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Chapter E of
**Sand Resources, Regional Geology, and Coastal Processes of the Chandeleur Islands Coastal System: an Evaluation of the Breton National Wildlife Refuge**

Scientific Investigations Report 2009–5252

**U.S. Department of the Interior**
**U.S. Geological Survey**

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Edited by Dawn Lavoie

In cooperation with the U.S. Fish and Wildlife Service

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# Chapter E. Geologic Mapping of Distribution and Volume of Potential Resources

By David Twichell,[1] Elizabeth Pendleton,[1] Wayne Baldwin,[1] and James Flocks[2]


## Abstract

A dense grid of high-resolution seismic data and vibracores have been used to define the shallow stratigraphy of the Breton National Wildlife Refuge and the inner shelf immediately surrounding the refuge. These data allowed mapping of the distribution and volume of sediment contained in the barrier island lithosome and identification of potential sand resource sites. The islands within the refuge are built upon the St. Bernard Delta Complex of the larger Mississippi River Delta Plain. These deltaic deposits are primarily fine grained with the exception of distributary channels that can be filled with sand and muddy sand. The barrier islands, which extend from Breton Island to the northern tip of the Chandeleur Islands, are the exposed parts of the barrier island lithosome that rests on top of the deltaic deposits. This lithosome is primarily sand; has a volume of approximately $1,600 \times 10^6$ $m^3$; and is unevenly distributed along its length. The lithosome is a broad sheet-like deposit at its southern end, is narrowest and thinnest in the vicinity of the Chandeleur Islands, and extends north of these islands into deeper water as the Hewes Point spit. The Hewes Point part of the lithosome exceeds 9 m in thickness and contains approximately 25 percent of its total volume. Hewes Point is the product of northward alongshore transport and as such represents sediment removed from the littoral zone of the barrier island system. Six areas have been identified as potential sand resource sites. Because of its location at the end of the littoral transport pathway, Hewes Point may be the most promising of the sites. Four distributary channel systems that are exposed on the innermost shelf may also be sand resource targets, but their irregular shapes and high mud content suggest that they are not ideal targets. A smaller deposit at the southern end of the study area that appears to be the sink for southerly directed alongshore transport is the sixth potential site. The lack of cores from this site, however, means that its sediment composition is unknown.


## Introduction

The Chandeleur Islands are a discontinuous barrier island chain along the eastern side of the Mississippi River Delta that trends northward from Breton Island for approximately 85 km (fig. 1). The Breton National Wildlife Refuge is located on the islands, which provide habitat for the brown pelican (*Pelecanus occidentalis*), least tern (*Sterna antillarum*), piping plover (*Charadrius melodus*), and other migratory shore birds, as well as sea turtles and a wide variety of fishes. During Hurricane Katrina in 2005 this island chain lost 84 percent of its areal extent (Sallenger and others, 2006). In the 2 years following the hurricane, the islands showed only limited and slow recovery, which raises the question: Will the islands recover or will they continue to diminish in size and eventually become submerged shoals?

In response to the extreme coastal change and land loss caused by Hurricane Katrina within the Breton National Wildlife Refuge, the U.S. Fish and Wildlife Service has sought aid in developing a clearer understanding of the evolution of these islands, the extent of sand associated with the island chain, and the presence of other potential sand resources around the islands, which are needed to continue effective management of the refuge and its wildlife. To achieve these goals, the U.S. Geological Survey (USGS) conducted a high-resolution geophysical survey of the sea floor and subsurface within 5–6 km of the islands and collected 124 vibracores (fig. 2). The geological data have been used to map and describe the shallow stratigraphy and potential sand resources within close proximity to the refuge. This chapter summarizes findings derived from the high-resolution seismic-reflection data collected around the islands. In addition to characterizing the geologic framework, these data, in concert with vibracore analyses, are utilized to map the distribution of the barrier island sand sheet (called the barrier island lithosome) and identify additional deposits that could serve as sand resource areas if island renourishment is pursued. Deposits shoreward

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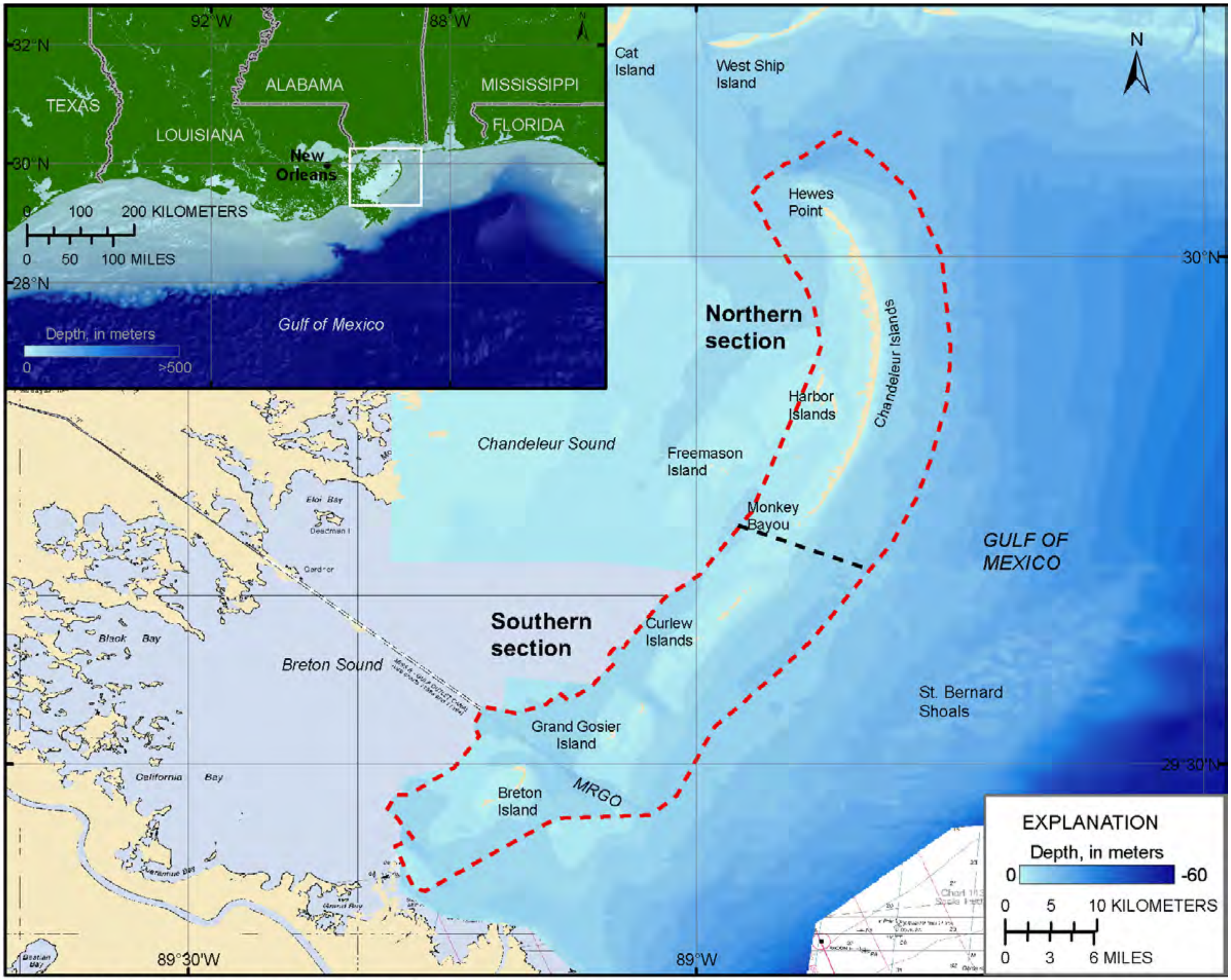


NOAA RNC 11366 is shown in the background

**Figure 1.** Location map showing the Chandeleur Islands, La., relative to other features. The Chandeleur Islands shoreline shown is from 2002. The inset bathymetry is from the Coastal Relief Model (Divins and Metzger, 2008). The bathymetry in the larger map is a composite of bathymetry collected in this study and sounding data from the National Geophysical Data Center.

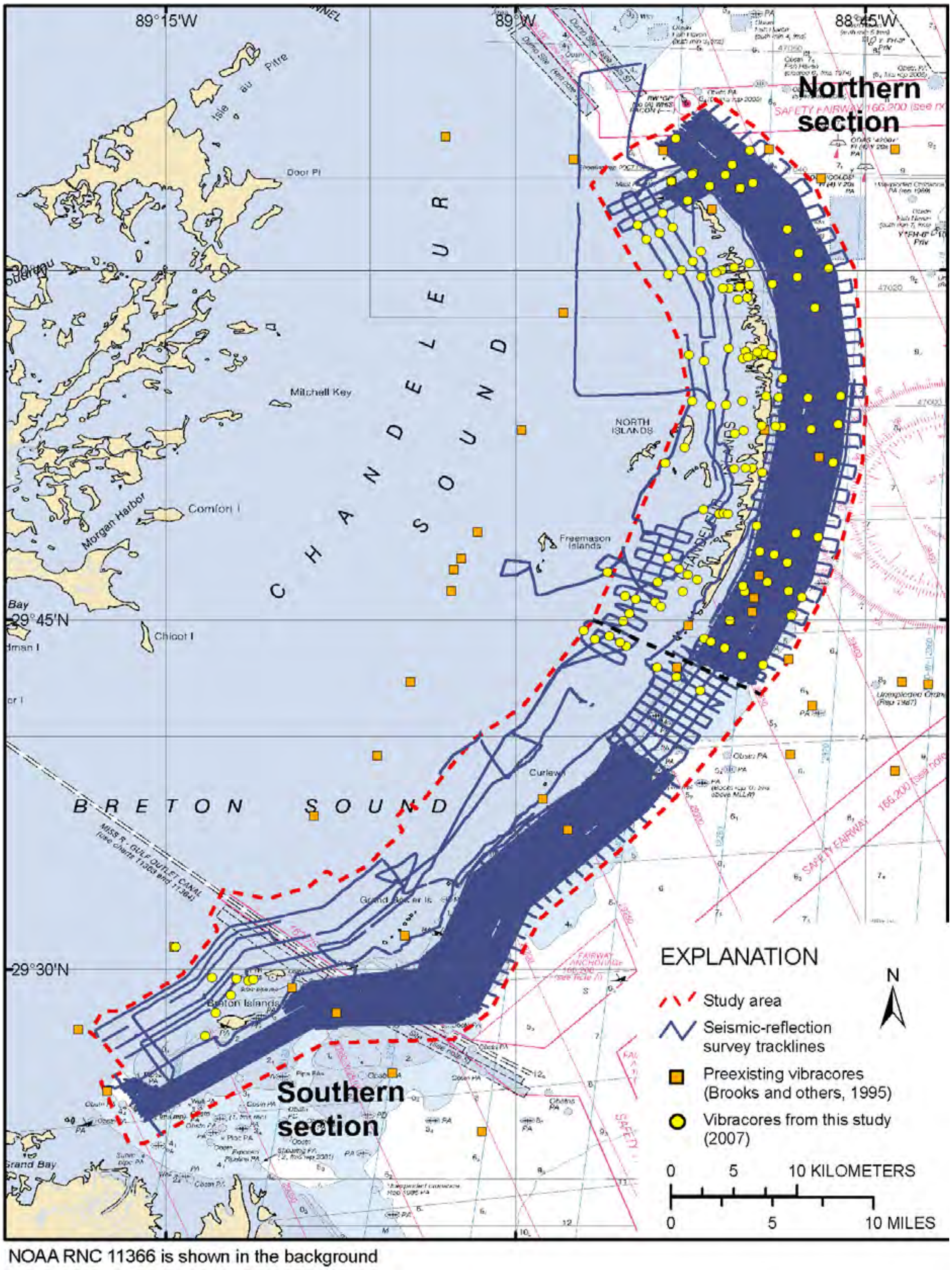


**Figure 2.** Locations of high-resolution CHIRP seismic-reflection tracklines and vibracore coverage in the vicintiy of the Chandeleur Islands, La.

of the islands were not evaluated for their resource potential because of the shallow water depths in this region and because this area is the platform on which the islands eventually would stand if they migrate shoreward. This chapter outlines the location and estimated sediment volume for six potential sand resource areas; chapter F provides textural analyses of sediment within the different resource areas on the basis of vibracore data.

## Setting

Several coastal and geologic studies conducted on and around the Chandeleur Islands have led to an improved understanding of their evolution (Penland and Boyd, 1981; Penland and others, 1985; Suter and others, 1988) and the processes that continue to shape them (Georgiou and others, 2005; Ellis and Stone, 2006), but no sand resource assessments have been conducted in this area to date. Previous studies show that the location of the Chandeleur Islands is controlled by the late Holocene development of the Mississippi River Delta (Penland and others, 1988), which started forming on the shelf about 7,000 years before present (BP). Frazier (1967) and McFarlan (1961) noted that the sites of active deltaic deposition shifted over time, and they described a framework of several smaller delta complexes that form the larger composite feature (fig. 3). One of the intermediate deltas, the St. Bernard Delta Complex, forms the foundation beneath the Chandeleur Islands. This delta complex was active from about 4,000 to 2,000 years BP when it advanced eastward across the inner shelf south of the present day State of Mississippi (Frazier, 1967; fig. 4*A*, 4*B*). Once the St. Bernard Delta Complex was abandoned, the Chandeleur Islands started to form about 2,000 years BP in response to erosion of deltaic headlands and spit elongation driven by alongshore transport (Penland and others, 1985; Brooks and others, 1995; fig. 4*C*). With continued subsidence of the underlying deltaic deposits the islands became separated from the subaerial part of the delta and consequently from their original sand source (fig. 4*D*). Historically, the islands have decreased in subaerial extent largely by narrowing, but they have not moved landward appreciably (Penland and Boyd, 1981; Williams and

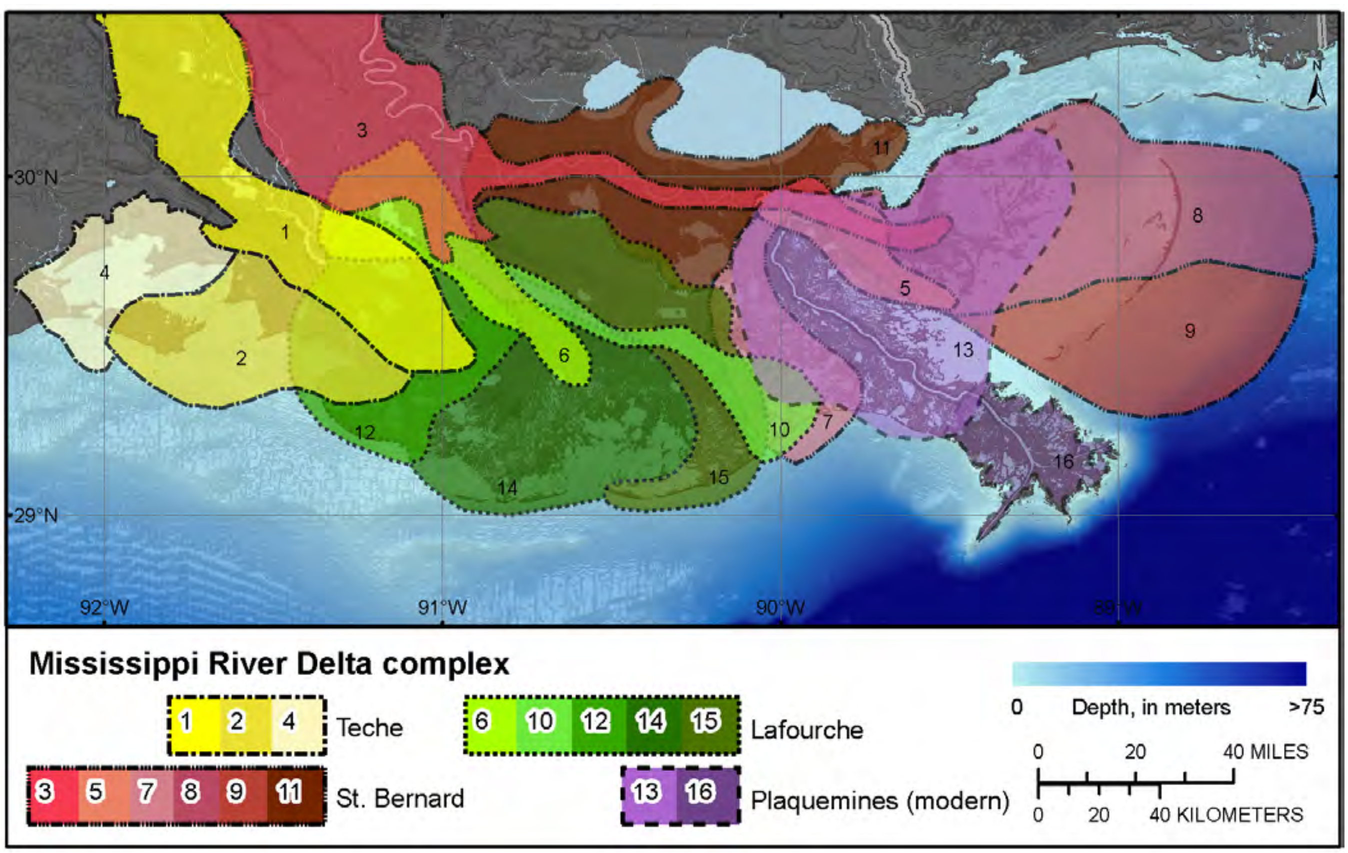


**Figure 3.** Mississippi River Delta Complex (adapted from Frazier, 1967, and Penland and others, 2002). The numbers and colors indicate the relative timing (1–16) of their development. The St. Bernard Delta Complex was active between 4,600 and 1,800 years before present (BP).

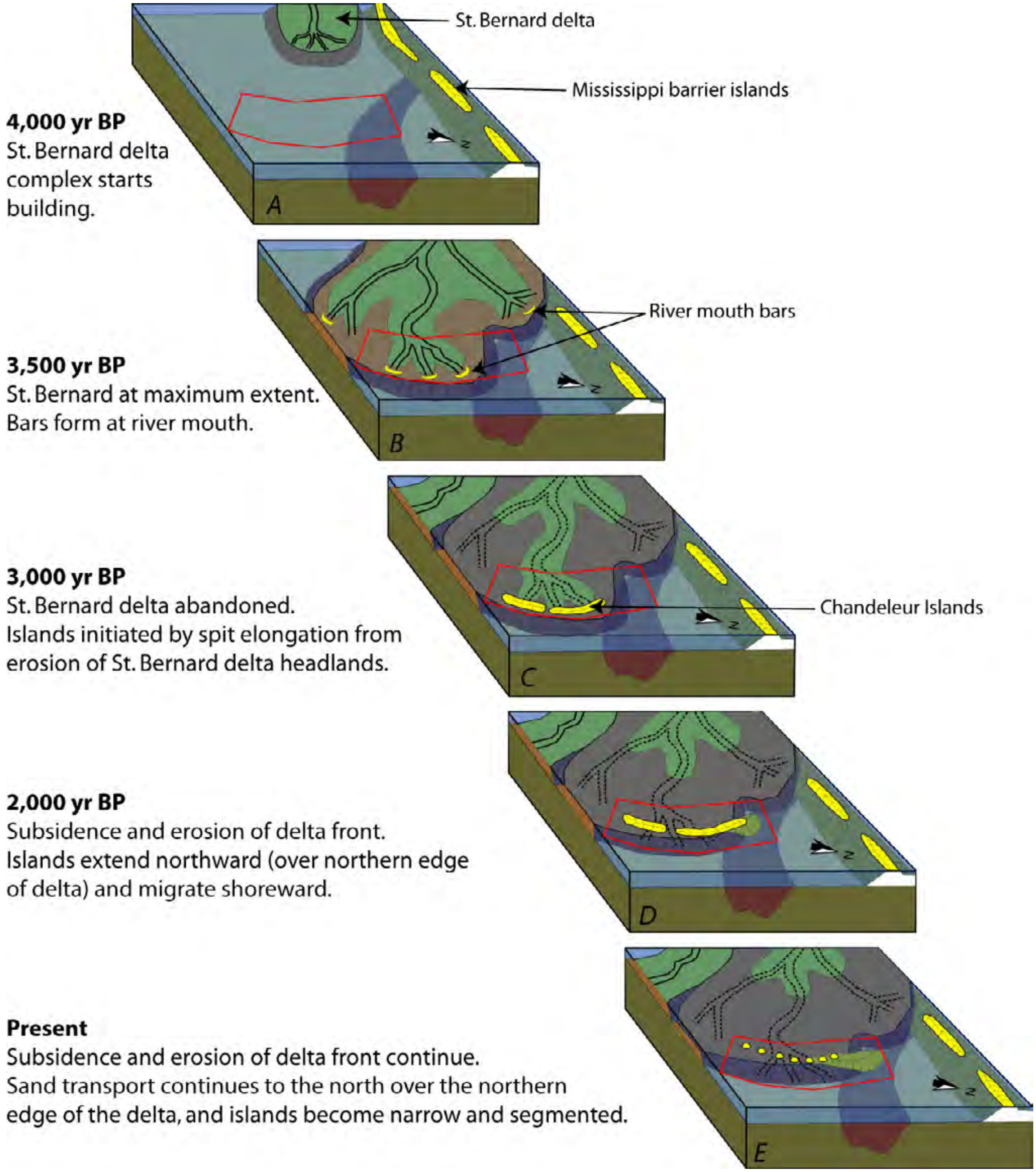


**Figure 4.** Schematic showing the evolution of the northern part of the Chandeleur Islands, La., region. *A*, *B*, The initial onset of the development of the St. Bernard Delta Complex. *C*, The abandonment of the delta complex and its reworking to form the initial Chandeleur Islands. *D*, Continued subsidence and isolation of the islands from their headland sources. *E*, The present, when the islands are greatly diminished in size and a large volume of sediment is transported northward out of the littoral system to Hewes Point. The red polygon indicates the approximate location of the northern half of the study area. BP, before present.

others, 1992, 2006; Miller and others, 2004). After Hurricane Katrina, the islands became more fragmented and greatly diminished in subaerial extent (Sallenger and others, 2006; fig. 4*E*; chap. B).

The St. Bernard Delta Complex, which was the source of sand for these islands, has been studied extensively by Fisk and others (1954), Frazier (1967), Coleman and Prior (1980), and Coleman (1988), who recognized subaerial and submerged subunits. The original St. Bernard Delta Plain consisted of a network of distributary channels separated by interdistributary marsh deposits (fig. 5). Distributary channels incised the subaerial part of the delta. They were mostly filled with muddy sand and sandy mud, but sand-rich bars were common at their mouths (Coleman, 1988). Interdistributary marsh deposits occupied areas between the channels and primarily consisted of organic-rich sandy silt. Delta-front deposits accumulated offshore of the distributary channel and interdistributary marsh deposits. These deposits contained silt layers and thin sand laminae that dipped gently seaward and graded into adjacent prodelta deposits. The proximal edge of delta-front deposits was sandier than the distal edge, which merged with prodelta muds. Prodelta deposits accumulated farthest from the river mouth and were the finest grained. These deposits primarily consisted of clay with occasional silt beds that were deposited on the continental shelf well beyond the subaerial extent of the delta (Kindinger and others, 1982). As the delta complex expanded, distributary channel and interdistributary marsh deposits advanced seaward over the previously deposited delta-front deposits that, in turn, advanced over prodelta deposits. After the delta complex was isolated from its fluvial source, these sedimentary facies became the primary source of local sediment supply as they were eroded by inner shelf waves and currents.

The Chandeleur Islands are located near the transition between the original delta plain and delta front of the St. Bernard Delta Complex, a transition that is reflected in the modern bathymetry. The bathymetry shows that the Chandeleur Islands occupy the transition between shallow delta plain now submerged under Chandeleur Sound and moderate depths offshore of the islands where delta-front and prodelta deposits accumulated (fig. 6). The mean depth west of the islands, in Chandeleur Sound, is generally less than 5 m. Depths increase to 10–16 m along the northern and eastern edges of the study area. The Chandeleur Islands rest on a narrow arcuate ridge that is about 4 km wide and rises about 4 m above the floor of Chandeleur Sound. The northernmost extent of the island chain is bounded by Hewes Point Shoal, a large sand deposit that extends northward from the islands into deeper water. Along the seaward side of the islands the sea floor has a slope of 3.6–5.0 m/km in water depths less than 8 m, except off Hewes Point, where the slope increases to 16.7 m/km in deeper water.

# Methods

## Seismic Data Acquisition

Approximately 1,250 km$^2$ of the inner continental shelf surrounding the Chandeleur Islands were surveyed by using CHIRP seismic-reflection systems during two cruises in July 2006 and two cruises in June 2007 (fig. 2). Two cruises along the eastern (seaward) side of the island chain were conducted aboard the Louisiana Universities Marine Consortium vessel

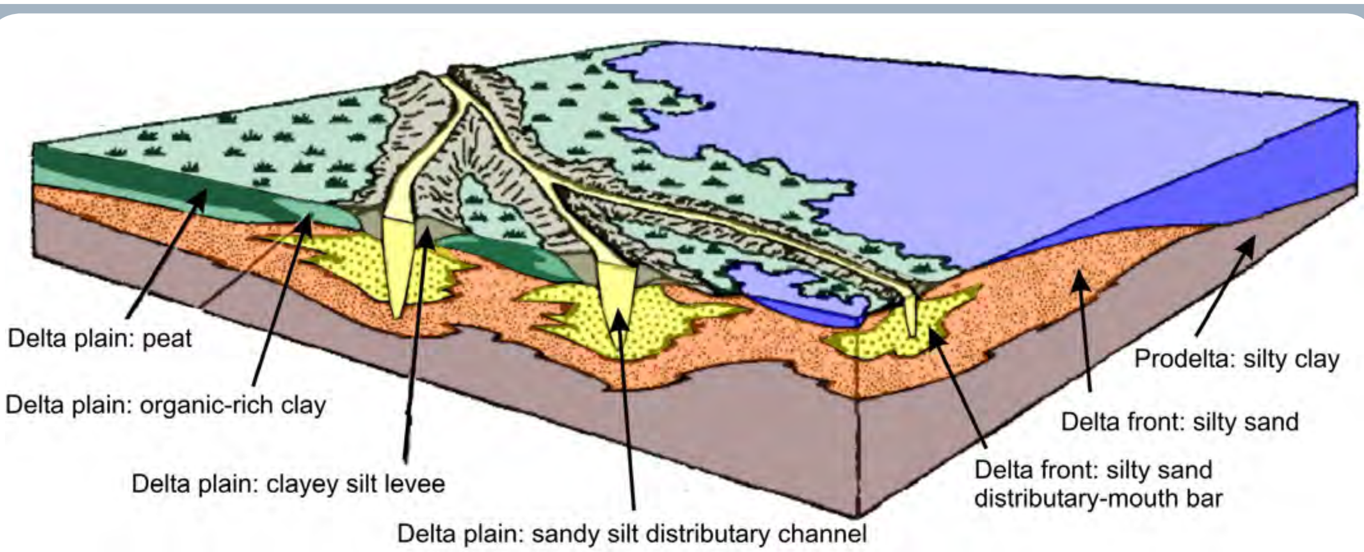


**Figure 5.** Block diagram showing delta stratigraphy of the original St. Bernard Delta Plain (4,000–3,000 years before present) upon which the Chandeleur Islands, La., formed (Frazier, 1967).

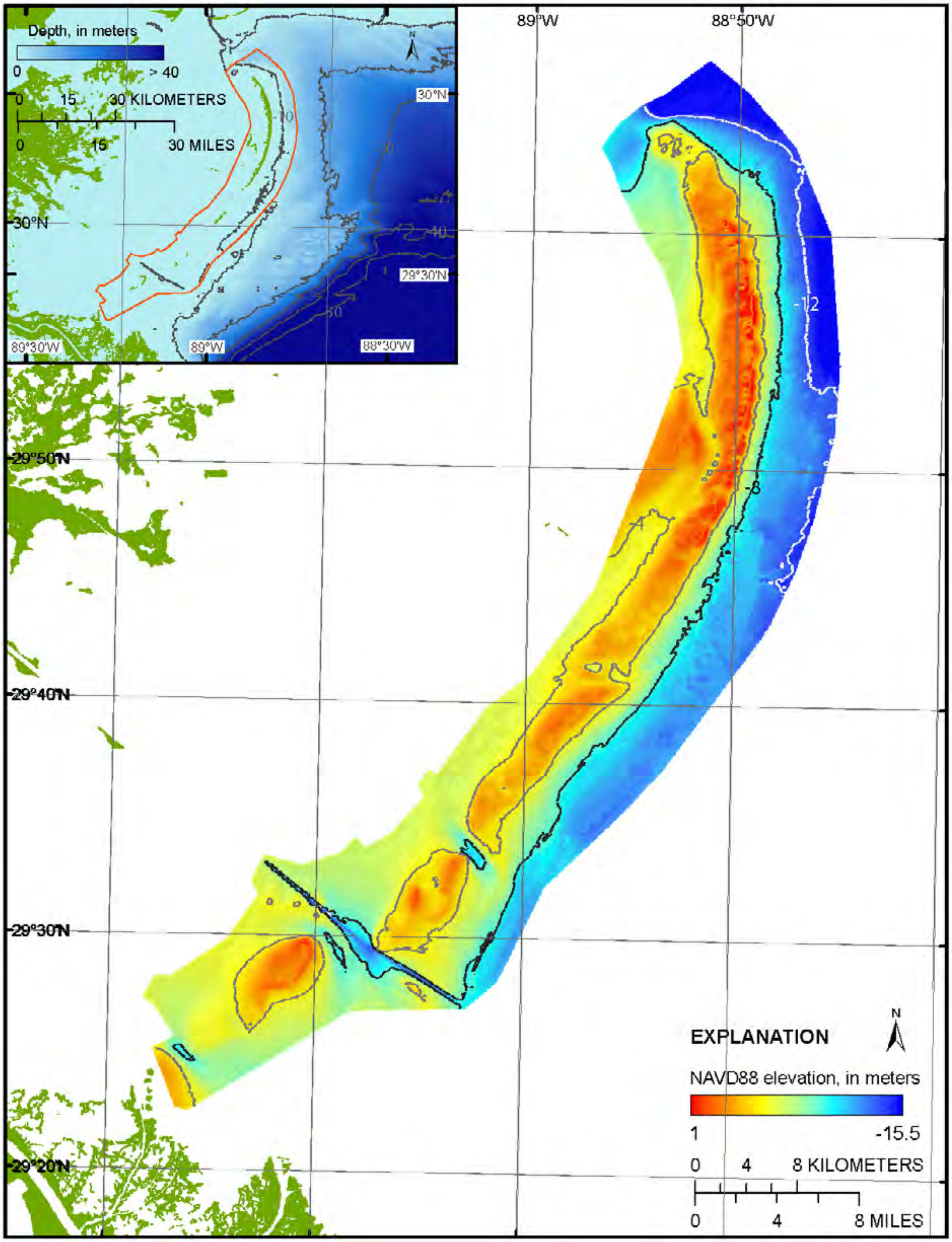


**Figure 6.** Interpolated bathymetry and lidar topography of the study area in the Chandeleur Islands, La., for the period from 2005 to 2007. Inset map shows the regional bathymetry along the eastern side of the Mississippi River Delta. The 2002 shoreline is shown on the inset map and in the background in solid green for reference. NAVD 88, North American Vertical Datum of 1988.

*R/V Acadiana*. Two cruises along the western (shoreward) side of the islands were conducted aboard the USGS vessel *R/V Gilbert*. Aboard the *R/V Acadiana*, data were collected in the area extending from 1–2 km seaward of the islands to 5–8 km offshore. Survey lines were spaced approximately 100–150 m apart in the shore-parallel direction and about 1 km apart in the shore-perpendicular direction. Aboard the *R/V Gilbert*, seismic data were collected along the back side of the islands extending from 1–3 km to 5–15 km shoreward of the islands. Survey lines were spaced approximately 1 km apart in the shore-parallel direction, and shore-perpendicular lines spaced about 750 m apart were concentrated at the northern end, the middle part, and the southern end of the island chain. Data were collected immediately seaward of the northern part of the islands from the *R/V Gilbert* as well because its shallower draft allowed surveying closer to shore than was possible with the *R/V Acadiana*. Positions of the ships and geophysical data were determined by using Differential Global Positioning System (DGPS) navigation. During acquisition, both vessels maintained speeds between 1.5 and 2.5 m/s.

In total, 3,550 km of high-resolution CHIRP seismic-reflection profiles were collected from the *R/V Acadiana* by using an EdgeTech (EdgeTech Marine, West Wareham, Mass.; product information at http://www.edgetech.com/productlinemarine.html) Geo-Star FSSB system and an SB-512i tow vehicle (0.5–12 kHz) (fig. 7). During July 2006, 1,895 km of CHIRP seismic-reflection data were collected off the northern part of the island chain by using Triton SB-Logger acquisition software (Triton Imaging, Inc., Watsonville, Calif.; product information at http://www.tritonimaginginc.com/site/content/products/sblogger/) to control the Geo-Star topside unit and digitally log trace data in the SEG Y rev 1 standard format (Norris and Faichney, 2002). Data were acquired by using a 0.25 s shot rate, a 20 ms pulse length, and a 0.7–12 kHz swept frequency. During June 2007, slightly less data (1,655 km) were collected off the southern part of the island chain because of system malfunctions caused by rough sea state. EdgeTech J-Star acquisition software was used to control the Geo-Star topside unit and digitally log trace data in the EdgeTech JSF file format. Data were acquired by using a 0.25 s shot rate, a 5 ms pulse length, and a 0.5–8 kHz swept frequency.

Nearshore, the *R/V Gilbert* was used to acquire subbottom data. In total, 900 km of high-resolution CHIRP seismic-reflection profiles were collected from the *R/V Gilbert* in 2006 and 2007. An EdgeTech X-Star system was used with an SB-424 towfish (4–24 kHz) in July 2006 and an SB-512i towfish (0.5–12 kHz) in June 2007. Both systems used a shot rate of 4 Hz (250 ms). During both cruises, Triton SB-Logger acquisition software was used to control the topside unit and digitally log trace data in the SEG Y rev 1 standard format (Norris and Faichney, 2002), and a CodaOctopus F190 motion sensor (Coda Octopus Products Limited, U.K., product information at http://www.codaoctopus.com/company/privacy.asp) was used to record the heave, pitch, and roll of the vessel.

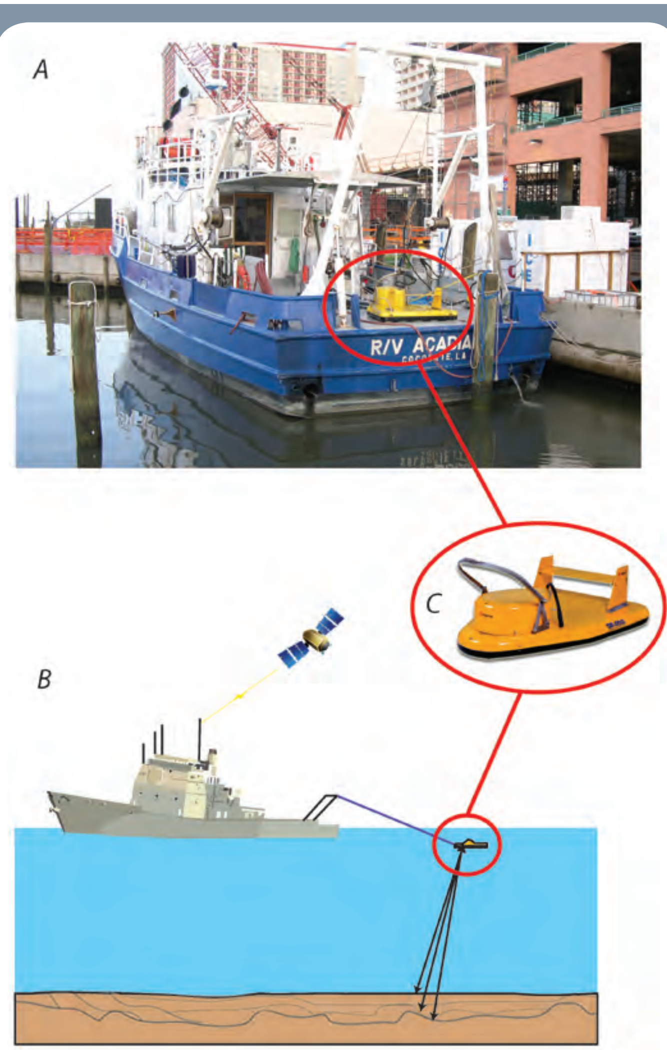


**Figure 7.** Equipment used to collect the high-resolution CHIRP seismic-reflection profiles for this study. *A*, CHIRP subbottom profiler on the after deck of the *R/V Acadiana*. *B*, Schematic showing deployment of the tow vehichle astern of the vessel. *C*, An EdgeTech product detail photograph of the SB-512i tow vehicle.

## Seismic-Reflection Data Processing and Interpretation

Postacquisition processing of the CHIRP seismic-reflection data was conducted by using a suite of software including SIOSEIS (SIOSEIS, 2007), Seismic Unix (Stockwell and Cohen, 2007), and SeisWorks 2D v. R2003.12.0 (a two-dimensional, digital seismic interpretation software package; Halliburton Energy Services, Inc., Houston, Tex.; product information at http://www.halliburton.com/ps/default.aspx?pageid=875&navid=220&prodid=PRN::11026259745705). A SIOSEIS script was used to vertically shift traces to account for towfish depth beneath the sea surface. A second SIOSEIS script was used to predict the vertical location of the sea floor by identifying peak amplitudes within a vertical window. Two-way travel times (in milliseconds) to the sea floor at each trace were recorded to an American Standard Code for Information Interchange (ASCII) text file. Next, all SEG Y trace data were imported into SeisWorks 2D, and sea floor values were imported as SeisWorks horizon data. Spurious sea floor values were edited for discrete traces through manual digitization of the SeisWorks horizon, and corrected values were exported to a new ASCII text file. SIOSEIS was also utilized to remove sea surface heave and mute water column portions of the traces by (1) loading the corrected sea floor times into the SEG Y trace headers; (2) smoothing the sea floor picks by using an along-track filter that approximates twice the period of sea surface heave to be removed; (3) creating a series of difference values between the raw and smoothed sea floor picks for each trace; (4) shifting traces up or down according to the difference values; and (5) muting each trace between time zero and the time of the smoothed sea floor pick, thus removing acoustic noise within the water column. Changes to the traces within each profile were saved to new "heave-corrected" SEG Y files and were used to interpret and map the different seismic facies. A full description of the processing steps and Joint Photographic Experts Group (JPEG) images of all of the seismic profiles collected from the *R/V Acadiana* are given in Baldwin and others (2008) and are included in appendix 5.

The geologic interpretation and resource distribution mapping of the CHIRP seismic-reflection data were conducted in SeisWorks 2D, ArcGIS (Environmental Systems Research Institute, Inc., Redlands, Calif.; product information at http://www.esri.com/), the Generic Mapping Tools (GMT; product information at http://gmt.soest.hawaii.edu/), and MatLab (The MathWorks, Inc., Natick, Mass.; product information at http://www.mathworks.com/). Horizons were digitized in SeisWorks 2D by tracing reflectors on heave-corrected seismic profiles for three primary facies: an acoustically transparent unit interpreted to be the barrier lithosome, an acoustically laminated unit interpreted to be delta-front and prodelta deposits, and a unit with steeply dipping reflections that was interpreted to be distributary channels. A surficial geologic map was created by digitizing the surficial exposure of the three facies on the seismic profiles (fig. 8). The digitized line segments for each of the three facies on all of the seismic profiles were converted to an ASCII text file (x,y recorded every 20 shots) and then exported from SeisWorks 2D for the generation of ArcGIS shapefiles. In ArcGIS, a polygon was drawn around the line segments to represent, in map view, the extent of each of the three facies (fig. 8*A*).

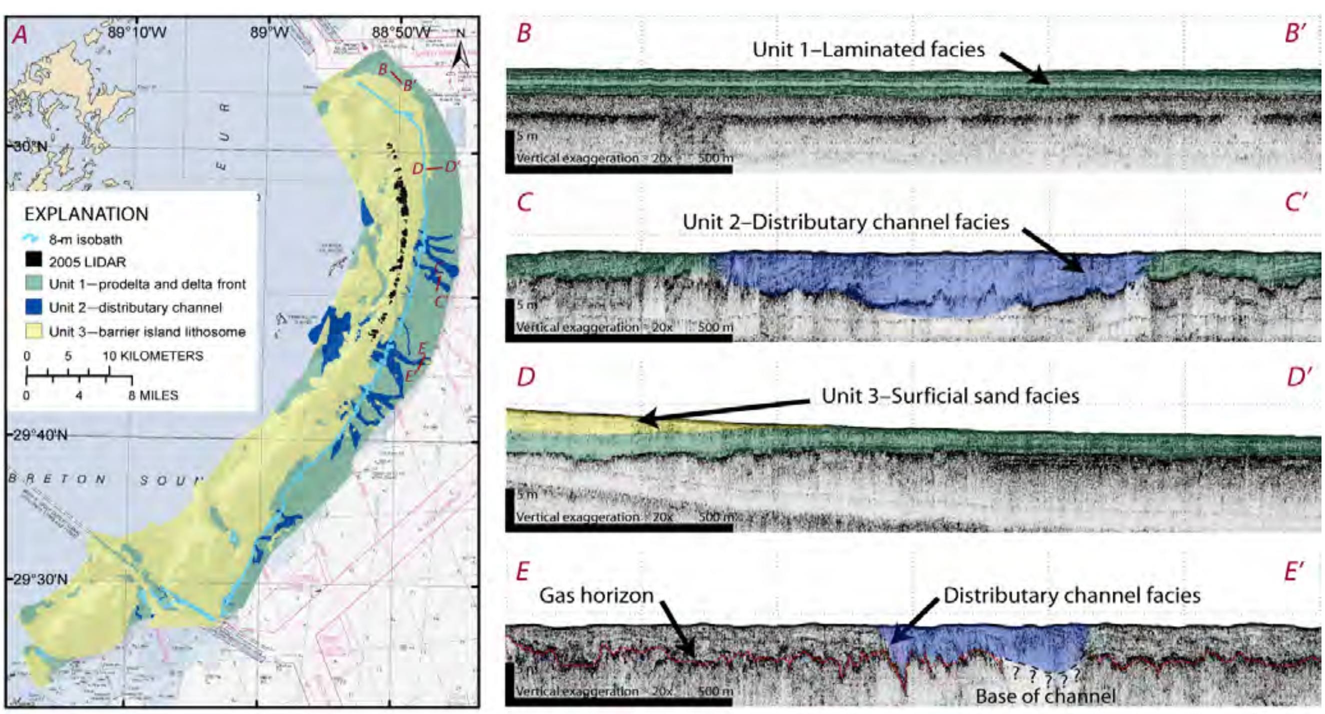


**Figure 8.** Surficial geologic map created by digitizing the surficial exposure of the three facies on the seismic profiles. *A*, The distribution of three different acoustic facies that are exposed on the sea floor surrounding the Chandeleur Islands, La. *B*, Example of the acoustically laminated prodelta and delta-front facies. *C*, Example of the acoustically transparent surficial sand facies. *D*, Example of the distributary channel facies with its steeply dipping reflections. *E*, Example of the irregular high-amplitude reflection that is interpreted to be gas in the sediment that blanks the acoustic signal.

Horizons digitized in SeisWorks were exported as x,y,z files (where z is the depth in milliseconds to the base of a sediment unit). These x,y,z files were then used to generate ArcGIS shapefiles or grids (100- to 200-m resolution). Two-way travel times (in milliseconds) measured from the seismic profiles were converted to depths (in meters) by assuming a constant sound velocity of 1,500 m/s through seawater and sediment (Chen and Millero, 1977). Total sediment volumes were calculated from sediment thickness grids in MatLab.

One challenge encountered in the seismic interpretation was the presence of gas in the shallow subsurface. Gas horizons are known to saturate the seismic signal and obscure underlying strata (fig. 8*E*). A discontinuous gas layer, generally occurring at depths greater than 3 m below the sea floor, was present throughout much of the study area. Distributary channel deposits commonly appeared to extend below this gas horizon, but the bases of the deposits were commonly obscured. Core logs were also inconclusive in identifying the base of distributary deposits. To address this gas-induced uncertainty, we chose to map the volume of these deposits in two ways. First, a distributary channel volume was estimated by creating a surface of the "base of channel" horizon, which was digitized along the base of channel deposits, where they were readily identifiable, and along the top of the gas layer, where the channel base was obscured (fig. 8*E*). Second, a minimum volume of distributary channel sediment, which assumed a constant sediment thickness of 2 m within distributary channel extents, was also reported (table 1).

## Vibracore Collection and Analysis

Once potential sand deposits were identified on the high-resolution seismic data, sediment cores were collected to confirm the nature of the deposits identified on the seismic data and provide samples for textural analysis (fig. 2). An effective means of quickly collecting sediment samples in shallow sandy environments is vibracoring, which utilizes a vibrating head to push a core barrel into the sediment. This technique preserves the sedimentary structures necessary for accurate interpretation of depositional environments and verification of sand resources. A complete description of the vibracoring systems used to collect sediment samples for this study is given in chapter F. Correlation between seismic-reflection profile interpretations and sediment core results allows sand resources to be mapped between and beyond individual core sites.

A total of 124 cores were collected during June 2007: 91 from the *R/V Gilbert* and 33 from the University of New Orleans (UNO) vessel *R/V Greenhead*. An additional 20 cores from a regional coring study conducted in 1987 (Brooks and others, 1995) that overlapped with our study area were used in this analysis. The vibracoring systems used in 2007 were capable of handling aluminum barrels with a diameter of 7.6 cm and lengths of up to 6.1 m. Upon recovery, the cores were cut into 2-m lengths. Core locations were logged by DGPS, and water depth was measured by echo sounder.

Personnel from the UNO Pontchartrain Institute for Environmental Sciences Coastal Research Laboratory analyzed the vibracores. The procedure began with splitting each vibracore in half lengthwise. One half was then visually described by using standard sediment logging methods, and the other half was sampled for textural analysis. Samples were taken from the different sedimentary units identified in each core and from the tops and bases of sand-rich intervals to allow for more effective textural classification. Between 4 and 11 texture samples were analyzed for sediment grain size from each core (average of 7 analyses per core). Each vibracore log includes a description of sediment texture, sedimentary structures, qualitative measure of sand percentage, physical characteristics, stratification type, sample location, and sample type. Analysis of the core data is presented in chapter F. Core description sheets were scanned and saved as Adobe Portable Document Format (PDF) files for digital access and are included in appendix 6. Original hardcopy description sheets are archived at the UNO Department of Earth and Environmental Sciences, and the split core sections were wrapped in plastic and stored at the UNO core storage warehouse.

## Fusion of Seismic-Reflection and Vibracore Data

The dense network of seismic-reflection data was ideal for generation of sediment thickness maps (isopach maps) in the backbarrier and seaward side of the Chandeleur Islands; however, few profiles were collected in and around the islands in areas that were too narrow and shallow (water depths less than 2.5 m) to safely navigate the survey vessels while towing geophysical equipment (fig. 2). To create continuous grids and maps covering the seaward to backbarrier extent of the study area, core log data were used to supplement the seismic data. In some locations cores provide only a minimum sediment thickness because the maximum retrievable vibracore (6 m in length) was shorter than the thickness of the sedimentary unit being mapped. Elevations at the base of the barrier island lithosome and distributary channel deposits interpreted from the seismic-reflection and core data were merged into two x,y,z files. A GMT gridding routine was used to create two elevation surfaces that passed through all point data in each file. Quality control consisted of identifying and removing spurious points that produced "bull's-eye" anomalies in the surface grids. The workflow for generating isopach maps (see fig. 9) was as follows:

6. Digitize "base of facies" horizon in SeisWorks 2D.

**Table 1.** Statistical summary of the twelve sand source bodies in the Chandeleur Islands, La., study area.

[Names of deposits that are sand rich and are potential sand resource sites are presented in boldface. The number corresponds to the sand body location in fig. 15. Sand bodies are also shown in figs. 11 and 14. km, kilometers; MSL, mean sea level; m, meters]

| Sand source body | Surface area ($km^2$) | Average depth below MSL (m) | Volume in millions of cubic meters, assuming 2-m thickness ($10^6 m^3$) | Volume in millions of cubic meters, based on cores and seismic data ($10^6 m^3$) | Volume in millions of cubic meters per unit area of the five barrier lithosome areas ($10^6 m^3/km^2$) | Average depth below barrier lithosome (m) | Percent of total area exposed beyond barrier lithosome |
|---|---|---|---|---|---|---|---|
| **Hewes Point (1)** | 118 | 7.0 | 236 | 379 | 3.2 | N/A | N/A |
| Chandeleur Islands | 188 | 3.3 | | 284 | 1.5 | N/A | N/A |
| Curlew Islands | 129 | 4.5 | | 220 | 1.7 | N/A | N/A |
| Grand Gosier Island | 135 | 5.7 | | 212 | 1.6 | N/A | N/A |
| Breton Island | 107 | 4.4 | | 224 | 2.1 | N/A | N/A |
| **North Islands distributary (2)** | 15 | 9.9 | 30 | 78 | | ≈0 | 98 |
| **Freemason Island distributary (3)** | 17 | 8.8 | 34 | 98 | | 0.1 | 93 |
| **Monkey Bayou distributary (4)** | 22 | 8.1 | 44 | 55 | | 0.3 | 67 |
| **Curlew Islands distributary (5)** | 10 | 8.3 | 20 | 51 | | 0.5 | 65 |
| **Southern offshore sand sheet (6)** | 36 | 6.0 | 71 | 75 | | N/A | N/A |
| Grand Gosier Island distributary | 4 | 5.9 | 8 | 15 | | 1.2 | 7 |
| Mississippi River-Gulf Outlet distributary | 6 | 6.8 | 12 | 25 | | 1 | 32 |
| Sum | 751† | | 455 | 1,641† | | | |
| Mean | | -6.6 | | | 2.0 | 0.5 | |

† The majority (more than 50 percent) of the southern offshore sand sheet is included in the Grand Gosier Island subregion; therefore, the sum volume (1,641 × $10^6 m^3$) and sum surface area (751 $km^2$) do not include the southern offshore sand sheet.

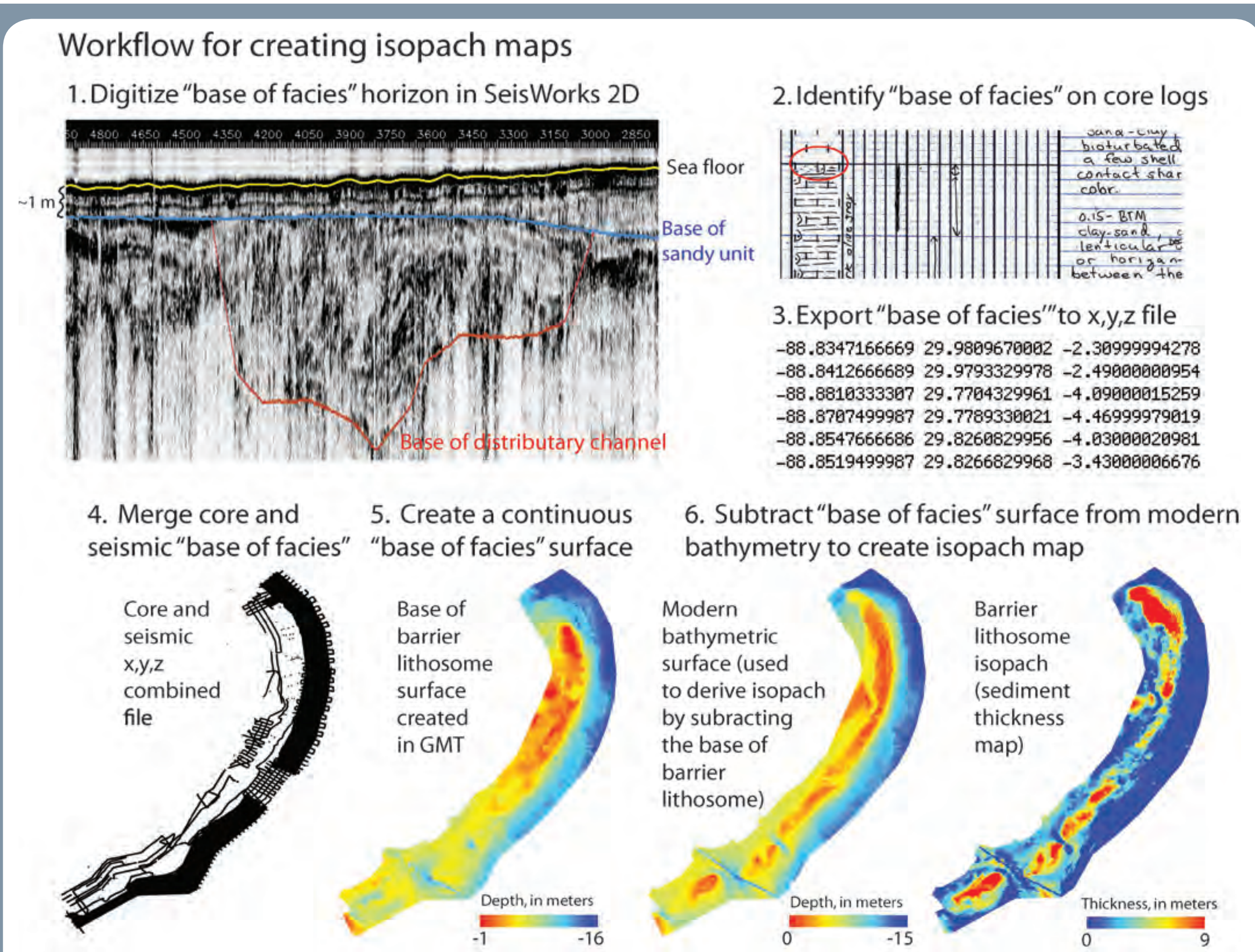


**Figure 9.** Data processing flow diagram showing the steps from interpreting a seismic profile to creating an isopach map. GMT, Generic Mapping Tools.

7. Identify "base of facies" on descriptive core logs.
8. Export horizon to x,y,z point file.
9. Merge core and seismic "base of facies" files.
10. Create a continuous "base of facies" surface by using GMT.
11. Subtract "base of facies" surface from modern bathymetry surface to create isopach (sediment thickness) map.

It is important to stress that these estimates, which are based on seismic profiles and core descriptions, are of the total sediment volume, not solely the volume of sand-sized sediment. Chapter F reports more precise estimates of sand-sized sediment availability that incorporate results from the sediment sample grain-size analyses.

## Results

We focused primarily on the barrier island lithosome and the distributary channel deposits offshore of the islands as potential sand sources because these were the two sedimentary facies with the highest sand content. Sand resource sites shoreward of the islands were not assessed as this area is the platform that the islands would retreat over if they were to migrate shoreward.

## Shallow Stratigraphy

Seismic-reflection profiles and vibracore data show the stratigraphy of the uppermost part of the St. Bernard Delta Complex and the overlying barrier island lithosome. Three acoustic facies were identified on the seismic profiles: Unit 1, nearly flat-lying moderate-to-high-amplitude continuous closely spaced reflections (fig. 8*B*); Unit 2, steeply dipping reflections commonly filling channel-shaped features (fig. 8*C*); and Unit 3, an acoustically transparent interval that, locally, contains short discontinuous reflections (fig. 8*D*). Unit 1 is exposed on the sea floor at the northern end and along the eastern side of the study area. The shoreward limit of the exposure of Unit 1 is in 4- to 5-m water depth in the central part of the study area and exceeds 12 m at the northern and southern limits of the study (fig. 8*A*). Unit 2 is incised into Unit 1 and is younger. Unit 3 is the youngest of the three units and overlies parts of the two older units.

Core data show that the three acoustic facies coincide with distinctive lithologic facies. Core sections that intersected Unit 1 recovered two facies: clay with scattered thin silt laminations and silty clay with thin sand laminations. The clay facies is consistent with prodelta deposits described by Fisk and others (1954) and Frazier (1967). Cores show that it crops out in deeper water at the northern end and along the eastern edge of the study area. The silty clay sections that contain thin sand beds are consistent with delta-front deposits (fig. 4) and are exposed on the sea floor offshore of the Chandeleur Islands in water depths of 5–12 m. These sedimentary facies could not be differentiated seismically and, for this reason, have been combined into one unit. Unit 2 displays channellike shapes in seismic profiles (fig. 8*C*) and a bifurcating nature in map view (fig. 8*A*). These morphological properties, and the higher sand content relative to delta-front and prodelta units (chap. F), indicate that Unit 2 represents distributary channel deposits. Unit 3 consists of sand and silty sand. This unit overlies the deltaic facies and is interpreted to be the barrier island lithosome (fig. 8*D*). Some of the discontinuous reflections seen in this unit are channel shaped. These shallow channels rarely can be traced from one seismic line to the next, and their discontinuous nature suggests that they are filled tidal inlet channels.

## Barrier Island Lithosome

The thickness, distribution, and volume of the barrier island lithosome (Unit 3) have been mapped throughout the study area. This sediment body extends from the northern tip of Hewes Point to the southern end of the platform beneath Breton Island (fig. 10). The total volume of the barrier island lithosome is approximately 1,600 × $10^6$ $m^3$. It has been divided into five sections to provide a clearer understanding of sediment distribution within the study area. From north to south, these five sections were named “Hewes Point,” “Chandeleur Islands,” “Curlew Islands,” “Grand Gosier Island,” and “Breton Island” (fig. 11). The surface areas of each section and the volume of sediment that each contains are summarized in table 1. The Hewes Point section contains the largest volume of sediment (379 × $10^6$ $m^3$), has the largest volume per unit area (3.2 × $10^6$ $m^3/km^2$), and is the thickest part of the barrier island lithosome (maximum thickness of 8.9 m). The profile in figure 12 shows the thickness of the Hewes Point deposit and illustrates how it has prograded northward over delta-front and prodelta deposits. The Chandeleur Islands section covers the largest area and contains the second largest volume of sediment (284 × $10^6$ $m^3$), but it has the smallest volume per unit area (1.5 × $10^6$ $m^3/km^2$). It also is the narrowest section of the barrier island lithosome (1.5–4.2 km wide) and, like the three sections to the south (Curlew Islands, Grand Gosier Island, and Breton Island sections), has a maximum thickness that does not exceed 5.5 m. Large parts of this section are less than 3 m in thickness (fig. 11). The Curlew Islands section is slightly broader than the Chandeleur Islands section (3.7–5.2 km wide), has a similar maximum thickness (5.2 m), and has a larger volume per unit area (1.7 × $10^6$ $m^3/km^2$). The Curlew Islands and Grand Gosier Island sections are separated by an erosional channel that exceeds 9 m in depth. The Grand Gosier Island section is 7–12 km wide, covers the smallest area of the five sections, reaches 5.4 m in thickness, and has the smallest volume of the five sections. The Breton Island section is separated from the Grand Gosier Island section by a broad erosional depression that was dredged to accommodate the Mississippi River-Gulf Outlet (MRGO) channel. This section also reaches a maximum thickness of about 5.5 m, but it is broader than the Chandeleur Islands and Curlew Islands sections (5.2–7.6 km wide) and has the second largest volume per unit area (2.1 × $10^6$ $m^3/km^2$).

In summary, nearly 40 percent of the sediment in the barrier island lithosome is contained in the two end sections (Hewes Point and Breton Island), while the narrower middle sections (Chandeleur Islands and Curlew Islands) have similar volumes but cover much larger areas and consequently have the smallest volumes per unit area (fig. 11). The southern four sections are all fairly uniform in thickness (less than 5.5 m), while the Hewes Point section is considerably thicker (table 1) because it, unlike the other sections, does not sit on the top of the St. Bernard Delta platform. Instead, the Hewes Point section has prograded northward over the edge of the delta platform accumulating on top of delta-front and prodelta deposits in deeper water (figs. 4*E*, 12, and 13). The deeper water provides accommodation space for this narrow north-trending spit. By contrast, the large volume of sediment at the southern end of the lithosome in the Breton Island and Grand Gosier Island sections is deposited in shallow water and thus is thin and has a sheetlike appearance (fig. 13).

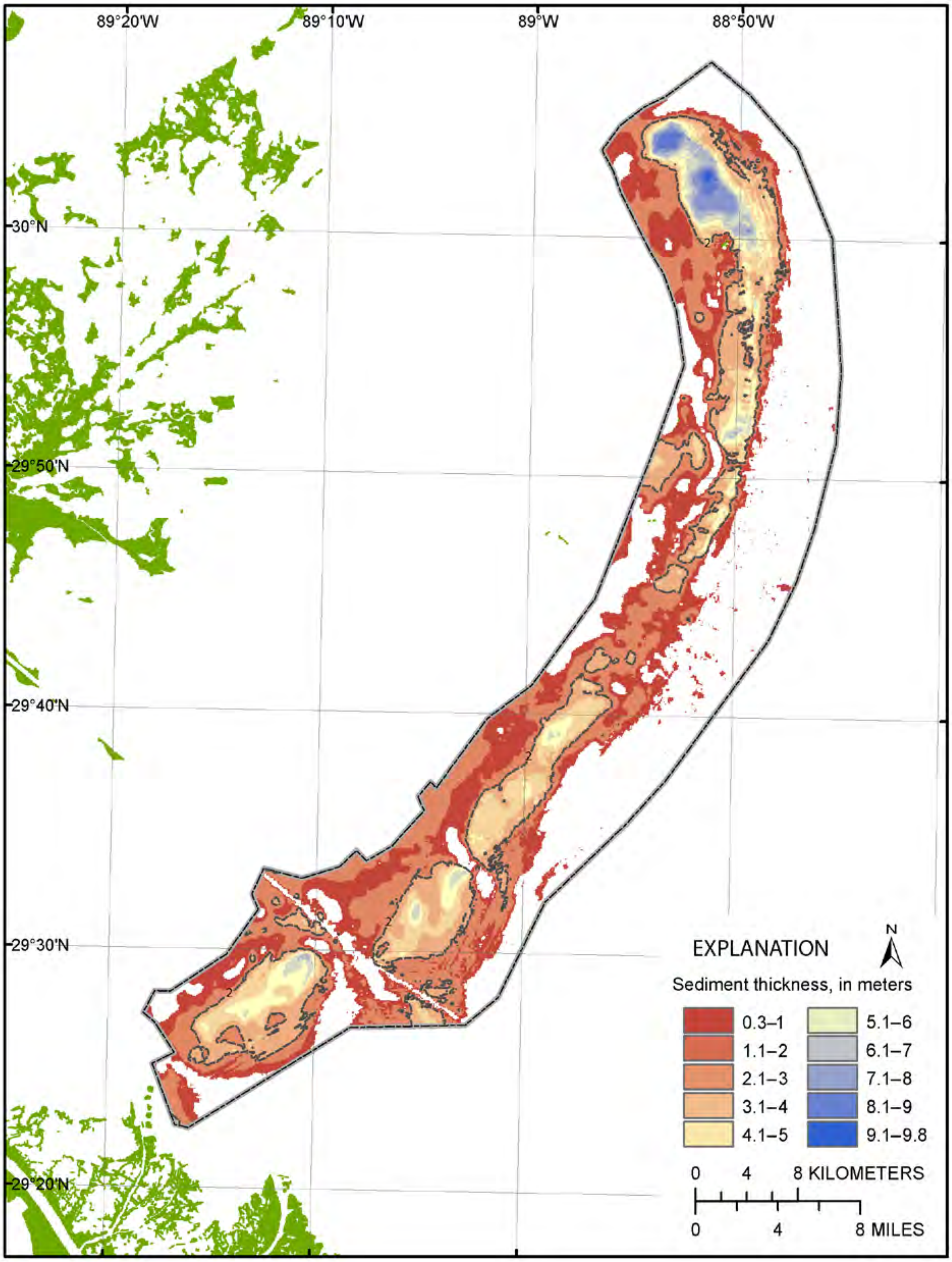


**Figure 10.** Barrier island lithosome isopach map of the Chandeleur Islands, La. The 2002 shoreline, exclusive of the Chandeleur Islands, is shown in the background for reference. The gray outline shows the extent of the study area.

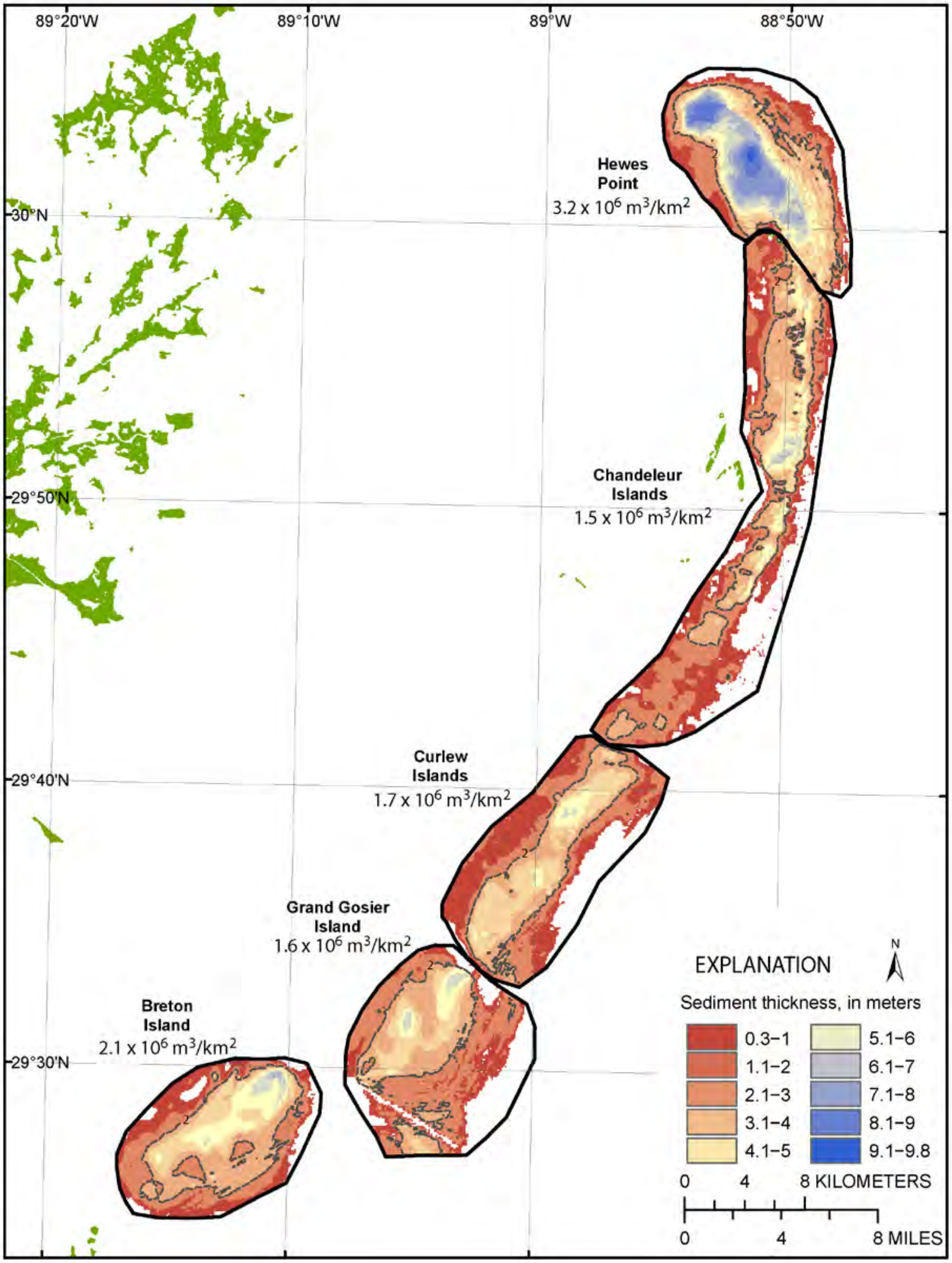


**Figure 11.** Barrier island lithosome isopach map of the Chandeleur Islands, La. (same as fig. 10), with the five subareas outlined. The 2002 shoreline, exclusive of the Chandeleur Islands, is shown in the background for reference. Volume of sediment in each of the barrier island regions is listed in table 1. Volume per unit area is shown adjacent to each subarea. The gray outline shows the extent of the study area.

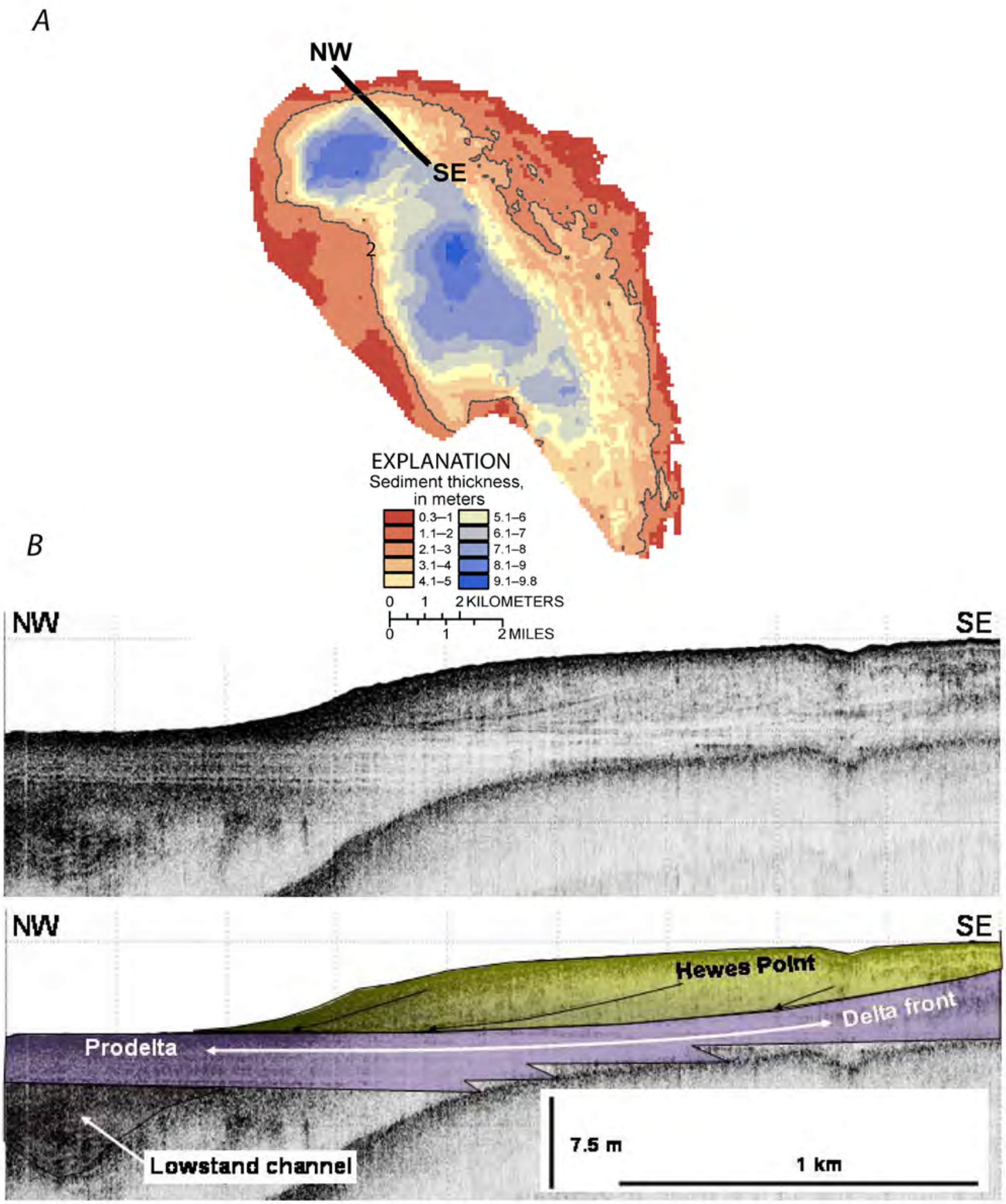


**Figure 12.** Seismic profiles across the Hewes Point section in the study area of the Chandeleur Islands, La. *A*, Isopach map showing the thickness of the Hewes Point deposit and the location of the seismic profile. *B*, Seismic-reflection profile showing progradation over delta-front and prodelta deposits.

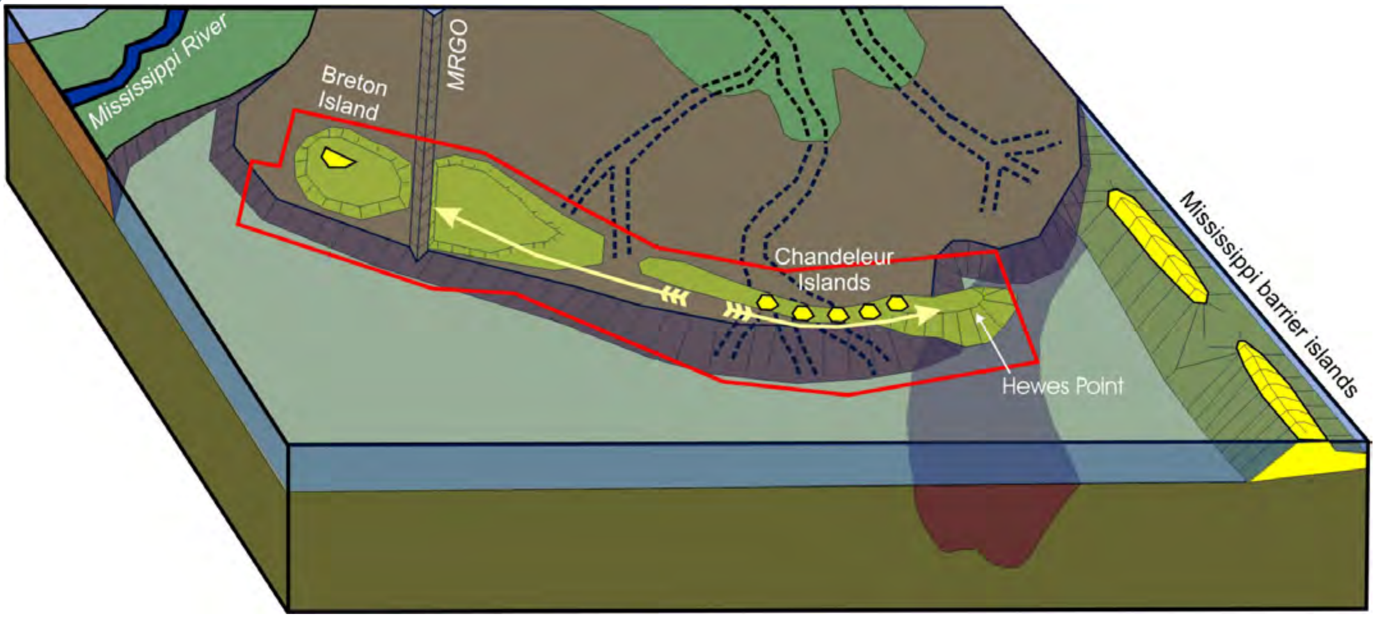


**Figure 13.** Illustrative diagram showing the distribution of sediment in the lithosome of the Chandeleur Islands, La., and the inferred long-term sediment transport pathways (yellow arrows) based on sediment distribution. The deposit at the northern end of the islands' transport path (Hewes Point) has accumulated beyond the edge of the original St. Bernard Delta, where water depths are deeper, and this increased accommodation space allows the deposit to be narrow but thick. The deposit at the southern end of the islands' transport path (around the Mississippi River-Gulf Outlet [MRGO]) is broad and thin because it has accumulated in shallow water on top of the St. Bernard Delta, where the lack of accommodation space resulted in a sheetlike geometry to the deposit.

# Potential Sand Resources off the Chandeleur Islands

The two stratigraphic units identified in the seismic-reflection profiles and cores that have the most potential to be sand resource sites are the northern and southern ends of the barrier island lithosome and the sections of the distributary channels that are exposed on the sea floor seaward of the islands (fig. 14). In total, six deposits have been identified that could contribute sediments suitable for shoreline renourishment. Two of these sites are modern deposits that developed contemporaneously or subsequent to the formation of the islands, and four are the offshore extensions of distributary channels that are associated with development of the St. Bernard Delta Complex.

## Modern Sand Deposits

The two sediment bodies of the barrier island lithosome that could serve as sand resource sites are Hewes Point and the offshore part of the broad, thin sand sheet north of the MRGO in the Grand Gosier Island section of the lithosome (fig. 15). These sites lie at the northern and southern ends of the coastal transport pathways described by Ellis and Stone (2006) and appear to represent sediment that has been removed from the littoral zone and is in a setting that modern oceanographic processes can no longer rework. The total volume of sediment in Hewes Point is $379 \times 10^6$ $m^3$, and approximately $190 \times 10^6$ $m^3$ is available within 2 m of the sea floor. The southern offshore sand sheet near the MRGO is smaller in areal extent and thinner. Much of this deposit is only 2 m thick, and assuming that it has a uniform thickness of 2 m, its total volume is $71 \times 10^6$ $m^3$ (table 1).

## Distributary Channel-Fill Deposits

Distributary channels developed across the St. Bernard Delta Complex during its formation and were filled with sediment once they were abandoned. The material that fills these channels can be quite varied. Coleman (1988) reported that deeper channel fills commonly consist of poorly sorted sands and silts containing organic debris while shallower fills can contain finer grained sandy silts. Seismic-reflection profiles have been used to map the channel extents (fig. 14), but the results of core analyses reported in chapter F provide more detailed descriptions of the lithologies they contain.

We have estimated sediment volumes contained in six distributary channel systems of which four are exposed on the sea floor offshore of the islands and are viewed as potential

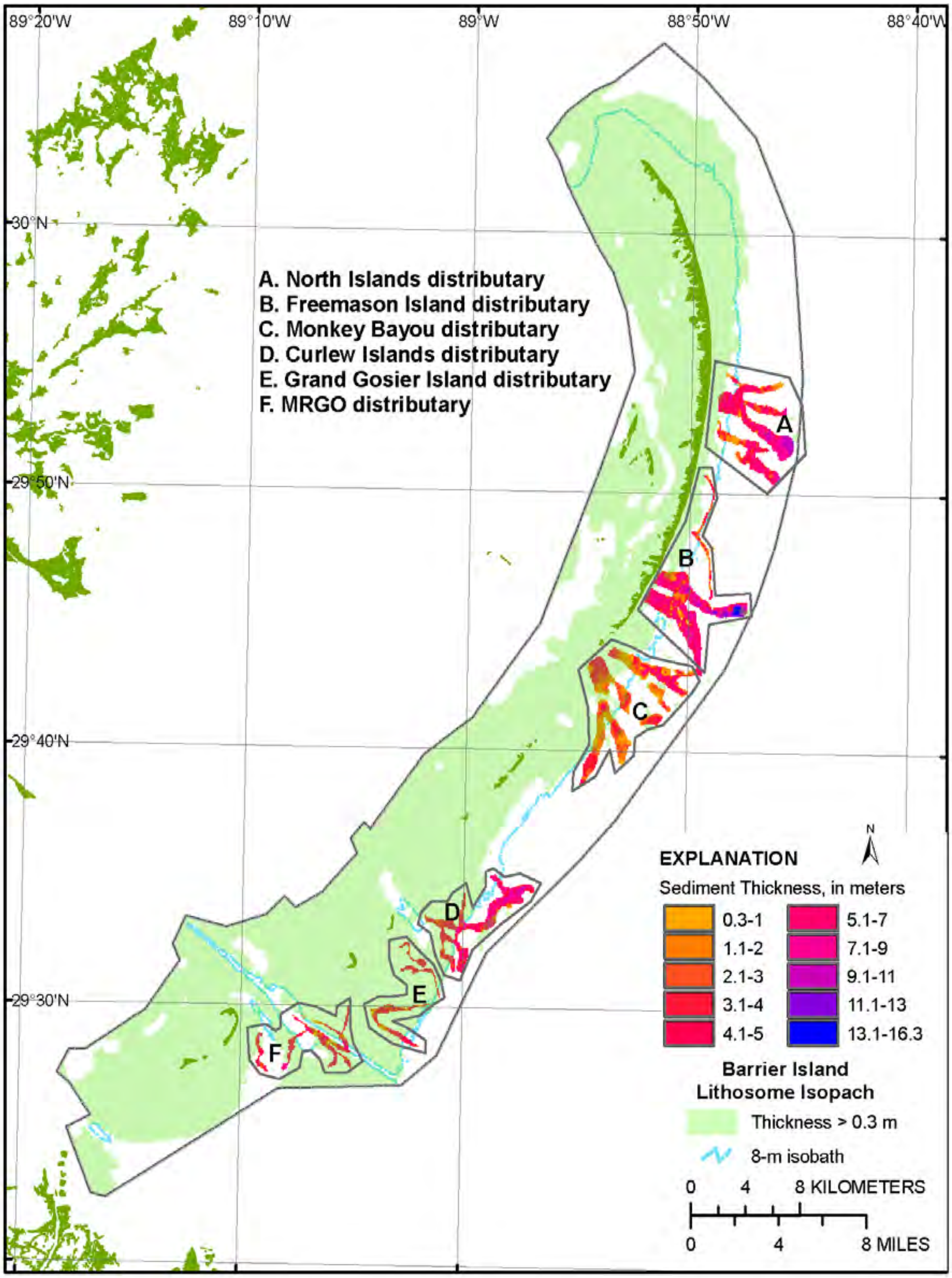


**Figure 14.** Isopach map of the distributary channel deposits within the Chandeleur Islands, La., study area (outlined in gray) and the subaerial extent of the barrier island lithosome (shaded in green). Note that parts of each of the distributary channel regions are buried by the barrier island lithosome. The percentage of the distributary channels exposed beyond the extent of the barrier lithosome is given in table 1. The 2002 shoreline is shown in dark green for reference. MRGO, Mississippi River-Gulf Outlet.

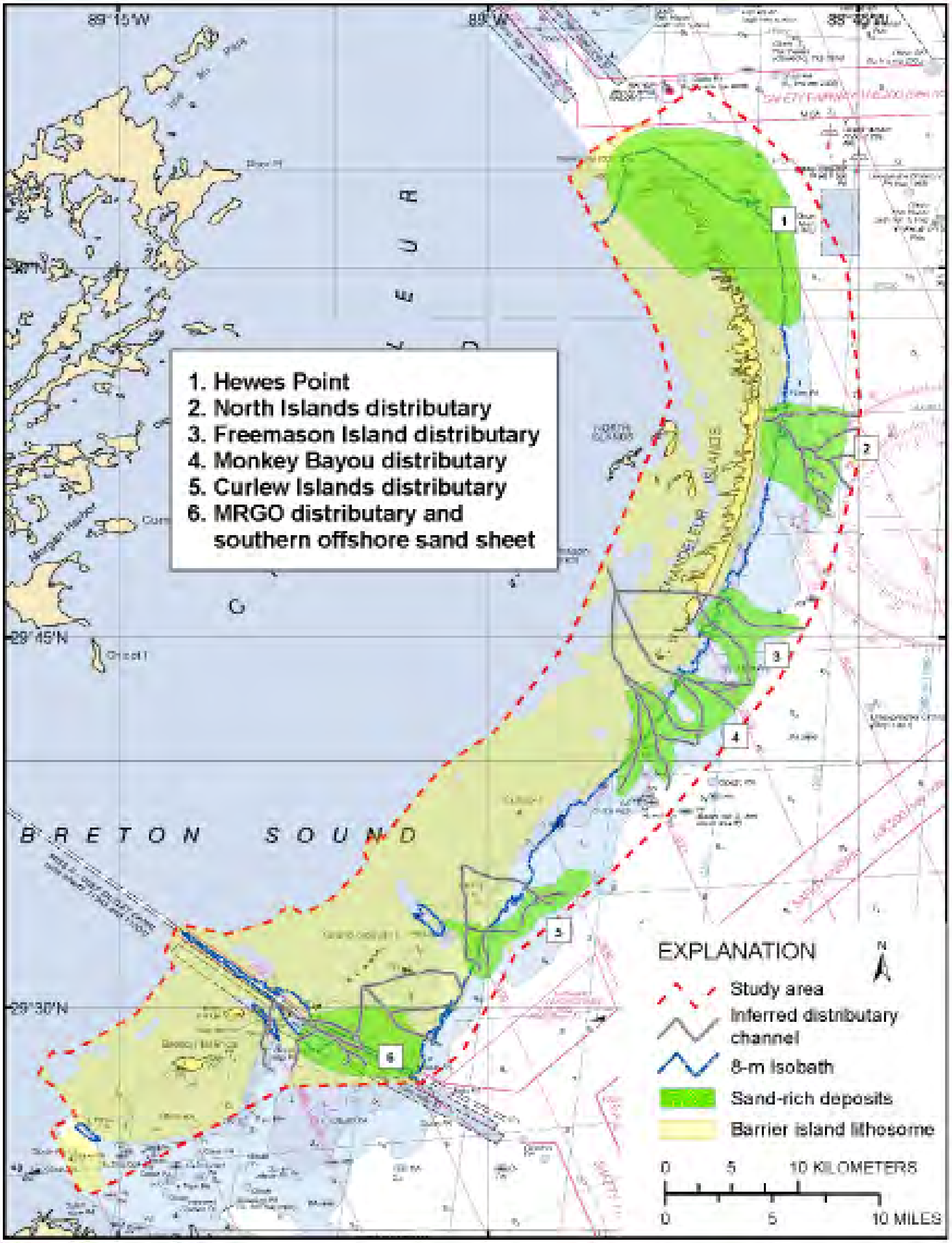


**Figure 15.** Potential sand-rich resource sites. Volumes of sediment in each of these six sites are given in table 1. MRGO, Mississippi River-Gulf Outlet.

resource sites (table 1). The two other distributary channel systems (Grand Gosier Island and MRGO distributaries) are much smaller in volume (table 1) and underlie potential resource site 6 (fig. 15). These two distributary channel systems are buried by what is interpreted to be a sand deposit associated with the barrier island lithosome, and it is the overlying inferred sand sheet that is viewed as the potential resource. For much of the study area, only the uppermost 2–3 m of channel systems could be interpreted with confidence because their deeper fills were often masked by shallow gas (fig. 8*E*). Consequently, sediment volume estimates reported in table 1 are for only the upper 2 m of the channel fills. The volumes range from 15 to 98 × $10^6$ $m^3$. In contrast to the Hewes Point or the southern offshore sand sheet deposits, the extents of distributary channel sites are narrower and less continuous and consequently may be more difficult to mine (figs. 8 and 14).

## Discussion and Recommendations

Analysis and interpretation of the dense network of high-resolution seismic-reflection data and integration with core log analyses have revealed six potential sand resource sites within the Chandeleur Islands study area (fig. 1). All six are surficial sites, but their sizes and geometries vary widely. Estimates of sediment volumes contained in the upper 2 m of each site range from as little as 20 × $10^6$ $m^3$ in the Curlew Islands distributary deposit to as much as 236 × $10^6$ $m^3$ in the Hewes Point deposit (table 1). In addition to variations in size, the geometry of each deposit is variable as well. The Hewes Point and southern offshore sand sheet sites are broad tabular deposits, while the four distributary sites consist of narrow bifurcating channels that are separated by adjacent fine-grained delta-front deposits (fig. 15). The Hewes Point and southern offshore sand sheet deposits account for approximately 70 percent of the total estimated sediment volume contained in the uppermost 2 m of the six sites (table 1). Sediment grain-size analyses show that much of the upper 2 m of the Hewes Point deposit contains more than 90 percent sand (chap. F). Unfortunately, no cores are available for the southern offshore sand sheet site, so its sand content remains unknown. Core logs of the distributary channel deposits show that they generally have a lower and more variable sand content. Sand content in the upper 2 m of seven cores collected from distributary channels averaged 53 percent with samples from each core showing a high degree of variability.

On the basis of its large size, estimated volume, and high sand content, the Hewes Point deposit represents the most promising sand resource site within the immediate vicinity of the Chandeleur Islands. Distributary channel deposits appear to be less desirable targets because they are smaller and more irregular in shape and their fills display variable grain-size distributions. The Hewes Point deposit, however, is part of the barrier island lithosome, and a full understanding of its relation to the regional sediment transport system and budget needs further study prior to committing to mining activities. Published sediment transport studies indicate a zone of divergence near Monkey Bayou at the southern end of the Chandeleur Islands, which is where the barrier island lithosome is narrowest and thinnest (Georgiou and others, 2005; Ellis and Stone, 2006). North of this divergence, net alongshore transport is directed to the north, whereas south of the divergence transport is southerly. Hewes Point extends northward beyond the northernmost extent of the Chandeleur Islands into deeper water. As such, it appears to be the depositional terminus of the alongshore transport system such that as sediment accumulates at Hewes Point in relatively deep water it may be removed from the littoral zone (fig. 13). Additional research is necessary to provide an understanding of the effects that tidal currents and storm waves from the north have on Hewes Point and whether these processes via an event-driven reversal in the dominant sediment transport direction reintroduce sediment to the littoral zone from Hewes Point. Alongshore transport to the south from the littoral divergence zone near Monkey Bayou may be responsible for the formation of the broad, thin southern offshore sand sheet immediately north of the MRGO (fig. 13). Before using this material for renourishment it will need to be sampled to determine its composition. In addition and similar to the investigation required at Hewes Point, circulation and wave modeling will be needed to determine how this shallow deposit would be redistributed by southeasterly storms.

Because of their proximity to the islands, the low sand content and the narrow and discontinuous nature of many of the distributary channel deposits, and our incomplete understanding of how the Hewes Point sand deposit may respond to dynamic oceanographic processes, it may be necessary to consider alternate sand resource sites. The St. Bernard Shoals area (fig. 1) is considerably farther away and in deeper water and thus is disconnected from the Chandeleur Islands littoral system. Consequently, removal of sediment from these offshore shoals would not affect the littoral system itself (chap. G).

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# Appendix E–1. Geophysical Data from Offshore of the Chandeleur Islands, Eastern Mississippi Delta (See Index Page To Access Data)

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