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Depositional History of the Lagniappe Delta, Northern Gulf of Mexico

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Abstract

The northern Gulf of Mexico continental shelf is characterized by superimposing deltas. One such delta, informally named Lagniappe, extends east of the Mississippi Delta from mid-shelf to the continental slope. This late Wisconsinan delta is adjacent to, but not associated with the Mississippi Delta complex: the fluvial source was probably the ancient Pearl and/or Mobile Rivers. The fluvially dominated Lagniappe Delta is characterized by complex sigmoid-oblique seismic-reflection patterns, indicating delta switching of high-energy sand-prone facies to low-energy facies. The areal distribution and sediment thickness of the delta were partially controlled by two diapirs.

Introduction

The morphology of the late Wisconsinan Lagniappe Delta has been influenced by (1) glacio-eustatic sea level fluctuations, (2) seaward accretion of the coastal plain across the shelf during the late Quaternary, (3) the barrier influence of diapiric uplifts. Figure 1 (Kolb and van Lopik 1958) shows the seven known Mississippi Delta complexes that have effectively extended the Louisiana coastal plain onto the continental shelf (Fisk 1944, 1956). Also shown in Figure 1 is the relative position of the previously undescribed Lagniappe Delta, that is adjacent to but not part of the present Mississippi Delta coastal plain complex.

Previous studies in this area used shallow borings to characterize the local geology. Coleman and Gagliano (1964) discussed the cyclic sedimentation of the Mississippi Delta complex, including the St. Bernard Delta that extends onto the Mississippi-Alabama shelf. Coleman's (1976) work on deltas also incorporated a discussion of sea level and deposition, utilizing the Mississippi and St. Bernard Deltas as examples. Studies on the effect of sea level changes on the Mississippi Delta were done by Frazier (1967, 1974), who used borings for his data.

Several investigators have identified Wisconsinan shelf margin deltaic deposits and fluvial systems. Roemer and Bryant (1977) discussed episodes of fluvial and deltaic deposition on the Louisiana shelf, whereas Berryhill and others (1982) presented paleographic maps of the Louisiana shelf edge and slope. More recently, Suter and Berryhill (1985) and Berryhill and Suter (1986) described upper Quaternary shelf margin delta deposits on the Texas and Louisiana continental shelf and margin in detail, using borings and seismic profiles to delineate sea level cycles.

The areal distribution of the Lagniappe was interpreted from 3,200 km of high-resolution single-channel seismic reflection profiles (Fig. 2). A variety of seismic equipment was used: a 400-Joule minisparker, 3.5-kHz transducer, 40- and 5-cu inch airguns, 12-kHz transducer, and a Geopulse Boomer[1] system. Travel time-to-depth conversion was made using a sound velocity of 1,500 m/sec, which is accurate for the water column and upper unconsolidated sediment.

Physiography

The Mississippi-Alabama shelf is a broad, smooth gently sloping (<0.1°) seafloor ranging in water depth from 0 to 75 m (Fig. 3). A shelf break has been formed

[1]Use of brand names within this article is for the purpose of identification only and does not imply endorsement by the U.S. Geological survey or the Minerals Management Service.

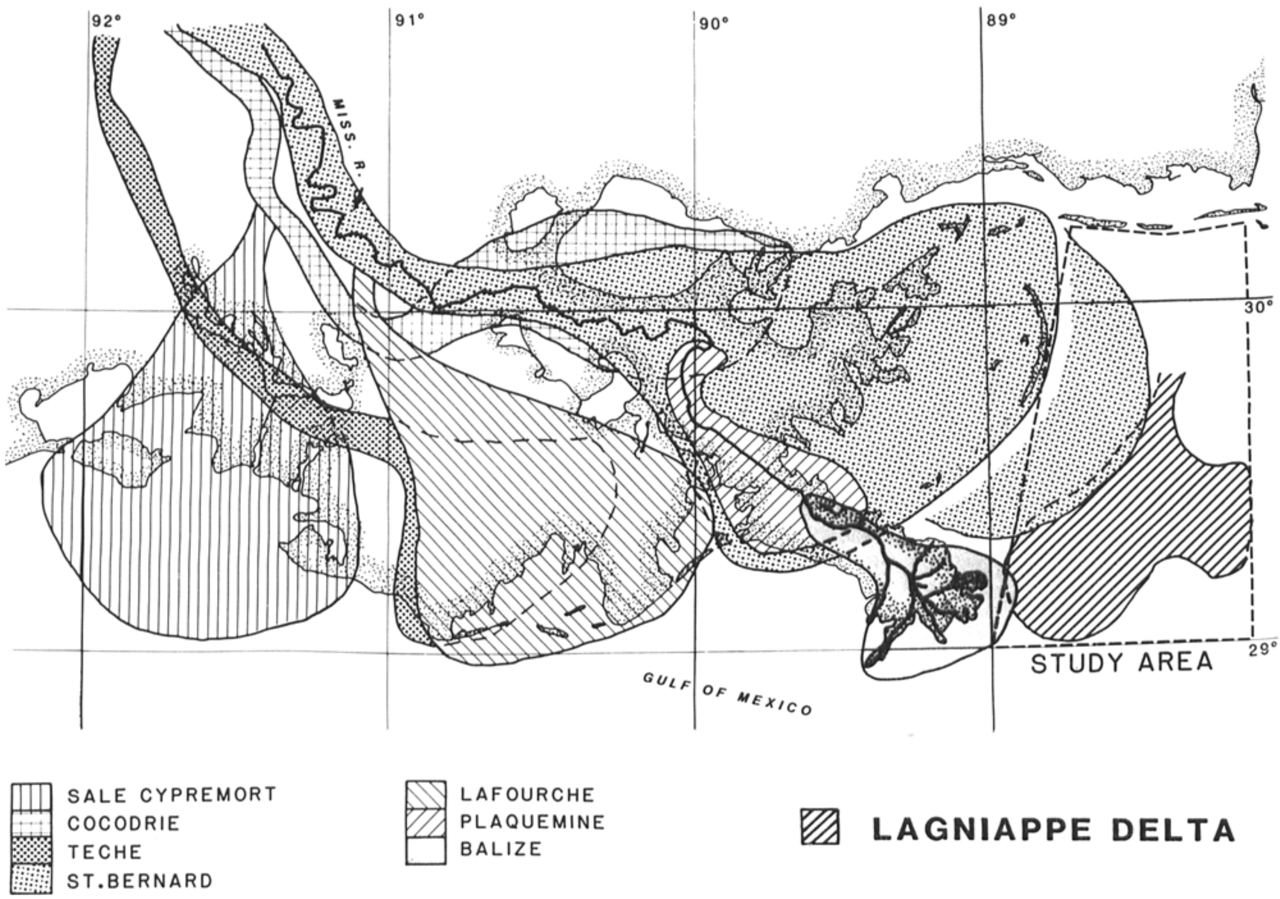

Figure 1. Location of study area and distribution of delta lobes associated with Mississippi River; dashed lines indicate study area and relative location of informally named Lagniappe Delta (modified from Kolb and van Lopik 1958).

by diapirs along the continental margin of this region. Average gradient shoreward of the shelf break is <0.1°, and average gradient basinward of the shelf break is ≥1.0°. The change in slope occurs at water depths of 75 to 80 m. The area was divided into the following regions on the basis of average sea floor gradient: (1) the shelf, 0 to 75 m, and shelf break which trend east-northeast to west-southwest; (2) the upper slope from the break seaward (75 to 400 m), with a gentle gradient of ~1.0°; and (3) the mid-slope area from 400 to 1,300 m deep, with an average gradient of 2.0°–2.5°.

The topography and shallow subsurface sediment characteristics of the Mississippi-Alabama shelf and slope are the results of deltaic offlap depositional sequences over onlap sediments, with intervening periods of erosion during lowstands. Little evidence of structural deformation is present on the shelf; in contrast, there are six diapirs with associated faulting at the shelf break and on the upper slope. Surface sediments of the area can be related to different depositional episodes (Frazier 1974, Kindinger and others 1982). Mazzullo and Bates (1985, p. 459) divided the present shelf into two distinct regions on the basis of surficial grain morphology and age "east of the Mississippi and St. Bernard Deltas, the outer 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 Birdsfoot lobes of the Mississippi Delta, is covered by Holocene sand, silt, and clay deposited in association with the Mississippi Delta (Ludwick 1964, Mazzullo and Bates 1985).

Stratigraphy

The nomenclature for seismic reflectors and sequences used in this article follows that of Vail and others (1977). Stratigraphic units have been defined by utilizing unconformities and correlatable conformities identified from seismic profiles. These units were

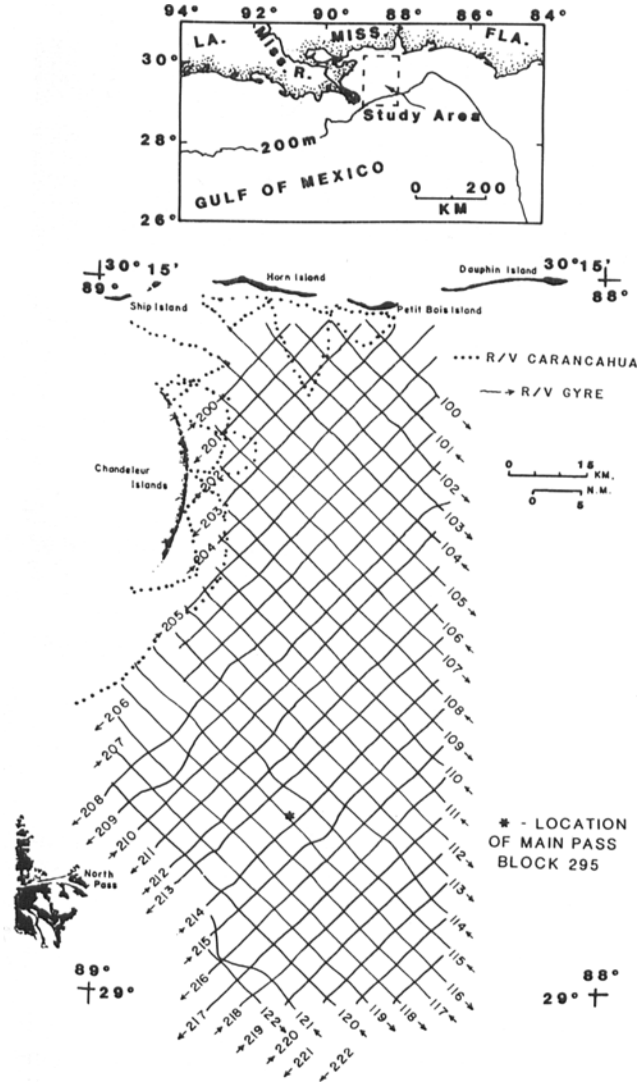

Figure 2. Seismic survey tracklines from 1981 cruises of the R/V *Gyre* and *Carancahua*.

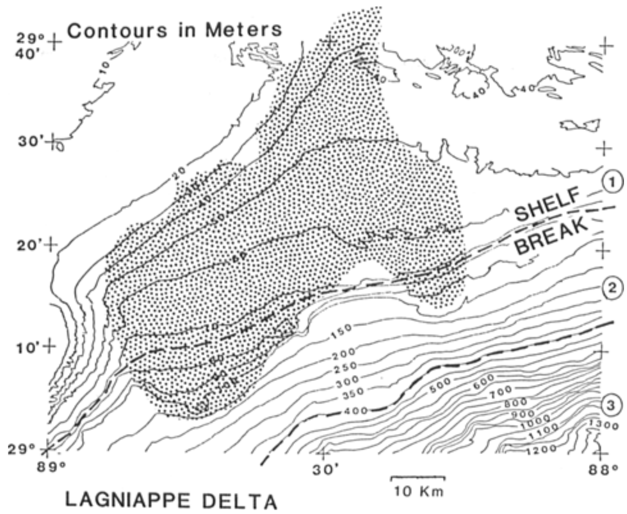

Figure 3. Bathymetric map of study area; dashed lines divide the three regions designated by average slope gradient: (1) shelf break shoreward (10 to 75 m), average gradient of <0.1°; (2) upper slope (75 to 400 m), average gradient of ≥1.0°; and (3) mid-slope (400 to 1,300 m), average gradient of 2.0° to 2.5°.

identified by superposition of geologic sequences and the seismic character of the sequences within the data (Fig. 4). The lower boundary of the oldest sequence is a prominent shelf-wide erosional unconformity identified as early Wisconsinan (Horizon D). This erosional surface was buried by thin parallel beds during the subsequent sea level rise and by thicker deposits of a late Wisconsinan progradational delta (Lagniappe Delta). Stratigraphic evidence leads to the Lagniappe Delta being deposited during the last major lowstand (late Wisconsinan). Data presented by Coleman and Roberts (1988), which includes seismic and boring data, agrees with this interpretation. A younger sequence deposited above the Lagniappe Delta also has a prominent shelf-wide erosional unconformity as its base: the upper boundary of the Lagniappe Delta. The stratigraphy of the younger sequence is the erosional unconformity overlain by transgressive deposits and the deltaic sediments of the St. Bernard Delta complex. The St. Bernard Delta ceased prograding about 1,200 yrs before present (Frazier 1967). The Chandeleur Islands are remnants of the St. Bernard Delta; the retreat path and processes have been described by Penland and others (1985).

Recent advances of time-stratigraphic techniques and methods in biostratigraphy, paleoclimatology, and isotope stratigraphy have led to precise correlations within an absolute time framework with a resolution of 10,000 to 20,000 years during the late Pleistocene (Williams 1984). Oxygen isotope records provide evidence of glacial-interglacial paleoclimatic cycles and glacio-eustatic sea level changes. It is possible to relate the sea level changes seen in oxygen isotope records to the stratigraphy of the Mississippi-Alabama shelf and slope. Figure 5 shows a comparison of the changes in oxygen isotope ratio for the late Quaternary (Williams 1984) with the sea level changes and episodes of shelf evolution interpreted from seismic profiles of the Mississippi Alabama shelf and slope. According to ages given for late Quaternary sea level changes by various investigators (Fig. 5), the approximate age of the Mississippi-Alabama episodes of shelf evolution would be: episode 1—early Wisconsinan lowstand, 150,000 yrs BP; episode 2—middle Wisconsinan highstand, 75,000 to 128,000 yrs BP; episode 3—late Wisconsinan lowstand, 11,000 to 98,000 yrs BP; episode 4—Holocene, 5,000 to 18,000 yrs BP; and episode 5—Holocene, present to 7,000 yrs BP.

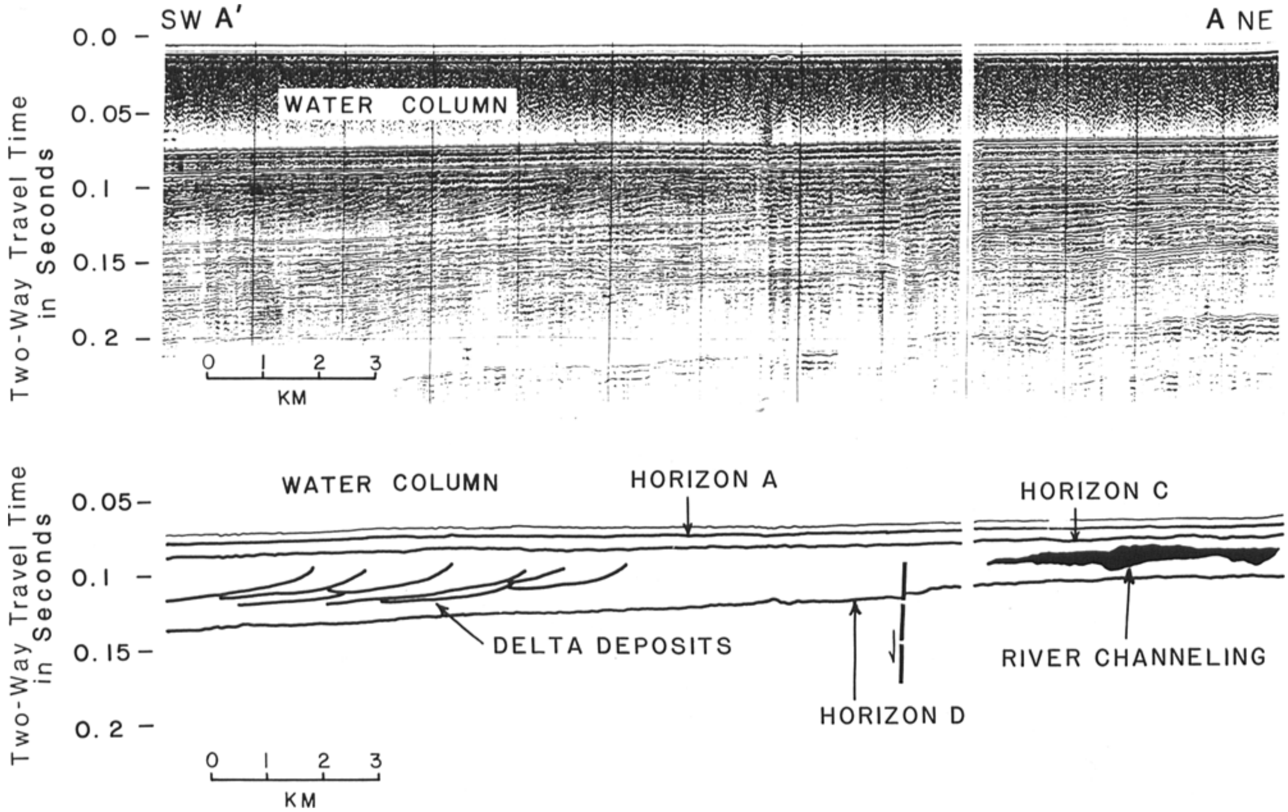

Figure 4. Seismic-reflection profile A–A′ showing highly contrasting seismic-reflection character of the geologic sequences and horizons. Horizon C = Pleistocene-Holocene transition unconformity. Horizon D = early Wisconsinan erosional unconformity with Lagniappe Delta foresets and stream channels (distributaries) are shown between Horizons C and D. Location of profile A–A′ is shown on Figure 7.

Lagniappe Delta Deposition and Diapiric Uplifts

Erosion of upstream coastal plains and the exposed inner and outer shelf during the late Wisconsinan sea level fall led to a major depositional episode (Fig. 6). The Lagniappe Delta is classified as a lobate fluvially dominated delta (Gallaway 1975) beginning at mid-shelf and building out to the shelf break. On the basis of internal framework of the accretionary front, as determined from seismic data, the fluvial source may have been the Pearl and/or Mobile Rivers. Suter and Berryhill (1985) reported that the Mississippi River drainage was to the west of its present position during Wisconsinan time. Mazzullo and Bates (1985) have also shown that the surficial sediments of this region are from southeastern rivers.

Average thickness of the Lagniappe Delta is 30.5 m, and the thickest portion (<90 m) was deposited shoreward and between two diapirs (Fig. 7). The fluvially dominated delta was prograded as delta complexes (Fig. 6) with framework facies of interbedded sands, shales, and clays (Fig. 8). Coleman and Roberts (1988) describe this sandy unit as a "coarsening upward vertical sequence." These progradation sediments appear in seismic profile as foreset and bottomset bedding (Fig. 9), characterized by multiple clinoform reflectors with a reflection character of low amplitude and low-to-moderate continuity. Seismic reflection patterns of the Lagniappe Delta are described as oblique (tangential), sigmoid, and complex sigmoid-oblique progradational patterns as defined by Mitchum and others (1977). The Lagniappe Delta being seen as a complex sigmoid-oblique pattern suggests that it may be due to delta switching, which may occur as a distributary changes direction of progradation (Berg 1982, Fig. 6). These high-energy to low-energy pattern shifts in the Lagniappe Delta represent sand-prone, delta-plain seismic facies coincident with upper horizontal reflections of the high-energy oblique progradational pattern shifting to a predominently shale, low-energy sigmoid pattern.

The main topographic features of the shelf break and upper slope are six salt/shale diapirs. Three diapirs pierce and deform the surface sediments; the other three fold the sediments to form rounded topographic highs (Kindinger and others 1982). Two of the pierce-

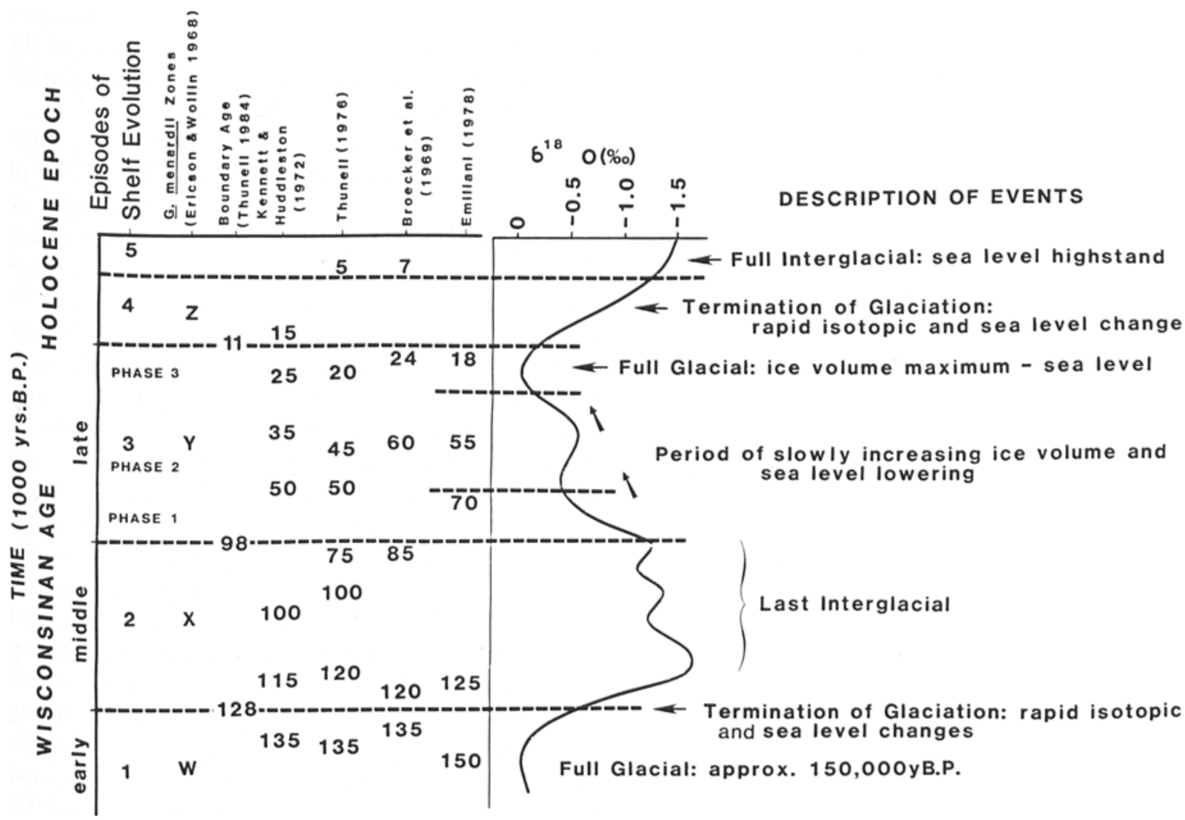

Figure 5. Schematic representation of the oxygen isotope record for the last 150,000 yrs and its approximate relation to major climatic and sea level changes of the late Quaternary (modified from Williams 1984). The ages are taken from models presented by Ericson and Wollin (1968), biostratigraphic zonation of *Globortalia menardii*; Thunnell (1984), ages of *G. menardii* boundaries; Kennett and Huddleston (1972), relative abundance of planktonic foraminiferal; Thunnell (1976), principal component analysis of species abundance data; Broecker and others (1969) $^{231}Pa/^{230}Th$ ratio; and Emiliani (1978), composite oxygen isotope record.

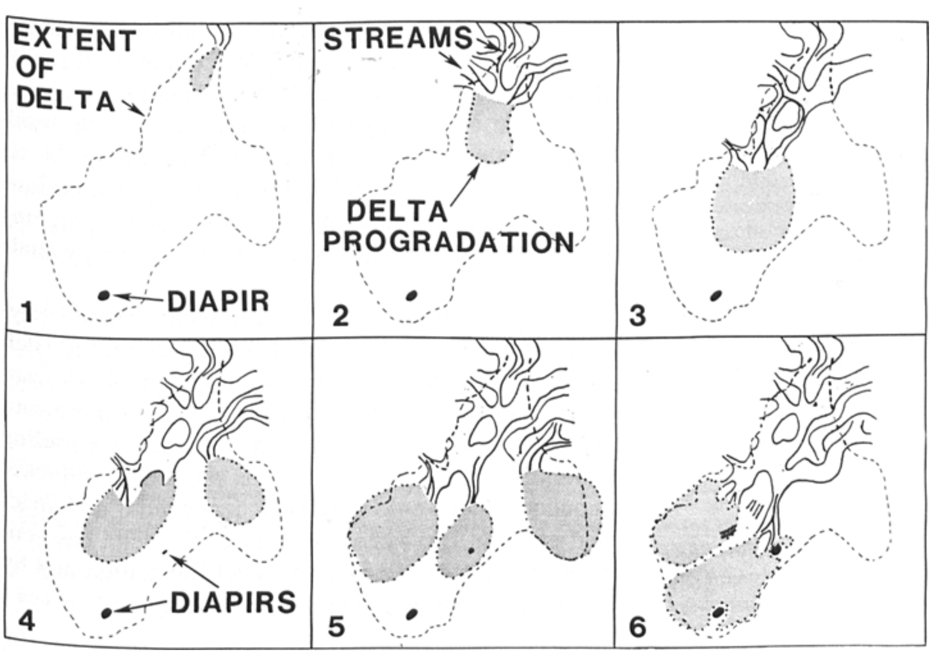

Figure 6. Schematic drawing showing how Lagniappe Delta and distributaries may have prograded (including delta switching) across shelf and around diapiric uplifts during late Wisconsinan lowstand. Frames 1 to 4 show a general basinward progradation of deltaic deposits. In frame 5 deltaic sediments are deposited on top of northeasternmost diapir; in frame 6 delta sediments are "ponded" between and prograded around the diapirs.

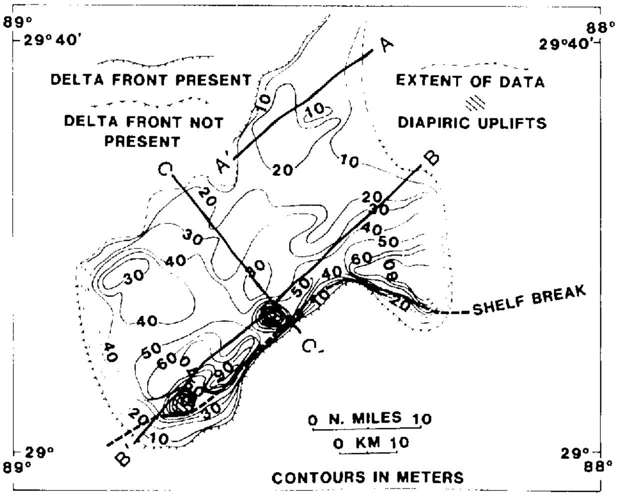

Figure 7. Isopach map showing sediment distribution of Lagniappe Delta with locations of seismic profile A–A′ (Fig. 4), line drawings B–B′ and C–C′ (Fig. 9). Dashed contours with and without hachures indicate extent of the seismic survey. Hachure downdip.

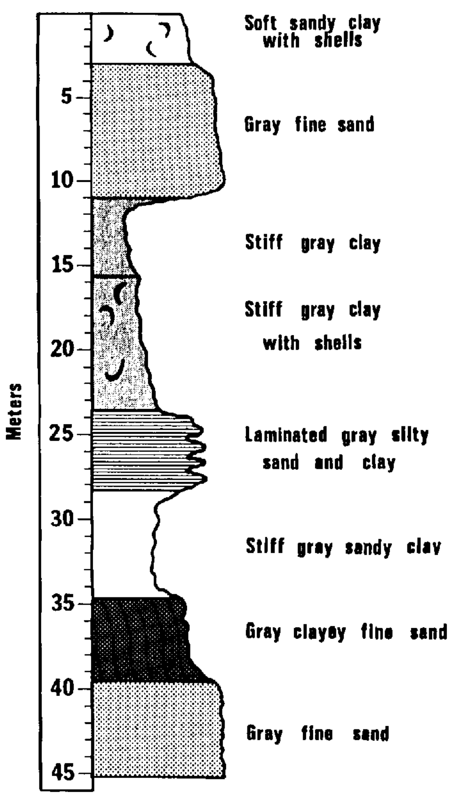

Figure 8. Composite stratigraphic column (from Main Pass Block 295) of Lagniappe Delta deposits. (JM Coleman, Personal Communication 1982).

ment diapirs, uplifted along the shelf break, act as a barrier, directly influencing basinward accretion of the Lagniappe Delta sediments and directing the prograding delta between and around the uplifts.

The diapirs to the west (left in profile B–B′, Figs. 7, 9), which is apparently the oldest, has 15 m of bathymetric relief. The top of the diapiric uplift is planar and forms an angular unconformity on the seaward side (Fig. 9). Because progradational sediments are present landward of the diapir, but are absent on top, movement probably occurred prior to the late Wisconsinan lowstand. During the late Wisconsinan lowstand, this emergent diapir was eroded and subsequently submerged as sea level rose. The angle of the beds onlapping the diapir flanks indicates continuing uplift movement (Fig. 9). The diapir to the east of B–B′ (shown in C–C′, Fig. 7, 9), has a topographic relief of ~20 m. Folded parallel strata overlie the diapir but these bedforms are not greatly distributed. Progadational sediments are present on either side of the feature, and bedforms discernible on top of the diapir exhibit no evidence of erosion. These relations suggest that diapiric uplift occurred during or after deposition of the Lagniappe Delta near the diapir, it is possible that the added delta load caused increased diapir movement at a rate of 13.3 cm/100 yrs since 10,000 yrs BP. [Total displacement (height of diapir above surrounding topography) 13.3 m/ 10,000 = 0.133 cm per year].

Conclusions

As the late Wisconsinan sea level retreated, distributaries from an unidentified river (possibly the Pearl and/or Mobile River) entered the Gulf of Mexico basin and deposited a prograding succession of fluvially dominated delta complexes and interdeltaic facies across the Mississippi-Alabama shelf from the mid-shelf to the shelf break. The Lagniappe Delta sequence is characterized by complex sigmoid-oblique seismic-reflection patterns, indicating delta switching of high-energy sand-prone facies to low-energy shale facies.

The geometry and sediment thickness of the Lagniappe Delta were controlled by diapirs on the shelf break that formed an effective barrier to basinward progradation. Sediments ponded in an area shoreward (behind) and between the diapirs, before prograding around the diapiric masses, thus producing a thicker sequence than would have been deposited if no barrier had existed. The basic geometry of the delta has generally been controlled by sea level fluctuation and by the presence of active and inactive diapirs.

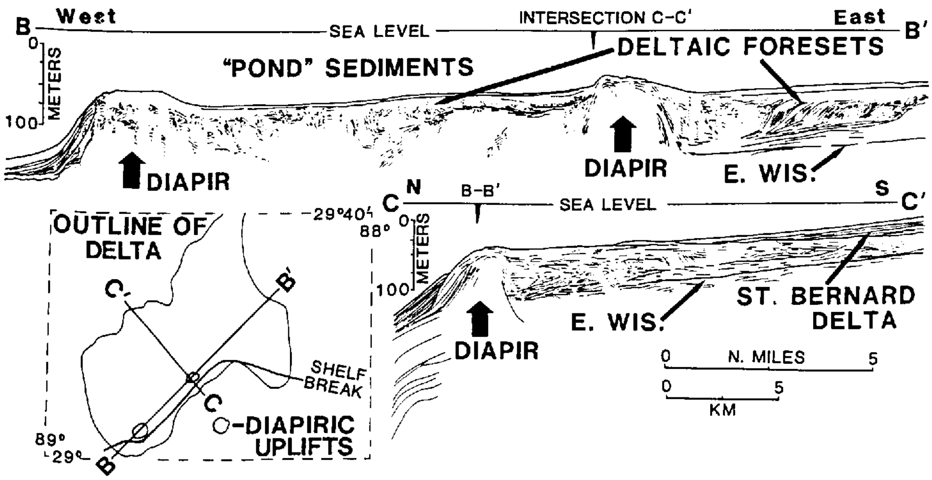

Figure 9. Line drawings of seismic sections B–B′ and C–C′ showing deltaic foresets of Lagniappe Delta and sediments "ponded" between the two diapirs. Diapir at left in section B–B′ has a planar erosional top, whereas diapir at intersection of B–B′ and C–C′ has folded deltaic deposits on top and no evidence of erosion. Relative positions on the early Wisconsinan unconformity, Lagniappe Delta, and St. Bernard Delta are shown. The Pleistocene-Holocene horizon is the water/sediment interface in B–B′ and is the base of the St. Bernard Delta in C–C′.

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