INNER SHELF DEPOSITS OF THE LOUISIANA-MISSISSIPPI-ALABAMA REGION, GULF OF MEXICO

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ABSTRACT

The late Quaternary morphology, shallow stratigraphy and sediment distribution of the Louisiana-Mississippi-Alabama inner shelf region are the product of transgressive and regressive sedimentary processes. Shelf sedimentary facies were deposited by deltaic progradation, followed by shoreface erosion and submergence. This information is based on interpretations and synthesis of more than 4,160 mi (6,700 km) of high resolution seismic profiles, 75 grab samples, and 77 vibracores.

The shelf can be divided into two main depositional regions. The southwestern region, east and south of the Mississippi River plain, was formed by early Holocene delta complexes, overlying a late Wisconsinan delta. Deposits of the late Wisconsinan delta consist of well-defined coarsening-upward sequences and represent deltaic progradation during low sea level stands. The relatively recent Mississippi delta complexes have deposits which consist of fine-grained sands, silt and clay. With the late Holocene rise in sea level, asymmetrical sand ridges (16 ft, or 5 m, relief) have formed due to marine reworking of shoreline features.

The northeastern region, offshore of the Mississippi-Alabama barrier islands, was formed by Pleistocene fluvial systems and Recent shoreface erosion and ravinement. Underlying the relatively thin Holocene sediment cover are relict fluvial sands which were deposited during the late Wisconsinan lowstand. Subsequent sea level rise allowed marine processes to rework and redistribute sediments forming the nearshore fine-grained facies and shelf sands sheet.

INTRODUCTION

Late Pleistocene and Holocene morphology of the Louisiana-Mississippi-Alabama inner shelf region is the product of transgressive and regressive sedimentary processes. Shelf and inner shelf morphology has been strongly influenced by subsidence and glacio-eustatic flucuations in sea level, which resulted in repeated rises and falls during the Quaternary (Ludwick, 1964; Frazier, 1974; Beard et al, 1982; Kindinger, 1988). Outbuilding of the shelf resulted primarily from coastal-plain extension during sea withdrawal across the shelf.

A broad shelf has formed east of the Mississipi River delta in Louisiana offshore of Mississippi-Alabama. The bathymetry and subsurface characteristics of the Louisiana-Mississippi-Alabama shelf are the result of deltaic deposition and intervening periods of erosion during lowstands. Typically, the progradational sediments overlie sediments deposited during transgression. Little evidence of structural deformation, such as faults or diapirs, is present on this shelf.

According to Frazier (1974), late Quaternary surficial sediments across the shelf relate to several different depositional episodes. The surficial and shallow subsurface sediments of the shelf are generally sandy as evidenced by grab samples, vibracores, and the presence of buried stream channel bedforms inferred from seismic profiles.

The inner shelf of Louisiana-Mississippi-Alabama is bordered on the west by the oldest and largest barrier island system in the Mississippi River delta plain (Fig. 1), the Chandeleur Islands arc (Penland et al, 1985). To the north is the Mississippi-Alabama barrier island chain lying parallel to the northern Gulf of Mexico coast. The basic shelf morphology was described by Ludwick (1964) and Frazier (1967). These studies and others used grab samples and shallow cores to characterize the local geology (Fisk, 1944, 1956; Curray, 1960; Coleman and Gagliano, 1964; Lehner, 1969; Frazier, 1974; Coleman, 1976; Beard et al, 1982). Generally, these studies discussed the cyclic sedimentation of the Mississippi River delta complex which includes the St. Bernard delta.

The surge in research towards understanding coastal processes and erosion has sparked new regional investigations into the geologic framework of the coastline and

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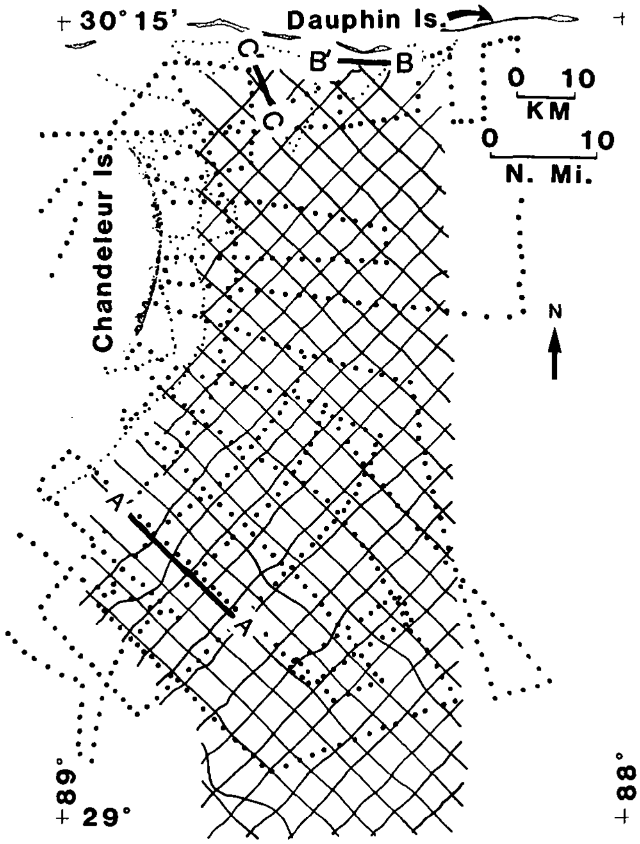


Figure 1. Location of high resolution single channel seismic reflection tracklines collected in 1981 and 1987.

continental shelf. The purpose of this paper is to describe the geologic framework and lithology of the Louisiana-Mississippi-Alabama inner shelf region.

DATA BASE

The Louisiana-Mississippi-Alabama inner shelf was surveyed in 1981 and in 1987-88 using high-resolution, single-channel seismic-profiling techniques as part of a cooperative project between the Louisiana Geological Survey and the U.S. Geological Survey. More than 4160 line-miles (6,700 line-kilometers) of reflection profiles were collected (Fig. 1). A variety of seismic equipment was used: a 400-Joule minisparker, 3.5- and 12-kHz transducers, 40- and 5-cubic-inch airguns, and a Geopulse Boomer system. During the 1981 cruises 75 surficial grab samples were collected across the area (Fig. 2). These data, along with 77 vibracores 40 ft (12 m) long taken in 1987 (Fig. 2) are currently being analyzed. Results are expected to be available in late 1989.

SURFICIAL SEDIMENTS

The Louisiana-Mississippi-Alabama shelf is a broad, smooth, gently sloping (<O.l°) sea-floor ranging from 0 (barrier island shoreface) to 246 ft (0 to 75 m) water depth where the shelf break has formed. Large areas of the shelf are covered by sandy sediments with smaller areas of prodelta and transitional facies (Fig. 3). The inner shelf sand-silt-clay percentages averaged from grab samples were 56, 26, and 18, respectively (Kindinger et al, 1982). Shoreline migration (regressive and transgressive) and coastal processes, such as delta building, longshore transport, shoreface erosion, submergence, and storms, have reworked the sediments and winnowed out much of the finer sediments.

Ludwick (1964) divided the Louisiana-Mississippi-Alabama shelf into six facies, including transition zones, based on surficial sediments. Mazzullo and Bates (1985) divided the present shelf into two distinct regions on the basis of surfical grain morphology and age. East of the Mississippi River delta plain, the shelf is covered by the Eastern Sand Deposit, a thin layer of relict well-sorted fine to medium quartzose sand of late Pleistocene and early Holocene age deposited by rivers of the southeastern United States. The westernmost part of the shelf, which includes the St. Bernard and modern delta complexes, is covered by Holocene sand, silt, and clay depo-

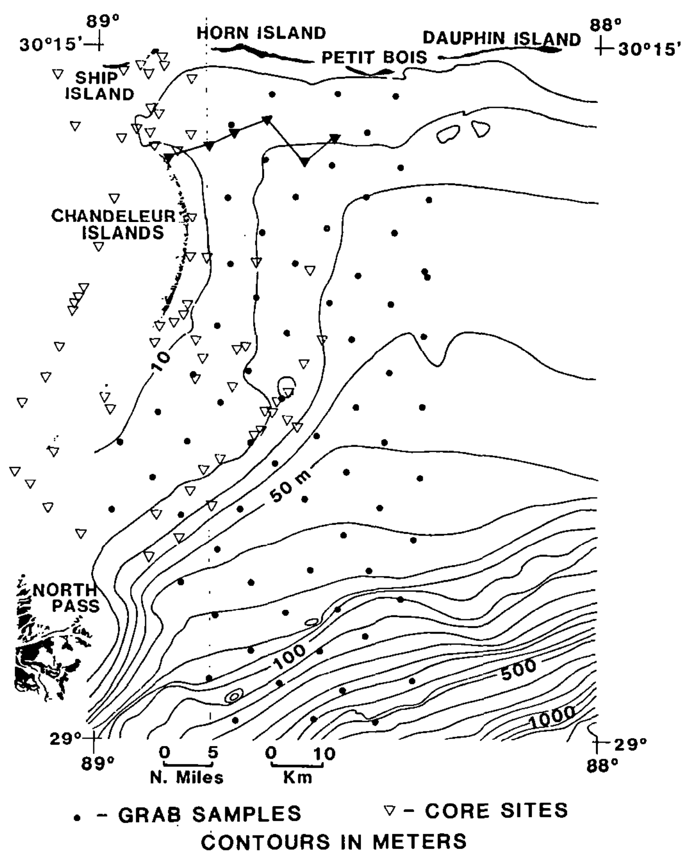
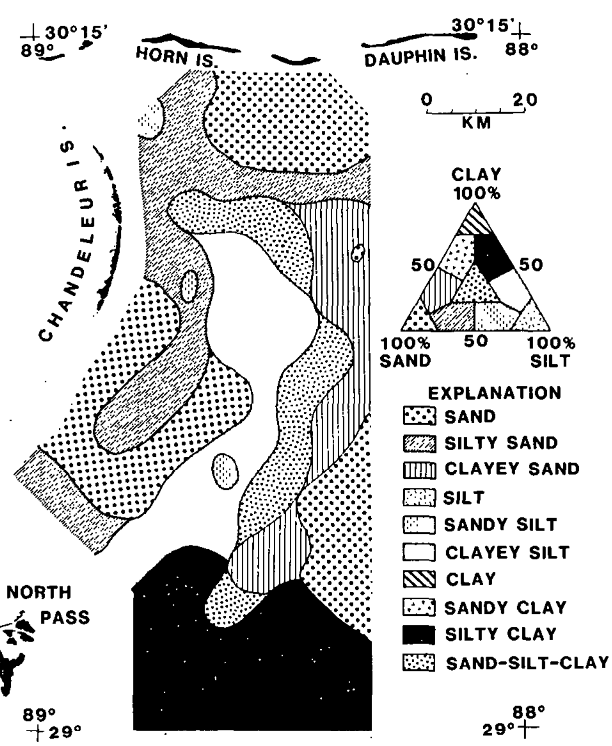


Figure 2. Bathymetry map of study area, including locations of 75 surficial grab samples and 77 vibracores. The linked vibracores are the samples used in the cross section in Figure 7.

sited in association with the Mississippi River (Ludwick, 1964; Mazzullo and Bates, 1985).

The distribution of the surficial sediments is the product of fluctuating sea level during the late Quaternary. The sands on the southeast side and in the northeast corner are the oldest sediments in this area (Fig. 4-A,C,D). These orthoquartzite sands were derived from the Cretaceous and younger sedimentary mantle of the Appalachians (van Andel and Poole, 1960) and were emplaced as fluvial and/or beach deposits during the last major lowstand 18,000 yrs B.P. (Ludwick, 1964; Frazier, 1974). The clayey silts extending across the central region are St. Bernard prodelta muds (Fig. 3). These muddy sediments are the approximate basinward limit of clay deposition during recent times (Frazier, 1974). The silty sand, sand-silt-clay and clayey sand to the north, east, and south of the clayey silt occur in a transition zone where the prodelta muds and eastern sands have mixed laterally and vertically. The southern end of the clayey-silt salient is a mixture of St. Bernard deposits and sediment presently being deposited from the Modern birdfoot delta (Fig. 5—Balize) of the Mississippi River.

The sand in the southwest corner below the Chandeleur Islands has been produced by reworking of the distributary mouth bar sands in a landward direction by wave erosion on the subsiding delta. Sand from the coalescing sand bars formed the Chandeleur Islands, and Chandeleur and Breton Sounds behind the island chain (Penland and Suter, 1983). Sand ridges found in this area formed during the most recent temporary stillstand (Kindinger, 1988). The silty sand and sandy silt located north, within, and to the south of the Chandeleur Islands sand salient represent reworking of the St. Bernard delta lobe as well as modern sedimentation processes. Murray (1976) reported that ebb-directed tidal flushing of the turbid Chandeleur-Breton Sounds estuary water flows to the north and south of the Chandeleur Island chain. The tongue of silty sand extending into the Chandeleur Island sand salient either represents settling of this finer-grained sediment into a naturally occurring depression, or may possibly be reworked lagoonal/tidal flat sediments deposited behind an earlier barrier ridge.



(FROM KINDINGER AND OTHERS, 1982)

Figure 3. Surficial sediment distribution showing extent of sandy sediments covering the shelf. From Kindinger et al (1982).

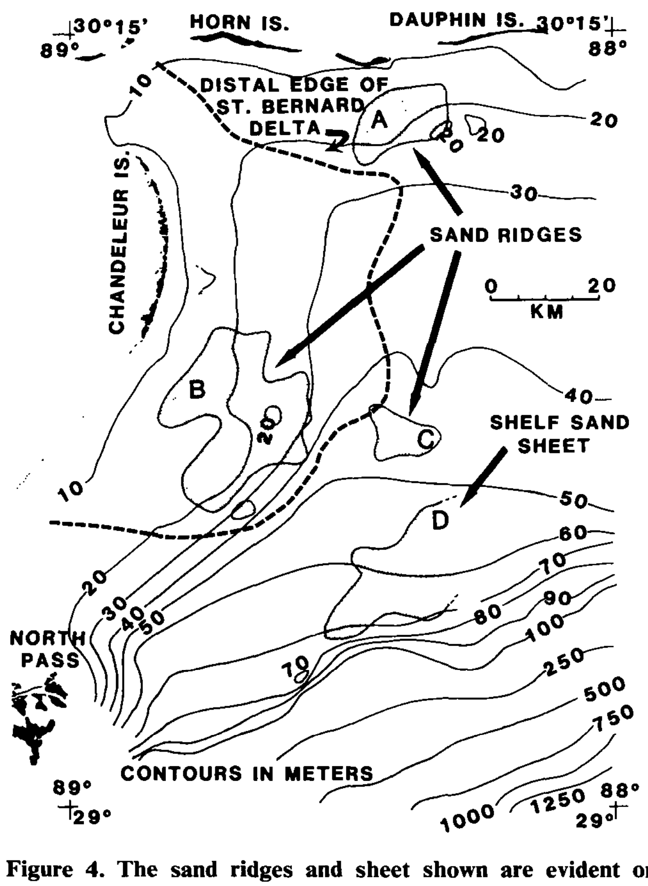


Figure 4. The sand ridges and sheet shown are evident on seismic profiles and have topographic relief, with some areas 16 ft (5 m). Sand Ridges A, B, and C are asymmetrical in cross section and Sheet D is relatively lens-shaped. A, C, and D are part of the Eastern Sand Sheet which covers much of the shelf. B is part of the St. Bernard delta complex.

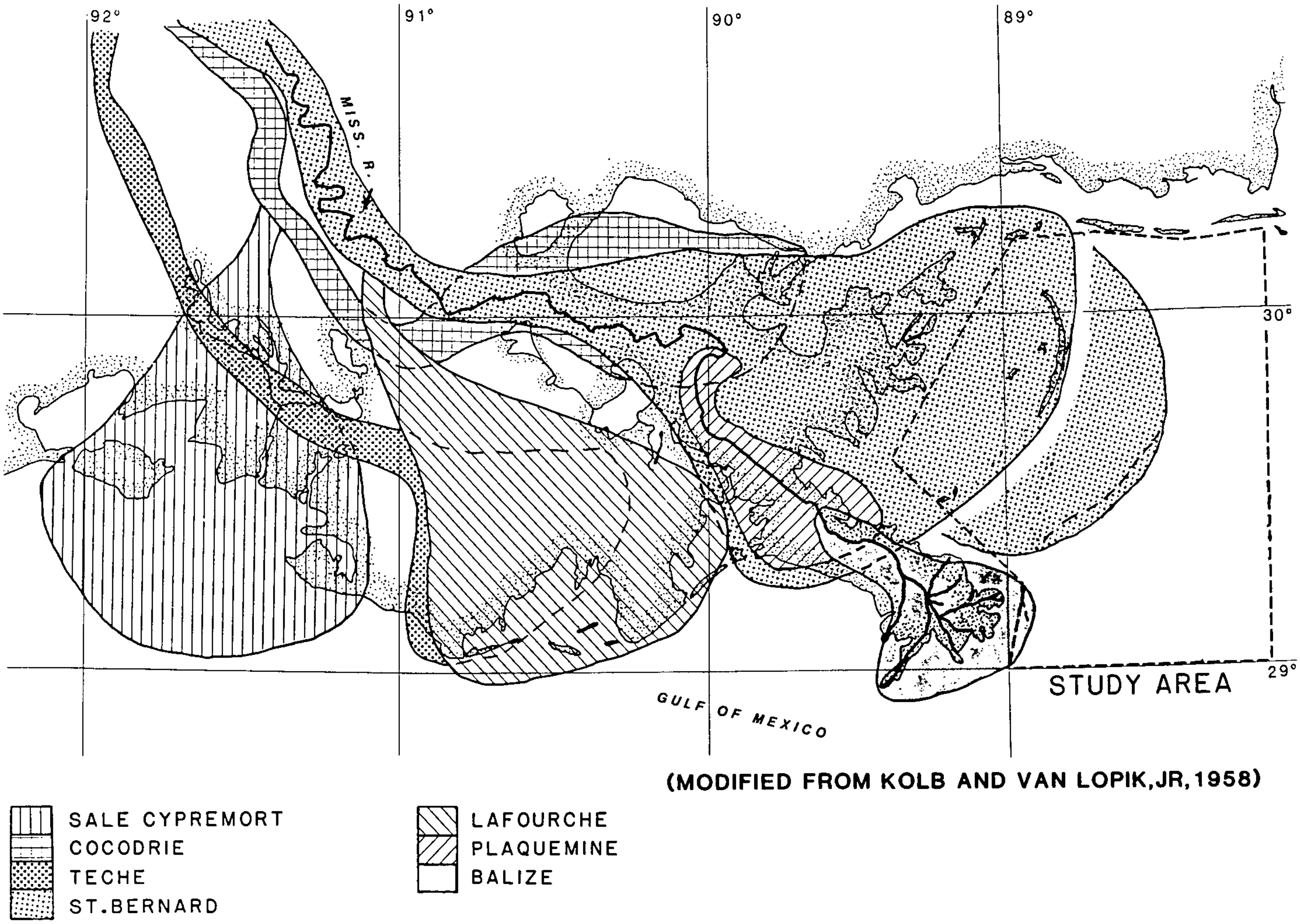


Figure 5. Recent delta complexes of the Mississippi River and the relative location of the study area. Modified from Kolb and van Lopik (1958).

STRATIGRAPHY AND LITHOLOGY

Stratigraphic units have been defined by utilizing unconformities and correlatable conformities identified from seismic profiles. These units were identified by superposition of sequences and seismic character of the sequences within the data (Fig. 6). The lower boundary of the oldest sequence is a prominent shelf-wide erosional unconformity identified as early Wisconsinan. The erosional surface was buried by thin parallel beds during the subsequent sea-level rise and by thicker deposits of a progradational delta, termed the Lagniappe delta by Kindinger (in press). Stratigraphic evidence indicates that this delta was deposited during the last major lowstand, the late Wisconsinan (Kindinger, 1988). Data from wellsite borings presented by Coleman and Roberts (1988) agree with this interpretation. The younger sequence deposited above the Lagniappe delta has a prominent shelf-wide erosional unconformity as its base which is also the upper boundary of the Lagniappe delta. The stratigraphy of the younger sequence is the erosional unconformity overlain by transgressive deposits and deltaic sediments of the St. Bernard Delta complex. The St. Bernard ceased prograding ~1,200 yrs B.P. (Frazier, 1967). The Chandeleur Islands are remnants of the St. Bernard delta; the retreat path and processes have been described by Penland et al (1985).

Southwestern Region — Louisiana Chandeleur Islands and St. Bernard Delta

The progradation of the St. Bernard delta complex was the most recent major geologic event in the area and covered the west-southwest region of the inner shelf with an average of 13 ft (4 m) of sediment (Kindinger, 1988). This delta thins evenly from west to east and has very little internal structure seen in seismic profile, except for obscure high-angle clinoforms near the pinchout on the shelf (Fig. 6). Frazier (1974) divided the formation of the lobe into six smaller units produced by six depositional episodes; only two of these units enter the Mississippi-Alabama inner shelf area. On the other hand, Coleman

(1976) considered the St. Bernard complex as the product of basically one event rather than delineating smaller units produced by each episode. This delta is cited as the classic example of a delta's destructive phase once abandoned by its river. Marine reworking of the unconsolidated mass of deltaic sediment immediately begins destroying it (Penland et al, 1988). The seaward margin of the delta consists of thin sedimentary beds in which

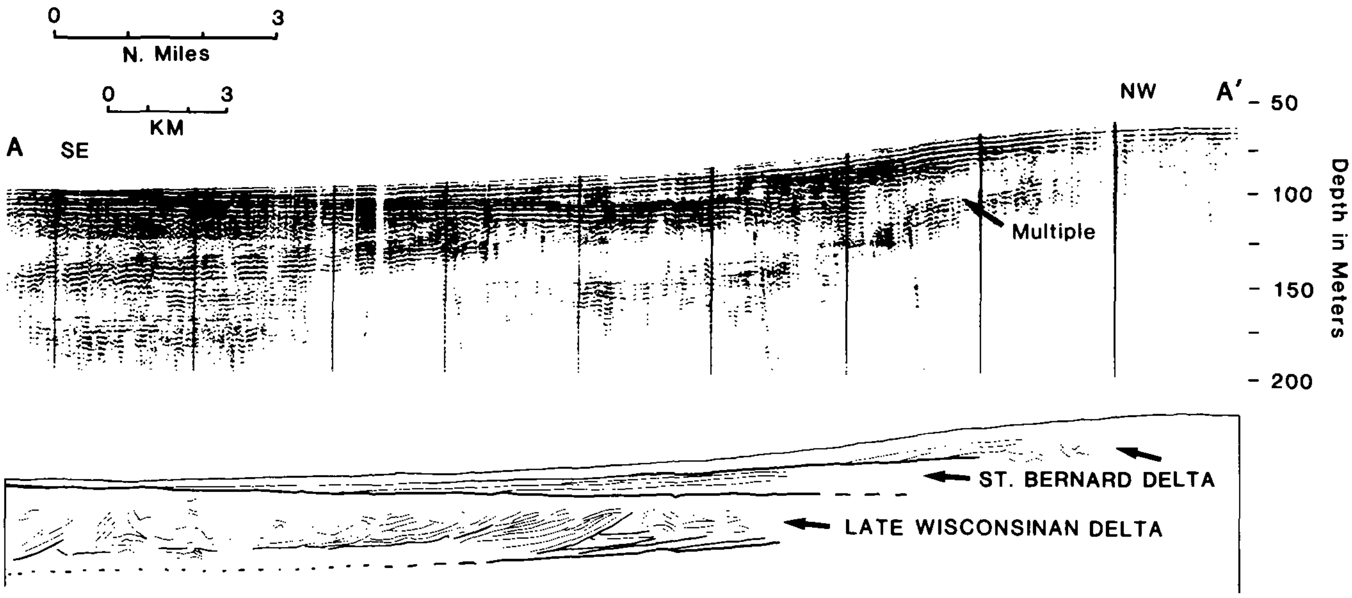


Figure 6. Seismic profile with line-drawn interpretation. The late Wisconsinan delta is bound below by an early Wisconsinan shelf-wide erosional unconformity and above by a Pleistocene-Holocene shelf-wide erosional unconformity. The St. Bernard overlies these deposits and thins to pinch at mid-shelf (Figure 4). Location of A-A′ is shown in Figure 1.

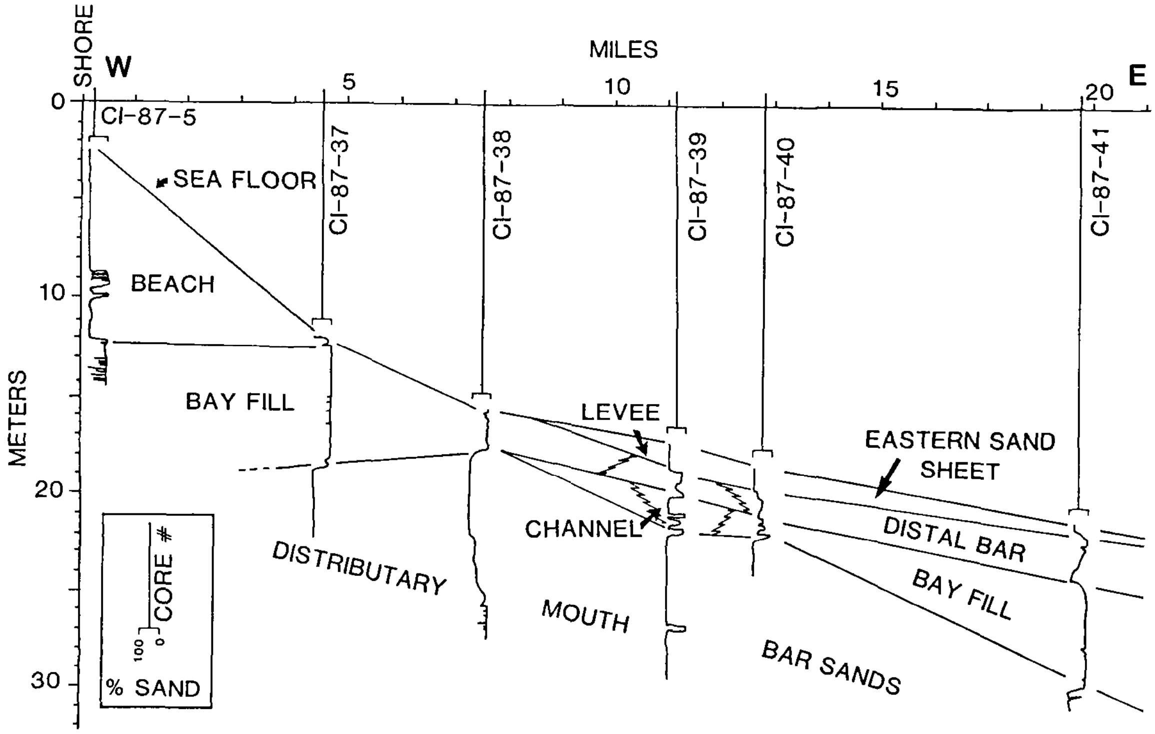


Figure 7. Cross section interpretated from lithologic descriptions of a vibracore transect. This cross section is from the northern flank of the St. Bernard delta with the western end located on the shoreface of the northern Chandeleur Islands. The log shown is percent sand visually described from each core. Location of cores is shown in Figure 2.

most of the progradational foresets have been reworked and destroyed.

In cross section typical delta facies are found within the St. Bernard delta complex; Figure 7 is an example from a series of vibracores on the northern delta flank adjacent to the northern extent of the Chandeleur Islands. It should be stressed that this is a preliminary interpretation of these vibracores. In core CI-87-5, nearest shore, a shoreface/beach sand (Chandeleur sand facies) overlies bay fill composed of clayey-silt to silty-clay with sand stringers. In the mid-section, core CI-87-39, channel and levee deposits overlay distributary mouth bar sands. The channel was confirmed by seismic profile interpretation. The shoreward extent of the Eastern Sand Sheet is visible in this core. Core CI-87-41 is a more complete sequence with similar facies including distal bar facies.

The sand ridges (Fig. 4-B) discussed above are a major feature of the southwestern region, which includes the Chandeleur sand deposit. A core taken on the crest through one ridge shows a 13 foot (4 meter) section of fairly clean sand over alternating beds of silt and silty-sand, topped by bay fill with silt and lenticular sands. An adjacent core taken in the trough contains a shell hash layer capping the corresponding bay fill section in the adjacent shoal crest core.

Northeastern Region — Mississippi-Alabama Nearshore Deposits

Several depositional processes have also affected the nearshore inner shelf. As discussed above, shoreline migration and coastal processes have reworked the sediments and winnowed out much of the finer material. Profile B-B′ (Fig. 8) shows a buried sand ridge whose superstructure has been truncated by a ravinement surface. Also truncated by this ravinement surface are shingled reflectors that may be associated with the sand ridge. The buried sand ridge is found at the east end of Petit Bois Island and is probably the remnant of the westerly migration of Petit Bois Island. The channels shown on the profile may have been stream or tidal channels. The most recent sea withdrawal left the inner shelf subaerially exposed, allowing streams to become entrenched in the area (Fig. 9). Cross section C-C′ shows stream incisions with channel deposits that are examples of the numerous channel incisions and deposits found throughout the inner shelf area. In general, the channel deposits consist of one or more of the following: coarse-grained sand, medium-grained sand, or poorly sorted medium- to silty fine sand. Much of the nearshore area is covered by the Eastern Sand Deposit. A typical example is Core CI-87-40 (Fig. 7). The sands are greenish-gray with high shell content including whole shells and hash.

CONCLUSIONS

The evolution of the Louisiana-Mississippi-Alabama shelf region is the product of transgressive and regressive sedimentary processes. Shelf sedimentary facies were deposited by deltaic progradation followed by shoreface erosion and submergence. The shelf can be divided into two main depositional regions, southwestern and northeastern. The southwestern region formed by the overlap of two ancestral Mississippi River delta complexes on a late Wisconsinan delta. Deposits of the late Wisconsinan delta consist of well-defined coarsening-upward sequences and represent deltaic progradation during low sea level. The relatively recent Mississippi delta complex deposits consist of fine-grained sands, silt and clay. With the late Holocene rise in sea level, marine reworking of an ancient shoreline produced asymmetrical sand ridges (16 ft or 5 m relief). The sand ridges were created by the winnowing of deltaic sediments deposited as distributary mouth bar sands by the St. Bernard delta.

The northeastern region offshore from the barrier islands of Mississippi-Alabama has formed by Pleistocene fluvial systems and shoreface erosion and ravinement. Relict fluvial sands, deposited during the late Wisconsinan lowstand and transgression, underlie the relatively thin Holocene sediment cover. Subsequent sea level rise allowed marine processes to rework and redistribute sediments to produce the nearshore fine-grained facies and shelf sands sheet.

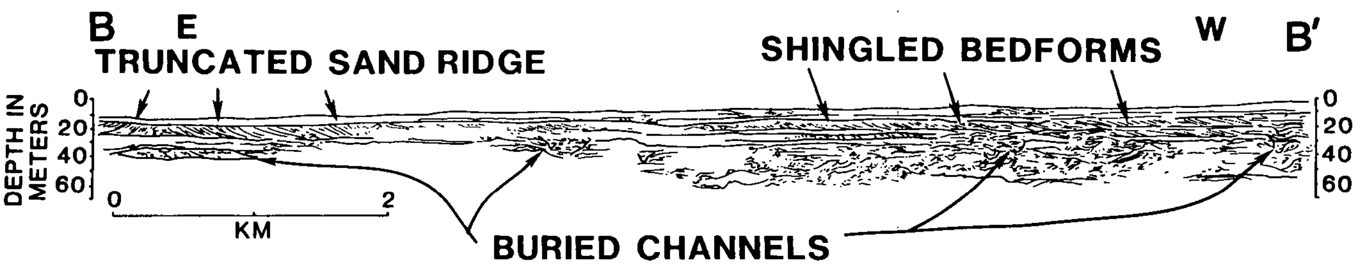


Figure 8. Line drawing of seismic profile. The truncated sand ridge shown to the east is the most eastern remnant of Petit Bois Island. Location of profile B-B′ is shown in Figure 1.

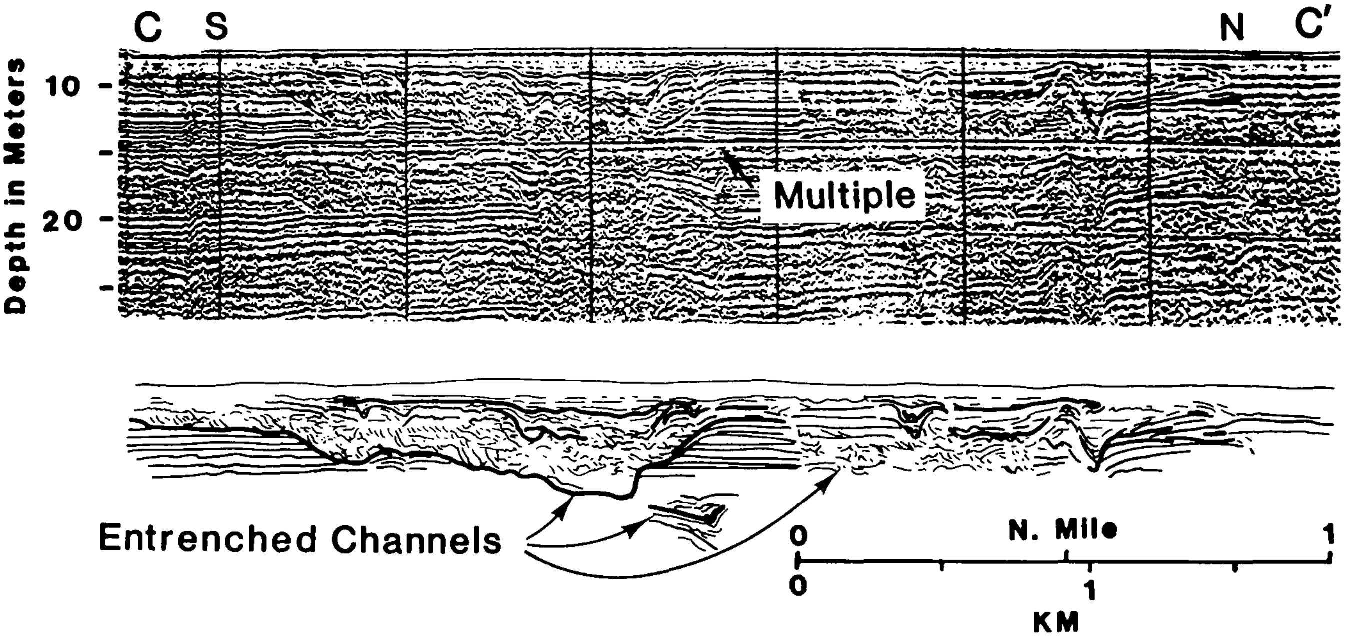


Figure 9. Seismic profile with schematic interpretation. This profile demonstrates the most recent entrenchment of the inner shelf during lower sea level. Much of the nearshore has been incised by similar channels. Location of profile C-C′ is shown in Figure 1.

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