

NEO-TECTONIC FRAMEWORK OF SOUTHEAST LOUISIANA AND APPLICATIONS TO COASTAL RESTORATION

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ABSTRACT

This study was conducted to test the hypothesis that most of the massive land loss in coastal Louisiana during the twentieth century resulted from fault induced subsidence. A regional structural framework was developed from published maps and papers to evaluate evidence of neo-tectonic events. Surface geomorphic signatures of faults were identified for well documented modern fault events and used to locate one hundred surface traces and/or scarps of suspected faults. The first appearance and temporal changes of suspected faults were identified from maps, aerial images, published descriptions and personal interviews and these geomorphic signatures were correlated with known subsurface faults from the regional framework map and from published north-south megaregional sections. These empirically derived megaregional sections are tied into linked tectonic systems of the Gulf Coast Salt Basin, thereby, correlating the surface features and changes to ongoing tectonic processes of the basin. These linked Gulf Basin tectonic processes are driven by crustal down-warping, rifting, sediment loading, compaction, salt movement and gravity slumping.

Magnitude, rate of movement and frequency of fault events were evaluated using maps, aerial imagery, geoarchaeological data, tide gauge records and measurements from re-leveled bench marks. Tests for vertical displacement of near-surface beds were made at six locales using vibrocores and McCauley auger samples.

The Prince William Sound, Alaska earthquake of March 27, 1964, with a magnitude of 8.3, sent shock waves throughout Southeastern Louisiana. It has been tentatively identified as one of the triggering mechanisms for modern regional fault movement and resulting accelerated rates of coastal land loss.

The structural model developed in this study provides a framework for systematic evaluation and understanding of fault processes, for conducting risk analysis of faults, and for planning and design of coastal restoration projects.

INTRODUCTION

Various explanations have been given for the massive land loss which has occurred in Southeastern Louisiana during the twentieth century. A growing body of converging evidence indicates that much, if not most of this loss is the result of fault induced subsidence (Fig. 1). This regional study investigated the relationships between geological faults and changes in landforms and environmental conditions in Southeast Louisiana. The study results confirm that most of the land loss has been caused by the land subsiding and becoming inundated and not erosion along the land-water interface.

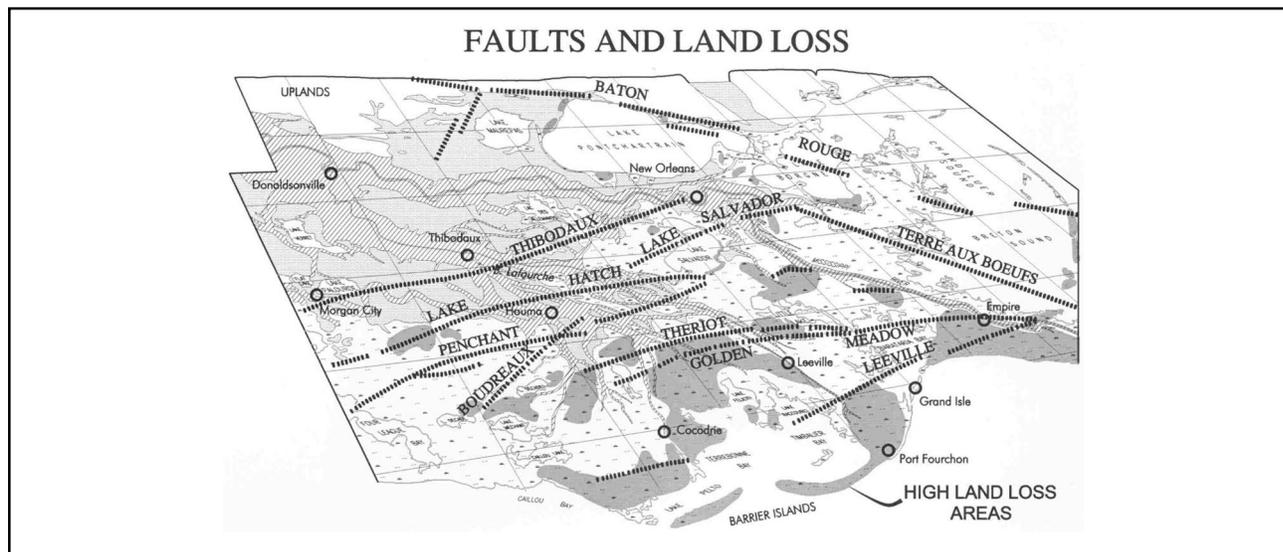


Figure 1. Perspective map showing relationship between faults and areas of high land loss in southeastern Louisiana (modified from Gagliano 1999).

Subsidence is the combined result of compaction/consolidation, eustatic sea level rise and faulting, but findings of this study indicate that fault movement is the primary driving process in the study area. Secondary effects of submergence include saltwater intrusion, increase in tidal movement, marsh die-back and accelerated edge erosion.

Geologists studying the land loss-subsidence phenomenon have debated the relative contributions of the causative processes. Using measurements of land loss for the period 1932-1990, and classifying loss by both geomorphic type of the affected loss area and process causing the loss, Penland et al. (2002:805-806) reported that 54.4% of the land loss in the Mississippi River Deltaic Plain resulted from submergence of land; 30.9% resulted from edge erosion and 14.8% was due to direct removal by human activity. Penland et al. (2002) attributed less than one percent of the submergence (land loss) to faulting and this occurred at a single locale on the down-dropped block of the Empire Fault in the Balize Delta (Penland et al. 1996). Penland et al. (2002) attributed most of the loss to secondary processes resulting from faulting such as altered hydrology, natural waterlogging and alteration due to hydrologic impoundment. However, re-evaluation of the causative processes in reference to the structural framework model developed in this study indicates that faulting was the primary causative process for most of the submergence.

Morton et al. (2002) recently advanced the hypothesis that subsidence is largely the result of fault movement caused by fluid withdrawal and pressure drops in oil and gas fields. However, study results reported in this paper indicate that vertical adjustments to regional tectonic movement which occurs mainly along deep-seated, east-west trending growth faults is the primary cause of submergence and resulting land loss in the deltaic plain (Gagliano 1999, Gagliano et al. 2003).

Differences in research conclusions may seem like frivolous academic disagreements. In an area that lost over 1200 square miles of land during the last 70 years and continues to lose 17.5 square

miles per year, does it matter whether the land is being lost to inundation or edge erosion? Yes, it matters because the success of the proposed \$14 billion joint federal and state "restoration program" depends on the feasibility of, and design for stabilizing the eroding edges and/or filling ever-enlarging subsidence holes with sediment.

The eroding edges are thousands of miles long and the Mississippi and Atchafalaya Rivers which built the land along a broad arc no longer transport enough sediment to the coast to even fill the holes developing each year, much less restore land where it has been lost (Meade 1996, Gagliano 1994). The historic sediment load of the Mississippi has diminished by 50% or more since the 1950s, largely because of sediment trapping by tributary dams (Meade 1996). Furthermore, 50% to 60% of the transported sediment is dumped directly into the Gulf through deep draft navigation channels at the major river outlets.

The proposed coastal restoration program addresses the symptoms of the disease by directing the limited sediment supply to areas of highest land loss. Unfortunately, these are also the areas of highest subsidence. If land loss is due largely to geological subsidence, the plan is flawed. If the very limited supply of sediment is allocated to areas of highest subsidence, the catastrophic rates of land loss will not be abated.

To test the fault induced land loss hypothesis the major objectives were to: 1) synthesize information concerning the known faults and salt domes of Southeastern Louisiana into a structural framework model; 2) identify, classify and characterize surface expressions of faults; 3) compare surface fault expressions to known subsurface faults; 4) evaluate causes of fault movement; 5) determine frequency and magnitude of fault events and 6) evaluate surface effects of fault events.

A century of oil and gas activity has made the subsurface of Southeastern Louisiana, which lies in the Gulf Coast Salt Dome Basin (Gulf Basin), one of the most understood geological provinces on earth. Thousands of wells have been drilled; hundreds of thousands of seismic lines have been run; and the geological literature is voluminous. The success of the oil and gas industry in this and other similar sedimentary basins throughout the world attest to the validity of the process-response models of sediment loading, compaction, salt movement and fault adjustments developed by geologists and geophysicists working in the Gulf Basin. A working premise of the present study was to use this solid foundation of research as a basis for understanding and predicting land form and environmental change.

STRUCTURAL FRAMEWORK

The major fault systems of the region have been known for many years (Fisk 1944, Frey and Grimes 1970, Murray 1960, Meyerhoff 1968, Worzel and Watkins 1973, Fails 1985 and 1990, Fails et al. 1995, Ingram 1991, and many others), but existing structural maps were either too generalized or too detailed for the purpose of this study. Therefore, a synthesis map (*Southeastern Louisiana Structural Framework*) was developed to depict the framework of regional faulting and landform and environmental changes (Fig. 2). Three primary sources were used to develop this map: 1) *Fault and Salt Map of South Louisiana* (Wallace 1966), 2) *Tectonic Map of the Gulf Coast Region, U.S.A.* (Tectonic Map Committee, Gulf Coast Association of Geological Societies and the American Association of Petroleum Geologists 1972) and 3) proprietary fault and salt dome data (Geomap Company 2000). The Wallace map, based on subsurface data assembled from oil and gas fields scattered across south Louisiana, was published at a scale of one inch to four miles and is one of the best sources of such information. The Tectonic Map Committee map has a scale of one inch to approximately 16 miles. The Geomap Company data is current, is digital, shows age of the faults and was used to verify faults depicted on the Wallace and Tectonic Map Committee maps.

CORRELATION OF REGIONAL FAULTS WITH MEGAREGIONAL SECTIONS

Another aspect of depicting the structural framework involved correlation of the known regional subsurface fault trends with north-south cross sections extending across the structural grain of the basin. In the mid-1990s, regional sections derived from seismic data and computer modeling

Through “palinspastic reconstruction,” using the sections and computer programs, Peel et al. (1995), Diegel et al. (1995), Stover et al. (2001) and others have restored the strata and structure exhibited in the megaregional sections to past configurations. This “unpeeling” of the sections provides a better understanding of the continuity of the driving processes and linkages between the processes and relative magnitude of the faults involved.

Much of the movement in Southeastern Louisiana has been related to specific listric faults that merge into the Oligocene-Miocene detachment surface at depths of 20,000 to 30,000 feet (Fig. 3). These faults are millions of years old and are linked to salt diapirs and other structural features.

Most of the twentieth century land loss area lies within the Terrebonne Trough, a salt depletion feature that is part of an intermediate-sized linked system of extension and compression faults (Peel et al. 1995 and Stover et al. 2001). The onshore area is an “extensional zone,” while “compressional zones” lie seaward of the coastal salt ridge in deeper offshore areas (Fig. 3). Extension on a passive margin creates space that will either “attract depocenters” (Curtis and Picou 1978) or result in local transgression.

SURFACE EXPRESSION OF FAULTS

Modern surface fault events were identified through literature searches and personal interviews and their geomorphical signatures were classified, described and used to delineate other surface faults on recent maps and aerial photographs (Fig. 4). Comparison of modern and historic aerial photographs and maps verified signatures and established the date of first appearance of fault-line scarps, associated breakup, fault alignments and other geomorphic indicators. Known and suspected surface faults were correlated with proven subsurface faults and related to the regional tectonic framework. Vegetation change, leakage of brine water and gas seeps along faults appear to be indicators of fault activity.

More than one hundred surface fault traces and/or fault-line scarps have been identified and evaluated with a 61% correlation between probable surface faults and known subsurface faults. Typically, the traces and scarps are broad, arc-shaped segments from 3 to 5 miles in length with associated areas of rapid land loss or wetland deterioration (“land loss hotspots”) on the down-dropped block. In some instances, relict distributary natural levee ridges that cross the faults have been severed and submerged. Down-dropped blocks usually are tilted toward the fault within the zone of deformation and exhibit vertical displacements of 1 to 4 feet. Based on these relationships, a methodology was developed for evaluating, dating and quantifying the amount and rate of fault movement and its effects on surface landforms.

QUATERNARY FAULT MOVEMENT

There is evidence that segments of the Baton Rouge, Golden Meadow, Theriot, Leeville and Venice Faults were active throughout the Pleistocene Period as well as during prehistoric Holocene (pre-1700 AD), historic and modern times. Surface effects of fault movement have occurred, and in some instances appear to be continuing, along other fault zones (e.g., Penchant, Lake Hatch, Lake Salvador, Thibodaux, Lac des Allemandes, and Frenier Fault Zones) north of the Golden Meadow Zone.

The Empire and Bastian Bay Faults are modern fault events that occurred along two segments of the Golden Meadow Fault Zone. Penland et al. (1996) and Kuecher et al. (2001) identified the Empire Fault (Fig. 5 and 6) as an example of surface expression of faulting that appeared in the salt marsh in the mid-1970s and resulted in massive submergence and land loss within a few years. Across coastal Louisiana marshes were most affected by the fault events, but ridges and gulf beaches were also severed and down-dropped. The Empire and Bastian Bay fault events proved to be the Rosetta Stone for deciphering the relationships among fault movement, subsidence and land loss in Southeast Louisiana.

The north-south cross section (Fig. 7) was developed from empirical data obtain from McCauley auger samples, depth measurements and relative marsh elevations (Gagliano et al. 2003) and used

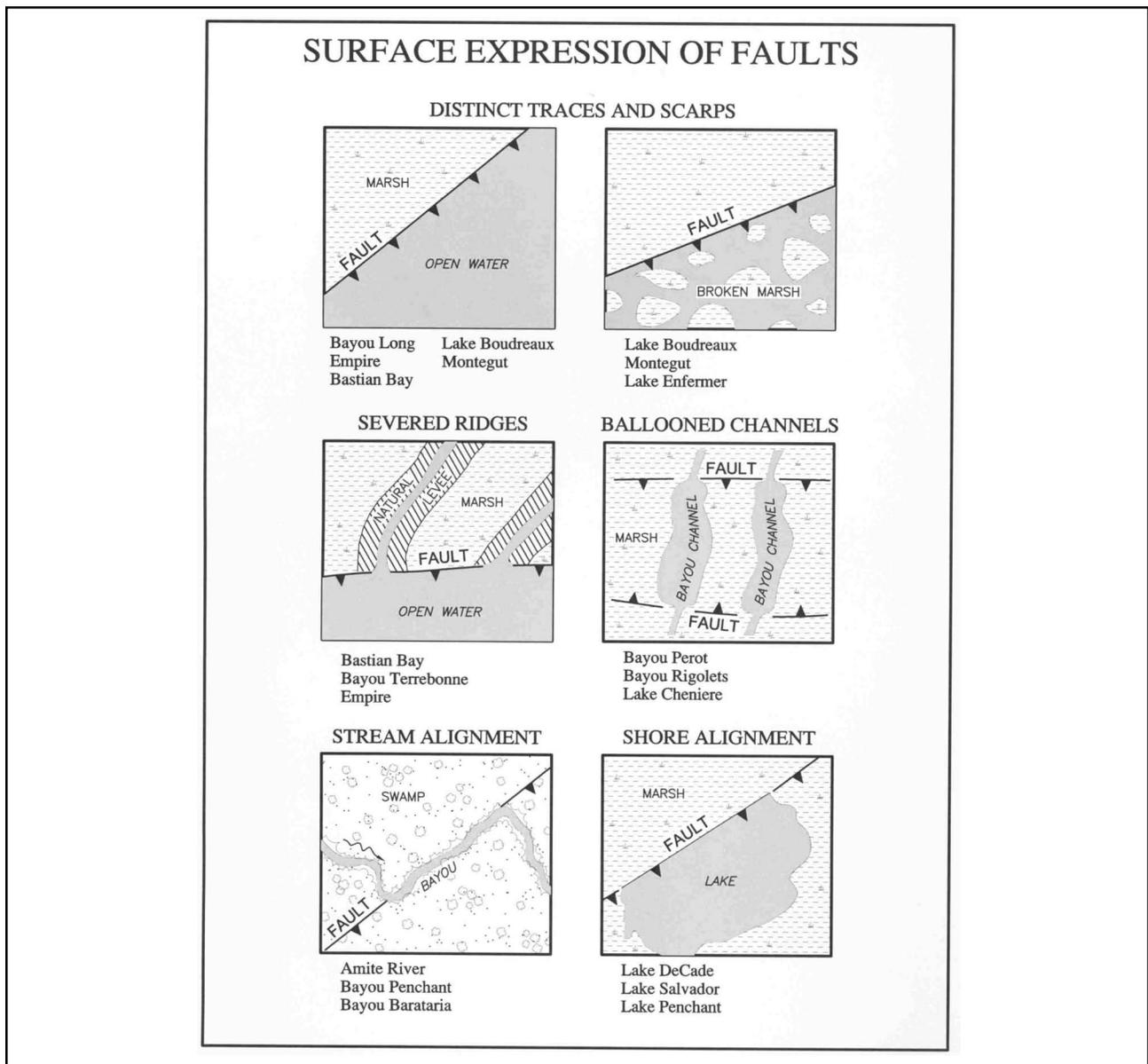


Figure 4. Geomorphological signatures of faults (after Gagliano et al. 2003).

to quantify the effects of the Empire Fault. This 5-mile long scarp with a 3.5 foot vertical displacement along the scarp, caused over 12,000 acres of marsh loss and displaced over 31 million cubic yards of sediment. Effects of the Bastian Bay Fault are evident at a coastal camp located south of this fault (Fig. 8). Since the mid-1970s, marshland around the camp has subsided and the building elevation reduced 4 to 4.5 feet as a result of fault movement.

EARLIER HOLOCENE FAULT MOVEMENT

The recognition and dating of historic and prehistoric signatures of fault events using ge archaeological data and historic maps provide evidence that alteration of landforms by fault-induced subsidence is an ongoing process. Some examples are the vertical displacement of an Early Holocene alluvial terrace of the Amite River by the Baton Rouge Fault (Fisk 1944:Figure 72), historic severance and submergence of the natural levees of Bayou Terrebonne and opening of Lake Barré by the Leeville Fault around the turn of the nineteenth to the twentieth century (Fig. 9) (Gagliano et al. 2003:84-87), control of alignment of the Teche-Mississippi relict trunk channel by the Frenier

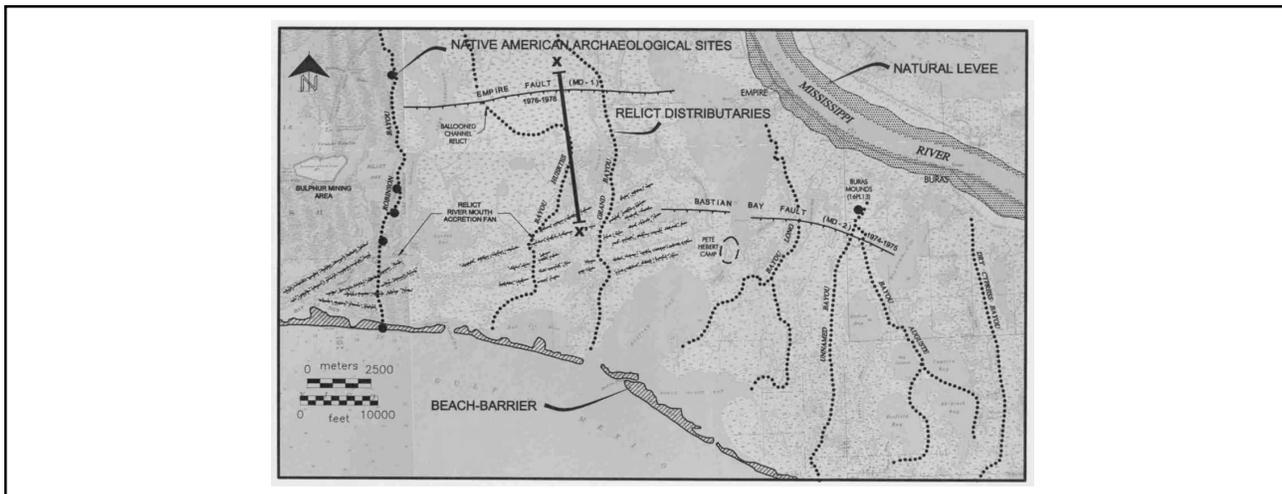


Figure 5. Topographic map showing landforms and conditions in the West Plaquemines Delta Plain circa 1941-1948. Relict Mississippi River subdelta distributaries and river mouth accretion ridges are shown. The locations of the Empire and Bastian Bay Faults, which appeared on the surface in the mid 1970s, are also shown (after Gagliano et al. 2003).



Figure 6. Aerial image showing the West Plaquemines Delta Plain in 1998. The Empire and Bastian Bay Faults became active during the 1974 through 1978 period, resulting in massive land submergence (after Gagliano et al. 2003).

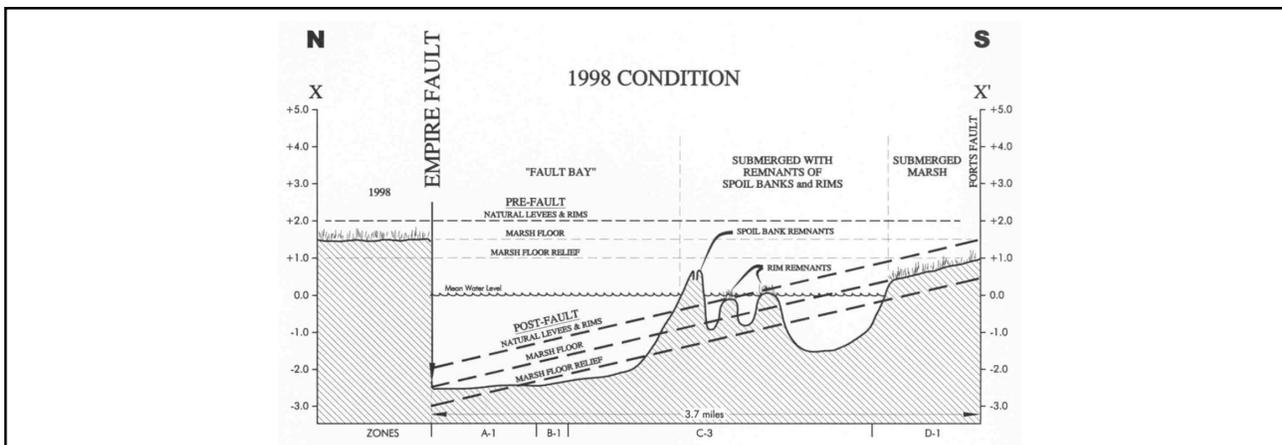


Figure 7. Section across the down-dropped block of the Empire Fault, showing submergence and tilting. The down-dropped surface slopes toward the fault plane as a result of rotation during fault movement. The location of this north-south section is shown as x-x' in Figures 5 and 6.



Figure 8. Photograph of Pete Hebert's camp, 2001. The camp is located one mile (1.6 km) south of the Bastian Bay Fault scarp (location shown in Figure 5). The camp was originally built on the bank of Bayou Ferrand in the 1960s. The land that the camp was built upon is now completely submerged and the elevation of the building has been reduced 4 to 4.5 ft (1.2 to 1.4 m) largely as a result of fault movement in the mid-1970s.

Fault (Gagliano et al. 2003:Table 3, Figure 20) and control of alignment of the Bayou Barataria relict distributary by the Lake Hatch Fault (Gagliano et al. 2003:72-74).

PLEISTOCENE FAULT MOVEMENT

There is abundant evidence of vertical fault displacement of both the base and the top of Pleistocene deposits. Topographic escarpments, shallow borings and sub-bottom profiles indicate vertical displacement of the top of the Pleistocene along the Baton Rouge and other faults in the Lake Pontchartrain area (Fisk 1944, Saucier 1963, Kolb et al. 1975, Lopez 1991, Lopez et al. 1997, McCulloh 2001, Penland et al. 2001 and Gagliano et al. 2003). Ten feet or more of displacement on this surface is common.

Sabaté (1968) evaluated the distinctive interglacial contact marking the bottom of the Pleistocene in a zone extending across Southeastern Louisiana (Fig. 10) and found the contact to be 1800 to 4300 feet below the surface. The base of the Pleistocene is breached by nine salt domes, some of which reach nearly to sea level, while others show sharp relief and are almost completely buried by the Pleistocene. Sabaté (1968:373) states that :

Faults with throws of up to several hundred feet cut many of the structures and influence soil and gas distribution. Many of these faults can be traced downward into the Miocene primary producing measures. Their characteristic downward increase in throw and thicker downthrown blocks qualify them as "growth" or "contemporaneous" faults...

Sabaté's map (Fig. 10) shows evidence of fault movement at the Pleistocene base along 80 miles of the Golden Meadow Fault Zone. A pronounced graben occurs along the Golden Meadow Fault in the Bayou Lafourche area and there is movement at Point au Fer in the same zone. The map also shows fault movement along segments of the Leeville Fault, particularly in the vicinity of salt domes and along the Coastal Salt Ridge, where the counter-basin Venice Fault along the north side of the ridge shows movement.

MAGNITUDE, RATE AND FREQUENCY OF VERTICAL MOVEMENT

In a seminal series of papers Penland and his associates (Ramsey and Moslow 1987, Penland et al. 1988, Penland et al. 1989) ferreted out effects of eustatic sea level rise by comparing tide gauge

records from stations across the northern Gulf of Mexico region. They used tide gauge records and measurements from re-leveled bench marks in Southeastern Louisiana to show spatial and temporal variation attributed largely to non-eustatic subsidence. Penland et al. (1988) found that the rates of relative sea level rise in Southeastern Louisiana were significantly higher than those measured at tide gauges and benchmarks located in tectonically stable areas, such as Pensacola, Florida. The rates of rise at Pensacola (0.0075 ft/yr) were assumed to represent eustatic sea level rise, and the difference between the rate of eustatic rise and the rates measured in Louisiana were assumed to be a measure of subsidence (Ramsey and Moslow 1987, Penland et al. 1989).

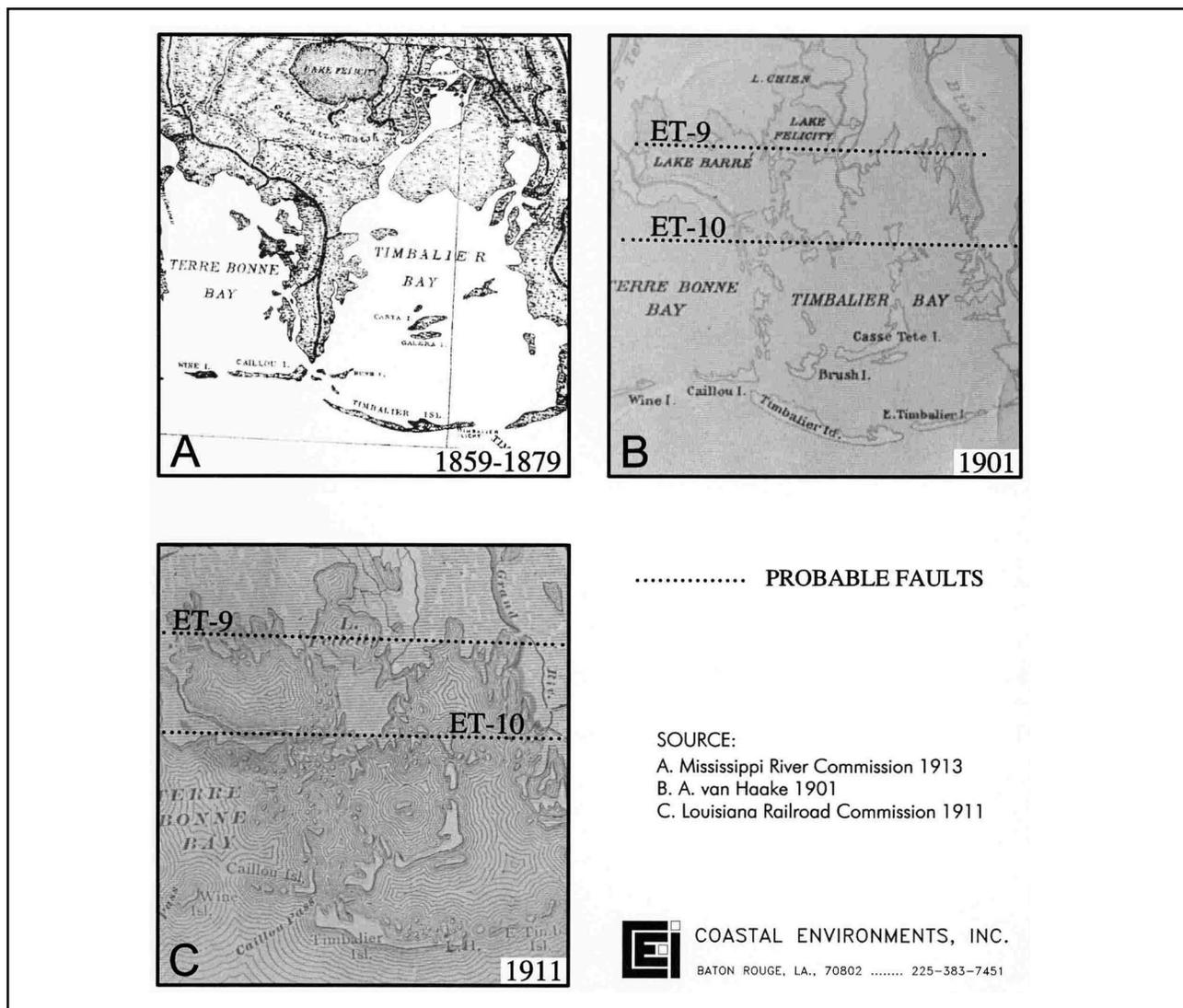


Figure 9. Comparison of historic maps showing the severance of the natural levees of Bayou Terre Bonne and the opening of Lake Barre between 1859-1879 and 1902. The locations of suspected faults have been added to the maps.

Penland et al. (1988) analyzed the tide records in 20-year epochs to average out long-term variations and found that many coastal Louisiana stations had a significant increase in rate of relative sea level rise between the two periods of analysis, Epoch 1 (1942 to 1962) and Epoch 2 (1962 to 1982) (Ramsey and Moslow 1987; Penland et al. 1988). Other researchers have used the Penland et al. (1988) analysis technique to gain further understanding of the causes of temporal and spatial variations in subsidence (Kuecher 1994, Kuecher et al. 2001, Gagliano 1999, Morton et al. 2002, and Gagliano et al. 2003).

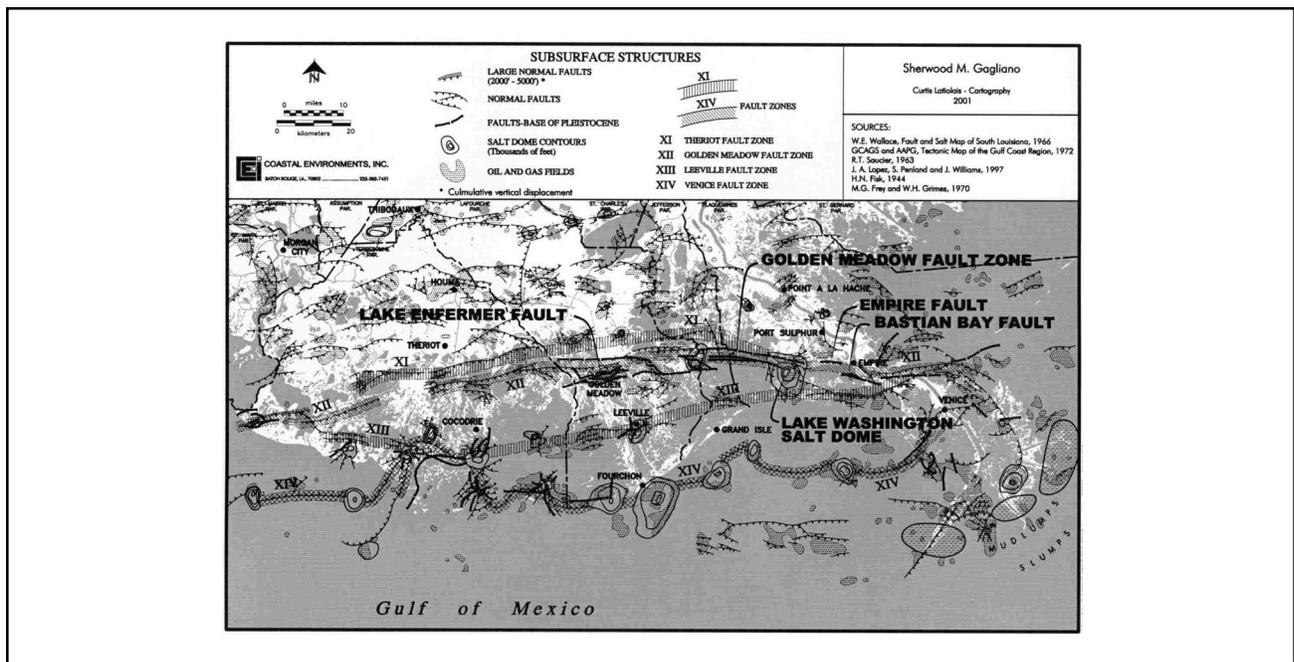


Figure 10. Map showing the locations of the Empire, Bastian Bay, and Lake Enfermer Faults in reference to regional fault zones, salt domes, oil and gas fields, and related features. Faults that displaced the base of the Pleistocene are also shown (modified from Wallace 1966, Sabaté 1968, and Gagliano et al. 2003).

For this investigation data from tide gauge records and re-leveled benchmarks were analyzed to determine amount, rates and time of occurrence of vertical movement at specific locations. These findings were correlated with movement along fault segments and faults in reference to the Tectonic model. Results indicate that the total measured amount, and calculated rate of vertical movement may be a function of the data point location in reference to the deformation fields of individual faults.

Re-evaluation of tide gauge records from the Corps of Engineers and the National Ocean Survey indicates that two specific years, 1964 and 1971, mark abrupt changes in recorded tidal elevation. These specific dates also mark abrupt changes in records from tide gauge stations that are widely distributed across the deltaic plain and that are also associated with different regional fault zones. For example, the gauge at Little Woods is on the Frenier Fault Zone, the gauge at Houma is on the Lake Hatch Fault Zone, the gauge at Golden Meadow is on the Golden Meadow Fault Zone and the gauge at Grand Isle is south of the Leeville Fault Zone.

Changes in recorded tide elevations before and after 1964 and 1971 are also found in data sets from re-leveled benchmarks. Some spikes and trends in the records are apparently related to floods, droughts and storms. However, the regional distribution of the stations whose records show abrupt changes, suggests another cause for the changes. It appears the 1964 changes coincide with the Prince William Sound, Alaska earthquake of March 27, 1964, which had a magnitude of 8.3 and generated tsunamis and tremors that were felt globally. There were reports of long-period surface waves setting up periodic oscillations in closed water body surfaces throughout the Gulf Coast region. The effects were noticed in the rivers and bayous of the New Orleans area where boats and barges were slammed against piers and/or torn from their moorings. There were also reports of boats breaking from their moorings in the marina at Venice, Louisiana, located in the active Balize Delta area. Accounts indicate that water movement had peak-to-peak oscillations on the order of 4 feet with a 20-minute duration (Anonymous 1964). In Baton Rouge, water in swimming pools, including the pool on the fourth floor of the Capital House Hotel, was disturbed (Jim Lacaffine 1964).

Fault movement is often episodic. The periodic movements have occurred over millions of years and continued to occur throughout the Quaternary into modern times. Intervals of active fault movement are separated by periods of dormancy or movement at a slow creep. In the latter instance, sedimentation rates may approximate the rate of fault movement and mask surface effects. In contrast, sediment deprivation characteristic of the late twentieth century accentuates surface signatures.

CAUSES OF FAULT MOVEMENT

Fault movement is a response to interactions among regional crustal movement and rifting, geosynclinal down-warping, sediment loading, compaction, salt movement and gravity slumping (linked Gulf Basin tectonic processes). These interactive processes are characteristic of the Gulf Basin and have been active for millions of years.

The relationship between regional faults and salt domes appears to play a role in activation of faults. The buoyant salt maintains its vertical position along the cracks. Differential movement between the low-density salt and down-building of overlying and adjacent sedimentary deposits appears to have a wedging (space creating) effect on the faults, which may initiate brine water and gas movement up fault planes. The water and gas in turn may lubricate the fault plane surfaces and cause instability along fault segments. Brine and gas may also cause vegetation changes at the surface and indicate areas of active or potential movement.

Localized natural and anthropomorphic events that may trigger fault movement include flood and storm water loading, compaction, dewatering and fluid withdrawal. Removal of oil, gas and produced water may cause localized subsidence and fault movement (White and Tremblay 1995, White and Morton 1997, Morton et al. 2002). Compaction, consolidation, and diagenesis of Holocene sediments also contribute to the overall subsidence rate. Adjustments to vertical changes resulting from these processes appear along fault lines.

Morton et al. (2002) cited correlations between subsidence rates and land loss "hot spots" with records of production and pressure drops in oil and gas fields in Terrebonne and Lafourche Parishes, Louisiana as evidence for activation of faults by fluid withdrawal. They concluded that subsidence is a function of fluid withdrawal, and therefore, a reduction in oil and gas production should result in a corresponding decline in subsidence rates.

The locations of many oil and gas deposits in Southeastern Louisiana, including those cited by Morton et al. (2002), are found in structural traps and expanded sections located on the down-dropped blocks of growth faults. Land loss hot spots also occur on down-dropped blocks of faults. Rates of change of each are dependent on fault movement, and both are, therefore, dependent variables.

This paper presents a different interpretation by distinguishing between localized anthropomorphic causes of accelerated subsidence and regional tectonic events. The latter are the climax of a gradual increase in instability resulting from the linked Gulf Basin tectonic processes. The long-term geological record is replete with episodic expansions of section on the down-thrown blocks of growth faults. The cusped, down-to-the basin pattern of growth faults is recorded hundreds, if not thousands of times in the geological record of the Gulf Basin. The probability that fluid withdrawal in the twentieth century caused the same response is remote. The expanded sections associated with these relict growth faults display the same patterns as those resulting from fault events which unfolded during the second half of the twentieth century. The only difference between these ancient movements and the modern ones may be that humans were present to witness and document the twentieth century fault events and the acceleration of secondary effects resulting from their activities.

IMPLICATIONS OF FAULT EVENTS

Fault movement changes surface elevations and slopes and affects natural surface features, such as wetlands, ridges, fastlands and barrier islands. Subsequently, fault movement can also affect flood protection and drainage levees, hurricane evacuation highways and oil and gas pipelines which cross these faults.

This study further established and evaluated the relationship of faults to local and regional land loss patterns. Direct associations were found between fault events and die-back of *Spartina sp* (“brown marsh”) (Fig. 11) as well as live oaks (*Quercus virginiana*) and bald cypress (*Taxodium distichum*). Small increments of vertical displacement along faults in the low-lying coastal landscape result in large areas of submergence and land loss.

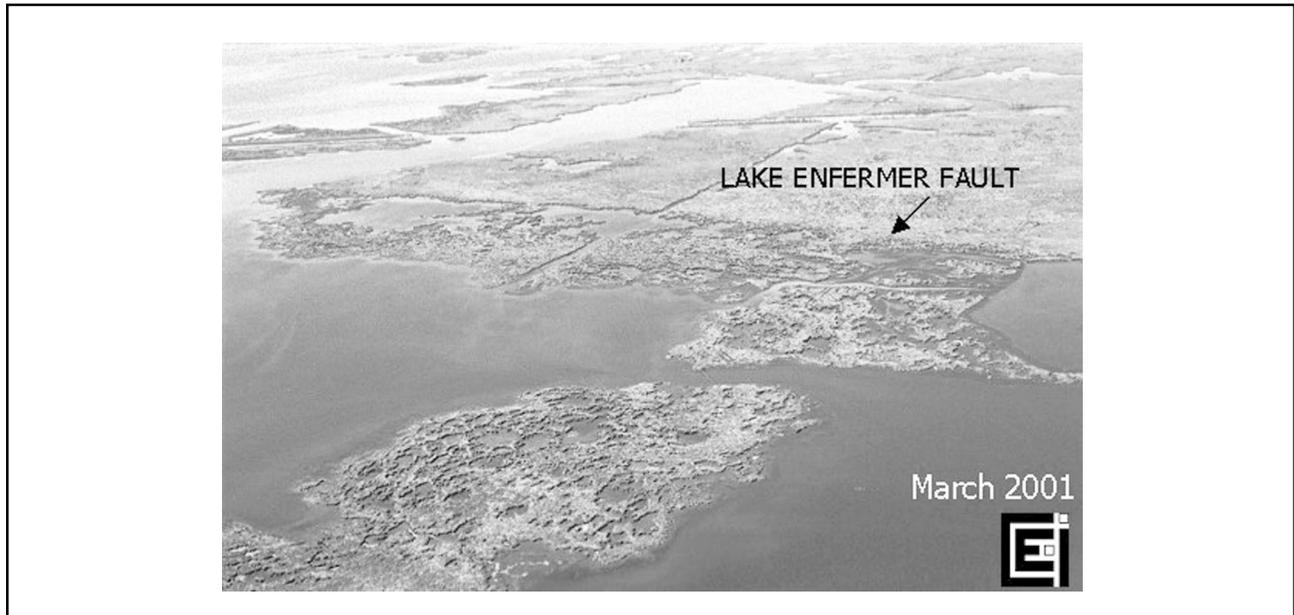


Figure 11. Brown marsh on the down-dropped block of the Lake Enfermer Fault, a segment within the Golden Meadow Fault Zone (after Gagliano et al. 2003).

Faulting is an underestimated natural hazard in the region. Geological faulting is relentless, irreversible and largely beyond human control. Faults and salt domes are permanent features of the region and some have remained periodically active for 100 million years or more and will continue indefinitely until there is a change in fundamental Gulf Basin linked tectonic processes.

Faulting should be included as a basic design parameter for multiple-use coastal restoration. To date, efforts to restore coastal Louisiana have been viewed largely as a fight against edge erosion, a horizontal process. In reality, submergence is a vertical process; the bottom is falling out. If the coast is to be stabilized and moved toward a sustainable condition this fundamental difference must be taken into consideration. The findings of the study have direct application to the planning and design of coastal restoration projects (barrier island restoration, controlled diversions, marsh rebuilding with dredge materials) as well as infrastructure projects such as flood protection levees, ports, locks and highways.

Until recently the relationship between geological faulting and coastal land loss had been largely neglected by researchers, and by the coastal restoration community. There has been a curious disconnect between subsurface oil and gas research and coastal restoration research. The coastal restoration community has been reluctant to accept faulting as a major cause of coastal land loss. This may be due, at least in part, to the psychological difficulty of dealing with the relentlessness and finality of the process.

However, this study matched projected surface traces of known subsurface faults with surface geomorphic signatures of faults in the coastal wetlands and linked the evidence to ongoing tectonic processes of the Gulf Basin, thereby, moving “fault induced subsidence” from the realm of a hypothesis to reality. Surface expressions of faults do exist, their appearance and growth have been identified and measured on aerial photographs, and their vertical displacement determined by

measuring movement of natural and man-made surface features. The challenge now is to use this information to design infrastructure capable of functioning long-term on a dynamic surface and to select coastal restoration measures appropriate for fault driven environmental conditions. (i.e. direct efforts to shore zone alignments that are sustainable, build essential infrastructures elements on structures, direct wetland restoration to areas with low subsidence rates.)

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DISCLAIMER

The interpretations, findings and recommendations presented in this paper are those of the authors and may or may not represent views or positions of the funding agencies.

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** The Baton Rouge Fault System is made up of two zones, the Denham Springs – Scotlandville Zone and the Baton Rouge Zone. It is the former that skirts the northern shore of lake Pontchartrain (McCulloh, 2003).*