BARRIER ISLAND SYSTEMS: MUSTANG ISLAND, TEXAS

Richard J. Moiola and John B. Wagner***
Dallas, Texas
**Sandstone Enterprises, **Nexen Petroleum USA*

INTRODUCTION

Mustang Island is one of a series of barrier islands that fringe approximately 500 kilometers (300 miles) of the Texas coast. The island is 27 kilometers (16 miles) long, 1.5 to 5.0 kilometers (1.0 to 3.0 miles) wide, and separates Corpus Christi Bay from the Gulf of Mexico (Fig. 1). Like most barrier islands, it is characterized by a relatively straight seaward shoreline and an irregular lagoonal/bay shoreline. To the northeast the island is separated from St. Joseph Island by Aransas Pass and to the southwest it is intermittently separated from Padre Island by Corpus Christi Pass. An ancient barrier island-strandplain sand body lies landward and parallel to the trend of the modern barrier island (Fig. 2).

Mustang Island occurs in a wave-dominated, microtidal setting that has a normal diurnal tidal range of 45 to 60 cm (1.5 to 2.0 feet). Moderate southeast winds prevail from spring to fall, whereas strong northerly winds accompanying polar fronts occur during the winter. Strongest winds occur during tropical storms and hurricanes, with hurricanes striking the Texas coast approximately every 1.5 years (Hayes, 1967). Longshore drift is predominantly to the southwest.

This guide focuses on the characteristics of the beach-dune-shoreface complex that dominates the seaward side of the island.

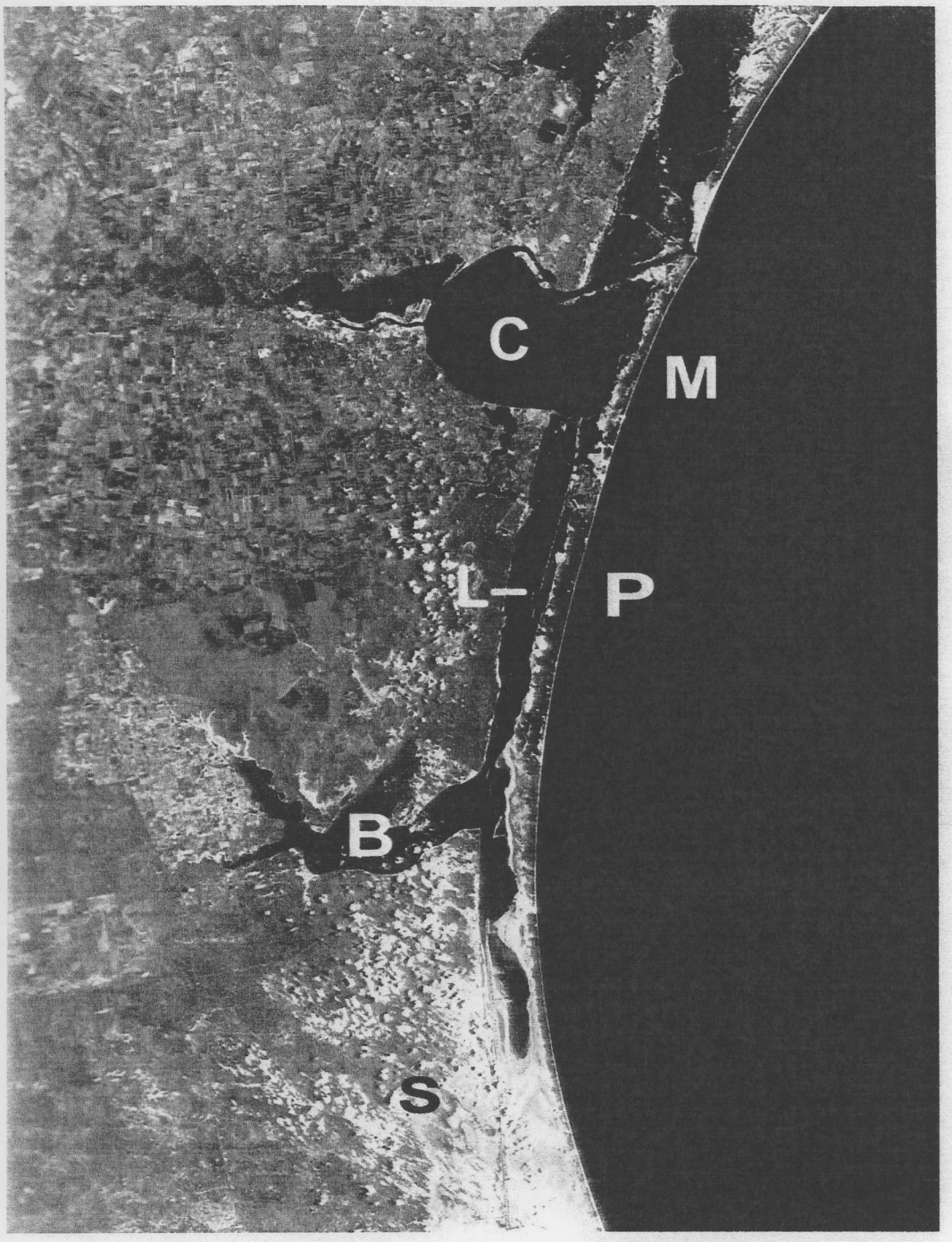


FIGURE 1. Satellite image of the Corpus Christi area. M: Mustang Island, C: Corpus Christi Bay, P: Padre Island, L: Laguna Madre, B: Baffin Bay, S; South Texas Eolian System.

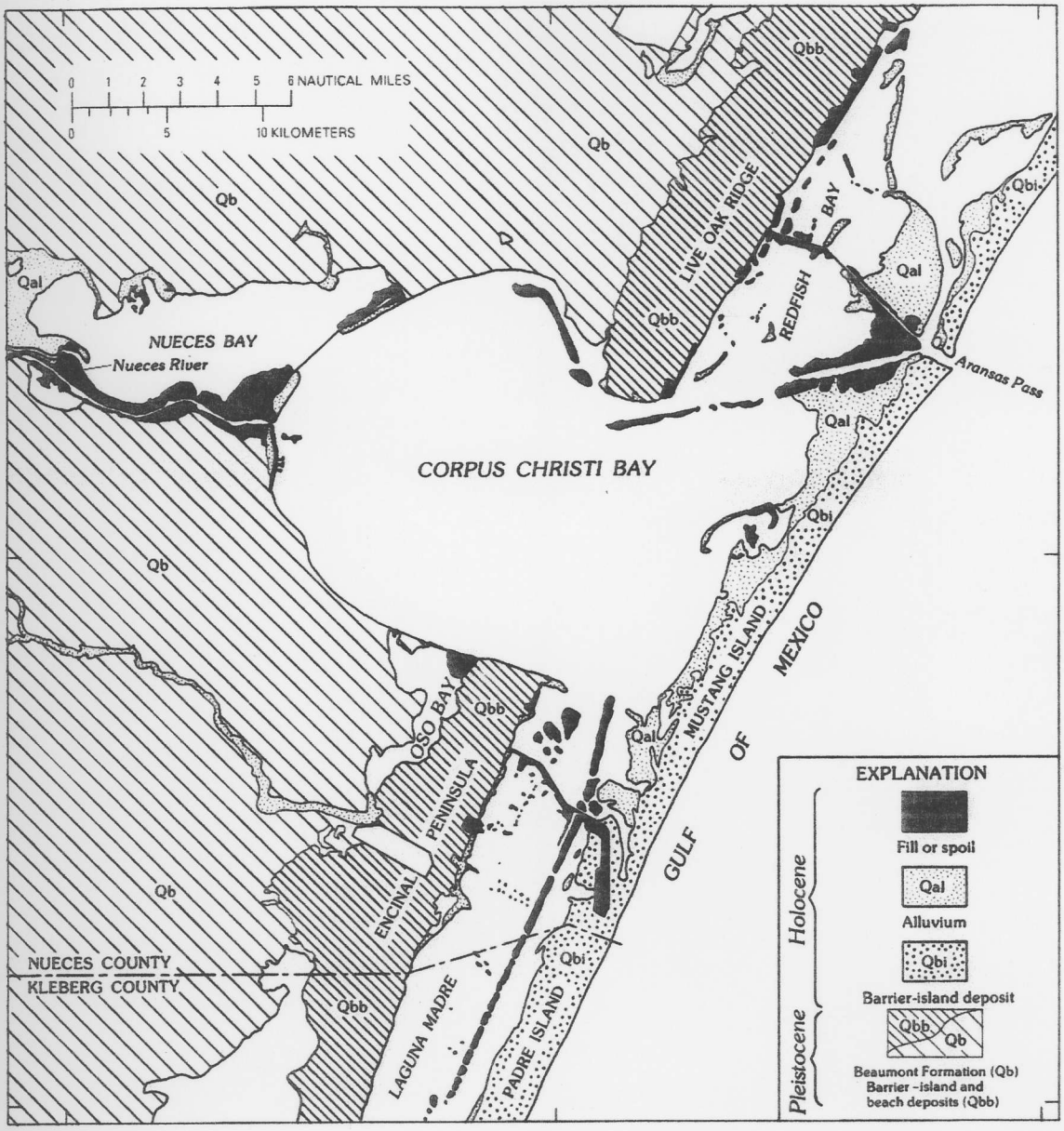


FIGURE 2. Geologic map of the Mustang Island area. Note location of Pleistocene barrier island-strandplain sand body that parallels trend of modern barrier island. Modified from Shideler (1986).

Sedimentary features will be examined primarily by digging trenches in the beach and dunes and by wading in shallow water in the lower part of the beach and upper part of the shoreface. If time permits, peels will be made using the technique described by Moiola and others (1969).

Related publications discussing the sedimentology of Mustang and adjacent islands include those of McKee (1957), Fisk (1959), McBride and Hayes (1962), Scott and others (1964), Milling and Behrens (1966), Hayes (1967), Andrews (1970), Dickinson and others (1972), Hunter and others (1972), Hill and Hunter (1973), Moiola and Spencer (1973), Brown and others (1976), Hill and Hunter (1976), Brown and others (1977), Hunter (1977), White and Galloway (1977), Morton and McGowen (1980), Weise and White (1980), Hummel and Kocurek (1984), Shideler (1986), Suter (1989), and Kocurek and others (1992).

MODERN BARRIER ISLAND SYSTEM

Mustang Island comprises five major environments: shoreface, beach, dune, vegetated barrier flat with dunes, and wind-tidal flat. A major tidal inlet with an associated flood tidal delta (Aransas Pass) occurs at the northeast end of the island and separates it from St. Joseph Island (Figs. 1 and 2). The inlet and tidal delta have been modified by dredging and construction begining in the late 1800's. In the past, the southwest end of Mustang Island was separated from Padre Island by a series of tidal inlets (Corpus Christi Pass, Newport Pass, and Packery Channel). Today, these inlets are open only following severe storms or hurricanes and then quickly heal. Washover fans and channels resulting from storms occur on the backside of the island, which is bordered by a bay-lagoonal complex (Corpus Christi Bay/Laguna Madre).

The modern barrier islands of the Texas coast are underlain by Pleistocene muds and sands. Cores drilled across Padre Isand (Fisk, 1959) indicate the barrier is about 10.5 to 12 m (35 to 40 ft) thick (Fig. 3). Shideler (1986) reported a thickness of approximately 25 m (80 ft) for Mustang Island. According to Fisk (1959) and Brown and others (1976, 1977), Mustang and Padre Islands began to form about 4,500 years B.P. as offshore shoals from sands eroded from submerged Pleistocene sediments on the adjacent shelf. The shoals soon became a series of emergent, low islands aligned parallel with the mainland shoreline. By about 3,500 years B.P. they began to coalesce by spit accretion to eventually form the present barrier island chain. Since their inception, Mustang and Padre Islands have gone through phases of accretion, equilibrium, and erosion at different rates and times.

As mentioned, the trip will focus on observing and discussing the sedimentological characteristics of the shoreface, beach, and dune components of the modern barrier island system.

SHOREFACE

The shoreface extends from the low tide line to storm wave base, a distance of approximately 1.5 to 3.5 km (1 to 2 mi) off the Texas Coast. It can be subdivided into an upper and lower zone. The upper shoreface extends from the low tide line to fair weather wave base and the lower shoreface from fair weather to storm wave base. Beyond the shoreface is the offshore that extends to the edge of the continental shelf.

The water depth of both fair weather and storm wave base is very variable and depends on the dynamics of the shelf setting. The depth of fair weather wave base typically ranges from 5 to 15 m (15 to 50 ft), and storm wave base typically ranges from 20 to 30 m (65 to 100 ft) but can be as much as 50 + m (160 + ft). The Texas coast occurs in a low energy, microtidal setting. Fair

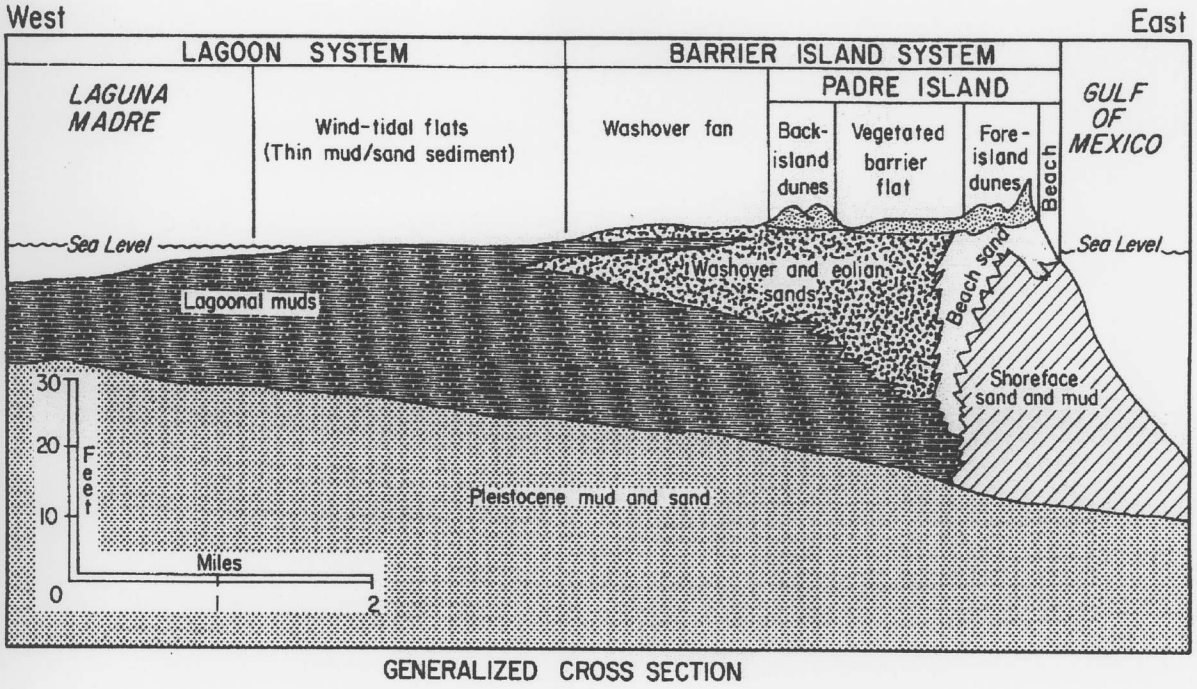


FIGURE 3. Cross-section of Padre Island based on borings taken across the central part of the island. Modified from Fisk (1959).

weather wave base off of Mustang Island is approximately 5 m (16 ft) and storm wave base is approximately 15 m (50 ft).

Upper Shoreface

The upper shoreface is a zone of relatively high physical energy where normal wind-driven waves feel bottom and break. The waves affecting the Texas coast are usually less than 1 m (3.3 ft) high. A series of breaker bars normally can be observed off Mustang Island (Fig. 4). The bars are aligned parallel or at an angle to the shoreline and are separated by intervening troughs.

Clean, fine- to very fine-grained sands with physical sedimentary structures formed by day-to-day processes and biogenic structures of the *Skolithus* facies dominate the upper shoreface. Stratification types include small- and medium-scale cross stratification, parallel stratification, and irregular scour and fill. Biogenic structures are predominantly vertical and inclined burrows made by filter-feeding organisms. On low-energy coasts such as this, abundant nearshore fauna can effectively rework and destroy much of the stratification.

Lower Shoreface

The absence of breaking waves, except during storms, results in the accumulation of fine-grained sediment in the lower shoreface. Biogenic activity dominates, and extensively burrowed/mottled mud with thin, highly reworked interbeds of silt and fine sand characterizes this zone. The silts and sand represent storm deposits that are reworked during fair weather times by organisms such as echinoids and polychaetes. Trace fossils of the *Cruziana* facies are typical. In settings where storm deposits have not been severly modified by biogenic activity, they are generally characterized by sedimentary structures such as hummocky cross stratification, parallel stratification, and graded bedding.

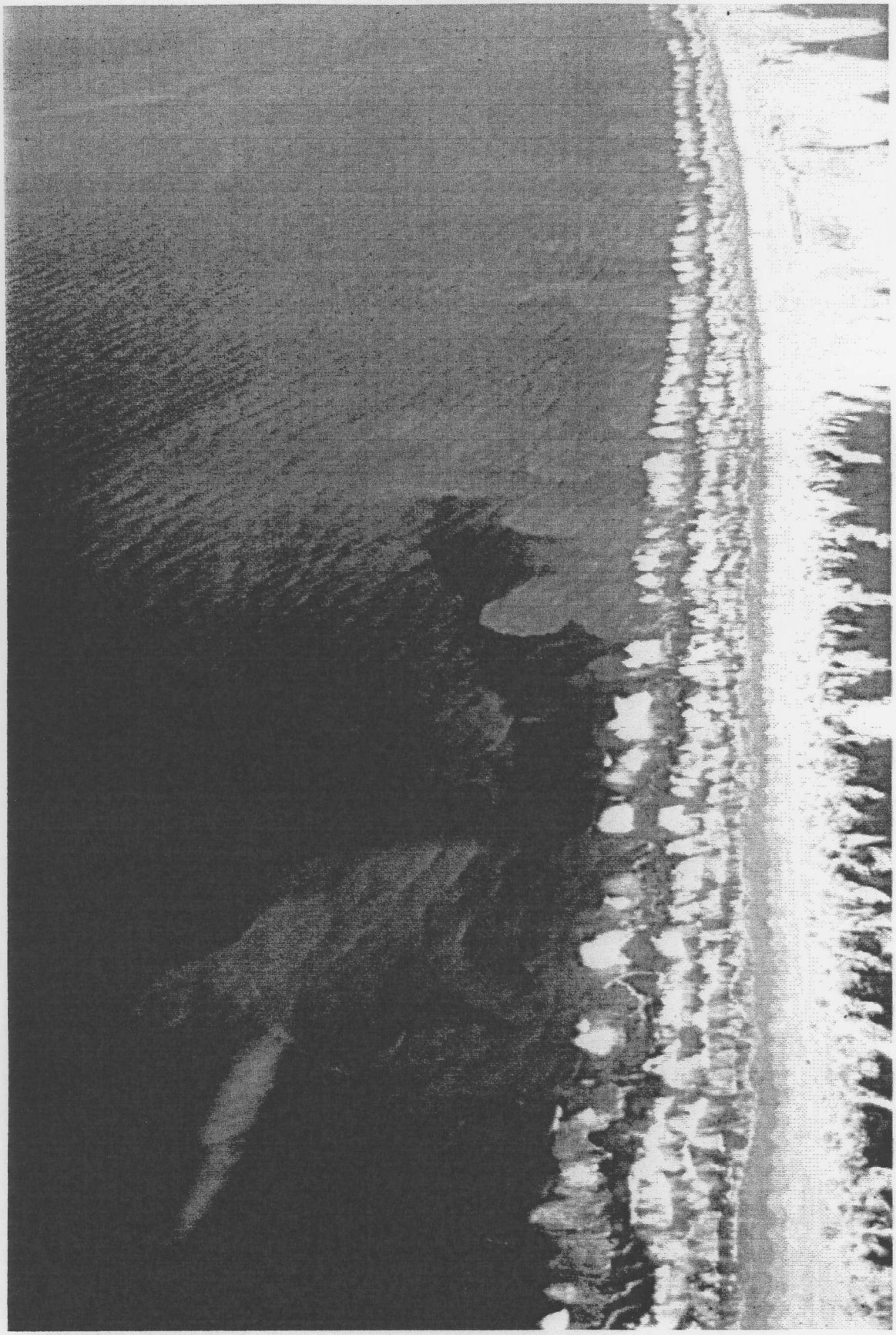


FIGURE 4. Photo of breaker bars along the shore of Mustang Island. Also note bedforms seaward of the bars.

Facies Model

A facies model for shoreface settings in general is illustrated in Figure 5.

BEACH

The Mustang Island beach is approximately 150 m (500 ft) wide and predominantly consists of fine sand with varying amounts of shell material. It can be subdivided into three zones: lower foreshore, upper foreshore, and backshore (Fig. 6). The lower foreshore extends from the low tide line to mean sea level, the upper foreshore from mean sea level to the berm crest (high tide line), and the backshore from the berm crest to the first dune ridge. Each zone is characterized by a distinct assemblage of sedimentary structures, and the asssemblages form a sequence typical of beaches along the Texas coast.

Lower Foreshore

The lower foreshore is dominated by filter feeding organisms whose burrowing activity disrupts the stratification produced by wave swash (seaward-dipping, very low angle cross stratification and inclined parallel stratification). The most conspicuous burrows are those made by *Callianassa* (Fig. 7), a decapod crustacean that densely populates the lower foreshore zone (Figs. 8 and 9).

These burrows, which commonly may extend 0.5 m (1.6 ft) or more into the substrate, have a well-developed wall structure composed of compacted sand pellets (Fig. 10) and are the modern analogues of the trace fossil *Ophiomorpha* that is very common in Tertiary and Cretaceous shoreline deposits (Weimer and Hoyt,

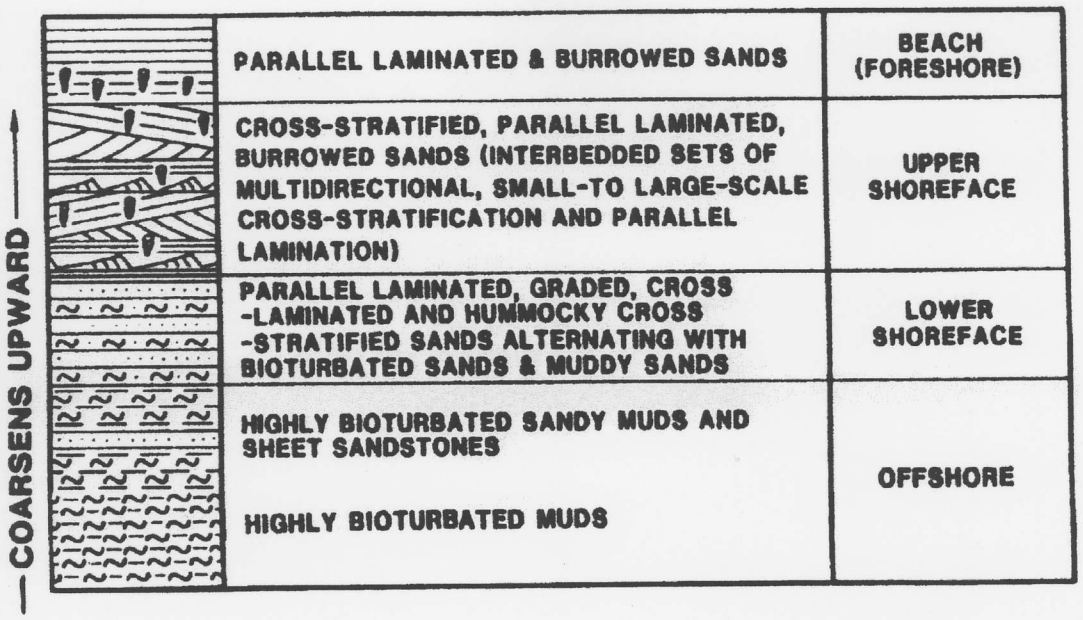


FIGURE 5. Facies model for shoreface settings in general.

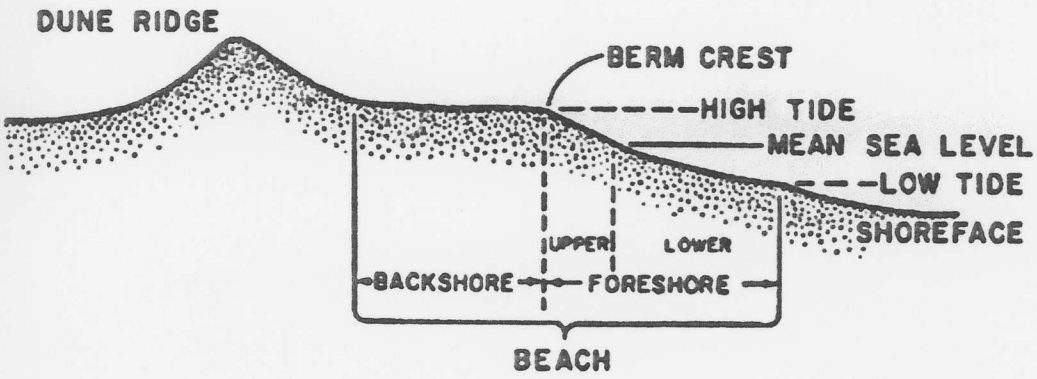


FIGURE 6. Schematic cross section showing beach components and their location.

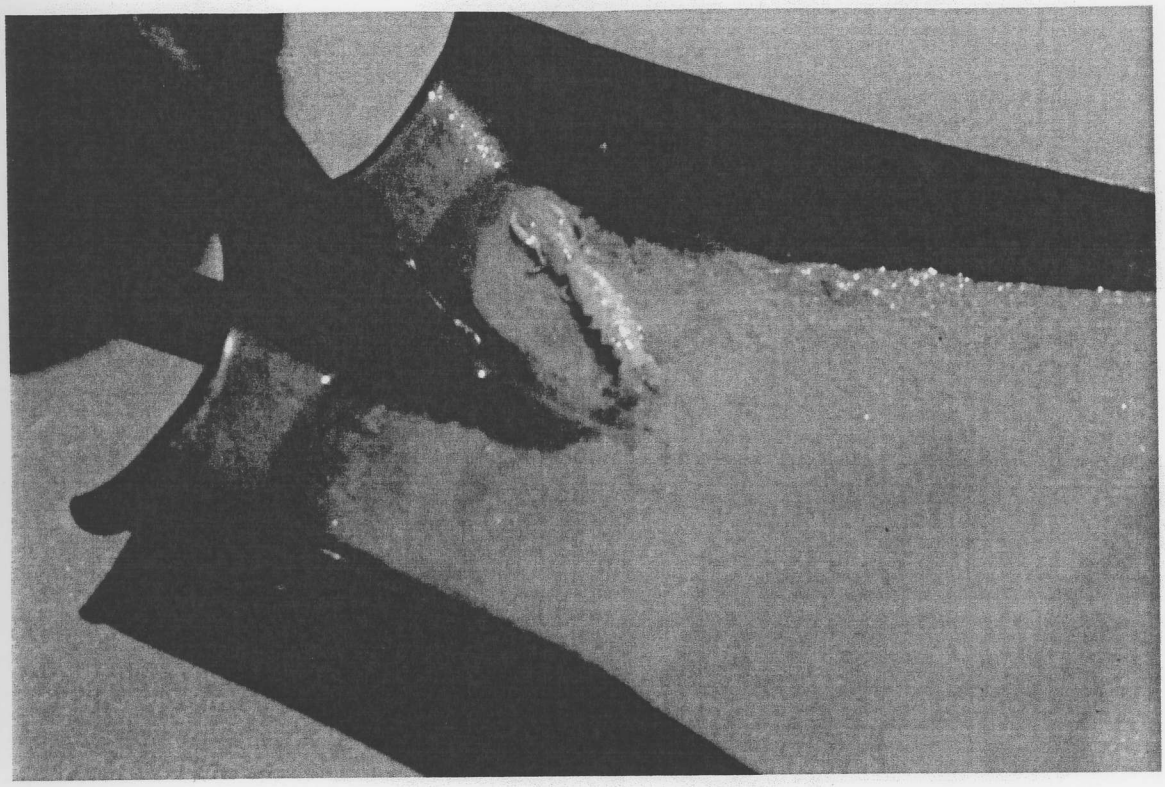


FIGURE 7. Photo of the decapod crustacean (ghost shrimp) *Callianassa*.

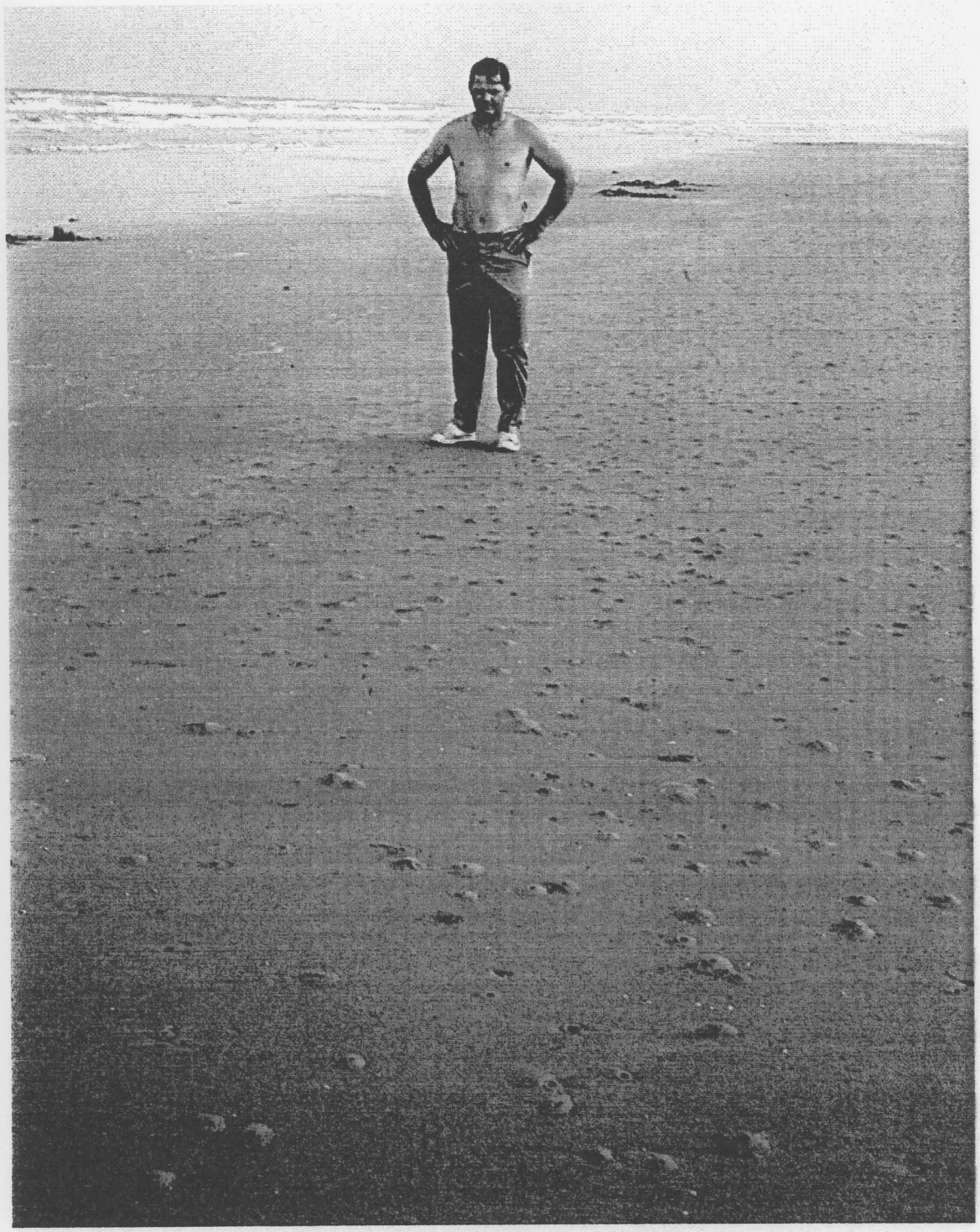


FIGURE 8. View of lower foreshore at low tide showing density of *Callianassa* burrows.

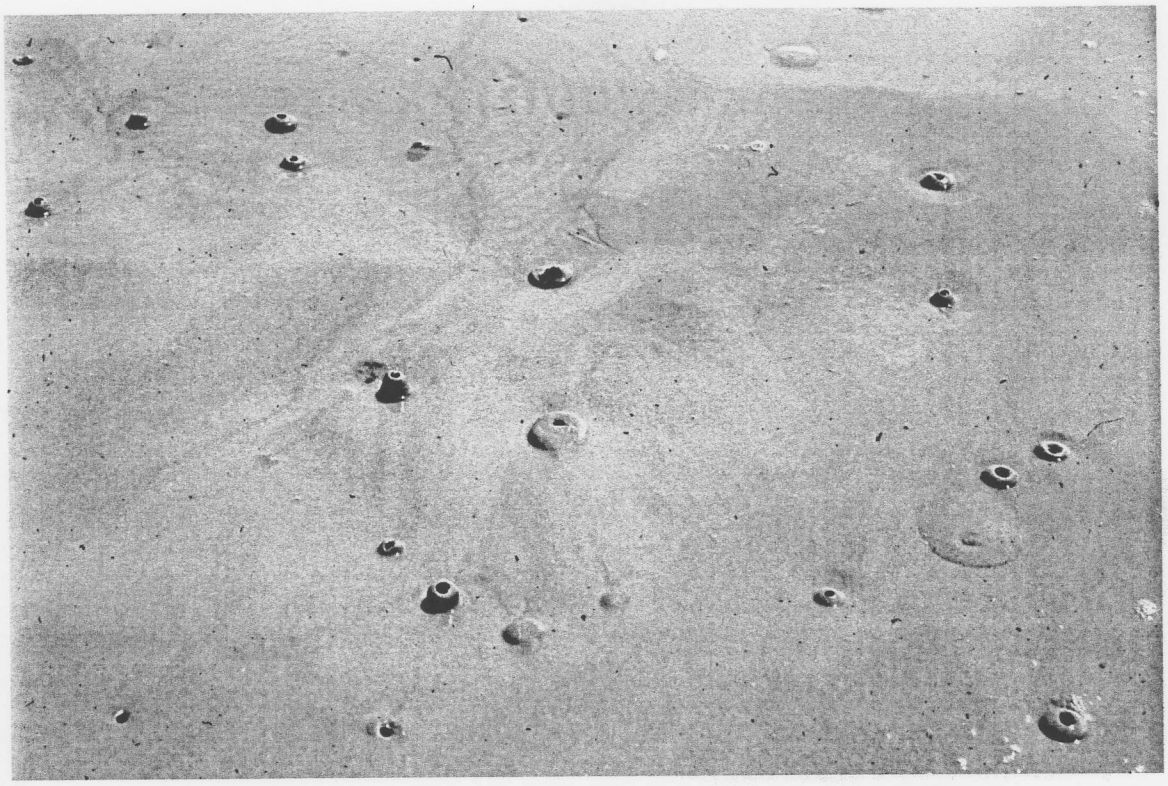


FIGURE 9. Close view of the surface expression of *Callianassa* Burrows in the lower foreshore.

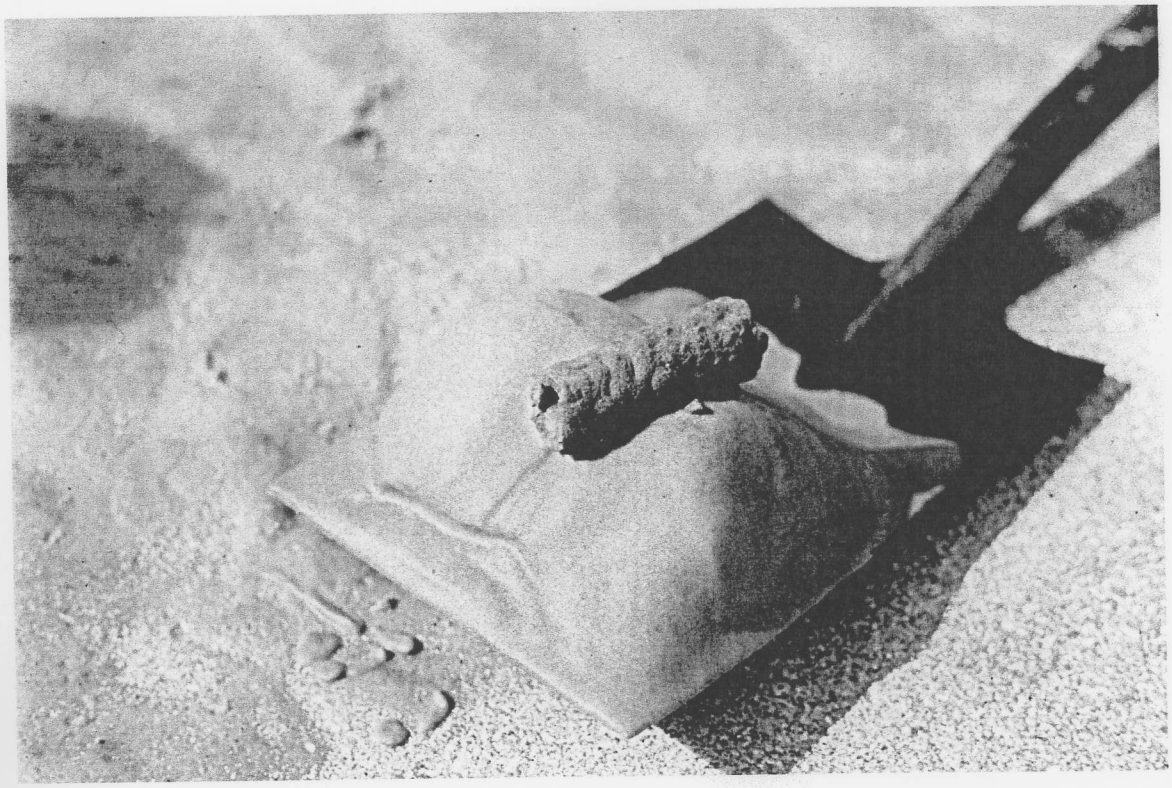


FIGURE 10. *Callianassa* burrow exhibiting characteristic knobby wall structue.

1964). Other burrowing organisms inhabiting this zone include the mole crabs *Emerita* and *Lepidopa,* the clam *Donax,* and various species of polychaete worms. As a result, the lower foreshore is characterized by an abundance of vertical burrows of the *Skolithus* facies.

Upper Foreshore

Physical processes dominate in the upper foreshore. The dominant sedimentary structure is even, very low angle stratification that is gently inclined (1 to 6 degrees) seaward (Fig. 11). The stratification is typically truncated, producing wedge-shaped sets. Steeply landward-dipping cross stratification related to the migration of ridge and runnel systems is not developed on Mustang Island.

In contrast to the lower foreshore, the upper foreshore is little disturbed by burrowing organisms. *Callianassa* burrows are virtually absent; more common are the burrows of the ghost crab *Ocypode.* They, however, do not occur in the abundance observed by Hill and Hunter (1973) in the upper foreshore of Padre Island.

Backshore

The backshore is characterized primarily by parellel stratification, irregularities in the stratification, and by gently to moderately dipping (9-16 degrees) cross stratification (Figs. 12 and 13). A variety of dip angles and directions, both seaward and landward, is associated with the cross stratification. Examples of small- to medium-scale tabular, wedge, and trough cross stratification are present, as well as zones of parallel and undulating stratification. Wind-sculptured surfaces, small scour troughs, and runoff channels all contribute to the diversity and irregularity of the stratification in the backshore. Hurricanes also have a major

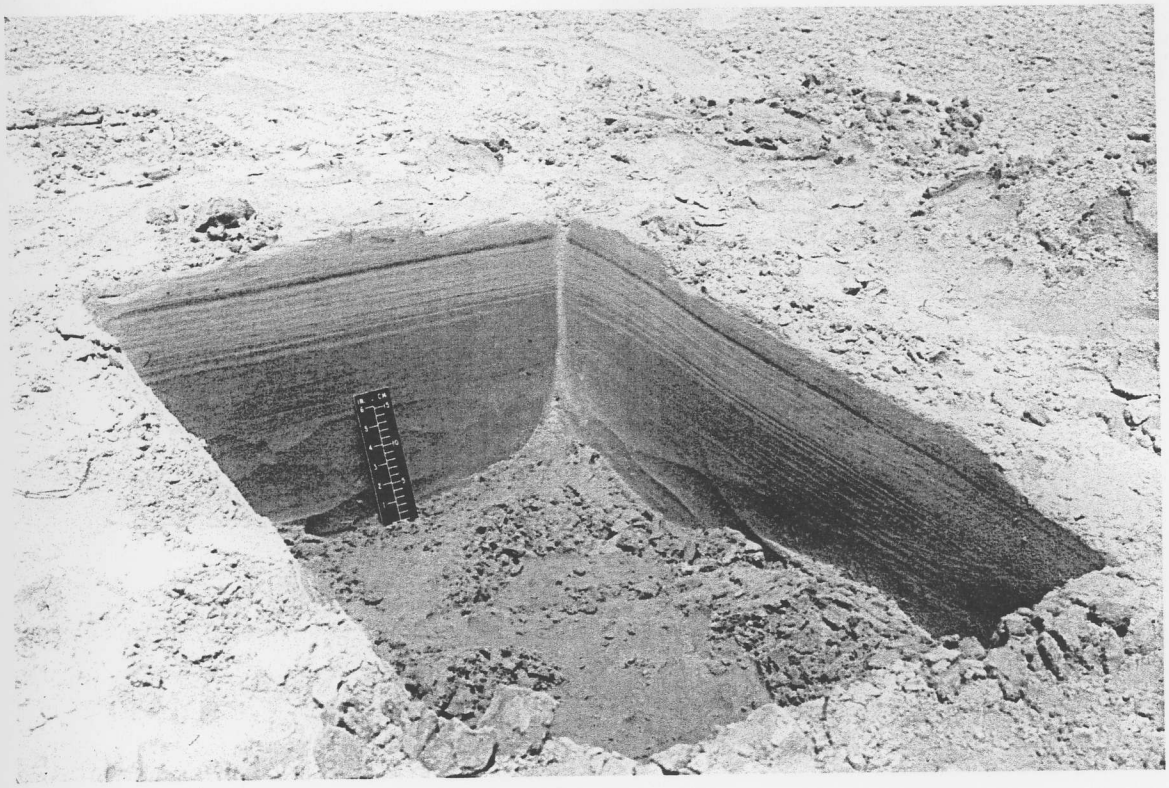


FIGURE 11. Trench in upper foreshore exposing characteristic parallel stratification that is dipping seaward (out of the photo) at a very low angle (3 degrees).

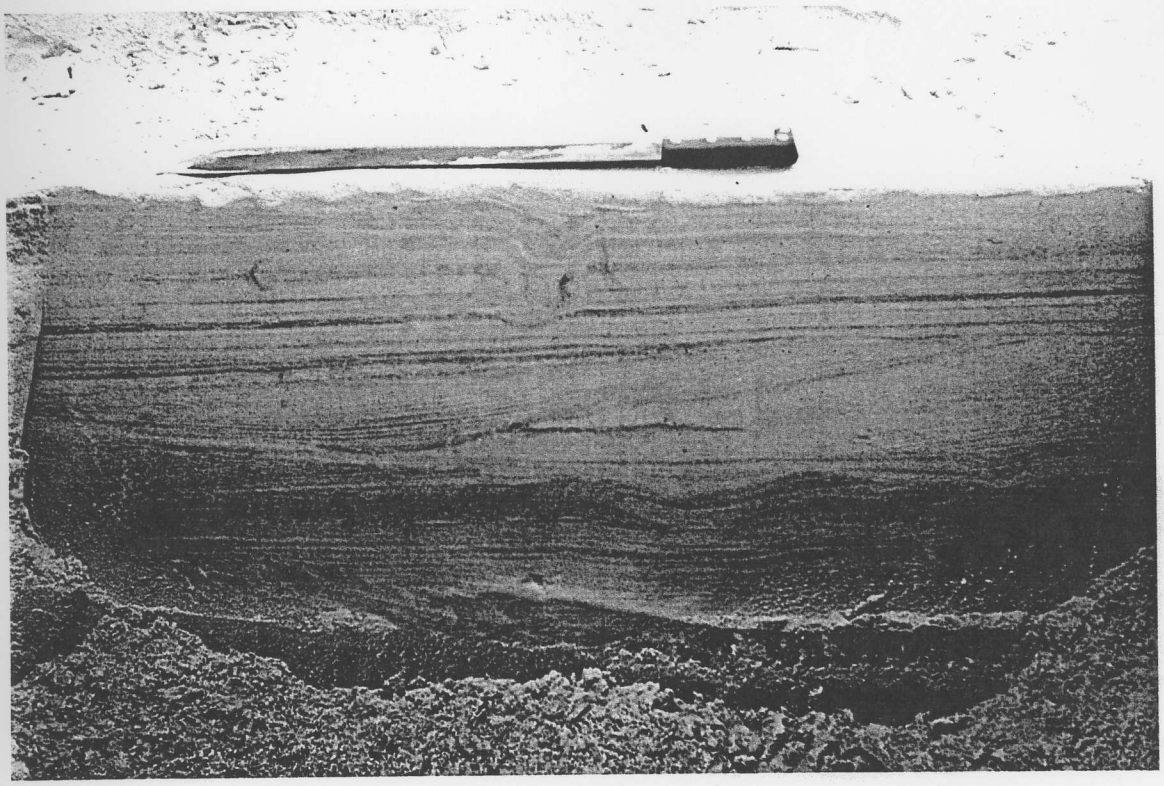


FIGURE 12. Trench in backshore showing parallel stratification, landward dipping cross stratification, irregular stratification, and collapsed burrow. Sea is to the right.

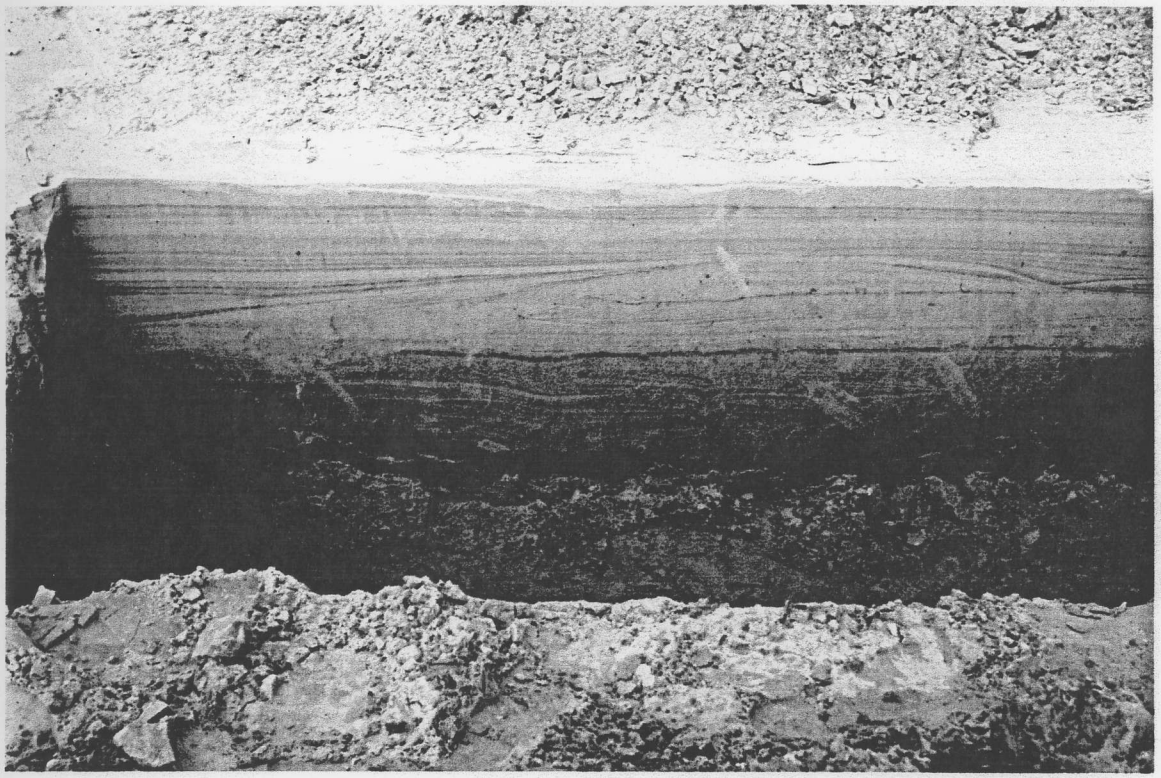


FIGURE 13. Trench in backshore displaying irregular nature of stratification; landward and seaward dipping cross stratification; and inclined, sand-filled ghost crab (*Ocypode*) burrows. Length of trench is approximately 2.5 m (8 ft) and sea is to the left.

impact on the backshore and their effects have been well documented by Hayes (1967).

Burrows of the ghost crab *Ocypode* (Fig. 14) are very abundant in the backshore and are the dominant biogenic structure. Their morphology in cross section varies from inlined to J-, Y-, and U-shaped. According to Hill and Hunter (1973) J- and U-shaped burrows dominate the seaward side of the backshore whereas Y-shaped burrows dominate the landward side. Also common are the burrows of rove bettles.

Unfortunately, as a result of man's activity in recent years to clean and remove trash from the backshore of Mustang Island, its natural characteristics have been severely modified.

Facies Model

The diagnostic characteristics of the lower foreshore, upper foreshore, and backshore are summarized in Figure 15. This model is representative of Texas coast beaches, and a similar sequence has been described in the Pleistocene Pamlico Formation (Fig. 16) of Florida by Howard (1971).

DUNES

The coastal dunes of Mustang Island occur along the front side of the island (foredunes) adjacent to the backshore and in the vegetated barrier flats on the backside of the island (back-island dunes). Most back-island dunes have originated from blowouts of localized sand areas susceptible to wind erosion because of devegetation. As a result of prevailing southeasterly winds, dune migration is generally to the northwest. Dune elevations are as much as 9 to 10 m (30 to 33 ft) and most dunes quickly become heavily vegetated and stabalized.

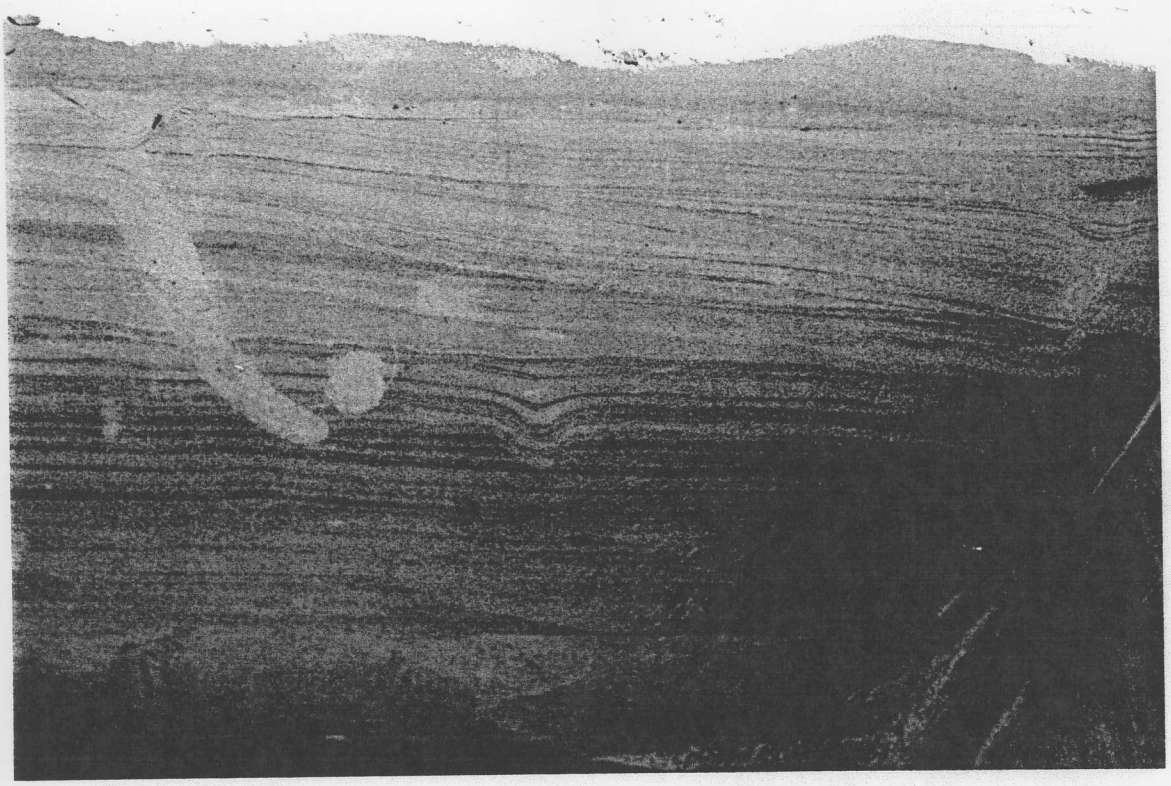


FIGURE 14. J-shaped and spherical *Ocypode* burrows, landward dipping cross stratification, and collapsed burrows in backshore trench. Length of J-shaped burrow is approximately 0.4 m (1.3 ft).

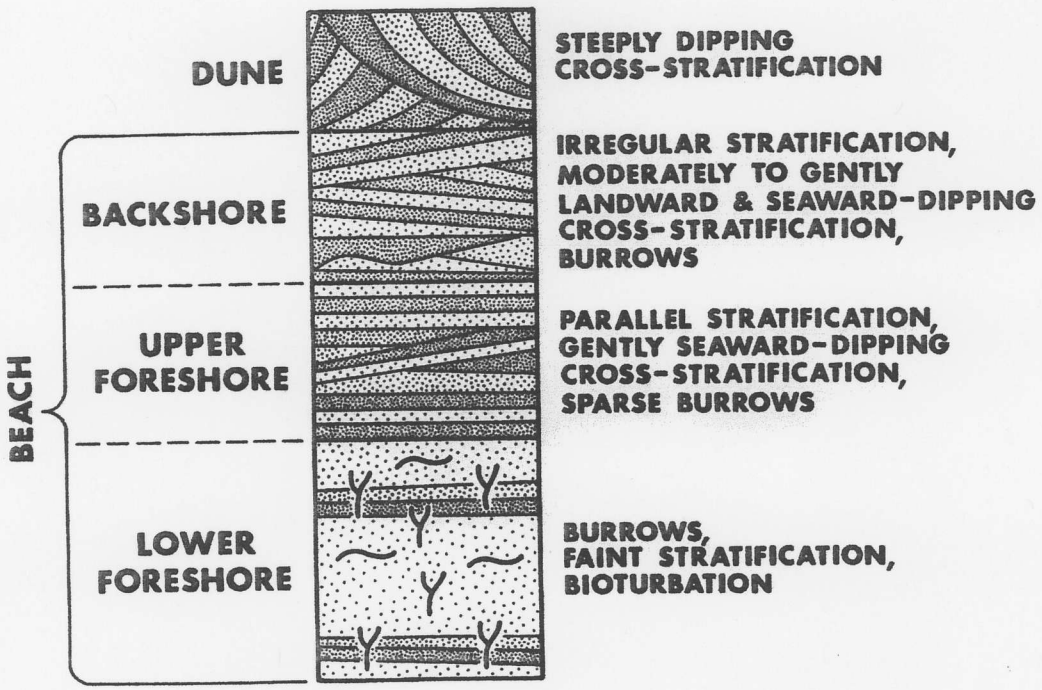


FIGURE 15. Beach facies model for Mustang Island and Texas coast in general.



FIGURE 16. Densely burrowed (*Ophiomorpha*) lower foreshore and parallel stratified upper foreshore succession in the Pamlico Formation (Pleistocene), St. Mary's River area, Florida. Height of outcrop face is approximately 3 m (10 ft).

Much more active dune fields are present on the backside of Padre Island where migration rates of as much as 30 m (85 ft) per year have been reported (Weise and White, 1980). Some of these dunes have migrated into Laguna Madre, and south of Baffin Bay wind deflation has led to the development of extensive dune fields on the coastal plain (South Texas eolian system; see Figs. 1 and 17).

Characteristics

The most conspicuous feature of the Mustang Island dunes is medium to large scale, steeply dipping (25+ degrees) cross stratification (Figs 18) formed by migrating bedforms (Fig. 19). McBride and Hayes (1962) measured dips as steep as 42 degrees on Mustang Island but dips exceeding 32 degrees are exceptionally rare. In addition to being steeply dipping, the cross stratification is frequently contorted or disrupted as a result of slumping and soft sediment faulting (Fig. 20 and 21). Often the base of the cross stratification makes a tangential contact with its lower bounding surface (Fig 22). The cross stratification occurs predominantly in sets bracketed by second-order bounding surfaces that have a tabular- or wedge-shaped geometry (Fig. 22).

The cross stratification within the sets is produced by three distinct processes (Fig. 23): grains avalanching down the slipface of the dune (sandflow/grainflow deposits; Fig. 24), grains blown beyond the brink of the dune and falling onto the slipface surface and dune apron (grainfall deposits), and by ripples migrating in various directions on the slipface and apron (wind ripple deposits).

Sandflow/grainflow deposits are the coarsest and have the highest permeability, whereas grainfall and ripple deposits are finer grained and have permeabilities 3 to 5 times lower. The difference in permeability between these "stratification types" becomes obvious when examining the dunes after a heavy rain (Figs. 25 and 26). From a reservoir perspective the permeability contrasts



FIGURE 17. Aerial photo of the south Texas eolian system near Baffin Bay. Dunes (transverse barchanoid ridges) are oriented perpendicular to wind direction (from left to right). Intervening interdune areas vary from wet to dry.



FIGURE 18. Acrylic resin peel showing tabular sets of steeply dipping cross stratification. Note interfingering of foresets and toesets. Length of peel is 0.9 m (3 ft).

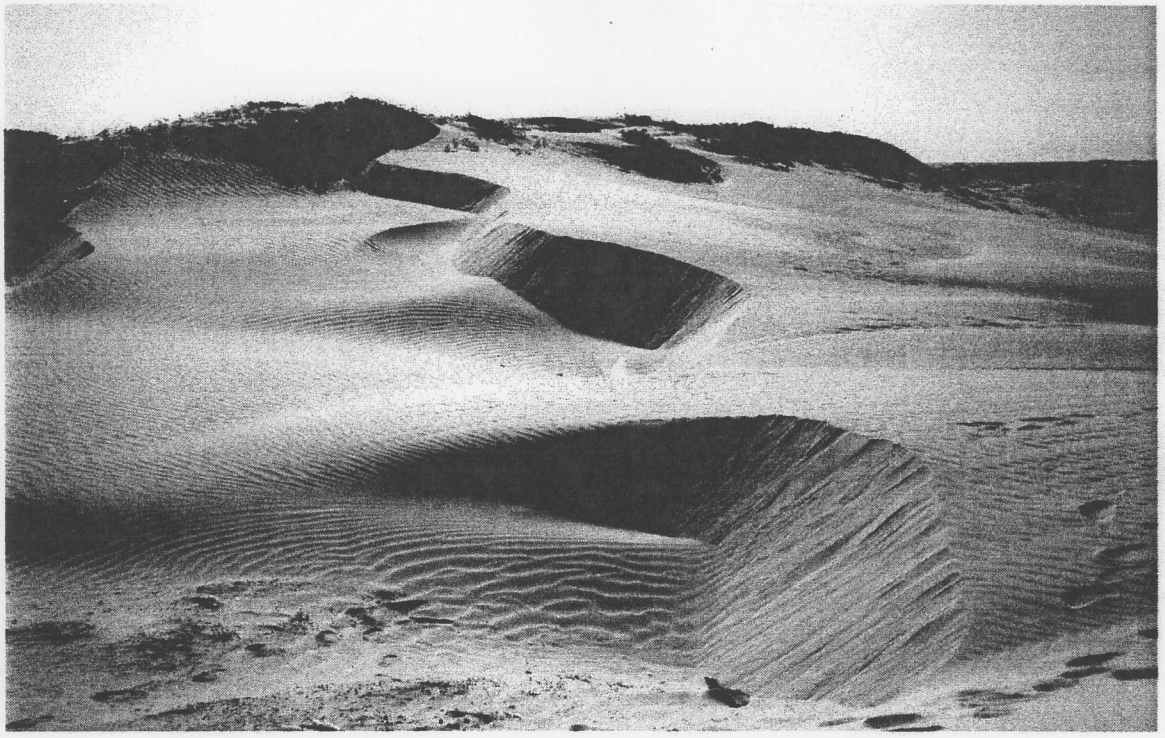


FIGURE 19. Migrating (from right to left) "dune" bedforms. Height of slipface on upper bedform is approximately1.2 m (4 ft).



FIGURE 20. Dune bedform displaying well developed, wind ripples migrating toward its brink and slumps at base of active slipface. Height of slipface is approximately 1 m (3.3 ft).

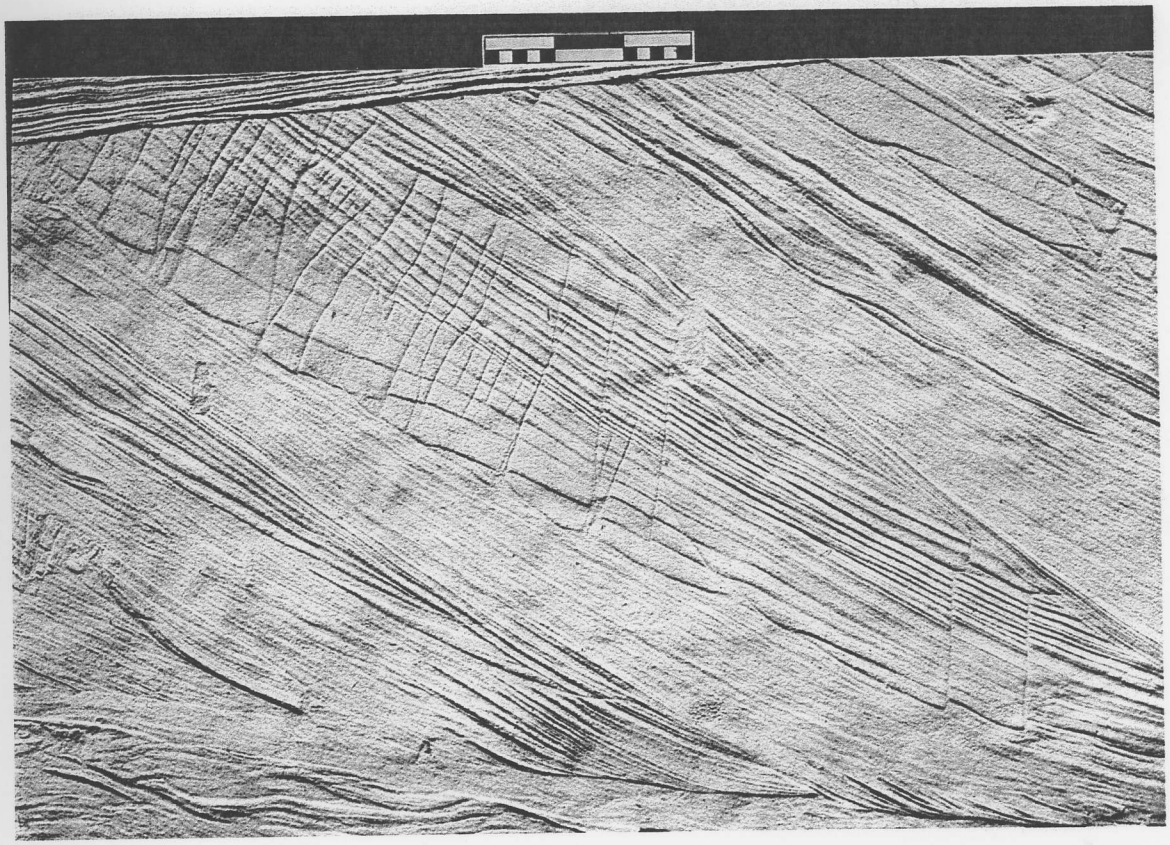


FIGURE 21. Acrylic resin peel displaying steeply dipping cross stratification disrupted by numerous soft sediment faults. Scale is 15 cm (6 in) long.



FIGURE 22. Steeply dipping cross stratification making a tangential contact with its lower bounding surface. Underlying set has a wedge-shaped geometry. Trench face is 0.8 m (2.75 ft) high.

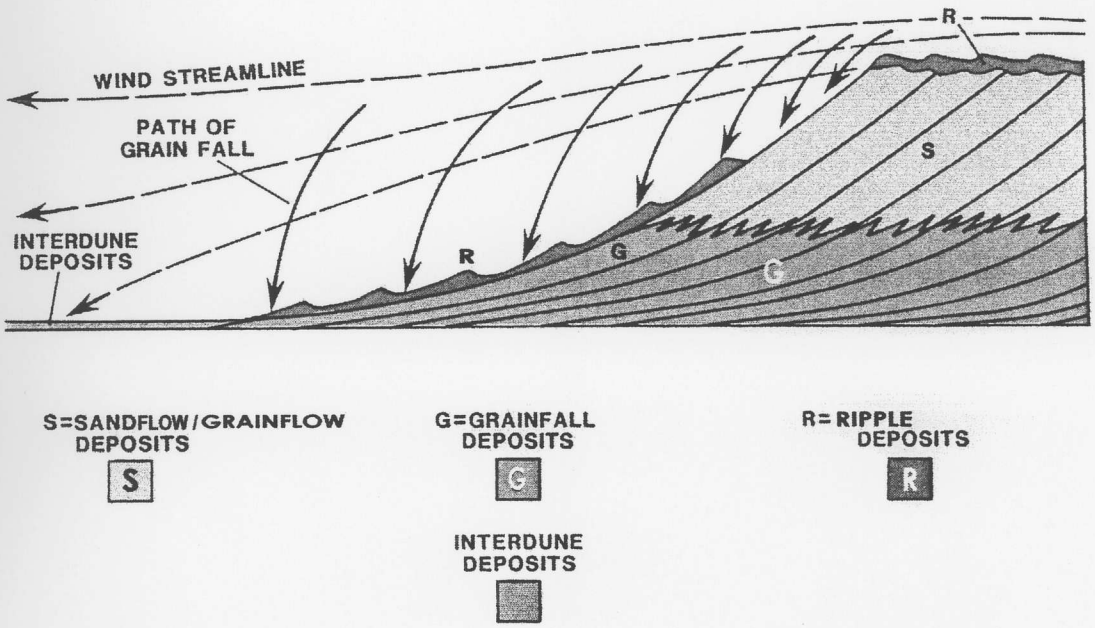


FIGURE 23. Schematic diagram illustrating formation and distribution of sandflow/grainflow, grainfall, and wind ripple deposits ("stratification types").

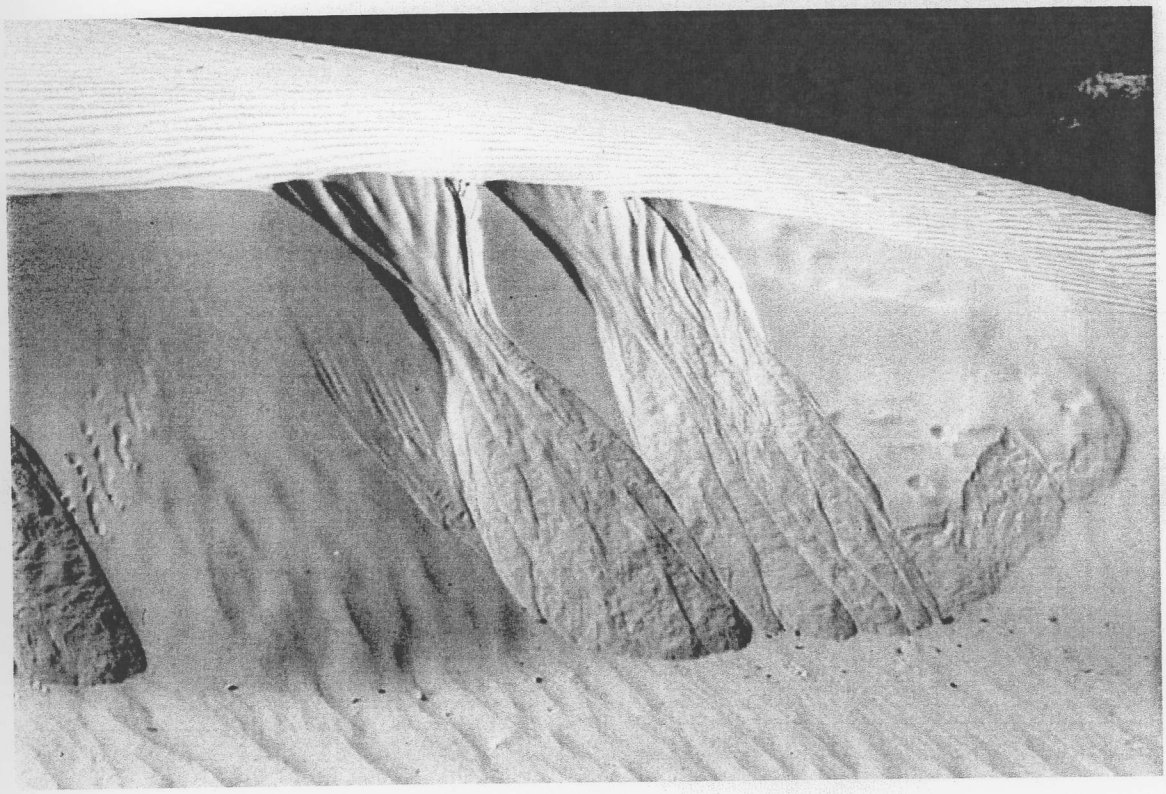


FIGURE 24. Slipface with sandflows/grainflows. Height of slipface is approximately 1 m (3.3 ft).



FIGURE 25. Photo of cross stratification in a dune following a heavy rain. Differential relief is related to permeability of stratification type. Wind ripple and grainfall strata retain moisture and exhibit relief whereas sandflow/grainflow strata transmit moisture and are preferentially deflated.

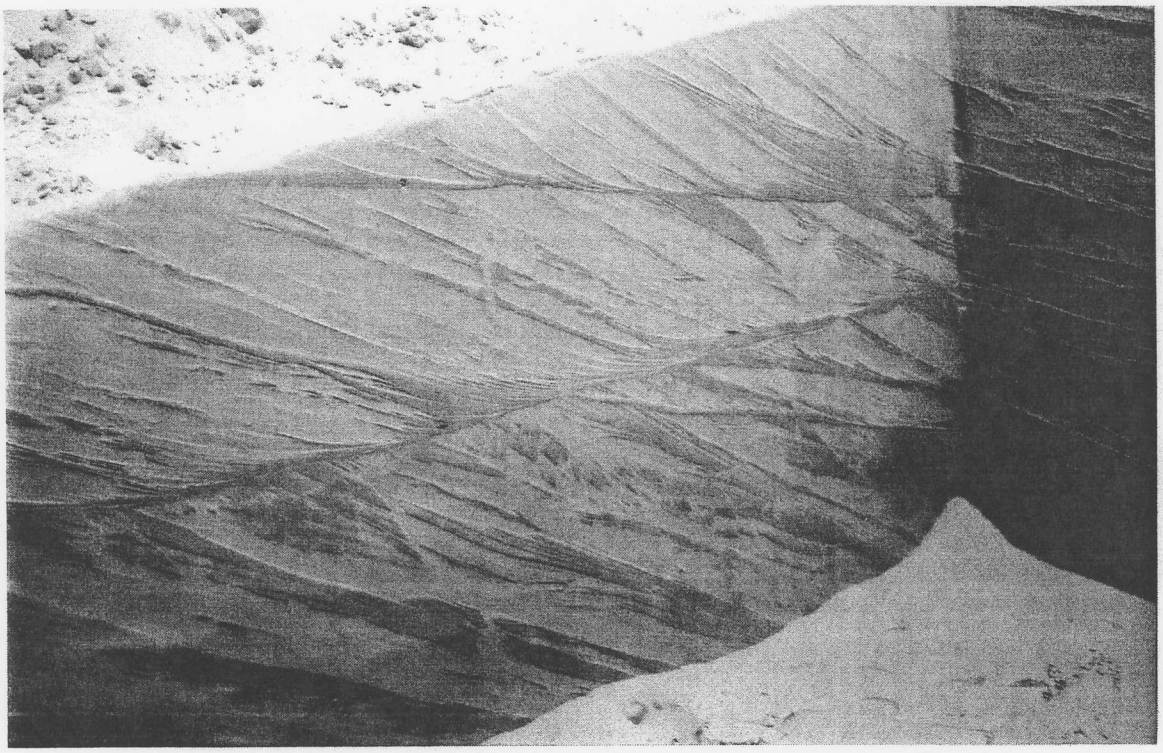


FIGURE 26. Trench in dune following a heavy rain. Variation in relief of steeply dipping cross stratification is related to differences in permeability of stratification types. Sandflow/grainflow deposits have a high permeability and dry quickly; whereas grainfall and wind ripple deposits have lower permeabilities, retain moisture, and standout in relief. Note interfingering of foresets and toesets, tangential basal contacts, soft sediment faults, and wedge-shaped geomertry of middle set. Height of trench face is 1.5 m (5 ft).

between stratification types on a cross strata by cross strata basis results in differential flow along, rather than across the statification and gives dunes a preferred anisotropy parallel to the slipface.

Biogenic structures in the dunes consist of features produced by plants; burrows made by ghost crabs, snakes, rodents, lizards, and insects; and the tracks and trails of various organisms (Fig. 27).

Summary Diagram

The general characteristics of eolian dune deposits are schematically summarized in Figure 28.



FIGURE 27. Tracks, ripples, and slumps on dune slipface. Horizontal length is approximately 4.5 m (15 ft).

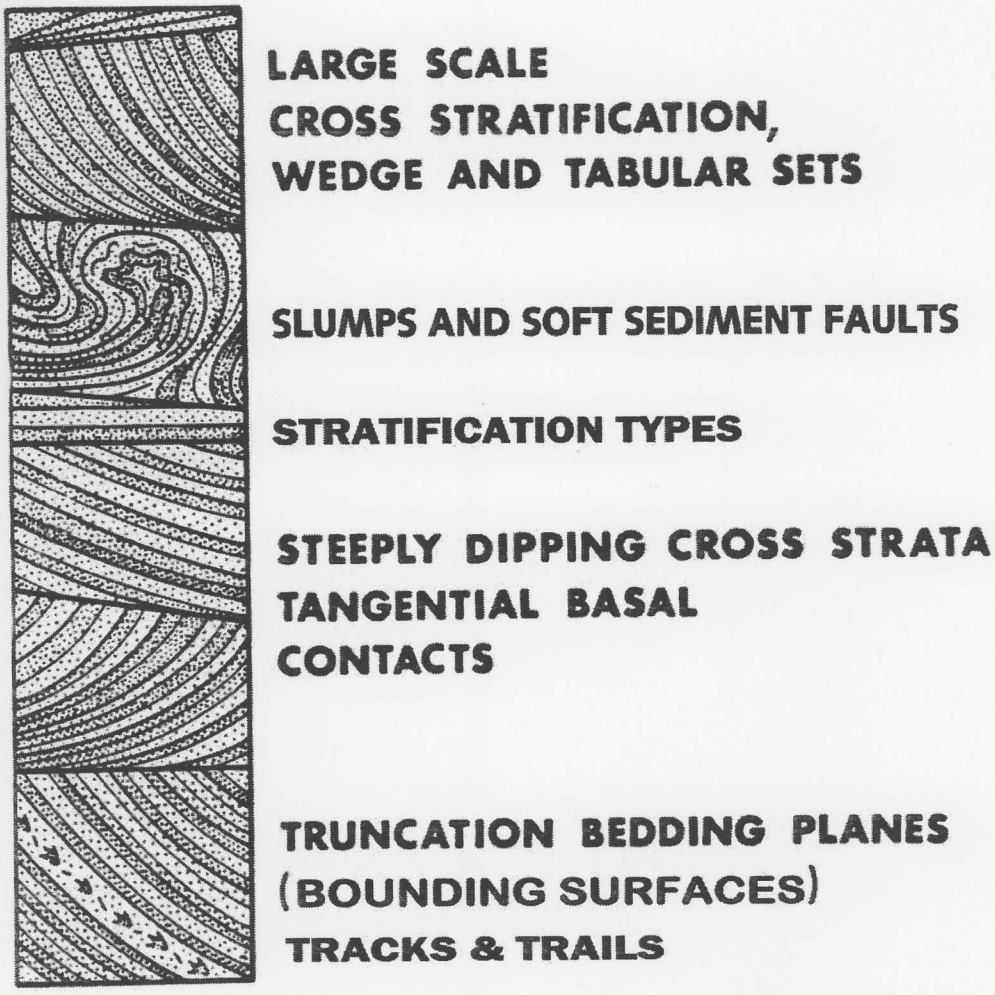


FIGURE 28. Schematic summary of the characteristics of dune deposits.

REFERENCES

Andrews, P. B., 1970, Facies and genessis of a hurricane washover fan, St, Joseph Island, central Texas coast: Texas Univ. Bureau Economic Geology Rept. Inv. 76, 147 p.

Brown, L. F., and others, 1976, Environmental Atlas of the Texas Coastal Zone – Corpus Christi Area: Texas Univ. Bureau Economic Geology, 123 p.

Brown, L. F., and others, 1977, Environmental Atlas of the Texas Coastal Zone – Kingsville Area: Texas Univ. Bureau Economic Geology, 131 p.

Dickinson, K. A., H. L. Berryhill, Jr., and C. W. Holmes, 1972, Criteria for recognizing ancient barrier coastlines: SEPM Spec. Pub. 16, p. 192-214.

Fisk, H. N., 1959, Padre Island and the Laguna Madre flats, coastal south Texas: Second Coastal Geography Conference, Louisiana State Univ., p. 103-152.

Hayes, M. O., 1967, Hurricanes as geological agents – Case studies of hurricanes Carla, 1961, and Cindy, 1963: Texas Univ. Bureau Economic Geology Rept. Inv. 61, 56 p.

Hill, G. W., and R. E. Hunter, 1973, Burrows of the ghost crab *Ocypode quadrata* on the barrier islands, south-central Texas coast: Journal Sed. Petrology, v. 43, p. 24-30.

Hill, G. W., and R. E. Hunter, 1976, Interaction of biological and geological processes in the beach and nearshore, north Padre Island, Texas: SEPM Spec. Pub. 24, p. 169-187.

Howard, J. D., 1971, Comparison of beach to offshore sequences in modern and ancient sediments: AGI Short Course Lecture Notes, Recent Advances in Paleoecology and Ichnology, p. 148-183.

Hummel, G., and G. Kocurek, 1984, Interdune areas of the back-island dune field, north Padre Island, Texas: Sedimentary Geology, v. 39, p. 1-26.

Hunter, R. E., and others, 1972, Modern depositional environments and processes, northern and central Padre Island, Texas: Gulf Coast Association Geological Societies Field Guide, Padre Island National Seashore, p. 1-17.
Hunter, R. E., 1977, Basic types of stratification in small eolian dunes: Sedimentology, v. 24, p. 361-387.
Kocurek, G., and others, 1992, Dune and dune-field development on Padre Island, Texas, with implications for interdune deposition and water table controlled accumulation: Journal Sed. Petrology, v. 62, p. 622-635.
McBride, E. F., and M. O. Hayes, 1962, Dune cross bedding on Mustang Island, Texas: AAPG Bull., v. 46, p. 546-551.
McKee, E. D., Primary structures in some Recent sediments: AAPG Bull., v.41, p. 1704-1747.
Milling, M. E., and E. W. Behrens, 1966, Sedimentary structures of beach and dune deposits, Mustang Island, Texas: Texas Univ. Institute Marine Sciences Pubs., v. 11, p. 135-148.
Moiola, R. J., R. T. Clarke, and B. J. Phillips, 1969, A rapid field method for makin peels of unconsolidated sands: Geol. Soc. America Bull., v. 80, p. 1385-1386.
Moiola, R. J., and A. B. Spencer, 1973, Sedimentary structures and grain size distribution, Mustang Island, Texas: Trans. Gulf Coast Association Geological Societies, v. XXIII, p. 324-332.
Morton, R. A., and J. H. McGowen, 1980, Modern depositional environments of the Texas coast: Texas Univ. Bureau Economic Geology Guidebook 20, 167p.
Scott, A. J., and others, 1964, Depositional environments, south-central Texas coast: Gulf Coast Association Geological Societies Field Trip Guidebook, 170 p.
Shideler, G. L., 1986, Stratigraphic studies of a Late Quaternary barrier type coastal complex, Mustang Island-Corpus Christi Bay area, south Texas Gulf Coast: USGS Prof. Paper 1328, 95 p.
Suter, J. R., 1989, South Texas Coast: Mustang and north Padre Islands: Gulf Coast Association Geological Societies Field Trip Guiodebook, South Texas Depositional Systems, p. 51-76.

Weise, B. R., and W. A. White, 1980, Padre Island National Seashore – A Guide to the Geology, and History of a Texas Barrier Island: Texas Univ. Bureau Economic Geology Guidebook 17, 94 p.

White, W. A., and W. E. Galloway, 1977, Guide to modern barrier environments of Mustang and north Padre Islands and Jackson (Eocene) barrier/lagoonal facies of the south Texas uranium district: Texas Univ. Bureau Economic Geology Research Note 7, 51 p.