# GEOMORPHOLOGY and SEDIMENTS of the NEARSHORE CONTINENTAL SHELF MIAMI to PALM BEACH, FLORIDA

by

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## ABSTRACT

The Continental Shelf bordering southeastern Florida between Palm Beach and Miami was surveyed by the U. S. Army Coastal Engineering Research Center to locate and evaluate sand deposits potentially usable for shore protection and restoration projects. Survey data covered that portion of the Continental Shelf between 15- and 100-foot depths, and consisted of seismic reflection profiles and sediment cores of the sea floor and shallow subbottom strata.

South of Boca Raton to Miami, much of the shelf is essentially rocky with a thin sediment veneer. Relatively thick deposits of sediment have accumulated locally in troughs on the shelf surface formed between low reef-like ridges lying parallel to shore. Shelf sediments south of Boca Raton consist almost entirely of sand-size calcareous skeletal fragments.

North of Boca Raton to Palm Beach, most of the shelf is overlain by a thick blanket deposit of homogeneous fine-to-medium, gray sand about half of which consists of quartz particles and the remainder of calcareous skeletal fragments.

A total volume of 201 million cubic yards of sand-size sediment occurs on the shelf south of Boca Raton. Although generally suitable for beach fill in terms of size, degradation of size by abrasion and fragmentation of the delicate particles may occur in the shore environment. More than 380 million cubic yards of sand-size sediment lies on the shelf north of Boca Raton. However, because of its fine size, this sand is not considered ideally suited for use on local beaches.

In terms of potential as beach sand, sand size sediment from the shelf bordering southeastern Florida is of marginal quality.

## FOREWORD

This report is the first of a series which will describe CERC's Sand Inventory Program.

David B. Duane, Chief of the Geology Branch and Edward P. Meisburger, a CERC geologist, prepared the report under the general supervision of George M. Watts, Chief of the Engineering Development Division. The field work was done by Alpine Geophysical Associates under contract (DA-08-123-CIVENG-65-57) to the Jacksonville District, Corps of Engineers.

Cores taken during the sand exploration are stored at the Smithsonian Oceanographic Sorting Center (SOSC). Microfilms of the seismic profiles,

the 1:50,000 navigational plots, and other ancillary data are stored at the National Oceanographic Data Center (NODC). Requests for information relative to those items should be directed to SOSC or NODC.

At the time of publication, Lieutenant Colonel Edward M. Willis was Director of CERC; Joseph M. Caldwell was Technical Director.

NOTE: Comments on this publication are invited. Discussion will be published in the next issue of the CERC Bulletin.

This report is published under authority of Public Law 166, 79th Congress, approved July 31, 1945, as supplemented by Public Law 172, 88th Congress, approved November 7, 1963.

CONTENTS



ILLUSTRATIONS

| Figure | | Page |
|---|---|---|

## Section I. INTRODUCTION

### 1. Background

Ocean beaches and dunes constitute a vital buffer zone between the sea and coastal areas and provide at the same time much needed recreational areas for the public. Neglect of the ocean beaches can result, and indeed often has resulted, in disastrous consequences either through long-term progressive erosion or through sudden overwhelming of coastal lands by storm waves and surges.

Under authority of Federal Laws the U. S. Army Corps of Engineers is directly involved in the study of beach erosion and storm protection problems. Through its various division and district offices and research facilities, the Corps conducts basic studies in coastal phenomena and coastal engineering techniques, develops plans of improvement for specific shoreline areas, designs protective structures, and in some instances, undertakes the project construction. Types of shore protection structures and methods, means of obtaining design criteria, and planning analysis are presented in Technical Report No. 4 (1966) of the Coastal Engineering Research Center (CERC). As indicated in Technical Report No. 4, 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, in many instances is too fine-grained and not suitable for long-term protection, because the fines are immediately winnowed out and removed. 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). Regardless of suitability of material in shallow back bay areas, the potential ecological damage consequent to dredging in shallow back bay areas made exploitation of these sources highly undesirable.

The problem of locating suitable and economical sand supply led the Corps to a search for new unexploited sand supplies. 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 Corps of Engineers' Coastal Engineering Research Center. Referred to as the Sand Inventory Program, it started in 1964 with

*Refers to LITERATURE CITED.

the purpose of finding the extent and characteristics of sand deposits on the nearshore Continental Shelf, in water depths of 15-100 feet. An initial phase in developing techniques for transferring offshore sand to the beach is described by Mauriello (1967).

The exploration phase of the program uses seismic reflection profiling supplemented by cores of the marine bottom. Additional supporting data for the studies are obtained from USC&GS hydrographic boat sheets and published scientific literature.

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 at approximately one statute mile intervals) was used to cover areas where a more detailed development of bottom and subbottom conditions were desired. Reconnaissance lines are one or 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 reveal the general morphologic and geologic aspect of the area covered and to identify the most promising places for additional data collection.

Core sites were selected on the basis of a continuing review of the seismic profiles as they became available throughout the course of survey operations. This procedure allowed selection on the best information available while permitting the contractor to complete coring operations in one area before moving his base to the next area. Fundamentals of planning and field techniques, i.e., sonic profiling, coring, and positioning, utilized in the conduct of CERC sand inventory programs are detailed in Appendix A.

Sediment cores taken during the field operation for the Florida Sand Inventory Program were examined megascopically aboard the vessel by the contractor, capped and shipped to CERC for further analysis.

Samples for laboratory processing were removed from the cores by drilling through the plastic liner at selected sampling intervals and withdrawing a 60- to 80-gram sample. All cores were sampled at top and bottom; additional samples were withdrawn at other intervals as needed to reflect vertical changes in grain size and lithology within the core.

Samples were air- or oven-dried, broken into component parts if necessary, and split to 8- to 10-gram portions. The portion selected for size analysis was rinsed in distilled water until a silver nitrate test for chloride was negative. Size analyses of the majority of samples were conducted on a Rapid Sediment Analyzer (RSA). The RSA at CERC, similar to those described by Zeigler (1960) and Schlee (1966), is used to determine the grain size distributional characteristics of sediment, especially grains in the size-range from 62 to 2,000 microns, as they settle through a 1-meter column of water. Coupled to a digital voltmeter and a card punch, pressure data from the RSA is recorded directly on punched cards and on a strip-chart (Figure 1). By means of a computer

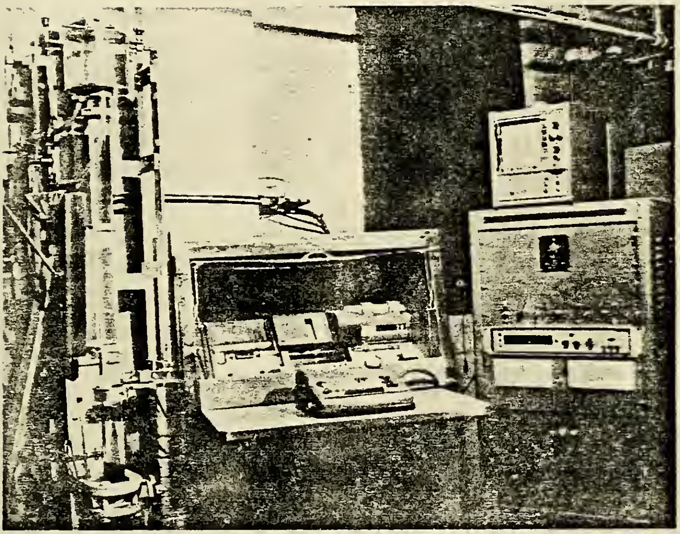


Figure 1. Rapid Sediment Analyzer. Settling tube and pressure tube are shown at left of photo; connecting tubes supply and drain water. At right is console housing digital voltmeter with timing and sampling circuitry; atop console is analog strip chart record for visual recording of pressure-time decay curve. In center is card punch for direct punching of data as sediment falls through metering column.

program which relates actual pressure and time decay to equivalent fall diameter, statistical parameters descriptive of the sediment size-distribution curve are calculated. An analogous computer program for sieve data computes the same granulometric parameters which are: median and mean diameter (central tendency); standard deviation (dispersion); skewness (asymmetry); and kurtosis (peakedness). These parameters are shown symbolically below:

MEAN

$$\overline{X}_\phi = \frac{\sum_{i=1}^{n} X_i f_i}{n}$$

STANDARD DEVIATION

$$\sigma_\phi = \sqrt{\frac{\sum_{i=1}^{n} (X_i-\overline{X})^2 f_i}{n}}$$

SKEWNESS

$$\alpha_1 = \frac{\sum_{i=1}^{n} (X_i-\overline{X})^3 f_i}{\sigma^3}$$

KURTOSIS

$$\alpha_2 = \frac{\sum_{i=1}^{n} (X_i-\overline{X})^4 f_i}{\sigma^4}$$

$f_i$ = frequency by weight of grains present in interval.

$n$ = number of sample classes.

$X_i$ = diameter of midpoint of sample interval, in phi units.

$\overline{X}_\phi$ = mean particle diameter expressed in phi units.

$\sigma_\phi$ = standard deviation expressed in phi units.

$\alpha_1$ = skewness.

$\alpha_2$ = kurtosis.

No allowance is yet made for the effect of sample mass on the fall diameter. Median diameter is also computed. While it is recognized that that measure of central tendency is not as sensitive as the mean, median is used extensively in this paper to facilitate comparison with earlier studies and available published data where median is also cited. Nevertheless, all samples analyzed by and for CERC in this Florida program and listed in Appendix B show mean as well as median values.

Certain samples were also processed in the laboratory for determination of the acid-soluble content. Visual examination of the samples shows that for south Florida shelf sediments the acid-soluble content is almost entirely calcium carbonate skeletal material. Weight percentage of acid-soluble constituents was determined by adding a dilute solution of hydrochloric acid to a carefully dried and weighed sediment sample of 10 to 20 grams. Acid was added until all physical evidence of reaction had ceased. Acid was then decanted, the residue thoroughly washed in distilled water, dried, and weighed. The soluble content was calculated as the percent, by weight, of the total sample lost to acid solution.

Visual classification of sediments in the laboratory was based on examination of samples under a binocular microscope and point counts of constituent particles of representative samples. Additional comments pertaining to sediment description are presented in Appendix C.

Determination of sand volumes was made by planimetering areas of accumulation depicted on the isopachous map (Figure 16). The data were consequently applied to the prismoidal formula:

$$V = 1/6\ H\ (S_0 + 4S_1 + S_2)$$

where

$V$ = Volume

$H$ = Height

$S_0$ and $S_2$ cross sectional areas of upper and lower bases, respectively.

$S_1$ = cross sectional area of the midsection.

## 2. Scope

Field work off the Florida east coast from Fernandina Beach south to Miami was accomplished in 1965 by Alpine Geophysical Associates, Inc. of Norwood, New Jersey, under contract to the Jacksonville District, Corps of Engineers. Funding and technical supervision of the contract, including layout of survey lines and selection of coring sites was provided by the Coastal Engineering Research Center with administrative support from the Jacksonville District office.

The area under study and reported in this document lies on that part of the Atlantic Continental Shelf which borders the southeastern coast of Florida between 25°40' N (Miami) and 26°48' N (Palm Beach) (Figure 2). Continuous seismic profiles and cores were obtained over the multiple reef area in the south and through a transition zone to the northern limit of the study area. The shelf region under study, comprising 141 square miles in area, was covered by 176 statute miles of geophysical survey in water depths ranging from 15 feet to 350 feet. The seismic profiles were supplemented by 31 three-inch I.D. cores ranging in length from 1.5 to 11 feet. Tracklines and core locations are shown on Figure 3.

Reports dealing with other sections of the Florida east coast based upon the 1965 data collection program will be published in due course.

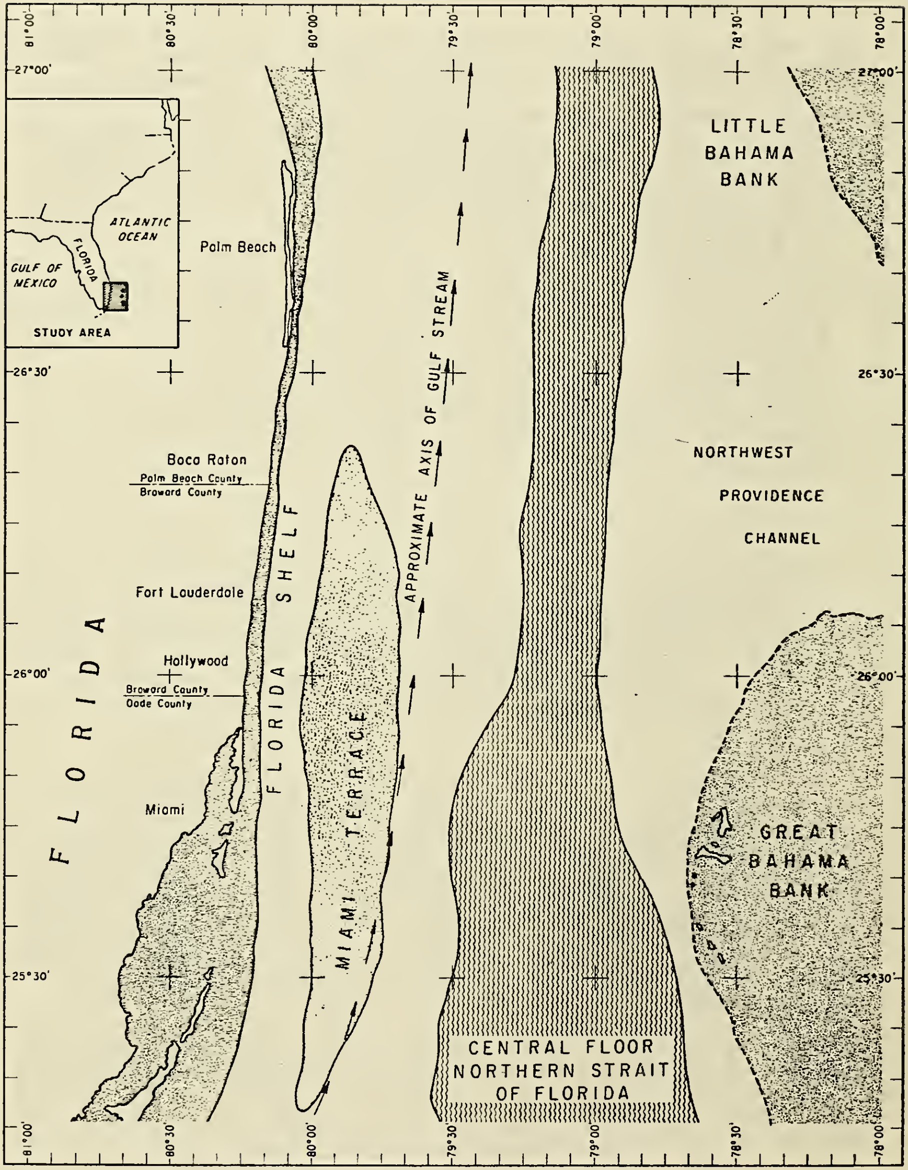



Figure 2. Chart of the northern part of the Straits of Florida.

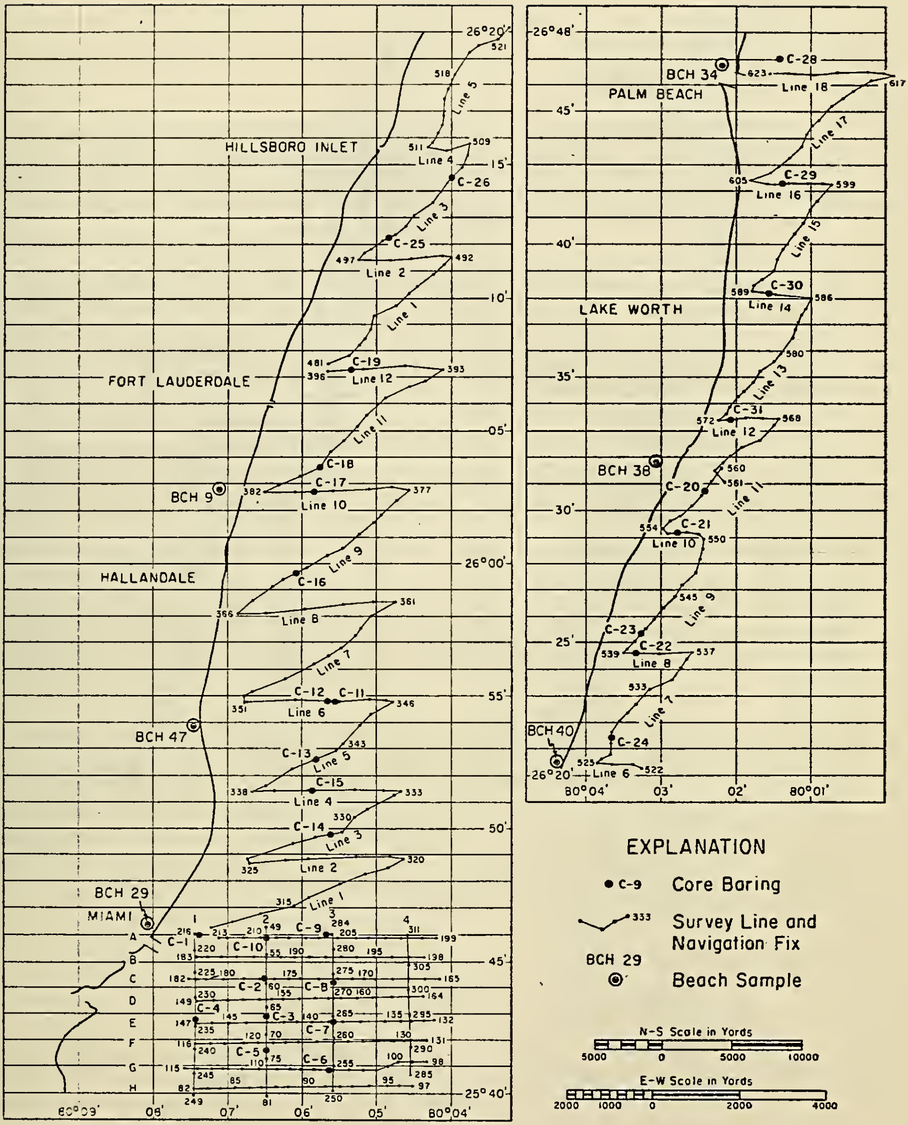



Figure 3. Plot of survey tracklines and core borings. Note change in horizontal scale which was enlarged to facilitate display.

Section II. HYDROGRAPHY AND GEOLOGY OF STUDY AREA

1. Hydrography

The northern Straits of Florida is a passage through which the Gulf Stream passes northward into the Atlantic Ocean. Flanking the Straits to the east is the Great Bahama Bank surmounted by the cays and islands of the Bahama Group; westward lies the mainland of Southeastern Florida (Figure 2).

The thalweg of the passage is broad and lies in the central part of the northern straits. The rise of the east side of the "valley" toward the Bahama Banks is relatively steep with slopes averaging 9 percent; overall the western slope of the Florida Strait is more gentle than the eastern with slopes averaging 4 to 8 percent. In the area of study the western slope is interrupted by a broad terrace at depths from about 720 to 1,200 feet (Siegel, 1959; Hurley, 1962). Shoreward of this terrace the slope again steepens and rises to the shelf which extends from approximately 70-foot depths to shore. The seaward edge of this near-shore shelf is marked by a drowned reef-like feature with an irregular crest which generally lies at 40- to 55-foot depths.

South of approximately 26°20' N the surface of this shelf rises from the outermost reef to shore in a series of step-like linear flats separated by rocky irregular slopes and ridges. North of 26°20' N, the step-like character of the topography gives way to a more or less constant sediment slope extending from shore to near the outer reef line (Figure 4).

Sediments on the shelf can be divided roughly into two distinct types. Southward of 26°20' N the dominant sediments are white to gray calcareous skeletal sands and gravel (Figure 5). The acid-soluble content of this sediment is generally over 80 percent. North of 26°20' N to the limits of this study area the dominant sediment type is a homogeneous fine to medium-grained gray sand composed of about 60 percent clear subangular and subrounded quartz grains and 40 percent brown, gray, or black calcareous skeletal fragments (Figure 5).

2. Geologic Setting

a. Stratigraphy and Geologic History

Strata cropping out or present in the shallow subsurface of southeastern Florida are summarized in the stratigraphic column of Table I. Along most of the east coast of Florida, rocks of the Pleistocene Anastasia Formation form the main coastal bedrock outcrop (Cooke, 1945). Locally, the Anastasia Formation is exposed in low cuts and benches along the shore. A submerged rocky platform bordering the shore in many places is probably formed on the Anastasia Formation.

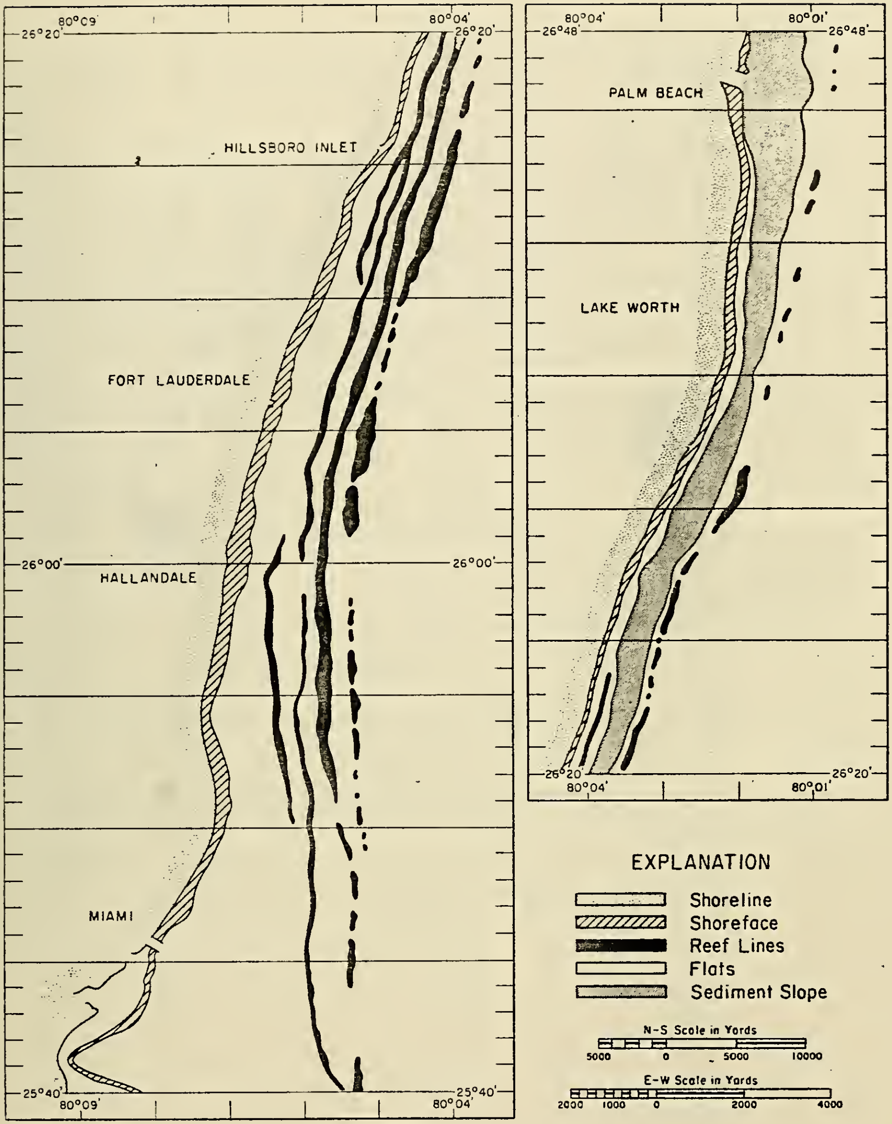



Figure 4. Plan of southeastern Florida shelf morphology.

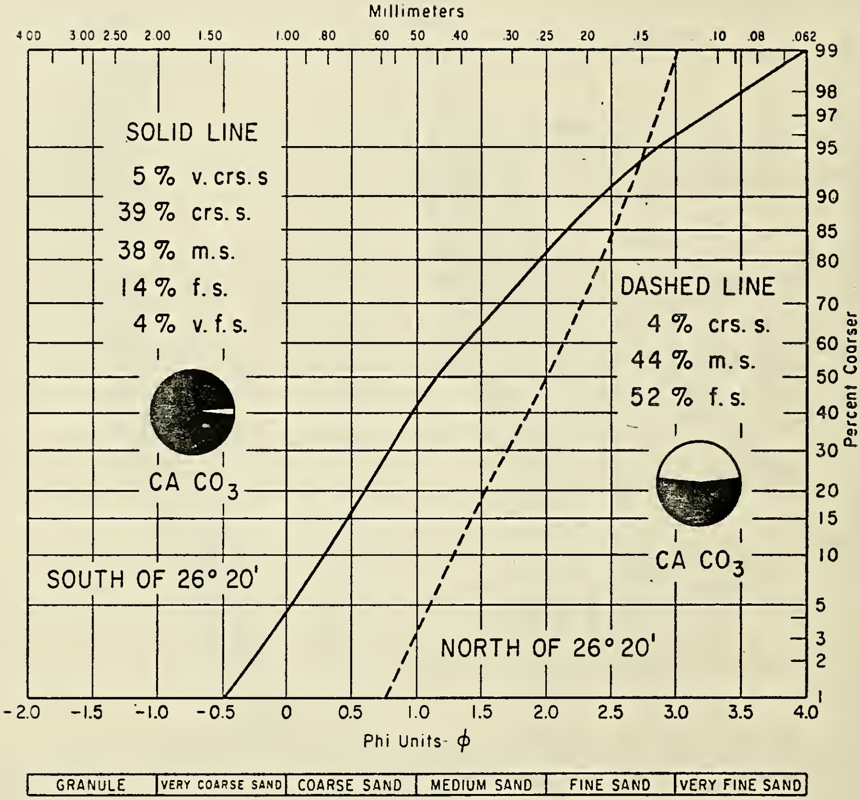



Figure 5. Average size distribution of shelf sediments. Note the difference in grain size and the concomittant difference in carbonate (shell) content.

TABLE I

Stratigraphic Column for Southeastern Florida
Approximate depths in feet below MSL*

| Formation | Geologic Age | Dade and Broward Co. | Palm Beach County | Character |
|---|---|---|---|---|
| Miami Fm | Pleistocene | 0-20 | Absent | Oolitic and bryzoan limestone |
| Key Largo Ls | Pleistocene | 20-50 | Absent | Coral reef and reef detritus |
| Anastasia Fm | Pleistocene | 20-120 | 0-230 | Sand, Limestone,and shell beds |
| Caloosahatchee Marl | Pleistocene | Probably absent | 230-330 | Shelly sand and shell marl. |
| Tamiami Fm | Late Miocene | 120-220 | 330-400 | Marly sand, marl and shell beds |
| Hawthorn Fm | Miocene | | 400-890 | Clayey and sandy marls |
| Tampa Fm | | 890-940 | 890-940 | Limestone and some marl |

* Miocene and post Miocene stratigraphy of Dade, Broward and Palm Beach Counties, Florida (Based on Cooke, 1945; Schroeder, et al, 1954; Schroeder, et al, 1958).

Although the classic aspect of the Anastasia Formation is that of a coquina, wells penetrating presumed Anastasia strata have encountered a complex series of interbedded limestones, calcareous sandstones, quartz sands and shell beds. Schroeder (et al, 1954) reports the formation has a thickness of 230 feet near the shore in Palm Beach County. To the south, in Dade and Broward Counties, strata identified as the Anastasia Formation reach a thickness of 120 feet under the coastal ridge.

Overlying the Anastasia along the coast are quartzose sands of late Pleistocene Pamlico age and Holocene (modern) beach and dune sediments. Near the Palm Beach-Broward County line the upper part of the Anastasia Formation undergoes a facies change and is recognized as the Miami Oolite which is the dominant stratigraphic unit cropping out on the southeastern tip of Florida. In this same region, Schroeder (et al, 1958) noted several wells which indicated that the lower part of the Anastasia Formation merged into or contained presumed elements of the Key Largo Limestone, a Pleistocene reef complex of considerable prominence in the northern Florida Keys (Hoffmeister and Multer, 1968).

Hoffmeister (et al, 1967) found the Miami Oolite to be clearly divisible into an upper oolitic facies overlying a lower facies characterized by extensive masses of colonial bryzoa. This bryzoan unit averages about 10 feet thick in the coastal area and contains a large number of bryzoan colonies up to 1 foot in diameter mixed with oolites, pellets and skeletal sand. The upper or oolitic facies reaches a thickness of approximately 30 feet under the coastal ridge. Hoffmeister proposed a redefinition of these units as the Miami Formation in recognition of the distinct importance of the lower unit.

Schroeder (et al, 1954) determined a thickness of possibly 100 feet of Caloosahatchee sediments locally underlying the Anastasia in Palm Beach County. The Caloosahatchee is mainly shelly sand, sandy shell marl, with minor amounts of limestone and sandstone.

Underlying the Caloosahatchee marl where present (and elsewhere the Anastasia Formation) along an uncomformable contact is the Tamiami Formation which was redefined by Parker (1951) to include all upper Miocene material in southern Florida. The thickness of this formation ranges from about 70 to 100 feet in the study area, and is composed of beds and lenses of sandstone, limestone, sand, and silty shell marls (Cooke, 1945; Schroeder, et al, 1954; Schroeder, et al, 1958).

Where these formations crop out or become exposed as the result of engineering works, they contribute sediment to the Holocene dunes, beach and offshore zone. However, the extent to which these formations now contribute sediment as a result of submarine outcrops is not definitely known. Locally, the presence of shell material in the littoral zone has been related to nearby exposures of coquina along the shore or nearshore bottom (Fineran, 1938); (Martens, 1931). Rusnak (et al, 1966) concluded that old shell material derived from coquina exposures may represent 20 to 60 percent of the carbonate material in east Florida beach sands. The remaining shell material is derived from modern biota and was found to be highest near inlets, where the environment favors large organic populations.

Using deepwater seismic profiles off northeastern Florida, Emery and Zarudski (1967) made correlations of onshore borings and wells with offshore deep borings at the series level. The deep borings were obtained under the Joint Oceanographic Institutions Deep Earth Sampling (JOIDES) program. However, at the formational level little is known concerning the stratigraphy of the Continental Shelf off either northeastern or southeastern Florida. However, it is probable that beds of Anastasia age underlie the Holocene surface sediments on the shelf throughout much of the study area. South of the Palm Beach-Broward County line the Miami Oolite may crop out on the bottom close inshore. Because of its slight dip and because the base lies only about 20 feet below sea level at the coast, the Miami Formation is not likely to exist in water depths greater than 20 feet.

The Key Largo Limestone and the Miami Formation are ascribed to the Sangamon interglacial. Coral reefs flourishing during Sangamon time created a shelter behind which the bryzoan facies of the Miami Formation began to form. During the later stages of this period the oolitic facies of the Miami Formation developed as a broad bar along the present-day coastal areas (Hoffmeister, et al, 1967). This depositional phase ended with the relative lowering of sea level and the consequent erosion and partial induration of the Miami and Anastasia Formations. The final depositional event of the Pleistocene in southern Florida occurred with the rise of the Pamlico Sea which inundated the coastal area leaving a sheet of quartzose sand covering the eroded surface of both Miami and Anastasia Formations. Subsequent to "Pamlico" time the relative sea level has been near or below its present stand.

Holocene deposits along the coast consist chiefly of littoral and dune sediments, lagoon fill and shelf facies sands, much of which is probably derived from erosion of Pleistocene deposits and from modern organic production.

b. Nearshore Shelf Morphology and Surface Sediment

A generalized plan of the principal morphological elements on the nearshore shelf off southeastern Florida is shown in Figure 4. This plan is based on USC&GS boat sheets at 1:20,000 scale and bathymetric profiles obtained in the course of the Florida Sand Inventory Program. A schematic topographic profile across these morphologic elements is illustrated in Figure 6. For the purposes of this report the study area has been subdivided into two sections based on natural differences; and referred to as Section A (25°49' N to 26°20' N) and Section B (26°20' N to 26°48' N).

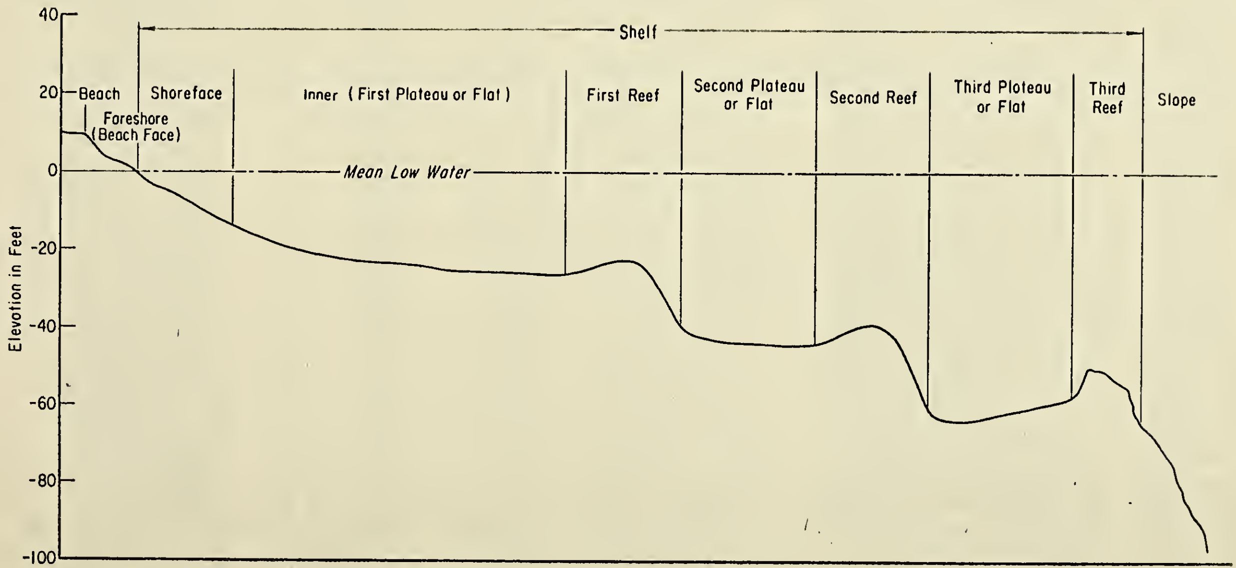



Figure 6. Schematic profile of southeastern Florida shore and shelf morphology.

Section A (Figure 7a) is characterized by a step-like bathymetric profile consisting of a series of linear plateaus (flats) each lower than its immediate shoreward neighbor. Separating the flats are irregular rocky ridges and slopes. In Section B (Figure 7b) the step-like character of the profile is replaced by a relatively thick mass of fine gray sand forming a gentle seaward slope over the central part of this portion of the shelf surface.

Immediately seaward of the low water line and terminating at -10 to -18 feet MLW is the shoreface slope evident in both Section A and B. This narrow zone seaward from the low tide shoreline is continuously influenced by the effects of waves, currents, and littoral sediment supply. At the seaward boundary of the shoreface slope the profile flattens and gives way to what is here referred to as the inner flat, a broad platform extending between depths of around -10 to -30 feet MLW. The surface of this flat is characterized by linear swales and ridges of low relief. The inner flat is essentially an exposed, partially lithified, deposit of algal plates, mollusk fragments, foraminifers, corals and unidentified calcareous material. A considerable portion of the unidentified fragments may be debris from Sabellariid reefs (Kirtley and Tanner, 1968). South of Port Everglades (26°06' N) the main part of the inner flat lies at around -16 to -25 feet MLW with some depths to 30 feet. Northward, this feature becomes narrower, shoaler and less conspicuous.

Succeeding the inner flat in Section A is a second plateau at a characteristic depth of -35 to -45 feet MLW. This plateau is separated from the inner flat by a rocky, irregular slope with 10 to 15 feet relief which is locally interrupted by a linear flat at around -30 feet MLW. The second plateau is level, and the surface for the most part is unconsolidated sediment. Its width ranges from 250 to 700 yards, but it is generally of the order of 350 yards and is terminated by a rocky reef-like ridge having irregular crest elevations of about 40 feet. South of 25°48' N, this reef line lies along the outer edge of the shelf and is succeeded by the major slope leading to the Miami Terrace.

North of 25°48' N the second reef is fronted by a third plateau with depths of -60 to -70 feet MLW. Like the second plateau this feature is a relatively level sediment-floored depression 250 to 400 yards wide. The surface of this plateau has a pronounced landward dip, particularly in the southern part of the region. Seaward of the third flat is a prominent reef-like ridge with 10- to 15-foot relief which is periodically interrupted by narrow passages and by very broad interruptions at around 26°00' N and just north of 26°30' N. The reef crests typically at approximately -50 feet MLW, but is quite irregular. Throughout Section A the shoreline is not quite parallel to the reef, consequently the shore trends progressively toward the reef from south to north, and the reef lies 3,500 yards seaward of Miami Beach but only about 1,500 yards seaward of Boca Raton. North of Boca Raton (26°20' N) the reef parallels the shoreline at a distance of about 1,500 yards.

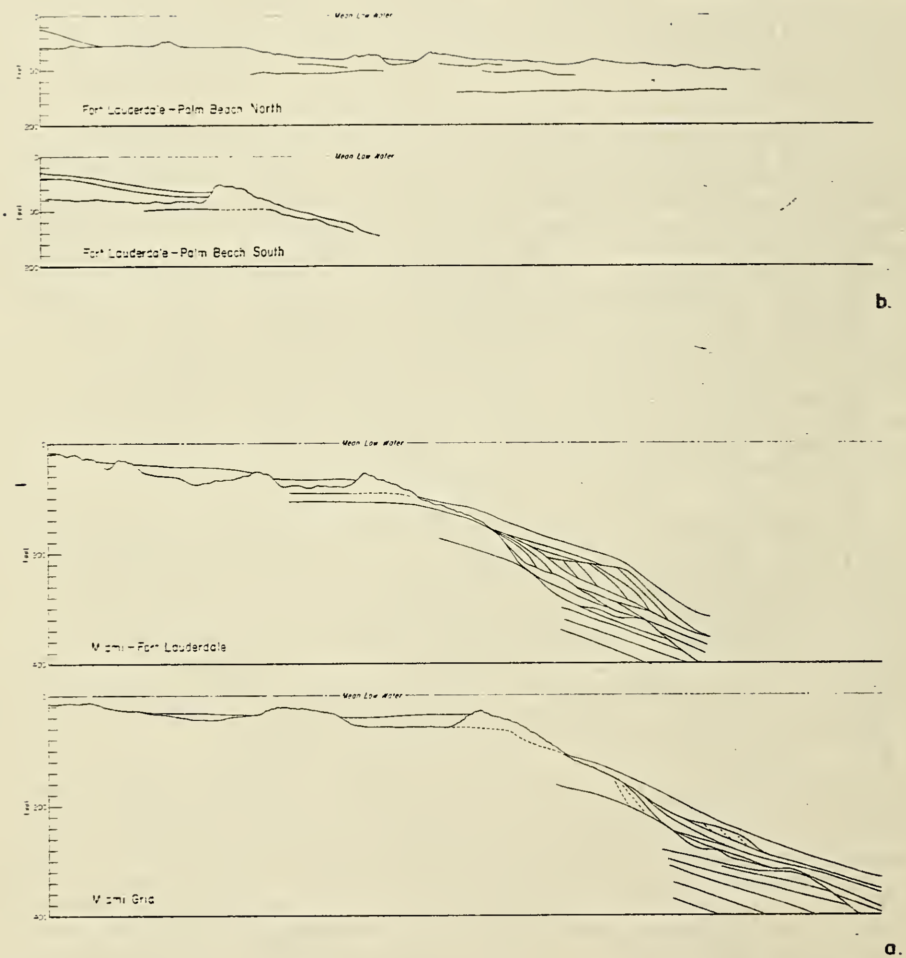



Figure 7. Shelf profiles off southeastern Florida showing subbottom reflectors: a) Section A (25°40' to 26°47' N) and b) Section B (26°20' to 26°47' N). Upper profile of (b) is line 18; other profiles are composite of two or three juxtaposed lines.

Both the inner flat and the third reef line are more or less continuous throughout the study area. North of about 26°20' N, i.e., Section B, the inner slope, the second plateau, and the second reef (and at least part of the third plateau) are overridden by a body of fine quartzose sand (Figure 7b). Topographically the shelf surface in Section B between the inner flat and the outer part of the third plateau exhibits in profile a long uniform sediment slope dipping continuously seaward (Figure 7b). While the shelf profile in Section B exhibits undulations, the relief is not great and the prominent stepped profile characteristics of Section A are no longer evident.

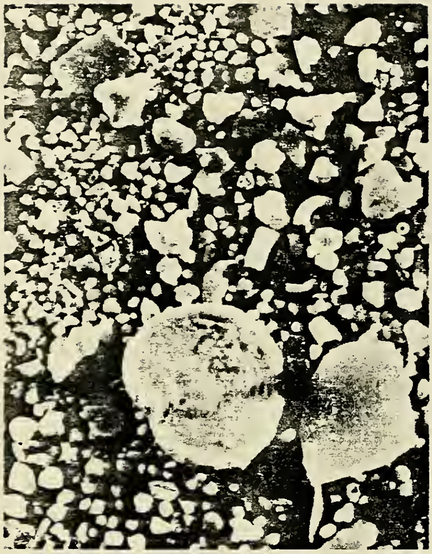
Information concerning the character of bottom surface sediments in the study area is based upon analyses of cores supplemented by USC&GS boat sheets and other sources. Most of the cores for this study were taken from a rather narrow depth zone, -35 to -48 feet MLW. Information obtained from the boat sheets and the other sources indicates similar characteristics in the surface sediments landward and seaward of this extensively sampled zone. Sediment exposed on the surface in Section A is white or gray, medium to coarse grained, carbonate skeletal sand with an average acid soluble content of more than 80 percent (Figures 8 and 9). Sediment comprising the marine bottom in Section B is characteristically gray, fine, and well sorted calcareous quartzose sand (Figure 10).

Size parameters and visual descriptions of surface samples, obtained for this report, are contained in Appendixes B and C.

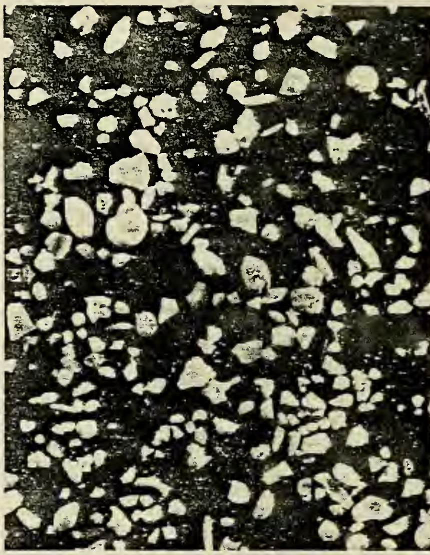
c. Nearshore Subbottom Morphology and Sediment Characteristics

(1) Character of Seismic Reflectors. Information concerning sediment thickness on the southeast Florida shelf was gathered from chart notations, core samples and continuous seismic profiles. Cross-sectional profiles along all east-west survey tracklines shown in Figure 2 are contained in Appendix D. These profiles are line drawings showing the position and alignment of the bottom-water interface and subbottom acoustic interfaces within sediment and rock masses. Figure 11, a photograph of the dual channel seismic reflection record is typical of the east-west profiles south of 20°20' N (Section A).

Seismic reflection techniques do not provide direct evidence of the character of bottom and subbottom materials. Direct evidence must normally be gathered by drilling or coring into subbottom strata, or by tracing a stratum to an exposure which can be sampled more directly. The correlation of sediment or rock characteristics between data points is made easier by seismic data since it is possible in some cases to continuously define the strata identified in the core. Nevertheless, even where good acoustic definition is available, considerable error is found where lateral changes of sediment or rock character occur within the same bounding acoustic interfaces.



Core 5   -1 foot



Core 6   Top

Core 17   -3 feet

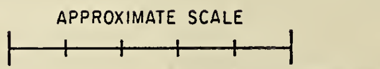
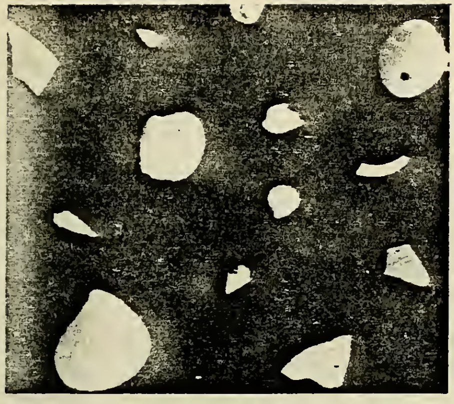
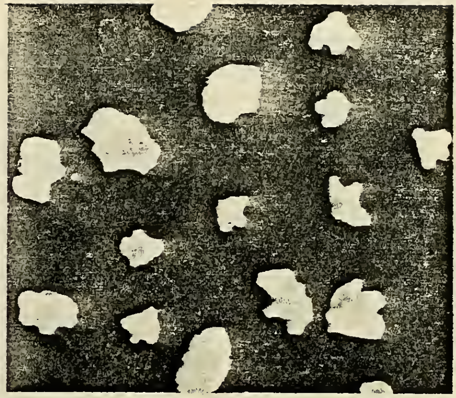


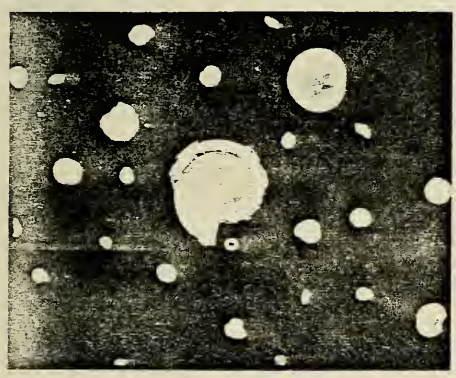

Figure 8.  Photomicrographs of typical Section A sediemnts.



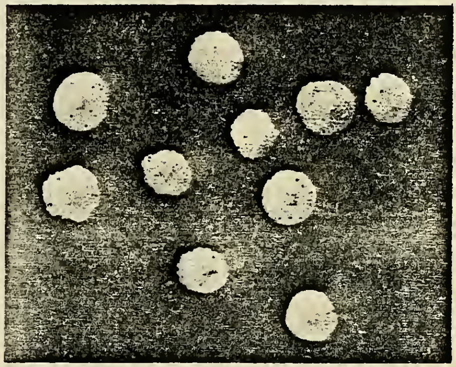
Mollusk shell



*Halimeda* plates



Foraminifera



Bryzoan colonies

Alcyonarian coral sclerites

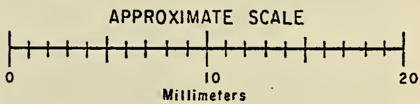
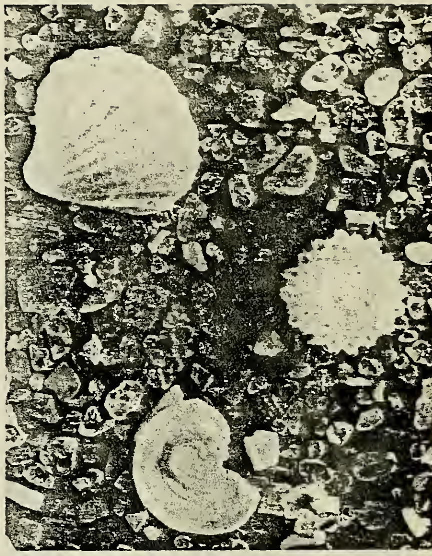
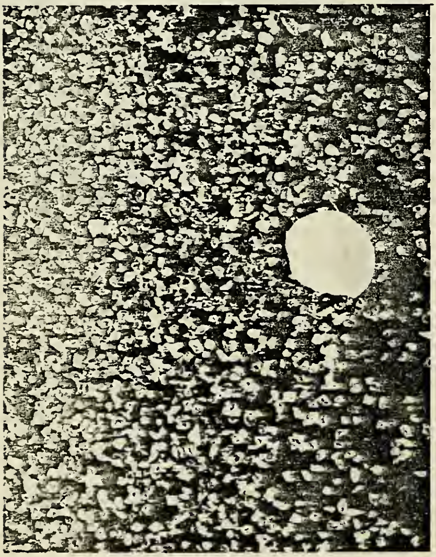



Figure 9. Photomicrographs of typical skeletal fragments in Section A sediments.

Core 21 -6 feet



Core 22 -5 feet



Core 30 -4 feet

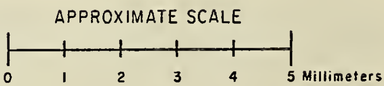



Figure 10. Photomicrographs of typical sediments from Section B.

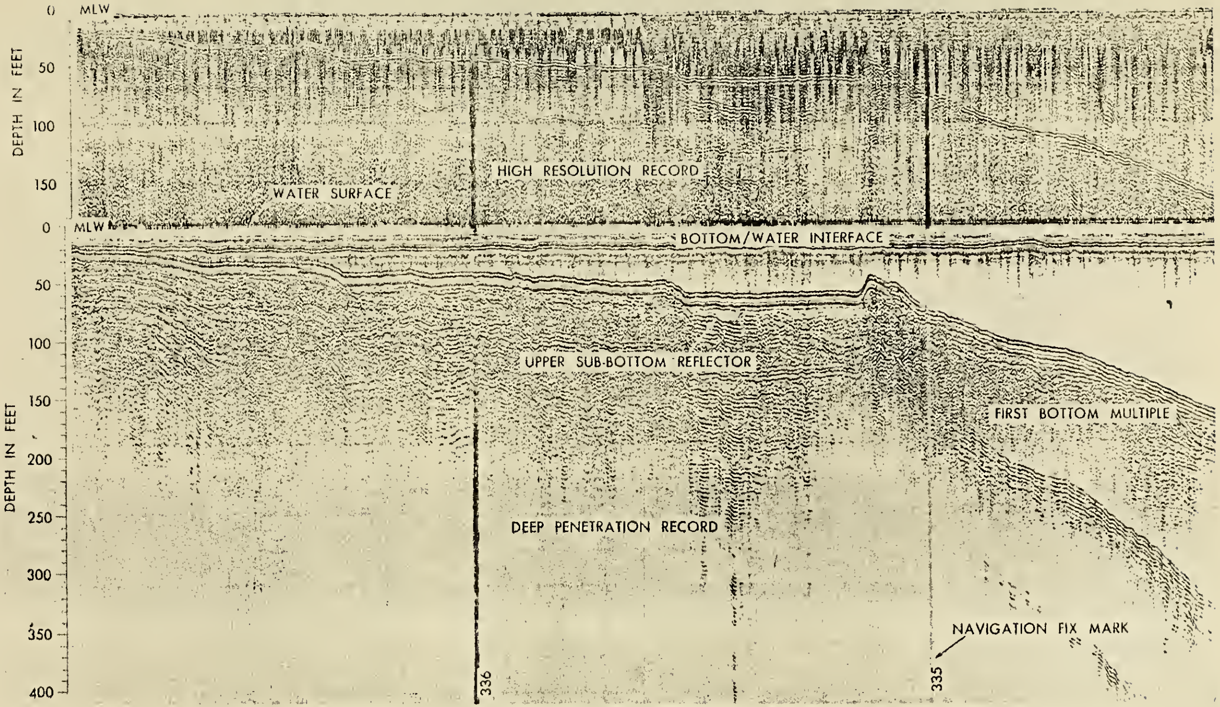



Figure 11. Typical dual channel marine seismic reflection record.

Delineation of acoustic interfaces by seismic reflection profiling is a reasonably accurate and straightforward procedure where the reflections are continuous or are interconnected by means of the survey tracklines. Interpolations between survey lines or between gaps in a line must be based on an assumption of continuity of slope or elevation or on an assumed configuration which is geologically reasonable. Subbottom reflecting horizons on the seismic records of south Florida are frequently interrupted by absorption or scattering of the signal near the bottom-water interface with consequent partial or total loss of subbottom resolution. This sound absorption is especially noticeable in the old reefs. For these reasons it is difficult to determine a regional reflector or to correlate over considerable distances with assurance that the same horizon is being used. Therefore, wholly reliable qualitative sediment data exists only in the close vicinity of coring sites and only to the depth of core penetration. In terms of acoustic interfaces, the bedrock delineation is considered to be reliable because the numerous exposures provide a large number of data points and because the characteristic irregular surface of bedrock provides a means of indirect identification.

(2) Bedrock Morphology. Extension of the bedrock surface between tracklines was facilitated by USC&GS chart notations, and bottom morphology where rock is exposed on the bottom. Extension of the gross outline and general elevations of the bedrock surface under sediments in the "flats" (or plateaus) is considered reliable. This surface, although not continuously definable is apparently step-like with principal levels at -15 to -25 feet MLW; -50 to -60 feet MLW; and -80 to -90 MLW. Reef-like features crop out on the seaward edges of these steps, and spill over onto the next lower level. Lesser irregularities on this surface are of localized and indeterminate form and cannot be extended in plan at the existing trackline spacing. Generalized bedrock topography in the Miami grid area is depicted in Figure 12. The density of subbottom profiles elsewhere in the study area is not adequate for purposes of mapping the bedrock surface.

(3) Regional Subbottom Morphology. Because of sound absorption, scattering, and the relatively thin veneer of sediments covering bedrock in the Miami grid area (and Section A in general) to water depths of approximately -70 feet MLW, no regional reflector within the sediment column would be discerned. However, seaward of this depth (the seaward limit of the third plateau on the upper continental slope a thick blanket of "modern" sediments overlies a regressive series of terraces extending to depths of approximately -300 feet MLW (Meisburger, 1968). Within this sediment envelope are numerous and prominent sonic reflectors some inclined at a steep angle seaward and resembling fore-set beds (Figure 7a). Whether they are indeed fore-set beds representative of a relic shoreface, or a fore-reef talus, is impossible to determine; they nevertheless are interpreted as progradational marine features. The stratigraphically highest of these deposits, extending from approximately -140 to -220 feet MLW is terminated by a prominent sonic horizon indicative of a terrace between -220 and -250 feet MLW. This terrace possibly relates to a fluctuation of the Holocene transgression at approximately 11,000 years B.P. (Curray, 1965). A deeper prominent reflector, dipping slightly from

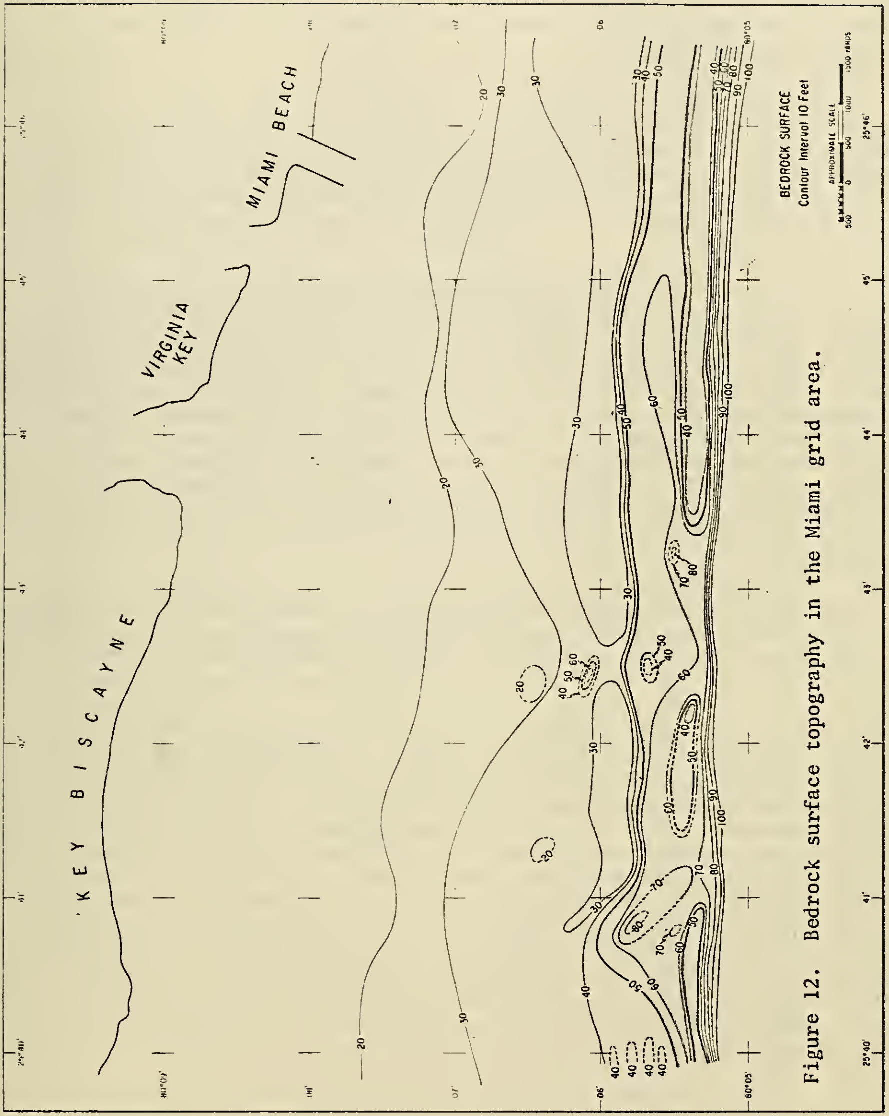



Figure 12. Bedrock surface topography in the Miami grid area.

-295 to -325 feet MLW, may correlate with a Holocene stillstand some 15,000 years B.P. This date corresponds to the maximum regression of Milliman and Emery (1968).

North of 26°20' N (Section B) to the limits of the study area (26°48' N), a blanket of sediment that almost exhibits sonic-isotropism covers all but the outermost of the three prominent "reef" lines present further south. The old reef surface is locally a prominent reflector; the bedrock structure consists typically of a series of step-like terraces with the actual topographic reef features forming the riser to each of the next lower steps.

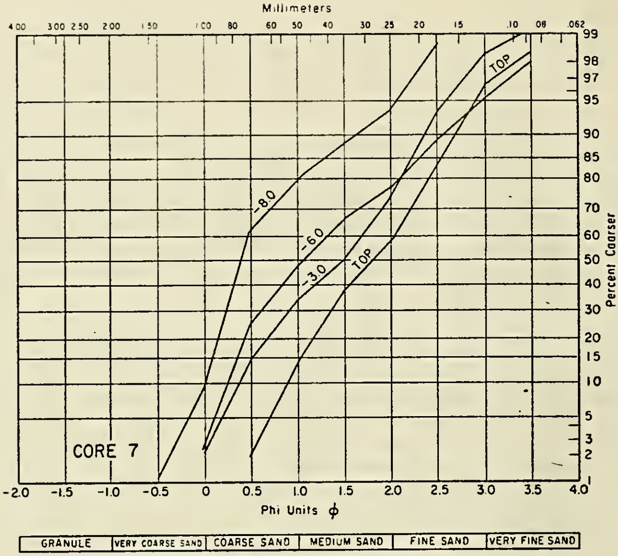
(4) Subbottom Sediment Characteristics and Distribution. Information concerning the character of subbottom sediments in the study area is based upon analyses of samples from 31 cores obtained during the field phase of the Florida Sand Inventory Program. These 3-inch (inside diameter) cores range from 1.5 to 11 feet long. Twenty-seven were taken in water depths of -35 to -48 feet MLW, thus are significantly representative of a limited shelf zone. Unpublished Corps of Engineers studies, chart notations, and the Broward County, Florida, "Bathymetric and Sand Inventory Survey" (Ocean Science Engineering, Inc., 1967) were used to supplement and extend core data. Granulometric statistics are contained in Appendix B; visual descriptions of core samples are contained in Appendix C.

The two distinct shelf sediment facies, distinguished in the surface sediments in the study area, persist in general aspects in depth. In Section A, sediments are more poorly sorted than in Section B to the north and are, on the whole, far less uniform in depth and in lateral extent. There is, moreover, a great dissimilarity in the composition of these sediments (compare Figures 8 and 10). The unconsolidated Holocene sediments in Section A are carbonate skeletal sands and gravels composed largely of the hard parts of the biota living in the warm shallow waters covering the shelf. About one-third of the skeletal fragments are intact or sufficiently complete to be readily recognized. The remaining two-thirds of the particles are probably derived from the same organisms constituting the identifiable fraction. Examples of the more prevalent skeletal constituents are shown in Figure 9. In comparison to the sands of Section B, quartz is rare in Section A sediments and generally represents less than 10 percent by weight of the total sample. Although of little significance in terms of volume, the quartz present in Section A is of interest in that many of the particles are considerably larger and better rounded than those in the northern section; numerous particles are frosted.

The largest contributors to the skeletal material of Section A sediments are marine algae with characteristic leaf-like or triform shapes *(Halimeda)*, and mollusks. Foraminifers, especially large benthonic mililolids such as *Peneroplis* and *Archias*, bryzoa, and corals are significant contributors. See Figure 9 a-e. Frequently encountered in minor amounts are echinoid spines, sponge spicules, alcyonarian sclerites, worm tubes, ostracod carapaces, and many smaller foraminifers. Of the nonskeletal material the dominant constituents are rod-shaped and elliptical pellets (possibly fecal), semiconsolidated calcarenite, oolites and agluttenated worm tubes. Locally such materials are volumetrically important and the calcarenites are especially evident in cores from the Miami grid which have presumably penetrated to bedrock. Constituents of the calcarenite fragments making up the rock at the base of several cores are similar to the finer carbonate skeletal sands occurring in the superposed unlithified strata. In general, these fragments are white or cream colored, many containing large, well-rounded quartz grains, and fragments of mollusk shell, foraminifers, spicules, and pellets.

In most of the Section A sediments (Figure 13), the wide range of sizes, poor sorting, and the character and condition of the constituent particles suggest that these sediments were formed more or less *in situ* with relatively little transportation involved. Indeed, numerous seismic profiles (Appendix A) show an asymmetrical accumulation of sediment filling the troughs shoreward of the second and third reefs. The surface slope of this accumulation is shoreward and is judged to be evidence supporting the idea of local source of sediment; the local source is the crest and seaward edge of the reef: debris from the reef is carried over the reef crest to be deposited in the shoreward trough. Much of the quartz present in the samples might possibly be eroded from exposures of quartzitic calcarenite (Anastasia Formation) cropping out on the nearshore bottom and especially in the vicinity of the inner flat where such rock appears in several cores and where wave erosion would be most effective. The quartz might also be windblown or represent material carried in the littoral stream from the north, albeit markedly diluted by the addition of large quantities of carbonate in the southern waters.

In Section B (north of 26°20' N), most of the material recovered in cores is a clean, homogeneous, fine to medium-grained sand (Figure 14). It is a calcareous quartz sand (55 to 65 percent quartz) comprised of subangular and subrounded clear quartz grains mixed with subrounded to rounded gray, black and brown calcareous particles (Figure 10). Minor amounts of presumably "fresh" skeletal material occur in most of the cores. Chiefly these consist of fragile mollusk fragments and foraminiferal tests. The quantity of such fragments is small, and there is little evidence that such organisms presently contribute substantial amounts of sediment to the shelf in Section B. Difference in sediments throughout Section B is not large; however, sediments of the southern part of Section B (cores 26, 24, 23, and 22) are generally somewhat coarser and higher in carbonate content than the sediments to the north (cores 21, 20, 31, 30, 29 and 28). In essence, sediments of the southern half of Section B seem to represent a transition from the extremes of the sediment in Sections A and B. In all Section B cores, sediment comprising the surface (0-2 cm) sample is finer than the material below; the same is not true of Section A sediments.



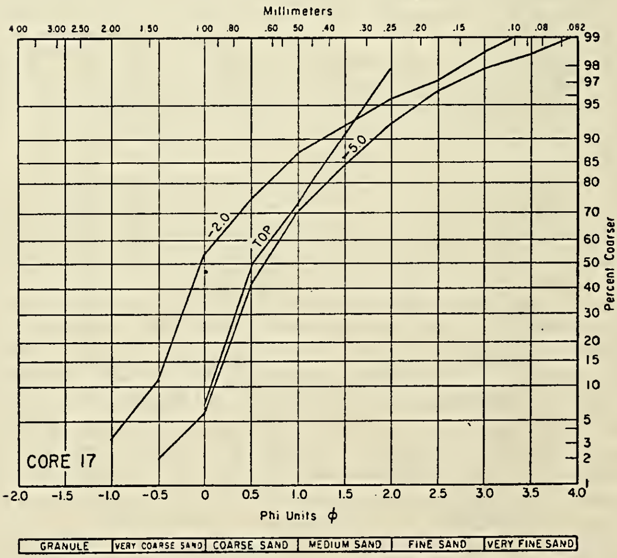
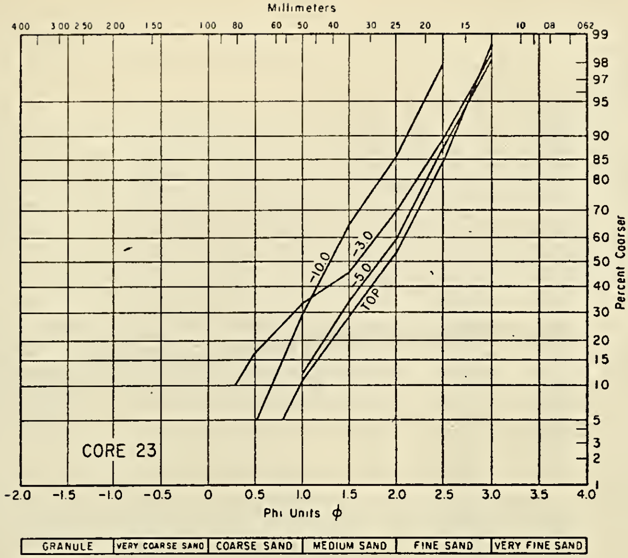




Figure 13. Cumulative curves, representative of offshore sediments in Section A.



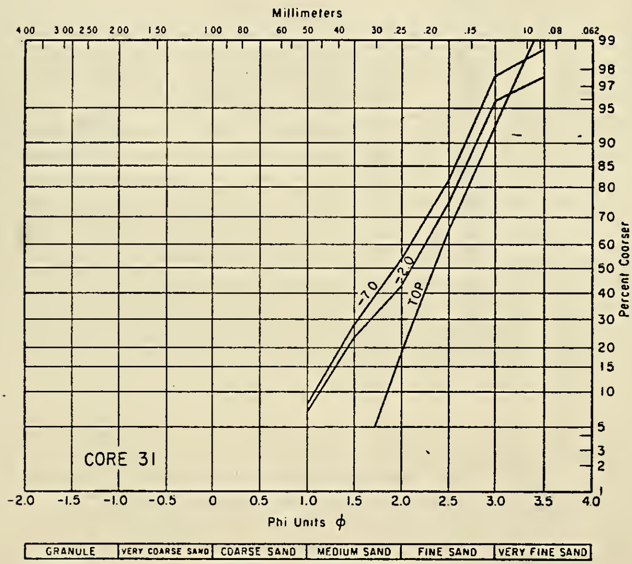




Figure 14. Cumulative curves, representative of offshore sediments in Section B.

d. Miami Grid Area

Tracklines were surveyed on a grid pattern in an approximate 3- by 7-mile area encompassing the shelf and upper slope off south Miami, Key Biscayne and Virginia Key (Figure 3). A total of 10 cores were taken on the shelf portion of the grid area. Analyses of the cores, geophysical profiles, and USC&GS boat sheets are the bases of Figures 12, 15, and 16 which show the bedrock surface, bottom morphology, and sediment thickness, respectively, in the Miami grid area.

The multiple-stepped bottom morphology described previously for Section A is typically developed in the Miami grid area and is depicted in profile in Figures 7 and 11. Adjacent to the shore is a well-developed terrace with the surface at 0 to -6 feet MLW. The slope terminates on the inner flat at approximately -12 to -18 feet MLW.

Relief of the inner flat is low. A broad irregular rocky ridge rising in places to -15 feet MLW rims the outer part of the plateau throughout most of the grid area, becoming less distinct toward the southern end of the area. Parallel to the shoreward edge of this ridge a broad shallow swale with central depths of -28 to -30 feet MLW extends through the northern half of the grid area.

The seaward slope of the ridge marking the outer edge of the inner flat drops to a linear flat at a characteristic depth of -35 to -40 feet MLW. This second flat, which is continuous with the second flat to the north, averages about 800 yards wide. Bordering the flat to seaward in the northern half of the grid area a reef-like rocky ridge cresting at -30 to -40 feet MLW marks the edge of the shelf. In the south, this reef is discontinuous, and where absent, the shelf break occurs at around -45 feet MLW. From -45 feet MLW to about -100 feet, the upper part of the continental slope is rocky or comprised of coarse reef debris. Below 100 feet, geophysical profiles show a thick section of sediments with seaward dipping bedding planes to the maximum depth of survey which is about -350 feet MLW. On the basis of depth and the configuration of the bedding, these sediments are presumed to be Pleistocene and Holocene shoreface deposits overlain by a thin blanket of more recent slope sediments. This assumption has not been confirmed.

Over most of the inner flat the bedrock surface is either exposed or close to the surface, and sediments in the grid area are thin and discontinuous. Linear troughlike depressions in the bedrock of the 40-foot flat contain a 5- to 15-foot accumulation of sediment (Figure 16). Rock is either exposed or covered by a thin veneer along most of the remainder of the shelf edge and upper slope to 100-foot depths. The only other extensive accumulation delineated by this sand inventory program lies in the southernmost part of the inner flat zone where between 5 and 10 feet of sediment have accumulated.

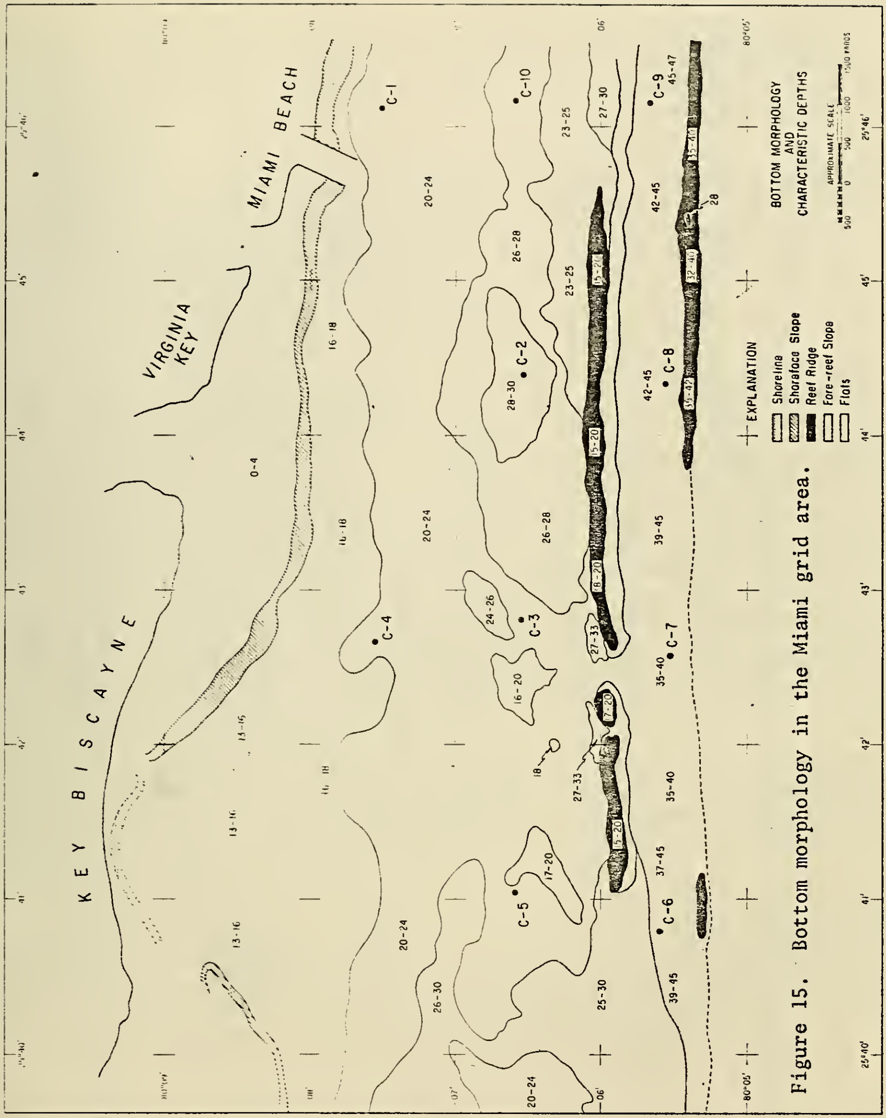



Figure 15. Bottom morphology in the Miami grid area.

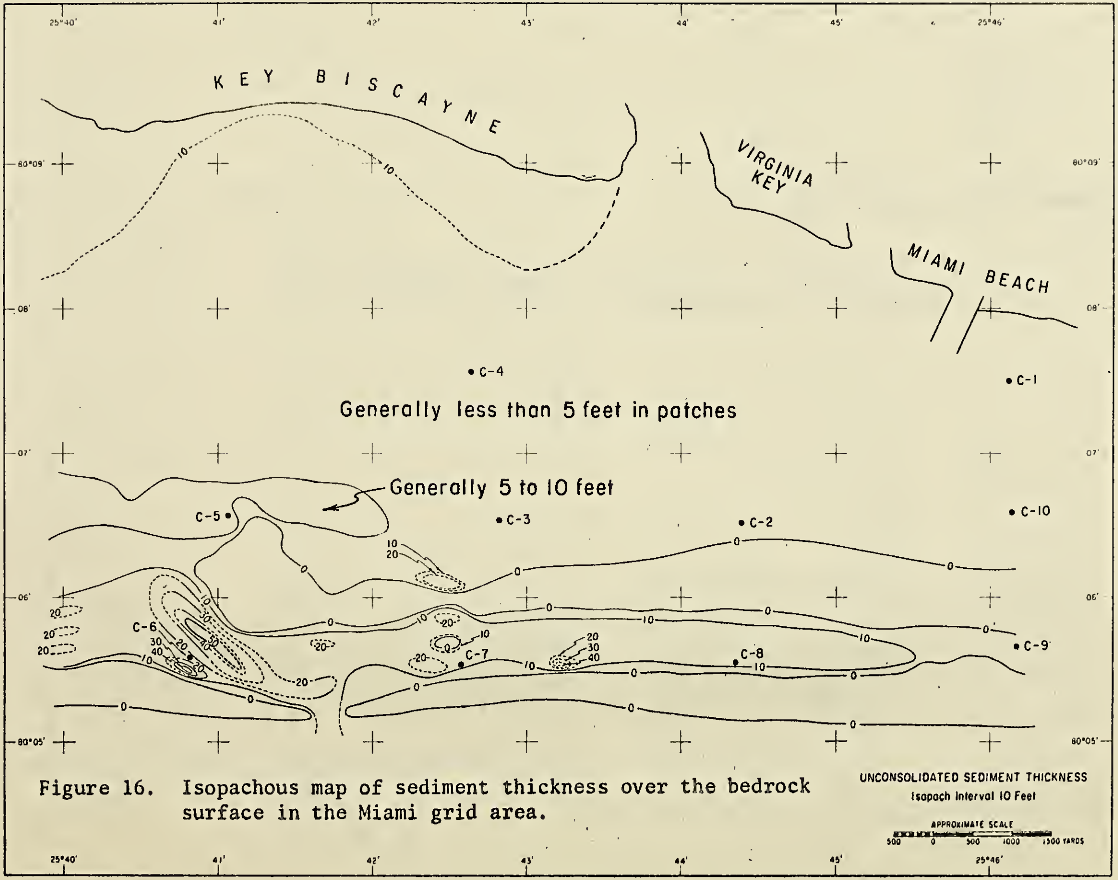



Figure 16. Isopachous map of sediment thickness over the bedrock surface in the Miami grid area.

Ridges are generally barren or contain only isolated, thin sediment patches. Other areas of Figure 16 indicating sediment accumulation represent the position of swales on plateaus where sediment accumulation of 2 or 3 feet occurs. Topographic highs which terminate the plateaus are generally barren of sediment, or contain only thin and areally small accumulations.

A large volume of sediment apparently does exist in the shoreface terrace because some borings have penetrated sediment sections 15 to 18 feet thick. Shallow waters and wave action precluded obtaining cores or seismic profiles; consequently no direct correlations of data from this area can be made with data obtained in the Miami grid.

e. Coastal Morphology and Sediment Characteristics

Between Government Cut at Miami and Lake Worth Inlet near Palm Beach the southeast Florida coastline extends in an almost straight line, bearing about 6° east from a north-south direction. It is a "barrier coast" in the coastal classification of Shepard (1963). The immediate coastal area lies along sandy barrier islands and spits backed by bays, lagoons, marshes and improved sections of the Intracoastal Waterway. The highly developed coastal zone is broken by seven inlets, and protected by numerous groins and almost 20 miles (29 percent) of seawalls and bulkheads. Most of these shoreline improvements are concentrated in the southern half of the area. Physical characteristics of the beach vary because it is influenced and localized by the numerous engineering structures and inlets. Figure 17 is a graphic plot of the median diameter of beach samples compiled from various sources. The wide range of median size between relatively closely spaced stations and the lack of agreement between data from different sources do not favor generalization.

The acid-soluble content of beach samples from the study area ranges from 45 to 85 percent. Visual examination shows that the acid-soluble content is almost entirely of biologic origin with mollusk fragments the most significant constituent. These fragments are generally tabular, sturdy, and well rounded; many have a high polish.

Occasional exposures of coquina rock appear along the beach. Numerous borings and probings in the waterways behind the beach encountered rock identified as limestone or coquina at less than -15 feet MLW; most probably the Anastasia Formation or its facies equivalent. Offshore the rocky surface of the inner flat generally commences at less than -15 feet water depth suggesting that the rock is continuous under the beach zone.

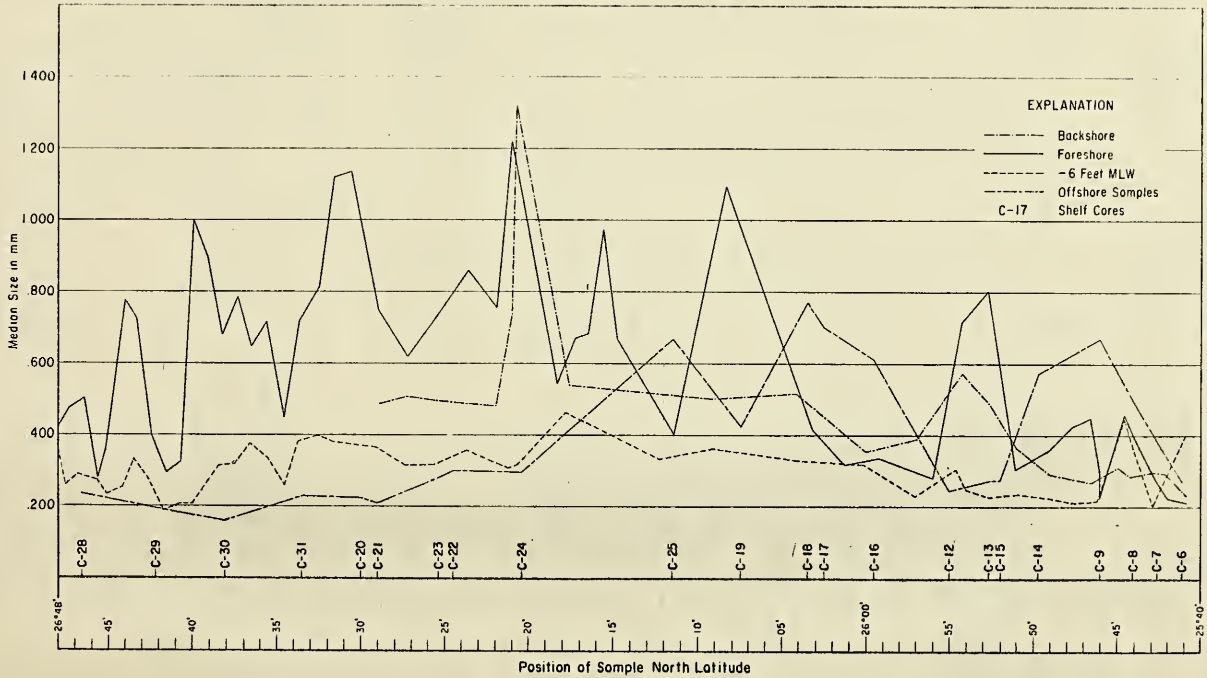



Figure 17. Median diameter of beach and nearshore and offshore samples in the study area. Offshore samples are from the tops of cores; core locations are plotted according to their latitude.

## 1. Sediment Distribution and Origin

Distribution of unconsolidated sediment on the shelf in Section A is largely controlled by configuration of the bedrock surface. Depressions such as the linear troughs between reef lines, shallow swales and bowls on the inner flat, and areas in the lee of topographic highs are favored sites of deposition. The effect of waves and currents on shelf sedimentation processes in this area are not known in detail.

Available data indicate there is little if any sediment transported into the shelf area from the north (Section B) where shelf sediments are finer and much higher in quartz than those of Section A. Introduction of sediment from the slope is also highly unlikely since it would require migration upslope and across the outer reef line.

No significant quantities of the material presently comprising the beach were found in the cores obtained offshore. Further, the general median sand size seaward from the beach shows a decrease to depths of -12 to -18 feet MLW (U. S. Army Engineer District, Jacksonville, 1956, 1960, 1961, 1963, 1965). Beyond this depth, the inner flat (essentially rocky) separates the nearshore zone from the shelf proper. Thus, there is a zone of relatively fine sand and rock separating two zones of coarser and compositionally dissimilar materials on the beach and shelf. Significant interchange of material between the beach zone and the shelf either in a landward or seaward direction within the study area is judged improbable.

Shelf sediments of Section A are judged to be produced more or less *in situ* from organisms presently comprising the biota of the shelf bottom, particularly that biota along the reef and slope lines. Sedimentary material thus produced could subsequently be swept into the adjacent troughs by wave or current action. Sediment produced under shallow water conditions extant during lower relative stands of sea level associated with late Wisconsin glaciation may account for some quantity of the trough sediments. However, as no age dating of these sediments has yet been undertaken, it is not possible to determine relative quantities of sediment contributed during Wisconsin or Holocene time.

Sediments comprising the beach and shoreface zone in Section A are believed to be a combined product of littoral drift from the north and south, local shell production, shoreward transfer of material eroded from the inner flat, and erosion of the shore. Impoundment of sediment at inlet jetties and other coastal engineering works is evidence of net drift from the north.

Much sand has been lost from the littoral zone during recent years; a conservative estimate is that a net loss of 10 to 15 million cubic yards has occurred in the past 30 years (Watts, 1962). This material is probably transported to the deeper water of the shelf or slope. If littoral sediment moving southward is lost to the littoral stream through movement into deeper water offshore, the character of the sediment indicates that offshore movement does not occur in Section A. Loss of beach material in the Miami area could then only be due to nearshore longshore movement, or solution of shell material. Rusnak (1966) concluded that loss by abrasion is insignificant. Because of the pH and composition of the sea water, loss by solution should be insignificant also. It is judged, therefore, that the observed loss of beach material (less that lost to inlets) is due to movement parallel to shore out of the area, rather than movement directly offshore.

The gray sand body covering most of the shelf in Section B is probably detrital in origin, but the source of this material is not clear. The black or dark gray coloration of most of the shell material in the sand provides the sand with a distinctive gray color. Such coloration of the shell material has generally been taken to indicate previous burial in a marsh or swamp environment; however, recent studies show that blackened skeletal fragments may form in a subbottom marine environment (Maiklem, 1967). Thus, the present color does not necessarily indicate a relict deposit or material eroded from a lagoon bottom or back beach source. In fact, on the Georgia nearshore Continental Shelf, recent sediment is colored gray and contains 25 percent or less of carbonate (Gorsline, 1963), Pilkey and Frankenberg, 1964), not too unlike the sediment in Section B.

It is unlikely the gray sand comes from offshore for reasons explained above, and a source area in the high carbonate environment to the south is improbable in view of the high quartz content and the shape and compositional difference of much of the skeletal material here. Also, sediment northward in the Fort Pierce area is dissimilar to sediment in Section B, which would preclude a northward source. One other difficulty with the explanation for a northern source is that within the zone where cores were taken there is a general decrease in average grain size northward; the trend, therefore, would be contrary to the premise of a decrease in grain size downdrift from a source. A possible explanation may be that the southward moving inshore sediments are washed seaward to deeper water in Section B and then drift back northward because of northerly offshore currents. Research presently underway by John Milliman (personal communication) indicates a narrow zone of sediment with relatively high quartz content (25-50 percent) extending offshore between Fort Pierce and Jupiter Inlet to approximately the 100-fathom line thence extending north for 150 miles and south for 90 miles. Current measurements near Miami show a northward drift over the shelf of about 0.5 feet per second (House Document 169, 75th Congress, 1937). General velocity of this drift is not competent to move particles greater than silt size (0.062 mm; $4\phi$) although periodic higher velocity northward currents capable of moving material in the size ranges characteristic of the gray sands of Section B might occur.

2. Sand Requirements

At the date of writing of the report, Beach Erosion Control and Hurricane Protection Studies conducted by the Corps on the Florida east coast, extending from Duval County at the north to Dade County at the south, were examined and proposed project requirements summarized by Duane (1968). The projects showed an initial fill requirement of some 26 million cubic yards of material with annual replenishment of slightly less than 2 million cubic yards. Over a 50-year maintenance period, 110 million cubic yards would be required.

Corps of Engineers studies prepared for specific beach erosion control projects in Palm Beach, Broward, and Dade Counties estimate requirements of nearly 21.5 million cubic yards of sand for initial fill and maintenance requirements of nearly 900,000 cubic yards annually. Thus, for a 50-year economic life, an additional need of approximately 45 million yards of sand can be forecast. Requirements for specific coastal sections within the limits of this study area are summarized in Table II.

Using erosion and shoaling data from Beach Erosion Control reports, Watts (1962) estimated that an annual net of 842,000 cubic yards of sediment had eroded shoreward of -18 feet MLW between Lake Worth Inlet and Government Cut (Miami) for at least 30 years prior to that report. The annual loss into inlets during this period was estimated at 200,000 cubic yards, leaving a net residual loss to the shore area of 642,000 cubic yards. Impoundment and shoaling data for Lake Worth Inlet indicates that around 230,000 cubic yards of material moves south annually into the inlet area (Watts, 1962). Even if the entire amount lost at Lake Worth Inlet were bypassed and allowed to reach the littoral zone to the south, a net annual deficit of 412,000 cubic yards of sand would occur in the littoral sand budget south to Government Cut. These figures indicate that such remedial measures as groins and inlet bypassing would not entirely prevent continued erosion of the beaches of southeast Florida and that periodic replenishment of at least some of the loss would appear to be the most effective measure of maintaining suitable beaches in the area.

### 3. Areas Suitable for Offshore Borrow

The density of data collected by CERC for this study is adequate for sand volume calculations in the Miami grid area only. A study of the sand resources on the shelf off Broward County (25°58' N to 26°20' N; Figure 18) was completed in 1967 by Ocean Science and Engineering Company (OSE) for the Broward County Erosion Control Committee who have made the results available to the Coastal Engineering Research Center. The Broward County Study is based on marine seismic reflection profiles run from about 100 yards offshore to 1 nautical mile offshore at 600-foot intervals along the entire county frontage; these were supplemented by two long cross lines parallel to shore. Sediment characteristics of the bottom and to -12 feet below the bottom were determined by use of several sampling techniques: a 12-foot long airlift sampling device, a water-jet probe, and diver inspection. From the two sources (CERC and OSE studies), it is possible to make reasonably reliable sand volume estimates for most of the region south of 26°20' N (Section A). Only tentative estimates for Section B can be made because of the reconnaissance nature of the CERC Sand Inventory

TABLE II

Fill Requirements in the Study Area

| | Initial | Annual |
|---|---|---|
| **Palm Beach County** | | |
| Jupiter Inlet to Lake Worth Inlet | 1,560,000 | 65,000 |
| Lake Worth Inlet to Boca Raton Inlet | 3,760,000 | 115,000 |
| Boca Raton Inlet to Broward County Line | 240,000 | 10,000 |
| **Broward County** | | |
| Palm Beach County Line to Hillsboro Inlet | 800,000 | 50,000 |
| Hillsboro Inlet to Port Everglades | 1,538,000 | 100,000 |
| Dania to Hollywood-Hallandale | 1,339,000 | 160,000 |
| **Dade County** | | |
| Broward County Line to Haulover Beach | 1,670,000 | 135,000 |
| Haulover Beach Park | 310,000 | 20,000 |
| Bakers Haulover to Government Cut | 1,670,000 | 135,000 |
| Key Biscayne and Virginia Key | 1,065,000 | 48,000 |

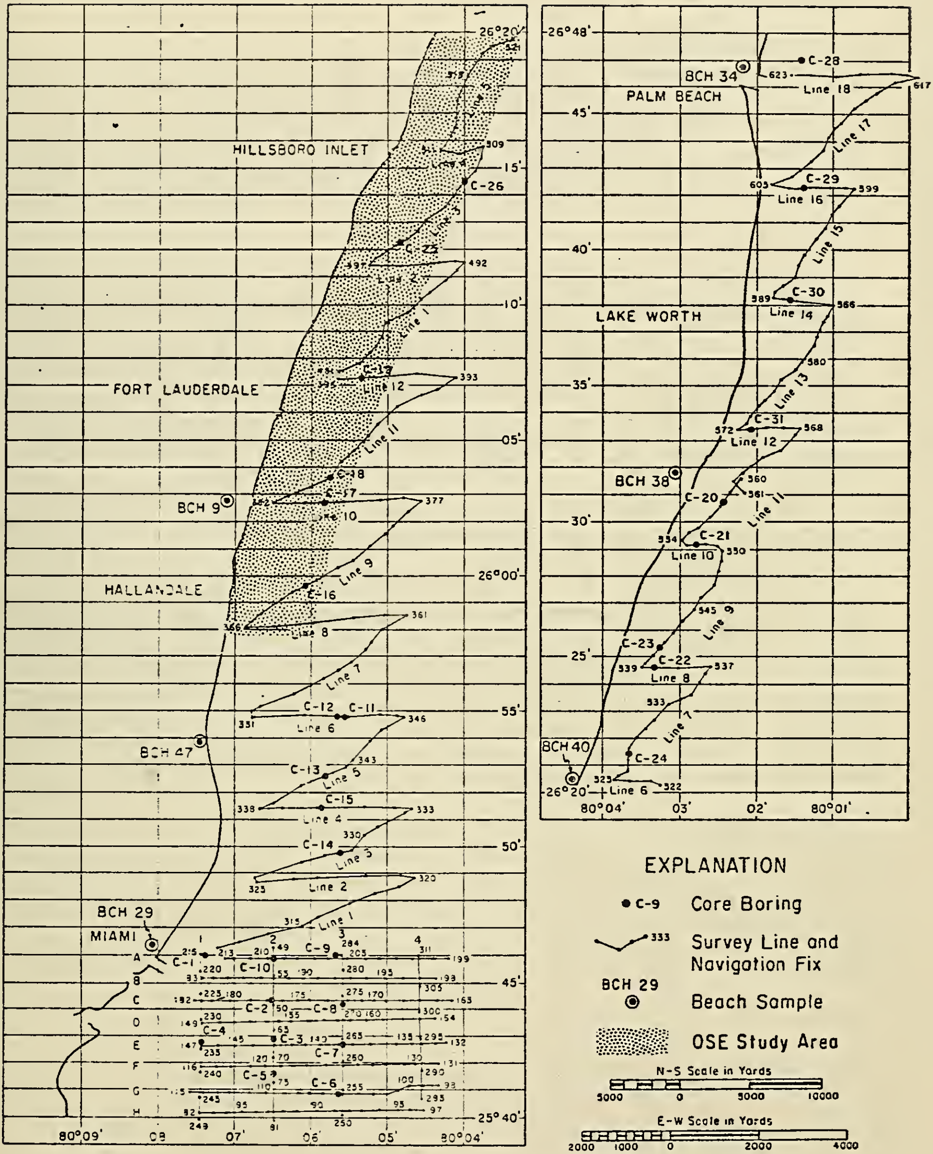



Figure 18. Limits of study by OSE for Broward County Erosion Control Committee.

program there, and because of the paucity of published information concerning the shelf in that area.

Because of the line spacing involved in the CERC exploration program at Miami, more closely spaced work might be required to more precisely define the most suitable bottow areas prior to exploitation. Such a program would be analogous to "development drilling" in the petroleum industry, and to "blocking-out the ore" in the mining industry; consequently, it is not a requirement unique to the offshore Sand Inventory Program. Quantities of sand available are summarized in Table III.

## SECTION A

The OSE Broward County report estimates a total sand volume of 66 million cubic yards within 1.2 miles offshore of Broward County. Of this material, 36 million cubic yards is concentrated in the 60-foot plateau, within 1 mile of the beach. The remaining 30 million cubic yards lies scattered in patches and thin blanket deposits in the 40-foot plateau and on the inner flat. Over half of this material is concentrated in the northern two-fifths of the segment where isolated sand pockets within the 40-foot plateau begin to coalesce into larger bodies.

From the south Broward County line to the Miami grid, a total of 66 million cubic yards of sand are estimated to occur.

In the CERC Miami grid area, 14 statute miles south of the OSE Study, there is a sand volume of 69 million cubic yards exclusive of the thin and discontinuous patches generally occurring on the inner flat. Of this amount, about 48 million yards are contained within the confines of the 40-foot flat 3 to 4 miles from the beach (Figure 19). A smaller concentration of about 5 million cubic yards lies on the offshore part of the inner flat (Figure 19). Because of the nature of known accumulations, similar but smaller areas of recoverable sand can be forecast with reasonable assurance to occur elsewhere on the flat.

Approximately 16 million cubic yards of unconsolidated sediment occur in the shoreface zone of Dade County. However, calculation of sediment volumes in the shoreface is based on sparse data; no seismic lines were run in this area due to the shallow water. Borings by the Corps of Engineers (Jacksonville District, 1961; 1968) indicated up to 18 feet of sediment in the shoreface off Key Biscayne and less than 5 feet off Virginia Key.

## SECTION B

On the basis of the limited data available, morphology of the shelf and subbottom, and geology of the region, the volume of material available within the shelf area of Section B (north of 26°20' N) is estimated at 380 million cubic yards. The bulk of the sand is believed to have characteristics similar to the fine gray sand recovered in the 10 cores

TABLE III

Estimated Sand Volumes Above the Bedrock Surface
(in cubic yards)

| | | Morphologic Unit | | | |
|---|---|---|---|---|---|
| Section | Subsection | Shoreface | First Flat | Second Flat | Third Flat |
| A | Miami Grid | 16,000,000 | 5,000,000 minimum | 48,000,000 | Not present |
| | Miami to South Broward County Line | No data | 15,000,000<br>about 1/3 may be available | 28,000,000 | 23,000,000 |
| | Broward County (OSE Report 1965) | No data | 5,000,000<br>About 1/2 may be available | 25,000,000 | 36,000,000 |
| | | | Sediment Slope | | Third Flat |
| B | Palm Beach County | No data | 380,000,000 | | Insufficient data |

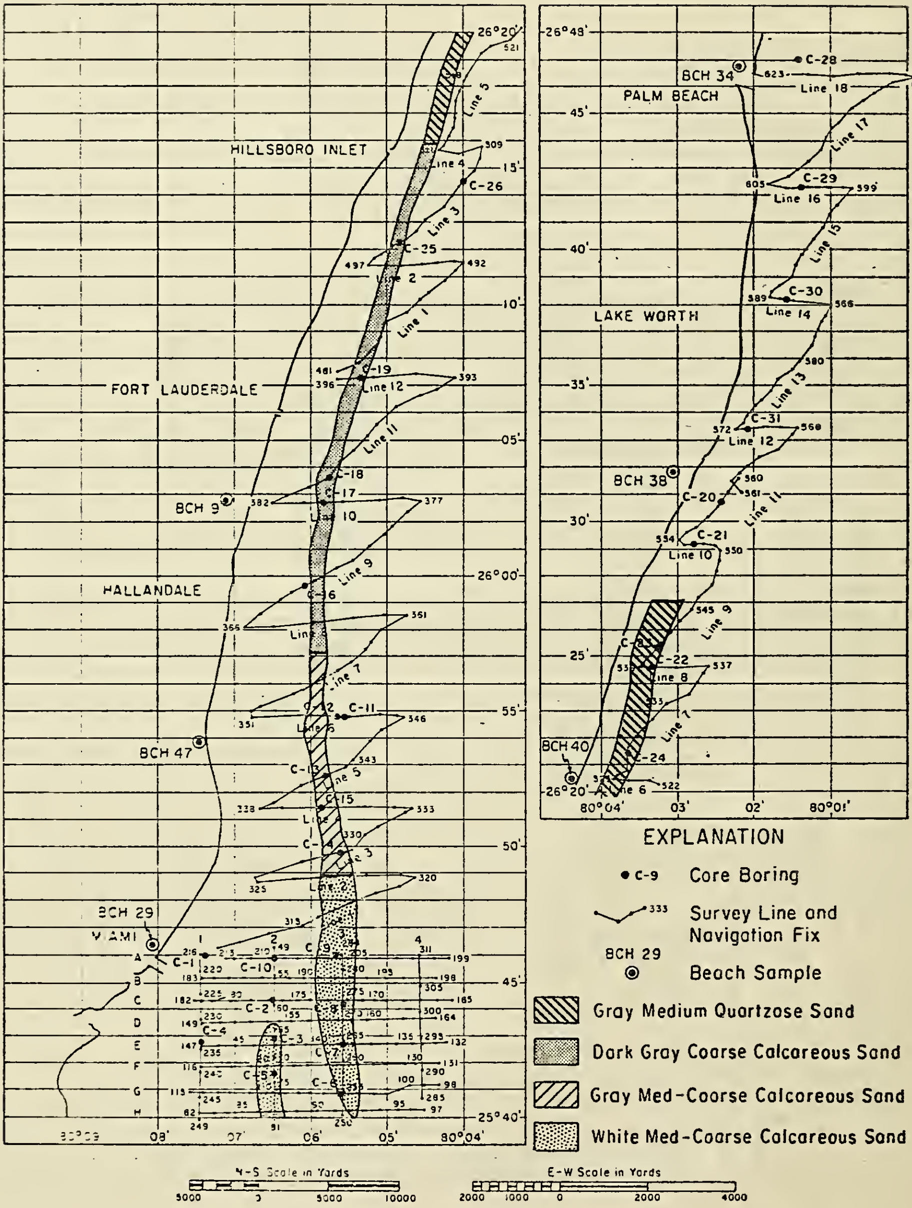



Figure 19. Areas most suitable for sand borrow.

collected. Near the reef lines and at depths not reached by the cores under the gray sand blanket, the sand may be similar to the calcareous sand of Section A.

4. Suitability

Corps of Engineers studies for Palm Beach, Broward, and Dade Counties indicate a possible requirement of some 6 million cubic yards of sand over a 50-year period; more than enough sand to meet these needs exists in the study area. Indeed, enough sand-size material exists offshore in just the Miami grid to meet initial requirements (21.5 million) and some years of annual nourishment.

Sand comprising the beaches of Dade and Broward Counties has a high carbonate content, but the aspect of the carbonate fraction existing offshore in the Miami grid is different (see Figures 20 and 21). Shell debris on the beaches is somewhat larger and much less delicate than the shell occurring in the potential offshore borrow zones. This is due to the difference in the type of organism contributing to the shell. Offshore the shell debris is from algae and foraminifers indigenous to the quieter offshore zones, while onshore it comes from mollusks indigenous to the high energy littoral zone (Figure 19). Although median diameters of beach and offshore sediment are not too dissimilar (Figure 17), the compositional differences indicate there is some question if the offshore sand-size material would maintain its integrity once placed on the beach; that is, it might disintegrate under surf action. Therefore, while ample material exists off Miami, the degree of its suitability can be determined only through further study.

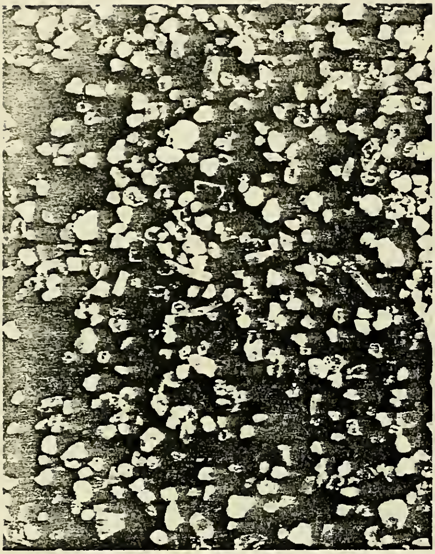
Sediment comprising the shoreface terraces and the bottom offshore in Section B are compositionally more suitable for beach fill but the size characteristics (small median diameter) make the sediment not wholly satisfactory for long-term projects.

## Section IV. SUMMARY AND CONCLUSIONS

The southeastern coast of Florida between Cape Florida and Lake Park is bordered by a narrow, shallow submarine shelf which is characterized by two distinct morphological and sedimentary aspects, one dominant in the north and the other dominant in the south.

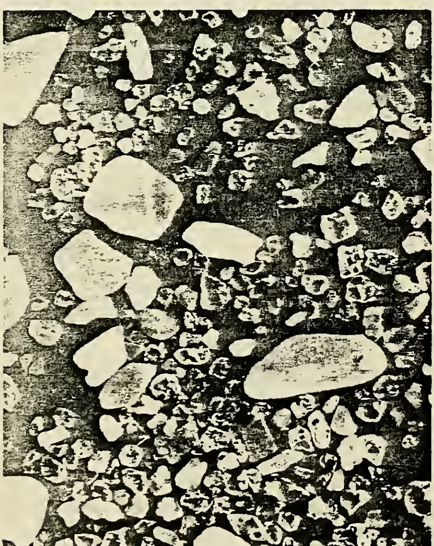
As part of a larger study, a subbottom exploration program covering this 141 square mile shelf area was carried out by the U. S. Army Corps of Engineers in 1965. In this program 176 miles of continuous seismic reflection profiles and 31 sediment cores were collected.

The low coast bordering the southeastern Florida shelf is covered by relatively thin sediment deposits consisting of late Pleistocene sands and Holocene beach and dune sediments. Underlying these sediments are



Beach 29

Beach 47



Beach 9

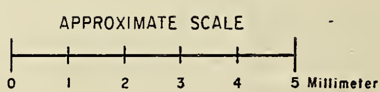
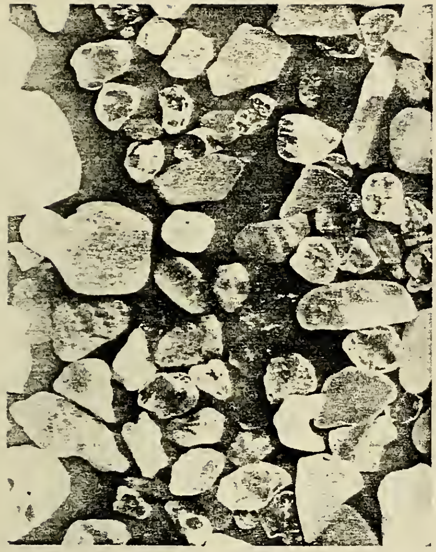
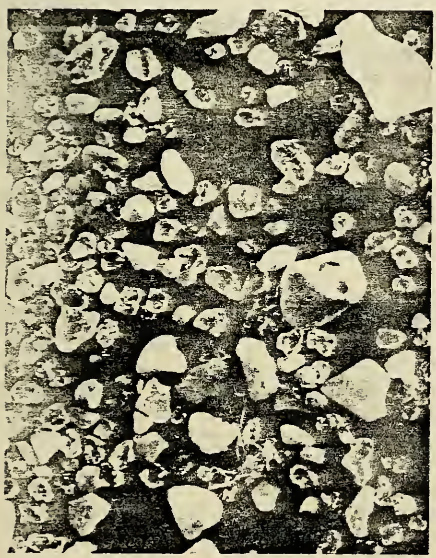



Figure 20. Photographs of typical beach material in Section A. (25°40'N to 26°20' N)



Beach 40

Beach 38



Beach 34

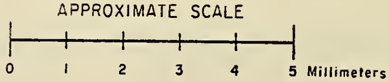



Figure 21. Photographs of typical beach material in Section B. (26°20' N to 26°47' N)

elements of the Pleistocene Miami and Anastasia Formation; both highly calcareous and rich in biogenous material. Bordering the shelf to seaward beyond the shelf break at around -70 feet MLW is the western slope of the northern Straits of Florida.

South of Boca Raton (26°20' N) the shelf is step-like in profile, consisting of two or three linear flats separated by low reef-like ridges. The two outer flats are formed by the underlying bedrock surface and the outer ridges which create trough-like linear depressions partially filled with sediment. The inner flat is predominantly rocky with thin and discontinuous patches of sediment throughout. Characteristically, sediments comprising the southern part of the shelf in the study area are composed of fragments of the biota, poorly sorted, and ranging in size from silt to very coarse sand. In the outer trough-like flats there are accumulations of about 5 to 15 feet of sediment. The deposits on the broad inner flat rarely exceed 5 feet in thickness and are generally much thinner than this.

The total volume of sediment in the two outer (second and third) flats is estimated to be 160 million cubic yards. About 100 million cubic yards is located in the second flat at around -35 to -50 feet and is therefore more readily accessible to existing dredging equipment. Sand accumulation on the inner flat may aggregate approximately 20 million cubic yards, but the location of most of this material and the nature of the deposit are not favorable from the standpoint of recovery. South of Government Cut at Miami, the shoreface terrace contains an estimated 16 million cubic yards of sediment but the removal of any substantial amount of this material may have an unfavorable effect on the shoreline.

In terms of accessibility and lateral continuity of the deposits, the most readily available supply of sand lies in the linear second flat at depth of -35 to -50 feet MLW, and from 1 to 3 miles offshore. The size characteristics of the material when compared to existing beach sediments on the adjacent coast are such that much of it would be usable for local beach restoration and nourishment. There is a difference, however, in the character of the constituent particles in that the offshore material contains a substantial amount of delicate material which may become mechanically degraded in the turbulent littoral zone. Further study and tests of the material are therefore needed to fully appraise its suitability.

North of Boca Raton (26°20' N) to the northern limit of the study area the shelf topography and sediments change dramatically. Most of the shelf here is covered by a blanket of homogenous fine to medium gray quartzose sand which produces a gently dipping relatively smooth shelf surface topography. Near the shore this sand blanket may reach a thickness of around 40 feet, thence it thins progressively seaward to a feather edge in the vicinity of the shelf break, a distance of approximately 1,500 yards from shore. The total volume of sand available in the northern shelf segment is estimated to be 380 million cubic yards.

In general, this sand is considerably finer than most sand presently found on southeastern Florida beaches and, therefore, of doubtful value for local beach nourishment projects.

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# APPENDIX A

## EXPLORATION TECHNIQUES



ILLUSTRATIONS

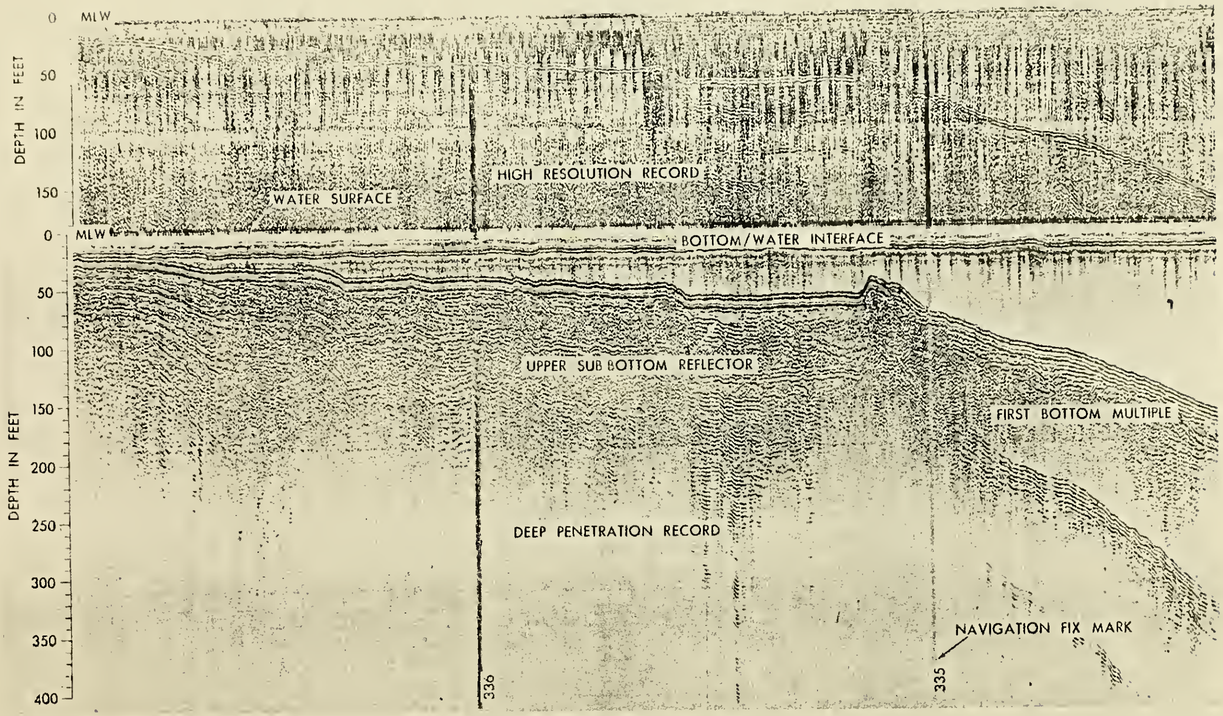



Figure A-1. Typical dual source seismic reflection profile.

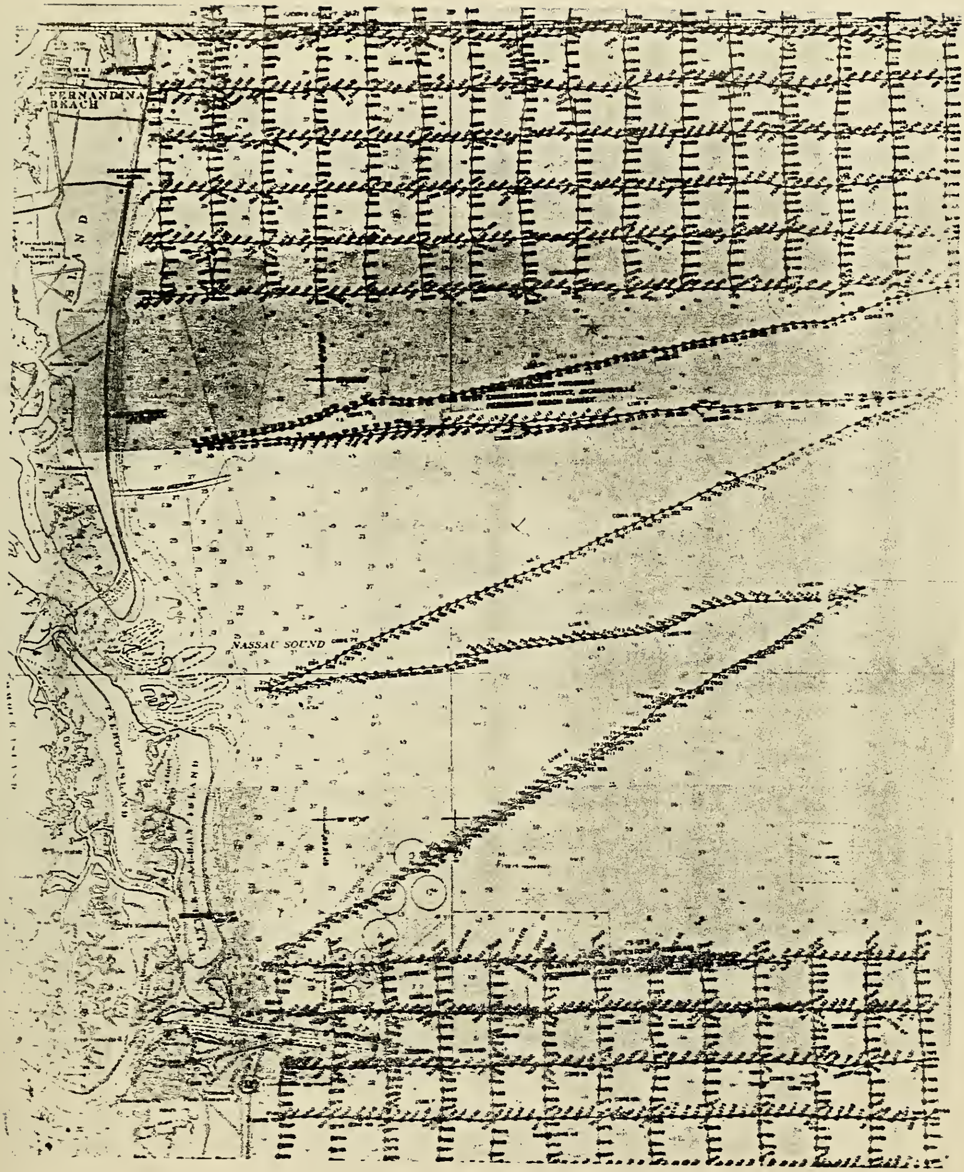



Figure A-2. Navigation chart with trackline overlays.

1. General

Procedure for the conduct of sand inventory projects has remained fairly consistent since their beginning. The few significant changes which have been made resulted from experience gained in earlier surveys. In general, the conduct of a particular survey is divided into three phases; planning, exploration, and data analysis.

2. Planning

Perhaps the most essential aspect of planning a regional subbottom survey is flexibility. Although it is a practice to gather available background data about the survey area to assist the planner, detailed information concerning the continental margins is generally deficient. Once the survey gets underway, new data is generated and a clearer picture of the area emerges. The new data often suggest desirable alterations in the basic plan. To prevent excessive downtime in offshore surveying, the plan should provide means for rapidly making changes.

Survey planning involves laying out tentative survey tracklines, determining the total survey mileage and the number of cores needed, and scheduling the time needed to complete all field work. It is equally important to schedule the field work at the most favorable season, since offshore operations are especially affected by weather and sea conditions. Existing dredge capabilities and economic hauling distances are significant factors in planning a reasonable offshore limit for the survey. Presently, surveys are terminated at either of 100-foot depths (MLW) or 10 miles offshore. The inshore termination depth is controlled by the safe operating depth needed, generally about 15 feet. These limiting conditions are guides only, and are often exceeded where local circumstances permit extension of survey boundaries.

In laying out survey tracklines, the pattern and density of lines are partly based on the need for sand in the area. If a large supply of sand fill is needed and onshore sources are limited, a detailed survey will be projected for the area even if information indicates only a marginal probability of finding a good offshore supply. In laying out lines near areas where the current need for sand fill is light, the most detailed coverage is given those regions where information indicates a promise of sand.

Basic trackline patterns used in the sand inventory surveys are illustrated in Figure A-3. A navigation overlay of a completed survey is shown in Figure A-2.

Grid patterns provide the most detailed coverage of an area and give maximum data control. Normal grid spacing is 1 statute mile, however, highly detailed seismic coverage of some sand deposits require much closer

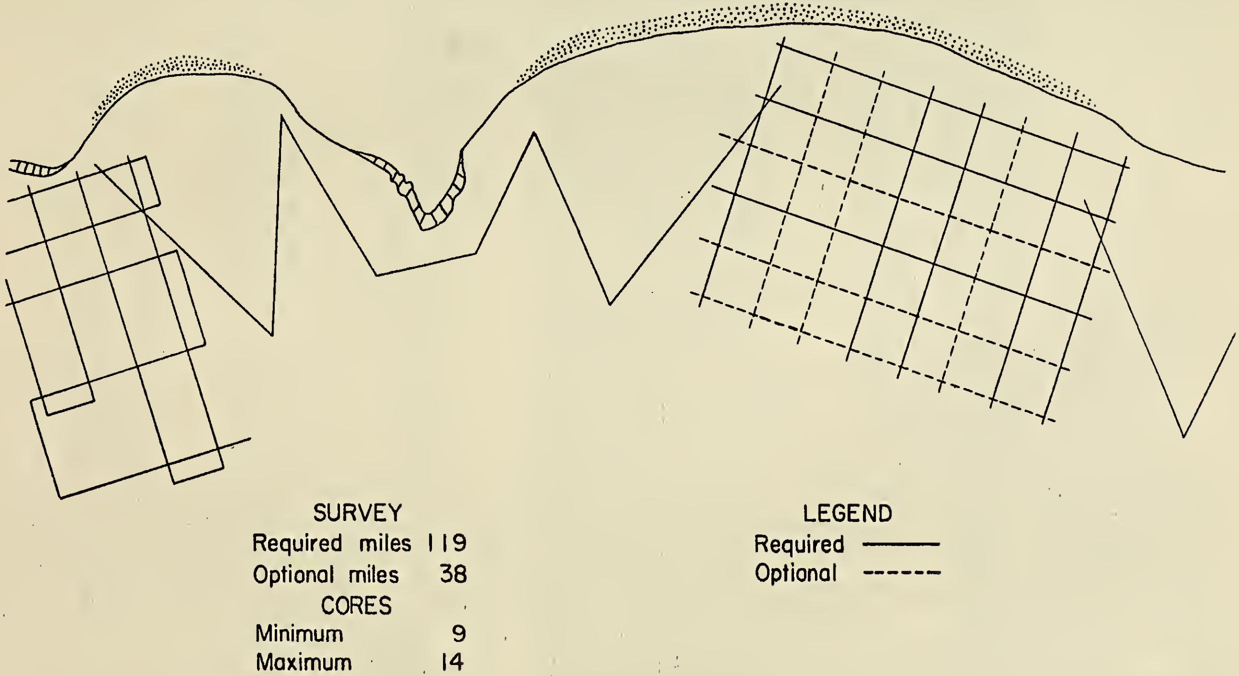



Figure A-3. Typical survey trackline configurations.

spacing. A less detailed trackline configuration is the "open rectangle' pattern shown on the left side of Figure A-3. Spacing of parallel lines may be at 1, 2, or 3 miles. Either a single pattern is used or two patterns are crossed to produce a grid as illustrated. Segments between grids or open rectangle surveys are covered by "reconnaissance" lines which are usually zigzag but may be altered to conform to shoreline and inner shelf configuration. Reconnaissance lines are adequate for tracing regional subbottom reflecting horizons between grids and for detecting any large sediment accumulations crossed.

A few tentative core locations may be selected during the planning stage, but most core sites are picked after the geophysical survey has been run and the records examined. This allows for a better selection than than one based on the generally meager information available during the planning stage.

If field survey work is to be let on contract, flexibility is gained by splitting the work into a minimum number of survey miles and cores and optional incremental work (Figure A-3). At the discretion of the Coastal Engineering Research Center, the whole or any part of the optional work may be subsequently ordered depending on the outcome of the minimum work. The value of flexible planning was illustrated by a recent Sand Inventory Survey in Long Island Sound. One grid area, near Bridgeport, Connecticut, was selected primarily on the basis of a need for sand in that particular place. After first survey results, it was apparent that prospects for suitable sand were not good in the grid area. However, a nearby reconnaissance line indicated considerable sediment accumulation, and a single core on the line revealed several feet of sand. Optional survey miles and cores were available, and a small grid was constructed around the spot with favorable indications. It was thus possible to delineate a sand deposit that could provide the material needed in the Bridgeport area.

3. Survey Operations

Since most of the sand inventory work is within 10 miles of the shore, the survey vessel need not be large, and accurate continuous position control poses no special technical problems.

General practice in sand inventory surveys has been to run the geophysical profiles for a limited area and then to study the records before selecting core locations and prescribing optional work. Coring and additional tracklines of geophysical data can then be completed, and the vessel can go to work in the next area. This mode of operation permits the contractor to shift his base along the coastline without being obliged to return for cleanup work.

To identify the uppermost strata revealed by sonic profiles, it is necessary to obtain samples of the material. This is done by coring through the overburden, or by surface sampling if the subbottom reflectors can be traced to an exposure. On the average, in CERC surveys, one core has been taken for every 7 miles of geophysical survey. The cores are 3 or 4 inches in diameter, and are taken with a pneumatic vibrator-hammer driving the coring device. Core length ranges from a few inches to 20 feet depending on the nature of the materials penetrated.

The average core length of about 12 feet is adequate for most sand inventory purposes; however, for foundation work and for scientific purposes, it is most desirable to sample deeper reflectors. At times deeper reflectors can be sampled by routing tracklines around a site where deep borings have been made in the past. For example, during sand inventory surveys off Virginia and New York, lines run to the Chesapeake and Ambrose light towers permitted use of data obtained in foundation studies made for the construction of these towers. It is also frequently possible to trace moderately deep reflectors on the geophysical profiles to points where they crop out or come within range of the corer at a high point on the reflector or a low point in the bottom.

### 4. Data Analysis

At the conclusion of field survey work all data must be assembled for processing, analyzed, and reduced to a report detailing the findings. The ultimate aim of each regional survey is to produce a report, or series of reports, dealing with the location and nature of sand deposits within the framework of a general exposition of pertinent aspects of the regional geography and geology, bottom morphology, sediment distribution, and subbottom structure. The more immediate task, however, is to provide Corps of Engineers District Offices for planning purposes brief, informal reports concerning sand deposits in areas where Federal Beach Erosion Control or Hurricane Protection projects are pending or authorized.

#### a. Seismic Records

One of the most difficult problems associated with analysis of a large quantity of seismic reflection profiles is their printout size. A 9-inch wide record covering 10 miles of trackline may be 25 to 30 feet long. As many as 40 such records may be produced in one grid area.

To lay out two or three of these records side by side for comparative analysis is not only cumbersome, but requires considerable space. There are several other difficulties which arise when comparing the raw records. Parallel records in a grid set will have been run on opposing ship headings; consequently the various bottom and subbottom features for adjacent tracks are mutually reversed. Further, because of differences in the vessel speed the horizontal scale is not constant either along a single line or from line to line. An added problem arises with records run in comparatively shallow water. If the water depth is less than the effective depth of subbottom penetration multiple reflections of bottom and subbottom acoustic interfaces will be superimposed on the record and may partially mask subbottom detail. Although the true reflectors can generally be sorted out at a given point of ambiguity, this interference deteriorates the continuity of the overall view, and increases the difficulty of comparative work.

The problems of space and opposed headings can be partly resolved by photographically reproducing records at a smaller scale. A more comprehensive method of achieving a manageable format is to "reduce" the records to line profiles, such as shown in Figure A-4. This process consists of delineating the acoustic interfaced lines on the record with pen, chalk or some other marker and manually transferring these lines, point by point, to a prepared graphic profile plot at reduced scale. In this process the horizontal scale differences are resolved, all line directions are put in the same sense, and the problem of multiple reflectors is eliminated. As useful as this manner of presentation is, it would not do to rely entirely on the line profiles since they do not show the character of the signal or the finer details of line configuration. It is necessary then to refer periodically to the original records, and for this purpose photographic reproductions are very useful.

b. Cores

Processing of sediment cores at CERC consists primarily of visual description and granulometric analysis of material. Representative samples are selected along the core at points determined by visual inspection through the clear plastic core liner. A hole is drilled in the liner at these points, and about 80 grams of material are removed after which the core is resealed by filling the hole with expanding foam plastic and wrapping with plastic tape. Each sample is inspected under a binocular microscope, and visually classified for color, texture, and gross mineralogy. Granulometric analysis of all sand-sized material is made with a modified Woods Hole-type rapid sediment analyzer (Ziegler, et al, 1960, and Schlee, 196 ), an instrument which provides size distribution data related to hydraulic diameters of equivalent spheres. The size analysis data is produced on both an analog recorder and on punched cards. The cards are processed by computer for printout of granulometric statistical measures such as mean diameter, median diameter, standard deviation, skewness, and kurtosis.

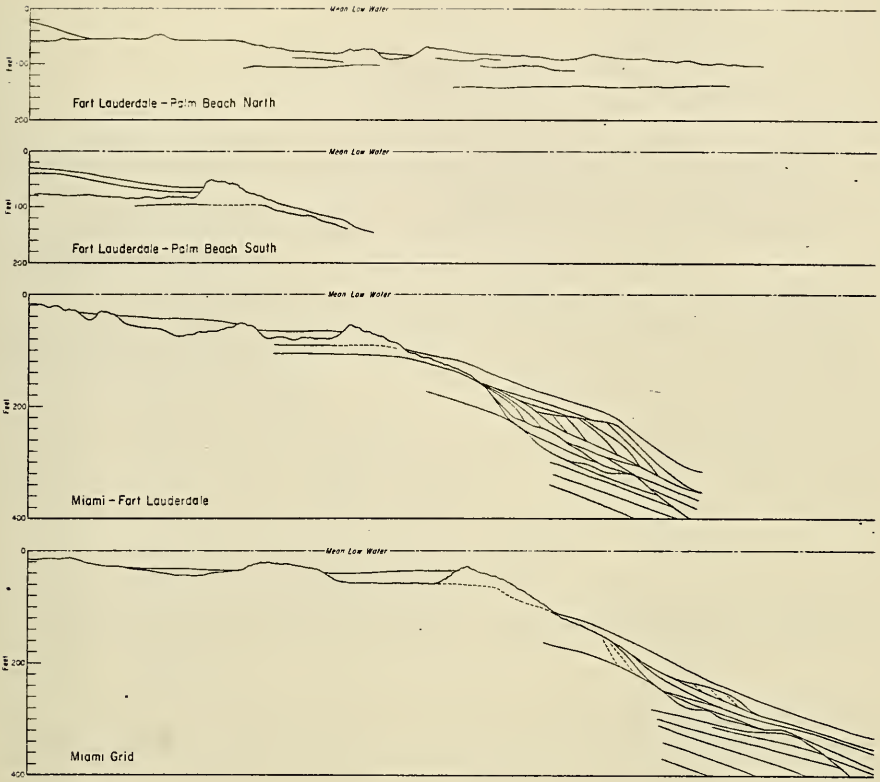



Figure A-4. Reduced seismic reflection profile data.

# APPENDIX B

## CORE DATA AND SEDIMENT DESCRIPTION

Appendix B contains graphic size distribution plots and visual description of sediments contained in cores from the study area.

Size distribution curves for selected samples are identified by notations on each curve showing depth of sample below the water-sediment interface.

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

1. Color descriptor
2. Color code per Munsell Soil Color Charts (1954 ed.)*
3. Dominant size or size range.
4. Major compositional element or elements with the dominant constituent listed last.
5. A phrase identifying readily recognized constituent elements with an estimated percentage occurrence in terms of total particles.

Described subdivisions of the core are indicated by limiting lines drawn across the graphic scale to the left of the descriptions. The hachured line shows the depth to the bottom of the hole.

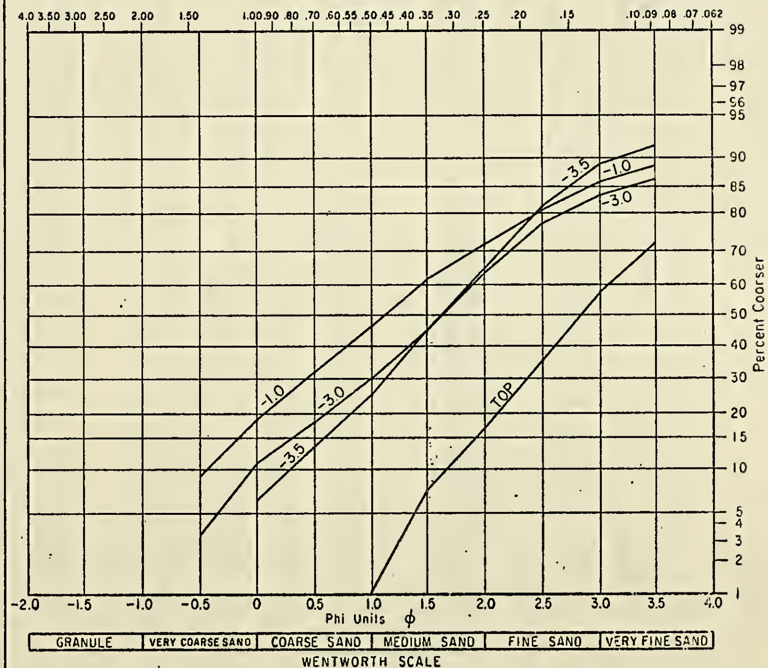
*Munsell Color Company, Inc., Munsell Soil Color Charts, 1954 Edition, Baltimore, Maryland.

## DESCRIPTION

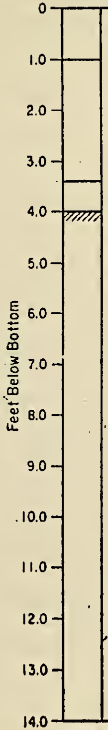
Light gray (10 YR 7/2), fine to medium calcareous sand.
Mottled black, gray, white; fine to coarse calcareous sand; 10% shell fragments, 20% quartz.
White (10 YR 8/1), fine to medium silty calcareous sand; 30% small calcarenite pebbles.
Light gray (10 YR 7/2), fine to medium calcareous sand; 30% small calcarenite pebbles.

Feet Below Bottom: 0, 1.0, 2.0, 3.0, 4.0, 5.0, 6.0, 7.0, 8.0, 9.0, 10.0, 11.0, 12.0, 13.0, 14.0

## SIZE ANALYSIS




PROJECT Florida Sand Inventory CORE NO. 1A WATER DEPTH 30' CERC I.D. NO. 712-2



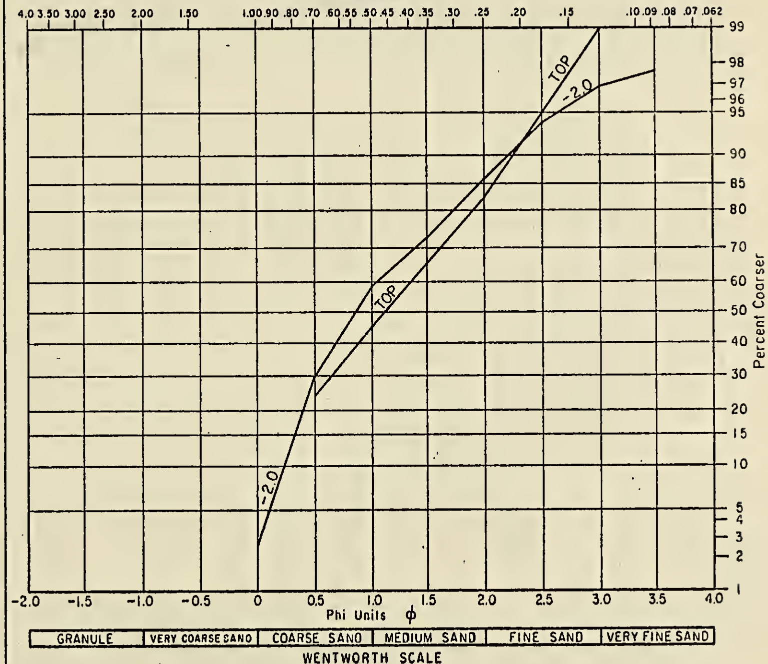

## DESCRIPTION

Light gray (10 YR 7/2), medium to coarse calcareous sand; 10% shell fragments.

White (10 YR 8/2), medium to coarse calcareous sand; 30% foraminifers mollusks, calcareous algae.

Very pale brown (10 YR 7/3), medium calcareous sand; 2" dark gray limestone fragment.

## SIZE ANALYSIS

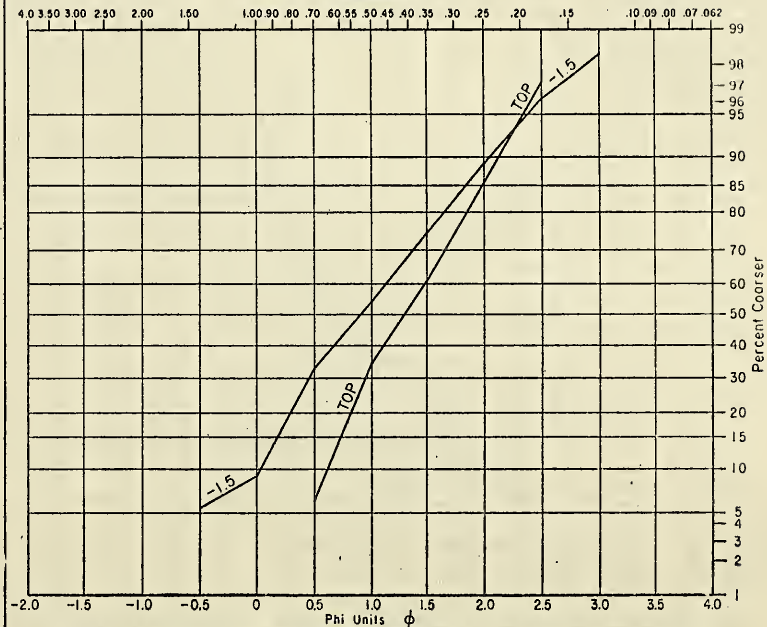



PROJECT FLORIDA SAND INVENTORY CORE NO. 2 WATER DEPTH 30' CERC I.D. NO. 712-3

## DESCRIPTION

| Feet Below Bottom | Description |
|---|---|
| 0 – 1.5 | Gray (10 YR 6/1), medium to coarse calcareous sand; 30% mollusk shell, calcareous algae, pellets. |
| 1.5 – 2.0 | Same except shell fragments larger; one 3" limestone fragment. |

## SIZE ANALYSIS

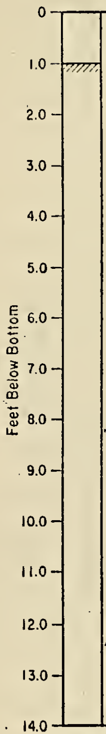



| GRANULE | VERY COARSE SAND | COARSE SAND | MEDIUM SAND | FINE SAND | VERY FINE SAND |
|---|---|---|---|---|---|

WENTWORTH SCALE

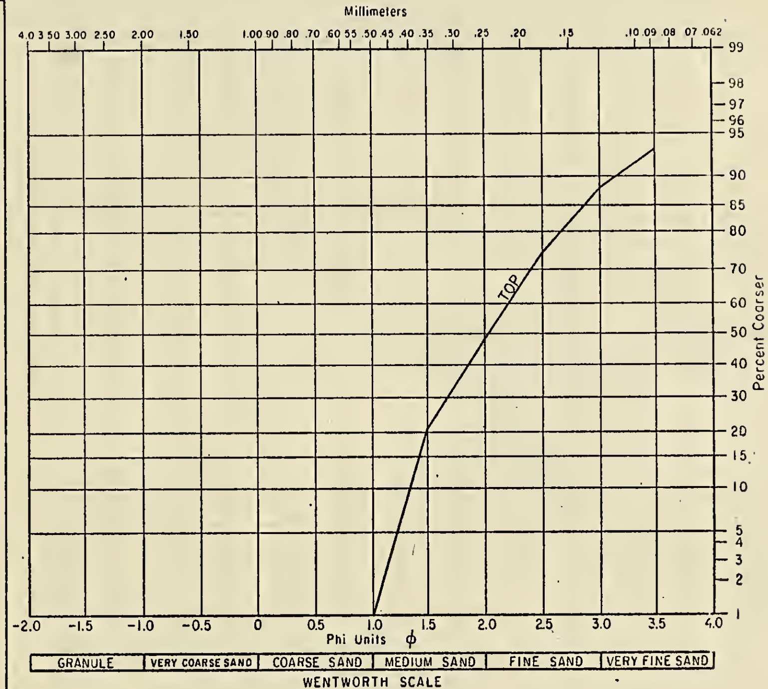
PROJECT FLORIDA SAND INVENTORY  CORE NO. 3  WATER DEPTH 27'  CERC I.D. NO. 712-4

## DESCRIPTION




Very pale brown (10 YR 7/4) fine to medium calcareous sand grading to silty sandy limestone gravel at -10".

## SIZE ANALYSIS

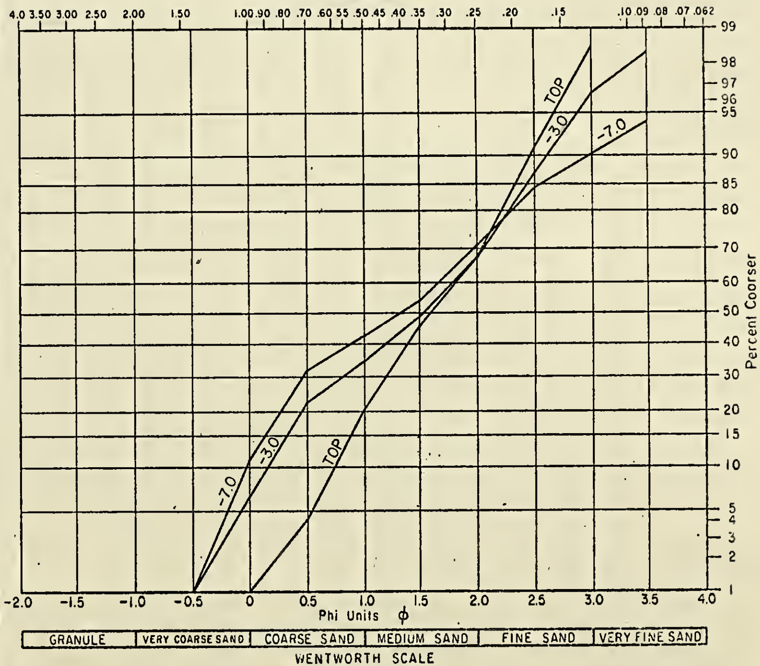



PROJECT FLORIDA SAND INVENTORY CORE NO. 4 WATER DEPTH 28' CERC I.D. NO. 712-5

## DESCRIPTION

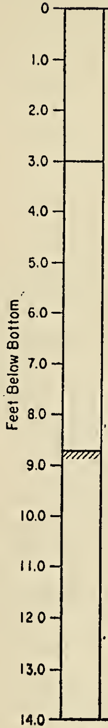
| Feet Below Bottom | Description |
|---|---|
| 0 | White (10 YR 8/2), fine to coarse calcareous sand; 10% shell fragments. |
| 3.0 | Light gray (10 YR 7/1) fine to coarse calcareous sand; 15% shell fragments, foraminifers. |
| 7.0 | Becoming silty |
| 8.0 | Consolidated rock (calcarenite). |

## SIZE ANALYSIS




PROJECT FLORIDA SAND INVENTORY CORE NO. S WATER DEPTH 28' CERC I.D. NO. 712-6

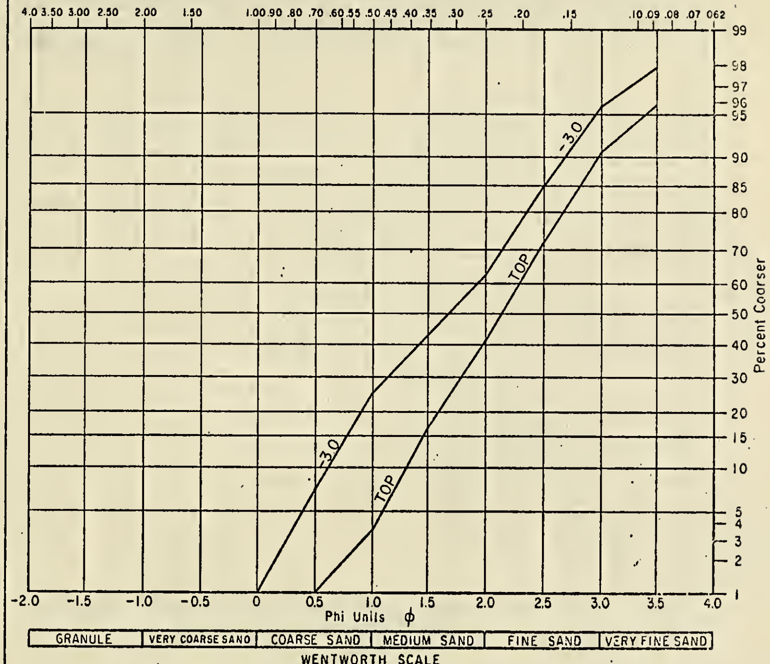
## DESCRIPTION



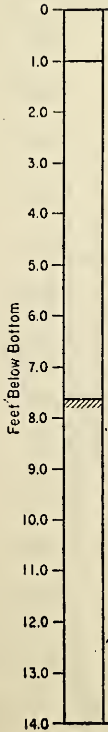

White (10 YR 8/2) fine to medium calcareous sand; small number light red spicules.

White (10 YR 8/1) fine to coarse calcareous sand; 20% foraminifers, calcareous algae, shell fragments, spicules, pellets.

## SIZE ANALYSIS




PROJECT FLORIDA SAND INVENTORY CORE NO. 6 WATER DEPTH 46' CERC I.D. NO. 712-7

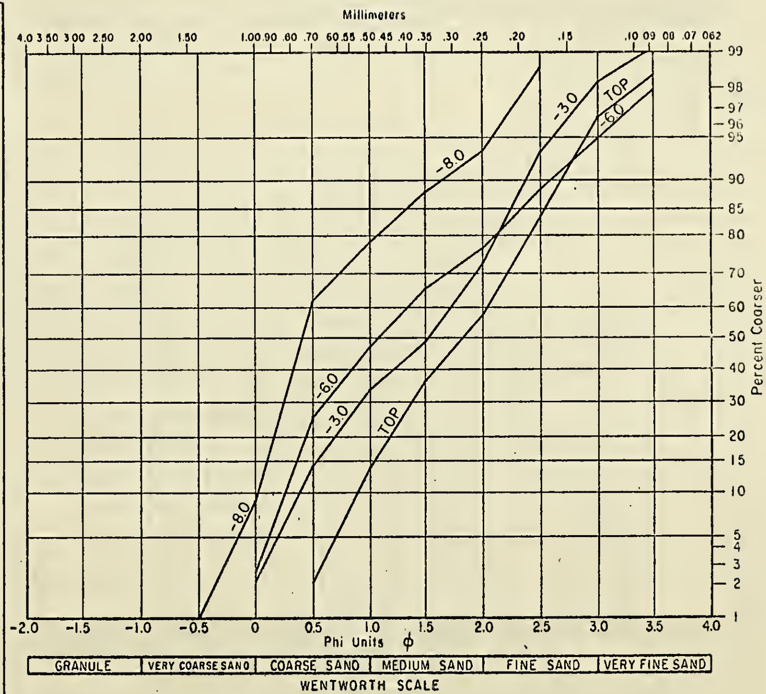



## DESCRIPTION

Light gray (10 YR 7/1) medium to coarse calcareous sand; 10% shell fragments.

Light gray (10 YR 7/1) medium to coarse calcareous sand; 25% shell fragments, calcareous algae, foraminifers, pellets.

## SIZE ANALYSIS

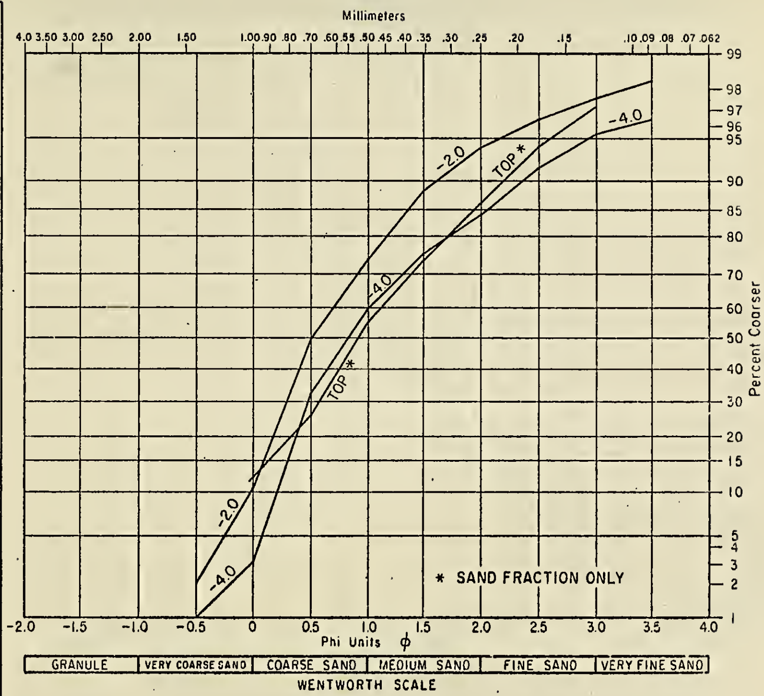



PROJECT FLORIDA SAND INVENTORY CORE NO. 7 WATER DEPTH 40' CERC I.D. NO. 712-8

## DESCRIPTION

| Feet Below Bottom | Description |
|---|---|
| 0–2.0 | Light gray (10 YR 7/2) medium to coarse calcareous sandy gravel with 50% calcarenite pebbles. |
| 2.0–6.0 | Light gray (10 YR 7/2) medium to coarse calcareous sand; 30% shell fragments, foraminifers, pellets, calcareous algae. |
| 6.0–6.5 | Same but with 1" calcarenite pebbles. |

## SIZE ANALYSIS




PROJECT FLORIDA SAND INVENTORY CORE NO. 8 WATER DEPTH 48' CERC I.D. NO. 712-9

## DESCRIPTION

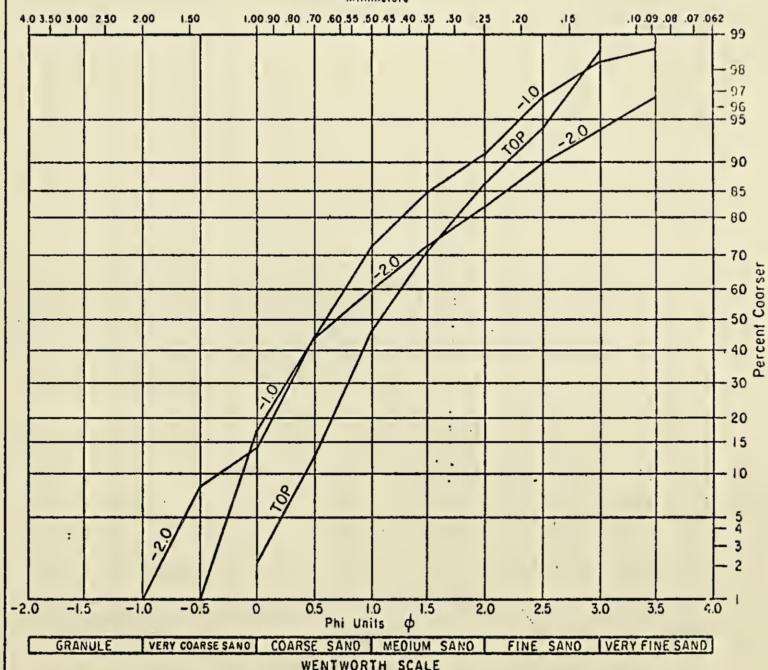
White (10 YR 8/2) medium to coarse calcareous sand.

White (10 YR 8/2) medium to very coarse calcareous sand; 20% shell fragments, calcareous algae, pellets.

White (10 YR 8/2) calcarenite pebbles 1/2" to 1".

Feet Below Bottom: 0, 1.0, 2.0, 3.0, 4.0, 5.0, 6.0, 7.0, 8.0, 9.0, 10.0, 11.0, 12.0, 13.0, 14.0

## SIZE ANALYSIS




PROJECT FLORIDA SAND INVENTORY CORE NO. 9 WATER DEPTH 50' CERC I.D. NO. 712-10

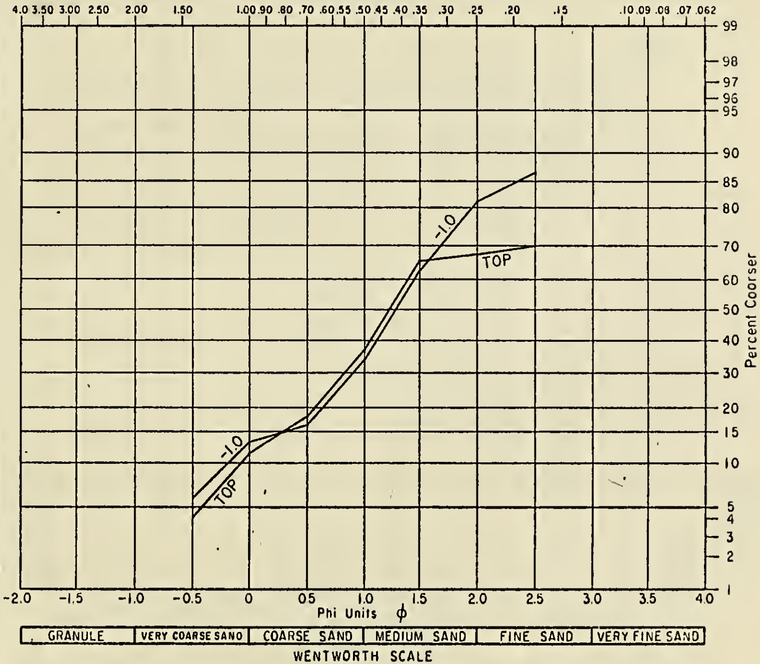
## DESCRIPTION

White (10 YR 8/2), medium calcareous sand.

White (9 YR 8/1) calcarenite pebbles and fine calcareous sand.

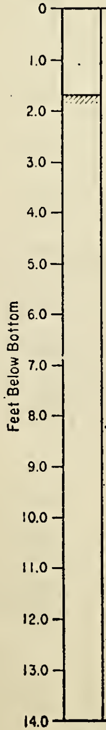
Feet Below Bottom: 0, 1.0, 2.0, 3.0, 4.0, 5.0, 6.0, 7.0, 8.0, 9.0, 10.0, 11.0, 12.0, 13.0, 14.0

## SIZE ANALYSIS



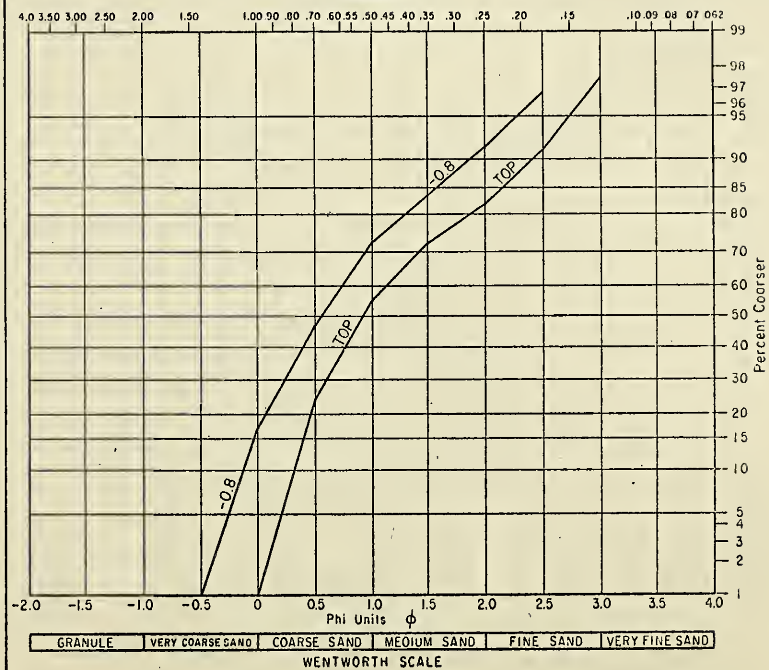

PROJECT FLORIDA SAND INVENTORY CORE NO. 10 WATER DEPTH 36' CERC I.D. NO. 712-11

## DESCRIPTION




Very pale brown (10 YR 7/3) medium to coarse calcareous sand; 25% shell fragments, *Halimeda* plates, pellets, foraminifers, grading coarser to bottom.

## SIZE ANALYSIS

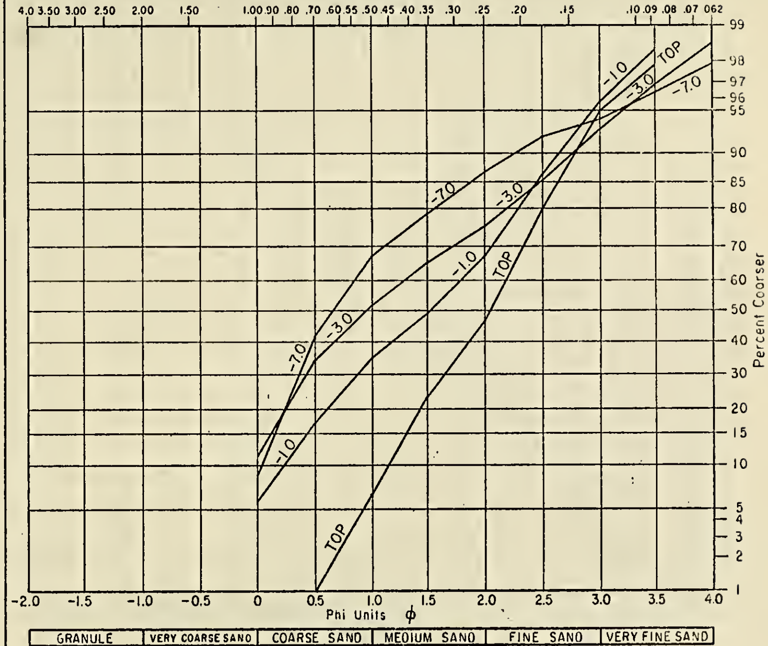



PROJECT FLORIDA SAND INVENTORY CORE NO. 11 WATER DEPTH SS' CERC I.D. NO. 712-12

## DESCRIPTION

| Feet Below Bottom | Description |
|---|---|
| 0–1.0 | Light gray (10 YR 7/2) fine to medium calcareous sand; foraminifers, spicules. |
| 1.0–3.0 | Same w/20% shell fragments, *Halimeda* plates. |
| 3.0–6.0 | Gray (10 YR 6/1) medium to coarse calcareous sand. |
| 6.0–7.5 | Light gray (10 YR 7/1) medium to coarse calcareous sand; 10% shell fragments. |
| 7.5–8.0 | Gray (10 YR 7/2), medium to coarse calcareous sand; 10% shell fragments, *Halimeda* plates. |

## SIZE ANALYSIS



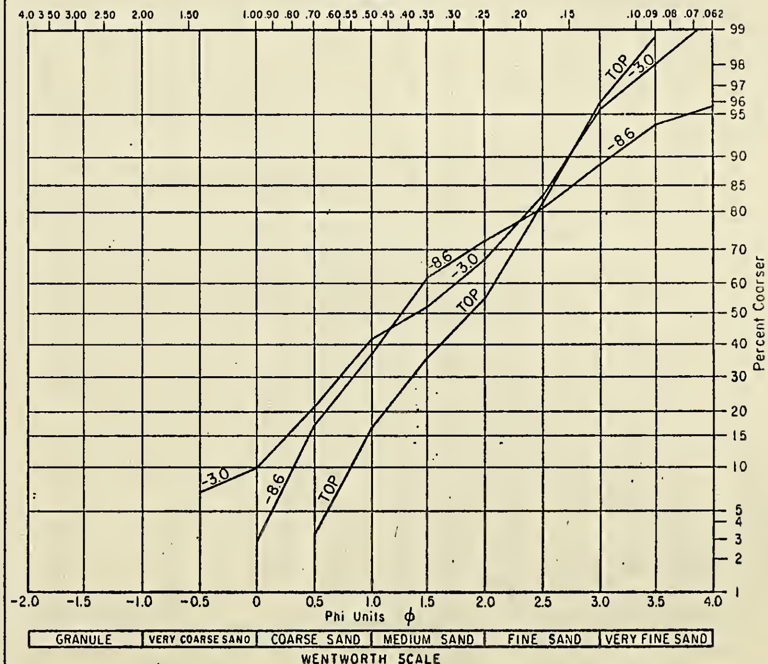

PROJECT FLORIDA SAND INVENTORY CORE NO. 12 WATER DEPTH 54' CERC I.D. NO. 712-13

## DESCRIPTION

Feet Below Bottom

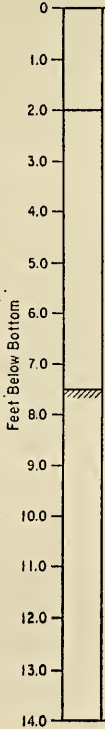
| Depth (ft) | Description |
|---|---|
| 0 – 8.0 | Light gray (10 YR 7/2) fine to medium calcareous sand; 20% shell fragments, foraminifers, spicules, *Halimeda* plates. |
| 8.0 – 9.1 | Light gray (10 YR 7/2) medium to coarse calcareous sand; 30% *Halimeda* plates, shell fragments, spicules, foraminifers. |

## SIZE ANALYSIS




PROJECT FLORIDA SAND INVENTORY CORE NO. 13 WATER DEPTH 50' CERC I.D. NO. 712-14

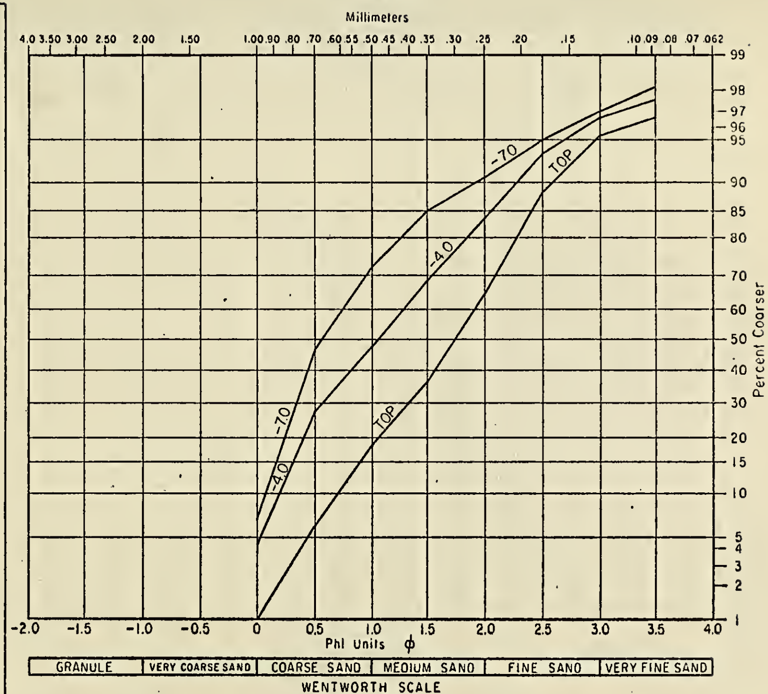
## DESCRIPTION




Light gray (10 YR 7/1) fine to medium calcareous sand; 10% foraminifers, *Halimeda* plates, mollusk shell, spicules.

Light gray (10 YR 7/1) medium to coarse calcareous sand; 10% *Halimeda* plates, 10% mollusk shell, foraminifers, calcareous algae.

## SIZE ANALYSIS

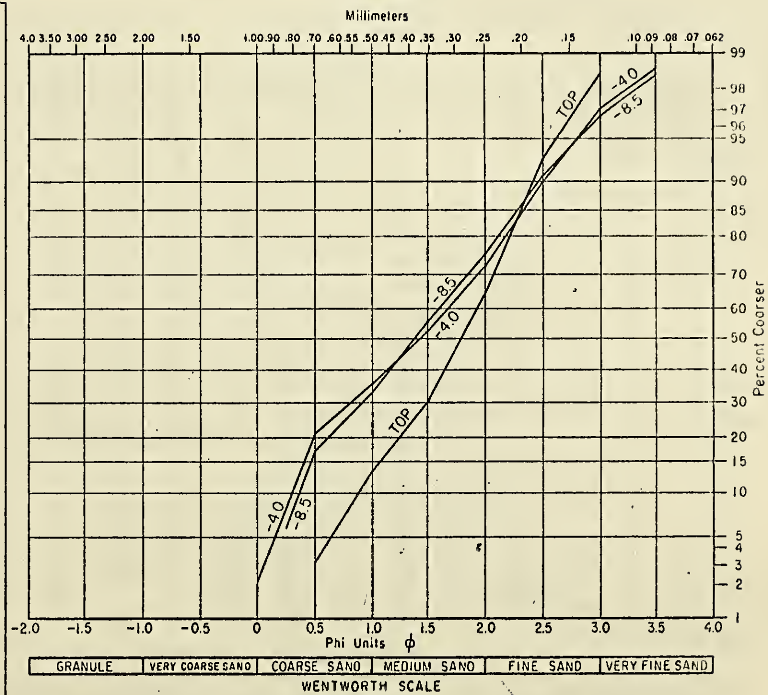



PROJECT FLORIDA SAND INVENTORY CORE NO. 14 WATER DEPTH 42' CERC I.D. NO. 712-1S

## DESCRIPTION

| Feet Below Bottom | Description |
|---|---|
| 0–2.0 | Light gray (10 YR 7/1) fine to medium calcareous sand; 10% shell fragments, foraminifers. |
| 2.0–7.0 | Gray (10 YR 6/1), medium to coarse calcareous sand; 30% *Halimeda* plates, shell fragments, foraminifers, spicules. |
| 7.0–8.5 | Same, but slightly finer. |

## SIZE ANALYSIS




PROJECT FLORIDA SAND INVENTORY CORE NO. 15 WATER DEPTH 44' CERC I.D. NO. 712-16

## DESCRIPTION

White (10 YR 8/2) coarse calcareous sand; 50% coral fragments, shell fragments.

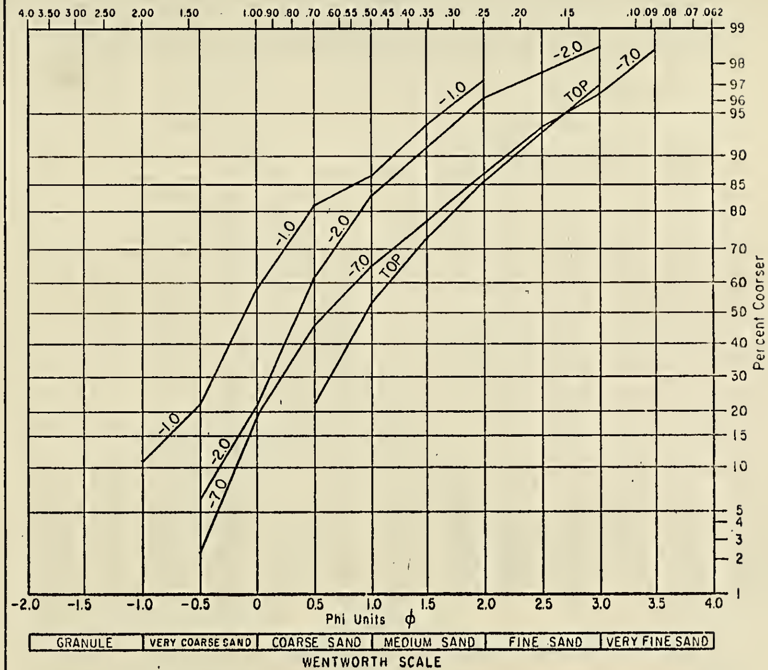
Gray (N6) coarse calcareous sand; 10% pellets, foraminifers.

Gray (N5) coarse to very coarse calcareous sand; 20% pellets, shell fragments, *Halimeda* plates.

Light gray (N7), coarse to very coarse calcareous sand; 50% *Halimeda* plates, shell fragments.

Same with small calcarenite fragments.

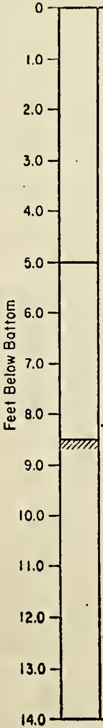
## SIZE ANALYSIS




Feet Below Bottom: 0, 1.0, 2.0, 3.0, 4.0, 5.0, 6.0, 7.0, 8.0, 9.0, 10.0, 11.0, 12.0, 13.0, 14.0

PROJECT FLORIDA SAND INVENTORY CORE NO. 16 WATER DEPTH 40' CERC I.D. NO. 712-17

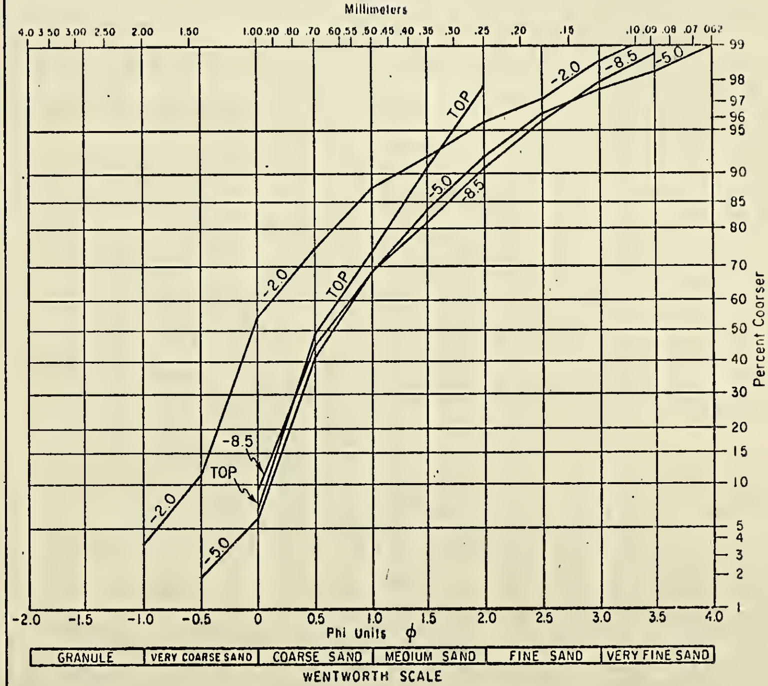
## DESCRIPTION




Speckled white, black and gray coarse to very coarse calcareous sand; 25% rod-shaped and pelletoid fragments.

Light gray (10 YR 7/1) medium to coarse calcareous sand; 15% *Halimeda* plates, 5-10% quartz.

## SIZE ANALYSIS




PROJECT FLORIDA SAND INVENTORY CORE NO. 17 WATER DEPTH 37' CERC I.D. NO. 712-18

## DESCRIPTION

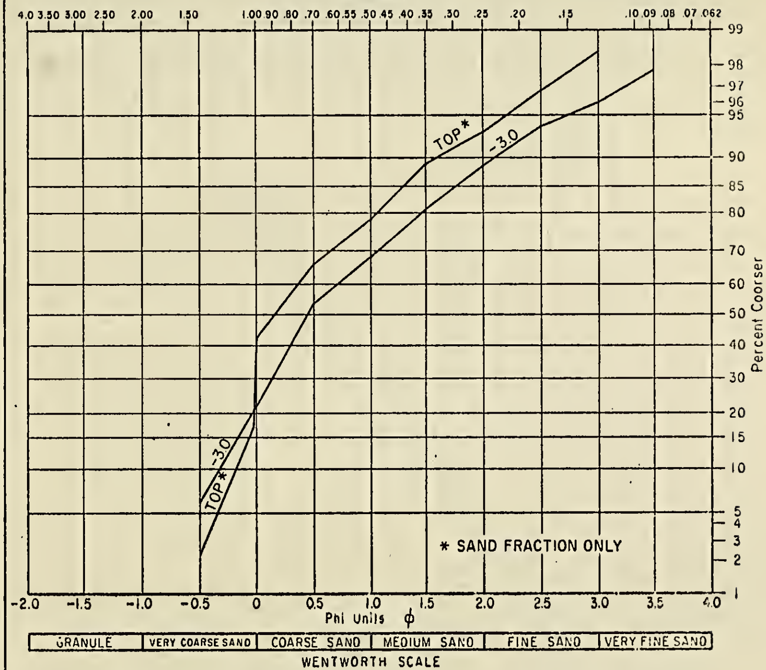
Feet Below Bottom: 0, 1.0, 2.0, 3.0, 4.0, 5.0, 6.0, 7.0, 8.0, 9.0, 10.0, 11.0, 12.0, 13.0, 14.0

Light gray (10 YR 7/2) medium to coarse calcareous sand; 10% 1/2" to 1" coral fragments, 10% pelletoid and rod-shaped particles, 15% mollusk shell, *Halimeda* plates, coral fragments.

Speckled, gray and white medium to coarse calcareous sand; 10% pelletoid and rod-shaped particles, 10% mollusk shells, *Halimeda* plates.

Light gray (10 YR 7/2) medium to coarse calcareous sand; 10% 1/2" encrusted coral fragments; 10% rods and pellets, 10% mollusk, *Halimeda* plates.

## SIZE ANALYSIS




PROJECT FLORIDA SAND INVENTORY CORE NO. 18 WATER DEPTH 36' CERC I.D. NO. 712-19

## DESCRIPTION

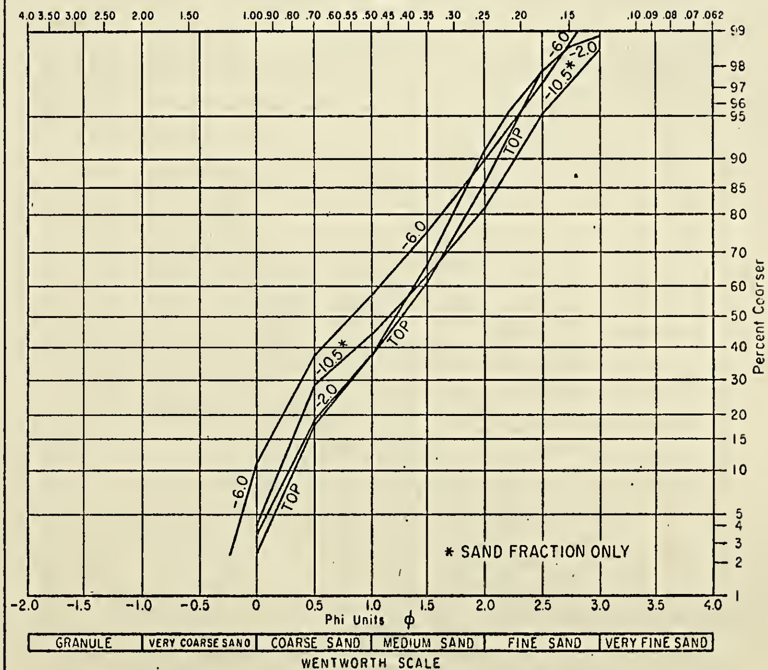
Feet Below Bottom

0 – 5.0: Gray (N5) medium to coarse calcareous sand; 10% shell fragments, pellets, *Halimeda* plates.

5.0 – 9.5: Gray (N5) medium calcareous sand.

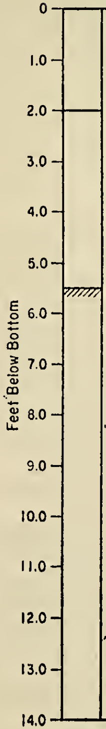
9.5 – 10.5: Same, mixed with coral fragments.

## SIZE ANALYSIS




PROJECT FLORIDA SAND INVENTORY CORE NO. 19 WATER DEPTH 47' CERC I.D. NO. 712-20

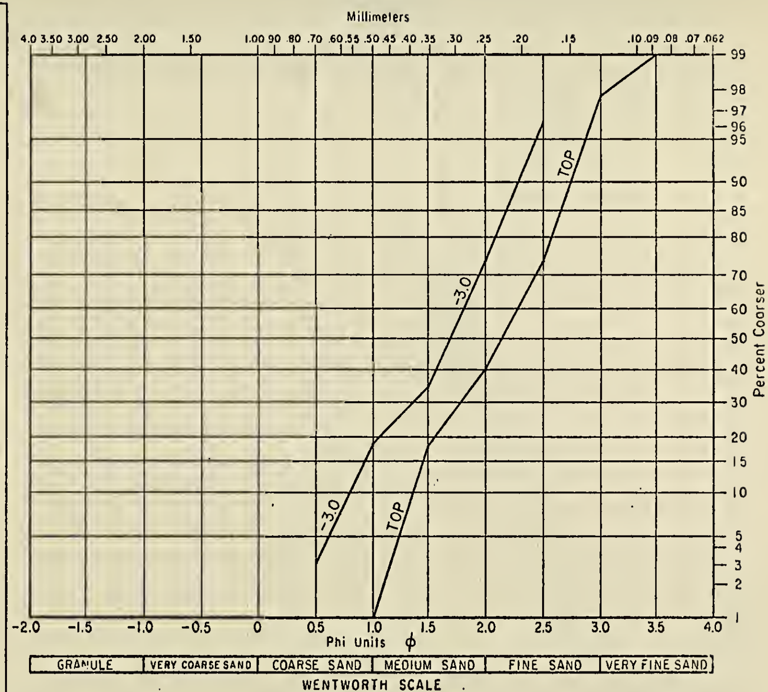
## DESCRIPTION




Light gray (10 YR 7/2) fine to medium quartzose sand; 40% white brown and black calcareous fragments.

Gray (N6) fine to medium quartzose sand; 40% white, gray and black calcareous fragments, 10% mollusk fragments, foraminifers, hemispheric bryozoa.

## SIZE ANALYSIS

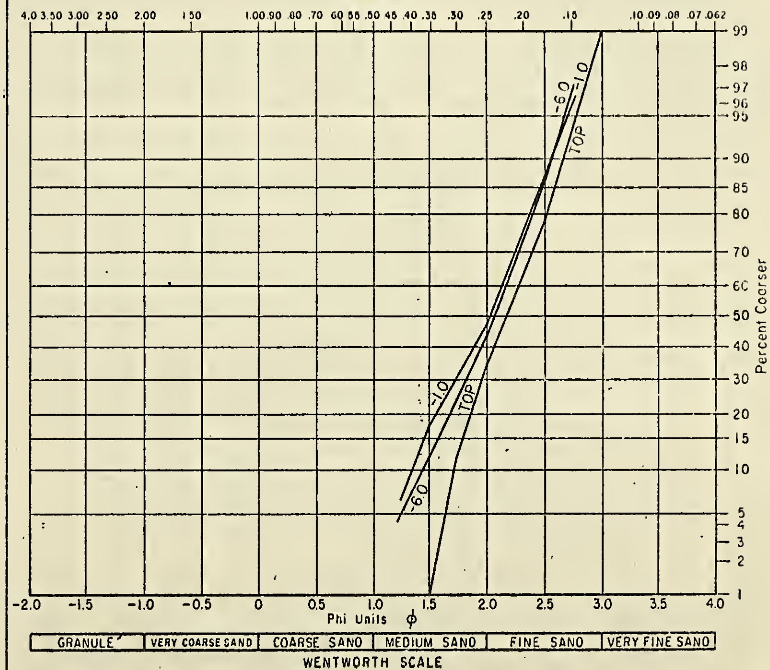



PROJECT FLORIDA SAND INVENTORY CORE NO. 20 WATER DEPTH 41' CERC I.D. NO. 712-21

## DESCRIPTION

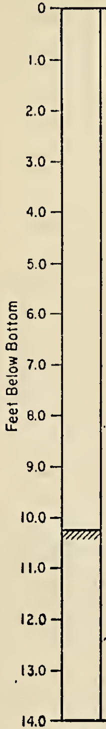
| Feet Below Bottom | Description |
|---|---|
| 0–2.0 | Light gray (10 YR 7/2) fine to medium quartzose sand; 30% black and brown calcareous fragments. |
| 2.0–6.0 | Gray (N6) fine to medium quartzose sand; 40% black, gray and white calcareous fragments. |
| 6.0– | Light gray (10 YR 7/2) fine to medium quartzose sand; 40% black, gray and white calcareous fragments, 10% mollusk shell and foraminifers. |

## SIZE ANALYSIS



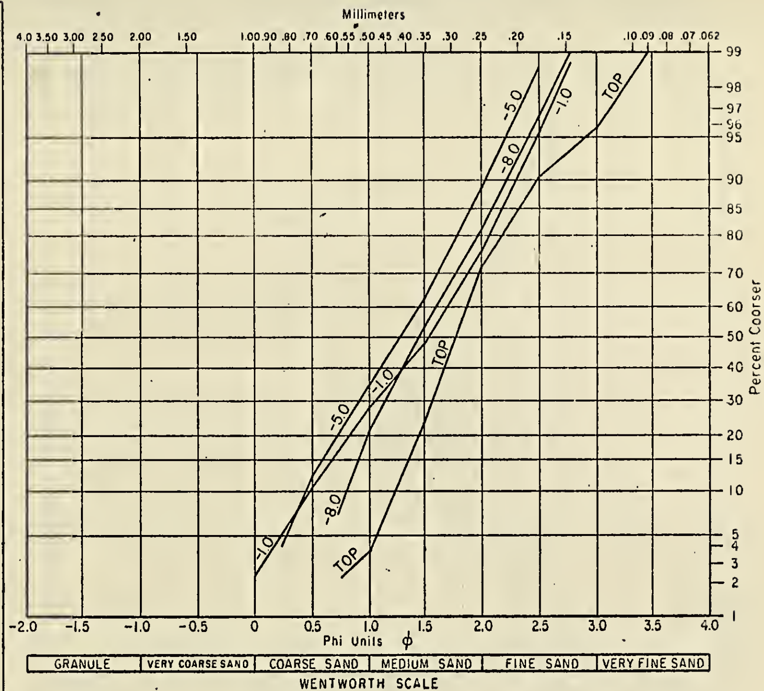

PROJECT FLORIDA SAND INVENTORY CORE NO. 21 WATER DEPTH 44' CERC I.D. NO. 712-23

DESCRIPTION




Gray (N6) medium quartzose sand; 40% black, gray and white calcareous fragments; 10% foraminifers, mollusks, hemispheric bryozoa.

SIZE ANALYSIS




PROJECT FLORIDA SAND INVENTORY CORE NO. 22 WATER DEPTH 40' CERC I.D. NO. 712-24

## DESCRIPTION

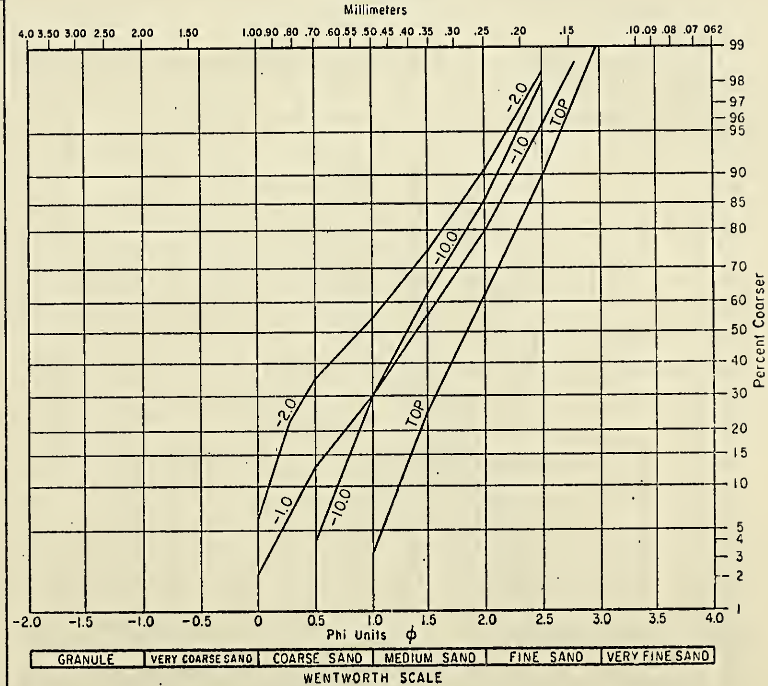
Light gray (10 YR 7/2) fine to medium quartzose sand; 40% white, brown, gray and black calcareous fragments.

Gray (10 YR 6/1) medium to coarse, calcareous quartzose sand; 40% black, brown and gray calcareous fragments; 10-20% mollusk shell.

Gray (10 YR 6/1) medium to coarse calcareous quartz sand; 40% gray and black calcareous fragments, 10% shell fragments, foraminifers, hemispheric bryozoa.

Feet Below Bottom: 0, 1.0, 2.0, 3.0, 4.0, 5.0, 6.0, 7.0, 8.0, 9.0, 10.0, 11.0, 12.0, 13.0, 14.0

## SIZE ANALYSIS



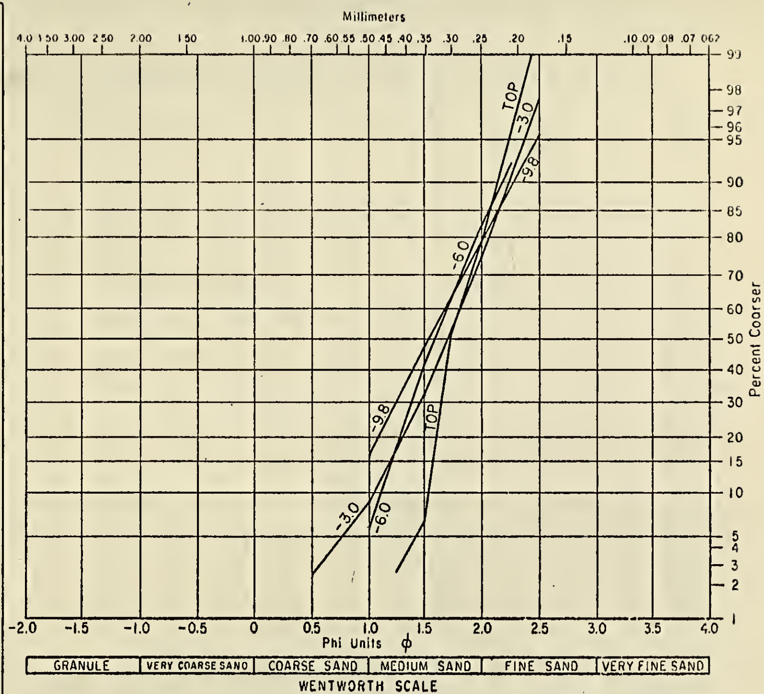

PROJECT FLORIDA SAND INVENTORY CORE NO. 23 WATER DEPTH 42' CERC I.D. NO. 712-25

## DESCRIPTION

Feet Below Bottom

| Depth (ft) | Description |
|---|---|
| 0–2.0 | Light gray (10 YR 7/1) fine to medium calcareous quartzose sand; 45% white, gray, brown calcareous fragments. |
| 2.0–11.2 | Gray (N6) medium quartzose calcareous sand; 45% quartz, 5% mollusk shell, foraminifers. |

## SIZE ANALYSIS




PROJECT FLORIDA SAND INVENTORY CORE NO. 24 WATER DEPTH 44' CERC I.D. NO. 712-26

## DESCRIPTION

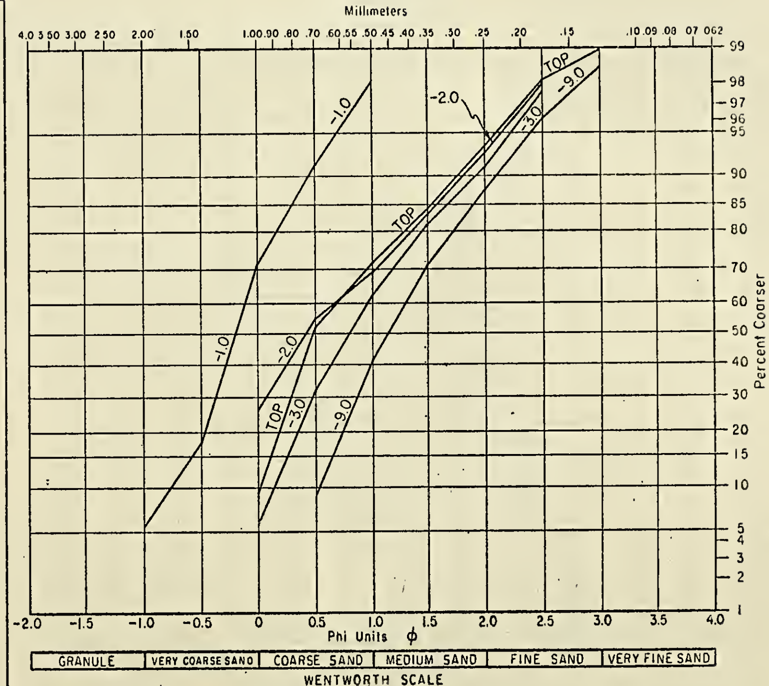
Feet Below Bottom: 0 – 14.0

**0 – 3.0:** Speckled black, gray, white, brown, coarse to very coarse calcareous sand; 10% quartz; 15% rod-shaped and pelletoid fragments; 15% mollusk shell, *Halimeda* plates, foraminifers.

**3.0 – 7.0:** Light gray (10 YR 6/1) medium to coarse quartzose calcareous sand; 20% quartz, 10% mollusk shell.

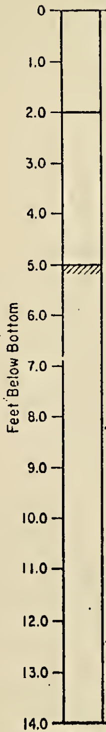
**7.0 – 10.8:** White (10 YR 8/2) medium to coarse quartzose calcareous sand; 45% quartz, 5% mollusk shell, foraminifers.

## SIZE ANALYSIS




PROJECT FLORIDA SAND INVENTORY CORE NO. 25 WATER DEPTH 39' CERC I.D. NO. 712-27

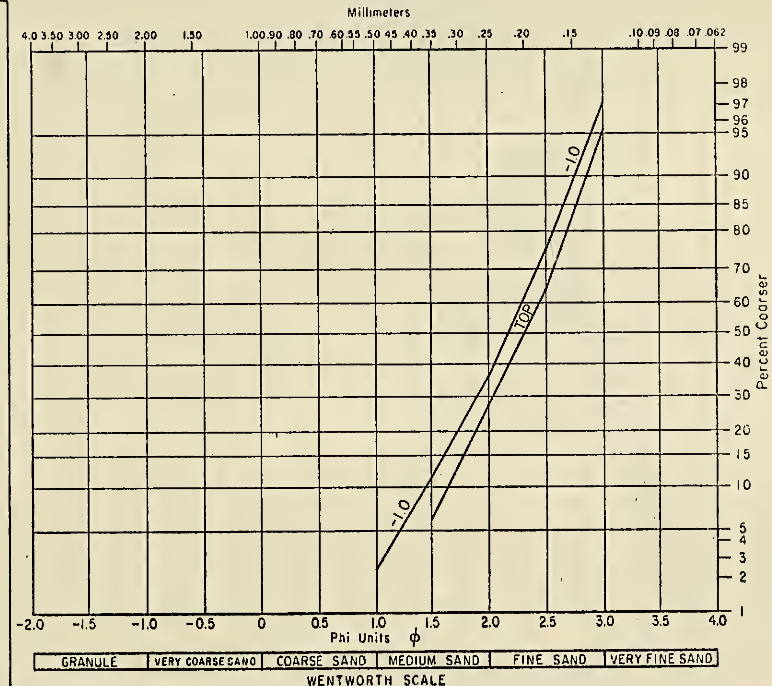
## DESCRIPTION




Gray (10 YR 6/1) fine to medium quartzose sand.

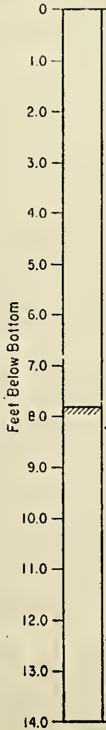
Light gray (10 YR 7/1) fine calcareous sand; 30% 1/8" to 3/4" pieces of calcarenite and coral.

## SIZE ANALYSIS



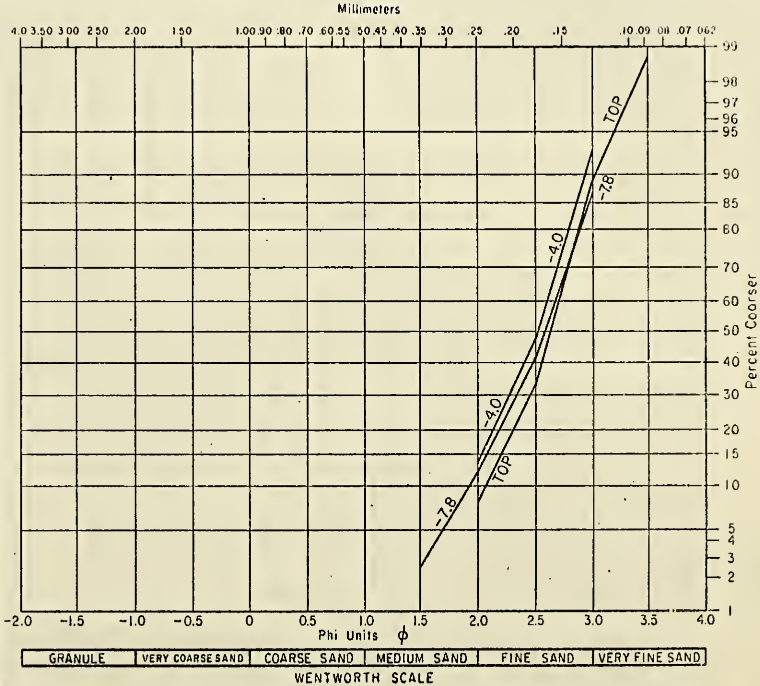

PROJECT FLORIDA SAND INVENTORY CORE NO. 26 WATER DEPTH about 50' CERC I.D. NO. 712-28

## DESCRIPTION




Light gray (N7) very fine to fine quartzose sand; 35% calcareous fragments.

## SIZE ANALYSIS

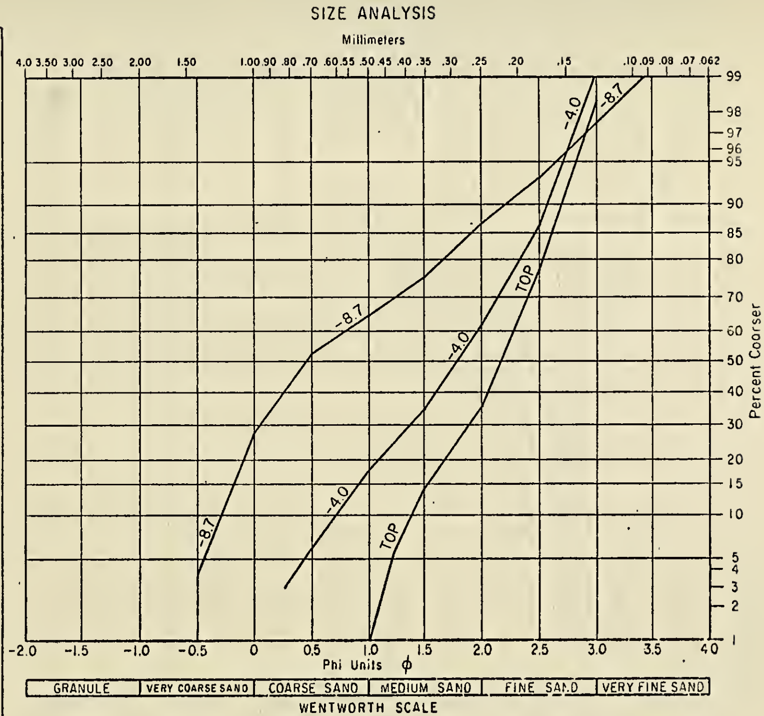



PROJECT FLORIDA SAND INVENTORY CORE NO. 27A WATER DEPTH 45' CERC I.D. NO. 712-30

## DESCRIPTION

| Feet Below Bottom | Description |
|---|---|
| 0 – 1.0 | White (10 YR 8/1) fine to medium quartzose sand; 40% black, brown, gray calcareous fragments. |
| 1.0 – 7.0 | Light gray (10 YR 7/1) fine to medium quartzose sand; 40% gray and white calcareous fragments. |
| 7.0 – 8.0 | Speckled gray and white, medium to very coarse calcareous sand; 30% quartz, 40% large mollusk shell, coral and calcarenite fragments. |

## SIZE ANALYSIS



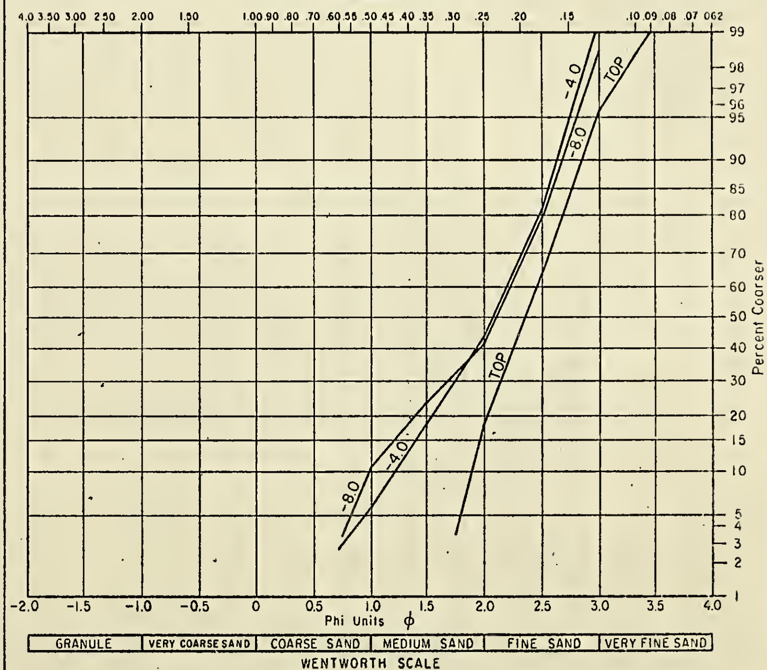

PROJECT FLORIDA SAND INVENTORY CORE NO. 28 WATER DEPTH 48' CERC I.D. NO. 712-31

## DESCRIPTION

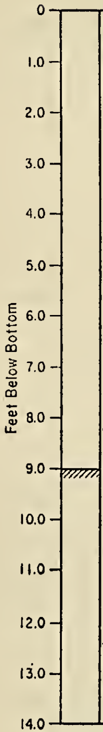
Feet Below Bottom: 0 – 14.0

Light gray (10 YR 7/1) fine quartzose sand; 35% black, gray, brown calcareous fragments.

## SIZE ANALYSIS



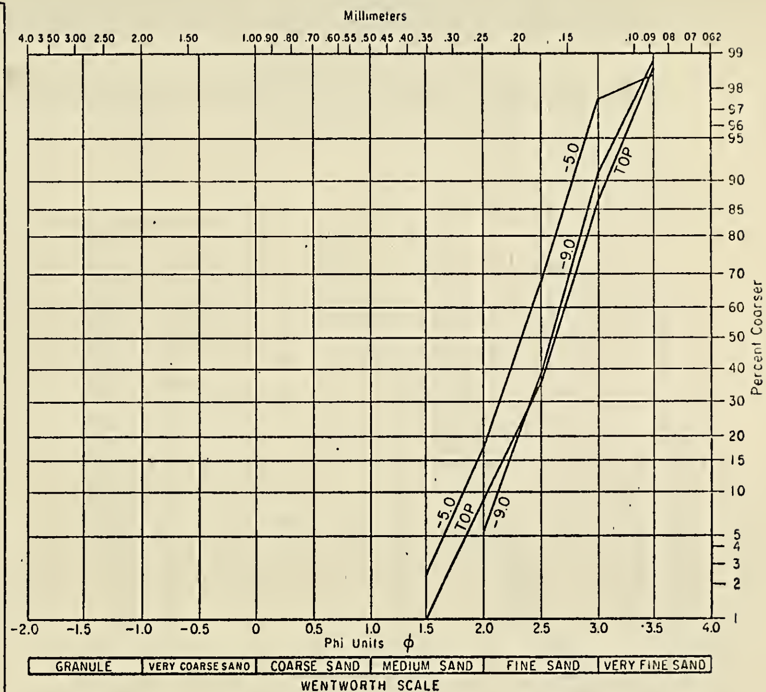

PROJECT FLORIDA SAND INVENTORY CORE NO. 29 WATER DEPTH 37' CERC I.D. NO. 712-32




## DESCRIPTION

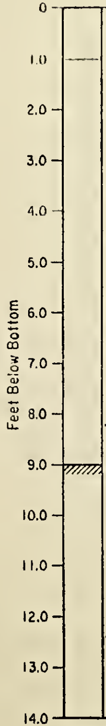
Light gray (10 YR 7/1) fine quartzose sand; 35% black, gray calcareous fragments.

## SIZE ANALYSIS




PROJECT FLORIDA SAND INVENTORY CORE NO. 30 WATER DEPTH 47' CERC I.D. NO. 712-33

## DESCRIPTION

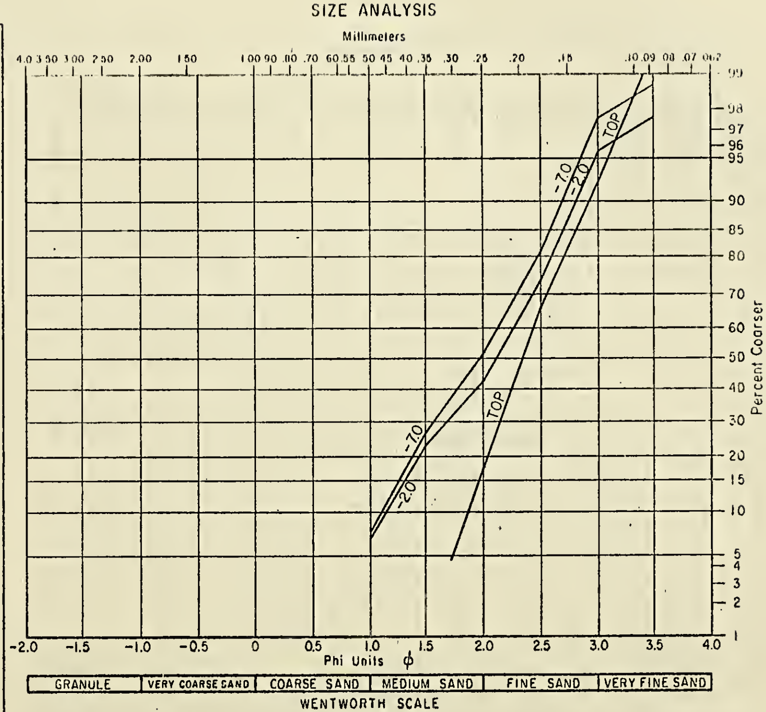



Gray (N6) fine quartzose sand; 35% white, gray, black calcareous fragments.

Gray (N6) fine to medium quartzose sand; 35% white, gray, black calcareous fragments, 5% hemispheric bryozoa, foraminifers.

Grades to yellowish gray, medium

## SIZE ANALYSIS




PROJECT FLORIDA SAND INVENTORY CORE NO. 31 WATER DEPTH 37' CERC I.D. NO. 712-34

# A P P E N D I X  C

## GRANULOMETRIC ANALYSES

SEDIMENT DESCRIPTION

| Core No. | Interval (feet) | Median ϕ | Median mm. | Mean ϕ | Mean mm. | Standard Deviation | Skewness | Kurtosis |
|---|---|---|---|---|---|---|---|---|
| 1 | 0 | 2.79 | .145 | 2.56 | .169 | .71 | -.23 | 2.50 |
| | 1 | 1.10 | .466 | .91 | .532 | 1.04 | .15 | 2.21 |
| | 3 | 1.62 | .326 | 1.36 | .389 | 1.01 | -.10 | 2.63 |
| | 3.5 | 1.74 | .300 | 1.57 | .336 | .92 | -.16 | 2.75 |
| 2 | 0 | 1.07 | .475 | 1.18 | .442 | .74 | .51 | 2.36 |
| | 2 | .82 | .565 | 1.02 | .492 | .74 | .81 | 3.04 |
| 3 | 0 | 1.30 | .405 | 1.32 | .399 | .60 | .19 | 2.36 |
| | 1.5 | .93 | .526 | .96 | .514 | .81 | .24 | 2.78 |
| 4 | 0 | 2.03 | .245 | 2.08 | .237 | .63 | .64 | 2.96 |
| 5 | 0 | 1.57 | .336 | 1.60 | .330 | .68 | .04 | 2.12 |
| | 1 | 1.33 | .398 | 1.47 | .361 | .95 | -.09 | 2.63 |
| | 3 | 1.55 | .343 | 1.43 | .371 | .95 | -.06 | 2.14 |
| | 6 | 1.59 | .332 | 1.69 | .310 | .91 | -.05 | 3.58 |
| | 7 | 1.39 | .381 | 1.27 | .413 | 1.01 | .25 | 2.15 |
| 6 | 0 | 2.17 | .222 | 2.09 | .234 | .59 | -.10 | 2.42 |
| | 3 | 1.73 | .302 | 1.67 | .315 | .82 | .21 | 2.49 |
| 7 | 0 | 1.78 | .291 | 1.79 | .290 | .68 | .12 | 2.60 |
| | 1 | 1.00 | .500 | 1.20 | .435 | .81 | .87 | 3.12 |
| | 2 | 1.40 | .379 | 1.44 | .369 | 1.06 | -.44 | 3.35 |
| | 3 | 1.79 | .290 | 1.74 | .300 | .95 | -.42 | 2.94 |
| | 4 | 1.27 | .414 | 1.49 | .355 | .87 | .23 | 2.16 |
| | 5 | 1.68 | .312 | 1.62 | .326 | .92 | -.21 | 2.28 |
| | 6 | 1.13 | .458 | 1.27 | .413 | .92 | .59 | 2.43 |
| | 7 | .60 | .658 | .86 | .550 | .67 | 1.41 | 4.07 |
| | 8 | .34 | .788 | .60 | .660 | .70 | 1.49 | 5.00 |
| 8 | 0 | 1.40 | .379 | 1.48 | .358 | .87 | .59 | 2.77 |
| | 2 | .50 | .707 | .68 | .622 | .78 | 1.58 | 6.75 |
| | 4 | .82 | .567 | 1.07 | .477 | .88 | 1.31 | 4.63 |
| 9 | 0 | 1.03 | .488 | 1.17 | .445 | .70 | .78 | 3.24 |
| | 1 | .59 | .664 | .72 | .606 | .78 | 1.33 | 5.49 |

SEDIMENT DESCRIPTION

| Core No. | Interval (feet) | Median ϕ | Median mm. | Mean ϕ | Mean mm. | Standard Deviation | Skewness | Kurtosis |
|---|---|---|---|---|---|---|---|---|
| 9 | 2 | .65 | .636 | .89 | .539 | 1.05 | .57 | 2.88 |
| 10 | 0 | 1.21 | .433 | 1.34 | .394 | .99 | -.05 | 2.01 |
| | 1 | 1.15 | .450 | 1.20 | .437 | .90 | -.19 | 2.60 |
| 11 | 0 | .89 | .539 | 1.14 | .455 | .79 | .89 | 2.91 |
| | 0.8 | ..56 | .676 | .68 | .624 | .73 | .95 | 3.49 |
| | 1.7 | 3.03 | .122 | 2.28 | .205 | 1.08 | -.73 | 1.82 |
| 12 | 0 | 2.04 | .244 | 1.96 | .257 | .60 | -.01 | 2.47 |
| | 1 | 1.53 | .347 | 1.48 | .358 | .93 | .13 | 2.32 |
| | 3 | .93 | .523 | 1.14 | .455 | 1.04 | .60 | 2.41 |
| | 7 | .61 | .655 | .85 | .557 | .86 | 1.29 | 4.43 |
| 13 | 0 | 1.90 | .268 | 1.82 | .284 | .73 | -.10 | 2.36 |
| | 2 | 2.08 | .236 | 1.98 | .253 | .63 | -.16 | 2.39 |
| | 3 | 1.45 | .366 | 1.36 | .390 | 1.08 | -.19 | 2.45 |
| | 6 | 1.32 | .401 | 1.46 | .362 | 1.04 | .46 | 2.00 |
| | 8.5 | 1.09 | .469 | 1.33 | .398 | .93 | .74 | 2.58 |
| 14 | 0 | 2.03 | .245 | 1.89 | .269 | .71 | -.33 | 2.34 |
| | 2 | .81 | .572 | 1.02 | .491 | .88 | .55 | 2.41 |
| | 5 | .84 | .557 | 1.01 | .496 | .84 | .74 | 3.04 |
| 15 | 0 | 2.11 | .231 | 2.06 | .240 | .56 | -.33 | 2.66 |
| | 1 | 1.88 | .272 | 1.79 | .218 | .73 | -.12 | 2.45 |
| | 6 | 1.75 | .297 | 1.70 | .308 | .76 | .15 | 2.17 |
| 16 | 0 | .71 | .611 | .87 | .546 | .89 | .67 | 3.26 |
| | 1 | .35 | .787 | .56 | .677 | .81 | .50 | 3.03 |
| | 2 | .29 | .819 | .46 | .727 | .72 | 1.52 | 6.54 |
| | 6 | .37 | .772 | .51 | .700 | .69 | .80 | 4.20 |
| 17 | 0 | .50 | .707 | .65 | .639 | .57 | .74 | 3.03 |
| | 1 | .58 | .667 | .73 | .601 | .65 | 1.23 | 5.03 |
| | 2 | .42 | .750 | .66 | .631 | .81 | 1.35 | 5.22 |
| | 3 | .50 | .708 | .72 | .608 | .67 | 1.91 | 5.68 |
| | 5 | .65 | .635 | .84 | .560 | .78 | 1.36 | 5.80 |

SEDIMENT DESCRIPTION

| Core No. | Interval (feet) | Median ϕ | Median mm. | Mean ϕ | Mean mm. | Standard Deviation | Skewness | Kurtosis |
|---|---|---|---|---|---|---|---|---|
| 17 | 6 | .72 | .605 | .90 | .537 | .90 | .36 | 3.47 |
| | 7 | .87 | .546 | 1.03 | .491 | .83 | .35 | 3.59 |
| | 8 | 1.03 | .491 | 1.23 | .425 | .74 | .79 | 2.78 |
| 18 | 0 | .63 | .646 | .90 | .534 | .83 | 1.26 | 4.14 |
| | 1 | .36 | .777 | ..67 | .630 | .91 | 1.55 | 5.28 |
| | 3 | .41 | .752 | .69 | .618 | 1.00 | 1.05 | 3.87 |
| 19 | 0 | 1.26 | .419 | 1.22 | .428 | .69 | -.05 | 2.13 |
| | 5 | .63 | .645 | .90 | .537 | 1.01 | .87 | 3.32 |
| | 7 | 1.58 | .335 | 1.52 | .348 | .81 | .20 | 2.69 |
| 20 | 0 | 2.18 | .221 | 2.10 | .233 | .54 | -.24 | 2.04 |
| | 2 | 2.12 | .230 | 2.08 | .236 | .54 | .17 | 3.34 |
| | 5 | 1.74 | .300 | 1.70 | .308 | .58 | -.25 | 2.55 |
| 21 | 0 | 2.34 | .197 | 2.31 | .202 | .41 | -.32 | 2.61 |
| | 4 | 2.21 | .216 | 2.17 | .222 | .45 | -.11 | 2.11 |
| 22 | 0 | 1.68 | .312 | 1.61 | .327 | .67 | -.25 | 2.27 |
| | 1 | 1.58 | .336 | 1.64 | .321 | .69 | .16 | 1.92 |
| | 2 | 1.32 | .401 | 1.40 | .380 | .76 | .31 | 2.38 |
| | 3 | 1.44 | .369 | 1.48 | .359 | .74 | -.37 | 3.10 |
| | 4 | 1.59 | .332 | 1.64 | .321 | .59 | .27 | 2.70 |
| | 7 | 1.69 | .310 | 1.69 | .310 | .52 | .39 | 2.58 |
| | 10 | 1.84 | .279 | 1.82 | .282 | .49 | -.05 | 2.37 |
| 23 | 0 | 1.94 | .261 | 1.87 | .273 | .60 | -.24 | 2.28 |
| | 3 | 1.63 | .323 | 1.49 | .357 | .81 | -.08 | 1.86 |
| | 5 | 1.84 | .280 | 1.79 | .289 | .61 | -.05 | 2.13 |
| 24 | 0 | 1.80 | .287 | 1.78 | .290 | .53 | -.10 | 2.40 |
| | 1 | 1.80 | .287 | 1.78 | .290 | .53 | -.05 | 2.38 |
| | 9 | 1.57 | .336 | 1.68 | .312 | .65 | .95 | 4.01 |
| | 9.8 | 1.58 | .334 | 1.58 | .334 | .53 | .20 | 2.43 |
| 25 | 0 | .58 | .667 | .75 | .593 | .72 | .72 | 2.66 |
| | 1 | .23 | .854 | .30 | .812 | .46 | .49 | 3.59 |

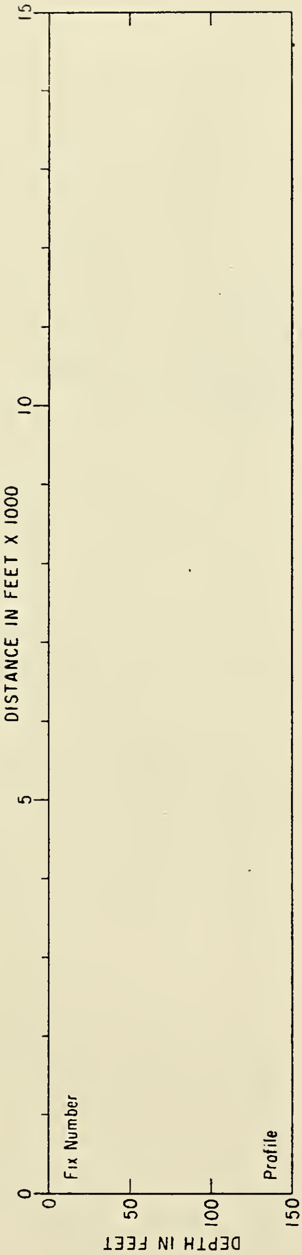
SEDIMENT DESCRIPTION

| Core No. | Interval (feet) | Median ϕ | Median mm. | Mean ϕ | Mean mm. | Standard Deviation | Skewness | Kurtosis |
|---|---|---|---|---|---|---|---|---|
| 25 | 2 | .40 | .759 | .63 | .648 | .77 | .77 | 2.55 |
| | 3 | .77 | .586 | .90 | .536 | .67 | .65 | 3.03 |
| | 9 | 1.15 | .451 | 1.23 | .427 | .62 | .70 | 3.29 |
| 26 | 0 | 2.35 | .196 | 2.28 | .205 | .48 | -.30 | 2.70 |
| | 1 | 2.21 | .216 | 2.14 | .227 | .51 | -.40 | 2.70 |
| 27A | 0 | 2.66 | .158 | 2.61 | .163 | .37 | -.04 | 3.63 |
| | 1 | 2.63 | .162 | 2.61 | .163 | .30 | -.21 | 2.94 |
| | 4 | 2.50 | .176 | 2.46 | .182 | .39 | -.34 | 2.39 |
| | 7.8 | 2.60 | .165 | 2.52 | .174 | .44 | -.66 | 3.02 |
| 29 | 0 | 2.43 | .186 | 2.38 | .192 | .46 | .17 | 3.07 |
| | 3 | 2.24 | .212 | 2.15 | .226 | .59 | -.38 | 2.34 |
| 30 | 0 | 2.66 | .159 | 2.60 | .165 | .40 | -.50 | 3.16 |
| | 9 | 2.62 | .163 | 2.58 | .167 | .35 | .02 | 2.89 |
| 31 | 2 | 2.13 | .228 | 2.05 | .242 | .65 | .06 | 2.72 |
| | 7 | 1.97 | .255 | 1.91 | .265 | .58 | -.19 | 2.26 |
| | 10 | 1.99 | .252 | 1.96 | .257 | .61 | .01 | 3.08 |

# APPENDIX D

## GEOPHYSICAL DATA

Appendix contains cross-section line profiles of the study based on seismic reflection profiles. Hachured lines represent the bedrock reflection. Solid lines show the bottom and strong subbottom reflectors. Dashed lines show weak reflectors. Ambiguous or very weak reflection surfaces are shown by a dash-dot line.



DISTANCE IN FEET X 1000
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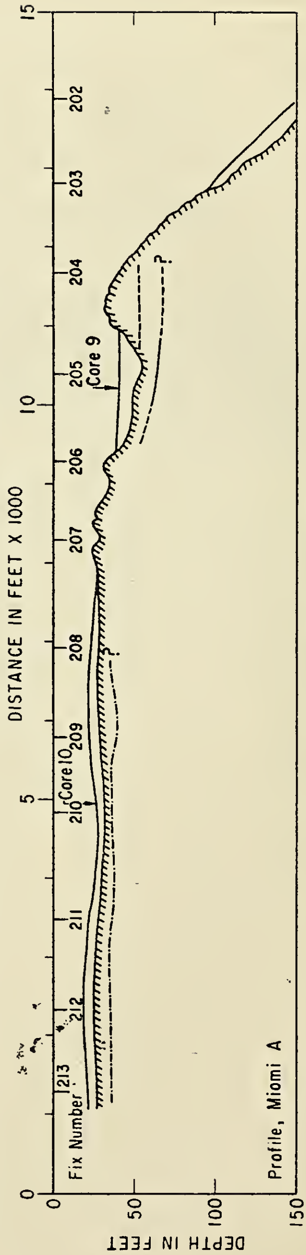
5
10
15
DEPTH IN FEET
0
50
100
150
Fix Number
Profile

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10
15
DEPTH IN FEET
0
50
100
150
Fix Number
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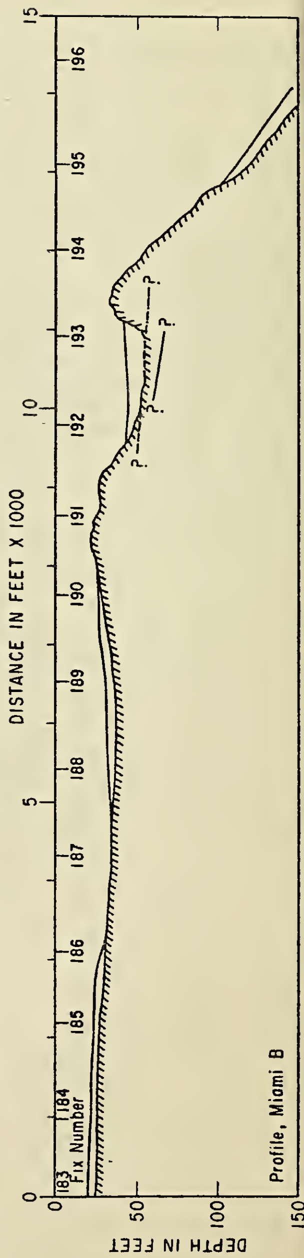
203
204
205
206
207
208
209
210
211
212
213
Core 9
Core 10
Profile, Miami A

DISTANCE IN FEET X 1000
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5
10
15
DEPTH IN FEET
0
50
100
150
Fix Number
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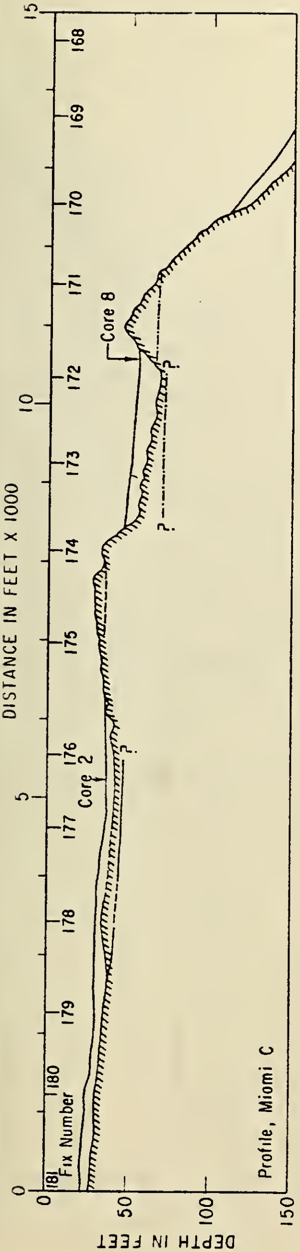
184
185
186
187
188
189
190
191
192
193
194
195
196
Profile, Miami B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DISTANCE IN FEET X 1000
DEPTH IN FEET
Fix Number
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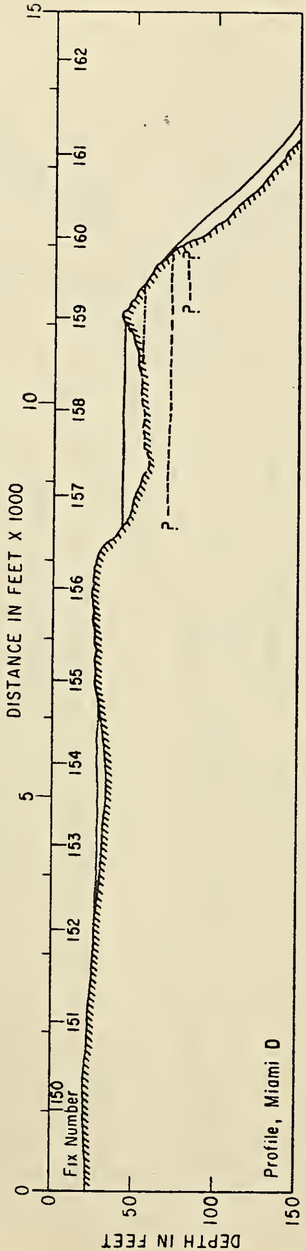
180
179
178
177
176
175
174
173
172
171
170
169
168
Core 2
Core 8
0
5
10
15
50
100
150
?


Profile, Miami D
DISTANCE IN FEET X 1000
DEPTH IN FEET
Fix Number
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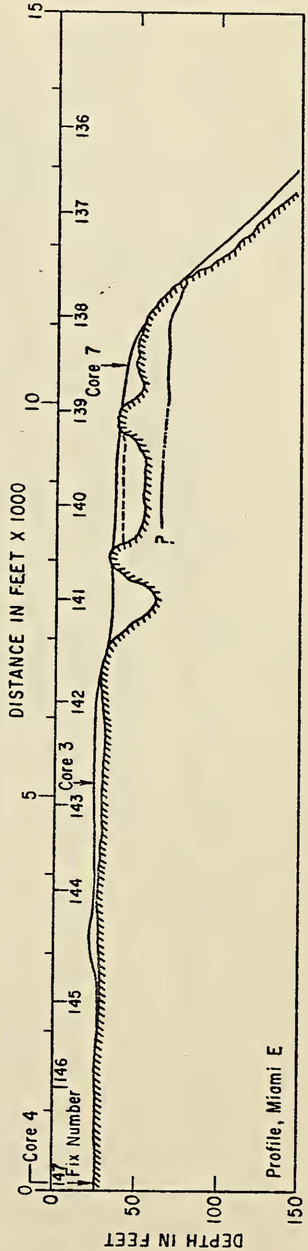
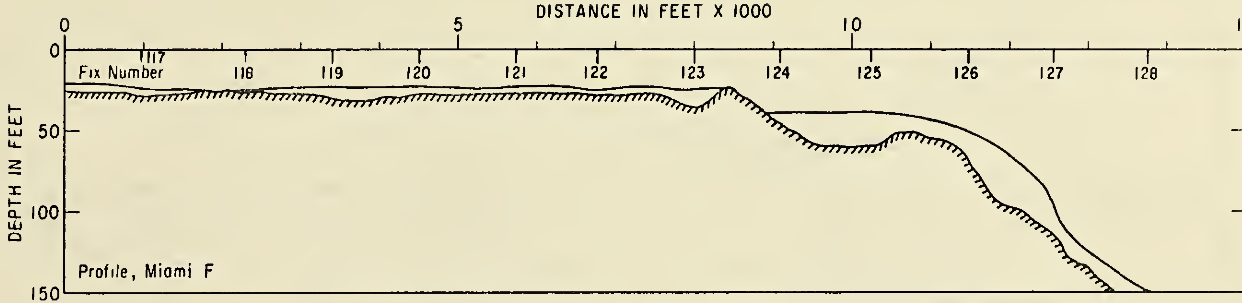
151
152
153
154
155
156
157
158
159
160
161
162
0
5
10
15
50
100
150
?


Profile, Miami E
DISTANCE IN FEET X 1000
DEPTH IN FEET
Fix Number
147
146
145
144
143
142
141
140
139
138
137
136
Core 4
Core 3
Core 7
0
5
10
15
50
100
150
?


DISTANCE IN FEET X 1000
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5
10
15
DEPTH IN FEET
0
50
100
150
Fix Number
117
118
119
120
121
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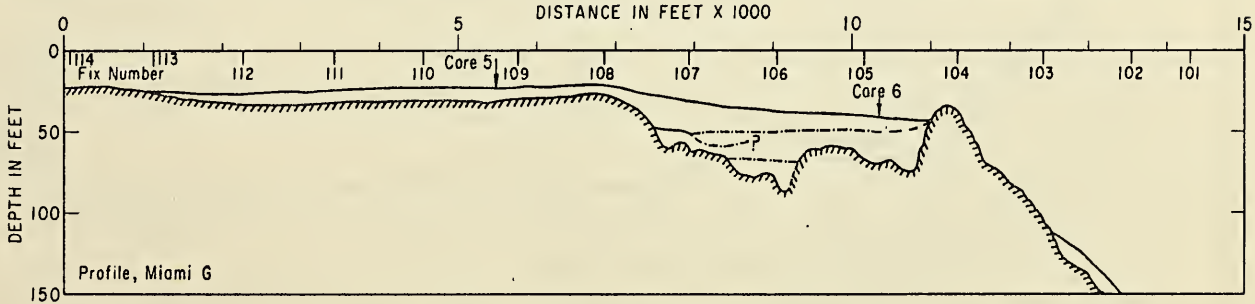
126
127
128
Profile, Miami F


DISTANCE IN FEET X 1000
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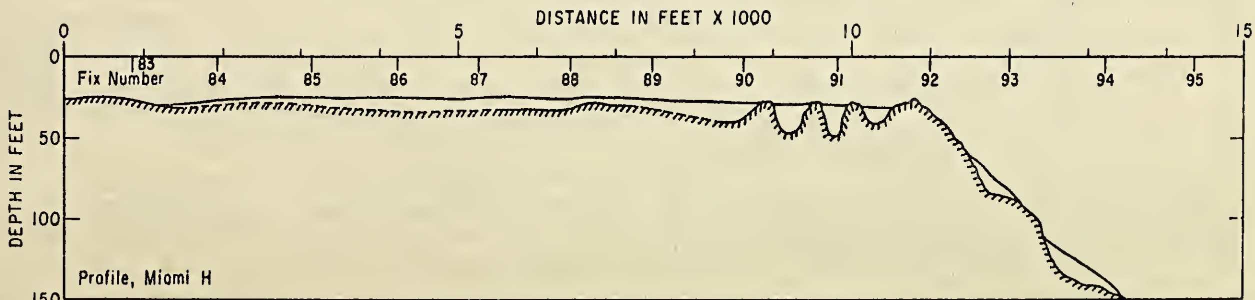
5
10
15
DEPTH IN FEET
0
50
100
150
Fix Number
114
113
112
111
110
Core 5
109
108
107
106
105
Core 6
104
103
102
101
?
Profile, Miami G


DISTANCE IN FEET X 1000
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10
15
DEPTH IN FEET
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100
150
Fix Number
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84
85
86
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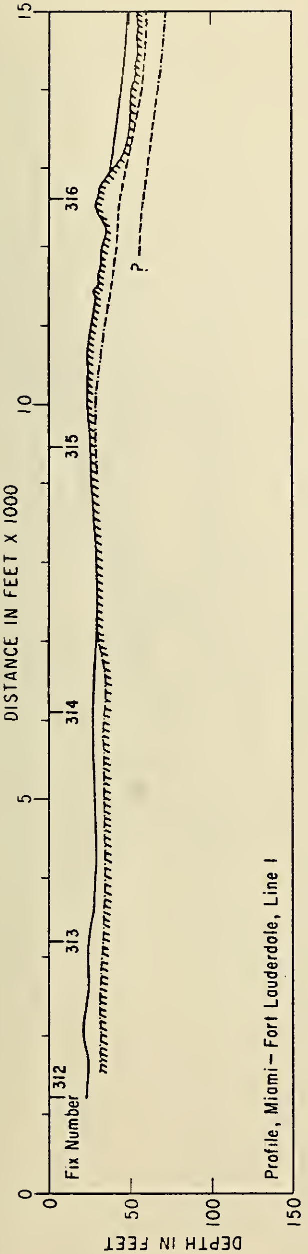
91
92
93
94
95
Profile, Miami H


DISTANCE IN FEET X 1000
DEPTH IN FEET
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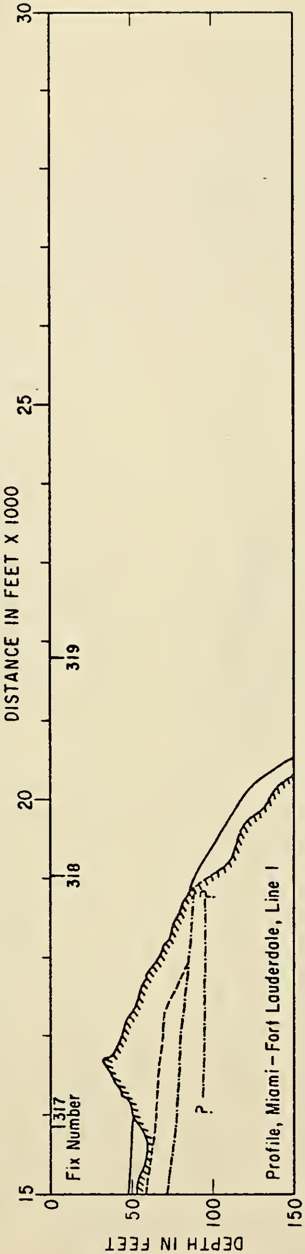
313
314
315
316
Profile, Miami – Fort Lauderdale, Line 1


DISTANCE IN FEET X 1000
DEPTH IN FEET
Fix Number
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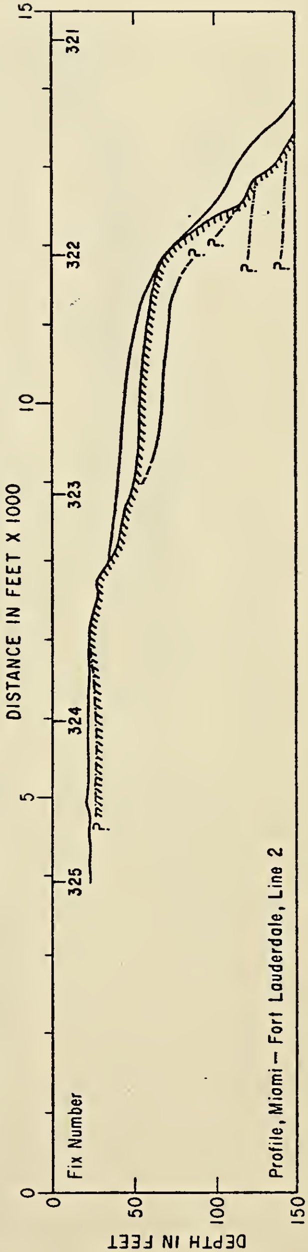
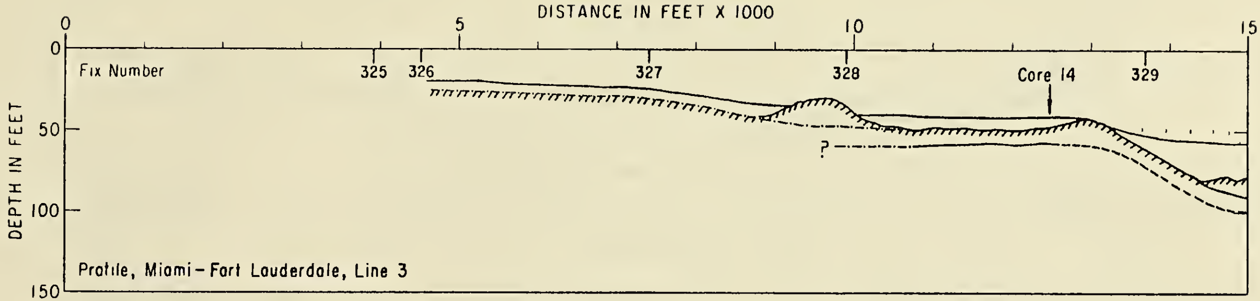
318
319
Profile, Miami – Fort Lauderdale, Line 1


DISTANCE IN FEET X 1000
DEPTH IN FEET
Fix Number
321
322
323
324
325
Profile, Miami – Fort Lauderdale, Line 2



DISTANCE IN FEET X 1000
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5
10
15
DEPTH IN FEET
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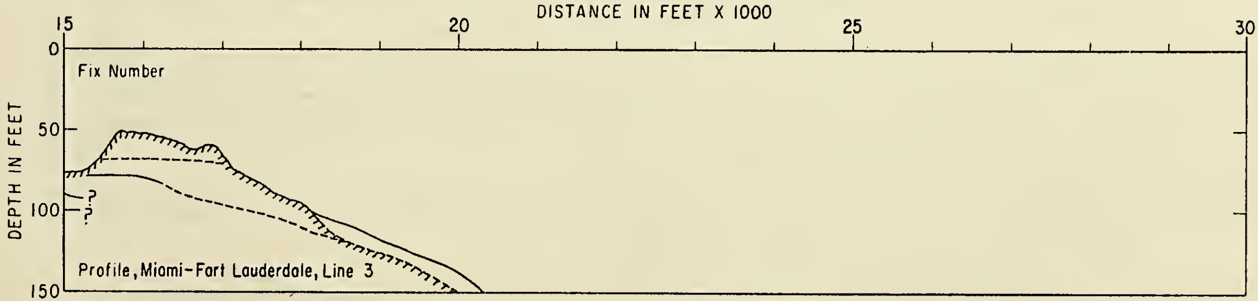
50
100
150
Fix Number
325
326
327
328
Core 14
329
?
Profile, Miami-Fort Lauderdale, Line 3

DISTANCE IN FEET X 1000
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25
30
DEPTH IN FEET
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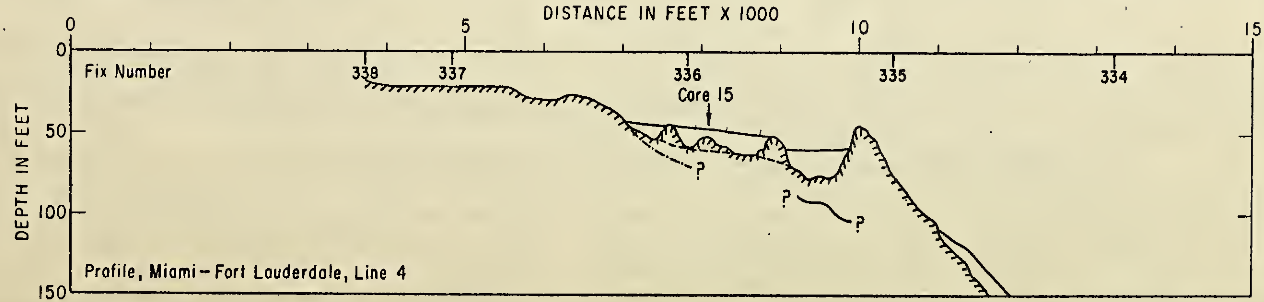
50
100
150
Fix Number
?
?
Profile, Miami-Fort Lauderdale, Line 3

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10
15
DEPTH IN FEET
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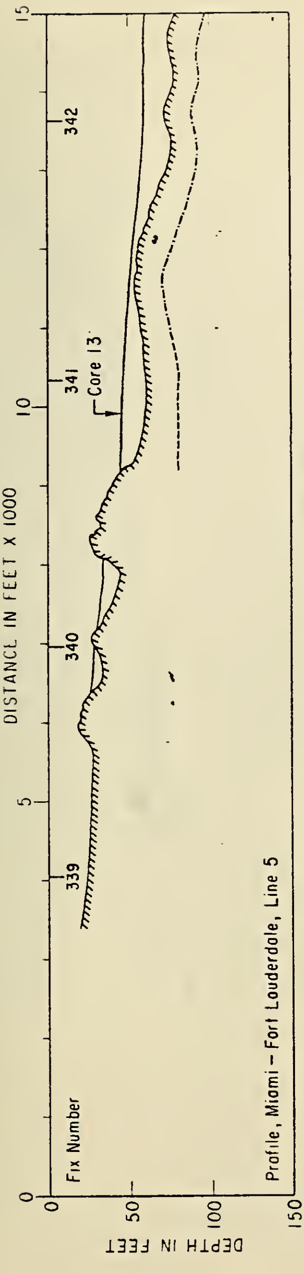
Fix Number
338
337
336
Core 15
335
334
?
?
?
Profile, Miami-Fort Lauderdale, Line 4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15
339
340
341
342
Core 13
Fix Number
Profile, Miami – Fort Louderdale, Line 5
DEPTH IN FEET
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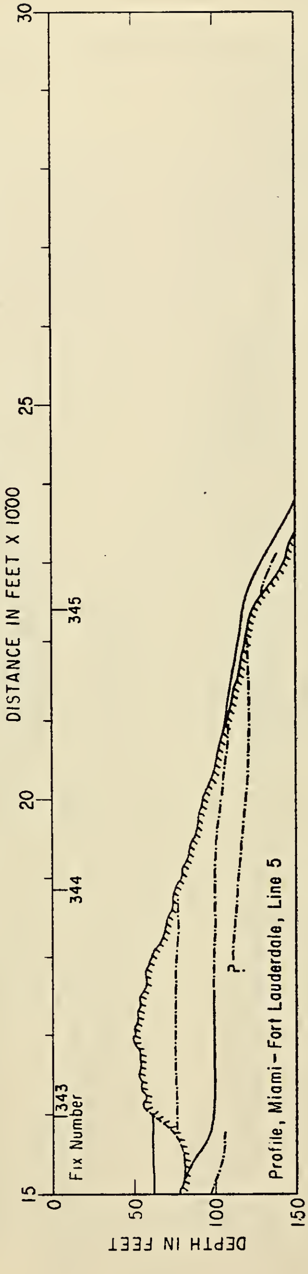
50
100
150


DISTANCE IN FEET X 1000
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344
345
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Profile, Miami – Fort Louderdale, Line 5
DEPTH IN FEET
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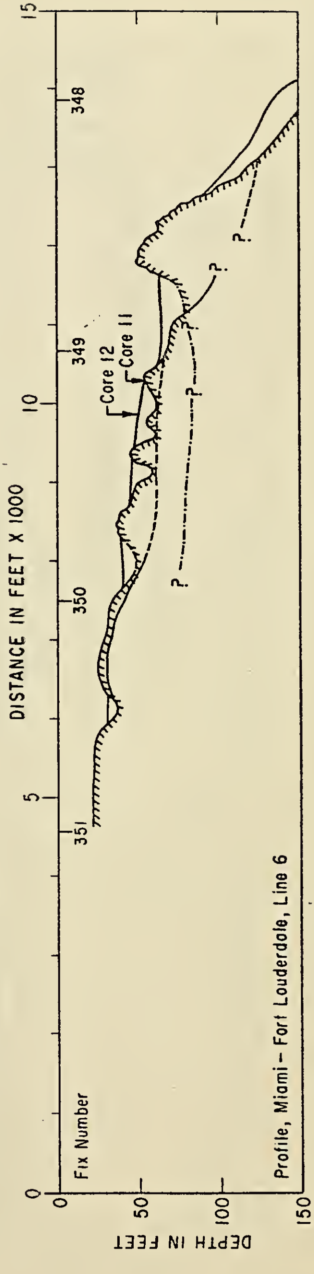
100
150


DISTANCE IN FEET X 1000
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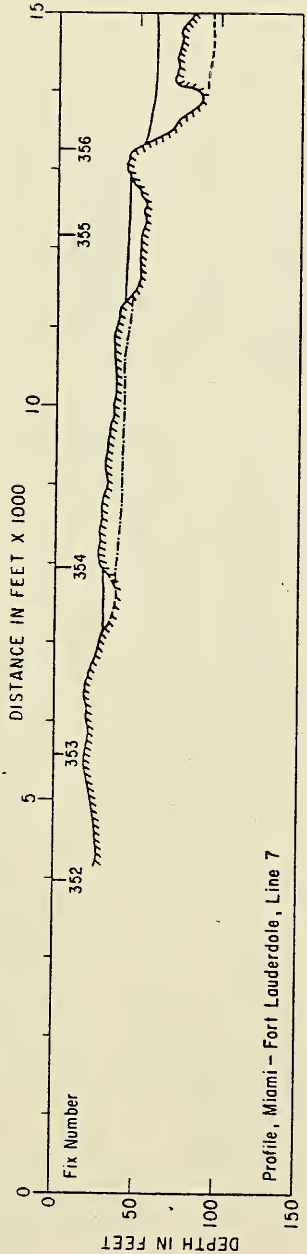
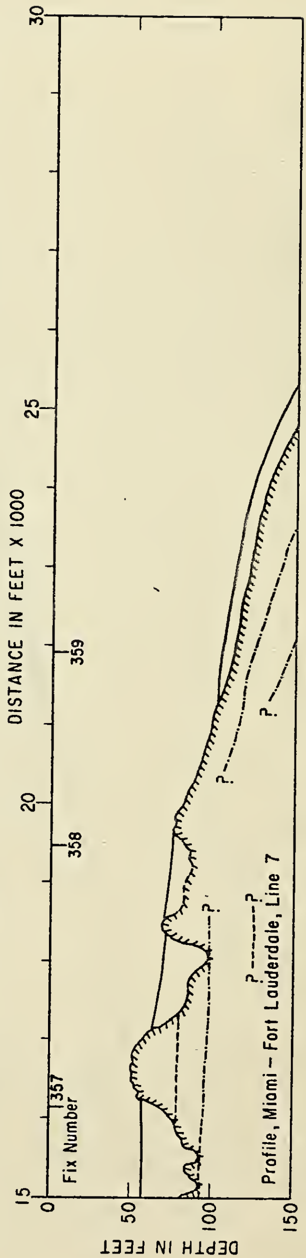
15
348
349
350
351
Core 12
Core 11
?
?
?
?
Fix Number
Profile, Miami – Fort Louderdale, Line 6
DEPTH IN FEET
0
50
100
150



DISTANCE IN FEET X 1000
DEPTH IN FEET
Fix Number
352
353
354
355
356
Profile, Miami – Fort Lauderdale, Line 7

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DEPTH IN FEET
Fix Number
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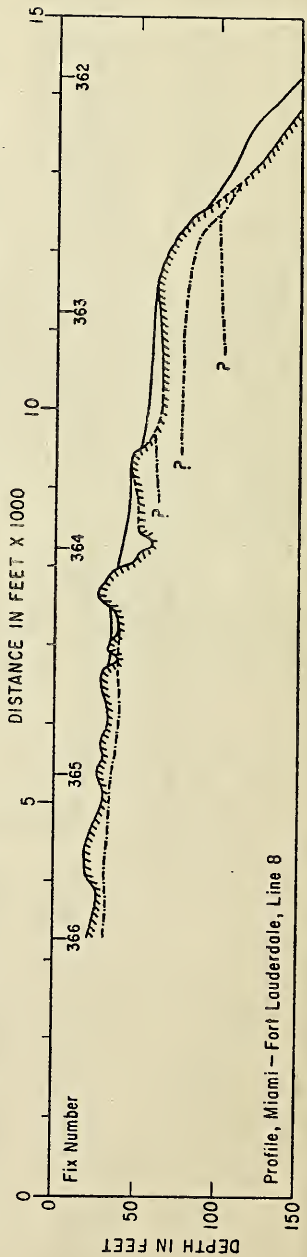
358
359
Profile, Miami – Fort Lauderdale, Line 7

DISTANCE IN FEET X 1000
DEPTH IN FEET
Fix Number
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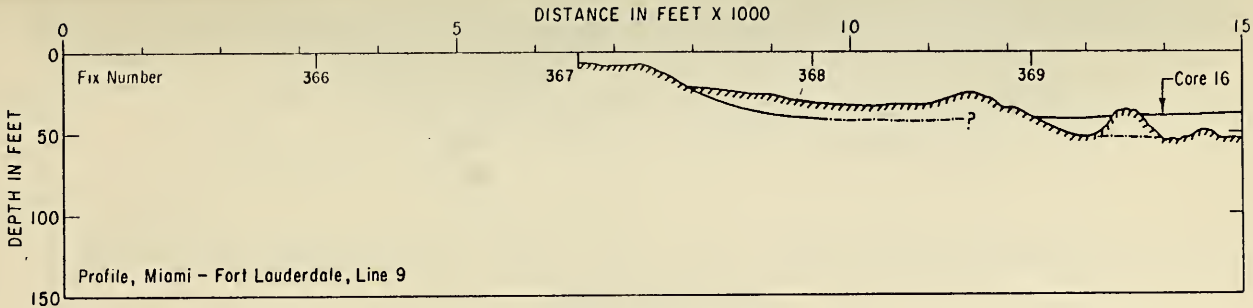
363
364
365
366
Profile, Miami – Fort Lauderdale, Line 8


DISTANCE IN FEET X 1000
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10
15
DEPTH IN FEET
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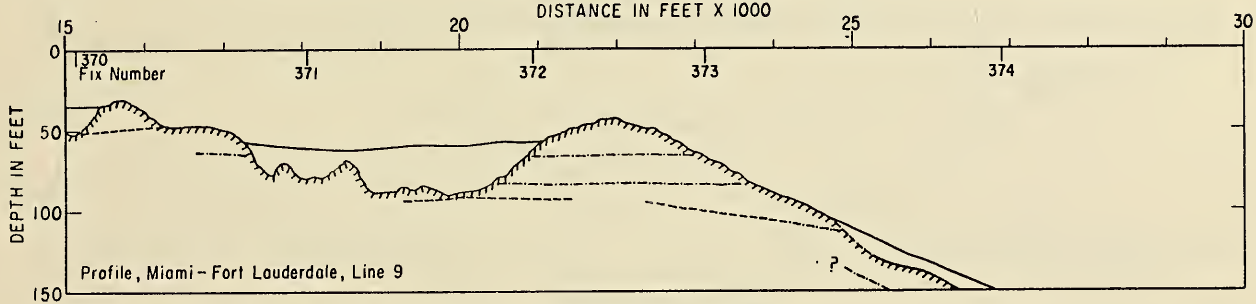
50
100
150
Fix Number
366
367
368
369
Core 16
?
Profile, Miami – Fort Lauderdale, Line 9


DISTANCE IN FEET X 1000
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25
30
DEPTH IN FEET
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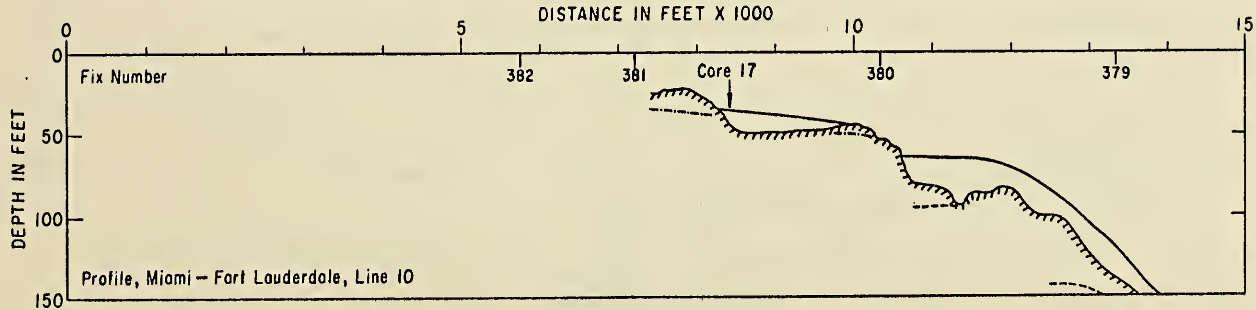
50
100
150
370
Fix Number
371
372
373
374
?
Profile, Miami – Fort Lauderdale, Line 9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15
DEPTH IN FEET
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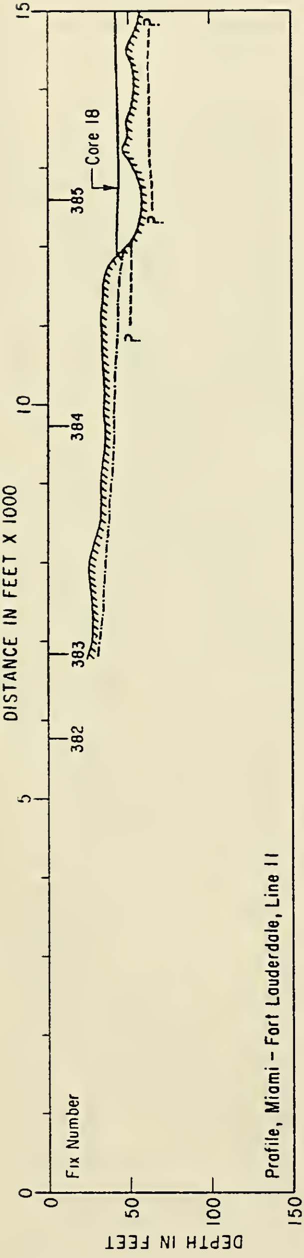
50
100
150
Fix Number
382
381
Core 17
380
379
Profile, Miami – Fort Lauderdale, Line 10



DISTANCE IN FEET X 1000
DEPTH IN FEET
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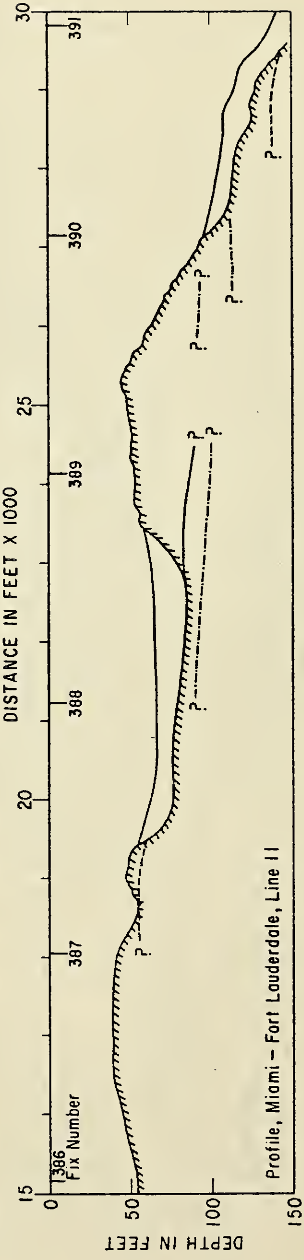
5
10
15
50
100
150
Fix Number
382
383
384
385
Core 18
?
Profile, Miami - Fort Lauderdale, Line 11

DISTANCE IN FEET X 1000
DEPTH IN FEET
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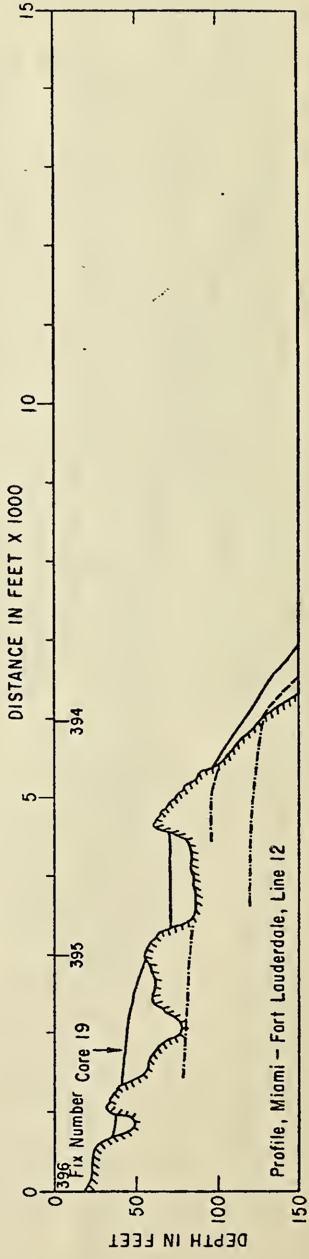
50
100
150
Fix Number
386
387
388
389
390
391
?
Profile, Miami - Fort Lauderdale, Line 11

DISTANCE IN FEET X 1000
DEPTH IN FEET
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5
10
15
50
100
150
Fix Number
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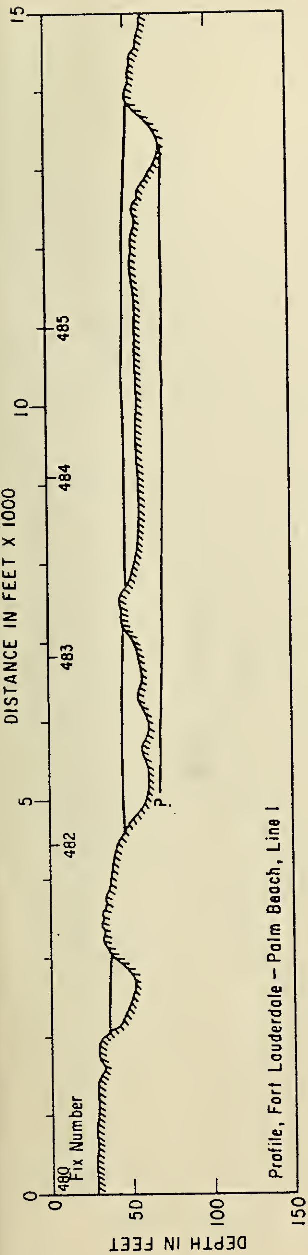
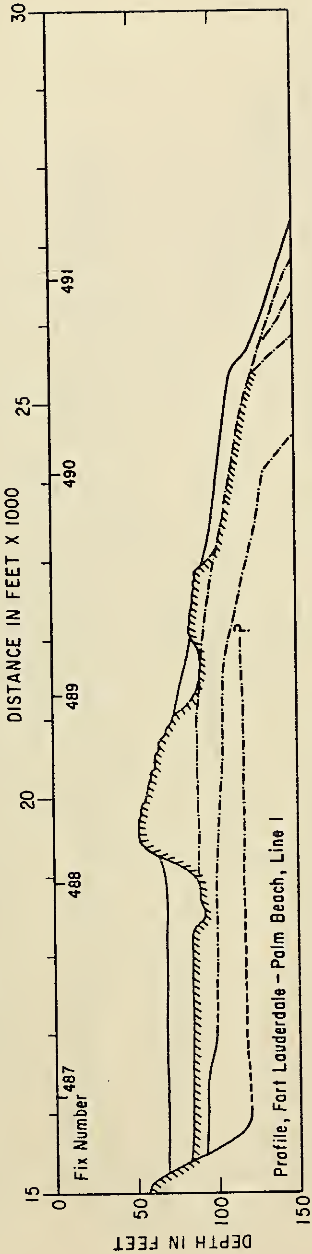
395
394
Core 19
Profile, Miami - Fort Lauderdale, Line 12



Profile, Fort Lauderdale – Palm Beach, Line I



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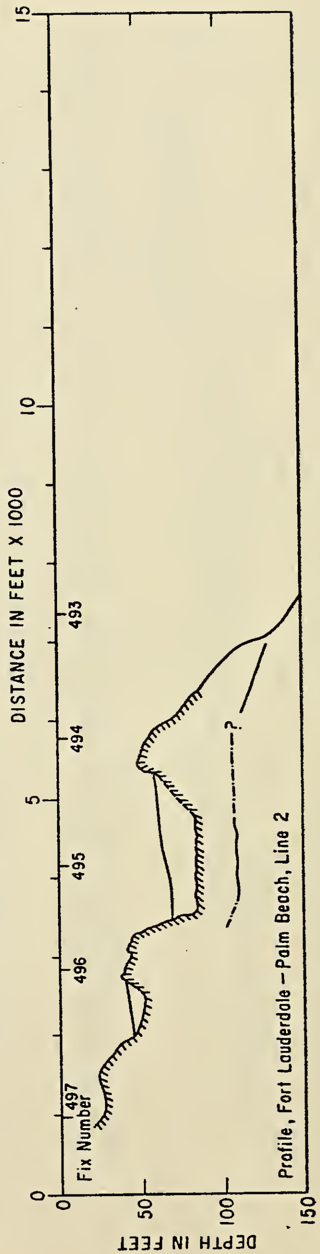

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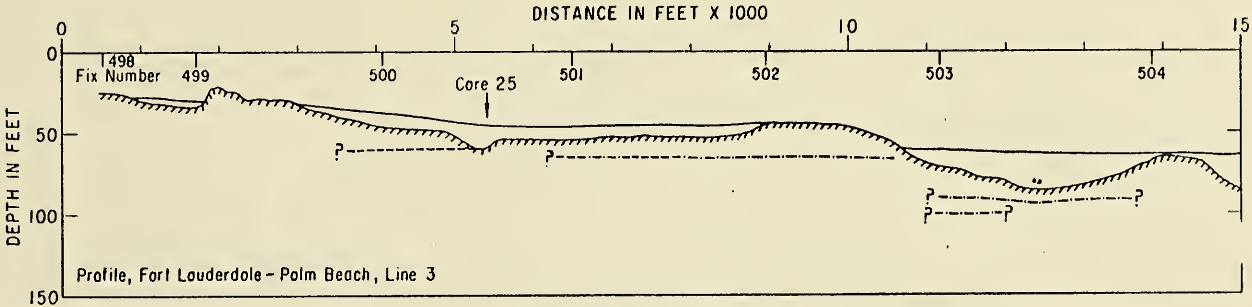
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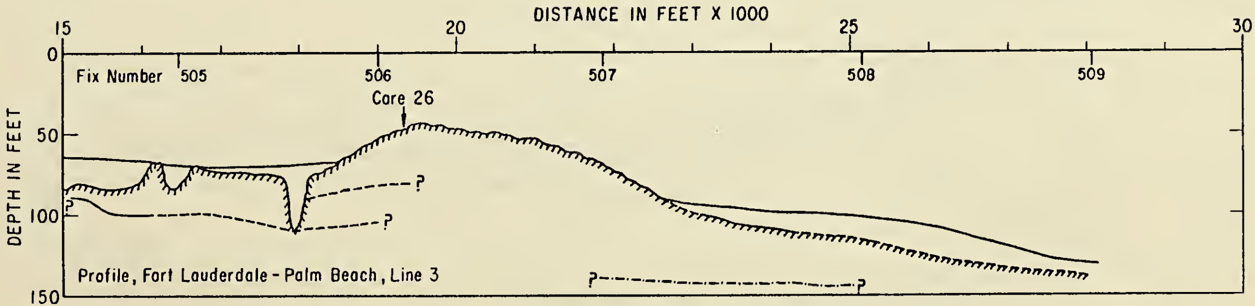
Profile, Fort Louderdole - Palm Beach, Line 3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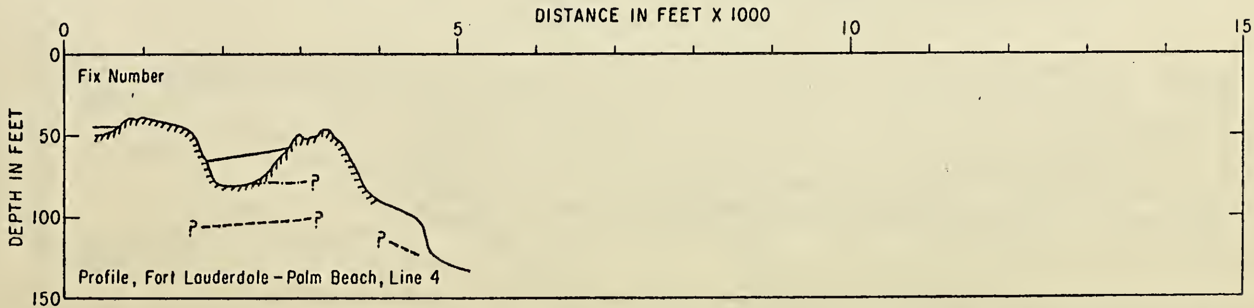
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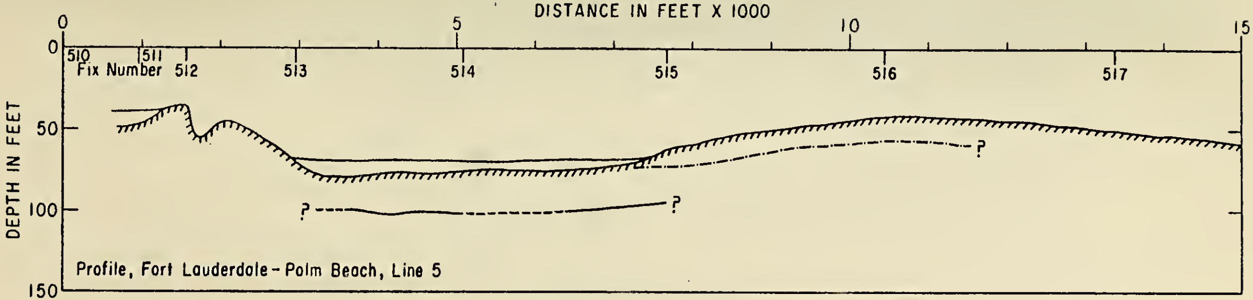

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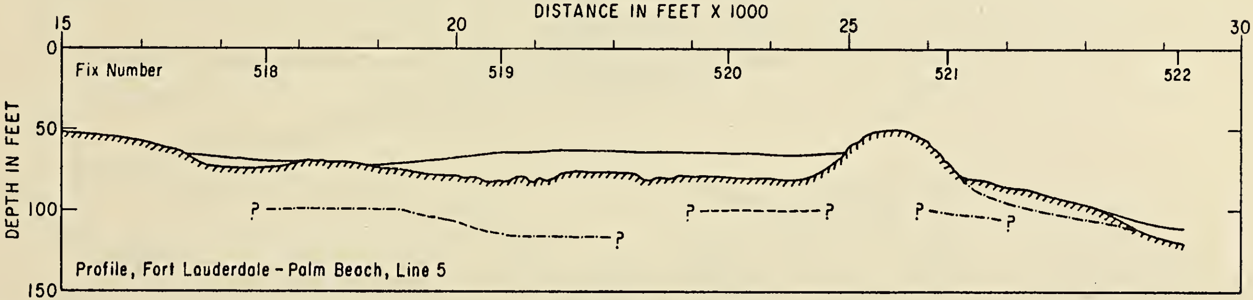
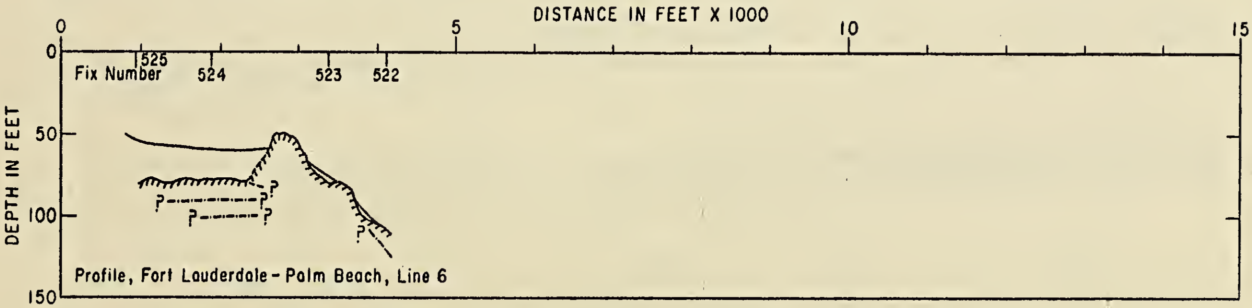


Profile, Fort Lauderdale - Palm Beach, Line 5



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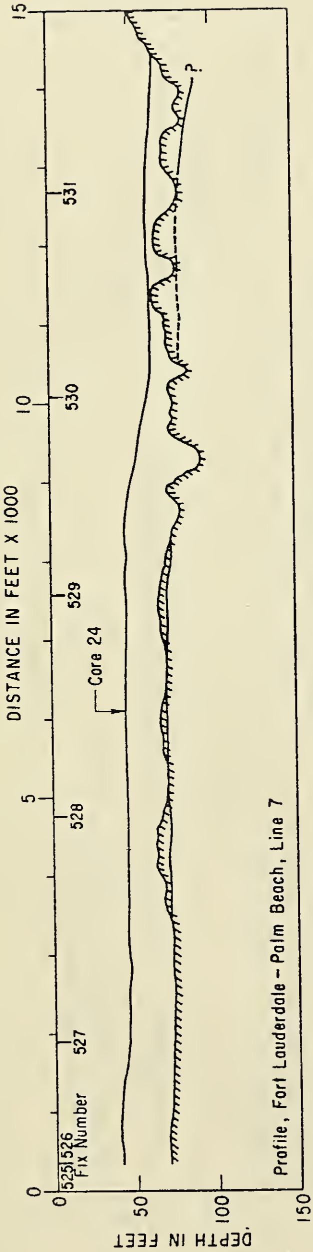

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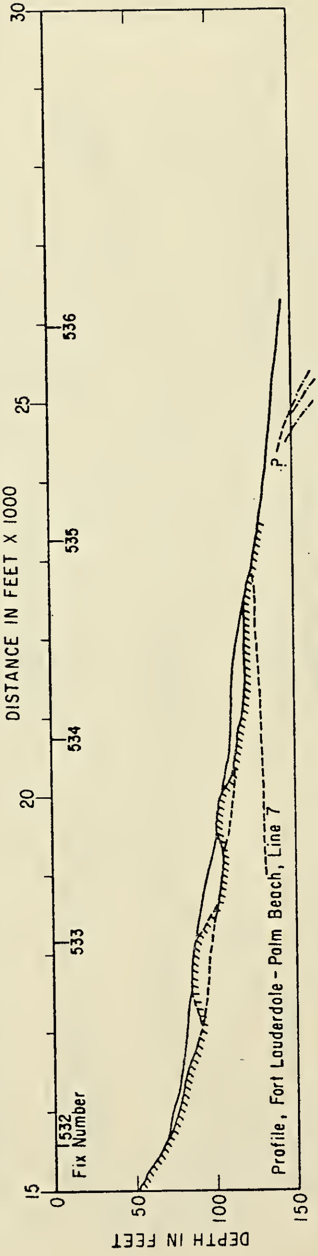
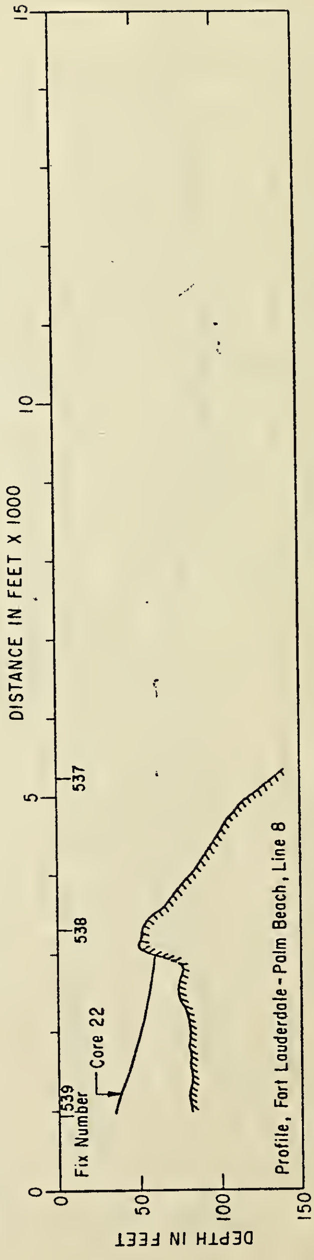
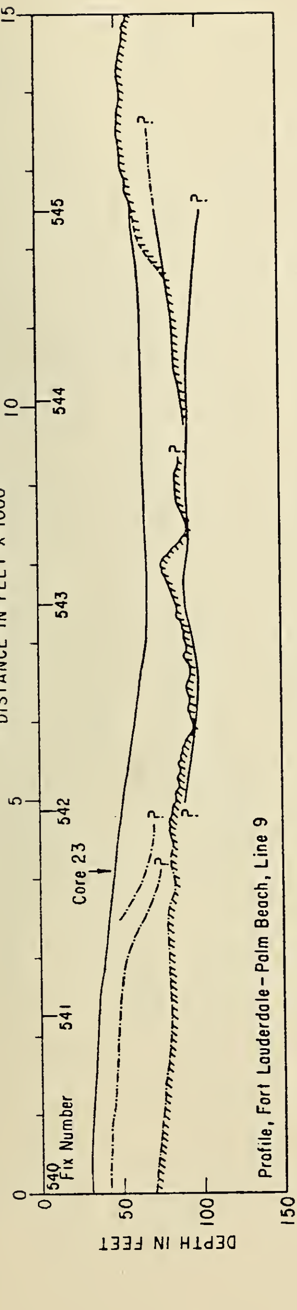


Profile, Fort Lauderdale - Palm Beach, Line 7



Profile, Fort Lauderdale - Palm Beach, Line 8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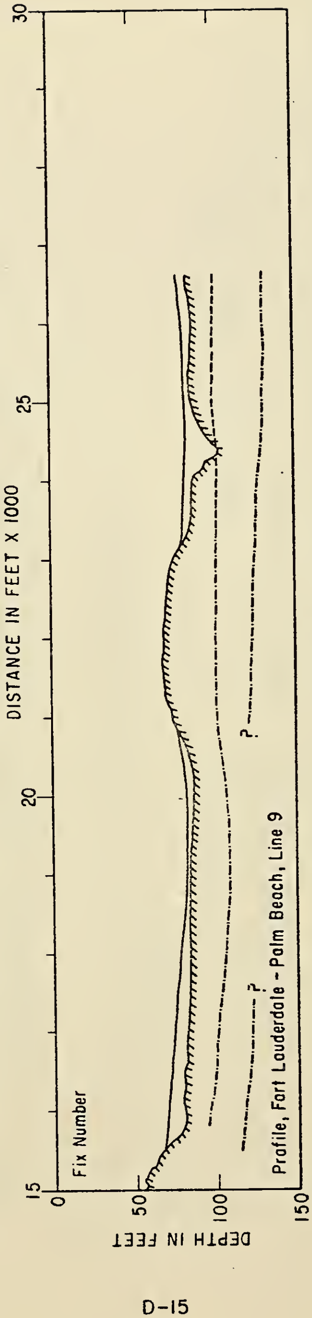
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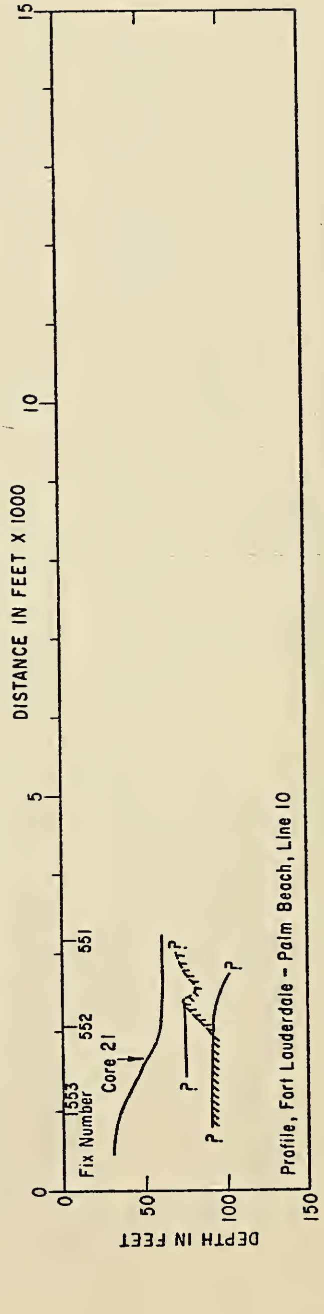
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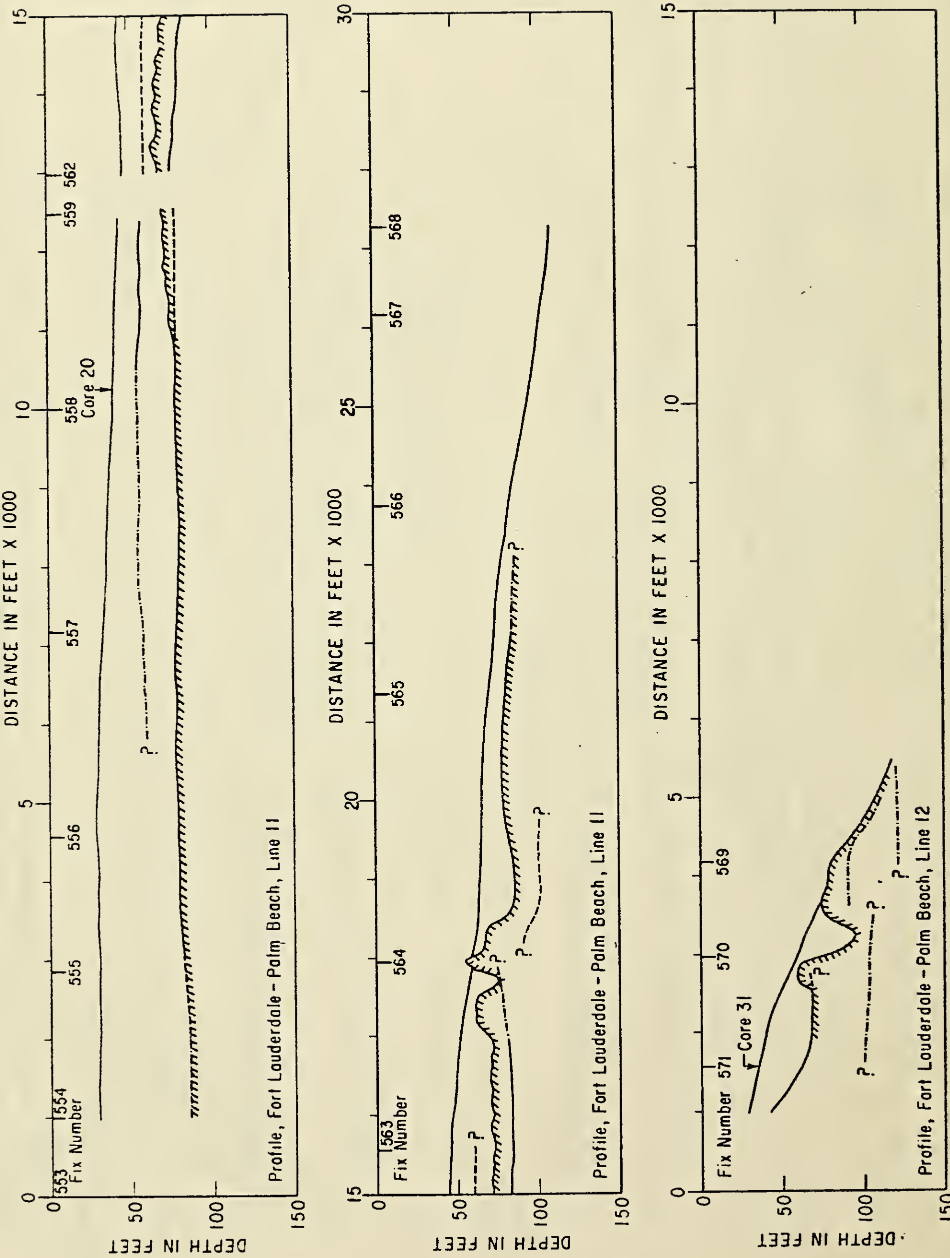
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Profile, Fort Lauderdale - Palm Beach, Line 11
DISTANCE IN FEET X 1000
DEPTH IN FEET
Fix Number
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565
566
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568
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Profile, Fort Lauderdale - Palm Beach, Line 12
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DEPTH IN FEET
Fix Number
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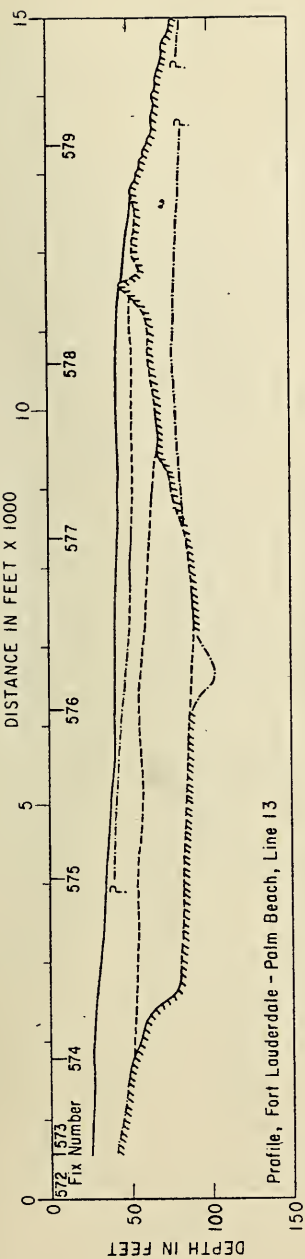
569
Core 31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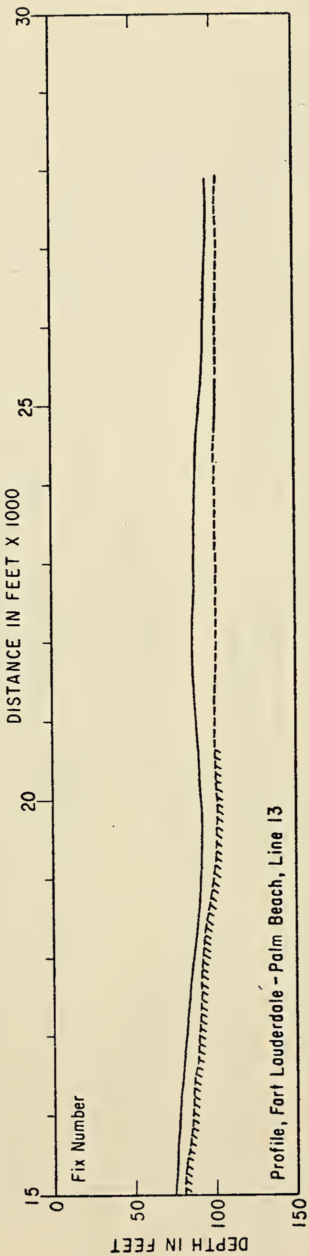
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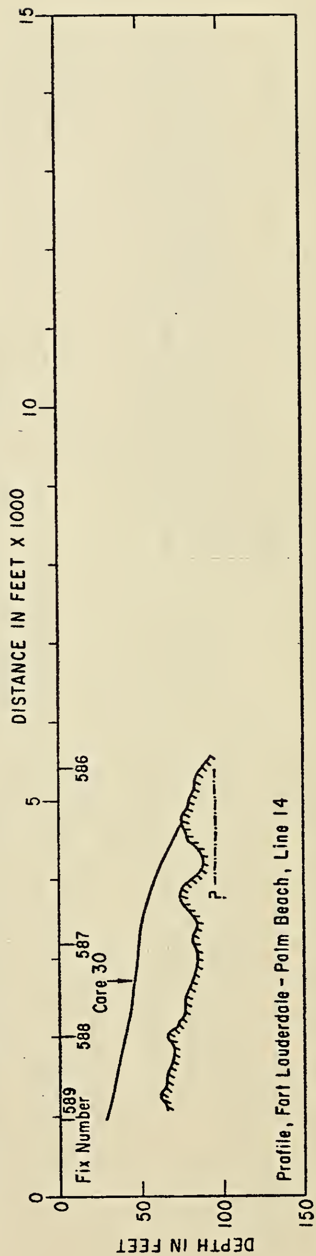
Profile, Fort Lauderdale - Palm Beach, Line 13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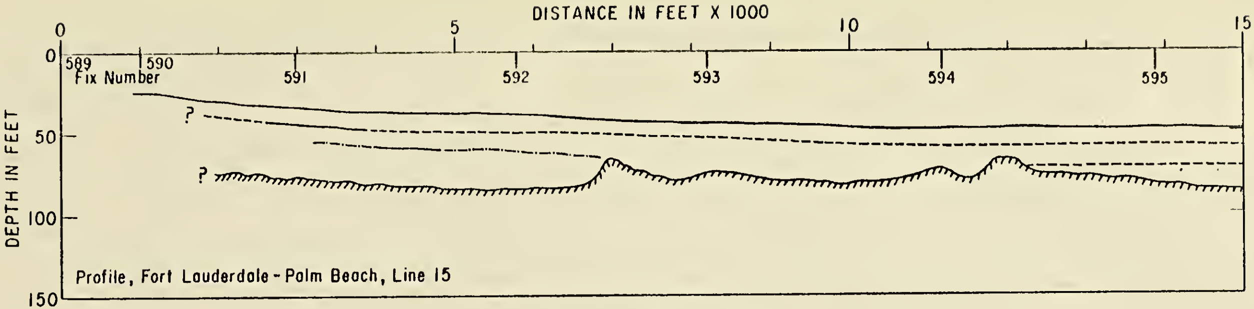
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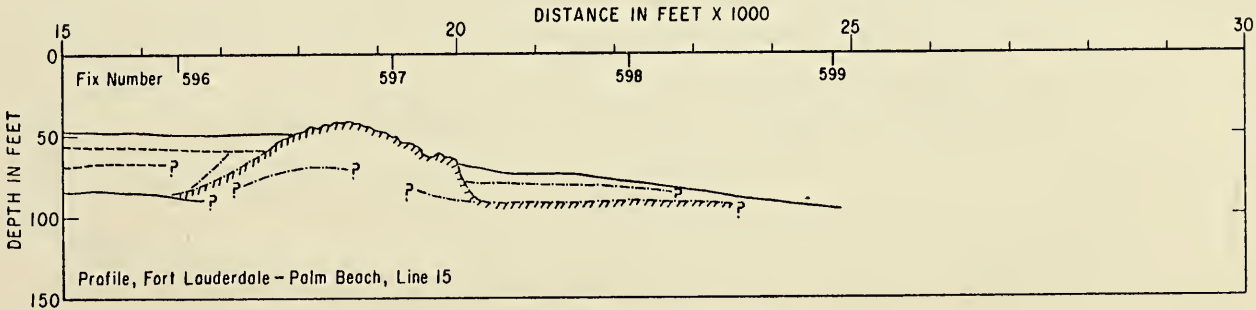
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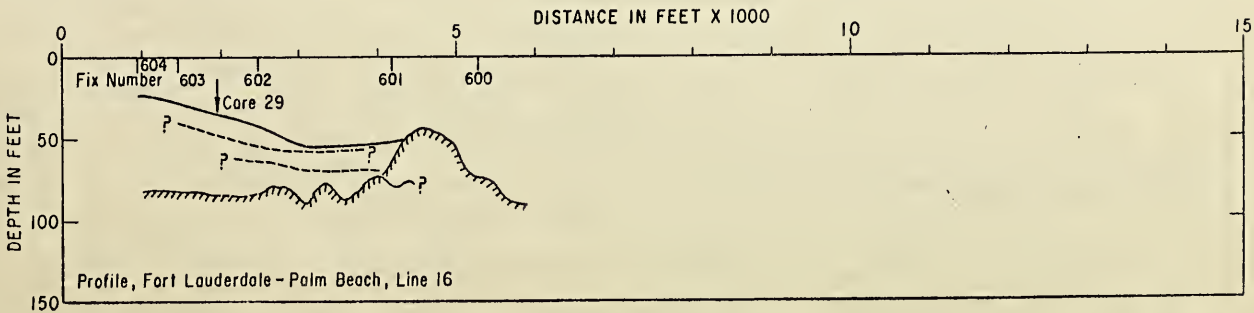
Profile, Fort Lauderdale - Palm Beach, Line 15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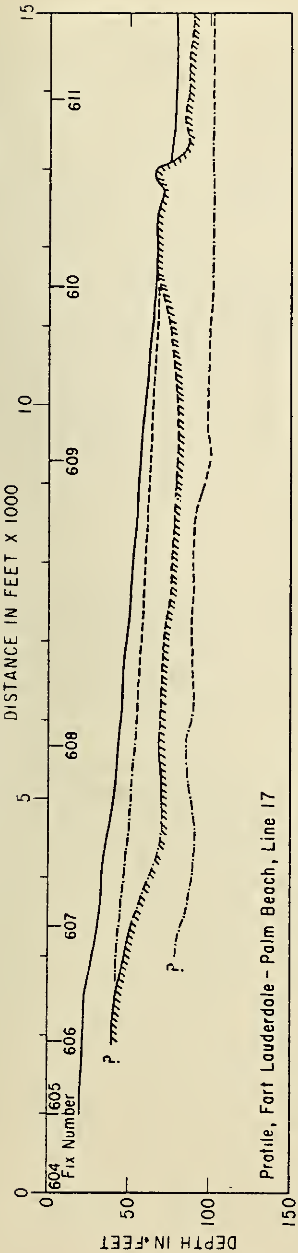
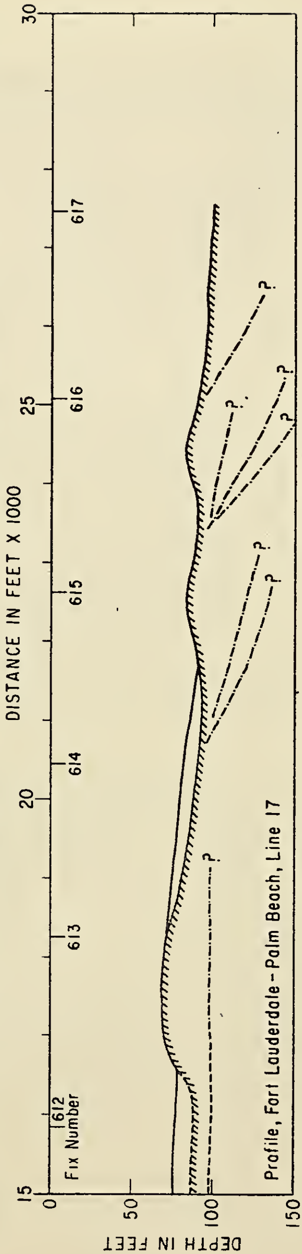
Profile, Fort Lauderdale - Palm Beach, Line 16




Profile, Fort Lauderdale - Palm Beach, Line 17

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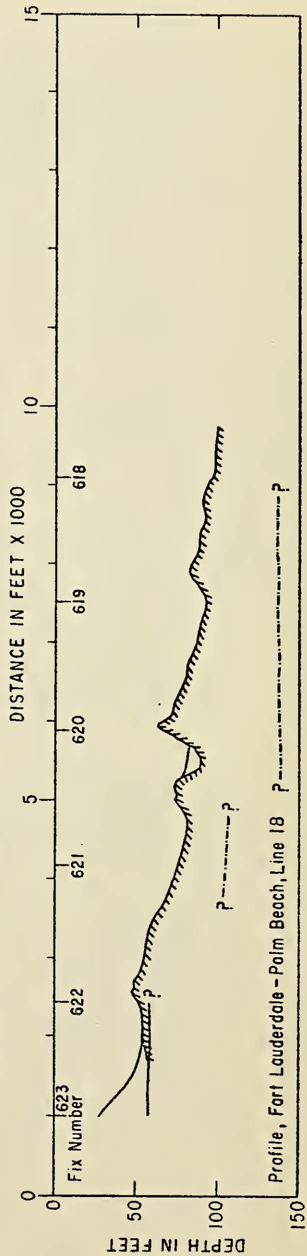


Profile, Fort Lauderdale - Palm Beach, Line 18

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13. ABSTRACT


The Continental Shelf bordering southeastern Florida between Palm Beach and Miami was surveyed by CERC to locate and evaluate sand deposits potentially useable for shore protection projects. Survey data covered 141 square miles of that part of the Continental Shelf between 15- and 100-foot depths, and consisted of seismic reflection profiles and sediment cores from the sea floor.

South of Boca Raton to Miami, much of the shelf is rocky with a thin sediment veneer. Relatively thick deposits of sediment have accumulated locally in troughs formed between low reef-like ridges lying parallel to shore. Shelf sediments south of Boca Raton consist almost entirely of sand-size calcareous skeletal fragments.

North of Boca Raton to Palm Beach, most of the shelf is overlain by a thick blanket deposit of homogeneous fine-to-medium, gray sand about half of which consists of quartz particles and the remainder of calcareous skeletal fragments. About 200 million cubic yards of sand-size sediment occurs on the shelf south of Boca Raton. Although generally suitable for beach fill in terms of size, degradation of size by abrasion and fragmentation of the delicate particles may occur in the shore environment.

More than 380 million cubic yards of sand-size sediment lies on the shelf north of Boca Raton. However, because of its fine size, this sand is not considered ideally suited for beach fill. In terms of potential as beach sand, sand-size sediments from the shelf bordering southeastern Florida is of marginal quality.


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| Beach sediments | | | | | | |
| Continental Shelf | | | | | | |
| Miami to Palm Beach, Florida | | | | | | |
| Seismic profiles | | | | | | |
| Sea bottom cores | | | | | | |