Journal of Coastal Research | 13 | 3 | 595–604 | Fort Lauderdale, Florida | Summer 1997

Regional Coastal Morphodynamics Along the United States Gulf of Mexico

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ABSTRACT

DAVIS, R.A., Jr., 1997. Regional Coastal Morphodynamics Along the United States Gulf of Mexico. *Journal of Coastal Research,* 13(3), 595–604. Fort Lauderdale (Florida), ISSN 0749-0208.

The Gulf Coast of the United States exhibits a wide range of shoreline dynamics depending on the relative rise of local sea level, interactions of wave and tide energy, and sediment supply. The general trend of increased erosion during the past several decades is due in part to rising sea level and perhaps more importantly, to human intervention in the form of impoundment of sediment along fluvial/estuarine systems and, more locally, by numerous hard structures, especially those designed for navigation.

Generally the Texas coast is fairly stable except for three eroding deltaic headlands. Parts of the chenier coast of Texas and Louisiana are severely eroding and parts are accreting. The open coast of the Mississippi Delta area is the most rapidly eroding shoreline in the Gulf of Mexico and has severe problems throughout most of its extent. The northeastern coast of the Gulf is eroding in the west, but the peninsula of Florida is fairly stable. Because of the great local variability, these generalizations do have exceptions.

ADDITIONAL INDEX WORDS: *Coastal erosion, sea level rise, sediment compaction, transgression, progradation, longshore sediment transport.*

INTRODUCTION

The Gulf Coast of the United States presents a wide variety of coastal conditions that range from severely eroding to prograding. The primary factors that determine the current coastal conditions are similar to coasts in general and include rate of sea-level change, amount and type of sediment supply, and physical energy along the coast. In addition, human interference with coastal dynamics is a problem that continues to expand although it varies geographically. This brief discussion will consider the current and historical conditions of the Gulf Coast from the Rio Grande River delta at the southern border of Texas, around the coast to Florida Bay at the southern tip of Florida. For discussion purposes the Gulf Coast will be divided into broad geomorphic patterns.

General Setting

The Gulf of Mexico is a fetch-limited Mediterranean that is currently fairly stable tectonically. It is surrounded by a wide range of Quaternary deposits that are almost exclusively unconsolidated. Except for the passage of cold fronts, tropical storms, and hurricanes, the Gulf Coast experiences low wave energy conditions; mean annual significant wave height is less than 0.75 m and the mean wave period is less than 5 seconds throughout (JORDAN, 1973). Swell conditions with wave periods up to 9 seconds occur along all coasts, especially during summer. During hurricanes wave heights in deep water may reach up to 9 meters with periods of 12 seconds (GRYMES and STONE, 1995).

Storm surges of near 3 m have been recorded at numerous locations from south Texas through the Florida panhandle over the past few decades in association with the passage of hurricanes (*e.g.* HAYES, 1967; STONE *et al.,* 1996).

Prevailing winds have a southerly component along virtually all of the coast. These conditions are particularly persistent during summer. Cold fronts are frequent in the winter and, except for the hurricanes, are the dominant agent of coastal change. These frontal systems tend to move south from the high latitudes over the high plains and across the Texas coast with strong winds from the north. The offshore wind component along this coast limits wave energy (DAVIS and FOX, 1975) and minimizes erosion. By contrast, much of the eastern Gulf Coast experiences a distinct increase in wave energy with an onshore component as frontal passage takes place. These fronts move across the Gulf from mid-October through early March at intervals of about 5–8 days (FOX and DAVIS, 1976).

Sediment supply ranges widely throughout this coastal region. The only major rivers that carry sediment directly to the open coast other than the Mississippi, are the Rio Grande, Colorado and Brazos in Texas, the Sabine at the Texas-Louisiana border, and the Suwannee in Florida. All others debouch their sediment load into the numerous estuaries along the coast or behind barrier islands. Nearly all of these rivers have dams or other types of restrictive structures along their courses that also limit their sediment discharge at the

97024 received and accepted in revision 12 March 1997.

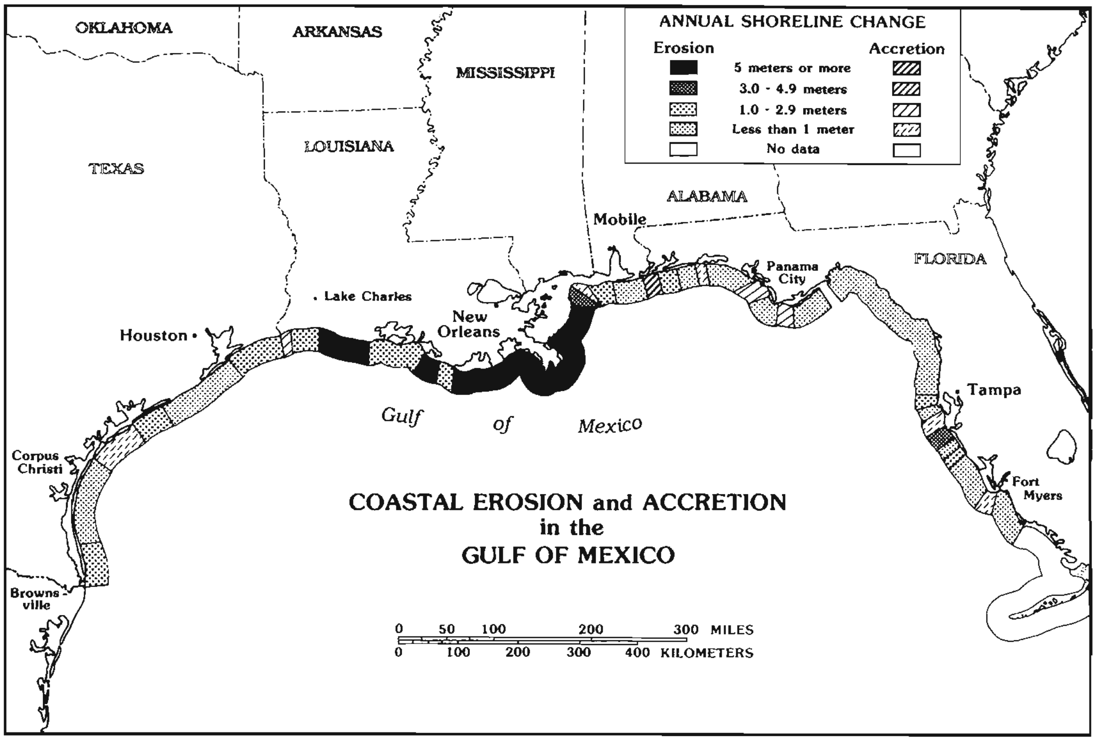

Figure 1. Map of the United States Gulf of Mexico coast showing general pattern and values of erosion and accretion. Rates are in meters/year (modified from DOLAN *et al.,* 1985).

coast. The Mississippi is the largest sediment source in the Gulf but only has significant impact on the northwestern Gulf Coast. Other important sediment sources are reworking of older deposits (*e.g.,* deltaic headlands and shoreface) and *in situ* production of biogenic skeletal material.

Sea-level change ranges widely but is well known throughout the Gulf Coast for about the past century. The Mississippi Delta complex represents an extreme condition with annual rates of sea-level rise of 10 mm. The Gulf Coast is characterized by a 2–3 mm/yr rise with south and central Texas, Mississippi, Alabama and the Florida panhandle being toward the high end of that range and the Florida peninsular coast being at the low end (NRC, 1987; HICKS and HICKMAN, 1988). This is largely due to the slight compaction of Quaternary sequences along most of the Gulf and the very thin Quaternary deposits located above the stable carbonate platform that comprises the Florida peninsula and adjacent west shelf. The east Texas coast from about Galveston Bay to western Louisiana is experiencing rates of sea level rise up to 1–2 mm/yr (NRC, 1987) due to a combination of sediment compaction and fluid withdrawal. All of these local and regional factors are overprinted with a eustatic rise in sea level of 12 mm/yr.

ASSESSMENT OF COASTAL CHANGE

The present condition of the Gulf of Mexico shoreline is quite varied throughout its extent (Figure 1). The rates of shoreline change have also varied greatly over the historical record. Some places have experienced change in only a few decades with most of these having some anthropogenic origins. At least a century of good data on shoreline change is available for the entire U.S. Gulf Coast. To the extent that these data allow, the discussion will consider both spatial and temporal changes. The interested reader is referred to the comprehensive summary of shoreline change reported by the Coastal & Shoreline Erosion Action Agenda (4.1) for the Gulf of Mexico (GMP, 1993).

Texas Coast

This section includes the coastal reach from the Rio Grande to the entrance to the Bolivar Peninsula east of Galveston Bay (Figure 2), most of the Texas coast and a total of 835 km. Most of the data in this section come from the work of MORTON (1977, 1979, 1991, 1993, 1994). Good data for most of this coastal reach extend back to approximately 1850. Erosion is generally associated with the deltas such as the Rio Grande and the Colorado/Brazos (Figure 2). These areas were headlands during the early Holocene as sea level rose and the shoreline transgressed. As such, they became sediment sources and sites of longshore transport divergence (PRICE, 1954; MORTON, 1979). Other parts of the Texas coast have been prograding through time, especially near the major convergence of littoral sediment transport in the central Padre Island area (Figure 2). This convergence has been documented through various means (WATSON, 1971; DAVIS, 1978) and has provided a major source of sediment in the "landcut" area

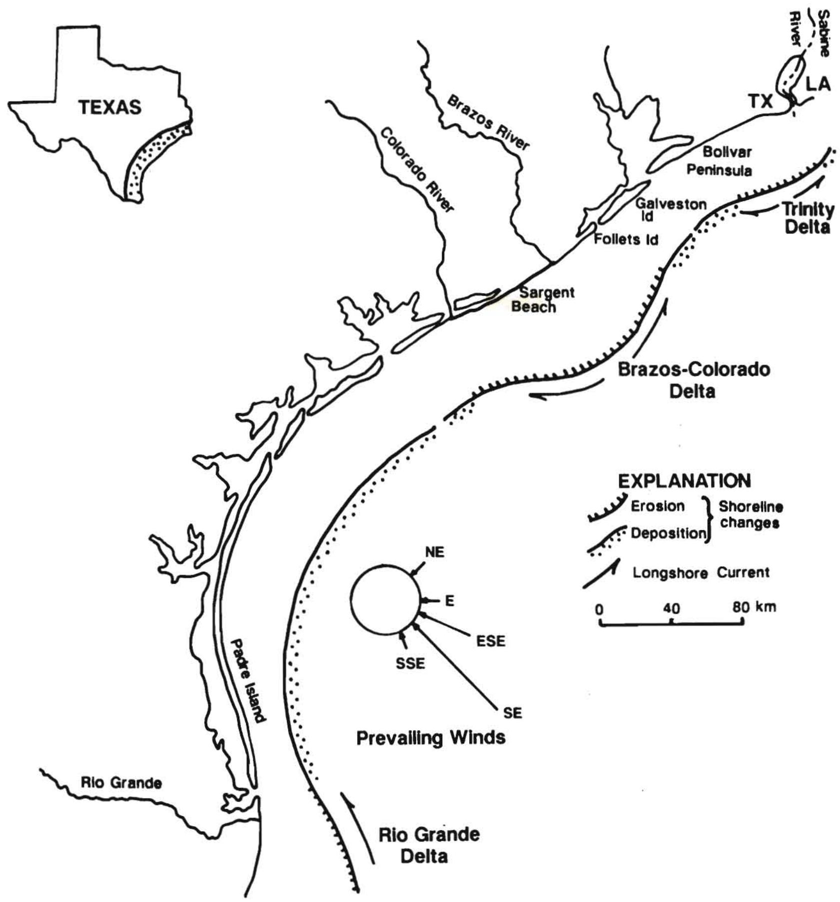

Figure 2. Texas coast showing major coastal elements and trends in coastal change. (from MORTON, 1979).

of southern Padre Island where landward transport by eolian processes is a major factor in coastal morphology.

Through time, behavioral changes of the shoreline have occurred along this coast. The deltaic headlands mentioned above have experienced erosion throughout the period of record. Prior to the late 1960s, the coast as a whole experienced a near balance between sediment supply and sediment removal. Since that time, about 70% of the Texas coast has been experiencing erosion with rates up to 10 m/yr (MORTON, 1993; GMP, 1993). This erosion has occurred due to the relative rise in sea level combined with a decrease in sediment supply. The primary sediment sources are the fluvial/deltaic areas, however, the combination of (1) reduced supply due to impoundments, (2) general lack of sand-sized sediment at deltas, and (3) compaction of the deltaic sequences has produced the current situation (MORTON, 1979).

Several areas of shoreline retreat are associated with developed portions of the Texas coast. The most severe problems of erosion along this coast have occurred on the headland area of the Brazos/Colorado deltas at Sargent Beach (Figure 3). Since development in the late 1950s and early 1960s, several hundred houses have been lost to coastal erosion (Figure 3). Annual erosion rates at this location have been up to 51 m (STAUBLE *et al.,* 1991). Serious erosion problems are also occurring along the southernmost part of Padre Island just north of the jetty at South Padre Island, Texas, and also on Folletts Island to the west of Galveston, a coastal reach that will be discussed in combination with eastern Louisiana in the following section.

Chenier Plain of East Texas and Western Louisiana

The coast that extends from High Island, east of Galveston Bay, to Southwest Pass at Vermillion Bay on the Texas and Louisiana coast (Figure 4) is characterized by an extensive chenier plain (FISK, 1955; BYRNE *et al.,* 1959). The sediments along this section of the coast contain mostly mud and shells; terrigenous sand is present as a thin ribbon along the shoreline except along the western end of High Island. These sediments are compacted through time, resulting in a relatively high rate of sea level rise in this area, typically about 5–7 mm/yr (NRC, 1987).

This region is characterized by reaches that alternate between erosion and accretion depending on their location relative to a sediment source. For example, on the Texas side, the highway along High Island has been closed for several years due to erosion. It is sediment starved as compared to the easternmost Texas coast adjacent to the Sabine River del-

Figure 3. Photograph of severe and chronic erosion at Sargent Beach, Texas (see Figure 2 for location) taken in 1972. At the present time 2 more blocks of houses have been lost to erosion.

ta where a sediment supply has resulted in accretion on both the Texas and Louisiana sides.

Much research has taken place along the Louisiana portion of the chenier plain (*e.g.,* BYRNES and MCBRIDE, 1995) thereby providing detailed analysis of shoreline changes over the past century. The general trend is one of erosion except at the passes and channel mouths where sediment is being supplied (Figure 4). Erosion rates over the century may be up to 9 m/yr and accretion is typically less than 3 m/yr (BYRNES and MCBRIDE, 1995). Hard structures have been built at several locations in an effort to control erosion. Both revetments and offshore breakwaters have been installed with little success. Although the patterns of shoreline advance and retreat have not changed with time, the rates of shoreline change have increased over the past century reflecting the decrease in sediment supply to the coast (BYRNES and MCBRIDE, 1995).

Mississippi Delta Plain Coast

To the east of the chenier plain the Gulf Coast is dominated by present and past lobes of the Mississippi Delta. Much of this reach of coast is characterized by some type of barrier/inlet system that has developed from the reworking of the deltaic lobes as sea level rose over them. The exceptions include Atchafalaya Bay and related marsh islands to the west, and the modern active lobe of the river with its associated distributaries (Figure 5). This is the most rapidly eroding coastal region in the United States (MORGAN and LARIMORE, 1957; STONE and PENLAND, 1992). Four barrier/strandplain systems are present along this reach. From west to east they are Isles Dernieres, Bayou Lafourche, Plaquemines shoreline, and the Chandeleur Islands (Figure 5).

These mud-rich deltaic lobes accumulated rapidly when they were actively receiving sediment. Now they are compacting, oil and gas are being removed from them in great quantities, there is little sediment being supplied by the modern active lobe of the Mississippi because of dams and other human interferences, and eustatic sea level is rising. The combinations of these factors has resulted in very rapid rates of relative sea-level rise; about a centimeter per year (NRC, 1987).

The result is that the low-lying barriers and their related marshes are becoming reduced in areas at dramatic rates (PENLAND and BOYD, 1981; PENLAND *et al.,* 1988; MCBRIDE and BYRNES, 1995). Beaches are being eroded, the entire island is migrating rapidly with a landward component as washover takes place (Figure 6), and the elevation of the islands is being reduced. In addition, the marshes on the land-

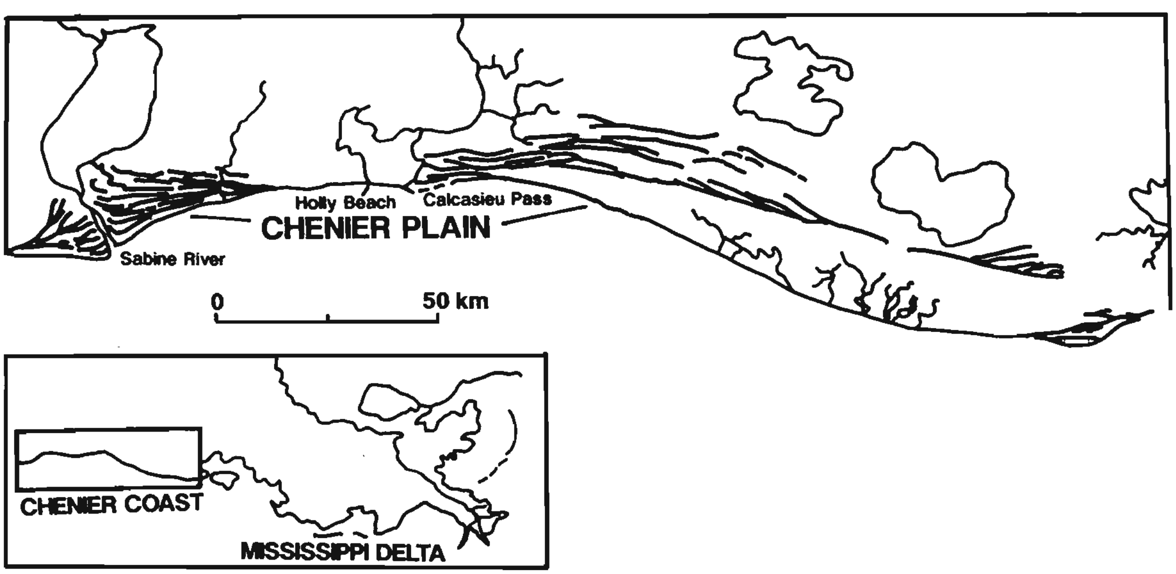

Figure 4. Map of the Chenier coast along western Louisiana and easternmost Texas (modified from GOULD and MCFARLAN, 1959).

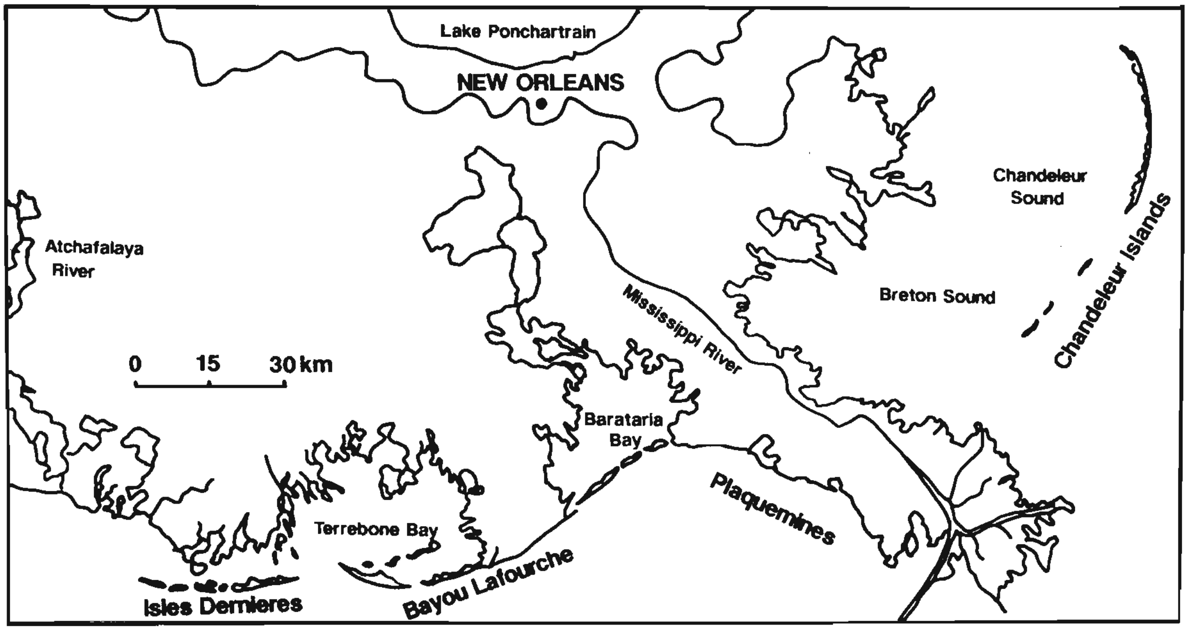

Figure 5. General map of the Mississippi Delta area showing the four barrier and strandplain areas that are all severely erosional.

ward sides of the islands are also being eroded. Some have completely disappeared during historical time and others are eroding so fast that their demise can be predicted in the next century (PENLAND *et al.,* 1988; MCBRIDE *et al.,* this volume).

The four islands that compose the Isle Dernieres coast have retreated up to almost two kilometers during the past century (MCBRIDE *et al.,* this volume). During the same period, Raccoon Island has lost about 80% of its area. Mean shoreline retreat is over 10 m/yr on the Gulf side and nearly 2 m/yr on the landward side. Some of the barriers in the Bayou Lafourche system have retreated at twice that rate and also show a lateral shift of nearly 100 m/yr. The Plaquemines coast has also displayed marked shoreline retreat but at annual rates that are less than the barriers to the west (MCBRIDE and BYRNES, 1995).

Figure 6. Oblique photo showing extensive washover of a narrow and low barrier along the Mississippi Delta coast.

The Chandeleur Islands are aligned nearly north-south and are east of the modern delta lobe (Figure 6). These low-lying barriers are washed over at least annually and have shown very rapid landward migration. Although there is variation in the rate of landward migration along this system, unlike the barriers west of the modern lobe, there is little seaward erosion on the Chandeleurs.

The overall situation on the Mississippi Delta plain is critical. There is loss of hundreds of acres of marshland each year, the barriers are diminishing in size and rapidly migrating landward and the only end in sight is the complete loss of the barriers. The only apparent solution to the problem lies in a combination of the return of fluids withdrawn and increasing the sediment supply from the river.

Northeast Gulf Coast: Mississippi, Alabama and Florida Panhandle

The coast along the eastern portion of the northern Gulf of Mexico is characterized by barrier islands. These barriers range from being several kilometers from the mainland in Mississippi to those that are essentially in contact with the mainland in the eastern part of the Florida panhandle (Figure 7). Wave energy generally increases to the east due to the sheltering effect of the Mississippi Delta and then decreases again toward the Apalachicola Delta in Florida. Longshore transport of sediment along this coast is generally thought to be east to west, however recent work has described a complex cellular transport system (STONE, 1991; STONE and STAPOR, 1996). Sediment sources along this coast are from; (1) a Pleistocene barrier complex along Grayton/Miri-

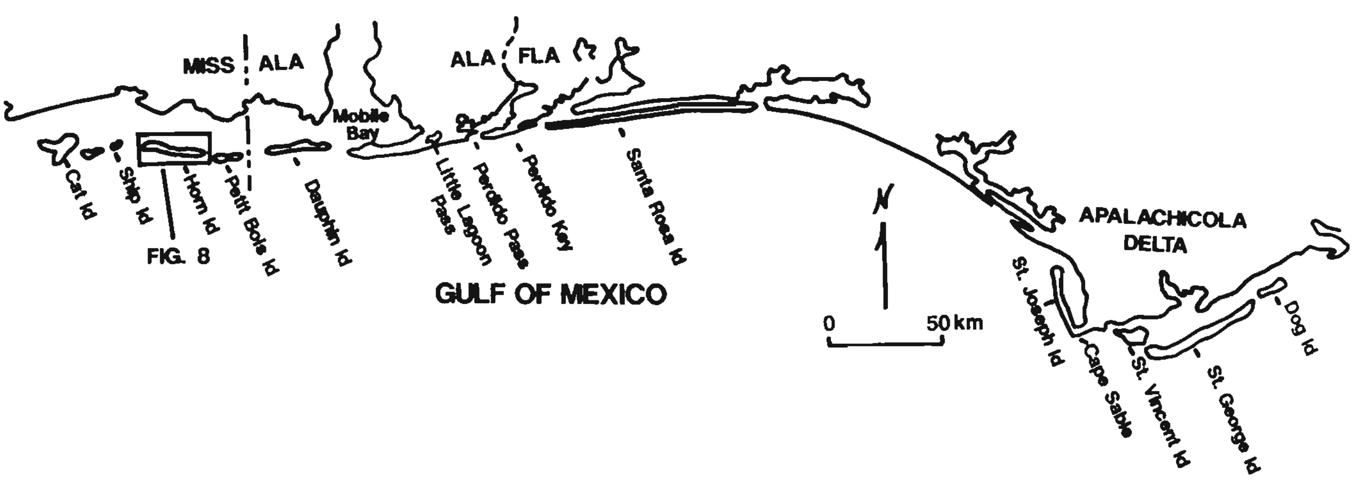

Figure 7. Map of the northeast coast of the Gulf of Mexico showing barrier islands from the Mississippi Delta through the Apalachicola Delta in Florida.

mar Beach in Florida, (2) Pensacola Beach on Santa Rosa Island, and (3) the inner shelf in the central part of the area (STONE, 1991). Residential development is widespread along the barrier coast of both Alabama and the Florida panhandle but is absent to nominal on the Mississippi coast.

As is the case for the Texas coast, data on shoreline changes along this reach extend back to the 1850s. These data show a constant migration of the Mississippi barrier islands toward the west (Figure 8) with rates up to over 30 m/yr (BYRNES *et al.,* 1991). Shoreline retreat is also widespread along this mainland coast where considerable armoring and development of the shoreline have occurred (BYRNES *et al.,* 1991; GMP, 1993). The chain of four barrier islands in Mississippi has experienced erosion of up to 3.0 m/yr over the 124-year period of record. Cat Island is the most stable and Ship Island tends to be the most erosive, however, all of the islands have displayed a loss of area since 1848 (BYRNES *et al.,* 1991).

The western part of the Alabama coast, specifically Dauphin Island, shows a similar pattern of erosion and westward migration as the Mississippi barriers (W. E. Smith, *pers. comm.*); erosion rates are up to 7 m/yr on the east end. There has also been landward migration and narrowing of the island as the result of Hurricane Frederic in 1979. The eastern part of the Alabama coast does not show a clear trend over the past few decades. Beach ridge truncation is prominent, however, indicating erosion in the more distant past. Jetties at two inlets (Perdido Pass and Little Lagoon Pass) have resulted in substantial downdrift (west) erosion (W. E. Smith, *pers. comm.*).

The Florida panhandle includes 350 km of open coast with two distinct segments; the western barrier/strandplain section which trends east-west, and the eastern portion associated with the Apalachicola Delta (Figure 7). Data for the western portion of the panhandle extend back to 1856 and show that erosion problems have existed on the western half of Santa Rosa Island and the eastern half of Perdido Key with rates ranging from 0.7 to 1.5 m/yr (BALSILLIE *et al.,* 1986; STONE, 1991). This erosion is attributed to a combination of increased wave energy due to inner shelf bathymetry and washover during hurricanes (STONE, 1991).

The Apalachicola area of the Florida Panhandle includes four barriers with very different shoreline orientations (Figure 7). The combination of different shoreline orientations and rates of sediment supply has resulted in highly variable rates of shoreline change. The barrier islands are typically eroding on the southeast-facing side and prograding on the southwest-facing side (DONOGHUE *et al.,* 1990). Greatest

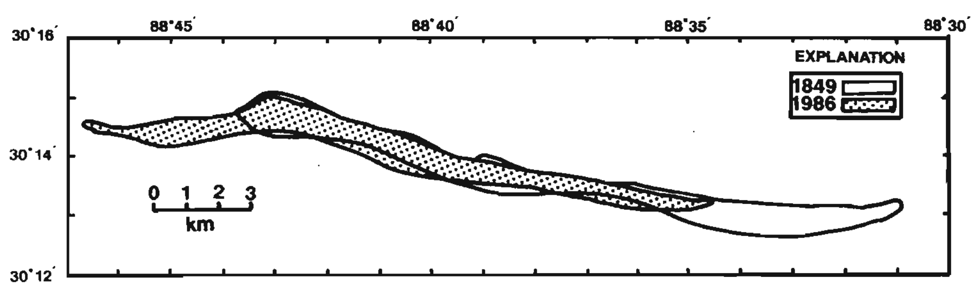

Figure 8. Horn Island on the Mississippi coast showing the alongshore migration over the past century (from BYRNES *et al.,* 1991).

Figure 9. Oblique aerial photo of Cape San Blas, Florida showing truncation of beach ridges on the eroding side of the cape.

rates of change are present adjacent to Cape San Blas (Figure 9) where erosion rates are up to 9 m/yr and accretion may be up to 19 m/yr (BALSILLIE and CLARK, 1992).

Florida Peninsula Coast

The Gulf peninsular coast of Florida can be divided into three distinct sections: the Big Bend area which is characterized by a open marsh coast and a dearth of sediment; the central barrier/inlet system; and the mangrove coast of the Ten-Thousand Islands/Everglades area (Figure 10). All of this coast is situated on the stable, carbonate platform that comprises the entire Florida peninsula.

The Big Bend area extends from the Ochlockonee River near the town of Panacea, Florida to the first barrier island to the south near Tarpon Springs, a distance along the irregular coast of approximately 400 km. The marshes along this coast are exposed to the open Gulf of Mexico and include the typical associated tidal creeks and oyster reefs with a few relict Pleistocene islands (WRIGHT, 1995). TANNER (1960) referred to it as a "zero energy" coast as an explanation for the absence of beaches and the presence of marshes along the open Gulf. In actuality, it is probably more appropriate to consider the area as a "zero sediment" coast because of the general lack of terrigenous sand sized sediment along this reach. The Suwannee River and its small delta provide the only significant fluvial input but bedload discharge is very small. The relatively high influence of tides over the very small waves have produced an irregular, tide-dominated coastal morphology. Recent detailed investigation of the coastline at numerous locations has shown pronounced shoreline stability (HINE *et al.*, 1988; DAVIS and HINE, 1989) although a recent map compiled by the Gulf of Mexico Program (1993) indicates erosion rates of 2 m/yr as typical.

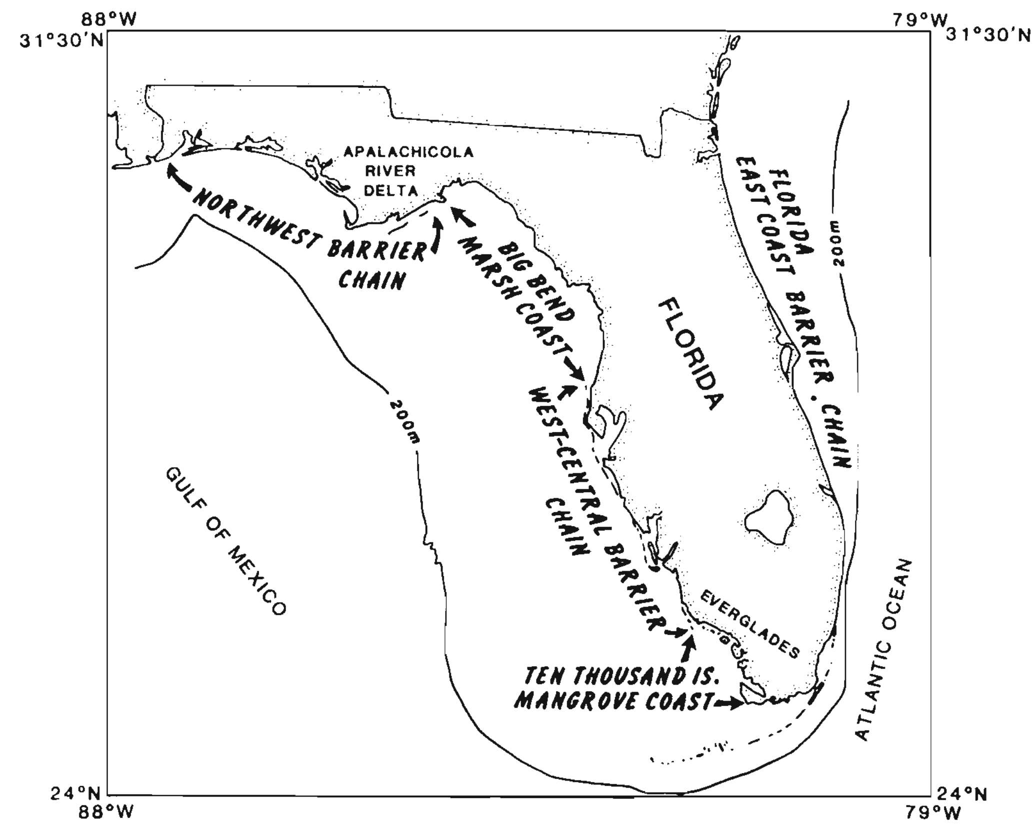

Figure 10. Map of Florida showing the major coastal provinces of the state.

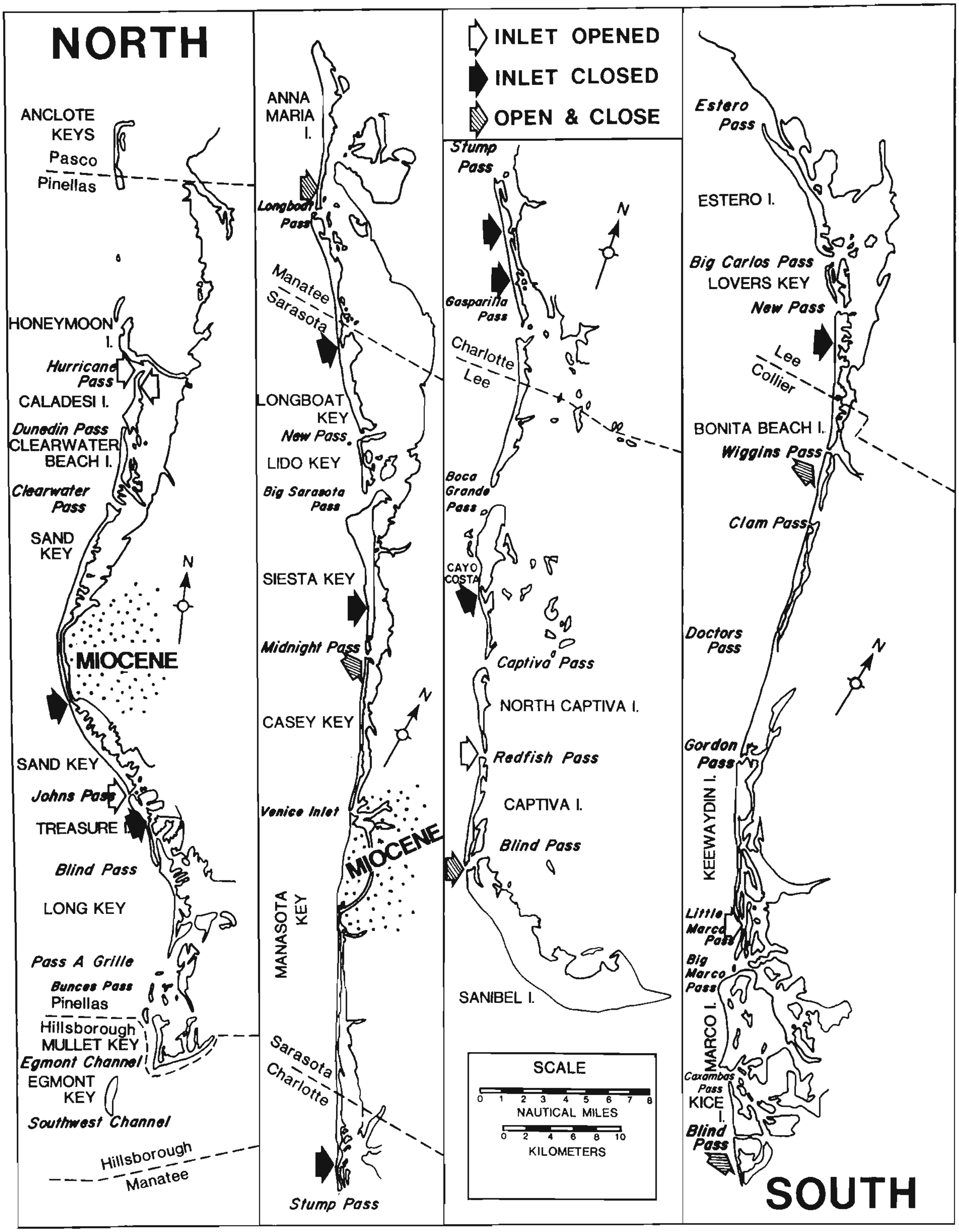

Figure 11. Strip map of the west-central Florida barrier/inlet system showing two Miocene bedrock headlands.

Figure 12. Oblique photo of Caladesi Island (see Figure 11), an excellent example of the mixed-energy, drumstick barrier as it appeared in 1979. The inlet in the foreground, Dunedin Pass, has now closed.

The Gulf peninsula of Florida has what is probably the most morphologically complex barrier island system in the world (DAVIS, 1988). It is composed of 30 barriers and a like number of inlets that extend for 230 km. This mixed-energy coast includes drumstick and wave-dominated barriers, wave- to tide-dominated inlets, and barriers that range from only a decade to millennia in age. Two broad headlands of Miocene carbonates are present adjacent to Sand Key and near Venice (Figure 11). Although some of the barriers are pristine, most have experienced extensive development and coastal structures are widespread. Sediment supply is quite limited along the Gulf peninsula of Florida with less than 10 m of Quaternary strata above the older carbonates along most of the coast (DAVIS and HINE, 1989). Beaches and barriers are composed of fine quartz sand reworked from older sediments along with the biogenic carbonate shell component that is continually being produced.

The numerous inlets, some structured and some natural, trap considerable sediment and strongly influence adjacent shorelines. It is impossible to characterize shoreline trends along this coast because of the variability. Several islands display the typical drumstick barrier characteristics of erosion at one end and progradation at another, *e.g.,* Caladesi (Figure 12), Siesta Key, Cayo Costa. Considerable erosion of beaches along highly developed portions of this coast has led to large beach nourishment projects, most of which have been highly successful, *e.g.,* Sand Key, Longboat Key and Captiva Island.

The southernmost coast of the U.S. Gulf of Mexico is dominated by mangroves and is characterized by very low wave energy (TANNER, 1960). Beaches are nearly absent along the open coast of the Ten Thousand Islands and the Florida Everglades except for the cuspate foreland at Cape Sable on the southern end of this coast. Beaches that are present are dominated by shell gravel debris. The combination of the wide and gentle gradient inner shelf with the sheltering effect of the coastline from the northerly winds of the winter frontal systems keeps the wave energy very low leading to tide-dominated morphology along this coast (DAVIS, 1988) although the tidal range is only about 1.2 m during spring conditions. The shoreline is generally stable due to the influence of the mangroves. Even during Hurricane Andrew in 1992, shoreline retreat was not significant (DAVIS, 1995; TEDESCO *et al.,* 1995).

SUMMARY

The shoreline of the Gulf of Mexico shows expected differences in its stability. Wave energy, sea level change and sediment supply are the primary factors in controlling its position with recent and local impact from human intervention. There are some generalizations can be made along with their respective rationales:

(1) Much of the Texas coast is stable except for areas dominated by old deltaic headlands which are now eroding and subsiding as the result of late Holocene transgression.

(2) The chenier coast of eastern Texas and western Louisiana is experiencing a combination of accretion and erosion. The latter is due to the diminishing sediment supply from the Mississippi/Atchafalaya system and sea-level rise caused by compaction and subsidence.

(3) The most rapidly eroding section of the entire Gulf Coast is the Mississippi Delta Plain coast and its associated barrier islands. Some barriers have already disappeared and others are forecast for the same fate in the next century.

(4) The northeastern Gulf Coast shows generally decreasing trends of rates of erosion from west to east with great variation in the Appalachicola Delta area.

(5) The peninsular coast of Florida is fairly stable except for local erosion problems within the barrier system of the central region.

ACKNOWLEDGEMENTS

Much of the information presented in this summary was obtained through the kind efforts of numerous colleagues including R. A. Morton of the University of Texas Bureau of Economic Geology, K. K. McKenna of the Texas General Land Office, G. W. Stone from Louisiana State University, W. E. Smith and R. Hummell of the Alabama Geological Survey and J. F. Donoghue at Florida State University.

LITERATURE CITED

BALSILLIE, J.H.; CHIU, T.Y., and DEMIRPOLAT, S., 1986. Long-term shoreline change for Escambia County, Florida. Florida Department Natural Resources, *Beaches and Shores Special Report No. 86-1.*

BALSILLIE, J.H. and CLARK, R.R., 1992. *The Gulf Coast of Florida: Overview of Physiography, Geology and Historical Shoreline Chance.* Florida Department National Resources, Division of Beaches and Shores.

BYRNE, J.V.; LEROY, D.O., and RILEY, C.M., 1959. The Chenier plain and its stratigraphy, southwestern Louisiana. *Transactions Gulf Coast Association of Geological Societies,* 9, 237–260.

BYRNES, M.R.; MCBRIDE, R.A.; PENLAND, S.; HILAND, M.W., and WESTPHAL, K.A., 1991. Historical changes in shoreline position along the Mississippi Sound barrier islands. Coastal Depositional Systems in the Gulf of Mexico: Quaternary Framework and Environmental Issues, Proceedings 12th Annual Research Conference, *Gulf Coast Section, SEPM,* 43–55.

DAVIS, R.A., 1978. Beach sedimentology of Mustang and Padre Island: a time series approach. *Journal Geology,* 86,35–46.

DAVIS, R.A., 1988. Morphodynamics of the west-central Florida barrier system: the delicate balance between wave and tide domination. *Coastal Lowlands, Geology and Geotechnology.* Dordrecht, The Netherlands: Kluwer, pp. 225–235.

DAVIS, R.A., 1995. Geologic impact of Hurricane Andrew on the Everglades coast of southwest Florida. *Environmental Geology,* 25, 143–148.

DAVIS, R.A. and FOX, W.T., 1975. Process-response patterns in beach and nearshore sedimentation: I. Mustang Island, Texas. *Journal of Sedimentary Petrology,* 45, 852–865.

DAVIS, R.A. and HINE, A.C., 1989. Quaternary geology and sedimentology of the barrier island and marshy coast, west-central Florida, U.S.A. 28th Intl. Geology Congress, Field Trip Guidebook T375, *American Geophysical Union* (Washington D.C.), 38p.

DOLAN, R.; ANDERS, F.J., and KIMBALL, S., 1985. Coastal erosion and accretion. *U.S. Geological Survey National Atlas.* Government Printing Office: Reston, Virginia.

DONOGHUE, J.F.; DEMIRPOLAT, S., and TANNER, W.F., 1990. Recent shoreline changes, Northeastern Gulf of Mexico. *In*: TANNER, W. F. (ed.), *Coastal Sediments and Processes,* Proceedings 9th Symposium Coastal Sedimentology, pp. 51–66.

FISK, H.N., 1955. Sand facies of recent Mississippi Delta deposits. *Proceedings 4th World Petroleum Congress* (Rome), Section 1-C, 377–398.

FOX, W.T. and DAVIS, R.A., 1976. Weather patterns and coastal processes, *In*: DAVIS, R. A. and ETHINGTON, R. L. (eds.), *Beach and Nearshore Sedimentation.* (Tulsa, Society Economic Paleo. Mineral., Special Publication 24, p. 1–23.

GOULD, H.R. and MCFARLAN, E., JR., 1959. Geologic history of the chenier plain, southwestern Louisiana. *Gulf Coast Association Geology Societies,* 9, 261–270.

GRYMES III, J.M. and STONE, G.W., 1995. A review of key meteorological and hydrological aspects of Hurricane Andrew. *In*: STONE, G. W. and FINKL, C. W. (eds.), *Impacts of Hurricane Andrew on the Coastal Zones of Florida and Louisiana: 22–26 August 1991.* Journal of Coastal Research, Special Issue No. 21, pp. 6–23.

GULF OF MEXICO PROGRAM, 1993. *Coastal & Shoreline Erosion Action Agenda (4.1) for the Gulf of Mexico.* Stennis Research Center, Bay St. Louis, Mississippi, 57p.

HAYES, M.O., 1967. *Hurricanes as Geological Agents—Case Studies from Hurricanes Carla, 1961, and Cindy, 1963.* University Texas, Bur. Economic Geology, Report Inv. No. 61, Austin, Texas, 56p.

HICKS, S.D. and HICKMAN, L.E., 1988. United States sea level variations through 1986. *Shore and Beach,* 56, 3–7.

HINE, A.C.; BELKNAP, D.F.; HUTTON, J.G.; OSKING, E.B., and EVANS, M.W., 1988. Recent geological history and modern sedimentary processes along an incipient, low-energy, epicontinental-sea coastline: northwest Florida. *Journal of Sedimentary Petrology,* 58, 567–579.

JORDAN, C.L., 1973. The physical environment, *In*: Florida Institute of Oceanography, *A Summary of Knowledge of the Eastern Gulf of Mexico, 1973* (St. Petersburg, Florida), pp. IIA-1 to 22.

MCBRIDE, R.A. and BYRNES, M.R., 1995. A megascale systems approach for shoreline change analysis and coastal management along the northern Gulf of Mexico. *Transactions Gulf Coast Association of Geological Societies,* 45,405–414.

MCBRIDE, R.A.; BYRNES, M.R., and HILAND, M.W., 1997. Regional variations in shore response along barrier island systems of the Mississippi River Delta. *Journal of Coastal Research,* this issue.

MORGAN, J.P. and LARIMORE, P.B., 1957. Changes in the Louisiana shoreline. *Transactions Gulf Coast Association Geological Societies,* 7, 303–310.

MORTON, R.A., 1977. Historical shoreline changes and their causes, Texas Gulf Coast. *Transactions Gulf Coast Association of Geological Society,* 28,

MORTON, R.A., 1979. Temporal and spatial variations in shoreline changes, Texas Gulf Coast. *Journal of Sedimentary Petrology,* 49, 1101–1111.

MORTON, R.A., 1991. Response of Holocene depositional systems tracts to sediment influx, Northern Gulf of Mexico. Coastal Depositional Systems in the Gulf of Mexico: Quaternary Framework and Environmental Issues. *12th Annual Research Conference, Gulf Coast Section, SEPM,* 149–158.

MORTON, R.A., 1993. Shoreline movement along developed beaches of the Texas Gulf Coast: a users' guide to analyzing and predicting shoreline chantes. *Texas Bur. Economic Geology,* Open File Report 93–1, 79p.

MORTON, R.A., 1994. Texas Barriers, *in* DAVIS, R. A. (ed.), *Geology of Holocene Barrier Island Systems.* Heidelberg: Springer-Verlag, pp. 75–114.

NATIONAL RESEARCH COUNCIL, 1987. *Responding to Changes in Sea Level: Engineering Implications.* Washington D. C.: National Academy Press, 148p.

PENLAND, P.S. and BOYD, R., 1981. Shoreline changes on the Louisiana barrier coast. *Oceans,* 81, 209–219.

PENLAND, P.S.; BOYD, R., and SUTER, J.R., 1988. Transgressive depositional systems of the Mississippi River Delta plain; a model for barrier shoreline and shelf sand development. *Journal of Sedimentary Petrology,* 58, 932–949.

PRICE, W.A., 1954. Dynamics environments: reconnaissance mapping, geologic and geomorphic, of continental shelf of Gulf of Mexico. *Transactions Gulf Coast Association of Geological Societies,* 8, 41–75.

STAUBLE, D.F.; BURKE, C.E., and LEVIN, D.R., 1991. Rapid erosion of a cohesive shoreline, Sargent Beach, Texas. Coastal Depositional Systems in the Gulf of Mexico: Quaternary Framework and Environmental Issues. *12th Annual Research Conference, Gulf Coast Section, SEPM,* 249–254.

STONE, G.W., 1991. *Differential Sediment Supply and the Cellular Nature of Longshore Sediment Transport Along Coastal Northwest Florida and Southwest Alabama Since the Late Holocene.* Ph.D. Dissertation, University of Maryland, 376p.

STONE, G.W. and PENLAND, P.S., 1992. Historic shoreline change along the northern Gulf of Mexico. *In*: MAJUNIDAR, S. K, *et al,* (eds.), *Natural and Technological Disasters: Causes, Effects and Preventive Measures.* The Pennsylvania Academy Science, 267–279.

STONE, G.W.; GRYMES III, J.M.; ARMBRUSTER, C.K.; XU, J.P., and HUH, O.K., 1996. Researchers study impact of Hurricane Opal on Florida coast. *EOS, Transactions American Geophysical Union,* 77, 181–184.

STONE, G.W. and STAPOR, F.W., 1996. A nearshore sediment transport model for the northeast Gulf of Mexico coast, U.S.A. *Journal of Coastal Research,* 12, 786–792.

TANNER, W.F., 1960. Florida coastal classification. *Transactions Gulf Coast Assocication of Geological Societies,* 10, 259–266.

TEDESCO, L.P.; WANLESS, H.R.; SCUSA, L.A.; RISI, J.A., and GELSANLITER, S., 1995. Impact of Hurricane Andrew on South Florida's sandy coastlines. *Journal of Coastal Research,* Special Issue No. 21, 59–82.

WATSON, R.L., 1971. Origin of shell beaches, Padre Island, Texas. *Journal of Sedimentary Petrology,* 41, 1105–1111.

WRIGHT, E.E., 1995. *Sedimentation and Straatigraphy of the Suwanee River Marsh Coastline,* Unpubl. Dissertation, University South Florida, St. Petersburg, 254p.