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GEOMORPHOLOGY and SEDIMENTS of the INNER CONTINENTAL SHELF, CAPE CANAVERAL, FLORIDA

by
Michael E. Field and David B. Duane

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MARCH 1974

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The Atlantic Inner Continental Shelf off central Florida was surveyed by the Coastal Engineering Research Center to obtain information on morphology, structure, and sediments of the seafloor bottom and shallow subbottom for use in interpretation of Quaternary history and delineation of sand deposits suitable for restoration of nearby beaches. Basic survey data consists of 360 statute miles of high resolution seismic reflection profiling and 90 sediment cores (10 to 20 feet long) collected in water depths of 25 to 90 feet below sea level.

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20. Abstract (Continued)

Analysis shows the shallow subbottom is characterized by two continuous mappable acoustic horizons which lie nearly parallel to the present surface. The lower one lies at about 40 to 80 feet subsurface and is mid-Pleistocene in age. The upper sonic reflector lies between 10 and 40 feet below bottom, and correlates well with a marked lithologic change from overlying unconsolidated sediments to deposits partially lithified by blocky, mosiac, calcite cement. Radiocarbon dates of intertidal shells and of overlying peats indicate this horizon is a pre-Holocene regressive surface. Slightly oolitic sediments comprising the layer are interpreted to represent a coastal complex deposited during a late Pleistocene (mid-Wisconsin) high sea level. Tertiary strata are truncated by a Pleistocene erosion surface lying at between -120 and -160 feet MSL. Overlying Quaternary sediments average about 80 feet in thickness.

Surficial sediments adjacent to Cape Canaveral are medium to coarse, well-sorted quartzose-mollusk sand. Areal distribution and thickness (up to 40 feet) of this modern sand is directly related to topography: deposits are thickest beneath topographic highs, generally less than 5 feet thick on flat areas, and absent in depressions. Late Pleistocene regressive sediments, which locally crop out, and overlying mid-Holocene, transgressive coastal (lagoon, barrier) sediments, have been reworked and reshaped to form an undulatory surface of active sediments. Late Quaternary and modern deposition has centered around the large, south trending, cape-associated shoals. The large plano-convex isolated shoals lying seaward of cape shoals, particularly The Bull Shoal, represent remnants of earlier cape-associated shoals segmented and stranded during late Holocene sea-level rise.

Studies of area beach sediments show them to be derived from: erosion of the shoreface; onshore transport from adjacent shoal regions; and southerly longshore transport into the area. Petrology, faunal assemblages, and textural characteristics indicate that local coastal and shelf sources have been more important in the genesis of modern areal beach sands than southerly longshore drift.

Nearly all of the surficial sand deposits are suitable for beach restoration, and the thick deposits associated with topographic highs are the most suitable. Extensive deposits of sand suitable as a borrow source comprise The Bull, Ohio-Hetzel, Chester and Southeast Shoals, which have minimum volumes of 32, 76, 9, and 15 ($x10^6$) cubic yards, respectively. Volumes of suitable sand in unsurveyed portions of Chester Shoal and Southeast Shoal are likely an order of magnitude larger. Total volume of surficial medium-grained sands within the confines of the study area is over 2×10^9 cubic yards.

PREFACE

This report is one of a continuing series which describes results of the CERC Inner Continental Shelf Sediment and Structure (ICONS) Study, previously referred to as the Sand Inventory Program.

Michael E. Field, a CERC geologist, prepared the report with the assistance and supervision of Dr. David B. Duane, Chief of the Geology Branch. As part of the research program of the Engineering Development Division the ICONS Study is under the general supervision of Mr. George M. Watts, Chief of the Division. The field data for the study were collected by Alpine Geophysical Associates, Inc., under contract DA-08-123-CIVENG-65-57, funded by CERC but awarded and administered by the Jacksonville District, Corps of Engineers.

Cores collected during the field program are stored at the University of Texas, Arlington Texas 76010. Microfilm of the seismic profiles, the 1:80,000 navigational plots and other ancillary data are stored at the National Solar and Terrestrial Geophysical Data Center (NSTGDC), Rockville, Maryland 20852. Requests for information relative to these items should be directed to NSTGDC or the University of Texas.

NOTE: Comments on this publication are invited.

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JAMES L. TRAYERS
Colonel, Corps of Engineers
Commander and Director

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GEOMORPHOLOGY AND SEDIMENTS OF THE INNER CONTINENTAL SHELF CAPE CANAVERAL, FLORIDA

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I. INTRODUCTION

1. Background.

Ocean beaches and dunes constitute a vital buffer zone between the sea and coastal areas, and also provide much needed recreation areas for the public. The construction, improvement, and maintenance of beaches through the artificial placement (nourishment) of sand on the shore is one of several protection methods. This technique has gained prominence in coastal engineering largely as a result of the successful program initiated at Santa Barbara, California, in 1938. (Hall, 1952.)

Where the specified plan of improvement involves shore restoration and periodic nourishment, large volumes of sand fill may be involved. In recent years it has become increasingly difficult to obtain suitable sand from lagoonal or inland sources in sufficient quantities and at an economical cost for beach fill purposes. This is due in part to increased land value, diminution and depletion of previously used nearby sources, and added cost of transporting sand from areas increasingly remote. Material composing the bottom and subbottom of estuaries, lagoons, and bays is often too fine-grained and not suitable for long-term protection. While the loss of some fines is inevitable as the new beach sediment seeks equilibrium with its environment, it is possible to estimate the stability of the beach fill and therefore keep the loss to a minimum through selection of the most suitable fill material. (Krumbein and James, 1965.)

The problem of locating a suitable and economical sand supply led the Corps of Engineers to a search for new unexploited deposits of sand. The search focused offshore with the intent to explore and inventory deposits suitable for future fill requirements, and subsequently to develop and refine techniques for transferring offshore sand to the beach. The exploration program is conducted through the U.S. Army Coastal Engineering Research Center (CERC). An initial phase in developing techniques for transferring offshore sand to the beach is described by Mauriello (1967). In 1968, nearly 1.5×10^6 cubic yards of sand were successfully transferred from offshore to Redondo Beach, California by Los Angeles District, Corps of Engineers.

Formerly called the sand inventory program, it was begun in 1964 with a survey off the New Jersey coast. Subsequent surveys included the inshore waters off New England, New York, Florida, Maryland, Delaware, Virginia, North Carolina, and California. Recognizing the broader application of the information collected in the conduct of the research program toward the CERC mission, especially in terms of Continental Shelf sedimentation (Field, Meisburger and Duane, 1971), and its potential application to historical geology (Field, 1974), and engineering studies of the shelf (Duane, et al., 1972), the sand inventory program is now referred to as the Inner Continental Shelf Sediment and Structure Program (ICONS).

2. Field and Laboratory Procedures.

The exploration phase of the ICONS program uses seismic reflection profiling supplemented by cores of the marine bottom. Additional supporting data for the studies are obtained from the National Ocean Survey (formerly U.S. Coast and Geodetic Survey) hydrographic boat sheets and related published literature. Planning, and seismic-reflection profiling, coring, positioning, and analysis of sediment obtained in the cores are detailed in *Geomorphology and Sediment Characteristics of the Nearshore Continental Shelf, Miami to Palm Beach, Florida*. (Duane and Meisburger, 1969.) However, a brief description of techniques is germane to this paper and follows.

a. Planning. Survey tracklines were laid out by the CERC Geology Branch staff in either of two line patterns: grid and reconnaissance lines. A grid pattern (line spacing about 1 statute mile) was used to cover areas where a more detailed development of bottom and subbottom conditions was desired. Reconnaissance lines are one of several continuous zigzag lines followed to explore areas between grids, and to provide a means of correlating sonic reflection horizons between grids. Reconnaissance lines provide sufficient information to show the general morphologic and geologic aspect of the area covered, and to identify the best places for additional data collection.

Selection of core sites was based on a continuing review of the seismic profiles as they became available during the survey. This procedure allowed core-site selection based on the best information available; it also permitted the contractor to complete coring in one area before moving his base to the next area.

b. Seismic Reflection Profiling. Seismic reflection profiling is a technique in wide use for delineating subbottom structures and bedding planes in sea floor sediments and rocks. Continuous reflections are obtained by generating repetitive high-energy, sound pulses near the water surface and recording "echoes" reflected from the bottom-water interface, and subbottom interfaces between acoustically dissimilar materials. In general, the compositional and physical properties which commonly differentiate sediments and rocks also produce acoustic contrasts. Thus, an acoustic profile is roughly comparable to a geologic cross section.

Seismic-reflection surveys of marine areas are made by towing sound-generating sources and receiving instruments behind a survey vessel which follows predetermined survey tracklines. For continuous profiling, the sound source is fired at a rapid rate, and returning signals from bottom and subbottom interfaces are received by one or more hydrophones. Returning signals are amplified and fed to a recorder which graphically plots the two-way signal travel time. Assuming a constant velocity for sound in water and shelf sediments, a vertical depth scale can be constructed to the chart paper. Horizontal location is obtained by frequent navigational fixes keyed to the chart record by an event marker, and by interpolation between fixes.

A more detailed discussion of seismic profiling techniques can be found in a number of technical publications. (Miller, et al., 1967), (Moore and Palmer, 1968.)

c. Coring Techniques. A pneumatic vibrating hammer-driven coring assembly was used for obtaining cores from the survey area. The apparatus consists of a standard core barrel, liner, shoe and core catcher with the driver element fastened to the upper end of the barrel. These are enclosed in a self-supporting frame which allows the assembly to rest on the bottom during coring, thus permitting limited motion of the support vessel in response to waves. Power is supplied to the vibrator from a deck-mounted air compressor by means of a flexible hoseline. After the core is driven and returned, the liner containing the cored material is removed and capped.

d. Processing. Seismic records are analyzed to establish the principal bedding or structural features in upper subbottom strata. After preliminary analysis, record data is reduced to detailed cross-section profiles showing all reflective interfaces within the subbottom. Selected reflectors are then mapped to provide areal continuity of reflective horizons considered significant because of their extent and relationship to the general structure and geology of the study area. If possible, the upper mapped reflector is correlated with core data to provide a measure of continuity between cores.

Cores are visually inspected and logged aboard ship. After delivery to CERC, these cores are sampled by drilling through the liners and removing samples of representative material. After preliminary analysis, a number of representative cores are split in order to determine details of the bedding. Cores are set up for splitting on a wooden trough. A circular power saw mounted on a base which is designed to ride along the top of the trough is set so as to cut just through the liner. By making a cut in one direction and then reversing the saw base and making a second cut in the opposite direction, a 120° segment of the liner is cut. The sediment above the cut line is then removed with a spatula, and the core is logged, sampled and photographed.

Samples from cores are examined under a binocular microscope, and described in terms of gross lithology, mineralogy, and the type and abundance of skeletal fragments of organisms.

3. Scope.

The area covered by this report extends along the east Florida coast and adjacent Continental Shelf, from south of Canaveral Harbor (28°20′ N.) north to False Cape (28°40′ N.). The adjacent coastal segment, from Canaveral Harbor to Fort Pierce, is covered in CERC's Technical Memorandum No. 34. (Meisburger and Duane, 1971.) Figure 1 is a map of the location of the survey area and major geographic features of the region. Field work (conducted between January and May 1965) and preliminary reduction of geophysical data in support of the study was accomplished by contract. (Alpine Geophysical Associates, Inc.) Data collected and reported consists of continuous seismic reflection profiles covering 360 statute miles of survey line and 90 sediment cores ranging from 6 to 14 feet long. (See Figure 2.) Ancillary studies were conducted on the seismic profiles and sediment cores obtained from the adjacent region to the south studied by Meisburger and Duane (1971) for comparison and correlation of sediments lying between the Fort Pierce and Cape Canaveral areas.

Basic data processing covered analysis and reduction of geophysical records, visual description and size analysis of sediment samples from the cores, and construction of large-scale navigation overlays showing the position of geophysical lines and cores. Field data was supplemented by literature pertaining to the region and by the National Ocean Survey hydrographic smooth-sheet coverage at 1:40,000 scale.

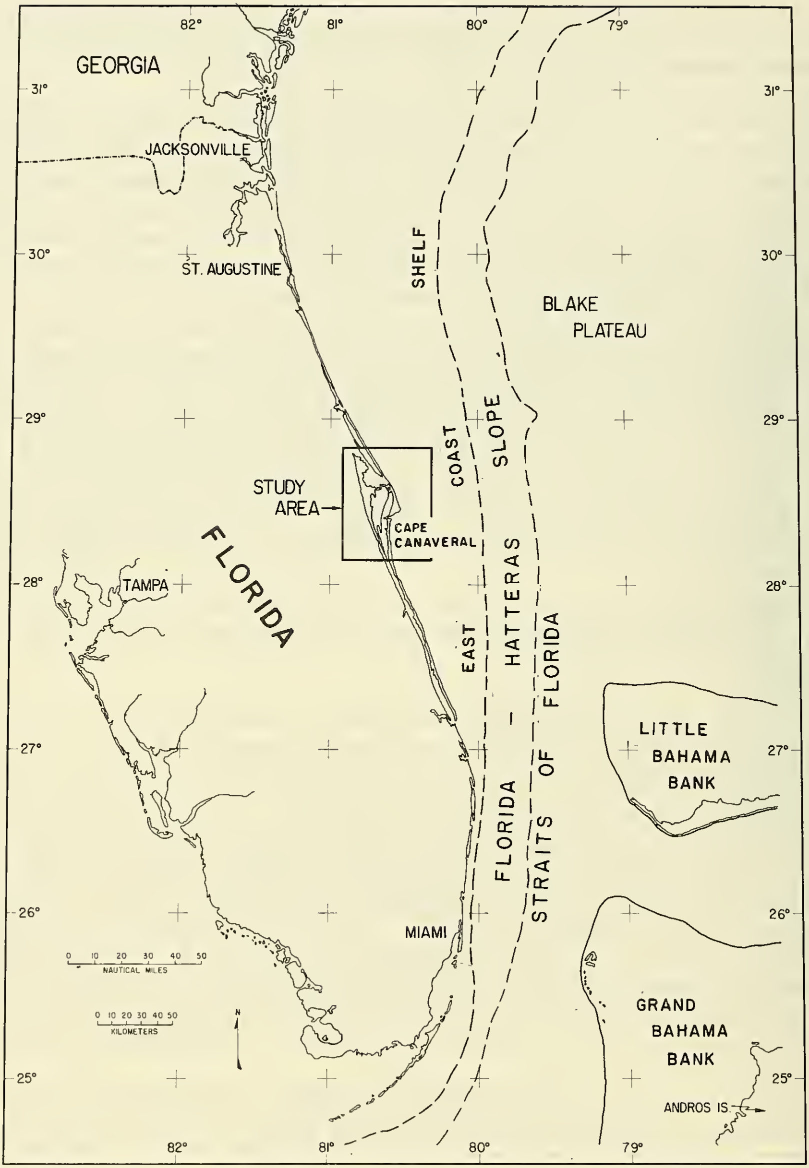


Figure 1. Map of the Major Physiographic Provinces of the Florida Continental Margin. The study area is outlined.

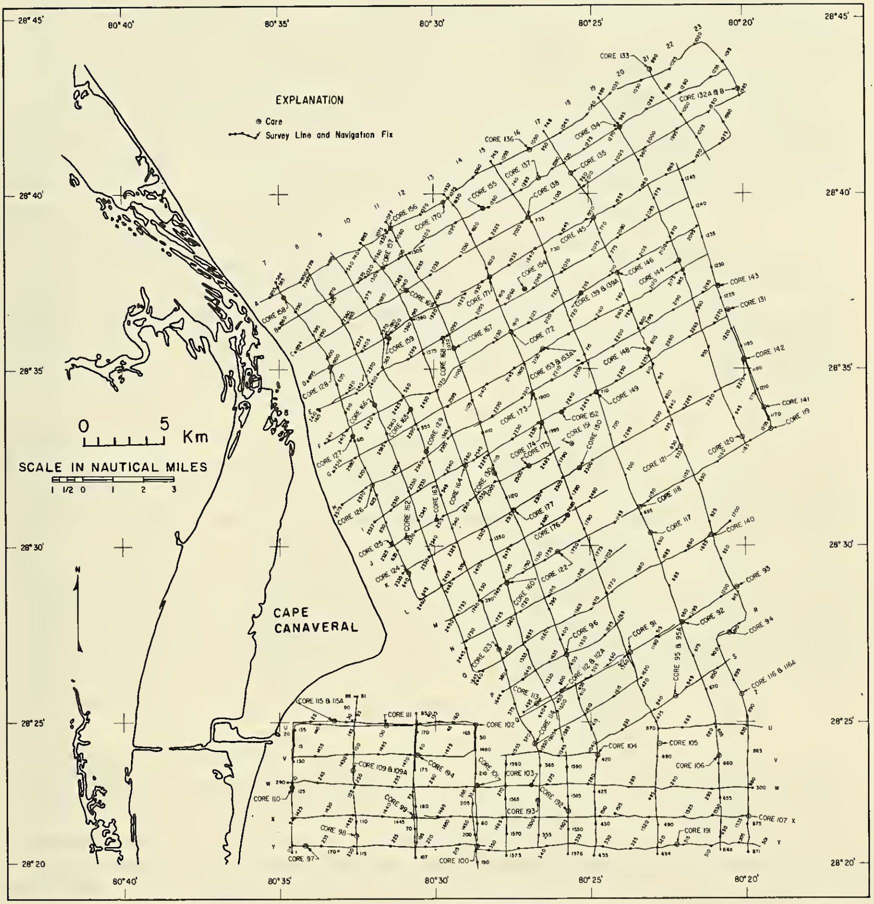


Figure 2. Navigation Plot Showing Geophysical Tracklines and Core Locations, Cape Canaveral Grid

4. Geology of the Survey Area.

a. Regional Stratigraphy and Geologic History. Peninsular Florida is underlain by thick sedimentary rock sequences of Tertiary and Quaternary age; the oldest of the exposed rocks belongs to the Eocene-Ocala Group. (See Table 1.) In coastal Brevard County, the Ocala Group lies between –160 to –200 feet MLW and dips southward and eastward to –380 feet MLW along the southern line of Brevard County and to –600 feet MLW in Indian River County. (Brown, et al., 1962.) Overlying the Eocene rocks is a thick section of Miocene, Pleistocene and Holocene marine clays, silts, sands, and shell deposits. Formation names, relative ages and surface occurrences have been compiled by Puri and Vernon (1964), for the entire state and is a useful guide to major rock types and locations.

Table 1. Stratigraphic Column; Upper Eocene to Recent: Atlantic Central Florida

Age	Group	Formation	Depth to Top of Formation* Brevard and Indian River Counties	Age (yrs. ea.)
Holocene			0 to ϕ 30	11×10^3
Pleistocene		Pamlico	Around + 30	
		Anastasia	0	
		Caloosahatchee	May occur locally	1×10^6
Pliocene				10×10^6
Miocene		Tamiami	60 to 230	
		Hawthorn	100 to 400	25×10^6
Oligocene		Suwanee	Around 400	40×10^6
Eocene	Ocala	Crystal River	160 to 600	
		Williston		
		Ingles		60×10^6

*In feet below MSL

Modified from Meisburger and Duane (1971)

A detailed summary of pre-Pleistocene formations of central Florida coastal counties has been presented by Meisburger and Duane (1971). Supporting evidence for their summary of the subsurface geology of Brevard County (based on the work of Brown, et al., 1962) has been obtained from core borings on Cape Canaveral collected by the U.S. Army, Corps of Engineers, Jacksonville District. The boring logs detail depth and nature of the major formations in that area, and agree with results presented by Brown, et al., (1962). An ICONS study (in progress) of northern Florida will describe the subsurface geology of that region.

Significant aspects of Brevard County subsurface geology are summarized as follows: Eocene strata lie beneath Cape Canaveral at about –210 feet MLW; Oligocene rocks are absent from the region; Miocene marine phosphatic clays and sands dipping eastward at a low angle lie at about –50 feet MLW, and above this depth upper Miocene or Pliocene unconsolidated sediments rest on a lower Miocene surface (Hawthorn Formation). Also, there is no clear evidence of major faulting in Brevard County subsequent to the close of the Eocene.

Post-Miocene history has resulted in numerous depositional sequences and erosional surfaces formed as a response to fluctuations in sea level. Multiple eustatic changes are judged the primary agent responsible for the existing land and Continental Shelf topography. Secondary agents of landform modification have been dissolution and dissection of the exposed limestone surface, accretion of modern sediments in lagoons, and modification and accentuation of shallow water features by normal marine processes.

b. Regional Marine Geology. The Florida Continental Shelf is the southernmost part of the East Coast Shelf (name proposed by Uchupi, 1968) and is bound on the north by the broad Georgia Shelf, on the south by the Straits of Florida and on the east by the steep Florida-Hatteras Slope. (See Figure 1.) Seaward of the Florida-Hatteras Slope is the broad flat platform of the Blake Plateau. The shelf in this region is composed of strata lying at low angles and dipping generally easterly and southeasterly. Slope of the shelf increases rapidly in a southern direction from 1 on 1,750 at Jacksonville to 1 on 200 at West Palm Beach. (Uchupi, 1968.) A marked narrowing of the shelf from north to south Florida accompanies this increase in gradient. Shelf width is about 82.5 miles at Jacksonville (30°30′N.) and steadily narrows to 2 miles at West Palm Beach (27°00′N.). (Uchupi, 1968.) The shelf at Cape Canaveral is about 32 miles wide and dips seaward at about 1 on 440.

Geology of the East Coast Shelf is well known relative to other shelves of the world. (Emery, 1969.) Structure, age, physiography, and sediment cover have been charted and described by many investigators in abundant literature during the past several decades. In particular, the works of Stetson (1938), Tyler (1934), Gorsline (1963), Curray (1965), Emery (1965), Pilkey and Field (1972), Pilkey (1968), Uchupi (1968, 1969), MacIntyre and Milliman (1970), Milliman (1972), have discussed regional aspects of the marine geology of the southeastern U.S. Continental Shelf. These investigators have charted bottom morphology, described textural and compositional parameters of the surficial deposits, and related these parameters to bathymetry, sediment sources, and shelf history. While these studies provide useful background material, the low density of samples, methods of sampling (surface grab) and areas of study (usually deeper parts of the central and outer shelf) limit their use for delineation of smaller sediment bodies within the bounds of this survey.

c. Coastal Morphology and Evolution.

(1) Coast Terraces. Morphology of peninsular Florida is dominated by a number of terraces aligned roughly parallel with the present coastlines. The terraces have long been recognized and their general characteristics are well documented. (Cooke, 1945), (Altschulter and Young, 1960), (Alt and Brooks, 1965), (Schnable and Goodell, 1968.) Most agree on the related positions and ages of the terraces; older terraces are higher and farther inland than younger ones. The Florida coastal terraces are similar to the isostatic reef terraces of Barbados described by Mesolello, et al., (1969) and the coastal terraces and plains from other regions of the world. (Donovan, 1962), (Oaks and Coch, 1963.)

The absolute age or exact number of the Florida terraces is not well established. Cooke (1941, 1945) identified four terraces in Florida on a topographic basis and assigned them to interglacial periods of the Pleistocene. However, the interpretation of coastal terraces as being solely a product of Pleistocene eustatic events has long been debated. (Flint, 1940, 1941), (Cooke, 1941.) Using stratigraphic data rather than topographic control, Altschulter and Young (1960) and Alt and Brooks (1965) have suggested that the oldest terraces may be late Tertiary and only the lower terraces were formed during the Pleistocene.

In Brevard and Volusia Counties the terraces and approximate elevations (in order of decreasing age) are: Penholoway, 80 feet; Talbot, 50 feet; Pamlico, 25 feet; and Silver Bluff, 12 feet. (Wyrick, 1960.) Only the lower two terraces are germane to this report. They represent the last two sea advances into the region; consequently, coastal sediments, shoreline evolution, and shelf analogies may be related and better understood through examination of their development.

According to Cooke (1945), both the Pamlico and Silver Bluff terraces were formed during brief transgressions associated with the Wisconsin glacial stage. As with the projected ages of the higher, older terraces, the ages assigned by Cooke (1945), are debated by recent investigators. Schnable and Goodell (1968), assigned the Pamlico terrace (25 feet) to the Sangamon (last interglacial 80,000-120,000 B.P.) and the Silver Bluff (12 feet) to mid-Wisconsin (30,000-40,000 B.P.). The age of the 25-foot terrace is ascribed by Alt and Brooks (1965), to one or more, older interglacial: Yarmouth, 500,000 B.P. and Aftonian, 800,000 B.P. Contrasts in ages assigned to the 25- and 12-foot terraces by various investigators working in different regions are largely a result of confusing stratigraphic associations. Alt and Brooks (1965) and Osmond, May and Tanner (1970), show that these conflicts may be due to repeated submergence and exposure of shell deposits and reoccupation of old shorelines which would alter carbonates and anomalous carbon-14 dates. Reoccurring submergence and exposure may also cause cementation of shell deposits at a time much later than original deposition of the shells, thus yielding inaccurate ages for samples dated *in toto*.

Sea level positions during the mid-Wisconsin transgression are not well known and thus their effect on coastal morphology during this time cannot be established. Numerous investigators have made an effort at resolving and providing insight into the problem of mid-Wisconsin sea level positions. (Curray, 1965, 1969), (Milliman and Emery, 1968), (Scholl and Stuiver, 1967.) Studies by Hoyt, Henry and Weimer (1968), and Hoyt and Hails (1967), indicate that the sea invaded the Georgia coastal region at least twice during the mid-Wisconsin. Further discussions and summaries of Pleistocene sea levels are contained in Curray (1969), and Guilcher (1969).

While it is not the intent of this study to evaluate the potential of onshore deposits for borrow areas, these coastal terraces may be considered a future source for beach nourishment materials. Samples of quartzose Pamlico sediments have a mean diameter of 0.21 mm (2.25 phi) and a standard deviation of 1.35 mm (0.44 phi); calcareous Silver Bluff sediments have a mean diameter of –0.536 mm (0.90 phi) and a standard deviation of 2.12 mm (1.10 phi), a reflection of the coarse shell component. These size values, and the proximity of the terraces to the shore make the terraces a feasible borrow source for beach nourishment material. Economic practicality of using the terraces for a borrow source depends on land values and transportation costs.

(2) Cañaveral Peninsula. Classically identified as a cuspate foreland (Gulliver, (1968), and Johnson, (1919), Canaveral Peninsula is a prominent extension of the surrounding adjacent Pleistocene coastline terrace complex. Aerial photos and topographic maps of the peninsula reveal extensive rows of low linear ridges striking nearly parallel to the present day coast as shown in Figure 3. The morphological pattern shown in the figure is interpreted as sequential seaward building of a series of beach ridges.

Figure 3. Topographic Map of Canaveral Peninsula Showing Orientation of Beach Ridges. Data compiled from aerial photos and topographic maps at 1:25,000 scale. Letters on map are explained in text.

From aerial photos and topographic maps, Kofoed (1963), interpreted the formation of the peninsula as having originated at False Cape 100,000 years ago and developed by growth of barrier islands and offshore bars fed by a predominantly southerly littoral drift and a less important northerly littoral drift. Other investigators have hypothesized a structural origin for the peninsula, based on faults in central Florida and data from wells drilled in the coastal region. (Brown, et al., 1962), (White, 1958, 1970), (Vernon, 1951.) A study of shallow structural characteristics of the east Florida inner shelf by Meisburger and Duane (1969), found no evidence of major faulting in the subsurface, although one minor deep fault striking north-south with the upthrown side seaward was mapped. If formation of the peninsula was initiated by structural deformation it is still unresolved. However, once initiated, normal nearshore processes probably are responsible for the accretion of the large quantities of sedimentary material comprising the cape and its associated shoals.

As the Canaveral Peninsula beach ridge complex formed, the salient part of the coast was on the north end of Merritt Island (A, Fig. 3) where local topography is bowed seaward. Coastal erosion attending the Holocene transgression resulted in truncation of Pleistocene beach ridges and formation of the present coastline at B in Figure 3. Beach ridge orientation seaward and south of False Cape (C, Fig. 3), indicates the ridge system was developed subsequent to earlier development at A. As the foreland built outward, it migrated southeasterly by littoral processes. Erosion on the north end and deposition on the south resulted in the present promontory at Cape Canaveral. Ridges on the north part of Cape Canaveral are aligned nearly normal to the present shoreline; truncation of these ridges is shown at D in Figure 3. South of Cape Canaveral the ridge system parallels the coast due to accretion on the downdrift side of the cape. (Shepard, 1963.) Rosalsky (1960), presented a similar interpretation of the development of the peninsula from maps and aerial photos.

II. INNER CONTINENTAL SHELF MORPHOLOGY AND STRUCTURE

1. Bottom Configuration.

a. General. Morphology of the central Florida Continental Shelf and shelf edge has been mapped by Uchupi (1968, 1969), and MacIntyre and Milliman (1970). These investigators noted the presence of consolidated ridges, perhaps former strandline deposits on the shelf edge, and unconsolidated ridges (called *sand swells* by Uchupi, 1968) on the surface of the inner and outer shelf.

Within the Cape Canaveral grid, the shelf surface is irregular due to constructional features (shoals) and erosional features (terraces or benches). Major shoals lie at depths of less than 60 feet while terraces are generally deeper. Most mapped terraces lie seaward of the study area; principal terrace depths in this region are 65, 80, 100, 130, 165, and 213 feet. (Uchupi, 1968.)

South of Cape Canaveral the inner shelf plain has a regular configuration (Meisburger and Duane, 1971), particularly in Canaveral Bight where the surface levels off at about 400 feet MLW. Adjacent to Canaveral Peninsula the inner shelf surface is highly irregular. Large shoals extend southeasterly from False Cape and Cape Canaveral. Isolated shoals and depressions mark the shelf surface to 10 miles from shore. Rock ledges and irregular, often steep, topography characterize the seaward edge of the survey area. Morphology, including shore-connected shoals, depressions, isolated shoals, and the 80-foot contour are schematically illustrated in Figure 4. North of the peninsula the bottom deepens, as noted by the shoreward trend of the 50- to 65-foot inner shelf plain (Fig. 4), and the surface becomes more irregular but has lower relief.

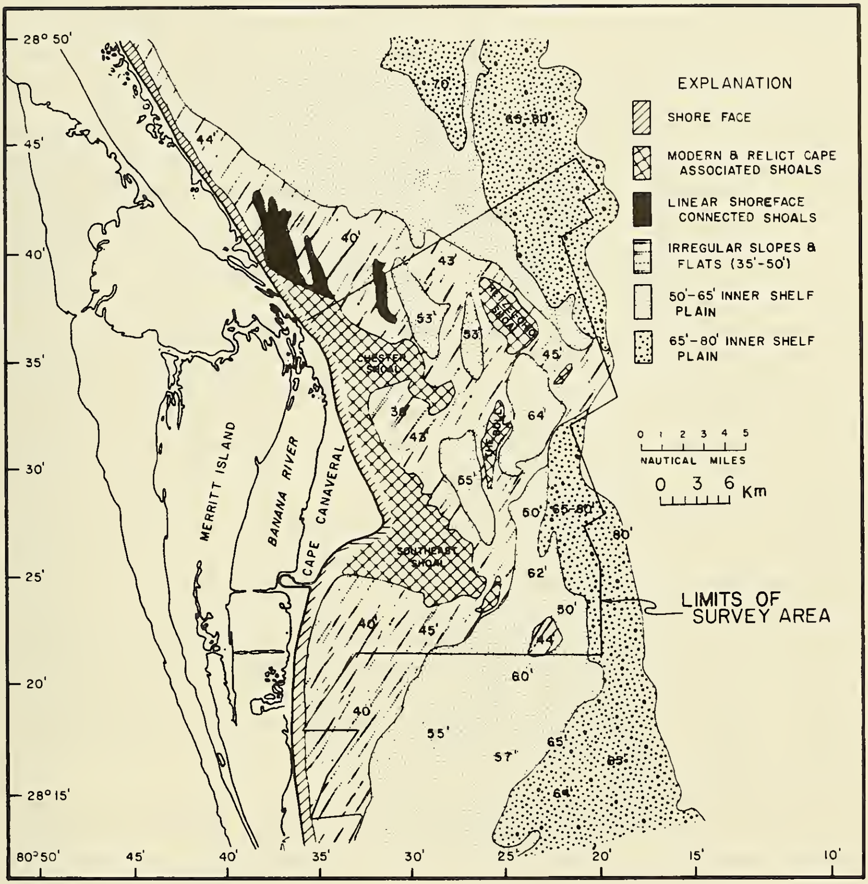


Figure 4. Morphological Subdivisions of the Cape Canaveral Inner Continental Shelf. Soundings are representative values from the National Ocean Survey (formerly U.S. Coast and Geodetic Survey) Chart 1245.

b. Shoreface. The term shoreface describes the nearshore area of the shelf extending seaward from the shore to a depth where bottom slope markedly changes to a lower grade. Depth of the shoreface base in the survey area is about 30 to 35 feet. South of Canaveral Harbor the shoreface is regular with a width of nearly 1,500 yards and the base defined by a gentle change of slope at about 30 feet. Average shoreface slope in this area is 1 on 150; just north of Canaveral harbor the slope is similar but the break lies at about 25 feet.

Interrupting the configuration of the shoreface as it trends east and north paralleling the coastline around Cape Canaveral is Southeast Shoal, extending from Cape Canaveral, and Chester Shoal, extending from False Cape. Between these features the shoreface has a gentle slope (1 on 250) and is nearly 2,500 yards wide. Southeast and Chester Shoals are *shore-connected* shoals (Fig. 4); they merge into the shoreface zone and are an integral part of the bottom morphology seaward of the shore. The tips of both southeasterly trending shoals have a northeast orientation.

Southeast Shoal is larger, more regular in plan view and more symetrical in cross section than Chester Shoal. The shallowest part of Southeast Shoal fringes the shore, while high parts of Chester Shoal are separated from the shore by a 30-foot slough. (See Figure 5.)

North of Chester Shoal a series of shoreface-tied linear shoals (A, B, and C, Fig. 5) extend north-northeast from the shoreface. The shoals are parallel, have similar shapes and depths (18-foot crest), and display a progressive stage of separation and isolation from the shoreface. The shoreface gradually deepens north of Chester Shoal from –40 feet immediately north of Shoal C, to –50 feet at the north end of Mosquito Lagoon, to –60 feet just south of Ponce de Leon Inlet. Widths are 1,200, 1,500, and 3,000 yards at these three locations with slopes of 1 on 90, 1 on 90, and 1 on 180, respectively.

c. Shoal Region. Morphology of the sea floor in Cape Canaveral grid is dominated by isolated shoals rising to depths of 15 to 25 feet below MLW from a base at 40 to 50 feet MLW. These shoals (The Bull, Ohio Shoal, Hetzel Shoal, and Shoals D and E) lie seaward of the large cape shoals. (See Figure 5.) Detailed bathymetry of the area (Fig. 5) shows the position, orientation and depth of the isolated shoals with respect to the cape shoals and shoreline. Shallow basins (–60 feet MLW) separate the isolated shoals from the shore-connected shoals.

The Bull lies 6.5 miles east of the shoreline and 2.8 miles southeast of the tip of Chester Shoal. Oriented in a northeast direction, like the tip of Chester and Southeast Shoals (Shoals D and E, Fig. 5), the Bull is about 5.1 miles long and slightly over 2 miles wide. Rising to within 15 feet of the surface, the shoal is visible in aerial photos, including Hetzel and Ohio Shoals which rise to 20 feet MLW.

Ohio Shoal and Hetzel Shoal, separated by a shallow, narrow slough lies 4 miles north of The Bull and 9 miles east of False Cape. (See Figures 4 and 5.) Both shoals are more irregular in shape than The Bull. Ohio Shoal has a northeast orientation, while Hetzel Shoal, and the combined form of both shoals is oriented northwest. Survey data shows the Hetzel-Ohio Shoal complex is slightly asymmetrical in cross section–the landward flank is steeper and more even than the seaward slope.

Several miles north of Chester Shoal lies a larger north-trending shoal (Shoal A, Fig. 5) which rises to 15 feet MLW. Shoal A is about 2.7 miles long and 1,100 yards wide. Between Shoal A and Chester Shoal the bottom is slightly deeper than 30 feet MLW, but near the

Figure 5. Bathymetry of the Cape Canaveral Inner Continental Shelf. Major relief features are indicated.

shoal the relatively flat bottom is approximately 40 feet MLW. Connection of Shoal A to Chester Shoal by this slight high, and the general configuration and orientation of Shoal A, indicates a morphological and perhaps genetic similarity between Shoal A, and Shoals B, C, and D. (See Figure 5.)

Isolated shoals and the cape shoals are actively changing in configuration by modern nearshore processes. Direct evidence of active reworking of shoals is from sediment characteristics and bathymetric profile data. Sediments collected from 10 feet subbottom indicate recent abrasion and transport (discussed later in Section III, a). Comparison of bottom profiles made in 1878, 1928, 1958, and 1965 by the Jacksonville District, Corps of Engineers, show an historical change in shoal shape and location. Corps of Engineers, (1966) maps of the 6-, 12-, and 18-foot depth contours show that all the shoals have changed in shape and are becoming shoaler. Cape shoals have broadened and thickened and, within the 18-foot contour, the isolated shoals have shifted slightly in a southeast direction. These historical profile data indicate that since 1898 accretion has occurred on the south or downdrift side of the cape shoals and erosion has occurred between the two shoals and west of Southeast Shoal in Canaveral Bight.

2. Shallow Subbottom Structure, Cape Canaveral Grid.

a. General. Delineation of thicknesses of major units, and sonic penetration to 500 feet subbottom by seismic reflection show that all strata have a consistent seaward dip. Units in the column dip gently eastward and southeastward and are mostly conformable. However, several hiatuses are evident, and result from planation and truncation of strata by a transgressing sea. Deeper subbottom units generally dip more steeply than upper subbottom strata; lower units have slopes of nearly 1 on 45 and upper units have slopes of less than 1 on 400. Internal reflectors between major seismic horizons are recognizable at times in the upper subbottom, and they generally dip steeply seaward relative to the dip of the confining reflectors. (See Figure 6.)

Deep structure of the Florida Atlantic Inner Continental Shelf reported by Meisburger and Duane (1969), showed the presence of two deep regional reflectors, both in the survey area of this report. The higher of the two deep, major acoustic reflectors, (referred to as the *red* horizon) dips gently from 130 feet in the center of the grid to −160 feet at the seaward edge. The lower reflector, called the *green* horizon, drops from −120 feet near the shoreface to nearly −500 feet in the grid center. (See Figure 6.) Horizons immediately beneath the red reflector dip more steeply and are truncated by the red. Erosional nature of the horizon and its depth and lateral extent suggests a probable age of early or mid-Pleistocene. Acoustic horizons underlying the red horizon dip eastward at slopes up to 140 feet per mile (1 on 40) and exhibit occasional broad undulatory folding. The green reflector shows signs of folding and probable faulting. (See Figure 7.) Based on correlation of seismics with onshore well data the green horizon is equivalent with the top of the Floridian artesian aquifer near the pre-Miocene–Miocene contact.

Above the red horizon and traceable over the grid area are two major shallow reflectors. The lower of the two reflectors, called the *yellow* horizon, lies about 20 to 50 feet below the sea floor; the upper one is termed the *blue* horizon, and lies 10 to 30 feet below the sea floor.

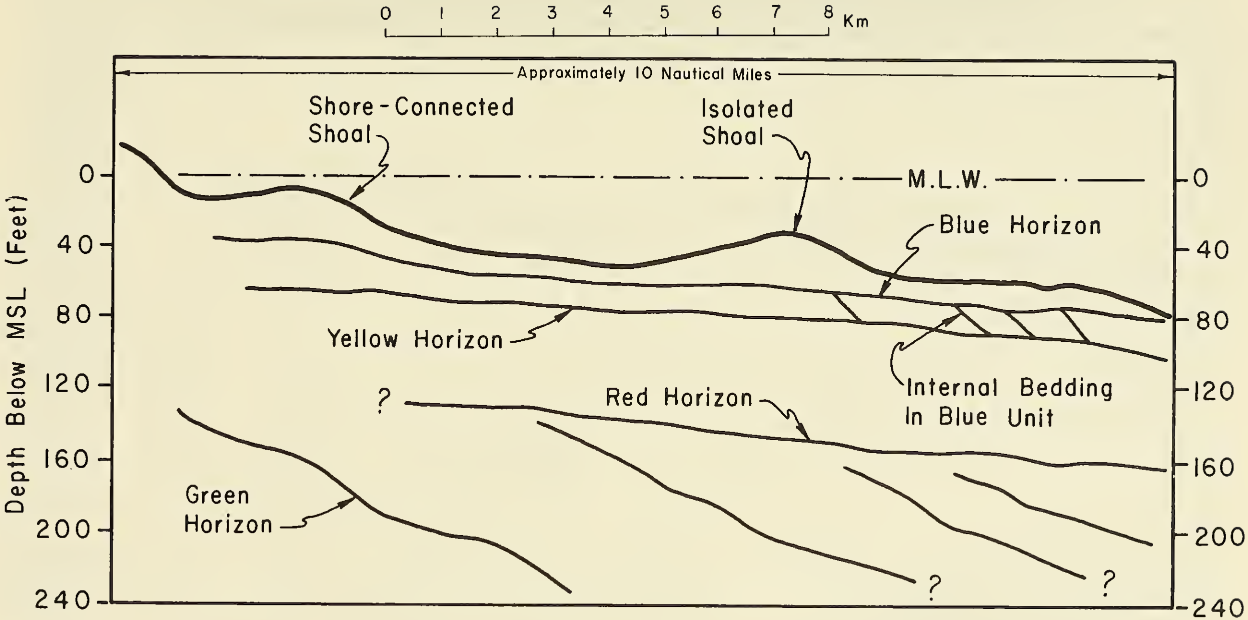
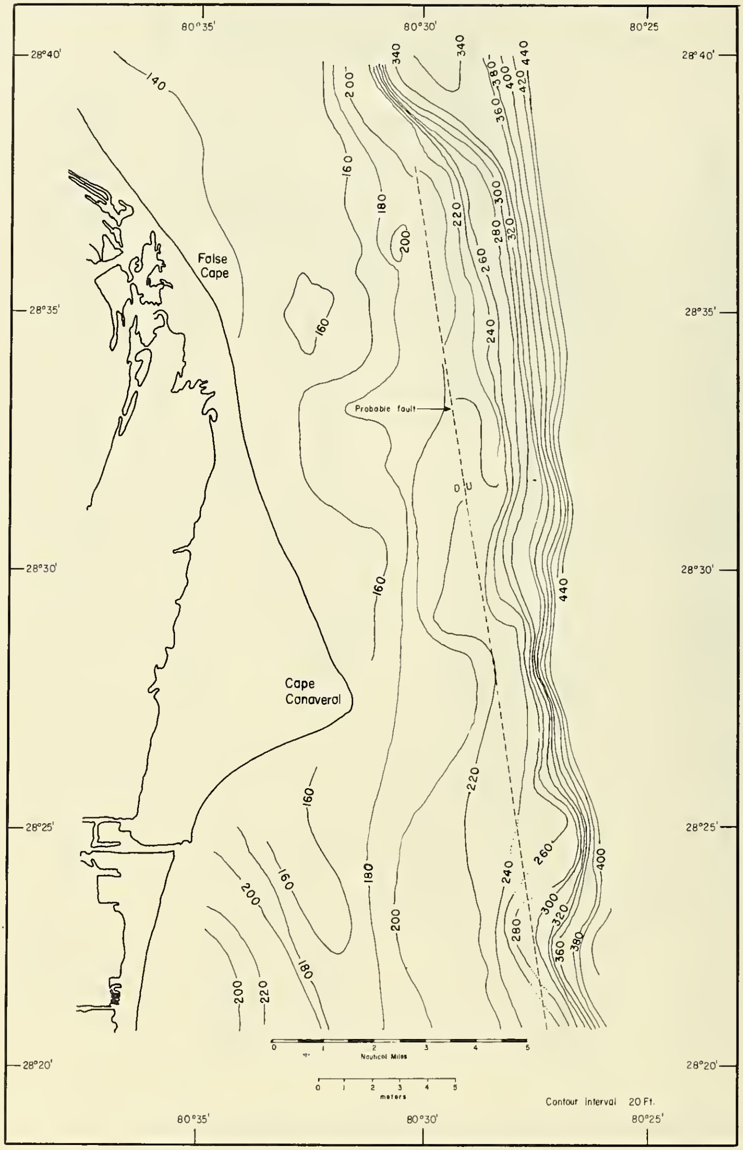


Figure 6. Schematic Profile Across the Cape Canaveral Inner Continental Shelf Showing Characteristics of Bottom Morphology and Major Shallow Acoustical Reflectors



From Meisburger and Duane (1969)

Figure 7. Structure Contour Map of the Green Horizon East of Cape Canaveral. Depths are in feet below MLW. Dashed line indicates probable fault.

b. Yellow Horizon. The yellow horizon lies at a subsea depth of about 60 feet MLW near the shore and dips seaward at a varying slope to about −125 feet MLW at the eastern edge of the survey area. The contour map of the yellow horizon (Fig. 8) shows most of the surface is of low relief and low inclination. Seaward of the 100-foot depth contour the surface dips more steeply and regularly, with an average slope of 1 on 500.

Slope change and small undulations and minor irregularities landward of the 100-foot depth contour further distinguish the character of the yellow horizon from the deeper part. These irregularities in the smooth surface indicate probable effects of subaerial exposure during periods of lower sea level. There is no apparent relationship between the yellow horizon configuration and the present sea-floor configuration.

An analogous surface, also termed the yellow horizon, has been mapped by Meisburger and Duane (1971), from Fort Pierce to Cape Canaveral. The surface has a near north-south strike and lies from −60 to −140 feet MLW in the Fort Pierce Inner Continental Shelf region. Although the surface is more regular at Fort Pierce than at Cape Canaveral it also exhibits a marked increase in slope at about −100 feet MLW. Between Cape Canaveral and Fort Pierce the reconnaissance geophysical survey lines follow the north-northwest orientation of the coastline; and thus the survey is up dip of both the Fort Pierce and Cape Canaveral areas and the yellow horizon rises accordingly. The surfaces are judged correlative in both study areas and of the same stratigraphic horizon.

No subbottom samples known definitely to be of the yellow horizon have been obtained in either survey. A recrystallized shell *Mercenaria campechiensis* filled with a lime matrix was found in the bottom of core 179 near Fort Pierce; penetration stopped just above the acoustic reflector. The shell, if derived from the yellow horizon, further suggests that the yellow surface underwent extensive subaerial exposure.

c. Blue Horizon. The blue horizon lies 10 to 30 feet above the yellow horizon and is similar to the yellow in slope, dip direction and general continuity. Stratigraphic position and structural character of the blue reflector are shown in Figure 6. Near shore the blue lies at about −40 feet MLW and drops off to −100 feet MLW at the outer edge of the study area. Most of the grid surface has an undulatory configuration marked by minor irregularities, similar to the yellow horizon. The blue surface also changes in slope and increases in regularity on the seaward side of the grid, where near −70 feet MLW, the slope increases to 1 on 700. (See Figure 9.)

Steeply inclined internal bedding is occasionally present below the blue horizon and above the yellow horizon. The bedding dips seaward and is more commonly associated with the outer part of the survey grid. The steep dip angle and monoclinal nature of these units suggest they represent progradational units.

Configuration of the blue horizon, as shown in Figure 9, slightly resembles the modern shelf surface. The pattern of the 60-foot depth contour may indicate the outline of a relict analog to the present Bull, Chester and Southeast Shoals. Comparison of Figures 4 and 9 show a possible similarity in size, shape, and orientation between features of the blue horizon and those on the present sea floor.

Detailed examination of the surfaces, however, show that similarities are only superficial; the blue is flat-lying or nearly flat-lying beneath the shoals. (See Figure 6.) Thickness of sediment overlying the blue horizon, indicates that increased sediment thicknesses as shown

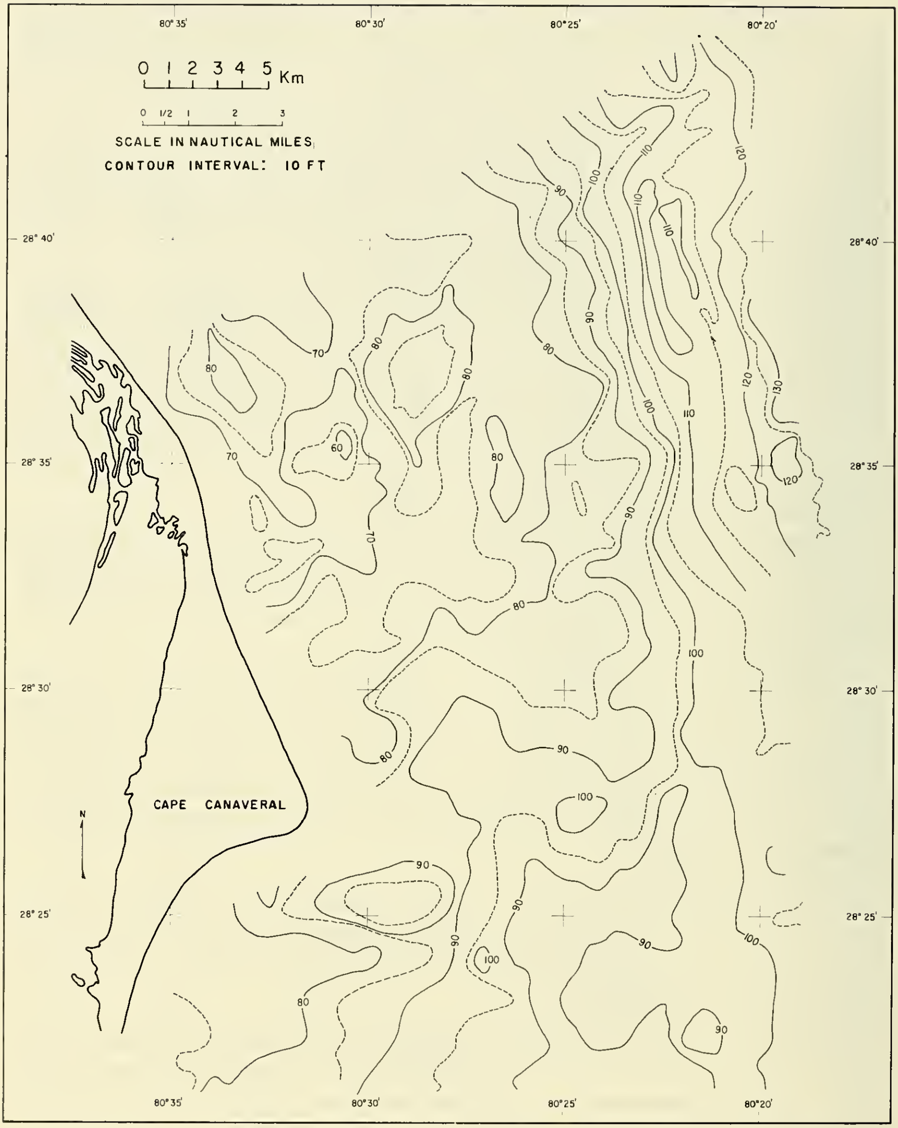


Figure 8. Structure Contour Map of the Yellow Horizon in the Cape Canaveral Grid. Depths are in feet below MLW. Note the irregularities in the surface nearshore, and the increase in dip at the outer edge of the study area.

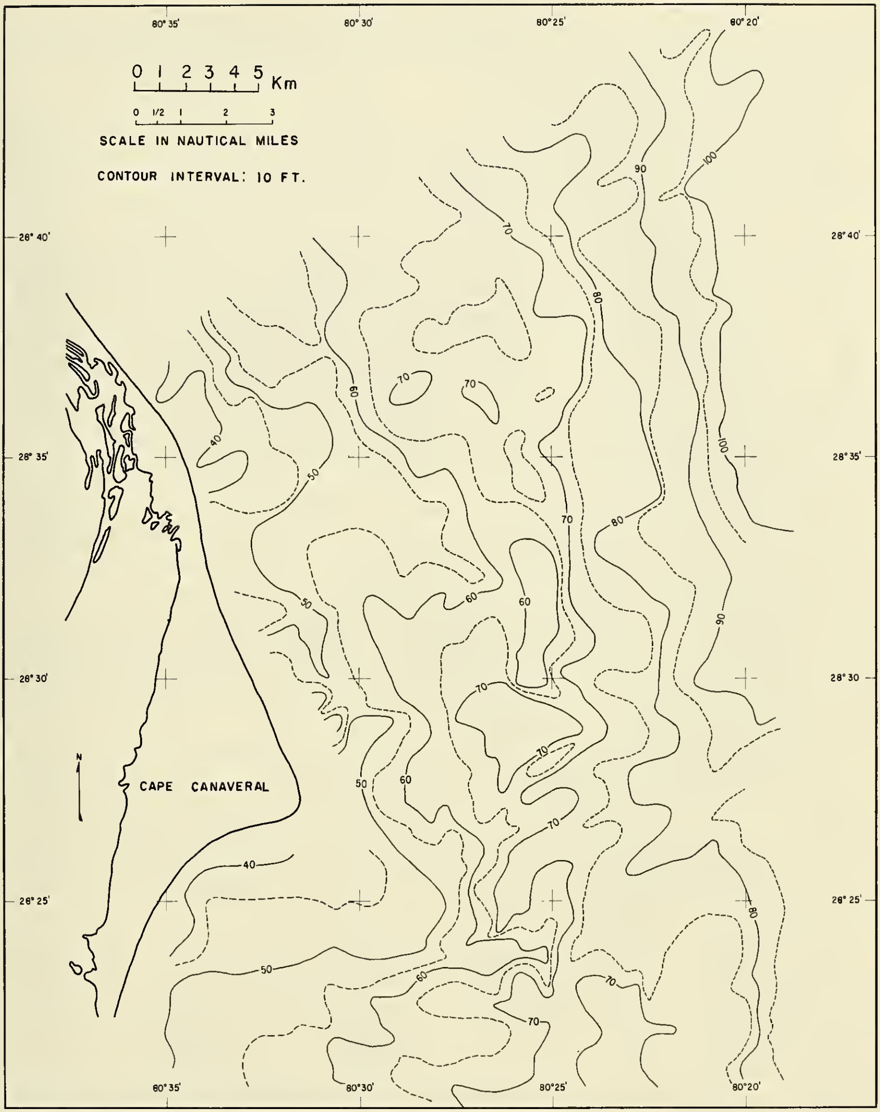


Figure 9. Structure Contour Map of the Blue Horizon in the Cape Canaveral Grid. Depths are in feet. Note similarity of surface configuration to that of the yellow horizon.

on the isopachous map (Fig. 10) correspond to shoal locations and the plano-convex nature of the shoals. Thicknesses greater than 20 feet are beneath Chester Shoal, Southeast Shoal, Ohio Shoal, Hetzel Shoal, and a small area in the northeast corner of the grid where the subbottom slope exceeds the sea-floor slope.

Locations of cores containing samples of the blue material are plotted in Figure 10. The recovered material (Type E) is a partially cemented skeletal sand which was judged deposited during the Pleistocene, and later subaerially exposed and cemented. (See Sections III, a. 5, and IV, a.)

The blue horizon is a continuous surface over most of the south and central Florida Atlantic Inner Continental Shelf. Meisburger and Duane (1971) have traced the surface from Fort Pierce to Cape Canaveral and characteristics of the blue are similar off Cape Canaveral; the surface is generally flat and uniform or gently dipping with only minor fluctuations, and internal seaward dipping reflectors are common on the outer edge of the study area. At Fort Pierce the blue horizon lies between –50 and –100 feet MLW and strikes nearly north-south. Northwest and up dip from Fort Pierce, the blue horizon features out against the yellow horizon and does not reappear until just south of Cape Canaveral.

III. SURFACE AND SUBBOTTOM SEDIMENT CHARACTERISTICS

1. Cape Canaveral Grid.

a. General. Sediment data are based on macroscopic and microscopic examination of 91 vibratory cores of 3-inch diameter and averaging 10 feet in length. Numbered core locations are plotted in Figure 2. Sediment samples were collected at 1-foot intervals from each core; selective cores were split and samples collected at closer intervals for examination.

In general, sediments of the Cape Canaveral Inner Continental Shelf are highly variable in grain size, sorting, composition, and lateral continuity. Although similar sediment types are correlative between individual cores and over small areas, the relation between major lithologies is more complex and diverse than that of inner shelf sediments along reconnaissance lines to the south or north.

Sands off Fort Pierce display a relatively simple surface and stratigraphic distribution. (Meisburger and Duane, 1971.) In that region lithologic differences are distinct and relative position in the sediment column is clear cut (i.e., Type B sediment is always overlain by Type A.) In contrast, Cape Canaveral sediment types are interbedded and interfingered. Some transitions in sediment character are gradual vertical changes while others are marked by abrupt contacts between sediments representing distinctly different environments of deposition.

Major sediment categories in the grid area are: 1) Type A—well-sorted, fine to coarse quartzose—calcareous sands; 2) Type C—muddy coarse shell sands and gravels; 3) Type H—very fine silty sands and muds; and 4) Type E—semiconsolidated, quartz-rich calcarenites. Letters assigned to lithologics are arbitrary and established for this program to simplify correlation and associations of sediment in one area to another. Therefore, Types A, C, and E are similar in character to sediments designated by those letters in the Fort Pierce area; Type H is not present in the Fort Pierce area. In both areas Type E is the lowest sediment stratigraphically and Types C and H are variable in their position. Of these four classes, only Type E is restricted in distribution, occurring in a few localities, generally the deeper parts of the grid. Execpt for calcarenite (Type E), these sediment categories are

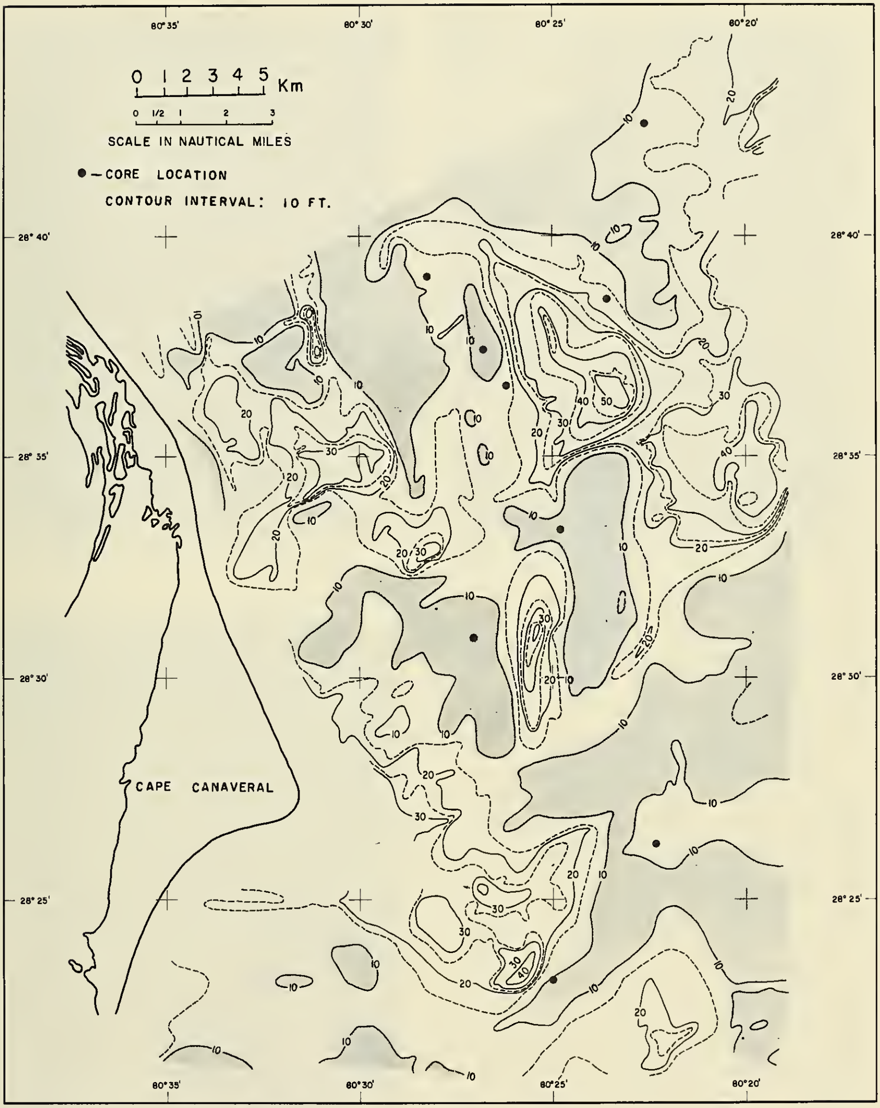


Figure 10. Isopach Map Indicating Depth Below Bottom (in feet) of the Blue Horizon. Gray areas indicate subsurface depths of less than 10 feet. Note the thicknesses of sand underlying the shoal surfaces.

broad classes differentiated from one another primarily by texture and secondarily by composition. Each type incorporates a broad range of sediments with regard to color, stratigraphic position, and immediate origin.

b. Type A Sediment.

(1) Physical Characteristics. The most common type of sediment in Cape Canaveral grid is a fine to coarse, moderately well-sorted sand called Type A sediment. (See Figure 11.) This sand is composed of nearly equal parts of terrigenous and biogenic material; the biogenic component generally decreases with reduction in mean grain size.

Mean grain size of Type A ranges from the middle of fine sand (0.177 mm or 2.50 phi) to the upper limits of coarse sand (0.841 mm or 0.25 phi); most samples have a mean size of between 0.125 mm (2.0 phi) and 0.707 mm (0.5 phi). Sorting of Type A sediments is good relative to other marine sediments in this region; standard deviations range from 0.841 mm (0.25 phi) to 0.420 mm (1.25 phi), very well-sorted to moderately well-sorted in terms defined by Friedman (1962). Standard deviation and mean grain size are plotted in Figure 12 for 131 representative Type A sediment samples. Variation in mean size and sorting in the figure reflects shell size and abundance rather than contribution of fines.

Type A sediments are predominantly light gray (10 yr. 7/1), dark gray (10 yr. 4/1) light brownish-gray and variegated. Variation in color is caused by relative abundance and color of carbonate grains, degree of iron staining of detrital grains, and relative abundance of fines. Surficial iron oxide grain coating is common in many Type A sediments, particularly in the upper 2 core-feet, and has a distinct red-brownish gray (5 yr. 7/2) color to the sediment. Compared to other areas of the southeastern U.S. Continental Shelf, Florida shelf samples consistently contain low abundance (H 4 percent) of iron-stained quartz grains. (Judd, Smith, and Pilkey, 1969.) High abundances (K 30 percent) of iron-coated grains in the study area suggest that either localized concentrations occur in the area or that coating of the grains occurred after collection of the samples, perhaps during storage of the cores.

(2) Composition. Type A sediments contain an admixture of nearly equal parts of terrigenous grains and biogenic carbonate grains. While similar in physical characteristics, Cape Canaveral Type A sediment is more quartzose than sands off Fort Pierce which are about 35 percent. (Meisburger and Duane, 1971.) Most samples contain between 40 percent and 60 percent calcium carbonate by weight; however, fine sands associated with shore-connected shoals contain as little as 15 percent carbonate, and in other areas of the grid, local concentrations of shell yield calcium carbonate values as high as 85 percent.

Terrigenous fraction is predominantly quartz with small amounts of feldspar, heavy minerals and phosphorite. Mica is absent from Type A sediments, perhaps as a function of the combined factors of source distance and grain durability. Quartz grains mostly show signs of recent abrasion and polishing, particularly in the shoal areas. Grains collected at depth of 12 feet subbottom from Hetzel Shoal, Ohio Shoal and The Bull have a high degree of polish and luster, similar to grains from shoal surfaces and the adjacent beaches. Between and seaward of shoals, grains are often covered with a superficial iron oxide and algal coating. Roundness of Type A quartz grains ranges between subrounded and angular; a small percentage of very angular to well-rounded quartz grains is present, however, probably indicating both recent breakage and diagenetic alteration.

Core 103 —1 foot

Core 116 Top

Core 117 —6 feet

Figure 11. Photos of Sediments Classed as Type A

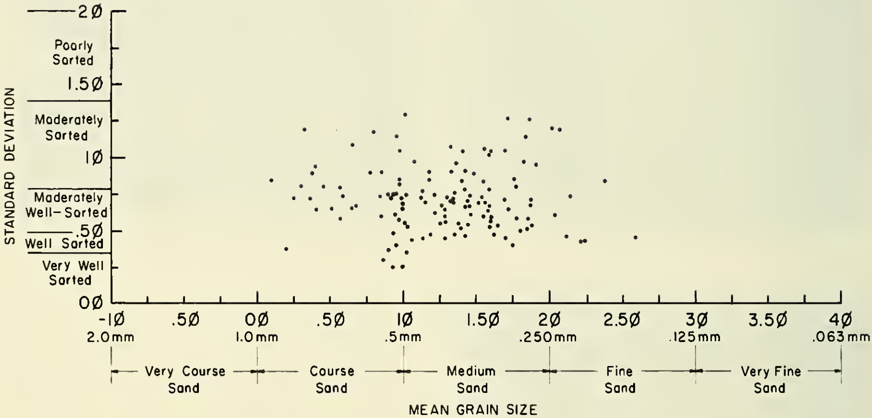


Figure 12. Plot of Standard Deviation versus Mean Grain Size for Type A Sediment Samples from 131 Cores

Feldspar content was determined by point counts of 12 representative samples stained by standard technique. (Hayes and Klugman, 1959.) The procedure consistently yielded values ranging from less than 1 to 2 percent feldspar; these results are similar to those reported by Field and Pilkey (1969) for the central Florida shelf.

Heavy mineral content of Type A sands is low, normally less than 1 percent; no distinct concentrations common to modern beach sands were observed. Specific identification of heavy minerals was not performed, but previous investigators Martens (1928), Tyler (1934), Pilkey (1963), Giles and Pilkey (1965), have listed minerals and abundances for Florida beach and offshore samples.

Most samples contain a low percentage of phosphorite grains in the fine fraction of the sand. Grains are black, blue-black, and amber; surfaces are well rounded and highly polished. In a study of phosphorite in the Georgia Continental Shelf and beach deposits, Pevear and Pilkey (1966), and Pilkey and Field (1972), described similar grains and interpreted their presence in nearshore sediments as evidence of net landward transport of shelf deposits. Gorsline (1963) reported minor percentages of phosphorite in sediments over much of the southeastern Continental Shelf and ascribed their presence to reworking from formations exposed during lower sea level.

Carbonate fraction of Type A sediments consists primarily of pelecypod shells and fragments with lesser amounts of gastropod fragments, barnacles, bryozoa, foraminifera tests, echinoid spines and dermal plate fragments, algae, and oolitic grains.

Table 2 lists the fauna in the Cape Canaveral grid, and their areal distribution, relative abundance, and associated sediment type.

The gravel size and very coarse sand-size particles are mainly pelecypod shells and rounded shell fragments; in finer sized fractions it is difficult to establish the specific contributors of the shell material. Most abundant of the pelecypods is *Mulinia lateralis*, a small ubiquitous clam found on the surface and at depth both in an oxidized state (brown, white) and in a reduced state (black, gray).

Fragments from *Mulinia lateralis* are often polished and always rounded; no angular shells were observed. Other major pelecypod contributors to the Type A carbonate fraction include *Chione cancellata* and *Aequipecten* sp. Lesser contributors are *Donax variabilis, Anomia simplex,* and *Glycymeris undata*.

The general characteristics of multicoloration and lack of angularity applied to *Mulinia lateralis* and also common to the other species, with the following exceptions: *Chione cancellata* is rarely blackened, and fragments of *Aequipecten* sp. and *Anomia simplex* are less rounded, perhaps due to the ease with which they fracture. All of the shells are *fresh* in appearance compared to the highly worn, bored and altered shells described from other regions of the shelf. (Pilkey, et al., 1969.)

The gastropod *Crepidula fornicata* is a common constituent of Type A sediments and is present as whole shells and fragments ranging in color from light gray to black and light brownish gray to dark brown. Frequently, admixtures of all colors are in a single sample. Previous studies have emphasized environmental significance of shell coloring (Maiklem, 1967), and one study (Doyle, 1967) has shown that a relationship may exist between shell color and former strand line deposits. Significance of the color of *Crepidula fornicata* and Type A fauna, either of individual species or as a group characteristic, is not determined. No consistent pattern of linear trends of shell coloring can be related to depth, sediment type, or distance from the present coastline.

Table 2. Lateral Extent and Abundance of Fauna in the Study Area

Fauna	Areal Distribution	Relative Abundance	Major Associated Sediment Type
Pelecypods			
Aequepecten sp.	Widespread	Common	A, C
Anadara notabilis (Röding)	Widespread	Common	C
Anadara transversa (Say)	Widespread	Common	C, H
Anamella eardia cuneimeris	Restricted	Very Rare	E
Anomalocardia cuneimeris (Conrad)	Restricted	Very Rare	A
Anomia simplex (Orbigny)	Common	Rare	A
Chione cancellata (Linne)	Widespread	Common	A, C, E
Chione grus (Homes)	Common	Rare	A, C
Chione intapurpurea (Conrad)	Common	Rare	A
Corbula dietziana (C.B. Adams)	Restricted	Very Rare	A
Crassinella lunulata (Conrad)	Restricted	Very Rare	A
Divaricella quadrisulcata (Orbigny)	Restricted	Rare	C
Donax variabilis (Say)	Restricted	Abundant	C, A
Glycymeris undata (Linne)	Common	Rare	A
Laevicardium laevigatum (Linne)	Restricted	Very Rare	A
Mactra fragilis (Gmelin)	Restricted	Very Rare	A
Mercenaria campechiensis (Gmelin)	Restricted	Common	E
Mulinia lateralis (Say)	Ubiquitous	Common	A, C
Ostrea sp.	Restricted	Rare	C
Tellina sp.	Restricted	Very Rare	A
Venericardia perplana (Conrad)	Restricted	Very Rare	A
Gastropods			
Crepidula fornicata (Linne)	Widespread	Common	A, C
olivella sp.	Restricted	Very Rare	C
other gastropod fragments	Restricted	Rare	A, C, E
Other Fauna			
barnacles	*Widespread*	*Common*	A, C
benthonic foraminifers	Common	Common	A, C, H, E
Bryozoa lunulutiform	Common	Rare	A, C
echinoid spines and plates	Common	Rare	A
Ostracods	Common	Rare	A, C, H, E

Nonmollusk contributors to the carbonate fraction of Type A sediments are echinoid spines and fragments, barnacles, bryozoans, and microfauna. Echinoid particles are rare and show signs of recent breakage. Fragments of barnacles are common, but are rarely more than a few percent of the sediment. This contrasts sharply with the high abundances of barnacles from the nearshore area near Fort Pierce, Florida. (Meisburger and Duane, 1971.) Lunulutiform bryozoans are occasional constituents of Type A sands and do not contribute significantly to sediment volume. Foraminifera, mostly benthonic and a few planktonic and occasional ostrocods comprise the calcareous microfauna.

Calcareous fecal pellets and oolitic grains (ooids) are also minor components of Type A sediments. Ooids frequently account for 5 percent and occasionally up to 15 percent of the carbonate fraction. Single ooids are polished and smooth and vary in color from black to reddish brown and sometimes white. Petrographic analysis of ooid thin sections shows that nuclei are (in order of decreasing frequency): quartz grains, pellets, mollusk fragments, and whole gastropods. Multinucleate ooids are also present, with one or more smaller ooids acting as one of the nuclei. Oolitic coatings are often superficial and high relief parts of the quartz nucleus are exposed. A complete range from well developed oolites to quartz grains with tiny amounts of carbonate in conchoidal hollows suggests grains have undergone abrasion subsequent to formation, rather than incomplete initial formation. Additionally, all grains lack the outer coating of acicular crystals common to ooids found further offshore (Terlecky (1967), MacIntyre and Milliman (1970), suggesting a different history and perhaps a different age. Aspects and significance of the ooids to sediment transport and history of the Cape Canaveral Inner Continental Shelf have been presented elsewhere. (Field, Meisburger and Duane, 1971) (Pilkey and Field, 1972.)

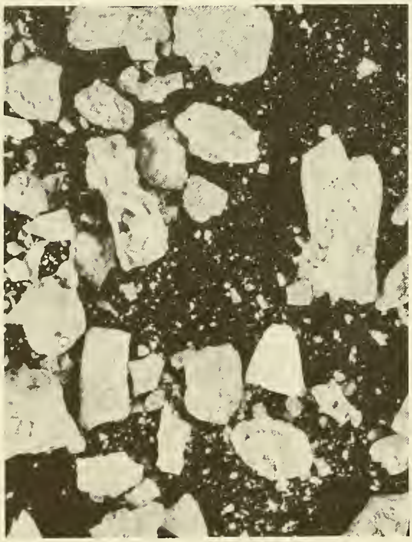
c. *Type C Sediment.* Sediments termed Type C are gray and brown, poorly sorted muddy shell gravels and silty gravelly sands. Photos of representative Type C sediments are shown in Figure 13. The chief characteristic of Type C deposits is the broad range of grain sizes, due both to admixtures of fines (silt and clay) with grains of medium size and larger, and to concentrations of fragmented shell debris which extend the size range on the coarse side. Color is primarily light gray, gray-brown, brown (10 yr. 7/1 through 10 yr. 5/3) and occasionally white and is a result of the abundance and nature of the mud fraction. Silt grains are from both terrigenous and calcareous sources; clay-size particles are chiefly terrigenous with minor amounts from carbonate sources.

The sand fraction of Type C sediments is similar in gross composition to Type A sediments; however, particle characteristics and specific fauna are different. Both terrigenous and bioclastic sand grains lack the high degree of rounding polish that indicates recent abrasion of Type A sands. Quartz grains retain the same shape and roundness but surfaces have a lower luster and are frequently etched and pitted. Shell fragments are more angular. Complete shells are not highly abraded at the umbo like many Type A shells, a characteristic caused by transport in a high energy environment such as the littoral zone. (Molnia, 1971.)

Of the fauna common to Type C sediments, *Anadara* sp. is the most characteristic. *Anadara transversa* (*Say*) and *Anadara notabilis* (*Röding*) are widespread in the study area and are commonly found in quantity. Other fauna include *Mulinia lateralis, Aequepecten* sp., barnacles, microfauna and fragments of whelks. Relative abundance and areal distribution of these and less abundant fauna are listed in Table 2.

Core 96 -1 foot

Core 161 - 4 feet



Core 170 - 3 feet

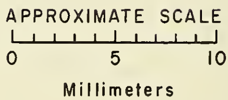


Figure 13. Photos of Sediment Classed as Type C

Type C sediments are found throughout the Cape Canaveral grid, mostly at shallow depths and occasionally on the surface; they do not occupy a set position in the shallow sediment column, but are above and below Type A and Type H sediments. Surface occurrences of Type C are restricted to deeper parts of the grid, mostly the seaward edge and the small basins landward of The Bull and the Ohio-Hetzel Shoal complex.

d. Type H Sediment. Terrigenous muds and very fine-grained sands usually light to dark brown in color (10 yr. 6/2 to 10 yr. 3/1), are Type H sediments. Type H material is quartzose and moderately well sorted for coarser sizes (very fine sand to coarse silt) and poorly sorted for finer sizes (fine silt to clay). Photos of some Type H sediments are shown in Figure 14.

Whole shells and fragments larger than coarse sand size are occasionally present; their distinctly different size, clean "fresh" surfaces, and low abundance suggests they are indigenous fauna. *Anadara* sp. is the most common faunal component (Table 2). Associated fauna are *Mulinia lateralis*, *Crepidula* sp., and echinoid fragments, but their presence in Type H sediments is not as marked as in Type A sands or Type C silty shell gravels.

Very fine sands and coarse silts are comprised of quartz and accessory detrital grains; carbonate content is normally below 10 percent and is contributed by indigenous microfauna, chiefly benthonic foraminifera. Ooids are absent in Type H sediments, but this may be a function of size differences rather than source differences.

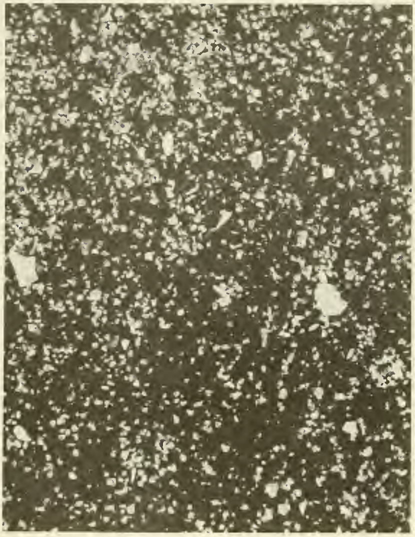
Fine silt components appear to be from a terrigenous source. Organic detritus is present in some muds, particularly in Canaveral Bight. Radiocarbon analysis of peat at −5.5 feet in core 100 yielded an age of over 7,000 B.P.

Type H sediments are present at the surface or at shallow depth throughout the grid. They are absent from the major shoals but are commonly found seaward of the shoals, at the base of the shoreface, and in Canaveral Bight. Cores from the shoreface base show that very fine sands and coarse silts of Type H sediment frequently occupy the entire upper subbottom from surface to the bottom of the core (usually 8 to 10 feet). In Canaveral Bight, all categories of Type H material are present, from very fine sand to clay. The silts, sands and clayey silts often grade vertically into one another from surface to core bottom. Several cores contain Type H sediment overlying Type A sands, a sequence that may represent modern deposition of fines over former beach or shoal deposits.

e. Type E Sediment. Type E sediments consist of white, creamy white and gray quartzose-calcareous sand partially lithified by calcite cement, similar to Type E sediment off Fort Pierce. The sediment is poorly sorted, due to high silt content and presence of gravel-size shells and shell fragments.

Quartz grains account for roughly 30 percent of the material and are fine to coarse sand size; individual coarse grains are often highly rounded with pitted surfaces presumably caused by chemical etching during postburial alteration. The carbonate fraction contains unidentifiable silt grains, mollusk gravel, and sand particles from both biogenic and inorganic sources.

Faunal components of Type E sediment are contributed mainly by *Chione cancellata*, *Mercenaria campechiensis*, gastropod fragments and benthonic foraminifera (Table 2). Shell material is characteristically white or light gray and poorly preserved; surfaces have been highly bored and channeled by organisms, and dissolution and chemical deterioration, probably occurring during subaerial exposure, is apparent. Shells of *Mercenaria* sp. are not rounded or polished.



Core 91 -4 feet

Core 96 -2 feet

Core 126 -2 feet

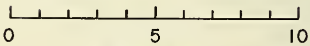


Figure 14. Photos of Sediment Classed as Type H

Other calcareous sand grains are benthonic foraminifera, fecal pellets, and oolitic sand grains. Meisburger and Duane (1971) recorded similar abundances in the Fort Pierce area. Pellets are more common than in other major sediment types and are calcareous. Except for color, ooids are similar in size, shape, layer thickness, and types of nuclei as those from Type A sediments. Type E ooids are white, creamy white, or gray; red-brown and black grains are absent.

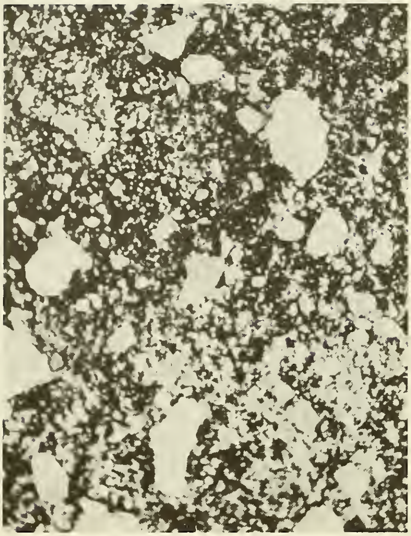
Core samples indicate that Type E sediment is commonly semiconsolidated to unconsolidated. (See Figure 15.) Associated with the loose sand, however, are fragments of well-cemented quartz-rich calcarenite. Petrographic analysis of thin sections of representative rocks revealed that framework grains are the same composition in roughly the same abundances as the surrounding unconsolidated sand. Grains cemented together by blocky mosaic calcite cement (called drusy mosaic by Friedman, 1964) normally indicates formation during subaerial exposure and reprecipitation of low magnesian calcite. (Friedman, 1964, 1968.) Submarine lithification is now recognized as a major process. (Alexandersson, 1969), (Allen, et al., 1969), (Shinn, 1969), (MacIntyre, Mountjoy, and d'Anglejan, 1971.) However, rocks from this area do not exhibit the mineralogic characteristics, such as acicular aragonite, described by these investigators. Additionally, the cementation appears as a widespread continuous layer, as discussed below. It is more likely, therefore, that Type E sediments were cemented during subaerial conditions.

Type E sediments are throughout the Cape Canaveral grid, with the exception of Canaveral Bight. Locations of cores are plotted on the isopachous map. (See Figure 10.) All cores containing Type E sediments were collected in areas with less than 30 feet of sediment on the blue reflector, and most with less than 10 feet of overburden. Several cores on the outer edge of the grid are associated with rock outcrops, ledges, and a hard bottom. (Moe, 1963.) Core 133, in the northeast part of the grid, contains Type E sand from the surface to −10 feet. In this area the blue reflector and presence of semilithified material is clear cut; an acoustic contrast exists between overlying unconsolidated Types A, C and H sediments and the locally cemented Type E sediment. Degree of cementation appears to increase with depth in Type E deposits. Therefore, the regional blue reflector probably does not correlate with the exact stratigraphic contact between unconsolidated Type E and overlying sediments but rather with a point several feet below the contact where consolidation increases.

2. **Canaveral Bight and Reconnaissance Area.**

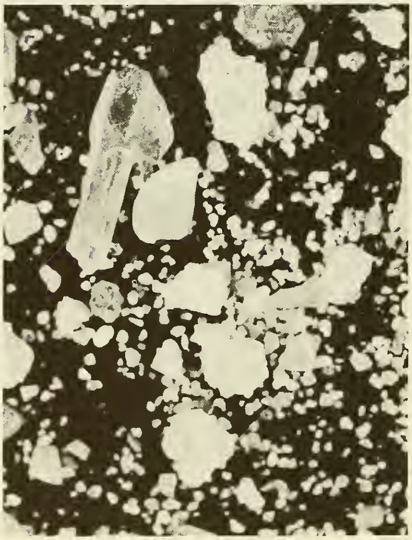
Uppermost shelf sediments in the southeastern part of the Cape Canaveral grid (Canaveral Bight) and south along the reconnaissance line to Vero Beach are distinct and subtle variations in sediment lithology of a mappable, lateral continuity. In general, the sediments are gray in color and consist of biogenous gravels, terrigenous sands and admixtures of terrigenous and calcareous silts and clays. As a result of high mud content, most of the sediments are poorly sorted. Medium-grained, well-sorted to moderately well-sorted sands are present locally, but their distribution is limited.

Gravel-size particles greater than 2 millimeters are chiefly pelecypod shells; minor contributors include other mollusk shell debris and fragments of semiconsolidated calcarenite. Shells are characteristically creamy white, white, and light gray. Shell fragments contained in clean quartz sands generally are well rounded; elsewhere they are angular.



Core 133 -10 feet

Core 133 -6 feet



Core 133 - 4 feet

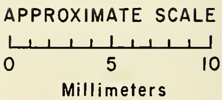


Figure 15. Photos of Sediment Classed as Type E

Sand-size material is predominantly detrital quartz and accessory heavy minerals. Feldspars rarely comprise more than 1 percent of the terrigenous minerals. Micas are generally absent. Biogenous carbonate grains are a significant part (between 10 and 60 percent) of the sands in this region. The grains are primarily mollusks; also present are foraminifera, ostracods, bryozoans and fragments of echinoids and barnacles. Nonskeletal and nonsilicate sand grains are less abundant and include relict ooids, detrital phosphorite grains, and calcarenite fragments.

Clays and silts are abundant in this segment of the study area. These muds are composed of terrigenous clay minerals, detrital quartz silt, and skeletal carbonate silt in various proportions. Calcareous silt constitutes the majority of the fines, mostly in the southern half of the region.

Lateral and vertical distribution of major sediment types is depicted in Figure 16. In general, individual lithologies are characterized by homogeneity and distinct similarities; individual types are correlated through as many as 12 cores and over a distance of 20 nautical miles. Shelf sediments to a subbottom depth of 12 feet in Canaveral Bight are uniform in lithology and extensive in areal distribution (Cores 97, 100, 101, 110, and 115, Fig. 16). The sediments are admixtures of modern terrigenous clays, detrital carbonate and quartz silt, and very fine quartz sands. Gravel-size shells and shell fragments are common in localized concentrations. The shells are light gray and white, and shell fragments are typically very angular, indicating lack of significant transport and abrasion subsequent to fracture. Principal contributor is *Anadara transversa*, but other mollusks are present. Fine calcareous particles in Canaveral Bight are skeletal fragments and tests. A well-sorted medium-grained quartzose sand is present in three of the cores at subbottom depths of 3, 5, and 6 feet. Occasional whole shells of *Mulinia laterata* and *Crepidula fornicata* are present, but most carbonate grains are sand size, blackened mollusk fragments with rounded and polished surfaces, benthonic foraminifera, ooids (1 to 4 percent), and lithoclasts.

Sands enriched in fibrous organic matter and sandy peats are in Canaveral Bight and on the reconnaissance line. (See Figure 16.) These sediments are found in Cores 100, 185, 183, and 181 at subsea depths of 55, 54, 62, and 48 feet respectively. Peaty layers in Cores 181 and 185 did not contain enough organic material to permit a radiocarbon analysis; tests fo Core 183, however, yielded a date of greater than 39,000 B.P. Carbon-14 analysis of the layer in core 100 suggests original deposition occurred 7,320 B.P., probably in an environment landward of the existing shoreline.

The cored sedimentary column changes near Melbourne. Four distinct and continuous lithologies comprise the bulk of sediment volume extending south from the area.

Surface sediment from Melbourne to Wabasso (Fig. 16) is generally a poorly sorted mixture of fines and shell gravel (Type C). The mud fraction of this 1- to 2-foot-thick layer is calcareous and of gray color, high water content, and high plasticity.

Beneath this surficial cover is a relatively thick (3 to 10 feet) and continuous layer of light gray, coarse and muddy, shell sand and gravel. Coarse sand and gravel constitutents are mollusks; *Mulinia lateralis* is the principal contributor. Fine sand-size grains are both detrital quartz and carbonate fragments.

The bottom layer in cores 183 through 186 is a light brownish-gray silty fine sand of quartz and carbonate grains, including abundant benthonic foraminifera. Silt content is from white calcareous grains of unknown origin.

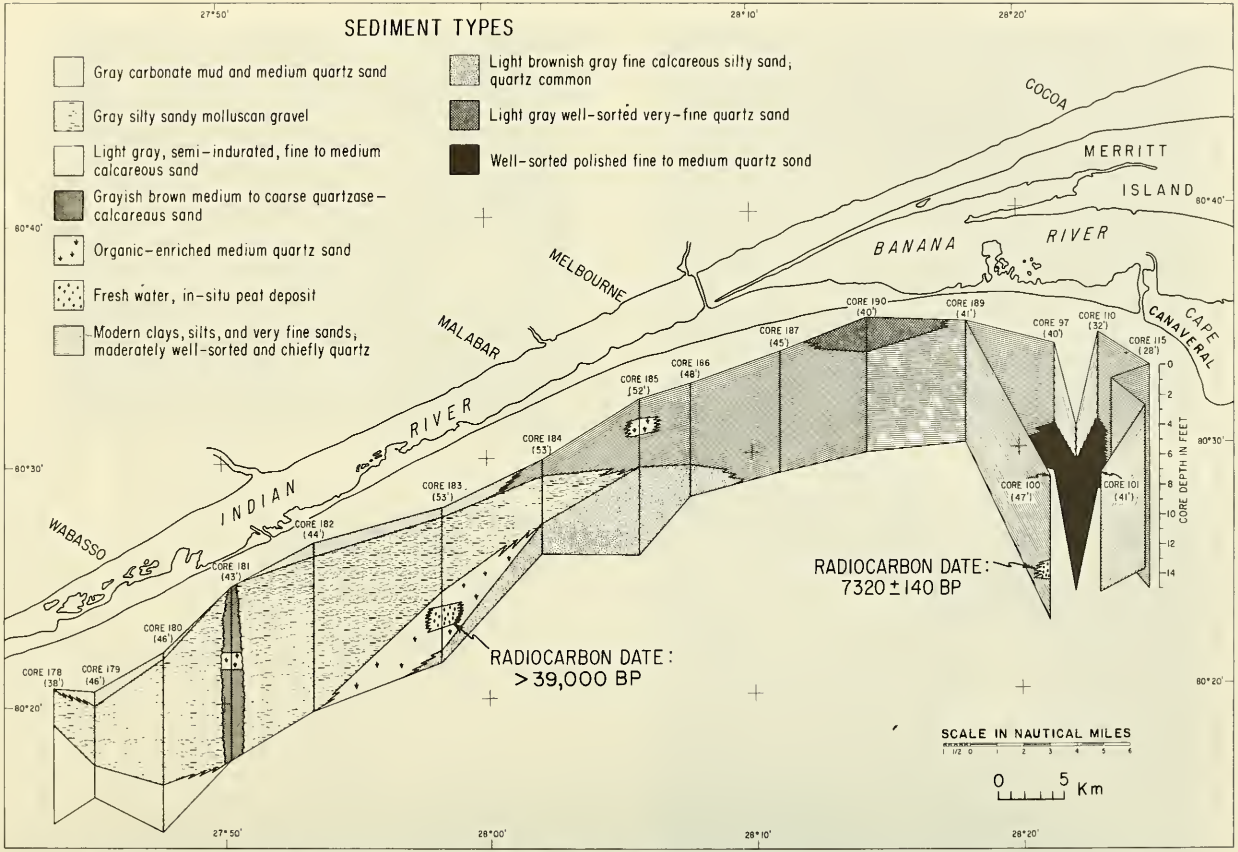


Figure 16. Fence Diagram Illustrating Spatial Distribution of Lithologies South of Cape Canaveral

Cores 178 through 180 contain Type E material with characteristics similar to those in the Cape Canaveral and Fort Pierce areas. However, the sediment included a number of large shells (*Mercenaria campechiensis*) which are chalky white, highly bored and altered, and contain large crystals of calcite indicative of subaerial exposure.

Sediment contained in core 181, primarily a brown, medium quartz sand, is anomalous compared to adjacent cored sands. (Figure 16.) The sand, about 80 percent quartz and 20 percent highly worn and bored pelecypod and barnacle fragments, is similar to those described by Meisburger and Duane (1971) from the Fort Pierce region. There are many similarities in sediment character of the Fort Pierce and Cape Canaveral shelfs, but distinct differences in faunal and mineral assemblages. This stretch of the shelf is considered a transition zone between the two areas.

3. Areal Beach Sediments.

Areal beach sediments range in size from coarse to fine sand and contain between 2 percent and 58 percent acid soluble material. These variations in grain size and shell content of beaches between Melbourne Beach on the south and Ponce de Leon Inlet on the north are a result of coastline orientation and exposure, availability of offshore source materials, and local Pleistocene coquina outcrops. Changes in sediment character are further induced by intense periodic storms, tidal fluctuations, and seasonal changes in wave direction.

Location, percent acid soluble material, mean grain size, and sorting are plotted in Figure 17 for each of 28 beach samples. Each location represents a single sample collected from the swash zone at a specific time; values shown in the figure are not fixed averages. The results show the subtle regional trends and overall variation in characteristics of areal beach sands.

Curves for mean sand size and shell content are directly related—nearly every increase in shell content is paralleled by an increase in mean grain size. This pattern indicates that mean sand size is primarily a function of composition, and is shown by the sorting curve. (Figure 17.) The sorting curve does not always parallel the other two, but decreases in grain size and shell content are frequently marked by a decrease in the standard deviation, indicating better sorting. It further demonstrates the influence of shell material in the areal beach sediments; sands containing lesser amounts of shell material are finer and appear to be better sorted than those enriched in biogenic sand.

Four distinct beach profiles along this coastal segment are shown in Fig. 17. Northern beaches (New Smyrna, Daytona) have a low profile; those opposite Mosquito Lagoon and south to Cape Canaveral are steeper. Beaches in the Canaveral Bight region (Cape Canaveral to Canaveral Harbor) are low profile beaches periodically covered by large piles of shell rubble. South of Canaveral Harbor, beaches have low and medium slopes but their profiles are occasionally disrupted by limestone outcrops. Northern low profile beaches are composed of fine quartz sand (Sample CN 106, Fig. 18). New Smyrna Beach and neighboring beaches are similar in morphology and composition to Daytona Beach on the north side of Ponce de Leon Inlet, and probably represent accumulations of sand from that region. The long stretch of steep beach near Mosquito Lagoon is undeveloped and almost inaccessible; only a few samples were obtained and little is known of the region. Of particular interest is the increase in percent soluble material from 2 percent near Daytona (Sample 012-106, Fig. 17) to over 30 percent opposite Mosquito Lagoon (Sample UM 12, Fig. 17). The change is persistent; all other samples north of Cape Canaveral contain 20 to 50 percent carbonate. Examination of aerial photos of the area for coquina outcrops revealed no surface exposures. These outcrops probably occur in the subtidal zone. The

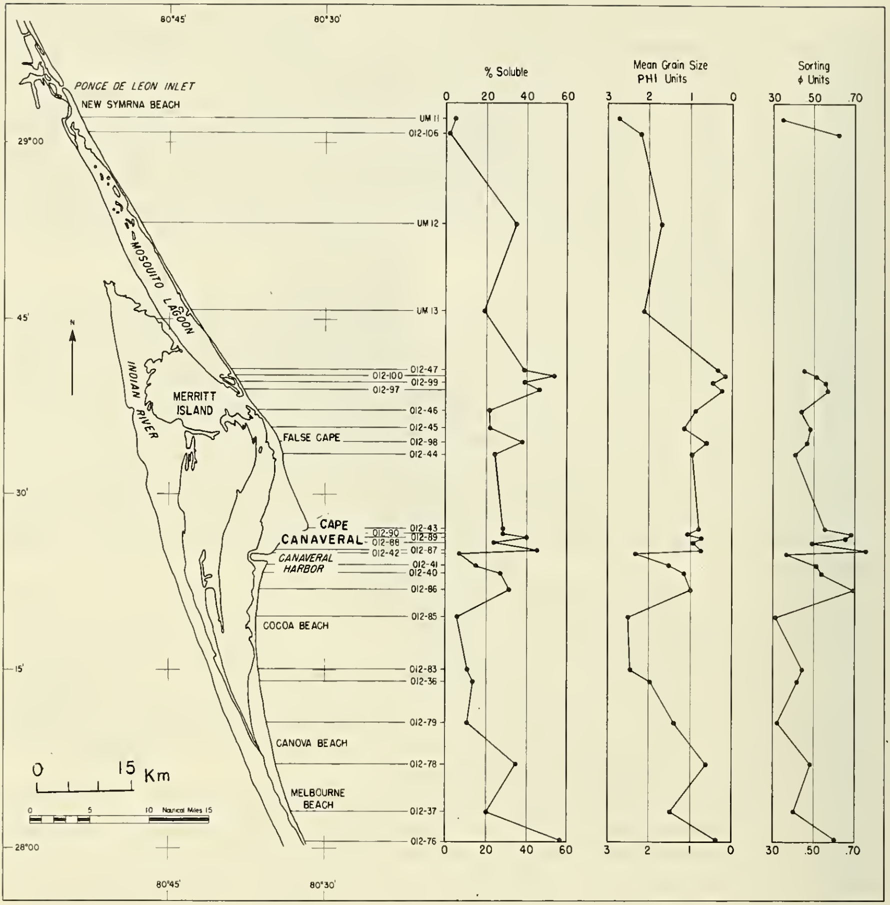


Figure 17. Percent Soluble, Mean Grain Size, and Sorting (Standard Deviation) Plotted for Areal Beach Samples. Note the similarities of the curves indicating the direct influence of shell material on textural parameters.

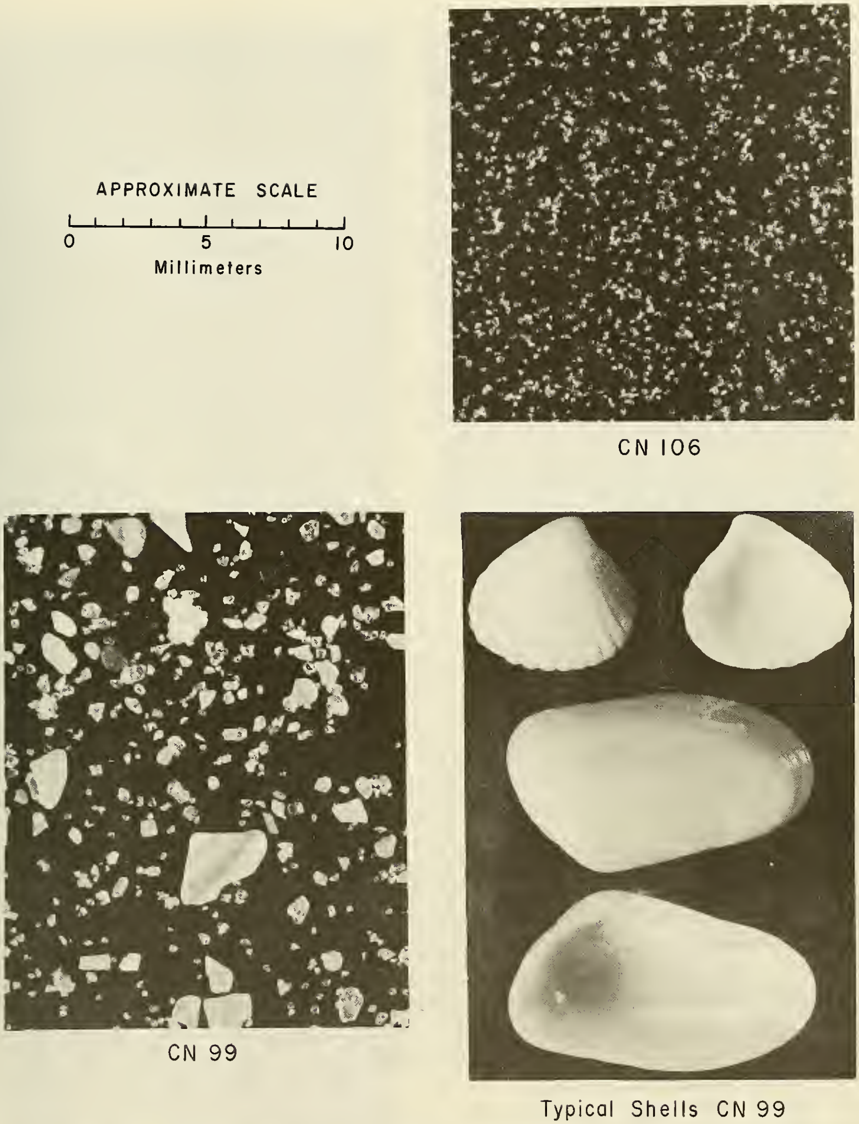


Figure 18. Photos of Typical Beach Sands North of Cape Canaveral. Sample numbers refer to locations in Figure 17. Shells in upper part of photo (CN99) are *Venericardia perplana*; lower, *Donax variabilis*.

likelihood of coquina outcrops is based on similarity of beach and dune morphology and sediments with other segments of the Florida Atlantic coast (Boca Raton, Jupiter Island, Cocoa Beach, Marineland Beach) that are partly nourished by local outcrops of Pleistocene coquina, usually assigned to the Anastasia Formation.

Of 13 samples collected a few miles north of False Cape south to Canaveral Harbor, 10 are coarse sand size and 3 are medium size. (Figure 19.) Sand accumulated behind the north structure at Canaveral Harbor (Sample 012-42, Fig. 17) is fine-sized and low in carbonate. The rubble piles of shell that occasionally mantle the beach between Cape Canaveral and Canaveral Harbor often exceed 8 feet in diameter and are mostly whole shells. These mounds are probably developed during storms which transport the organisms from the adjacent shoreface and shoals onto the beach, thus periodically contributing shell material to the beaches.

South of Canaveral Harbor, beaches become progressively coarser and shell-enriched for a short distance in response to local coquina outcrops. The outcrops represent a remnant strand line, as indicated by composition and seaward dip of 8 degrees, that is being actively uncovered and eroded. Between Cocoa Beach and Canova Beach, shell content and grain size increase in a southerly direction; source material is injected locally into the littoral drift system from large exposures of coquinoid limestone which are present from −3 feet MLW to the berm crest along the coast between Canova and Melbourne Beaches. (Figure 20.)

Components of beach sands are similar to Type A sediments. Terrigenous contribution is predominantly quartz; nearly absent are both accessory light minerals (chert, feldspar, mica) and heavy minerals. Carbonate grains are well rounded and highly polished. Whole shells and large fragments, commonly found in storm rubble piles, show signs of some abrasion before deposition on the beach. Particle color covers the spectrum of red, red-brown, brown, black, gray, and white. Nearly all shell material is "fresh" in appearance; that is, few shells have a bored and worn surface comparable to the relict reworked material from the outer shelf. All shells having red and red-brown coloration are fresh, suggesting that the color is taken soon after death of the fauna by alteration of the organic matrix. Worn shells are frequently gray and black in color, possibly indicating color is derived secondarily by reduction of original iron oxide coating.

Mollusks are the primary contributors of carbonate material, whether from living fauna or reworked coquina deposits. Venus clams, cockles, arcs and other pelecypods are the chief source. However, whelks, conchs and other gastropods, presumably indigenous to the large shoals off False Cape and Cape Canaveral, contribute a significant amount of shell to beaches in that vicinity. The presence of ooids are of particular note, for the grains are derived only from a submarine source, thus indicating contribution of shelf material to the beaches. (Pilkey and Field, 1972.)

IV. DISCUSSION

1. Sediment Distribution and Origin.

a. General. The upper subbottom of the Cape Canaveral survey area contains four distinct lithologies designated Types A, C, E, and H. Type A is commonly exposed on the surface and Type E is always the lowermost unit stratigraphically. Types A, C, and H are present in different vertical positions; their repetition and varying stratigraphic position are due in part to assignment of types on a basis of descriptive lithology rathern than facies

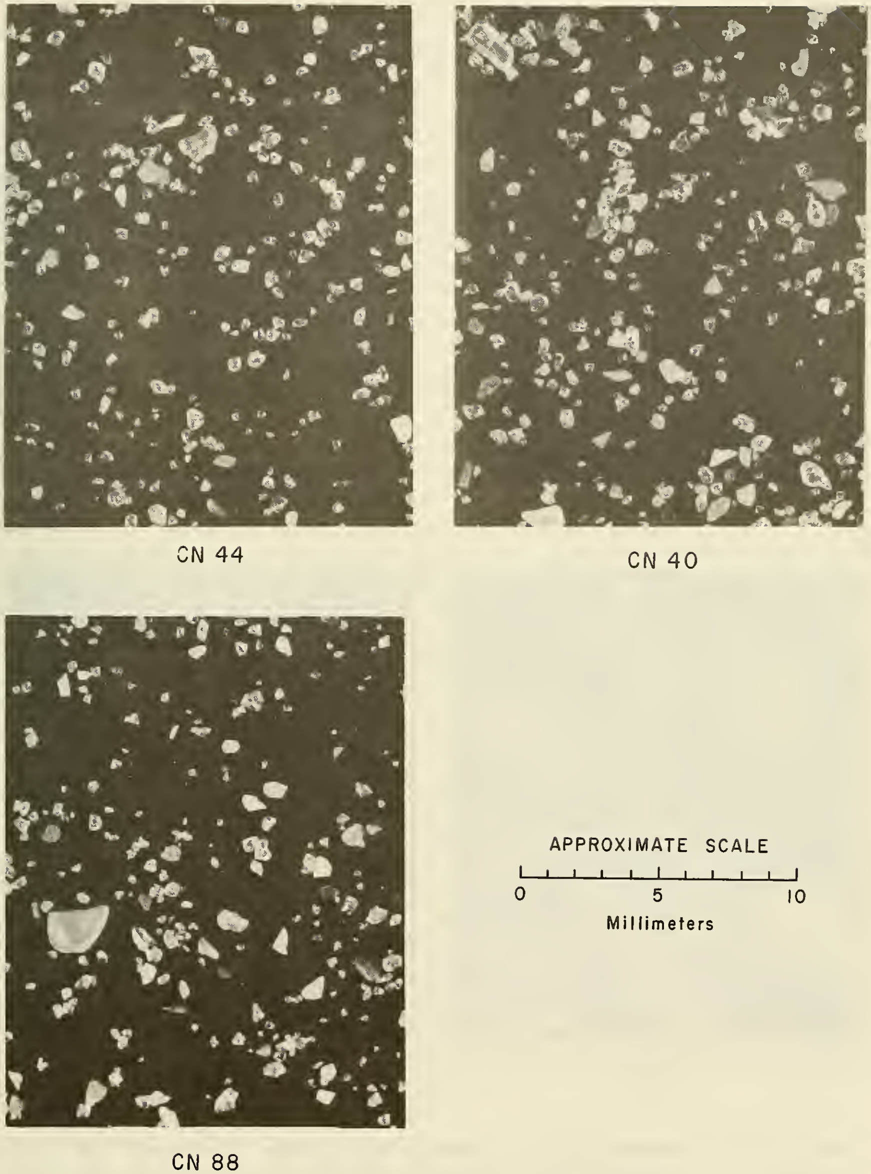


Figure 19. Photos of Typical Beach Sands Adjacent to Cape Canaveral. Sample numbers refer to locations in Figure 17.

CN 83

CN 76

APPROXIMATE SCALE

0 5 10

Millimeters

CN 76

CN 78

Figure 20. Photos of Typical Beach Sands South of Cape Canaveral. Sample numbers refer to locations in Figure 17. Beach photo shows sediment being derived locally by erosion of outcropping coquina.

relationships. Certain generalizations can be stated with regard to age and origin of each type. Type E is a partially lithified Pleistocene calcarenite that in some areas is the source rock for overlying units. Poorly sorted overlying sediments (Type C) are relict from a Holocene lower sea level. Surficial layers of mud in Canaveral Bight and lenses of very fine sand at the bases of Chester and Southeast Shoals are judged to be redistributed modern deposits (Type H) as are the medium and coarse sands (Type A) which blanket the inner shelf in sheet and shoal deposits.

b. Semiconsolidated Sediments (Type E). Three lines of evidence indicate that Type E material is derived from the geologic strata generating the continuous and mappable seismic reflection of the blue horizon. First, the lithologic difference between Type E and overlying sediment types is marked, particularly the occasional appearance of an intergranular cement that is likely to produce a widespread acoustic contrast such as depicted by the blue horizon. Second, there is a correlation between location of cores containing Type E material and areas of thin overburden (all 20 feet and most 10 feet). Third, strata associated with the blue horizon seem to crop out or lie near the surface at the outer edge of the grid, described earlier by Moe (1963) as an uneven bottom with numerous rock ledges and terraces over 6-foot relief.

Type E sediment is chiefly skeletal fragments and quartz; the fauna is similar to that of other sediment types of the grid area, such as the abundance of *Mercenaria campechensis* and *Chione chancellata*. Both pelecypods indicate clean or slightly muddy sand substrata in an intertidal or subtidal environment. (Stanley, 1970.) *Donax variabilis* shells in core 144 at −6 feet subbottom depth corresponds to the position of the blue horizon; *Donax* inhabit the intertidal zone and are excellent indicators of shoreline position. (Abbott, 1968), (Stanley, 1970.) Less than 5 percent of calcareous oolitic grains (ooids) are in rock fragments and unconsolidated sands of Type E material. Formation of ooids usually occurs in a warm, saline, agitated water, by concentric deposition of calcium carbonate around detrital skeletal and terrigenous grains, and are good indicators of an original shallow water environment. (Monaghan and Lytle, 1965), (Newell, Purdy and Imbrie, 1960), (Ginsburg, et al., 1963.) These lines of evidence suggest that Type E sediments were deposited in a shallow marine environment and later partially lithified under subaerial conditions.

c. Relict Holocene Sediments. Type C sediment, judged a relict deposit, is present throughout the grid in variable thicknesses, usually less than 3 feet. Occasionally the sediment is exposed at the surface, mostly in the shallow depressions near the shoals. The sediment is nearly ubiquitous, but its characteristics vary and its distribution lacks continuity.

The wide variation in grain size of Type C sediments due to the mixture of terrigenous silt and sand and calcareous sand and gravel, and the faunal assemblage, is indicative of the origin of the material. Poor sorting suggests a low energy environment where sediments accumulate by a variety of slow processes, such as a lagoon or lee side of a barrier. Principal fauna are representative of protected waters. *Crepidula fornicata, Anadara* sp. are mollusks which typically inhabit a quiet marine environment. (Bernard, Le Blanc, and Major, 1962), (Stanley, 1970.) Ooids are occasionally in Type C sediment, and their presence suggests that some sand-size Type C sediment is from bottom erosion of the underlying blue layer (Type E sediments). The fauna of the blue layer and the evidence of coquina exposures in this area, suggests that some shells associated with Type C sediment are not indigenous fauna.

d. Modern Mud Layers and Sand Bodies on the Inner Shelf. Large volumes of Type H sediment (very fine sands and silts) are restricted in distribution to the surface and subsurface of Canaveral Bight and the area adjacent to the shoreface north of Cape Canaveral. (Figure 21.) Layers of Type H material are at shallow sediment depths near the seaward edge of the grid, but their origin is different from either small single shell and tests, thin angular shell fragments, or a small percentage of carbonate silt.

Type H material mostly represents both Holocene and modern deposition of fine-grained sediments in protected areas where littoral processes are less active compared to the shoaler open coast. Large swells approach Cape Canaveral from the east and northeast and hurricanes passing within a 150-mile radius occur once every 3 years. (U.S. Army, Corps of Engineers, 1967.) The area between the two shore-connected shoals is partly protected from these rigorous forces and is the site of deposition of fine and very fine sands selectively sorted from the shoals and upcoast beaches. Canaveral Bight is protected from northeast swell by the projection of the cape and associated shoals. Surficial muds and very fine sands are derived by bottom erosion, shore erosion south of Canaveral Harbor, winnowing of fines from the shoal areas near the cape, and perhaps a small fraction from turbid sediment-laden water from Canaveral Harbor.

Definitive studies required to assess the source most influential in terms of volume input to the bight area are beyond the scope of this report. However, it seems probable that deposition is minimal. The peat layer in core 100 (Fig. 16) at a subsurface depth of 6.5 feet was deposited about 7,320 B.P. No well defined breaks in the sediment character indicate a hiatus, but deposition has probably been discontinuous since the formation of the peat in a lagoon or swamp environment. The rate of deposition of Type H sediment in the bight, based on the age and depth of the peat deposit is approximately 0.1-foot per 100 years.

Type A sediments mantle most of the Cape Canaveral survey area, and specific sediment characteristics vary with location. All of the sands are well sorted, medium to coarse and of nearly equal fractions of terrigenous and calcareous grains. The thickest accumulations of Type A sediment are in the shoals region and the seaward edge of the grid. Figure 21 is a map of Type A thicknesses as determined from core sample data; it shows the influence of the shoals, and the nearly continuous surface extent of the sand. Shore-connected and isolated shoals are plano-convex features on a flat or nearly flat surface. (Figures 6 and 10.) It cannot be determined from available data if Type A sediments extend from the shoal crests down to the blue horizon, but 14-foot-long cores from the shoals indicate they extend to at least that depth.

Type A sand is the result of older sediments being actively reworked, sorted and redistributed by bottom currents, storm waves and organisms. This sediment which has petrographic criteria of being remnant from a earlier depositional environment, but is actively reworked can be described as *palimpsest*. (Swift, Stanley and Curray, 1971.) Evidence for this recent activity is the wide surficial cover, the consistent medium-to-coarse grain size, and distinct lack of fine-grained sediments in the sorting values. The abraded polished nature of the calcareous fraction and the near absence of easily abraded biogenic grains strongly suggests continual transport of this sediment. Samples from 14 feet beneath the shoal have textural and grain characteristics identical to those from the surface, indicating the shoal sediment at that depth may have been recently in motion.

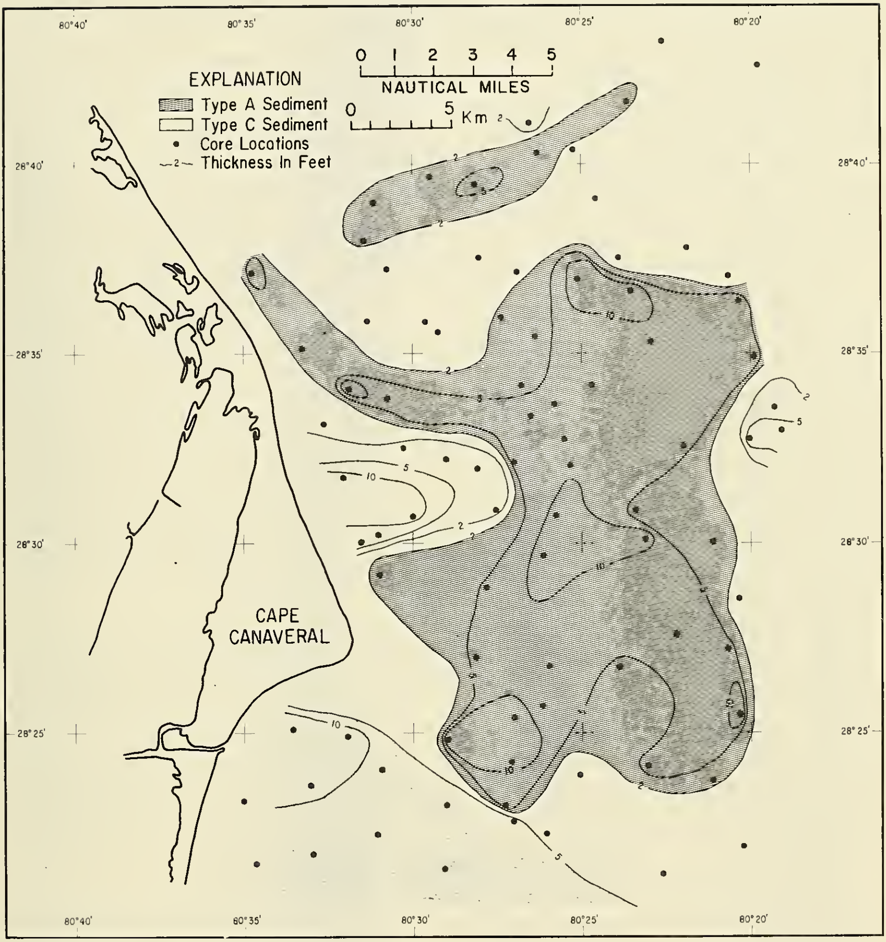


Figure 21. Surface Distribution and Isopach Map of Sediment Thickness of Types A and C. This map is based on data from sediment cores; sediment character was not extrapolated beyond the core length.

Terrigenous fraction of the Type A sand is derived ultimately from the complex metamorphic rocks of the southeastern United States as shown by Pilkey (1963, 1968). Paucity of heavy minerals and feldspar suggests that the sediment has undergone one or more previous stages of deposition, erosion and transportation. Calcareous fraction contains both modern shells formed and deposited under conditions similar to those at present and older reworked biogenic grains from underlying sediments. Evidence for derivation of Type A sands from older underlying sediments (mainly Type E) is the presence of fauna not indigenous to the survey area, such as lagoonal species, and of the small percentage of oolitic grains. Ooids are not forming in this area at present and those in surface deposits resemble Type E ooids in size, nucleii, and degree of completeness. Figure 22 shows the occurrence of ooids in beach, shoal and subsurface deposits. The ooids are from Type E sediment; elsewhere, the occurrence of ooids implies that erosion and reworking are taking place.

e. Beach Sediments. Beach sands in the Cape Canaveral region are derived and maintained by lateral transport of littoral currents and by onshore transport from optimum wave conditions. Florida rivers are near grade and are not effective conduits of sand to the Atlantic Ocean. Effect of transport by the larger Georgia rivers which drain the Piedmont Province is unknown. Sediments transported into the region by littoral processes are from erosion of Volusia County beaches and the coastal formations which occasionally crop out on the beach, in the littoral zone and offshore. Sediments delivered to the beaches from offshore originate from modern biogenic production and bottom erosion. Storm deposits of organisms living on the shoreface periodically nourish the carbonate fraction of the beach sands. Onshore transport of Type A sand is inferred from the similarity of beach sand and Type A shelf sand. Especially indicative of this mode of supply is the presence in all Cape Canaveral beach sands of oolitic grains, which are exclusively from offshore sources. (Pilkey and Field, 1972.)

2. Quaternary Development of the Inner Shelf.

The marked influence of eustatic sea-level fluctuations associated with Pleistocene glaciation is evident in the subbottom geologic record of the Cape Canaveral area. Undulatory tertiary strata (green horizon) are evident only below 160 feet. (See Figure 7.) Above this depth, strata bear evidence of having been truncated and buried through terrestrial and marine processes acting in response to fluctuations of sea level. The red horizon (Fig. 6) probably represents the lowermost surface cut by Pleistocene seas. Interpretation of the geologic history of the upper subbottom (20 feet) is simplified and facilitated by the recovery of subsurface core samples. Ages of the upper subbottom units are schematized and correlated to eustatic events in Figure 23.

The yellow horizon is a shallow mappable surface lying an average of 80 feet below the sea floor and dipping at an angle slightly greater than the sea floor. A lack of samples from the yellow surface precludes analysis of its characteristics or origin. However, two samples from just above the yellow horizon indicate that the surface is as old as the Sangamon interglacial, and probably was formed during the regression or transgression associated with that time. Shotton (1967) places the midpoint of the Sangamon (last) interglacial at about 105,000 B.P. *In situ* plant debris having a radiocarbon age of 39,000 B.P. (core 185) indicates sediments of the underlying yellow layer are at least that old. A large shell (*Mercenaria* and *campechiensia*) obtained from core 178 at −8 feet is altered to chalk with occasional 0.5-mm crystals of calcite on the exterior and in boring and solution cavities, indicating exposure of the shell to subaerial conditions.

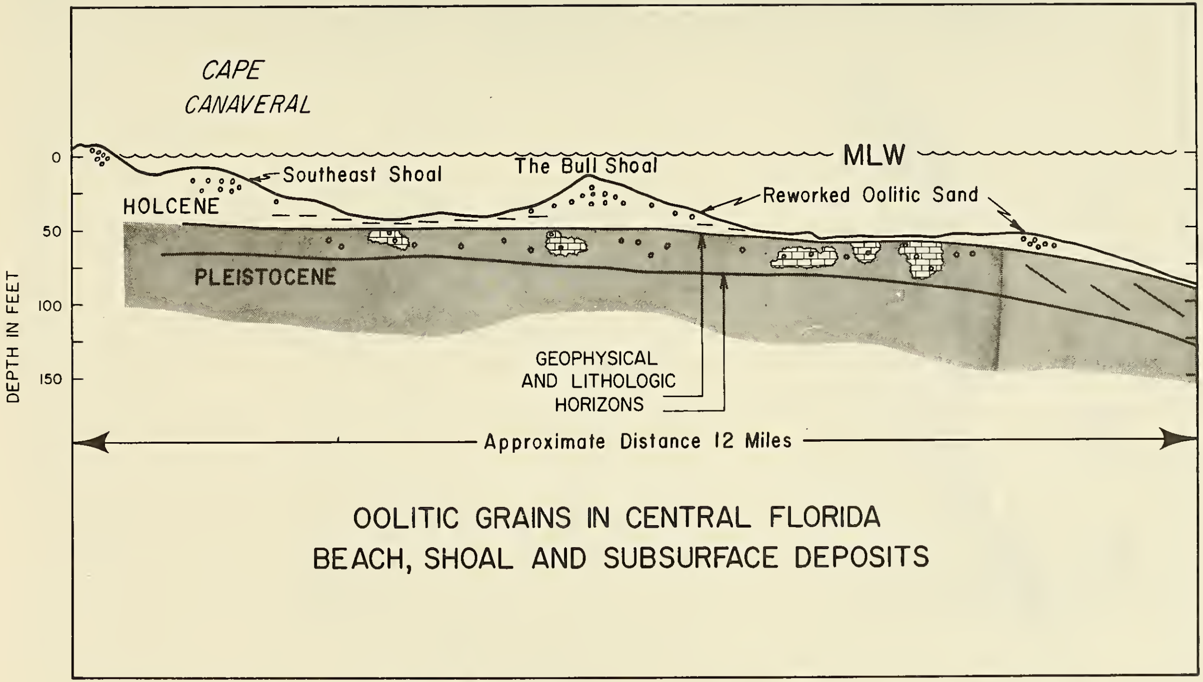


Figure 22. Schematic Diagram Showing the Vertical and Horizontal Occurrence of Ooids. Ooids in surficial deposits show the derivation of some surface sediment from underlying deposits; ooids on beaches suggest an exchange of material is occurring between the beach and the shoals.

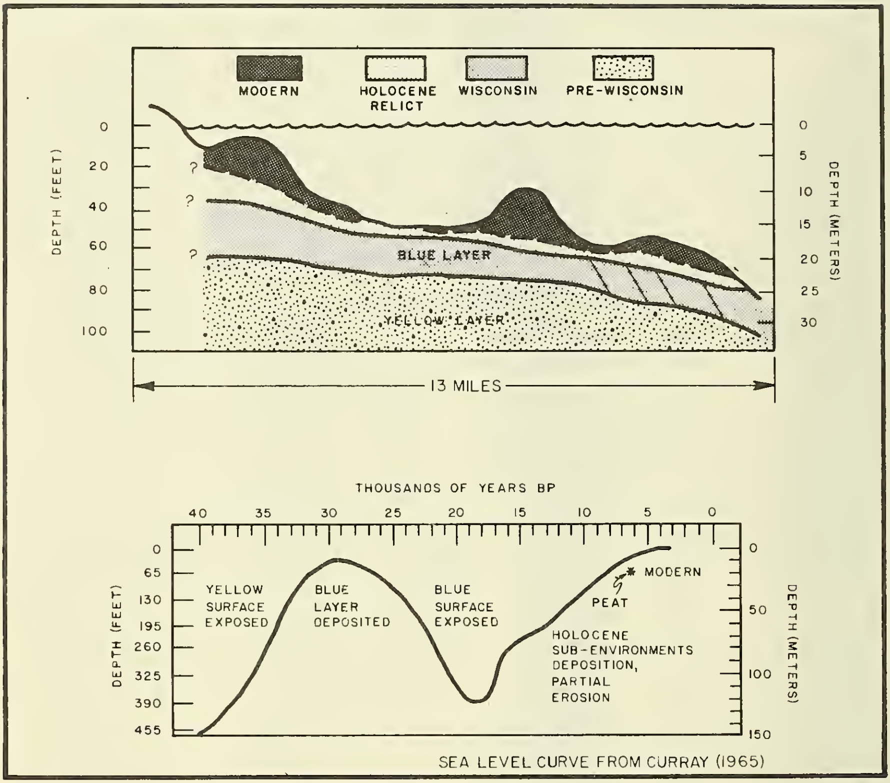


Figure 23. Cross Sectional Profile of the Cape Canaveral Inner Continental Shelf Showing Interpretations of Relative Age and Quaternary History. Major events are plotted on Curry's sea level curve.

The blue layer, well defined by mapping of upper reflector surface (blue horizon) and recovery of sediments comprising the layer (Type E), is a lagoon-barrier-inner shelf sedimentary complex deposited during initial stage of the late Wisconsin regression and later exposed subaerially until inundated by the Holocene Transgress. Evidence for its relative age development (Fig. 23) is that peats which stratigraphically overlie the blue horizon at Fort Pierce, Cape Canaveral and Jacksonville, are mid-Holocene in age (7,000 to 10,000 B.P.) and subbottom samples from the blue layer (Type E material) show subaerial exposure. Thus deposition occurred at least before the late Wisconsin low sea level. Deposition during regression is postulated from abundance of acoustically defined and steeply inclined seaward dipping internal stratification in the blue layer and correlation of the blue horizon with a subsurface strand line deposit of *Donax variabilis* (Core 144) having a radiocarbon age of 23,500 B.P. (Field, 1974.) Interpretation of environment of deposition is from abundance of lagoonal and intertidal biota (*Chione cancellata, Mulinia lateralis, Mercenaria campechiensis,* and *Donax variables*) and the presence of oolitic grains, generally accepted as indicators of shallow, agitated water masses. Elevation of the mid-Wisconsin sea level high is not firmly established (Curray, 1969), but substantial evidence shows that the sea covered the shelf to the approximate position of modern coastal regions. (Guilcher, 1969), (Hoyt, Henry, and Weimer, 1968.) The age and materials of onshore Cape Canaveral relict barriers (Osmond, May, and Tanner, 1970), agree with those of a similar deposit offshore. (Field, 1974.) Exposure of the blue layer following the late Wisconsin regression probably resulted in differential weathering and formation of a soil profile. Preceding the last sea level rise, it is judged the surface of the blue layer exhibited the general characteristics of a low-lying limestone plain described by Legrand and Stringfield (1971), and similar in appearance to the present coastal province of Florida between Cape Canaveral and Fort Pierce.

Overlying the blue horizon are relict and modern Holocene lagoon and nearshore deposits. Preservation of a peat deposit (Core 100) of probable freshwater origin suggests the following sequence of events—subsequent to the last lowering of sea level as the ocean transgressed the inner shelf about 5,000 to 8,000 B.P., the exposed, weathered surface of the blue layer was inundated, eroded, and later mantled by coastal deposits. The poorly sorted character of Type C sediments, and the abundance and unabraded, fractured appearance of lagoonal mollusks indicates a quiet, protected environment. Mantling most of the study area is a well-sorted, medium-to-coarse quartzose-calcareous sand (Type A) which is presently being reworked and redistributed. These surficial sediments have been generated in part by biogenic activity and southerly littoral transport of eroded coastal materials; most, however, have been derived by bottom erosion of the underlying Pleistocene deposits. Most erosion of the older weathered surface occurred as the sea transgressed the area, but both physical and biological erosion are still active in some areas. At a few locations in the grid area the Pleistocene surface (blue layer) crops out; seaward, numerous ledges, outcrops, and rock surfaces have been delineated by Moe (1963). Derivation of surficial sands from the Pleistocene substrate is evidenced by similarities in composition between the two layers. Specifically, the modern sands contain ooids, clasts of intergranular carbonate cement, few heavy minerals, similar fauna, and well rounded quartz grains characteristic of the underlying semilithified sediments. Thus Type A sands, actively resorted at present, display attributes of a previous depositional environment and are interpreted as *palimpset* sediments, defined by Swift, Stanley and Curray, (1971).

Development of the prominent, isolated shoals Ohio-Hetzel and The Bull, located in the center of the survey grid, appears to be related to the formation of the large shoals (Southeast and Chester) extending southeast from Cape Canaveral and False Cape. The ends of both shoals trend perpendicular to the major axis of the cape shoals, giving each a hammerhead appearance. The ends of Chester Shoal and Southeast Shoal have a northeast-southwest orientation, whereas the shoals lie northwest-southeast. (See Figure 5.) The Bull has a northeast-southwest trend and is nearly the same size and shape as the tip of Chester Shoal. Alignment and similarities in sediments and structure between The Bull and the end of Chester Shoal suggest the former represents an earlier extension of Chester Shoal which was separated and stranded by a retreating shoreline. Ohio-Hetzel Shoals probably have a similar origin, but it is speculative to interpret the genesis solely on basis of topography. On the updrift side of Chester Shoal, small linear shoals have developed. (See Figures 4 and 5.) Data are not available on the structure or sediments of these shoals. However, bathymetric evidence suggests they represent various stages in the formation, separation, and isolation from the shoreface. High luster and smooth polish of grains from depths of 13 feet in shoaler areas of the survey grid, suggest sediments are probably being reworked to those depths or have been recently buried. Periodic historical depth surveys substantiate some movement of the shoals, and the major direction of shift is southeast.

3. Inventory of Sand Deposits.

a. Sand Requirements. Sand volume requirements for initial fill and annual nourishment of Brevard County beaches are detailed in the Beach Erosion Control Study of Brevard County by the Jacksonville District (U.S. Army, Corps of Engineers, 1967); a more recent assessment of shoreline conditions are presented in the Regional Inventory Report, National Shoreline Study. (U.S. Army, Corps of Engineers, 1971.) Fill requirements for Brevard County are itemized in Table 3. Sixteen miles of Brevard County shoreline are undergoing severe erosion and require about 6.75 million cubic yards of fill for initial restoration of beaches to meet present design standards. The more recent National Shoreline Study lists 23 miles with a critical erosion condition. Nourishment of the Kennedy Space Center, Cape Kennedy Air Force Station, city of Cape Canaveral, Patrick Air Force Base, and Atlantic and Melbourne will require 747,000 cubic yards per year. Of the 37.3 million cubic yards needed for periodic nourishment over a 50-year period, 12 million cubic yards will be supplied by the sand bypassing system at Canaveral Harbor to the city of Cape Canaveral beach area. The remainder must come from borrow sources. Inland and lagoonal borrow sources are abundant in this region; however, letters from the Florida Board of Conservation, U.S. Fish and Wildlife Service, and the Florida Game and Fresh Water Fish Commission (U.S. Army, Corps of Engineers, 1967, Appendix G) state the importance of inland and lagoonal water masses for propagation and support of biologic communities, and that sand for beach nourishment should be obtained from offshore sources.

Parts of Volusia County coastal area are undergoing severe erosion and the Jacksonville District is presently seeking authority for a Beach Erosion Control (BEC) study of the area. Of 23 proposed Florida BEC studies, Volusia County rates the third highest in priority, and Daytona Beach and the stretch south of Ponce de Leon Inlet (New Smyrna Beach area) are the most critical areas in the county. (U.S. Army, Corps of Engineers, 1967.) Preliminary examination of seismic and core data from the Volusia County part of the Inner Continental

Shelf indicates that offshore sand deposits suitable for beach nourishment may be sparse. Therefore, deposits from the Cape Canaveral area are a potential borrow source for nourishing Volusia County beaches.

Table 3. Fill Requirements for Brevard County

Brevard County	Beach Length	Initial Fill	Nourishment	
			Annual	50-Year
	(mi.)	X 10^6 *	X 10^6 *	X 10^6 *
Kennedy Space Center	4.9	2.50	0.195	9.75
Cape Kennedy A.F. Station	4.0	2.00	0.162	8.10
City of Cape Canaveral	2.8	0.998	0.240†	12.00
Patrick Air Force Base	2.3	0.700	0.082	4.10†
Indialantic-Melbourne	2.0	0.603	0.068	3.40
Totals	16.0	6.801	0.747	37.35

*In cubic yards

†To be furnished by sand transfer plant at Canaveral Harbor

b. Suitability. Offshore deposits compare favorably to beach sands in both granulometric and compositional characteristics. Of 119 beach samples collected from 12 representative profiles in the Cape Canaveral area by the Jacksonville District, the median size ranges from 0.08 to 1.07 mm (3.8 to –0.1 phi). Average median diameters by position on the beach for all the profiles are summarized in Table 4. Beach samples collected at MLW (Fig. 17) range in mean size from 0.196 to 0.910 mm (2.35 to 0.14 phi); the average mean size for the 27 samples is 0.48 mm (1.10 phi). Comparison of the two average diameters from MLW of 0.42 mm (U.S. Army, Corps of Engineers, 1967), and 0.48 mm (this study) with the size distribution of Type A sands (Fig. 12) shows a correlation between the offshore and onshore sand sizes. The spread of mean sizes in Figure 12 and Table 4 further indicates a range of sizes sufficient to provide material for the entire beach profile, from dune to –30 feet MLW.

Beach sands and offshore Type A sands are similar in mean size, sorting, composition, and particle characteristics. (See Figures 12, 17, and 25.) Mean size versus percent insoluble residue is plotted in Figure 25 for 27 beach sands and 20 representative Type A samples. Beach sands exhibiting insoluble residue percentages similar to shelf percentage are (considering total sample) generally coarser in size, probably due to the addition of both coarse, coquina-derived, shells and fresh shells not yet abraded or fragmented. Sands which have undergone selective sorting in the beach zone are finer and more quartzose than the shelf sands. The carbonate of beach and offshore sands is durable; the preponderance of mollusk shells and fragments and the paucity of other more easily abraded biogenic material (calcareous algae, echonoid fragments) qualifies Type A sediment as a suitable source for beach nourishment. Because of variation in properties other than composition, such as texture and spatial distribution, some Type A deposits are not recoverable or deemed unsuitable as a borrow source.

Table 4. Comparison of Mean Grain Size and Standard Deviation for Sands from Potential Borrow Areas and Beach Profiles

Offshore Borrow Area Sands				
Potential Borrow Area	Mean Size (Median)		Standard Deviation	
	(mm)	(ϕ)	(mm)	(ϕ)
The Bull	0.28 to 0.51 0.29 to 0.66	1.83 to 0.97 1.80 to 0.74	0.67 to 1.82	0.58 to 0.86
Ohio-Hetzel Shoal	0.27 to 0.73 0.29 to 0.68	1.87 to 0.46 1.81 to 0.57	1.20 to 2.32	0.26 to 1.21
Chester Shoal	0.39 to 0.67 0.39 to 0.69	1.35 to 0.57 1.36 to 0.58	0.65 to 0.73	0.62 to 0.44
Southeast Shoal	0.31 to 0.77 0.33 to 1.12	1.69 to 0.37 1.62 to 0.17	1.46 to 2.1	0.54 to 1.07

Canaveral Beach Profile Sands			
Position on Profile	Median Size		
	(mm)	(ϕ)	
Dune	0.38	1.39	
Dune to MHW	0.38 to 0.49	1.39 to 1.00	
MLW	0.42	1.25	
Depths of 3, 6, and 12 ft.	0.13 to 0.22	2.95 to 2.18	
Depths of 18 and 30 ft.	0.29 to 0.36	1.72 to 1.48	

c. Potential Borrow Areas. Approximately 60 × 10^6 cubic yards of Type A sand lie in the Cape Canaveral grid at thicknesses of over 5 feet. (See Figure 21.) This computation, based on core data, indicates a minimum volume of sand available as a borrow source since the total sand thickness was not always penetrated.

Four areas are suited as borrow sources based on their textural similarities with areal beach sands and the known consistent thickness of the deposits. These potential borrow areas (Fig. 26) are: Chester Shoal, Southeast Shoal, The Bull and Ohio-Hetzel Shoal. Photos of representative samples from three of the shoal areas are shown in Figure 24. Figures 27 through 34 show detailed bathymetry and representative geophysical profiles of each shoal. The blue reflecting horizon is the base level for computations of maximum volume of suitable sand; minimum volumes are computed to the first sonic or lithologic change. Textural and mineralogic properties of sediments comprising the blue layer indicate it is unsuited for use in beach nourishment.

Chester Shoal was not completely surveyed and no attempt has been made to estimate its total reserves. The volume of sand suitable for recovery from the part of Chester Shoal shown in Figure 27 is judged to be 8.8 × 10^6 cubic yards; if suitable material extends to the blue horizon, reserves are more than 93 × 10^6 cubic yards. The blue horizon lies at 20 to 40 feet beneath the bottom in this area. (See Figure 28.) Cores 164, 165, and 166 contain suitable material to depths of 7, 8, and 12 feet, respectively; no samples below 12 feet are available for analysis.

Core 122 -4 feet

Core 139A -1 foot

Core 166 -9 feet

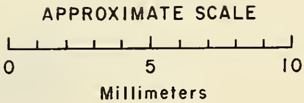


Figure 24. Photos of Typical Sediments from Shoal Areas

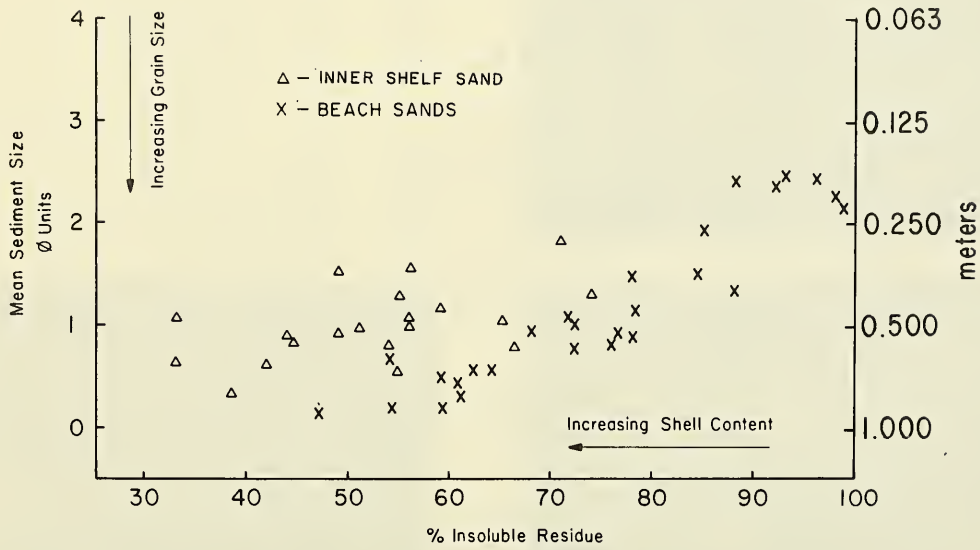


Figure 25. Mean Grain Size versus Percent Soluble Material for Beach and Type A Sands

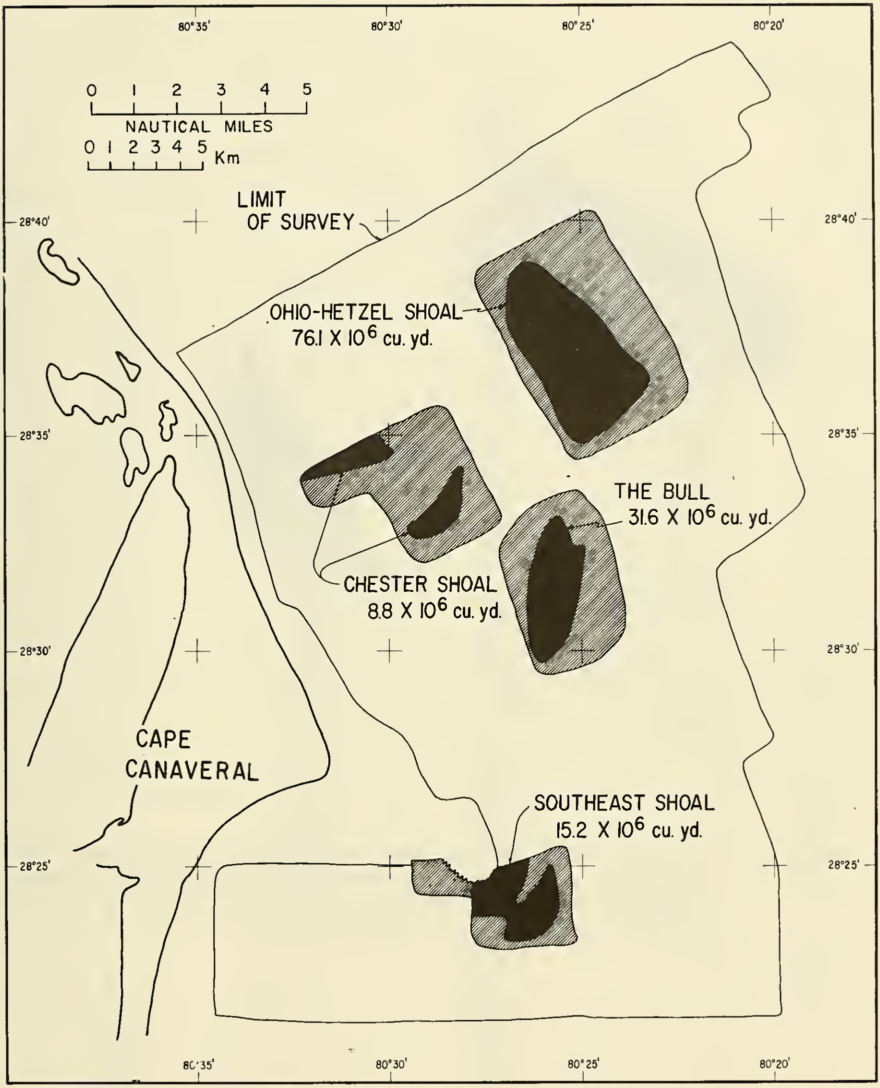


Figure 26. Potential Borrow Areas in the Cape Canaveral Grid Area. Dark areas are plotted in Figures 27, 29, 31, and 33; light gray areas indicate limits of borrow areas.

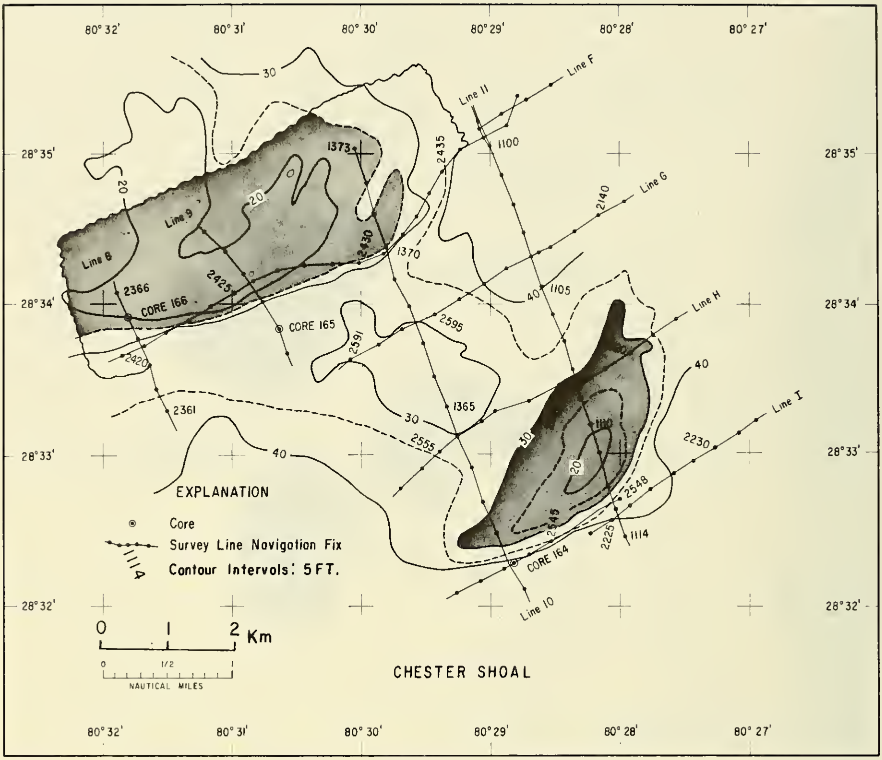


Figure 27. Bathymetry of Chester Shoal Showing Geophysical Tracklines and Core Locations. The shaded parts in this figure and in Figures 29, 31, and 33 indicate the areas used for volume computations of sand reserves.

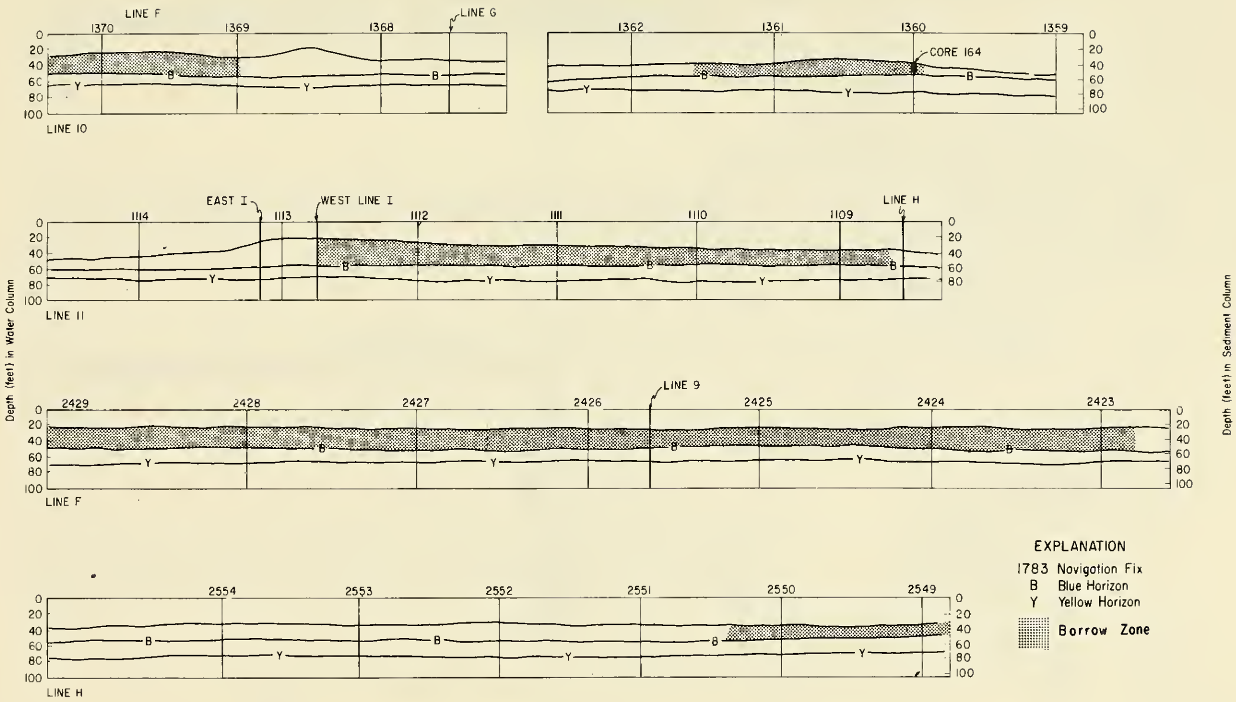


Figure 28. Interpreted Geophysical Profiles Across Representative Sections of Chester Shoal

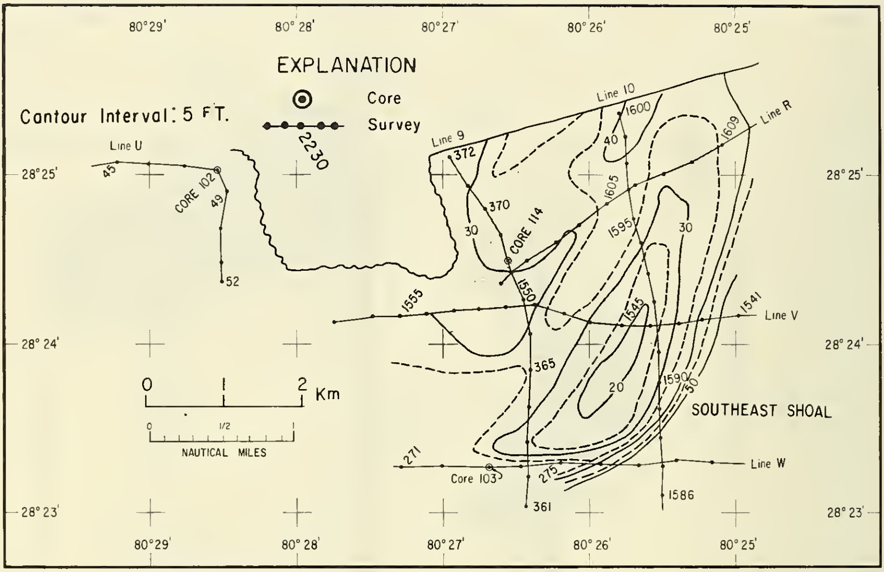


Figure 29. Bathymetry of Southeast Shoal Showing Geophysical Tracklines and Core Locations

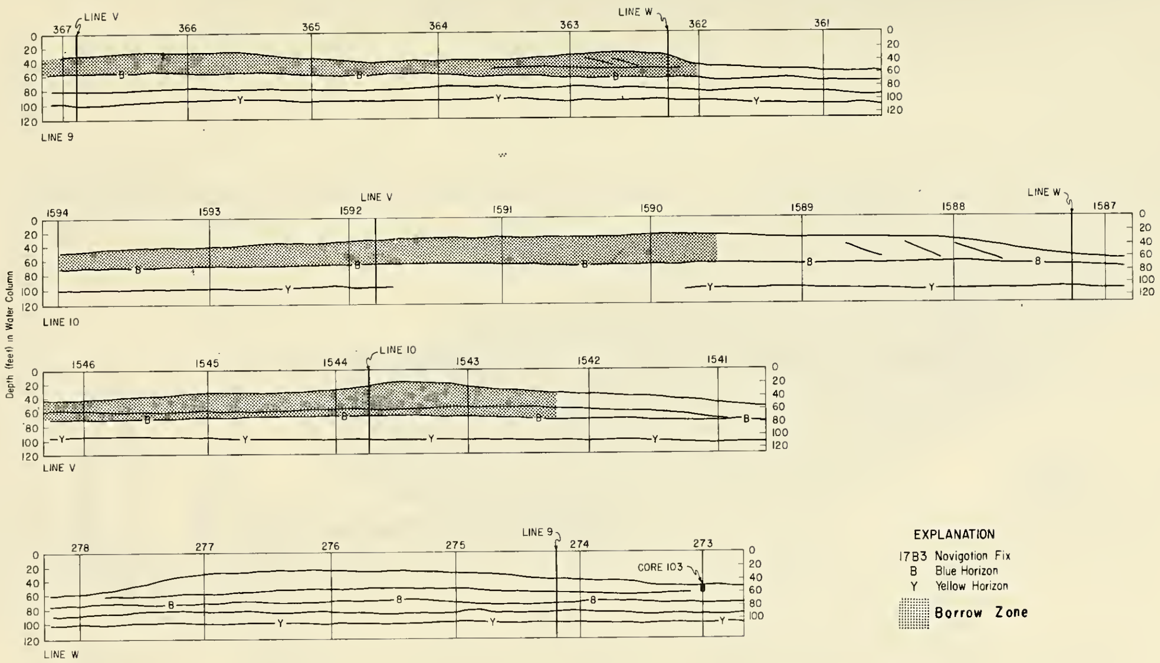


Figure 30. Interpreted Geophysical Profiles Across Representative Sections of Southeast Shoal

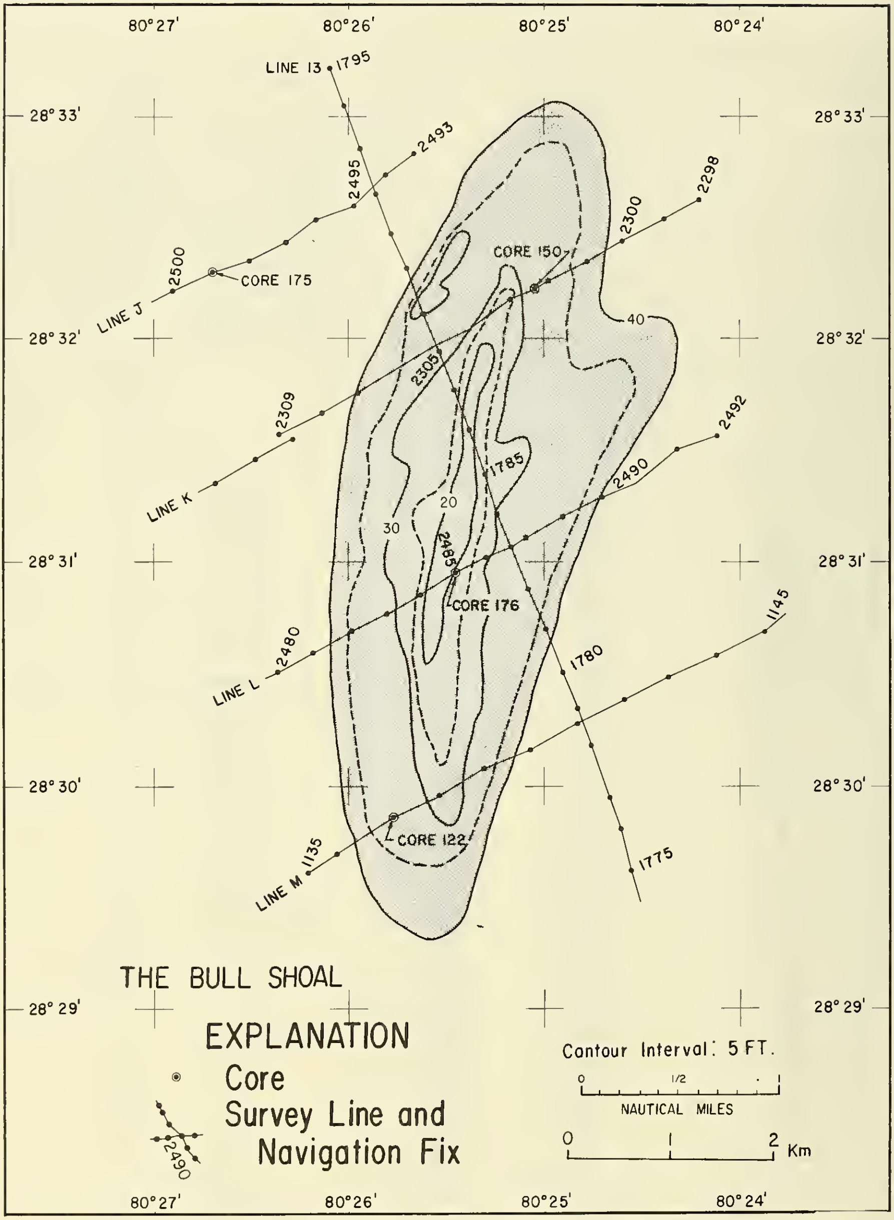


Figure 31. Bathymetry of The Bull (shoal) Showing Geophysical Tracklines and Core Locations

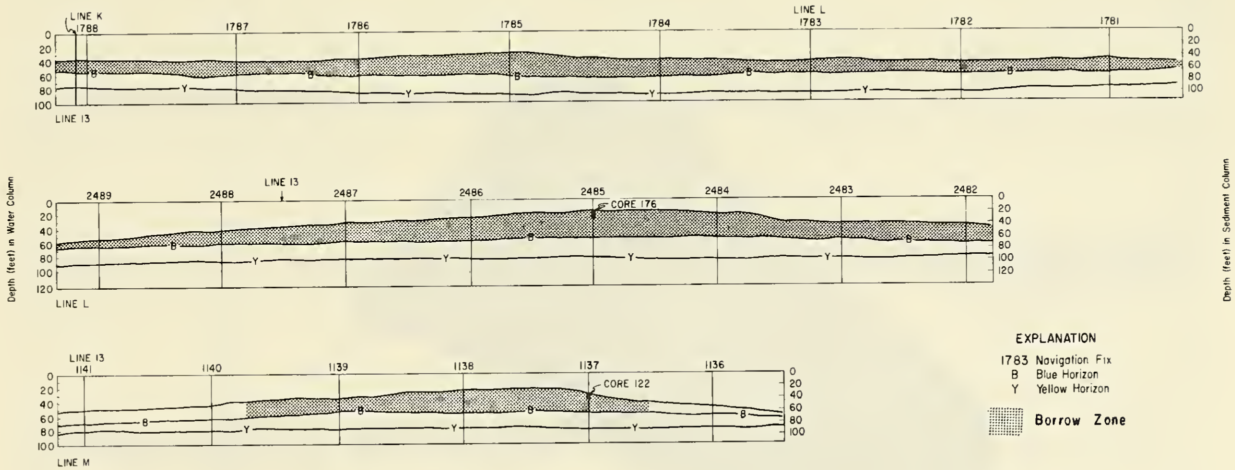


Figure 32. Interpreted Geophysical Profiles Across Representative Sections of The Bull (shoal)

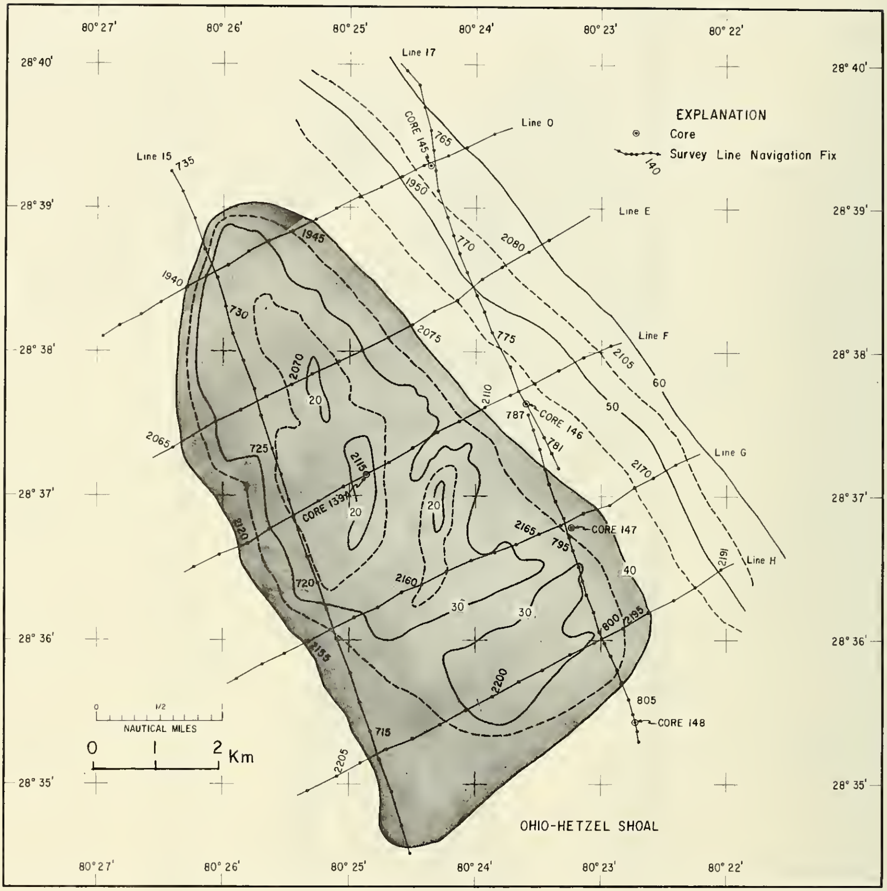


Figure 33. Bathymetry of Ohio-Hetzel Shoal Showing Geophysical Tracklines and Core Locations

Figure 34. Interpreted Geophysical Profiles Across Representative Sections of Ohio-Hetzel Shoal

The distal end of Southeast Shoal (Fig. 29) contains 91.6×10^6 cubic yards of unconsolidated sand on the blue horizon. (See Figure 30.) Of this volume a minimum 15.2×10^6 cubic yards are highly suitable for beach nourishment, as shown by sediments from 10, 7, and 11 feet below bottom recovered in Cores 102, 103, and 114, respectively. Judging from sediment characteristics from this part additional large volumes of suitable sand are probably available elsewhere in the shoal. Proximity of these regions to the beach and shallow depths precluded collection of core or seismic data; the character of these additional reserves is not known.

The Bull (Figs. 31 and 32) contains sand volumes in excess of 112.4×10^6 cubic yards overlying the blue horizon, and at least 31.6×10^6 cubic yards are usable. Core 176 from the crest of The Bull, and Core 122 from the flank contain well-sorted, medium-to-coarse sand to subsurface depth of −13 and −10 feet. The character of sediment lying between the blue horizon, which lies 40 feet below the crest and the core bottom at −10 feet below the crest, is not known. Homogeneity in sonic characteristics and absence of internal stratification, and the fresh polished nature of subbottom sands (Fig. 13) suggest that Type A sands extend under the shoal to near the surface of the blue. The maximum volume of 112×10^6 cubic yards may be suitable for placement on adjacent beaches.

The combined volume of suitable sand in Ohio-Hetzel Shoal (Fig. 33) is 76.1×10^6 cubic yards; the total volume of unconsolidated material potentially available exceeds 350×10^6 cubic yards. Core 139A on the crest, and Core 148 on the flank show suitable sand to subbottom depths of 11 feet. Changes in the sonic character of sediments between the blue horizon and the crest (line H, Fig. 34) are not continuous beneath the shoal and sediment lithology may not change significantly.

These four shoal areas provide a viable and economic volume of sand that may be used as a borrow source for beach nourishment and other needs. Different sources of sand are available to a given coastal area for borrow, but removal from offshore regions probably provides the least ecological changes. (U.S. Army, Corps of Engineers, 1971a, 1971b), and as inland sources diminish, offshore sand is becoming an increasingly attractive source. Utilization of these sand bodies should be planned and monitored carefully and in accordance with guidelines for shore management established by the Corps of Engineers. (U.S. Army, Corps of Engineers, 1971a.)

V. SUMMARY

The Continental Shelf off Cape Canaveral, Florida is a submerged plain extending the entire width of the shelf and underlain by Miocene strata to at least −500 feet MLW, as correlated by seismic reflection data with coastal boring logs. An apparent unconformity lies at −160 to −180 feet MLW which is judged to mark the Pleistocene–pre-Pleistocene surface.

The shallow subbottom is characterized by two continuous mappable acoustic horizons which lie nearly parallel to the present surface. The lower reflector lies at about −80 to −120 feet MLW and is interpreted as mid-to late Pleistocene in age. The upper sonic reflector lies between −40 to −110 feet MLW; this depth correlates with a marked lithologic change from overlying unconsolidated sediments to deposits partially lithified by blocky mosaic calcite cement. Carbon-14 dates of shells from this upper horizon and overlying peats indicate this lithologic and acoustical horizon marks the pre-Holocene surface. Oolite bearing sediments of the layer represent a coastal complex quartzose-calcareous deposited during a late Pleistocene high sea level (mid-Wisconsin interstadial.)

Surficial sediments in the Cape Canaveral grid are primarily medium-to-coarse, well-sorted quartzose-mollusk sand, varying in thickness from 1 to 13 feet; in places the sand may be 40 feet thick. Areal distribution and thickness of this modern sand is closely related to topography; deposits are thickest beneath topographic highs, generally less than 5 feet thick on flat areas, and absent in depressions. Sediments in the survey area are both relict and modern; the latter derived from reworking of the former and are described as *palimpsest* sediments. The subsurface, partially both the Pleistocene sediment which occasionally crop out and the mid-Holocene transgressive relict coastal sediments, have been reworked by physical and organic processes and reshaped to form an undulatory surface of active palimpsest sediments. Late Quaternary and modern deposition has centered around the large, south-trending, shore-connected shoals. The large plano-convex isolated shoals lying seaward of cape shoals, particularly The Bull, are judged to represent remnants of earlier shore-connected shoals that were segmented and stranded during a sea level rise and the concomitant coastal and shoal retreat.

Area beach sediments contain fine-to-coarse quartz and shell sand. Individual beaches vary in proportions of these two components and there is a direct relationship between increase in shell content and increase in mean grain size. Mid-tide samples range in mean grain size from 0.25 to 2.5 phi, with an average mean of 1.25 phi. Beach sands of Atlantic Central Florida are judged to be from coastal erosion of the shoreface, onshore transport of materials from adjacent shoal regions, and southerly longshore transport of materials into the area. Contribution to the beach from the shelf is evidenced by the marked petrologic similarities of the deposits, in particular the presence of a small percentage of oolitic grains derived exclusively from the immediate shelf. Quantity and content of biogenic fractions and the large mean grain size of both total samples and insoluble fractions, relative to updrift beaches, indicate that coastal erosion and retreat have been more important in the genesis of modern areal beach sands than southerly longshore drift.

Texture and composition of the sand vary throughout the grid, but nearly all Type A sand is suitable for beach restoration and the thick deposits associated with topographic highs are the most suitable. Extensive sand deposits suitable as a borrow source comprise The Bull (minimum volume 32×10^6 cubic yard), Ohio-Hetzel Shoal (minimum volume 76×10^6 cubic yard), and Chester Shoal (minimum volume 9×10^6 cubic yard.) Calculations of suitable sand volume on the shore-connected shoals (Southeast, Chester) were made only for areas where data coverage was considered dense enough for reliable interpretation. Based on core samples and seismic data from other parts of shoals, and extrapolation to unsurveyed shoal areas, such as the small shoals trending northeast of Chester Shoal, the volume of suitable sand may be an order of magnitude greater than calculated.

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APPENDIX A

SELECTED GEOPHYSICAL PROFILES

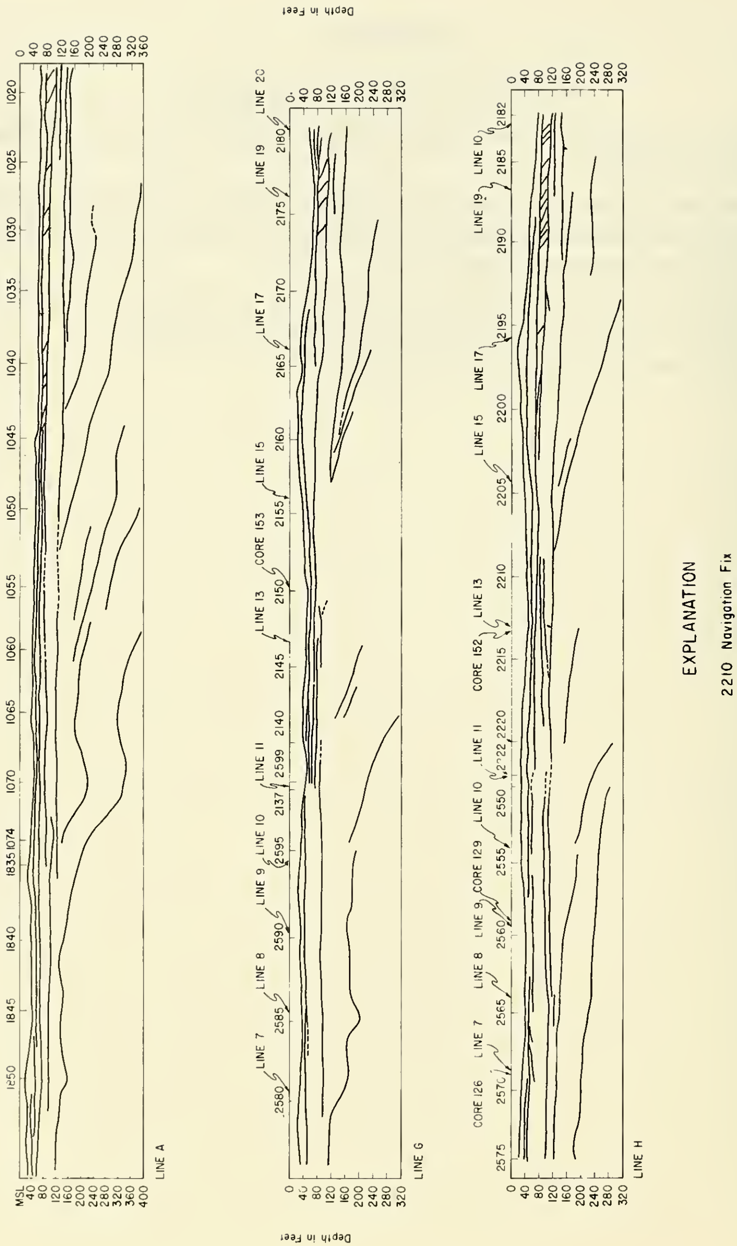
Appendix A contains line profile drawings of selected seismic reflection records from the Cape Canaveral grid area.

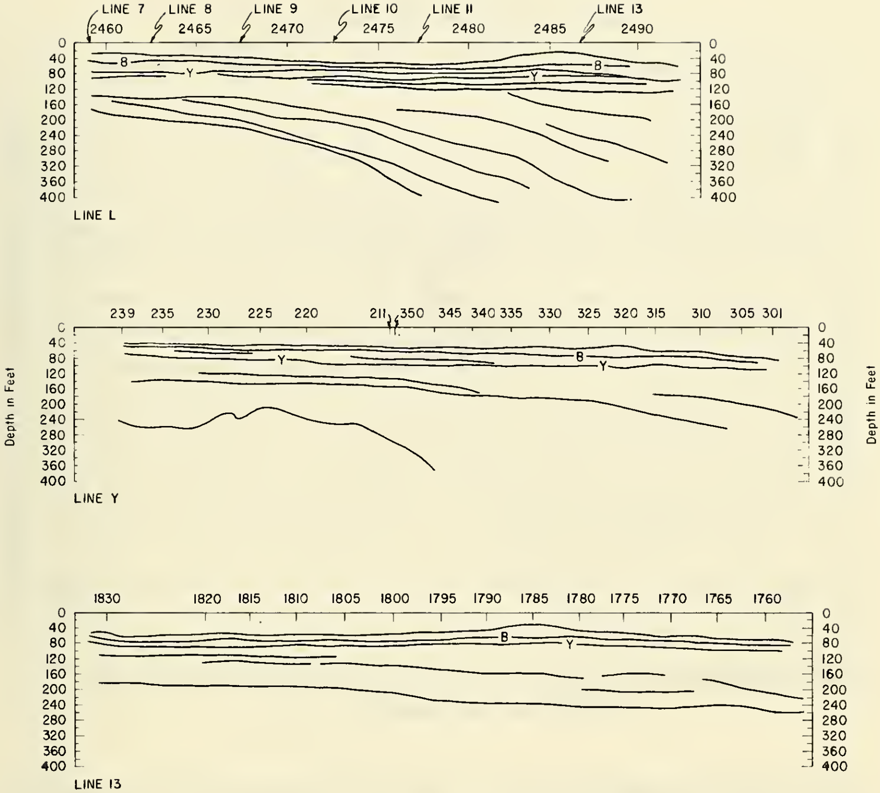
Fix numbers and point of crossing lines are plotted along the upper margin of the profile.

The bottom and all subbottom reflectors are delineated and those reflectors mentioned in the text are identified by letter symbols.

All depths are in feet below mean sea level; and based on an assumed sound velocity of 4,800 feet per second in water and 5,440 feet per second in the subbottom.

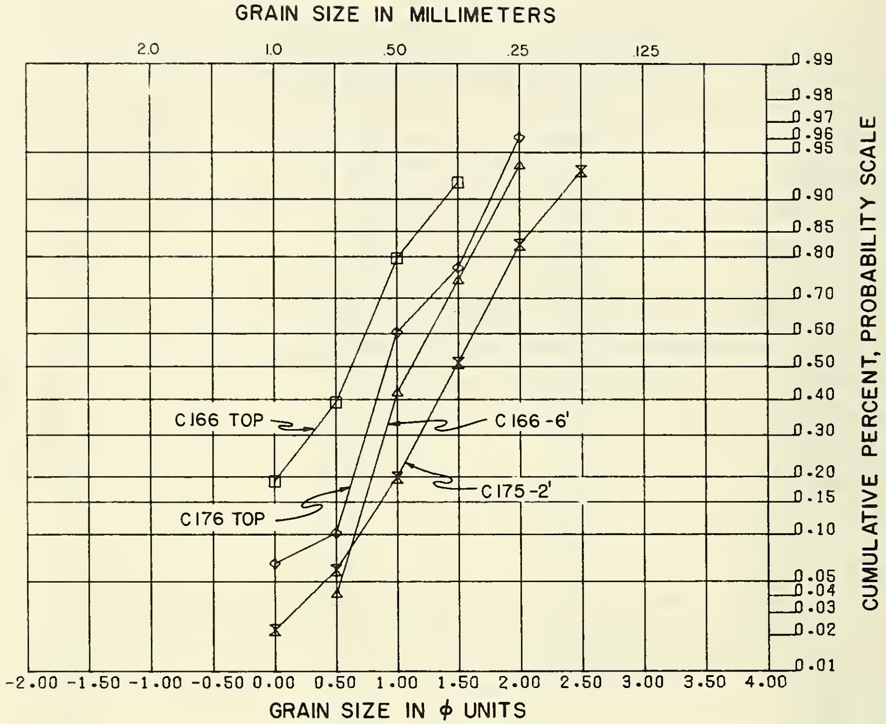
Position of lines and fixes are plotted in Figure 2.


LINE A
LINE G
LINE H
Depth in Feet
EXPLANATION
2210 Navigation Fix

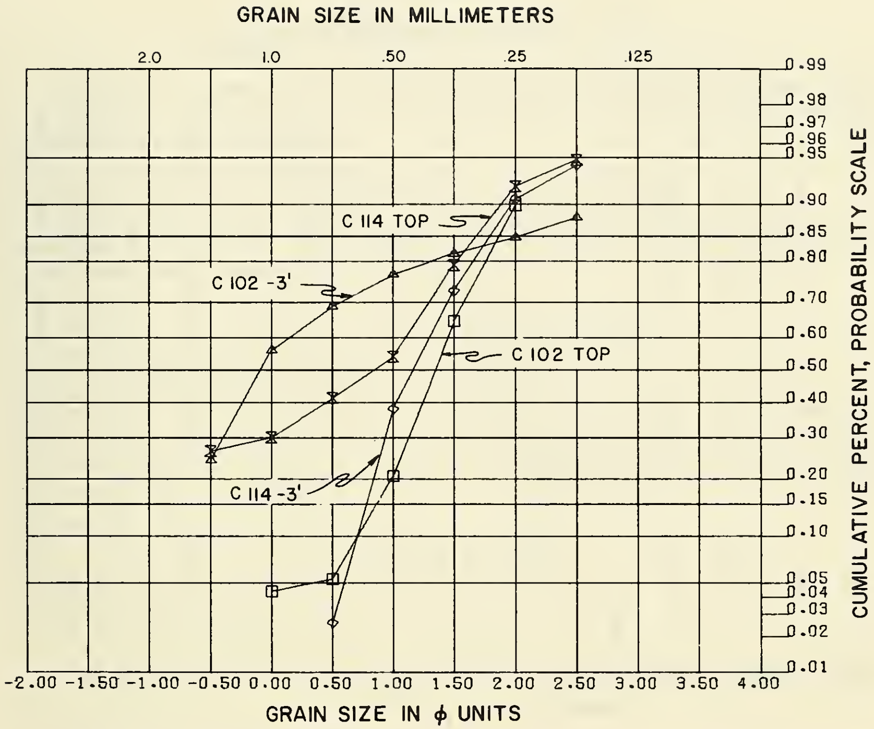


EXPLANATION

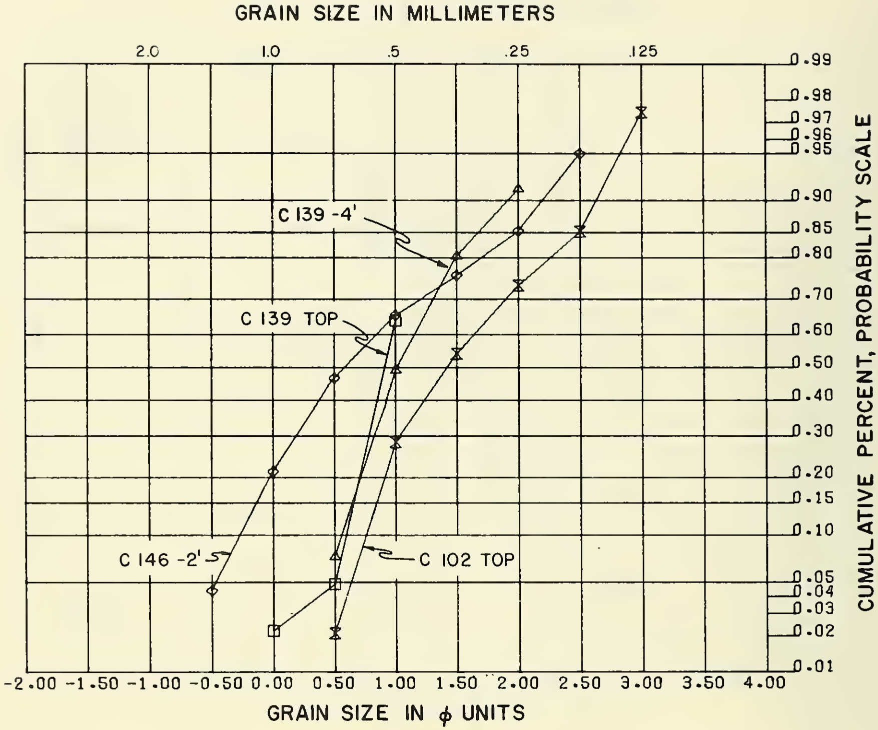
1783 Navigotion Fix
B Blue Horizon
Y Yellow Horizon



Graphic Size Distribution Curves fcr Selected Samples from Chester and The Bull Shoals. Location of Samples is shown in Figures 2, 27, and 31.



Graphic Size Distribution Curves for Selected Samples from Southeast Shoal. Location of samples is shown in Figures 2 and 29.



Graphic Size Distribution Curves for Selected Samples from Ohio-Hetzel and Southeast Shoals. Location of samples is shown in Figures 2, 29, and 33.

APPENDIX B

SEDIMENT DESCRIPTIONS OF SELECTED CORES

Appendix B contains visual description and textural data of sediments contained in cores from the four delineated borrow areas. Cumulative curves of selected samples from cores in the areas are presented graphically.

Core number, CERC identification number, water depth, and sample depth in core are listed to the left. The cores are plotted in Figures 2, 27, 29, 31, and 32.

Visual descriptions are based on both megascopic and microscopic examination. The descriptive statement generally contains the following elements in the order listed:

1. Color.
2. Color code per Munsell Soil Color Charts (1954 edition).*
3. Dominant size or size range.
4. Major compositional element or elements with the dominant constituent listed first.
5. Phrases identifying readily recognized constituent elements with an estimated frequency of occurrence in terms of total particles. The frequency terms indicate the following percentages:
   a. Abundant, 30 to 50 percent of total particles.
   b. Common, 10 to 30 percent of total particles.
   c. Sparse, 2 to 10 percent of total particles.
   d. Trace, less than 2 percent of total particles.
6. Mean size and sorting (standard deviation) values are placed at the end of the visual description.

*Munsell Color Company, Inc., Baltimore, Maryland

APPENDIX B

Sediment Descriptions of Selected Cores

CERC ID No.	Core No.	Water Depth (ft.)	Interval (ft.)	Description
			Southeast Shoal	
114	102		0 to 6.5	Gray-brown (2.5 year 5/2), medium to coarse quartzose-calcareous sand; very coarse to coarse shell layer at –1 ft. Mean size: 0.1 to 1.8 phi. Standard deviation: 0.3 to 0.9 phi.
			6.5 to 10 btm	Gray (5 year 5/1), medium, poorly sorted, quartzose-calcareous sand; increased silt content at 6.5 to 7 ft.
115	103	35	0 to 7.5	Gray-brown (10 year 5/2), medium to coarse, well-sorted, quartzose-calcareous sand; ooids sparse.
			7.5 to 10.8 btm	Brownish gray (2.5 year 6/2), very fine to fine quartzose sand; calcareous grains (fragments, microfaunal tests) common.
128	114	30	0 to 11.3 btm	Light brownish gray, medium, well-sorted, quartzose-calcareous sand; ooids sparse to trace. Mean size: 0.7 to 1.4 phi. Standard deviation: 0.37 to 0.63 phi.
			Bull Shoal	
138	122	25	0 to 10.1 btm	Gray (10 year 5/1), medium to coarse, well-sorted, quartzose-calcareous sand; mollusk fragments abundant, ooids trace.
170	150	26	0 to 4.5	Gray (N7), medium to coarse, well-sorted, quartzose-calcareous sand; mollusk fragments common.
			4.5 to 7.6 btm	Gray (N5), fine to medium, quartzose-calcareous sand.
196	175	33	0 to 5 btm	Light gray (2.5 year 7/2), medium, well-sorted, quartzose-calcareous sand; mollusk fragments abundant. Mean size: 1.3 to 1.8 phi. Standard deviation: 0.4 to 0.9 phi.
197	176	13	0 to 13 btm	Variegated medium to coarse, well-sorted, quartzose-calcareous sand; mollusk fragments abundant, ooids sparse. Mean size: 0.97 to 1.4 phi. Standard deviation: 0.37 to 0.51 phi.

Sediment Descriptions of Selected Cores—Continued

CERC ID No.	Core No.	Water Depth (ft.)	Interval (ft.)	Description
		Ohio-Hetzel Shoal		
159	139A	15	0 to 12 btm	Variegated medium to coarse, well-sorted, quartzose-calcareous sand; mollusk fragments abundant, ooids sparse. Mean size: 0.9 to 2 phi. Standard deviation: 0.3 to 1 phi.
166	146	45	0 to 3.5 btm	Olive-gray to gray (5 year 4/2 to 4/1), fine to coarse, quartzose-calcareous sand; quartz content increases to 85 percent between 2 and 3.5 ft.; ooids sparse. Mean size: 0.8 to 2.3 phi. Standard deviation: 0.2 to 0.6 phi.
167	147	30	0 to 11 btm	Light gray to light brownish gray (10 year 7/2 to 6/2), medium, well-sorted, quartzose-calcareous sand; mollusk fragments common, ooids sparse, microfaunal tests trace.
		Chester Shoal		
185	164	42	0 to 8.5	Gray (5 year 6/1), medium, well-sorted, quartzose-calcareous sand; mollusk fragments abundant, ooids sparse.
			8.5 to 9.7	Light brown (10 year 6/3), very fine to fine moderately well-sorted, quartzose sand; shell fragments abundant, microfaunal tests, mica sparse.
186	165	28	0 to 7.5	Gray brown (10 year 5/2), medium to coarse, well-sorted, quartzose-calcareous sand; ooids sparse.
			7.5 to 11 btm	Gray (5 year5/1), fine to medium, moderately well-sorted, quartzose-calcareous sand; ooids trace; microfaunal tests sparse.
187	166	20	0 to 4	Gray (10 year 6/1), coarse quartzose-calcareous sand; mollusk fragments and whole shells abundant; ooids sparse. Mean size: 0.57 to 1.07 phi. Standard deviation: 0.5 to 0.7 phi.
			4.0 to 12	Gray (10 year 6/1, medium well-sorted, quartzose-calcareous sand; mollusk fragments common; ooids sparse. Mean size: 1.2 to 2.0 phi. Standard deviation: 0.24 to 0.44 phi.

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Geomorphology and sediments of the lnner Continental Shelf, Cape Canaveral, Florida, by Michael E. Fields and David B. Duane. Ft. Belvoir, Va., U.S. Coastal Engineering Research Center, 1974.

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