Journal of Coastal Research	9	2	462–480	Fort Lauderdale, Florida	Spring 1993

Tidal Inlet Evolution in the Mississippi River Delta Plain

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ABSTRACT

LEVIN, D.R., 1993. Tidal inlet evolution in the Mississippi River delta plain. *Journal of Coastal Research*, 9(2), 462–480. Fort Lauderdale (Florida), ISSN 0749-0208.

A sequence of tidal inlet morphologies ranging from wave- to tide-dominated occurs along the shoreline of the Mississippi River Delta Plain. There is no appreciable variation in the mean tidal range (0.35 m) or mean significant wave height (0.5 m) in this reach of coastal Louisiana. The arrangement of sand bodies in the individual inlets is associated with the tidal prism exchanged between the respective bay and the Gulf of Mexico, and sediment supply.

This study presents the argument that temporal changes in tidal prism and sediment supply results in a sequential change of inlet morphology. This inlet evolution is noted during the abandonment phase of individual delta lobes of the Mississippi River. During the first stage of abandonment, represented by headlands flanked by barrier spits, high rates of subsidence cause bays to expand. As bay area increases, tidal prism increases causing wave-dominated inlets to evolve tide-dominated morphologies. At the beginning of the second stage of delta lobe abandonment (barrier island arc systems) the sediment supply becomes limited. The spits confining tide-dominated inlets fragment causing the inlet throat to widen; tidal current strength decreases and waves begin to fill the main ebb channel with sands derived from the ebb tidal delta.

ADDITIONAL INDEX WORDS: *Inlets, transgression, barrier islands, tidal prism.*

INTRODUCTION

The morphology of a tidal inlet is the result of multiple, interactive variables. In 1975, Hayes correlated tidal range with the occurrence of inlet morpho-types: Wave-dominated inlets occur in microtidal regimes and tide-dominated in mesotidal regimes. Later, tidal inlet distribution was described in terms of the mean tidal range and mean wave height affecting a specific coastal reach (Hayes, 1979). More recently, inlet sand body morphologies have been associated with the relative sediment transport potential of waves and tidal currents (Hubbard *et al.*, 1979; Davis and Hayes, 1984).

Tidal prism is considered the parameter that exerts the most influence on inlet throat cross-sectional area (Escoffier, 1940; O'Brien, 1969; Oertel, 1975; Jarrett, 1976) and inlet morphology (Mehta, 1975; O'Brien and Dean, 1977; Davis and Hayes, 1984). Larger tidal prisms require proportionally larger throat cross-sections than a channel affected by a smaller tidal prism (Leconte, 1904; Brown, 1928; O'Brien, 1969; Jarrett, 1976). Inlets affected by increasing tidal prisms tend to enlarge their channel area (Fitzgerald and Nummedal, 1983; Suter and Penland, 1987) and associated tide-formed sand bodies (Walton, 1977). Temporal decreases of bay area result in decreasing tidal prism, smaller inlet cross-sections and an increase in wave formed inlet shoals (Gammisch *et al.*, 1988).

Tidal prism is an especially important determinant of inlet morphology in the Mississippi River Delta Plain (MRDP) region of coastal Louisiana (Figure 1). Wave energies along the MRDP are low and do not exhibit appreciable alongshore variation. The microtidal range is also constant. By fixing these variables the distribution of tidal inlet morphologies along the delta plain must then be associated with bay area and tidal prism. In addition, high rates of landloss and relative sea level rise (RSLR) in the MRDP causes bay areas to expand significantly in less than a century (Gagliano *et al.*, 1981; Salinas *et al.*, 1986). The increased tidal prism of the expanding bays causes a commensurate boost in tidal current velocities. The faster currents augment sand transport capabilities in the inlet and cause sand body morphologies to change in a non-random fashion. The increase in tidal prism also supports the establishment of stable multiple inlet systems.

92028 received 26 March 1992; accepted in revision 10 July 1992.
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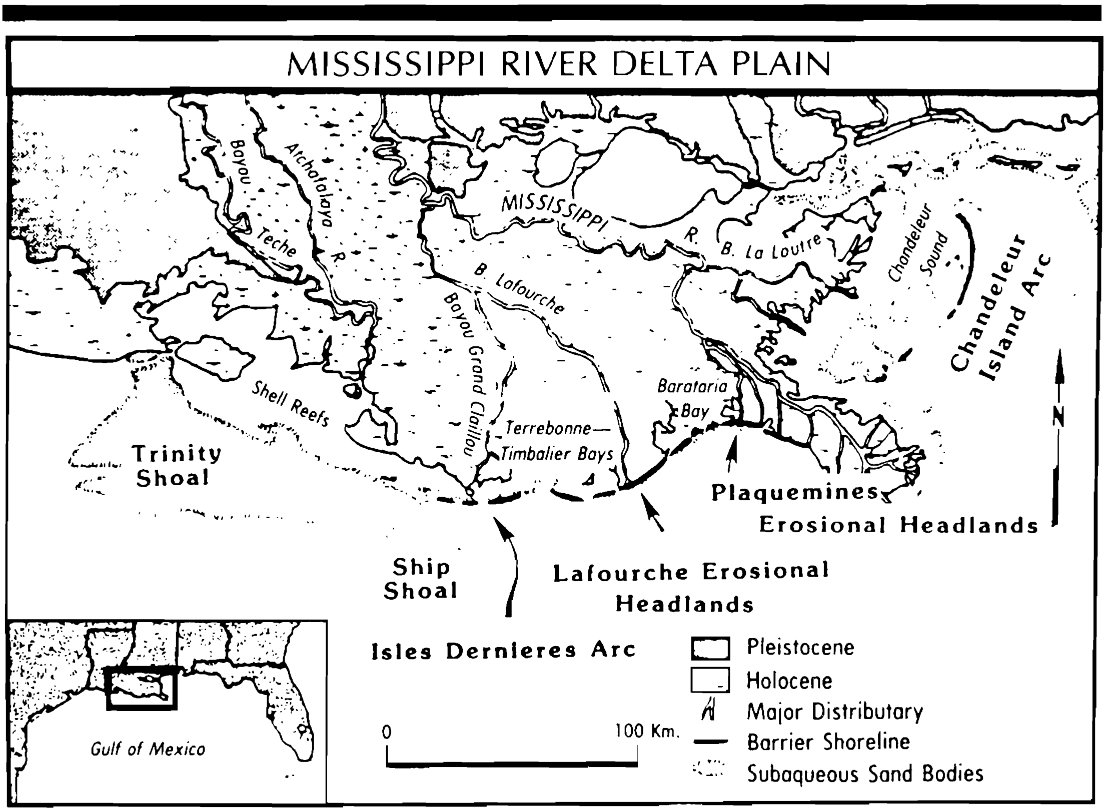


Figure 1. Location map of shoreline features in the Holocene Mississippi River Delta Plain, southeastern Louisiana. Remnants of abandoned delta lobes are found as (1) erosional headlands with flanking barriers, (2) barrier island arc systems, and (3) inner shelf shoals (Modified from PENLAND and SUTER, 1983).

To date the influence that sediment supply has on inlet morphology has been discussed in terms of channel stability (BRUUN *et al.,* 1974), natural by-passing (BRUUN and GERRITSEN, 1960; BRUUN, 1986), disruption at coastal structures (FITZGERALD and FITZGERALD, 1977; BYRNE *et al.,* 1975) and the inability of tidal currents to displace sand in shoaled channels (BRUUN and ADAMS, 1988; WEBB *et al.,* 1991; HUME and HERDENDORF, 1992; WALKER and JESSUP, 1992). In Louisiana, inlet morphologies are affected by rapid (<100 years) temporal increases in tidal prism and decreases in longshore sediment supply.

This paper will describe five inlet morpho-types occurring along the transgressive Mississippi River delta shoreline. It will also discuss the relationship between inlet morphology and the characteristics of the barrier system that it occupies, such as: age, bay size, sediment supply, and morphology. Finally, a model that explains the evolution of tidal inlet morphology in abandoned delta lobes of the MRDP will be offered.

STUDY AREA—THE MISSISSIPPI RIVER DELTA PLAIN

Physical Setting

Tides in the MRDP are largely diurnal (MARMER, 1954) with a mean range of 0.35 m (U.S. DEPARTMENT OF COMMERCE, 1988). Meteorological tides of up to 1.2 m frequently account for 50 percent or more of the daily water level fluctuations (WAX, 1978; BOYD and PENLAND, 1981). Hurricanes and tropical storms can create surges of several meters (BROWER *et al.,* 1972; BOYD and PENLAND, 1981). Average wave heights in this reach of coastal Louisiana are 0.5 m (U.S. ARMY CORPS OF ENGINEERS, 1972). The dominant direction of longshore sediment transport is site specific due to the variability of shoreline shape, orientation and exposure (PENLAND and BOYD, 1981).

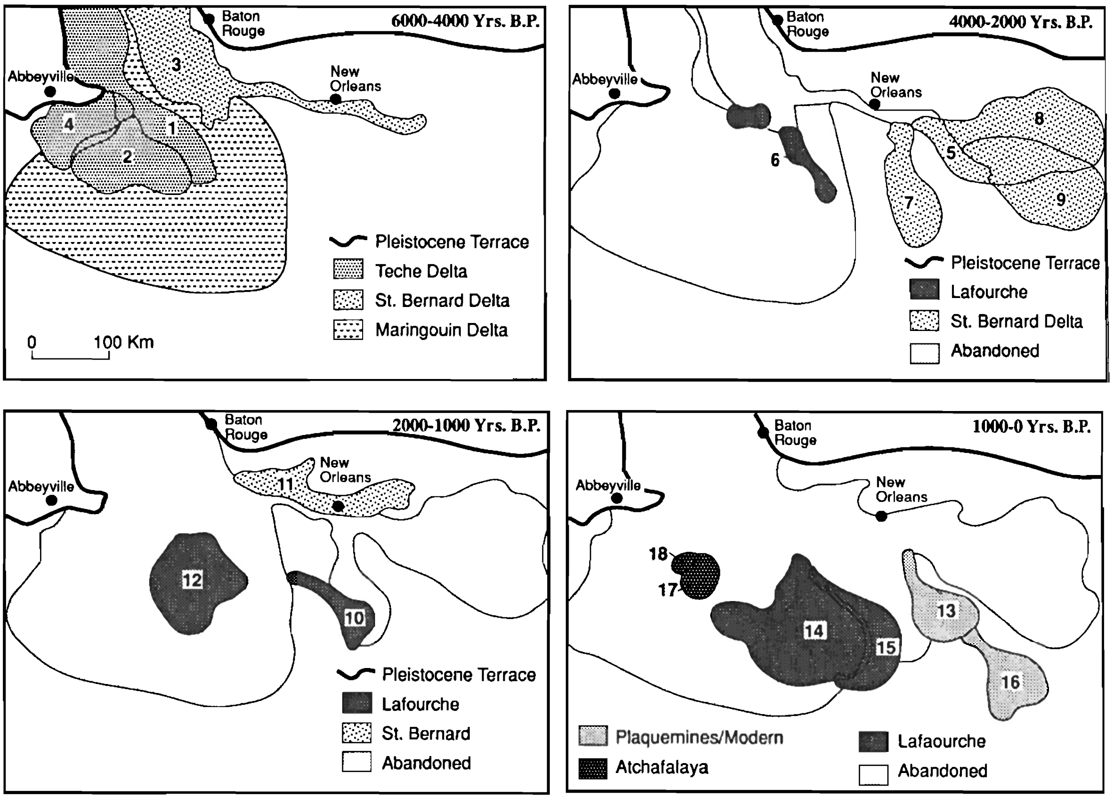


Figure 2. The chronology of delta lobe growth and abandonment in the Mississippi River Delta Plain (modified from FRAZIER, 1967).

Geologic Setting

The coalescence of eighteen delta lobes deposited by the Mississippi River comprises the Holocene delta plain (Figure 2) (FRAZIER, 1967; VAN HEERDEN and ROBERTS, 1980). Presently, the entire delta plain is transgressive with the exception of the Bird Foot (Figure 2, Lobe 16) and Atchafalaya River delta complex (Figure 2, Lobes 17 and 18). The transgressive barrier shoreline contains remnants of past delta lobes (PENLAND and BOYD, 1981). The most recently abandoned lobes, Late Lafourche (Lobe 15) and Plaquemines (Figure 2, Lobe 13), exhibit erosional headlands with flanking spits and barrier islands (Figure 1). The next oldest lobes, the Early Lafourche (14) and St. Bernard (Lobes 8 and 9), are represented by the Isles Dernieres and Chandeleur Barrier Island Arc systems, respectively (Figure 1). Subaqueous sand bodies, Ship and Trinity Shoals, located in the nearshore region of southwest Louisiana (Figure 1) are thought to be remnants of the Maringouin delta (Figure 2) (PENLAND and BOYD, 1981; NUMMEDAL *et al.*, 1984).

Barrier Formation

Once delta lobes are abandoned, spits grow from headlands across interdistributary bays (KOLB and VAN LOPIK, 1958). This represents stage 1 of PENLAND and BOYD's (1981) model of delta lobe abandonment (Figure 3). Stage 2 occurs when subsidence causes the headland to detach from the mainland creating a lagoon behind a barrier island arc system. The barrier island arc system contains a finite amount of sand that is constantly reworked and eroded by waves and tides. In addition, high rates of local RSLR contribute to the continued areal loss of the barrier. Eventually adjacent submarine shoals enlarge at the expense of barrier erosion and inner-shelf shoals (stage 3) form (PENLAND and BOYD, 1981).

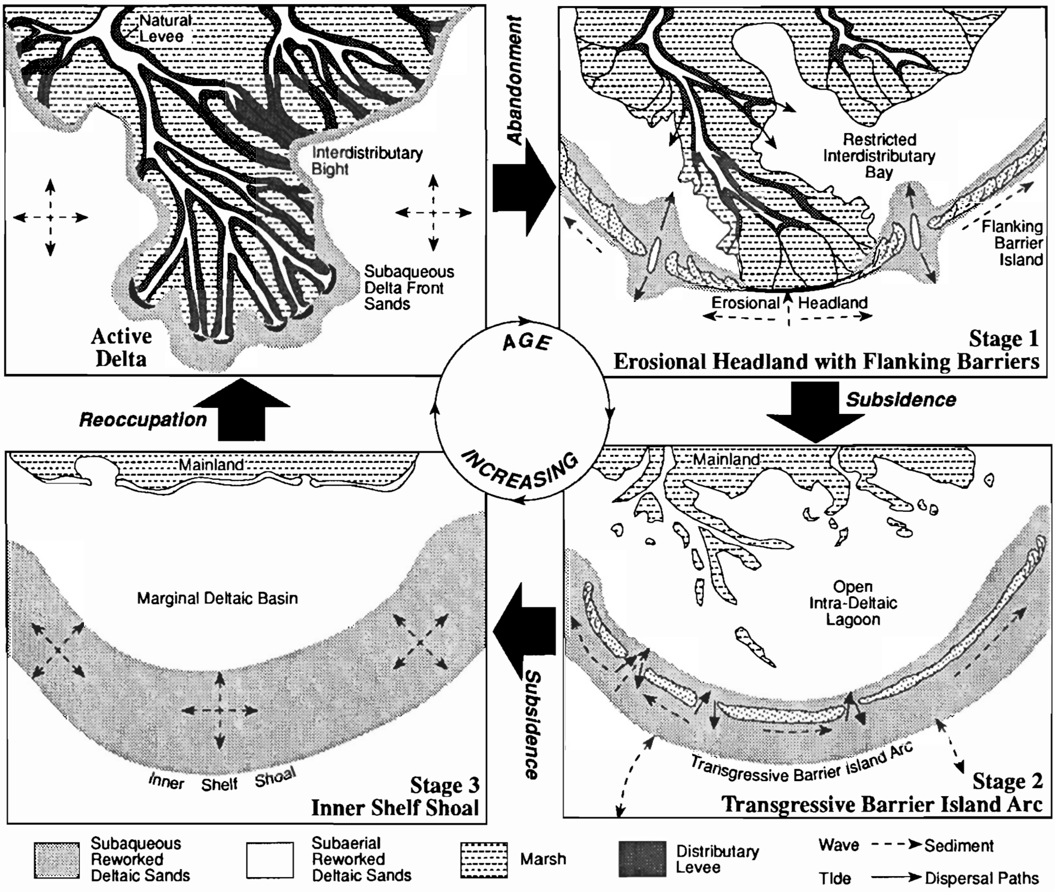


Figure 3. A model depicting the evolution of barrier island systems in an abandoned lobe of the Mississippi River (modified from PENLAND and BOYD, 1981).

Relative Sea Level Rise

Once an active delta lobe is abandoned the arrested sediment supply is one of the main reasons for landloss in the MRDP. Without sediment renewal RSLR inundates low points of elevation (GAGLIANO *et al.*, 1981). Present rates of sea level rise along the delta plain were measured by dividing radiocarbon dates of in-situ peats by their depth of burial. This calculation is thought to approximate the average rate of RSLR. The rates of rise range from 0.3 cm/yr (LEVIN, 1990) to 0.85 cm/yr (PENLAND *et al.*, 1987; CONNER and DAY, 1988). Rates of RSLR measured from tide gage data recorded since the 1950's nears 1.20 cm/yr (SWANSON and THURLOW, 1973; RAMSEY and MOSLOW, 1987). These high rates of rise abate with depth into the subsurface (GERDES, 1982; IL, 1987; LEVIN, 1990). Landloss combined with RSLR documented in the delta plain since the early 1800's cause the bay areas behind the barrier shorelines to increase. Bay area increase causes tidal prism increase and tidal currents to accelerate accordingly. As tidal currents intensify inlets evolve different morphologies concurrently with MRDP barrier island development. It is the interaction of temporally changing tidal currents with incident wave energy that controls tidal inlet morphology (BYRNE *et al.*, 1975; NUMMEDAL and HUMPHRIES, 1978).

DATA

Tidal Inlet Morphology

Tidal inlets on the Mississippi River Delta Plain include five morpho-types: two wave-dominated,

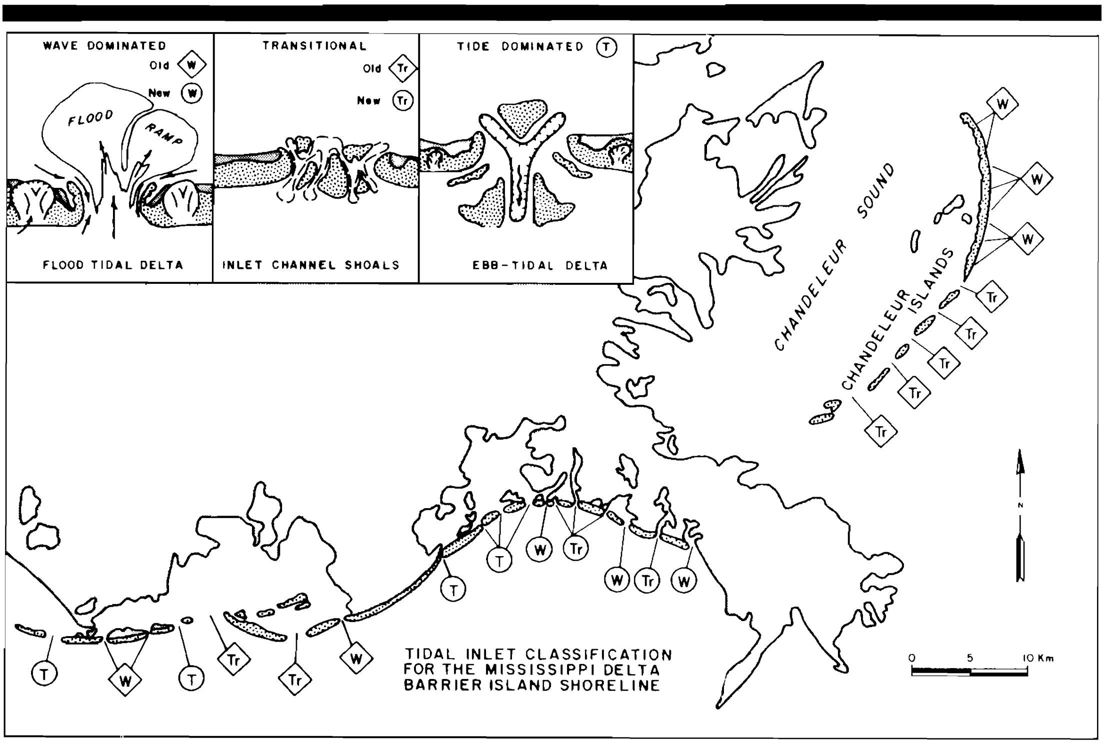


Figure 4. Distribution of tidal inlet morpho-types along the Mississippi River delta. There are five distinct inlet types: new and old wave-dominated, new and old transitional and tide-dominated.

two transitional, and one tide-dominated (Figure 4). As bay area increases in a stage 1 barrier, tidal prism through the inlet increases. This causes the inlet to evolve from a wave-dominated to transitional and then tide-dominated morphology (Figure 5). In stage 2, barrier arcs, the sediment supply is limited. Even though the bay area continues to increase, numerous leaks through and around the barrier flanks results in decreased through-the-inlet tidal prism. Inlets subsequently evolve from a tide-dominated to transitional and then wave-dominated morphology. The two types of wave-dominated and transitional inlets are referred to as new and old and are differentiated by distinct differences in inlet sand body type. Descriptions of each inlet type follow.

Wave-Dominated—New

Shallow inlet throats in new wave-dominated inlets may be periodically closed by longshore sediment transport. Intertidal flood-tidal deltas form landward of the inlet throat by the combined transport power of waves and the incoming tides. The lobate, sandy accumulation may become supratidal and vegetated. Pass Ronquille is the type example of a young wave-dominated inlet (Figures 6 and 7).

Transitional—New

This inlet type occurs when ebb directed sediment transport is equal to the combined transport potential of flooding waves and tidal currents. Sandy shoals separated by variable depth channels form between barriers within the inlet throat. Slight seaward and landward bulges of inlet sand bodies may define rudimentary ebb- and flood-tidal deltas (Figure 5). Quatre Bayou Pass, depicted in charts from 1886, exemplifies this inlet type (Figures 6 and 8).

Tide-Dominated Inlets

Where tidal prism through an inlet is large enough tidal energies dominate wave energies and features associated with tide-dominated inlets are exhibited; including, deep main ebb channels, well developed ebb- and flood-tidal deltas, and mar-

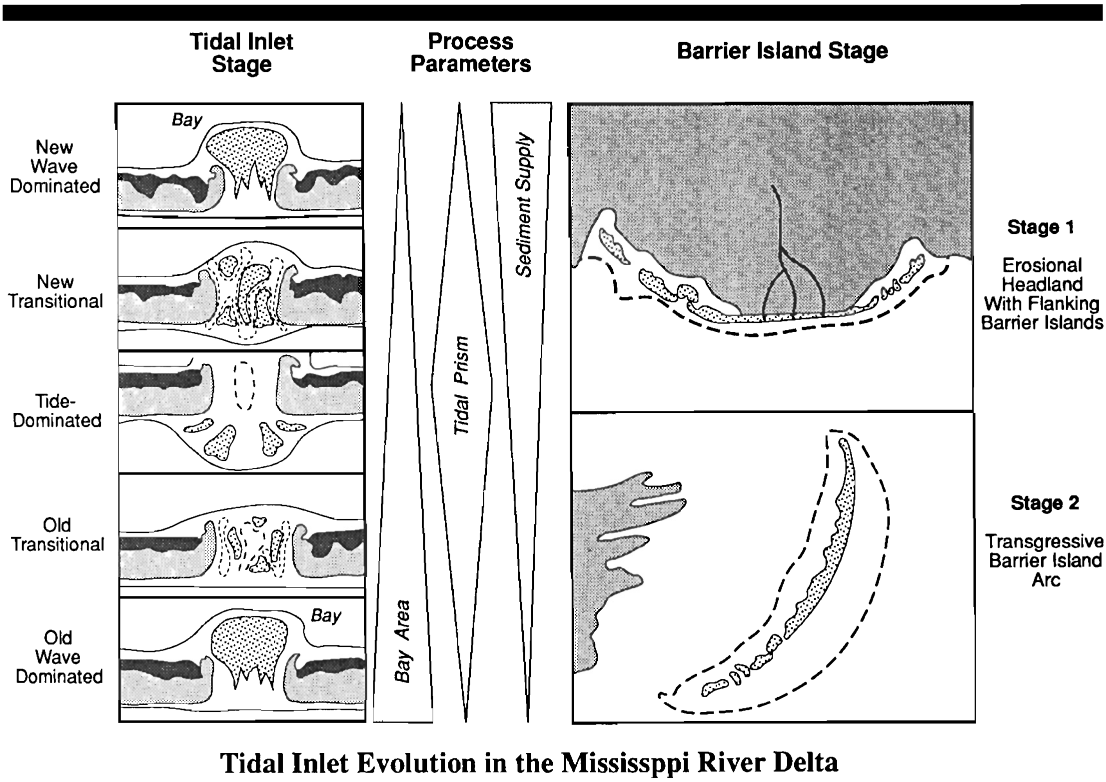


Figure 5. Summary diagram of tidal inlet evolution in a deteriorating delta lobe.

ginal flood channels (Figure 5). Barataria Pass (Figures 6 and 9) is the most impressive of these inlet types in the MRDP. It has throat depths exceeding 20 meters and an ebb tidal delta that contains nearly as much sand as that contained in the adjacent barrier islands (Shamban, 1985).

Transitional—Old

Old transitional inlets contain deteriorated remnants of tide-dominated inlets. The main ebb channel is poorly defined and filled with sediments derived from the ebb delta and flanking spits (Figure 5). Similar to the new transitional inlet, the inlet throat is shoaled. However, in this inlet the shoals are commonly fragments of the old barrier terminus. Little Pass Timbalier, as mapped in 1956, exhibits characteristics of this inlet type (Figures 6 and 10).

Wave-Dominated—Old

The old wave-dominated inlets are similar in appearance to the new type. The major difference at this stage is that the flood-tidal delta is subtidal (Figure 5). The southern Chandeleur Islands contain excellent examples of this inlet type.

RESULTS

Tidal Inlet Location and Evolution

The location of the five inlet morpho-types along the MRDP is highly associated with the age of the barrier system (Table 1). New wave-dominated, new transitional and tide-dominated inlets are associated with flanking barrier islands of the MRDP. Old transitional and wave-dominated inlets occur in barrier arc systems.

Inlets in Flanking Barrier Islands

The growth of flanking spits across interdistributary bays increasingly constricts the tidal flow between the bay and Gulf. Initially, due to the limited tidal prism contained by the young, spit-confined bay, tidal currents are weak and wave energies dominate. A flood-tidal delta will form

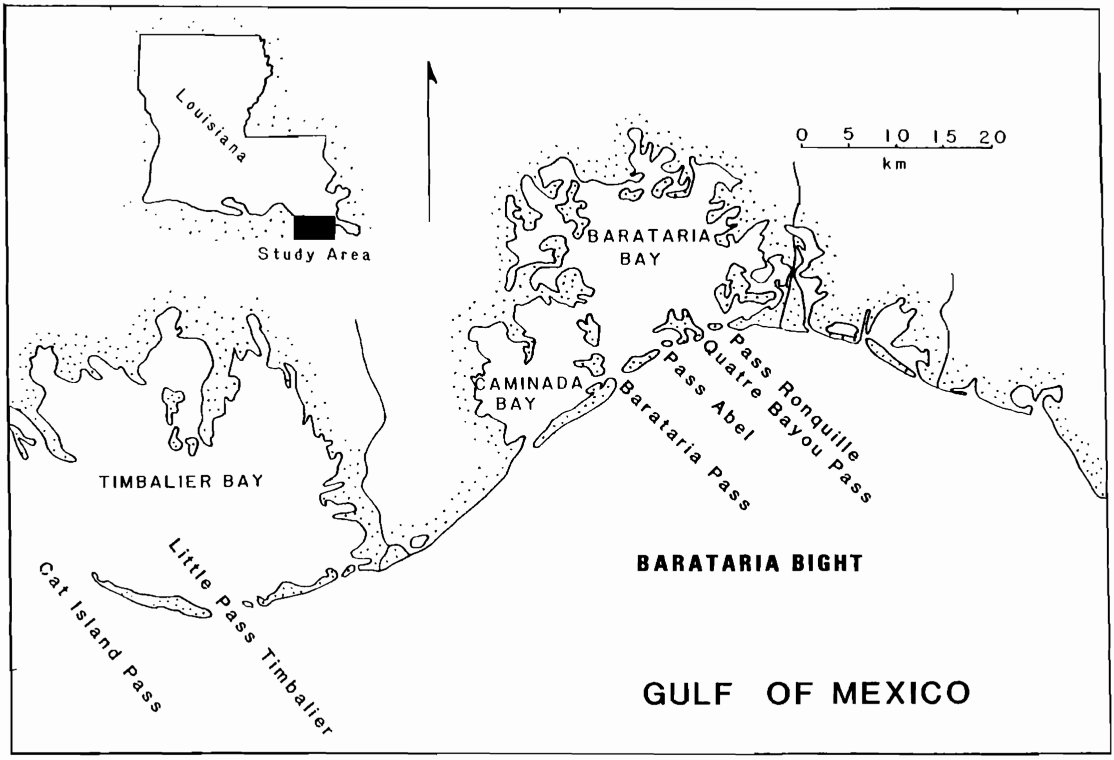


Figure 6. Location map of inlets, barriers and bays to the immediate west of the modern Mississippi River.

on the landward side of the inlet throat. Associated ebb-tidal deltas are small or absent.

Contemporaneous with the growth of the spit system the back bay area increases due to subsidence and wave induced erosion of the bay perimeter (ADAMS *et al.*, 1976; GAGLIANO *et al.*, 1981). LINDSTEDT (1982) reported that Barataria Bay (Figure 6) increased its open saline and brackish water environments over 50% between 1892 and 1978. Independent studies conducted by LINDSTEDT (1982) and BRITSCH and MAY (1987) showed that the Barataria Bay area increased by 282 km^2, or 23%, between 1932 and 1978 (Table 2). The whole tidal prism of Barataria Bay is not available to the tidal inlets. Frictional effects of shallow bays and water retention by mud flats and low-marsh decreases the tidal prism that is actually exchanged through the tidal inlet (BYRNE *et al.*, 1975). Regardless, the expanding bay area causes tidal current velocities to increase and an improvement of sediment transport effectiveness through the inlet. New transitional inlets will form that contain shoals in the inlet throat (HUBBARD *et al.*, 1979). As tidal currents intensify further, tide-dominated inlets evolve (Figure 5). Tide-dominated inlets occur where flanking spits have built across large interdistributary bays or an initially small back bay area has been greatly enlarged. In lieu of a large tidal range the increased bay area produces a larger tidal prism that is exchanged between the bay and the Gulf. The best examples of tide-dominated inlets occurring along the MRDP are found at the entrances to Barataria Bay and Bay Ronquille (Figure 6).

Inlets Along the Barataria Barrier Shoreline

The eastern Barataria Bight shoreline consists of a series of headlands that were connected by Grande Terre Island prior to 1841 (Figure 11). Presently, the low-profile, Grande Terre barrier is part of a transgressive shoreline flanked and breached by four tidal inlets. From west to east

Figure 7. Oblique aerial photograph of Pass Ronquille, 1982, looking south into the Gulf of Mexico. Note the lobate, sandy, flood-tidal delta building into the bay. Scale is approximate.

the inlets are Barataria Pass, Pass Abel, Quatre Bayou Pass, and Pass Ronquille (Figure 6). All but Pass Ronquille are tide-dominated inlets.

Tidal Inlet Evolution in the Barataria Barrier Shoreline

Barataria Pass formed when Grande Isle spit built across the front of Caminada and Barataria Bay (Figure 12) forming a constricted passage against the westward end of Grande Terre Island (GERDES, 1985). Historical accounts (COWDON, 1877) and charts dating back to the early 1800's show no evidence that Barataria Pass has recently been other than a tide-dominated inlet (SHAMBAN, 1985). However, the inlets east of Barataria Pass have only recently (last 100 yr) been breached or modified to accommodate the continually increasing tidal prism of Barataria Bay. A detailed chart published in 1841 depicts Pass Abel (named Cut Off in this map) as a breach in Grande Terre Island (Figure 11). Charts dated 1886 indicate that Quatre Bayou Pass had a transitional morphology and Pass Abel was closed (Figure 12). During the 19th Century Pass Abel was apparently an ephemeral inlet. Pass Ronquille, the eastern-most inlet in the Barataria shoreline, did not open until the 1930's and was then wave-dominated. Quatre Bayou Pass and Pass Abel developed tide-dominated morphologies some time prior to 1956 and 1978, respectively, while Pass Ronquille remained wave-dominated through 1982. Recent breakup of the marsh on the northern margin of Bay Long has caused the capture of Bay Ronquille waters and an increase in tidal prism to Pass Ronquille. Since 1982, Pass Ronquille has evolved sand bodies of a new transitional inlet. The sands of the flood-tidal delta are being transported seaward, shoaling the inlet throat.

Where there is an adequate longshore sediment

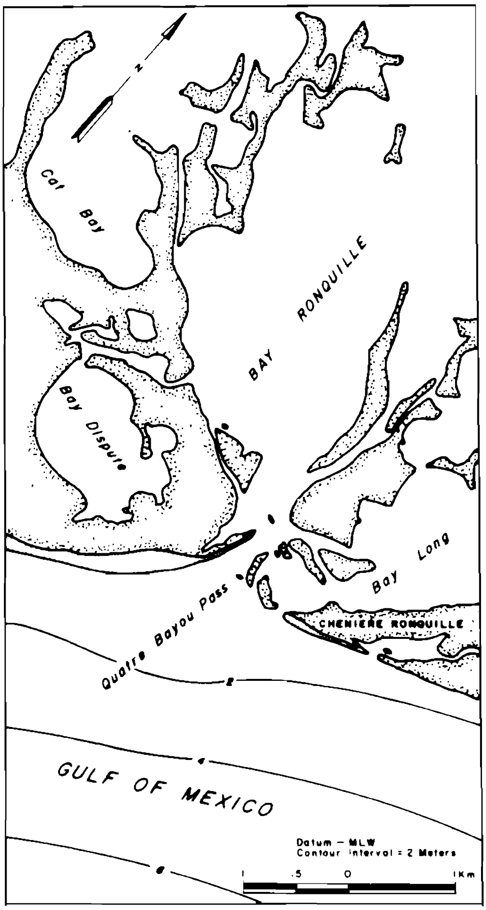


Figure 8. Quatre Bayou Pass, 1886. This is a new transitional inlet formed in an old distributary channel. Refer to Figure 6 for inlet location.

supply replenishing flanking barrier spits inlet evolution is the result of changes in tidal prism through bay area increase (Figure 5). FITZGERALD and NUMMEDAL (1983) found no substantial lag time between bay enlargement and a corresponding increase in tidal inlet cross-sectional area.

Inlet widths essentially doubled at Barataria Pass and Quatre Bayou Pass and increased five-fold at Pass Abel between 1932 and 1971 (Table 3) (HOWARD, 1983). The Quatre Bayou channel cross-sectional area increased by a factor of 3.4 from 550 m^2 to 1890 m^2 between 1841 and 1934. The channel cross-section measured again in 1982 had not increased significantly since 1934, despite continued bay enlargement (Table 4). Inlet cross-sections at Barataria Pass increased by a factor of 1.6 between 1878 and 1934. No appreciable increase in channel cross-section has occurred in Barataria Pass since then (SHAMBAN, 1985) while both Quatre Bayou Pass and Pass Abel continue to expand.

This is an excellent example of a stable multiple inlet system. Unlike other multiple inlet systems where one inlet offers a hydraulically favored path for tidal flow while the other fills (WARD, 1982; VAN DE KREEKE, 1990) the combined inlet cross-sections in the eastern Barataria shoreline increased concurrently as Barataria Bay expanded facilitating an efficient transmission of the tidal wave between the bay and Gulf.

Inlet Deterioration in a Flanking Barrier Shoreline

When longshore sediment supply is ample, the relationship between inlet cross-section and tidal prism is straightforward. An increase or decrease in tidal prism causes the inlet cross-section to enlarge or reduce, respectively. When the longshore sediment supply to flanking spits is not sufficient to replenish sands removed by waves, the inlet cross-section expands due to wave erosion and not by tidal prism increase. If tidal prism is held constant during throat enlargement tidal currents in the inlet will decrease. In the Barataria region inlets are presently widening due to a depleted longshore sediment supply. Wave erosion caused Quatre Bayou Pass to widen by 15 m between February and May of 1983. Pass cross-sections continue to widen by wave erosion. The resultant diminishing tidal currents allow wave energies to remold the sand body morphology.

When flanking spits erode and fragment, tide-dominated inlets evolve an old transitional inlet morphology. A 1956 bathymetric map of Little Pass Timbalier (Figure 10) shows relict features of an inlet that was once tide-dominated. A loss of sediment supply from adjacent, eroded barriers and the parent headland resulted in barrier breaches and significant inlet widening. Tidal current velocities through the inlet decreased and waves eroded the ebb delta causing the terminal lobe to flatten landward. Sands derived primarily from the ebb delta have partially filled the main ebb channel. Similar inlet expansion and channel fill was documented in Cat Island Pass, Louisiana by SUTER and PENLAND (1987). The processes responsible for morphologic change at Little Pass Timbalier and Cat Island Pass will eventually oc-

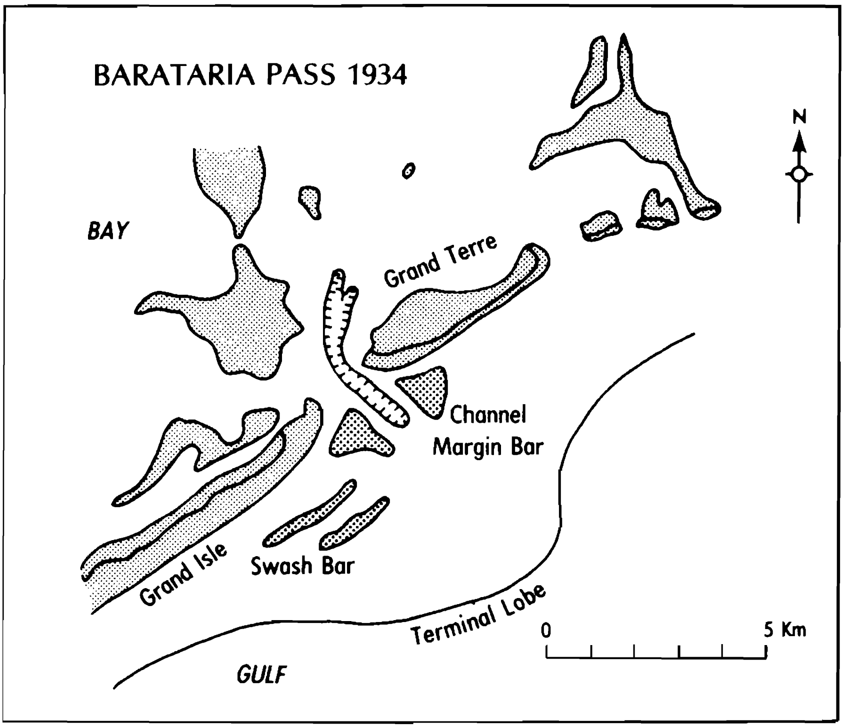


Figure 9. Barataria Pass, 1934. This is a tide-dominated inlet with a large ebb-delta, deep main ebb channel, and marginal flood channels. Refer to Figure 6 for inlet location.

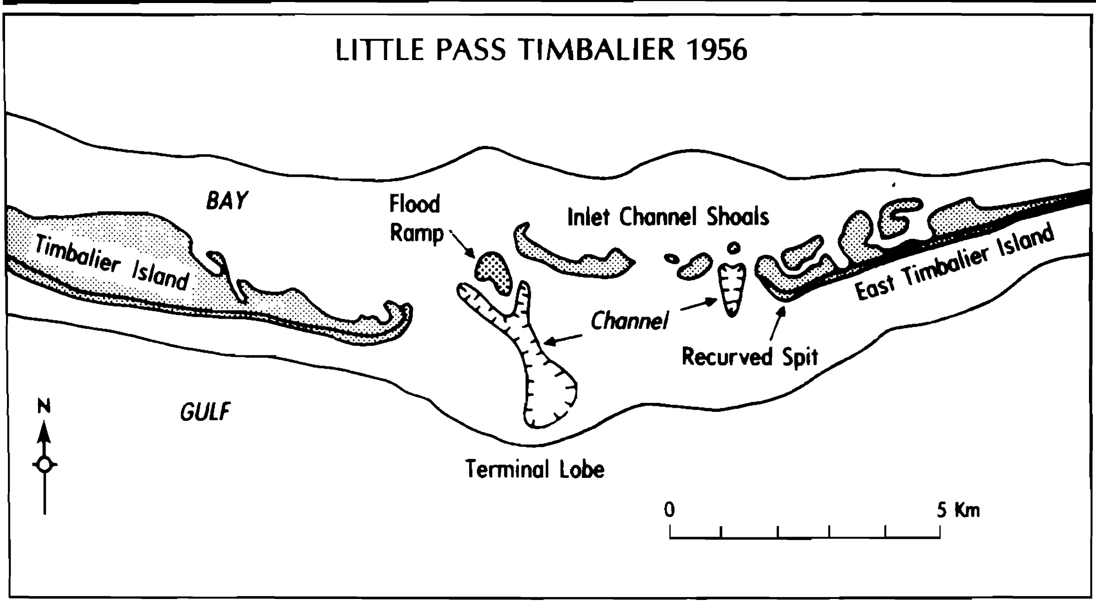


Figure 10. Little Pass Timbalier, 1956. This is an old transitional inlet. The main ebb channel is filling with sands derived from the ebb delta and adjacent barrier spits. Refer to Figure 6 for inlet location.

Table 1. *Coastal parameters associated with inlet type in abandoned delta lobes of the Mississippi River Delta Plain.*

Barrier Shoreline	Related Delta Lobe	Stage of Abandonment	Sediment Supply	Tidal Prism	Inlet Type
Shell Island	Modern/Plaquemines	Recent	Available	Limited	New Wave-Dominated
East Barataria	Plaquemines	Flanking Barrier	Available	Limited	New Wave-Dominated* New Transitional
East Timbalier	Late Lafourche	Flanking Barrier	Available	Limited	New Wave-Dominated
Grand Isle	Late Lafourche	Flanking Barrier	Available	Large	Tide-Dominated
Grand Terre	Plaquemines	Flanking Barrier	Limited	Large	Tide-Dominated**
Timbalier	Late Lafourche	Flanking Barrier	Limited	Large	Old Transitional
West and East Isles Dernieres	Early Lafourche	Barrier Island Arc System	Available	Large	Tide-Dominated
Central Isles Dernieres	Early Lafourche	Barrier Island Arc System	Limited	Limited***	Old Transitional Old Wave-Dominated
Northern Chandeleurs	St. Barnard	Barrier Island Arc System	Available Limited	Limited***	Old Transitional
Southern Chandeleurs	St. Barnard	Barrier Island Arc System	Limited	Limited	Old Transitional Old Wave-Dominated

*Pre 1982 conditions, inlet is presently evolving into a new transitional inlet

**Sediment supply has become limited causing tide-dominated inlets to evolve to old transitional morphotypes

***Despite the large tidal prism offered by the bay, the numerous tidal inlets within the local shoreline distribute the volume and minimize the tidal current through individual openings

cur in the eastern Barataria inlets and at other inlets located in deteriorating flanking barrier and barrier arc systems.

Inlets in Barrier Island Arcs

The inlets that incise stage 2, barrier island arc systems (Figure 3) are deteriorating tide-dominated, old transitional and old wave-dominated types. During stage 2 of PENLAND and BOYD's (1981) model, inlets evolve from tide-dominated to old transitional and then old wave-dominated as the barrier island arc erodes (Figure 5).

The Chandeleur Barrier Island Arc system represents the final subaerial remnant of the St. Bernard Delta lobe (Figure 1). The Chandeleur Islands separate Chandeleur Sound from the Gulf of Mexico. The islands are also flanked on either extreme by nearly 20 km of open water (Figure 1). The barriers are incised by numerous inlets that combine with the open flanks of the arc system to form a non-restrictive tidal passage (HART, 1975). The tidal currents passing through each individual inlet are generally very weak. Inlets that were tide-dominated at the end of stage 1 of lobe deterioration in the St. Bernard delta lobe evolved into older transitional inlets once the sediment supply of the barrier arc became insufficient to heal new breaches (Figure 13). Presently, this barrier arc system is extremely fragile. Inlet widening continues regularly and new inlets form with each passing storm (KAHN, 1985). Sand left in the system is transported bayward and added to a subaqueous flood-tidal delta (Figure 14). In the final stage of inlet evolution, the old wave-dominated inlet has a subtidal flood delta (Figure 5). The flood delta in the new wave-dominated inlet is intertidal.

Table 2. *Barataria Bay area increase between 1892 and 1978.*

Year	1892	1932	1960	1978
Bay Area (km^2)	955	1,209	1,292	1,491

CONCLUSIONS

Five inlet morpho-types occur along the shoreline of the Mississippi River Delta Plain. They are (1) new wave-dominated inlets with intertidal flood tidal deltas, (2) new transitional inlets with shoal choked throats, (3) tide-dominated inlets exhibiting deep channels and large ebb tidal deltas, (4) older transitional inlets with ebb tidal deltas flattened landward at the terminal lobe, infilling tidal channels and spits detached from the adjacent barriers, and (5) older wave-dominated inlets with subtidal flood tidal deltas.

In an abandoned lobe of the Mississippi River Delta Plain tidal inlets evolve from wave to tide-dominated and back during the transgressive phase of delta lobe abandonment. This cycle of

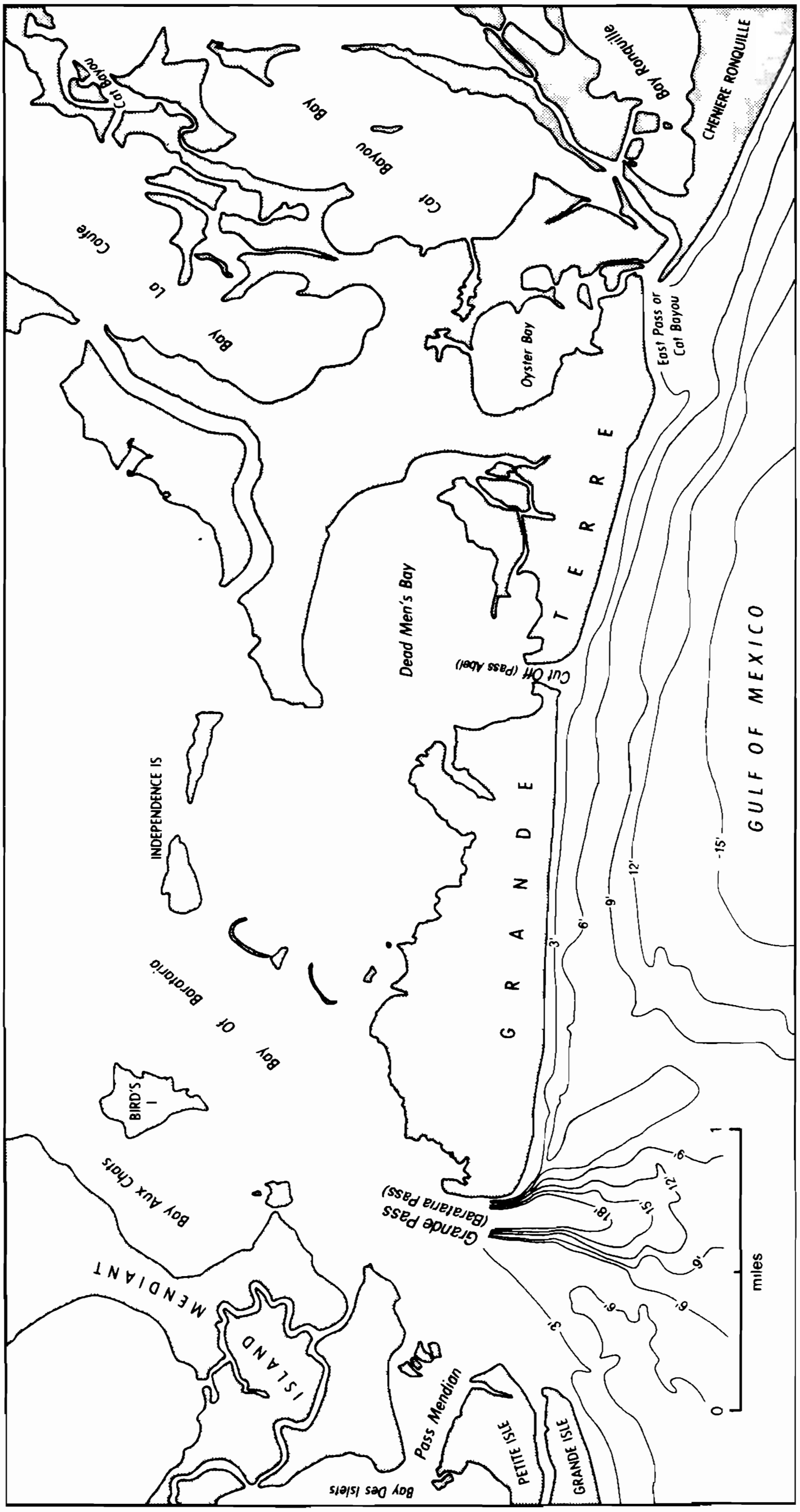
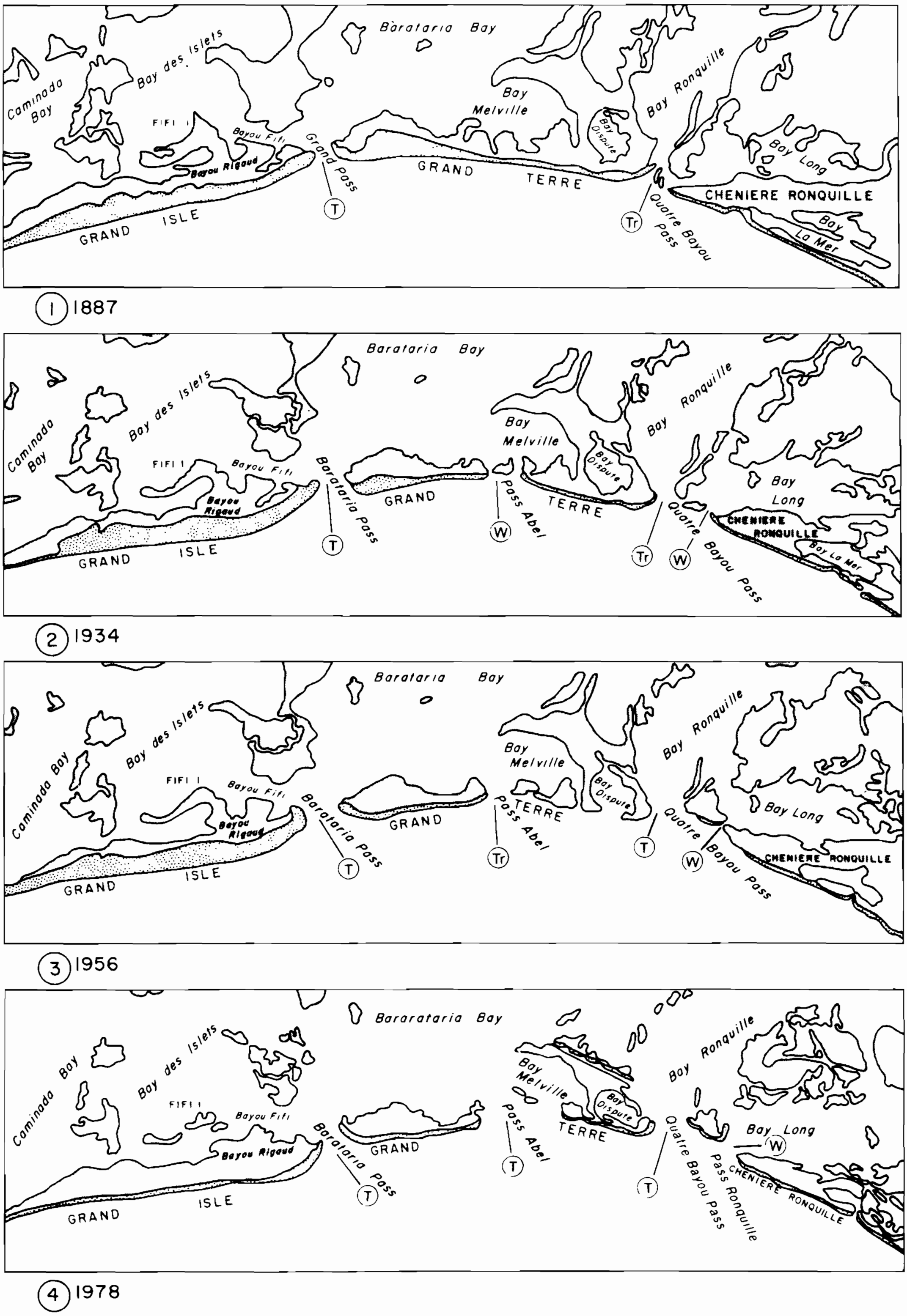


Figure 11. Grande Terre Barrier, 1841. Pass Abel is the modern title for Cut Off. Quatre Bayou was called East Pass or Cat Bayou in this map. Refer to Figure 6 for general location. For scale conversion 1 mile equals 1.6 kilometers.


Barataria Bay
Caminada Bay
Bay des Islets
FIFI I
Bayou Fifi
Bayou Rigaud
Grand Pass
GRAND ISLE
Bay Melville
Bay Dispute
GRAND TERRE
Bay Ronquille
Bay Long
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Bay des Islets
FIFI I
Bayou Fifi
Bayou Rigaud
Barataria Pass
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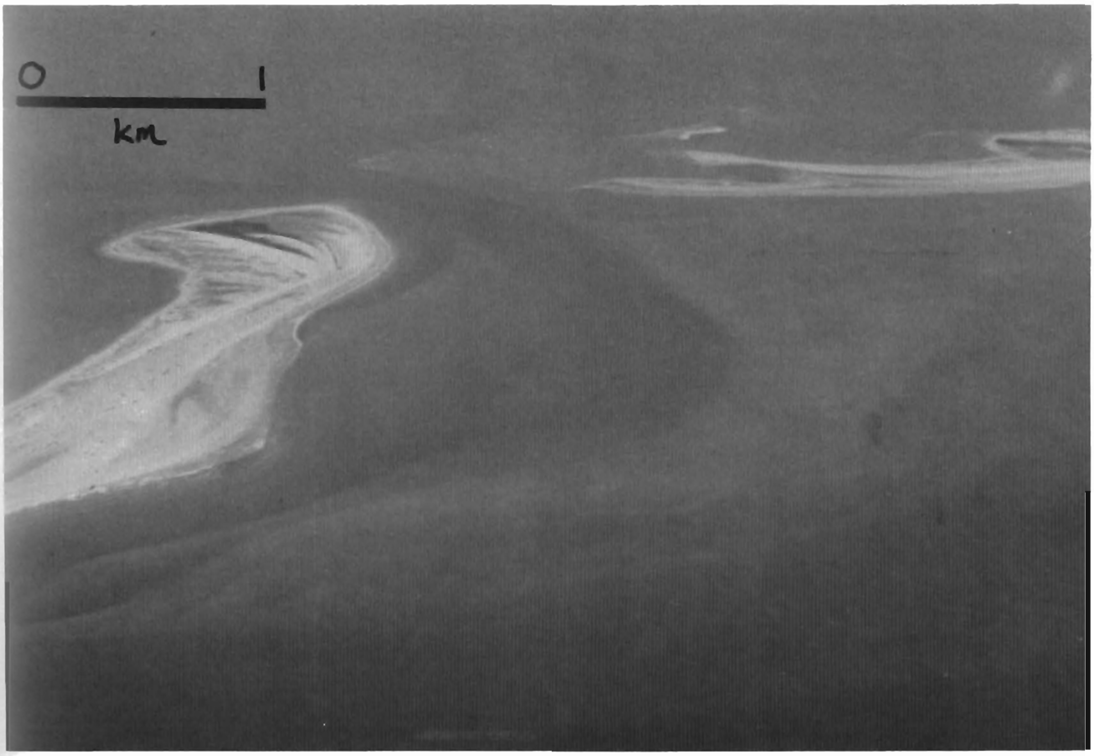

Figure 13. Oblique aerial photograph of an old transitional inlet in the southern Chandeleur Islands. The main ebb channel is being filled by sands derived from the ebb-delta. Landward is to the upper left of the photograph. (Photograph by Shea Penland.) Scale is approximate.

Table 3. *Change in pass width for Barataria tidal inlets.*

Year	1841	1932	1956	1971	1982	1983
Barataria Pass	—	654 (m)	702	1,042	—	647*
Pass Abel	—	129	304	751	2,200	—
Quatre Bayou	220	650	—	1,050	1,200	—

*Width decreased by artificial means

←

Figure 12. Inlet evolution in the eastern Barataria shoreline, 1887–1978. Barataria Pass has been tide-dominated since before 1887. Pass Abel was ephemeral and wave-dominated before becoming permanently established around 1934. Quatre Bayou pass has evolved from a new transitional inlet type to a tide-dominated between 1887 and 1956. Pass Ronquille did not breach until 1934. Refer to Figure 6 for overall location and scale.

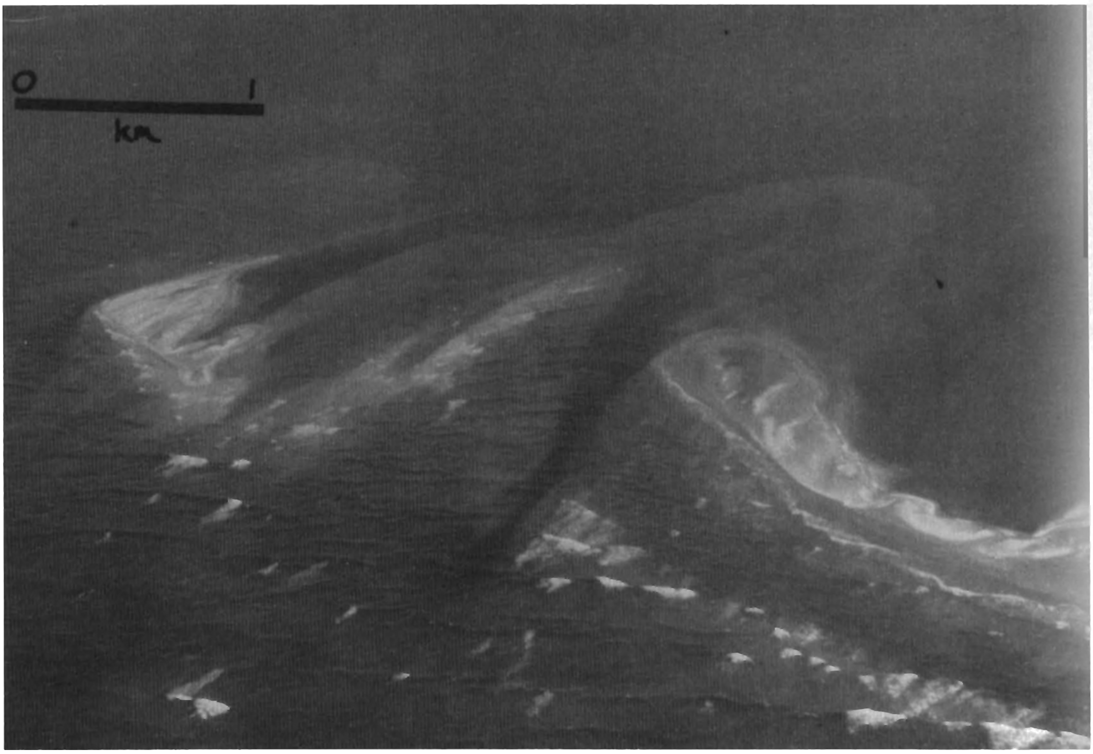

Figure 14. Oblique aerial photograph of an old wave-dominated inlet located in the southern Chandeleur Islands. The flood tidal delta is entirely sub-tidal. Landward is to the upper right of this photograph. (Photograph by Shea Penland). Scale is approximate.

inlet evolution can be tracked visually by using HAYES's (1979) plot of inlet type versus tidal range and wave height (Figure 15). In flanking barrier island systems the temporal change in inlet morphology is concurrent with tidal prism increase due to back bay enlargement. As the tidal prism through the inlet increases wave influenced inlet sand bodies are less prevalent. During later stages of delta lobe abandonment when barrier island arcs are prevalent and sediment supply is limited, barriers breach and the total inlet cross-sectional area increases at a greater rate than tidal prism. As a result tidal currents through-the-inlet decrease and wave influenced sand bodies become dominant. This sequential change of inlet morpho-type occurs in an area where alongshore variations in tidal range and wave energies are insignificant. This research illustrates the relative influence that tidal prism and sediment supply have on tidal inlet morphology.

Table 4. *Barataria region tidal inlet throat cross-section change from 1841 to 1984.*

Year	1841	1878	1934	1982	1984
Barataria Pass	—	4,240	6,840	—	6,290
Pass Abel	—	300	900	—	1,900
Quatre Bayou Pass	550	—	1,140	1,775	—

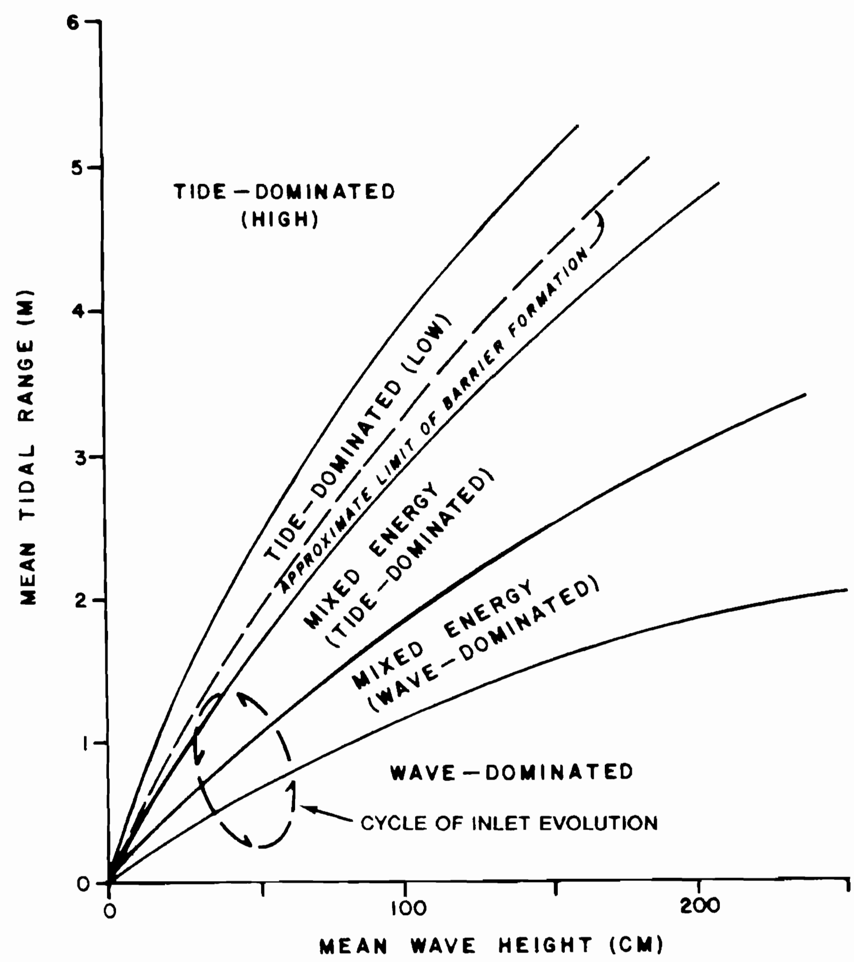

Figure 15. The cycle of inlet evolution in the Mississippi River Delta Plain plotted on a NUMMEDAL and HAYES (1980) diagram depicting expected inlet type as a function of mean wave height and mean tidal range.

ACKNOWLEDGEMENTS

This work was funded, in part, by Sohio, Arco, GCAGS, Rockefeller Scholarships, and the Department of Marine Sciences, Louisiana State University. Pete Lackey, Eliza McClennen, Clarence Dupe and Mary Lee Eggert drafted the figures. Photographs were printed by Ernest Barbaris. Scott Dinnel and Dag Nummedal are thanked for reviewing the preliminary drafts of this manuscript. Per Bruun and another anonymous reviewer offered helpful suggestions to improve manuscript quality.

LITERATURE CITED

ADAMS, R.D.; BARRETT, B.B.; BLACKMON, J.H.; BANE, B.W., and MCINTYRE, W.G., 1976. *Barataria Basin: Geologic Processes and Framework.* Center for Wetland Resources, Louisiana State University, Baton Rouge, Louisiana, Sea Grant Pub. No. LSU-T-76-006, 117p.

BOYD, R. and S. PENLAND., 1981. Washover of deltaic barriers on the Louisiana Coast. *Transactions of the Gulf Coast Association of Geological Societies,* 31, 243–248.

BRITSCH, L.D. and MAY, J.R., 1987. *Louisiana Shoreline Mapping Program.* United States Geological Survey.

BROWER, W.A.; MESERVE, J.M., and QUAYLE, R.G., 1972. *Environmental Guide for the U.S. Gulf Coast.* NOAA, Environmental Data Service, National Climatic Center, Asheville, North Carolina.

BROWN, E.I., 1928. Inlets on sandy coasts. *Proceedings of the American Society of Civil Engineering,* 54, 505–553.

BRUUN, P., 1986. Morphological and navigational aspects of tidal inlets on littoral drift shores. *Journal of Coastal Research,* 2(2), 123–145.

BRUUN, P. and ADAMS, J., 1988. Stability of tidal inlets: Use of hydraulic pressure for channel stability. *Journal of Coastal Research,* 4(4), 687–701.

BRUUN, P. and GERRITSEN, F., 1960. *Stability of Coastal Inlets.* Amsterdam, Holland: North Holland, p. 123.

BRUUN, P.; GERRITSEN, F., and BHATKA, N.P., 1974. Evaluation of overall entrance stability of tidal entrances. *Proceedings 14th Coastal Engineering Conference,* Copenhagen, Denmark, pp. 1566–1584.

BYRNE, R.S.; BULLOCK, P., and TYLER, A.G., 1975. Response characteristics of a tidal inlet, a case study, *In:* CRONIN, L.E. (ed.), *Estuarine Research.* New York: Academic, 2, pp. 201–216.

CONNER, W.H. and DAY, J.W. Jr., 1988. Rising water levels in coastal Louisiana; Implications for two forested wetland areas in Louisiana. *Journal of Coastal Research,* 4(4), 589–596.

COWDON, J., 1877. *The Barataria Ship Channel and its Importance to the Valley of the Mississippi.* Report to the Army, Part of the Louisiana Collection, Louisiana State University, Baton Rouge, Louisiana, 41p.

DAVIS, R.A., JR. and HAYES, M.O., 1984. What is a wave dominated coast? *In:* GREENWOOD, B. and DAVIES, R.A. (eds), *Hydrodynamics and Sedimentation in Wave Dominated Coastal Environments,* 60, 313–329.

ESCOFFIER, F.F., 1940. The stablity of tidal inlets. *Shore and Beach,* 8(4).

FITZGERALD, D.M. and FITZGERALD, S.A., 1977. Factors influencing tidal inlet throat geometry. *Coastal Sediments, 1977.* Charleston, South Carolina: ASCE, pp. 563–581.

FITZGERALD, D.M. and NUMMEDAL, D. 1983. Response characteristics of an ebb-dominated tidal inlet channel. *Journal of Sedimentary Petrology,* 55(3), 833–845.

FRAZIER, D.E., 1967. Recent deltaic deposits of the Mississippi River, their development and chronology. *Transactions of the Gulf Coast Association of Geological Societies,* 17, 287–315.

GAGLIANO, S.M.; MEYER-ARENDT, K.J., and WICKER, K.M., 1981. Land loss in the Mississippi River deltaic plain. *Tranactions of the Gulf Coast Association of Geological Societies,* 31, 295–300.

GAMMISCH, R.A.; HOBBS, C.H., III, and BYRNE, R.J., 1988. Revolution of tidal inlet drainage basin systems. *Journal of Coastal Research,* 4(4), 543–550.

GERDES, R.G., 1982. Stratigraphy and History of Development of the Caminada-Moreau Beach Ridge Plain, Southeast Louisiana. M.Sc. Thesis, Department of Geology, Louisiana State Univ., Baton Rouge, Louisiana, 185p.

GERDES, R.G., 1985. The Caminada-Moreau beach Ridge Plain *In:* PENLAND, S. and BOYS, R. (eds.), *Transgressive Depositional Environments of the Mississippi River Delta Plain: Louisiana Geological Survey Guidebook Series, No. 3.* pp. 127–140.

HART, W.E., 1975. A Numerical Study of Current Velocities and Water Levels in Louisiana's Chandeleur-Breton Sound. Unpublished Ph.D. Thesis, Department of Marine Sciences, Louisiana State University, Baton Rouge, Louisiana, 235p.

HAYES, M.O., 1975. Morphology of sand accumulations in estuaries. *In:* CRONIN, L.E. (ed.), *Estuarine Research, Vol. 2, Geology and Engineering.* New York: Academic, pp. 3–22.

HAYES, M.O., 1979. Barrier island morphology as a function of tidal and wave regime. *In:* LEATHERMAN, S.P. (ed.), *Barrier Islands: From the Gulf of St. Lawrence to the Gulf of Mexico.* New York: Academic, pp. 1–27.

HOWARD, P.C., 1983. Quatre Bayou Pass, Louisiana: Analysis of Currents, Sediments and History. Unpublished M.S. Thesis, Department of Geology, Louisiana State University, Baton Rouge, Louisiana, 111p.

HUBBARD, D.K.; OERTEL, G., and NUMMEDAL, D., 1979. The role of waves and tidal currents in the development of tidal inlet sedimentary structures and sand body geometry: Examples from North Carolina, South Carolina, and Georgia. *Journal of Sedimentary Petrology,* 49, 1073–1092.

HUME, T.M. and HERDENDORF, C.E., 1992. Factors controlling tidal inlet characteristics on low drift coasts. *Journal of Coastal Research,* 8(2), 355–375.

IL, Y.H., 1987. Evolution and Sedimentary Sequences of the St. Bernard Delta. Unpublished M.S. Thesis, Louisiana State University, Baton Rouge, Louisiana, 193p.

JARRETT, J.T., 1976. Tidal prism-inlet area relationships. *General Investigation of Tidal Inlets,* Report

3. U.S. Army Corps of Engineers, Coastal Engineering Research Center, Ft. Belvoir, Virginia, 45p.

KAHN, J.H., 1985. Geomorphic recovery of the Chandeleur Islands, Louisiana, after a major hurricane. *Journal of Coastal Research,* 2(3), 337–344.

KOLB, C.R. and VAN LOPIK, J.R., 1958. *Geology of the Mississippi River Deltaic Plain, Southern Louisiana.* U.S. Corps of Engineers, WES, Reports 3-483 and 3-484, 2 volumes.

LECONTE, L.J., 1904. 1905. Discussion of: Notes on improvement of river and harbor outlets in the United States, by Watts, P.A. *Transactions, ASCE,* 55, 306–308.

LEVIN, D.R., 1990. Transgressions and Regressions in the Barataria Bight Region of Coastal Louisiana. Unpublished Ph.D. Thesis, Department of Marine Science, Louisiana State University, Baton Rouge, Louisiana, 385p.

LINDSTEDT, D., 1982. Increase in Bay Area and Tidal Prism in Barataria and Caminada Bays. Unpublished Technical Report, Department of Geology, Louisiana State University, Baton Rouge, Louisiana, 14p.

MARMER, H.A., 1954. *The Currents in Barataria Bay.* Texas A&M Research Foundation, Project No. 9, 30p.

MEHTA, A.J., 1975. Hydraulics of tidal inlets: Simple analytical models for engineers, Parts I and II of notes on a short course in coastal engineering topics. UFL/COEL-75/019, 020, Coastal and Oceanographic Engineering Laboratory, University of Florida, Gainesville, Florida.

NUMMEDAL, D.; CUOMO, R.F., and PENLAND, S., 1984. Shoreline evolution along the northern coast of the Gulf of Mexico. *Shore and Beach,* 52(1), 11–17.

NUMMEDAL, D. and HUMPHRIES, S.M., 1978. Hydraulics and dynamics of North Inlet, South Carolina, 1975–1976. *GITI Report #16,* U.S. Army Corps of Engineers, Coastal Engineers Research Center, 214p.

O'BRIEN, M.P., 1969. Equilibrium flow area of inlets on sandy coasts. *Journal of Waterways and Harbors Division, American Society of Civil Engineers,* 95(1) 43–52.

O'BRIEN, M.P. and DEAN, R.G., 1977. Hydraulics and sedimentary stability of coastal inlets. *Proceedings 13th Coastal Engineering Conference American Society of Civil Engineers,* 11, 761–779.

OERTEL, G.F., 1975. Ebb-tidal deltas of Georgia estuaries. *In:* CRONIN G. (ed.), *Estuarine Research, Volume II, Geology and Engineering.* New York: Academic, pp. 267–276.

PENLAND, S. and BOYD, R., 1981. Shoreline changes on the Louisiana barrier coast. *Oceans,* pp. 209–219.

PENLAND, S.; RAMSEY, K.E.; MCBRIDE, R.A.; MOSLOW, T.F., and WESTPHAL, K.A., 1987. *Relative Sea Level Rise and Subsidence in Louisiana and the Gulf of Mexico.* Louisiana Geological Survey, Coastal Geology Technical Report, 125p.

RAMSEY, K.E. and MOSLOW, T.F., 1987. A numerical analysis of subsidence and sea level rise in Louisiana. *In:* KRAUS, N.C. (ed.), *Coastal Sediments '87.* American Society of Civil Engineers, New Orleans, Louisiana, pp. 1673–1688.

SALINAS, L.M.; DELAUNE, R.D., and PATRICK, W.H., 1986. Changes occurring along a rapidly submerging coastal area: Louisiana, USA. *Journal of Coastal Research,* 2(3), 269–284.

SHAMBAN, A., 1985. Historical Evolution, Morphology and Processes of Barataria Pass, Louisiana. Unpublished M.S. Thesis, Department of Geology, Louisiana State University, Baton Rouge, Louisiana, 320p.

SUTER, J.R. and PENLAND, S., 1987. Evolution of Cat Island Pass, Louisiana. *Coastal Sediments '87,* American Society of Civil Engineers, pp. 2078–2093.

SWANSON, R.L. and THURLOW, E.I., 1973. Recent subsidence rates along the Texas and Louisiana coast as determined from tide measurements. *Journal of Geophysical Research,* 78, 2665–2671.

U.S. ARMY CORPS OF ENGINEERS, 1972. *Grand Isle and Vicinity, Louisiana Review Report: Beach Erosion and Hurricane Protection.* New Orleans District, New Orleans, Louisiana.

U.S. DEPARTMENT OF COMMERCE, NATIONAL OCEANIC ATMOSPHERIC ADMINISTRATION, 1988. *Tide Tables, East Coast of North and South America.* Washington, D.C.: U.S. Government Printer.

VAN DE KREEKE, J., 1990. Can multiple tidal inlets be stable? *Estuarine, Coastal, and Shelf Science,* 30, 261–273.

VAN HEERDEN, I.L. and ROBERTS, H.H., 1980. The Atchafalaya Delta—Louisiana's new prograding coast. *Transactions of the Gulf Coast Association of Geological Societies,* 30, 497–506.

WALKER, D.J. and JESSUP, A., 1992. Analysis of the dynamic aspects of the River Murray Mouth, South Australia. *Journal of Coastal Research,* 8(1), 71–76.

WALTON, T.L., 1977. A relationship between inlet cross-section and outer bar storage. *Shore and Beach,* April, 1977, pp. 9–13.

WARD, G.H., JR., 1982. Pass Cavallo, Texas; Case study of tidal-prism capture. *Journal of Waterways, Port, Coastal and Ocean Engineering,* 108(WW4), 513–525.

WAX, C.L., 1978. Barataria Basin: Synoptic Weather Types and Environmental Responses. Coastal and Wetland Resources, Louisiana State University. CWR-LSU, 60p.

WEBB, C.K.; STOWE, D.A., and CHUNG, H.H., 1991. Morphodynamics of southern California inlets. *Journal of Coastal Research,* 7(1), 167–187.

□ RÉSUMÉ □

Une séquence de diverses morphologies typiques de goulets tidaux, comprise entre formes à dominante tidale et à dominante marine se produit sur le littoral de la plaine du delta du Mississipi. Il n'y a pas de variation notable du marnage moyen (35 cm) ou de la hauteur moyenne significative de la houle (50 cm) dans cette partie de la côte de Louisiane. L'agencement des corps sableux dans les différents goulets est lié au prisme de marée échangé entre chaque baie et le Golfe du Mexique, et l'apport sédimentaire.

Cette étude montre que les modifications dans le temps du prisme de marée et l'apport sédimentaire se traduisent par des séquences de la morphologie des goulets. Cette évolution est soulignée durant la phase d'abandon de lobes individuels du delta du Mississipi. Au cours de la première étape de l'abandon, représentée par l'arrière pays flanqué de flèches barrière, une forte subsidence provoque l'extension de la baie. Tandis qu'elle croit enn surface, le prisme tidal augmente et provoque la formation de goulets à dominance marine, et développe des morphologies de ce type. Au commencement de cette seconde étape d'abandon du lobe du delta (systèmes d'arcs barrières), l'apport sédimentaire demeure limité. Les flèches confinées aux fragments de goulets à dominance tidale provoquent l'élargissement du rétrécissement du goulet; le courant de marée décroît en force et la houle commence à remplir les principaux chenaux de jusant par des sables provenant du delta de jusant.—*Catherine Bousquet-Bressolier, Géomorphologie E.P.H.E., Montrouge, France.*

□ RESUMEN □

En la planicie costera del Río Mississippi, se presenta una secuencia morfológica en los pasos de marea, que van, desde los dominados por las olas hasta aquellos dominados por las mareas. No existe una variación apreciable ni en la amplitud media de la marea (0,35 m) ni en la altura significativa media de la ola (0,50 m). En esta parte de la costa de Louisiana, la distribución de los cuerpos de arena en los pasos individuales están asociados con el prisma de marea y los intercambios entre la bahía respectiva y el Golfo de Méjico, y el aporte de sedimentos.

Estos estudios evidencian que ante cambios temporales en el prisma de marea y en el suministro de sedimentos se presenta un cambio sequencial en la morfologia del paso. Las evoluciones de los pasos se han manifestado durante la fase de abandono de los lóbulos individuales del representada por los cabos flanqueados por barrreras de espigas con una alta tasa de subsidencia, producen la expansión de las bahías. Como el área de la bahía se incrementa, el prisma de marea aumenta produciendo un paso dominado por las olas que luego evoluciona a una morfología dominada por la marea. Al inicio de la segunda etapa del lóbulo del delta abandonado (sistemas de barreras de islas en arco) se limita el aporte de sedimentos. Confinando las espigas a pasos fragmentados dominados por las mareas se producen otros cuyas bocas se ensanchan; las velocidades de las corientes de marea decrecen y las olas comienzan a invadir el canal principal de reflujo con arenas derivadas del delta de marea de reflujo.—*Néstor W. Lanfredi, CIC-UNLP. La Plata, Argentina.*