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RELICT SEDIMENT DEPOSITS IN A MAJOR TRANSGRESSIVE COASTAL SYSTEM

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by

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CONTENTS

FIGURES

INTRODUCTION

The surficial geology of the Continental Shelves and Coastal Plains of the Atlantic Ocean and the Gulf of Mexico has been primarily produced by a series of transgressions and regressions of the coastal zone in response to the pulsating Pleistocene glacial advances and retreats. The most recent phase is the post-Wisconsin glacial rise of sea level which began between 18,000 and 15,000 years B. P. (Curray, 1965; Fairbridge, 1960; and Milliman and Emery, 1968). This Holocene transgression proceeded very rapidly up until about 7,000 to 5,000 years B. P. when the rate of sea level rise slowed considerably. This change probably represents the period of time when most of the present or recent coastal system was developed. According to most investigators (Stanley, 1969) sea level has continued a slow, but not necessarily systematic, rise since and continuing into the present. Consequently, the resulting transgression of the coastal zone in response to this Holocene and recent sea level rise is the dominant process effecting coastal sediments. It is the potential imprint of the transgressing system upon relict sediment features which is the subject of this paper.

The subject of relict versus modern geometries and sediments in our present coastal and shelf environments is neither a new subject nor a closed one. For example, several of the authors in the recent A. G. I. short course on <u>The New Concepts of Continental Margin Sedimentation</u> (Stanley, 1969) spent considerable time reviewing this controversial topic. Few geologists question the fact that many of the present coastal and shelf sediments were originally deposited under quite different environmental conditions and sea level stands; nor will anyone question the fact that the coastal environments have been changing rapidly in recent times. The major and controversial question seems to be how much of the present sediment regime is relict; how old, or how recent, are the sediment compositions, textures, and geometries? Do any of the anomalous nearshore shelf sediments display a heritage of their past history and how long will such survive?

Emery (1968) has classified relict sediments as those which are produced from an earlier, different environment, whereas residual sediments are those produced in situ through the weathering of bedrock. On the basis of the work of Curray (1965) and Emery (1968), Swift (1969) sees a major twofold division of the sediments as being either relict (a product of an earlier different environment) or modern (a product of the present existing environment).

Relict sediments occur both on the continental shelf and within estuaries as a result of intra-estuarine erosion. It is possible that continued transgression of a barrier system could re-expose several types of estuarine sediments on the shelf areas which could produce extremely complex facies relationships. The objectives of this paper are 1) to examine the occurrence, mode of formation, and geometry of the modern and relict sediments within a major estuary and to identify possible sediment characteristics and trends which could be useful in recognizing relict sediments on the shelf, and 2) to consider a possible relict origin for some of the nearshore shelf features exposed seaward of a transgressing barrier system. The conclusions reached in this paper are based upon detailed sediment studies in the barrier island coastal systems of North Carolina and the Gulf Coast area of Central Florida.

BARRIER ISLAND-ESTUARINE SYSTEM OF THE NORTHEASTERN

NORTH CAROLINA ATLANTIC COAST

ABSTRACT

Recent investigations have emphasized the importance of relict Pleistocene and Early Holocene deposits and topographic features exposed on the continental shelf as a result of the Late Holocene transgression. Many of these deposits can be attributed to wave and current erosion of the retreating coastline, or to the deep channeling and backfilling of shifting inlets in a barrier island system. However, stratigraphic investigation of the Roanoke Island estuarine complex behind the northern portion of North Carolina's Outer Banks barrier island chain demonstrates that significant development of relict sediments can also occur within the estuary itself.

Extensive shallow core drilling and seismic sub-bottom profiling in the Roanoke Island area show an alternating seaward progression of barrier island or beach, and open to restricted estuarine sediments, which demonstrate an extremely complex pattern of deposition. This complex pattern is attributed to (1) the broad, extremely low gradient of the surrounding coastal plain, and (2) the dominant influence of the Albemarle River drainage system. Significantly, many of the depositional trends diverge greatly from those of the modern shoreline. Evidently, the very low relief in the adjacent mainland area coupled with slight fluctuations of the sea have resulted in regional flooding and large scale erosional and sedimentary response to the extent that the identification of Late Pleistocene shorelines as recognized in areas to the south and north is most difficult.

Throughout the estuary the Pleistocene and Early Holocene sediments are presently being exhumed as a result of (1) the shifting barrier island inlets

which control tidal currents and fresh water discharge, and (2) storm and wind tides. Distinct erosional trends and channels develop parallel to the modern coastline as the freshwater head strives to maintain access to the shifting inlet discharge sites. When the inlet migrates or closes, old channels are abandoned, filled up with modern sediment, and new ones cut. Analysis of inlet change within the area since 1585, documents frequent opening and closing of inlets which can be directly related to the present distribution of relict sediments. It is concluded that the intra-estuarine erosion and reworking of relict Pleistocene and Early Holocene deposits is a significant process within this type of estuary, and with subsequent transgression would produce a very complex time-stratigraphic framework in relict continental shelf deposits, characterized by intermixed sediments and greatly modified geometry of the sediment units.

DISCUSSION

The first study area lies on the east coast of the U. S. just behind the Outer Banks barrier chain of North Carolina (Figure 1). Figure 2 is an exceptional photo taken during the Apollo 9 spaceflight which shows many of the features of the area which are identified in Figure 3: The Outer Banks barrier island chain and inlets; the sandy shoals off Cape Hatteras, Cape Lookout and the inlets; and the enclosed estuaries of Pamlico Sound, Albemarle Sound, and Croatan and Roanoke Sounds. It can be seen that at present the northernmost inlet in the barrier island chain is Oregon Inlet, just south of Roanoke Island. The significance of this is that with the tremendous fresh water discharge from the Albemarle drainage system the north part of the area is essentially one of fresh water. Lunar tides within the shallow sounds are insignificant, but wind tides can be as high as 3 meters. Thus, when west or

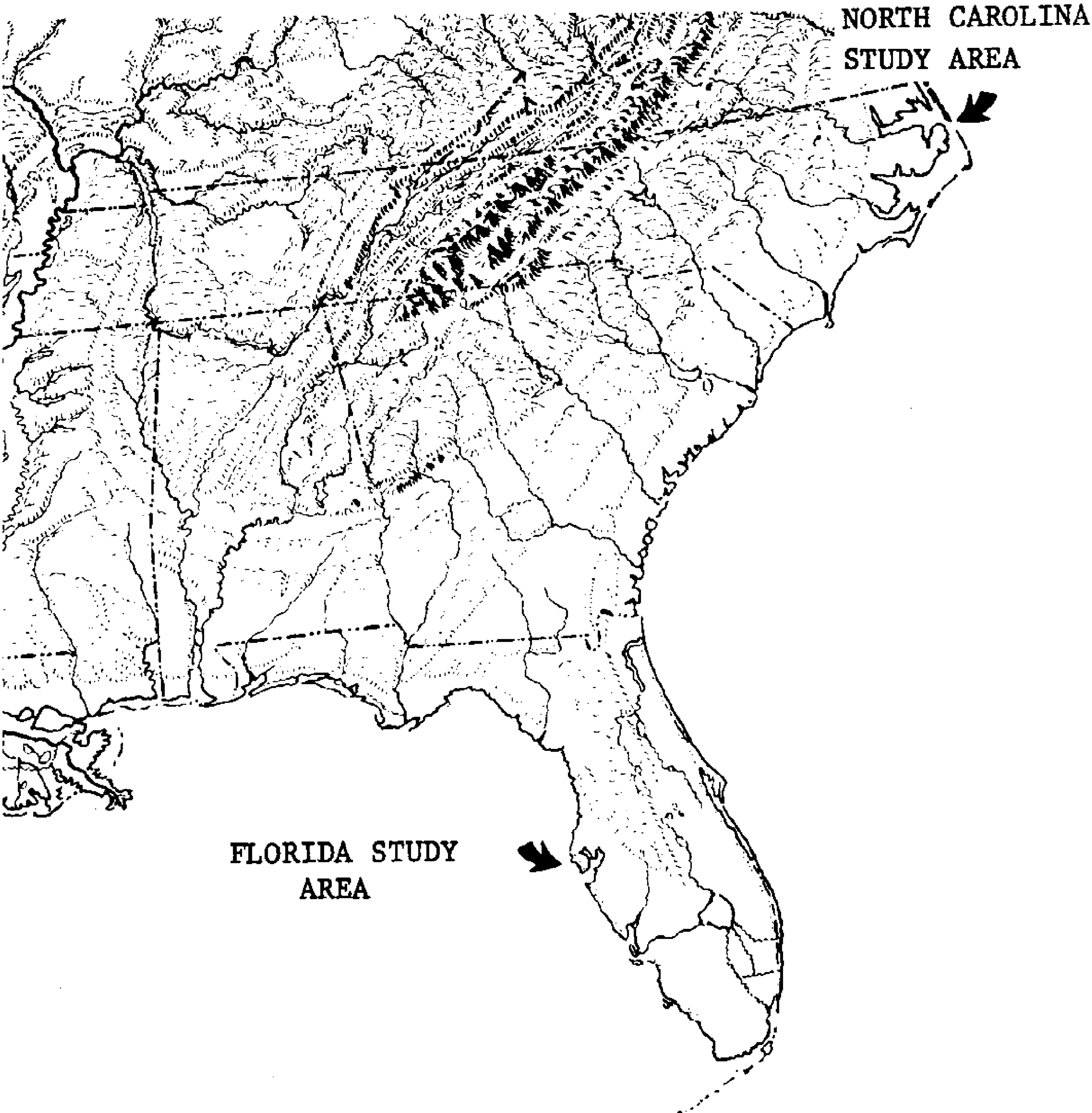

Figure 1. Map of southeastern United States showing the location of the two study areas: 1) Roanoke Island, Dare Co., North Carolina; and 2) Indian Rocks, Pinellas Co., Florida.

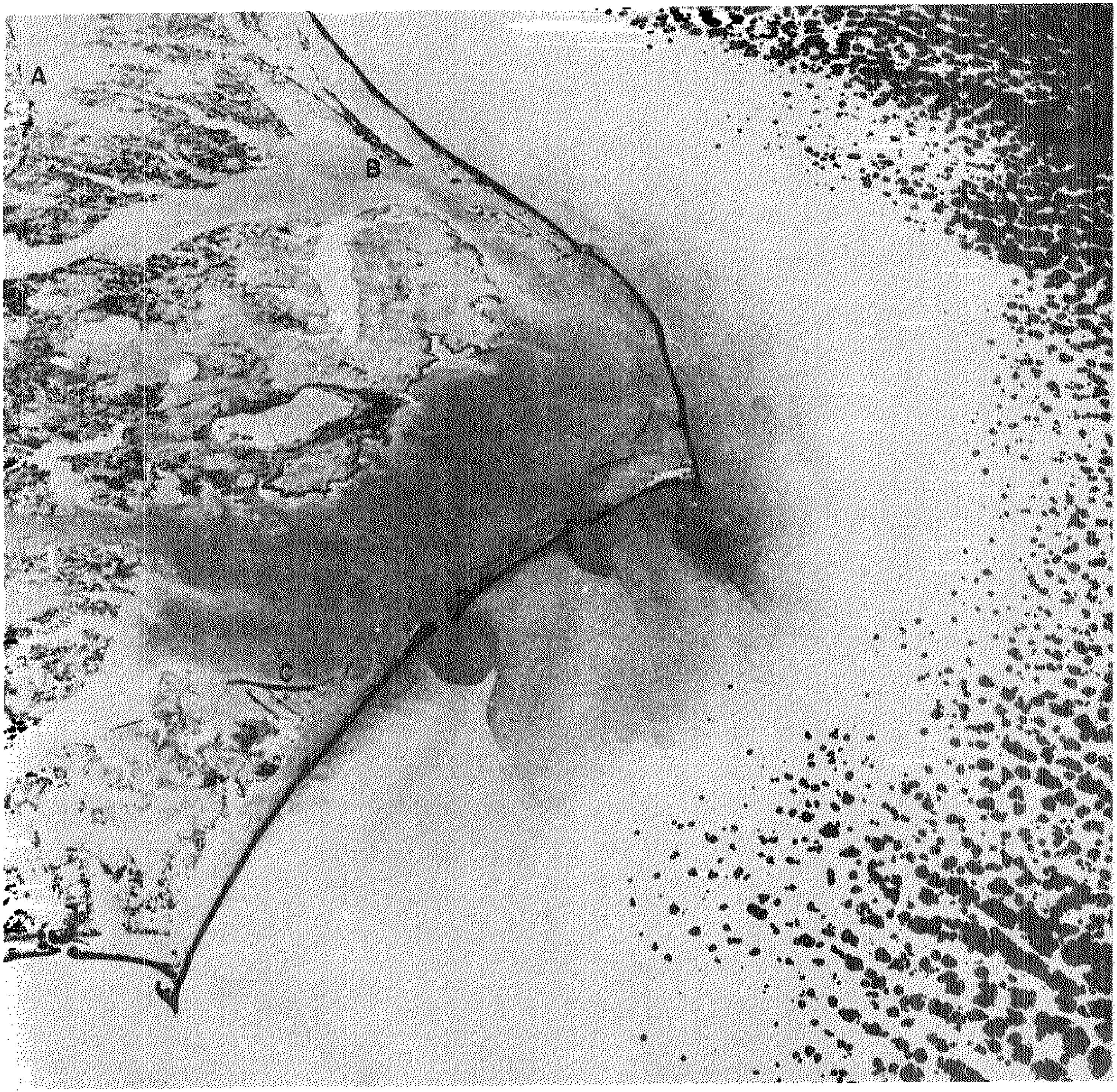

Figure 2. Apollo 9 space shot of the Outer Banks of North Carolina. This is a negative print from a color positive which gives the following gray-tone patterns: 1) sand bodies occur as black images, 2) sandy sediments as various shades of grey, 3) vegetated areas as the lightest gray, and 4) clouds on the right side of the photo occur as a black speckled pattern. Notice the prominent Pleistocene beach ridges (a, b, and c) and the large plumes of sand in front of the inlets.

Figure 3. Location map of northeastern North Carolina showing the Roanoke Island area.

northwest winds are coupled with periods of high fresh water discharge, considerable erosion and channeling takes place within the narrower parts of the estuaries, such as in Croatan Sound where the Albemarle drainage surges south to empty into Pamlico Sound and Oregon Inlet. These wind driven tidal surges, along with frequent changes in direction of the fresh water discharge in response to the opening and closing of inlets in the barrier island chain, have been the major sedimentological processes producing relict sediments within the area.

Map coverage of the area dates back to the late 16th century when Sir Walter Raleigh attempted the first colonization of the new world on the north end of Roanoke Island. Figure 4A, a map from 1590, shows several inlets north of today's Oregon Inlet with extensive island masses between Roanoke Island and the mainland. In Figure 4B, a map from 1733, Croatan Sound is called "The Narrows" and is almost completely blocked off at the southern end by islands. Discharge for the Albemarle Drainage was at that time through Roanoke Inlet. The 1808 map (Figure 4C) shows similar relationships. The map of 1833 (Figure 4D), however, shows considerable change. No longer is there a major landmass blocking the south end of Croatan Sound, and no longer can inlets be seen north of Oregon Inlet. The association is not coincidental, for historical records show that by 1817 Roanoke Inlet and all other inlets north of Oregon Inlet were closed and have remained so up to the present. With this closure, drainage from the Albemarle was forced southward and the process of channeling and exposure of relict sediments within the area began; these processes are continuing today.

Figure 5 summarizes this historical sequence into 3 phases: (1) 1585-1817 with drainage from the Albemarle through Roanoke Inlet and deposition

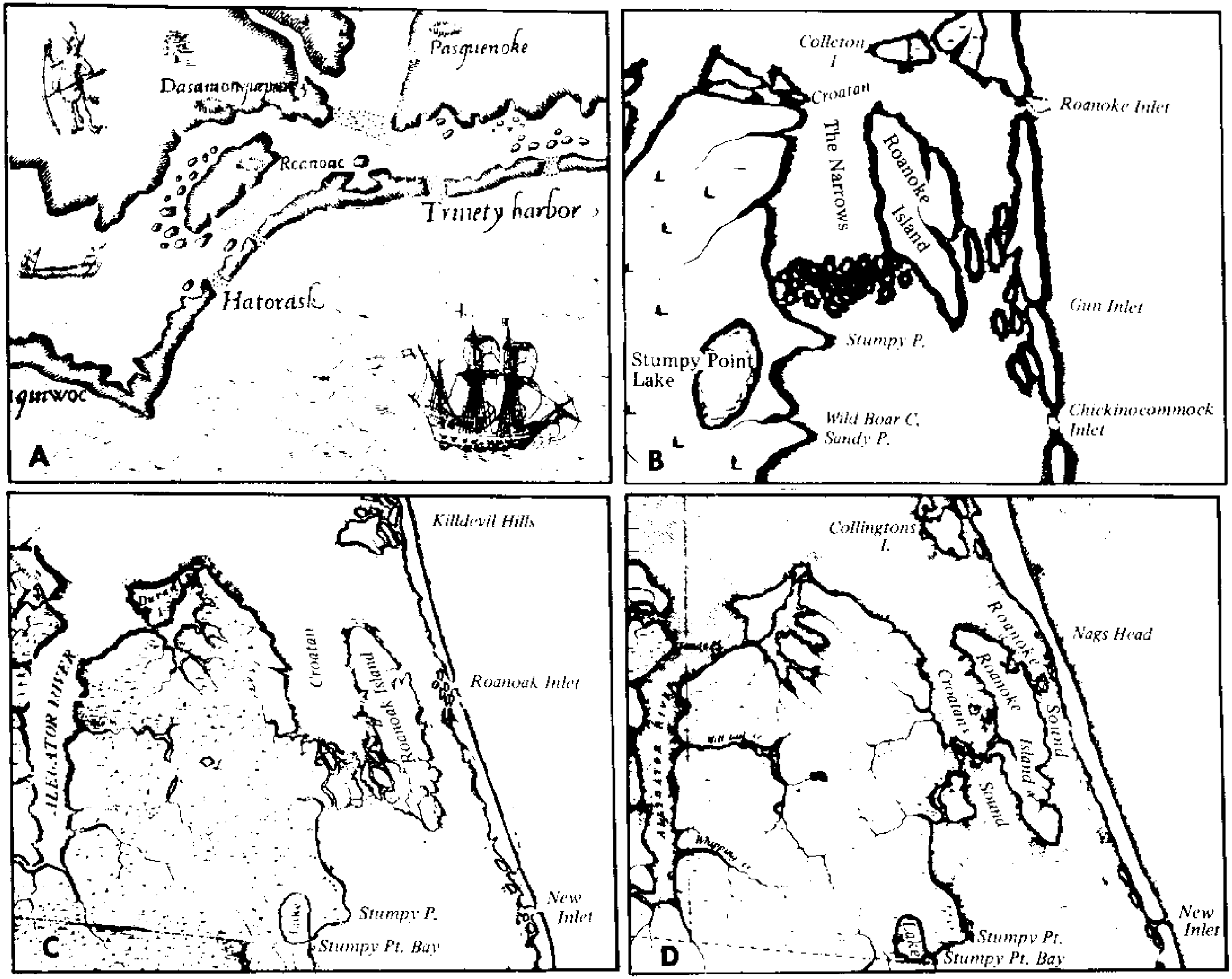

Figure 4. Historical maps of the Roanoke Island, North Carolina area (from Cumming, 1966). These figures are portions of the following maps: A) 1590 map by White and DeBry, B) 1733 map by Moseley, C) 1808 map by Price and Strother, and D) 1833 map by McRae and Brazier. Notice the following: 1) the abundance of marsh islands occurring between the southwest end of Roanoke Island and the mainland in Figures 4A (1590), 4B (1733), and 4C (1808) and their subsequent decrease in Figures 4D (1833) and 3 (present day); 2) the change in both the number and location of the inlets through time in Figures 4A, 4B, 4C, and 4D; and 3) the general estuarine shoreline recession through time as indicated by the change of inland Stumpy Point Lake in Figure 4B (1733) to a narrow-mouth bay in Figures 4C (1808) and 4D (1833) and to a very wide-mouth bay in Figure 3 (present day).

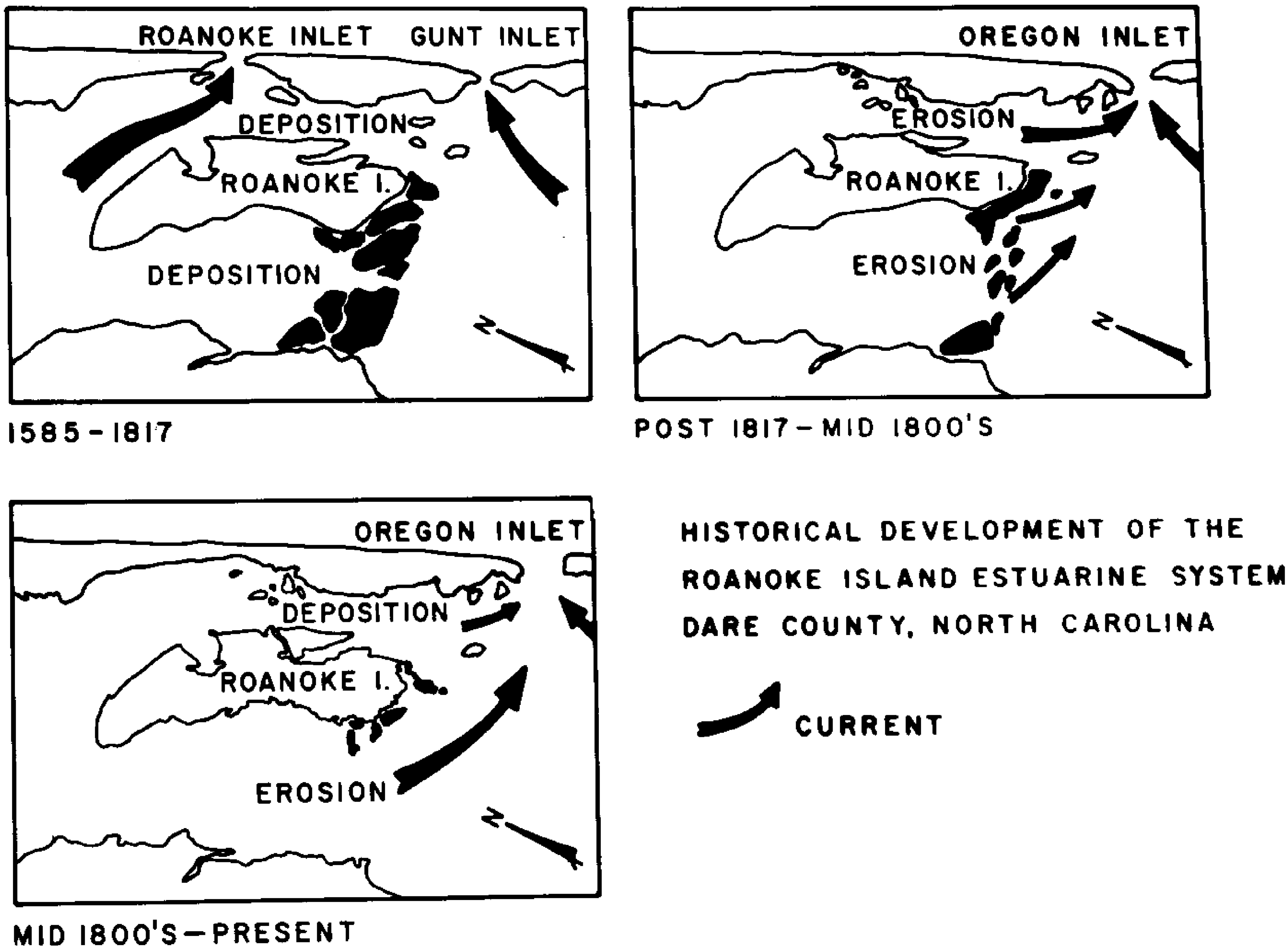

Figure 5. Interpreted historical development of the estuarine system around Roanoke Island, from 1585 to the present, in response to inlet closing. The size of each arrow represents the relative volume and direction of the fresh water discharge.

within Roanoke and Croatan Sounds, (2) 1817-mid 1800's with Roanoke Inlet closed with southward drainage eroding both Roanoke and Croatan Sound; and (3) mid 1800's to the present with continued erosion and widening of Croatan Sound exposing relict sediments, while Roanoke Sound is abandoned by major currents and becomes shoal through wind and storm sediment influx from the barrier island.

Detailed mapping utilizing SCUBA, shallow core drilling, and extensive sub-bottom profiling verify this development and suggest that it is only a portion of a continuing process in which channels are cut, filled, and re-exposed as the estuarine waters maintain their discharge to the opening and closing inlets.

Both bathymetric and topographic relief is low within the area (Figure 6). Land areas consist of quartz sand with higher elevations averaging less than 3 meters and lower areas covered with up to 2 or more meters of peat. The sounds are shallow, averaging less than 3 meters. Greatest depths occur between 6 and 7 meters, along the center of Croatan Sound, where the present erosion is taking place.

Generally speaking, surface sediment distribution is closely related to bathymetry (Figure 7). Fine sand is dominant and ubiquitous, but is most extensive in Roanoke Sound where it is deposited from wind and storm washover. Very fine sand and organic rich muds are presently being deposited in deeper, less turbulent areas. Medium, coarse, and gravelly sands are less common, but are important in that they comprise much of the relict sediments being exposed along the deeper channels of Croatan Sound, and the eroding shorelines of Roanoke Island and the adjacent mainland. Clayey sediments are rare but do occur as relict sediments, primarily in the deeper portions of Croatan Sound,

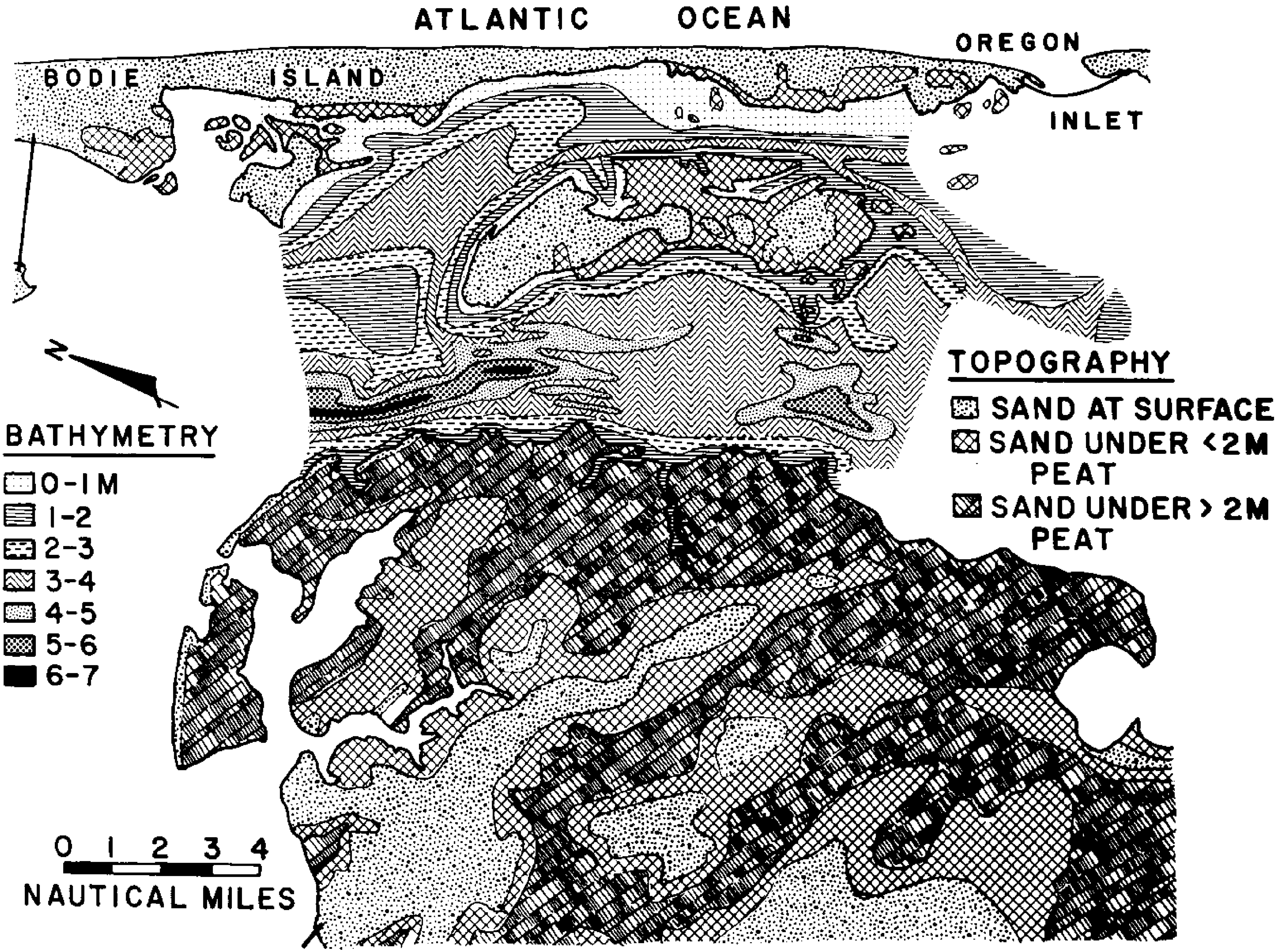

Figure 6. Generalized topographic and bathymetric map of the Roanoke Island, North Carolina, area. The bathymetry is based upon continuous fathometer profiling by the authors, in combination with the U. S. C. & G. S. "smooth sheets" and hydrographic charts. The relationship of sediment type to topography on the mainland of Dare County is based in part upon a soil survey conducted by West Virginia Paper & Pulp Co. of Manteo, N. C.

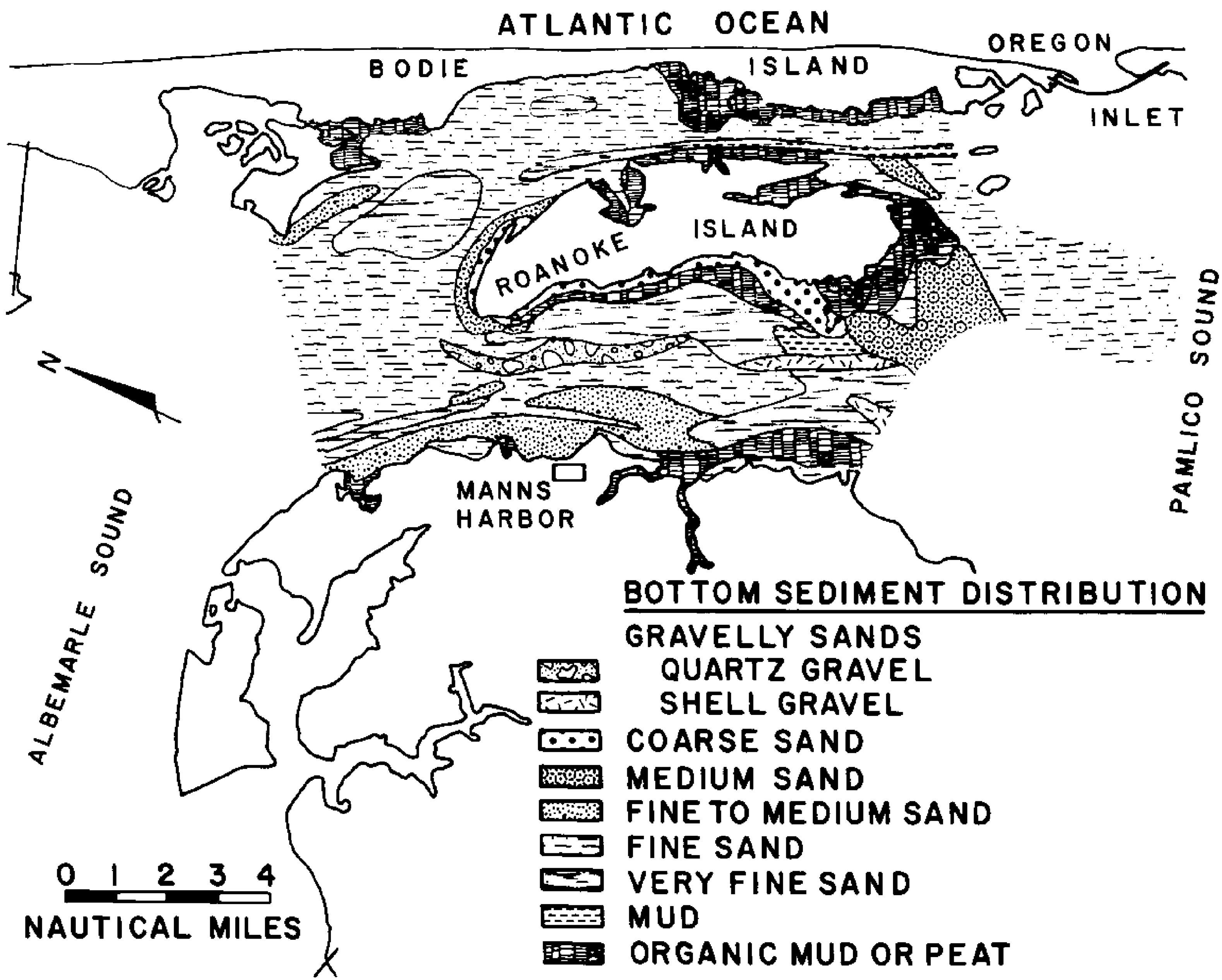

Figure 7. Generalized map of the estuarine surface sediment distribution in the Roanoke Island, North Carolina, area.

but are generally beneath a few centimeters of surficial sand. Figure 8 is a profile across Croatan Sound from the north end of Roanoke Island to Manns Harbor which illustrates the relict-modern sediment relationships.

Seven meter core holes throughout the area reveal a consistant 3-part stratigraphy: 1) A lower transgressive marine fossiliferous sand with a faunal assemblage characterized by the little surf clam Mulinia lateralis (Figure 9), 2) A middle regressive fluvial or possible deltaic gravelly sand, and 3) A transgressive upper Late Holocene to modern sand unit. Coring and sub-bottom profiling reveal that the lower two units are fairly continuous, except in the center of Croatan Sound where they have been exposed through the north-south channeling associated with the opening and closing of the northern inlets as previously discussed. The rather rapid rate of this downcutting and exposure is shown by the four bottom profiles from 1851 to 1971 (Figure 8). That the channeling and filling has been a repetitive process is demonstrated by a sandy clay unit which contains in the upper meter or so a high salinity, open-bay fossil assemblage characterized by Barnea costata (Figure 10). This faunal assemblage occurs in growth position and is exposed on the sound bottom where the water is presently 0-8 ppt salinity. Carbon-14 dates for this shell assemblage give 2,140± years BP. Whereas age dates on the Mulinea assemblage from the lower fossiliferous unit range from 24,560± years BP up to 30,660± years BP.

The Barnea assemblage and associated clay channel fill are considered to be generally correlative with the establishment of the present barrier island during the Holocene transgression which produced the present enclosed estuarine system.

In addition to the north-south trending channels discussed above, detailed acoustic sub-bottom profiling has revealed the existence of extensive channel

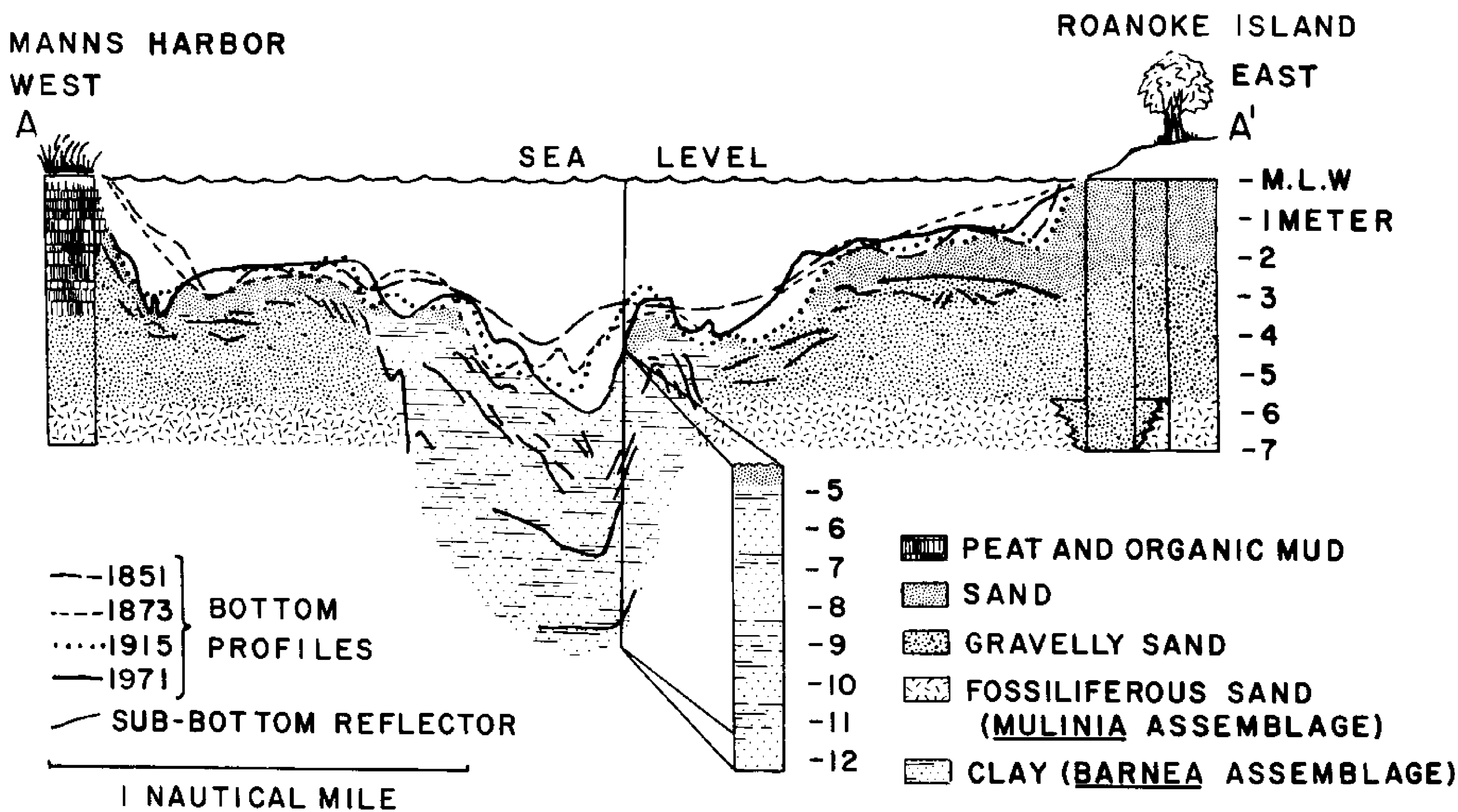

Figure 8. Geologic cross-section through Croatan Sound (west-east along highway 64-264 bridge) showing bottom and shoreline retreat. The stratigraphy in this section is based upon four core holes, surface sediment studies, and acoustic sub-bottom profiling (sub-bottom reflectors). Note the clay filled sub-bottom channel, with an age-date of 2140± years BP at the surface, which cuts through the older three part stratigraphy, the lower bed which age-dates between 24,560± and 30,660± years BP. The bottom profiles from years 1851 through 1915 were obtained from the U. S. C. & G. S. "smooth sheets" for this area. The 1971 bottom profile is based upon the authors' survey.

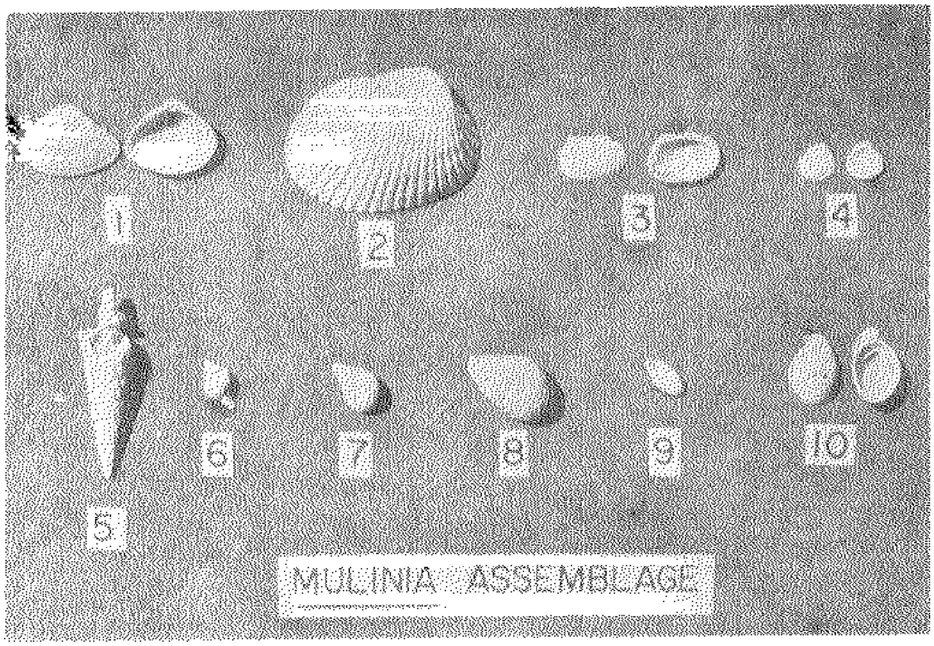

Figure 9. Mulinea lateralis fossil assemblage (1).

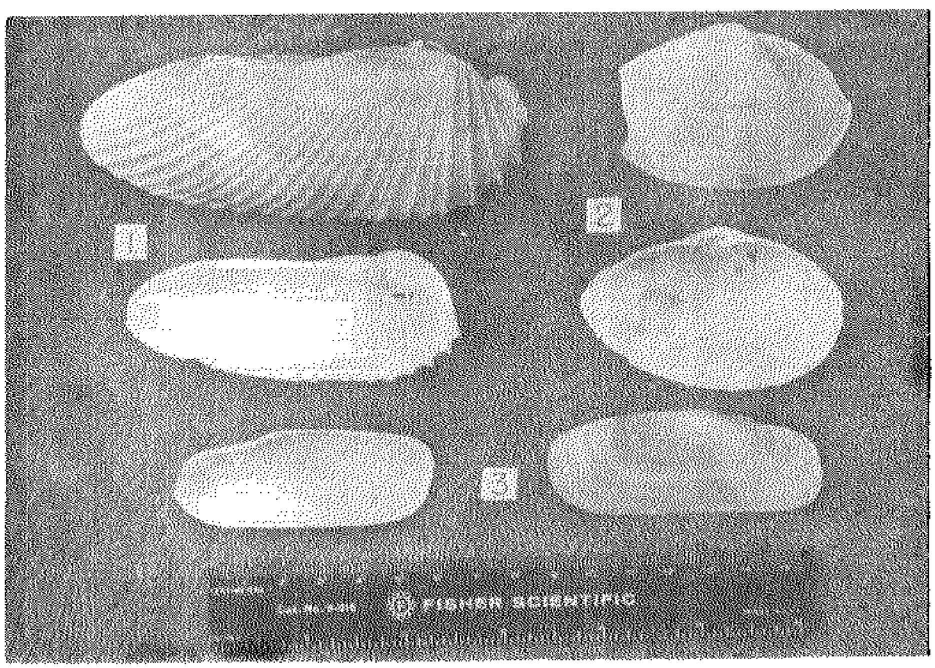

Figure 10. Barnea costata fossil assemblage (1).

systems which transect the area at right angles to the coastline (Figure 11). Figure 12 shows a typical profile of the relict buried channels. Tops average 5 meters below sea level and extend down to a maximum of -16 or -17 meters, with average width at the top about .4 kilometers. Typically, the channels are as symmetric with a steep south side, and show migration to the south as evidenced by prograding fill on the north side. In plotting the channels, two types were recognized: well and poorly defined (Figure 11). In Croatan Sound many of the poorly defined segments can be attributed to the subsequent north-south channeling and exposure described earlier; however, in other cases it is due to the masking of the reflectors by organic muds on the bottom. At least some of the channels, such as those that extend beneath Roanoke Island, are considerably older than the north-south trending channels, and are possible fluvial or tidal channels related to the middle gravelly sand unit which occurs between -2.5 and -6 meters within the area (Figure 11). The length, depth and geometry of the channels suggest that they are not similar in origin to the present barrier island inlet channels.

At the north end of the island, however, the channels may not be too old since they intersect the barrier island chain at the site of the historic Roanoke Inlet. The southernmost of these channels was the only one recorded by sub-bottom profiling which could be traced seaward of the barrier island chain. This suggests that the same processes that have been in operation since the development of the barrier island are still operating in response to continued Holocene transgression.

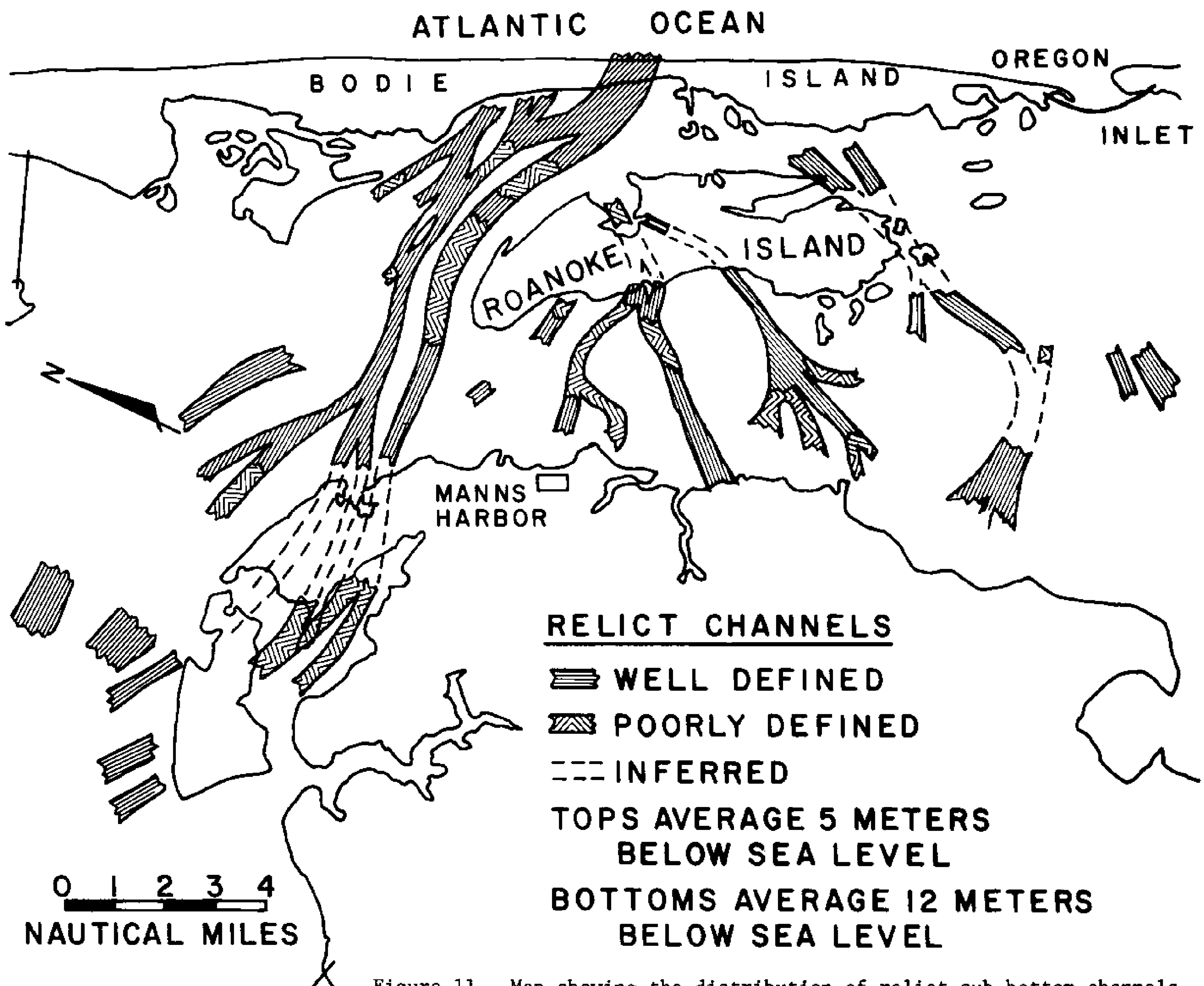

Figure 11. Map showing the distribution of relict sub-bottom channels through the Roanoke Island, North Carolina, area. This map is based upon a 500 mile survey utilizing a multiple frequency acoustic sub-bottom profiler.

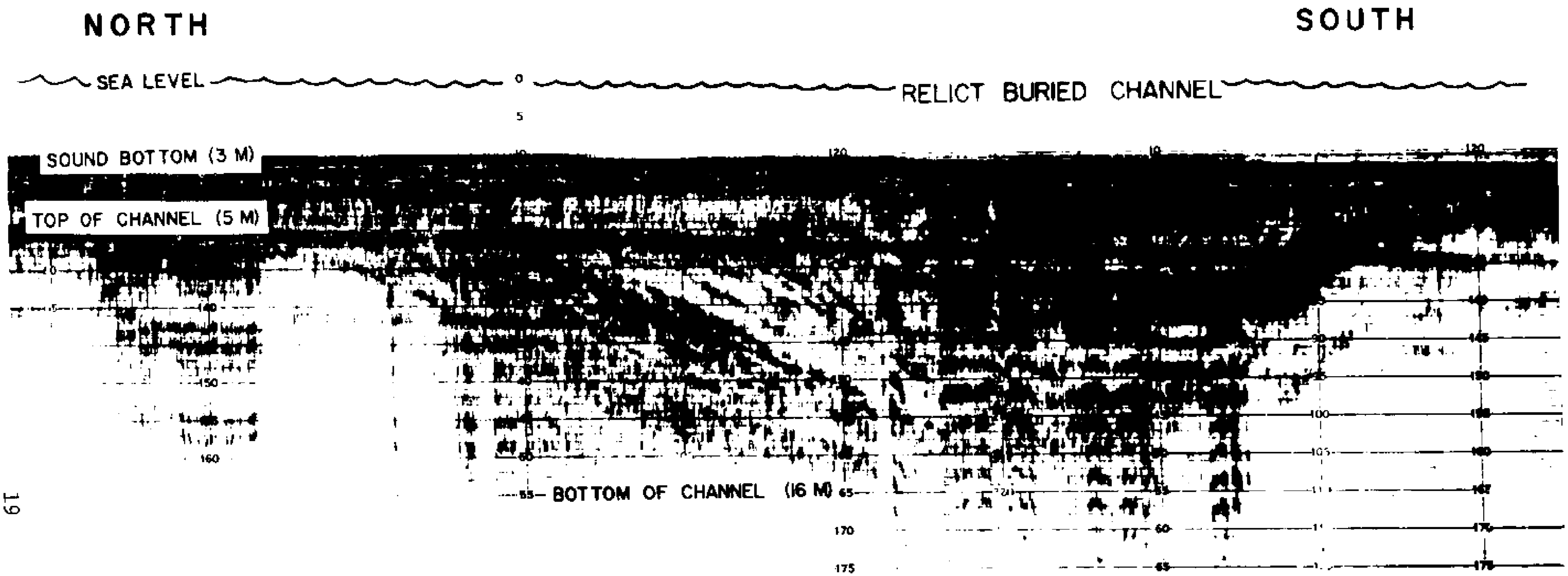

Figure 12. Cross-sectional profile of a relict sub-bottom channel. Note the channel has a steep cut bank on the south side with more gentle channel-fill dip slopes on the north side, thus suggesting a general southward channel migration.

SUMMARY

In summary, two types of relict estuarine deposits have been recognized: a system of channel scour and deposition parallel to the coast formed in response to the opening and closing of inlets in the barrier island chain, and a system of older fluvial or tidal channels which trend perpendicular to the coast and have been subsequently modified by the coast-parallel scour and erosion. The effect of continued transgression across these deposits can only be guessed but it is conceivable that either of these two systems of relict estuarine sediments could be re-exposed on the shelf itself presenting complex facies relationships.

BARRIER ISLAND-NEARSHORE SYSTEM OF THE CENTRAL FLORIDA GULF COAST

ABSTRACT

The barrier island-nearshore sediment environments of the Central Florida Gulf Coast near Indian Rocks demonstrate complex interrelationships between the modern coastal environments and the relict sediments of earlier Holocene coastal systems. A pre-Holocene wave-cut surface in the Miocene and Pliocene carbonate rocks at 15 to 20 feet below sea level flanks an erosional headland and forms a plane upon which the coastal sediments of the Holocene transgression are deposited.

The Late Holocene barrier island-lagoonal system first developed on the Miocene rock surface somewhat seaward of its present location at a lower still-stand. With continued slow rise of the sea, the barrier system has migrated up and over the lagoonal sediments and intersected the Miocene headland. The result is a sequence of relict lagoonal and barrier island sediments in the nearshore environment which are not in equilibrium with the present energy regime. Consequently, the morphology of the units is actively being modified and the sediments are being redistributed. The day-to-day processes operating on the relict sediments and the Miocene surface demonstrate a succession of biological and hydrological corrosion. Organisms encrust, bore into, and break up the rock, and burrow and bulldoze the nonindurated or partially indurated sediments. Benthic organisms also play an important role in sediment sorting by ingesting and excreting the fine fractions. These processes supply the bulk of the nourishing sediments which maintain the present barrier island-lagoonal system as indicated by the concentration and distribution of mineral components such as phosphorite, carbonate rock fragments and heavy minerals.

These in-place processes are believed to be one of the more important daily mechanisms operating to reestablish an equilibrium between the relict sediments and the new environmental regime to which they now belong.

The sediment system consists of 5 to 15 feet of modern barrier sands and shell perched on top of, and seaward of, the modern lagoonal mud and sands. The latter extend beneath the present barriers and are exposed across much of the inner-most portion of the nearshore environment. The lagoonal sediment is about 10 feet thick under the barrier, and thins and deepens seaward from 1/4 to 1 1/2 miles offshore where it laps onto the Miocene rock surface. Situated on top of both the uncorroded Miocene rock surface and the western edge of the relict lagoonal sediments is a complex series of 2 to 7 foot high bars composed of sand and shell similar to the barrier island sediments. The sediments of the bars commonly grade downward into the underlying relict lagoonal sediments. The bars trend obliquely to the present barriers and parallel to the present recurved inlet spits. It is believed that these bars are not modern constructional offshore bars, but rather that they are remnants of the transgressing barrier island itself. The present geometry suggests that the bars may represent either the relict recurved inlet spits themselves or possibly portions of the old barrier modified by surge channels during rapid transgression.

DISCUSSION

The second study area is a modern barrier island-nearshore system in the Central Florida Gulf Coast region near Indian Rocks (Figure 1). This area, lying just west of the metropolitan region of Tampa, Clearwater, and St. Petersburg (Figure 13), is situated on the west flank of the south-southeast plunging Ocala Arch of Peninsular Florida and demonstrates the potential influence

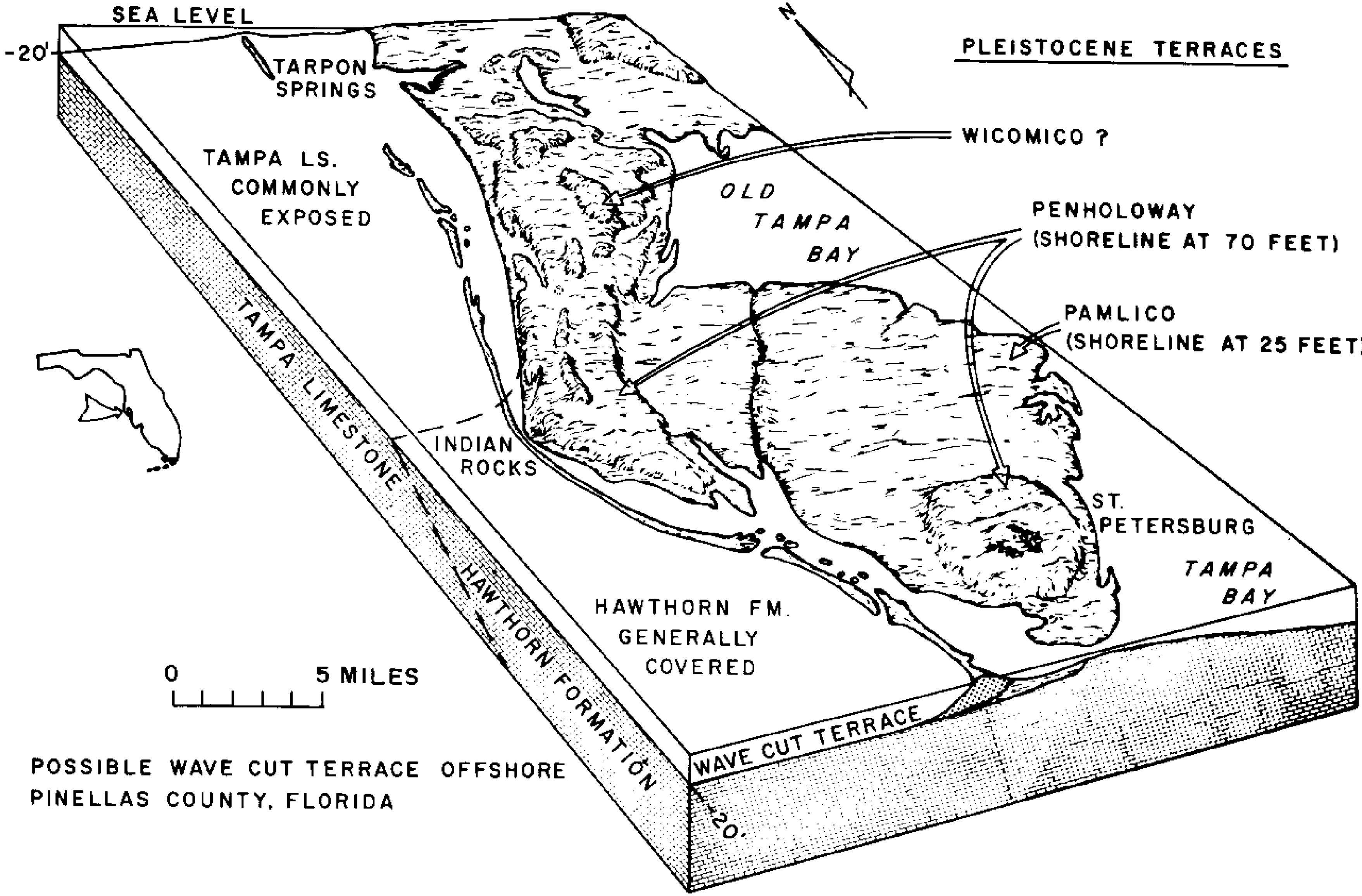

Figure 13. Block diagram location map and geologic cross-section of Pinellas Co., Florida, showing the Pleistocene terraces and offshore wave-cut terrace.

of ancient systems upon the modern coastal morphology and sediment deposits.

The study area is characterized by a broad cape structure which extends seaward into the Gulf of Mexico at Indian Rocks (Figure 13). This prominent structure is composed of southwest dipping indurated carbonate and sandy carbonate rocks of Late Tertiary age (Miocene and Pliocene). A previous interglacial stillstand has cut a terrace and escarpment into these rocks producing the prominent rock headland at Indian Rocks. The trace of the escarpment follows the east shoreline of the lagoons and impinges on the Gulf Shore only at the apex of the headland. The terrace lies at a depth of about -16 feet at the escarpment and dips gently seaward to about -20 feet between one and two miles offshore. The rock headland forms the nucleus for the well developed Late Holocene barrier island-open bay and lagoon system which developed over the rock terrace surface 20 miles north and south of the headland.

The barrier is very narrow with a steep beach and forebeach profile at the Indian Rocks Headland. The barrier becomes slightly wider with a much broader and gentler beach and forebeach profile both north and south of the headlands. The barrier is characterized by numerous shallow inlets which have a recorded history of rapid migration northward and southward away from the headland respectively. Two new barriers have formed on the north end of the barrier chain during the past decade. These new islands are presently being stablized by the development of a vegetative cover. Behind the barriers are the narrow north-south trending modern lagoons which gradually broaden and become open bays north and south away from the headland. They are very shallow, low energy bodies of water with generally normal salinity and have a characteristic bay type fauna and flora.

The Florida Gulf Coast area is particularly good for the study of relict sedimentation for three reasons. 1) A continuous and regular Tertiary rock surface underlies the entire region and forms an ideal reference plane upon which the sediments of the Late Holocene barrier system have been deposited. 2) This is generally a very low energy coast. This coastal system represents the northernmost development of barrier islands along the Gulf Coast of Peninsular Florida and lies just south of Tanner's (1960) "Zero Energy" sector; it is situated in the low to moderate coastal energy level sector (10 to 35 cm average annual breaker heights) as compared to the very high energy coastal area of northeastern North Carolina (100 cm average annual breaker height). 3) at present, the area has essentially no major outside source of sediments due to the very low topographic relief, the lack of major rivers discharging into the area, and the fact that it is greatly removed from the major sedimentation source of the Appalachian Mountains.

Figure 14 is a geologic map of the surface sediments within the study area and Figure 15 contains two geologic cross-sections through the study area. For the purposes of this brief discussion, the sediments are condensed into five basic sedimentological units:

1. Sandy Carbonate Rock. This unit is predominately a fossiliferous, slightly phosphatic sandy limestone and dolomite. To the south, the carbonate is overlain by an indurated very shelly fine grained sand. These two Late Tertiary units occur throughout the study area and form the terrace at 16 to 20 feet below sea level upon which the Holocene units were deposited. Where exposed on the sea floor, the carbonate rock surface is highly corroded, pitted, and animal encrusted, forming extensive and beautiful "sponge gardens" and scattered pockets of residual rock fragment and shell hash sediments.

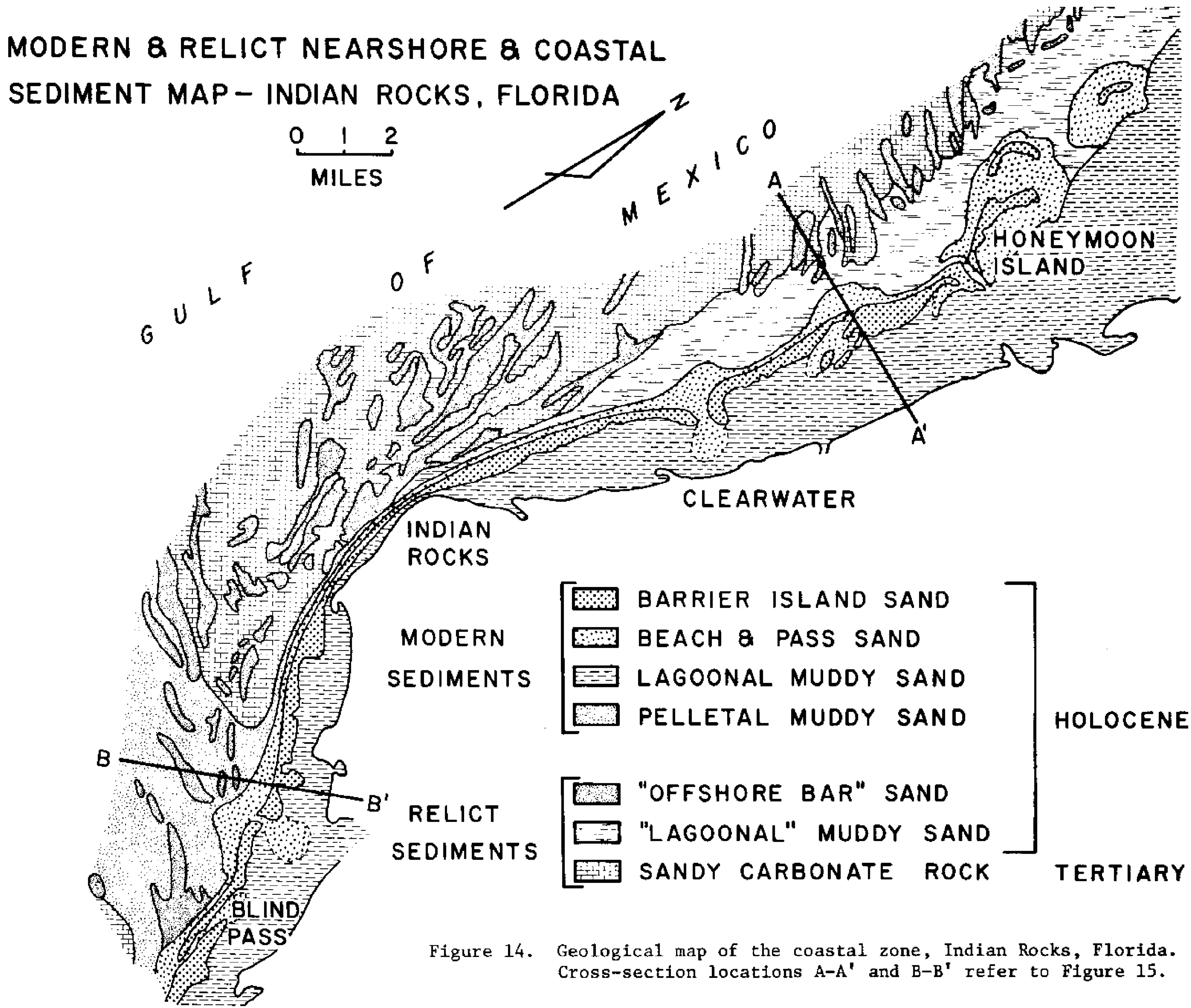

Figure 14. Geological map of the coastal zone, Indian Rocks, Florida. Cross-section locations A-A' and B-B' refer to Figure 15.

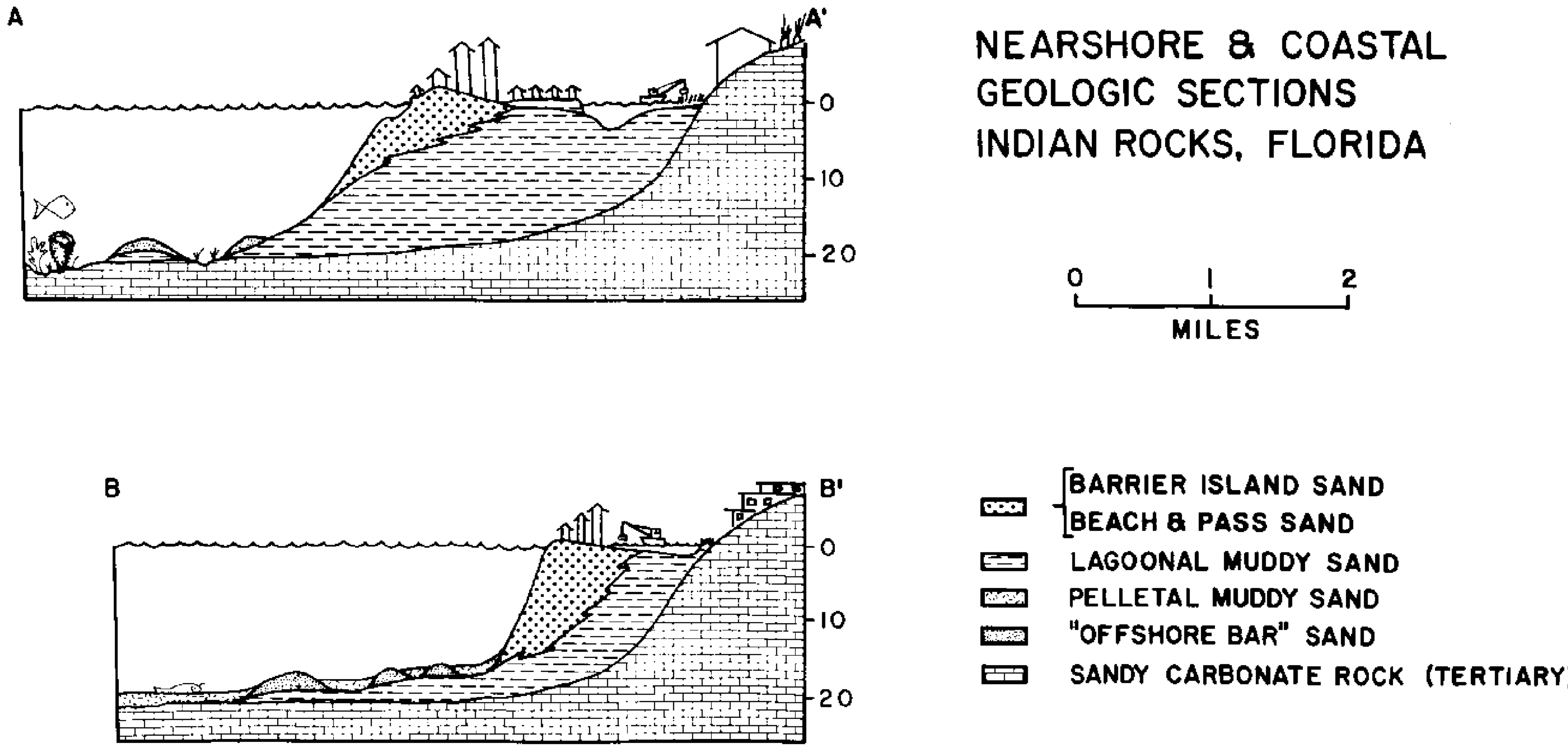

Figure 15. Generalized geologic cross-sections of the coastal zone, Indian Rocks, Florida. The location of the cross-sections is given in Figure 14.

2. Lagoonal Muddy Sand. Seaward of the barrier, this unit is a gray fossiliferous muddy sand and sandy mud. At the base, this unit commonly becomes very peaty and contains a brackish water fauna. Upward the unit contains abundant plant fragments and contains an open bay fauna. This unit is exposed over a broad band to the north, diminishes in extent towards the headland, and increases again southward; however, in the latter case, it is commonly overlain by the pelletal muddy sand unit. The lagoonal muddy sand unit extends landward beneath the barrier and merges with identical modern lagoonal and bay sediments east of the barrier. Consequently, we interpret the offshore sediments to be of a lagoonal origin also.

3. Barrier Island, Beach, and Pass Sand. On the sediment map (Figure 14) the barrier island and beach and pass sands have been differentiated only to outline the location of the barrier islands themselves. These sediments are generally well sorted, clean, fine to medium grained sands with abundant lenses of abraided shell gravel, some Tertiary limestone pebbles, and coarse phosphate grains. This sediment sequence actually contains many different subunits; the sediment composition is fairly similar throughout, however, and differs primarily in the sediment structures and the living fauna. This sequence of units is everywhere superimposed upon the lagoonal muddy sands.

4. Offshore Bar Sand. This unit is composed of clean, well sorted, fine grained quartz sand and shelly sand which occur as sand bars or ridges seaward of the barrier island, beach, and pass sands. These sand ridges occur throughout the study area overlying the carbonate rock surface and commonly have an internal core of undisturbed

lagoonal muddy sand. These structures trend obliquely to the present barrier islands, varying from north-south to northwest-southeast to almost east-west (Figure 14). The bars extend from the proximity of the toe of the present barrier sand wedge seaward for an unknown distance. They rise from a foot or two up to seven feet above the surrounding limestone surface or lagoonal sediment; the low bars are broad, flat, highly burrowed and contain a surface film of brown organic matter; the higher bars are often sharp-crested, assymetrical features and have well developed oscillation ripples. The upper sediments of the bar structures consist of sand and shell of generally the same composition and character as the barrier island beach and pass sand and shell. The northern bars, wherever cored, grade vertically downward into a core of muddy sands, which are interpreted to be lagoonal sediments (see Figures 14 and 15), and to a smooth uncorroded limestone surface. Between the bars, the Tertiary limestone is exposed. The rock swales show a dramatic sequence of biological corrosion and erosion which increases from the smooth uncorroded surface below the bars themselves to a highly irregular and increasingly corroded surface into the central areas between the bars. Figure 16 demonstrates the lateral and vertical sediment relationships of the northern bars.

5. Pelletal Muddy Sand. This unit is a soft, squishy, dark gray muddy sand which occurs as local scattered patches in the northern part of the area, but forms an extensive and continuous bed up to two feet thick which overlies everything in the southern portion of the area (Figures 14 and 15). The mud consists primarily of fecal pellets about 1 mm in diameter.

RELICT "OFFSHORE BARS"
INDIAN ROCKS, FLORIDA

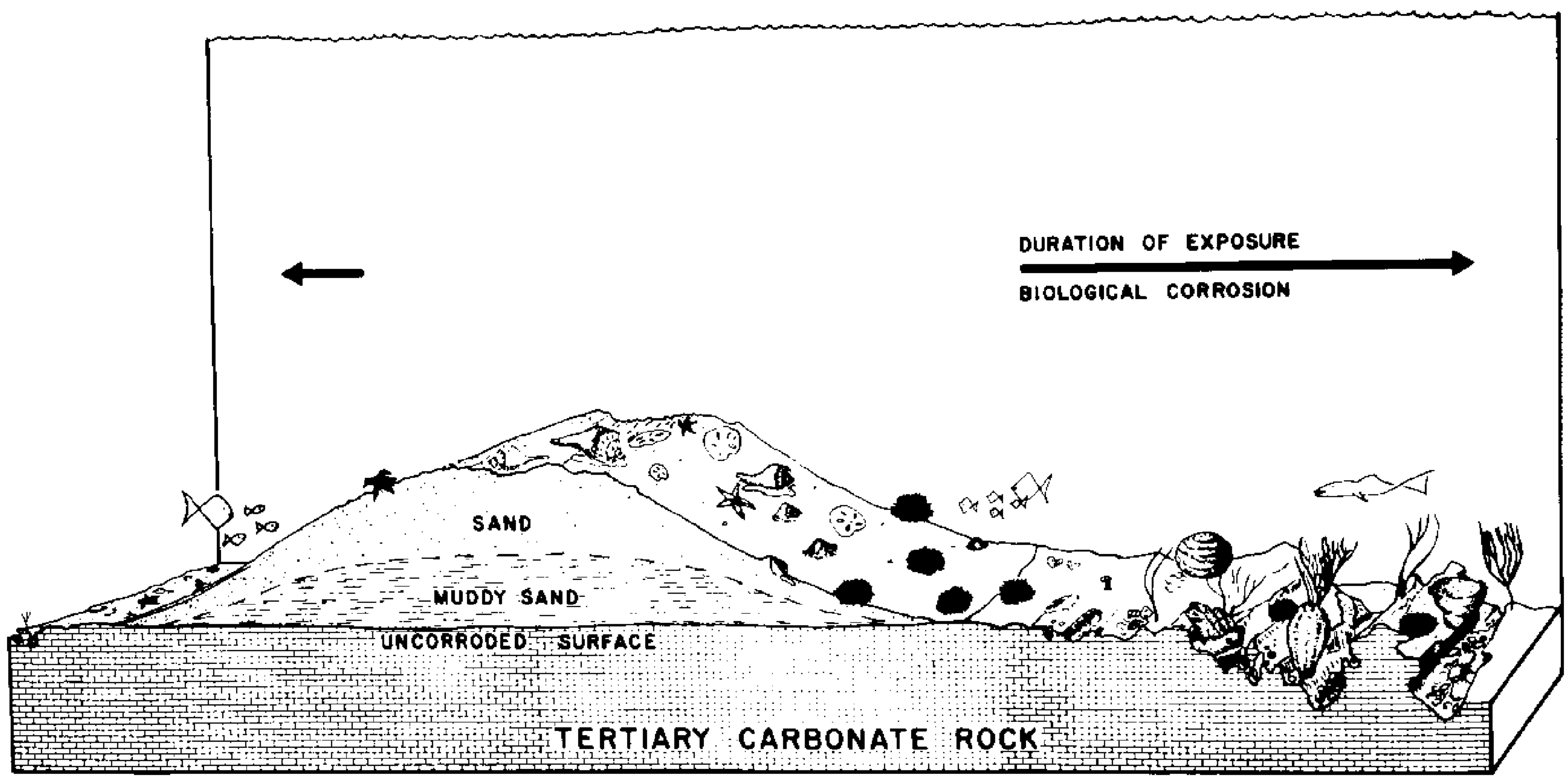

Figure 16. Generalized geologic section through a relict "offshore bar" in the northern portion of the study area, Indian Rocks, Florida. Notice the core of muddy sand and the change from an uncorroded carbonate surface below the bar to an increasingly corroded surface away from the bar. Dimensions of such "bars" vary between 2-7 feet in height and are commonly several hundred feet in width.

Detailed sediment analyses of the distribution patterns and the textural characteristics of the phosphorite; Tertiary limestone rock fragments; the heavy mineral assemblage; and the distribution of the living, dead, and fossil faunal assemblages suggest that the sediments producing the modern barrier island system are being derived internally by the exhumation of the older nearshore relict and residual sediment units (Winston, Riggs, O'Connor, and Breuninger, 1968). Extensive seafloor observations, utilizing SCUBA diving, suggests that the relict sediment units are readily attacked by biological and physical corrosion and erosion processes to produce the sediments necessary for maintenance and the apparent continued growth of the modern barrier system. The day-to-day processes operating on the relict sediments demonstrate a succession of biological and hydrological corrosion (Figure 16). The indurated sandy carbonate rock is rapidly perforated and broken up by boring infauna; it is chewed into fragments and dissolved by encrusting and sessile benthic flora and fauna. The clastic products of these processes, along with the authigenic skeletal material, accumulates as local and ephemeral deposits on the resulting irregular rock surface. The non-indurated sediments are rapidly pitted, burrowed, and bulldozed by fish, crustaceans, mollusks, polychaetes, and echinoderms. The result is a general loosening of the sediment thereby permitting differential sorting by surface organisms which waft and selectively ingest and exrete the finer fractions. The products of these in-place processes then respond to the hydraulic energy of the modern environment, including high energy storms. These daily in-place biological processes and the effects of the subsequent bydraulic regime are believed to be one of the more important mechanisms operating to reestablish an equilibrium between the relict sediments and the new environmental regime in which they now occur.

Two of the major sediment units are products of modern sedimentation, one unit is obviously relict, and two others are of both relict and modern origin. The pelletal muddy sand unit and the barrier island, beach, and pass sand unit are both forming and in equilibrium with the existing environmental conditions. The pelletal muddy sand unit has just recently begun to form in the offshore area with far-reaching consequences. The dark pelletal mud is forming in response to the very extensive modification of the lagoons by man (particularly Boca Ciega Bay in the southern portion of the area) which has suspended fantastic quantities of clay and organic matter. These suspended sediments are flushed out through the inlets producing a local turbid-water offshore environment. The suspended muds are partially removed by filter-feeding benthic organisms (mostly polychaetes) and excreted as fecal pellets which then accumulate in extensive ephemeral deposits. This has had a drastic effect on the prolific benthic organic populations inhabiting this area and has seriously reduced recreational potential of the area in terms of fishing and bathing.

The barrier island, beach, and pass sand unit is obviously a product of the modern system and is maintained through erosion of the relict sediment units in the nearshore environments which are no longer at equilibrium. The lagoonal mud sand unit is exposed over large portions of the nearshore area and extends landward beneath the barrier and merges with identical modern lagoonal and bay sediments east of the barrier. Consequently, this unit consists of both modern and relict deposits depending on their present geographic location. The sandy carbonate rock (Tertiary unit) is, with little question, a product of very different environmental conditions. The relict lagoonal muddy sand and sandy carbonate rock units are actively being modified by biologic and hydraulic corrosion and erosion processes of the present system, and are the source for much of the "new" sediment being contributed to the modern units.

The offshore bar sands and their topographic bar structures appear to be both modern and relict. The distribution of the bars, the change in degree of organic corrosion from uncorroded below the bars and the increasing corrosion on the exposed carbonate rock surfaces away from the bars, and the common existence of a core of lagoonal sediment suggests that most of the bars are not presently mobile structures, nor have they been. Most of these structures appear to be mobile only in the fact that they are actually being decreased in size through the day-to-day biological and hydrological corrosion and erosional processes. In essence then, some of these features appear to be "destructional bars" in which the relict lagoonal muddy sands are eroded, winnowed, and sorted exposing the underlying carbonate surface. The resulting bar morphology, the well sorted surface sands which grade downward into the unmodified lagoonal muddy sands, and the surface sediment structures are all products of, and are in equilibrium with, the modern environmental conditions. Other bars may be remnant features of the transgressing barrier island itself. The orientation of these bars suggests that they might be old inlet features such as recurved inlet spits and tidal bars and deltas formed inside the lagoon and left stranded by the migrating inlets. They were subsequently buried by the transgressing barrier island and re-exposed in the nearshore system following transgression. Analysis of old hydrographic surveys of the U. S. C. & G. S. suggest that two of the bars may have shifted slightly in location through time; so it is possible that a few of the bars may be a product of the modern hydraulic regime.

Similar nearshore ridge and swale topography has been interpreted both as relict barrier and beach ridge topography and as a direct result of the modern hydraulic regime. There is little question that such ridges are tremendously effected by the modern hydraulic system, in particular, high energy storms. But, could not the real answer to the origin of such bar and ridge structures be somewhere between the purely relict and modern endpoints? Could the initial location and orientation of such structures represent relict coastal features which are now being modified and changed in response to the new environmental and energy regimes within which they now occur? Thus, they could represent multiple processes and display characteristics of all regimes through which they have persisted; the older characteristics would systematically be modified and destroyed with time. Present evidence thus supports both relict and modern origins for this type of offshore bar; consequently very detailed work is needed to determine the relative importance of the past environmental history and the present hydraulic regime in establishing the origin of nearshore ridge and swale topography.

SUMMARY

It appears that the present barrier island system in the Indian Rocks area, was initially established on the Tertiary rock surface somewhat seaward of its present location at a lower stillstand. With the continued rapid rise of the Late Holocene sea, the barrier system has migrated up and over the lagoonal system to its present location. Thus, any sediment feature formed in the lagoonal areas would have been buried by the migrating barrier and subsequently exhumed in the nearshore area following the transgression. The question is for how long would such inherited features have an influence on the modern system? Obviously, the rate of modification and destruction of relict features is a function of the rate of transgression, the energy, and the sediment supply. In the Indian Rocks area, the energy level is very low and there appears to be no major outside sediment supply, thus the relict features and sediments should be recognizable for a relatively longer period of time. Consequently, we believe that this area carries a strong heritage of its past history. In conclusion, we feel there is a need to take a closer look at more of our present sediment systems for relict deposits that are being actively modified by the day-to-day biological corrosion and erosion processes and the physical hydraulic regime.

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