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Subsurface Controls on Transgressive Tidal Inlet Retreat Pathways, Mississippi River Delta Plain, U.S.A.

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ABSTRACT

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Tidal inlets and associated barriers along the Mississippi River delta plain are migrating landward in response to rapid relative sea-level rise, backbarrier land loss, and tidal prism increases. Bathymetric data, vibracores, and high-resolution subbottom profiles are used to construct a stratigraphic model of the modern Timbalier Islands including Little Pass Timbalier and Raccoon Pass tidal inlets as well as the relict, landward Terrebonne barrier island trend. Large sand deposits comprising relict ebb deltas are associated with the Terrebonne paleo-barrier trend. Modern inlets are aligned with relict inlets. Moreover, modern inlets have migrated approximately 3 km in a landward direction during the past 100 years with little lateral migration, indicating a tendency of retreating inlets to remain fixed in former inlet channels. Cores from Little Pass Timbalier show that tidal currents are presently scouring into underlying relict Terrebonne ebb tidal delta deposits and introducing this sand into the modern littoral system. Stratigraphic data from modern inlet systems show that tidal inlet retreat paths may also coincide with former distributary channels. Finally, during periods of delta reoccupation and progradation, it appears that relict tidal inlet channels may control the pathway of advancing distributaries. Collectively, these processes lead to an amalgamation of deltaic coastal sand deposits.

ADDITIONAL INDEX WORDS: *ebb tidal delta, inlet migration, relict tidal inlet*

INTRODUCTION

High rates of relative sea-level rise (> 1 cm/yr) in the Mississippi River Delta Plain (MRDP) results in the landward migration of barrier islands at rates locally in excess of 10 m/yr (PENLAND AND RAMSEY, 1990; MCBRIDE *et al*., 1992). Barrier shoreline retreat, coupled with an increasing backbarrier tidal prism size, results in a complex tidal inlet morphologic evolution that includes: landward migration, widening and deepening of the inlet throat, and expansion of tidal deltas (FITZGERALD *et al*., 2004; MINER *et al*., 2005).

The transgressive barrier islands of the MRDP are the result of deltaic progradation, abandonment, and reworking by marine processes. Significantly, the antecedent geomorphology of deltaic progradational events has a strong control on tidal inlet geometry, position, and distribution. The presence of tidal inlets can similarly influence the location and geomorphology of subsequent distributary network progradation.

This paper focuses on understanding the antecedent geological controls on tidal inlet retreat pathways and distributary progradational events. The objective of this study is to determine the morphologic and stratigraphic relationship between the modern inlets and antecedent deposits including fluvial distributaries and relict transgressive tidal inlets associated with earlier deltaic progradational events. The area of investigation includes Raccoon Pass and Little Pass Timbalier, adjacent tidal inlets that are located along a deteriorating deltaic headland (Bayou Lafourche headland) and flanking barrier island systems (Timbalier Islands) (Figure 1). A brief description of the methods and database can be found in MINER *et al.* (this volume) and a detailed account is given in KULP *et al.* (2006a).

DELTAIC SHORELINE EVOLUTION

The Lafourche delta complex formed as the Mississippi River prograded across the earlier formed Teche delta complex approximately 2,500 yr BP (FRAZIER, 1967). The oldest Lafourche delta lobe that prograded the study area was the Bayou Terrebonne distributary network, active between 830 and 1,270 yr BP (Figure 2) (PENLAND *et al*., 1988; see summary by KULP *et al.,* 2005). The modern course of Bayou Lafourche represents the position of the last major distributary channel of the Lafourche complex that prograded into the study area 710 yr BP and continued prograding until approximately 300 yr BP (FRAZIER, 1967; PENLAND *et al*., 1988; KULP *et al.,* 2005).

Subsequent to the abandonment of the Terrebonne distributaries, marine transgressive processes became dominant and the abandoned lobe became an erosional headland. During the transgressive phase continual reworking of the distributary mouth bars and relict shorelines by shoreface retreat provides a sand source for a sandy barrier shoreline that is backed by bays and lagoons. The Terrebonne shoreline formed during this transgressive event and is evident in a linear trend that consists of Casse Tete Island, Devil's Bay Point, the landward limit of the Cheniere Caminada beach ridges, and Fifi Island north of Grand Isle (Figures 1 and 2) (GERDES, 1982).

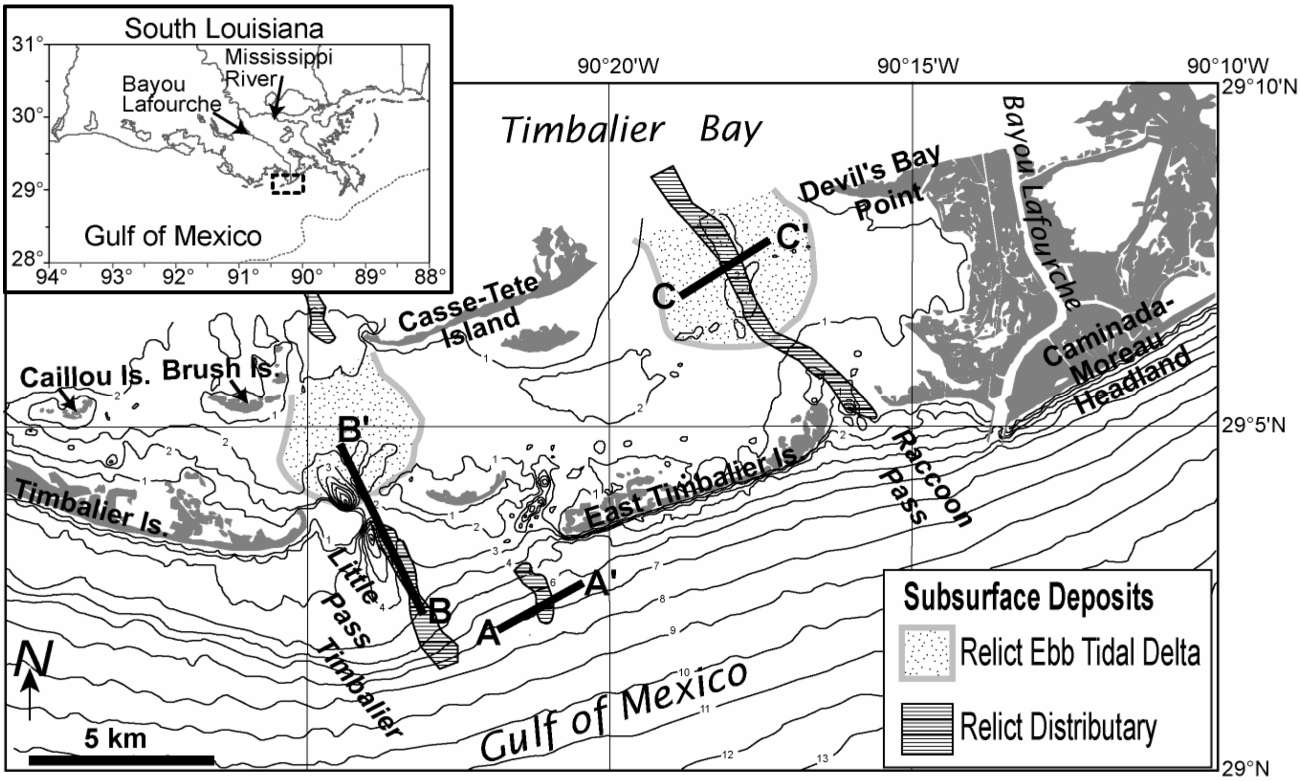

Figure 1. Base map of the study area along the south-central Louisiana shoreline. Map shows the spatial relationship of modern and relict tidal inlets and distributary pathways to the modern and paleo shorelines. Bathymetric contour interval is 1 m relative to MLLW for the 1980's. Bathymetric and shoreline data from LIST *et al.* (1994).

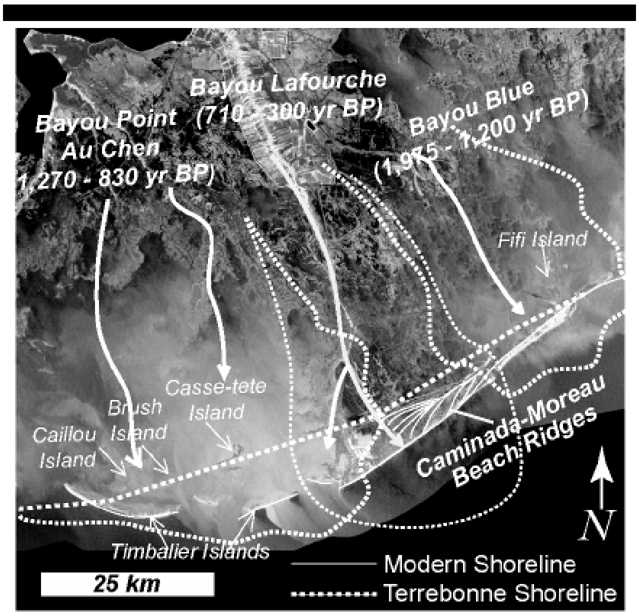

Figure 2. Map of the study area showing the suggested chronology of paleo-shorelines and distributary advancements. Shoreline and delta lobe locations and associations are based on data from FRAZIER (1967), GERDES (1982), PENLAND *et al*. (1988), and KULP *et al*. (2005).

Following fluvial abandonment and subsequent transgression of the Terrebonne shoreline, distributary reoccupation of the Lafourche complex took place as the Bayou Lafourche distributary network began to prograde approximately 710 yr BP and bypassed the seaward extent of the Terrebonne transgressive shoreline (GERDES, 1982; KULP *et al*., 2005). Seaward progradation of the Bayou Lafourche distributaries began to have a "groyne effect" on the updrift side of the headland. Sand derived through longshore transport from the eastern portion of the Terrebonne shoreline (Fifi Island) and Grand Terre island farther east began to form the Caminada-Moreau regressive beach ridges abutting the protruding deltaic headland. Abandonment of the Lafourche distributary network 300 yr BP, resulted in transgression and marine reworking of the previously progradational Lafourche delta lobe to form the present-day Caminada-Moreau erosional headland with flanking barrier islands (PENLAND *et al*., 1988).

Within the present transgressive phase, the Caminada-Moreau beach ridge plain has become the major sand source for lateral spit accretion to the east and west of the headland. Breaching of these spits has resulted in the formation of tidal inlets and nearly symmetrical flanking barrier island systems (PENLAND *et al*., 1988). The flanking barrier islands consist of the Timbalier Islands to the west and Grand Isle to the east.

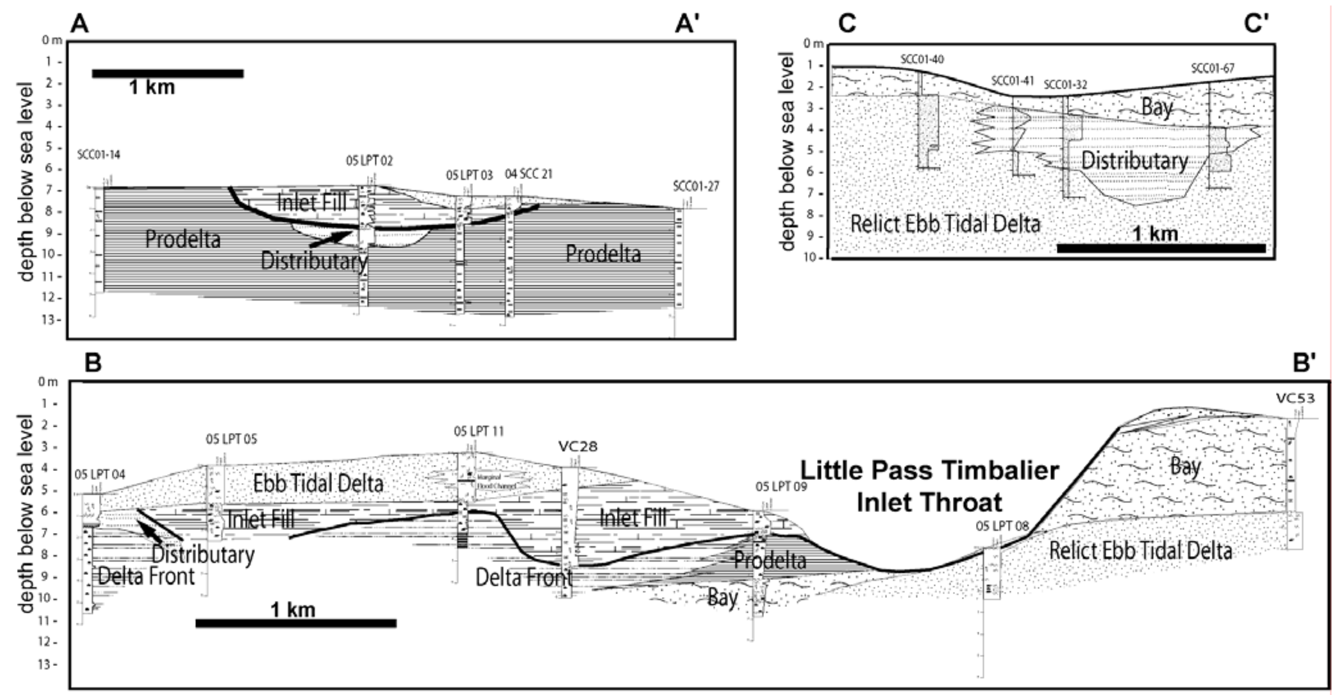

Figure 3. Stratigraphic cross sections that demonstrate the subsurface controls on inlet retreat pathways: A) paleo-distributary control of inlet location, B) distributary control (at 05LPT05) and relict inlet control (05LPT08 and VC53), and C) relict inlet controlling distributary pathway. Note in A that the prodelta consists of fine-grained, cohesive deposits that are erosion-resistant relative to the distributary deposits. Location of each cross section is on Figure 1.

RESULTS AND DISCUSSION

Paleo-distributary Control of Modern Tidal Inlet Retreat Pathways

The stratigraphic investigation of the Timbalier barrier shoreline resulted in the identification in distributary associated deposits underlying the inlet channel fill at Little Pass Timbalier and the modern inlet position of Raccoon Pass (Figures 1 and 3). The investigation of KULP *et al*. (2006b) revealed that Raccoon Pass is downcutting into a distributary fill deposit and previous workers have suggested this for other inlets along the Louisiana coast (FISK, 1944; LEVIN, 1995). This vertical facies relationship is important to understanding the genesis and evolution of the MRDP tidal inlets.

At Little Pass Timbalier a breaching event between 1880 and 1930 resulted in the formation of a new, main ebb channel (MINER *et al*., 2005). Vibracore 05LPT04 sampled at the location of the 1930's Little Pass Timbalier channel position show distributary deposits located seaward and underlying tidal inlet fill deposits (Figure 3B). Historical maps and a time-series analysis of barrier island migration in WILLIAMS *et al.* (1992) show that this breach probably occurred in the location of a former distributary location.

Vibra-cores (05LPT03 and 05LPT02) sampled along the Little Pass Timbalier retreat path show distributary channel deposits that have a sharp contact with overlying inlet fill deposits (Figure 3A). Subbottom profile sections show channel fills associated with the distributary deposits in the cores. Cores sampled in the vicinity of the cores that show the inlet fill/distributary relationship that did not penetrate inlet fill are composed entirely of fine-grained prodelta and delta front deposits.

A stratigraphic study conducted by KULP *et al.* (2006b) determined that Raccoon Pass was downcutting into former distributary deposits. Those deposits and the retreat path of Raccoon Pass trend along the axis of a distributary channel fill identified in vibracores and shallow subbottom profiles located landward of Raccoon Pass (Figure 1).

Because MRDP Barrier islands form by a means of mainland detachment and backbarrier submergence due to RSLR (PENLAND *et al*., 1988), the formation is a gradual process in which the backbarrier morphology and lithology is influential on early stages of the barrier island/inlet system development. During the early stages of distributary abandonment, as fluvial input begins to decline, marine processes begin to affect the distal portions of the distributary mouth, simultaneously the interior marshes subside to form interdistributary bays (COLEMAN, 1981). Natural levees along the abandoned distributaries remain subaqueously exposed, channeling the increasing input from tidal currents (RUSSELL, 1939). The distributary complex becomes a network of tidal channels draining the bays, while concurrent backbarrier land loss continually increases bay-tidal prism size. The distal portion of the distributary has a relatively abundant amount of coarse-grained sediments from distributary mouth bar deposition (FISK, 1955), and possibly relict shorelines (GERDES, 1982). This coarse-grained constituent is available for reworking to form the early transgressive sandy shorelines. If tidal currents dominate over wave action, then the distributary channel would remain open along the shoreline as a tidal inlet.

As the shoreline migrates landward, the inlets will be most stable along a migration path that follows a former distributary channel. This is because the distributary deposits are flanked by more erosion resistant prodelta and delta front clays. As tidal currents scour into the substrate, the distributary deposits are easily excavated and the distributary fill has the potential to govern the inlet retreat pathway. It has been proposed by previous workers that MRDP tidal inlets occupy former distributary channels (LEVIN, 1995; KULP *et al.*, 2006b) and the occupation of incised fluvial valleys by modern tidal inlets has been observed in Texas (SIRINGAN and ANDERSON, 1993) as well as along the Atlantic coast (MORTON and DONALDSON, 1973; IMPERATO *et al.*, 1988).

The resulting stratigraphic architecture reflects the regressive component of the fluvio-deltaic deposits and a transgressive component in the inlet fill and shoreface deposits.

Relict Inlet Control of Modern Tidal Inlet Retreat Pathways

The MRDP is the result of multiple, spatially and temporally offset deltaic depocenters that prograde seaward, are abandoned by fluvial processes, and become erosional headlands dominated by marine forces. This cyclic process results in amalgamated transgressive shorelines such as the Timbalier Islands and relict Terrebonne shoreline (Figure 2).

Relict inlets associated with the Terrebonne shoreline have been identified in vibracores. These relict inlets are somewhat aligned with the modern inlets. Landward and subjacent to Little Pass Timbalier is a large subsurface sand deposit, identified in vibracores and interpreted to be a relict ebb tidal delta associated with the Terrebonne shoreline (Figure 1). At the main ebb channel of Little Pass Timbalier, tidal currents are presently scouring into underlying relict Terrebonne ebb tidal delta deposits and introducing this sand into the modern littoral system (Figure 3B).

The relict ebb tidal delta is bounded by bay fill prodelta clays, which are more erosion resistant than the massive sand comprising the relict ebb tidal delta. As tidal currents scour the substrate, the sands are preferentially eroded and the inlet is currently migrating across the relict ebb tidal delta.

Inlets Controlling Distributary Course

During fluvial reoccupation of a formerly abandoned distributary system, progradation beyond the relict transgressive shoreline may occur (Figure 4). Such is the case with the Bayou Lafourche distributary and the Terrebonne shoreline (Figures 1 and 2). Cores from relict inlets of the Terrebonne shoreline show a vertical shift in depositional facies from tidally produced deposits up to fluvio-deltaic deposits. When correlated and mapped, the region of the relict inlet consists of sediment bodies interpreted to represent a distributary channel that dissects the relict ebb tidal delta deposit (Figure 3C). While subsurface tidal inlet deposits may contribute somewhat in determining the route of an advancing distributary, existing bay and inlet channel morphology and hydraulics have the dominant control.

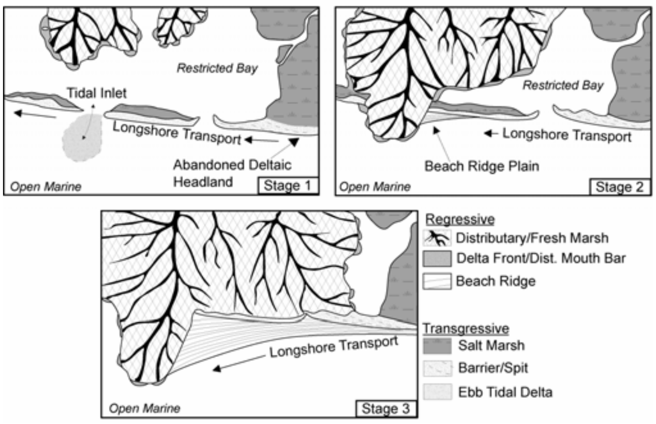

Figure 4. Conceptual model demonstrating the bypassing of a transgressive barrier shoreline by an advancing distributary via a tidal inlet channel. Note the "groin effect" that the prograded distributary has on the littoral system resulting in the development of beach ridges. From KULP *et al*. (2005).

CONCLUSION

Modern transgressive tidal inlets, relict inlet systems, and distributary channels of the MRDP have the potential to control subsequent inlet and distributary channel position, and in the case of the landward migrating tidal inlet, antecedent deposits may control the retreat pathway. Stratigraphic data show that modern inlets occupy former distributary locations and that inlet landward retreat is probably fixed along the paleo-distributary course. Relict tidal inlet deposits appear to control modern inlet retreat pathways. Moreover, tidal inlets have the potential to be reoccupied by an advancing distributary. While antecedent morphology that controls hydrodynamics is the dominant control on the location and position of transgressive tidal inlets and prograding distributaries, the erodability of the channel substrate relative to adjacent fine-grained deposits serves to direct inlet retreat routes. The genetic relationship between transgressive tidal inlet deposits and progradation distributary deposits results in the amalgamation of fluvio-deltaic and tidally generated coastal facies.

LITERATURE CITED

COLEMAN, J.M., 1981. *Deltas: Process of Deposition and Models for Exploration*. Minneapolis, Minnesota: Burgess, 124 p.

FITZGERALD, D.M.; KULP, M.A.; PENLAND, S.; FLOCKS, J., and KINDINGER, J., 2004. Morphologic and Stratigraphic Evolution of Muddy Ebb-Tidal Deltas along a Subsiding Coast: Barataria Bay, Mississippi River Delta. *Sedimentology*, 51, 1157-1178.

FISK, H.N., 1944. *Geological investigations of the alluvial valley of the lower Mississippi River.* Vicksburg, Mississippi: U.S. Army Corps of Engineers, Mississippi River Commission, 78p.

FISK, H.N., 1955. Sand facies of recent Mississippi delta deposits. *4th World Petroleum Congress Proceedings, Section I*, pp. 377-398.

FRAZIER, D.E., 1967. Recent Deltaic Deposits of the Mississippi River: Their Development and Chronology. *Gulf Coast Association of Geological Societies Transactions*, 17, 287-315.

GERDES, R.G., 1982. Stratigraphy and history of development of the Caminada-Moreau beach ridge plain, southeast Louisiana. Baton Rouge, Louisiana: Louisiana State University, Master's Thesis, 185p.

IMPERATO, D.P.; SEXTON, W.J., and HAYES, M.O., 1988. Stratigraphy and Sediment Characteristics of a Mesotidal Ebb-Tidal Delta, North Edisto Inlet, South Carolina. *Journal of Sedimentary Petrology*, 58(6), 950-958.

KULP, M.A.; FITZGERALD, D.; PENLAND, S.; MOTTI, J.; BROWN, M., FLOCKS, J.; MINER, M.; MCCARTY, P., and MOBLEY, C., 2006b. Stratigraphic Architecture of a Transgressive Tidal Inlet-Flood Tidal Delta System: Raccoon Pass, Louisiana. *Journal of Coastal Research, Special Issue 39, in press*.

KULP, M.A.; FITZGERALD, D., and PENLAND, S., 2005. Sand-rich lithosomes of the Holocene Mississippi River delta plain. *In:* BHATTACHARYA, J.P. and GIOSAN, L. (eds.), *River Deltas-Concepts, Models, and Examples*. Society of Economic

Mineralogists and Paleontologists Special Publication No. 83, pp. 277-291.

KULP, M.A.; FLOCKS, J.; KINDINGER, J.; PENLAND, S.; FERINA, N., and DREHER, C., 2006a. *Geology and Sand Resources in the Vicinity of East Timbalier Island*. Reston, Virginia; U.S. Geological Survey, Open File Report, OFR 2006-1039.

LEVIN, D.R., 1995. Occupation of a relict distributary system by a new tidal inlet, Quatre Bayou Pass, Louisiana. *In*: Flemming, B.W., and Bartholoma, A., (eds.), *Tidal signatures in modern and ancient sediments*. International Association of Sedimentologists Special Publicaion 24, p. 71-84.

LIST, J.H.; JAFFE, B.E.; SALLENGER, A.H., JR.; WILLIAMS, S. J.,MCBRIDE, R.A., and PENLAND, S., 1994. *Louisiana Barrier Island Erosion Study: Atlas of Seafloor Changes from 1878 to 1989*. Reston, Virginia: U.S. Geological Survey and Louisiana State University, Miscellaneous Investigations Series I-2150-A, 81p.

MCBRIDE, R.A.; PENLAND, S.; HILAND, M.W.; WILLIAMS, S.J.; WESTPHAL, K.A.; JAFFE, B.E., and SALLENGER, A.H., JR., 1992. Analysis of Barrier Shoreline Change in Louisiana from 1853 to 1989. *In*, Williams, S.J., Penland, S., and Sallenger, A.H. (eds.), *Louisiana Barrier Island Erosion Study, Atlas of Shoreline Changes in Louisiana from 1853 to 1989.* Reston, Virginia: U.S. Geological Survey and Louisiana State University, Miscellaneous Investigations Series I-2150-A, pp. 36–97.

MINER, M.D., KULP, M.A., AND FITZGERALD, D.,M., Tidal versus Shoreface Ravinement and Tidal Inlet Fill Preservation Potential For Transgressive Tidal Inlets, Mississippi River Delta Plain, U.S.A., *Proceedings of the 2007 International Coastal Symposium.* (Gold Coast, Australia), *this volume*.

MINER, M.D.; FITZGERALD, D.M., and KULP, M.A., 2005. Morphologic Evolution of a Transgressive Tidal Inlet, Little Pass Timbalier, Louisiana. *Gulf Coast Association of Geological Societies Transactions*, 55, 532-542.

MORTON, R.A. and DONALDSON, A.C., 1973. Sediment Distribution and Evolution of Tidal Deltas along a Tide-Dominated Shoreline, Wachapreague, Virginia. *Sedimentary Geology*, 10, 285-299.

PENLAND, S. and RAMSEY, K.E., 1990. RSLR in Louisiana and the Gulf of Mexico: 1908-1988. *Journal of Coastal Research*, 6(2), 323-342.

PENLAND, S.; BOYD, R., and SUTER, J.R., 1988. Transgressive Depositional Systems of the Mississippi Delta Plain: A Model for Barrier Shoreline and Shelf Sand Development. *Journal of Sedimentary Petrology*, 58(6), 932-949.

RUSSELL, R.J., 1939. Louisiana Stream Patterns. *American Association of Geologists Bulletin,* 23(8), 1199-1227.

SIRINGAN, F.P. and ANDERSON, J.B., 1993. Seismic Facies, Architecture, and Evolution of the Bolivar Roads Tidal Inlet/Delta Complex, East Texas Gulf Coast. *Journal of Sedimentary Petrology*, 63(5), 794-808.

WILLIAMS, S.J.; PENLAND, S., and SALLENGER, A.H., JR., 1992. *Louisiana Barrier Island Erosion Study, Atlas of Shoreline Changes in Louisiana from 1853 to 1989*. Reston, Virginia, U.S. Geological Survey and Louisiana State University, Miscellaneous Investigations Series I-2150-A, 103p.

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