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Geomorphic Recovery of the Chandeleur Islands, Louisiana, After a Major Hurricane [1]

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ABSTRACT

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Geomorphic changes in the Chandeleur Islands, Louisiana, were monitored during the two years following the passage of Hurricane Frederic in September 1979. Rates of beach accretion and closure of hurricane channels on these transgressive, microtidal barrier islands were affected by subsequent storms, including major frontal passages in the winters of 1978-79 and 1979-80 and three tropical cyclones that passed through the Gulf of Mexico in 1980. The hurricane's modification of barrier geomorphology was still evident twenty-four months after Frederic. Fourteen hurricane channels remained open and the mean beach width of the islands was 60 m in September 1981. Prior to the hurricane the beach was continuous throughout the study area and the mean beach width was 170 m. The slow, incomplete recovery of the barriers lends support to the hypothesis that the Chandeleurs are evolving 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 relic St. Bernard Delta surface underlying the islands.

ADDITIONAL INDEX WORDS: *Barrier island, beach accretion, Chandeleur Islands, geomorphic change, Hurricane Frederic, overwash, tropical cyclone.*

INTRODUCTION

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 (Figure 1). Frequent tropical cyclones in the northern Gulf of Mexico and the lack of sand supply to the Chandeleurs contribute to the high erosion rates. This transgressive, wave-dominated, microtidal barrier chain is an ideal site for study of storm response and subsequent recovery of a natural barrier island system.

NUMMEDAL *et al.* (1980) and KAHN and ROBERTS (1982) assessed the immediate impacts of Hurricane Frederic on northern Gulf coast barriers in 1979. This paper describes morphological changes of the Chandeleur Islands in the two years following Frederic. Mechanisms and rates of barrier rebuilding were studied through field reconnaissance and comparison of aerial photos taken thirteen months prior to Frederic and three, twelve, and twenty-four months after Frederic.

Numerous studies in the past 25 years have focused on the impact of individual tropical cyclones on the morphology of Atlantic and Gulf coast barriers. These studies have typically assessed 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, very few published reports have dealt with the natural recovery of barriers — particularly undeveloped barriers without stabilized foredunes — as geomorphic equilibrium is reestablished in the months

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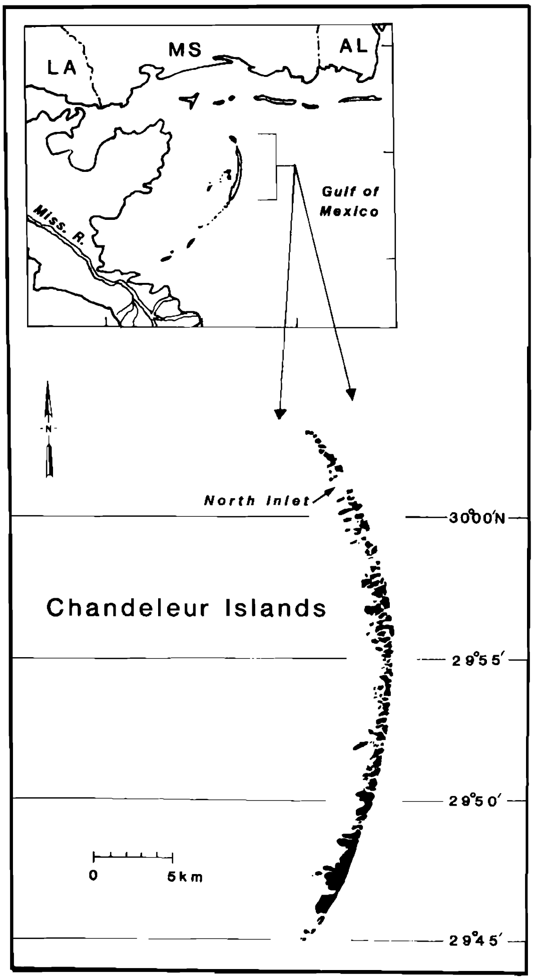

Figure 1. The study area includes the northern and central portions of the Chandeleur Islands, north-northeast of the modern delta of the Mississippi River.

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 OTVOS take place on a time scale of years-to-decades. In contrast, GODFREY *et al.* (1979) reported that washover fans on Atlantic barriers are partially revegetated within a year after major storms.

Because of 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 gain further knowledge of the poststorm recovery time scale.

DESCRIPTION OF THE STUDY AREA

The Chandeleur Islands are an 80-km long chaln of narrow barrier islands composed of reworked sands from the Mississippi River's abandoned St. Bernard Delta. Two lobes of this delta extended seaward of the present-day barriers these sub-deltas were active 3000 to 1700 years BP (FRAZIER, 1967). RUSSELL's (1936) boring of the Chandeleurs indicates that the subsidence rate 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 (Figure 1) and is part of the Breton National Wildlife Refuge. South-southwest of the study area, the island chain consists of a discontinuous series of small islets and shoals.

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 island area is decreasing (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 in which no tropical cyclones move through 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 dune elevations of up to 4 m. This zone is bordered by marsh of black mangrove (*Avicennia germinans*) and salt marsh cordgrass (*Spartina alterniflora*), which extends into Chandeleur Sound. The barriers in the southern half of the study area have virtually no dunes. Maximum island elevations are 1.5 m and the barriers are dominated by extensive washover flats that are fringed on the sound-shore by mangrove marsh. Significant wave heights are less than 1 m during fair weather (BRETSHNEIDER 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 sustained 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 Chandeleurs or the adjacent Mississippi Delta. Major hurricanes severely erode the beaches, overwash most of the island area, and breach the barriers (WRIGHT *et al.*, 1970; KAHN, 1980; BOYD and PENLAND, 1981).

The Chandeleurs are also frequently overwashed when tropical cyclones move through the Gulf of Mexico several hundred kilometers offshore or when winter cold fronts ("northers") cross the northern Gulf coast. BOYD and PENLAND (1981) analyzed tide data and estimated wave setup and wave runup for major frontal passages, tropical storms, and hurricanes. They found conditions sufficient for oceanic overwash of more than two-thirds of the Chandeleur coast occur 10 to 30 times annually.

HURRICANE FREDERIC

The eye of Hurricane Frederic passed 60 km east of the Chandeleur Islands on a north-northwesterly path, two hours before making landfall near the Alabama-Mississippi border (Figure 2). Frederic had maximum winds of greater than 200 km/h at landfall and produced a peak storm surge of 3.7 m on the Alabama coast. Frederic's effects were greatest on the barrier beaches from the point of landfall on Dauphin Island, Alabama, to Pensacola, Florida, 100 km east of landfall, and on the Chandeleurs (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 and barrier physiography (KAHN and ROBERTS, 1982). The greatest morphological changes occurred in the low-lying, southern portions of the study area that face southeast. In addition to extreme beach erosion, a strip of marsh (ranging in width from 30 to 100 m) bordering the 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.

In contrast, overwash in the northern half of the study aera 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 to the east of the study area, the water level in Chandeleur Sound rapidly dropped 1.0 m after cresting 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 two and one-half, five 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. Through the process of ridge migration and welding, the beach profile began to readjust to low-energy conditions as is characteristic following severe storms (SONU, 1970; HAYES, 1972).

Sediments for beach recovery were supplied by the large subtidal sand lobes that had been deposited by the storm-surge ebb in the northern half of the study area Between mid-October and mid-December, the subaerial beach at the north tip of the study area (30°03′ North latitude) accreted 40 m. Beaches in the southern half of the study area did not prograde as rapidly, but most of the southern barriers — which had no subaerial beach two and one-half weeks after Frederic — had a 30-m wide beach by mid-December.

Another prominent morphological change during the autumn months was the partial blockage of many hurricane channels by intertidal sand spits

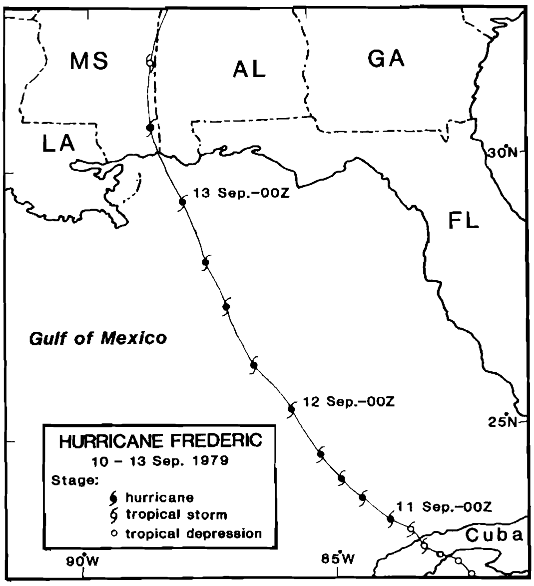

Figure 2. The track of Hurricane Frederic through the Gulf of Mexico in September 1979. The eye of the storm passed 60 km east of the Chandeleur Islands (NATIONAL WEATHER SERVICE, 1979)

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 the subtidal sand lobes noted above.

December 1979 to June 1980

Two pronounced morphological changes were observable on the June 1980 Chandeleur aerial photos. The unvegetated sand spits at the northern and southern extremes of the study area were each approximately 150 m longer than in December 1979. This spit elongation to both the northwest and southwest indicates that littoral drift direction in the study area is variable, an expected consequence of seasonal wind shifts in the northern Gulf. The other major change in this six-month period was the partial revegetation of washover deposits overlying marsh. Most of the revegetated areas were adjacent to hurricane channels; only a few newly vegetated areas bordered on the sound shore. There was no indication that extensive marsh was being formed on the sound side of the barriers following Frederic. Revegetation in the northern Chandeleurs was occurring on discrete washover deposits, but in the southern Chandeleurs revegetation was taking place 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 during the first six months of 1980. Subaerial beach width did not change measurably at most locations during this period.

June 1980 to September 1981

The Chandeleurs were affected by three tropical cyclones during the latter half of 1980 (Figure 3). Though none of these storms passed through the Mississippi Sound, they caused meteorological tides of 0.27 m (Hurricane Allen), 0.55 m (Tropical Storm Danielle) and 0.55 m (Hurricane Jeanne) 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 Chandeleurs, the meteorological tide in Mississippi Sound was greater than 0.3 m on 5 successive days. Tides of this magnitude, accompanied by swell from the distant storm, would likely cause repeated overwash of most of the southern Chandeleurs, where maximum barrier elevations are 1.5 m above mean sea level.

Extensive overwash of the southern half of the study area was evident on the September 1981 aerial photos, but there were no newly opened hurricane channels. The overwash caused by the tropical cyclones of 1980 deposited sediments on top of the subaerial beach and on the marsh just landward of the beach. Scour pools — circular or oval, water-filled depression of 5 to 50 m in length, which were ubiquitous at the beach-marsh interface after Frederic — were covered by washover deposits between June 1980 and September 1981 (Figure 4). The vegetation line receded 20 to 30 m on the southern Chandeleurs as a result of overwash during this period.

The width of the unvegetated subaerial beach on the Gulf side of the Chandeleurs increased 10 to 80 m in this period. The greatest widening of Chandeleurs beaches occurred in the southern half of the study area, where beach width increased an average of 45 m. This widening of the unvegetated beach was mainly a result of the 1980 overwash in the

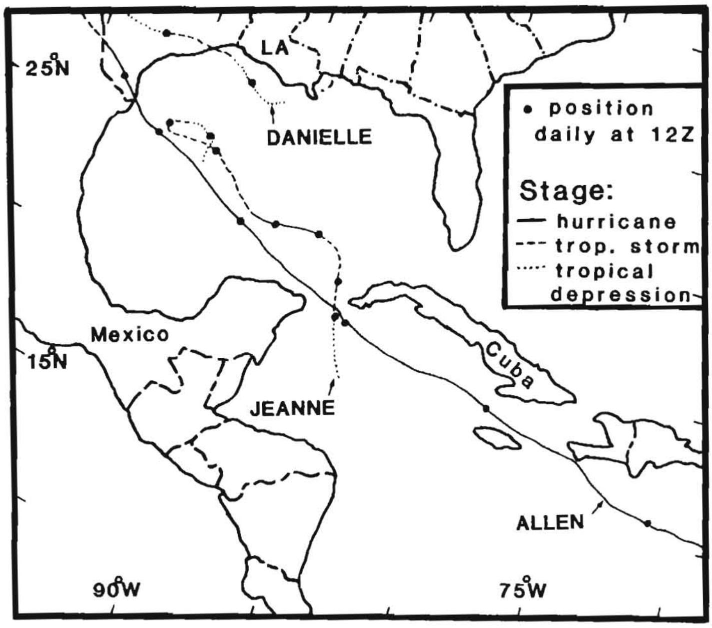

Figure 3. Tracks of the trree tropical cyclones that affected the study area in 1980: Allen, 5-10 August; Danielle, 5-6 September, Jeanne, 9-15 November. (Source: National Hurricane Center, Atlantic-Caribbean-Gulf of Mexico Hurricane Trrak Chart, 1980).

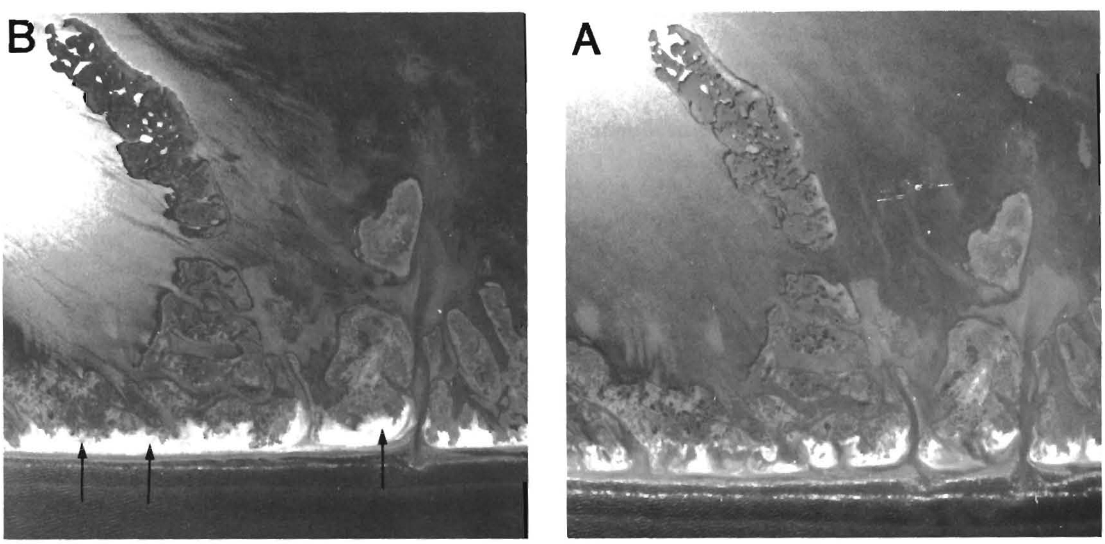

Figure 4. Vertical aerial photo comparison of barrier morphology in the south-central part of the study area: (A) June 1980 and (B) September 1981; Gulf of Mexico at bottom of pictures. Note the closure of hurricane channels, the filling of depressions at the beach-marsh interface by washover deposits (indicated by arrows), and the widening of the beach. (Scale approximately 1:20,000).

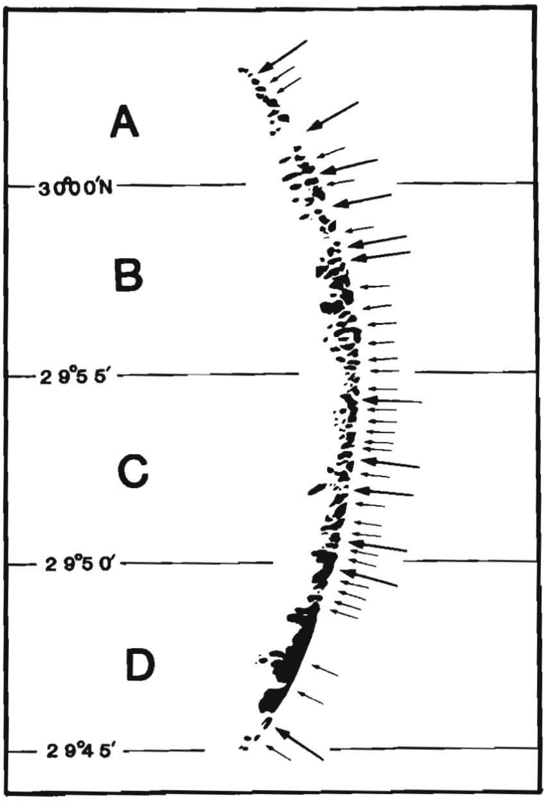

Figure 5. Forty-two hurricane channels breached the Chandeleurs during Hurricane Frederic. Small arrows indicate channels that were closed by September 1981; large arrows show channels that remained open to tidal flow.

southern Chandeleurs, rather than a consequence of shoreline accretion.

The spits at both ends of the study area grew appreciably. The north spit (30°03' North latitude) was 120 m longer in September 1981 than in June 1980. The south spit (29°45' North latitude) accreted 300 m during this period. Less than one-third of the 42 major hurricane channels cut by Frederic remained open two years after the storm (Figure 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 remaining open channels 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 revegetated areas were small, scattered deposits overlying marsh that was buried during Frederic. September 1981 aerial photos showed no evidence of new marsh forming on the sound side of the barriers, nor was there extensive new vegetation 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 in which the subaerial form of the Chandeleurs was not appreciably altered. This lack of constructive change in early 1980 is probably a result of the comparatively stormy winter climate in the northern Gulf 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).

Comparison of December 1979 and June 1980 aerial photos yields no evidence of large-scale overwash during this period, but tide records from Biloxi, Mississippi, 40 km north of the Chandeleurs, 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 barriers in the first half of 1980.

In the remainder of 1980, the Chandeleurs were affected three times by tropical cyclones, and the southern half of the study area was extensively overwashed. Between November 1980 and May 1981, meteorological tides of greater than 0.3 m in conjunction with frontal passages occurred on 8 occasions. These relatively mild storms again retarded closure of hurricane channels and beach recovery.

No tropical cyclones occurred 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 Chandeleurs and, by Septemher 1981, the study area appeared significantly different than it did in the months immediately after Hurricane Frederic.

Two years after Frederic struck the Chandeleurs, clear morphological evidence of the hurricane's

Figure 6. Oblique aerial view of small island reemerging by aggradation of shoals at southern end of study area (29°45' North latitude); Gulf of Mexico at lower left of picture (white pelicans for scale). Photo taken three months after Hurricane Frederic

passage remained. Prior to Frederic, the islands had a broad, continuous Gulf beach, unbroken along the 35-km length of the study area. The mean width of the unvegetated beach was 170 m in the northern Chandeleurs and 80 m in the southern barriers, 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 recovery rates observed from 1979 to 1981, it wlll take several successive summers without the passage of a hurricane or an intense tropical storm through the northern Gulf 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

The findings of this study support the hypothesis 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 in the southern Chandeleurs. Significant areas of new marsh do not seem to be forming on the sound-side washover deposits. Hence, a net loss of island area is taking place.

The processes of long-term barrier degradation have reached an advanced stage in the southernmost part of the Chandeleur chain to the south of the study area, which is most directly exposed to tropical storms (Figure 6). 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 low, narrow and fragmented (OTVOS, 1982). PENLAND *et al.* (1981) proposed a three-stage model of deltaic barrier development linked to the destructive phase of the delatic cycle. They suggested that the Chandeleurs 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 islands. Because the Chandeleur barrier system has no outside sediment source and is located on a subsiding deltaic surface, the Chandeleurs will become narrower and lower in profile during future decades. Given no radical reduction in the level of tropical cyclone activity in the northern Gulf, much of the study area will assume a shoal-islet morphology during the next 50 years, just as the ephemeral barriers to the south of the study area have during the past 100 years. Such a transformation is underway at the southern end of the study area and is expected to progress further northward along the Chandeleur arc in conjunction with future hurricane impact.

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