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Geomorphic Recovery of the Chandeleur Islands, Louisiana, After a Major Hurricane

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ABSTRACT

The processes of geomorphic change in the Chandeleur Islands, Louisiana, were monitored for two years after the passage of Hurricane Frederic in September 1979. Rates of beach accretion and hurricane-channel closure on these transgressive, microtidal barrier islands were affected by subsequent storms, including major frontal passages in the two following winters and three tropical cyclones that passed through the Gulf of Mexico in 1980.

Twenty-four months after Frederic, the hurricane's geomorphic modification of the islands remained evident. In September 1981, the Chandeleur barriers were still segmented by 14 hurricane channels and the mean beach width was 60 m, whereas prior to Hurricane Frederic the barrier beach was continuous throughout the study area and the mean beach width was 170 m.

The slow partial recovery of the barriers lends support to the hypothesis that the Chandeleur Islands are being transformed from a continuous chain of barrier islands into a series of small islets and shoals. This transformation is a consequence of the frequent passage of tropical cyclones through the northern Gulf of Mexico, the lack of a sediment supply to the Chandeleur barrier system, and the subsidence of the St. Bernard Delta surface underlying the islands.

Key Words: Barrier Island Arc, Beach Accretion, Chandeleur Islands, Geomorphic Change, Hurricane Channel, Hurricane Frederic, Overwash, Spit Growth, Storm Surge, Tropical Cyclone.

The Chandeleur Islands, Louisiana, located northeast of the Mississippi River Delta, are one of the most rapidly receding barrier island systems in the United States (Fig. 1). The high shoreline erosion rates of the Chandeleurs are principally due to the frequent occurrence of tropical cyclones in the northern Gulf of Mexico, and the lack of sand supply to the islands. The dynamic character of this transgressive, wave-dominated, microtidal barrier chain makes it an ideal site for study of barrier island storm response and subsequent recovery. Nummedal et al. (1980) and Kahn and Roberts (1982) described Hurricane Frederic's landfall and impact on northern Gulf coast barriers in September 1979. This paper summarizes the morphological changes the Chandeleur Islands have undergone in the two years following Hurricane Frederic. Mechanisms and rates of barrier rebuilding were studied through field reconnaissance, and through comparison of aerial photos taken thirteen months prior to Frederic and three, twelve, and twenty-four months after Frederic.

In the past 25 years, numerous studies have focused on the impact of individual tropical cyclones on the morphology of the barrier islands and beaches of the Atlantic and Gulf coasts. Many studies have dealt with the changes in island profiles caused by overwash, the breaching of barriers to form ephemeral inlets, and the rapid post-storm welding of ridge-and-runnel features to the upper foreshore (Hayes 1967; Sonu 1970; Pierce 1970; Dolan and Godfrey 1973; Nummedal et al. 1980). However, there have been very few published reports dealing with the natural recovery, or rebuilding, of barriers in the months and years following the passage of a major hurricane.

Otvos (1982) documented the repeated re-emergence of northern Gulf barriers—including Grand Gosier and Curlew islands in the southern portion of the Chandeleur chain—following hurricanes that reduced the islands to shoals. Cleary et al. (1979) produced a four-stage descriptive model of barrier physiography to explain the geomorphic cycle of foredune recession, foredune breaching and overwash, revegetation of washover fans, and foredune redevelopment. The physiographic changes described by Cleary et al. and by Otvos take place on a time scale of years-to-decades. In contrast, Godfrey et al. (1979) reported that washover fans on Atlantic coast barriers are partially revegetated within a year after major storms.

Due to the infrequency of aerial photo coverage and topographic surveys, the precise time scale of barrier island recovery—beyond the initial welding of ridges and closure of hurricane channels observed during field studies in the weeks after a storm—remains unknown. The purpose of this study of the Chandeleur Islands is to observe processes and rates of barrier recovery.

DESCRIPTION OF THE STUDY AREA

The Chandeleur Islands are in an 80-km long chain of narrow barrier islands composed of reworked sands of the Mississippi River's abandoned St. Bernard Delta. Two lobes of this delta extended seaward of the present-day barriers; these subdeltas were active 3000 to 1700 years BP (Frazier 1967). Russell's (1936) boring of the Chandeleurs indicates that the rate of subsidence since deltaic abandonment has averaged approximately 24 cm/yr (Kahn 1980). The study area comprises the northern 35 km of the arc, from approximately 30°03′ to 29°45′ north latitude (Fig. 1). South-southwest of the study area, the island chain consists of a discontinuous series of small islets and shoals.

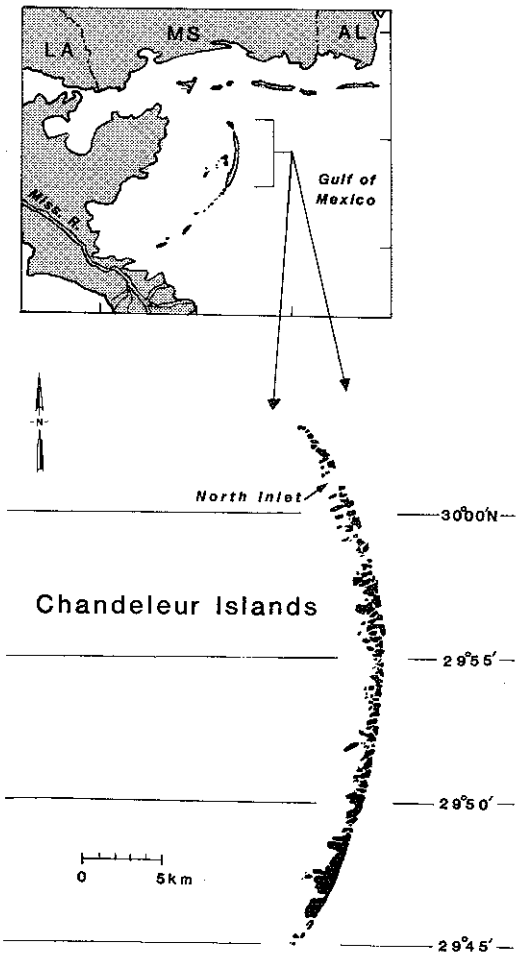

FIG. 1.
The Study Area Includes the Northern and Central Portions of the Chandeleur Islands, North-Northeast of the Modern Delta of the Mississippi River.

The Chandeleurs are migrating rapidly to the west over the subsiding St. Bernard Delta surface. Measurements from charts dating back to 1855 and from aerial photos dating back to 1947 indicate that long-term Gulf shoreline erosion rates range from a minimum of 2 m/yr in the north-central part of the study area to greater than 12 m/yr at the northern and southern ends of the study area, and that there is a long-term trend of decreasing island area (Kahn 1980).

The Chandeleur barriers range from 400 to 1700 m wide. The narrow Gulf beach is composed of fine quartzose sands mixed with varying amounts of coarse shell debris. During extended periods without tropical cyclones in the northern Gulf, such as October 1965 to July 1969 and October 1975 to June 1979, the beach is continuous along the entire length of the study area. In the northern half of the study area the beach is backed by a dune-and-swale zone, with foredunes up to 4-m high. This zone is bordered by marsh of black mangrove (*Avicennia germinans*) and/or salt marsh cordgrass (*Spartina alterniflora*) which extends into Chandeleur Sound. There are virtually no dunes on the barriers in the southern half of the study area. Maximum elevations are 1.0 to 1.5 m on the berm crest of these washover-flat islands, which are fringed by a comparatively wide mangrove marsh extending into Chandeleur Sound (Treadwell 1955). Significant wave heights in this part of the Gulf of Mexico are less than 1.0 m during fair weather (Bretschneider and Gaul 1956), and the mean tide range is 0.4 m.

A major force in the evolution of the Chandeleurs is the frequent passage of tropical cyclones, particularly in August and September. Forty-nine tropical storms and 23 hurricanes, 13 of which were classed as major hurricanes—maximum winds greater than 179 km/h, storm surge greater than 2.6 m—have made landfall since 1900 on the northern Gulf coast between Mobile Bay, Alabama (88° west longitude), and Marsh Island, Louisiana (92° west longitude). Several extremely destructive hurricanes, including Camille (1969), have made landfall on the Chandeleur Islands or the adjacent Mississippi Delta. Major hurricanes cause overwash and severe beach erosion, and breach the barriers in many places (Wright et al. 1970; Kahn 1980; Boyd and Penland 1981).

Many tropical cyclones, moving through the Gulf of Mexico several hundred kilometers offshore, as well as the frequent passage of cold fronts ("northers") in winter, also have an impact on the geomorphology of the Chandeleurs. Boyd and Penland (1981) analyzed tide data and estimated wave setup and wave runup for major frontal passages, tropical storms, and hurricanes. They found that conditions suitable for oceanic overwash of more than two-thirds of the Chandeleur coast occur 10 to 30 times annually.

HURRICANE FREDERIC

On 12 September 1979 the eye of Hurricane Frederic passed 60 km to the east of the Chandeleur Islands on a north-northwesterly path, two hours before crossing Dauphin Island, Alabama, and making landfall near the Alabama-Mississippi border (Fig. 2). Frederic was a major hurricane with maximum winds of greater than 200 km/h at landfall. The storm produced a maximum storm surge of 3.7 m at Gulf Shores, Alabama. The effects of Frederic were most pronounced on the Chandeleurs and along the barrier beaches from Dauphin Island to Pensacola, Florida, 100-km east of the point of landfall, where there was a 3.1-m surge (Nummedal et al. 1980).

The severity of Frederic's impact within the study area varied as a consequence of the wide range of shoreline orientations—which determine the exposure of island segments to waves, wind, and storm surge—and barrier physiography—which determines the topographic threshold and the character of overwash—in the Chandeleur Islands (Kahn and Roberts 1982). The greatest morphological changes occurred in the low-lying, southern portions of the study area that face southeast. The subaerial beach was severely eroded, a strip of marsh 30 to 100-m wide at the interface of the marsh and unvegetated beach was destroyed by wave scour, and 25 "major hurricane channels" (defined by Hayes [1967] as breaches eroded

below mean sea level) were cut through the islands south of 29°55′ north latitude.

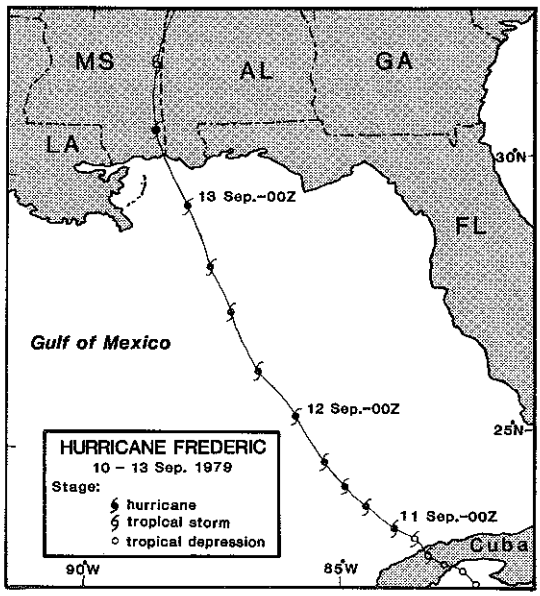

FIG. 2.
The Track of Hurricane Frederic through the Gulf of Mexico in September 1979.
The eye of the storm passed 60 km east of the Chandeleur Islands two hours prior to landfall near the Alabama-Mississippi border (National Weather Service, 1979).

In contrast, overwash in the northern half of the study area was channeled into preexisting breaks in the foredune line. This concentrated flow cut 17 major hurricane channels through the barriers north of 29°55′ north latitude. All of these channels were at locations that were breached by Hurricane Camille ten years earlier. As Frederic passed east of the study area, the water level in Chandeleur Sound rapidly dropped 1.0 m after cresting approximately 0.8 m above the predicted high tide. The return flow from the sound to the ocean (the process that Hayes [1967] refers to as "storm-surge ebb") was funneled through the northern Chandeleur hurricane channels, transporting sediment to the Gulf side of the barriers and depositing large subtidal sand lobes, which are visible on aerial photographs as far as 1000 m offshore.

POST-STORM RECOVERY

September to December 1979

Aerial and ground reconnaissance of the Chandeleurs was conducted 2½, 5 and 14 weeks after Hurricane Frederic. The predominant mode of sediment transport, during the first two weeks after the storm, was the landward movement of sand from the nearshore zone as the beach profile began to readjust to low-energy conditions, through the process of ridge migration and welding, as is characteristic following severe storms (Sonu 1970; Hayes 1972).

The large lobes of sand deposited offshore of the major hurricane channels in the northern half of the study area supplied sediments for beach recovery. Between mid-October and mid-December the subaerial beach at the north tip of the study area (30°03′ north latitude) accreted 40 m, due to the landward migration of a 0.3-m high ridge to the upper foreshore. Beaches in the southern half of the study area generally did not prograde as rapidly; but most of the southern barriers—which had *no* subaerial beach 2½ weeks after Frederic—had a 30-m wide subaerial beach by mid-December.

Another prominent morphological change during the autumn months was the partial blockage of many hurricane channels by intertidal sand spits that built northward across the inlet mouths. Despite spit growth, nearly all of the breaches were still sufficiently open to allow tidal exchange of water through the channels in mid-December. Closure of the breaches was more pronounced in the northern half of the study area; this was at least partly the result of a greater sediment supply to the nearshore zone of the northern barriers in the form of sand lobes seaward of the hurricane channels.

December 1979 to June 1980

There were two pronounced morphological changes observable in the June 1980 Chandeleur aerial photography. The unvegetated sand spits at the northern and southern ends of the study area were each approximately 150-m longer in June 1980 than in December 1979. This spit growth to both the northwest and the

southwest indicates that littoral drift direction in the study area is variable, an expected consequence of the seasonal shifts in wind direction in the northern Gulf.

The other change observed in this six-month period was the partial revegetation of washover deposits overlying marsh areas. Most of the revegetated areas were adjacent to hurricane channels; only a few of these areas with new vegetation border on the sound shore. There is no indication that major new marsh areas were being formed on the sound side of the barriers as a result of Hurricane Frederic. In the northern Chandeleurs, the areas showing signs of revegetation were discrete washover deposits. Revegetation in the southern half of the study area typically occurred on small patches of overwashed sediment scattered widely over the marsh surface.

The hurricane channels that remained open in December 1979 were not altered by spit-building processes during the first six months of 1980. At most locations there was no measurable change in subaerial beach width.

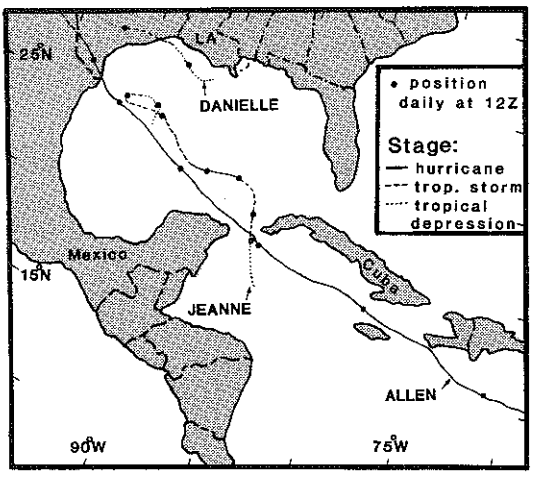

FIG. 3.

Tracks of the Three Tropical Cyclones in the Gulf of Mexico that Affected the Study Area in 1980: Allen,1-11 August; Danielle, 4-7 September; Jeanne, 8-16 November.

Source: National Hurricane Center, Atlantic-Caribbean-Gulf of Mexico Hurricane Track Chart, 1980.

June 1980 to September 1981

The Chandeleur Islands were affected by three tropical cyclones—Hurricane Allen, Tropical Storm Danielle and Hurricane Jeanne—during 1980 (Fig. 3). Though none of these storms passed through the Mississippi Sound region, they caused meteorological tides of 0.27 m, 0.55 m, and 0.55 m, respectively, above the predicted high tide at Bay St. Louis, Mississippi, 50 km northwest of the study area (National Ocean Survey unpublished data). As Hurricane Jeanne stalled in the western Gulf more than 500 km away from the study area in November 1980, the meteorological tide in Mississippi Sound was greater than 0.30 m for five successive days. Tides of this magnitude, accompanied by swell from the distant storm, could result in repeated overwash of most of the southern half of the study area, where maximum barrier elevations are less than 1.5 m above mean sea level.

Extensive overwash of the southern half of the study area is shown on the September 1981 photos, but there were no newly opened hurricane channels. The overwash caused by the tropical cyclones in 1980 deposited sediments on top of the subaerial beach and on the marsh just landward of the beach. Scour pools—rounded or elongated, water-filled depressions measuring 5 to 50 m wide, ubiquitous at the beach-marsh interface after Frederic—were filled with washover deposits between June 1980 and September 1981 (Fig. 4). The vegetation line receded 20 to 30 m on these islands as washover deposits buried the marsh.

The width of the active sand zone (unvegetated subaerial beach) on the Gulf side of the Chandeleurs increased 10 to 80 m during this period. The greatest widening of beaches occurred in the southern half of the study area, where beaches were widened by an average of 45 m. This large increase in the width of the active sand zone was mainly a consequence of the overwash and recession of the vegetation line that occurred in the southern part of the study area during the three Gulf tropical cyclones of 1980, rather than a consequence of beach accretion.

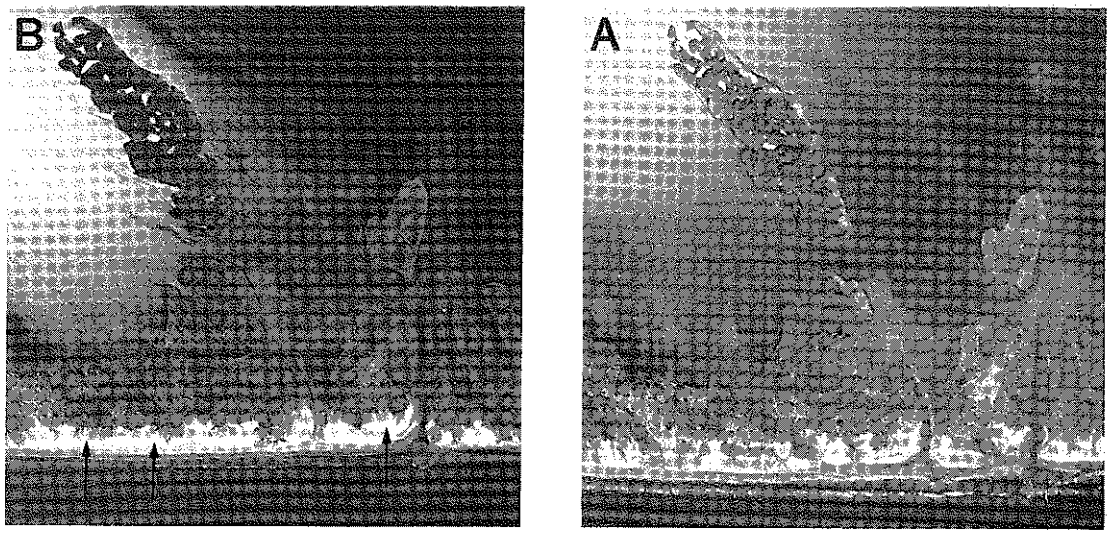

FIG. 4.

Vertical Aerial Photo Comparison of Barrier Morphology in the South-Central Part of the Study Area: (*A*) June 1980 and (*B*) September 1981, Gulf of Mexico at Bottom of Pictures, Chandeleur Sound at Top.
This area was overwashed during the latter half of 1980. Note the closure of hurricane channels, the filling of depressions at the beach-marsh interface with washover deposits (indicated by arrows), and the widening of the active sand zone. (Scale approximately 1:20,000.)

The spits at both ends of the study area grew appreciably. In September 1981 the north spit near Chandeleur Lighthouse was 120 m longer than it was in June 1980. The south spit near 29°45′ north latitude accreted 300 m during this 15-month period.

Less than one-third of the 42 major hurricane channels created by Frederic remained open two years after the storm (Fig. 5). Six of these 12 open channels were partially blocked by spits or welded ridges such that tidal exchange was occurring only at higher tidal levels. All but one of the channels that remained open were either in the northernmost 12 km of the Chandeleur arc or in the south-central part of the study area.

Revegetation of washover deposits continued during this period. In most cases, the areas being revegetated were small, scattered deposits overlying marsh that was buried during Frederic. September 1981 aerial photos show no evidence of new marsh forming on the sound side of the barriers, nor was there extensive new growth of grasses on the Gulf beaches or dune areas.

DISCUSSION

The relatively rapid beach accretion and spit growth in the first three months after Frederic was followed by a six-month period (December 1979 to June 1980) in which the subaerial form of the Chandeleur barriers was not significantly altered. The lack of constructive change in early 1980 is probably a result of the comparatively stormy winter regime in this region. The highest monthly percentages of waves greater than 1.5 m in the northern Gulf are in February, March and April (Roberts 1974). Passage of intense cold fronts across the northern Gulf coast during the late winter and early spring frequently elevates water levels, intensifies longshore currents and generates large wind waves that erode barrier

beaches (Davis and Fox 1975; Boyd and Penland 1981).

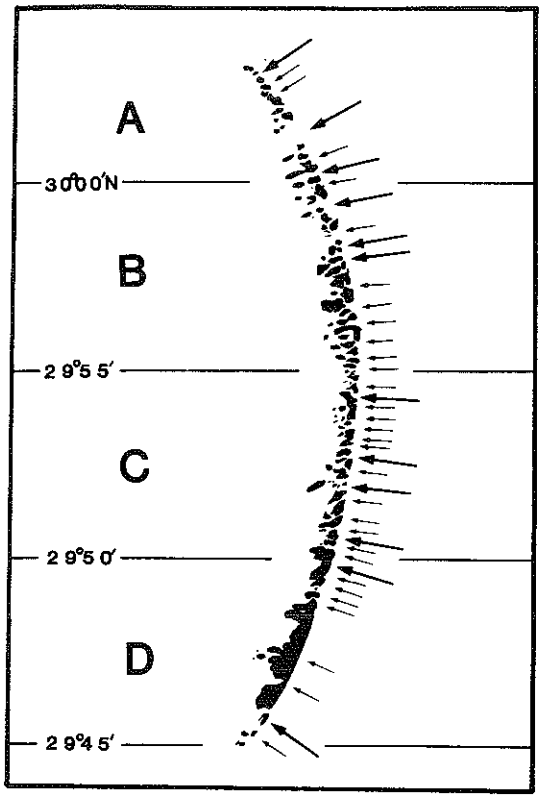

FIG. 5.
Forty-Two Major Hurricane Channels Breached the Chandeleurs during Hurricane Frederic.
Small arrows represent locations of channels that were closed by September 1981; large arrows represent locations of channels that were still open in September 1981.

Comparison of December 1979 and June 1980 aerial photos yields no evidence of large-scale overwash during this period, but tide records at Biloxi, Mississippi, 40 km north of the study area, indicate that meteorological tides of at least 0.3 m occurred on 19 days during this period (National Ocean Survey unpublished data). Minor erosion of the subaerial beach associated with these frontal passages retarded recovery of the Chandeleur barrier arc in the first half of 1980.

In the remainder of 1980, the Chandeleurs were affected three times by tropical cyclones in the Gulf of Mexico, and there was extensive overwash in the southern half of the study area. Between November 1980 and May 1981 there were meteorological tides of greater than or equal to 0.3 m associated with frontal passages on 8 occasions. These relatively mild storm events again retarded the closure of hurricane channels and the recovery of Chandeleur beaches.

There were no tropical cyclones in the open waters of the Gulf of Mexico during the 1981 hurricane season. This unusual absence of tropical storm activity enhanced the recovery of the Chandeleur Islands, and by September 1981 the study area appeared significantly different than it did in the months immediately after Hurricane Frederic.

Two years after Hurricane Frederic hit the Chandeleur Islands, there was clear morphological evidence of the storm's passage. Prior to Hurricane Frederic the islands had a broad, continuous Gulf beach, unbroken along the 35-km length of the study area. The mean width of the active sand zone was approximately 170 meters in the northern half of the study area and 80 meters in the southern half. In contrast, as of September 1981, the barrier arc was segmented by 12 hurricane channels and the average beach width was 60 m.

Based on the rates of recovery observed from 1979 to 1981, it will take several successive summers without the passage of a hurricane or an intense tropical storm through the northern Gulf of Mexico until the entire study area will regain a continuous Gulf beach through closure of the remaining hurricane channels. Even a tropical storm of minimal intensity in the Mississippi Sound region could set back the cycle of geomorphic recovery that this transgressive, deltaic barrier system undergoes following a major hurricane such as Frederic.

CONCLUSIONS

This study lends credence to the supposition that the Chandeleur Islands are being transformed from a continuous barrier island arc into a series of small islands and shoals (Penland et al. 1981). Some of the morphological changes

caused by Frederic appear to be permanent—most notably the destruction of strips of mangrove marsh, up to 100-m wide, at the beach-marsh interface of the barriers in the southern part of the study area—and there is no indication that new marsh is forming on washover deposits on the sound side of the barriers.

The processes of long-term barrier degradation have reached an advanced stage in the exposed southern part of the Chandeleur chain to the south of the study area (Fig. 6). In the area south of 29°45′, a number of former islands have been transformed into shoals (and, in some instances, reemerged) in recorded history, and the remaining islands—Curlew, Grand Gosier and Breton—are narrow and fragmented (Otvos 1982). Penland et al. (1981) proposed a three-stage model of deltaic barrier development associated with the destructive phase of the deltaic cycle. They suggested that the Chandeleur Islands were formed as an erosional headland with flanking barriers (stage 1), and that the southern Chandeleurs are presently in transition from a transgressive barrier island arc (stage 2) to an inner shelf shoal system (stage 3).

The impact of Hurricane Frederic on the study area and the incomplete recovery of the barriers imply a large net loss of sediment from the subaerial islands. Since the Chandeleur barrier system has no outside sediment source and is located on a subsiding deltaic surface, if tropical cyclone frequencies stay relatively constant, the islands in the study area will become narrower and flatter in coming decades. Within several hundred years much of the study area will assume a shoal-islet morphology similar to the ephemeral barriers to the south of the study area. Such a transformation is in progress at the southern end of the study area and is expected to occur further northward along the barrier arc in conjunction with future hurricane impact.

FIG. 6.

Vertical Aerial View of Southern End of Study Area (29°45′ North Latitude), Gulf of Mexico at Bottom of Picture.

A discontinuous series of small, sparsely vegetated islands grades into shoals to the south of the study area. (Scale approximately 1:20,000.)

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