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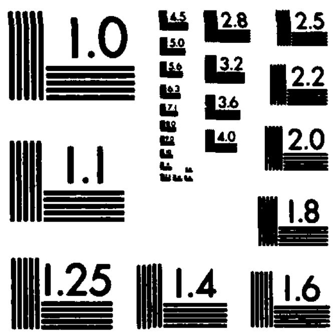

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WAVE REFRACTION AND BEACH CHARACTERISTICS OF A CAPE ASSOCIATED SHORELINE, BREVARD COUNTY, FLORIDA

BY JAMES EDWARD CLAUSNER

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WAVE REFRACTION AND BEACH CHARACTERISTICS
OF A CAPE ASSOCIATED SHORELINE,
BREVARD COUNTY, FLORIDA

by

JAMES EDWARD CLAUSNER

A THESIS

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JAMES EDWARD CLAUSNER

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August 1982

ABSTRACT

Wave Refraction and Beach Characteristics
in a Cape Associated Shoreline,
Brevard County, Florida. (August 1982)

James Edward Clausner, B.S., F.I.T.

Chairman of Advisory Committee: Dr. Donald Stauble

In this thesis is presented a study of the beach characteristics of S. Brevard County, Florida, and the effects of wave refraction on those characteristics. In October, 1980 twenty-one profiles with sand samples were taken at equal intervals over the beaches of S. Brevard County. From the data, two types of beaches were evident. Wide, flat, fine grained beaches, with few shells were found in the northern part of the study area. To the south; narrower, steeper, coarser grained beaches with more shells were found.

Wave refraction studies of the area were done by computing wave packet trajectories. The velocity of the wave packets was assumed to be the geometric group velocity theory. The refraction diagrams and wave energy distribution plots showed that Cape Canaveral and its shoals created a shadow zone of low wave energy in the northern part of the study area. Further south the wave

energy increased. The low energy zone had fine sand and a flat slope, the higher energy zone had coarser sand and a steeper slope. The 8, 10, and possibly 12 second northeast waves most strongly controll the beach characteristics with 6 and 8 second east waves also having an effect on the beach. Little landward migration of the dune face was found in the areas identified as having erosion problems in previous studies during the period from 1972 to 1980.

ACKNOWLEDGEMENT

I would like to thank my advisor, Dr. Stauble, for his overall direction and critical reviews of this thesis. Dr. Breeding spent a large amount of time helping me with the wave refraction portion of this thesis, I thank him for that. The F.I.T. Computer Center staff was very generous and patient during the countless runs of WAVPAK and provided me with mountains of printouts and numerous plots. I sincerely appreciate their efforts. I would also like to thank Rick Hushla, Mark Hansen, Frank Saksa, and the other graduate and undergraduate students who helped me with the field and laboratory work.

My wife, Dana Fay, endured many financial, physcial, and emotional burdens during the course of my master's program and thesis. I thank her for the love and strength she gave me, without her this thesis would not have been possible. Barbara Young, gave me the personal insight and counseling I needed at a difficult time, I would like to thank her again for her efforts. I would like to thank my step father, Bob Baylis, for the instruction and use of his word processor.

Finally, I would like to acknowledge the Coastal Sciences Program, Environmental Sciences Division, Office of Naval Research, who provided financial support for the computer work under contract No. N00014-C-0677.

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WAVE REFRACTION AND BEACH CHARACTERISTICS OF A CAPE ASSOCIATED SHORELINE, BREVARD COUNTY, FLORIDA

INTRODUCTION

The beaches of Brevard County, south of Cape Canaveral (Fig. 1), exhibit rapid profile changes over a short distance. They appear to be broad and flat in Cocoa Beach and grade into narrower and steeper beaches to the south. The purpose of this study was to determine if in fact the the beaches are truly different, and if they are, is Cape Canaveral Shoal one of the reasons for the differences. From profile and sand sample data the foreshore slope, grain size distribution, and percent shell content were calculated. Slope and grain size distribution are easily determined and have been used repeatedly as parameters for evaluating differences in beaches (Bascom, 1951; Komar, 1976). Studies of the east coast of Florida have shown the amount of shells in the beach sand significantly influences slope and grain size distribution (Field and Duane, 1974; Meisburger and Duane, 1971; Rusnak et al., 1966).

This thesis is modeled after the papers contained in the Journal of Sedimentary Petrology.

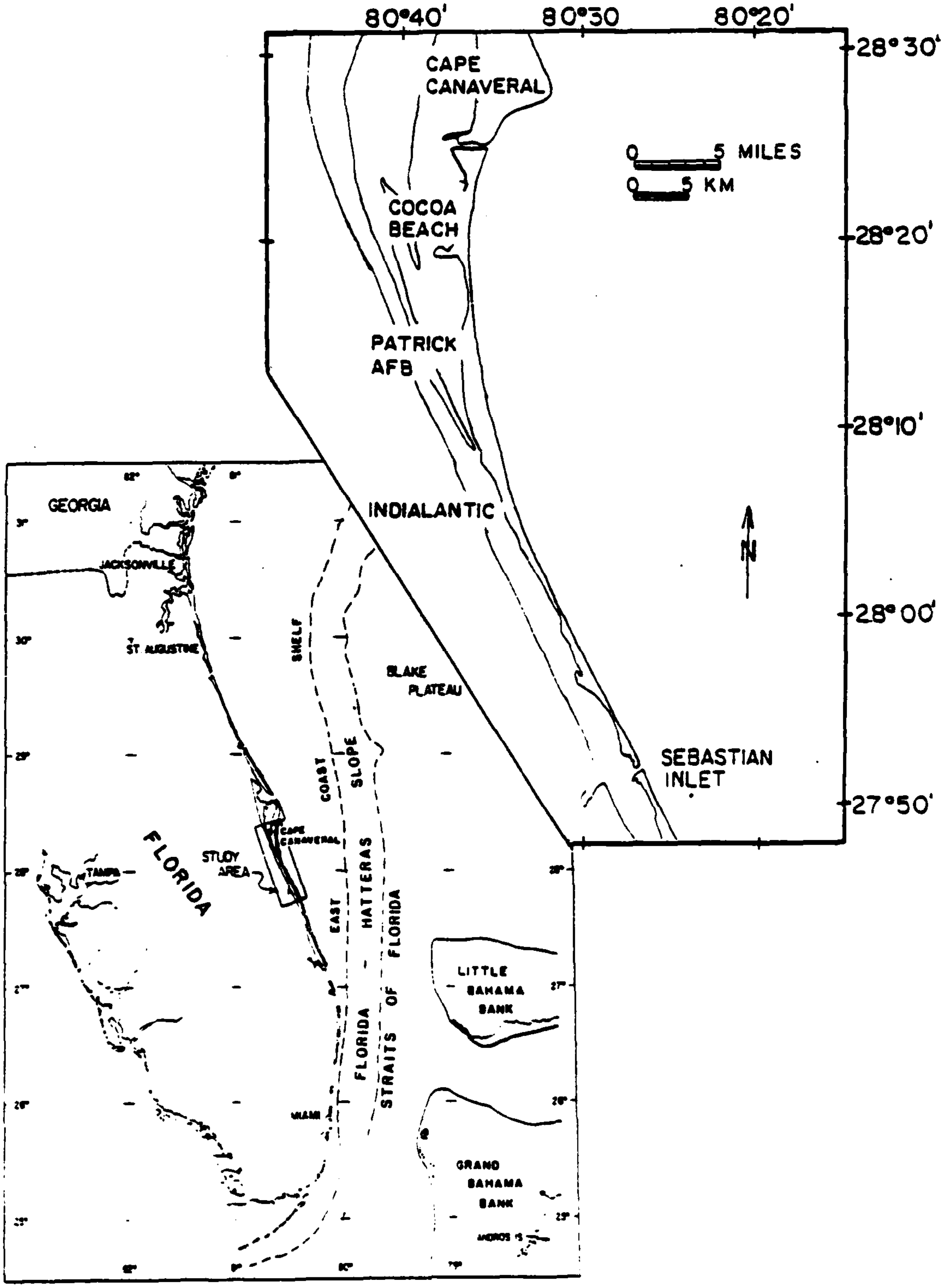

FIG. 1--Locator map.

Reasons for beach parameter differences include the relative amounts of wave energy reaching the beach (Bascom, 1951; Short, 1979) and differences in sediment sources (Komar, 1976; Shepard, 1973). Wave energy is primarily controlled by wave climate and wave refraction (Breeding, 1972; Colonell and Goldsmith, 1970). Wave energy in this study was calculated from wave refraction diagrams (Breeding et al., 1978; Breeding, 1978a), to see if Cape Canaveral and its associated shoals significantly affected the wave energy distribution along the South Brevard County beaches between Canaveral Inlet to the north and Sebastian Inlet to the south (Fig. 1).

Physical Setting

Brevard County is located in the middle of Florida's east coast. It has 116 km of coastline, 52 km are north of Canaveral Inlet, and 64 km are south. The beaches of Brevard County are on the Atlantic side of a holocene barrier island with lagoons (the Indian and Banana Rivers) behind them. Pleistocene coquina rocks underlie the barrier island. The rocks have prominent outcrops in the surf zone from Patrick Air Force Base (PAFB) to Sebastian Inlet (U.S. Army, 1967). Off Brevard County the adjacent continental shelf is divided into an inner and outer shelf with the division at 21 m. After the shelf break at 70 m the Florida Hatteras slope descends to the Blake Plateau at a depth of 700 m (Field and Duane, 1974).

Cape Canaveral is one of the larger capes in the world, being 56 km long and projecting out into the Atlantic Ocean 16 km. It is classified as a cuspate foreland (Shepard, 1973). However, the origin of the Cape is still being debated.

Brooks (1972) summarized the geology of Cape Canaveral. May (1972) estimates the age of the Cape Canaveral Lagoon complex to be from 30 000 to 100 000 years. White (1958) thinks the Cape was started by a right hand transverse fault. Another theory is that cuspate forelands sometime form as deposits in the quiet water zone between two coastal eddies (Kofoed, 1963; Shepard, 1973). Whatever method is responsible for the origin of Cape Canaveral, the present coastal processes are maintaining it and moving it southward (U.S. Army, 1967). Like other cuspate forelands, eg. Cape San Blas, Cape St. George complex, and Cape Hatteras outer banks complex, the offshore bathymetry is dominated by shoals (Fig. 2). However, unlike most other capes, Cape Canaveral is probably not of deltaic origin (Stauble and Wanke, 1974; Swift et al., 1972). Even so, wave

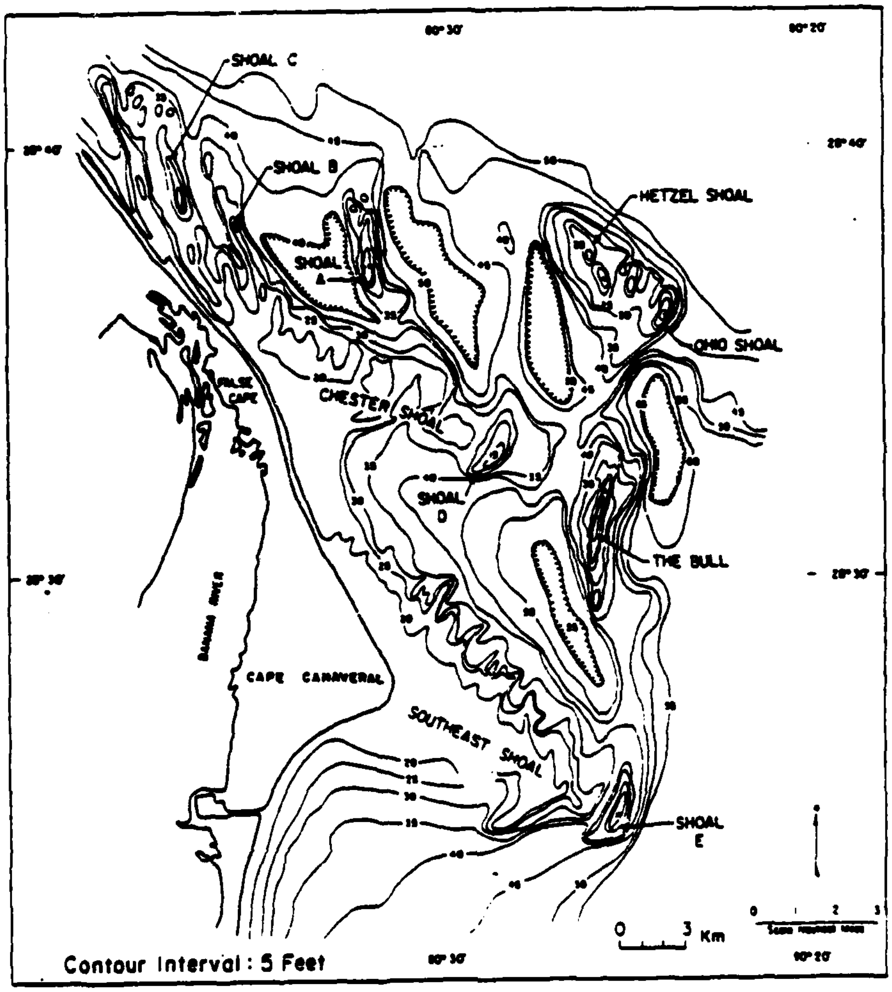

FIG. 2--Cape Canaveral shoals (From Field and Duane, 1974).

refraction around the shoals is thought to be a major factor in the formation and movement of capes and other rthymic features (Dolan and Ferm, 1968; Breeding, 1981a).

Wind data complied from readings at Cocoa Beach (Fig. 3) show that the strongest winds are from the northern sector. Prevailing winds are from the north and east during the winter and from the east and southeast during the summer (U.S. Army, 1967).

Large waves are generated by northeasters during the fall and winter. The wave rose (Fig. 4) shows that 59% of the swells greater than 3.7 m come from the northeast, 32% come from the east, and 9% come from the southeast. For medium swells, 1.8 to 3.7 m, 14% come from the north, 46% come from northeast, 20% come from the east, and 10% come from the southeast. For the small swells, less than 1.8 m, 10% come from the north, 26% come from the northeast, 30% come from the east, 25% come from the southeast, and 9% come from the south (U.S. Army, 1967). The incomming waves produce a southerly longshore drift from September to February, during March and April the drift direction is uncertain, and from June to August the drift is northerly (U.S. Army, 1967).

The tides are semidurinal with a mean tide range of 1.07 m, spring tide range is 1.25 m.

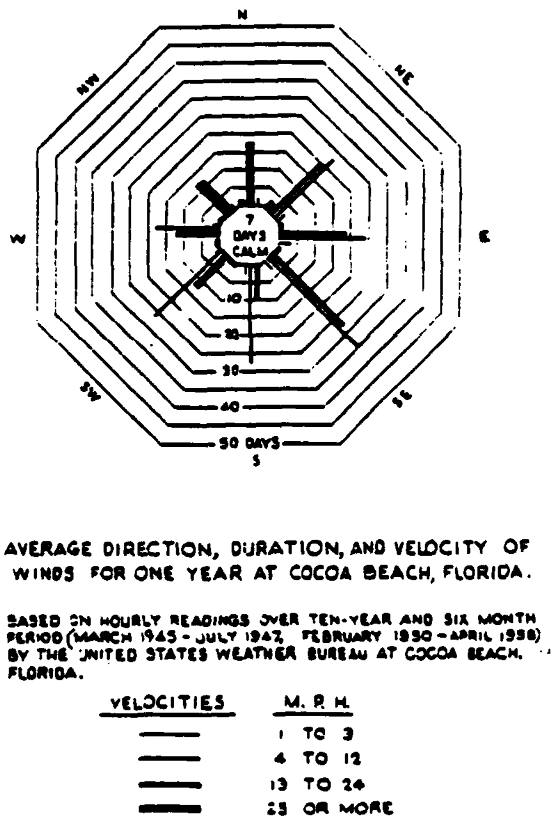

FIG. 3--Wind rose. (From U.S. Army,]967)

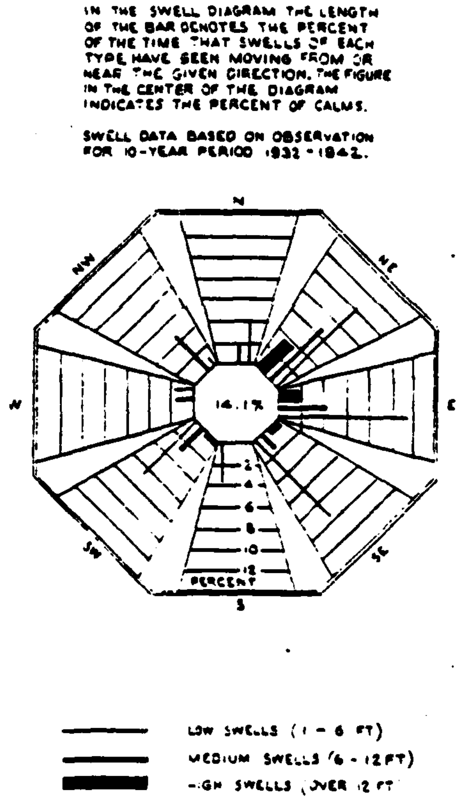

FIG. 4--Wave rose (From U.S. Army,]967)

Previous Investigations

The U.S. Army Corps of Engineers (1967) in a study of beach erosion along the southern Brevard shoreline, including 44 profile locations, found beach erosion severe enough to require beach nourishment along a 4.6 km section south of Canaveral Inlet, a 3.7 km section at Patrick Air Force Base (PAFB), and a 3.3 km section from Indialantic to Melbourne Beach. The erosion at Canaveral Inlet was blaimed on construction of the Canaveral Jetties which block the predominating southerly drift. Reasons for erosion at PAFB and and Indialantic to Melbourne Beach are unclear, but it may have been caused by an increase in wave energy at those locations or destruction of the natural dune due to poor construction practice. Wave refraction diagrams produced as a part of this study will be used to investigate this hypothesis.

In studies of the geomorphology and sediments on the beach and inner continental shelf off Cape Canaveral Field and Duane (1974) found coarse to fine sand on the beach and a direct relationship between an increase in grain size and the percentage of shell fragments. Meisburger and Duane (1971) in a study of the beach and inner continental shelf from Cape Canaveral to Palm Beach, described the beach sediments as calcareous quartoze sand, with the coarser foreshore sand occuring near outcrops of the Anastasia formation.

Researchers of the Coastal and Oceanographic Engineering Laboratory of the University of Florida (1976) monitored the beach nourishment project south of Canaveral Jetty. They found a southerly drift of the nourishment sand. Hushla and Stauble in their (1981) study of the same project had similiar results. Sand lost from the nourishment project was deposited on beaches to the south. These results indicate that most of the wave energy comes from the northeast, with a resulting net longshore drift to the south.

BEACH PROFILES

The beach profile chapter is divided into three sections. The first section, beach variations, conatins a description of the factors that control the characteristics of the beach. In the next section, field and laboratory work, how and where the beach profiles were taken are described along with the method for calculating the slope and erosion data. Analysis and results of the beach data are presented in the final section.

Beach Variations

The beach is very sensitive to the physical forces of waves, currents, and winds (Bascom, 1964). The length of the study areas is small, 57 km, and the climate, winds and their associated currents have similiar effects over the length of the study area.

The type and availability of beach sediment also significantly effect the beach. Field (1981) stated that no substantial amounts of sediment presently come out of the rivers on the east coast and on to the surrounding beaches. Canaveral Inlet is a man made structure, flow from the Banana River through the inlet is controlled by locks. Consequently little if any sediment is supplied by that inlet. While the flow through Sebastian Inlet is significant, it is flood dominate with most of the sediment transported being trapped in the inlet (Meta et al., 1976).

The sand on the beaches of Brevard County originally came from the Appliachians (Field and Duane, 1974). The current source of sand is the continental shelf (Field and Duane, 1974). The main transport mode of this sand is wave induced currents which are directly affected by the wave energy distribution (Komar, 1976). Among the most responsive to wave energy and easily measured portions of the beach is the foreshore.

The foreshore is the sloping portion of the beach face, extending from the berm crest, or lacking a berm crest to the upper limit of the swash at high tide, down to the lower limit of the backwash at low tide (Komar, 1976). The slope of the foreshore is a result of dynamic equilibrium between the uprush and backwash. Factors affecting the slope of the foreshore include grain size, sorting, permeabliity, and wave energy. There is general aggreement that the two controlling factors are grain size and wave energy.

Bascom (1951) in his study of California beaches, found for a given amount of wave energy that the slope increases with an increase in median grain diameter.

Bascom (1951) and Wiegel (1964) relate the slope to grain size at the mid-tide point, a point half way between the high and low tide lines. The mid-tide point is the most stable point of the foreshore over time (Bascom, 1951), making it the best point for comparison between different beaches. Other authors have observed the increase in slope with an increase in grain size, among them Sonu (1972), Davis (1974), and Short (1979).

Bascom (1951) also found that for a given grain size an increase in wave energy produces a flatter slope. King (1972) also observed this phenomenon, however, she found that grain size was the more important factor in controlling beach slope.

Field and Laboratory Work

Because the beach changes with each tidal cycle, all the profiles were taken concurrently at the same low tide. Four survey teams measured a total of 21 profiles. The profiles were evenly spaced at approximately 3.2 km intervals from Canaveral Inlet to Sebastian Inlet (Fig. 5). To accurately locate the profiles and to allow erosion data to be calculated, the selected profiles were taken at the benchmarks established along the South Brevard coastline by the State of Florida's Department of Natural Resources (DNR) in 1972. A transit, 100 m tape,

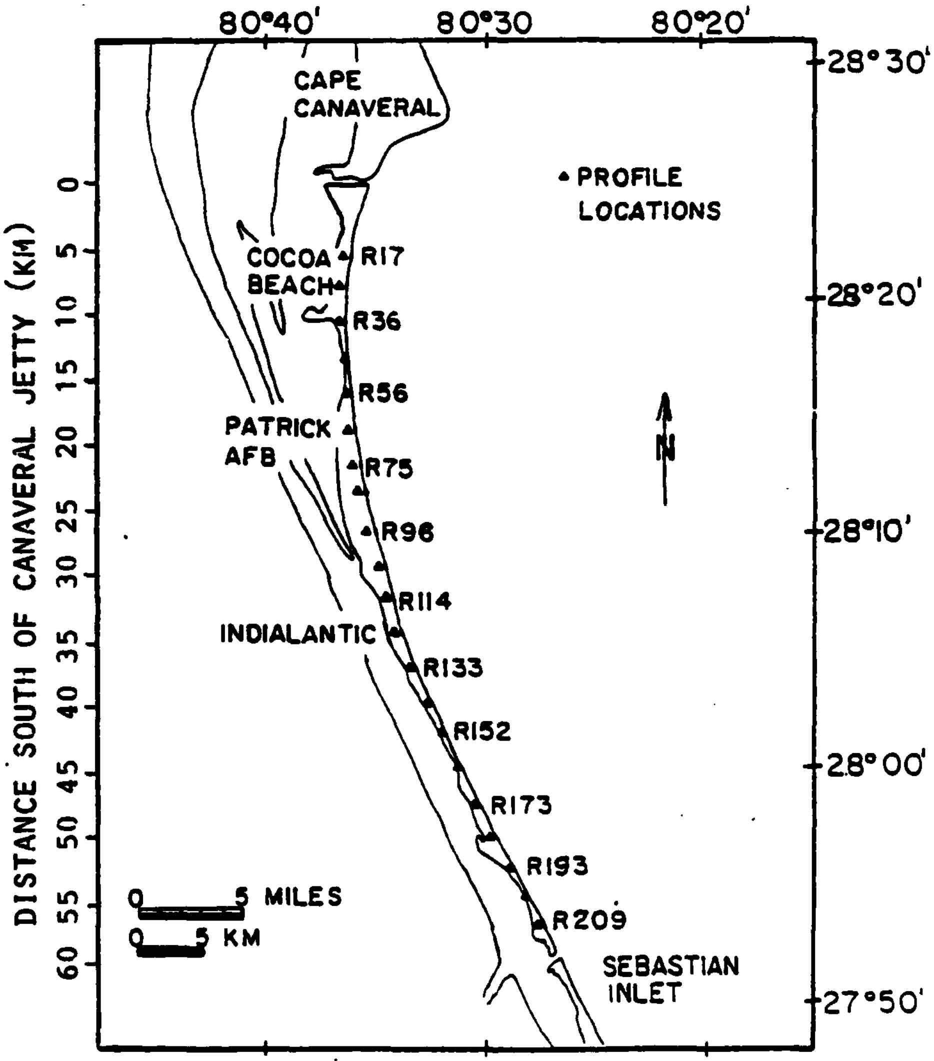

FIG. 5--Profile locations.

and a 7.5 m rod read to the nearest 0.01 m were used to take the profiles.

The northern most profile, R17 is 4.8 km south of Canaveral Jetty. The profile point was moved south of Canaveral Inlet to eliminate the effects of the 1975 Canaveral Beach nourishment project which went from the Canaveral South Jetty 3.5 km south to R12. On the southern end of the study area, the last profile was R209, which is 3 km north of the Sebastian Inlet North Jetty. This profile point was moved to the north of Sebastian Inlet to eliminate the effects of the jetty which traps the southerly longshore drift. Profiles were taken ± two hours around low tide.

Foreshore slope was graphically (Fig. 6) determined from plots of the profiles 1) taken in this study, 2) taken the DNR in 1972, and 3) taken by the Corps of Engineers in 1965. Accretion and erosion were determined by measuring the advance or retreat of the face of the dune. This method was used rather than volumetric changes because the profiles were taken at different times of the year. The seasonal changes in the profiles might show unrealistic changes with the volumetric method. The width of the beach was calculated by measuring the distance from the break in the dune slope to the point point where the plot crossed MSL (zero elevation).

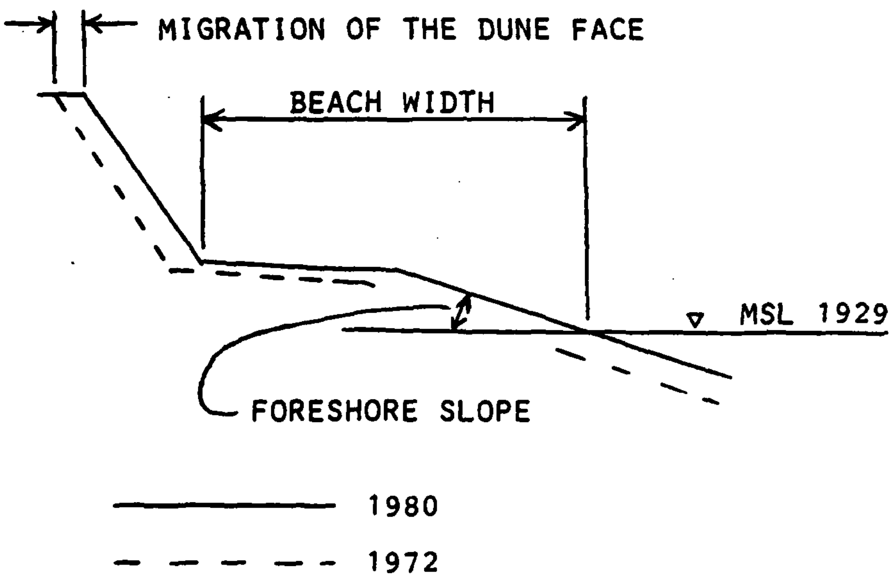

FIG. 6--Foreshore slope, dune face migration, and beach width definitions.

Results

The data are presented using the South Canaveral Jetty as a zero point. All the distances are measured in kilometers from that point along the shoreline south to the last profile location, R209, 60.8 km from the South Canaveral Jetty. When the profile data are discussed, the DNR profile location will be given first, followed by the distance in parenthesis.

The beach profiles showed significant differences in the beaches of South Brevard County. Wide flat beaches were found in the northern end of the study area which grade into narrower steeper beaches to the south.

In Figure 7 is a plot of data from the Corps of Engineers taken during May and June of 1965; the DNR, taken from Sept. to Nov., 1972; and the present study, taken on 4 Oct. 1980, to compare foreshore slope versus distance. The 1980 data eliminates the temporal variations included in the other studies. However, all the studies showed a similiar trends, three zones are evident. Zone I (0 to 20 km) has flat beaches, with slopes of two degrees or less. After 20 km, the slopes get progressively steeper throughout zone II until about 30 km. South of 30 km, zone III, the average slope varies between 6 and 9 degrees but with a good deal of

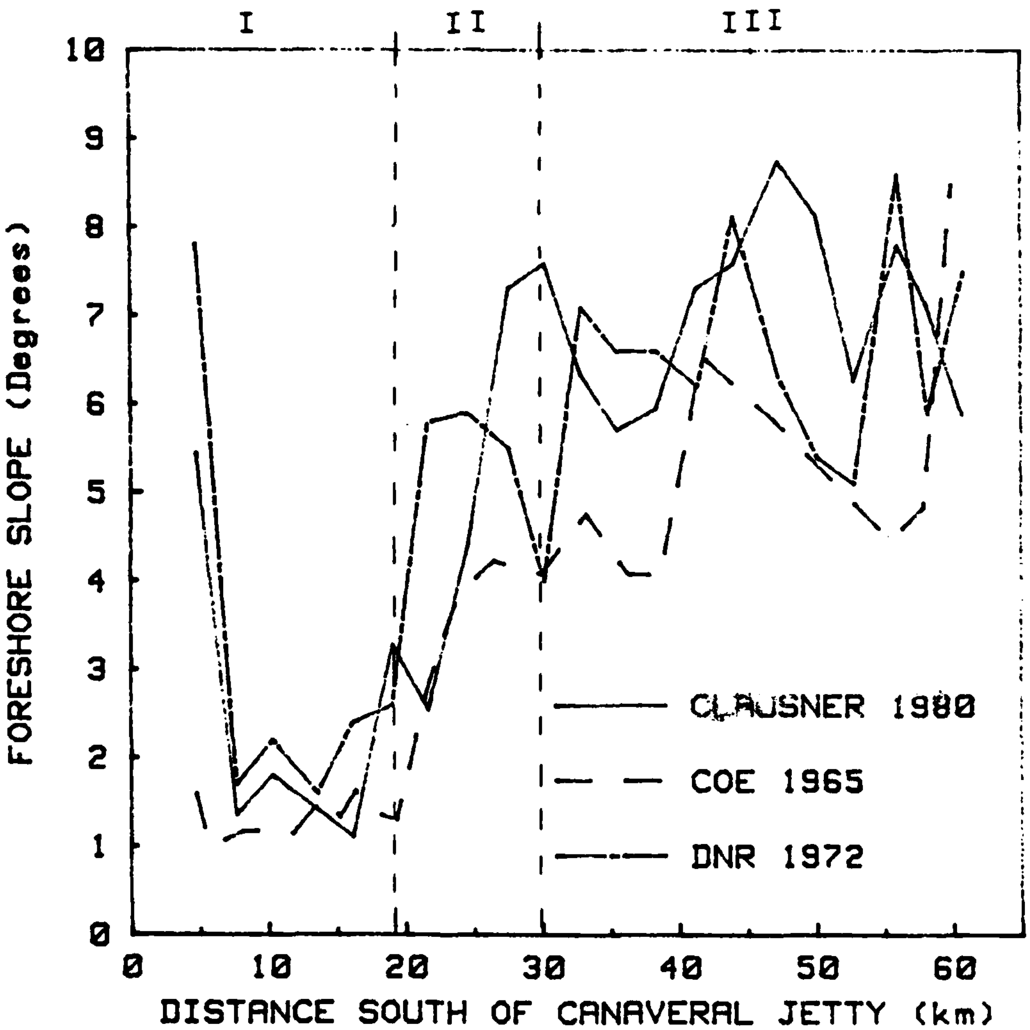

FIG. 7 -- Foreshore slope versus distance.

perturbation. The author's and the DNR's slopes are generally steeper than the Corps of Engineers' slopes. This is to be expected since most of the author's and the DNR's data were taken in the early fall, after the summer accretion which increases the foreshore slope (Sonu, 1972). The larger variations in the slopes of the southern portion of the county are due to steeper beaches being more responsive to changing conditions, since they absorb energy over a shorter distance (King, 1972).

The northern most profile of the DNR's and this study's data is very steep. However, the 1965 Corps profiles showed the beach to be flat in the same location. The recent increase in slope is probably due to local placement of beach fill which occurred during the late 1960's and early 1970's to combat erosion caused by construction of the Canaveral Jetty system (COEL, 1976).

In Figure 8 is a plot of foreshore slope range over time. It shows that although the slopes change with the season, the trends remain constant throughout the year. This present study's slope data falls within these ranges. Clausner and Highberg's (1974) data were based on six readings spread from spring through fall. F.I.T.'s data, taken by graduate students (Stauble, personal communication), was based on 11 monthly readings

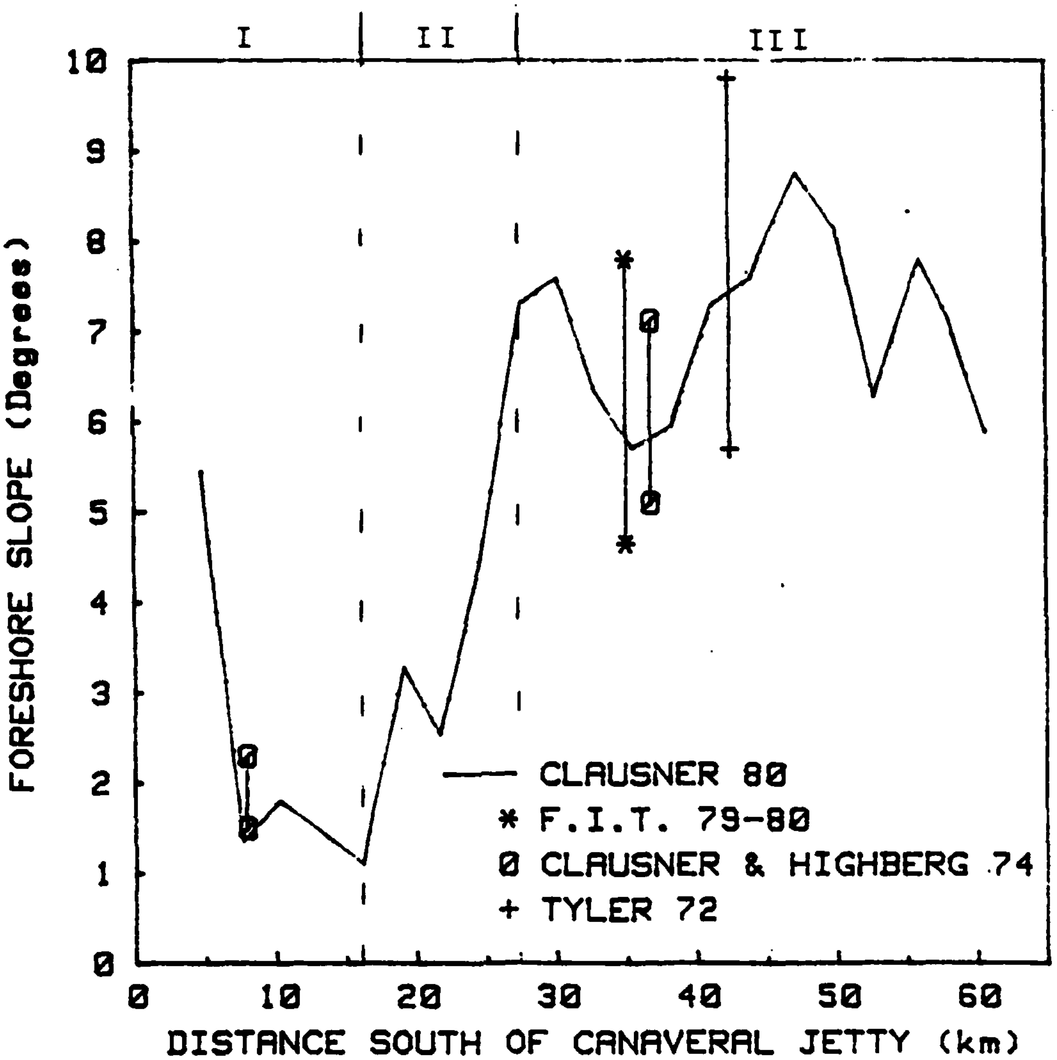

FIG. 8--Foreshore slope versus distance over time.

spread over one year. Tyler's (1972) data was based on daily readings taken from February through March. As shown in the previous figure zone I has flat slopes with little variation. At Indialantic (36 km) the slope is steeper with a greater range. Further south there is an even greater range. However, Tyler's data were not referenced to Mean Sea Level,and some of the steeper slopes may actually be due to including a scarp cut out of the berm in the calculation of foreshore slope.

In Table 1 are presented the beach characteristics from the profiles taken in this study. In Figure 9 are shown three typical profiles from this study: one from the flat area of zone I, R26 (7.7 km); one from the transition area (zone II), R66 (19.1 km); and one from the steeper south portion of the county (zone III), R193 (56.0 km). Plots of all the profiles taken for this study are contained in Appendix A.

From the data in Table 1 it can be seen that zone I (7.7-16.2 km) is flat, with a slope less than two degrees and wide, averaging over 60 m. In zone II (16.2 to 30.2 km) the slope increases, from 3.3 to 7.3 degrees, and the beach narrows, from 48 to 38 km. From 30.2 to 60.7 km (zone III) the slope stays relatively steep, varying between 5.7 and 8.7 degrees and the width stays between 30 and 40 m.

Table 1.--Beach characteristics. A positive value of migration of the dune face indicates the dune is accreting, a negitive value means it is eroding. The migration values are based on the years 1972 to 1980.

Location	Distance (km)	Foreshore Slope (degrees)	Beach Width (m)	Migration of the Dune Face (m)
R17	4.4	5.4	22	*
R26	7.7	1.4	69	+1.25
R36	10.3	1.8	72	+1.75
R47	13.6	1.4	64	NC
R56	16.2	1.1	61	*
R66	19.1	3.3	44	-1.25
R75	21.7	2.5	35	-1.50
R85	24.6	4.4	40	*
R96	27.6	7.3	34	-2.00
R105	30.2	7.6	40	NC
R114	32.9	6.3	40	NC
R123	35.5	5.7	40	NC
R133	38.4	6.0	30	NC
R143	41.3	7.3	33	NC
R152	44.0	7.6	35	*
R164	47.3	8.8	40	-3.00
R173	50.1	8.1	40	-3.00
R182	52.8	6.3	30	-3.00
R193	56.0	7.8	43	-6.00
R200	58.1	7.1	32	NC
R209	60.7	5.9	35	*

NC = No Change

* Not calculated, based on a new benchmark not yet resurveyed by the state.

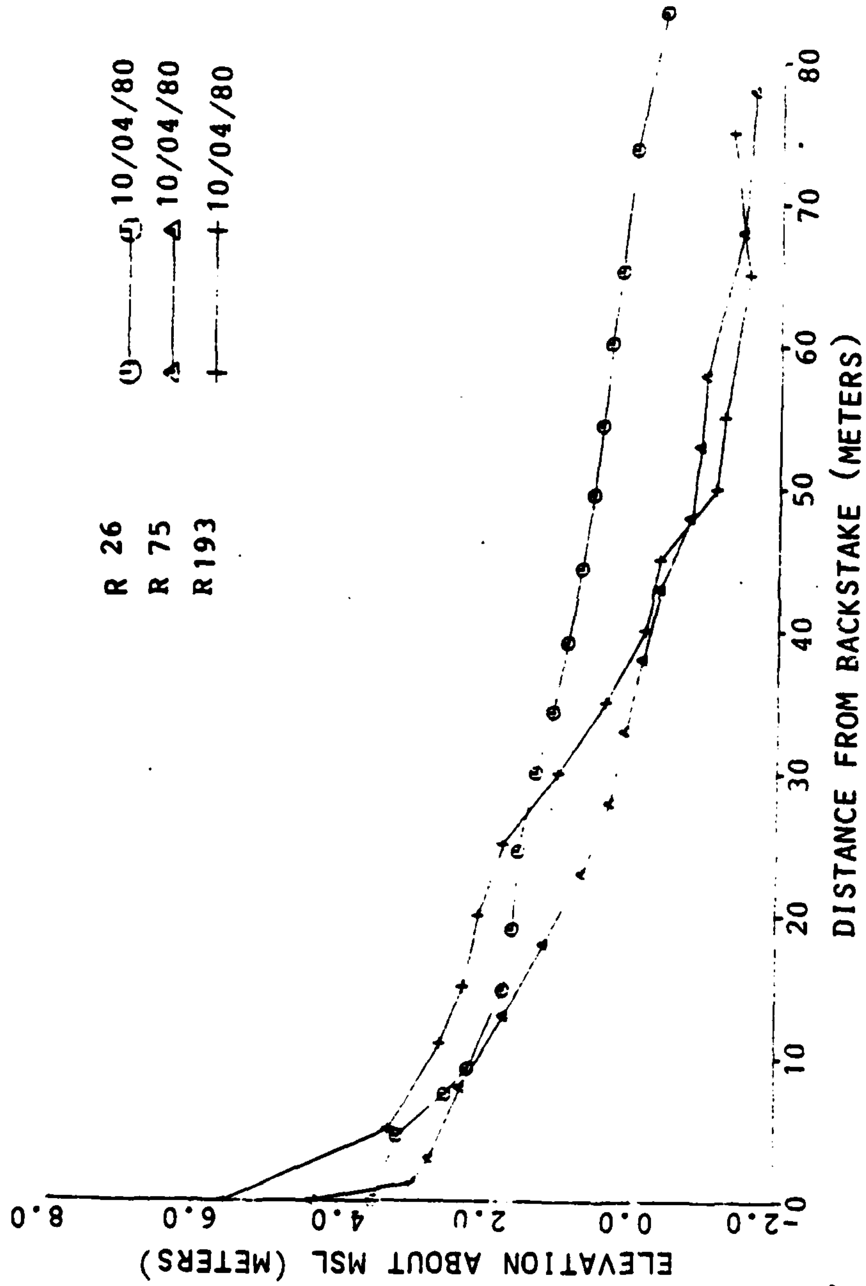

FIG. 9--Typical profiles.

Profiles R17, R56, and R209 have new benchmarks which have not yet been referenced to Mean Sea Level (MSL) 1929 by the state. Slope and width data were estimated at these locations, and no erosion data were calculated. At R85, the DNR profile sighted over a sea wall that was avoided in this study, and consequently erosion could not be calculated. At R193, the DNR's and this study's distance from the benchmark to the dune differ greatly. The erosion figure of 6 m is probably due to an error in measurement.

The erosion data are contained in Table 1. Locations R26 and R36 (7.7 and 10.3 km) were the only ones that accreted between 1972 and 1980. This was probably due to sand from the nourishment project at Canaveral Jetty moving south with the longshore drift (Hushla and Stauble, 1981). There was some erosion at R66 and R75 (19.1 and 21.7 km) which are located on Patrick Air Force Base (PAFB). However, the amount of erosion was small being only 0.2 m per year. Other than 0.25 m per year of erosion at R96 (27.6 km), there was no measureable erosion of the front of the dune until R164 (47.3 km). There was fairly consistent erosion from R164 to R193 (47.3 to 56.0 km). The amount of erosion, 0.38 m per year, is still faily low (Sorensen, 1978), and well within ranges reported for the region in past years (U.S. Army, 1967). This southern area is sparsely populated, with most of the dunes still in their natural state.

SEDIMENT ANALYSIS

The sediment analysis chapter is divided into two sections, 1) a description of the field and laboratory work, and 2) a discussion of the resulting grain size distribution and percent shell content found in the sand samples.

Field and Laboratory Work

When the profiles were taken a 200 gram sediment sample of the upper centimeter of the beach was collected by hand at the mid-tide point. The mid-tide point was located by noting the distance along the profile of the previous high tide mark and measuring the distance to the water at low tide. The mid-tide point was taken to be halfway between these two points.

The sediment samples were taken to the laboratory, washed in fresh water, dried in an oven at 110°C, then split with a mechanical splitter to a weight of approximately 100 grams. Samples were sieved for 30 minutes through stacked 1/4 phi interval sieves, starting with -1.0 to 4.0 phi. Sieve analysis was performed according to procedures discussed by Folk (1968). The percent shell material in the samples was determined by the acid soluble method (U.S. Army, 1971).

Statistical measures of sediment distribution were performed with the aid of a computer. From each sample the following parameters were calculated: mean size, a measure of the central tendency; standard deviation or sorting, a measure of the dispersion about the mean; skewness, the degree of symmetry about the mean; and kurtosis, a ratio that compares the sorting between the central portion of the probabiltiy curve and the tails (Folk, 1968). The statistical measures of grain size distribution were calculated using moment measures because they are the most accurate (Friedman and Sanders, 1978). Folk's (1968) graphic measures were also calculated because they are widely used.

Results

Using the same method as the profile data, when the sand sample data are discussed, the DNR profile location will be given first, followed by the distance along the shoreline in paraentheses.

The sediment data also show a strong distinction between the northern and southern parts of Brevard County. Table 2 contains the moment measure values of the mean, standard deviation, skewness, and kurtosis. Weight percentage values and graphic values of the grain size distributions for all the samples are in Appendix B.

Table 2.--Statistical measures of grain size distribution. (Based on the method of moments)

Location	Dist. (km)	Mean (phi)	Sorting (phi)	Skewness	Kurtosis	Percent Soluble
R17	4.8	2.18	1.13	-0.28	-1.00	24.5
R26	7.7	3.18	0.39	-0.44	8.61	8.3
R36	10.3	3.05	0.38	-0.59	10.24	10.3
R47	13.6	3.02	0.38	-0.20	6.13	12.5
R56	16.2	2.93	0.39	-0.34	6.73	8.8
R66	19.1	2.48	0.44	-0.29	1.00	11.1
R75	21.7	2.05	0.71	-0.62	1.90	17.7
R85	24.6	2.21	0.48	-1.21	10.19	17.3
R96	27.6	1.75	0.70	-0.83	3.33	22.9
R105	30.2	1.86	0.59	-0.71	3.06	19.9
R114	32.9	1.47	0.81	-0.30	-0.08	32.2
R123	35.5	1.33	0.83	-0.31	-0.01	30.5
R133	38.4	1.62	0.80	-0.51	1.25	26.9
R143	41.3	1.88	0.79	-0.78	2.54	24.4
R152	44.0	1.67	0.82	-0.66	1.56	28.8
R164	47.3	1.52	0.67	-0.51	1.73	28.6
R173	50.1	1.87	0.54	-0.48	2.78	21.7
R182	52.8	1.82	0.54	-0.22	2.14	23.1
R193	56.0	1.66	0.78	-0.61	1.81	27.8
R200	58.1	1.86	0.49	-0.46	3.13	23.2
R209	60.7	1.56	0.62	-0.59	2.67	26.2

In Figure 10 is a plot of the mean and slope versus distance. Two different sand size beaches (zones I and III) with a short transition area (zone II) between them are evident. From R26 to R56 (7.7 to 16.3 km) the sand is very fine (Wentworth, 1922). It averages over three phi. From R56 to R85 (16.3 to 24.6 km), the mean grain size increases. Here the sand is classified as fine sand, 2 to 3 phi. The sand continues to increase in grain size going south from R85 (24.6 km), reaching a maximum size of 1.32 phi at R123 (35.5 km), in Indialantic. All the sand from R96 (27.6 km) south is medium sand, 1 to 2 phi. South of R123 (35.5 km), the grain size averages around 1.75 phi, but it varies with some regularity.

These regular variations could be due to rhythmic variations in the shorline with a spacing of about 8 km. An exmaination of the Indialantic areas using aerial photography by Stauble (personal communication) has shown rhythmic features with a spacing of approximately 1.7 km. The spacing of this study's data points was too large to show features of that magnitude.

Figure 10 also shows that the mean and slope are closely related. This relationship has been found by other authors (Komar, 1976; King, 1972). However, the mean's peak at 35.5 km is not matched by the slope.

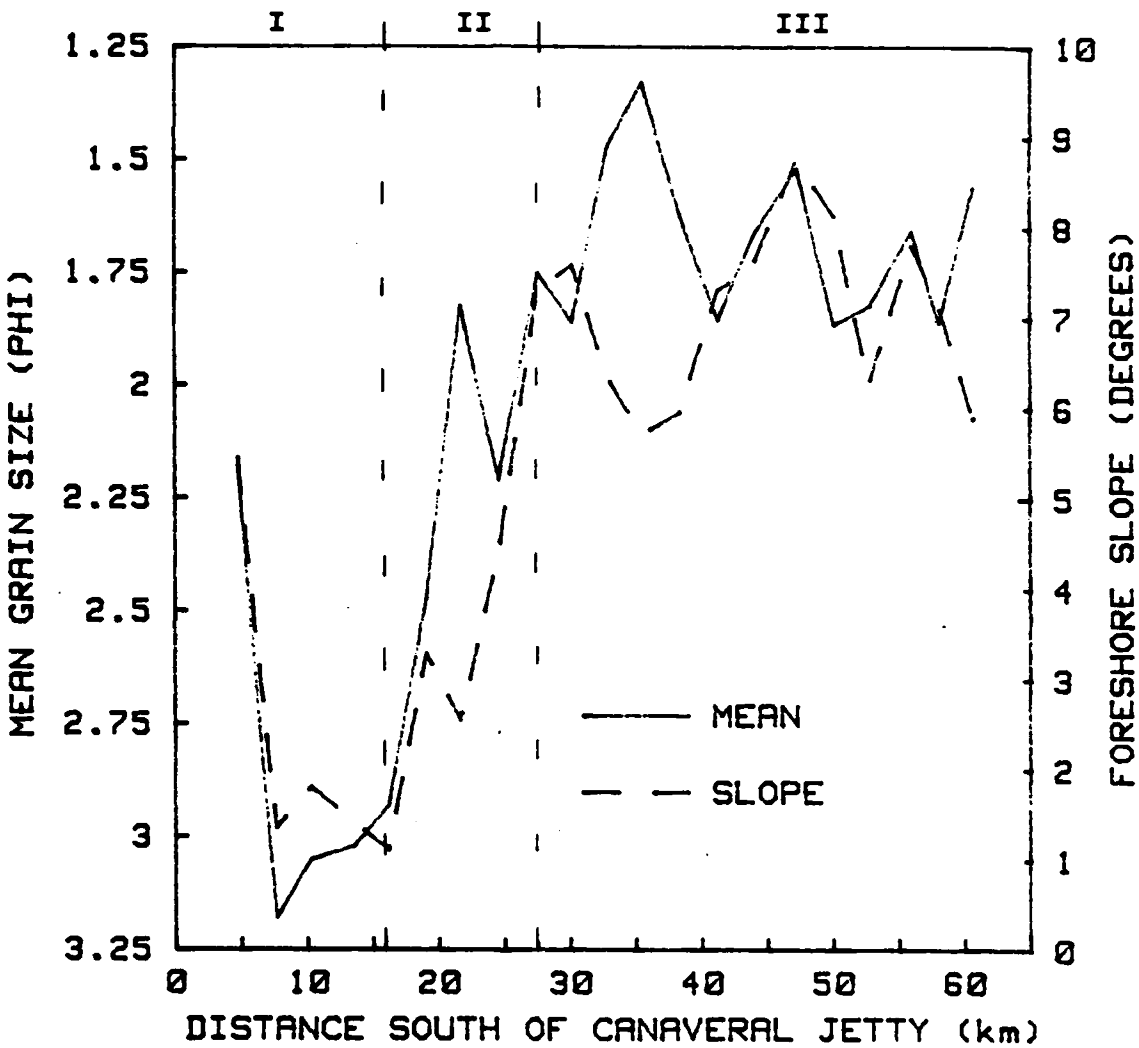

FIG. 10—Mean and foreshore slope versus distance.

The mean and slope plots do agree from 40 km south to 58 km.

At R17 (4.4 km) the sample is much coarser than the rest of Cocoa Beach and has by far the highest sorting coefficient of any of the samples. This is most likely due to a combination of the native fine sand that is found in the rest of Cocoa Beach, and coarse shell material that has washed down from the Canaveral Nourishment Project or from fill material placed locally on the beach to combat erosion.

The mean grain size of the sample at R85 (24.6 km) was significantly finer than those on either side of it. The sand sample was taken at the crest of a small berm on the foreshore. Berms are depositional features (Komar, 1976) which trap fine grain sediments (Schwartz, 1967). A sea wall is just south of the profile at R85, and it may have caused the deposit. What ever its cause the sample is unusual. It has a large negitive skewness and a large kurtosis value. This makes R85 very different from any of the other sand samples.

Figure 11 is a plot of mean grain size versus standard deviation. This type of plot has been used to show differences in populations (Friedman, 1961). Here it clearly shows the differences between the samples from zone I

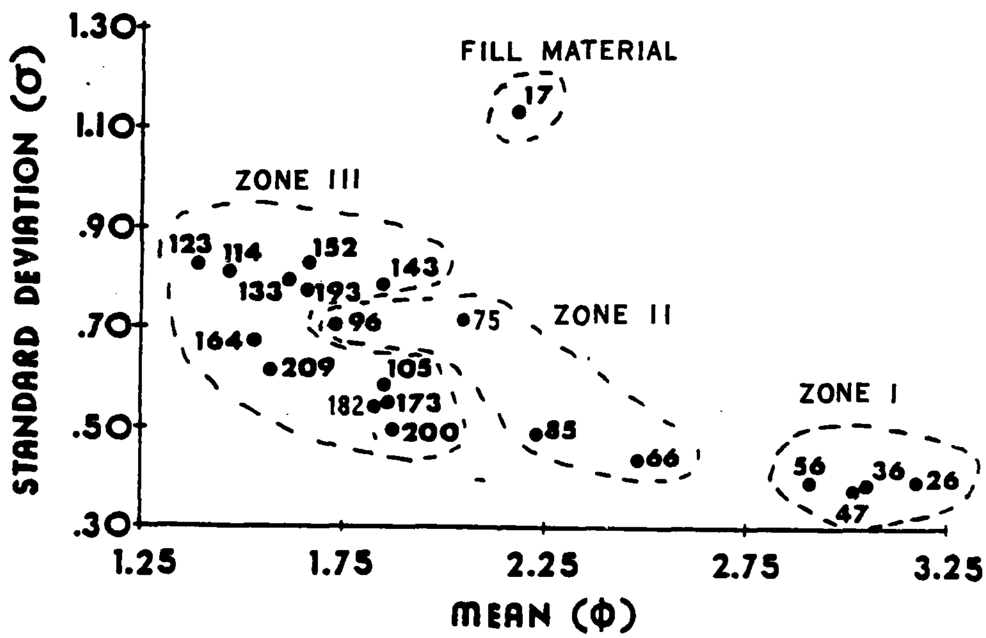

FIG. 11--Mean versus standard deviation. Numbers indicate profile location.

and the rest of the samples. Zone I's samples (R26, R36, R47, and R56), are very fine to fine grained and very well (0-0.35 phi) to well sorted (0.35-0.50 phi). Zone II's samples are fine to medium grained and moderately well sorted (0.50-0.80 phi). Zone III's samples are medium grained and moderately well sorted to moderately sorted (0.80-1.40 phi) (Wentworth, 1922). Location R17 stands out again, having the highest sorting coefficient, 1.4 phi. This is due to having characteristics of the Port Canaveral fill material, fine sand with a high percentage (25%) of coarser $CaCO_3$ shells.

As shown in Figure 12, the percent soluble, or shell content, versus distance data for this study agrees well with that of past studies (Field and Duane, 1974; Rusnak et al., 1966). Once again three zones are evident. In zone I, 7.7 to about 16 km (Cocoa Beach to N. PAFB), the shell content is low, less than 14 percent. South of 16 km (zone II) shell content increases and reaches a maximum of 32 percent at 33 km (N. Indialantic). South of 33 km (zone III) the shell content decreases slightly, averaging 26 percent down to Sebastian.

Data from all the researchers shows an increase in shell content just south of Canaveral Jetty, at 2 to 5 km. Since Field and Duane's (1974) and Rusnak et al.'s (1966)

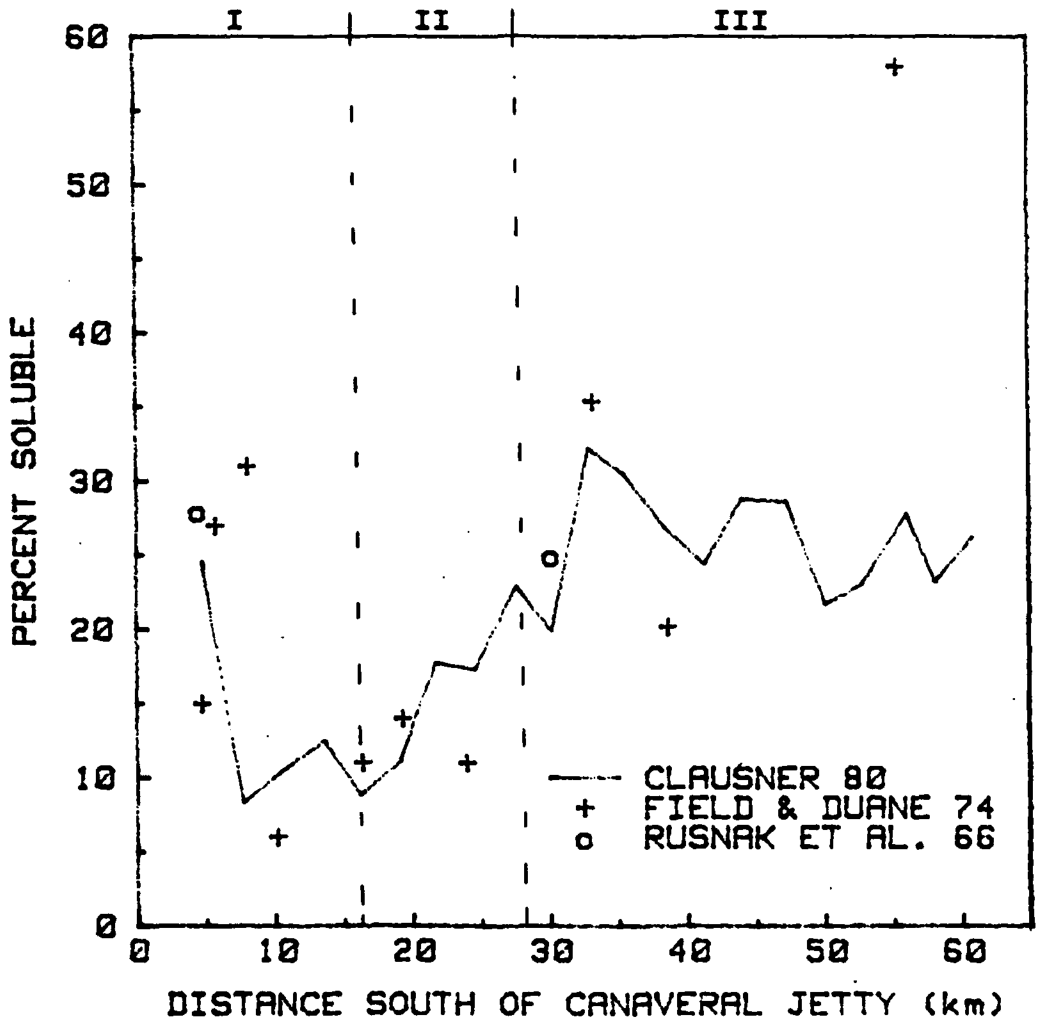

FIG. 12--Percent soluble versus distance.

data were taken before the nourishment project in 1975, this author believes that the increase in shell content here is due to local nourishment in which sand with large amounts of shells were used. From an analysis of refraction diagrams, discussed in the next chapter, it was found that the wave energy from the dominant northeast and east waves is lower in this area. As a result, the longshore drift is not strong enough to carry many of the shells south to the rest of Cocoa Beach. In fact, the sample at R26 (7.7 km), the next sample point south, had the lowest shell content of the study. There it was 8.3 percent.

The very high percent soluble value, 59 percent, at 54 km (see Fig. 12), was found by Field and Duane (1974). This was likely due to sampling a pocket of shell hash or pile of shells. These are occasionally found on Brevard's beaches after storms (U.S. Army, 1967).

Mean grain size and percent soluble versus distance are plotted in Figure 13. The three zones can be seen. With the exception of the northernmost point, R17, zone I (0-16 km) has fine grains and few shells. Zone II (16-28 km) has sharply increasing values of mean grain size and the amount of shells. In zone III, the average values are high and vary regularly. It is clear that the shell content very strongly controls the mean grain size. This agrees with the observations of Field and Duane (1974).

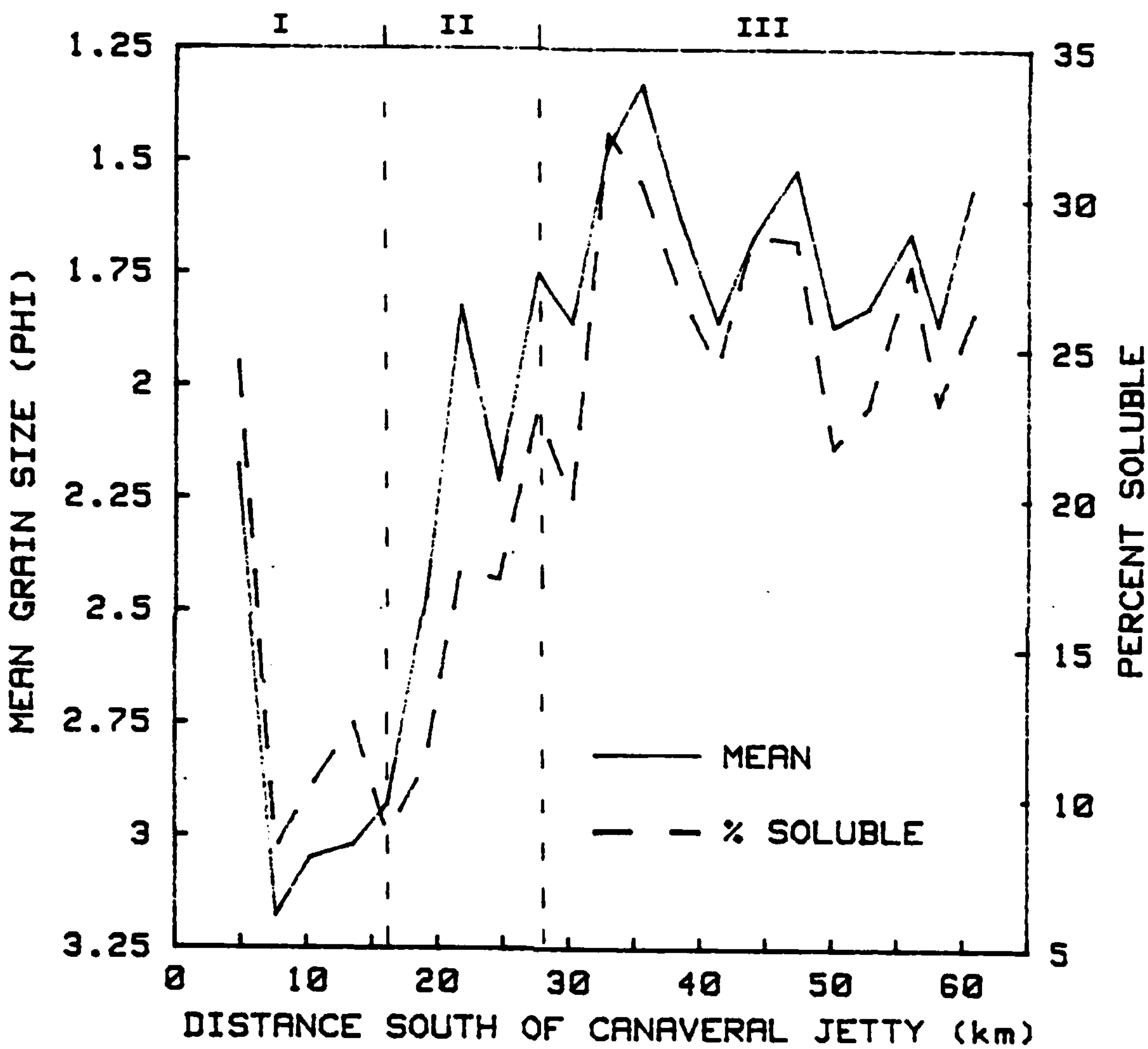

FIG. 13--Mean and percent soluble versus distance.

WAVE REFRACTION

The wave refraction chapter is divided into three sections: 1) theory, 2) the generation of the wave refraction diagrams, and 3) a discussion of the results.

Theory

Most researchers agree that the amount of wave energy reaching the beach is primarily controlled by wave refraction (Komar,1976). As the waves approach the beach the crests bend and become more parallel to the bottom contours (Fig. 14). Wave paths are tracked with orthogonals, also called wave rays, which are lines normal to the wave crests. The distance b is the deep water spacing between adjacent rays, and b is the spacing at any depth. When wave rays become concentrated b decreases causing an increase in energy and wave height. When the wave rays spread out, b increases, leading to a decrease in energy and wave height.

The bending or refraction of the wave rays is due to changes in velocity, a result of the change in water depth for a given wave period. Refraction for a monochromatic wave is described mathematically by Snell's Law

$$\frac{\sin i}{\sin r} = \frac{c1}{c2} \qquad (1)$$

where i is the incident angle, r is the refracted angle,

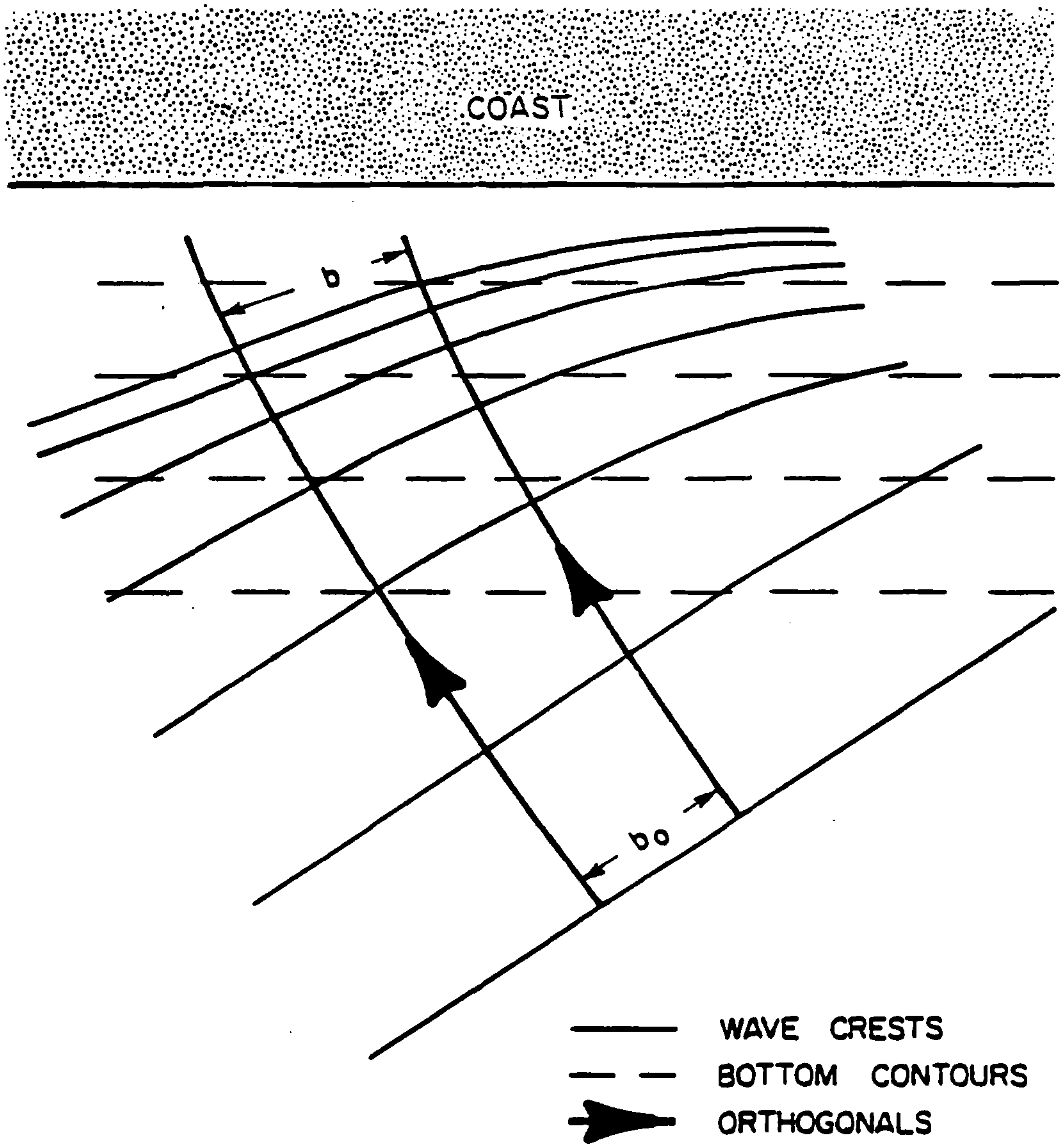

FIG. 14--Refraction defintions.

c1 is the velocity before refraction, and c2 is the velocity after refraction. The phase velocity of an individual wave, c, is

$$c = \sqrt{g/k \tanh kh} \qquad (2)$$

where g is the acceleration of gravity,

$$k = 2\pi/\lambda \qquad (3)$$

is the wave number, λ is the wavelength, and h is the water depth. The phase velocity can also be expressed as:

$$c = \lambda/T \qquad (4)$$

where T is the wave period. Fortunately, wave velocity calculations can be greatly simplified by defining deep and shallow water such that the tanh kh reduces to easily used values. Deep water is defined as occuring when the relative wave steepness ratio h/λ is greater than 1/2, then $\tanh kh \rightarrow 1$, and $c = \sqrt{g/k}$. Waves are not refracted in deep water because the velocity is independent of depth. Shallow water is defined as h/λ less than 1/25, then $\tanh kh \rightarrow kh$. Equation (2) reduces to $c = \sqrt{gh}$. In shallow water the wave velocity is only a function of depth. The depths between deep and shallow water, $1/2 < h/\lambda < 1/25$, are called transitional or intermediate, and the full velocity equation (2) must be used.

Wave energy is transmitted in wave groups. A wave group is the interference pattern produced by the addition of component sine waves of almost equal frequencies and directions. It consists of a series of packets of individual waves separated by regions of calm. The individual waves in a wave packet are called wavelets. The The wave packets are sometimes referred to as hydrons (Purser and Synge, 1962). The velocity of the roup, U, has been defined (Kinsman, 1965) as

$$U = \left[1+\left(\frac{2kh}{\sinh\ 2kh}\right)\right]\frac{c}{2} \qquad (5)$$

In deep water sinh 2kh is very large, making $U = c/2$. In shallow water sinh 2kh = 2kh, and equation (5) reduces to $U = c$.

Wave groups and individual waves refract differently because they travel at different velocities. For a given period gravity water waves have constant group and phase velocities in deep water. In Figure 15 the ratio of the group and phase velocities at any depth to the value in deep water are plotted as a function of kh, the relative water depth. The subscript d denotes deep water. For large values of kh the group and phase velocity ratios both asymptotically approach the value one. The maximum phase velocity occurs in deep water, while the group velocity maximum occurs at an intermediate depth (kh=1).

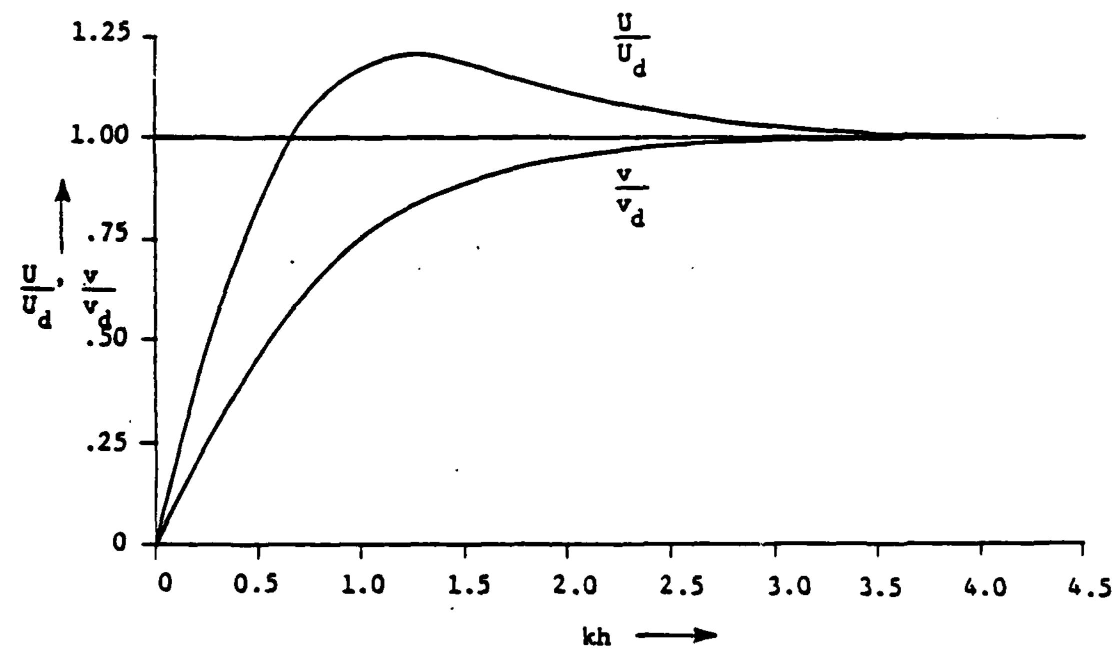

FIG. 15--Group and phase velocity ratios (From Breeding, 1972).

As the wave group travels into areas of dispersion, depths where the phase velocity and group velocity differ, the wavelets will be refracted in a different direction than the group. To relate the differences in the refraction directions of the group and the wavelets, Breeding (1978b) defined G, the geometric group velocity as

$$G = U \cos\phi \qquad (6)$$

where

$$\phi = \theta - \gamma \qquad (7)$$

The direction of movement of the wave group is denoted by θ, and γ is the direction of movement of the wavelets. Breeding used this definition to state a new refraction law for a wave packet:

> the component wave refract according to Snell's law with phase velocity, the wavelets refract according to Snell's law with the wavelet velocity, and the group refracts according to Snell's law with the geometric group velocity.

Breeding (1978b) was able to verify this refraction law by hindcasting waves from hurricane Fifi which passed through the Carribean Sea is 1974.

Wave ray paths calculated using individual wave phase velocity refract and become more perpendicular to the depth contours as the ray proceeds from deep water towards shore no matter what the initial angle (Fig. 16). The wave groups on the other hand follow paths where the angle

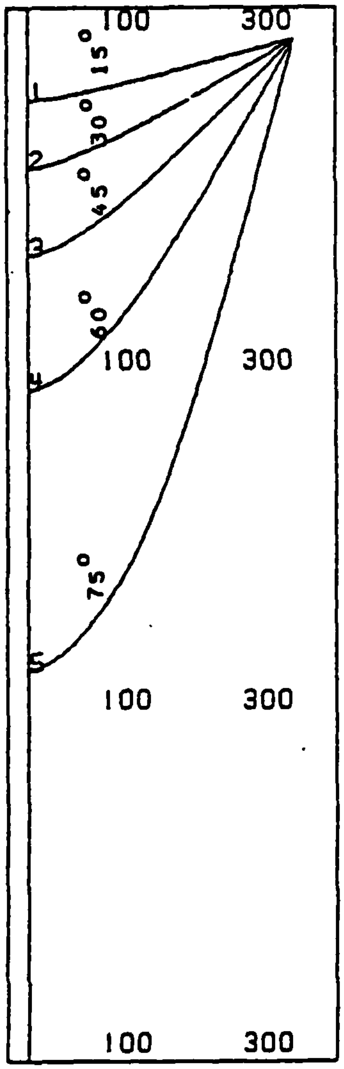

FIG. 16--Monochromatic wave trajectories for a 20 second wave (parallel depth contours). (From Breeding, 1978c)

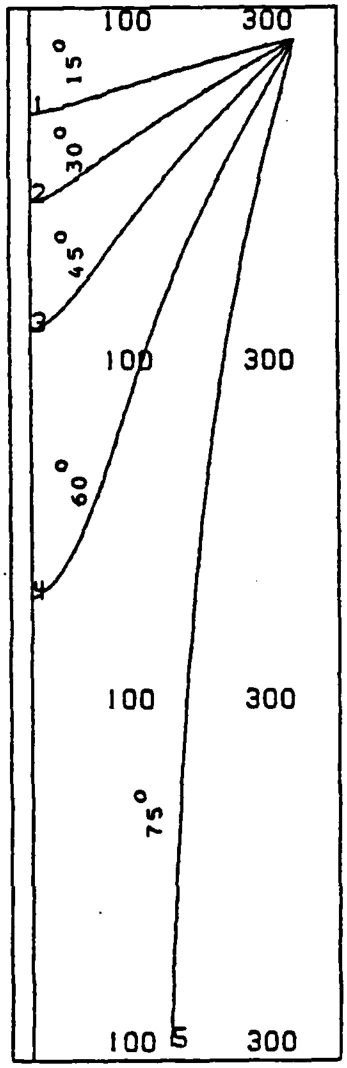

FIG. 17--Hydron trajectories for a 20 second wave (parallel depth contours). (From Breeding, 1978c).

between the normal to the depth contour and the orthogonal first increases to the point of maximum group velocity, undergoes a point of inflection, then decreases shoreward like the individual waves (Fig. 17). For large angles of incidence the rays will actually be turned parallel to the shore (Breeding, 1978c).

Wave refraction diagrams were originally done graphically, which is very time consuming and practical only for smooth contours. The best graphical method is the orthogonal method. Tangents to the incoming wave rays are drawn between adjacent depth contours. A special protractor defines a new ray direction by turning the original ray through a circular arc proportional to the ratio of the velocities at the two contours. A more complete discussion can be found in the Shore Protection Manual (CERC, 1977).

The first computer program developed to plot wave ray paths was done by Wilson (1966) using phase velocities. Worthington and Herbich (1970) produced a program that also calculated wave height. Breeding, Matson, and Riahi (1978) wrote a wave refraction program called WAVPAK. WAVPAK computes trajectories and wave heights of wave packets moving with the geometric group velocity. It was used in this study.

The operation of WAVPAK is similiar to other wave refraction programs. An offshore area of interest is divided up into square grids, the water depth of the intersection points are then read off the chart. The grid is put into the computer in the form of a matrix. At each ray point a quadratic surface equation is fitted to the twelve nearest grid points. The path of each ray is calculated using the formula for ray curvature. Snell's Law with phase velocity is used to determine the angle of the wavelets along the group trajectories. The wave height is calculated by using refraction, shoaling, and friction coefficients. The program was modified to calculate both the height of a breaking wave at each ray point, and the deep water wave height required to produce a breaking wave at that point.

In early investigations using wave refraction diagrams, it was possible to correlate areas of increased wave energy (i.e., areas of wave ray convergence) to increased erosion in study areas of approximately 15 km (Goldsmith and Colonell, 1970). In a second group of studies it was shown that areas of coarse grained sediment generally correspond to areas of increased erosion (Colonell and Goldsmith, 1971). In this study wave refraction diagrams were used to visually present how the distribution of wave rays along the coast corresponds to observed beach characteristics. Beaches with low energy energy characteristics should be found in areas where a comparatively few wave rays reach the shore. Beaches with high energy characteristics should be found in areas where comparatively more wave rays reach the shore. To help quantify the data, wave energy distribution along the shoreline was calculated. The plots of wave energy distribution were compared with plots of slope, mean grain size, and percent shell content to see if the beach characteristics correlated with the predicted wave energy distribution.

The major problem in obtaining accurate wave predictions is inaccurate water depths and locations from old charts (Sallenger et al., 1975). Smooth sheets from the National Ocean Survey were used to obtain the water depths for the wave refraction studies, and most of the sheets were from 1955 to present. A second problem is a lack of accurate wave data for this area. Wave data from Daytona Beach, 129 km morth of the study area was used. The Coastal Engineering Research Center has been operating Daytona Beach's wave gage since 1965. The University of Florida installed a wave gage at Vero beach in 1979, 25 km south of the study area. Significant wave periods from this gauge were complied and compared with results from the longer Daytona Beach data.

Wave Refraction Diagrams

The wave refraction program, WAVPAK (Breeding et al., 1978; Breeding, 1978a), was run on FIT's VAX computer. Wave ray diagrams were done on FIT's Calcomp plotter.

Two depth grids were used. The larger grid, 178 km long and 185 km wide, extended from latitude 29°04'N to 27°28'N and from longitude 80°55'W to 79°00'W (Fig. 18). Normally depth grids just extend out to the depth required for deep water for the longest wavelength. Deep water is considered to be $h = 0.64\lambda$ because the group speed is almost constant for deeper depths (Breeding, 1978b). In this study the maximum period wave was 14 seconds, for which deep water is 306 m. This grid goes out past that depth to include the Gulf Stream, to allow the grid to be used in later studies of wave refraction due to currents. Grid spacing of the large grid was 1.85 km (1 nautical mile), creating a grid 96 by 100 points. Smooth sheets and charts used to construct the large and small grids are listed in Table 3.

A second smaller grid was constructed to allow more accurate tracking of wave ray paths in the nearshore zone where the depths change more rapidly. The small grid was 99 km long and 44 km wide, extending from latitude 28°39'N

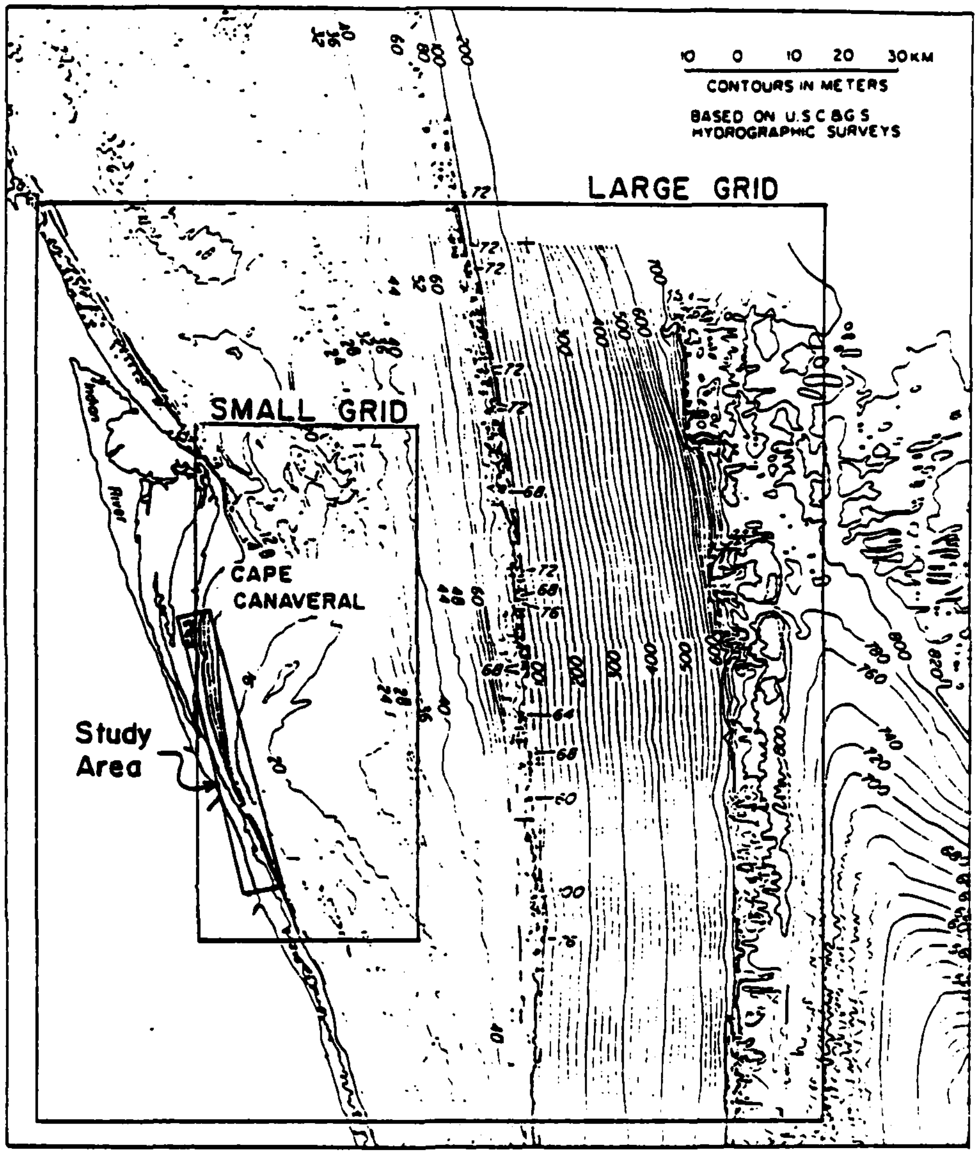

FIG. 18--Water depth grids.

Table 3.--Charts and smooth sheets used for the water depth grids.

	No.	Date	Scale	
Large Grid	11476	1962	1:80000	*
	11484	1965	1:80000	*
	H8840	1965	1:80000	
	H8839	1966	1:80000	
	H8714	1962	1:100000	
	H8713	1962	1:100000	
Small Grid	H8840	1965	1:80000	
	H8839	1966	1:80000	
	H8341	1956	1:20000	
	H8342	1956	1:20000	
	H8343	1956	1:20000	
	H8344	1956	1:20000	
	H8345	1956	1:40000	
	H5028	1930	1:20000	
	H5032	1930	1:40000	
	H5034	1930	1:40000	
	H5039	1930	1:40000	

* Charts

to 27°49'N and from longitude 80°37'W to 80°10'W. Grid spacing was 0.46 km (1/4 nautical mile), creating a grid 196 by 96 points.

Ideally, a series of wave gauge arrays spread throughout the county would have provided the wave height, period, and direction needed for this study. Unfortunately no wave data for Brevard County existed at the time of this study.

Analysis of the records from the Daytona Beach wave gage showed significant wave energy in the 6 to 14 second range, with a peak at 8 to 9 seconds (Thompson, 1977). As mentioned earlier, the directional wave data from the U.S. Army (1967) showed that most of the waves come from the northeast and east. Based on this information, computer runs were made for waves with periods of 6, 8, 10, 12, and 14 seconds from the northeast, 45°, and east, 90°. Waves from the southeast, 135°, are fetch limited by the Bahamas, which block the longer period waves generated farther out in the Atlantic. Since less wave energy comes from the southeast, and because computer time was limited, only 6 and 10 second period waves were run from that direction.

The University of Florida has a non directional wave gage at Vero Beach, 25 km south of the study area. The data from that gage was not available until after the computer runs were made. Howvever, the data is for the most part consistent with the Daytona beach data. Yearly averaged data from the Vero Beach gage showed that 79 percent of the waves were between 5.9 and 12.5 seconds, with a peak at nine seconds. Twenty percent of the waves were between 4.4 and 5 seconds, probably locally generated waves. Apparently the spectrum is shifted towards the shorter periods as the wave climate moves from Daytona Beach 180 km south to Vero Beach. The 6 second wave refraction diagrams would probably be very similiar to a 4.4 or 5.0 second wave refraction diagram and no additional runs were made.

To reduce the number of computer runs, no input value of wave height was used. Wave height affects only the bottom friction calculations. Instead, as a measure of wave energy, K_r, the refraction coefficient was calculated at each point along the ray. The energy of a breaking wave (E_b) in shallow water is given by the equation

$$E_b = K_r{}^2 K_s{}^2 K_f{}^2 E_i \qquad (10)$$

where K_s is the shoaling coefficeint, K_f is the friction coefficient, and E_i is the initial energy value (Le Mehaute, 1976). K_r is independent of wave height, and is defined by

$$K_r = \sqrt{\frac{b_o}{b}} \qquad (11)$$

where b is the spacing between the wave rays, and b_o is the deep water spacing. The ratio b_o/b is initially equal to one. An increase in K_r corresponds to a decrease in b, signifying that the wave rays are converging. Conversely, a decrease in K_r corresponds to an increase in b, indicating that the wave rays are spreading out.

Results

The wave refraction diagrams are plotted with nautical mile (1.852 km) divisions on the axis. When the refraction diagrams are discussed, the grid location in nautical miles will be given first, followed by the distance along the shoreline in parenthesis. All of the refraction diagrams and K_r versus distance plots are presented in Appendix C.

The wave refraction diagrams and wave energy versus distance plots for the northeast waves showed a shadow zone from Canaveral Inlet to N PAFB (0-20 km). In the shadow zone only a few low energy rays reached the beach. After 20 km the number of rays and the energy of the rays increased going further south. Refraction diagrams of waves from the east produced evenly spaced rays with almost equal amounts of energy. However, there was still a shadow zone just south of Cape Canaveral, although it only extended down to 15 km. For rays from the southeast refraction diagrams showed that most of the rays were concentrated from Canaveral Inlet to Cocoa Beach.

The computer runs using the small grid were not successful. This occurred because the grid spacing for water depths was not sufficiently small enough to accurately model rapid changes in the direction of the water depth contours for portions of the water depth grid. Because no conclusions could be drawn from the results of the runs with the small grid only the data from the large grid was used in this study.

The zones exhibited in the foreshore slope, mean grain size, and percent soluble are plotted on the K_r versus distance graphs for the northeast and east waves. The northeast waves K_r plots had the best agreement with the beach characteristics zones. Low K_r values were found in zone I (0-16 km), which has flat slopes, fine grains, and few shells. Increasing K_r values were found in zone II (16-30 km), matching the increasing values of the beach characteristics. In zone III (30-60 km), the K_r values and the beach characteristics have relatively high values with regular variations. Reasons for this are discussed in the next section.

All the K_r versus distance values for waves from the northeast are plotted on Figure 19. The linear regression line shows that K_r , a measure of the wave energy due to refraction, increases going south. The coefficient of

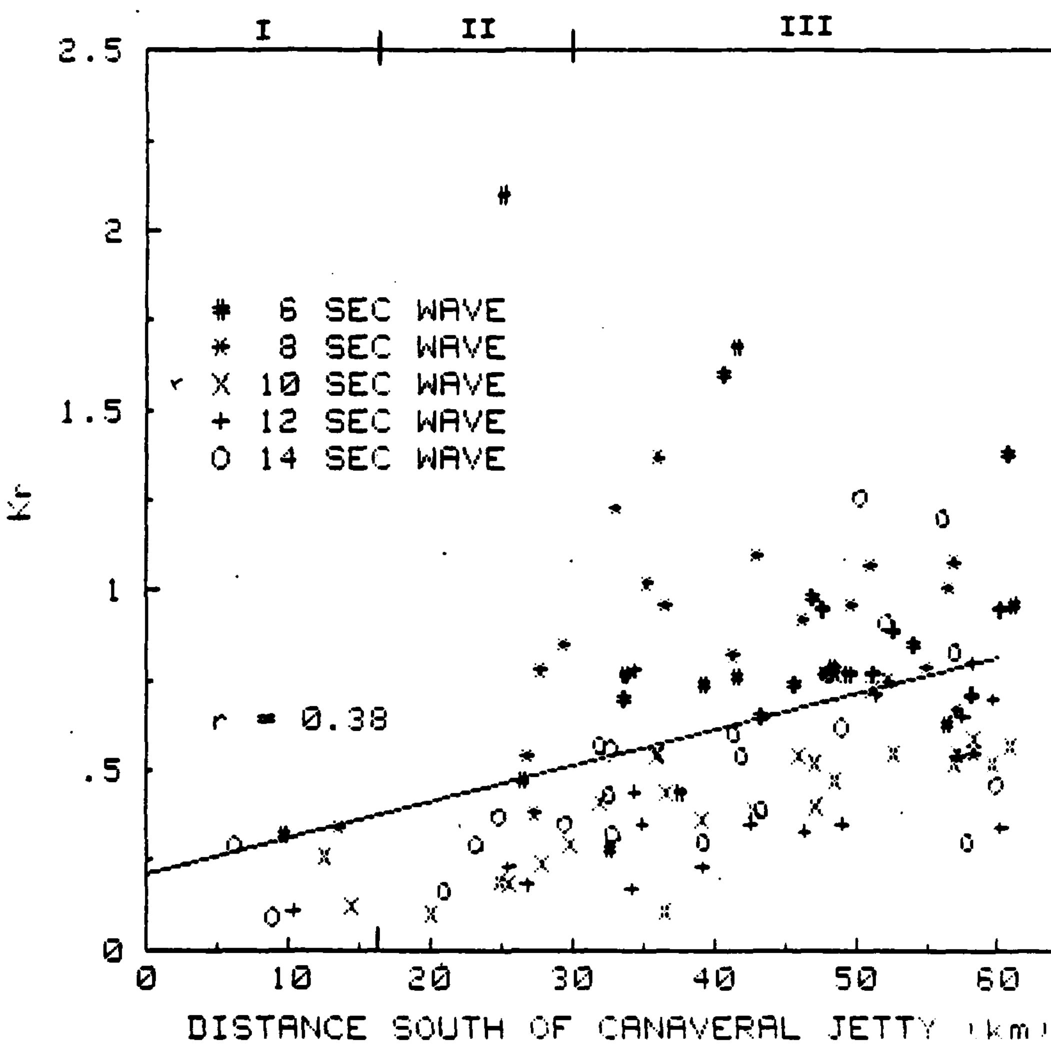

FIG. 19--K_r versus distance for NE waves.

linear regression, r, is 0.38, so the data is not very linear; however, the trend is obvious. From 0 to 20 km K_r is small, but from 20 km on south it increases. Twenty km is the middle of PAFB, an area of erosion identified by the U.S. Army (1967) and found to still be eroding in this study. Possible reasons for this fact will be discussed in the next section.

Figure 20, a plot of the K_r versus distance values for a ten second wave, is typical of the waves from the northeast. Only three rays, all with low K_r values, make it to shore north of 20 km. After that point the K_r values generally increase going south. The wave energy peaks at 35 km (Indialantic), 46 km, and 48 km.

Figure 21, the refraction diagram for a ten second wave, is typical of the northeast waves. All of the waves from the northeast are strongly refracted by the shoals off Cape Canaveral. This results in a shadow zone in the northern part of the study area from grid location 56.45 to 45 (0 to 19 km). This includes Cocoa Beach and the northern part of PAFB. South of grid location 45 (19 km), the number of rays reaching the shore increases. As the periods increase, patterns of ray convergence and divergence become more obvious due to the increased refraction of the longer waves.

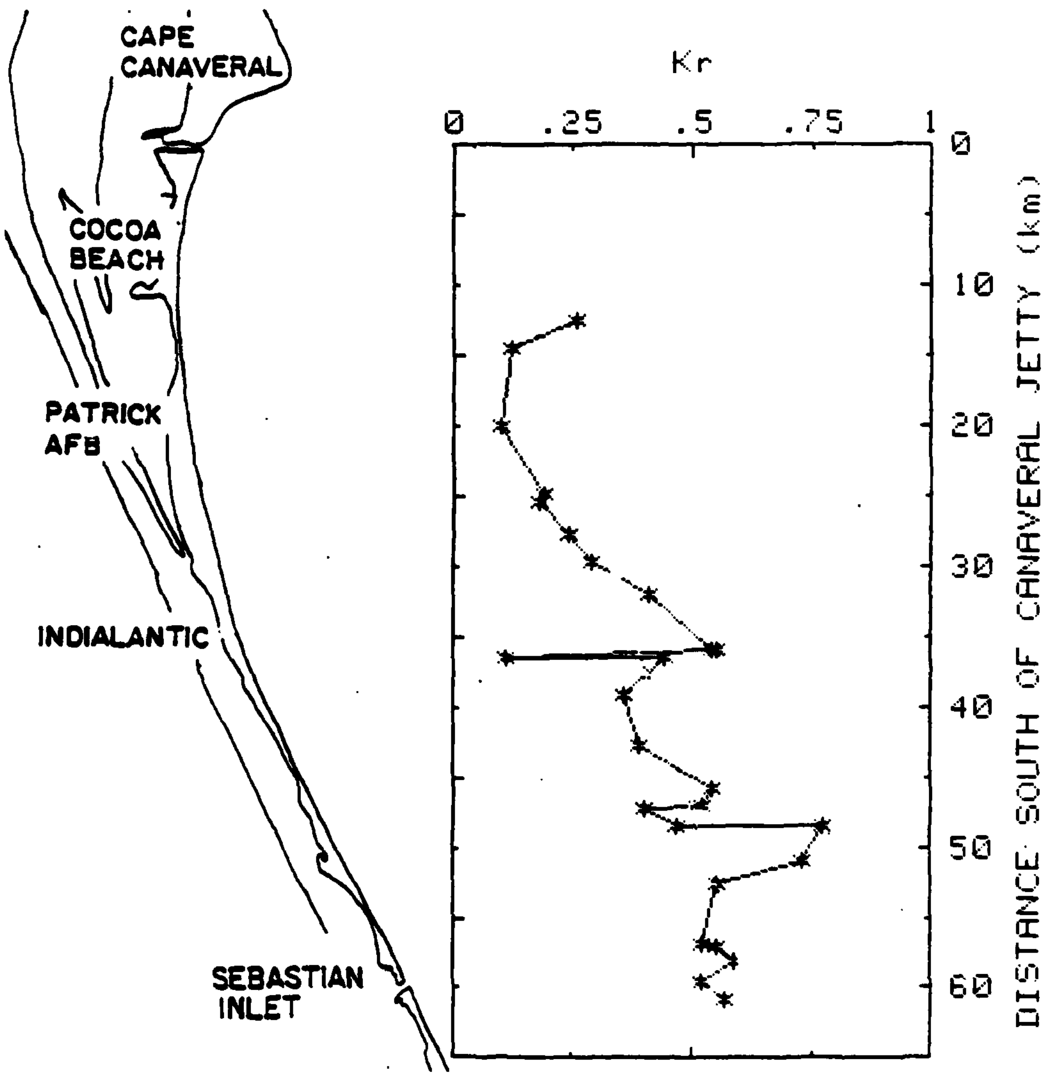

FIG. 20--K_r versus distance for 10 second NE wave.

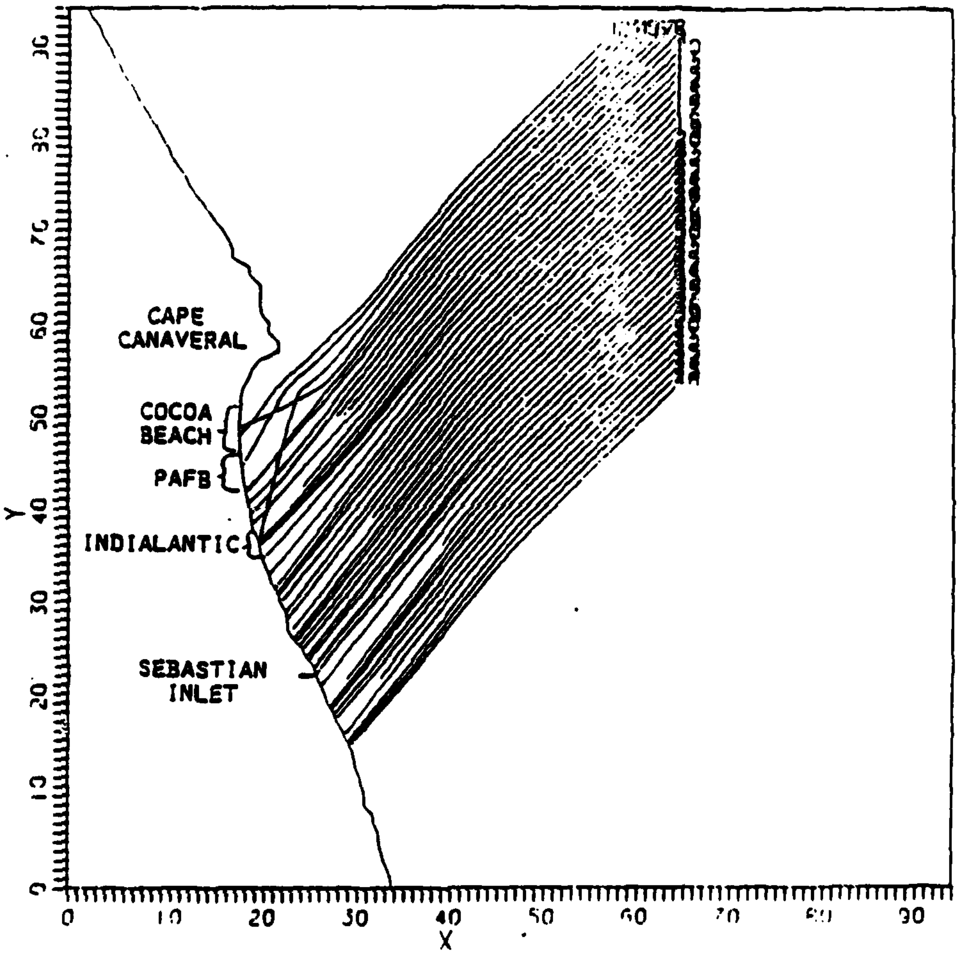

FIG. 21--Refraction diagram for 10 second NE wave.

The K_r versus distance values for all the waves from the east are plotted on Figure 22. In contrast to the northeast waves, the linear regression line for all the data points shows a slight decrease in wave energy going south. Even though the overall energy level is relatively constant for waves from the east, the zone of low energy just south of Canaveral Jetty remains. However, the K_r values increase to the level of the rest of the county at 15 km, as opposed to 20 km for the northeast waves. The K_r values for the east waves are higher than the values for the northeast waves. This is because they are refracted less, since the rays are closer to being perpendicular to the bottom contours.

Figure 23 is a plot of the K_r versus distance values for an eight second wave from the east. It shows higher K_r values than the northeast wave of that period, most of the values are over 1.0. There is a slight increase in K_r going south, although the coefficient of linear regression is low, 0.097. Still, with the exception of one point, a low energy zone can be seen at the north end of the study area. The energy level increases until about 15 km, after that point the K_r values vary widely, with a peak at 30 km.

Figure 24, the refraction diagram for an eight second wave is typical of the refraction diagrams for

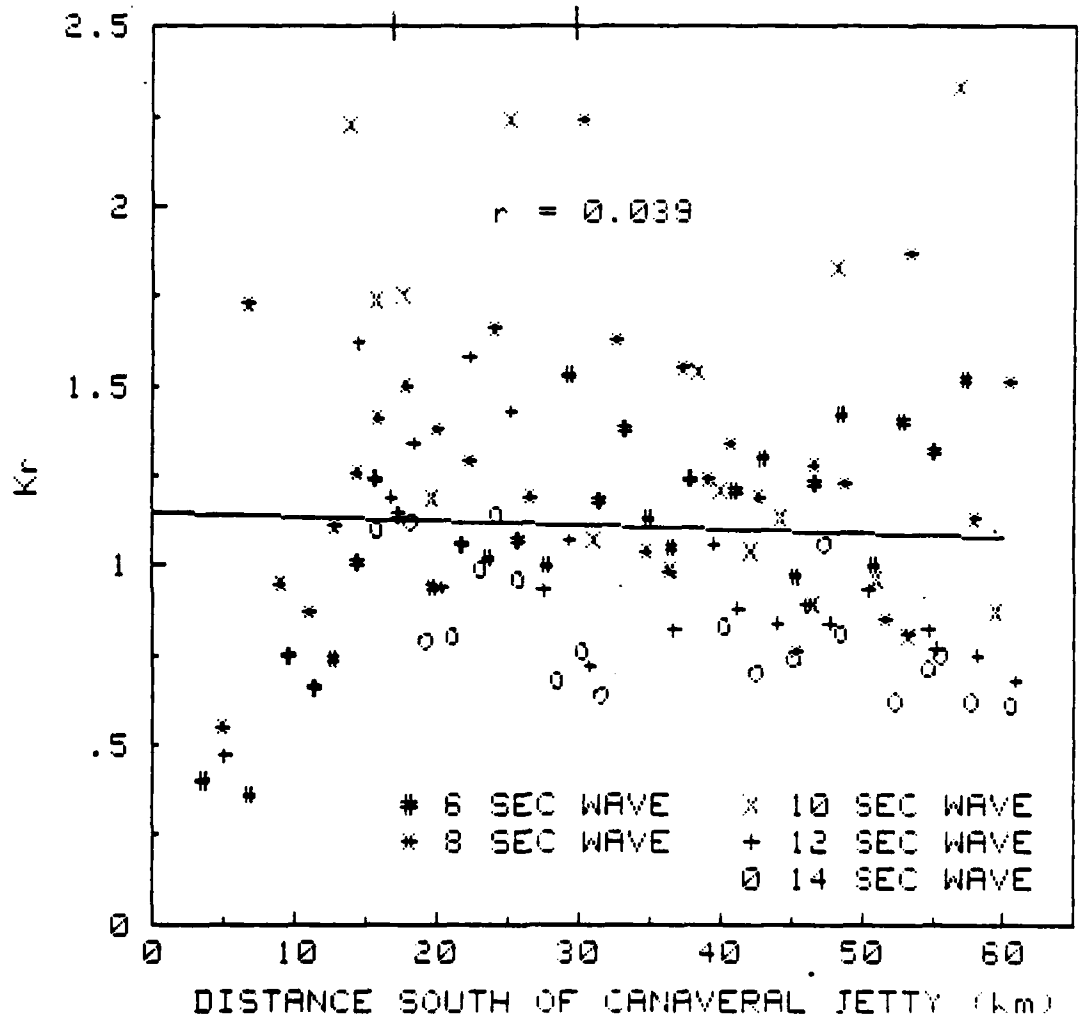

FIG. 22--K_r versus distance for E waves.

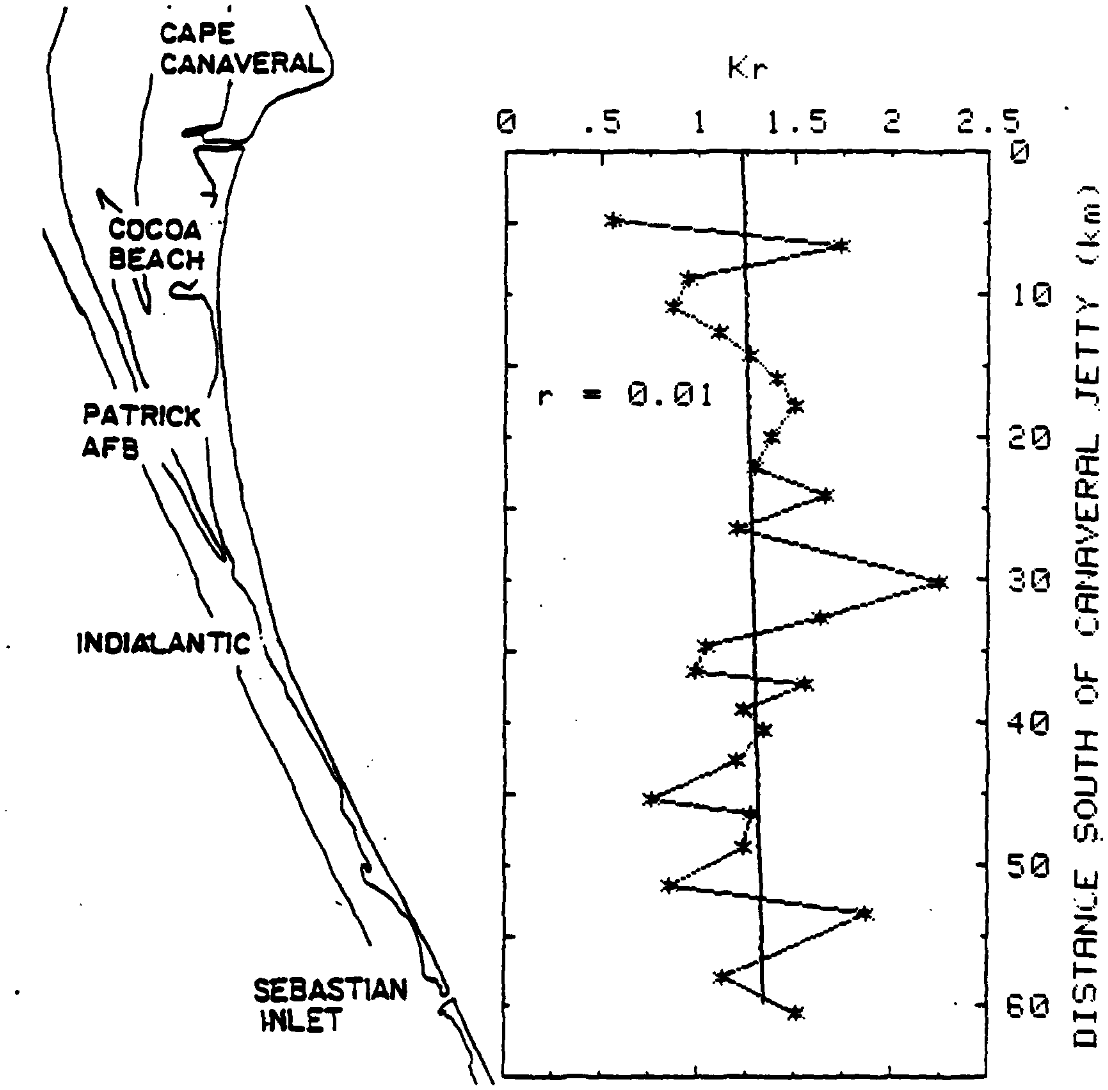

FIG. 23-K_r versus distance for 8 second E wave.

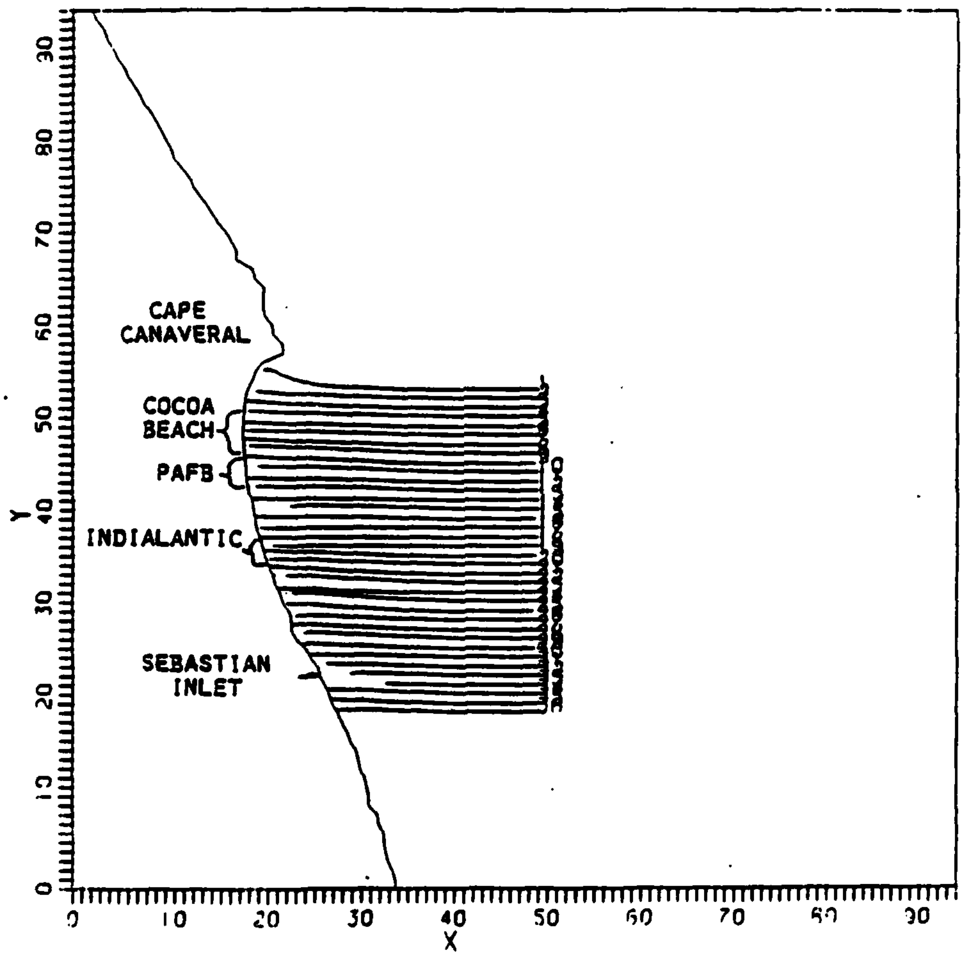

FIG. 24--Refraction diagram for 8 second E wave.

eastern waves. The shoals off Cape Canaveral still refract the waves in the northern part of the study area, resulting in fewer rays reaching the shore from y=56 to y=49 (0 to 13 km). Other than those refracted by the Cape's shoals, the six and eight second wave rays generally come straight into shore.

The longer period waves are bent towards the north above y=38 (35 km) and are refracted towards the south below that point. This seems reasonable when Figure 18 (page 47) is reexamined. All the contours deeper than 28 m run approximately north-south. However, the 24, 20, and 16 m contours are bowed towards the coast, with the most shoreward point of the contours at about 35 km. This depression offshore of Indialantic causes the observed change in the refraction direction.

The refraction diagrams for waves from the southeast, 135 , only yield qualitative results. The water depth grid spacing was too large to keep track of the rapid changes in the directions of the water depth contours. This situation causes accuracy problems with any refraction program. The problem was greater in this case, since for many rays the water depth contours became abruptly parallel to the direction of the wavelets. This causes a problem in computing the ray curvature of a wave packet.

The conventional group velocity is usually a good approximation to the geometric group velocity (Breeding, 1978b). Since the conventional group velocity is independent of the wavelet direction, it was used in the ray curvature calculations to improve the operation of the wave prediction program for waves from the southeast. The runs produced a graphic picture of the ray paths. However, the K_r values were very high, and were not used. Because of the problems just described, and since little of the total energy comes from the southeast only two computer runs were made. Wave periods of 6 and 10 seconds were considered.

Figure 25 is the refraction diagram for a six second wave from the southeast. The rays are strongly refracted and concentrated in the northern part of the study area from y=56 to y=52 (0 to 6 km). Very few rays reached the rest of the study area. The diagrams show that the Cocoa Beach to Canaveral Inlet areas would be areas of increased wave energy and probable erosion during periods of large waves from the southeast.

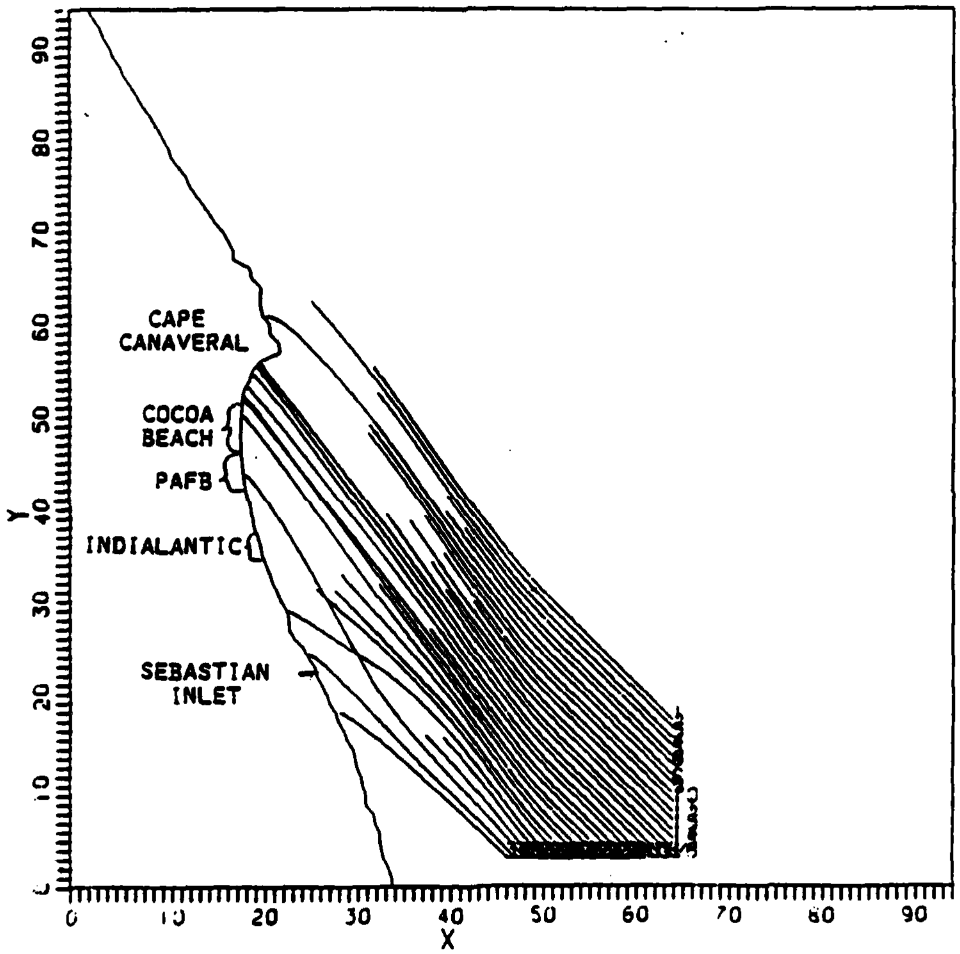

FIG. 25--Refraction diagram for 6 second SE wave.

DISCUSSION

An analysis of the beach profile, grain size distribution, and wave refraction data shows that the beaches of South Brevard County have different characteristics from those to the north. Flat (less than two degrees), fine grained (average three phi), low percentage shell content (less than 12 percent) beaches were found in the low wave energy zone in the northern part of the study area. Steeper (6 to 9 degrees), coarser grained (1.3 to 1.9 phi), higher percentage shell content (22 to 32 percent) beaches were found to the south in a higher wave energy zone. Plots of the 8 and 10 second northeast waves had the best agreement with the beach characteristics. The amount of recent erosion was low in the areas identified as requiring beach nourishment by the Corps of Engineers (U.S. Army, 1967). Construction practices are likely the major contributor to the erosion, with wave energy a secondary factor.

The interrelationship between the foreshore slope, mean grain size, and percent soluble (shell content) can be clearly seen in Figure 26. Three zones are evident. Zone I has flat, fine grained, low percentage shell beaches. It extends from the northern part of the study area through Cocoa Beach down to 16 km. Zone II, a transtition zone, extends from 16 to 25-30 km. In this zone all the values increase dramatically. Zone III (30-60 km) has relatively constant values, but all three parameters have definite maximums and minimums. At 45 and 55 km there are peaks for all three parameters.

Figure 26 clearly shows that these characteristics are strongly related. The relationship between slope and mean grain size is to be expected (Komar, 1976; King, 1972). Larger grains increase the interlocking between the grains and the larger pore spaces reduce the backwash, which helps to maintain the increased slope.

The effect of shell content on the mean and slope has not been as widely recognized. It has been observed by other researchers studying the baches on the east coast of Florida (Meisburger and Duane, 1971; Field and Duane, 1974). Hansen (1982) in his study of the South Brevard County beaches found that nearly all of the shells were in the coarser grain sizes, from -1 to 1 phi. Therefore, the increase in mean grain size with an increase in shell content is logical.

Location R17 (4.4 km) was eliminated from the plot in Figure 26 and all subsequent discussion. As stated previously, this section of beach was flat in 1965. Subsequent local nourishment with high percentage shell

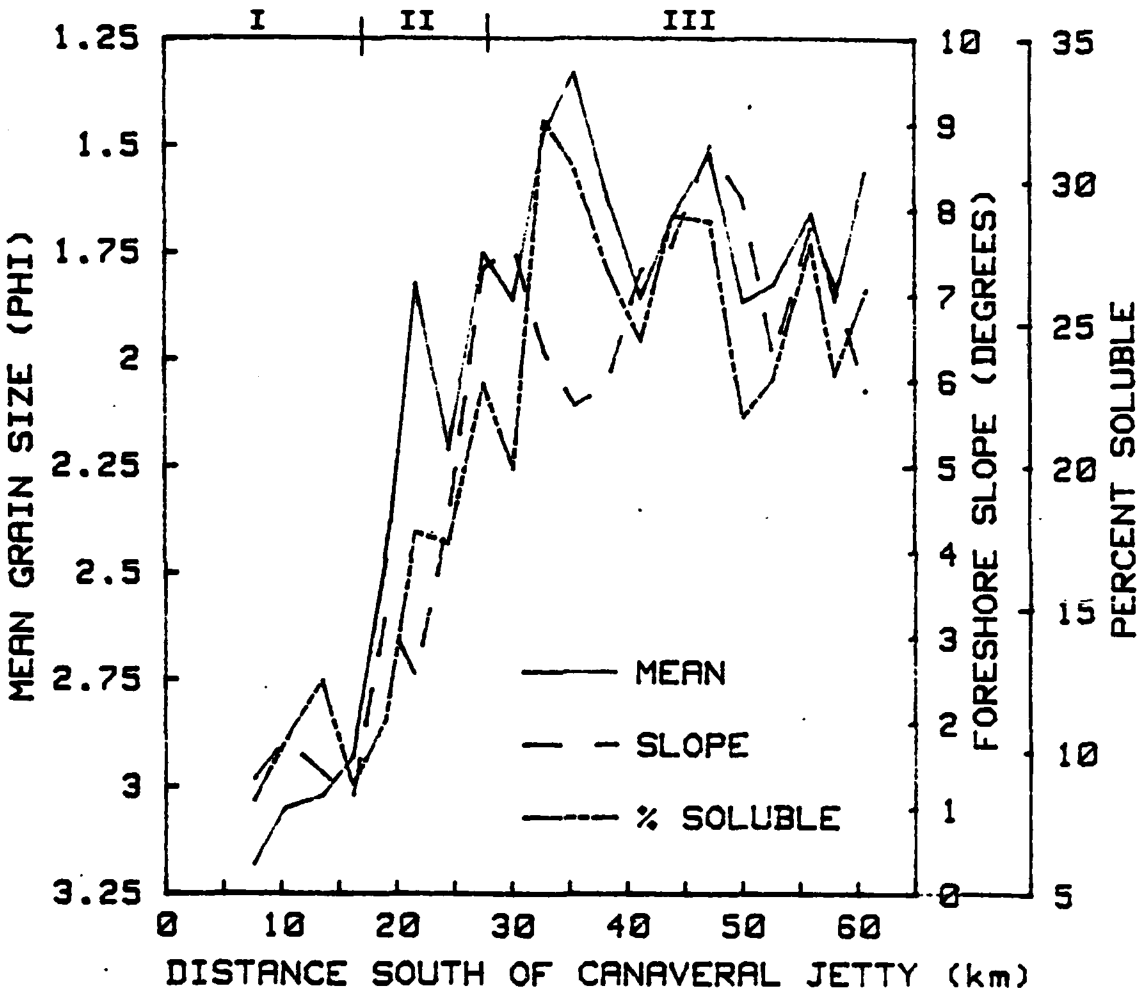

FIG. 26--Foreshore slope, mean grain size, and percent soluble versus distance.

content sand and the possible southerly drift of shells from the Canaveral nourishment project have artifically increased slope, mean, and percent shell content.

The foreshore slope is probably the most natural beach parameter to correlate with the wave energy. It integrates the beach characteristics over most of the foreshore. Mean and percent shell content are values at single point and can vary over the foreshore (Bascom, 1951; Komar, 1976; and Sonu, 1972) or with the season. They are also sensitive to sampling procedures (Lenhoff, 1979).

The overall shape of the K_r (proportioanal to the square root of the wave energy) versus distance curves for 8 and 10 second waves from the northeast are similiar to the curve of the foreshore slope (Fig. 27). All have low values in the northern end (zone I) of the study area. The low K_r values are due to the waves being blocked or significanty refracted by Cape Canaveral and its shoals. The low wave energy allows the finer grains to remain on the beach decreasing the slope.

The K_r values increase as one moves south because the influence of the Cape Canaveral shoals diminish. The increase in wave energy puts the smaller grains into suspension, leaving behind the larger grains which increases the mean grain size and the foreshore slope.

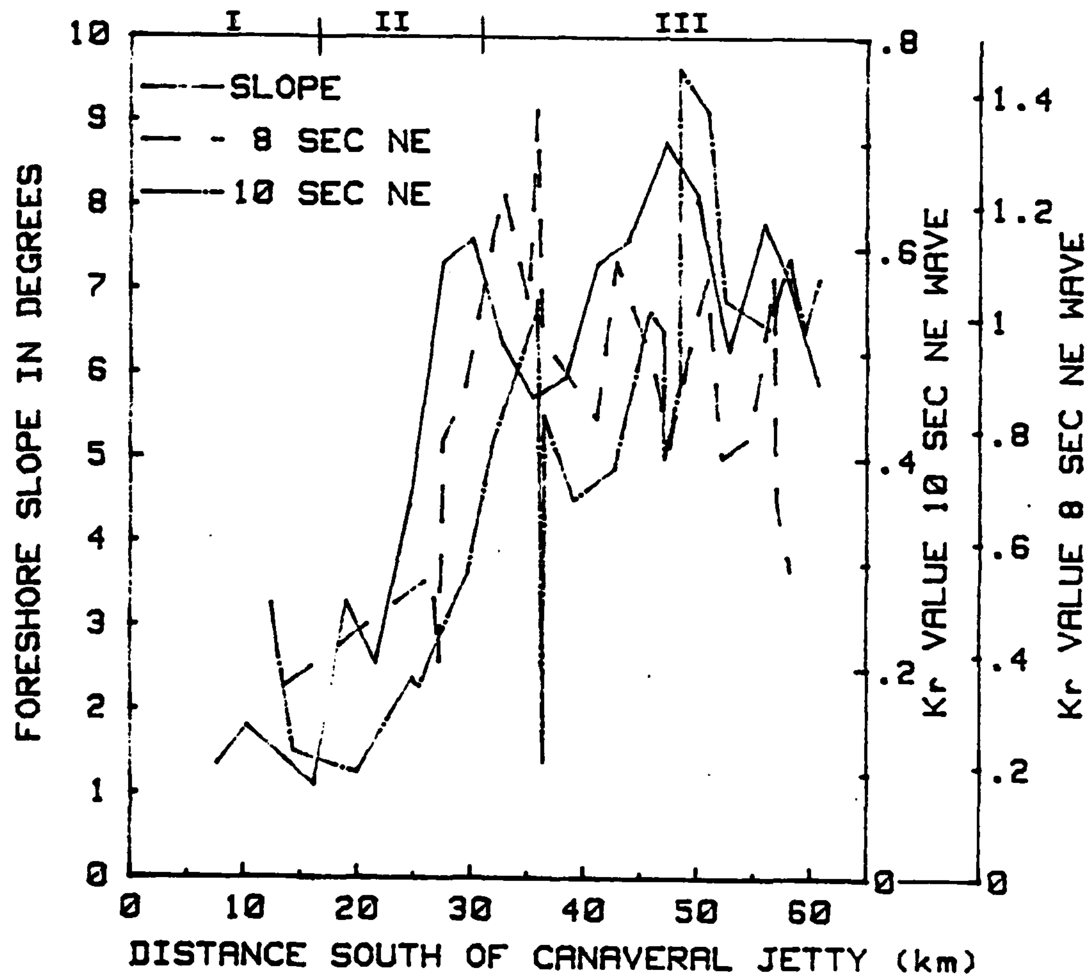

FIG. 27--Foreshore slope versus K_r values for 8 and 10 second northeast waves.

The peaks in the slope do not match exactly the waves' K_r value peaks in zone III. However, a change in the incident direction of ± 10 degrees could significantly change the location of the peaks of the K_r curves. Also, K_r is only one factor affecting longshore transport. The wavelet direction is another factor (Breeding, 1981a). With these limitations, the agreement of the slope with the K_r values is good. In addition, this study's slope values are based on the data from a single day. Figure 7 (page 17) shows that the slope's peaks do change in respone to tides, storms, and the season (Sonu, 1972).

Errors in the smooth sheet and chart locations and water depths (Sallenger, et.al, 1975) plus changes since the smooth sheets and charts were produced also put some error into the wave ray paths. Also, there is probably some error, perhaps as much as 1/4 to 1/2 km, in the transfer of the grid locations from the charts and smooths sheets to the computer grid. Still, although the agreement is not exact, it is good. It seems likely that the northeast waves, particularly the 8 and 10 second waves have the largest influence on the beach characteristics in South Brevard County.

As noted earlier, the Daytona Beach (Thompson, 1977) and Vero Beach wave spectrums had their peaks at 8 to 9 seconds and 9 seconds respectively. Also, the U.S. Army (1967) showed that the majority of the large waves come from the northeast. Due to these facts the agreement between the slope and the 8 and 10 second northeast wave K_r plots is not surprizing. The 12 second wave from the northeast also has the same basic shape as the 8 and 10 second waves, however, it does not fit quite as well.

Figure 28 plots the 8 and 10 second northeast waves' K_r values versus the mean grain size. The fit is not quite as good as with the same waves plotted versus the slope (Fig. 27). The increase of the mean from 16 to 20 km is not modeled well by the waves which increase farther south. However, the mean grain size's peak at 35 km is matched by both waves, as is the relative minimum at 40 km. The remaining portion of the mean curve is not well followed by the waves' K_r values for the same reasons that the slope curve did not follow the K_r curves. Since the mean and percent shell content curves are very similiar, a separate plot of the K_r values versus percent shell content was not made.

Energy (K_r) values versus distance plots from the east waves did not model the beach characteristics nearly as well as did the northeast waves. The best fit was with the shorter period waves, 6 and 8 seconds (Fig. 29). The short period east waves energy levels are

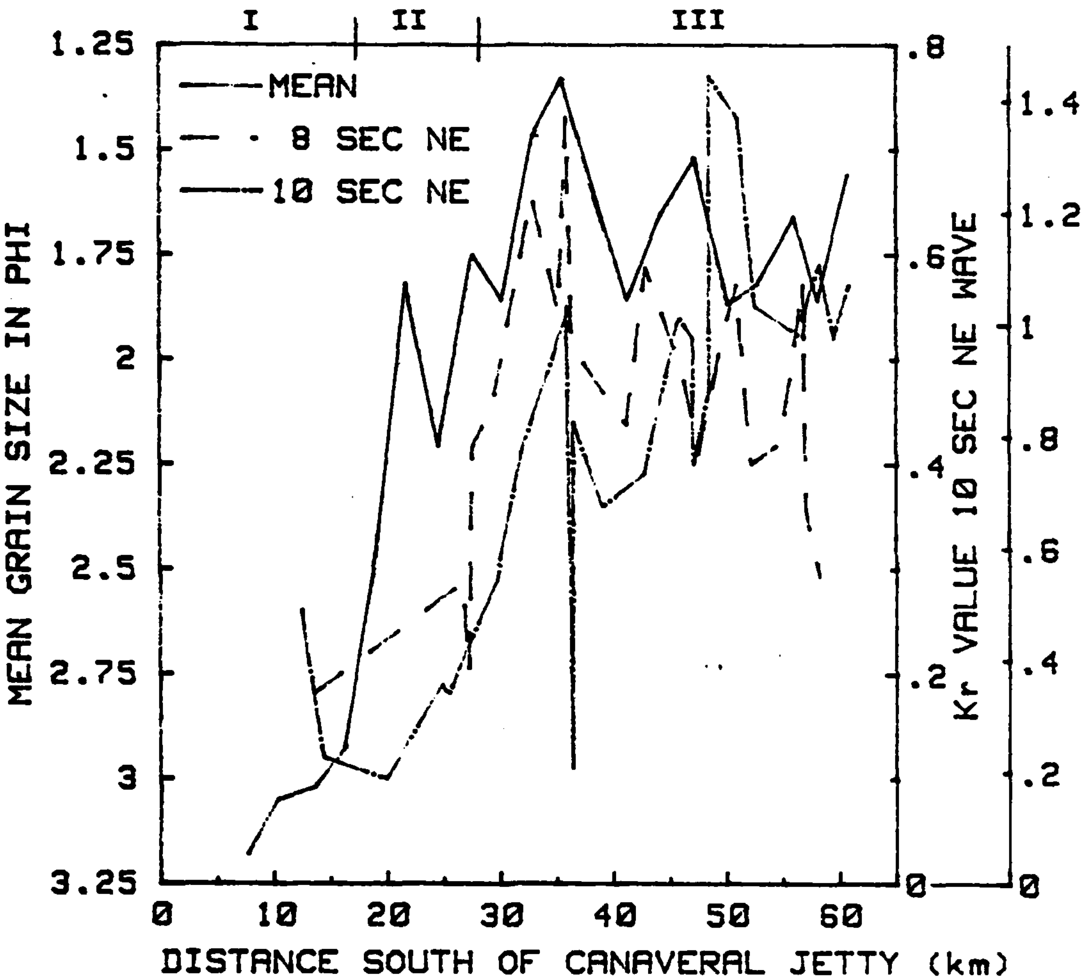

FIG. 28--Mean versus K_r values for 8 and 10 second northeast waves.

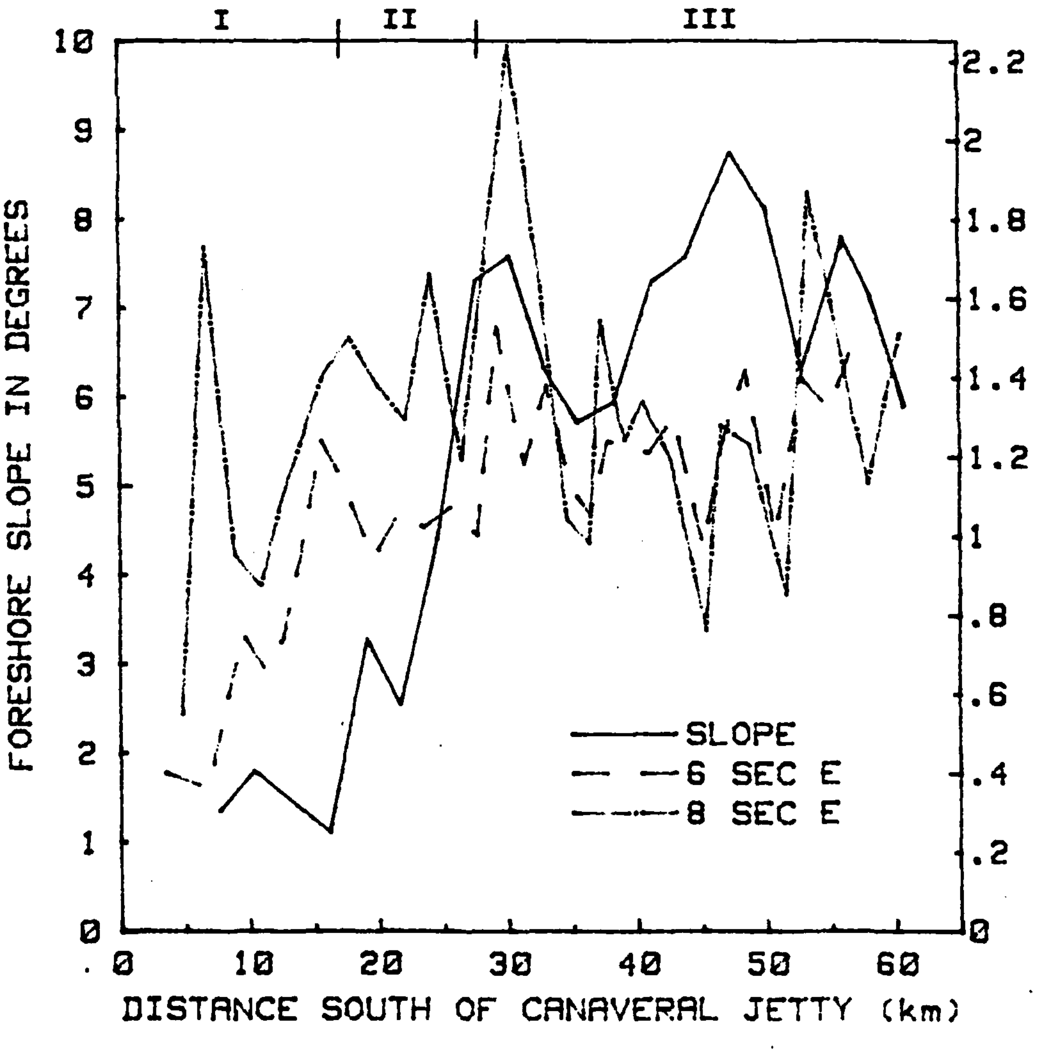

FIG. 29--Foreshore slope versus K_r values for 6 and 8 second east waves.

more constant with relatively high values in the northern part of the study area. Here the Canaveral Shoals do not block the east waves as much as they do the northeast waves.

The east waves high energy values in the northern part of the study area do not correlate with the flatter slope. In fact, the slope increases after the 6 and 8 second east waves' K_r values increase, but before the 8 and 10 second northeast waves' K_r values increase. This shows the influence of both sets of waves. It appears that the middle period (8 to 12 second) northeast waves are the major factor in controlling the South Brevard Beaches, but that the short period east waves also exert an influence.

The results of this study were different from past studies of wave refraction effects on beach characteristics which looked at response to a specific event. Fisher et al. (1975) conducted a study which defined small specific zones of erosion when wave hindcasting for a particular storm was used. This study was not designed to do that since the wave hindcast data was not available and repeated profiles were impractical. This study did show general trends. Coarse grain sand was found in the higher energy zones, but these were not generally areas of increase erosion as were found by Goldsmith and Colonell (1971). A beach in equilibrium with the waves can have a large amount of sediment transport, but still have little erosion (Komar, 1976). Perhaps sites of short term erosion for specific storm events could be identified and documented if detailed wave and pre and post storm profile data were available.

The coarsest grains were found at 32-35 km, the region that Figure 28 showed to be the highest wave energy point for the northeast waves. But, shell content must also be considered a significant influence on grain size. A study of the interrelationship between wave energy and the amount, distance offshore, and elevation of the coquina rock outcrops might answer the question, but would be very hard to perform.

It was noted that the point at which the wave energy from the northeast waves begins to increase is 20 km. This location (the middle of PAFB) is an area of erosion identified by the U.S. Army (1967) and was found to still be e eroding in this study. The dunes at PAFB have been significantly altered by construction. The officer's club sits well out on the foreshore, and most all of the natural vegetation has been removed. It appears that poor construction practices are causing more of the erosion problem than is the increase in wave energy.

The same is probably true of the zone identified as requiring beach nourishment by the U.S. Army (1967) at

Indialantic-Melbourne Beach (35-40 km). There was no measurable erosion of the beach face in this area from 1972 to 1980. While the wave energy for the northeast waves does peak in the northern part of Indialantic, the lack of recent dune face migration suggests that the problem is similiar to the one at PAFB. The major part of the problem is probably due to over development on the dunes, while wave energy plays a secondary role.

The alternating zones of wave ray concentration and diffusion found by Goldsmith et al. (1974) were somewhat evident in the longer period waves from the northeast. Zones 10 to 12 km in length for 12 second waves could be seen. These zones are smaller than the ones found by Goldsmith et al. (1974) at Cape Hatteras, which were 28 to 46 km for waves of 12 to 14 seconds. The spacing is probably a function of both the period and offshore bathymetry, which is different for Cape Hatteras and Cape Canaveral.

The shorter period waves did not have a regular pattern, although more wave rays and a finer water depth grid might show a regular pattern of alternating zones of wave energy. It is interesting to note that for six to eight second waves Goldsmith et al. (1974) found alternating wave energy zones as short as 1.8 km, while

Stauble (personal communication) has observed rhythmic beach features 1.7 km in length in South Brevard County. Breeding (1981a) has postulated that wave refraction is one possible cause of these rhythmic beach features.

CONCLUSIONS

(1) Wave refraction diagrams and wave energy calculations are consistent with the beach characteristics in South Brevard County. The dominant waves from the northeast were significantly refracted by Cape Canaveral's shoals producing a region of fewer rays with low energy in the northern part of the study area. In this area are low energy beach characteristics, flat slopes and fine grains. The low wave energy allows the finer grains to remain on foreshore. Further south the number and energy of the wave rays increased. The slope and mean grain size also increased, which suggests an increase in wave energy. Higher wave energy suspends the finer grained particles and moves them offshore, leaving behind the coarser grains.

(2) The wave energy distribution plots seemed to indicate that middle period northeast waves of 8, 10, and possibly 12 seconds are most important in controlling the beach characteristics of South Brevard County. Short period, 6 and 8 second, east waves may also significantly influence the area. They seem to shift the point at which the beach shows higher wave energy charactristics to the north.

(1) Erosion problems at PAFB are probably due to two factors. The most important is over developement of the

dunes followed by increased wave energy. From 1972 to 1980 the beaches at Indialantic-Melbourne Beach were fairly stable. "Erosion" at this location is only a problem where development has taken place on the dune.

The following are some suggestions for further research.

(1) Acquire directional wave data for South Brevard County. Then conduct wave refraction studies with the actual period, direction, and relative percent of occurence data to see how well the data matches the beach characteristics.

(2) Repeat the wave refraction study using monochromatic waves to see if the resulting wave energy distribution better predicts the beach characteristics than found in this study for wave packets. The wave packets were assumed to move with geometric group velocity.

(3) Select an area where rhythmic topography, a sinuous shoreline and offshore bar, is present. At that point make a wave refraction study using a more detailed grid and take closely spaced profiles and sand samples at regular intervals. This should give some insight as to how the rhythmic features migrate and/or change with varying wave period and direction.

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

In this thesis is presented a study of the beach characteristics of S. Brevard County, Florida, and the effects of wave refraction on those characteristics. In

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October, 1980 twenty-one profiles with sand samples were taken at equal intervals over the beaches of S. Brevard County. From the data two types of beaches were evident. Wide, flat, fine grained beaches, with few shells were found in the northern part of the study area. To the south; narrower, steeper, coarser grained beaches with more shells were found.

Wave refraction studies of the area were done by computing wave packet trajectories. The velocity of the wave packets was assumed to be the geometric group velocity theory. The refraction diagrams and wave energy distribution plots showed that Cape Canaveral and its shoals created a shadow zone of low wave energy in the northern part of the study area. Further south the wave energy increased. The low energy zone had fine sand and a flat slope, the higher energy zone had coarser sand and a steeper slope. The 8, 10, and possibly 12 second northeast waves most strongly controll the beach characteristics with 6 and 8 second east waves also having an effect on the beach. Little landward migration of the dune face was found in the areas identified as having erosion problems in previous studies during the period from 1972 to 1980.

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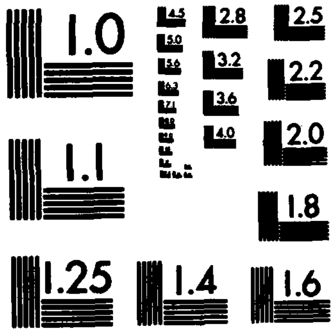
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