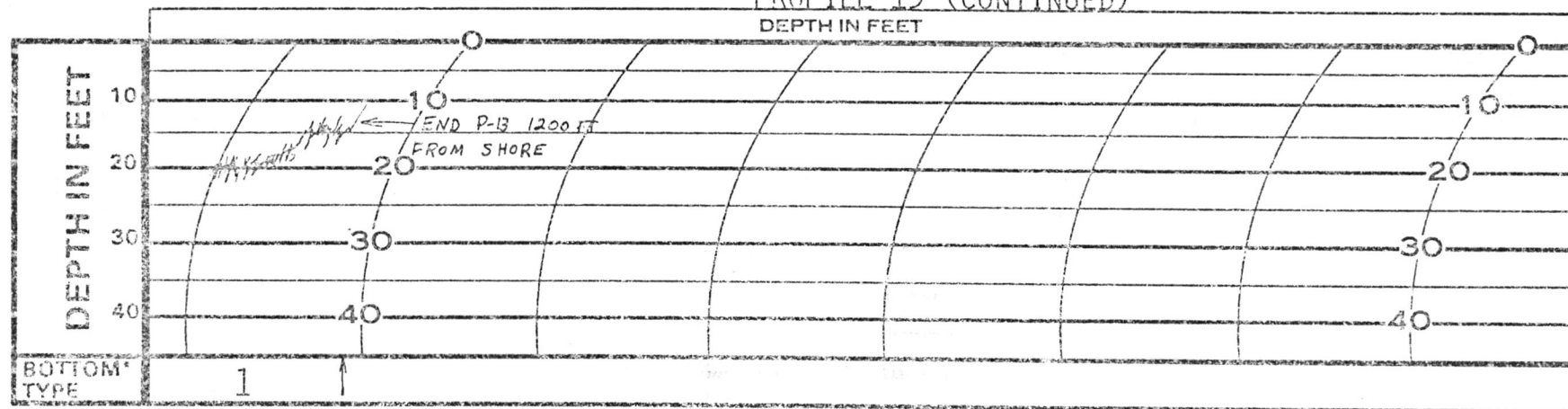
PROFILE 13

DEPTH IN FEET



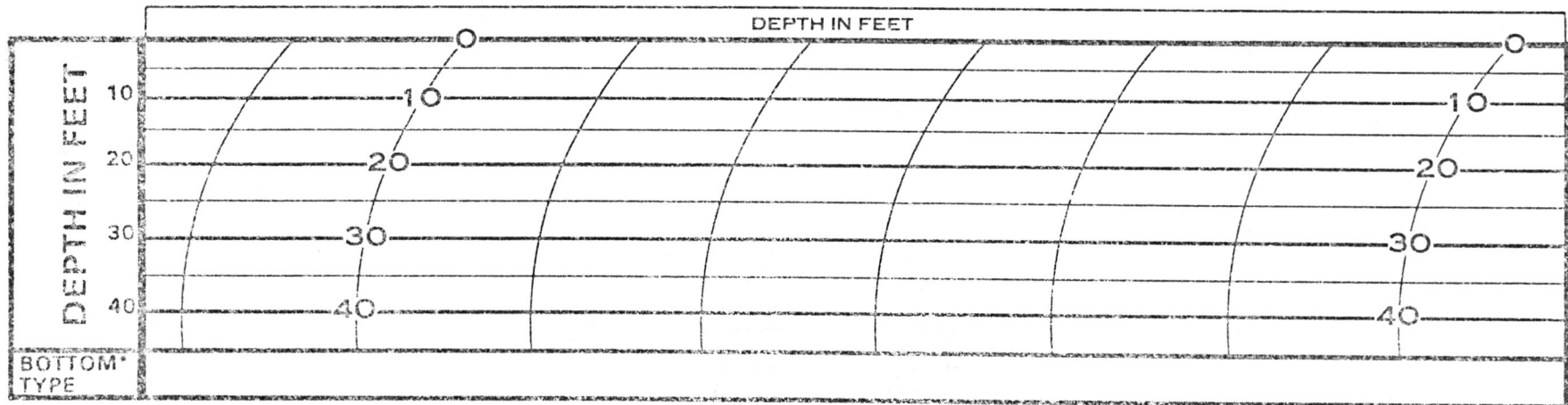
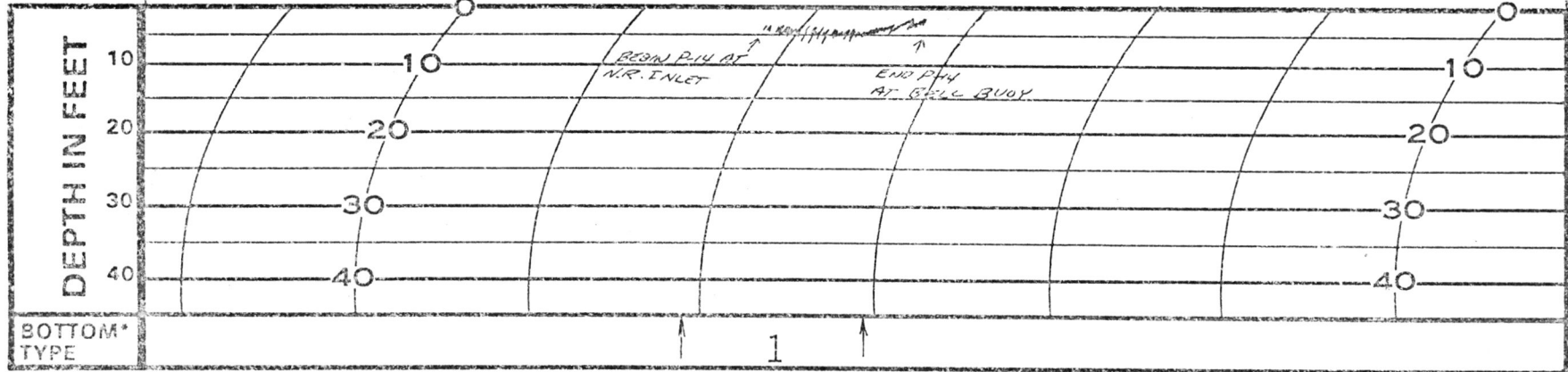
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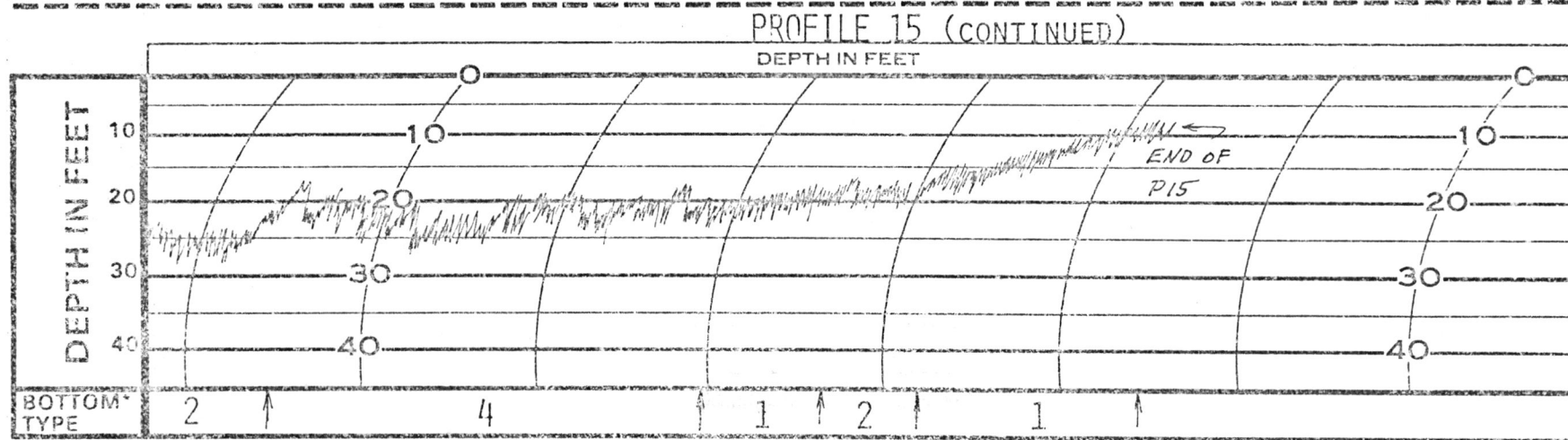
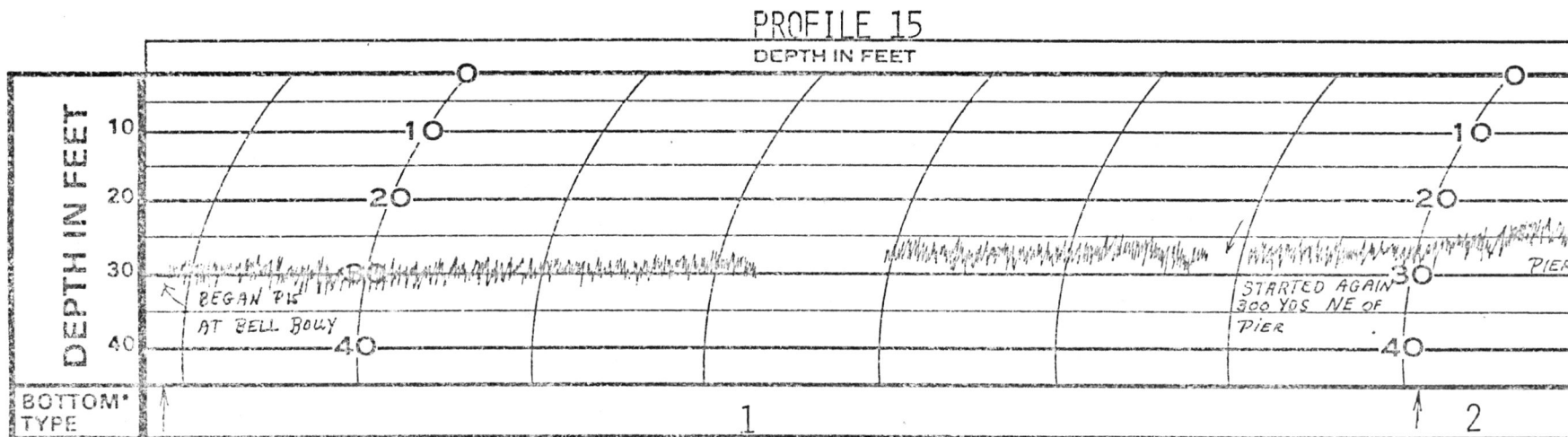
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PROFILE 14

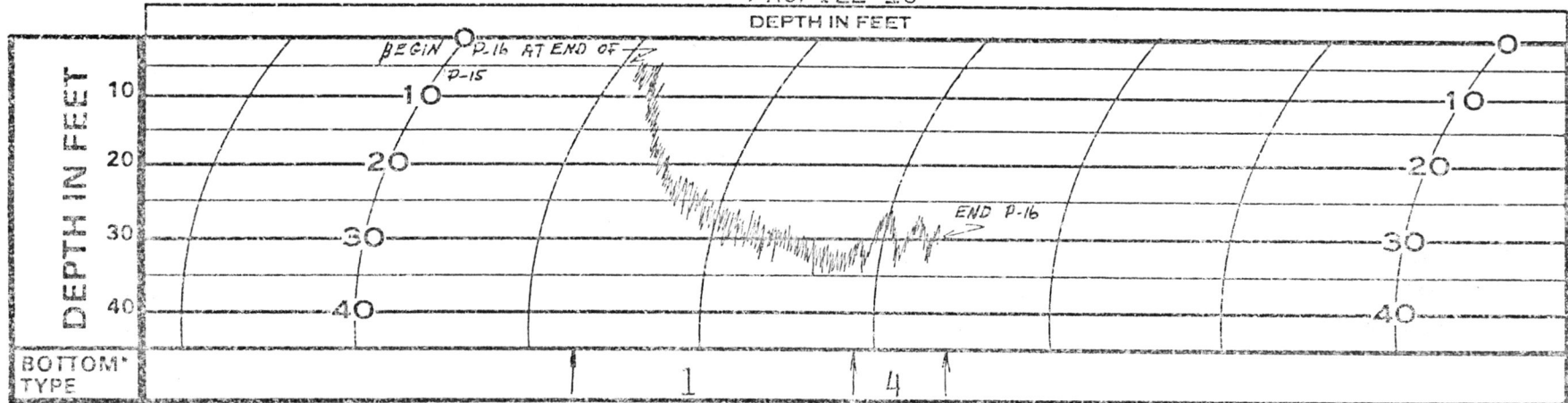
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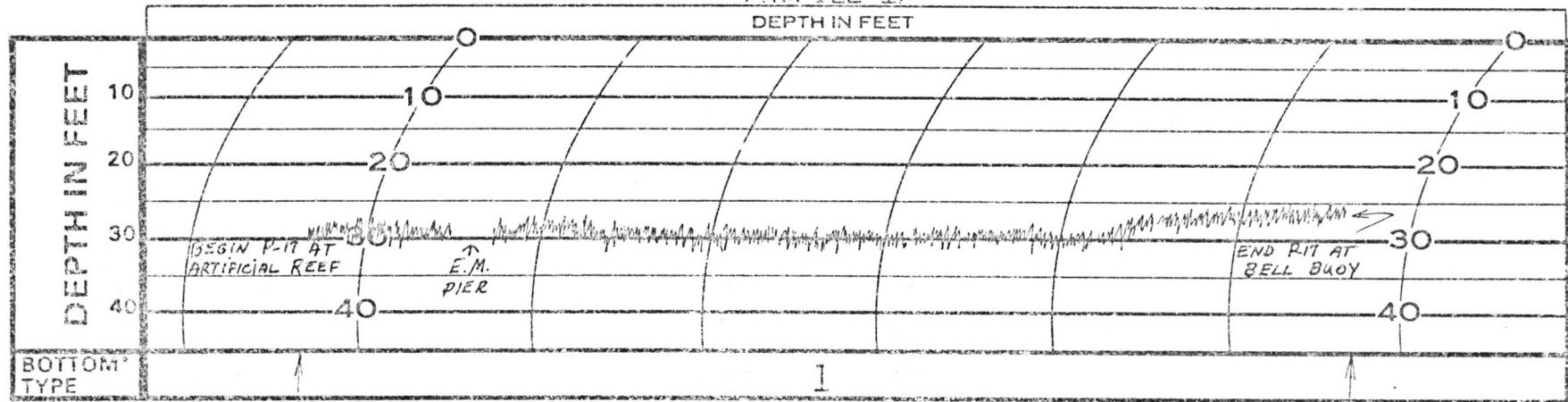
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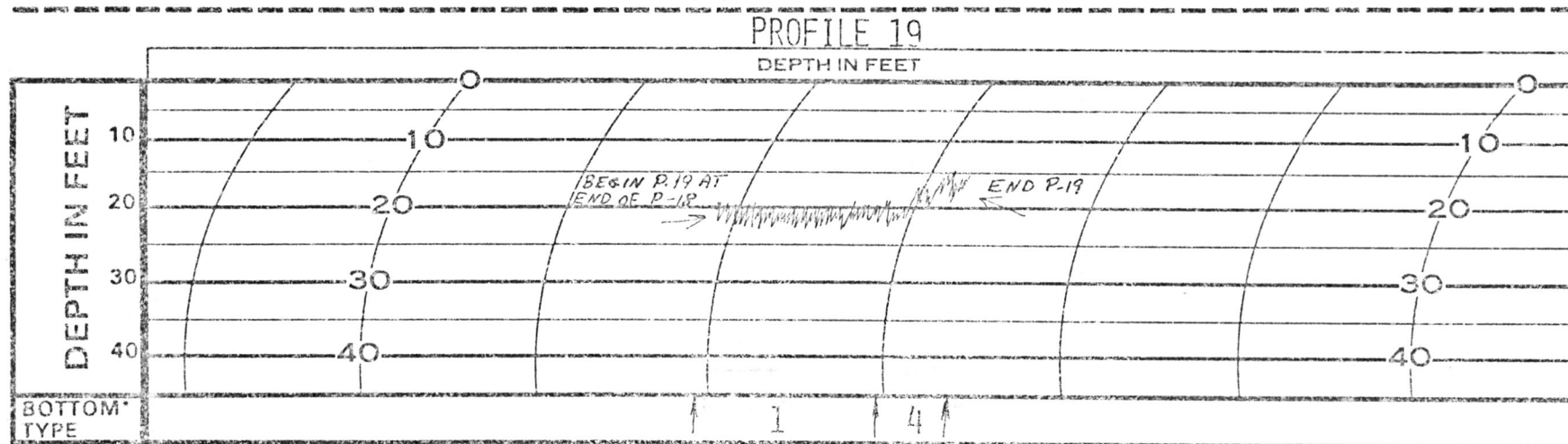
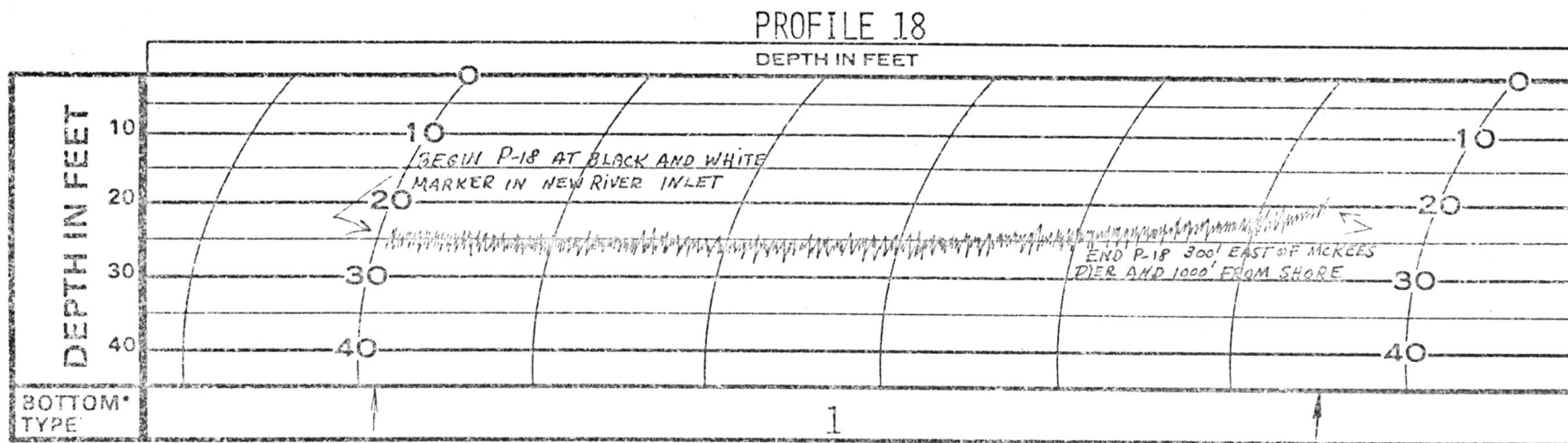
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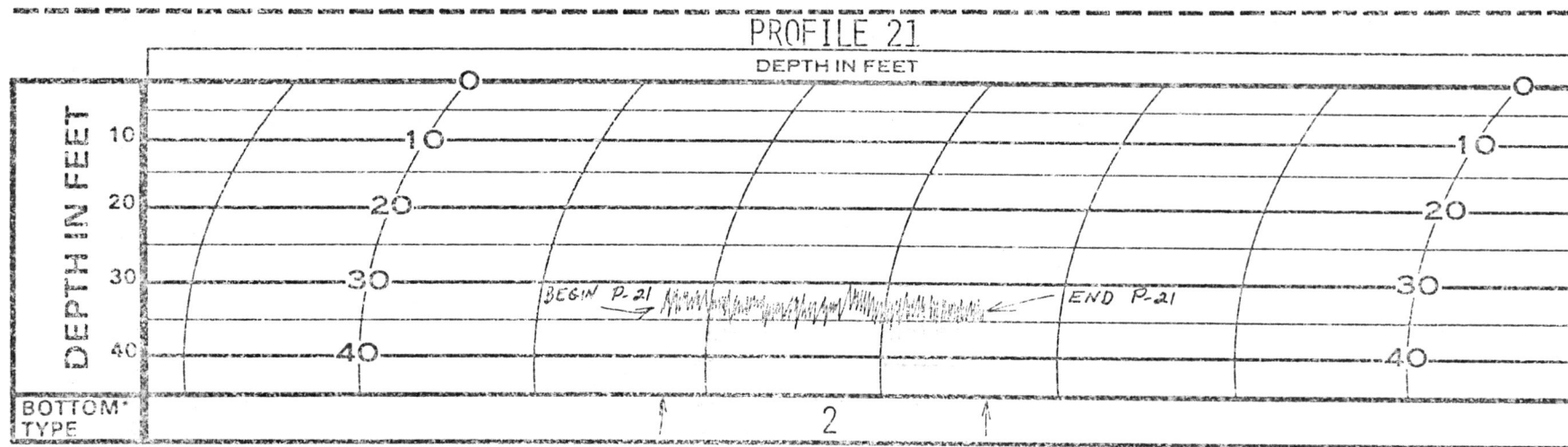
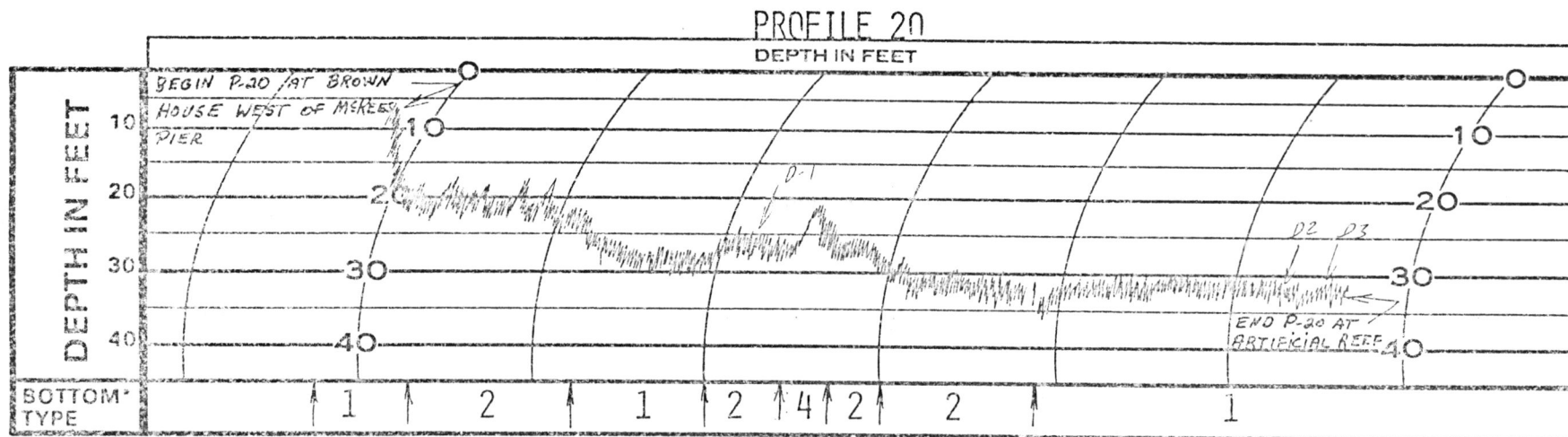


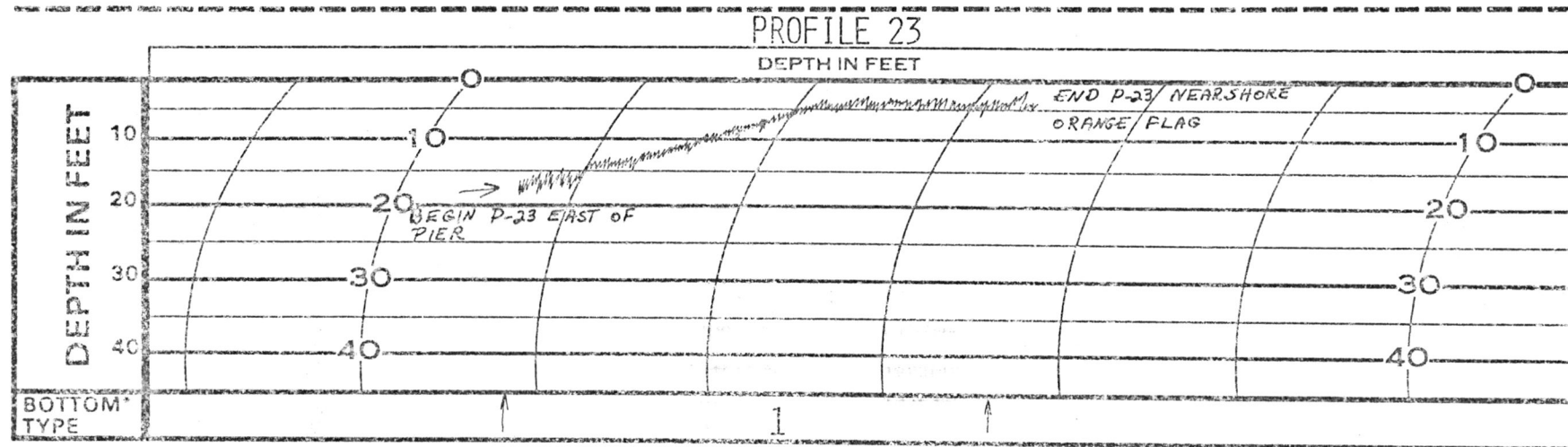
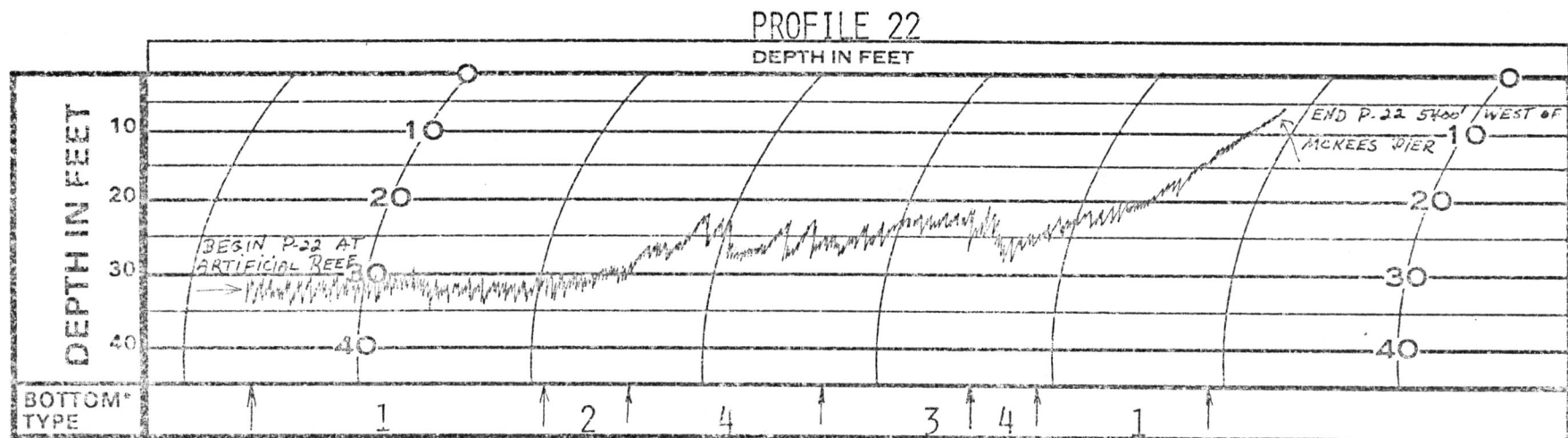
PROFILE 17

DEPTH IN FEET



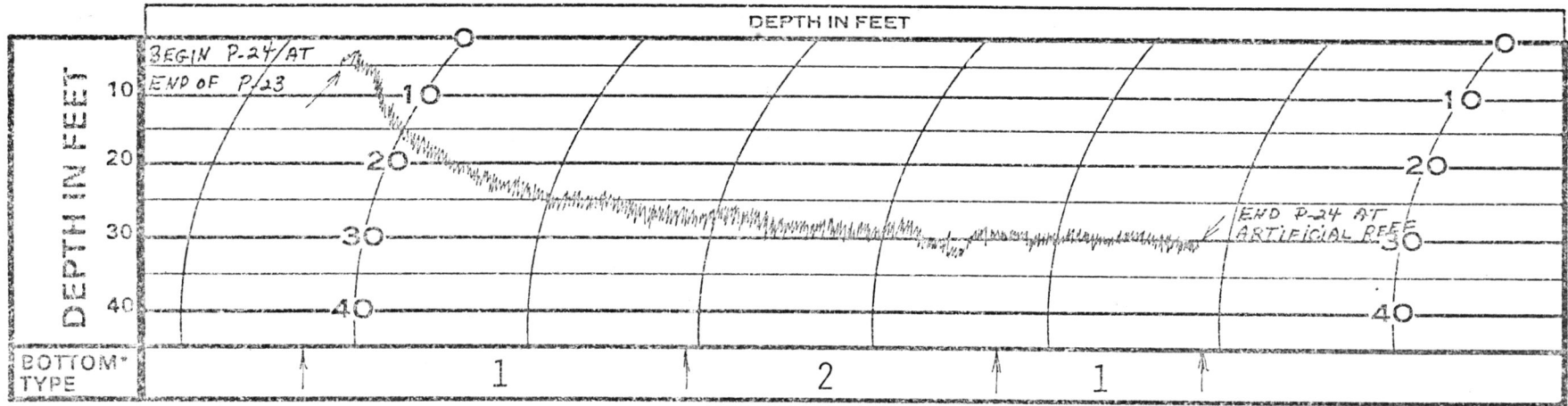






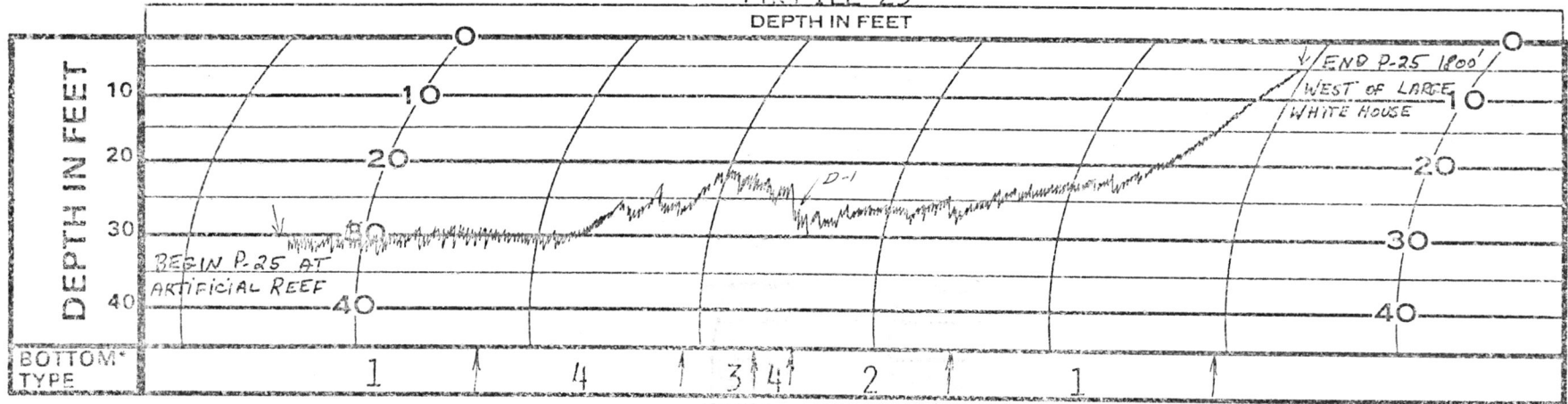
PROFILE 24

DEPTH IN FEET



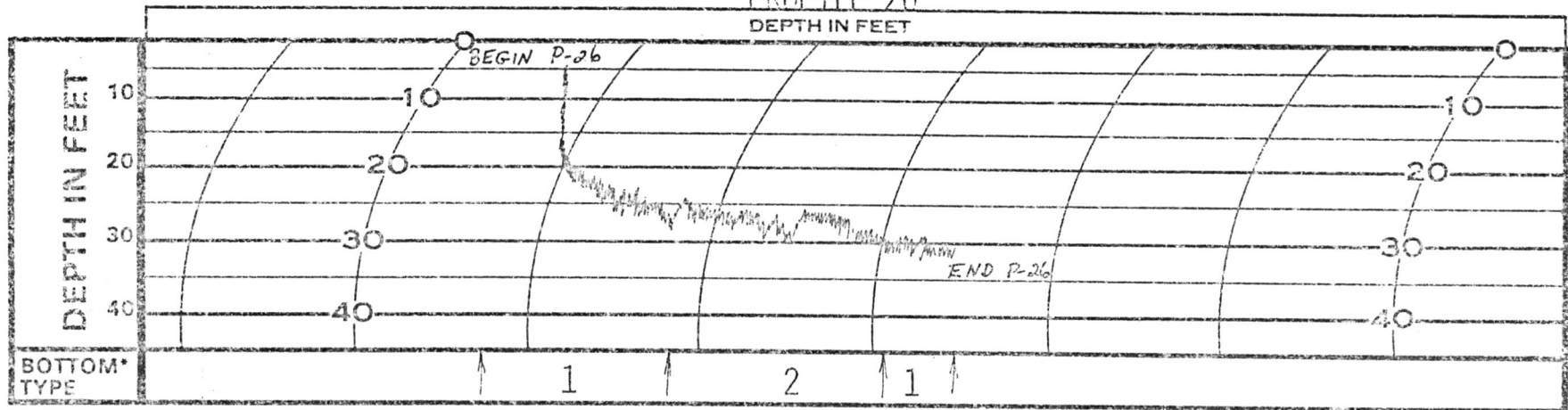
PROFILE 25

DEPTH IN FEET



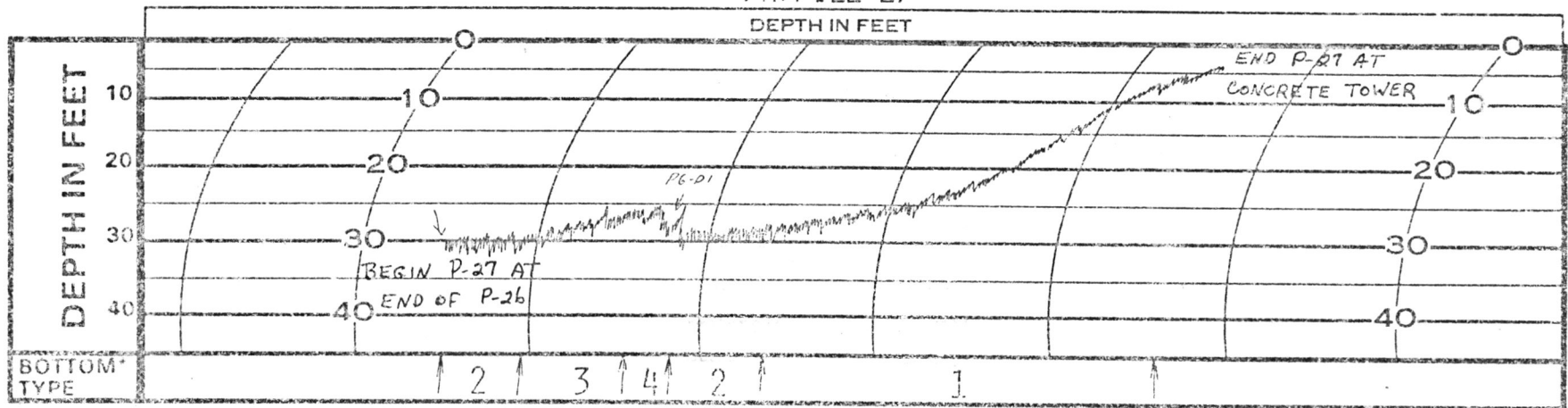
PROFILE 26

DEPTH IN FEET

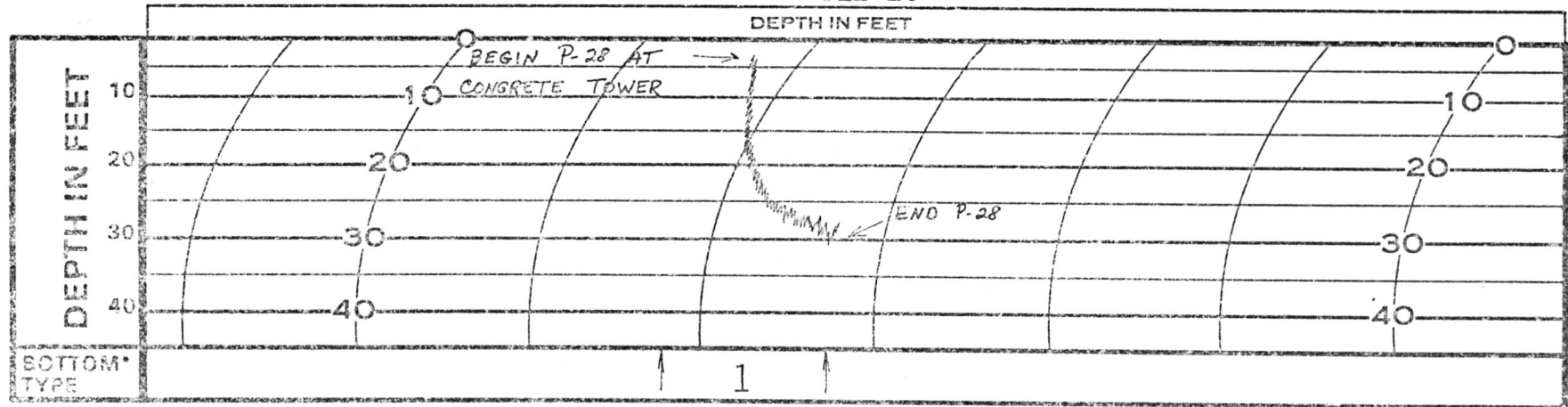


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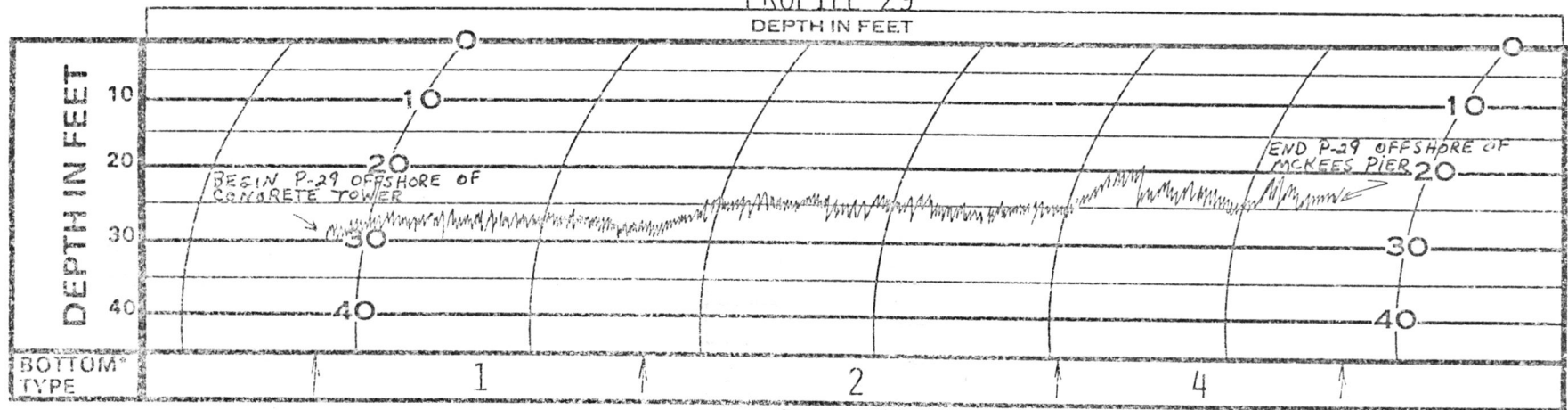
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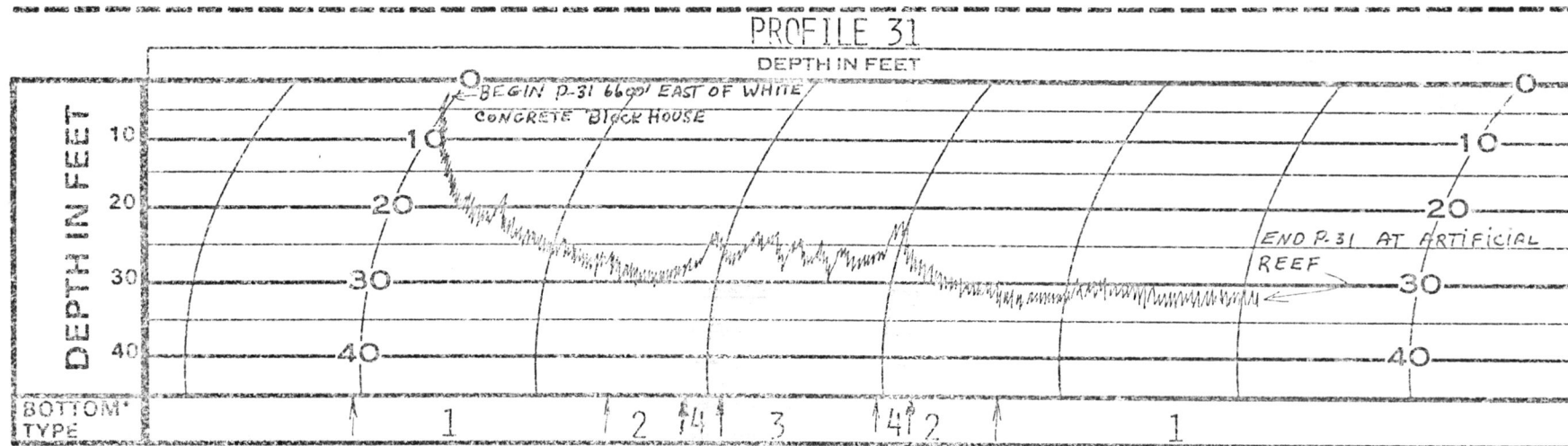
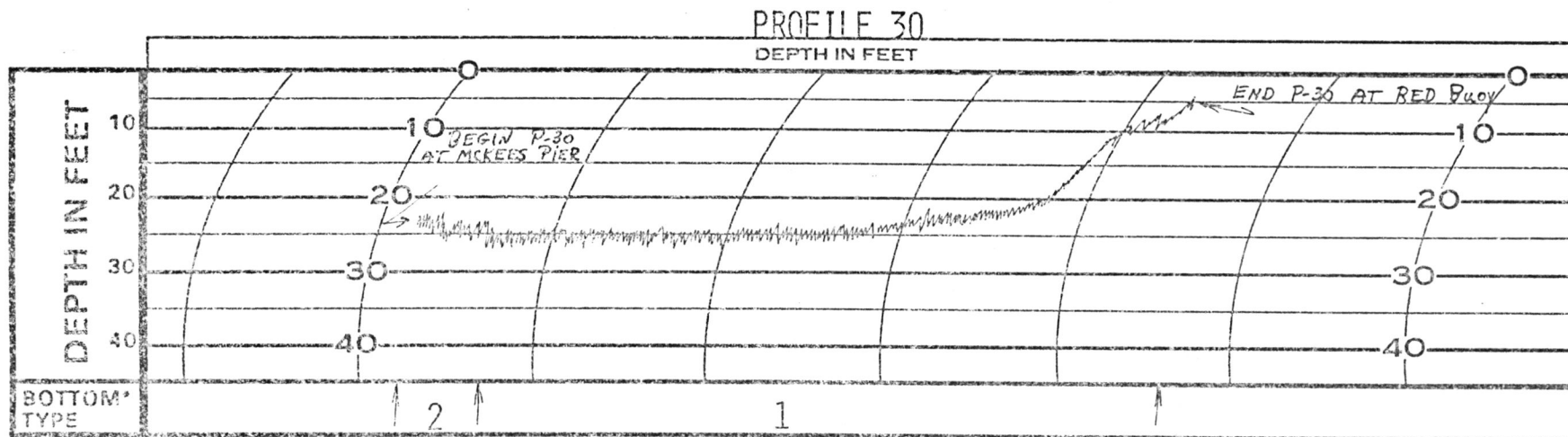


PROFILE 28



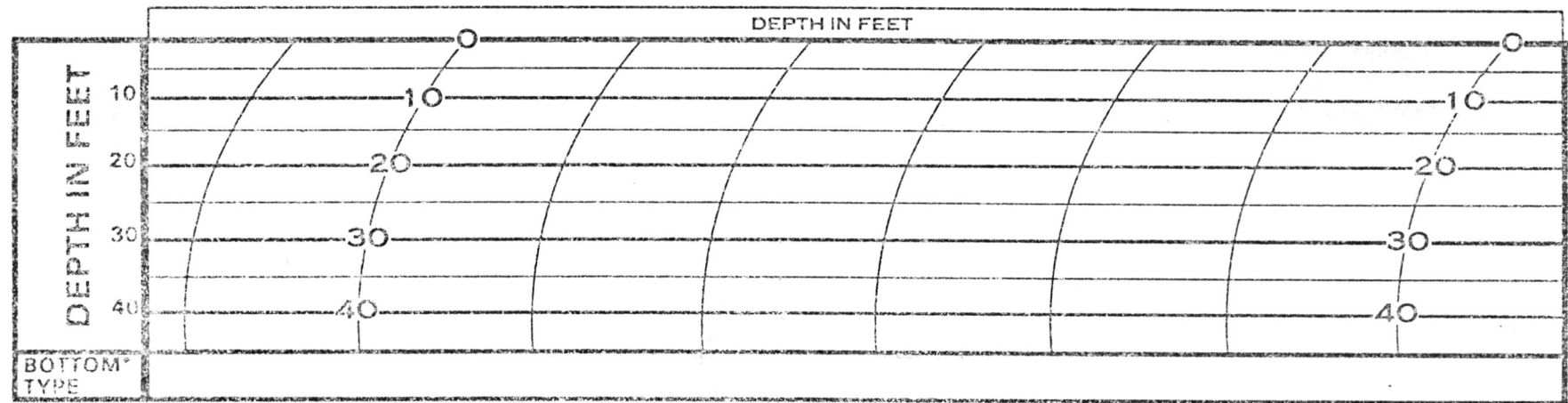
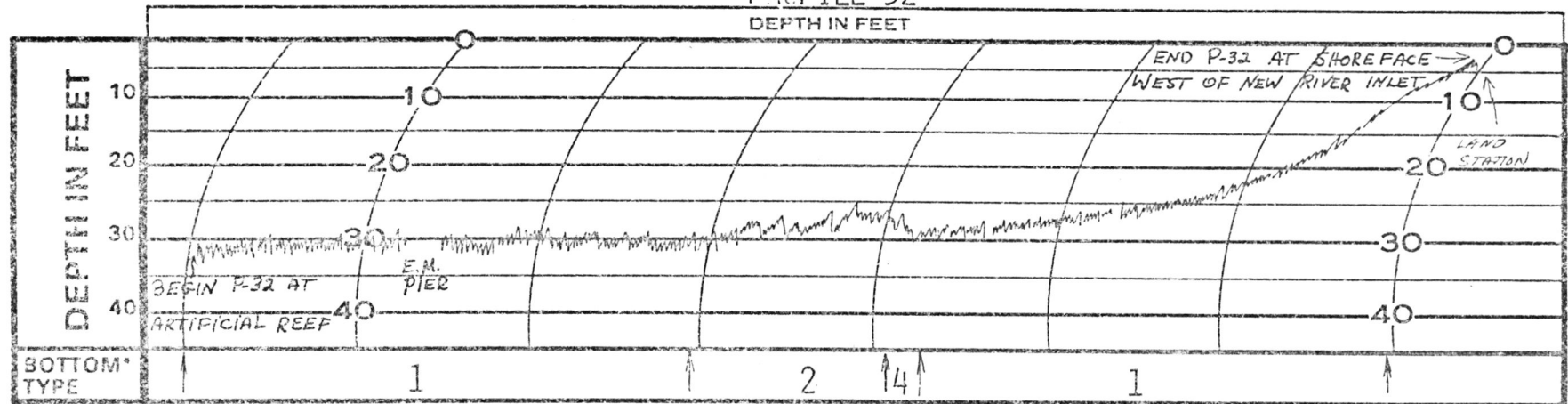
PROFILE 29





PROFILE 32

DEPTH IN FEET



APPENDIX II

SUMMARY OF LOGS FROM EACH DIVE STATION *

* See Figure 4 for the station locations.

PROFILE NUMBER 2 STATION NUMBER 1

DATE 7-14-74

WEATHER Clear , wind 0 to 5 mph

SEA STATE glass calm

WATER VISIBILITY

A. SURFACE 15 feet

B. BOTTOM 10 feet

BOTTOM ENERGY CONDITIONS no motion

BOTTOM BED FORMS low (2-3 feet) rock mounds, gravelly ripples

STRATIFICATION none obserable in gravelly sediment

SEDIMENT TEXTURE very coarse gravel cobble

COMPOSITION OF GRAVEL nearly all (98%) coarse material is composed of fossil shell and limestone rock.

SEDIMENTARY STRUCTURES the cork surface is highly corroded and channeled, channels are filled with gravel and coarse sand.

BIOGENIC STRUCTURES abundant calcareous algae partially cementing sediment, abundant bivalve borings.

BIOTA: Saxacava rugosa, Lithophagus sp., Arca sp. (Turkey Wing clam), Ascenaria, and broken sea fans

COMMENTS: Bottom topography is made of small low sediment free rock mounds with gravel accumulations where rock mounds coalesce. A six foot deep by thirty feet in diameter depression was found filled with loose leafy seaweeds. This material must have collected in the depression during or soon after a storm?

PROFILE NUMBER 2 STATION NUMBER 2DATE 7/14/74WEATHER clear 0-5mphSEA STATE calm

WATER VISIBILITY

A. SURFACE 8- 10 feetB. BOTTOM 8- 10 feetBOTTOM ENERGY CONDITIONS no motionBOTTOM BED FORMS low (less than three inches) irregular ridgesSTRATIFICATION no noticeableSEDIMENT TEXTURE very coarse gravel and cobbleCOMPOSITION OF COARSE GRAINS mostly rounded cast andmold limestone chunksSEDIMENTARY STRUCTURES noneBIOGENIC STRUCTURES occassional encrusting calcareousalgae, boring clamsBIOTA loose seaweed, occassional attached spongeCOMMENTS Dug into bottom approximately 1 foot and did notfind a rock substrate.

PROFILE NUMBER P-2 STATION NUMBER 3

DATE 7/14/74

WEATHER clear 0-5 mph wind

SEA STATE calm

WATER VISIBILITY

A. SURFACE 8-10 feet

B. BOTTOM 8- 10 feet

BOTTOM ENERGY CONDITIONS no motion slight current

BOTTOM BED FORMS patchy areas of coarse sand and cobbles

STRATIFICATION no apparent

SEDIMENT TEXTURE coarse sand and pea gravel to cobble

COMPOSITION OF COARSE GRAINS cast and mold limestone

SEDIMENTARY STRUCTURES Occasional low troughs with abundant fragmented plants.

BIOGENIC STRUCTURES abundant boring clams

BIOTA loose fragmented algae

COMMENTS This is the location of the artificial reef. No reef was present at the time of this study. Later, Dr. Bob Bishop and Dr. Scott Snyder dropped rock samples overboard at this point to determine the nature and rates of boring organisms in Onslow Bay.

PROFILE NUMBER 3 STATION NUMBER 1DATE 7-15-74WEATHER clearSEA STATE 1-2 feet

WATER VISIBILITY

A. SURFACE 5 feetB. BOTTOM 1 footBOTTOM ENERGY CONDITIONS slight bottom motionBOTTOM BED FORMS no visible formsSTRATIFICATION slightly muddy at topSEDIMENT TEXTURE coarse sandy to gravelly shell unitCOMPOSITION OF COARSE GRAINS mostly broken and wornshell and moldic limestoneSEDIMENTARY STRUCTURES noneBIOGENIC STRUCTURES no visible structuresBIOTA found a lone sand dollar broken and wornCOMMENTS Poor visibility obstructed a good view of
bottom. Lost sight of diving partner twice.Visibility was greatly reduced by suspended material
generated whenever the bottom was disturbed.

PROFILE NUMBER P-4 STATION NUMBER 1DATE 7-16-74WEATHER clearSEA STATE 1-2 feet

WATER VISIBILITY

A. SURFACE 6 feetB. BOTTOM 6 feetBOTTOM ENERGY CONDITIONS slight bottom motionBOTTOM BED FORMS low discontinuous ripplesSTRATIFICATION noneSEDIMENT TEXTURE medium to fine pebbly sandCOMPOSITION OF COARSE GRAINS worn shells and lime-
stone pebbles.

SEDIMENTARY STRUCTURES

BIOGENIC STRUCTURES occasional trails produced by
worms or hermit crabs.BIOTA none observedCOMMENTS P4-1 has a less coarse bottom texture than
observed at P3-1.

PROFILE NUMBER 4 STATION NUMBER 2

DATE 7-16-74

WEATHER clear

SEA STATE 1-2 feet

WATER VISIBILITY

A. SURFACE 8 feet

B. BOTTOM 8 feet

BOTTOM ENERGY CONDITIONS none

BOTTOM BED FORMS Slightly irregular mounds and depressions.

STRATIFICATION mounded sediments are coarser than depression's sediment.

SEDIMENT TEXTURE Coarse gravelly sand on mounds, pebbly to fine sands in depressions.

COMPOSITION OF GRAVEL 100% worn shells and limestone fragments.

SEDIMENTARY STRUCTURES Elongate mounds up to 6 inches

high composed of gravelly sand. Pebbly medium sands are found in depressions.

BIOGENIC STRUCTURES rare fecal mounds of worms and bivalves.

BIOTA: Loose algae and live attached sponge.

COMMENTS: Loose rock chunks four to six inches in diameter were found approximately 1 foot below the sediment. The rocks were slightly blackened in color.

PROFILE NUMBER 4 STATION NUMBER 3

DATE 7-16-74

WEATHER clear

SEA STATE 1-2 feet

WATER VISIBILITY

A. SURFACE 8-10 feet

B. BOTTOM 8-10 feet

BOTTOM ENERGY CONDITIONS none

BOTTOM BED FORMS up to 15 feet undercut scarps

STRATIFICATION complex

SEDIMENT TEXTURE coarse pebbly, sandy bottom

COMPOSITION OF COARSE GRAINS broken and worn shells,
soft to hard limestone boulders to pebbles

SEDIMENTARY STRUCTURES abundant mounds of coarse sediment
surrounded by rippled medium to coarse sand.

BIOGENIC STRUCTURES abundant borings and encrusted rock,
vermitid reef growth, and coralline encrustations

BIOTA abundant urchins, Lytechinus, calcareous algae,
sea fans, and boring bivalves. common vermitid reef
material.

COMMENTS Exposed scarp 10 to 15 feet above bottom.

Where best developed scarp is undercut with large 5 to
10 feet boulders at base. At one place the scarp had
a well developed "talus slope" developed on the shore-
ward side. The material composing the base of the scarp
was observed to be softer than overlying material.

PROFILE NUMBER 6 STATION NUMBER 2DATE 7-16-74WEATHER clearSEA STATE calm

WATER VISIBILITY

A. SURFACE 10 feetB. BOTTOM 10 feetBOTTOM ENERGY CONDITIONS noneBOTTOM BED FORMS shoreward facing scarps 5 to 6 feet highSTRATIFICATION sand overlying rockSEDIMENT TEXTURE coarse sandy gravelsCOMPOSITION OF COARSE GRAINS broken and whole shellsand limestone boulders to gravel.SEDIMENTARY STRUCTURES abundant boring bivalves.undercut scarp. and "low" rocky mounds.BIOGENIC STRUCTURES common vermitid reef growthsome coral.BIOTA Abundant sponges, fans, calcareous algae.common vermitid reef growth.COMMENTS Vermittid reef growth appears to be betterdeveloped here than at P4-3. Sponge and fans are mostcommon at the top of the exposed scarp. Talus fromscarp is composed of boulders 1 to 2 feet in diameter,and decrease in average size shoreward from the scarp.

PROFILE NUMBER 7 STATION NUMBER 1

DATE 7-17-74

WEATHER clear

SEA STATE calm

WATER VISIBILITY

A. SURFACE 5 feet

B. BOTTOM 3 feet

BOTTOM ENERGY CONDITIONS none

BOTTOM BED FORMS boulders 1 to 2 feet resting on coarse
sandy bottom.

STRATIFICATION none

SEDIMENT TEXTURE coarse gravelly shelly sand

COMPOSITION OF COARSE GRAINS whole and broken shell
and moldic limestone

SEDIMENTARY STRUCTURES small 1 to 2 foot limestone

boulders encrusted by vermitid gastropod growth

BIOGENIC STRUCTURES vermitid gastropod growth and
abundant bivalve borings.

BIOTA vermitid gastropods, boring bivalves and
occasional small (1-3 inch) sponges.

COMMENTS A loose rocky substrate was found 1 foot
below the sediment surface. The boulders were not
attached to the rocky substrate and could be rolled.

PROFILE NUMBER 7 STATION NUMBER 2

DATE 7-17-74

WEATHER clear

SEA STATE calm

WATER VISIBILITY

A. SURFACE 3 feet

B. BOTTOM 3 feet

BOTTOM ENERGY CONDITIONS none

BOTTOM BED FORMS loose boulders and limestone plates.

STRATIFICATION 1 foot of sediment overlying loose rocky substrate.

SEDIMENT TEXTURE coarse boulder gravelly sand.

COMPOSITION OF COARSE GRAINS worn limestone boulders
and broken shell.

SEDIMENTARY STRUCTURES loose gravelly sand with 2 feet
vermitid covered boulders.

BIOGENIC STRUCTURES vermitid gastropod growth, bivalve
borings

BIOTA Arbacia, boring bivalves, loose algae vermitid
gastropods, minor sponge growth.

COMMENTS Site is similar to P7-2, boulders are
slightly larger but no more common. Bottom
visibility is poor so the actual distribution of
the boulders cannot be determined.

PROFILE NUMBER 7 STATION NUMBER 3

DATE 7-17-74

WEATHER clear

SEA STATE calm

WATER VISIBILITY

A. SURFACE 3 feet

B. BOTTOM 3 feet

BOTTOM ENERGY CONDITIONS none

BOTTOM BED FORMS large boulders attached to bottom.

STRATIFICATION thin gravelly sediment veneer

SEDIMENT TEXTURE coarse gravelly sand.

COMPOSITION OF COARSE GRAINS broken shell and limestone
boulders and gravel.

SEDIMENTARY STRUCTURES large (+2 feet) boulders that
could not be moved surrounded by gravelly sands.

BIOGENIC STRUCTURES moderate vermitid growth on
upper surface of boulders

BIOTA vermitid gastropods, Arbacia, boring bivalves,
loose algae and occasional sponge growth.

COMMENTS Site is similar to P7-2 and P7-1. Boulders
appear to be more flattened and vermitid gastropod
growth is restricted to upper most surface of boulders.
Boulders could not be moved (assumed they are
attached to rocky substrate).

PROFILE NUMBER 13 STATION NUMBER 1DATE 8-6-74WEATHER cloudySEA STATE 2-3 feet swells

WATER VISIBILITY

A. SURFACE 6 feetB. BOTTOM 5 feetBOTTOM ENERGY CONDITIONS slight bottom motionBOTTOM BED FORMS noneSTRATIFICATION gravel pavement on rock substrateSEDIMENT TEXTURE course sand and bouldersCOMPOSITION OF COARSE GRAINS broken shell, and rounded
bouldersSEDIMENTARY STRUCTURES irregular scarpsBIOGENIC STRUCTURES abundant vermitid gastropods and rare
bryozoa cup growthBIOTA vermitid gastropods, Arbacia, and boring bivalves

COMMENTS The distribution of scarps is not as regular at
this site as seen at the West Onslow Beach localities. Scarps
are 2 to 6 feet high and have abundant vermitid reef growth at
scarp crest. Unusual bryozoa growth form discovered at the
base of the scarps.

PROFILE NUMBER 13 STATION NUMBER 2DATE 8-6-74WEATHER cloudySEA STATE 2-3 feet swells

WATER VISIBILITY

A. SURFACE 5 feetB. BOTTOM 5 feetBOTTOM ENERGY CONDITIONS slight bottom motionBOTTOM BED FORMS noneSTRATIFICATION gravel pavement on rock substrateSEDIMENT TEXTURE coarse sandy gravel with occasional bouldersCOMPOSITION OF COARSE GRAINS rounded limestoneSEDIMENTARY STRUCTURES common scarps irregular in shape
and distributionBIOGENIC STRUCTURES abundant vermitid gastropod growth
at top of scarps. boring bivalve holes.BIOTA vermited gastropods, sponge, Arbacia, boring bivalves,
bryozoa cup growth.COMMENTS Scarps are very irregular and more reduced than at
site P13-1. Highly bored disc-shaped boulders more than 3
feet long and 6 inches thick were found. Bryozoa cup growth
is common.

PROFILE NUMBER 13 STATION NUMBER 3DATE 8-6-74WEATHER cloudySEA STATE 2-3 feet swells

WATER VISIBILITY

A. SURFACE 6B. BOTTOM 3BOTTOM ENERGY CONDITIONS slight bottom motionBOTTOM BED FORMS irregular rock surfaceSTRATIFICATION gravel pavement covering rock substrateSEDIMENT TEXTURE coarse sandy gravelCOMPOSITION OF COARSE GRAINS limestone and broken shellSEDIMENTARY STRUCTURES deep (3-6 inches) groves in rocksurface filled with coarse sand and gravelBIOGENIC STRUCTURES abundant bryozoa cup growth. abundantboring bivalve holes.BIOTA bottom is nearly void of attached forms except forBryozoa cups that have formed on clean rock surfaces. Arbacia,boring bivalves are present.COMMENTS The rock surface is clean and irregular. Sedimenthas accumulated in groves in rock. Rock surface is soft and showsabundant siphons of boring bivalves.

PROFILE NUMBER 13 STATION NUMBER 4

DATE 8-6-74

WEATHER Cloudy, becoming more windy (10-15 mph)

SEA STATE Swells 2 to 3 feet, slightly choppy.

WATER VISIBILITY

A. SURFACE 3 feet

B. BOTTOM 3 feet

BOTTOM ENERGY CONDITIONS Some motion of loose sand grains on the bottom.

BOTTOM BED FORMS Pronounced ripples in sandy areas.

STRATIFICATION Coarse sediment on top of the bottom

SEDIMENT TEXTURE Coarse to medium pabbly sand.

COMPOSITION OF GRAVEL Broken shell material (80%), and moldic limestone cobbles (20%).

SEDIMENTARY STRUCTURES Continuous oscillation ripples occasional debris covered rock surfaces.

BIOGENIC STRUCTURES Abundant boring bivalves, small keyhole limpets, and loose leaves of algae.

BIOTA: Arbacia, boring bivalves, small keyhole limpets and loose leaves of algae.

COMMENTS: The bottom is covered with a 6" thick loose coarse sandy gravel. Thicker sediments occur along filled channels approximately 1 foot deep. Occasional loose boulders are easily broken up by hand. Boring bivalves are the major destructive agent acting on the rock surfaces.

PROFILE NUMBER 14 STATION NUMBER 1DATE 8-1-74WEATHER overcast / rain / thunderstorm threateningSEA STATE swells 6 feet

WATER VISIBILITY

A. SURFACE 1 footB. BOTTOM unknownBOTTOM ENERGY CONDITIONS high flow ratesBOTTOM BED FORMS antidunes forming along flank of bar.STRATIFICATION bar is convex-upSEDIMENT TEXTURE coarse pebbly sandCOMPOSITION OF COARSE GRAINS broken and smooth shelland rock pebbles and bouldersSEDIMENTARY STRUCTURES well developed swash zonealong outline of barBIOGENIC STRUCTURES bird tracksBIOTA Sea gullsCOMMENTS Location of site is on ebb-tide inlet mouthbar. Elongate and parallel to main inlet channel.Most of the shells are bay type species (oysters,
scallops, clams) suggesting a transport of sedimentfrom the inland bays near New River Inlet.

PROFILE NUMBER 14 STATION NUMBER 2DATE 8-1-74WEATHER overcast thunderstorm threateningSEA STATE calm

WATER VISIBILITY

A. SURFACE 0.5 feetB. BOTTOM 0.5 feetBOTTOM ENERGY CONDITIONS very strong currents, unusual
for calm sea state.BOTTOM BED FORMS antidunes (sand "explodes" around feet.STRATIFICATION none visibleSEDIMENT TEXTURE very coarse shelly pebbly gravelCOMPOSITION OF GRAVEL 80% coarse shell and quartz,
20% limestone rock cobbles.SEDIMENTARY STRUCTURES rapidly moving mega ripples
and anti dunes.BIOGENIC STRUCTURES none visibleBIOTA: One blue crab.COMMENTS: Site is located on inlet mouth bar not
exposed at low tide. Current was very strong, Very
hard to stand up on the bottom because of the sand
washing from underneath ones feet.

PROFILE NUMBER P19 STATION NUMBER 1DATE 8-11-74WEATHER clearSEA STATE calm

WATER VISIBILITY

A. SURFACE 8 feetB. BOTTOM 8 feetBOTTOM ENERGY CONDITIONS slight bottom motionBOTTOM BED FORMS clean rock surfaceSTRATIFICATION noneSEDIMENT TEXTURE cobble gravelCOMPOSITION OF COARSE GRAINS moldic limestoneSEDIMENTARY STRUCTURES 4 inches to 6 inches wide channelsfilled with coarse gravelBIOGENIC STRUCTURES abundant boring bivalve holesBIOTA Arbacia, boring bivalves, loose seaweeds, oneattached sea fan

COMMENTS Bottom is composed mostly of a clean rock surface
with grooves filled with gravel. The rock is hard on the surface
but soft approximately 4 to 6 inches beneath the surface,
Exposed edges of boulders or small ledges can be broken with
the hand.

PROFILE NUMBER P-19 STATION NUMBER 2DATE 8-11-74WEATHER clearSEA STATE calm

WATER VISIBILITY

A. SURFACE 8 feetB. BOTTOM 8 feetBOTTOM ENERGY CONDITIONS very slight motionBOTTOM BED FORMS rippled sands and discontinuous scarpsSTRATIFICATION Loose coarse covering soft rock surfaceSEDIMENT TEXTURE coarse pebbly sandCOMPOSITION OF GRAVEL 60% whole and broken shells, 40%
broken and rounded limestone rock.SEDIMENTARY STRUCTURES bottom is rippled is most
sandy areas.BIOGENIC STRUCTURES Ancient oyster reef, Crassostrea
gigantissima, abundant boring bivalves, and small encr-
usting coral forms.BIOTA: Boring bivalves, calcareous algae, attached
seaweed, turkey wing clams (Arca sp.), Arbacia and
others.COMMENTS: Bottom is composed of low rock mounds, One
such mound was composed wholly of vertical (in situ)
fossil oyster shells, overlain by a moldic limestone
The mound was undercut, and oyster shells eroded.

PROFILE NUMBER P19 STATION NUMBER 3DATE 8-11-74WEATHER clearSEA STATE calm

WATER VISIBILITY

A. SURFACE 8 feetB. BOTTOM 8 feetBOTTOM ENERGY CONDITIONS very slight motionBOTTOM BED FORMS low rock scarps (less than 2 feet high)STRATIFICATION none observedSEDIMENT TEXTURE very coarse sand to bouldersCOMPOSITION OF COARSE GRAINS mostly moldiclimestone bouldersSEDIMENTARY STRUCTURES loose boulder and coarsesand moundsBIOGENIC STRUCTURES none observedBIOTA loose seaweeds, abundant boring bivalvesCOMMENTS Bottom is composed of irregular moundsof coarse sand to boulders. Some boulders exceed2 feet in diameter and are platy. Abundant fossiloyster shells make up approximately 40% of thecobble component. The remainder of the cobbles aremade up of bioeroded moldic limestones.

PROFILE NUMBER P20 STATION NUMBER 1DATE 8-12-74WEATHER cloudySEA STATE low (2 to 3 feet) ground swells

WATER VISIBILITY

A. SURFACE 4 feetB. BOTTOM 2 feetBOTTOM ENERGY CONDITIONS slight motionBOTTOM BED FORMS rippled bottomSTRATIFICATION Thin layer of dark mud overlying fine sand.SEDIMENT TEXTURE muddy medium to fine sand.COMPOSITION OF GRAVEL Live sabellariid worms coating small gastropod shells with coarse sand.SEDIMENTARY STRUCTURES thickly laminated mud and fine sands.BIOGENIC STRUCTURES Unusual sabellariid worm encrusting shells, also, abundant tracks on the bottom.

BIOTA: Surpulid worms, sabellariid worms, "hermit crabs"

COMMENTS: Bottom is composed of compact fine sand covered by a thin muddy layer, unusual sabellariid worms generate a discontinuous pebbly zone. Site is a lower shore face of the beach sequence.

PROFILE NUMBER P20 STATION NUMBER 2DATE 8-12-74WEATHER cloudySEA STATE low (2-3 feet) ground swells

WATER VISIBILITY

A. SURFACE 4 feetB. BOTTOM 0 to 1 footBOTTOM ENERGY CONDITIONS noneBOTTOM BED FORMS none observedSTRATIFICATION soft mud overlying very coarse gravel.SEDIMENT TEXTURE muddy pebbly sandy gravelCOMPOSITION OF COARSE GRAINS mostly (greater than
50%) pebbles of moldic limestoneSEDIMENTARY STRUCTURES upper muddy surface is
slightly laminatedBIOGENIC STRUCTURES Found one dead parchment worm
tube sack.BIOTA minor icicle sponges, abundant boring
bivalves.

COMMENTS We felt our way across the muddy bottom
along what appeared to be a major channel
structure trending east west. Sides of the channel
were composed of large highly bored moldic
limestone blocks. Sponges lived on exposed rock
bottom in base of channel.

PROFILE NUMBER P20 STATION NUMBER 3DATE 8-12-74WEATHER cloudySEA STATE low (2-3 feet) ground swells

WATER VISIBILITY

A. SURFACE 4 feetB. BOTTOM 4 feetBOTTOM ENERGY CONDITIONS slight bottom motionBOTTOM BED FORMS low rippled gravel covering rock surfaceSTRATIFICATION gravel on rock surfaceSEDIMENT TEXTURE very coarse sandy gravelCOMPOSITION OF COARSE GRAINS approximately 80%limestone, the remainder shell.SEDIMENTARY STRUCTURES extensive gravel pavementBIOGENIC STRUCTURES abundant bivalve borings inlarger limestone rocks.BIOTA boring bivalvesCOMMENTS A Blank bottom composed of extensive and welldeveloped gravels overlying a gray soft moldiclimestone. Occassional exposed surface of rockysubstrate.

PROFILE NUMBER P25 STATION NUMBER 1DATE 8-12-74WEATHER cloudySEA STATE swells 3 to 4 feet

WATER VISIBILITY

A. SURFACE 8 feetB. BOTTOM 6 feetBOTTOM ENERGY CONDITIONS very slight bottom motionBOTTOM BED FORMS minor rippled surface, 2-3 inches highSTRATIFICATION noneSEDIMENT TEXTURE medium to coarse sands at base of scarp.COMPOSITION OF COARSE GRAINS whole and broken shells,limestone bouldersSEDIMENTARY STRUCTURES poorly developed scarps 3 to 5 feet.abundant talus at base.BIOGENIC STRUCTURES abundant boring bivalves, worm trials,Arbacia scrape marks.BIOTA Abundant Arbacia, boring bivalves, attached seaweed, seafans, encrusting corals, Ascenaria common vermitid reef growth,and icicle sponges. and more.COMMENTS Species diversity is high. Low scarps underlain byfossil oyster shells (Crassostrea gigantissima). Tops of scarpsare flat with vermitid growth along crest. Occasional sand andgravel patches occurs between areas of heavily algal encrustedrock substrate. Shoreward of scarps is a flat clean coarse sandybottom.

PROFILE NUMBER P32 STATION NUMBER 1

DATE 10-3-74

WEATHER cool and clear

SEA STATE 1 foot breaking waves on beach

WATER VISIBILITY

A. SURFACE 0

B. BOTTOM unknown

BOTTOM ENERGY CONDITIONS breaker and swash zones have high energy

BOTTOM BED FORMS planar bedding in swash zone

STRATIFICATION planar bedding

SEDIMENT TEXTURE medium to coarse sand in swash zone

COMPOSITION OF COARSE GRAINS variety of broken and worn shells, quartz cobbles, and limestone boulders

SEDIMENTARY STRUCTURES Beach is slightly cusped with slight beach scarp at high tide line.

BIOGENIC STRUCTURES bird tracks and human foot prints

BIOTA birds and humans

COMMENTS Beach contains abundant rock boulders and cobbles with the same composition as those found offshore. Rocks are well rounded and tend to be harder to break than those found offshore. This could reflect the fact that only the hardest rocks are transported to the beach without being broken up.

APPENDIX III

BIOTA OF THE STUDY AREA

BIOTA OF THE STUDY AREA

The following is a detailed Key to the biota found to live in, on, and around the ocean bottom in the study area. Most of the specimens presented were listed in a report by A. S. Pearse and L. G. Williams (1951). Species identified by the author are marked by a "*" symbol, the remainder of the species were presented in the Pearse and Williams report.

PORIFERA

Demospongia

- Spongia graminea Hyatt *
- Phyllospongia lanuga de Laubenfels
- Ircinia fasciculata (Pallas) *
- Dysidea sp.

Haplocerina

- Haliclona (Topsent)
- Haliclona oculata (Linne)

Poecilosclerina

- Microciona prolifera (Ellis and Solander)
- Thalysseurypon carteri (Topsent)
- Thalysseurypon foliacea (Topsent)
- Myrmekioderma sp.

Halichondrina

- Higginsia coralloides Higgin
- Phakellia folium Schmidt

Homaxinella sp.

Pseudaxinella sp.

Hymeniacidon heliophila (Parker)

Ciocalapata sp.

Hadromerina

Pseudosuberites melanos de Laubenfels.

Cliona caribboea (Carter)

Epipolasida

Dorypleres sp.

Choristida

Myriastr fibrosa (Schmidt)

Geodia gibberosa Lamarck

Craniella crania (Mueller)

Gionchyra cavernosa (Lamarck)

Calcispongiae

Lucetta floridana (Haeckel)

COELENTERATA

Hydrozoa *

Sertularia gracilis Hincks. *

Sertularia conica Allman *

Monostaechas quadridens McCrady

Clytia johnstoni (Alder)

Eudendrium carneum (Clarke)

Aglaophemia rigida Allman

Anthozoa *

Astrangia astraeiformis Leidy. * coral

Cyclista leucolena (Agassiz)

Leptogorgia virgulata (Lamarck) *
Gorgonia bipinnata (Verrill)

PLATYHELMINTHES

Polycladida *

Coronadena mutabilis (Verrill) *

Heteronemerta

Micrura leidy (Verrill)

Hoplonemertea

Oerstedtia dorsalis (Abildgaard)

Amphiporus ochraceus (Verrill)

Amphiporus sp.

Proneurotes multioculatus Montgomery

BRYOZOA

Cyclostomata

Crisia eburnea (L.)

Crisia elongata [Milne-Edwards]

Crisulipora orientalis Canu and Bassler

Ctenostomata

Amathia vidovici (Heller)

Amathia convoluta [Lamouroux]

Sundanella sibogae (Harmer)

Cleilostomata *

Aetea anguina (L.)

Membranipora tenuis Desor

Canopeum commensale Kirkpatrick and Metzlaar

Crassimarginatella leucocypha Marcus
Thalamoporella gothica var. floridana Osburn
Caulibugula sp.
Cribrilina punctata (Hassall)
Hippothoa hyalina (L.)
Schizoporella unicornis (Johnston)
Schizoporella floridana Osburn
Microporella ciliata (Pallas)
Hippororina contracta (Walters)
Smittina trispinosa var. spathulata (Smitt)
Adeona violacea (Johnston)

ANNELIDA

Polynoidae

Harmothoe aculeata Andrews
Lepidonotus variabilis Webster
Lepidonotus sublaevis Verrill

Chrysotyelidae

Bhawania goodei Webster

Phyllodocidae

Nereiphylla fragilis (Webster)

Syllidae

Trypanosyllis zebra Grube
Syllis sp.

Nereidae

Platynereis dumerilii (Audouin and M. Edwards)
Ceratonereis tridentata (Webster)
Ceratonereis versipedata Ehlers

EunicidaeEunice rubra GrubeEunice filamentosa GrubeMarphysa sanguinea (Montagu)Lysidice ninetta Audouin and M. EdwardsLumbrineridaeLumbrineris latreilli Audouin and M. EdwardsLumbrineris inflata MooreDorvilleidaeDorvillea sociabilis (Webster)OrbiniidaeNaineris laevigata (Grube)CirratulidaeCirriformia sp.CapitellidaeDasybranchus lumbricoides (Grube)MaldanidaeEuclymene sp.Sabellariidae *Sabellaria floridensis Hartman *Terebellidae *Amphitrides bruno-comata EhlersSabellidae *Sabella melanostigma (Schmarda) *Sabella microphthalma VerrillMegalomma near lobifera (Ehlers)

Serpulidae *

- Eupomatus dianthus (Verrill)
Vermiliopsis annulata (Schmarda) *
Salmacina dysteri Huxley
Spirorbis sp.

Hirudinea

- Pontobdella macrothela Schmarda

Sipunculida

- Siphonosoma cumanense (Keferstein)

ECHINODERMATAAsteroidea *

- Luidia alternata (Say)
Thyraster serpentarius (Muller and Troschel)
Asterias forbesi (Desor)
Echinaster spinulosus Verrill)*

Ophiuroidea

- Amphiopholis gracillima (Stimpson)
Ophiothrix angulata (Say)
Ophionereis reticulata (Say)
Ophiopholis aculeata (Linnaeus)*

Echinoidea *

- Arbacia punctulata (Lamarck) *
Lytechinus variegatus (Lamarck) *
Clypeaster prostratus Ravenel
Mellita quinquiesperforata (Leske)

Holothuroidea *

- Cucumaria pulcherrima (Ayers) *
Thyone briareus (LeSueur)

MOLLUSCAPelecypoda *

Nucula proxima Say
Arca umbonata Lamark *
Arca reticulata Grelin *
Pteria colymbus Roding
Ostrea permollis Say *
Anomia onslowensis Richard *
VolSELLa americana Leach
Lithophaga bisulcata Oribigny *
Gregariella coralliophaga Gmelin
Lyonsia beana Oribigny
Chama macerophylla Gmelin *
Taras semiaspara Philippi
Chione grus Holmes *
Rupellaria typica Jones
Rupellaria cuneiformis Spengler
Cumingia tellinoides Conrad
Saxicava rugosa Linne' *

Amphineura *

Acanthochitona spiculosa Reeve *

Gastropoda *

Diodora cayenensis Lamarck *
Calliostoma euglyptum Adams
Turbo castaneus Gmelin *
Crepidula aculeata Gmelin
Crepidula fornicata Linne' *
Crepidula plana Say
Vermicularia spirata Philippi *
Hipponyx sp.
Simnia uniplicata Sowerby *
Pseudoneptunea mulangulata Philippi

Urosalpinx cinereus (Say)
Favartia cellulosa (Conrad)
Anachis avara (Say)
Aplus tinctus (Conrad)
Nassarius vibex (Say) *
Phos sp.
Fasciolaria distans (Lamarck) *
Fasciolaria gigantea (Kiener)
Marginella nivosa (Hinds)
Pleuroploca gigantea (Kiener) *

Cephalopoda

Octopus sp. *
Loligo pealei (LeSueur)

ARTHROPODA

Pycnogonida

Anoplodactylus lentus (Wilson) *

Crustacea

Cirripedia

Calanus eburneus (Gould)
Balanus amphitrite niveus*(Darwin) on crab:
Lenaeodiscus porcellanae (Muller)
Sacculina hirsuta (Boschma) on crab:
Pilumnus dasypodus (Kingsley)

Isopoda

Cirolana impressa (Harger)
Sphaeroma quadridentatum (Say)
Paracerceis caudata (Say)
Erichsonella attenuata (Harger)
Bopyro choprae (Pearse)
Diplophryrus synalpheii (Pearse)

Amphipoda

Lysianopsis alba Holmes
Ampelisca schellenbergi Shoemaker
Ampelisca sp., S.
Leucothoe spinicarpa (Abildg.)
Colomastix pusilla Grube
Stenthoë sp.
Batea catharinensis Muller
Elasmopus sp.
Elasmopus rapax Costa
Melita fresnelii (Audonin)
Macra sp.
Macra inaequipes (Costa)
Lembos smithi (Holmes)
Photis pugnator Shoemaker
Eurystheus maculatus (Johnston)
Eurystheus erythrophthalmus (Latreille)
Synamphithoe pelagica (M.-Edw.)
Cerapus tubularis Say
Erichthonius brasiliensis Dana
Corophium simile Shoemaker
Unciola laminosa Pearse
Caprella acutifrons Latreille

Decapoda

Natantia

Peneidea

Sicyonia laevigata Stimpson
Crangon formosus (Gibbes)
Crangon nornanni (Kingsley)
Synalpheus fritzmuelleri Coutiere
Synalpheus fritzmuelleri elongatus Coutiere
Synalpheus longicarpus (Herrick)
Synalpheus minus (Say)
Synalpheus townseni Coutiere

CarideaLatreutes parvulus (Stimpson)Thor floridanus KingsleyReptantiaAnomuraPetrolisthes galathinus (Bose)Porcellana soriata SayPericlimenes longicaudatus (Stimpson)Periclimenes sp.Periclimenacus sp.Processa sp.Paguristes torgugae SchmittPagurus near bonairensis SchmittPagurus sp.Paguridae sp.BrachyuraSpeloeophorus nodosus (Bell)Portunus sayi (Gibbes)Callinectes sapidus RathburnCallinectes sp.Leptodius agassizii Milne-Edw.Pilumnus dasypodus KingsleyPilumnus floridanus StimpsonPilumnus pannosus RathbunPilumnus sayi RathbunMetoporphaphis calcarata (Say)Podochela riisei StimpsonEpialtus dilatatus Milne-Edw.Epialtus sp. near sulcirostris StimpsonEpialtus sp. near minimus LockingtonPelia mutica Gibbes

Mithrax (Mithraculus) forceps (Milne-Edw.)

Mithrax (Mithrax) pleuracanthus Stimpson

Microphrys antillensis Rathbun

Stomatopoda

Gonadactylus oerstedii Hansen

CHORDATA

Tunicata

Amaroucium stellatum Verrill *

Tridemnum savignii (Herdman)

Didemnum canididum lutarum Van Name

Didemnum (Polysyneraton) amethestum (Van Name)

Eudistoma carolinense Van Name

Eudistoma capsulatum (Van Name)

Eudistoma hepaticum (Van Name)

Clavelina pieta (Verrill)

Clavelina picta Verrill

Ecteinascidia turbinata (Herdman)

Ascidia interrupta Heller

Symplegma viride Herdman

Polyandrocarpa Eusynstylea tincta Van Name

Styela partita (Stimpson)

Styela plicata (LeSueur) *

Distaplia bermudensis Van Name

Molgula occidentalis Traustedt

Molgula manhattensis (DeKay)

Pisces

Selachii

Carcharias taurus Rafinesque

Sphyrna tiburo (L.)

Sphyrna zygaena L.
Raja eglanteria Lacepede
Dasyatis americana [Hildebrand and Schroeder]
Manta birostris (Walbaum)

Teleostomi

Galeichthys milberti (Cuvier and Valenciennes)
Leptocephalus conger L.
Brevoortia tyrannus (Latrobe)
Synodus faetens (L.)
Strongylura marinus (Walbaum)
Mugil cephalus (L.)
Mugil curema Cuvier and Valenciennes
Scomber scombrus (L.)
Auxis thazard [Lacepede]
Scomberomorus maculatus (Mitchill)
Gymnosarda alleterata (Rafinesque)
Sarda sarda [Bloch]
Decapterus punctatus (Agassiz)
Caranx hippos (L.)
Caranx crysos (Mitchill)
Vomer setapinnis (Mitchill)
Trachinotus carolinus (L.)
Seriola dumerili (Risso)
Seriola zonata (Mitchill)
Pomatomus saltatrix (L.)
Coryphaena hippurus (L.)
Prionotus tricanthus (Peck)
Centropristes striatus (L.)
Lutianus blackfordi Goode and Bean
Orthopristis chrysopterus (L.)
Haemulon parra (Desmarest)
Haemulon sciurus (Shaw)
Haemulon macrostomum [Gunther]

Stenotomus aculeatus Cuvier and Valenciennes
Lagodon rhomboides (L.)
Archosargus probatocephalus (Walbaum)
Archosargus unimaculatus (Bloch)
Diplodus holbrooki (Bean)
Cynoscion regalis (Block and Schneider)
Sciaenops ocellatus (L.)
Leiostomus xanthurus Lacepede.
Micropogon undulatus (L.)
Menticirrhus saxatilis (Bloch and Schneider)
Progonias cromis (L.)
Tautoga onitis (L.)
Balistes carolinensis (Gmelin)
Spheroides maculatus (Bloch and Schneider)
Lagocephalus laevigatus (L.)
Stephanolepis hispidus (L.)
Prionotus carolinus (L.)
Opsanus tau (L.)
Gobiesox strumosus Cope
Hypsoblennius hentz (LeSueur)
Chasmodes bosquianus (Lacepede)
Paralichthys lethostigmus Jordan and Gilbert
Achirus fasciatus Lacepede
Stymphrus plagiusa (L.)

Mammalia

Tursiops truncatus (Montague)
Delphinus delphis (L.)

ALCAE

SCHIZOPHYTA

HormogonalesCalothrix confervicola (Born)

CHLOROPHYTA

UlotrichalesEntocladia viridia ReinkeUlvella lens CrouanCladophoralesChaetomorpha brachygona HarvChaetomorpha linum (Mull)Cladophora delicatula (Mont)Cladophora pellucida (Huds)SiphonalesAvrainvilles mazei Murray and BoddleCaulerpa prolifera ForsskCodium decorticatum Howe *SiphonocladialesValonia utricularis Roth

PHAEOPHYTA

EctocarpalesEctocarpus elachistaeformis HeydrEctocarpus Mithellae HarvEctocarpus terminalis KutzLithoderma fatiscens Kuckuck Zonaria tournefortii *SphacelarialesSphacelaria furcigera KutzSphacelaria tribuloides Menegh