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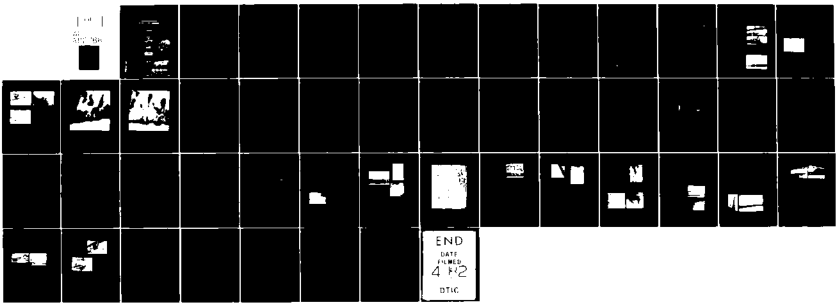

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HURRICANE IMPACT ON GULF COAST BARRIERS

Final Report No. 2 to the
Office of Naval Research

for Contract No.
N00014-78-C-0612

This Collection of Reprints Consists of
the following ONR technical reports.

Technical Report No. 2.
Geologic Response to Hurricane Impact on Low-Profile Gulf Coast Barriers.
By: Dag Nummedal, Shea Penland, Robert Gerdes, William Schramm, Jacob Kahn, and Harry Roberts.

Technical Report No. 3.
Hurricane Impact at Dauphin Island, Alabama.
By: Shea Penland, Dag Nummedal and William E. Schramm.

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INTRODUCTION

Hurricanes and tropical stroms play decisive roles in the evolution of the shorelines of the Gulf of Mexico. Along the rapidly transgressive deltaic headlands of the northwestern gulf coast the stratigraphic record of the Holocene barriers is dominated by deposits laid down in the form of washover fans and terraces. Within interdeltaic embayments, where wide regressive beach ridge barrier islands have developed contemporaneously with erosion of the adjacent headlands one finds that hurricanes play a less significant geologic role. Because of the extensive dune ridges, which produce generally high relief on such islands, most storms are capable only of producing isolated interdune fans. Consequently, the correct interpretation of barrier washover sands in the geologic record and a comparison of the extent of that facies to the volume of the other barrier island facies, may help identify the paleogeographic setting of barriers in the rock record.

The hurricane effects reported in these two technical reports carry perhaps even greater environmental geologic significance. When Hurricane Frederic made landfall at Dauphin Island, Alabama, the impact was not one of wholesale, random destruction. Instead, the property destruction and the amounts of shoreline erosion followed a predictable pattern controlled by nearshore bathymetry. Maximum shoreline retreat and property destruction on Dauphin Island occurred just downdrift of the point of shoreline re-attachment of the ebb-tidal delta flank. Historical accounts demonstrate that both the 1916 and 1947 hurricanes breached the island in the same areas.

The report demonstrates that if it is possible to effectively plan the use of low-lying coastal lands such that the hazards of, and economic loss from, hurricane impacts will be minimized.

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GEOLOGIC RESPONSE TO HURRICANE IMPACT ON LOW-PROFILE GULF COAST BARRIERS

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ABSTRACT

Hurricane *Frederic* made landfall near Pascagoula, Mississippi at midnight September 13, 1979. At the time of landfall the central pressure had dropped to 946 mb, onshore winds in excess of 200 km/hr were lashing the Alabama coastline and the open coast storm tide peaked at 365 cm at Gulf Shores, Alabama.

Vertical aerial photography obtained in 1976 and again 9 days after *Frederic* made landfall, combined with multiple reconnaissance overflights and ground surveys by the authors provided the data base for determination of shoreline erosion and the distribution of hurricane scour and sedimentary deposits.

Erosion of the Gulf beach at Dauphin Island proved to follow a predictable pattern controlled by nearshore bathymetry whereas retreat of the shoreline of the Mississippi Sound margin was an unexpected occurrence, apparently due to a hydraulic jump as washover currents entered the deep water of Mississippi Sound. Large-scale sediment redistribution on Dauphin Island proper was a consequence of the storm surge flood. However, the ebb surge was responsible for the reopening of three inlets across Little Dauphin Island.

Hurricane *Frederic* also had a major impact on the Chandeleur Islands, Louisiana. Even though the maximum surge height on the left side of the hurricane track was only 1.3 m, pre-existing hurricane channels and washovers acted as conduits for the flood and ebb surge.

INTRODUCTION

Hurricanes are major, perhaps the dominant, agents in the development of barrier island morphology along the northern and western shores of the Gulf of Mexico. Large-scale washover fans (Andrews, 1970), hurricane channels and runways with their associated deposits (Hayes, 1967) and relocated tidal passes (McGowen and Scott, 1975; Morton and Pieper, 1976) are the major sedimentary responses to large hurricanes on the Texas coast. Large washover fans are rare along the Louisiana, Mississippi and Alabama shores. A typical hurricane response along this upper Gulf Coast is the complete leveling of supratidal sand banks, temporary fragmentation of low barrier chains (Wright *et al.*, 1970), the formation of wide permanent new tidal passes, as for example "Camille Cut" in Ship Island, and the formation of nearly continuous washover terraces on some islands and barrier beaches (Penland and Ritchie, 1979; Schramm *et al.*, 1980).

Whatever the precise process and sedimentary response, the frequency and magnitude of Gulf Coast hurricanes is such that their impact on barrier island stratigraphy is considerable. In 1979 alone, two hurricanes and one tropical storm made landfall on the northern Gulf Coast (fig. 1). It is the objective of this paper to identify and explain the patterns of island response, as well as the morphology and sedimentary structures of the hurricane deposits and their stratigraphic implications.

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The new field data presented in the paper are based on observed effects of hurricane *Frederic* (1979) on Dauphin Island, Alabama, and the Chandeleur Islands, Louisiana. The terminology is largely based on previous studies along the Texas coast, and many comparisons are made with the western Gulf Coast barriers in order to establish a reasonably complete set of criteria characterizing barrier island hurricane response.

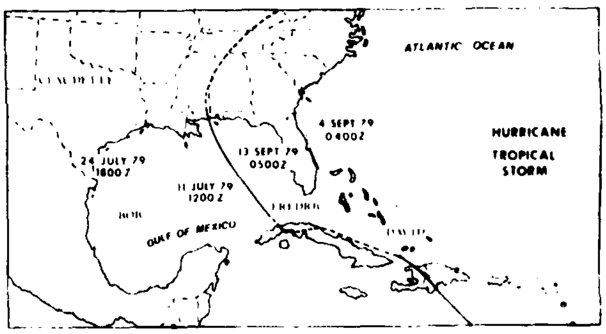

Figure 1. Tracks of the four tropical cyclones making landfall in the U.S. during 1979.

METEOROLOGICAL CHARACTERISTICS OF FREDERIC

Four hurricanes affected the U.S. coastline in 1979 (fig. 1). Of these, *Frederic* was one of the most devastating hurricanes of the century. The estimated total property damage was about 2 billion dollars (Wall Street Journal, Nov. 23, 1979). Most damage was wind-related in the coastal counties of Alabama, Mississippi, and northwest Florida.

Frederic followed an initial course close to that of its predecessor *David*, and remained a relatively weak storm throughout the Caribbean (fig. 1). However, as it left the northwest coast of Cuba on September 10, it quickly intensified while moving across the warm waters of the Gulf of Mexico. It moved at an average speed of 16 km/hr and traversed the Gulf in 2.5 days. This forward speed was about the same as hurricane *Carla* (Hayes, 1967). Because of its relatively slow advance and huge lateral extent, *Frederic* developed a large storm surge. After crossing Dauphin Island, Alabama, *Frederic* made landfall near Pascagoula, Mississippi, at 00:00 approximately CDT, (5:00 Z) September 13 (fig. 2). A maximum storm tide of 365 cm (12 ft) was reached at Gulf Shores, Alabama. This value appears to reflect the peak tide along the open coast, although the same height was recorded at the head of Mobile Bay. An open coast storm tide of this magnitude compares well with the 396 cm maximum *Carla* tide at the Port Aransas south jetty. However, at Port Lavaca on Matagorda Bay, hurricane *Carla* produced a 670 cm storm tide (Harris, 1963). Apparently, the highest tide ever recorded on the Gulf Coast was that produced by Hurricane *Camille* which reached 731 cm at Bay St. Louis. Figure 3 shows the elevation of high water marks reported after *Frederic* along the upper Gulf Coast. As expected, the maximum storm tide was recorded 30 kilometers to the right (east) of the site of hurricane landfall. In order to compare *Frederic* to other major Gulf hurricanes over the last two decades the relevant parameters have been listed in table 1.

In terms of geological effects of a hurricane, the surge height is the single most important parameter. The surge height controls the extent of flooding, and additionally controls the energy of the breakers, a fact that is often overlooked. Deep water hurricane waves typically have such heights that they will break and reform multiple times before reaching shore. Any wave will break in a mean water depth roughly equivalent to its height (Munk, 1949). Therefore, by increasing water depth in the nearshore through a storm surge, higher breakers are brought closer to shore. The factors which affect the surge height, therefore, must all be considered as independent variables influencing the geological effects of any given storm. These factors include the storm intensity, path, overwater duration, speed, atmospheric pressure variation, spatial extent (size) of the storm, shape of the coastline, and the offshore bathymetry. Because the inner shelf slope is relatively steep off Alabama, the coastal surge of *Frederic* was less than that which would have resulted from an identical storm making landfall in, for example, western Louisiana (fig. 4). In fact, hurricane *Camille's* extremely high surge was a function of the shallow shelf along its path (CERC, 1977).

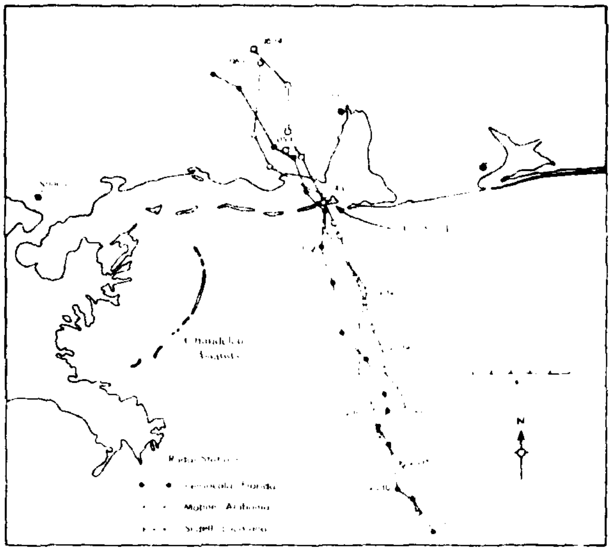

Figure 2. U.S. Weather Service radar positions of hurricane *Frederic*, between the evening of September 12 and the morning of September 13, 1979.

Deep water parameters for hurricane *Frederic* were recorded by NOAA's data buoy EB 42003, located at 26°N, 86°W, directly in the path of the hurricane (fig. 5). This time series demonstrates a maximum wave height of 9.1 m coincident

Name	Date	Landfall	Central Pressure at Landfall (mb)	Maximum Wind Speed (km/hr.)	Forward Speed (km/hr.)	Peak Open Coast Tide (m)	Maximum Tide (m)
Carla	9/11/61	Pass Cauallo	931	282	14.5	3.96	6.70
Beulah	9/20/67	Brownsville	923	219	17.0	2.44	2.87
Camille	8/18/69	Bay St. Louis	905	218	24.0	7.31	7.31
Celia	8/03/70	Corpus Christi	964	259	19.0	2.80	3.48
Fern	9/10/71	Port O'Connor	981	137	14.5	1.68	1.68
Frederic	9/13/79	Pascagoula	943	234	15.5	3.65	3.65

Data from (1) Hayes (1967) and CERC (1977), (2) U.S. Army Engineers (1968), (3) CERC (1977) and Wright *et al.* (1970), (4) U.S. Army Engineers (1970), (5) U.S. Army Engineers (1971), (6) Weather Service Hurricane Warning Office (1979).

Table 1. Meteorological parameters of some recent Gulf Coast hurricanes.

with a maximum wind speed of 118 km/hr. At the time of landfall the strongest winds reached 205 km/hr, the associated central pressure dropped to 946mb (fig. 6). The highest sustained winds at the Dauphin Island causeway reached 230 km/hr.

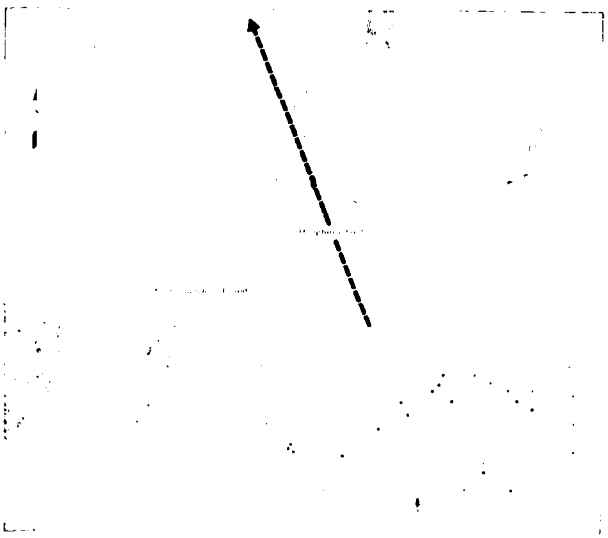

Figure 3. Elevation of highwater marks after the landfall of *Frederic*. The inset of the storm tide elevations shows the asymmetry of the surge.

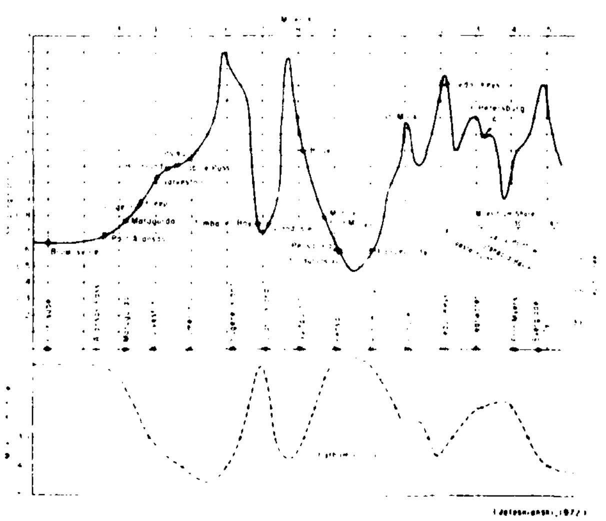

Figure 4. Shoaling factors and nearshore bathymetry along the Gulf Coast.

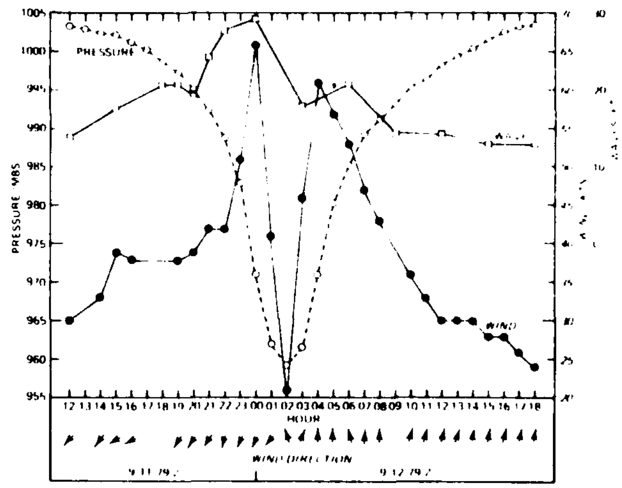

Figure 5. Deep water time series of hurricane *Frederic's* physical parameters (Diez, 1980).

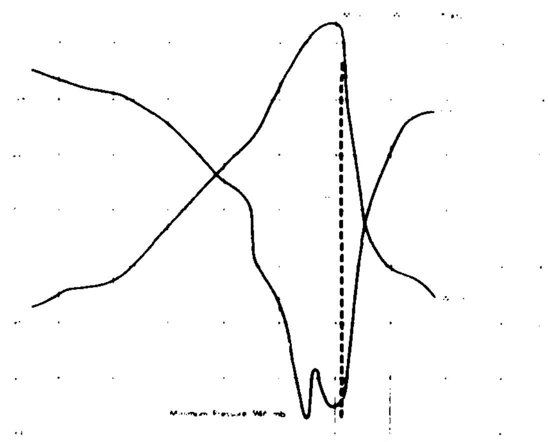

Figure 6. Wind speed and central pressure time series for hurricane *Frederic* for the time period of September 8 through 19, 1979 (U.S. Weather Service, 1979).

Water level variations in Chandeleur Sound were documented by a continuously recording tide gage at Gardner Island, La. (fig. 7). This water level time series can be well explained in terms of the Ekman transport associated with shifts in wind direction recorded at Biloxi airport (table 2). The very rapid fall in water level between 0700 CDT and 2300 CDT on September 12th, correlates with the pre-landfall shift in local wind direction from NE via N to NW. The associated Ekman transport flushed water out of Chandeleur Sound to the south.

As hurricane *Frederic* moved inland it caused moderate precipitation (20-30 cm) and spawned numerous tornados. Rainfall and resulting river flooding are important geological responses to hurricanes along the mainland shores (McGowen, 1970). These are, however, outside the scope of this paper.

Figure 7. Water level time series at Gardner Island, Louisiana during the passage of *Frederic*.

Time (CDT)	Duration	Effect	Wind Direction at Biloxi	Ekman transport
[illegible] Sept 9 [illegible] Sept 11	48 hrs	Gradual rise in water level from +30 cm to +55 cm	NE	NW
1900 Sept 11 0700 Sept 12	12 hrs	Flood surge Water level rise from +55 cm to +125 cm	NE	NW
0700 Sept 12 2300 Sept 12	16 hrs	Rapid ebb surge Water level drop from +125 cm to +8 cm	N-NW	SW
2300 Sept 12 0400 Sept 13	5 hrs	Static water level	NW-SW	SE
0900 Sept 13		Resumption of regular tide cycle		

Table 2. Storm surge sequence in Chandeleur Sound. Compare to water level curve in figure 7.

ISLAND DEVELOPMENT AND MORPHOLOGY

The differentiation between high-profile and low-profile islands serves as a useful basis for an analysis of the effects of hurricane overwash. It is also a basis for a genetic classification of Texas barriers in that low-profile barriers are relatively young transgressive landforms found in association with erosional deltaic headlands. High-profile islands commonly are older regressive barriers formed in interdeltaic bights (Morton and McGowen, 1979; Morton, 1979). This classification established for Texas also appears to apply well to barriers farther east. The Chandeleur Islands certainly are low profile in the sense that they lack multiple well defined dune ridges, they are highly transgressive (Treadwell, 1955) and are associated with a deltaic "headland", specifically, the abandoned St. Bernard subdeltas of the Mississippi River (Frazier, 1967). Dauphin Island, except for its small eastern Pleistocene core (Otvos, 1979), is also a low profile barrier, probably transgressive, and associated in an unknown way with the erosion of the Baldwin County shoreline, Alabama and the ancestral Mobile River valley. The intervening islands of Petit Bois, Horn, Ship and Cat Islands are all high profile, regressive barrier islands (figs. 8, 9, and 10).

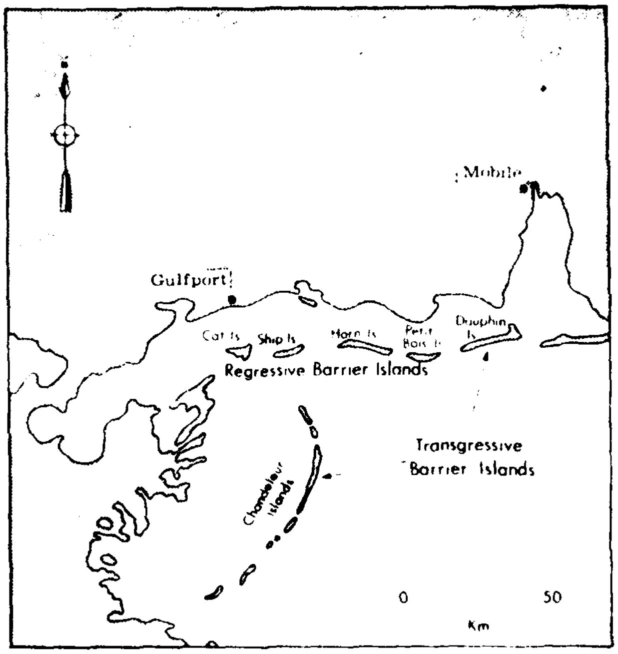

Figure 8. Location map of the northern Gulf Coast barrier islands. Note the peripheral locations of the two transgressive systems, Dauphin Island and Chandeleur Islands; and the central location of the regressive islands.

Otvos (1970, 1979) presents evidence favoring an origin of these upper Gulf Coast barriers through vertical shoal-bar aggradation (the deBeaumont theory), probably about 3,000 to 4,000 years ago. Open marine nearshore deposits underlie the present islands. In all probability the orientation of the Alabama-Mississippi barrier trend is related to the presence of the Pleistocene high at Dauphin Island. This high may have controlled the alignment of the incipient shoals further west.

The impacts of numerous hurricanes prior to *Frederic* have left indelible imprints on the morphology of the upper Gulf Coast barriers. The present separation of Dauphin and Petit Bois Islands was caused by the 1740 hurricane (Otvos, 1979); Dauphin Island itself has been breached twice in this century. In 1916 an 8.5 km cut was opened to the west of the Pleistocene core (Hardin *et al.*, 1975). 0.5 km of this scar was reopened for a short time by the 1947 hurricane. Ship Island has been cut 4 times during the last 130 years (in 1852, 1893, 1947 and 1965); before *Camille* in 1969 permanently sepa-

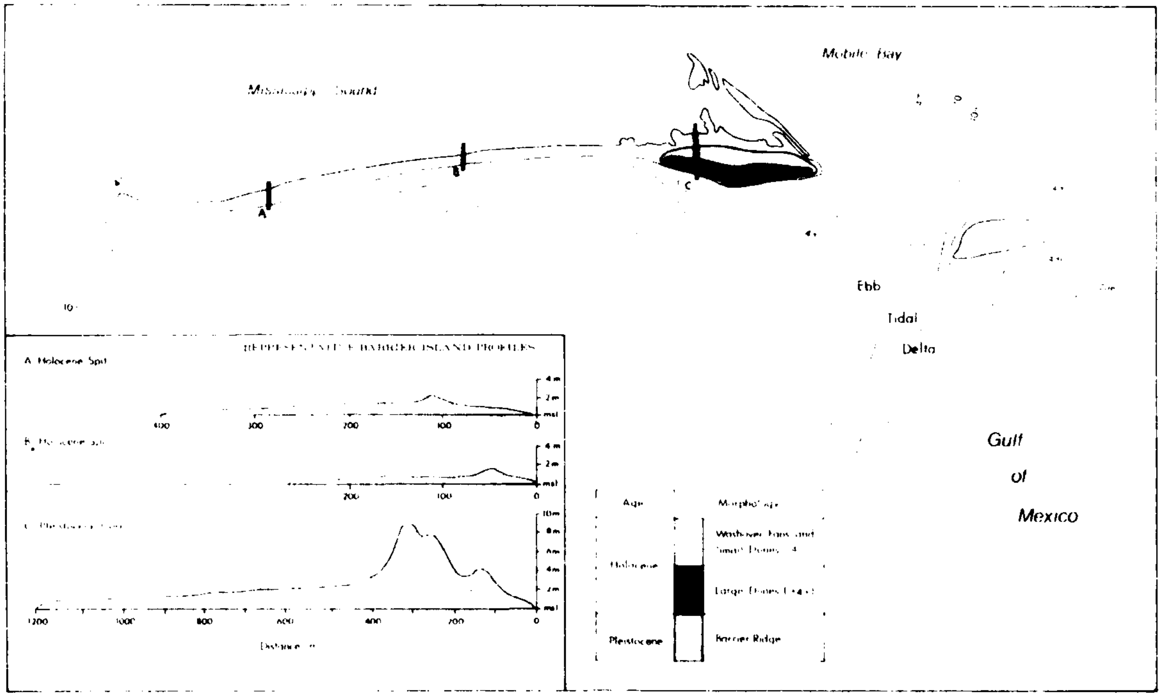

Figure 9. Morphological map of Dauphin Island, Alabama (Data base: vertical and oblique aerial photographs and field inspections).

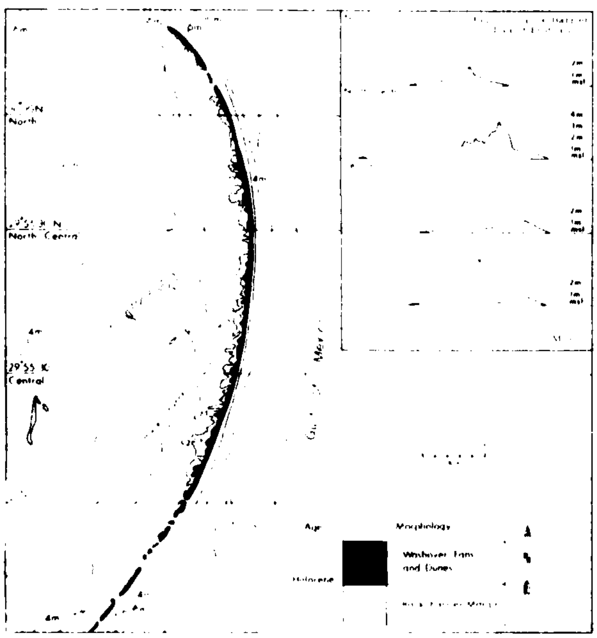

Figure 10. Morphological map of the Chandeleur Islands, Louisiana (Data base: vertical and oblique aerial photographs and field inspections).

rated east and west Ship Island. Segments of the Chandeleur Islands have undergone numerous episodes of hurricane destruction and reemergence (Otvos, 1970). Hurricane *Camille*, which produced a 6 m storm tide at the Chandeleur Islands (Wright *et al.*, 1970), fragmented the northern 32 km long Chandeleur Islands into about 50 separate islets.

HURRICANE FLOOD-SURGE RESPONSE DAUPHIN ISLAND

Gulf Beach – The amount of shoreline retreat at Dauphin Island due to the effects of hurricane *Frederic* was determined from two sets of vertical aerial photography. The latest pre-hurricane photo set was obtained in October, 1976. The earliest post-hurricane photos were those obtained by the Army Corps of Engineers, Mobile District, on September 22nd, 1979. Precise measurements of the position of the high water line relative to a common baseline on the two photo sets produced the shoreline retreat map in figure 11. The plotted hurricane-related retreat is corrected for the amount of shoreline erosion expected to have taken place between 1976 and 1979 through "normal" processes. Based on values in Hardin *et al.*, (1976), this was estimated to have been about 3 m/year, *i.e.* 9 m total.

The magnitude of shoreline retreat during hurricane *Frederic* varied considerably along the Gulf beach of Dauphin Island (fig. 11). The least amount of erosion occurred in the Dauphin and Bienville beach areas near the center of the Pleistocene core of the island. This reduced erosion is related

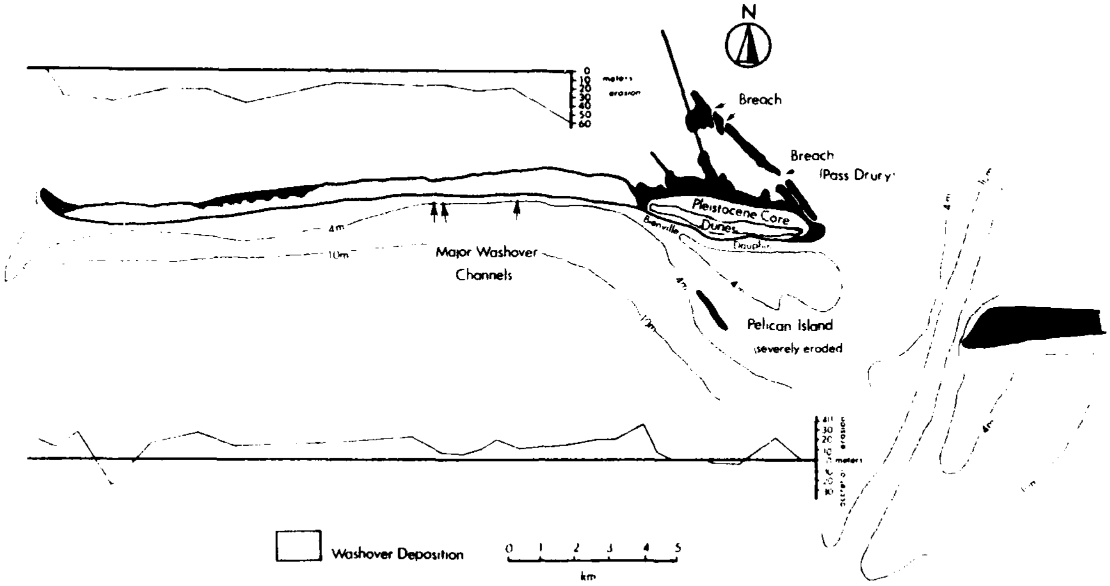

Figure 11. Vertical air photo derived mean high water shoreline retreat values for the Gulf and Sound shores of Dauphin Island, after the passage of *Frederic*.

to the sheltering effect of the supra-tidal shoals of the ebb-tidal delta of the Mobile Bay entrance. These shoals, Sand and Pelican Islands, while themselves being levelled into subtidal shoals greatly reduced the wave energy reaching the shore of the main island. In fact, hurricane wave refraction around the flank of the ebb tidal delta platform, and these shoals, may have turned the Dauphin and Bienville beach areas into a zone of longshore transport convergence, causing a slight beach accretion during the storm.

Shoreline retreat was much higher both east and west of the Bienville beach area. The increased erosion at the east end of Dauphin Island reflects an increase in distance and water depth between the shallow ebb-tidal delta margin and the island shore. Based on the track of hurricane *Frederic*, peak wave energy flux probably struck the island from the SSE. The east end of Dauphin Island is openly exposed to waves from that direction.

Maximum shoreline retreat, about 40 m, was observed to have occurred immediately west of the high dunes fronting the Pleistocene core of the island (fig. 9 and 11). This location coincides with the downdrift margin of the ebb-tidal delta. Preliminary refraction analysis for hurricane waves arriving from the SE or SSE suggests that the ebb-delta swash platform margin focused wave energy at this very location. Along the western two-thirds of Dauphin Island shoreline retreat averaged 15 meters.

To our surprise the Mississippi Sound shore of Dauphin Island suffered more retreat than the Gulf shore; the average amount of retreat was about 25 m. Along the Mobile Bay side of Little Dauphin Island there was an average shoreline re-treat of 20 m, and the reopening of three inlets, the largest being Pass Drury (fig. 12).

Compared to other recent hurricanes, *Frederic* was not excessively erosive. For example, *Carla*, which struck the Texas coast in 1961, eroded the Padre Island foredunes by an average of 30 m and caused local dune scarp retreat by as much as 100 m on Mustang Island (Hayes, 1967). The shore of Matagorda peninsula was eroded 250 m by hurricane *Carla* (McGowen and Scott, 1975).

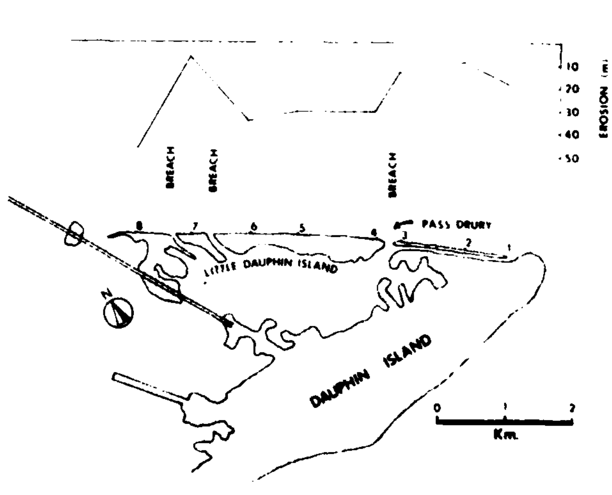

Figure 12. Vertical air photo derived mean high water shoreline retreat values for Little Dauphin Island after hurricane *Frederic*.

In light of hurricane wave refraction, the pattern of erosion along the Gulf beach of Dauphin Island is readily explicable. The pattern, however, is not transferable as a basis for prediction of storm erosion along other Gulf coast barriers. In fact, this erosion pattern corresponds more to a response expected for mesotidal east coast barriers. Normally, those are the barriers with a "drumstick" shape and large associated ebb-tidal deltas (Hayes, 1979). The Dauphin Island morphology is somewhat of an anomaly for the microtidal Gulf Coast; an anomaly which is due, in part, to the Pleistocene core and the large river discharge of the Mobile River contributing to the formation of the ebb-tidal delta at the bay entrance.

During the peak of a hurricane the deep water wave height (H_0) and wave length (L_0) are such that the wave steepness (H_0/L_0) greatly exceeds 0.025, the value found by Johnson (1956) to differentiate erosional from accretionary waves. Steep waves remove more sand from the beach during backrush than they supply during uprush because the constant pounding of the waves permit no time for beach face water percolation and sediment settling. Consequently, the immediate post-hurricane beach has a smooth, upward concave profile. During waning stages of a storm the wave steepness decreases and sediment is returned to the beach face, generally in the form of a landward migrating ridge with a steep landward-dipping slipface (Davis *et al.*, 1972). This high ridge was quite prominent on Dauphin Island only 9 days after the hurricane. The presence of ridge-and-runnel stratification (Davis, 1978) would be quite diagnostic of a storm deposit in a Gulf Coast type barrier beach because significant ridge topography is rare during fair-weather conditions. Furthermore, the underlying storm beach strata would dip at a much gentler seaward angle than those of the fair weather beach. The Dauphin Island storm beach was very fine grained. There was a noticeable absence of deep water fauna washed up on the beach (contrast Hayes, 1967).

Vegetated Flats — Only a few minor hurricane channels were formed at the eastern (Pleistocene) part of Dauphin Island. The associated deposits were small interdune fans. The extensive dune ridge fronting the Pleistocene core, locally reaching an elevation of 14 m, was not breached.

The Holocene Dauphin Island is a low profile barrier reaching a typical elevation of from 1.5 to 2 meters above MSL along the storm berm (fig. 9). Only insignificant incipient dunes existed prior to *Frederic*. Earlier hurricane washovers are visible in pre-*Frederic* aerial photographs. These were probably caused by hurricane *Camille*.

Figure 13 demonstrates the variability in hurricane overwash morphology. A continuous washover terrace formed along the entire Holocene part of the island. Along most of it, this terrace extends across the island to the shoreline of Mississippi Sound. Only three major channels developed; two of these near the end of the paved road in the housing development (fig. 13). Minor channels were abundant, in particular within the housing development. Some of these had scoured well below the MSL at the back side of the island. Large scour holes, some many meters in diameter and up to a meter deep had formed in what appeared to be a random distribution across the barrier grass flat (fig. 14). A review of pre-*Frederic* air photos revealed an abundance of similar depressions probably dating back to earlier hurricanes.

The continuous washover terrace is an apparent characteristic storm response on a low profile barrier island. Numerous examples are know, both for hurricanes (e.g. Matagorda Peninsula, Morton, 1978) and for extratropical storms on North Carolina's outer banks. (Pierce, 1970).

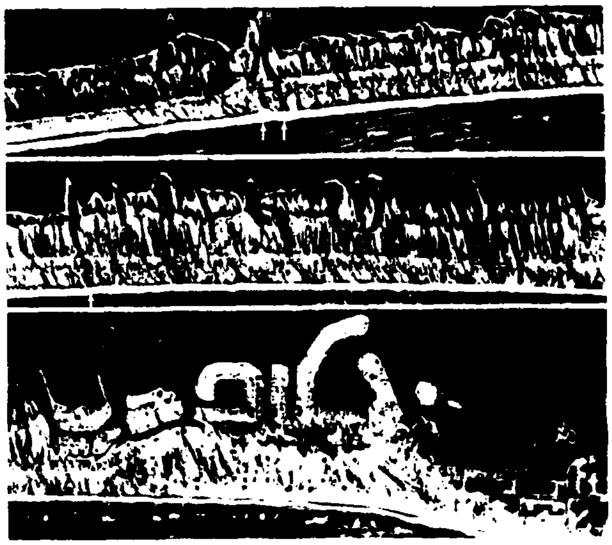

Figure 13. A sequence of vertical air photos, west to east, along the central portion of Dauphin Island after hurricane *Frederic*. Arrows indicate the major hurricane channels. Note the flame-shaped washover fans and back-barrier scour. Gulf is at bottom of each photo, Mississippi Sound at top. Photos taken September 22, 1979.

Figure 14. Oblique aerial view of scour pits in the washover terrace on central Dauphin Island

Stratigraphically, the Dauphin Island washover terrace type of storm deposit would be recognizable through the following criteria. Large lateral extent of horizontal, upper flow regime, planar stratification. Each set is some 10 to 20 cm thick. Tabular cross-stratif ation of variable thickness is associated with fan marg s. Minor hurricane channels are floored by a coarse lag overlain by trough and or ripple drift stratification in respon to landward-migrating megaripples and ripples. Ripples would commonly be draped by mud, reflecting settling of fines in stagnant ponds after storm subsidence. Deep, steep-sided cut-and-fill structures would be left by the barrier flat scour holes. Texturally, the fill would change upwards from coarse scour lag through sand to mud. Above the mud the scour hole would be infilled by aeolian sand. In the major hurricane channels one might expect to find bidirectional troug cross-stratification with the upper beds formed in respons the storm surge ebb.

Back-Barrier margin – The post-*Frederic* Mississippi Sound margin of Dauphin Island is deeply indented by narrow, deep channels which lead into flame-shaped lagoonal fans (fig. 13 and 15). The fan size is generally proportional to the size of the feeder channel. Between the major shore-normal channels the barrier is backed by a nearly continuous deep trough (fig. 13).

Figure 15. Close-up view of back-barrier scour and flame-shaped wash-over fans. Photo taken September 22, 1979.

The erosion of this trough and channels is responsible for the back barrier erosion depicted in figure 11. Back-barrier erosion was caused by an intense hydraulic jump (Chow, 1959) formed where the shallow sheet of water flowing across the barrier flat in an upper flow regime condition suddenly encountered the deeper water of Mississippi Sound (Schramm *et al.*, 1980). This should be similar to the scour at the base of a spillway. The entrained sediment would be deposited in a flame-like fan, due to mixing of washover and Sound water and consequent reduction in sediment transport capacity. The higher the velocity of the washover current, the more elongate the fan, because mixing would be most effective along the lateral margins of the jet. Large-scale development of back barrier flame-shaped fans is only known from *Carla's* impact on Matagorda peninsula (Morton, 1978) and *Frederic's* effects on Dauphin Island. It appears that this morphology requires a rather unique relationship between the hurricane tide height and the barrier profile.

These fans are characterized by wide continuous upper-flow regime plane beds and some trough-stratification reflecting lagoon-ward migrating megaripples in the fan apices. Some fan margins were built to above normal sea level, thus leaving stagnant ponds subject to suspended sediment fall out after the storm. The resulting mud layers, commonly drapping the fan-apex bedforms, quickly become burrowed together with the upper layers of the underlying sand.

STORM SURGE EBB DAUPHIN ISLAND

The maximum impact of a hurricane is normally felt on the right hand side of the hurricane track, because the translatory speed of hurricane movement and the rotational speed of winds around the hurricane center here are additive. During approach and landfall, these winds are directed onshore. The storm surge flood sequence discussed above is the normal response. After inland passage of the hurricane eye, coastal winds will shift and generally blow from left to right along the shore in the area of landfall. The ocean surge quickly subsides and strong ebb-directed currents flush out of coastal bays (Pierce, 1970; Hayes, 1967; McGowen and Scott, 1975).

This ebb-surge has its own unique assemblage of sedimentary responses. Hayes (1967) documented that it was related to the deposition of shallow-shelf graded beds and, within the barrier island system, helped deepen the major hurricane channels. Because of the unique morphology of central Padre Island, consisting of fore-island and back-island dunes separated by a wide low swale, the storm surge ebb currents flowed down this swale in a general shore-parallel direction. The resulting hurricane "runway" is a diagnostic hurricane feature for islands like Padre Island, but it has not been observed elsewhere. The major ebb surge effect on Dauphin Island was the breaching of three inlets through Little Dauphin Island (fig. 16 and 17). Some evidence exists for seaward return flow in both minor and major hurricane channels. The opening of Pass Drury by the ebb-surge is documented by the following data: 1) Immediately after opening there was a large sand body on the Mobile Bay side of the inlet. In essence this is the ebb-tidal delta of Pass Drury. 2) All channel markers in Dauphin Island Bay, west of the inlet, were bent to the east. 3) Post-hurricane hydrography in Pass Drury has indicated that during "winter" wind conditions the inlet is flood dominated. These observations support Pierce's (1970) opinion about the opening of tidal inlets by ebb surge flow. However, well-documented examples of inlet cutting by flood flow also exist (see discussion in Greenwood and Keay, 1979).

The post-hurricane modifications of the Dauphin Island shoreline have been relatively minor. As expected, wave action along the shores of Mississippi Sound and Mobile Bay have developed land-ward migrating swash bars along the crests of the flame-shaped fans (fig. 18) and the Pass Drury ebb tidal delta. However, as of this writing, 9 months after *Frederic*, Pass Drury is still open and the Mississippi Sound fans are still very distinct.

Figure 16. Pass Drury at Little Dauphin Island on September 22, 1979.

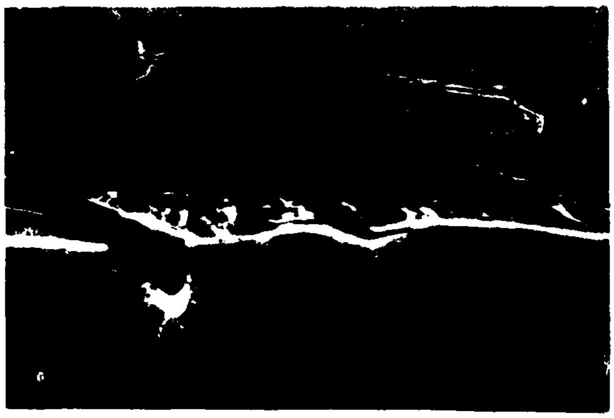

Figure 17. Pass Margaret at Little Dauphin Island on September 22, 1979.

Stratigraphically, the evidence for storm surge ebb, in a setting like Dauphin Island, is going to be rather limited. Some seaward-directed trough and tabular sets of cross-stratification would have developed in the hurricane channels. These would overlie landward-directed cross strata associated with the flood surge. In fact, this bidirectional cross-stratification in scoured channels normal to the beach might be a diagnostic storm-response feature. In many places, the sequence would be fining upward and capped by drape-laminations of mud. The stratigraphic characteristics of storm-induced inlets like Pass Drury is quite complex. Suffice it here to say that the base of the sequence will be a scoured surface into fine grained Mobile Bay sediments, overlain by ebb-oriented trough stratification associated with the initial building of the ebb tidal delta. Planar lamination probably developed along the crest. Overlying this will be tabular sets of cross-strata dipping in a flood-direction, reflecting the large flood-oriented sandwaves which dominated the inlet after the storm. The sequence will be capped by tabular sets of cross-strata and beach lamination reflecting the landward migration of post-hurricane swash bars.

Figure 18. Modification of the flame-shaped washover fans six months after the passage of *Frederic*. Note the landward migration swash bars along the fan crest. (See fig. 13 (Point B) relocation of this oblique aerial photo). Photo taken March 12, 1980.

CHANDELEUR ISLANDS

Figure 10 demonstrates the variability in topographic relief along the Chandeleur Islands chain. Only the north-central segment of the island arc has any significant foredune relief. The remainder of the islands should certainly be classified as low-relief barriers.

The Chandeleur Islands were segmented into numerous inlets by hurricane *Camille* in 1969. The flood-surge of hurricane *Frederic* reopened most of these major channels. In fact, no "new" major hurricane channels were cut by *Frederic*. Within the northern 16 km of the barrier islands, *Frederic* reopened 21 major channels. The channels are typically 150 m to 300 m wide at the throat. There is a variety of channel morphologies. Landward of the dunes some cuts widen, some merge, and others become narrow and sinuous. A detailed comparison of pre-storm and post-storm photographs reveals that the plan view form of distal portions of the channels is almost always identical to that of pre-existing tidal channels in the back-island marsh.

A 1 km wide segment of low barrier flats in the northern part of the islands was completely overwashed and eroded to just below sea level. This site has historically been the largest and most frequently re-opened inlet in the Chandeleur Islands proper, commonly referred to as "North Inlet". Figure 19 shows the fan morphology in the area of "North Inlet". Large-scale rhomboid bedforms (Morton, 1978) dominate the fan surfaces.

The features so far described were formed in response to the storm surge flood. Flood-oriented large bedforms are prevalent in many of the hurricane channels. Storm surge ebb modified, and probably deepened, many of the major hurricane channels. Prime evidence of this is seen in the presence of "ebb-surge deltas": sediment fans at the seaward side of many major hurricane channels (fig. 20). These individual fans or ebb-surge deltas, initially extended 50 to 180 m seaward of the neighboring shoreline. These ebb deposits are likely sources of longshore drift material for the rapid sealing of the seaward termini of many storm channels.

Figure 19. Vertical airphoto of the "North Inlet" segment of the Chandeleur Islands. Note broad fan-shaped back-barrier deposits with large scale rhomboid features. Photo taken on December 10, 1979.

As demonstrated in the map of response recovery features of the Chandeleur Islands (fig. 21), the southern half of the chain underwent a different set of hurricane-related changes. This difference reflects both the change in shoreline attitude (the southern part faces ESE whereas northern half faces ENE) and pre-storm topographic relief (fig. 10). The southern half is much flatter, with a maximum elevation of between 1 m and 1.5 m, and devoid of foredunes. The islands are rapidly transgressive leaving extensive areas of exhumed marsh peat with well preserved mangrove roots on the beach face. The back-barrier marsh is in an advanced state of deterioration due to island subsidence.

Much of this southern segment of the Chandeleur Islands responded to *Frederic* through a complete loss of the subaerial beach. The beachface marsh outcrops were in places eroded back more than 50 m. Large washover fans were deposited, some extending several hundred meters into Chandeleur Sound. A large amount of sediment was also deposited in very thin sheets, only a few centimeters thick, on top of the southern Chandeleur marsh surface. Small "flood-surge" deposits could be detected on the sound side of many storm channels. There were no "ebb-surge deltas", however, south of 29°55'N latitude. Seven of the storm channels in the southern half of the Chandeleur Islands were "new", *i.e.* they did not simply

Figure 20. Vertical airphoto of the north-central segment of the Chandeleur Islands. Note the partially modified ebb surge deposits off the channel mouths. Photo taken December 10, 1979.

reoccupy *Camille* channels.

CONCLUSION

The impact of hurricane *Frederic* on Dauphin Island, Alabama and the Chandeleur Islands, Louisiana, domonstrated that shore erosion, and the related destruction of property, followed a predictable pattern controlled by near-shore bathymetry. Maximum shoreline retreat and property destruction on Dauphin Island occurred just downdrift of the point of shoreline re-attachment of the ebb-tidal delta. Historical accounts for Dauphin Island demonstrate that both the 1916 and 1947 hurricanes breached this island in the same area.

The storm surge flood modified Dauphin Island according to a pattern determined largely by pre-storm island topography: 1) In the eastern high-dune region it cut only a few minor hurricane channels, terminated at their landward edge by small inter-dune fans. 2) On the western Holocene spit the hurricane caused complete overwash, cutting three major hurricane channels and hundreds of minor ones. Erosion occurred by wave backrush at the Gulf beach and by scarp retreat through hydraulic jump at the Mississippi Sound-island margin. Scour holes developed across the barrier flat.

The sedimentary deposits consist of thin continuous sand sheets on the barrier flats, scour hole and channel fills and large flame-shaped fans in the shallow waters of the Sound margin.

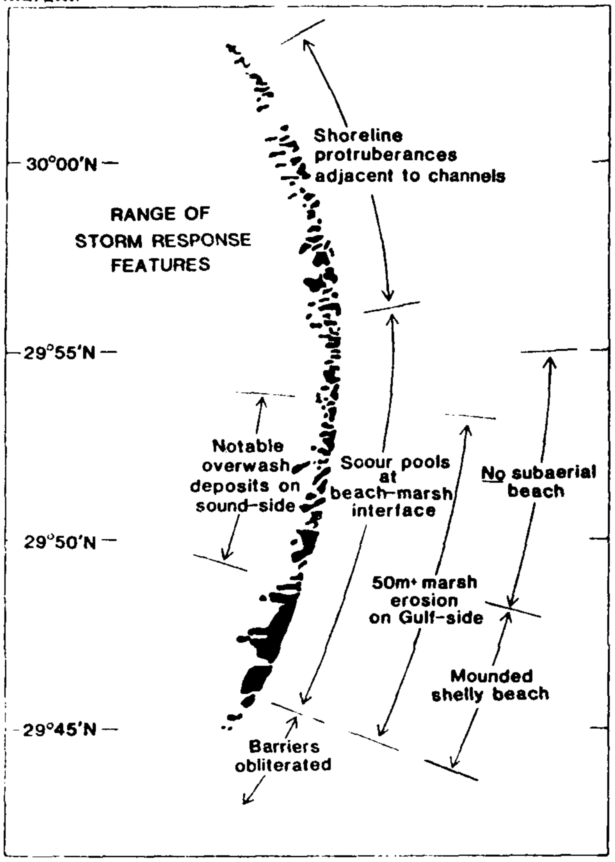

Figure 21. Map of Chandeleur Islands summarizing the response/recovery features within different segments of the barrier island chain (Kahn, 1980).

Storm-surge ebb had only minor effects on Dauphin Island proper. However, the surge ebb was responsible for the reopening of three inlets across Little Dauphin Island. One of these has closed and the other two still remain open nine months after the hurricane's landfall.

Hurricane *Frederic* also had a major impact on the Chandeleur Islands of the Mississippi Delta, even though they were located on the left side of the hurricane track and subject to only a 1.3 m maximum surge. Due to intense dissection of the Chandeleur Island by hurricane *Camille* in 1969, *Frederic* essentially reopened the older hurricane channels. The hurricane deposits in the Chandeleur Islands ranged from channel fill and back-barrier fans, to thin sand sheets on the marsh surface and "ebb-surge" deltas at the seaward end of some of the major hurricane channels.

The frequency and magnitude of Gulf Coast hurricanes is such that the deposits here described should dominate the barrier stratigraphy. It should also be noted that the preservation potential of these hurricane deposits is higher than that of any other subaerial or inter-tidal barrier facies.

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BIBLIOGRAPHY

Andrews, P. B., 1970, Facies and genesis of a hurricane-washover fan, St. Joseph Island, central Texas coast: Texas Bureau of Economic Geology, p. 147.

Chow, V. T., 1959, Open-channel hydraulics: MacMillian Publishing Co., New York.

Davis, R. A., W. T. Fox, M. O. Hayes, and J. C. Boothroyd, 1972, comparison of ridge and runnel systems in tidal and non-tidal environments: Jour. Sed. Pet., v. 42, p. 413-421.

Diaz, H. F., 1980, Fall coastal climate review: Coastal Oceanography and Climatology News, v. 2, no. 2, p. 14-15.

Frazier, D. E., 1967, Recent deltaic deposits of the Mississippi River, their development and chronology: Gulf Coast Assoc. Geol. Socs. Trans., v. 17, p. 287-315.

Greenwood, B., and P. A. Keay, 1979, Morphology and dynamics of a barrier breach: a study in stability: Canadian Jour. of Earth Sciences, v. 16, p. 1533-1546.

Hardin, J. D., C. D. Sapp, J. L. Emplaincourt, and K. E. Richter, 1975, Shoreline and bathymetric changes in the coastal area of Alabama: Geological Survey of Alabama, p. 177.

Harris, D. L., 1963, Characteristics of the hurricane storm surge: Technical Paper no. 48, U.S. Dept. of Commerce, Washington, D.C.

Hayes, M. O., 1967, Hurricanes as geological agents: case studies of hurricanes Carla, 1961, and Cindy, 1963: Texas Bureau of Economic Geology Report of Investigations 61, 56p.

, 1979, Barrier island morphology as a function of tidal and wave regime: Barrier Islands, S. P. Leatherman, ed., p. 1-27.

Jelesnianski, C. P., 1972, "SPLASH-special program to list amplitudes of surges from hurricanes: National Weather Service, Unpublished Manuscript, National Oceanic and Atmospheric Administration, Rockville, Md.

Johnson, J. W., 1956, Dynamics of nearshore sediment movement, AAPG Bull., v. 40, p. 2211-2232.

Kahn, J. H., 1980, The role of hurricanes in the long-term degradation of a barrier island chain: Chandeleur Islands, Louisiana. Unpublished Master of Science Thesis Louisiana State University.

McGowen, J. H., 1970, Gum Hollow fan delta, Nueces Bay, Texas: Texas Bureau of Economic Geology Report of Investigations 69, 91p.

, and A. J. Scott, 1975, Hurricanes as geologic agents on the Texas coast: Estuarine Research, L. E. Cronin, ed., p. 23-46.

Morton, R. A., 1978, Large-scale rhomboid bed forms and sedimentary structures associated with hurricane w over: Sedimentology, v. 25, p. 183-204.

, 1979, Temporal and spatial variations in shoreline changes and their implication, Examples from the Texas Gulf Coast: Jour. Sed. Pet., v. 49, p. 1101-1112.

, and M. J. Pieper, 1975, Shoreline changes on Brazos Island and South Padre Island (Mansfield Channel to mouth of the Rio Grande): Texas Bureau of Economic Geology Geological Circular 76-4, p. 42.

, and C. D. Winker, 1979, Distribution and significance of coarse biogenic and clastic deposits on the Texas inner shelf: Gulf Coast Assoc. Geol. Socs. Trans., v. 29, p. 306-320.

Munk, W. H., 1949, The solitary wave theory and its application to surf problems: Annals of the New York Academy of Sciences, v. 51, p. 376-462.

Otvos, E. G. Jr., 1970, Development and migration of barrier islands, northern Gulf of Mexico: Reply: Geological Society of America, Bull. v. 81, p. 3783-3788.

, 1979, Barrier island evolution and history of migration, north central Gulf Coast: Barrier Islands, S.P. Leatherman, ed., p. 291-320.

Penland, S. and W. Ritchie, 1979, Short-term morphological changes along the Caminada-Moreau coast, Louisiana: Gulf Coast Assoc. of Geol. Soc. Trans., v. 29, p. 342-346.

Pierce, J. W., 1970, Tidal inlets and washover fans: Jour. Geology, v. 78, p. 230-234.

Price, W. A. and R. H. Parker, 1979, Origins of permanent inlets separating barrier islands and influence of drowned valleys on tidal records along the Gulf Coast of Texas: Gulf Coast Assoc. Geol. Socs. Trans., v. 29, p. 371-385.

Schramm, W. E., S. Penland, R. G. Gerdes and D. Nummedal, 1980, Effect of Hurricane Frederic on Dauphin Island, Alabama: Shore and Beach v. 48, no. 4.

Scott, A. J., R. A. Hoover, and J. H. McGowen, 1967, Effects of hurricane Beulah on Texas coastal lagoons and barriers: Lagunas Coasteras, un Simposio. Mem. Simp. Intern. Laguna Costeras. UNAM-UNESCO, Nov. 28-30, 1967, p. 221-236.

Treadwell, R. C., 1955, Sedimentology and ecology of southeast coastal Louisiana: Louisiana State University, Coastal Studies Institute, Tech. Rept. 6, p. 78.

U.S. Army, Corps of Engineers, 1968, Report on hurricane Beulah, 8-21 September 1967: Galveston Engineer District, p. 26.

, 1970, Report on hurricane Celia, 30 July-5 August, 1970: Galveston Engineer District, p. 13.

, 1972, Report on hurricane Fern, 7-13 September, 1971: Galveston Engineer District, p. 11.

, Shore Protection Manual: U.S. Coastal Engineering Center, Fort Belvoir, Virginia.

Wright, L. D., F. J. Swaye and J. M. Coleman, 1970, Effects of hurricane Camille on the landscape of Breton-Chandeleur Island chain and the eastern portion of the lower Mississippi Delta: Louisiana State University, Coastal Studies Institute, Tech. Rept. 76, 32 p.

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13. ABSTRACT

Hurricane Frederic made landfall near Pascagoula, Mississippi at midnight September 13, 1979. At the time of landfall the central pressure had dropped to 946 mb, onshore winds in excess of 200 km/hr were lashing the Alabama coastline and the open coast storm tide peaked at 365 cm at Gulf Shores, Alabama.

Vertical photography obtained in 1976 and again 9 days after Frederic made landfall, combined with multiple reconnaissance overflights and ground surveys by the authors provided the data base for determination of shoreline erosion and the distribution of hurricane scour and sedimentary deposits.

Erosion of the Gulf beach at Dauphin Island proved to follow a predictable pattern controlled by nearshore bathymetry whereas retreat of the shoreline of the Mississippi Sound margin was an unexpected occurrence, apparently due to a hydraulic jump as washover currents entered the deep water of Mississippi Sound. Large-scale sediment redistribution on Dauphin Island proper was a consequence of the storm surge flood. However, the ebb surge was responsible for the reopening of three inlets across Little Dauphin Island.

Hurricane Frederic also had a major impact on the Chandeleur Islands, Louisiana. Even though the maximum surge heights on the left side of the hurricane track was only 1.3 m, pre-existing hurricane channels and washovers acted as conduits for the flood and ebb surge.

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Shea Penland, Dag Nummedal and William F. Schramm.

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HURRICANE IMPACT AT DAUPHIN ISLAND, ALABAMA

by

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ABSTRACT

Hurricane Frederic made landfall near Pascagoula, Mississippi at midnight September 13, 1979. At the time of landfall, the central pressure had dropped to 946 mb; onshore winds in excess of 200 km/hr were lashing the Alabama coastline, and the open coast storm tide peaked at 365 cm at Gulf Shores, Alabama.

Vertical aerial photography obtained in 1976 and again 9 days after Frederic made landfall, combined with multiple reconnaissance overflights and ground surveys by the authors, provided the data base for determination of shoreline erosion and the distribution of hurricane scour and sedimentary deposits.

Erosion of the Gulf beach at Dauphin Island proved to follow a predictable pattern, controlled by nearshore bathymetry, whereas retreat of the shoreline of the Mississippi Sound margin was an unexpected occurence. Apparently this retreat was due to a hydraulic jump as washover currents entered the deep water of Mississippi Sound. Large-scale sediment redistribution on Dauphin Island proper was a consequence of the storm surge flood. The ebb surge, however, was responsible for the reopening of three inlets across Little Dauphin Island.

The wave-induced property destruction on Dauphin Island was most intense immediately west of the area of high dunes. This segment of the island, the easternmost portion of the Holocene spit, has been breached twice in this century. Wave refraction analysis demonstrates that this is an area of wave energy focusing. Therefore, during future storm events, breaching, or at the very least severe property destruction, in this area seems inevitable. A sensible land use plan for Dauphin Island should include a search for alternative, and potentially safer, areas for development.

INTRODUCTION

During the 1979 hurricane season, six tropical cyclones were spawned in the North Atlantic; four of these made landfall in the United States, three of which were of hurricane strength (fig. 1). Hurricane _Frederic_

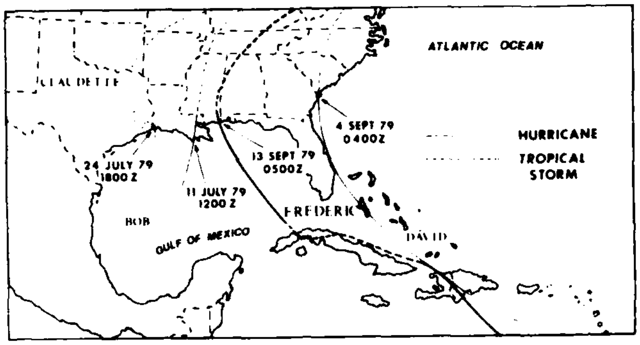


Figure 1. Tracks of the four tropical cyclones which made landfall in the United States during 1979.

made landfall near Pascagoula, Mississippi after crossing over Dauphin Island, Alabama at 00:00 CDT, September 13, 1979 (fig. 2). Total property damage in the coastal counties of Mississippi, Alabama, and northwest Florida was estimated at near 2 billion dollars (Wall Street Journal, Nov. 23, 1979), making _Frederic_ the costliest hurricane disaster ever to hit the United States.

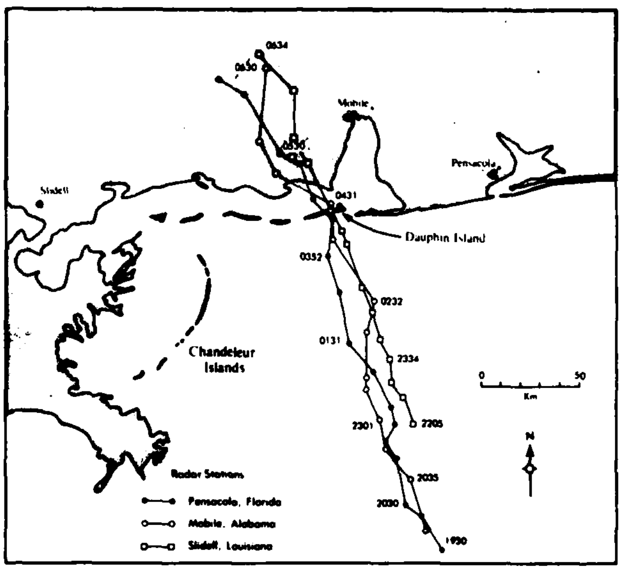


Figure 2. U. S. Weather Service radar positions of hurricane _Frederic_, between the evening of September 12 and the morning of September 13, 1979, Greenwich Time. (Data from: New Orleans Area Weather Service Forecast Office).

The objectives of this paper are: (1) to describe the changes in the physical environment of Dauphin Island caused by _Frederic_, (2) to assess the factors responsible for variations in shoreline erosion along Dauphin Island's beaches, (3) to review pertinent aspects of historical hurricane impacts on the upper Gulf Coast, and (4) to use this integrated information on hurricane response to evaluate the presently established pattern of island land use. It will be shown that the residential development which has occurred on Dauphin Island over the last 25 years is environmentally unsound, and very vulnerable to storms. An analysis of all of Dauphin Island suggests alternative and safer sites of development.

EVOLUTION OF UPPER GULF COAST BARRIERS

Otvos (1970, 1979) suggests that the Mississippi/Alabama barriers originated through vertical shoal-bar aggradation (the deBeaumont theory) some 3 to 4 thousand years ago. Non-barred, open, marine nearshore sediments underlie the islands. The location of the barriers is related to the presence of the Pleistocene core at the east end of Dauphin Island, which may have controlled the formation of the incipient shoals further west. Once the shoals became subaerial barriers, they migrated westward by erosion of their updrift end and spit growth on the downdrift end.

Two distinctly different barrier island morphologies have developed: low-profile and high-profile islands. Generally, low-profile barriers are transgressive sand bodies, whereas high-profile barriers are regressive. Low-profile barriers are characterized by (1) narrow widths, (2) low, irregular dunes, and (3) high washover density. High-profile barriers, in contrast, are (1) wide, (2) high, with well defined fore-dunes and multiple parallel accretionary ridges, and (3) have few washover features (Morton and McGowen, 1979).

Dauphin Island is a combination low- and high-profile barrier (fig. 3). The eastern end of the island consists of a Pleistocene core 5 km long and 2.6 km wide, with large landward-migrating sand dunes up to 14 m high. This higher portion of the island is vegetated by a dense stand of pine. Prior to Frederic, the 19 km long Holocene spit west of this core was characterized by an almost continuous washover terrace with small discontinuous dunes. The barrier width ranged from 300 to 600 m. The other barrier islands on the upper Gulf Coast, Petit Bois, Horn, and Ship Islands, are all high-profile regressive barriers.

The upper Gulf Coast barriers are frequently and extensively modified by hurricanes. A major event was the separation of Petit Bois and Dauphin Islands during the 1740 hurricane (Otvos, 1979). U.S. Coast and Geodetic

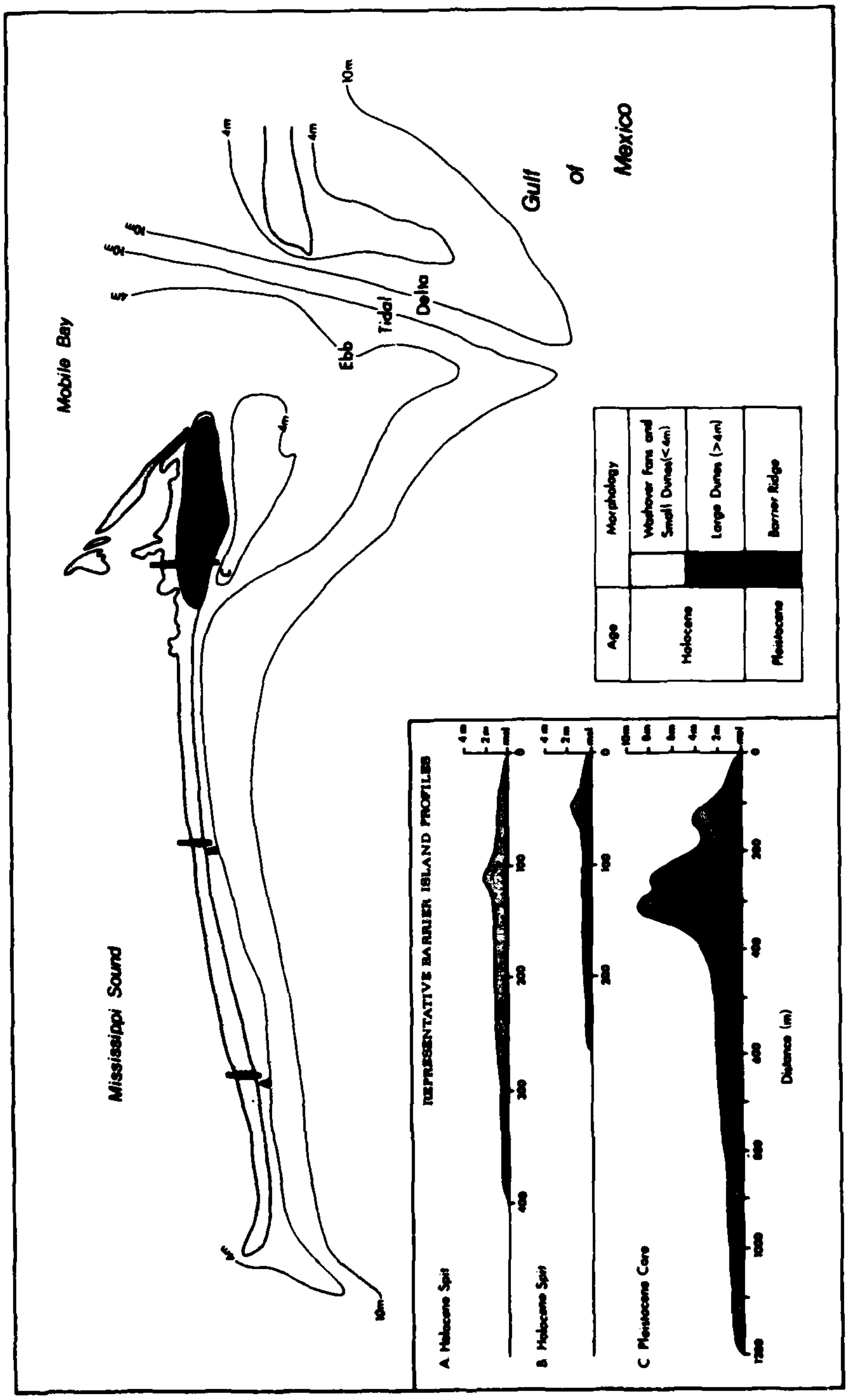


Figure 3. Morphological map of Dauphin Island, Alabama, illustrating the high-profile Pleistocene core and low-profile Holocene spit.

Survey charts from the 1850's indicate that Dauphin Island was breached by the 1852 hurricane. In this century, Dauphin Island has been breached twice. An 8.5 km breach was initially opened west of the Pleistocene core (fig. 4) by the July, 1916 hurricane (Hardin, et al.1976). Hurricanes in October of 1916, 1917, and 1923 helped to prolong the existence of this breach. The last recorded breach took place in 1947. This was a fairly narrow breach (0.5 km wide) which closed quickly. The 1947 breach occurred within the segment originally breached in 1916.

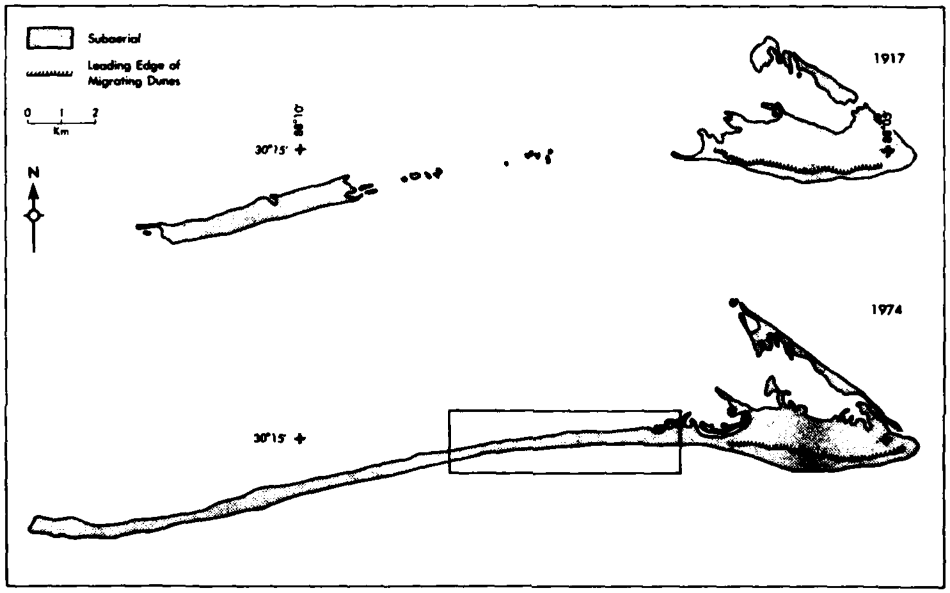


Figure 4. Maps of Dauphin Island in 1917 and 1974. The breach in the island was created by the July 5, 1916 hurricane. The black box encloses the area of extensive residential development on the Holocene spit and is also the location of the area covered by the vertical mosaic in figure 13. (Maps from: Hardin et al. 1976).

According to Waller and Malbrough (1976), Ship Island has been divided by hurricane breaches at least four times in the past 130 years (1852, 1893, 1947, and 1965). Hurricane Camille in 1969 created "Camille Cut," permanently separating the east and west portions of Ship Island. A tidal channel 3.5 m deep developed in this new breach, with an associated ebb-tidal delta. Numerous other examples of hurricane breaching have been documented by Otvos (1979) for Petit Bois (in the 1940's), Ship Island (1916-17), and Horn Island (in the 1700's and 1800's).

HURRICANES AFFECTING COASTAL ALABAMA

After the settlement of Mobile in 1702, the record of hurricanes affecting Alabama is fairly complete. In a 269-year period between 1711 and 1980, 56 tropical cyclones of hurricane intensity have crossed the Mississippi/Alabama coast, or near enough to have affected Dauphin Island (U.S. Army Corps of Engineers, 1967a and 1967b). Table 1 lists the physical characteristics of most storms affecting the region since 1772. Simpson and Lawrence (1971) predict that between Biloxi, Mississippi and the mouth of Mobile Bay, the annual probability of landfall for a tropical storm is 13 percent, for a hurricane 6 percent, and for a great hurricane 1 percent. These storms typically occur between June and October, most frequently in August and September.

CHARACTERISTICS OF HURRICANE FREDERIC

Frederic developed from a tropical depression located 1050 km southwest of the Cape Verde Islands on August 29, 1979. By the afternoon of September 1, it had strengthened to hurricane force (sustained winds 120 km/hr) and was moving at 32 km/hr towards the west-northwest. After moving across the northern Lesser Antilles, and much of the Greater Antilles, Frederic diminished to a tropical depression on September 6. After crossing western Cuba on the 10th of September, Frederic regained hurricane strength. It traversed the Gulf of Mexico in two and a half days at an average speed of 16 km/hr. Because of its slow speed and huge lateral extent, Frederic developed a large storm surge. The peak open coast storm tide during landfall on September 13 was recorded at Gulf Shores, Alabama, where the water reached 365 cm above MSL (fig. 5). This peak storm tide occurred 30 km to the east (right) of the point of landfall.

Storm tides decreased rapidly to the west of the point of landfall. Pascagoula recorded only 185 cm and Bay St. Louis a mere 100 cm above MSL. Figure 5 demonstrates the asymmetry with regard to the observed storm tide distribution at the point of hurricane landfall.

Figure 6 presents synoptic charts of hurricane Frederic's circulation between midnight (CST) on September 12 and 0600 (CST) on September 13, 1979. The maps demonstrate the rapid shift in winds over Dauphin Island from northeast via north to west and southwest during hurricane passage. The sequence of geological events recorded at Dauphin Island reflects quite distinctly this sequence of

Table 1

Hurricanes Affecting Coastal Alabama (1772-1979)

Date of Landfall	Landfall Location	Name of Storm	Saffir/Simpson Scale	Lowest[2] Recorded Pressure	Maximum[3] Recorded Wind	Bay St Louis	Pass Christian	Gulfport	Biloxi	Pascagoula	Bayou La Batre	Coden	Dauphin Island	Mobile	Gulf Shores	Source
						Elevation of Storm Tide above Mean Sea Level[4]										
4 Sept 1772		*	*			*	*		*	*	*	*		249		U S Army Corps of Engineers, 1967a
21 Aug 1852		*	*			*	*	*	*	*		*		243		U S Army Corps of Engineers, 1967a
11 Aug 1860		*	*	*	*	*	*			*	*	*		195	*	U S Army Corps of Engineers, 1967a
15 Sept 1860		*	*	*			*	*	*	*		*	*	213		U S Army Corps of Engineers, 1967a
30 July 1870		*	*				*	*	*	*	*	*		213	*	U S Army Corps of Engineers, 1967a
19 Aug 1888	Lake Charles, La	*	*					*	*	*			*	220		U S Army Corps of Engineers, 1967a
2 Oct 1893	Pascagoula, Miss	*	*	974.1	116	329	*	*	*	*		*		256	149	U S Army Corps of Engineers, 1967b
15 Aug 1901	Grand Isle, La.	*	2	994.5	145		Mississippi Sound 180-240 cm above normal					*	*	226		U S Army Corps of Engineers, 1967a
27 Sept 1906	Mobile, Ala	*	3	955.4	145			*	190		*	330		277	360	U S Army Corps of Engineers, 1967a
20 Sept 1909	Grand Isle, La	*	4	993.8	105		Mississippi Sound 240-365 cm above normal					*	*	213		U S Army Corps of Engineers, 1967a
14 Sept 1912	Mobile, Ala	*	1	998.6	96		Mississippi Sound 120-150 cm above normal					*	*	135		U S Army Corps of Engineers, 1967a
29 Sept 1915	Grand Isle, La	*	4	952.3	200	360	390	275	275			304		195		U S Army Corps of Engineers, 1967b
5 July 1916	Gulfport, Miss	*	3	954.7	172		*	131				330	235	330	345	U S Army Corps of Engineers, 1967b
18 Oct 1916	Pensacola, Fla	*	2	977.8	208	*	*					*	*	98		U S Army Corps of Engineers, 1962a
28 Sept 1917	Pensacola, Fla	*	3	963.3	200						*	*		38		U S Army Corps of Engineers, 1967a
21 Sept 1920	Houma, La	*	2	985.6			Mississippi Sound 150-180 cm above normal					*		*	*	U S Army Corps of Engineers, 1967b
15 Oct 1923	Houma, La	*	1	995.9	98		Mississippi Sound 150-180 cm above normal					*	*			U S Army Corps of Engineers, 1967b
26 Aug 1926	Houma, La	*	3	962.5	112		Mississippi Sound 120-150 cm above normal					*	*		*	U S Army Corps of Engineers, 1967b
20 Sept 1926	Pensacola, Fla	*	4	958.8	245	70	182	182	165		*		*	137		U S Army Corps of Engineers, 1967a
1 Sept 1932	Bayou La Batre, Ala	*	1	987.0	145		Mississippi Sound 120-150 cm above normal					*	*	137	*	U S Army Corps of Engineers, 1967a
6 Aug 1940	Port Arthur, Tx	*	2	999.6	82		Mississippi Sound 150-180 cm above normal					*	*			U S Army Corps of Engineers, 1967b
10 Sept 1944	Mobile, Ala	*	3	*	*		Mississippi Sound 180-240 cm above normal					*	*	*		U S Army Corps of Engineers, 1967a
19 Sept 1947	New Orleans, La	*	4	969.3	177	463	408	426	338	274	250	186		143	241	U S Army Corps of Engineers, 1967b
4 Sept 1948	Grand Isle, La	*	1	993.1	126	180		152	170	120	180	180	*	118		U S Army Corps of Engineers, 1967b
4 Sept 1949	Grand Isle, La	*	*	*	*	152		*	131	*		*	*	119	*	U S Army Corps of Engineers, 1967b
30 Aug 1950	Mobile, Ala	"Baker"	1	983.2	120		Mississippi Sound 120-180 cm above normal					*	*			U S Army Corps of Engineers, 1967a
24 Sept 1956	Fort Walton Beach, Fla	"Flossie"	2	983.6	192	82	90	121	100	97	192	192	100	66	174	U S Army Corps of Engineers, 1967a
15 Sept 1960	Pascagoula, Miss	"Ethel"	1	975.8	145	*	*	150	151	137		*	150	118	*	U S Army Corps of Engineers, 1967a
3 Oct 1964	Franklin, La	"Hilda"	3	965.6	217		Mississippi Sound 120-180 cm above normal					*	107	128	100	U S Army Corps of Engineers, 1967a
29 Aug 1965	Grand Isle, La	"Betsy"	3	952.1	245		Mississippi Sound 120-180 cm above normal					*	*	*	*	U S Army Corps of Engineers, 1966
17 Aug 1969	Bay St Louis, Miss	"Camille"	5	905.0	320	*	689	673	563	387	*	*	*	225	*	Roberts, 1969
13 Sept 1979	Pascagoula, Miss	"Frederic"	3	946.0	234	100	90	125	150	185	275	275	310	365	365	U S Weather Service, 1979

[1] (Neumann et al, 1978) [2] millibars [3] kilometers per hour [4] centimeters * no data

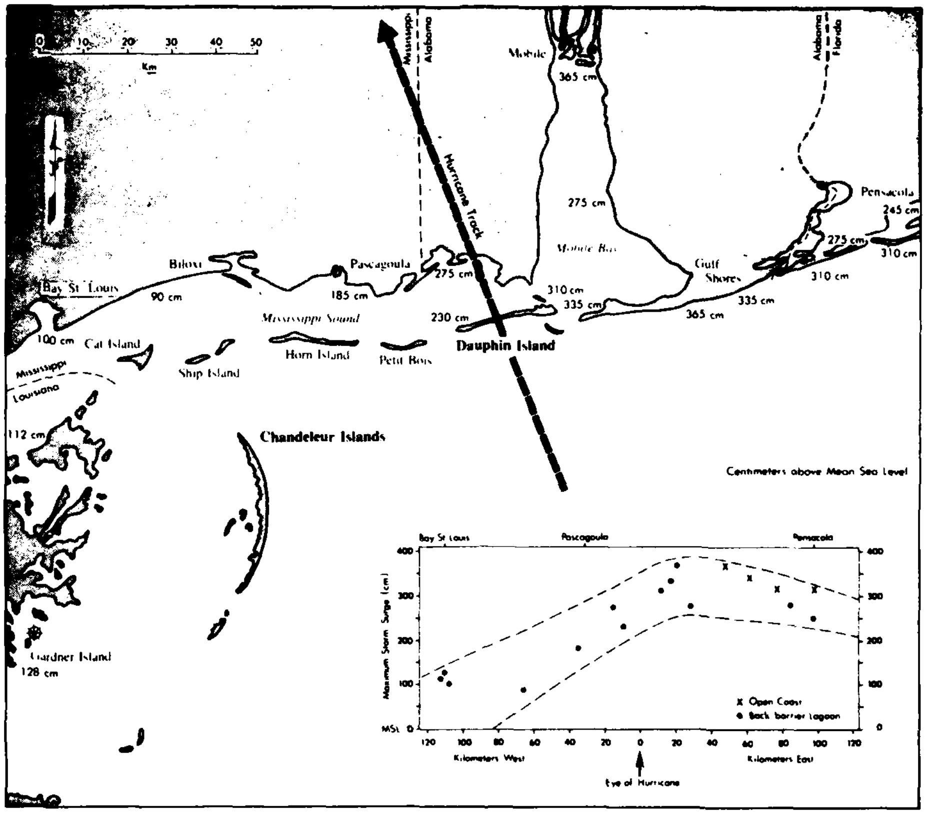


Figure 5: Distribution of maximum storm tide elevations during landfall of Frederic. The inset shows the asymmetry of the storm tide at the point of landfall.

wind change.

NOAA's data buoy EB 42003 located at 26° N, 86° W was directly in the path of Frederic and recorded its deep water wave and meteorological characteristics (fig. 7). This time series records a maximum wave height of 9.1 m coinciding with a maximum wind speed of 118 km/hr. At landfall the strongest winds reached 205 km/hr , associated with a minimum central pressure of 946 mb (fig. 8). The highest winds at the Dauphin Island causeway were recorded at 234 km/hr.

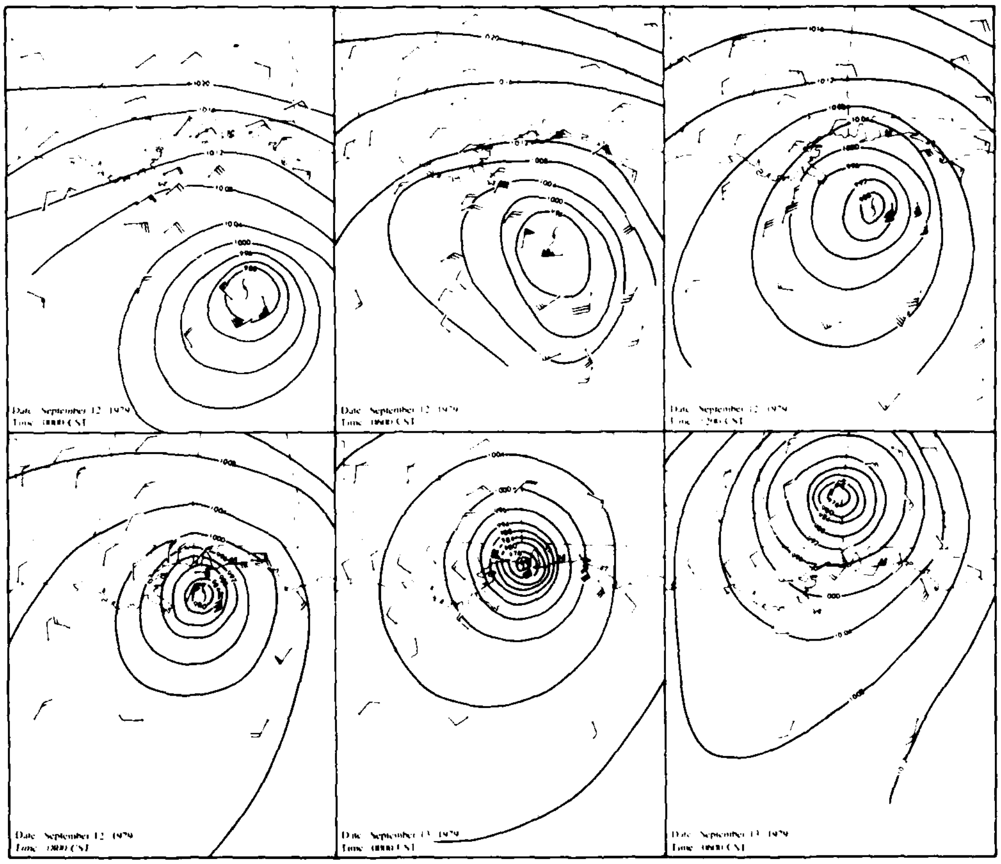


Figure 6. Synoptic surface weather maps of Frederic. (Data from: New Orleans Area Weather Service Forecast Office.)

Figure 7. Deep water time series of Frederic's physical parameters recorded at NOAA's data buoy EB 42003 (from Diez, 1980).

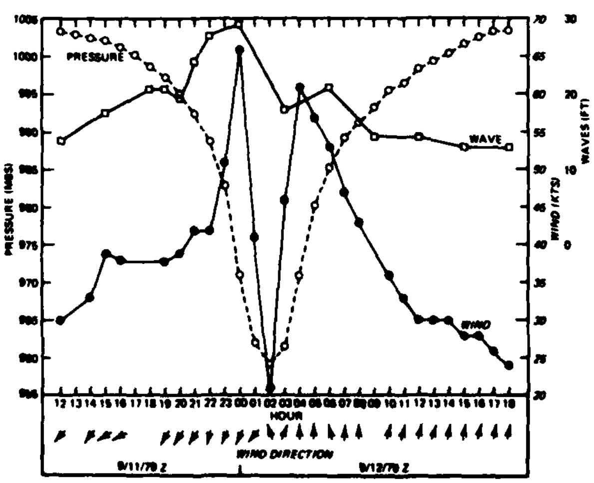
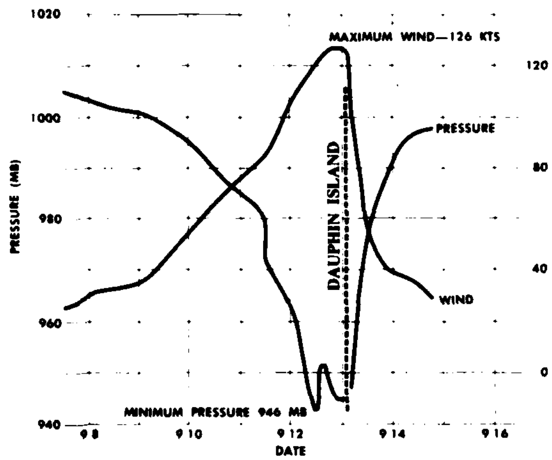


Figure 8. Wind velocity and central pressure time series for hurricane Frederic between September 8 and 19, 1979 (Data from: U.S. Weather Service Hurricane Warning Office, 1979).



FLOOD-SURGE RESPONSE

General

The geological effects of a hurricane on a barrier island can be separated according to three different stages of the hurricane cycle. First is the impact associated with rising water levels due to the storm surge. This stage is associated with strong onshore winds and intense wave-induced beach erosion. The effects on Dauphin Island are discussed here under "flood-surge response." After landfall, the winds generally blow offshore or alongshore; the water level drops rapidly, and another set of processes, the deepening or cutting of tidal passes, dominates. The specific effects on Dauphin Island are discussed under "ebb-surge response." Finally, for months or perhaps years after a major hurricane, the affected island is out of equilibrium with the normal "fair-weather" processes. The gradual restoration of the island under these conditions is discussed under the heading "post-storm recovery."

Gulf Beach

The amount of shoreline retreat at Dauphin Island was measured from two sets of high-quality vertical aerial photographs. The pre-hurricane photographs are dated October, 1976. The post-hurricane photographs were obtained by the U.S. Army Corps of Engineers, Mobile District, on September 22, 1979. Precise measurements to the high water line, relative to a common baseline on both sets of photos, were used to produce the shoreline retreat map in figure 9. The plotted hurricane-related retreat is corrected for the amount of shoreline erosion expected to have taken place under "normal" processes between 1976 and 1979. Hardin et al., 1976 estimate this value to be 3 m/year, or a total of 9 m.

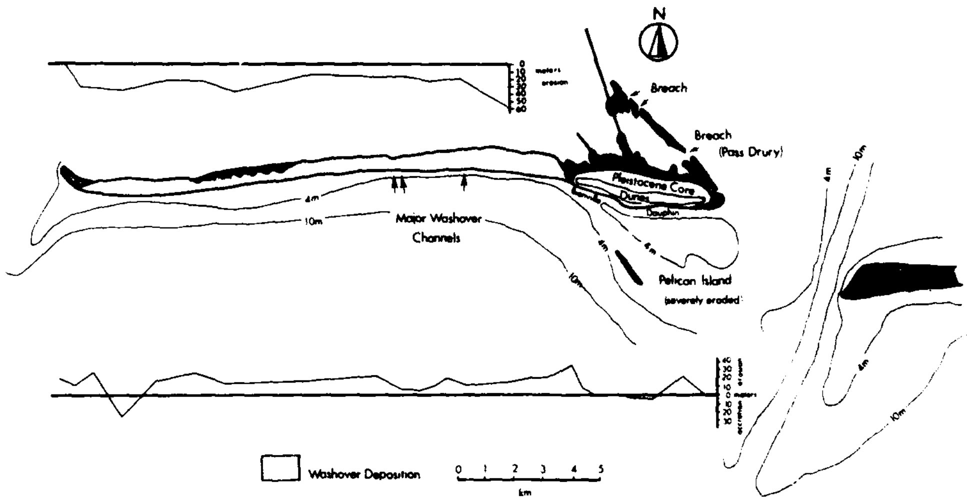


Figure 9. Shoreline retreat values for the Gulf and Sound shores of Dauphin Island.

The amount of shoreline retreat varied considerably along the Gulf beach of Dauphin Island (fig. 9). The least amount of erosion took place near the center of the Pleistocene core at Dauphin and Bienville Beach areas. This small amount of erosion is related to the sheltering effect of the supra-tidal shoals on the west flank of the ebb-tidal delta. These shoals, Sand and Pelican Islands, were nearly leveled to subtidal shoals by the hurricane. These sand bodies greatly reduced the amount of wave energy reaching the shoreline. It appears that hurricane wave refraction around the ebb-tidal delta platform and these shoals may have created a zone of longshore transport convergence at Dauphin and Bienville Beaches. East and west of these beaches, the amount of shoreline retreat was much greater. The increase in erosion along the east end of Dauphin Island reflects an increase in distance and water depth between the shallow ebb-tidal delta margin and the island shore. Based on the track of Frederic, surface weather charts, and post-storm barrier morphology, the peak wave energy that struck the island appears to have arrived from the southeast. The east end of Dauphin Island was openly exposed to hurricane waves coming from that direction. The east end shore retreated about 20 m.

A maximum shoreline retreat of about 40 m occurred immediately west of the high dunes fronting the Pleistocene core of the island (fig. 3 and 9). At this location, the downdrift margin of the ebb-tidal delta is attached to the shoreface. Refraction analysis for hurricane waves arriving from the SE or SSE suggests that the ebb-tidal delta swash platform focused wave energy at this very location.

Shoreline retreat averaged 15 m along the western two-thirds of the island. In light of hurricane wave refraction, the pattern of erosion along the Gulf beach of Dauphin Island is readily explicable. The pattern, however, is not transferable as a basis for prediction of storm erosion along other Gulf coast barriers. In fact, this erosion pattern corresponds more to a response expected for mesotidal east coast barriers. Normally, those are the barriers with a "drumstick" shape and large associated ebb-tidal deltas (Hayes, 1979). The Dauphin Island morphology is rather an anomaly for the microtidal Gulf coast: an anomaly which is due in part to the Pleistocene core, in part to the large discharge of the Mobile River contributing to the formation of the ebb-tidal delta at the bay entrance.

<u>Dunes and Barrier Flats</u>

The dune complex on the Pleistocene part of Dauphin Island was eroded along most of its front but only locally breached by minor hurricane channels (fig. 10).

Figure 10. Two breaches, now closed by landward bar migration, through low areas in the dune complex at the east (Pleistocene) end of Dauphin Island. (Courtesy of Irving Mendelssohn. Photo taken September 28, 1979.)

The low-profile Holocene spit of Dauphin Island had a typical elevation of 1.5 to 2 meters above MSL (fig. 3). Prior to <u>Frederic</u>, only small discontinuous dunes resting on a nearly continuous washover terrace existed. The response of this spit to hurricane overwash includes the formation of: (a) a continuous washover terrace (fig. 11), (b) large scour holes (fig. 12), and (c) major and minor washover channels (fig. 13).

The continuous washover terrace on Dauphin Island extends across the island to the Mississippi Sound shoreline (fig. 11). The thickness of the sand sheets varies

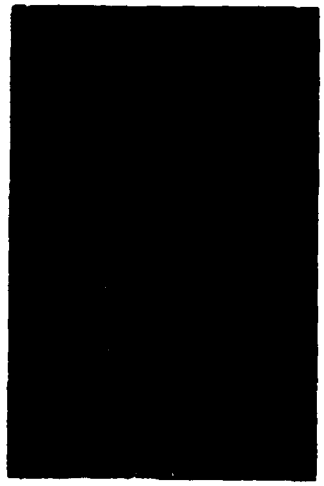


Figure 11. View of washover terraces toward the west end of Dauphin Island, immediately after the passage of _Frederic_. (Photo taken Sept. 15, 1979.)

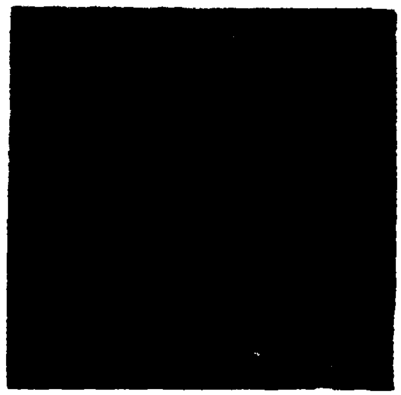


Figure 12 (A) (above). View towards the north of scour holes on the barrier flat.
Figure 12 (B) (right). Ground photo of a single scour hole in the washover terrace. (Photo taken June 21, 1980).

from 110 cm to 20 cm and tends to be thicker towards the back-barrier side of the island. From east to west, the washover thickness generally decreases as the relative elevation of the barrier increase , and the height of the storm tide decreased.

Large scour holes, some many meters in diameter and up to a meter deep, had formed in what appeared to be a random distribution across the barrier flat (fig. 12). Pre-_Frederic_ air photos revealed an abundance of similar depression, most likely dating back to earlier hurricanes.

Minor hurricane channels[1] were abundant along the entire island, particularly within the housing development (fig. 4 and 13). Typically, these minor channels are scoured deepest into the old storm berm and then shoal landward. They are oriented at an oblique angle to the beach toward the northwest, reflecting the dominant wave approach during the flood surge (fig. 14). Only three

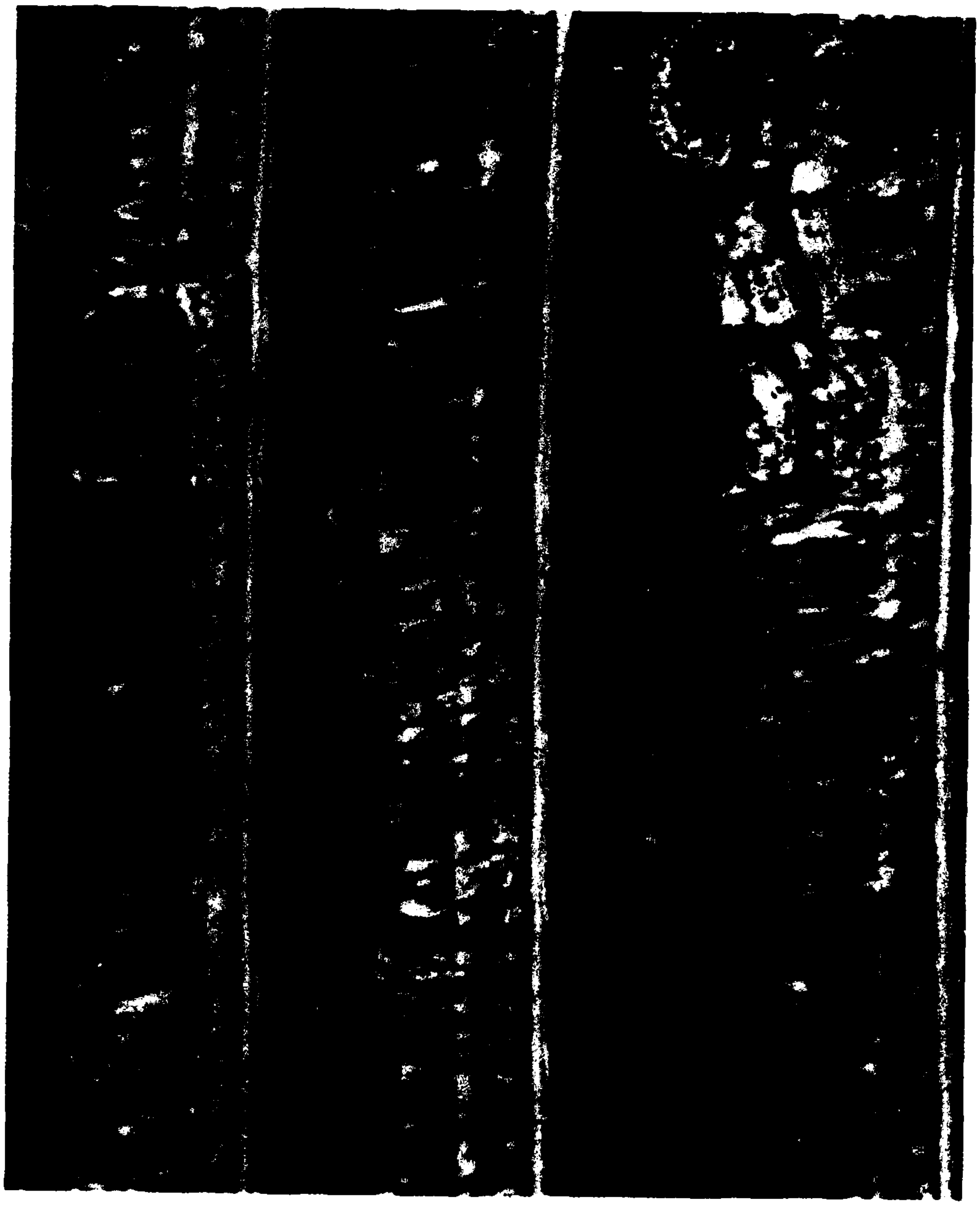


Figure 13. A sequence of vertical air photos, west to east, along the central portion of Dauphin Island after Frederic. Note minor (A) and major (B) washover channels in addition to flame-shaped washover fans (C) and back-barrier scour (D). Gulf is at the bottom of each photo, Miss. Sound at top. (Photo taken Sept. 22, 1979) For location of this mosaic, see figure 4.

Figure 14. Minor washover channels scoured into the beach crest oriented towards the northwest. (Photo taken on Sept. 22, 1979.)

major hurricane channels[2] developed. These, however, are not natural occurences; they are associated with two pre-existing drainage canals and a dirt road (see figure 13, B').

Back-Barrier Margin

To our surprise, the Mississippi Sound shoreline of Dauphin Island retreated more than the Gulf shore; the average amount of retreat was about 25 m (fig. 9). Back-barrier erosion was caused by an intense hydraulic jump (Chow, 1959) that developed where the shallow sheet of water flowing across the barrier flat in an upper flow regime entered the deeper water of Mississippi Sound (Schramm et al. 1980). The scouring action of overwash is responsible for shoreline retreat and for the formation of a nearly continuous deep trough along the back-barrier margin with large flame-shaped washover fans extending into Mississippi Sound (fig. 13, 14, and 15). Deep ramps lead from this scoured trough onto the washover fans. The fan size is generally in proportion to the size of the ramp channel. As overwash entered Mississippi Sound, scouring the back-barrier margin, the entrained sediment was deposited in flame-shaped fans, due to mixing of overwash and Sound water and consequent reduction in sediment transport capacity. The higher the velocity of the overwash current, the more elongated the fan, because mixing is most effective along the lateral margins of the jet.

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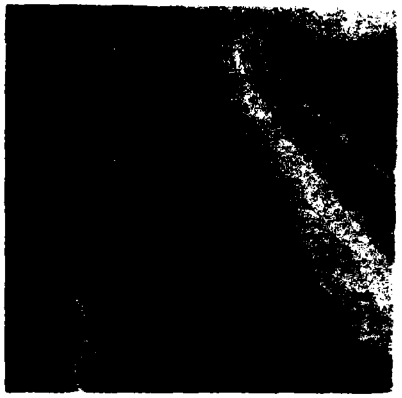
[1]Minor hurricane channels are those cut through a beach berm or foredune ridge above MSL.
[2]Major channels are those which are cut below MSL and remain active after subsidence of the storm surge (Hayes, 1967).



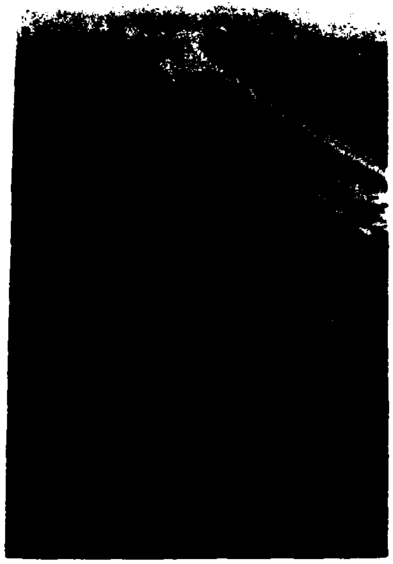


Figure 15 (A) (above). Pre-*Frederic* photo of the back-barrier margin of Dauphin Island. (Photo taken Dec. 17.)

Figure 15 (B) (above right). Post-*Frederic* photo of same area. Note flame-shaped washovers (1) and scour trough (2). (Photo taken Sept. 22, 1979.)

EBB-SURGE RESPONSE

The ebb-surge primarily affected Little Dauphin Island by breaching or reopening three inlets and forming a deep scour trough along the Mobile Bay margin with flame-shaped washover fans extending into the bay (fig. 16).

The reopening of Pass Drury by an ebb-surge flowing from Mississippi Sound to Mobile Bay via Little Dauphin Island Bay is documented by the following data (fig. 17): (1) Immediately after opening, there was a large sand body on the Mobile Bay side of the inlet, i.e. the ebb-tidal delta of Pass Drury. (2) Several channel markers in Dauphin Island Bay, west of the inlet, were bent to the east in the direction of ebb flow. (3) Post-hurricane hydrography in Pass Drury immediately after opening indicated that the inlet is flood dominated, in spite of the existence of the "ebb-tidal delta." However, on Dauphin Island proper, the morphologic evidence indicates that hurricane channels were cut by flood flow. The most common sequence of inlet-cutting through barrier islands is probably one in which the storm-surge flood initiates the breach, and the ebb currents deepen it into a major channel (Hayes, 1967; Greenwood and Keay, 1979).

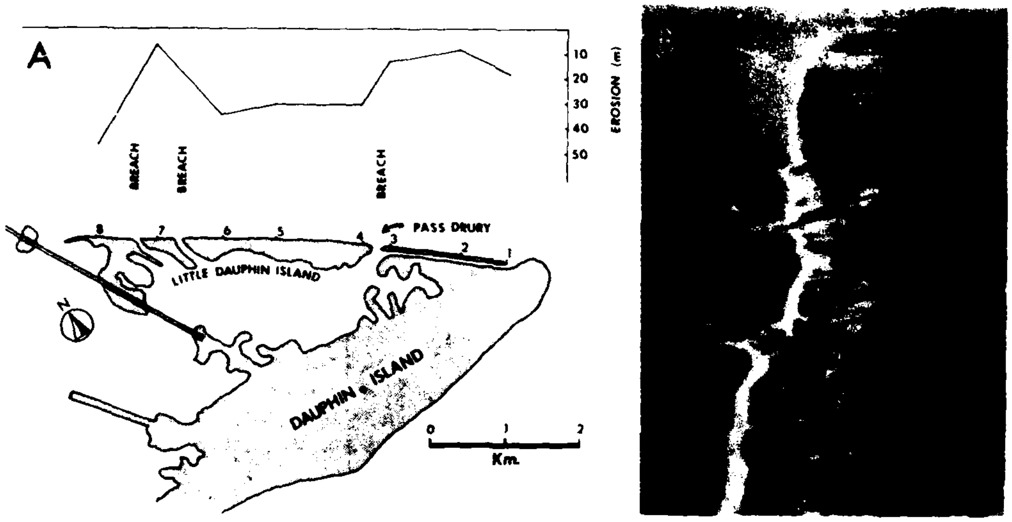


Figure 16(A). Shoreline erosion and breaching at Little Dauphin Island.
Figure 16(B). An aerial view along Little Dauphin Island towards the southeast. Note the flame-shaped sand bodies associated with each newly breached inlet extending into Mobile Bay. (Photo taken March 12, 1980).

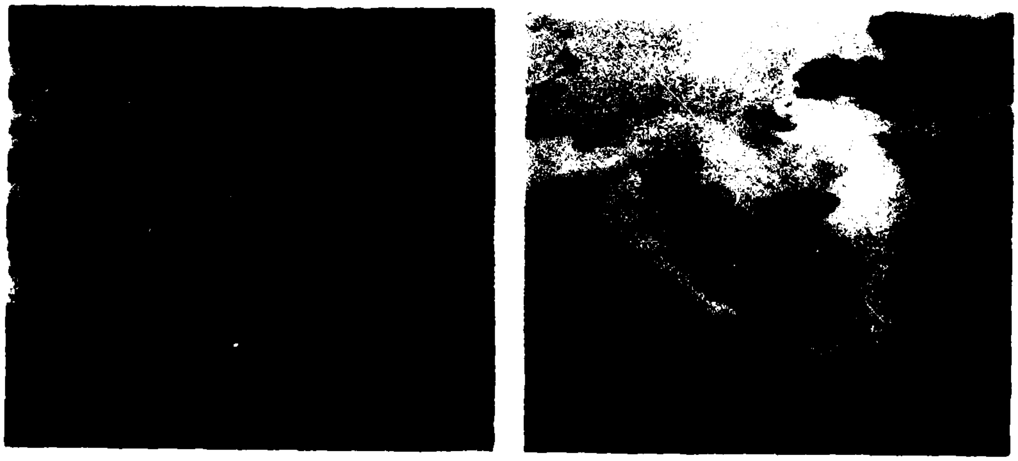


Figure 17(A). Pre-Frederic air photo of the location of Pass Drury before breaching. (Photo taken Dec. 17, 1978.)
Figure 17(B). Post-storm air photo of Pass Drury with ebb-surge oriented sand body extending into Mobile Bay. (Photo taken October 25, 1979.)

POST-STORM RECOVERY

Gulf Beach

The immediate post-hurricane beach on Dauphin Island had a smooth, upward - concave profile. During the waning stages of the storm, the wave steepness, the ratio of deep water wave height (H_o) to wave length (L_o), decreased below 0.025, the value found by Johnson (1956) to differentiate between erosional and accretionary waves. Under these wave conditions, sediment was returned to the beach face in the form of a landward-migrating ridge with a steep landward-dipping slipface. This landward-migrating ridge was quite evident on the Gulf beach of Dauphin Island only 9 days after the hurricane (fig. 18). A beach profile established 3 days after Frederic and resurveyed 8 days later measured 9 meters of accretion (fig. 19). By March 8, 1980, the profile showed only slight additional accretion.

Figure 18. Oblique air photo of a major hurricane channel (A) closed by a large accretionary ridge only 9 days after Frederic. (Photo taken Sept. 22, 1979.)

A

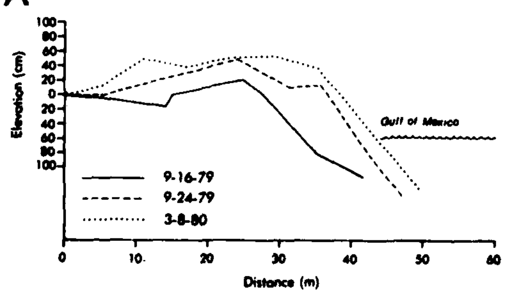
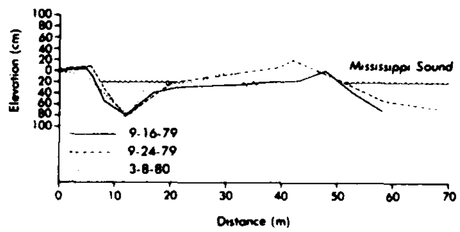


Figure 19 (A). Beach profile illustrating beach recovery after Frederic.
Figure 19 (B). Ground photo of accretionary ridge (light) overlapping the smooth post-storm profile. (Photo taken Sept. 24, 1979.)

Mississippi Sound and Mobile Bay Shoreline

The post-storm recovery along the back-barrier margin of Dauphin Island took place at a slower pace because of the lower wave energy of Mississippi Sound. The termini of the large washover fans were slowly reworked and smoothed. A beach profile established 3 days after Frederic made landfall was resurveyed 8 days later showing only minor change (fig. 20). By March, 1980, considerable change had

Figure 20. Back-barrier beach profile illustrating the reworking of the washover fan margin. (Photo taken June, 1980.)



taken place. The flame-shaped washover fans formed by Frederic had been smoothed and reworked landward, forming a nearly continuous ridge along the entire sound side of Dauphin Island, enclosing a series of inter-connected ponds (fig. 21). These ponds fill with fine sediment and provide the framework for the development of back-barrier marshes along Dauphin Island. A similiar pattern of recovery was observed along the Mobile Bay shoreline of Little Dauphin Island (fig. 22).

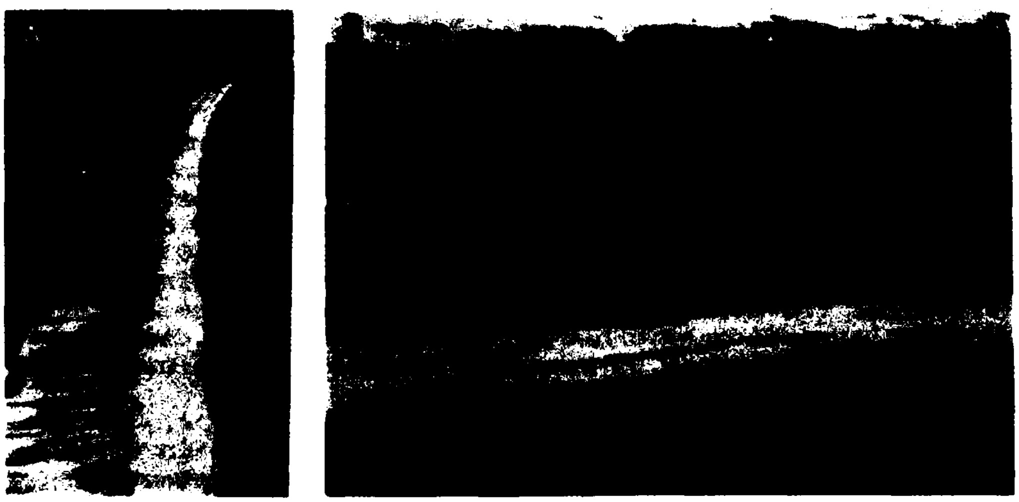


Figure 21 (A). An oblique air photo of the smoothed, reworked washover fan margins forming a nearly continuous ridge.(Mar. 12, 1980).(B) Air photo of a small pond. Note the straight ridge (June 21, 1980).Compare w/ fig. 13 and 15.

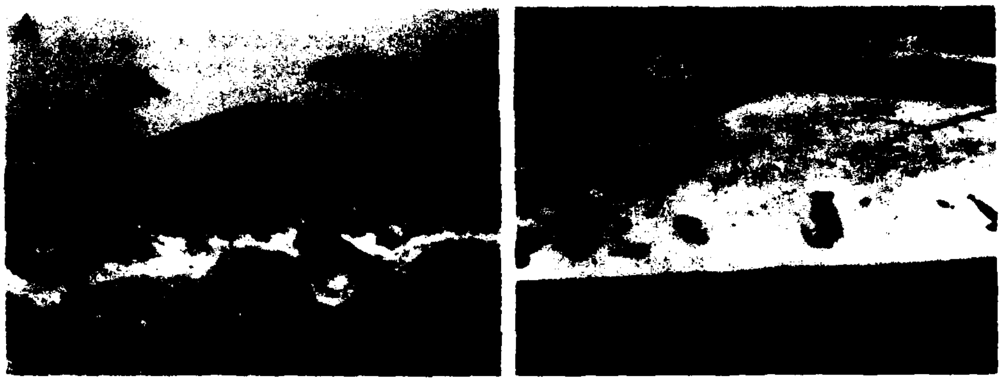


Figure 22 (A). Ebb-surge scour and deposition at Little Dauphin Island. Mobile Bay at bottom and Dauphin Island Bay at top. (Photo taken Sept. 15, 1979).
Figure 22 (B). Oblique air photo of the barrier beach which had welded onto Little Dauphin Island by June 21, 1980. (Photo taken June 21, 1980).

EFFECTS OF MAN-MADE STRUCTURES

Dauphin Island was connected to the Alabama mainland by a causeway across Mississippi Sound in 1955. The bridge connection initiated rapid residential development on the island. High and relatively protected areas on the Pleistocene eastern core of the island were subdivided and made ready for the housing boom. However, the low Holocene spit west of the dune ridge (fig. 4) caught most of the attention of land developers because of the more aesthetic view; it offered views of the Gulf of Mexico unobstructed by any foredune ridges. It was known to the original founders of the Dauphin Island Development Corporation that this particular area had been an open breach between 1916 and some time in the late 1940's. It was also known and documented by air photos (Hardin et al. 1976) that the breach had reopened in 1947. These facts, however, appear to have had little impact on the decision to center the western development at this most vulnerable of all locations on the island.

The intensity of storm-surge related damage in the western development was primarily due to two first-order effects: the refractive focusing of wave energy by the western flank of the Mobile Bay ebb-tidal delta and the low profile inherited from earlier breachings. There were, however, a wide range of second-order scour effects, many of which were clearly directly caused by man-made structures and features.

Shore-normal low features, for example driveways, drainage and boat canals, and marina entrances, acted as conduits for the rising flood waters, became preferentially scoured, and caused the formation of all the major, and most minor, hurricane channels. The presence of strong currents through the marina in the western development is quite evident in the existence of large Mississippi Sound flame-shaped fans immediately behind the navigation channels (fig. 23). The two major hurricane channels at the western extremity of the development (fig. 13) occupy the previous locations of a dirt road and a drainage canal.

Figure 23 (A). Pre-Frederic vertical air photo of marina-style subdivision. (Photo taken October, 1976.)
Figure 23 (B). Post-Frederic vertical air photo of same subdivision. Note the beach erosion and breaches through the marina into Mississippi Sound. (Photo taken Sept. 22, 1979.)

House-support pilings induced turbulence in the overwash currents. This, in turn, accelerated scour and produced linear channels (fig. 13, 24) or crescentic scour zones downcurrent of many homes (fig. 25). Areas between many crescentic scours became zones of sediment deposition, locally causing sand accumulations as much as one meter thick (fig. 24).

It should be pointed our that the 1916 and 1947 hurricanes, both of which had smaller storm tide elevations than Hurricane Frederic (Table 1), breached Dauphin Island; Frederic did not. The reasons for this are unclear, because data from the former hurricanes are scanty. The possibility should not be ruled out, however, that there might be some element of strengthening of the island with the construction of multiple homes, paved roads, and lawns. The location of the western development is certainly unwise from the point of view of property safety. A development within the island's Pleistocene core, which was

Figure 24. Scour channels and zones of sediment deposition downcurrent of some houses within the western development.

Figure 25. Crescentic scour zones related to "obstacles" on the back-barrier side of the western development.

hardly damaged by Frederic, would have made much more economic sense. However, it does not follow that the sediment budget for the developed portion of the Holocene spit has been changed in an adverse way.

DISCUSSION AND CONCLUSIONS

The many instances of hurricanes breaching Gulf coast barriers, the significant alteration of Dauphin Island documented in this paper, and observations of the multitude of geological alterations on the south Texas coast caused by Hurricane Allen a week before this writing, have convinced the authors that hurricanes play a dominant role in the evolution of barrier island morphology and stratigraphy along the U.S. Gulf Coast. The significant geological effects of hurricanes include the following:

(1) Island breaching and the formation of multiple major and minor hurricane channels.

(2) On low-profile barriers hurricanes normally deposit continuous washover terraces as the barrier flats

and deep erosional channels and fans in the back-barrier lagoon.

(3) On high-profile barriers one generally experiences extensive dune scarp retreat and localized foredune breaching with the deposition of attendant interdune fans (Scott and McGowen, 1975).

The frequency of hurricanes along the Gulf Coast is high enough to cause repeated impacts during the lifetime of any given man-made development project. Therefore, major efforts should be undertaken to try to predict the distribution of different hazard zones on any given island prior to its development. The observations presented in this paper of Hurricane Frederic's impact on Dauphin Island should help identify some of the factors which must be considered in such an assessment. These factors include:

(1) The island topography. On Dauphin Island the eastern high-dune region was cut by only a few minor hurricane channels, whereas the low western Holocene spit was completely overwashed.

(2) The nearshore bathymetry. Maximum shoreline erosion and property damage on Dauphin Island occurred immediately downdrift of the ebb-tidal delta flank. This is a zone of wave energy focusing due to refraction around the tidal delta shoals.

(3) The geometry of man-made features. Roads, canals, and other shore-normal structures acted to localize erosion and created both minor and major hurricane channels. Property damage was especially severe adjacent to these channels.

Hurricane Frederic was a severe hurricane of the magnitude which should be considered in proper planning of Gulf Coast barrier development. Many of its destructive effects could have been predicted, and property damage could have been greatly reduced if an effort had been made to do so prior to the construction of the western development.

ACKNOWLEDGEMENTS

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BIBLIOGRAPHY

Chow, V. T., 1959. Open-Channel Hydraulics. MacMillian Publishing Co., New York.

Diaz, H. F., 1980. Fall Coastal Climate Review. Coastal Oceanography and Climatology News, 2(2):14-15.

Greenwood, Brian and P. A. Keay, 1979. Morphology and Dynamics of a Barrier Breach: A Study in Stability. Canadian Journal of Earth Sciences, 16(8): 1533-1546.

Hardin, J. D., C. D. Sapp, J. L. Emplaincourt, and K. E. Richter, 1976. Shoreline and Bathymetric Changes in the Coastal Area of Alabama. Geological Survey of Alabama, Information Series No. 51, p. 177.

Hayes, M. O., 1967. Hurricanes as Geological Agents: Case studies of Hurricane Carla, 1961, and Cindy, 1963. Texas Bureau of Economic Geology Report of Investigations 61, 56 p.

Hayes, M. O., 1979. Barrier Island Morphology as a Function of Tidal and Wave Regime. Barrier Islands, S. P. Leatherman, ed., p. 1-27.

Johnson, J. W., 1956. Dynamics of Nearshore Sediment Movement. American Assoc. of Petroleum Geology Bulletin, 40(9):2211-2232.

McGowen, J. H. and A. J. Scott, 1975. Hurricanes as Geologic Agents on the Texas Coast. Estuarine Research, L. E. Cronin, ed., p. 23-46.

Nummedal, Dag, Shea Penland, Robert G. Gerdes, William E. Schramm, Jacob Kahn, and Harry H. Roberts, 1980. Geologic Response to Hurricane Impact on Low-Profile Gulf Coast Barriers. Gulf Coast Association of Geol. Society, v. 30 (in press).

Otvos, Jr., E. G., 1970. Development and Migration of Barrier Islands, Northern Gulf of Mexico: Reply. Geological Society of America, Bull. v. 81:3783-

Otvos, Jr., E. G., 1979. Barrier Island Evolution and History of Migration, North Central Gulf Coast. Barrier Islands, S. P. Leatherman, ed., p. 291-320.

Schramm, W. E., Shea Penland, R. G. Gerdes, and Dag Nummedal, 1980. Effect of Hurricane Frederic on Dauphin Island, Alabama. Shore and Beach, v. 48(3): 20-25.

Simpson, R. H. and M. B. Lawrence, 1971. Atlantic Hurricane Frequencies Along the U.S. Coastline. NOAA Technical Memorandum NWS SR-58. U.S. Dept. of Commerce, National Weather Service, 14 p.

U.S. Army Corps of Engineers, 1967a. Hurricane Survey of the Alabama Coast. U.S. 90th Cong., 1st Session, House Doc. 108, 74 p.

U.S. Army Corps of Engineers, 1967b. Hurricane Survey of the Mississippi Coast. U.S. 90th Cong., 1st Session, House Doc. 99, 92 p.

Waller, T. H. and L. P. Malbrough, 1976. Temporal Changes in the Offshore Islands of Mississippi. Water Resources Institute, Mississippi State University, 109 p.

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13. ABSTRACT

Hurricane Frederic made landfall near Pascagoula, Mississippi at midnight, September 13, 1979. At the time of landfall, the central pressure had dropped to 946 mb; onshore winds in excess of 200 km/hr were lashing the Alabama coastline, and the open coast storm tide peaked at 365 cm at Gulf Shores, Alabama.

Vertical aerial photography obtained in 1976 and again 9 days after Frederic made landfall, combined with multiple reconnaissance overflights and ground surveys by the authors, provided the data base for determination of shoreline erosion and the deposition of hurricane scour and sedimentary deposits.

Erosion of the Gulf beach at Dauphin Island proved to follow a predictable pattern, controlled by nearshore bathymetry, whereas retreat of the shoreline of the Mississippi Sound margin was an unexpected occurrence. Apparently, this retreat was due to a hydraulic jump as washover currents entered the deep water of Mississippi Sound. Large-scale sediment redistribution on Dauphin Island proper was a consequence of the storm surge flood. The ebb surge, however, was responsible for the reopening of three inlets across Little Dauphin Island.

The wave-induced property destruction on Dauphin Island was most intense immediately west of the area of high dunes. This segment of the island, the easternmost portion of the Holocene spit, has been breached twice in this century. Wave refraction analysis demonstrates that this is an area of wave energy focusing. Therefore, during future storm events, breaching, or at the very least severe property destruction, in this area seems inevitable. A sensible land use plan for Dauphin Island should include a search for alternative, and potentially safer, areas for development.

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