Sediment Sampling Analysis To Define Quality of Sand Resources

Chapter F 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
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Edited by Dawn Lavoie

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

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Chapter F. Sediment Sampling Analysis To Define Quality of Sand Resources

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

Abstract

The Chandeleur Islands and surrounding waters provide habitat for a variety of threatened wildlife species, a platform for human infrastructure and recreation, and protection of interior environments and populations by reducing storm impact. A diminishing budget of sandy sediment needed to maintain the islands is continually scavenged by storms, reworked by prevailing wave climate, and inundated by a relative sea level rise, resulting in a net loss of island area. Researchers over the past two decades have documented an increasing inability of the island chain to recover from storm-induced breaching and dune erosion through the natural redistribution of sediment. In 2005, Hurricane Katrina overtopped the islands with up to 10 m of storm surge and caused catastrophic erosion of the shoreface and protective dune system. The event prompted a collaborative effort between State and Federal agencies to characterize the geologic framework of the Chandeleur Islands, which is composed of a sandy barrier island platform resting unconformably on the late Holocene St. Bernard Delta lobe of the Mississippi River. This geologic information provides insight into the storm response, evolutionary history, and fate of the barrier system. This chapter reports the results of sedimentologic investigations around the islands, which include the interpretation and analysis of a series of sediment vibracores collected in 2007 to ground-truth the geophysical surveys conducted the previous year (chap. E). The study characterizes several distinct depositional components that compose the barrier island platform and underlying deltaic stratigraphy. These deposits include sandy marine-transgressive deposits (barrier island, spits, overwash sheets, and inlet channel deltas) overlying mixed sand-mud facies of the older deltaic deposits (distributary and interdistributary, delta front and prodelta). The transition between adjacent units is typically subtle, and analysis of physical (for example, grain size) and textural (for example, bedding) characteristics is necessary to identify the environment of deposition. In the event that shoreline renourishment becomes a viable option for island management, the results of this study will provide the physical information necessary to identify the location and quality of suitable sand resources around the islands.

Introduction

The Chandeleur Islands, La., were formed through the erosion and reworking of the deltaic headland of the abandoned St. Bernard Delta Complex, a distributary of the Mississippi River (Suter and others, 1988; Brooks and others, 1995). During the past 4,000 years, distributaries of the Mississippi River discharged into the eastern Louisiana continental shelf, depositing sediments as a series of delta sublobes (fig. 1). The constructional phase of each lobe was rapid, about 1,000 years (Frazier, 1967; Roberts, 1997), and consisted of components found in prodelta, delta-front, and distributary environments (Coleman, 1982). (A plan diagram of these components is shown in fig. 5 of chap. E.) The textural composition of these deposits is a function of fluvial energy and proximity to the distributary mouth. The distributaries deposited sand-size sediments directly at the river mouth (mouth bar and delta front), whereas fine-grained materials were carried in suspension farther away from the distributaries, where they settled into extensive blankets of mud across the sea floor (prodelta).

Decrease in fluvial gradient and accommodation space of the receiving basin resulted in the distributary abandoning the delta complex for a more favorable gradient. The delta entered an abandonment phase, in which fluvial sediments were no longer supplied to the system. The delta deposits began to dewater, compact, and subside (Frazier, 1967; Coleman, 1982; Penland and others, 1988), leading to a regional relative sea level rise. Waves and currents reworked the delta deposits and winnowed out the fine-grained material. The coarser material was concentrated into shoals, which continued to develop through littoral processes into barrier island systems. During

[1]U.S. Geological Survey, St. Petersburg, Fla.

[2]U.S. Geological Survey, Woods Hole, Mass.

this time estuarine environments in the area developed fine-grained interdistributary and backbarrier deposits. As sea level continued to rise, less source sediment was available to the barrier system, which began to deteriorate as sand was continually removed from the system by littoral processes and storm impact.

Deltaic and marine-transgressive shelf deposits produce distinctive physical properties that can be identified through acoustic (seismic) profiling and direct sampling (table 1). Brooks and others (1995) identified fluvial-marine deposits across the eastern Louisiana shelf (fig. 2) and provided a regional-scale description of the stratigraphy around the Chandeleur Islands. To supplement this information, in 2006 and 2007 the U.S. Geological Survey and collaborators at the University of New Orleans collected high-resolution seismic profiles and sea floor measurements around the islands. The seismic surveys (see chap. E) were followed by the collection of 124 vibracores to ground-truth the acoustic data (fig. 3). Interpretation of geophysical and sediment core data showed that the stratigraphy consists primarily of a thick sequence of prodelta and delta-front sandy silts, incised by sand, and silt-filled distributary channels. These deposits are overlain by the sandy modern barrier island platform. The relative positions, spatial extent, and elevations of these deposits determine the origin, history, and fate of the barrier island system. Chapter E provides a description of the seismic character of the deposits; this chapter provides a description of their physical characteristics.

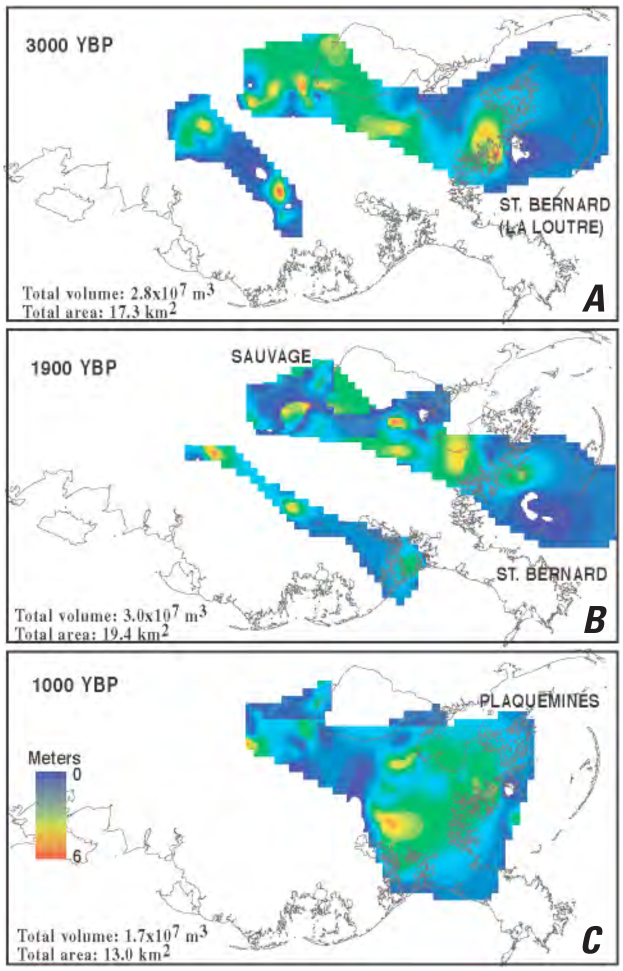

Figure 1. Isopachs of subdelta lobe progradations occurring along the eastern Louisiana coast during three time periods. *A*, Progradations 3,000 years before present (YBP). *B*, Progradations 1,900 YBP. *C*, Progradations 1,000 YBP. Thickness of deposit is shown by color scale. The modern shoreline is overlaid onto the subdelta lobes for reference. Two subdelta progradations of the St. Bernard complex set the stage for development of the Chandeleur Islands. Modified from Frazier (1967) and Flocks (2006).

Methods

Vibracore Acquisition

Following the seismic survey of the Chandeleur Islands, a sediment-coring strategy was developed to ground-truth the interpretations from the seismic profiles and to directly sample stratigraphic variation. Vibracores were obtained from onboard the 15-m-long *R/V Gilbert* by using a hydraulic crane to position and recover the vibracore rig. The rig is capable of handling aluminum barrels up to 6 m long with a diameter of 7.6 cm (fig. 4). The barrels were vibrated into the sediment by using a Rossfelder model P-3 electric motor in a waterproof housing driving offsetting concentric weights. Brass core catchers were riveted to the base of each barrel to inhibit loss of sediment during recovery, along with a check valve at the top to create a vacuum on the sediment. A linear transducer and wire line were attached to the top of the rig to measure penetration of the barrel into the sea floor. Upon recovery, the barrel was removed from the rig and cut to the length of core penetration. The ends of the core sample were capped, and the barrel was labeled with a unique identifier. Core length was measured and compared to the linear transducer reading to estimate compaction. Collected cores were transported to the core analysis laboratory at the University of New Orleans (UNO) for curation and description. Each core was visually described by using standard sediment logging methods, photographed in 1-m intervals, wrapped in plastic sleeves, and archived at the UNO Department of Earth and Environmental Sciences. To fit the page, the core photograph mosaics shown in this report are vertically compressed, which causes some features to appear distorted. Each core log includes a

Table 1. Description of delta-related facies identified in this report for the Chandeleur Islands, La., study area.

[Layout of facies shows depth and age relation between deposits, with Units F and ETD being surficial and youngest]

Facies	Depositional environment	Physical characteristics	Seismic characteristics
Barrier platform	Marine	Massive, medium to fine sand, some shell lag	Distinct basal reflector, seaward-dipping reflections
Ravinement	Marine	Erosional, shell lags and sands	Distinct seaward-dipping reflection throughout study area
Interdistributary bay	Estuarine/ fluvial	Laminated to bioturbated silts with abundant organic material	Low-angle, parallel reflections with acoustically transparent "fill"
Distributary channel	Fluvial	Fining-upward sequence of silty sands, grading into laminated sandy silts. Massive bedding, also with wavy or x-bedded laminations	High-angle reflections, distinct dogleg reflections and acoustic noise
Delta front	Fluvial	Laminated silts and lenticular sands	Dipping parallel reflectors with occasional high-angle cross-cutting reflections
Prodelta or marine	Fluvial or marine	Laminated silts and clays, grading upward to sandy silts	Horizontal to low-angle reflections

description of sedimentary texture, which includes observed sand, silt, and clay percentages; sedimentary structures; physical characteristics; stratification type; sample interval; and location. The logs were scanned and saved as Adobe Portable Document Format (PDF) files for digital access (app. F–1). From each core, subsamples were taken at 80-cm intervals for textural analysis. Additional samples were taken from the tops and bottoms of sand-rich intervals greater than approximately 0.6 m thick to allow for more effective textural classification of sandy sedimentary packages.

Grain-Size Analysis

Textural analyses of sediment samples taken from the vibracores were performed at the U.S. Geological Survey Center for Coastal and Watershed Studies in St. Petersburg, Fla., by using a Beckman Coulter LS 200 particle-size analyzer. This instrument utilizes laser diffraction to measure the size distribution of sedimentary particles between 0.375 and 2,000 µm. The utility of the LS 200 is the high reproducibility of measurements, rapid acquisition of results, ability to accurately and quickly provide quantitative measure of extremely small grain-size fractions, and customizable data output.

Sediment samples from selected intervals downcore were disaggregated in a sodium hexametaphosphate solution and resuspended through stirring and sonication for dispersement into the LS 200 module bath. The samples were dispersed by pipette until a desired 8–12 percent solution concentration was obtained. This procedure was repeated three times per sample, and the measurements were averaged to produce a single analysis per sample. If one measurement departed from the other two by one standard deviation, then the measurement was evaluated and removed if necessary. In a few cases samples were reanalyzed to ensure reliable results.

The LS 200 shines a laser on particles suspended in solution. The light is scattered in characteristic patterns based on particle size. These patterns are measured by photodetectors as intensity per unit area and broken down into 92 size-classification channels. The relative amplitude of light intensity for each channel is interpreted as the relative volume of spherical particles of that size. From the bin counts produced by the LS 200, cumulative weight percentages for 5th, 10th, 16th, 25th, 50th, 75th, 84th, 90th and 95th percentiles were calculated. From these measurements, mean grain size and sorting (Inman, 1962) were reported in millimeter and phi intervals. Percentages of sand, silt, and clay were reported for each core interval as tables in this chapter and in appendix F and are included in this report graphically as ternary plots. Statistical moments that correspond to sorting, skewness, and kurtosis were also calculated by following the procedure outlined in Folk (1968).

Data Processing

Vibracore description sheets were converted from paper copies to digital files by following the procedure outlined in

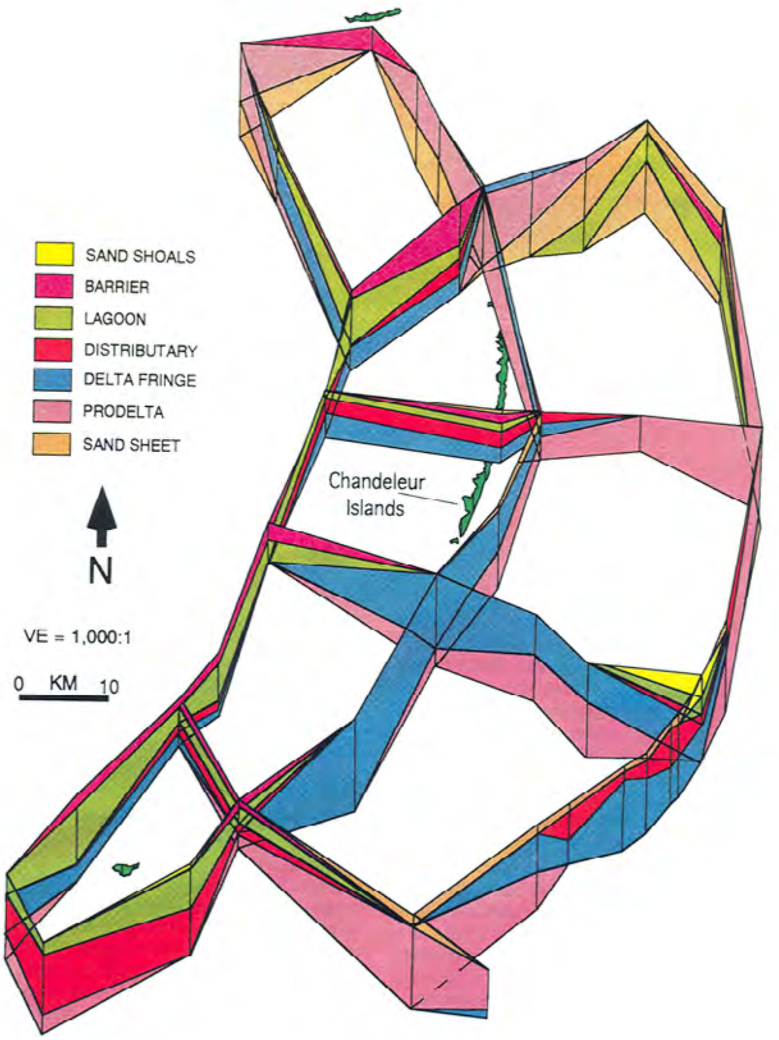

Figure 2. Fence diagram of stratigraphy across the eastern Louisiana shelf. The deposits are associated with the St. Bernard Delta Complex of the Mississippi River. The position of the modern Chandeleur Islands is shown for reference. Modified from Brooks and others (1995).

Flocks (2004). Output of the qualitative descriptions allows for statistical analysis of textural similarities which determine stratigraphic units between cores. These results were used to generate abundance graphs of common textures and bedding. Ternary plots of sand/silt/clay ratios were generated from the LS 200 grain-size data. Contour plots of the grain-size data were generated by using CPS-3 gridding software.

Results

Distinct sedimentary deposits were identified on the basis of integrated analysis and interpretation of the seismic and core data (fig. 5; table 2). The deposits were divided into two groups on the basis of their stratigraphic relation and process of formation. The first group comprises the deeper deposits associated with the development of the St. Bernard Delta (prodelta, delta front, distributary, interdistributary). The second group comprises the units that are overlain by deposits formed during the marine transgression that followed the abandonment of the St. Bernard Delta (tidal inlet, overwash, barrier sand deposits).

Descriptions of the deposits are provided in the following section.

St. Bernard Deposits

Fine-Grained Prodelta, Delta-Front, and Interdistributary Deposits

The stratigraphy below the barrier island chain is primarily composed of prodelta and delta-front muds of the St. Bernard Subdelta Complex (Brooks and others, 1995). Throughout the Mississippi River Delta Plain, prodelta muds exhibit high lateral continuity and low lithologic variation (Coleman, 1982). The distribution of this deposit is shown in figure 8*A* of chapter E, where it is described as laminated mud/clay (Unit 1). Core interpretations and grain-size analyses characterize the deposit as massive and poorly sorted clayey silts (fig. 6) that are gray in color. The base of this unit consists of massive fine silts to laminated clays. This texture represents prodelta deposits, suspension deposits that settle out of the water column some distance away from the distributary mouth. Since the concentration of muds in the water column can be seasonally episodic and of short duration (floods, eddies, storm resuspension, and others), laminations are common but very thin and are difficult to determine without x-ray profiles. Cores collected from the northern portion of the study area penetrated deeper into the unit (table 2, prodelta muds) and contain fine silts and a massive texture. Around the islands, the

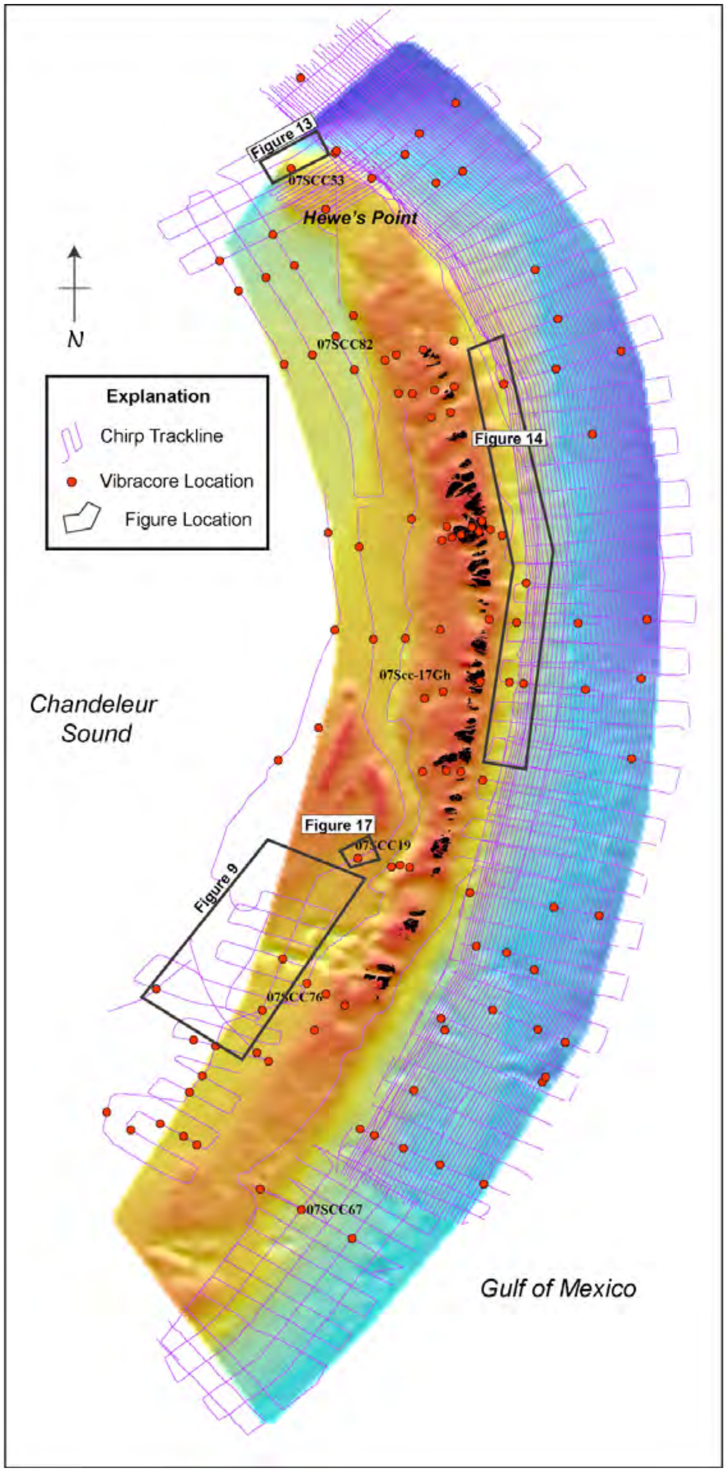

Figure 3. Location of seismic profiles and vibracores collected around the Chandeleur Islands, La., in 2006. Color-shaded relief represents bathymetry from the 2006 survey. Island shoreline positions (black polygons) were identified by using airborne laser altimetry data collected in 2006.

Figure 4. Vibracore rig being deployed from the *R/V Gilbert*. The vibracore consists of an electric motor spinning offset concentric weights, which vibrate an aluminum barrel into the unconsolidated sediment. A hydraulic crane is used to deploy and recover the rig.

prodelta grades vertically into delta-front sediments that were deposited more proximal to the distributary mouth. Delta-front sediments contain small lens-shaped (lenticular) sand laminations (fig. 7) and sometimes thin silt/clay laminations (fig. 8). Lenticular-sand deposits form in sand-starved, low-energy environments. Episodic increases in current velocity, such as wind-driven waves in shallow water, concentrate the little sand that exists into thin laminae within the mud matrix (Coleman, 1982). The bimodal texture results in a high deviation from the mean grain size (poorly sorted), with a larger portion of the distribution in the silt fraction (fine skew) (fig. 6).

Sediment core interpretations of these fine-grained deposits noted very few shells, little organic material, and limited bioturbation. The lack of bioturbation indicates a very high particulate sedimentation rate, typical of prodelta and delta-front deposits (Coleman, 1982). Scattered layers of shells were observed as lag deposits that may indicate increased current velocity, possibly caused by storm events. Bioturbated zones may represent periods of decreased sedimentation.

Off the southern part of the Chandeleur Islands, the deposit is incised by distributary channels (fig. 5). In this area, root traces and organic material are present in the muds that flank the channels, suggesting a transition from delta-front to interdistributary (marsh/lagoon) environments. The transition from upper prodelta to delta-front to interdistributary deposits is virtually indistinguishable, indicating very subtle changes in depositional environments over time. High-resolution pollen analysis, age dating, or x-ray profiles would be necessary to further constrain these environmental boundaries.

Distributary

Deltaic distributaries are the conduits for particulate and bedload transport to the receiving basin. Modern analogs within the Mississippi River Delta include channels that range in size from meters to a kilometer in width and up to 30 m deep (Coleman, 1982). Distributaries in the modern “birdsfoot delta” resemble a reverse dendritic pattern, with smaller channels radiating seaward from a main trunk. In the

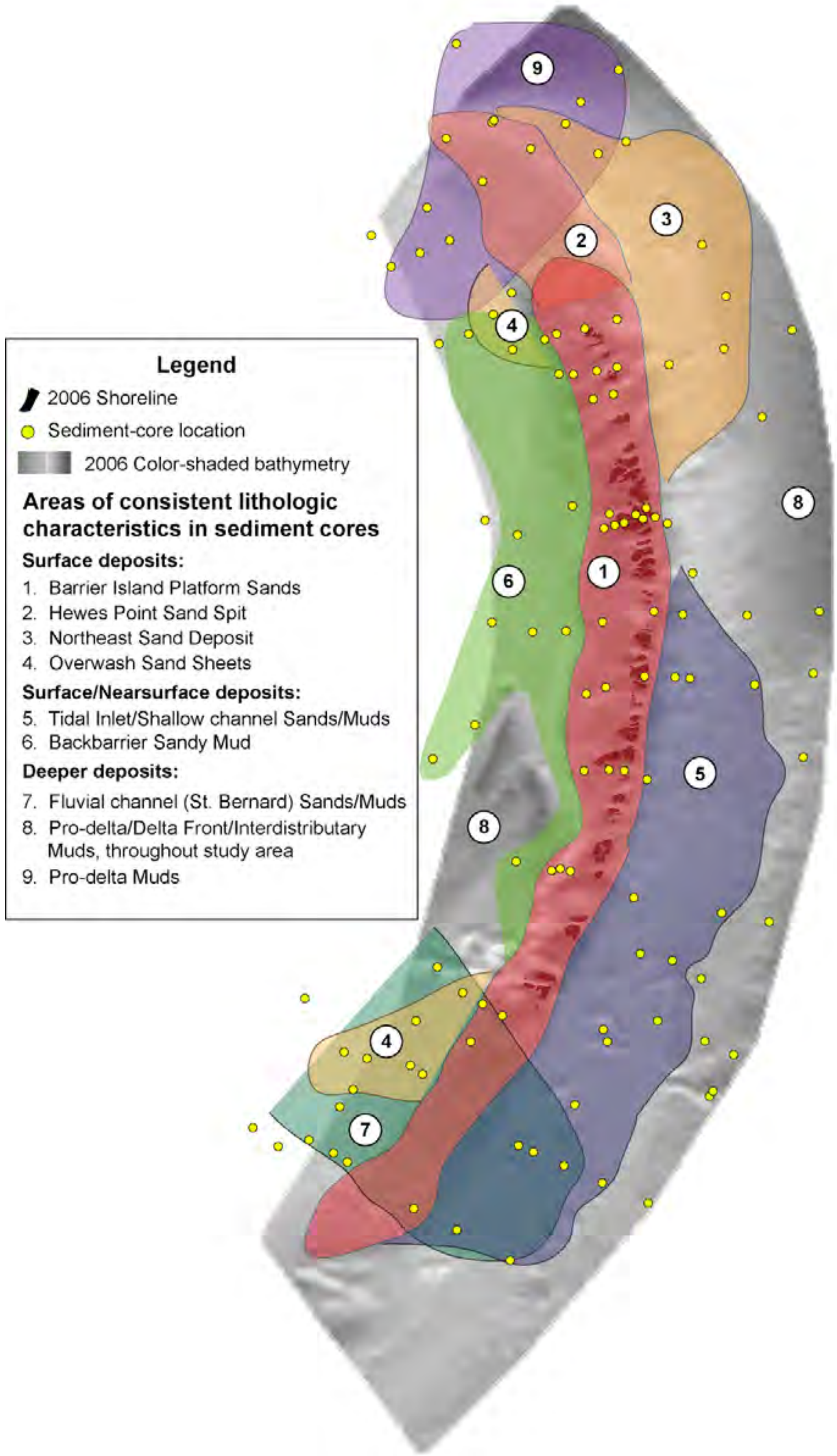

Figure 5. Location of deposits identified in this study in the area of the Chandeleur Islands, La. Spatial extents were interpreted by using seismic profiles (chap. E) and sediment core data. See table 2 for physical descriptions of deposits.

Table 2. Physical descriptions of deposits identified in this study in the area of the Chandeleur Islands, La.

[m, meters; mbsl, meters below sea level; mbsf, meters below sea floor; mm, millimeters; %, percent; Vf, very fine; med., medium; mod., moderately]

Reference	Deposit	No. of samples in average*	Average depth (mbsl)	Average top (mbsf)	Average base (mbsf)	Average thickness (m)**
1	Barrier platform sand	191	-2.12	0.00	3.21	3.16
2	Hewes Point sand pit	27	-6.16	0.00	3.53	3.53
2	Hewes Point base	6	-8.53	2.51	3.68	1.17
3	Northeast sand deposit	25	-9.63	0.00	1.62	1.61
4	Overwash sand sheets	17	-3.66	0.00	0.25	0.25
5	Tidal inlet/nearsurface channel sands	81	-6.23	0.12	1.34	1.22
6	Backbarrier sandy mud	24	-4.43	0.16	1.52	1.36
7	St. Bernard distributary mixed	53	-9.22	2.87	4.10	1.23
8	Interdistributary (rooted zone) muds	41	-6.42	1.57	3.73	2.16
8	Prodelta/delta front/ interdistributary mixed	245	-10.89	1.16	4.11	2.94
9	Prodelta muds	51	-12.20	0.02	4.36	4.35
	Sea floor composite (0–1 m)	236	-5.00	0.00	1.00	1.00
	Chandeleur Islands composite	414	-8.63	0.70	2.70	2.00

Reference	Deposit	Mean grain size phi (mm)	Wentworth size class***	Amount sand (%)	Amount silt (%)	Amount clay (%)
1	Barrier platform sand	3.2 (0.11)	Vf sand	85.2	11.9	2.8
2	Hewes Point sand pit	2.6 (0.15)	Fine sand	97.1	2.1	0.7
2	Hewes Point base	3.1 (0.11)	Vf sand	92.6	5.6	1.8
3	Northeast sand deposit	3.5 (0.01)	Vf sand	84.4	12.6	3.0
4	Overwash sand sheets	3.6 (0.08)	Vf sand	79.1	16.4	4.5
5	Tidal inlet/nearsurface channel sands	3.8 (0.07)	Vf sand	72.1	22.2	5.7
6	Backbarrier sandy mud	4.4 (0.05)	Coarse silt	58.9	32.7	8.5
7	St. Bernard distributary mixed	4.5 (0.04)	Coarse silt	52.8	38.3	8.8
8	Interdistributary (rooted zone) muds	6.4 (0.01)	Fine silt	19.2	53.5	27.3
8	Prodelta/delta front/ interdistributary mixed	6.6 (0.01)	Med.-fine silt	13.7	57.3	29.0
9	Prodelta muds	6.7 (0.01)	Fine silt	12.3	55.2	32.4
	Sea floor composite (0–1 m)	3.8 (0.07)	Vf sand	72.6	20.6	6.8
	Chandeleur Islands composite	5.7 (0.02)	Coarse silt	31.4	47.4	21.2

Table 2. Physical descriptions of deposits identified in this study in the area of the Chandeleur Islands, La.—Continued

[m, meters; mbsl, meters below sea level; mbsf, meters below sea floor; mm, millimeters; %, percent; Vf, very fine; med., medium; mod., moderately]

Reference	Deposit	Sorting (folk) phi	Sorting classification	Skewness (positive)	Skew direction (fine to coarse)	Kurtosis	Peakedness description
1	Barrier platform sand	0.53	mod. well sorted	0.24	fine-skew	1.53	very leptokurtic
2	Hewes Point sand pit	0.26	very well sorted	0.07	symmetrical	1.25	leptokurtic
2	Hewes Point base	0.29	very well sorted	0.21	fine-skew	1.54	very leptokurtic
3	Northeast sand deposit	0.46	well sorted	0.24	fine-skew	1.58	very leptokurtic
4	Overwash sand sheets	0.71	moderately sorted	0.24	fine-skew	1.34	leptokurtic
5	Tidal inlet/nearsurface channel sands	0.65	mod. well sorted	0.25	fine-skew	1.42	leptokurtic
6	Backbarrier sandy mud	0.89	moderately sorted	0.44	strong fine-skew	1.59	very leptokurtic
7	St. Bernard distributary mixed	0.76	moderately sorted	0.29	fine-skew	1.50	leptokurtic
8	Interdistributary (rooted zone) muds	1.19	poorly sorted	0.03	symmetrical	1.10	leptokurtic
8	Prodelta/delta front/ interdistributary mixed	1.16	poorly sorted	0.12	fine-skew	0.97	leptokurtic
9	Prodelta muds	1.28	poorly sorted	0.02	symmetrical	0.97	leptokurtic
	Sea floor composite (0–1 m)	0.66	mod. well sorted	0.22	fine-skew	1.38	leptokurtic
	Chandeleur Islands composite	1.05	moderately sorted	0.18	fine-skew	1.23	leptokurtic

* Each sample is an average of six analysis runs.

** Core sample may not have reached base of deposit.

*** Composite description; deposit may contain alternating intervals of different size (see sorting).

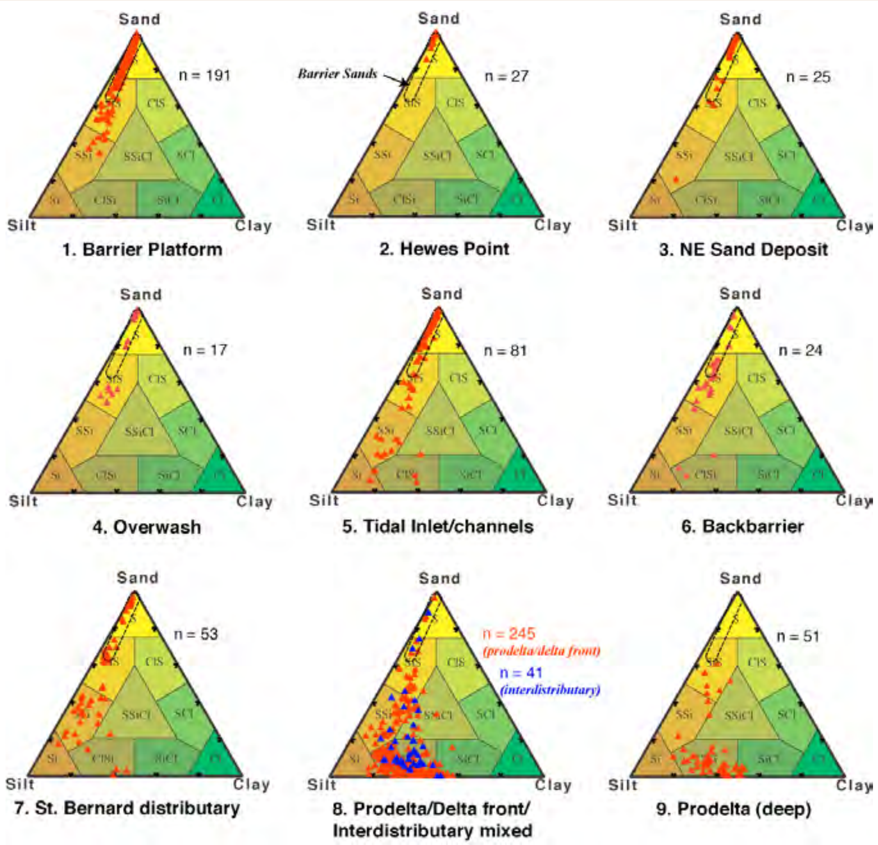

Figure 6. Ternary diagrams of sand (S)/silt (Si)/clay (Cl) ratios in samples collected from deposits outlined in this study in the area of the Chandeleur Islands, La. Texture parameters were measured by laser diffraction analysis. Distributions of barrier platform sands are shown in each diagram for comparison (dashed polygon).

stratigraphic record of the delta plain, however, this pattern is not often retained. Maps of drainage patterns on the near shelf in the northern Gulf of Mexico often show parallel and disconnected channels (Kindinger, 1989; Kindinger and others, 1994; Flocks and others, 2006), a result of the transitional nature of delta progradations and marine ravinement. Figure 15 in chapter E illustrates an interpreted distributary channel configuration mapped across the Chandeleur Islands by using a dense grid of seismic profiles collected during this study. The channels that are detectable in seismic profiles (fig. 9) are concentrated in the southern half of the main island chain. The locations of these channels play an important role in the evolution of the islands by providing sediment to the shoreface. During island development, sea level rise and littoral processes eroded sand from these channels and transported the sediment northward.

Sediment cores collected from the distributary deposits contain mixed lithologies and bedding types (fig. 10). These channels are sandier than adjacent interdistributary and delta-front deposits, but they also contain intervals of muddy material, leading to a wide distribution in texture. Distributary deposits contain over 50 percent sand, but their mean grain size ranges from very fine sand to coarse silt. Bedding within the deposits is also mixed (fig. 11). Sand layers occur in massive and laminated beds. The laminated bedding is often

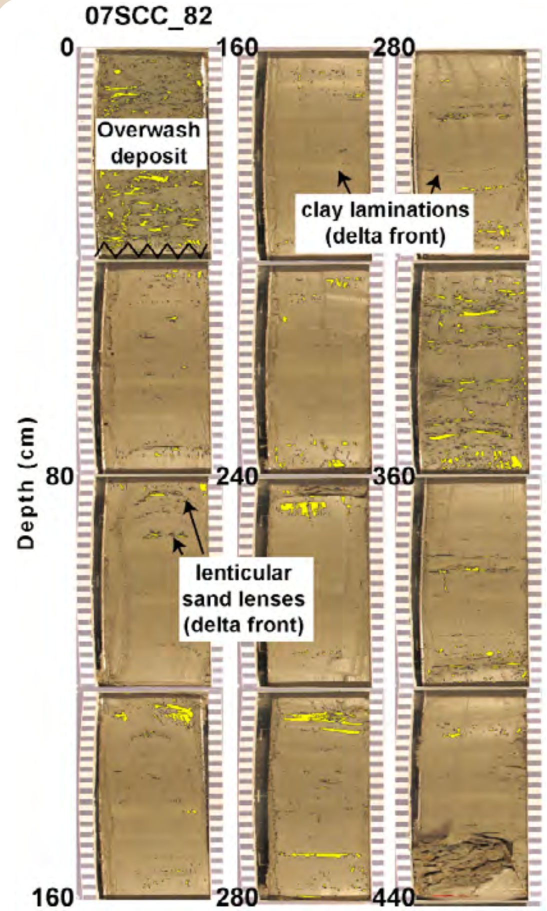

Figure 8. Sediment core (07SCC_82) that contains prodelta/delta-front deposits typical of the study area in the Chandeleur Islands, La. (see fig. 3 for core location). Sand lenses within laminated muds are highlighted.

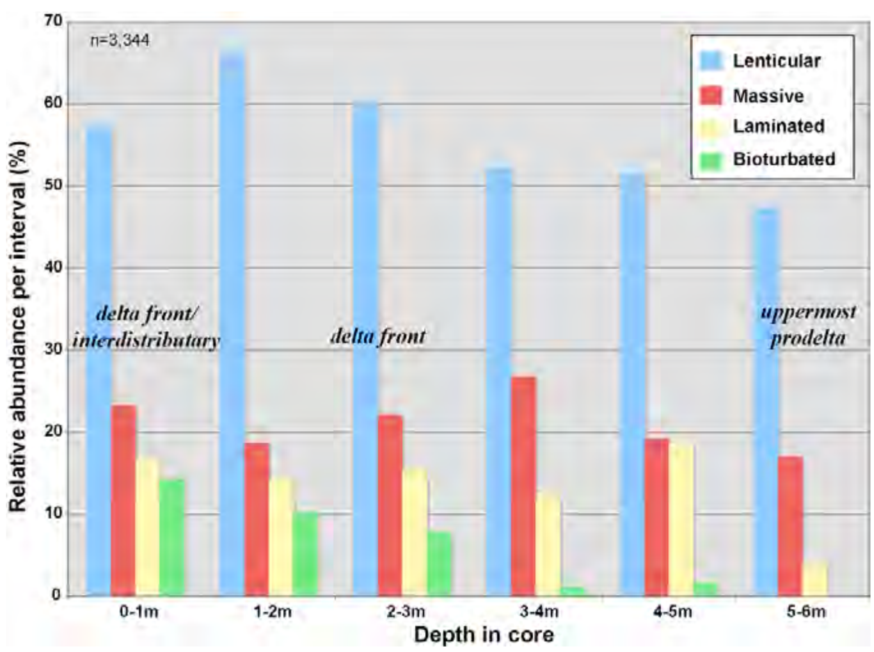

Figure 7. Distributions of predominant bedding type and bioturbation throughout the prodelta, delta-front, and interdistributary deposits in the Chandeleur Islands, La., study area. Based on sediment core interpretation.

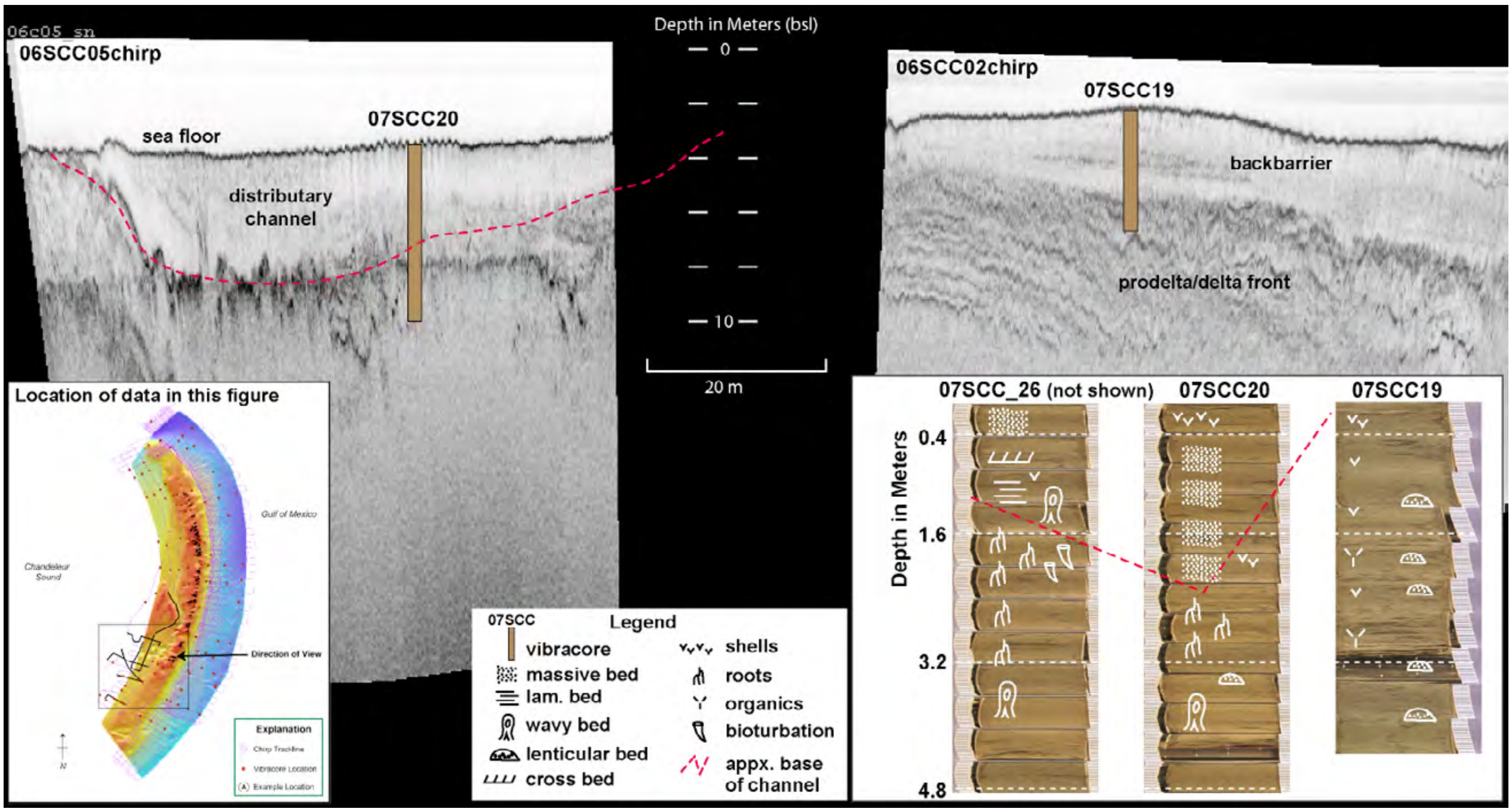

Figure 9. Seismic profiles showing a large distributary channel incised into the prodelta/delta-front deposits. Locations of these profiles are shown in map inset and in figure 3; for scale, the vibracores shown are 4 m in length. The vibracores obtained from the channel show massive and cross-bedded sands surrounded by muds and lenticular sands. Root traces are found within the surrounding muds and are interpreted to be interdistributary deposits.

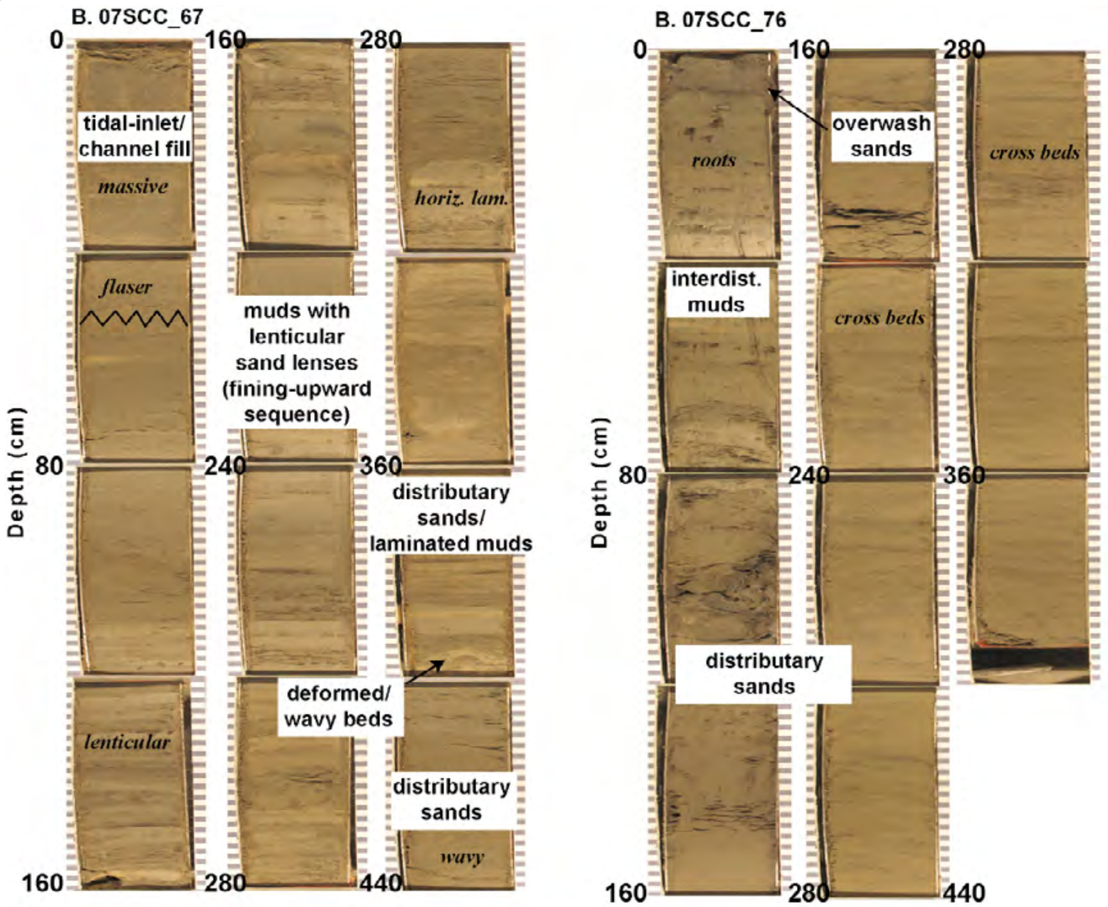

Figure 10. Representative cores from the distributary deposit in the Chandeleur Islands, La., study area showing a fining-upward sequence of sand and muds overlain by massive sands associated with the modern barrier platform. Various types of bedding are visible within the cores. See figure 3 for core locations. Horiz., horizontal; lam., laminated; interdist., interdistributary.

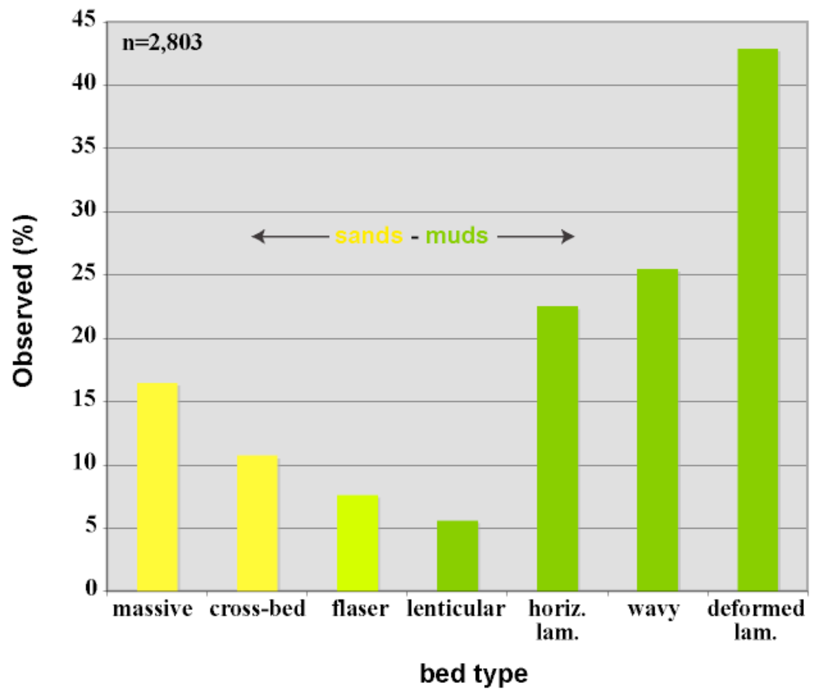

Figure 11. Relative percentages of observed bed type within the distributary deposit in the Chandeleur Islands, La., study area (compiled from 26 cores). Horiz., horizontal; lam., laminated.

deformed, wavy or crossbedded. Mud intervals are typically laminated and may contain lenticular sands. Since these deposits are fluvial, shell material and bioturbation are rarely observed. The sand distribution is similar to that of the barrier island platform, and the deposit potentially represents a suitable source for renourishment.

Transgressive Deposits

Upon abandonment of the St. Bernard Delta lobe, active deposition across the lobe decreased. The delta environment entered the transgressive phase of development, when dewatering caused compaction in the fluvial deposits and subsidence at the surface, causing the marsh surface to drop below sea level. Throughout the study area, the prodelta/delta front is overlain by shell lag, which in turn is capped by sands of the barrier island platform. The shell lag represents the ravinement surface associated with sea level rise and marine transgression across the marsh platform. During the transgressive phase, wave and current energy scoured the fluvial deposits and concentrated the sand into shoals. Rare sand ripples and scour features that are present within the upper intervals in some of the cores are indicative of erosion and transport during this time; however, the amount of sediment removed during marine inundation cannot be determined from the sediment cores. Vertical development and amalgamation of the shoals led to subaerial extension into barrier island deposits via littoral processes to shape the island arc. The modern barrier platform, tidal, and estuarine deposits are primarily composed of sands eroded from distributary deposits during the marine transgression.

Barrier Deposits

The core components of the barrier island chain are the sand deposits that compose the shoreface, subaerial dunes, and inlets. The islands contain the highest concentration of sand found in the Louisiana barrier islands system. These deposits are well sorted, have an average grain size of very fine sand, and exhibit very little deviation around the median grain size (fig. 6). Sediment texture distribution is skewed toward the fine sand-size fraction (table 2).

Although shell deposits can be found in abundance on the islands, most of the subaqueous barrier platform is distinctly clear of shells and organic material (fig. 12). When present, shells occur in lags, concentrated during high-energy events such as storms. Cores collected from the deposit exhibit very little bedding structure (more than 90 percent contain massive bedding). Sediment grain size in cores along the barrier islands' shoreface shows a consistent decrease in distribution around the median grain size from south to north. This trend suggests that sands are further concentrated because of winnowing caused by nearshore transport processes, which leads to an increase in the average grain size and sorting at the end of this transport system.

Much of the barrier platform rests on interdistributary and delta-front deposits. These deposits provide a vital foundation for sand deposition, which itself is protected from erosion by the sand deposits during normal wave activity. The sand is easily mobilized by storm events, which can redistribute sand and expose the marsh platform to wave attack.

Hewes Point Barrier and Northeast Sand Deposits

The prevailing wave climate across the Chandeleur Islands region is from the southeast, and littoral processes continually transport sands northward along the shoreface, as evidenced by active spit development off the north end of the island at Hewes Point (fig. 5). Hewes Point cores show an average increase in grain size of 0.05 mm and an increase in sand percent from 85 percent (barrier platform) to 97 percent when compared to the barrier platform cores. These sands are very well sorted and nearly homogenous in size (fig. 6). The spit deposit is more than 7 m thick in places (fig. 13). The volume calculated from seismic profile interpretations is estimated to be more than $350 \times 10^6 m^3$ of sediment. For the purposes of sand resources, the Hewes Point sand deposit is suitable for direct placement on the shoreface and may provide a quasi-renewable source because it will be replenished by littoral processes.

The Hewes Point barrier spit is accompanied by a similar subaqueous sand deposit that extends to the northeast, seaward of the island axis (fig. 14). Littoral processes are also responsible for concentration of sand in this northern area. While the deposits are less well sorted and contain more silt-sized sediment than does the Hewes Point spit, the composition and texture of the subaqueous sand bodies make them a suitable source for borrow material (fig. 5). Although both deposits have low shell concentration, the spit contains a higher percentage of shell lag.

Tidal/Shallow Fluvial Channel Fill

The near surface (less than 2 m below sea floor [mbsf]) of the southern portion of the island chain is marked by small-scale, high-angle reflectors in seismic profiles (fig. 14). These patterns are consistent with channel-fill deposits in the Louisiana coastal zone (Flocks and others, 2006) and represent small-scale distributaries, tidal inlets, or spit-progradation deposits. It is likely that the deposits represent reworked distributaries that were subsequently occupied by tidal inlets

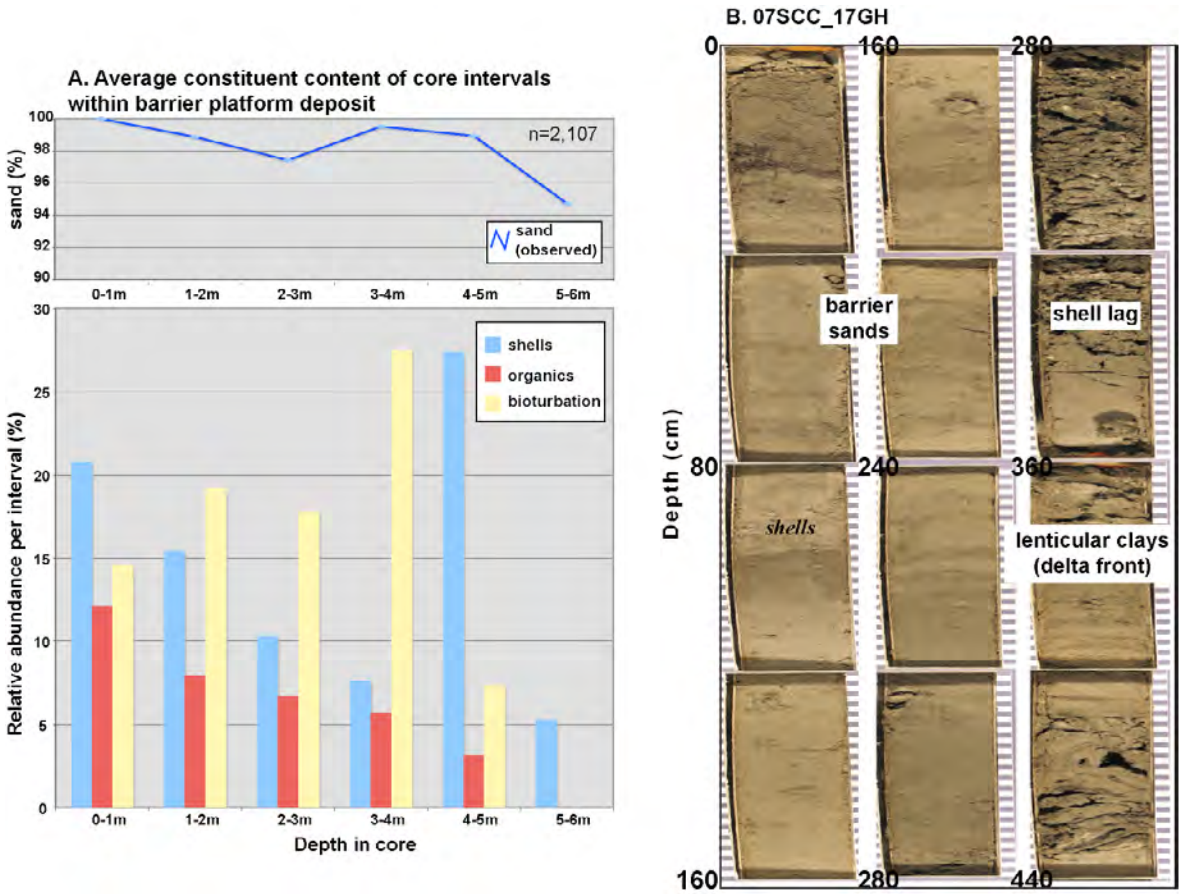

Figure 12. Relative percentages of sand and textural constituents within the barrier platform deposits in the Chandeleur Islands, La., study area (compiled from 33 cores) observed during core interpretations. *A*, Shells and organic material make up only a small portion of the unit, which is predominantly sand. *B*, Representative core (07SCC_17GH) from the deposit showing the well-sorted sand overlying delta-front muds. Cores show a prominent shell lag at base of barrier sands and increasing content of shell lags (although not abundant) upcore. See figure 3 for core location.

following marine ravinement. The features are laterally discontinuous and can contain similar material to both the underlying distributary channel and the island platform (fig. 10). On average, the deposits contain 73 percent very fine well-sorted sand (table 2). The bedding is commonly described as massive, although laminated and deformed bedding occur. The massive texture is more prevalent at the top of the section (fig. 15), which may be a product of reworking by wave action. Although the textural parameters of these deposits are similar to those of the barrier platform, the deposits may not be viable sources for sand renourishment because of their thin, discontinuous nature and their proximity to the barrier platform. The sands within these deposits represent an important natural source for replenishment, and their removal may impact the stability of the shoreface.

Backbarrier Deposits and Overwash Sand Sheets

Shallow deposits on the bay side of the barrier island chain represent the transition from earlier delta-front deposits to modern estuarine conditions. This zone is generally protected from normal nearshore wave and current energy, which allows fine-grained material to accumulate in layers within periodic high-energy deposits. This process leads to a mixed sediment of very fine sand to silt, strongly skewed toward the latter (table 2). The most distinct characteristic of these deposits is the wavy and deformed alternating beds of sand and silt that are observed in many of the cores (fig. 16). A seismic profile and core overlay show the gradual transition from the delta-front lenticular muds to the slightly coarser

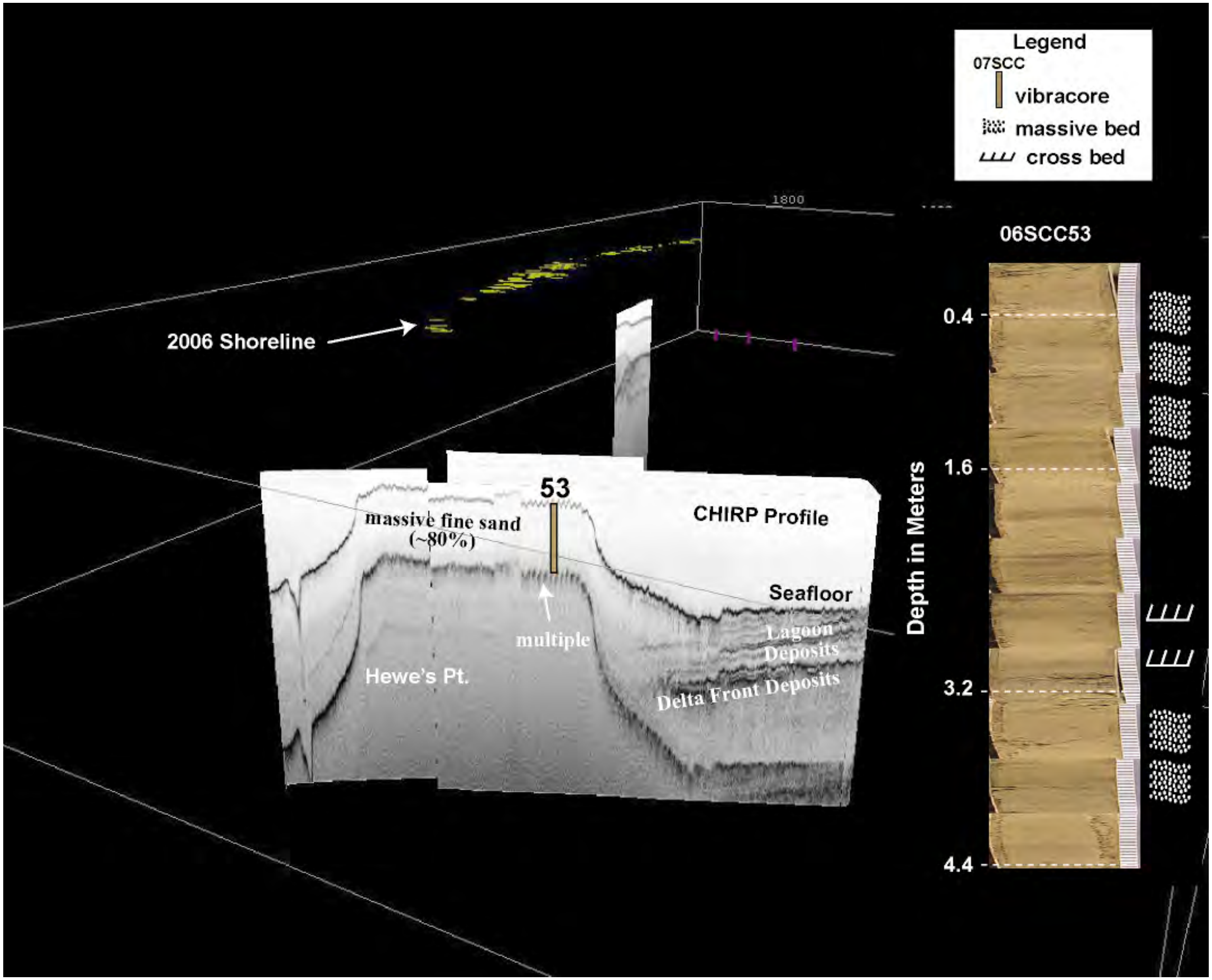

Figure 13. Seismic profile showing cross section of the subaqueous portion of Hewes Point, La., north of the modern shoreline (yellow polygons) of the Chandeleur Islands, La. (see fig. 3 for location of core). The point is composed of massive, clean sands overlying delta-front deposits.

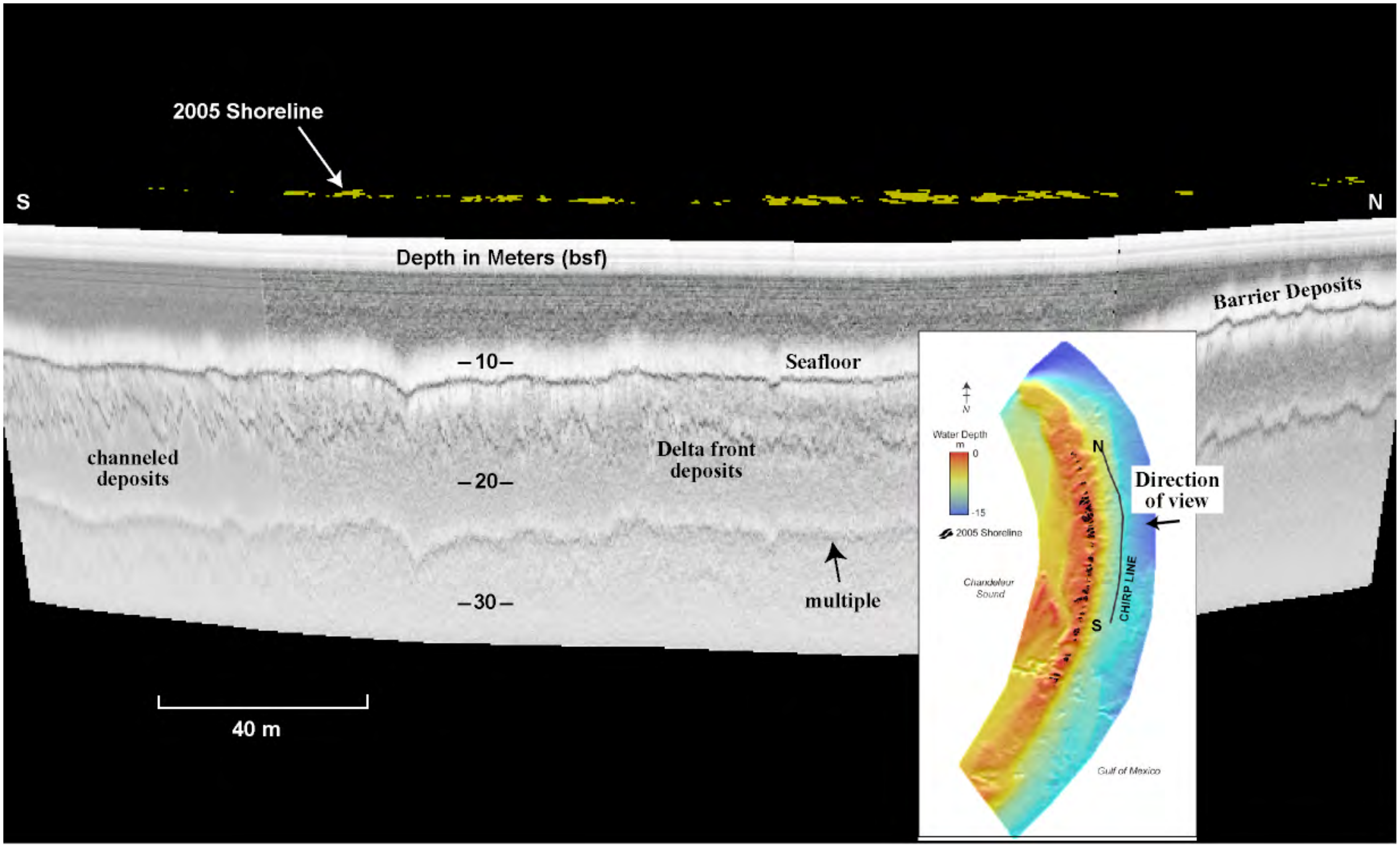

Figure 14. Seismic profile on the Gulf of Mexico side of the Chandeleur Islands, La., showing the high-angle acoustic reflectors that represent channel-fill deposits. The features may represent tidal inlets or older fluvial channels that incise delta-front muds. Location and direction of view of profile is shown in map inset. The offshore sandy extension of the Hewes Point, La., sand spit is shown on the right side of the profile. See figure 5 for the location of this deposit.

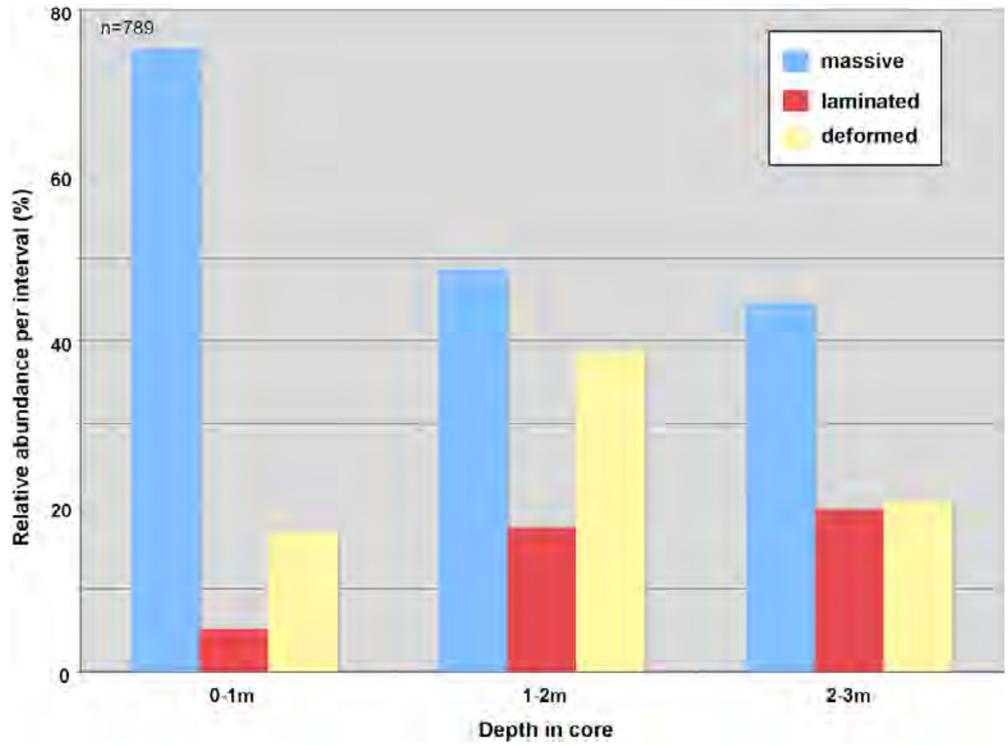

Figure 15. Relative percentages of observed downcore bed type within the tidal/distributary deposit (compiled from 32 cores) in the Chandeleur Islands, La., study area.

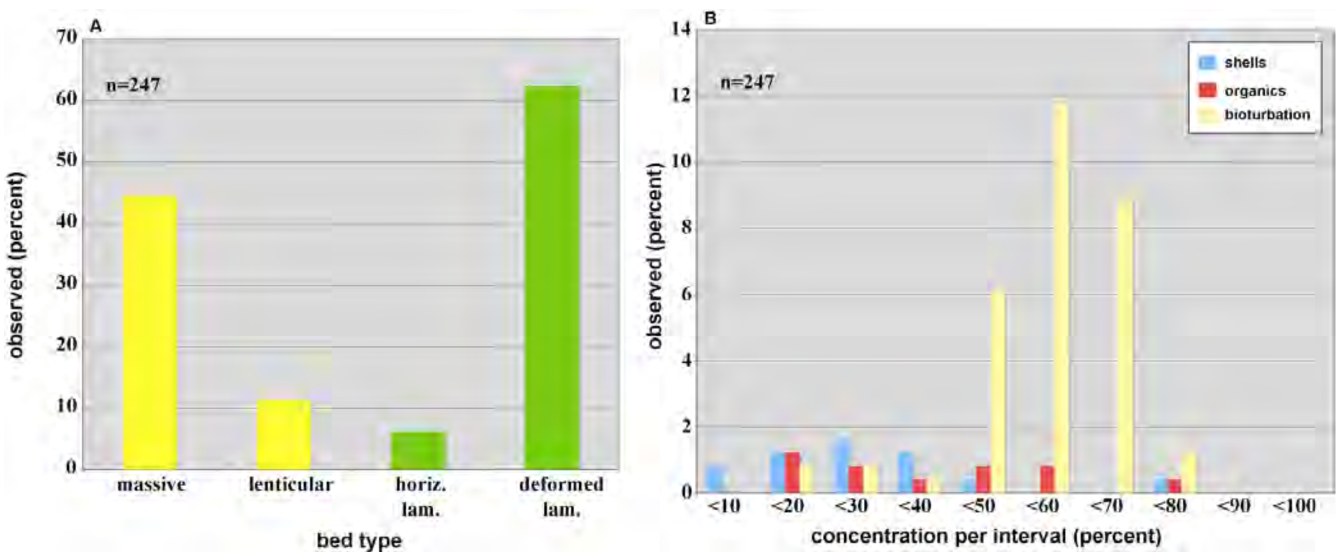

Figure 16. Relative percentages of observed bed type and texture content within the backbarrier deposits in the Chandeleur Islands, La., study area. *A*, Bed type. *B*, Texture content. Deposits contain massive or deformed bedding, and 73 percent of the deposit contains intense bioturbation (50–70 percent). Horiz., horizontal; lam., laminated.

grained backbarrier deposits, with an increase in shell content upcore (fig. 17). Shell material is typically concentrated in distinct lags, and bioturbation is common (fig. 16*B*). Although average sand content exceeds 50 percent, the mixed nature of these deposits (table 2) makes it difficult to obtain a suitable texture similar to that of the barrier platform for renourishment purposes.

Mainland of the islands, thin discontinuous sheets of sand occur at the surface, adjacent to breaches in the barrier chain. These deposits are typically less than 0.5 m thick and rest unconformably on backbarrier, barrier platform, and distributary deposits. The positions of these features indicate that they are overwash deposits from storm events or are flood tide delta deposits (fig. 5). On average the sheets consist of 79 percent very fine sand and are moderately sorted (table 2). These thin and laterally discontinuous features are not favorable sand sources, and their removal may affect inlet dynamics and interfere with natural breach-closing processes.

Sea Floor Sediments

Wave and current-driven processes mobilize sediment in the nearshore. The texture and grain size of the available sediment influence the extent of littoral transport and shoreface erosion. Thus, to understand the present dynamics of a barrier island system, accurate characterization of the top 1 m of sediment is necessary. Most of the cores collected adjacent to the islands contain a layer of sand at the surface. In core 07SCC_02 (fig. 18), as much as 1 m of sand rests unconformably on delta-front muds with a shell lag between the two facies. In other areas this surface sand layer is less than 30 cm thick. A ternary plot of the sand/silt/clay ratios from all of the core tops (less than 1 m depth) shows the predominance of sand, with a slightly wider distribution of grain size in some of the intervals with increasing depth (fig. 19). The ternary distributions show an increase in sand content with decreasing water depth, decreasing sample depth, and distance north. Average sand content of the top 1 m of cores collected is almost 73 percent (table 2).

Average grain size and sand content in the upper 1 m of sediment are shown in figure 20. Fine sand is prevalent in the surface adjacent to the subaerial portions of the islands, with a transition to silt-size sediments within 1 km offshore. Sorting values also follow this pattern, with moderately to well-sorted sediments adjacent to the shoreline and moderately to poorly sorted sediments offshore. Surface sediments behind

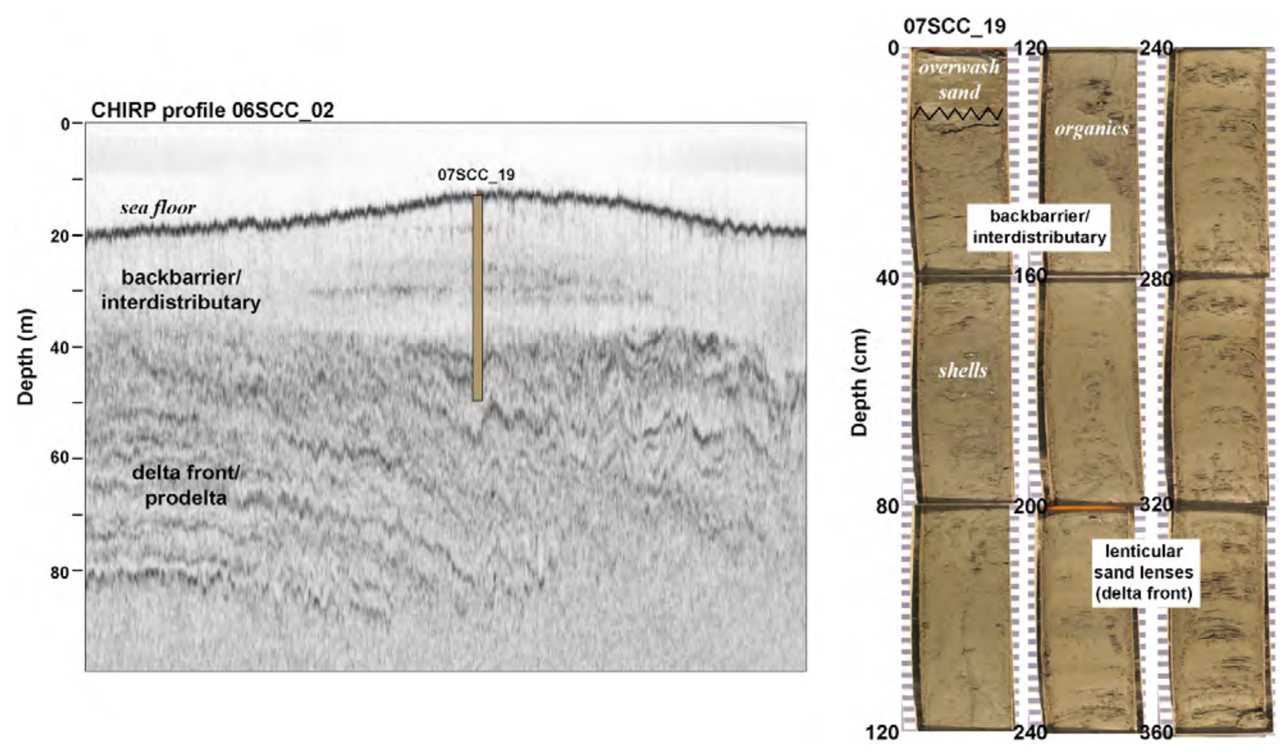

Figure 17. *A*, CHIRP profile showing vertical transition from prodelta to backbarrier deposits on the bay side of the Chandeleur Islands, La. (see fig. 3 for location of core). *B*, Although acoustically distinct, vibracore 07SCC_19 shows only subtle textural transition from lenticular in a clay matrix (delta front), overlain by laminated muds with organics and increasing shell content (interdistributary/backbarrier).

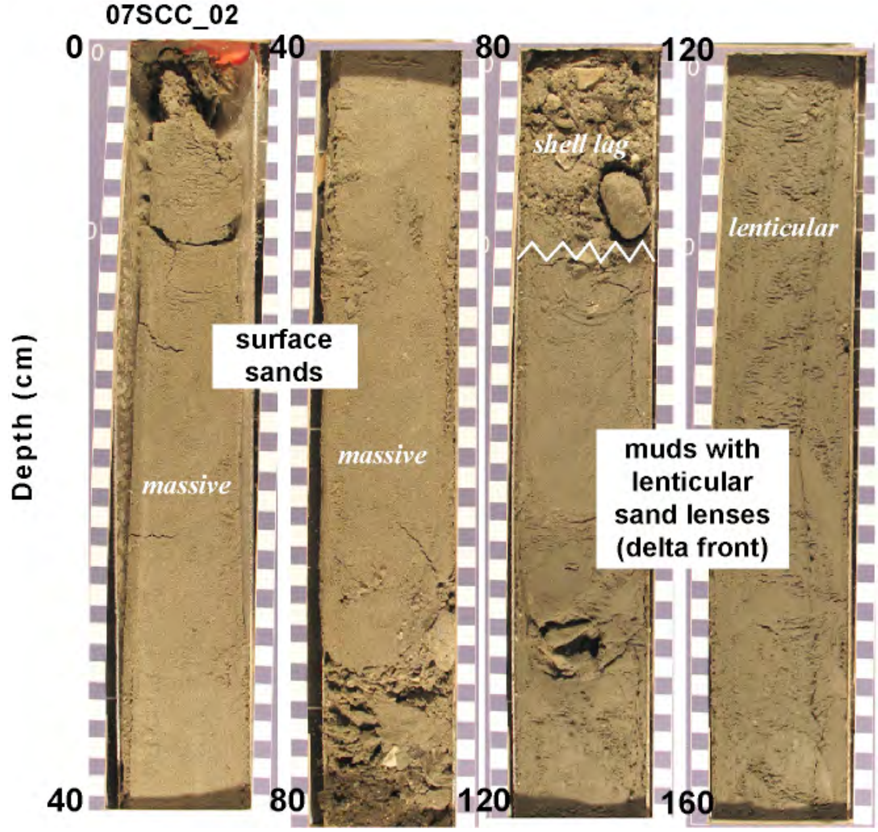

Figure 18. Top 1.6 m of vibracore 07SCC_02 showing a shell lag overlain by 1 m of massive sand. Location of core is shown in figure 3.

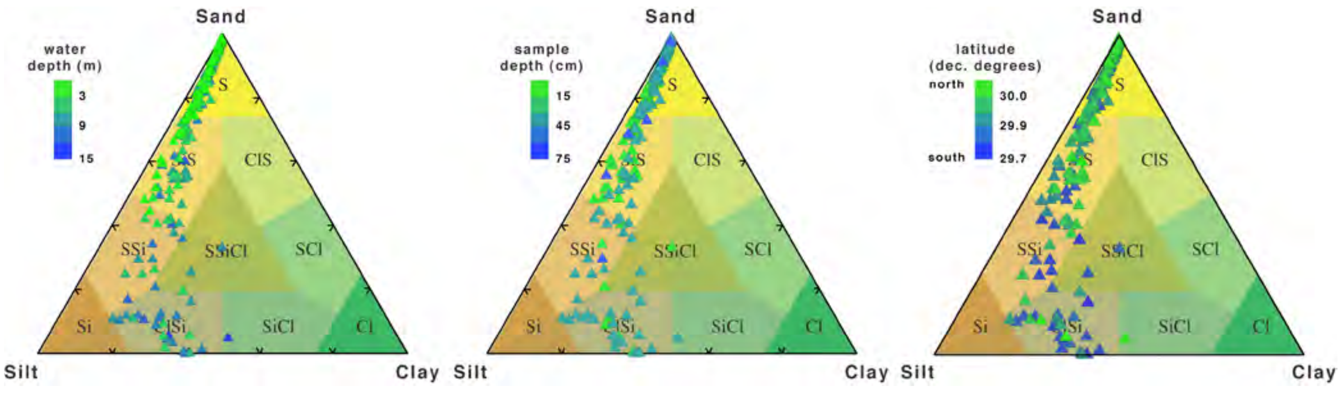

Figure 19. Ternary plots of sand (S)/silt (Si)/clay (Cl) ratios from the surface intervals (less than 1 m) of all cores collected during this study in the area of the Chandeleur Islands, La. The data points are the same for each ternary plot, but the color shading (blue to green) relates to water depth, sample depth in core, and latitude. Together the ternary plots show that the samples become sandier with decreasing water depth, decreasing sample depth, and increasing latitude (north).

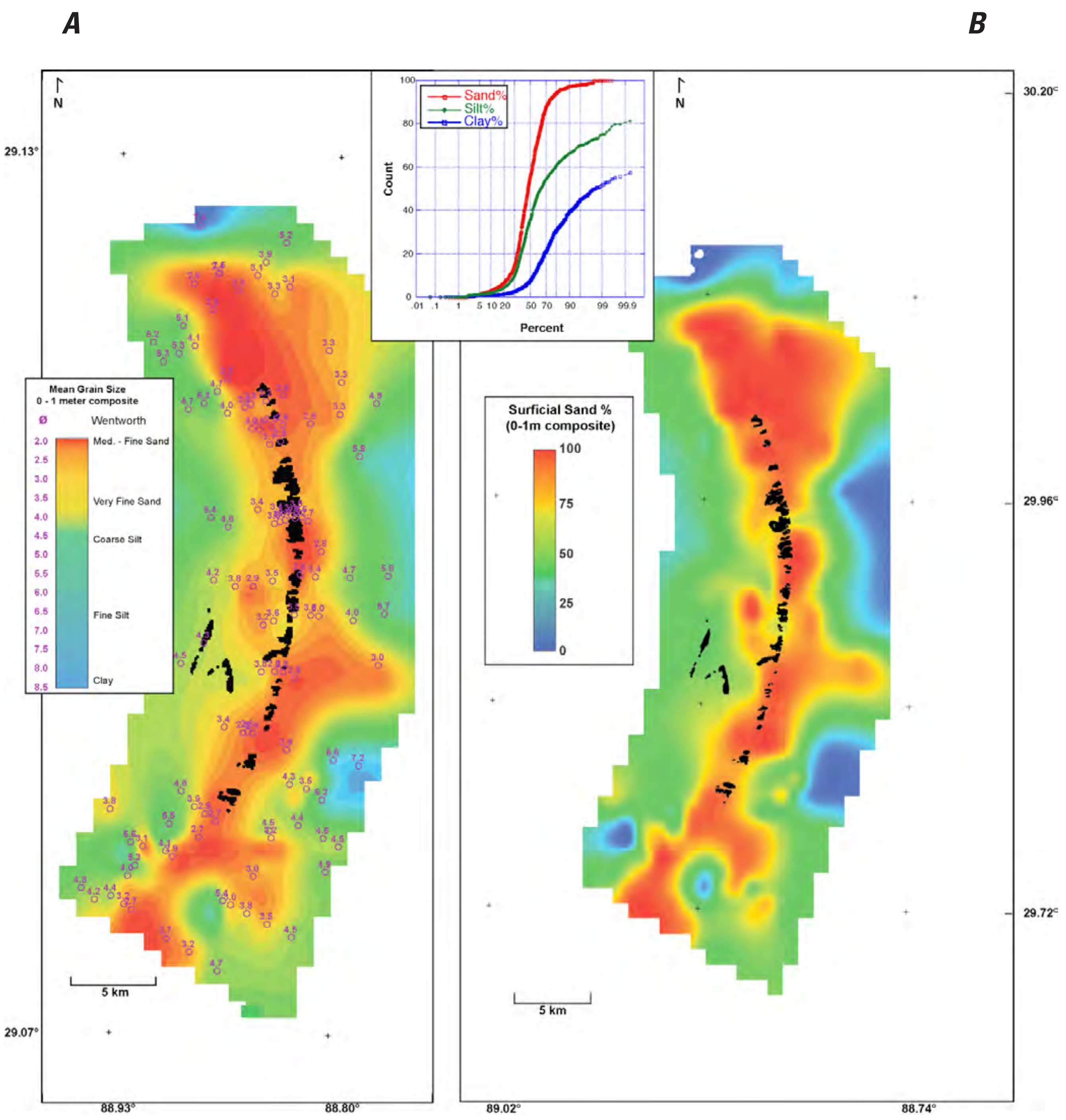

Figure 20. Color-shaded contour plots of the grain size and percent sand for a composite of the top 1 m of sediment in the Chandeleur Islands, La., study area (islands shown in black). *A*, Mean sediment grain size. *B*, Percent sand. Core locations are shown as circles, annotated with the mean grain size (phi). Grain size and associated Wentworth classification are shown in legend. Cumulative assemblages of sand, silt, and clay are shown in top inset.

the islands tend to collect more fine-grained material, so their composite distributions are skewed toward the smaller grain size (fig. 21). From south to north, the distribution becomes narrower and more peaked around the sample's median grain size, at the expense of the fine-grained material contained in the tail of the distribution. This pattern results from the littoral process removing fine-grained material from the system as it reworks and transports the sediments from south to north.

Potential Borrow Sites

Through the interpretation and analysis of the seismic and sediment core data, six potential borrow sites have been identified offshore (see fig. 15 in chap. E); these sites contain sediment resources of suitable sand content and texture to replenish sand lost from the system through littoral transport and storm impact. These deposits include older, buried

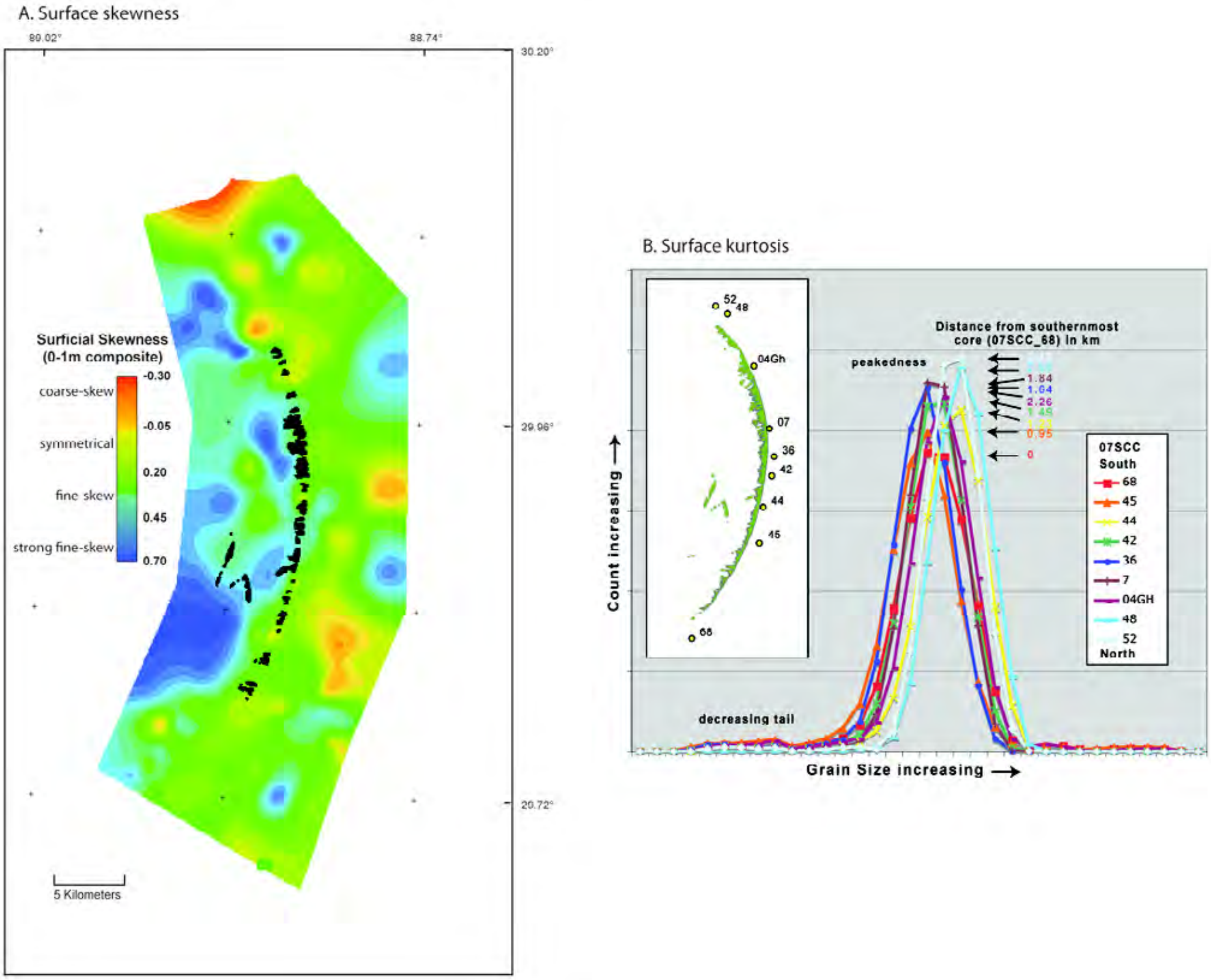

Figure 21. Sediment sorting of the barrier islands deposits. *A*, Color-shaded contour plot of skewness values for the composite top 1 m of sediment. Skewness is a measure of the grain-size distribution in a sample that reflects departure from the mean grain size. The plot shows that the surface sediments behind the island chain have increased fine-grained components. *B*, Plots of grain-size distribution in the upper 1 m of cores located along the front side of the barrier island chain (locations shown inset). Kurtosis reflects distribution of sediment grain size around the mean. The grain-size distributions in the samples decrease in variability around the mean grain size progressively northward in the transect (the curves become more peaked). The plot shows that the surface samples are increasingly sorted northward in the transect at the expense of the fine-grained material.

distributary sands and modern transgressive sand sinks. The units are end-members of the littoral process that developed and maintains the barrier island system. The deposits described earlier in this chapter include distinct units between 1 and 4 m thick. The following descriptions include whole-core composites of samples collected from these sites since selective removal of sandy material for restoration purposes would be difficult.

Hewes Point Sands

The prograding spit and offshore sand deposit include the highest sand content in the study area, and arguably in the Mississippi River Delta Plain. These sands are well sorted and clean of organics and shell material. This deposit is the result of littoral processes transporting material across the barrier island platform and as such is similar material to what is found on the shoreface. Sediment cores collected from this deposit ranged from 3 to 5 m in length, although few penetrated the entire unit, and sand estimates exceed $240 \times 10^6\,m^3$. Whole-core composites contain an average of 69 percent sand (table 3), which is much lower than the center of the deposit (table 2) because some of the cores on the flank penetrate underlying prodelta units.

Distributary Sands

The distributary units are identified as potential borrow sites because of their spatial extent, proximity to the surface, and high sand content. These deposits are the source of sand found along the shoreface of the islands and are suitable material for renourishment. Unlike the Hewes Point deposits, however, these sediments contain a mix of sands and muds associated with fluvial and marine infilling of the incised channels. The grain-size statistics of the deposits based on whole-core composites are classified as moderately sorted fine sand to clay (table 3). Massive-bedded sands occur more often mid-depth in the unit (fig. 22). Sand content within this interval (2–4 mbsf) exceeds 60 percent (fig. 22).

Table 3. Physical characteristics of deposits in the Chandeleur Islands, La., study area that have sand resource potential.

[Results are whole-core composites and contain samples from stratigraphy above and below the deposit. Physical characteristics of the isolated deposits are shown in table 2. dd, decimal degrees; m, meters; mbsf, meters below sea floor; mm, millimeters]

Deposit (no. of samples)		Longitude dd	Latitude dd	Water depth (m)	Core length (m)	Sample depth (m)	Relative depth (mbsf)
Hewes Point	minimum	-88.88902	29.99058	4.1	3.0	0.0	7.1
(79)	maximum	-88.79880	30.07000	9.8	4.9	4.8	14.7
	average	**-88.84472**	**30.04498**	**7.0**	**4.3**	**2.1**	**9.1**
Distributaries	minimum	-88.89954	29.69943	4.0	3.3	0.0	7.3
(81)	maximum	-88.80237	29.79908	11.0	5.5	5.4	16.5
	average	**-88.84147**	**29.74560**	**8.8**	**4.5**	**2.1**	**10.9**

Deposit (no. of samples)		Mean grain size phi (mm)	Wentworth classification	Sorting (folk) phi	Sorting classification	Sand (%)	Silt (%)	Clay (%)
Hewes Point	minimum	7.7 (0.05)	Very fine silt	2.21	Very poorly sorted	0.9	0.0	0.0
(79)	maximum	2.3 (0.20)	Fine sand	0.21	Very well sorted	100.0	68.9	45.6
	average	**4.0 (0.06)**	**Very fine sand**	**0.58**	**Moderately well sorted**	**69.5**	**21.7**	**8.7**
Distributaries	minimum	8.2 (<0.01)	Clay	1.72	Poorly sorted	0.0	1.6	0.5
(81)	maximum	2.6 (0.15)	Fine sand	0.25	Very well sorted	97.9	79.9	55.0
	average	**5.7 (0.02)**	**Medium silt**	**0.94**	**Moderately sorted**	**31.3**	**46.3**	**22.4**

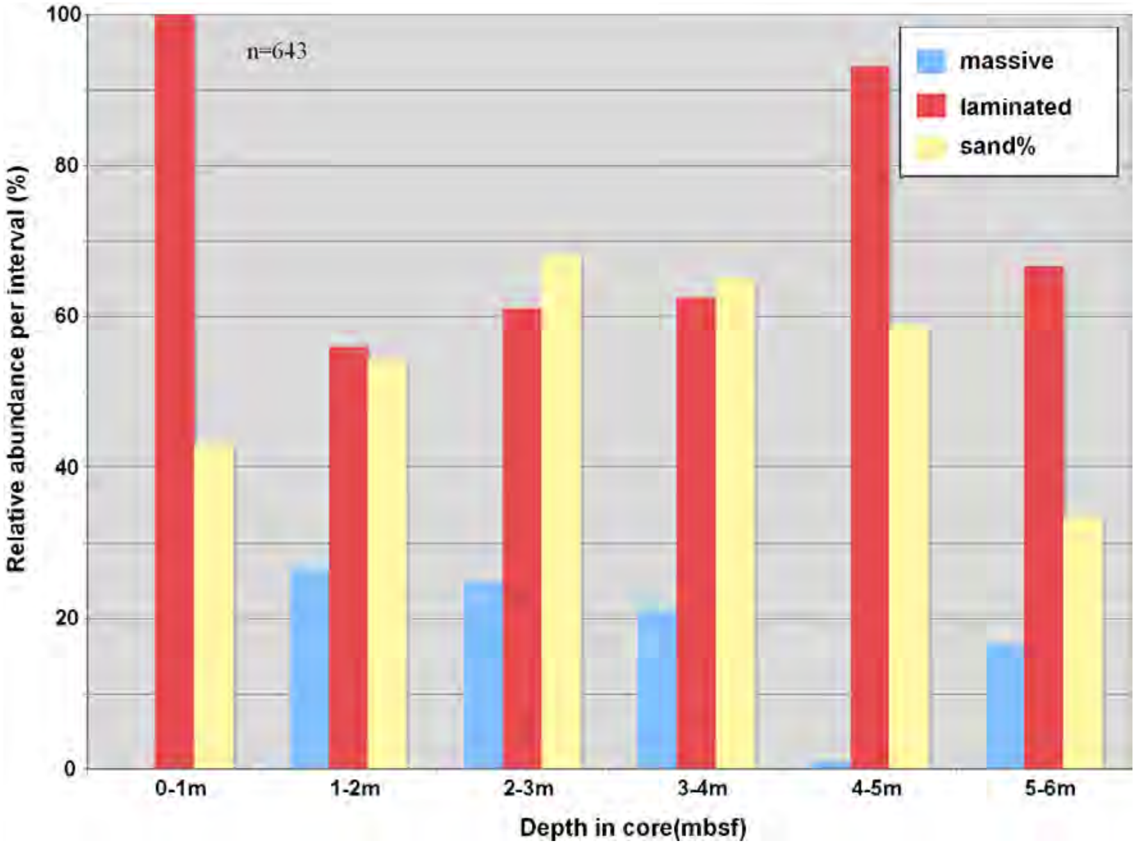

Figure 22. Distribution of bed type and sand content within the distributary deposit showing that sands are not uniformly distributed within the unit but are concentrated in massive and laminated beds 2–4 m below sea floor.

It should be noted that removal of material from the distributary deposits located adjacent to the islands could potentially alter the hydrodynamic regime by increasing tidal flow across the southern portion of the islands. Further study is necessary to determine how this would affect littoral transport along the barrier island chain.

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Appendix F–1. Core Descriptions (See Index Page To Access Data)

Appendix F–2. Geographic Data (See Index Page To Access Data)

Appendix F–3. Grain Sizes (See Index Page To Access Data)

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