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Geology of the Chenier Plain of Cameron Parish, southwestern Louisiana

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ABSTRACT

The Chenier Plain of southwestern coastal Louisiana is a Holocene strand plain composed of wooded beach ridges (cheniers) and intervening mudflat grassy wetlands. The mudflats form as prograding tidal flats along the open, but low-energy Gulf of Mexico coast; cheniers form from winnowing of sand and shells from the mudflats by waves during transgression. Mudflats are deposited when a Mississippi River delta lobe is nearby to the east, and cheniers are formed when distributaries switch to a more distant location farther east. All of the cheniers have formed within approximately the past 3000 yr or less and are progressively younger toward the present coastline. Spits are attached to the cheniers at estuaries; they grow westward in response to the dominant longshore currents. Currently, mudflats are prograding in Vermillion Parish to the east, while cheniers form in eastern Cameron Parish along with some regressive beach ridge development in western Cameron Parish.

This coast is microtidal with low wave energy. A high rate of subsidence as well as sea-level rise characterizes the Chenier Plain, which is subject to increased wave energy and mud transport every year during many cold-front passages and periodic storm surges associated with tropical cyclones of much lower frequency. Major storm surges can inundate the entire Chenier Plain, wreaking havoc on human settlements.

Keywords: Chenier Plain, Louisiana, Holocene, Chenier, mudflat, hurricane, Gulf of Mexico, Mississippi River delta lobe, spits, estuaries, longshore current, Cameron Parish, Vermillion Parish, beach ridge, sea-level rise, microtidal, subsidence, cold front, tropical cyclone, storm surge.

INTRODUCTION

This paper reviews and summarizes the geology of the Chenier Plain of southwestern Louisiana, especially its western portion in Cameron Parish. Many geologists have contributed to the present-day understanding of the development of the upper Holocene sediments and the landforms of the Chenier Plain, and much of their work is summarized in this paper.

Definitions

A chenier plain is a strand plain consisting of long, narrow-wooded beach ridges (cheniers) and intervening mudflats with marsh or swamp vegetation (Otvos and Price, 1979). The word chenier is derived from the Cajun French word, *chene*, meaning oak, the dominant tree growing on crests of high cheniers in southwestern Louisiana, where cheniers were first named by Russell and Howe (1935) (see Figures 1 and 2). A few other examples of

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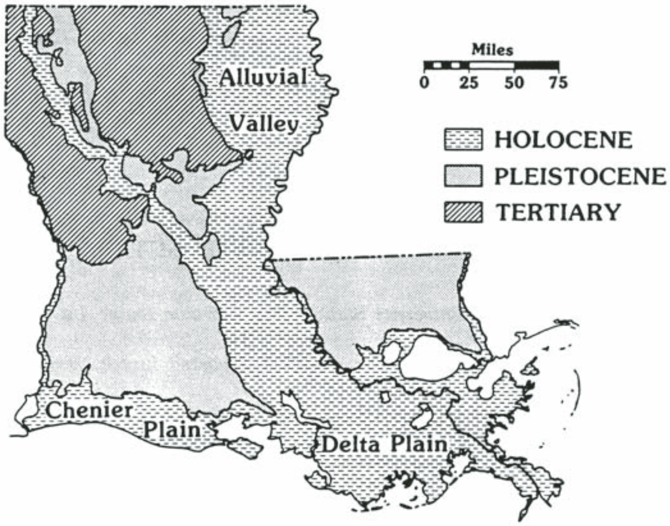

Figure 1. Geologic map of Louisiana locating Chenier Plain. From Penland and Suter (1989, Fig. 1).

cheniers are present on Earth including the extensive mud belt of Suriname. Recently, Taylor et al. (1996, p. 414) suggested that the term *chenier complex* be used instead of *chenier plain* for an area with at least two cheniers separated by muddy units.

Early Work

Formation of the Chenier Plain is related to the process of delta switching of the Mississippi River to the east which affects the down-drift area to the west (Kolb and van Lopik, 1958; Frazier, 1967). Howe et al. (1935) and Russell and Howe (1935) first interpreted the Chenier Plain to have formed by alternating suspended sediment deposition and wave erosion of sandy mud, leaving the chenier ridges stranded as winnowed sand and shell deposits. This alternation was controlled by the Mississippi River shifting delta lobes from closer to (depositing mud) and farther from (allowing waves to build cheniers) the Chenier Plain, respectively. After the Chenier Plain sediments were cored, Fisk

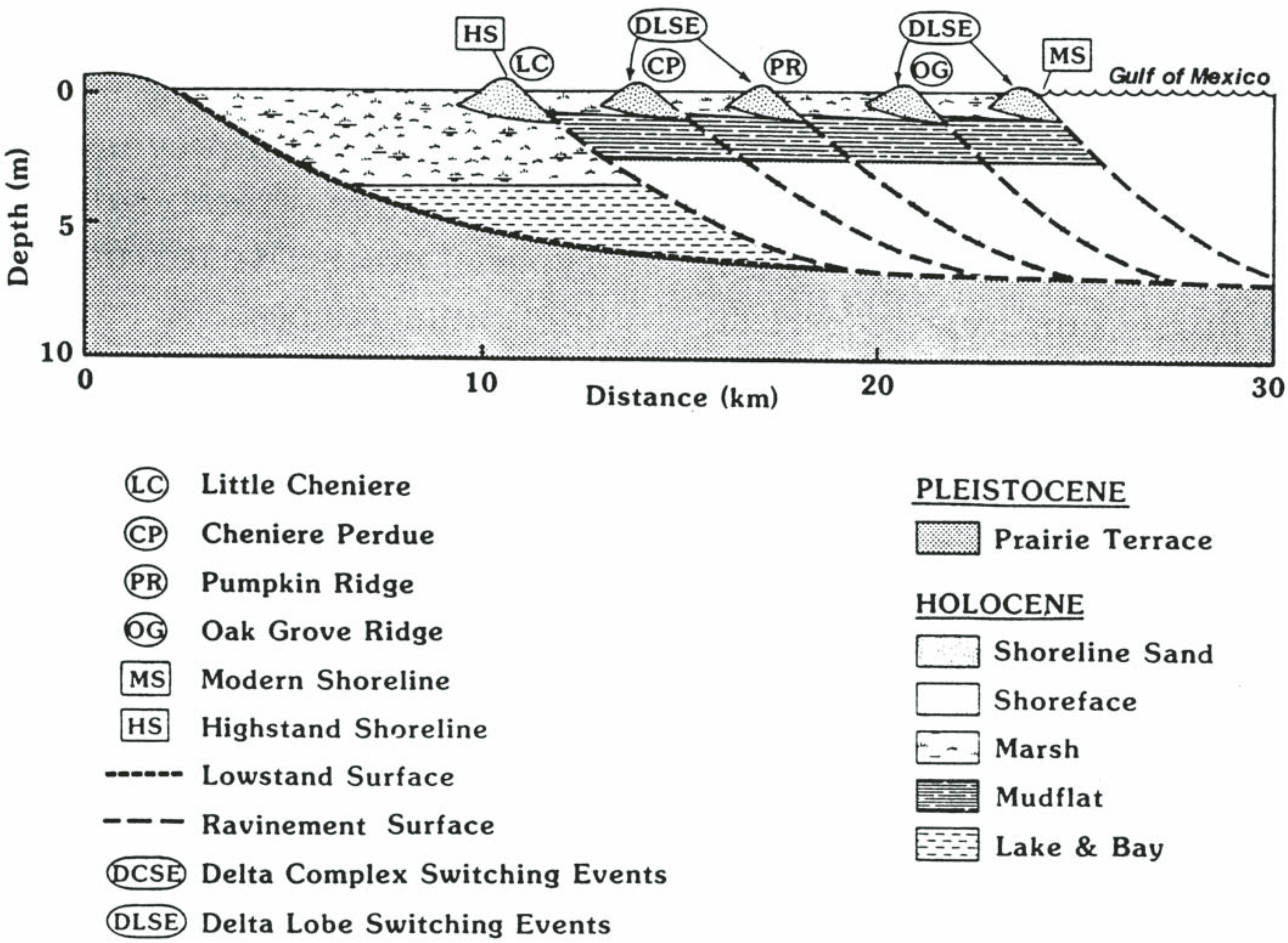

Figure 2. Idealized cross section across Chenier Plain with chronostratigraphic interpretations of facies belts. Cheniers become younger from left (inland) to right (seaward). Modified from Penland and Suter (1989, Fig. 18 therein).

(1955) constructed maps of sediment thickness, and Price (1955) described their origin. Gould and McFarlan (1959) and Byrne et al. (1959) presented more detailed studies of the Chenier Plain architecture and age.

According to radiocarbon dates of shells, the oldest cheniers (such as Little Chenier) are farthest landward (Fig. 2), and were shown to be nearly 3000 years old (late Holocene); cheniers are progressively younger closer to the modern coastline (Brannon et al., 1957; Gould and McFarlan, 1959). Penland and Suter (1989), in one of the most comprehensive papers on the Chenier Plain, presented data showing that sea level in southwestern Louisiana was 5–6 m lower than present ~3000 yr B.P., and that all the present cheniers were built after a rapid rise to near present sea level, which was attained at ~2500 yr B.P. All of these workers agreed that formation of the Chenier Plain was closely related to availability of suspended mud from the lobe- and distributary-shifting Mississippi River. Most early workers tied chenier formation to switching between major delta complexes such as the Teche and Lafourche, but Penland and Suter (1989, p. 257) presented evidence of control of chenier formation by switching among individual delta lobes within the Lafourche delta complex during the past 2500 yr or less. Some of the >2500 yr B.P. dates of Gould and McFarlan (1959) could be too old because of redeposition of older shells in younger cheniers. However, most of the radiocarbon dates were obtained from fragile *Mulinia* shells rather than more durable, easily reworked shells such as *Crassostrea* (Taylor et al., 1996, p. 419).

PROCESSES

Chenier Plain construction was described by Hoyt (1969, p. 301–302) in the following steps: (1) prograding deposition of coastal mudflats with included sand and shells that is rapid enough to preclude removal of fines; (2) reworking of mudflat sediments during shoreline retreat, building a chenier ridge of sand and shells while fines are reworked and transported offshore and alongshore (see Fig. 3); and (3) extension of cheniers by the longshore current into areas not being actively eroded.

Growth of spits, which extended the cheniers into bays, was described by Gould and McFarlan (1959, p. 268–269). These spits, which are slightly younger than the chenier to which they are attached, are most common near the mouths of the Sabine and Calcasieu Rivers (Fig. 4), and, to a lesser extent, the Mermentau River. Todd (1968) described a process of dynamic diversion of longshore drifting sediment by interaction with tidal currents exiting river and estuary mouths, causing deposition of spits, especially on the eastern updrift side. Ebb-tidal flow causes surf suppression and decrease of longshore current velocity, causing deposition of spits on the updrift side. Easterly reversals of longshore-current direction by wave refraction around entrance

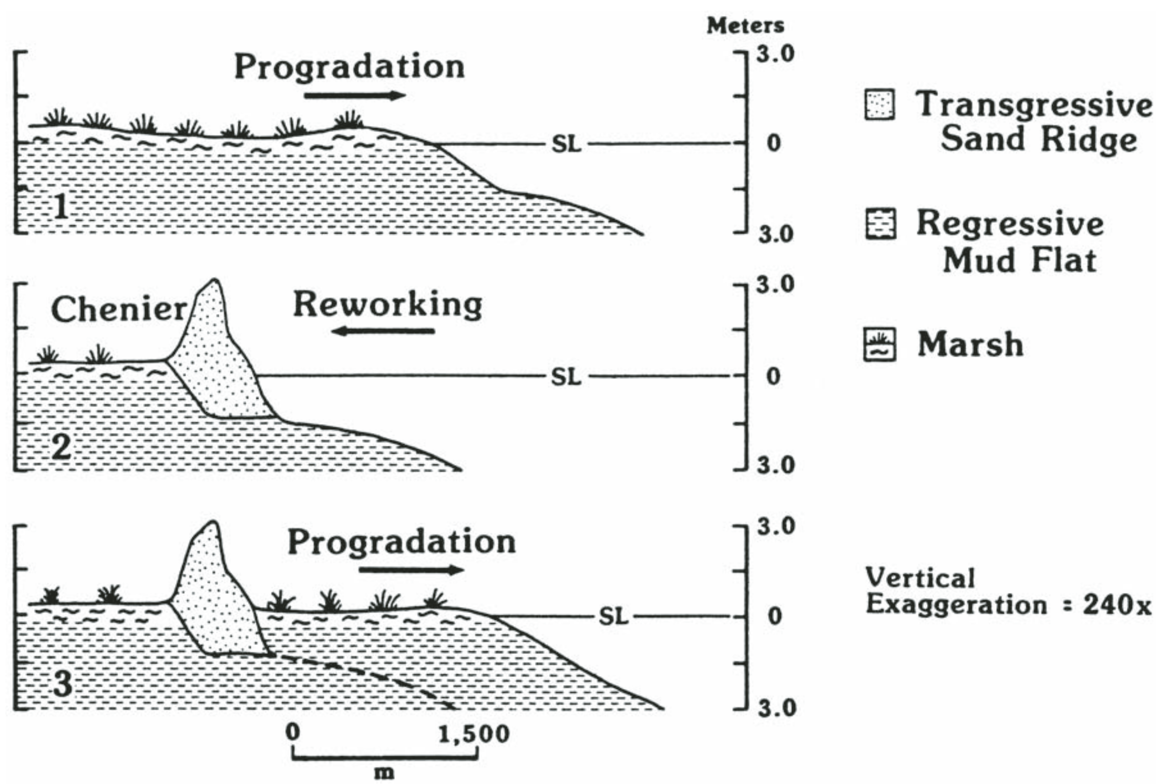

Figure 3. Hoyt's Chenier Plain process model. From Penland and Suter (1989, their Fig. 2).

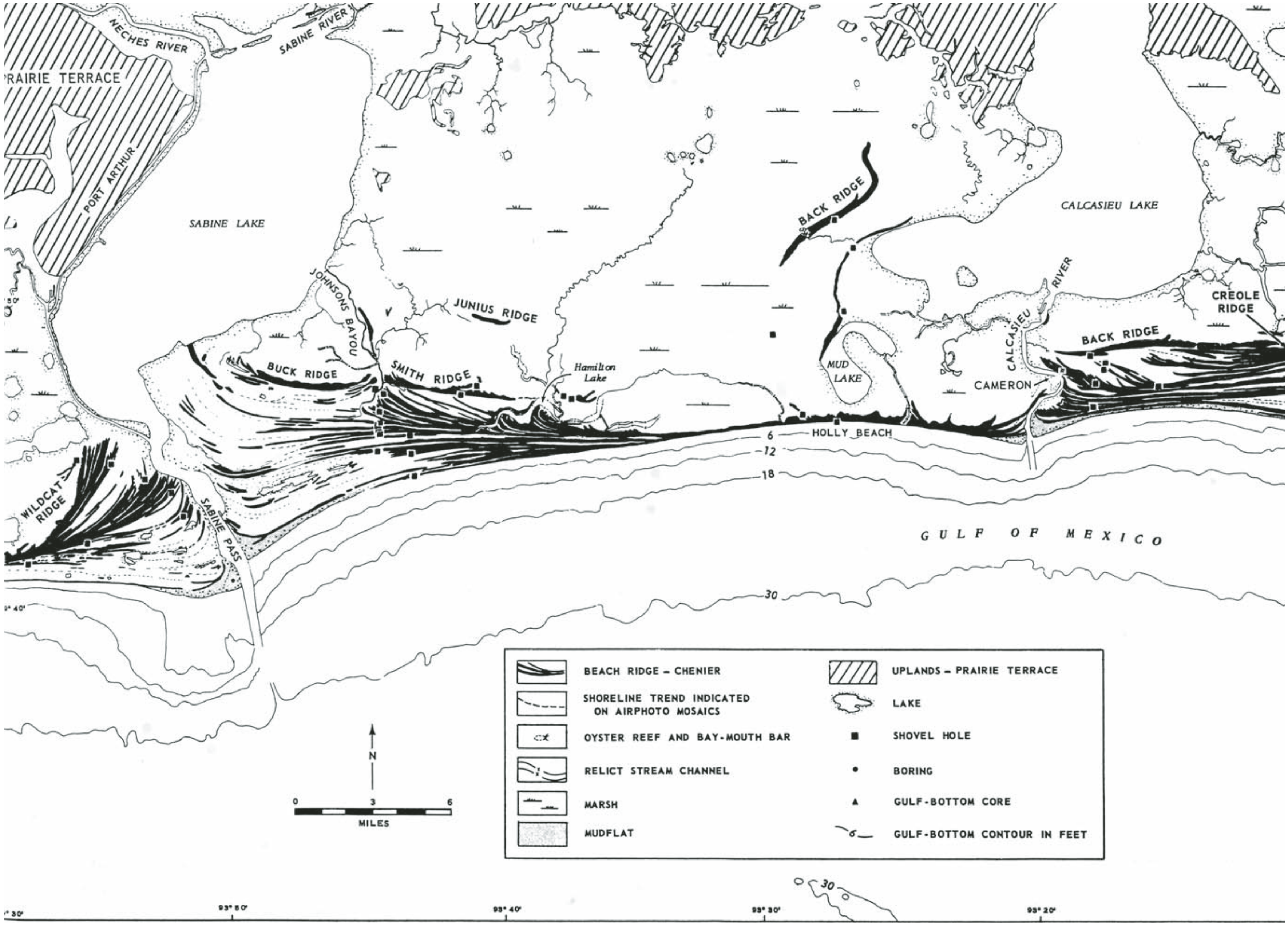

Figure 4. Map of western Chenier Plain with beach ridges-cheniers and upland Prairie Formation (Pleistocene) outcrops (terraces). Note curved spits east of Sabine River mouth and Calcasieu River mouth. Ridges along coast near Johnsons Bayou (former Sabine distributary) are true beach ridges rather than cheniers. Other ridges are cheniers and spits. Modified from Byrne et al. (1959).

shoals have built spits at the west sides of the Sabine and Calcasieu river mouths against the dominant westerly regional longshore drift (Taylor et al., 1996, p. 420). Westside spits are poorly developed on the Mermentau River, but the river has been deflected 20 km to the west by spit growth on the east side (Fig. 5).

After initial construction, active cheniers may build up several meters higher than sea level by moderate storm surges above normal sea level and by dune-building between storm surges. Severe storm surges associated with major hurricanes may overwash active cheniers, flattening dunes, and producing washover sand deposits landward into the adjacent marsh. As the shoreface and dune parts of cheniers are eroded by waves and longshore currents, they may retrograde onto washover sands.

Just after completion of this manuscript, an excellent new paper on the Chenier Plain by McBride et al (2007) was brought to my attention. It develops a six-stage geomorphic process-response

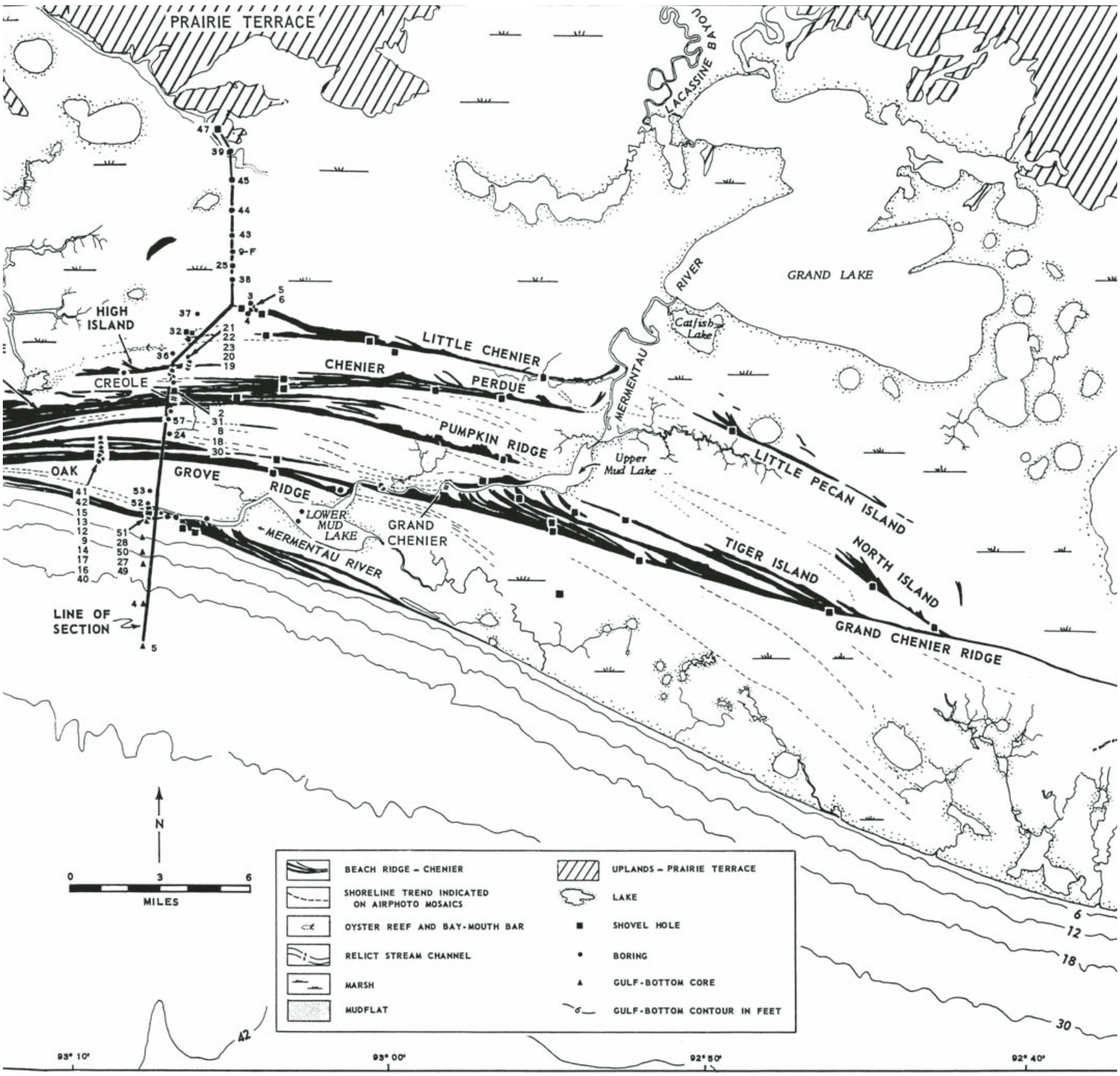

Figure 5. Map of eastern Chenier Plain with cheniers, spits, and upland (Prairie terrace). Note curved spits south of Mermentau River east of Grand Chenier. Little Chenier is the oldest dated chenier on the Chenier Plain. Modified from Byrne et al. (1959).

model to describe Chenier-Plain evolution which should be studied by anyone interested in the Chenier Plain.

INTERNAL STRATIGRAPHY

The internal stratigraphy of the Chenier Plain has been well described by Byrne et al. (1959), Gould and McFarlan (1959), Hoyt (1969), and Penland and Suter (1989). Figure 6 illustrates a classic cross section of offshore, nearshore, marsh, and chenier (washover, beach, and dune) lithofacies. Figure 7 illustrates a typical vertical stratigraphic column through a chenier succession of lithofacies. These figures are sufficient for this general paper, however, the reader who seeks more detail on individual beds and sedimentary structures in a chenier that has been excavated should see Gremillion and Payne (1977).

A complete regressive-transgressive cycle in the Chenier Plain sediments at a chenier ridge location would consist of the stratigraphic units in Table 1.

Units 1–2 are deposited during regression and units 3–4 are deposited during transgression by reworking. Unit 1 may be absent because of nondeposition or erosion prior to mudflat formation. The contact between units 2 and 3 is typically a diastem produced by wave scour. Unit 4 may show paleosol development. An erosional surface formed near the shoreline may truncate Unit 4. Modern marsh sediments, although not part of the chenier cycle, may overlie these units. A more detailed description of the Chenier Plain sediments is given in Penland and Suter (1989; their Table 1).

Variations on the chenier ridge succession exist at locations where spits and beach ridges have developed instead. Spits typically build at entrances to bays, so they rest on bay mud or tidal-channel sand deposits and contain spit platform and foreshore

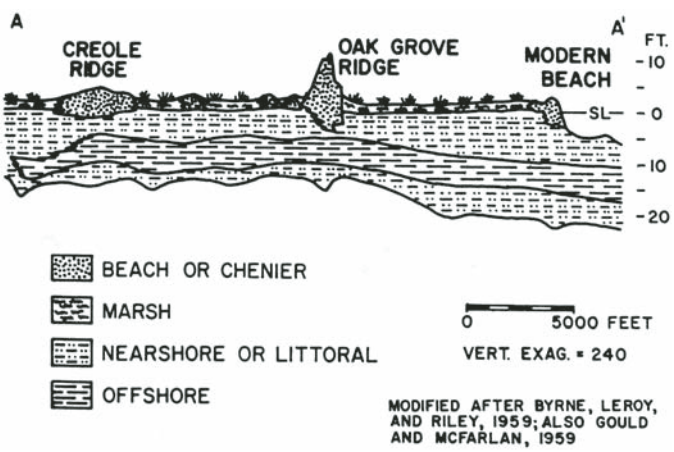

Figure 6. Cross section along north-south line from Creole Ridge to Gulf of Mexico shoreface with lithofacies units. Cheniers are older to left. Line of section is from Creole to Gulf of Mexico shown on Figure 5. From Hoyt (1969, Fig. 3).

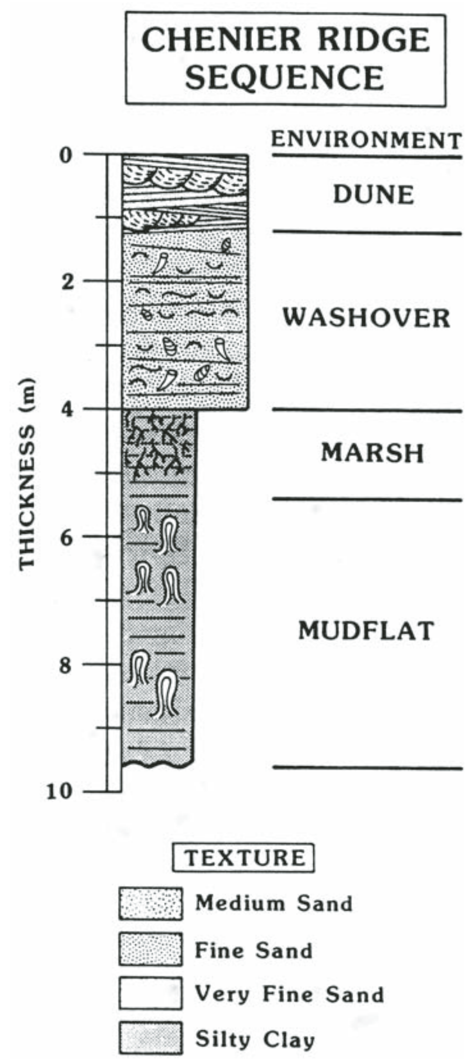

Figure 7. Idealized stratigraphic model of chenier vertical lithologic succession with depositional environments identified. Modified from Penland and Suter (1989, Fig. 7).

TABLE 1. CHENIER STRATIGRAPHIC UNITS IN A REGRESSIVE-TRANSGRESSIVE CYCLE

4. Coastal dune sand with root structures and possible paleosol.	Transgressive
3. Washover sand with reworked shallow marine and brackish shell fauna.	
2. Mudflat silty mud with marginal shallow marine fauna and ichnofauna.	Regressive
1. Offshore mud with normal shallow marine fauna.	

sands below the coastal dune sand (Penland and Suter, 1989, their Fig. 7). Most spits are connected to cheniers.

True beach ridges, which are regressive in nature and contain fresh-water marsh sediments rather than marine mudflat sediments between them, are developed only in the Johnson Bayou area in the westernmost Chenier Plain in Louisiana. They were originally identified as cheniers, but careful examination of the vertical succession in excavations by Kaczarowski (1980) supported their beach-ridge origin. The vertical succession in beach ridges is from shoreface to foreshore to dune deposits (Penland and Suter, 1989, their Fig. 7). As might be expected, these beach ridges are generally younger (<900 yr B.P.) than the cheniers inland of them, and these beach ridges are the only significant area of prograding sandy/shelly shoreline today (Byrnes et al., 1995, their Fig. 2).

Both beach ridges and cheniers have obviously steeper slopes on the seaward side than on the landward. Dunes tend to be higher on modern beach ridges than cheniers.

MODERN CONDITIONS

The Chenier Plain today is in a time of transition—the eastern part in Vermillion Parish is beginning to accumulate prograding mudflats at a rapid rate, the central part in eastern Cameron Parish is still in the erosional, chenier-forming stage, and the western part in western Cameron Parish is experiencing a period of slow, regressive beach-ridge building. All of this is occurring on a microtidal, low–wave-energy coast. According to Byrnes et al. (1995, p. 113), tides range from 0.6 to 0.8 m (mean to spring); locally generated wind waves from the south and southeast dominate 18% and 22% of the time, respectively; and breaking wave heights average 0.5 m with a 5-second period. Net longshore sand transport is 47,000–76,000 m^3/yr to the west, based on shoreline erosion calculations, according to the U.S. Army Corps of Engineers (1971). The offshore slope is fairly low, averaging 1:125 out to the 10 m depth contour line (Taylor et al., 1996, p. 415). The rate of relative sea-level rise at the Calcasieu Pass tide-gauge station is 0.57 cm/yr, based on the period 1942–1988 (Fig. 8), but this is only half of the rise at the Grand Isle station on the Mississippi Delta, where subsidence is greater (Penland and Ramsey, 1990, their Table 2). Relative sea-level rise in the delta is 10 times faster than on most of the rest of Earth (Penland and Ramsey, 1990, p. 323).

The high rate of subsidence is the dominant factor in shoreline erosion on the Louisiana coast, including the Chenier Plain coast, in spite of the low energy of waves and tides on this microtidal coast. The Johnsons Bayou beach ridges on the westernmost Louisiana coast between the Sabine River and Ocean View beach, as mentioned above, are prograding (3.5 m/yr from 1883 to 1994) according to Byrnes et al. (1995, p. 116). According to Byrnes et al. (1995), the Calcasieu headland coast (Fig. 9), which is devoid of cheniers other than the modern beach, from Ocean View beach through Peveto Beach to Calcasieu Pass (Fig. 9) is retreating, especially in the western area between Ocean View beach and Holly Beach, at an average rate of 1.2 m/yr (1883–1994). Retreat has been greater in recent years, and breakwaters, a revetment to protect the highway, and artificial beach nourishment have been put in place to contest coastal erosion in this area. The eastern area between Holly Beach and the Calcasieu River has been eroding at approximately the same rate as the chenier coast to the west. The area near Calcasieu Pass, especially on the east side of the jetties, has been developing a prograding mudflat in the wave shadow of the shoals off Calcasieu Pass. This section of the coast has very low wave energy at

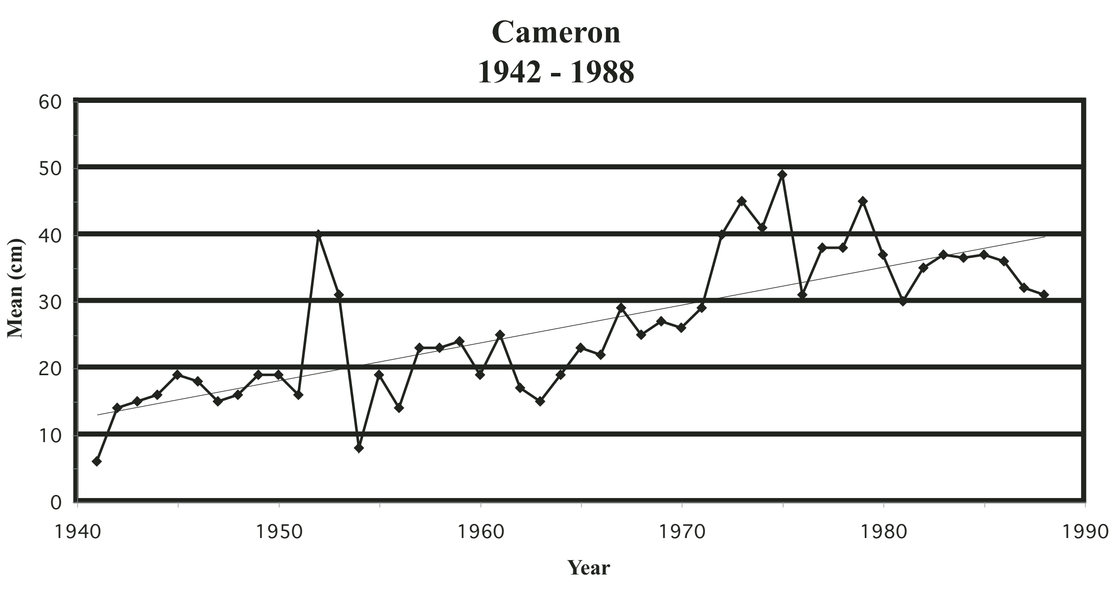

Figure 8. Water level time-series graph for Calcasieu Pass tide-gauge station near Cameron, Louisiana for period of 1942–1988. Mean relative sea-level rise is 0.57 cm/yr. Adapted from Penland and Ramsey (1990, their Fig. 9).

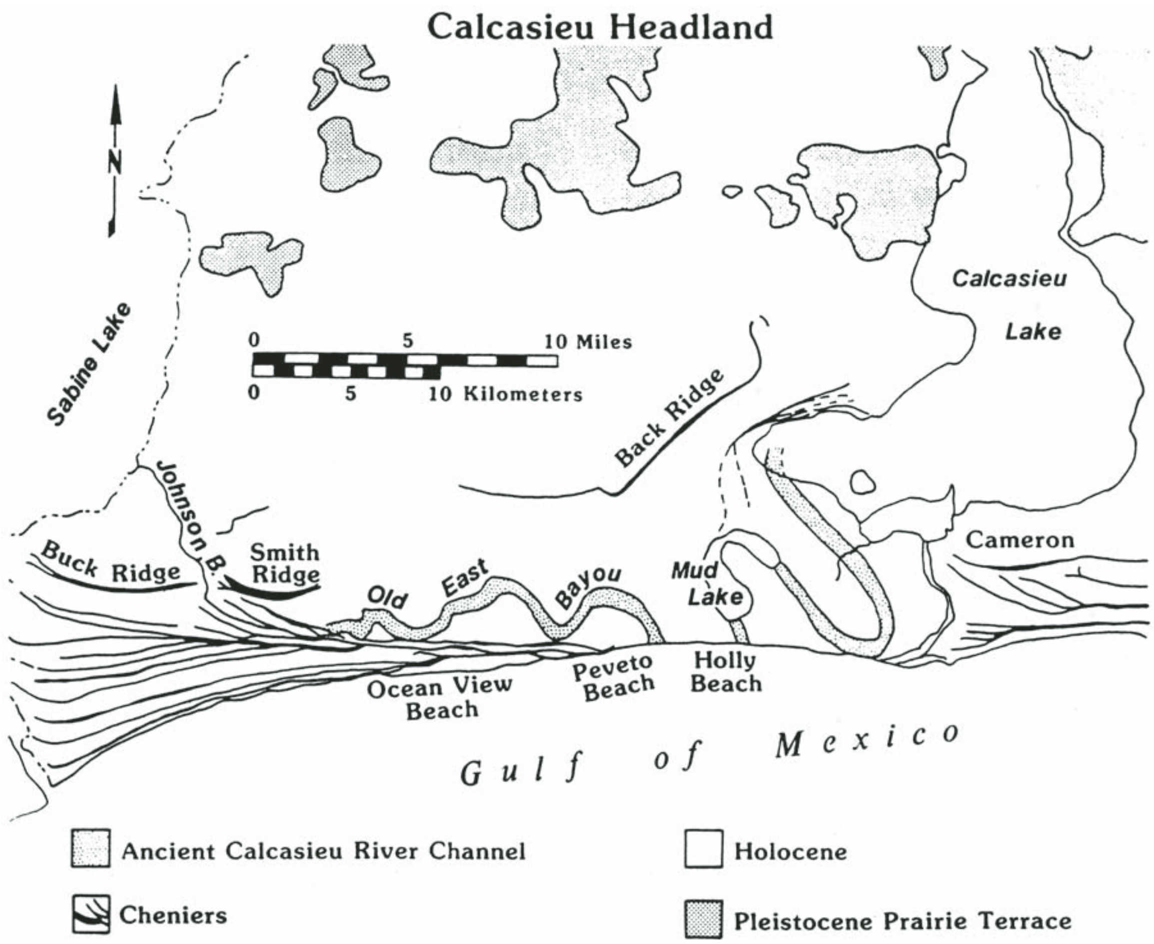

Figure 9. Landforms of the Calcasieu headland area. Ridges along coast near Johnsons Bayou are true beach ridges. Other ridges to north and near Cameron are cheniers and spits. From Penland and Suter (1989, their Fig. 12).

the shoreline. Some of the mudflat was eroded by the storm surge of Hurricane Rita during September, 2006, leaving shell-armored mud balls on the remaining mudflat. A similar hurricane, Audrey, in 1957, affected the same area. Chenier Plain response to Hurricane Bonnie, a category 1 storm during 1986, was described by Nakashima (1989).

Modern accretion of mudflats west of Vermillion Bay in the eastern Chenier Plain of Vermillion Parish began during ca. 1950 A.D. (Morgan et al., 1953), coincident with the development of the new subaqueous delta and its discharge plume in Atchafalaya Bay, just east of Vermillion Bay, the first pulse of sediment accumulation in this area after 1000 yr (Wells and Kemp, 1981, p. 409). The Atchafalaya mud stream (Figs. 10 and 11) has been building mudflats at the high rate of ~50 m/yr (Huh et al., 2001, p. 79). Huh et al. (2001; their Fig. 8) illustrated a new mudflat (Fig. 12) that had attained a width of 770 m (510 m of which is subaerial) in 11 yr (1987–1998). Roberts et al. (2002, p. 850) also concluded that winter cold-front passages (20–30/yr) and tropical storms every few years result in a water level set-up and shore-normal transport of mud from the nearshore shelf onto the shoreface, where it is stranded on these new mudflats. The suspended fine mud in the nearshore zone attenuates wave energy, facilitating mud deposition at the very low-energy shoreline (Wells, 1986, p. 428).

CONCLUSIONS

The Chenier Plain is a strand plain consisting of long, narrow-wooded beach ridges (cheniers) and intervening mudflats with marsh or swamp vegetation. It formed by alternating suspended sediment deposition and wave erosion of sandy mud, leaving the chenier ridges stranded as winnowed bed load sand and shell deposits as the Mississippi shifted delta lobes from closer to and farther from the Chenier Plain, respectively. The Chenier Plain today is in a time of transition—the eastern part is beginning to accumulate prograding mudflats at a rapid rate, the central part is still in the erosional, chenier-forming stage, and the western part is experiencing a period of slow regressive beach-ridge building. All of this is occurring on a microtidal, low–wave-energy coast affected by frequent winter cold-front passages and

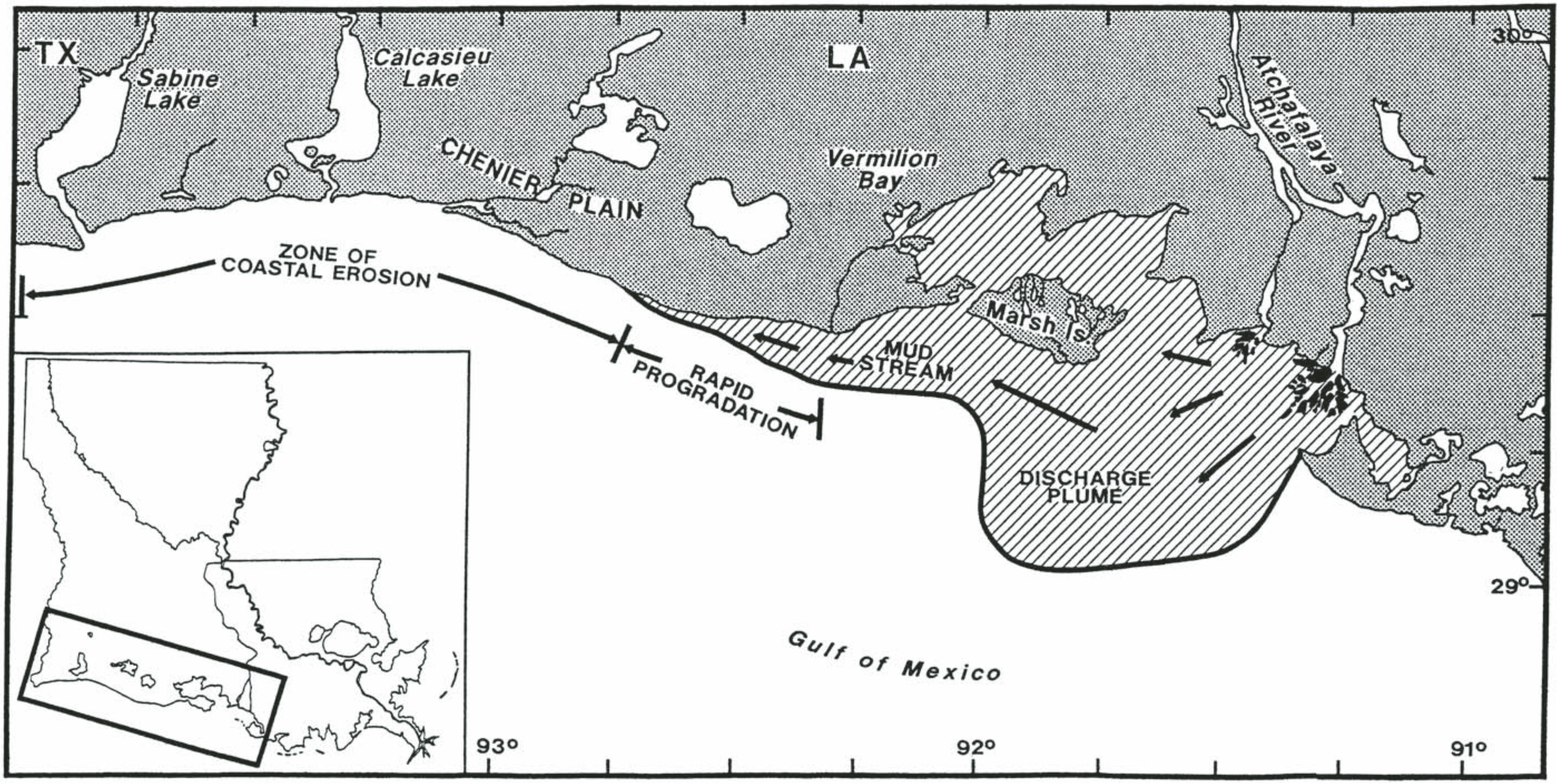

Figure 10. Map of Atchafalaya discharge plume and mud stream that deposits mudflats on eastern Chenier Plain. Note zone of coastal erosion on western Chenier Plain. From Huh et al. (2001, their Fig. 2).

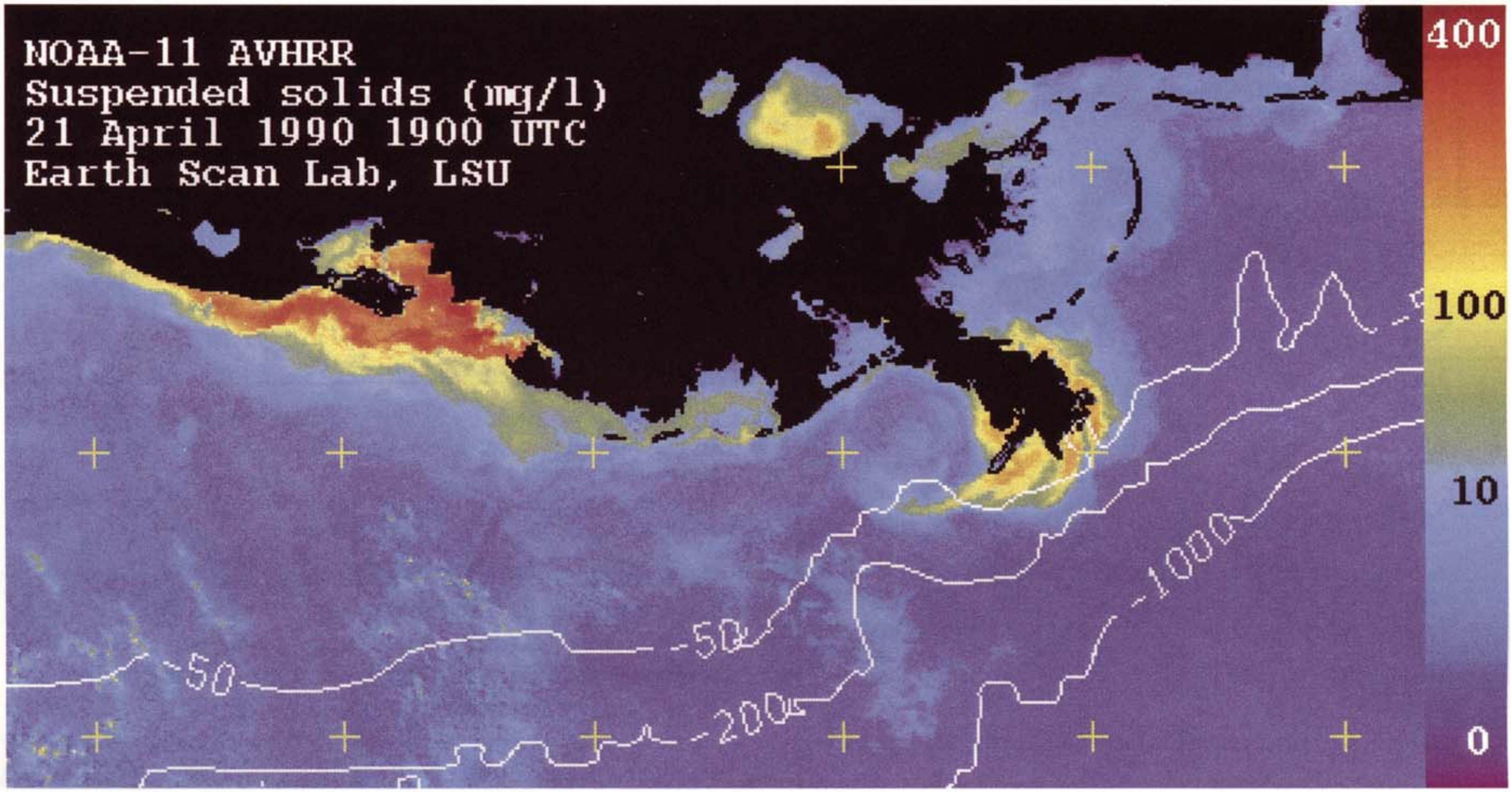

Figure 11. NOAA satellite AVHRR reflected solar radiation image of Louisiana coastal area, calibrated to suspended sediment content of water, 21 April 1990. Note Atchafalaya discharge plume (orange-to-yellow colors) coming out of Atchafalaya Bay and hugging coast westward. This is the normal modern condition. Depths in meters. From Huh et al. (2001, their Fig. 5a).

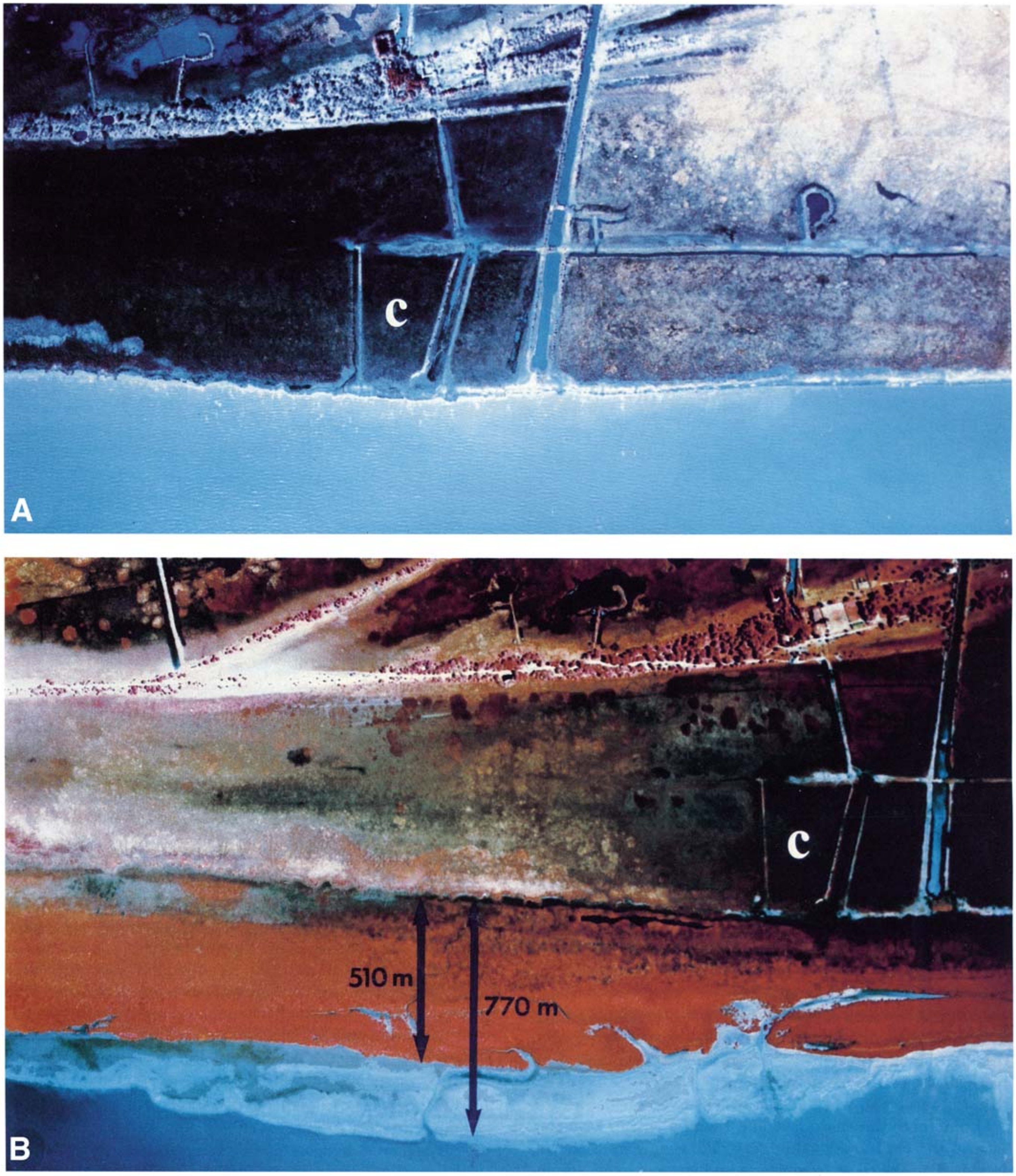

Figure 12. Aerial photographs of triple canal site (c) west of Atchafalaya Bay, Vermillion Parish, on eastern Chenier Plain coast. Upper photo (A): 27 January 1987. Lower photo (B): 4 April 1998. On (B), note plant-covered mudflat (red) extending 510 m from previous shoreline and plant-free mud (light blue) on shoreface between 510 and 770 m. From Huh et al. (2001, their Fig. 8).

occasional tropical storms that influence coastal processes. Major tropical cyclone landfalls near the west end of the Chenier Plain can produce storm surges that inundate the entire Chenier Plain, wreaking havoc on human settlements.

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Notes