Padre Island National Seashore Field Guide

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1972 GCAGS CONVENTION FIELD TRIP

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PART II – NATURAL HISTORY OF PADRE ISLAND

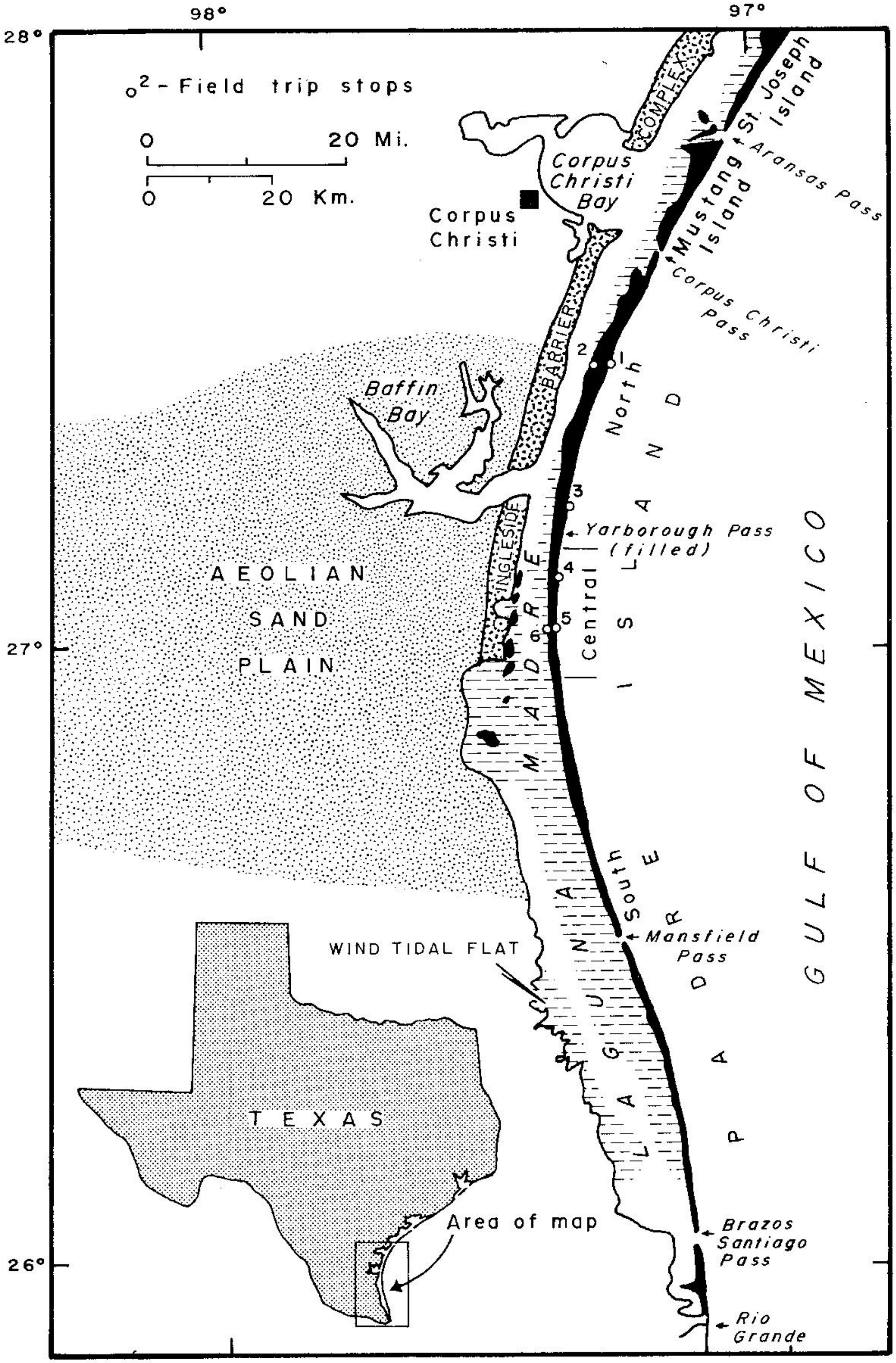

Fig. 1. – Location of Padre Island and the field trip stops.

MODERN DEPOSITIONAL ENVIRONMENTS AND PROCESSES, NORTHERN AND CENTRAL PADRE ISLAND, TEXAS[1]

Ralph E. Hunter[2], Richard L. Watson[3],
Gary W. Hill[2], and Kendell A. Dickinson[4]

ROAD LOG

Total mileage	Mileage from last reading	
0.0	0.0	Leave Malaquite Beach parking lot, Padre Island National Seashore, turning right (northeast) on Park Road 22.
3.7	3.7	Turn right (east) on beach access road near north end of Padre Island National Seashore.
4.2	0.5	STOP 1 on beach at north end of restricted beach zone. Because of the prohibition of vehicular traffic for 4.4 miles to the south, burrowing organisms of the beach have been able to attain their natural distribution and population levels. The beach is discussed on p. 6, the foredunes on p. 6. Just north of the beach access road is an active blowout dune field, shown in fig. 11; the active dune fields are discussed on p. 9. Return to Park Road 22 via beach access road.
4.7	0.5	Turn left (south) on Park Road 22.
5.2	0.5	Pass Grasslands Nature Trail. The northwest-trending grassed ridge is a stabilized longitudinal dune ridge left behind when the back-island active dune field passed over this area. The grassed flat is a deflation flat, formed by wind erosion of dune sand down to the level of damp sand.
5.8	0.6	Pass another stabilized longitudinal dune ridge, shown in fig. 2.
5.9	0.1	Turn right (northeast) on gravel road to oil storage tank.
6.5	0.6	STOP 2 at edge of back-island active dune field. Figure 2 is a map of the area. The active dune fields are discussed on p.9; the deflation flats over which you have just crossed are discussed on p.11. If conditions permit, drive across the dune field to the wind-tidal flats, discussed on p.13, and return to this point. Return to Park Road 22 via gravel road.
7.1	0.6	Turn right (south) on Park Road 22.
8.3	1.2	Pass Island Ranger Station.
8.7	0.4	Pass leading edge of an active blowout dune field which had advanced to the edge of the road in 1967. A pond was dredged to halt the advance of the dunes temporarily. Other active blowout dune fields can be seen along this road.
9.8	1.1	Pass Malaquite beach.
10.6	0.8	Turn right (south) on beach. For a distance of 3.3 miles, the foredune ridge is well developed except where active blowout dune fields are in contact with the beach.
13.9	3.3	For a distance of 3.5 miles, the foredune ridge that was present in 1948 has been extensively activated; the sand is now in the form of active dunes that are moving inland (northwestward). An attempt is under way to form a new foredune ridge by artificial planting.
16.9	3.0	Pass four-wheel drive warning sign. STOP 3 will be someplace in the next 9 miles, depending on local beach conditions. This section of beach is commonly called "Little Shell." For discussion see p. 23.
24.9	8.0	Pass Yarborough Pass, an artificial pass filled within a year after it was dredged.
25.9	1.0	STOP 4 will be someplace in the next 6 miles, depending on local beach conditions. This is the transition zone of the shell beaches. For discussions see p. 4.
31.9	6.0	STOP 5 will be someplace in the next 3.7 miles, depending on local beach conditions. This section of beach is commonly called "Big Shell." For discussion see p. 24.
35.6	3.7	Turn right on unimproved road to the abandoned Dunn Ranch headquarters.
36.2	0.6	STOP 6. Fig. 28 is a map of this area, which is typical of the central part of the island as discussed on p. 24. If conditions permit, return to the beach via the unimproved road along the back part of the island, stopping to look at the wind-tidal flats. After returning to the beach, return along it to the north.
62.2	26.0	Trip ends at Malaquite Beach.

INTRODUCTION

This trip furnishes an opportunity to observe landforms, sediment types, and sedimentary structures in two traverses across the island, one across the northern part and one across the central part (fig. 1). Along shore between these two localities, changes in beach morphology, sediment type, and shell types can be observed. One object of the trip is to observe features that will help geologists to identify coastal deposits in the stratigraphic record. Another object is to give trip participants an increased knowledge of environmental problems arising from man's use of the coastal region. We hope that all those who take the trip will enjoy the unique coastal environment preserved in Padre Island National Seashore.

PHYSICAL ENVIRONMENT

Padre Island is part of a curving chain of barrier islands and spits that stretches some 200 miles along the Texas coast from the Brazos River delta on the northeast to the Rio Grande delta on the southwest (fig. 1). Padre Island itself extends a distance of 110 miles without a permanently open natural pass; it is now divided by Mansfield Pass, which is artificially maintained. The wide separation of passes along the Texas barrier chain is characteristic of barrier island coasts having a low tidal range (Table 1), but another factor operating to deprive Padre Island of natural

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[1] Publication authorized by the Director, U.S. Geological Survey
[2] U.S. Geological Survey, Corpus Christi Texas
[3] University of Texas Marine Science Institute, Port Aransas Texas
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TABLE 1. – Some geologically significant characteristics of the Texas coastal environment.

Environmental parameter		Brownsville – Brazos Santiago Pass	Corpus Christi – Aransas Pass	Galveston – Galveston Channel	Port Arthur – Sabine Pass
Mean diurnal tidal range, in feet[1]		1.4	1.7	1.4	1.9
Mean annual precipitation, in inches[2]		26.65	26.72	44.64	52.37
Resultant wind speed, in miles per hour, and direction[3]	January	2.7 from 130°	3.2 from 095°	3.0 from 071°	2.2 from 090°
	April	9.5 from 128°	8.8 from 125°	5.8 from 129°	5.7 from 153°
	July	11.0 from 140°	10.2 from 144°	7.8 from 186°	3.4 from 184°
	October	3.6 from 095°	4.9 from 090°	4.2 from 087°	3.2 from 074°
	Annual	6.0 from 127°	6.1 from 121°	not available	2.4 from 131°

[1] Data are for the tidal passes, from U.S. National Oceanic and Atmospheric Administration, National Ocean Survey, Tide tables, 1972, east coast of North and South America.

[2] Data are for the period 1931-1970, from U.S. National Oceanic and Atmospheric Administration, Environmental Data Service, Local Climatological Data, Annual Summary with Comparative Data, 1970, Brownsville, Corpus Christi, Galveston, and Port Arthur.

[3] Data from (1) U.S. Geological Survey, 1970, The National Atlas of the United States of America; (2) U.S. Weather Bureau, Climatography of the United States, No. 82-41 (Corpus Christi and Brownsville, 1951-1960) and No. 30-41 (Port Arthur, 1950-1955); (3) U.S. National Oceanic and Atmospheric Administration, Environmental Data Service, Local Climatological Data, 1967-1971, Port Arthur.

passes is the absence of large rivers emptying into Laguna Madre, which separates Padre Island from the Texas mainland (Phleger, 1969). Elsewhere along the Texas barrier chain, the large bays and rivers provide a sufficiently large tidal prism and fresh-water outflow to maintain about one open pass for each bay (Price, 1952).

On Padre Island, a larger role has been played by wind action in shaping the landforms and in transporting sand than on the more northeasterly part of the Texas barrier chain. Wind action has been important on Padre Island in part because of low rainfall and in part because the winds are strong and predominantly onshore (Table 1).

Hurricanes are another important geologic agent on Padre Island, as on other parts of the Texas barrier chain (Hayes, 1967; McGowen and others, 1970). During these storms, surges of high water wash over low parts of the island, eroding the beaches, cutting passes, and depositing sand as washover fans in Laguna Madre. Additional erosion of the passes occurs when the water pushed into the lagoon escapes to the Gulf during the waning stages of the storm. The passes cut by hurricanes are usually closed by sand deposition within a short time, but the healed passes remain low and are commonly reopened during subsequent hurricanes. Passes cut by hurricanes are abundant on the low narrow southern part of Padre Island but are uncommon along the central and northern parts where the island is wide and protected from wave attack by a vegetated foredune ridge typically more than 15 feet high.

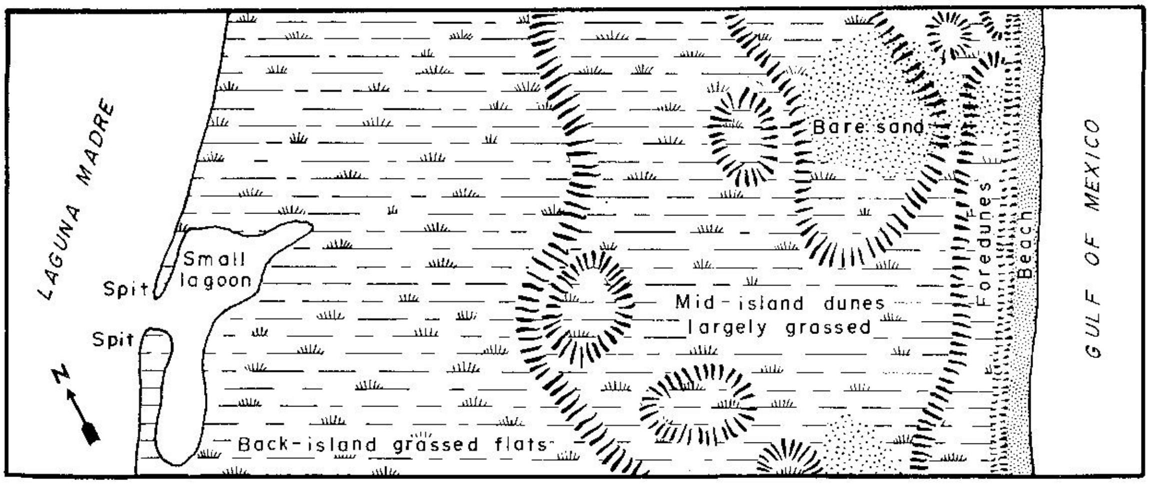
Waves are the dominant force acting on the Gulf beach and shoreface of Padre Island. The wave energy is great enough, the sediment mobile enough, and the time of geologic activity has been long enough for the shoreface and inner continental shelf to approach an equilibrium form (Price, 1954a, b). The direction of longshore sediment transport is discussed in the section on longshore variations in beach sediment and origin of the shell beaches.

Geologically significant aspects of the Texas coastal environment have been discussed in more detail by Curray (1960) and Lohse (1955).

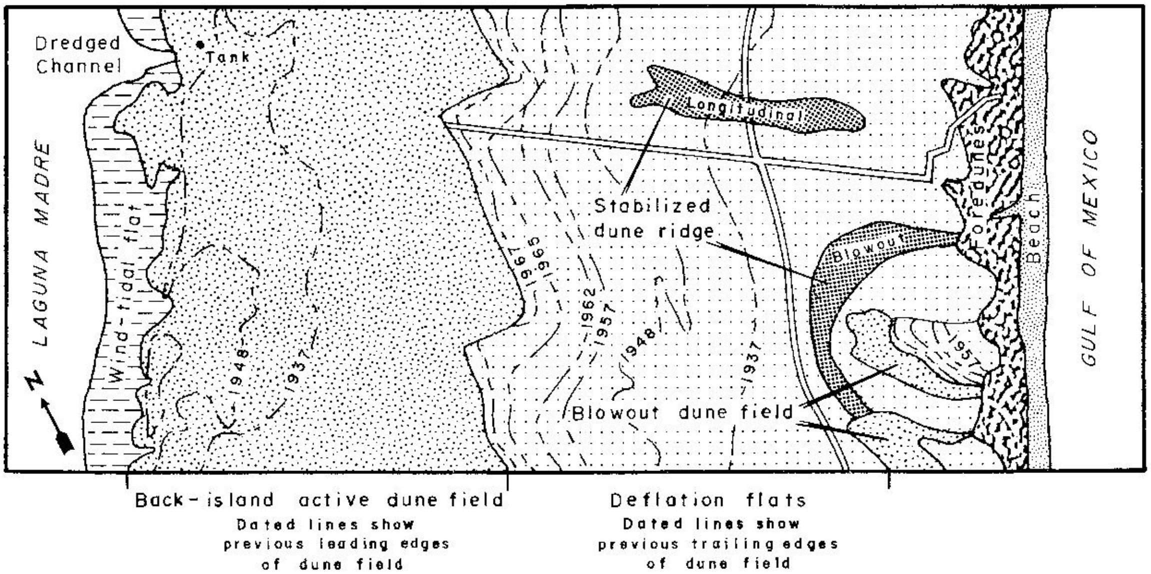
STRUCTURE AND AGE OF PADRE ISLAND

The Padre Island sand body overlies Pleistocene muds and sands. The top of the Pleistocene sequence is marked by a weathered zone in central Padre Island (Fisk, 1959) and by a shell layer in the South Bird Island quadrangle (Hunter and Dickinson, 1970); it is at a rather uniform depth of about 60 feet below sea level in the South Bird Island quadrangle, whereas farther south, in central Padre Island, it is only 25 to 50 feet below sea level (Fisk, 1959). The sand body continues to thin southward, and muds that are presumably part of the Pleistocene Rio Grande delta crop out locally on southern Padre Island (Rusnak, 1960). In cross section, the sand body is lenticular, grading seaward into Holocene marine muds that are probably very thin and grading landward into Holocene lagoonal muds and sands that pinch out at the mainland shore of Laguna Madre.

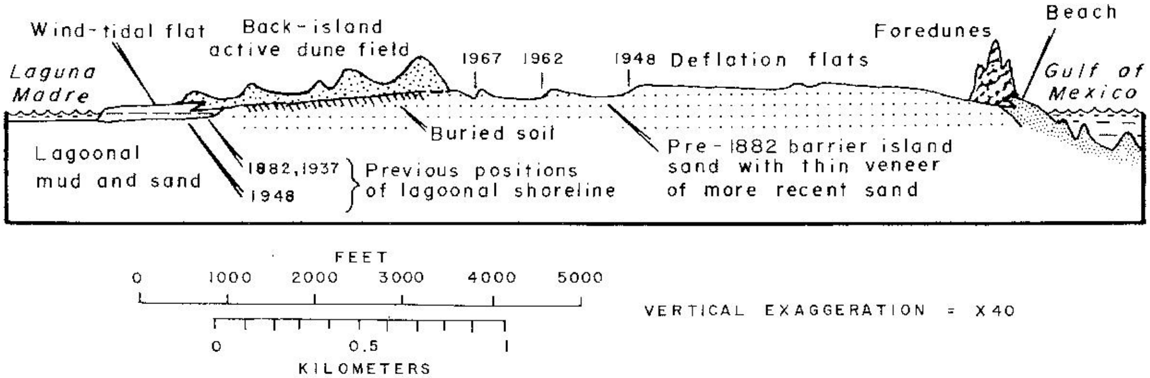
Radiocarbon dating of shells from Padre Island and



PADRE ISLAND 1882
(FROM USC&GS CHART No. 210)



PADRE ISLAND 1968



CROSS SECTION 1968

Fig. 2. – Changes in a typical part of northern Padre Island from 1882 to 1968. The mapped area is in the vicinity of the Chevron Plant, South Bird Island 7.5-minute quadrangle (Hunter and Dickinson, 1970) and is the locale for STOP 2 of this field trip. The scale applies to both maps and to horizontal distances on the cross section.

other barrier island sand bodies indicates that the barrier islands along the Texas coast began growing about 5000 years ago (Fisk, 1959; LeBlanc and Hodgson, 1959; Bernard and LeBlanc, 1965). By that time, sea level had risen to within 20 feet of its present level (Curray, 1960; Shepard, 1960). During the last few thousand years, some parts of the barrier chain have prograded seaward by the deposition of sand on their shorefaces, whereas other parts have remained stationary or have moved landward by shoreface erosion (Dickinson, 1971; Dickinson and others, 1972). On their landward sides, the islands have prograded into the lagoons by the deposition of sand washed or blown across the islands.

The long-term progradational nature of St. Joseph and Matagorda Islands, northeast of Padre Island, is shown by the presence of parallel beach and/or foredune ridges (McGowen and Garner, 1972). Such ridges are not present on Padre Island; but their absence is not necessarily indicative of a lack of progradation, for any ridges that once existed would have been destroyed by the extensive dune movement on Padre Island. The erosional nature of the Padre Island shoreline south of Mansfield Pass is shown by a comparison of the first accurate coastal charts, surveyed in the late 1800's, and maps surveyed in the period 1948-1955. Shoreline erosion of 1000 feet in less than a century can be documented in southern Padre Island. The Gulf shoreline of central and northern Padre Island has been relatively stable. No consistently measurable changes are evident from comparisons of the first U.S. Coast and Geodetic Survey chart surveyed in 1860-1882, aerial photographs taken in 1937, and recent maps and photographs; this condition of stability extends to about the southern limit of "Big Shell" beach, 30 miles north of Mansfield Pass. The vertical uniformity of the sand body in the northern part of the island, as shown by size analysis of drill-hole samples (Dickinson, 1971), suggests a stable Gulf shoreline since the origin of the island. Minor progradation may have taken place on central Padre Island, as suggested by exposures of shell gravel, probably a beach deposit, in depressions between dunes of the foredune ridge. This progradation, however, may have occurred at any early date in the island's history, long before the growth of the present foredunes, which form essentially a single ridge.

TRAVERSE ACROSS NORTHERN PADRE ISLAND

(STOPS 1 AND 2)

By Ralph E. Hunter, Gary W. Hill
and Kendell A. Dickinson

From its northern tip to a point 3 miles south of Yarborough Pass, Padre Island has a nearly invariant series of landforms arranged in zones parallel to shore. The South Bird Island 7.5-minute quadrangle, mapped by Hunter and Dickinson (1970), is typical of northern Padre Island and will serve as the locale for a traverse across the several geomorphic zones (fig. 2). The beach, foredunes, and an active blowout dune field can be seen at stop 1. The back-island active dune field, deflation flats, and wind-tidal flats can be seen at stop 2.

SHOREFACE

The sea floor beyond wading depth will not be accessible to participants of this field trip. Indeed, it is hardly visible even to divers using SCUBA because of the high turbidity usually found in the nearshore water. However, a short description of the shoreface will be given here because its deposits form an integral part of the barrier sand body.

The shoreface is a relatively narrow, steep, concave slope which grades seaward into a much wider, gently sloping, nearly planar surface that has been called a ramp (Price, 1954a, b). On a cross section of the Texas coastal plain and continental margin, the shoreface stands out as the steepest depositional surface of regional extent landward of the continental slope (fig. 3).

The nearshore part of the shoreface can be differentiated from the offshore part by the presence of a series of bars and troughs (fig. 4).

Offshore part of shoreface. – Seaward of the outer bar, the shoreface slopes away from shore without major reversals in slope direction. The bottom sediment consists of sand that decreases in grain size and becomes more clayey seaward (fig. 5). The transitional zone between sand and mud occurs on the lower part of the shoreface, at a depth of 45 to 50 feet. Mud and sand are thinly interbedded in the transitional zone, but burrowing organisms have partially mixed the sediments, thus producing mottled structures. The shell content of the sand is low, averaging only 0.8 percent.

The sand surface is rippled to the maximum water depth at which sand occurs on this part of the shelf. Starfish, sea pansies (*Renilla* sp.), sand dollars (*Mellita quinquiesperforata*), and polychaete worms are the most common benthonic species. Some faint bedding is present but, in general, the sand is nearly structureless because of intense bioturbation.

Nearshore bar-and-trough system. – North of the shell beaches on Padre Island, the nearshore part of the shoreface consists typically of a series of three bars and intervening troughs (fig. 4) whose contours are almost perfectly parallel to shore. Farther south, the bars are more commonly discontinuous and irregular in plan view, and the shoreline is marked by giant cusps. At times the bars are arranged en echelon, meeting the shoreline at very acute angles.

Bars of the type found along the Texas coast have commonly been called break-point bars, because waves break while passing over the bars. However, it is not clear whether breaking waves are directly responsible for the origin of such bars, as suggested by some wave-tank experiments (Keulegan, 1948; King and Williams, 1949; McKee and Sterrett, 1961), or whether the bars grow in response to hydrodynamic processes not directly related to breaking waves. The question is difficult to investigate in nature because the bars are equilibrium forms, moving back and forth with changing wave conditions but seldom growing from a previously planar bottom. However the bars originate, their maintenance as stable forms implies that sand must be carried seaward across the bars in amounts large enough to balance the amount carried landward by wave surge. How this equilibrium is achieved is a question more amenable to study than the question of bar origin, but a thoroughly satisfactory answer is not yet at hand.

Three kinds of sedimentary structures produced by waves and currents have been found in the bar-and-trough system of northern Padre Island. The most common

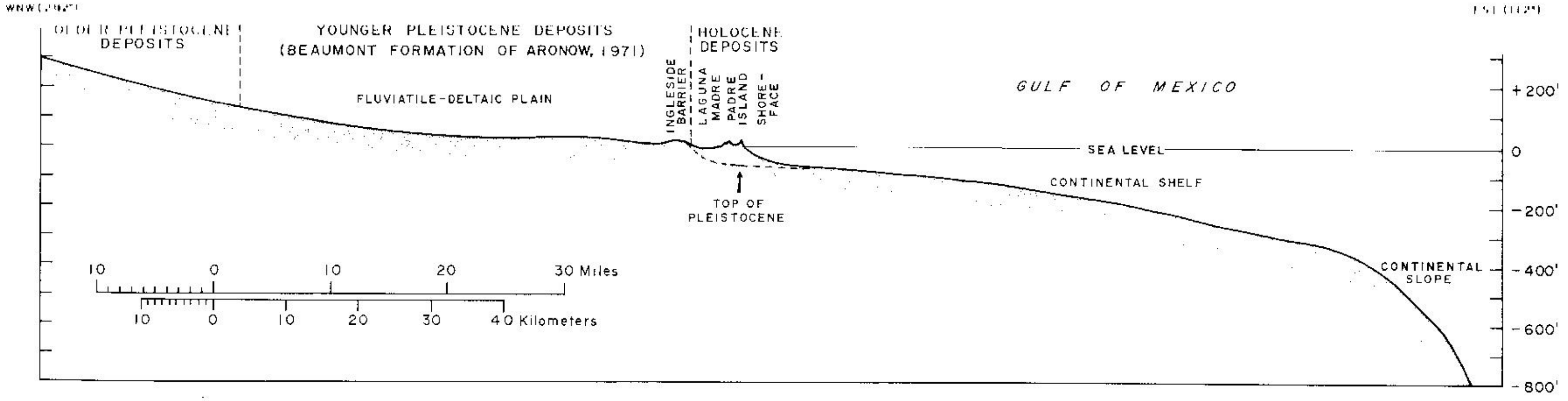


Fig. 3. – Cross section of part of Texas coastal plain and continental margin. The line of section is normal to shore, crossing the shoreline in the South Bird Island 7.5-minute quadrangle, near stop 2 of this field trip (See fig. 1). The thickness of Holocene deposits on the continental shelf is poorly known.

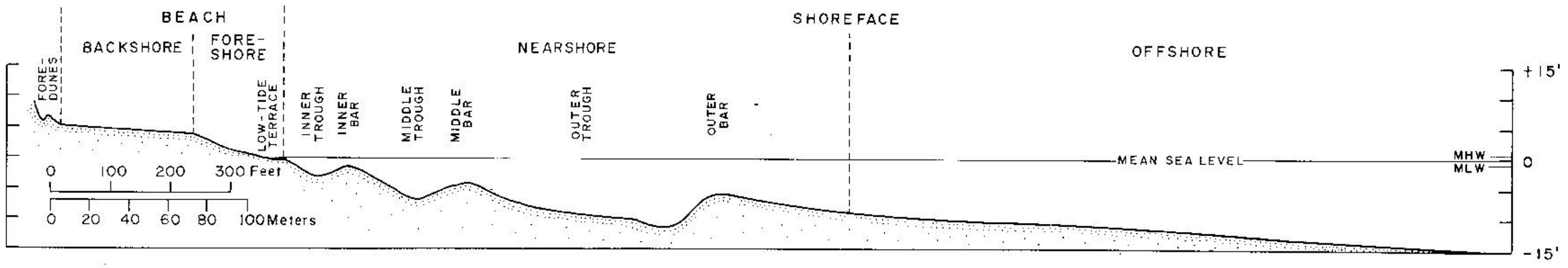


Fig. 4. – Profile of beach and shoreface. The morphology is typical of northern Padre Island during summer conditions. An ephemeral bar and runnel commonly replace the low-tide terrace. The part of the profile beyond wading depth was measured by fathometer.

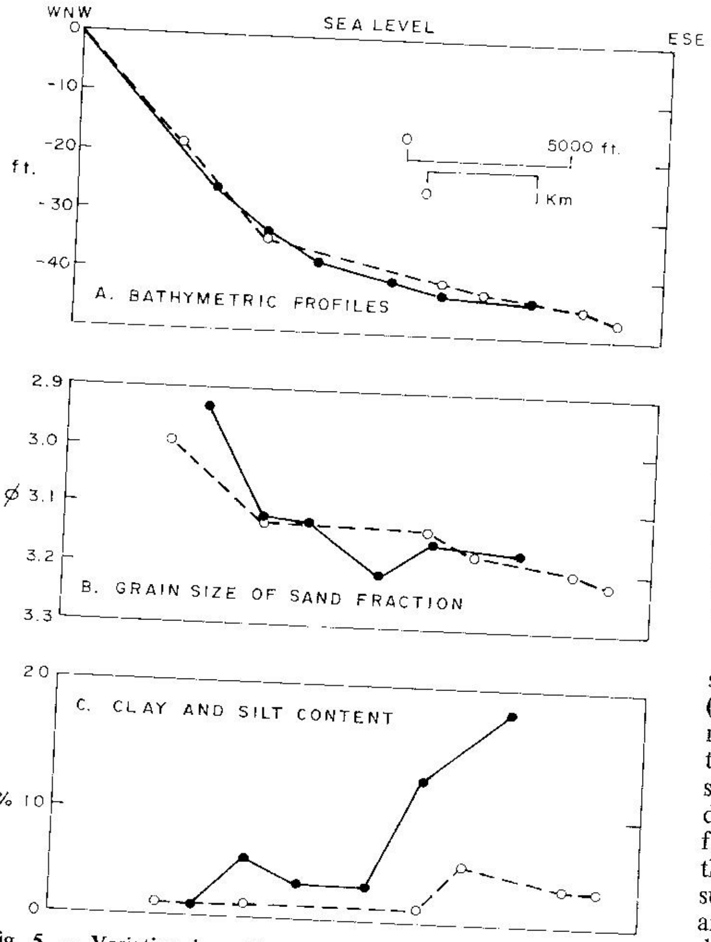


Fig. 5. – Variation in sediment texture across the shoreface of northern Padre Island. The two lines of samples are in the South Bird Island 7.5-minute quadrangle.

bedform is sand ripples. They tend to be aligned parallel to wave crests, are less than 2 cm in height, and are spaced 5 to 15 cm apart. Ripples in the troughs tend to be irregular in plan view, whereas those near the bar crests are straighter, lower, and more active in their response to wave surge. The internal structure produced by deposition on the rippled surfaces is small-scale lenticular crossbedding, usually without any well-defined preferred orientation of dip direction (fig. 6A). Whenever the waves are high enough to break on the bars, the bar crests are planar, and planar lamination is produced in the sand (fig. 6B). Whenever strong longshore currents flow in the troughs, megaripples ranging from 10 to 60 cm or more in height are formed. The internal structure produced by the migrating megaripples is medium-scale (units 4 to 100 cm thick) crossbedding that dips in the direction of the current (fig. 6C, D).

Current-produced sedimentary structures in the nearshore tend to be destroyed by burrowing animals. The burrowers can be divided into two broad groups based on gross burrow orientation. Species that produce deep vertical burrows are dominant in the inner nearshore, whereas species that burrow horizontally are more common in the outer nearshore. Ghost shrimp (*Callianassa*), which construct deep vertical burrows, are the dominant burrowing species throughout the nearshore. Sand dollars (*Mellita quinquiesperforata*), which burrow horizontally (fig. 7A), are abundant seaward of the middle bar. Common but less conspicuous horizontal burrowers and surface crawlers include the olive shells (*Oliva sayana, Olivella mutica*), moon shells (*Polinices duplicatus*) and auger shells (*Terebra cinerea*). Brittle stars and a variety of polychaetes produce burrows with both vertical and horizontal components (fig. 7B).

BEACH (STOP 1)

The form of the beach varies with changing wave conditions. Hurricanes and other severe storms produce especially striking changes, eroding the beach to a gently sloping planar surface (Hayes, 1967). The sand eroded from the beach during such storms is deposited in nearshore areas and is gradually carried back to the beach by normal wave activity. In its normal condition, the beach is made up of a nearly flat backshore, which, after its full development, is above the realm of normal wave activity, and a seaward-sloping foreshore washed daily by waves (fig. 4). A terrace near the low-tide line commonly separates the foreshore from the inner trough, although this terrace is often replaced by an ephemeral bar and runnel.

The dominant internal structure of the beach is gently seaward-dipping planar lamination produced by wave swash (McKee, 1957; Milling and Behrens, 1966). As in the nearshore, however, burrowing organisms tend to destroy the primary structures and form their own distinctive structures. The ghost crab (*Ocypode quadrata*) is the dominant burrowing species on the backshore and upper foreshore. Variations in the areal density, size, and shape of the ghost crab burrows (fig. 8) can be used to define subenvironments of the beach (Frey and Mayou, 1971; Hill and Hunter, unpub. manuscript). The lower foreshore is dominated by the deep burrows of the ghost shrimp (*Callianassa islagrande*) (figs. 7C and 9). Within and especially between these two populations can be found large numbers of polychaetes (particularly *Heteromastis* sp.), mole crabs (*Lepidopa* sp., *Emerita* sp.), auger shells (*Terebra cinerea*), and the coquina clam (*Donax* sp.), which produce a variety of burrows (fig. 7C, D).

FOREDUNES (STOP 1)

Landward of the beach along most of northern Padre Island is a hummocky ridge of vegetated dunes, the foredunes, composed of sand blown from the beach by onshore winds. It is not definitely known whether the foredunes grew to essentially their present size before being stabilized by vegetation or whether vegetation was present from the very beginning of foredune development and was

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Fig. 6. – Sedimentary structures, produced largely by waves and currents, in the nearshore bar-and-trough system, northern Padre Island. The cores are 13 cm wide.

A. – X-radiograph of box-core peel from inner trough. Small-scale crossbedding formed by migration of ripples; down-bowing of bedding at edges of peel is artificial. B.– Box-core peel from inner bar. Planar bedding formed by deposition on planar bar crest; note vertical burrows. C.– X-radiograph of box-core peel from inner trough. Medium-scale crossbedding formed by migration of megaripples; the crossbedding dips northward, in the direction of the longshore current. D.– Box-core peel from middle trough. Small-scale crossbedding at top of section formed by migration of ripples, as in fig. 6A; planar bedding in middle may have formed by deposition on megaripple crest; crossbedding at base probably formed by migration of megaripple, as in fig. 6C.

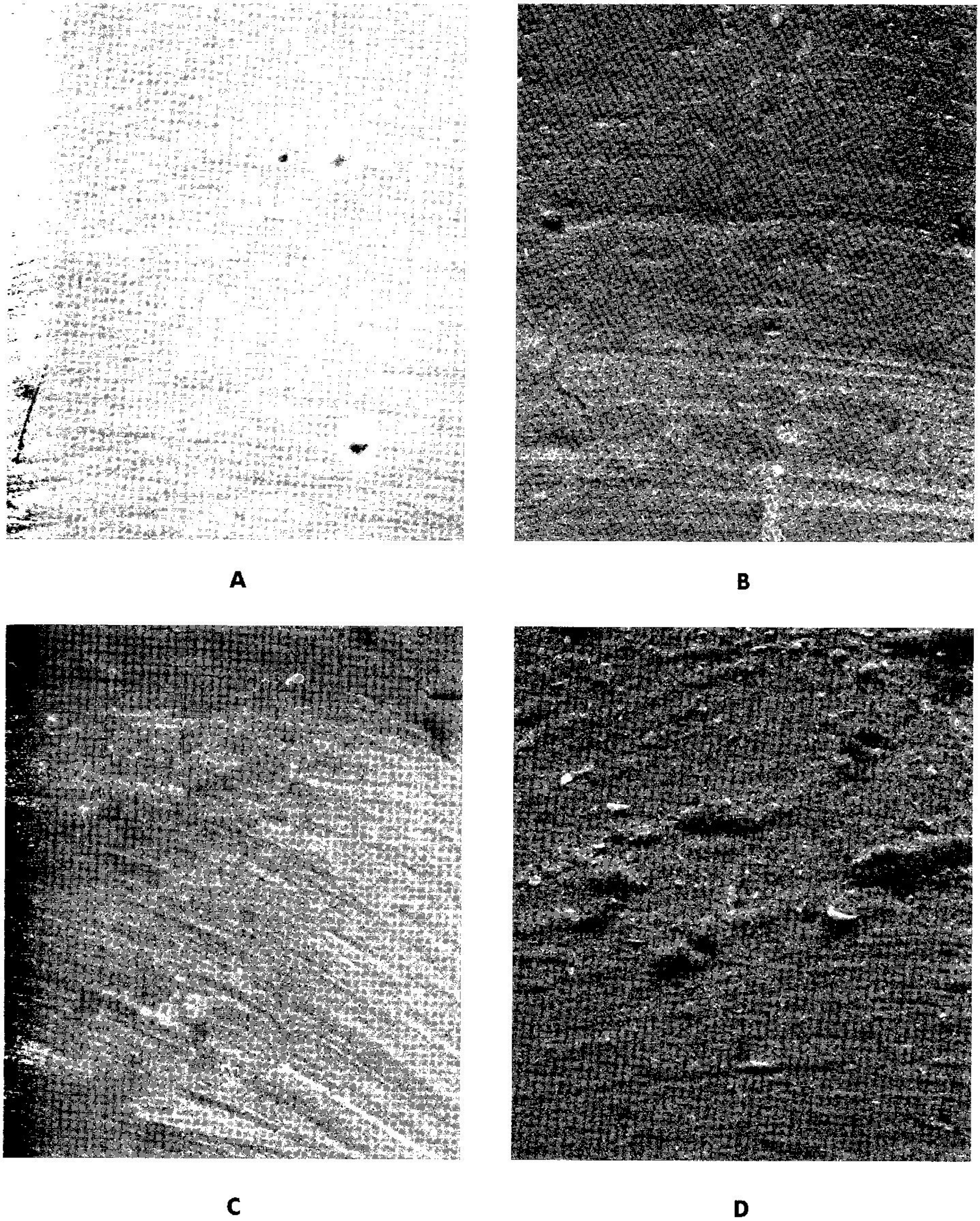

Figure 6

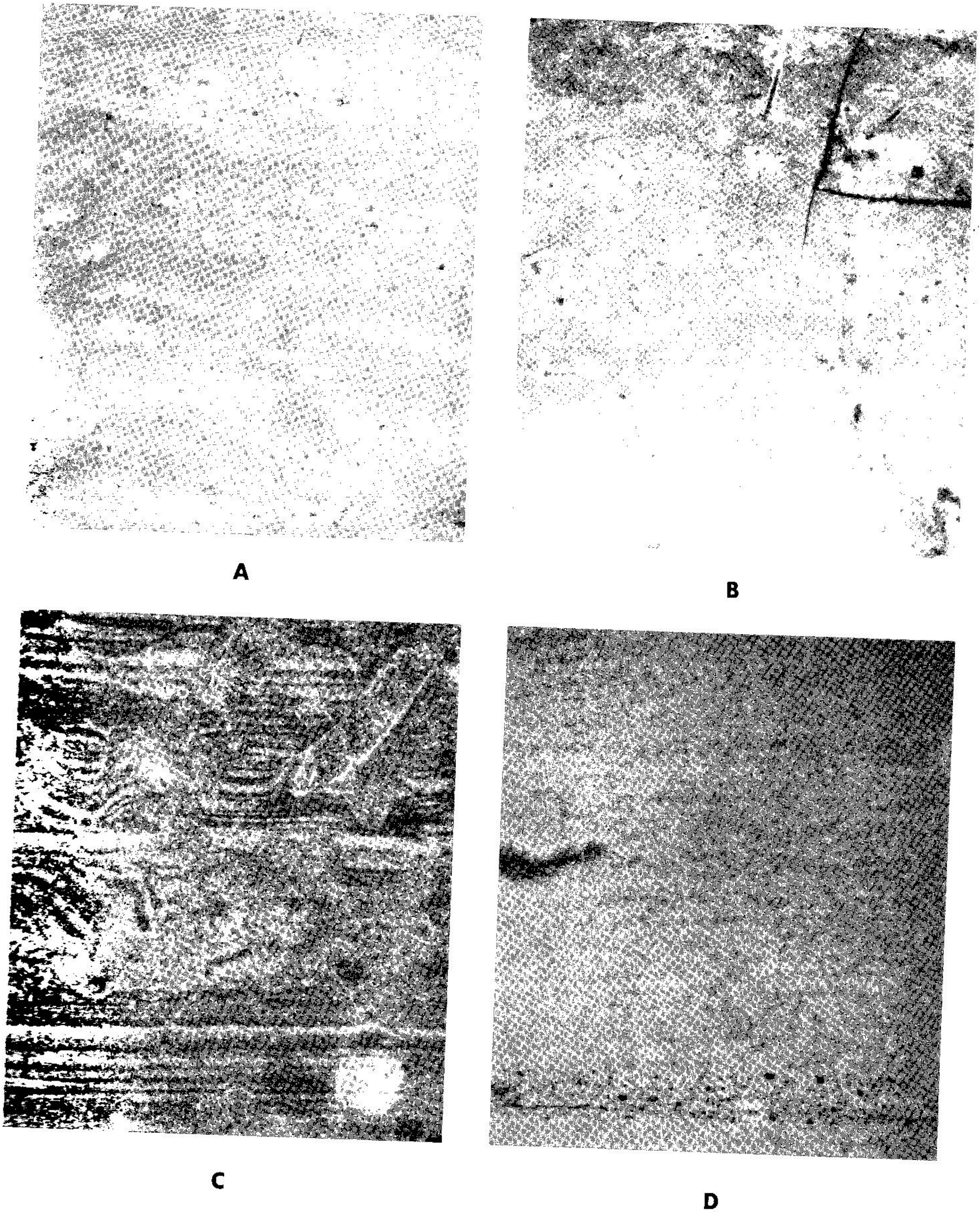

Figure 7

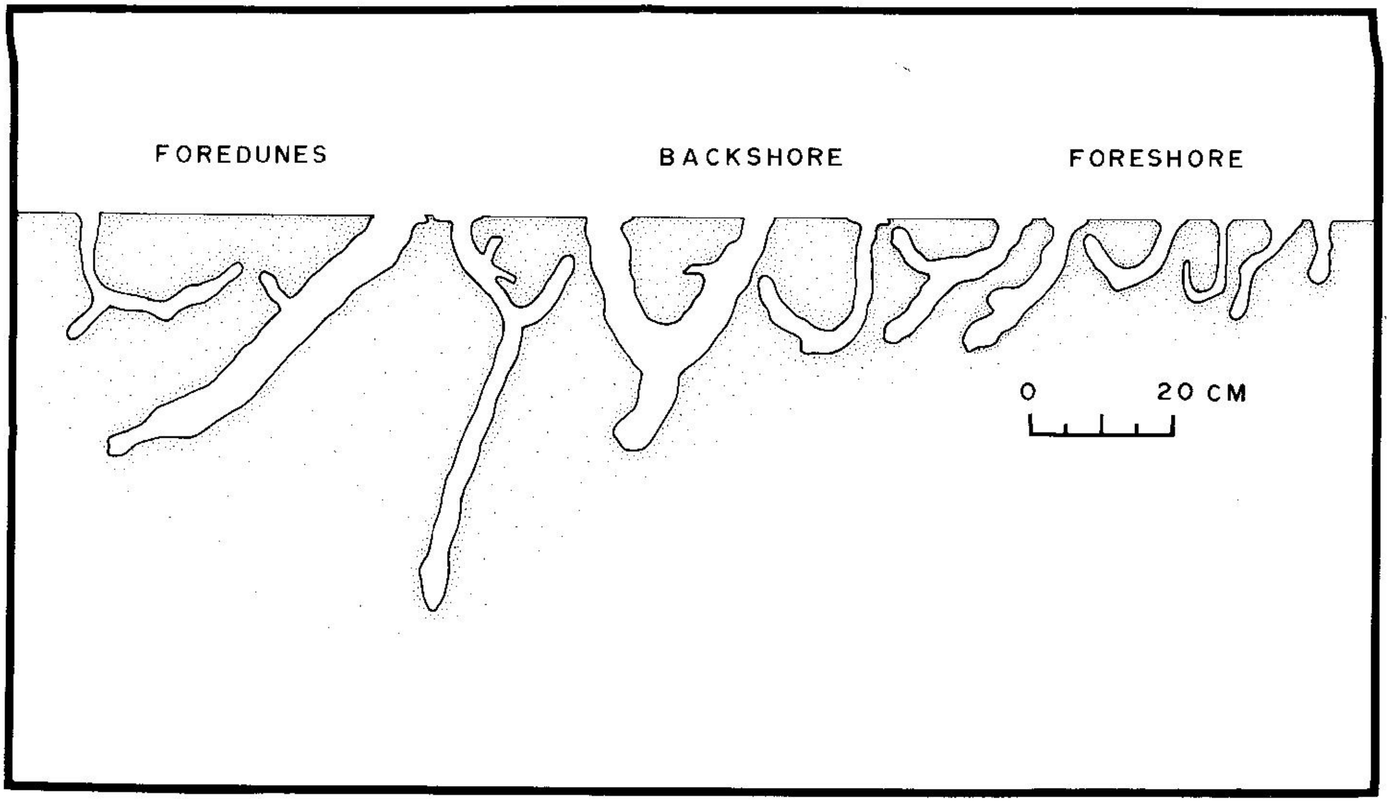

Fig. 8.– Representative ghost crab (*Ocypode quadrata*) burrows of a beach cross section, northern Padre Island (Hill and Hunter, unpub. manuscript).

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directly responsible for trapping and binding the sand making up the dunes. Although the foredunes may have had less vegetative cover in the earlier stages of their development, it seems evident that they soon had enough vegetation to prevent them from migrating inland. Where the vegetative cover has been locally destroyed by drought, fire, overgrazing, or other disturbances by man, the dunes have been transformed into actively migrating forms that move inland and are thus no longer foredunes.

The dominant internal structure of the foredunes is medium-scale crossbedding. It dips predominantly in the downwind quadrant (northwestward), but two dip-direction modes are present, at angles to either side of the yearly resultant wind direction (McBride and Hayes, 1962; fig. 10B, F). This bimodality is related to the shapes of the foredunes; the individual mounds making up the foredune ridge typically have pointed or lobate leeward projections (fig. 10A), and as sand is deposited on the side slopes of these projections, bimodal crossbedding is produced. These leeward projections form in two ways, as wind-shadow accumulations leeward of vegetated dune mounds (Hayes, 1967) and as blowout dunes, which in plan view are typically parabolic and convex in the downwind direction.

Several kinds of biogenic structures occur in the foredunes. Most common is indistinct irregular bedding formed by the accumulation of sand around plants; bedding irregularity may also be produced by the growth and decay of plant roots. Several species of animals are responsible for a variety of burrows to be found in the foredunes. The ghost crab (*Ocypode quadrata*) is common, especially on the lightly vegetated seaward slope of the dune ridge. Other animals that excavate or utilize burrows in the foredunes include a variety of snakes, lizards, and rodents.

ACTIVE DUNE FIELDS (STOPS 1 and 2)

The dunes actively migrating across northern Padre Island at present have originated almost entirely by the devegetation of once-stabilized dunes. In a dry period beginning in 1948, for example, previously existing and newly formed small blowouts in the foredune ridge were greatly enlarged and began moving downwind (northwestward) (fig. 11). As long as the blowouts were connected to the beach by unvegetated sand, sand blown from the beach must have been added to the active dunes. In a few years, however, most of the blowout dune fields became separated from the beach by the formation of a vegetated foredune ridge and by newly vegetated deflation flats left behind the moving dunes. Very little if any sand is

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Fig. 7. – Sedimentary structures, produced largely by burrowing organisms, in the nearshore bar-and-trough system and beach, northern Padre Island. The cores are 13 cm wide. A.– X-radiograph of box-core peel from outer bar. Abundant horizontal burrows in shelly sand, probably produced by sand dollars; original bedding largely destroyed. B.– X-radiograph of box-core peel from outer trough. Vertical and curved polychaete worm tubes, together with other burrows; original bedding largely destroyed; cracks are artificial. C.– X-radiograph of box-core peel from low-tide terrace. *Callianassa* burrow defined by cemented wall, other irregularly shaped burrows, and intensely bioturbated interval between intervals with partially preserved bedding; the planar bedding was formed by wash swash. D.– X-radiograph of box-core peel from backshore. Sand intensely bioturbated by small burrowing organisms, either polychaete worms or burrowing insects; note porous interval near base and remnant bedding.

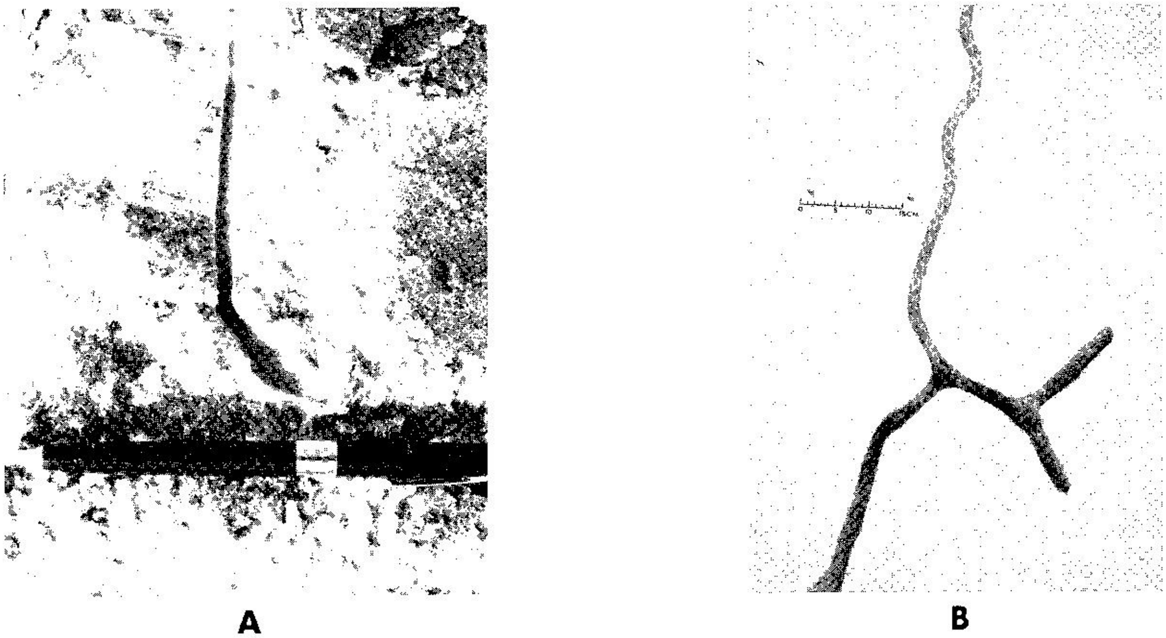


Fig. 9. – Burrows of the ghost shrimp (*Callianassa islagrande*). A.– Narrow, upper section of burrow and its junction with larger, main section. B.– Cast of main section of burrow. The large knob at top of burrow cast is artificial.

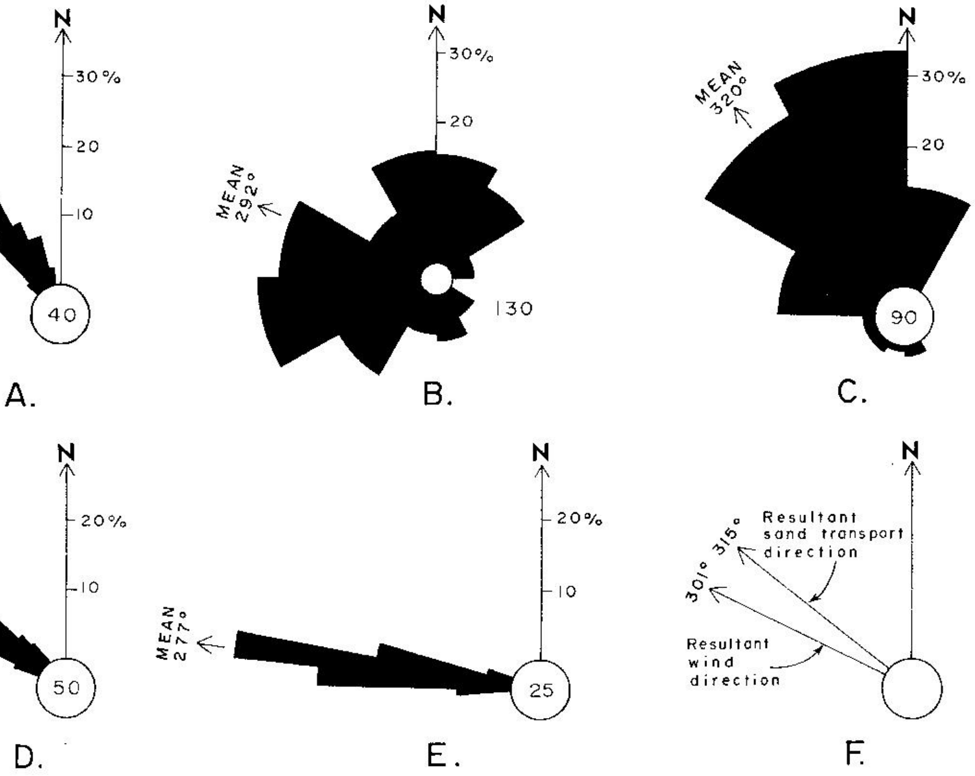


Fig. 10. – Rose diagrams showing orientations of wind-formed features. Measurements were made in the South Bird Island 7.5-minute quadrangle unless otherwise noted; number of measurements indicated within central circle of diagram. A.– Directions of elongation of blowouts, blowout dunes, and wind-shadow drifts in the foredunes; measurements from aerial photographs. B.– Dip directions of crossbedding in the foredunes, Mustang Island, Texas (McBride and Hayes, 1962). C.– Dip directions of crossbedding in the basal few feet of the back-island dune field. D.– Directions of migration of distinctive reentrants and salients in the blowout and back-island dune fields; measurements from aerial photographs. E.– Trends of large oblique dunes in the back-island dune field; measurements from aerial photographs. F.– Resultant wind and sand transport directions calculated from wind data collected during 1951-1960 at Corpus Christi. The relative sand transporting power in a given direction, Q, was calculated from the equation $Q = N(V-v)^3$, where N is the proportion of all wind observations that are in the given direction, V is the mean wind speed from the given direction, and v is the threshold wind velocity, here taken as 10 miles per hour (Boker, 1956).

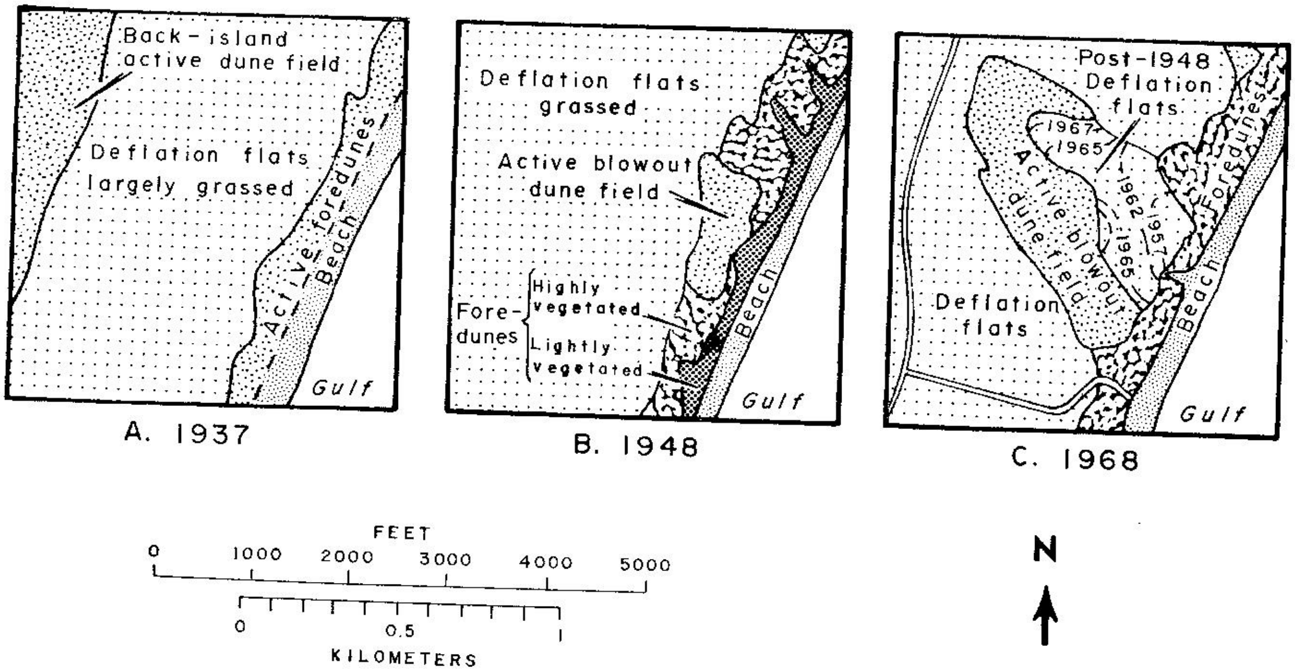


Fig. 11. – Development of a typical blowout dune field, northern Padre Island. The field illustrated is in the vicinity of the beach access road near the north end of Padre Island National Seashore, South Bird Island 7.5-minute quadrangle (Hunter and Dickinson, 1970) and is the locale for STOP 1 of this field trip.

blown across these vegetated areas, and the blowout dune fields have continued to move without further addition of sand except by the engulfment of vegetated dunes in their path. On southern Padre Island, in contrast, the active dunes are periodically supplied with sand washed across the island during hurricanes (Hayes, 1967).

A period of dune activation more widespread than that beginning in 1948 took place in the late 1800's. Although this dune activation was related to several severe droughts, overgrazing was another factor probably responsible for devegetation of the dunes (Price and Gunter, 1943). The vegetated dunes that existed in the central and seaward zones of the island before this period of activation have since moved northwestward across the island to form the present back-island active dune field (figs. 2, 10D, and 12).

The active dune fields contain a variety of dune types, best exemplified in the large back-island dune field. Transverse and barchan dunes less than 10 feet high are readily formed by a few weeks of moderate to strong winds from the southeast. These dunes, typical of summer conditions, are greatly modified by the occasional strong northerly winds of winter. The only dunes that persist throughout the year are large dunes elongated in an east-west direction (fig. 13). These dunes, which are not parallel to either of the two dominant seasonal components of the annual wind distribution, are of the type that has been called "oblique dunes" on the Oregon coast (Cooper, 1958). Although these dunes were earlier interpreted as being longitudinal in the sense of being elongated parallel to the yearly sand transport direction (Hunter and Dickinson, 1970), more comprehensive wind data suggest that they are oriented obliquely to this direction (fig. 10E, F) as well as to the seasonal components. The orientation of these dunes may owe its stability to the fact that it is parallel to one arm of the summer barchan dunes and is transverse to the northerly winter winds (Price, 1958, p. 53-54).

The internal structures of the dunes are occasionally well exposed on broad wind-scoured horizontal surfaces. These exposures are formed by wind scour after the dunes have been thoroughly wetted by heavy rains; similar surfaces are preserved in ancient dune deposits (Stokes, 1968). The internal structure of a barchan dune, as exposed on one of these wind-scoured surfaces, is illustrated in figure 14. The eolian crossbedding exposed on these surfaces dips unimodally to the northwest, approximately in the resultant sand-transport direction calculated from wind data (fig. 10C, F).

Three major kinds and one transitional kind of eolian stratification can be recognized in the dune deposits (Table 2). Each of the major types forms on one of three kinds of depositional surfaces that occur in dune fields: rippled surfaces, smooth leeward-sloping surfaces, and slipfaces marked by sand avalanches (fig. 15). Each of the types can be recognized by the distinctness of the contacts, thickness, regularity, internal grading, packing, and dip angle of the strata (Table 2 and fig. 16). Any of these stratification types can be deformed by the slumping of coherent sand masses down dune slipfaces (fig. 15D); the resultant deformational structures have been described by McKee and others (1971).

Biogenic structures are less common in the active dune deposits than in the other deposits of Padre Island. However, burrowing insects are present in the dune fields.

DEFLATION FLATS (STOP 2)

The low areas left behind the migrating dune fields may be called deflation flats, as they form by deflation of the

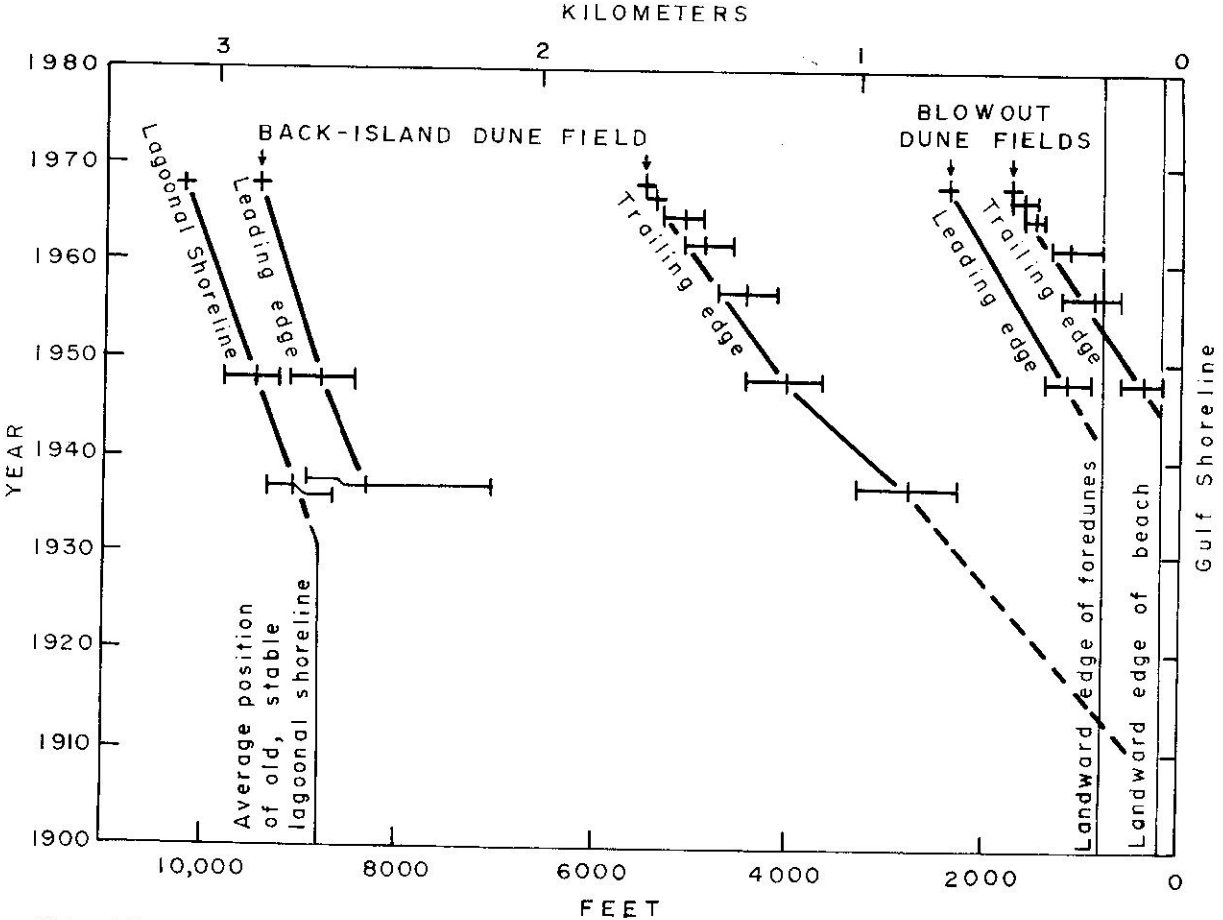


Fig. 12. – Rate of lagoonal shoreline progradation and rates of movement of active dune fields across Padre Island, South Bird Island 7.5-minute quadrangle. The measurements of distance from the Gulf of Mexico shoreline were adjusted so that the 1968 position of a given feature at a given measurement point was the average position of the type of feature measured. The horizontal bars show the range in measurements at different points in the quadrangle.

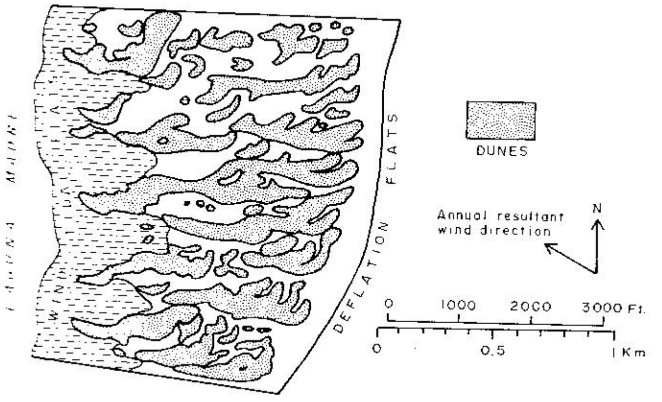


Fig. 13. – Distribution of dunes in a typical area of the back-island active dune field, South Bird Island 7.5-minute quadrangle. Interpreted from aerial photograph taken in September 1968. The large dunes trending east-west are oblique dunes. The unpatterned areas between the dunes are interdune flats.

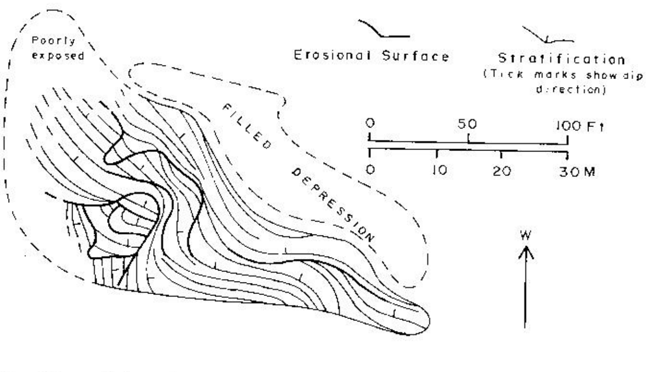


Fig. 14. – Internal structure of a barchan dune, as exposed on a horizontal wind-scoured surface in the back-island active dune field, South Bird Island 7.5-minute quadrangle.

TABLE 2. – Characteristics of structural types of eolian stratification.

Structural type of stratification	Type of depositional surface	Place of origin in dune fields	Dip angle	Thickness of strata; sharpness of contacts	Grain segregation and size grading	Packing	Form of strata
Climbing wind-ripple stratification	Rippled	Windward slopes, low-angle leeward slopes, flats	Low: typ. 0-20° max. 25°	Thin: typ. 2-3 mm; sharp	Distinct, inverse	Close	Tabular
Climbing wind-ripple pseudostratification[1]	Rippled	Leeward slopes	Intermediate: typ. 15-25°	Fairly thin; gradational[2]	Fairly distinct, inverse[2]	Close to intermediate	Tabular[2]
				Thin; gradational[3]	Indistinct, variable[3]		Wavy tabular[3]
Parallel stratification	Smooth	Leeward slopes	Intermediate: typ. 20-30° max. 36°	Thin where well exposed; gradational	Indistinct, variable	Intermediate	Tabular
Sand-flow cross-stratification[4]	Avalanched	Slipfaces	High: typ. 28-34°	Thick: typ. 2-5 cm; sharp	Distinct, inverse[5]	Open	Tongue shaped to roughly tabular

[1] The pseudostratification is accompanied by wavy parallel stratification. The pseudostratification is defined by the lines joining successive positions of ripple crests.

[2] Refers to the pseudostratification component of the structure.

[3] Refers to the wavy parallel stratification component of the structure.

[4] Slumping, another form of avalanching on slipfaces, does not produce a new type of stratification but, rather, deforms the original stratification.

[5] Distinct grain segregation occurs only near the basal contact; the bulk of the cross stratum is nearly structureless. Normal grading may occur near the toe of the cross stratum.

sand making up the dunes. However, they are not perfectly flat but rather are marked by a series of low ridges and troughs formed by dune migration during alternating wet and dry periods, in a manner shown in figure 17. Small dune mounds and larger ridges aligned longitudinally to the direction of sand transport were also left behind the moving dune fields because of stabilization by vegetation.

As the deflation flats are essentially erosional surfaces, the sand underlying these flats is perhaps the oldest sand exposed on northern Padre Island. It differs from the other, younger sands in being slightly coarser, a feature probably indicative of a southern source (Dickinson, 1971). In many parts of the deflation flats, this older sand is probably covered by a thin veneer of more recent eolian sand. Muddy sand rich in algal remains has been deposited in the intermittently flooded depressions.

The sand underlying the deflation flats is nearly structureless, probably because it has been thoroughly mixed by the growth and decay of plant roots and by burrowing animals. Animals that burrow or utilize burrows in the deflation flats include the pocket gophers, ground squirrels, mice, snakes, and a variety of small insects.

WIND-TIDAL FLATS (STOP 2)

The lagoonal margin of Padre Island is marked by flats that are occasionally covered by the waters of Laguna Madre. The variations in water level in Laguna Madre are not primarily due to astronomical tides but rather to wind-set-up tides, in which wind pushes water into, out of, or against one side of the lagoon (Rusnak, 1960; Hayes, 1967). The most drastic flooding of the flats is produced by the storm surges and heavy rains accompanying hurricanes.

The wind-tidal flats of northern Padre Island are underlain largely by sand blown or washed from the back-island dune field. Only the upper couple of feet of sand was deposited on surfaces similar to the present flats.

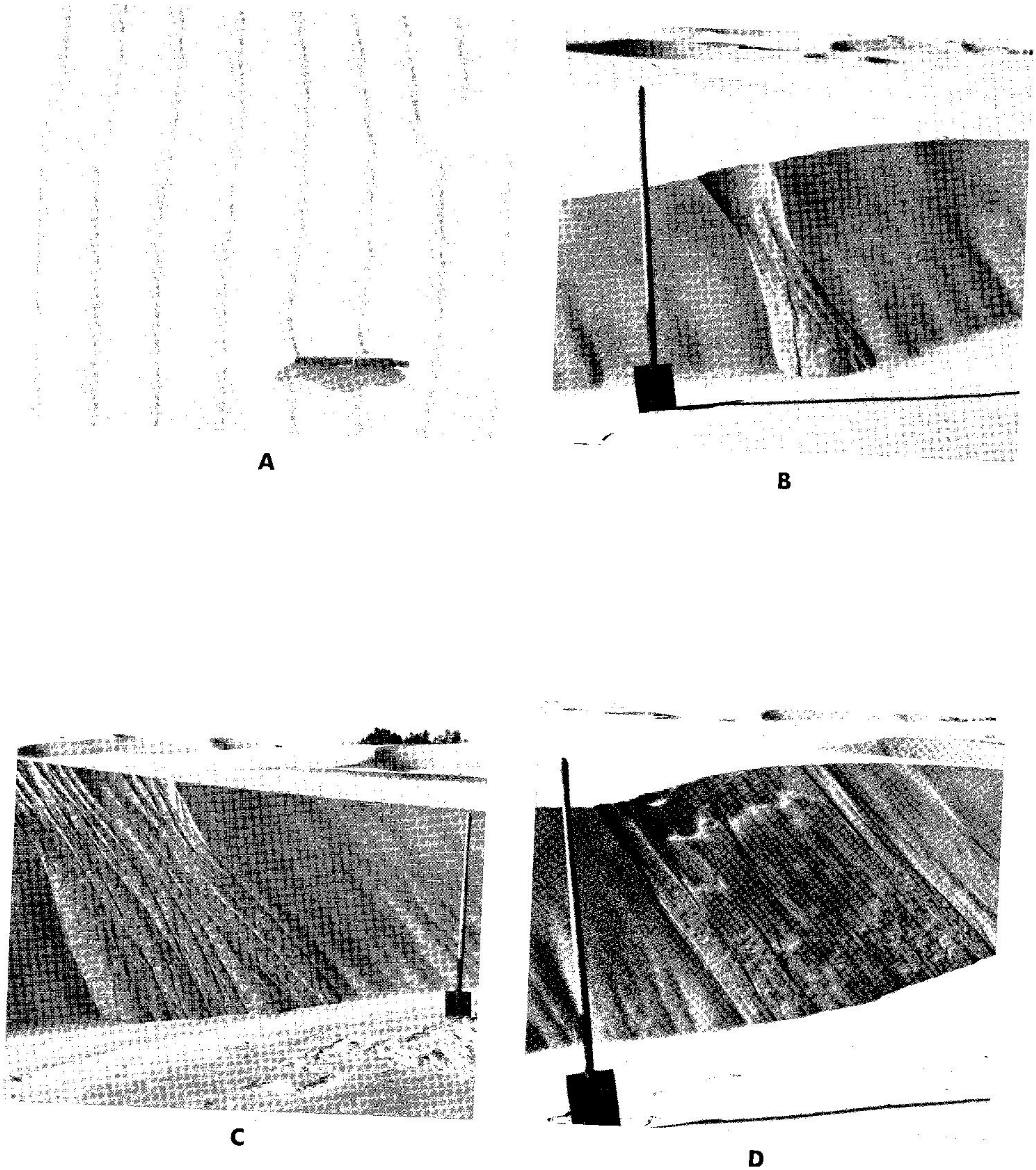


Fig. 15. – Types of depositional surfaces in dune fields. A.– Wind ripples. Although wind ripples in dune fields occur on both windward-facing and leeward-facing slopes, the leeward-facing slopes are much more likely to be depositional surfaces. B.– Slipface marked by a sand flow, a type of avalanche in which the grains move relatively to each other. Note that portions of the slipface are smooth; here, sand has fallen onto the surface but has not undergone further movement by avalanching. C.– Slipface marked by a composite sand flow. On relatively high slipfaces such as this, an initial sand flow triggers other flows along its margins, leading to a composite flow. D.– Slipface marked by slumps with subsidiary sand flows. A slump is a type of avalanche in which a sediment mass moves as a unit along a shear surface at the base of the mass.

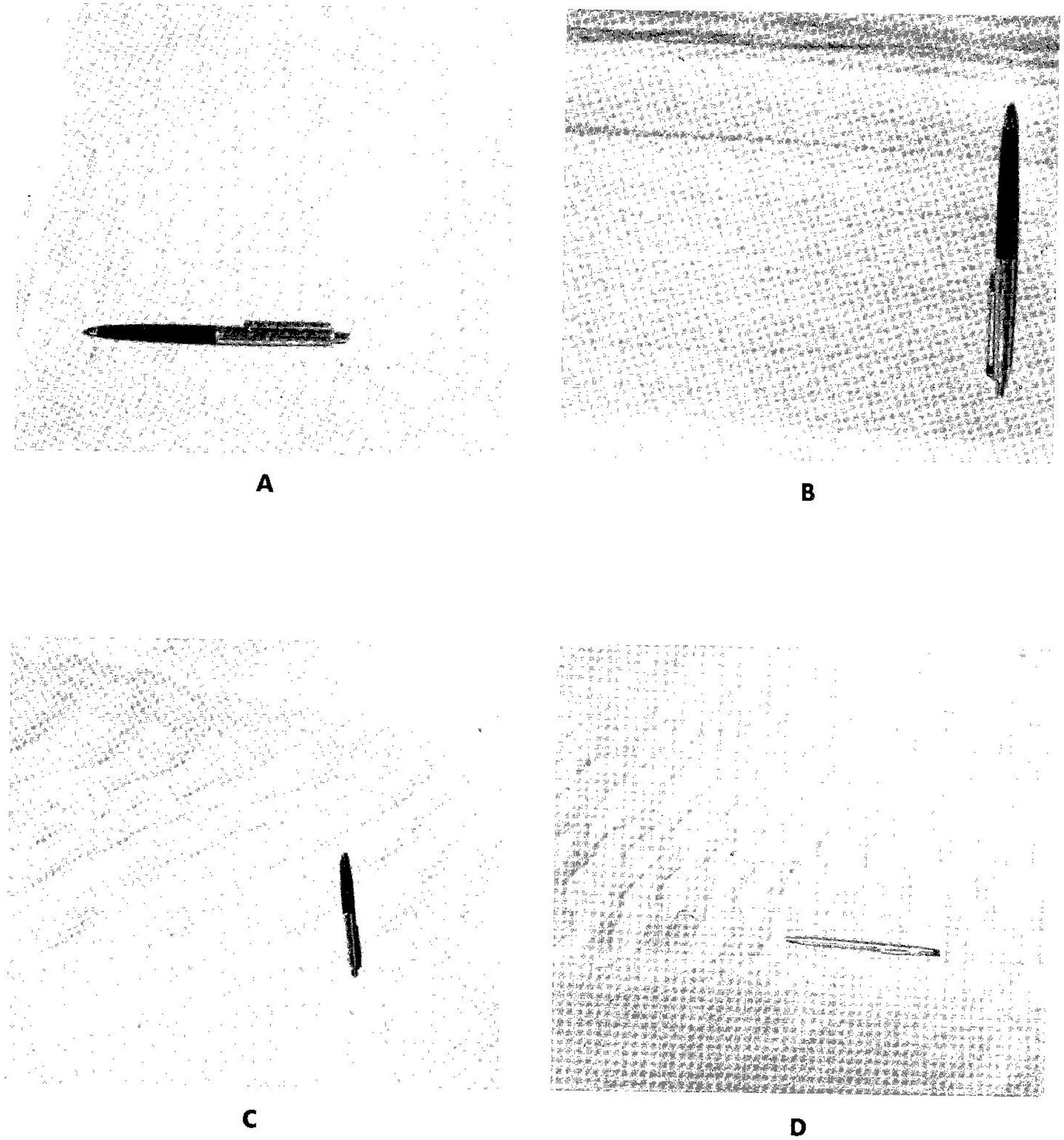
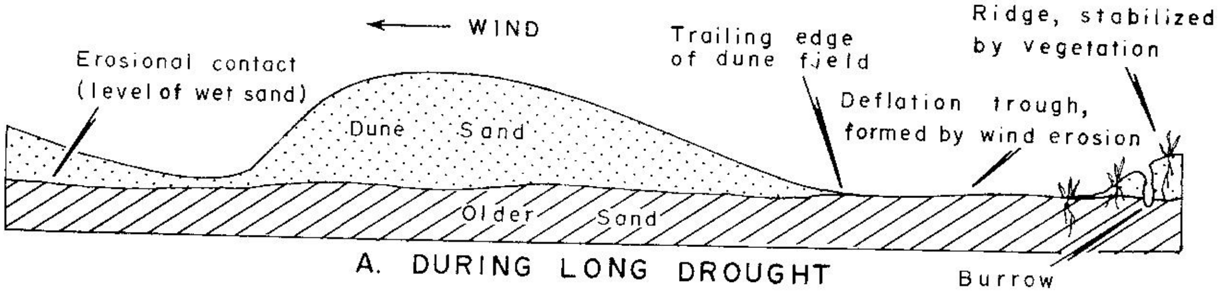
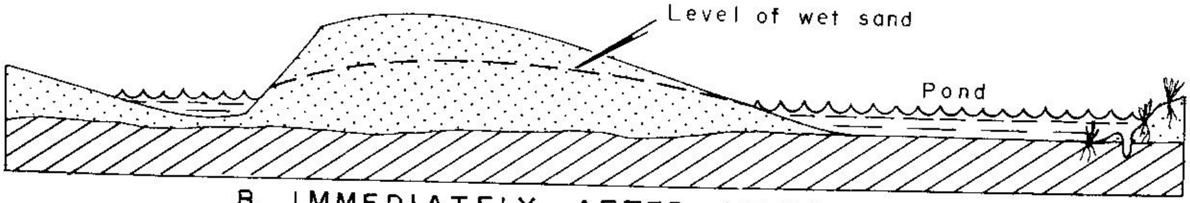


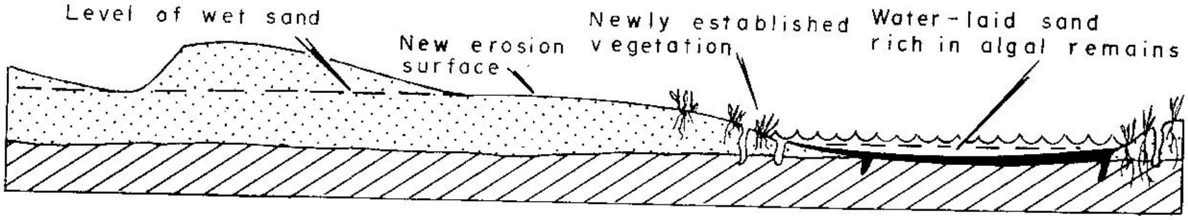
Fig. 16. – Structural types of stratification in dune sands. A.– Stratification formed by climbing wind ripples, exposed on a horizontal wind-scoured surface and on a vertical trench face. Each layer was produced by a single wind ripple that climbed at a low angle, or migrated across a surface on which relatively slow deposition was taking place. Note that ripple foresets within the layers are not visible. B.– Parallel stratification exposed on a horizontal wind-scoured surface; the stratification dips toward the top of the photo. This type of stratification is formed by sand falling on a smooth surface, such as occurs in the wind shadow leeward of a dune crest. C.– A type of stratification transitional between the types shown in A and B, exposed on a horizontal wind-scoured surface; the stratification dips toward the top of the photo. This type of stratification is formed when wind ripples climb at a high angle, or migrate across a surface on which relatively rapid deposition is taking place. Two components coexist in this structure: (1) pseudo-stratification defined by successive positions of individual wind ripples, and (2) wavy parallel stratification defining successive positions of the rippled depositional surface. D.– Sand-flow cross-stratification, exposed on a horizontal wind-scoured surface and in a vertical trench face. The light-colored lenses on the horizontal surface are cross sections through the toes of tongue shaped sand flows such as those shown in figure 15B.



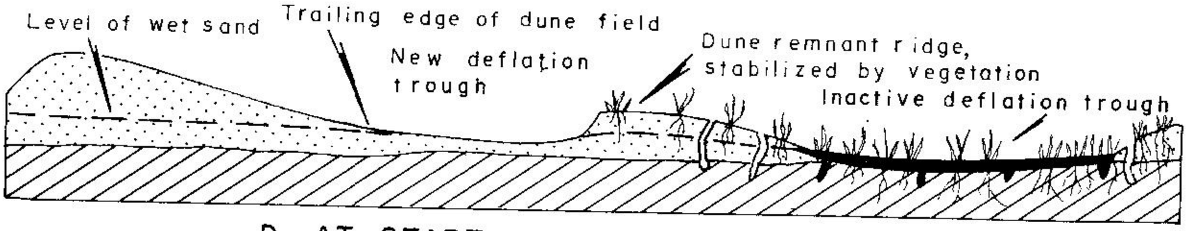
A. DURING LONG DROUGHT



B. IMMEDIATELY AFTER HEAVY RAIN



C. DURING LONG WET PERIOD



D. AT START OF ANOTHER DROUGHT

Fig. 17. – Schematic cross sections across the trailing edge of the back-island active dune field, illustrating the manner in which low ridges and troughs are formed in the deflation flats. The troughs are eroded down to the level of wet sand during droughts, while the ridges are stabilized by vegetation that invades the edge of the dune field during wet periods.

Below that and down to a depth of about 5 feet, the sand was deposited subaqueously on a relatively steep slope that formed the eastern edge of Laguna Madre and gradually prograded westward into the lagoon. Below a depth of about 5 feet is a mud bed which probably formed the floor of Laguna Madre before the back-island dune field began encroaching on the lagoon. Thin mud layers rich in algal remains occur throughout the sand section; one such layer was deposited as an aftermath of Hurricane Beulah in 1967, when the flats were extensively flooded by very turbid water.

LAGUNA MADRE

Like the Gulf shoreface of the island, the sediments of Laguna Madre will not be accessible to participants of this field trip, but a short description is included because of the intimate association of the island and lagoon. Laguna Madre is a shallow water body whose northern part has a maximum water dpeth of 8 feet. The thickness of Holocene deposits in northern Laguna Madre is about 20 feet. If it is assumed that deposition in the lagoon began about 5,000 years ago, the rate of vertical infilling has been about 0.4 foot per 100 years (Rusnak, 1960). Lateral infilling by dune migration from Padre Island has been much more rapid, at a rate of about 35 feet per year since 1948 (fig. 12).

The bottom sediment of northern Laguna Madre consists of muddy shelly sand which contains Foraminifera, plant fragments, coated grains, and polychaete worm tubes. The mean grain size of the sand fraction averages 2.6 ϕ, only slightly finer than the 2.5 ϕ average of Padre Island sands. Among dead whole shells in the bottom sediment, *Anomalocardia cuneimeris* and *Mulinia lateralis* are dominant, being present in all samples and averaging 89 and 6 percent, respectively. Other species present in amounts greater than 1 percent in one or more samples are the pelecypods *Tellina tampaensis, Macoma tenta*, and *Laevicardium mortoni*, and the gastropods *Cerithium variabile, Retusa canaliculata, Turbonilla interupta, Acteon punctostriata*, and *Crepidula fornicata*.

Despite the digging of the intracoastal waterway, which disrupted the depositional patterns in Laguna Madre in 1949, certain patterns of sedimentation are still visible or have become visible again (fig. 18). Sediments are coarser, and a lower diversity of invertebrate fauna is present on the mainland side of the lagoon. The clay and silt fraction is greater on the island side, and the shell fraction (coarser sediment) is greater on the landward side. These depositional patterns are apparently related to wind-produced energy levels, which are greater on the mainland side because the predominant wind direction is from the southeast in Laguna Madre, and the waves on the mainland side of the lagoon have greater fetch.

LONGSHORE VARIATIONS IN BEACH SEDIMENT AND ORIGIN OF THE SHELL BEACHES (STOPS 3, 4, AND 5)

By Richard L. Watson

Central Padre Island, Texas, is the site of beaches that are composed of as much as 80 percent shells and shell fragments. This zone of shell accumulation is in the center of a major terrigenous province, and it coincides with the location of a postulated convergence of nearshore Gulf of Mexico currents and littoral drift.

Numerous outcrops of shell conglomerate occur along the mainland shore of Laguna Madre adjacent to central Padre Island. These rocks apparently are lithified equivalents of the shell-rich beach sediments of Padre Island and are probably a part of the ancient Ingleside Barrier Complex (fig. 1). These ancient shell beaches probably formed by the same mechanism as the modern shell beaches of Padre Island, and a study of the origin of the modern shell beaches may provide the means for interpreting the current patterns that produced the ancient shell beaches.

The material in this section is largely reprinted from a paper published by Watson in 1971.

TERRIGENOUS SEDIMENTS

The source rivers for many of the barrier-island sands of the Texas coast have been identified by analysis of the heavy minerals of the beach sands (Bullard, 1942). Within the area of shell beaches on central Padre Island is a transition from a southern sedimentologic province, having sands characterized by their content of basaltic hornblende and pyroxene from the Rio Grande, to a northern sedimentologic province, having sands characterized by the more durable heavy minerals, such as garnet, staurolite, rutile, zircon, and tourmaline (fig. 19). The heavy minerals of the northern province are indicative of source rivers such as the Nueces, Guadalupe, and San Antonio, which drain areas of sedimentary rocks that contain only relatively stable heavy minerals. The existence of a transition zone on central Padre Island between sediments derived from the Rio Grande and sediments derived from rivers farther north along the coast is supported by the finding of van Andel (1960) and van Andel and Poole (1960), who mapped heavy-mineral distributions in the bays, beaches, and continental shelf of the Gulf of Mexico (fig. 20 and Table 3). Van Andel further suggested that most of the distribution of Rio Grande sediments north of the present mouth of the Rio Grande may be explained as the result of the formation of the barrier islands by reworking of Pleistocene deltaic sediments of the nearshore Gulf. He noted, however, that some longshore drift of Rio Grande sediments to the north is indicated by a small northward displacement of the northern limit of the Rio Grande province on Padre Island as compared with the lagoon and with the morphological boundary of the delta. Hayes (1964, 1965) traced a finer grain-size mode from the northern province and a coarser grain-size mode from the southern Rio Grande province to a central transition zone where they mix (fig. 21). These heavy-mineral and grain-size mode transition zones coincide and are within the area of shell beaches on Padre Island (fig. 24).

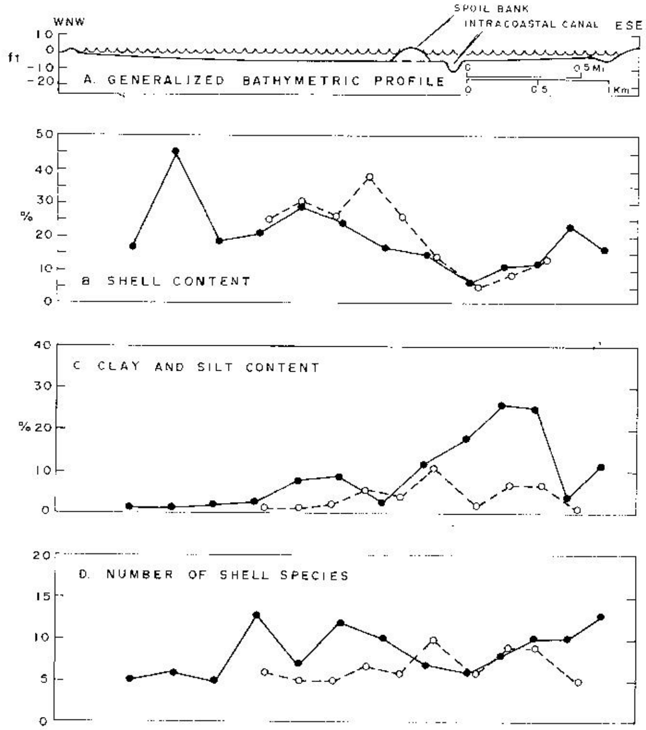


Fig. 18. – Variation in sediment character across Laguna Madre. The two lines of samples are in the South Bird Island 7.5-minute quadrangle. Both lines extend from mainland shore to island shore; they are superimposed in such a way that the position of the intracoastal canal on each sample line is directly below the position shown on the generalized bathymetric profile.

SHELL SEDIMENTS

Assemblage distribution. – Throughout the study area, large accumulations of shell material are found only on the Gulf of Mexico beaches; only very small shell concentrations occur in the foredunes, active dune fields, barrier island flats, and wind-tidal flats. Two distinct shell assemblages occur along the beaches of Padre Island. The southern sedimentologic province (from 38 miles north of Mansfield Pass southward to the Rio Grande) is

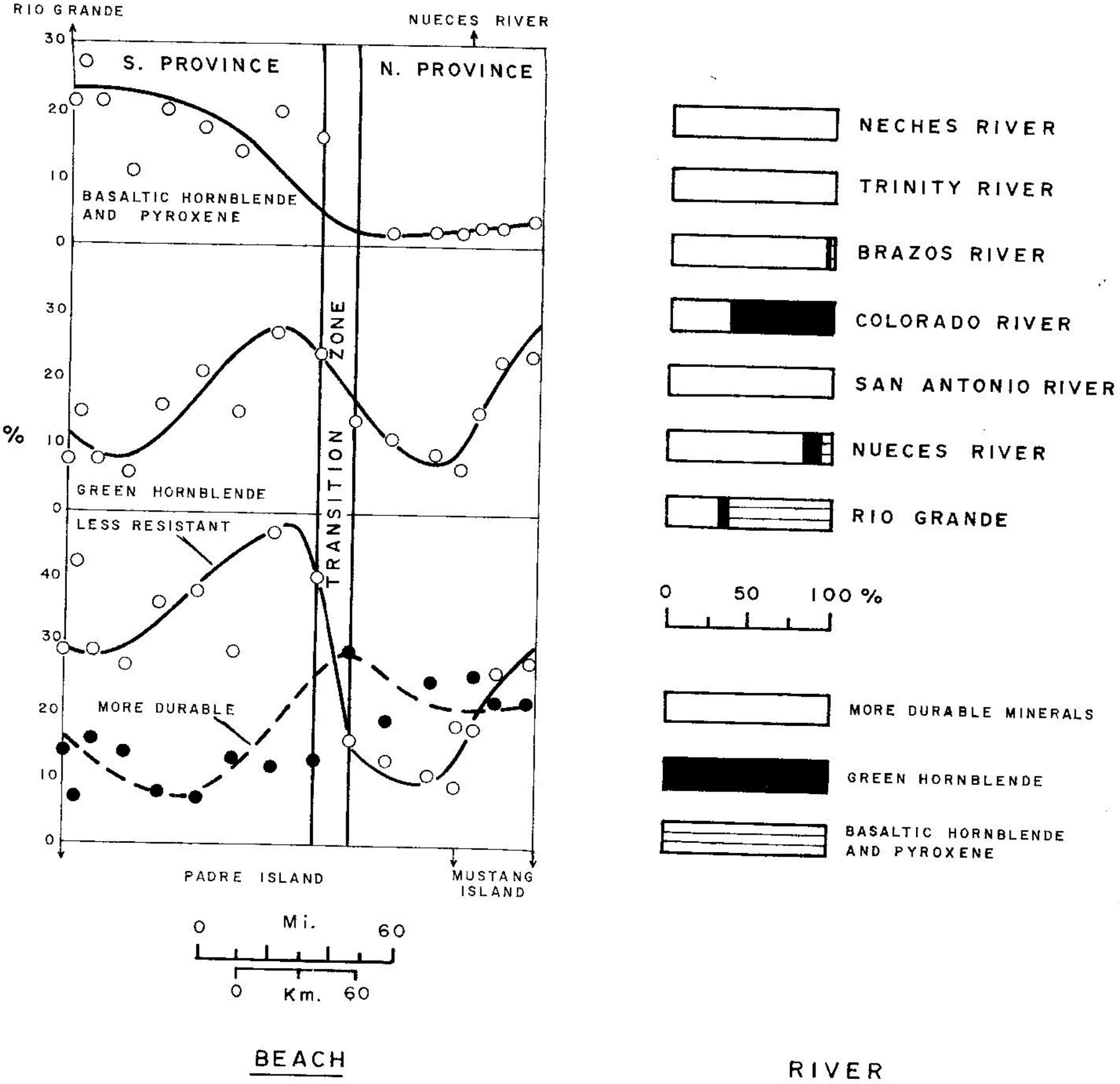


Fig. 19—Heavy-mineral distribution in beach and river sands, Texas Gulf coast. Modified after Bullard (1942).

characterized by *Eontia ponderosa* Say, *Mercenaria campechiensis* Gmelin, and *Echinochama arcinella* Linne (figs. 22 and 23). In the northern sedimentologic province, the shells are almost entirely *Donax* sp. Say. The transition zone between the northern and southern sedimentologic provinces is characterized by a lower total shell content and a somewhat greater accumulation of *Anadara braziliana* Lamarck, *A. ovalis* Bruguiere, and *A. baughmani* Hertlein, three species which are common to both provinces.

With the exception of *Donax*, the source of each species is uncertain. During the course of the study, *Donax* was observed to live in the edge of the surf in dense colonies all along Mustang Island south to the southernmost limit of the northern sedimentologic province on Padre Island. As can be seen from the shell percent curve (fig. 23), there is no accumulation of *Donax* or any other species north of 55 miles north of Mansfield Pass. Thus, *Donax* appears to live and die in the surf zone throughout the northern sedimentologic province and is carried south to accumulate near the southern end of the northern province. The *Anadara* probably live throughout the study area in the shallow shelf zone, either within the surf or slightly beyond it. The *Mercenaria*, *Eontia*, and *Echinochama* common to the southern province probably represent an older reworked shell assemblage. No unabraded valves were found. The *Mercenaria* are highly discolored and have been dated, the 10 dates ranging from 1240 to 7180 years old (personal

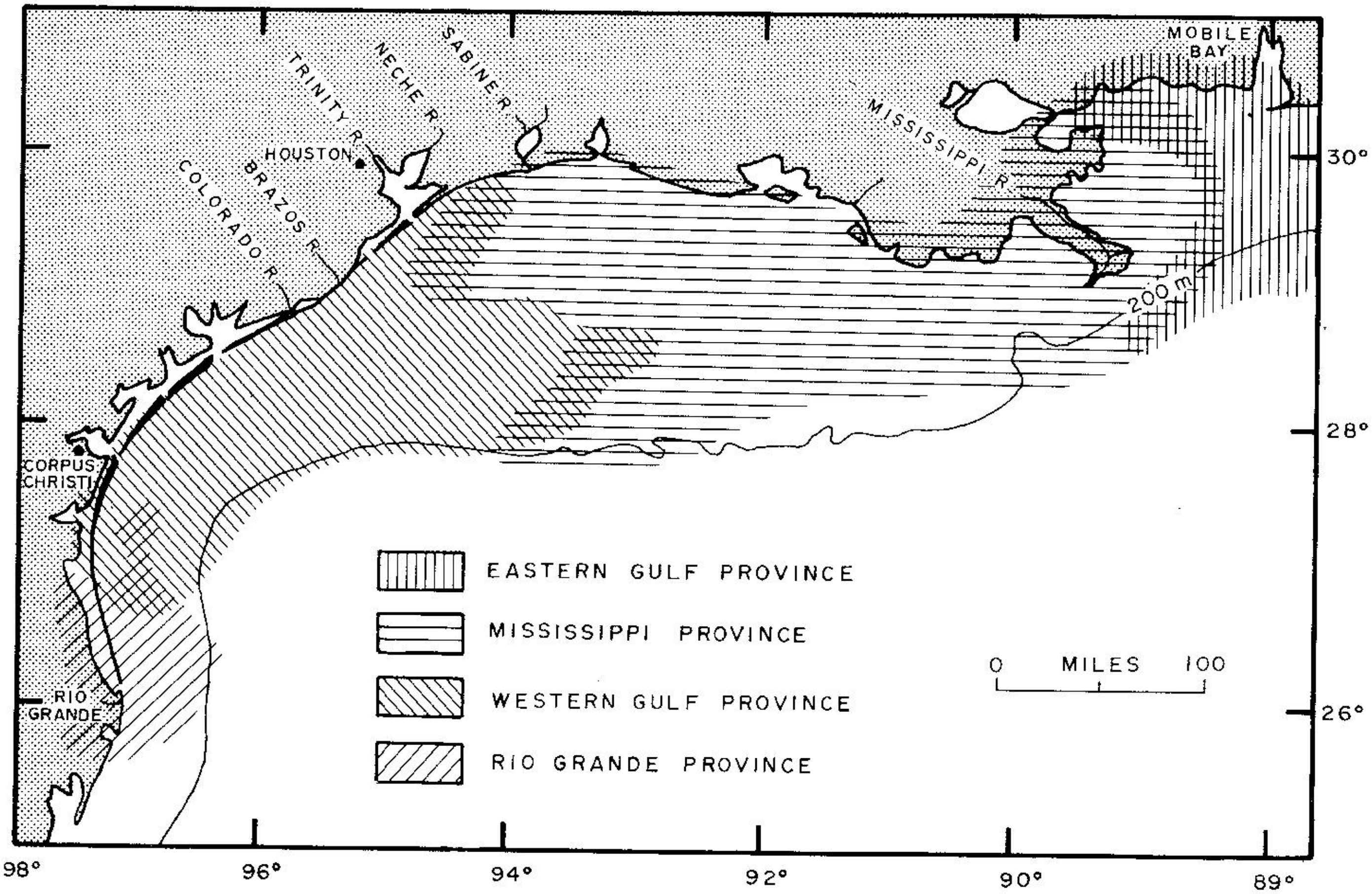


Fig. 20. – Heavy-mineral distribution, northwest Gulf of Mexico. Simplified after van Andel (1960).

TABLE 3. – Average heavy-mineral composition of associations characterizing northern Gulf of Mexico provinces

[In percent of total nonopaque fraction. Modified from van Andel (1960).]

Province	Source	Hornblende[1]	Tourmaline	Epidote	Zircon	Garnet	Staurolite	Kyanite	Pyroxenes	Basaltic hornblende	Others	No. of samples
Eastern Gulf	Cretaceous, Tertiary, Quaternary, S. Appalachians	13	12	16	12	2	16	16	3		10	31
Mississippi	Mississippi River	40	2	16	2	9			25	2	3	116
Western Gulf	Complex	58	5	17	4	7	1	1	3		3	127
Rio Grande	Rio Grande	23	3	15	6	10	1	2	24	7	9	41

[1] Not including basaltic hornblende.

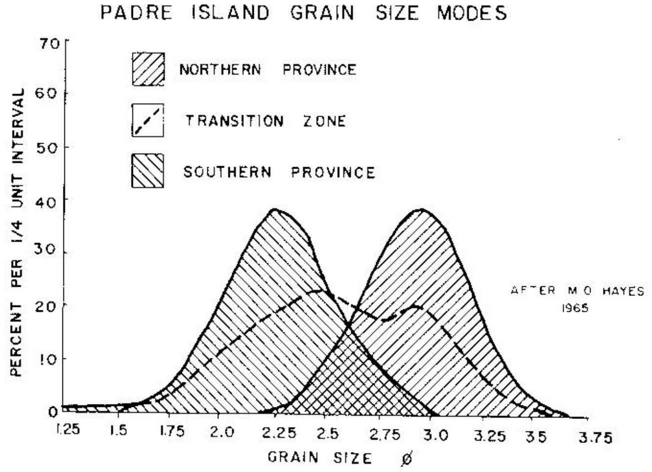


Fig. 21. – Frequency distribution curves for three Padre Island dune samples (Hayes, 1965, p. 234). Note near normality of "coarse" south end-member and "fine" north end-member, as opposed to the strong bimodality of the central sample.

communication, E. William Behrens, 1971). The *Echinochama* usually live attached to a hard substrate in youth. Adjacent to the southern province offshore are numerous submerged ridges of sandstone. This is a likely source for the *Echinochama*, or they may be reworked from an unknown source.

Even though the source for the southern assemblage is unknown, the distribution of abraded valves of the species present indicates their alongshore direction of transport. South of a point about 25 miles north of Mansfield Pass, whole but abraded valves of *Mercenaria* are common. The percentage of whole valves decreases to the north. Still farther north, whole *Mercenaria* valves are absent, and only abraded plates remain. Finally, as one passes through the transition zone into the northern province, it becomes impossible to find even small fragments of *Mercenaria*. Thus, distribution and changing character of the assemblages suggest that the *Mercenaria, Eontia,* and *Echinochama* assemblage has a source to the south and is being transported north, the *Donax* assemblage has a source to the north and is being transported south, and the *Anadara* group has a wide source and is being introduced into both the northern and southern provinces.

Shell concentration alongshore. – Approaching the area from the north, the shell content abruptly increases from less than 1 percent to nearly 50 percent in a distance of only 4 miles (fig. 23). The northernmost high shell concentration between 55 and 45 miles north of Mansfield Pass is composed of the shell assemblage of the northern sedimentologic province; this section of beach is commonly known as "Little Shell." From 40 miles north of Mansfield Pass to about 30 miles north of Mansfield Pass, there is another high in shell content corresponding to an accumulation of the species common to the southern province; this section of beach is commonly known as "Big Shell." Except for a low concentration at Mansfield Pass, the shell content fluctuates around 20 percent in the remainder of the area to the south. Thus, within the area of shell

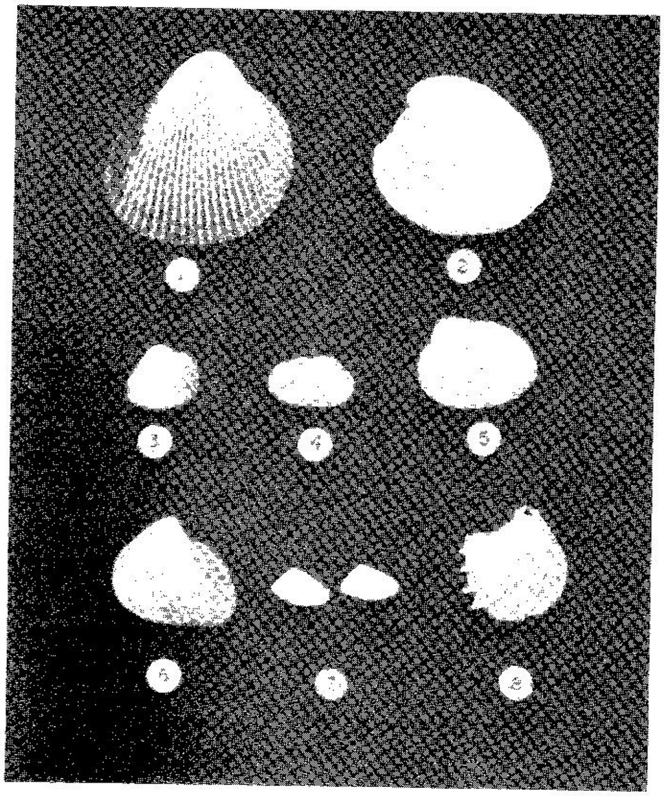


Fig. 22. – Abundant pelecypods of Padre Island shell beaches.

1. *Dinocardium robustum* Solander
2. *Mercenaria campechiensis* Gmelin
3. *Anadara braziliana* Lamarck
4. *Anadara baughmani* Hertlein
5. *Anadara ovalis* Bruguiere
6. *Eontia ponderosa* Say
7. *Donax* sp.
8. *Echinochama arcinella* Linne

The diameter of the white number circles is 1.5 cm.

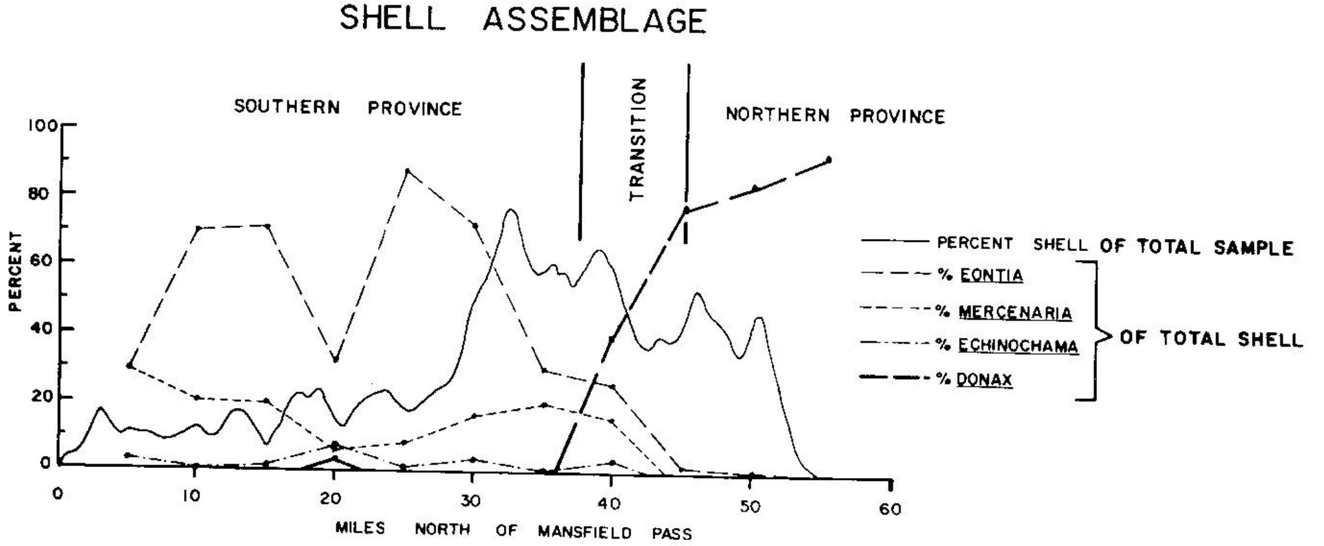


Fig. 23. – Shell assemblage distribution. Note that the abundance of the species of the southern province decline in the transition zone and are virtually nonexistent in the northern province. *Donax* makes up most of the northern province but declines in abundance in the transition zone and is not found in the southern province, except in one small colony about 20 miles north of Mansfield Pass. The transition zone based on shell assemblage corresponds with a low in shell content. The shell percent curve is the second derivative of a three point moving average.

beaches, there are three major zones based on shell concentration. These correspond with the three shell assemblage zones.

Local correlation with dune topography. – A study of the topographic maps of Padre Island shows a central belt of high foredunes, which roughly corresponds with the zone of maximum shell content. A careful study of the location of the many local maxima on the shell-content graph (fig. 23) and the location of high and continuous parts of the foredune ridge shows a nearly perfect correlation. That is, where the dunes are high and continuous, there is a local maximum in shell content. Where the dunes are low or where there is a hurricane channel or washover fan there is a local minimum of shell content. The high continuous dunes serve as an impenetrable wall to all but the most powerful storms. Coarse shell deposited on the beach in the vicinity of these dunes must remain there because no physical process can remove it. The wind is competent to remove only the finer material which is predominantly terrigenous sand. In contrast, where this wall is breached by hurricane washovers, the shell is periodically removed at least in part by being washed into the interior of the barrier island. This process is self-reinforcing. Where the dunes are the highest and most continuous and the shell content is high, the backshore elevation is usually very high because the coarser grained shell material builds steeper beaches than the fine terrigenous sand. Because of the high backshore produced by the high dunes, only the largest storms with very high tides can reach the foot of the dunes. Thus protected, the dunes can build still higher and become stronger and better able to resist future wave attack. It should not be inferred that the regional maximum in shell content is a result of the presence of high and continuous dunes. Elsewhere on Mustang and Padre Islands, there are similar areas of well-developed foredunes adjacent to beaches with less than 1 percent shell material. Positive correlation between shell content and foredune development occurs only in the littoral drift convergence.

Transition zones. – A map of the postulated longshore drift convergence area (fig. 24) shows the transition zones determined by Bullard (1942) and by van Andel and Poole (1960) for heavy minerals and by Hayes (1964, 1965) for grain-size modes. The transition zone based on shell assemblage and shell content falls within the limits of Bullard's samples and only a short distance north of the transition zone as defined by Hayes. The shell data may be somewhat more accurate, because of the close sample spacing. All these data support the suggestion that there is a sedimentologic transition zone produced by longshore drift convergence in the central part of Padre Island. The shell assemblage and shell-content data limit the width of the transition zone to about 8 miles.

Shell concentration normal to shore. – Shell content was determined on 10 traverses across the beach normal to the shoreline. The shell distribution seaward of the storm berm is irregular. Nearly pure shell deposits occur in parts of the active berm crest and in the horns of active cusps. The storm berm contains either the maximum or nearly the maximum shell content in a profile across the beach. The shell content then diminishes toward the foredunes (fig. 25). The foredunes, vegetated flats, and wind-tidal flats further inland are composed nearly completely of terrigenous materials.

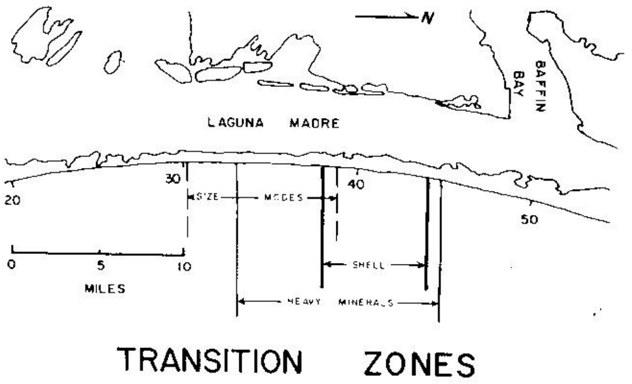


Fig. 24. – Transition zones shown by grain size, heavy minerals, and shell content. The transition zones for heavy minerals (Bullard, 1942; van Andel, 1960), for grain-size modes (Hayes, 1965), and for shell percent and assemblage distribution (this study) are shown. The numbers along the shore of Padre Island indicate the distance in miles north of Mansfield Pass.

SEDIMENTARY PROCESSES

A high shell concentration such as is found on Padre Island can be the result of three possible conditions: an extremely high shell supply, and extremely low terrigenous sediment supply, or some sorting phenomenon leading to a shell concentration. There is no evidence of an extreme abundance of living communities. In fact, the greatest abundance of living *Donax*, the main contributor to the northern assemblage, is on Mustang Island and northern Padre Island where the shell content of the beaches is less than 1 percent (fig. 23). Terrigenous sediment is not lacking, as central Padre Island is one of the widest barrier islands of the coast, Laguna Madre inland from central Padre Island is completely filled with sand blown from Padre Island, and old shell beaches exposed in depressions behind the frontal dunes of the foredune ridge indicate that the island has accreted seaward during its history. Therefore, the shell concentration on Padre Island must be a sorting phenomenon.

Longshore drift. – Evidence is abundant for a convergence of littoral drift on central Padre Island in addition to the sedimentologic evidence of the three transition zones described above. According to Lohse (1955), the currents of the south Texas coast move northward to a meeting place about lat. 27° N. Curray (1960) correctly observed that the convergence is not actually stationary, but migrates north and south along the coast in response to seasonal changes in wind direction. Drift-bottle data for the Texas and Louisiana coasts indicate that most of the currents are directly wind driven (Kimsey and Temple, 1963, 1964; Watson and Behrens, 1970). Further data, gathered in 1970 using releases of ballasted drift bottles and seabed drifters, provide additional evidence that nearshore currents frequently converge in the vicinity of Padre Island (Hunter, Garrison, and Hill, unpub. data). These data indicate that the nearshore currents tend to be driven in the direction of the seasonal winds, that is, northward during the summer and southward during the winter. However, southward currents tend to persist through the spring and early summer months long after the southerly winds have become established, thereby tending to maintain a convergence of nearshore currents in the vicinity of central Padre Island.

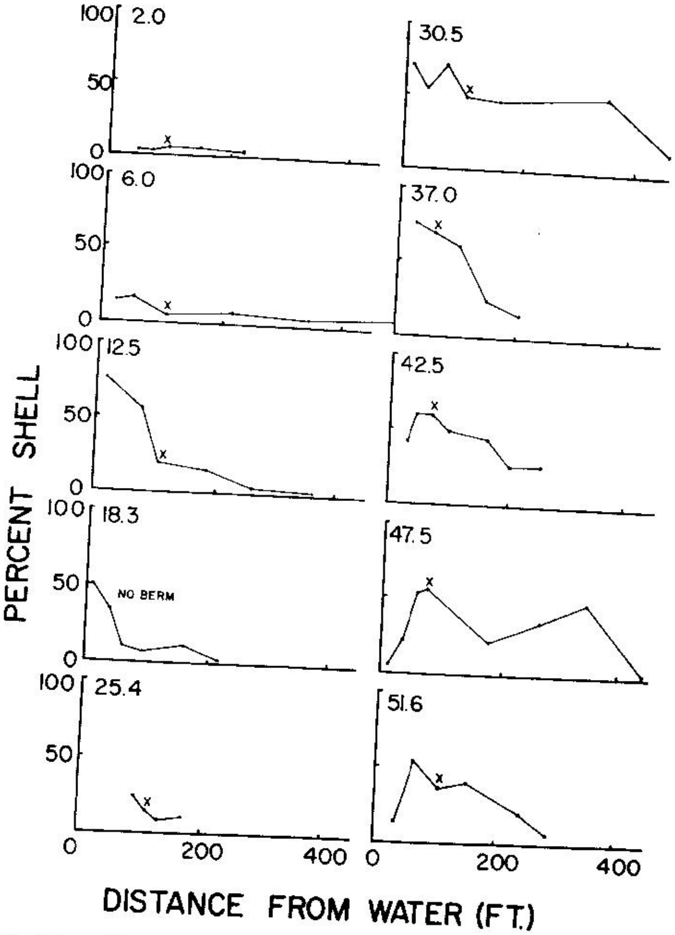


Fig. 25. – Shell distribution along traverses perpendicular to the shoreline. The shell concentration versus distance landward from the edge of the water is plotted for a series of 10 traverses across the width of the beach throughout the study area. The number in the upper left-hand corner of each graph is the distance in miles that the traverse is north of Mansfield Pass. The small x by the trace of the graph denotes the approximate location of the crest of the storm berm on each traverse. The shell content is irregular seaward of the storm berm and decreases landward from it.

Monthly wind data collected by the U.S. Weather Bureau station at Corpus Christi for the years 1951-1960 give the average velocity and duration for each 16 compass directions. Monthly, annual, and 10-year vector resultants were determined for both velocity and velocity squared for the Corpus Christi data (fig. 26). The annual resultant for the 10-year period ranges between 111° and 135° with a 10-year resultant of 121°. The resultant for V^2 ranges between 110° and 135° with a 10-year resultant of 123°. Data for 1965 and and 1966 fall within the limits of the 10-year data described above. In addition, Price (1933) presented a vector diagram of the wind direction, duration, and square of the velocity for the period 1923-1930. The annual vector sum derived from this diagram is 120°. Thus, several different computations of the vector sum of the winds for Corpus Christi all provide an annual vector sum of about 120°.

A wind blowing into a concave shoreline such as the south Texas coast will produce waves, which in turn will produce a convergence of longshore drift at the point where the wind direction is normal to the shoreline (fig. 27). The direction of the net annual resultant wind for Corpus Christi is about 120°, which is normal to the shoreline in the vicinity of Aransas Pass. This suggests a net convergence of longshore drift in that area. Although at any one time sediment is either moving north or south through the entire area, the long-term effect is the net convergence of longshore drift.

The convergence location determined by wind analysis at a single point is only approximate. Sedimentation at inlets can also be used to estimate the location of the long-term convergence. The south jetty of Mansfield Pass has accumulated a huge fillet of sand, whereas the beach just north of the north jetty is eroding. This indicates a strong net littoral drift to the north at Mansfield Pass. Aransas Pass had a history of migration to the south before stabilization (U.S. Army Corps of Engineers, undated). Spit development at Corpus Christi Pass during its closure following Hurricane Beulah in 1967 demonstrates that the net drift at that point is southward. Therefore, if the net littoral drift is southward at Corpus Christi Pass and northward at Mansfield Pass, there must be a net convergence of littoral drift between these two points. This convergence provides the mechanism to supply large amounts of shell material to central Padre Island. It will, however, provide a very large terrigenous supply as well. In fact, it should result in the greatest total longshore sediment supply of any beach anywhere along the coast, as sediment is being brought in from the south and from the

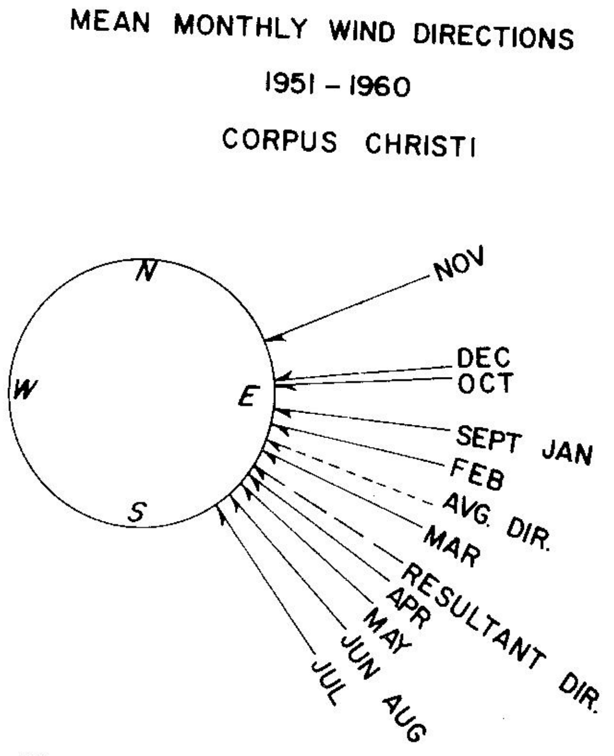


Fig. 26. – Mean monthly wind directions for Corpus Christi 1951-1960. Directions shown represent the average of the monthly vector resultants determined for 10 years of wind data collected at Corpus Christi. The RESULTANT DIR. shown is the vector resultant for the entire 10-year period. The AVG. DIR. is the average of all of the monthly vector resultant directions for the 10 year period. The resultant direction and the average direction separate the winter regime of northers from the summer regime of strong southerlies if March is taken to be a transitional month.

north, and once into the convergence area, littoral drift can no longer carry it away.

Wind deflation. – Within the convergence area, shell is concentrated on the beach by wind deflation of finer grains. The much finer terrigenous sand can be blown inland to form the foredunes, vegetated flats, and the wind-tidal-flat infill of Laguna Madre. Some of the sand may also eventually contribute to the aeolian sand plain on the mainland (fig. 1). As the coarse shell material cannot blow inland and cannot be removed by littoral drift, it concentrates on the beaches of the convergence area. Only small amounts are washed inland on hurricane washover fans where the foredune ridge is poorly developed. Thus, the combination of a convergence of littoral drift and subsequent wind deflation of the finer terrigenous sand results in a huge accumulation of shell material in the center of an abundant supply of terrigenous sediment. Abundance of organisms or lack of terrigenous sediments is not necessary to provide this carbonate concentration.

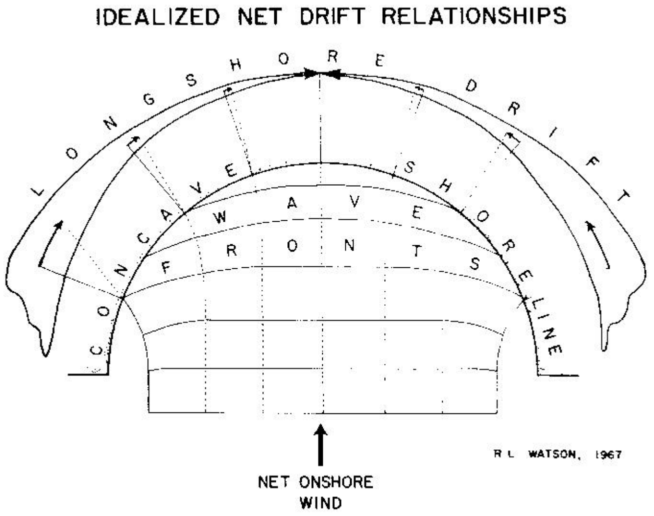


Fig. 27. – Idealized net drift relationships An onshore wind blowing onto a concave shoreline will produce wave fronts normal to the wind direction. These wave fronts move shoreward and are incompletely refracted. As they break, the waves generate a longshore current because of their oblique approach to the shoreline. This current is strongest at the greatest distance from the central point where the waves approach the shoreline at the greatest angle. The current decreases in magnitude toward the center where it diminishes to zero because the waves approach parallel with the shoreline at the point where the wind direction is normal to the shoreline and no current is generated.

PALEOENVIRONMENTAL INTERPRETATIONS

The results of this study of recent sediments can be directly applied to the explanation of some other recent and some Pleistocene sediments in the same area. The old shell beach sediments behind the frontal dunes of the foredune ridge on central Padre Island must surely represent a shell beach directly analogous to the present one. The shell-rich rock outcropping along the west shore of Laguna Madre is probably a Gulf beach of the Pleistocene(?) Ingleside Barrier Complex. Cursory field examination demonstrates that it has approximately the same assemblage composition as the modern shell beaches and has both a northern and southern assemblage province with the transition zone in approximately the same location as on the modern beaches. Therefore, the general configuration, wind circulation, and thus the littoral drift patterns were probably very similar to those of the present on this ancient Gulf of Mexico beach.

SUMMARY

1. A littoral drift convergence on central Padre Island causes shell and sand from the entire coast to accumulate in the convergence area.

2. Shell is concentrated on the beach by aeolian deflation of finer grained terrigenous sand.

3. The excess sand is blown inland to contribute to the extensive infilling of Laguna Madre by wind-tidal flats, and perhaps ultimately to contribute to the aeolian sand plain of the mainland.

4. The great similarity of the Pleistocene shell beaches of the Ingleside Barrier Complex suggests that the general coastline configuration and wind patterns were similar to modern wind patterns at the time of their formation.

5. Large carbonate accumulations can occur as a result of a sorting process in an area of great terrigenous sediment supply.

SHORT SUMMARY OF FIELD TRIP STOPS 3, 4, and 5

STOP 3. Northern sedimentologic province. – This stop is in the northern sedimentologic province, which is characterized by terrigenous sediments supplied from rivers to the north and from relict Pleistocene sediments derived from these rivers and their deltaic deposits. The more durable heavy minerals, such as garnet, staurolite, rutile, zircon, and tourmaline, are common. Green hornblende from the Colorado River is also present (Bullard, 1942). The terrigenous sediments are characterized by the relatively fine size mode of northern Padre Island (fig. 21). The shell assemblage here is dominated by *Donax* sp. (fig. 22). Living *Donax* are sometimes found along these beaches and are living in large colonies along northern Padre Island and Mustang Island. The *Donax* spend their entire life cycle in the shallow surf zone. They move onshore and offshore from the swash zone to water a few feet deep with the changing seasons. After they die, their shells are carried southward by the net southward littoral drift along northern Padre Island to this area in the northern sedimentologic province where they accumulate by aeolian deflation of the finer grained terrigenous sediments, which blow inland to the interior of the island and ultimately contribute to the foredunes, vegetated flats, and the wind-tidal flats that are slowly filling Laguna Madre.

Note the complete absence of species or fragments of the shells of species characteristic of the southern sedimentologic province (fig. 22). As this stop is north of the transition zone between northward-moving longshore currents to the south and southward-moving longshore currents here, no sediment from the southern sedimentologic province can be transported this far north. In addition to the *Donax*, there are numerous whole shells and fragments of the *Anadara* sp. assemblage, such as *Anadara baughmani, A. Braziliana*, and *A. ovalis*. These species occur throughout the area and are not limited to a particular province. They are probably living at present in either the surf zone or the shoreface beyond.

Shell content in the northern sedimentologic province ranges from near zero on northern Padre Island and

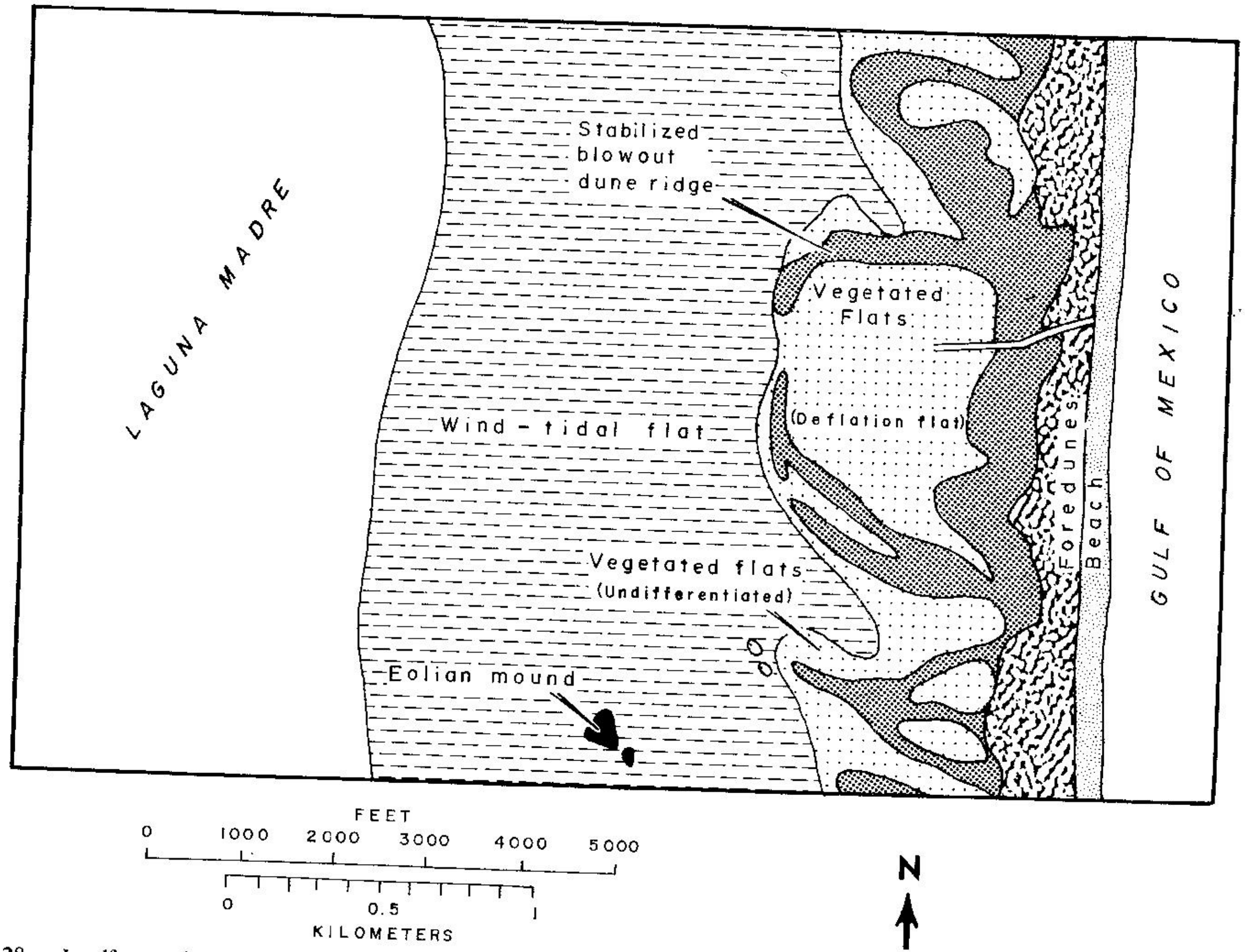


Fig. 28. – Landforms of a typical section of central Padre Island. The mapped area is in the vicinity of the abandoned Dunn Ranch, Potrero Cortado 7.5-minute quadrangle, and is the locale for STOP 6.

Mustang Island in the source area for the *Donax* to a minimum of about 55 percent near the transition zone at the heart of the littoral drift convergence (fig. 23).

STOP 4. Transition zone. – This stop is in the transition zone between the northern and southern sedimentologic provinces. The terrigenous sediments and the shell sediments of both provinces are mixed in this zone which is about 8 miles wide (figs. 23 and 24). Note that, with the exception of a small colony of living *Donax* in the southern sedimentologic province, the species characteristic of the northern province are absent in the southern province, and vice versa. This is also true for the grain-size modes of Hayes (1965) and for the heavy minerals studied by Bullard (1942) and van Andel and Poole (1960). Members of the *Anadara* assemblage (fig. 22) are common.

STOP 5. Southern sedimentologic province. – This province is characterized by terrigenous sediments from the Rio Grande. The modal grain size is coarser than that in the northern sedimentologic province (fig. 21) and the heavy-mineral assemblage is characterized by the presence of basaltic hornblende and pyroxene. The shell assemblage is characterized by *Mercenaria campechiensis, Eontia ponderosa*, and *Echinochama arcinella* (fig. 22). The source for these species is unknown, but most or all of them are probably reworked from older sediments. The *Mercenaria* have been radiocarbon dated; 10 dates range from 1240 to 7180 years old. All are highly worn and discolored, indicating burial and considerable abrasion during transport. The *Echinochama* live attached to a hard substrate in adolescence and may have a source in the numerous ridges of sandstone offshore from southern Padre Island. The source for the *Eontia* is unknown but may be the same as that for the *Mercenaria*.

There is considerable evidence for transport of these sediments to the north. At Mansfield Pass there is a great accumulation of sediment behind the South Jetty, indicating net transport to the north. Also, south of this stop, whole *Mercenaria* are very common. As one moves toward the north and finally enters the transition zone, only abraded plates of *Mercenaria* remain, indicating increasing abrasion and fragmentation to the north and thus transport to the north. There are no *Mercenaria* or fragments north of the transition zone.

TRAVERSE ACROSS CENTRAL PADRE ISLAND (STOPS 5 AND 6)

By Ralph E. Hunter

Central Padre Island may be differentiated from the northern and southern sections by distinctive features of the beach, foredunes, vegetated back parts of the island, and wind-tidal flats (fig. 28). If defined in the most restrictive sense, on the basis of features in the vegetated part of the island, it extends from 3 to 15 miles south of Yarborough Pass, or from 42 to 30 miles north of Mansfield Pass.

BEACH (STOP 5)

The southern and transitional assemblages of the shell beaches, as defined by Watson (1971 and this guidebook), compose the central section of the island. This section of beach is commonly known as "Big Shell' and is characterized, apart from its shell content, by its high berm and steep foreshore. Its character is more fully described in the section on longshore variation of beach sediment and origin of the shell beaches.

FOREDUNES (STOP 5)

The foredunes of central Padre Island differ from those to north and south by their greater height, more continuous vegetative cover, and greater topographic continuity. An explanation for these differences is offered in the section on longshore variation in beach sediment and origin of the shell beaches.

ACTIVE DUNE FIELDS

Only a few small blowout dune fields are presently active in the central section of Padre Island, and no back-island dune field is present. The vegetative cover of central Padre Island has been more extensive than that of the northern and southern sections since at least 1937, the date of the earliest available aerial photography.

STABILIZED BLOWOUT DUNE FIELDS (STOP 6)

Vegetated sand ridges 5 to 20 feet high are common on central Padre Island. Their origin as blowout dune fields is indicated by their parabolic, convex-downwind form, enclosing low deflation flats between the arms of the parabola (fig. 28). At least some of these sand ridges can be recognized as areas of bare sand on the earliest accurate map of the area, surveyed in the late 1800's. They became stabilized by vegetation sometime before 1937. No other part of the island contains such large areas that have remained unchanged for so long a time.

Eastward, the individual stabilized dune ridges merge into a gently lagoonward-sloping platform on whose eastern edge the foredune ridge is built. The presence of shells on this platform, some of them at elevations of 15 or 20 feet above sea level, suggests that hurricane surges washed over the platform before formation of the present foredune ridge.

VEGETATED BARRIER FLATS (STOP 6)

Low flats vegetated by grass occur both upwind (southeastward) and downwind (northwestward) from the stabilized blowout dune ridges (fig. 28). Those flats upwind from the ridges are deflation flats left behind the formerly moving dunes, whereas those downwind of the ridges and bordering the wind-tidal flats may be either old deflation flats, left behind dunes that have since moved into Laguna Madre and dissipated, or old washover fans. The flats upwind and downwind of the ridges are grouped together here because their underlying deposits, consisting of structureless sand, are probably in lateral continuity beneath the intervening ridges of stabilized dune sand.

WIND-TIDAL FLATS (STOP 6)

The wind-tidal flats along the Laguna Madre margin of central Padre Island are much wider than those in the South Bird Island quadrangle; however, wide wind-tidal flats are not restricted to the central section of the island as defined here but extend some distance north and south (fig. 1). The sand that makes up a large part of the wind-tidal flat deposits must have been washed or blown across the island, but in the central section this must have occurred largely before the foredune ridge and vegetative cover formed to their present extent. In fact, the somewhat lesser extent of wind-tidal flats behind the "Big Shell" beach (in the vicinity of stop 5, fig. 1) than in the areas immediately to the north and south is probably due to the relative protection from hurricane washovers and wind activity furnished by the high foredune ridge and vegetative cover of this section of the island (Hayes, 1967, p. 26-27).

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