

Late Holocene Record of Community Replacement Preserved in Time-Averaged Molluscan Assemblages, Louisiana Chenier Plain

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PALAIOS, 1998, V. 13, p. 488–499

Late Holocene relict shorelines of the southwestern Louisiana chenier plain contain molluscan assemblages that vary greatly in taxonomic composition and bioclast preservation. Taxonomic composition varies with ridge age: older ridges are oyster rich, whereas younger ridges are dominated by infaunal bivalves. Taphonomic features can be separated into those caused by biostratinomic and those caused by pedogenic processes. Pedogenic alteration generally increases as ridge age increases, whereas biostratinomic alteration reflects the prevalence of reworked bioclasts in assemblages. These molluscan assemblages are extensively time averaged, causing temporal overcompleteness of depositional units (i.e., amount of time averaging for bioclasts within a unit is much greater than the time it took for that unit to form).

Chenier-plain progradation over the last 3,000 years both caused and preserved the observed trend in community composition. This trend was caused by community replacement related to changing substrate stability and by changes in the source of reworked bioclasts, both of which operated in response to progradation. Net progradation also allowed this trend to be preserved because time averaging occurred episodically and shorelines were effectively separated into discrete generations. Although coastal deposits are not typically viewed as ideal sites for high-resolution paleoenvironmental studies, millennial-scale community trends can be detected in this setting.

INTRODUCTION

Records of long-term community dynamics and their potential causes are being used increasingly for managing biotic resources and for predicting potential consequences of future environmental change (e.g., Southward et al., 1975, 1995; Barry et al., 1995). The temporal dimension of many ecologic data sets, however, is shorter than the ex-

pected generation time of community members and the reoccurrence interval of relevant environmental processes (Jackson, 1992, 1994; Southward, 1995; Van Valkenburgh, 1995; Aronson and Precht, 1997). Climatic oscillations over tens to thousands of years occurred in the Holocene (Dickinson, 1995; O'Brien et al., 1995; Keigwin, 1996; Dean, 1997; Alley et al., 1997), and probably had major influences on nearshore benthic communities. In addition, temporal and spatial scales of data sets affect the apparent stability of communities (Kidwell and Bosence, 1991; Jackson, 1992; Pandolfi, 1996). Replicate sampling over decades to a century may be required simply to characterize community membership in coastal-subtidal and continental-shelf settings (Kidwell and Flessa, 1995).

Modern death assemblages and Quaternary fossil assemblages provide historical data on community dynamics (Jackson, 1992; Kidwell and Flessa, 1995; Jablonski and Sepkoski, 1996; Stoner and Ray, 1996; Aronson and Precht, 1997). Short-term population fluctuations typically are not preserved in these assemblages but, rather than being a hindrance, time averaging may serve to filter short-term noise so that long-term trends in community composition and structure can be detected (Fürsich and Aberhan, 1990; Jackson, 1992; Kowalewski, 1996; Kidwell and Flessa, 1995; Stoner and Ray, 1996).

A temporal trend in community composition occurs in late-Holocene relict-shoreline deposits of the southwestern Louisiana chenier plain. Older ridges are oyster rich, whereas younger ridges are dominated by infaunal bivalves. The objectives of this study are to: (1) document patterns of variation in taxonomic composition and preservation for both relict and modern shorelines of the chenier plain; and (2) determine the cause(s) of these patterns of variation. We found that the temporal trend primarily represents an episode of community replacement, which is preserved because the net progradational nature of the chenier plain effectively separated shorelines into discrete generations that provide an episodically time-averaged census of shallow-marine biota.

STUDY AREA

The southwestern Louisiana chenier plain, a marginal-deltaic environment of the Mississippi River, has undergone net progradation over about the last 3,000 years (Byrne et al., 1959; Gould and McFarlan, 1959). It is composed primarily of marsh-capped mud. Linear sand- and/or shell-rich ridges, a majority of which are parallel to sub-parallel with the modern shoreline, are interspersed with the muds (Fig. 1). These ridges are relict shorelines called cheniers. In the classic model of chenier-plain evolution, delta switching causes mudflat progradation to alternate with chenier formation, which occurs during shoreline retreat (Hoyt, 1969; Fig. 2). Cheniers, however, are not exclusively transgressive deposits, and regressive and laterally-accreted segments are common (Taylor et al., 1996). Below, we use the terms chenier and ridge interchangeably.

Sample Locations

Eighteen samples are used in this study. Sample localities are from the central part of the chenier plain where

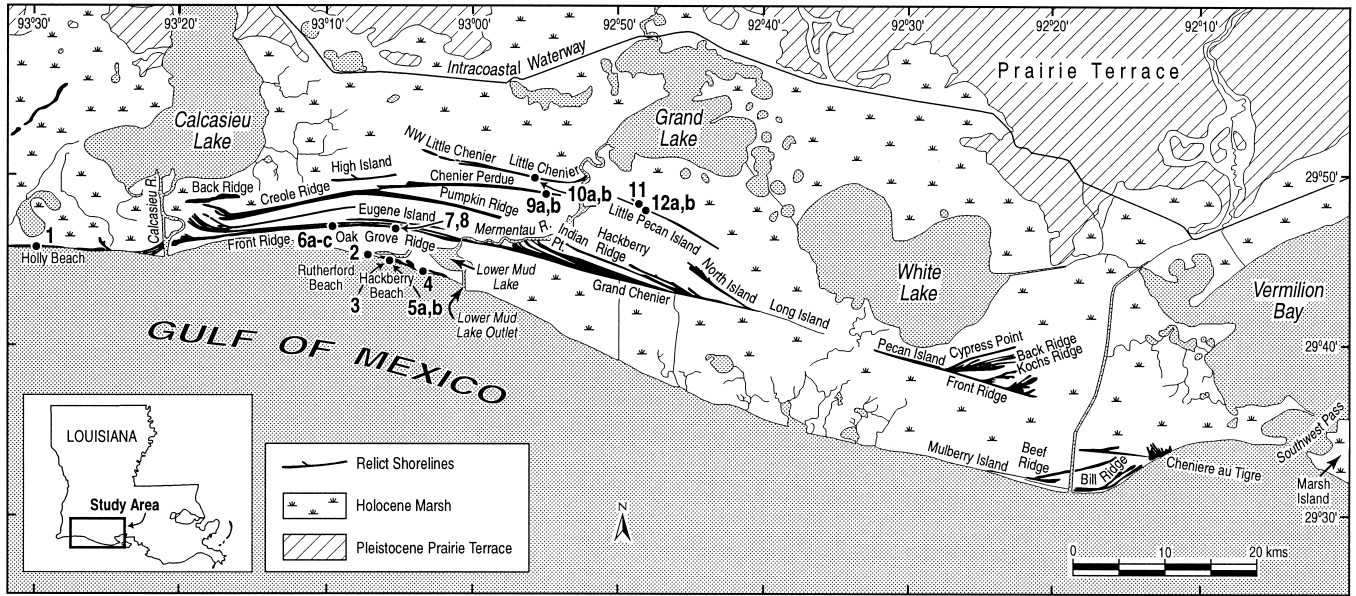


FIGURE 1—Map of the study area with sample localities plotted and labeled. See Table 1 for brief locality descriptions. After Taylor et al. (1996).

multiple generations of well-developed ridges occur (Fig. 1). Table 1 provides brief sample descriptions, and Figures 3 and 4 illustrate selected localities and sampled units. Four samples were collected (samples 1–4) along the modern coastline at beaches with wave-concentrated shell accumulations. The direction (transgressive, regressive, or laterally accreted) and amount of shoreline movement differs among these localities (Byrnes et al., 1995a; Table 1).

Remaining samples are from 6 ridges representing 4 relict shorelines of the chenier plain (Fig. 5). Estimated ages of these shorelines are from Gould and McFarlan (1959), and all dates are reported in radiocarbon years (see below). The relict spit complex at Hackberry Beach (samples 5a–b) was the youngest ridge sampled with an estimated age of 600 yr B.P. Front Ridge (samples 6a–c) and Oak Grove Ridge (samples 7–8) are adjacent segments of the most laterally extensive shoreline preserved on the chenier plain (called the Grand Chenier trend), which formed about 1,100 yr B.P. Chenier Perdue (samples 9a–b) is part of the 2,100 yr B.P. shoreline trend. Little Chenier (samples 10a–b) and Little Pecan Island (samples 11, 12a–b) have been interpreted as part of the same shoreline trend (Howe et al., 1935; Taylor, 1996; Taylor et al., 1996) and represent one of the oldest preserved shorelines of the chenier plain with an estimated age of 2,800 yr B.P.

ESTIMATES OF TIME AVERAGING IN LOUISIANA CHENIERS

Only general statements regarding time averaging in Louisiana cheniers are possible because available data are problematic for several reasons. First, most dates are not fully documented. Information on material/species used, detailed description of locality and horizon, and analytical error have been published (in Brannon et al., 1957; McFarlan, 1961) for only 17 of 127 dates used by Gould and McFarlan (1959) to construct their chenier-plain chronology. Available dates are reported in radiocarbon years, are not corrected for reservoir effects, and are not calibrated to calendar years. Second, all samples used for dating apparently were bulk samples (containing more than one shell). The date derived from a bulk sample is a weighted average age of all specimens in that sample (e.g., Roy, 1991). When more than one species is included in a bulk sample, an undetermined amount of variation due to differences in carbon fractionation among species also is incorporated. Third, because radiocarbon dates are not evenly distributed among ridges and the range of a sample tends to increase with sample size (especially when sample size is small), apparent time averaging increases with the number of dates per ridge.

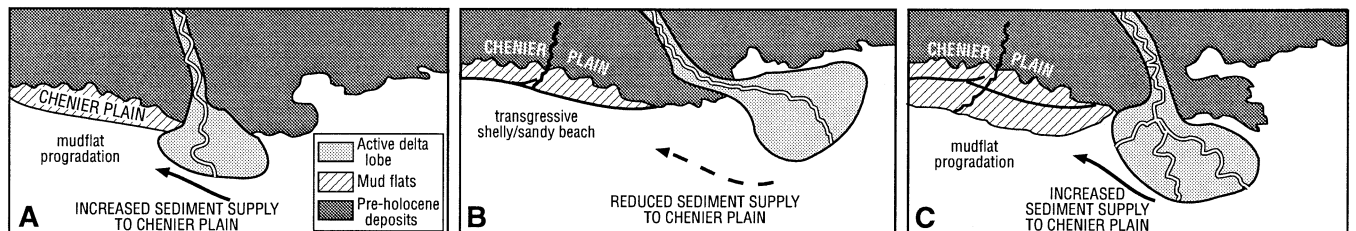


FIGURE 2—Classic model of chenier-plain evolution. (A) Time 1, delta switches west. (B) Time 2, delta switches east. (C) Time 3, delta switches west. After Taylor et al. (1996).

TABLE 1—Sample locality descriptions.

Locality	Shoreline Movement ^{1,2}	Sample ³	Description of Deposit Sampled	Sample Depth (m)
Modern Barrier Beaches				
Holly Beach	stable (+0.1 m/yr)	1	<i>Mulinia lateralis</i> -dominated shell lag	surface
Rutherford Beach	regressive (+2.7 m/yr)	2	<i>Anadara ovalis</i> -dominated shell lag	surface
Hackberry Beach	transgressive (−8.7 m/yr)	3	<i>M. lateralis</i> -dominated shell lag	surface
Perched beach west of Lower Mud Lake Outlet	transgressive (−8.7 m/yr)	4	<i>M. lateralis</i> - and <i>A. ovalis</i> -dominated shell lag	surface
Ridges ⁴				
Relict spit complex at Hackberry Beach	lateral	5a	<i>M. lateralis</i> - and <i>A. ovalis</i> -dominated graded shell bed	0.2–0.5
		5b	<i>M. lateralis</i> - and <i>A. ovalis</i> -dominated graded shell bed	0.5–0.7
Front Ridge	regressive	6a	<i>M. lateralis</i> -dominated shell bed	0.99–1.17
		6b	<i>M. lateralis</i> -dominated shell bed	1.9–2.04
		6c	<i>M. lateralis</i> -dominated graded shell lens	2.69–2.8
Oak Grove Ridge	transitional from regressive to transgressive	7	<i>M. lateralis</i> -dominated shell bed	2.4–2.55
		8	<i>M. lateralis</i> -dominated shell bed	1.15–1.3
Chenier Perdue	transgressive	9a	<i>Ostrea equestris</i> - and <i>M. lateralis</i> -dominated graded shell bed	0.4–0.65
		9b	<i>O. equestris</i> -dominated graded shell bed	0.65–0.8
Little Chenier	transgressive	10a	<i>O. equestris</i> - and <i>Crassostrea virginica</i> -dominated shell bed	0.8–1
		10b	<i>O. equestris</i> - and <i>C. virginica</i> -dominated shell bed	1–1.2
Little Pecan Island	lateral	11	<i>O. equestris</i> - and <i>M. lateralis</i> -dominated shell bed	0.6–0.8
		12a	<i>O. equestris</i> - and <i>M. lateralis</i> -dominated shell bed	0.4–0.65
		12b	<i>O. equestris</i> - and <i>M. lateralis</i> -dominated shell bed	1.35–1.5

¹ Direction and rate of change for modern shoreline from Byrnes et al. (1995a).

² Net direction of movement for ridges from Taylor et al. (1996). Direction of shoreline movement along the length of a ridge can change, and only the direction at the sample locality is listed in this column.

³ Samples from different stratigraphic levels of the same measured section are labeled with the same sample number but different letter suffixes. Samples from different measured sections of the same ridge are given different locality numbers.

⁴ Ridges are arranged in relative order from youngest to oldest. See text for estimated ages of ridges, and Figure 5 for radiocarbon dates from ridges as well as a relative shoreline chronology.

Nevertheless, radiocarbon ages of bioclasts from cheniers indicate that assemblages are extensively time-averaged and overcomplete (the amount of time averaging for bioclasts in a depositional unit is much greater than the time it took for the unit to form; Kowalewski, 1996). Although we do not have absolute ages to confirm how long former shorelines were active, we can make a rough estimate using available data. The minimum radiocarbon date of the oldest well-developed and well-dated shoreline (S4 = Little Chenier, Little Pecan Island, and Cypress Point) is 2,520 yr B.P. From this shoreline seaward, there are 11 recognized coarse-grained barrier shorelines (relict and modern) and 10 intervening mudflats or marsh areas,

for a total of 21 depositional episodes. Assuming that the duration of a depositional episode is constant over time and is the same whether a barrier shoreline or a mudflat is forming, then each shoreline was active for about 120 years (= 2,520 yr ÷ 21). The age range of dated bioclasts, however, is >1,000 years for most ridges (Fig. 5). In addition, the maximum age range for a single ridge is 4,750 years (at Pecan Island) and for an entire relict shoreline is 4,900 years (shorelines 6 and 10; see Fig. 5). Shells older than the oldest chenier, estimated to be about 3,000 years old, also are common.

Although the minimum radiocarbon date of a shoreline decreases seaward, as is expected in progradational de-

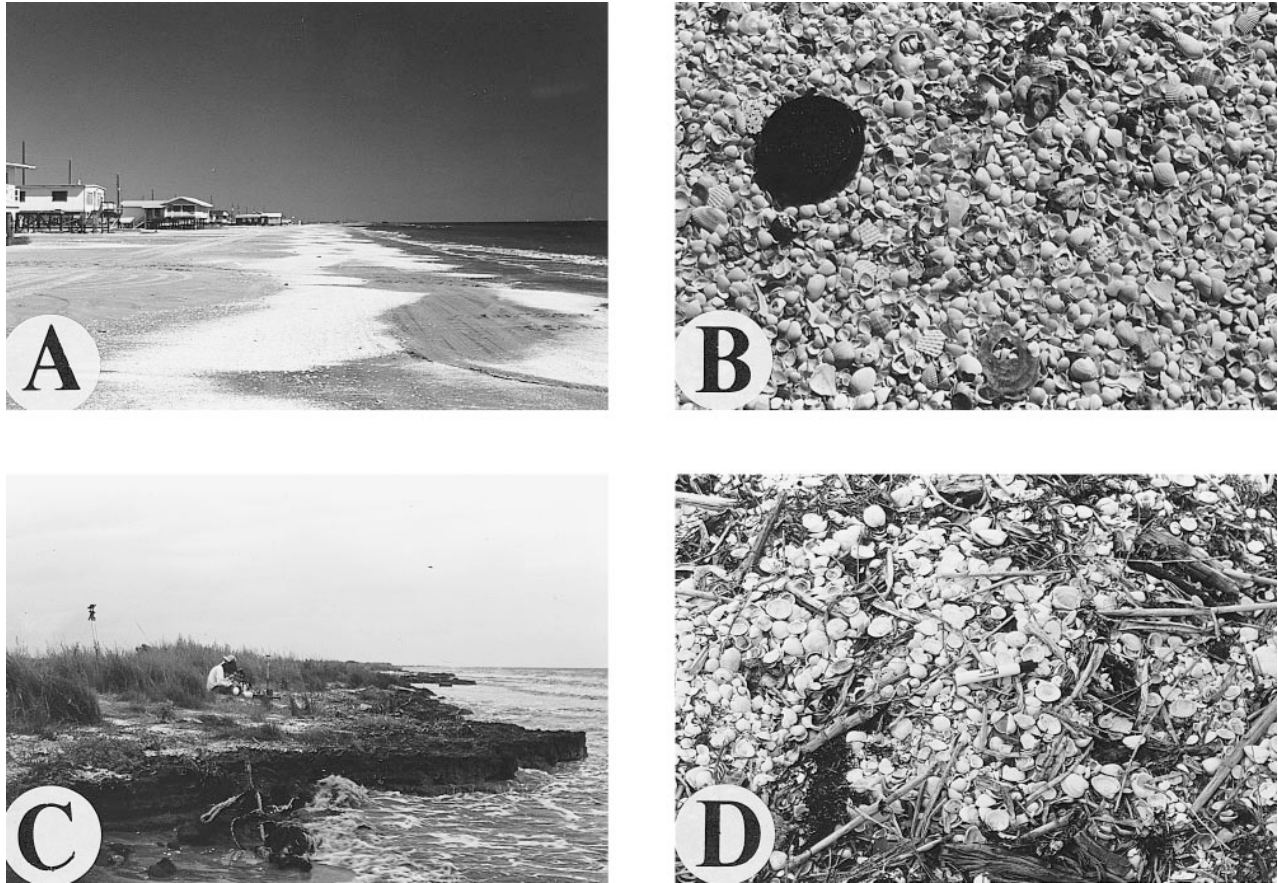


FIGURE 3—Photographs of selected modern beach localities. (A) Swash-zone shell lags at Holly Beach (sample locality 1, October, 1995). (B) Close-up of Holly Beach shell lag. Lens-cap diameter is 50 mm. (C) Perched beach west of Lower Mud Lake Outlet (sample locality 4; July, 1996). Note dark, fine-grained marsh mud being eroded in foreshore. Surveying tripod is located on crest of shell-rich washover deposits of perched beach. (D) Close-up of locality 4 perched beach deposits. Marker in center of photo is 12 cm long.

posits, the amount of time averaging does not show an apparent trend. The two shorelines with the most radiocarbon dates (shorelines 6 and 10) show comparable age ranges, indicating that reworking was a common process associated with shoreline formation throughout chenier-plain history. Reworking was facilitated by the spatial complexity of shoreline dynamics. The modern coast consists of alternating cells of advance and retreat with up-drift erosion providing sediment for downdrift advance of the coastline (Byrnes et al., 1995a). Also, based on cross-cutting relations, older ridges often were cannibalized when younger ridges formed (Fig. 1; Taylor et al., 1996). In this setting, extensive localized erosion and longshore transport could supply reworked sediment downdrift for incorporation into younger ridges.

METHODS

Bulk sediment samples of approximately equivalent volumes (average = 5.5 liters) were washed and sieved, with bioclasts >4 mm retained for analysis. Bivalves and gastropods dominate assemblages. Whole valves and fragments containing the hinge for bivalves, and whole shells and fragments containing the spire for gastropods were picked and counted.

Average-linkage cluster analyses using an Euclidean

distance metric were employed to compare the taxonomic composition of samples (Q-mode) and the co-occurrence of species among samples (R-mode). For these analyses, the total number of bivalve valves was divided by two for an estimate of the number of individuals, and percent abundances of the 17 most common mollusk species (>0.75% in at least one sample) were included.

To examine bioclast preservation, we used a method similar to Kowalewski et al. (1994). To control for differences in susceptibility to taphonomic breakdown among species, only *Mulinia lateralis*, which is common to dominant in all samples, was used. Preservation of *M. lateralis* generally reflects preservation of the entire assemblage from which it was derived (see Anderson et al., 1995). Samples of *M. lateralis* were mechanically split and at least 100 randomly selected valves were retained for analysis. One sample contained fewer than 100 *M. lateralis* valves (sample 2; $n = 56$ valves), and additional randomly selected valves from another bulk sediment sample taken at that locality were added to bring the count to ≥ 100 valves for the taphonomic analysis. Three ranks (good, fair, poor) were defined for each of 13 preservational features listed in Table 2, and data were plotted on ternary taphograms (see Kowalewski et al., 1994, 1995). Bioerosion and encrustation were tallied separately for internal and external valve surfaces but these data were pooled for

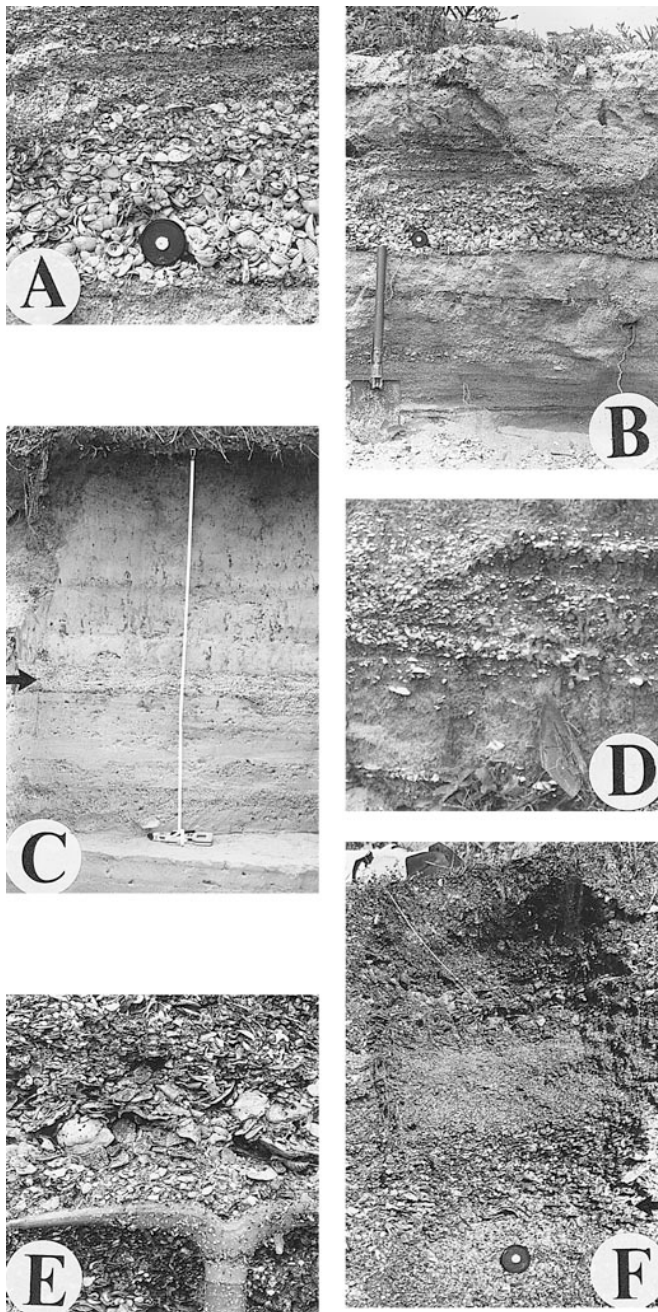


FIGURE 4—Photographs of selected ridge localities. (A) Close-up and (B) outcrop of sampled graded shell bed, relict spit complex, Hackberry Beach (samples 5a, 5b). Lens-cap diameter is 50 mm. Relict spit complex primarily consists of sandy shell hash with coarse shell lenses and lenticular shell beds. (C) Cleaned upper portion (1.6 m from end of tape to bench) of dip wall of sand pit at Front Ridge. Stratigraphic level of sample 6a is marked with arrow. (D) Weathered exposure of same bed as sample 6a. Trowel blade in lower right is 15 cm long. Both Front Ridge and Oak Grove Ridge are predominately composed of fine-grained sand with bioclasts occurring as scattered individuals, in stringers, lenses and tabular beds. (E) Close-up of oyster-rich graded shell bed at Chenier Perdue (samples 9a, 9b). Pick from the left side of photo to handle is 17 cm long. (F) Cleaned borrow-pit dip wall at Chenier Perdue. Base of sampled graded shell bed is marked with arrow. Lens-cap diameter is 50 mm. Chenier Perdue, Little Chenier, and Little Pecan Island are primarily composed of such oyster-rich deposits.

the analyses. Internal and external luster were tallied and analyzed separately. In addition, average taphonomic scores for each feature in each sample were calculated. Ranked values of these average scores were used in R-mode and Q-mode average-linkage cluster analyses using an Euclidean distance metric.

RESULTS

Molluscan Assemblages

Cluster analysis reveals two main clusters of samples (labeled A and B in Figure 6), both of which contain a pair of subclusters. Cluster A includes all samples from the three youngest ridges [Front Ridge (samples 6a–c), Oak Grove Ridge (samples 7, 8), and the Hackberry Beach relict spit complex (samples 5a–b)], as well as 3 of 4 beach samples (samples 1, 3, 4). *Mulinia lateralis* is the most abundant species in these samples (47–91% of individuals). Samples of the larger subcluster (A1) are overwhelmingly dominated by *Mulinia lateralis* (>73%). In the smaller subcluster (A2), *Mulinia lateralis* remains abundant, but *Anadara ovalis* and other arcids also are common (*A. ovalis* 23%–26% and all arcids up to 36% of assemblage). Taxonomic differences between these subclusters probably relate to bioclast size because Subcluster A1 includes samples from finer-grained shell accumulations than Subcluster A2. In addition, samples 5a and 5b are from the same graded bed but fall into separate subclusters. The outlier sample from Rutherford Beach (sample 2) appears to be an extreme case of the grain-size/species-composition trend, and in this sample *Anadara ovalis* dominates (70% of individuals). The Rutherford Beach sample was collected higher on the foreshore than other beach samples and probably formed under higher-energy conditions.

The second main cluster (B) includes samples from the three oldest ridges [Chenier Perdue (samples 9a–b), Little Chenier (samples 10a–b), and Little Pecan Island (samples 11, 12a–b)]. In these samples, *Ostrea equestris* (42%–60%) is abundant. In addition to *O. equestris*, *Mulinia lateralis* (21%–44%) is common in subcluster B1, whereas *Crassostrea virginica* is common (33%–36%) in subcluster B2. Subclusters of Cluster B are not differentiated by grain size, but instead may represent assemblages from somewhat different paleoenvironments. Subcluster B2 (Little Chenier samples only) contains a greater abundance of brackish-water species, including *Crassostrea virginica* and *Rangia cuneata*, than subcluster B1. The reasons for these differences are addressed below.

Taphonomy

Patterns of bioclast preservation among relict and modern shorelines of the chenier plain are complex (Figs. 7, 8). R-mode cluster analysis reveals two clusters of variables, which reflect biostratinomic versus pedogenic processes (Fig. 9). Biostratinomic processes include bioerosion, encrustation, edge chipping, fragmentation, rounding, and cracking. Encrustation was not observed on any *Mulinia* examined, and bioerosion was relatively low, except at Little Chenier (samples 10a–b; see Fig. 7). Few valves are cracked, but a wide range of preservational states were observed among samples for other biostratinomic features.

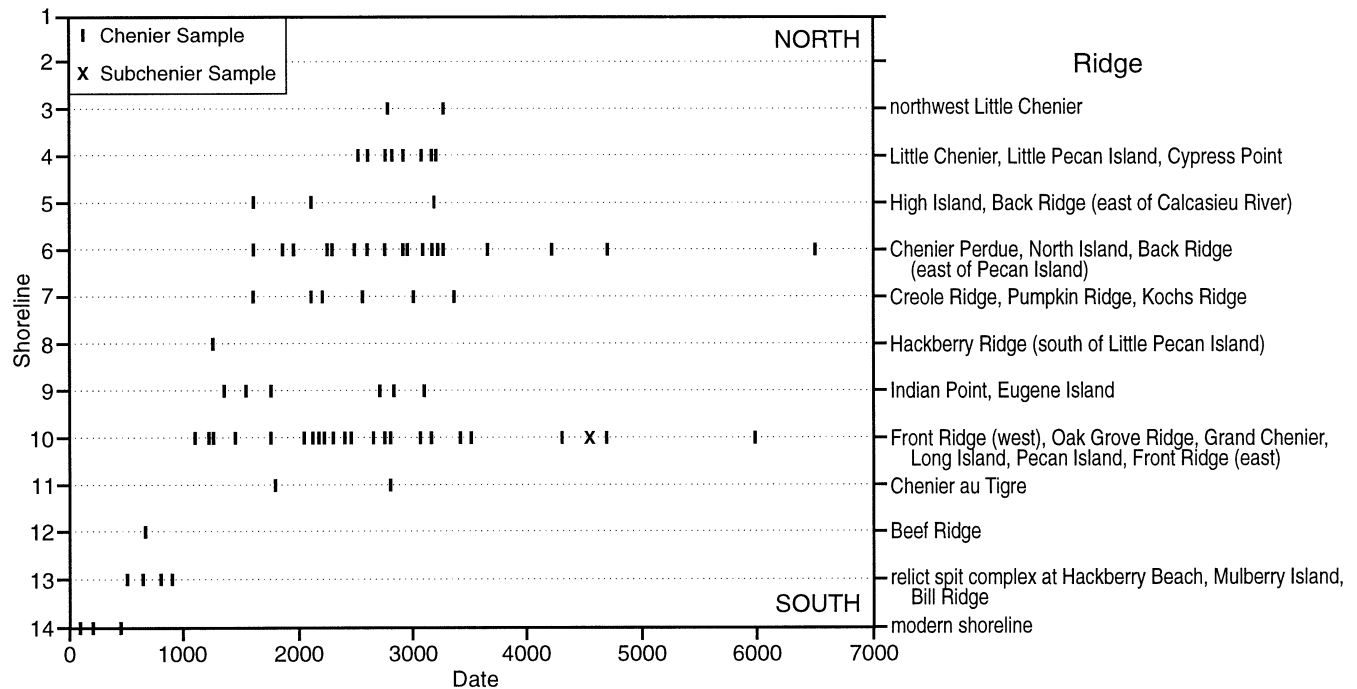


FIGURE 5—Radiocarbon dates of shells, Louisiana chenier plain east of the Calcasieu River. Dates are from Brannon et al. (1957), Gould and McFarlan (1959), and McFarlan (1961). Dates are reported in radiocarbon years, are not corrected for reservoir effects, and are not calibrated to calendar years. Shoreline numbers are after shoreline chronology of Taylor (1996) and Taylor et al. (1996). Ridges corresponding to each shoreline are listed on the right. Only ridges with radiocarbon ages used in this figure are listed.

Luster features (internal features, internal luster, and external luster) are classified as pedogenic features, although all samples (including beach samples) show relatively high alteration (Fig. 8). Loss of luster in beach samples probably indicates that: (1) reworked shells already altered by pedogenic processes are incorporated into beach sediments, and/or (2) that both biostratigraphic and pedogenic processes affect luster. Loss of luster can occur in marine settings prior to and after burial, as well as during exposure to meteoric water (Kowalewski et al., 1994 and references therein). Beach samples (samples 1–4), however, tend to show less alteration than ridge samples (Fig. 8), which indicates that luster probably is affected by both biostratigraphic and pedogenic processes.

Other pedogenic features include precipitation, dissolution along rootlets, precipitation along rootlets, and peeling. Dissolution and precipitation along rootlets are minor, although more prevalent in fine-grained shell beds of older ridges. Precipitation and peeling show a wide range of preservational states among samples.

In a Q-mode cluster analysis, samples were grouped according to the degree of biostratigraphic (low or high B) and pedogenic (low or high P) alteration (Fig. 9). The low B/low P cluster includes the Holly Beach sample (sample 1), both Oak Grove Ridge samples (samples 7, 8), and a Little Pecan Island sample (sample 12a), all of which have low to moderate alteration of all taphonomic features. Other beach samples (samples 2–4), as well as samples from the relict spit complex at Hackberry Beach (sample 5a–b), fall into the high B/low P cluster. These samples show moderate to very high alteration of biostratigraphic features, but low to moderate pedogenic alteration. The low B/high P cluster includes all Front Ridge (samples 6a–c), all Chen-

ier Perdue (samples 9a–b), and one of the Little Pecan Island samples (sample 12b). In these samples, biostratigraphic features show low to moderate alteration whereas pedogenic features are moderately to very highly altered. The high B/high P cluster contains both Little Chenier (samples 10a–b) and one of the Little Pecan Island samples (sample 11), and in these samples, all taphonomic features show moderate to high alteration. Unlike other ridges, Little Pecan Island samples show relatively large differences in preservation, which may relate to the complex geomorphology and stratigraphy of this ridge (McBride et al., 1997; C. McGimsey, pers. comm., 1997).

Patterns of Variation in Assemblage Composition and Preservation

Modern assemblages from adjacent transgressive and regressive shorelines can differ substantially in taxonomic composition and preservation (e.g., Albertzart and Wilkinson, 1990). Similarly, Anderson et al. (1995), using a preliminary data set, proposed that assemblage composition and preservation could be used to distinguish transgressive and regressive ridges of the Louisiana chenier plain. Except for biostratigraphic alteration, however, this inference is not well supported by a larger data set.

Differences in taxonomic composition are related to sample age. Older ridges [Chenier Perdue (samples 9a–b), Little Chenier (samples 10a–b), and Little Pecan Island (samples 11, 12a–b)] are rich in oysters (Cluster B; Fig. 6). Younger ridges [Oak Grove Ridge (samples 7–8), Front Ridge (samples 6a–c), and relict spit complex at Hackberry Beach (samples 5a–b)] and the modern shoreline (sam-

TABLE 2—Taphonomic features examined in *Mulinia lateralis*.

Feature	Description	Type of process
Encrustation ¹	Encrusted by aquatic organism(s)	Biostratinomic
Bioerosion	Bioeroded by aquatic organism(s) (e.g., algae, sponges, bryozoa)	Biostratinomic
Cracking	Hairline cracks in valve	Biostratinomic
Fragmentation	Valve breakage	Biostratinomic
Rounding	Edges and hinge rounded	Biostratinomic
Edge chipping	Nicks along valve edge	Biostratinomic
Dissolution along rootlets	Linear pattern of dissolution on valve surface	Pedogenic
Precipitation along rootlets	Carbonate tube or tube remnant on valve surface	Pedogenic
Internal Features	Visibility of adductor muscle scars and pallial line	Pedogenic
Internal Luster	Presence of original luster on valve's inner surface	Pedogenic
External Luster	Presence of original luster on valve's outer surface	Pedogenic
Precipitation	Carbonate, iron-oxides, manganese compounds coating valve surface	Pedogenic
Peeling	Outer layers of valve surface intact or "peeled off"	Pedogenic

¹ This feature was tallied, but no valves of *M. lateralis* were encrusted, and therefore this feature was not included in cluster analyses.

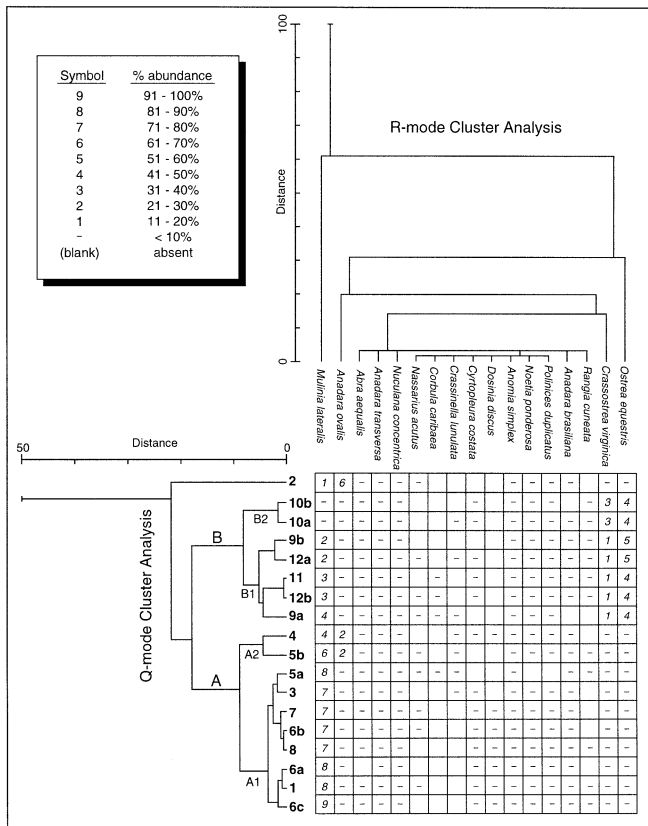


FIGURE 6—Two-way cluster diagram showing groupings of samples and taxa as well as relative abundance of taxa in each sample. See Table 1 for sample information.

ples 1–4) contain *Mulinia*- or *Mulinia*/*Anadara*-rich assemblages (Cluster A).

Older ridges (samples 9–12) typically display greater pedogenic alteration than younger deposits (samples 1–8). However, one Little Pecan Island sample (sample 12a) has low pedogenic alteration and all Front Ridge samples (samples 6a–c) have high pedogenic alteration relative to ridge age. Pedogenic alteration does not appear to decrease with increasing depth, indicating that these processes act to a significant depth (+2 m) in cheniers. For example, the three Front Ridge samples range from about 1 m to 2.75 m below the surface, but all show high pedogenic alteration and tend to cluster together on ternary taphograms of these features (Fig. 8). In addition, for two Little Pecan Island samples from the same measured section (samples 12a at 0.5 m and 12b at 1.5 m below the surface), the shallower sample is less altered.

The degree of biostratinomic alteration apparently reflects whether reworked bioclasts are an important component of assemblages. Most beach samples (samples 2–4) show high biostratinomic alteration, and the major bioclast source for these beaches is older ridges, such as the relict spit complex at Hackberry Beach (McBride et al., 1997). Holly Beach (Sample 1) is the only modern shoreline sample with low biostratinomic alteration, and bioclasts appear to be derived from local subtidal communities.

Ridge geomorphology confirms the correspondence of biostratinomic alteration to reworking. Longshore drift from east to west is the primary means of sediment transport along the chenier plain, and typically, updrift erosion supplies sediment for downdrift lateral or seaward accretion (Byrnes et al., 1995a). Localities with low biostratinomic alteration [eastern Little Pecan Island site (samples 12a–b), Chenier Perdue (samples 9a–b), Oak Grove Ridge (samples 7–8), and Front Ridge (samples 6a–c)] are from areas where few preexisting ridges were truncated (Fig. 1), indicating that older ridges were not a primary bioclast

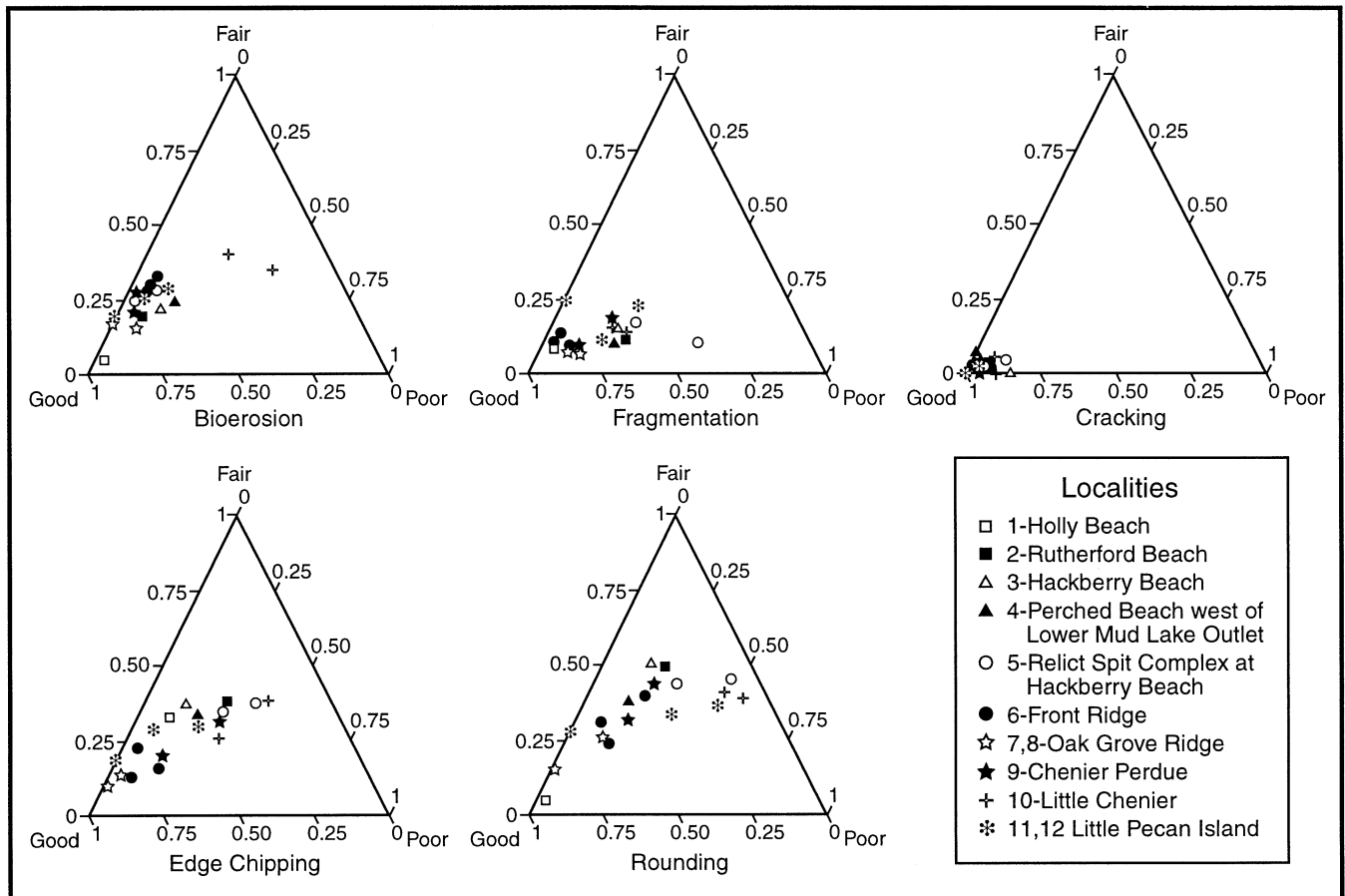


FIGURE 7—Ternary taphograms (see Kowalewski et al., 1995) illustrating preservation of *Mulinia lateralis* according to five biostratigraphic features. See Table 1 for locality descriptions and Table 2 for taphonomic feature descriptions.

source. The relict spit complex at Hackberry Beach (samples 5a–b) and the western Little Pecan Island (sample 11) site show high biostratigraphic alteration. Here, sample localities are within zones of lateral accretion where truncation and cannibalization of previously accreted spits probably occurred. Little Chenier (samples 10a–b) also show high biostratigraphic alteration, and, although this ridge truncates some minor shorelines, few ridges are truncated in the vicinity of the sample locality (Fig. 1). Most reworked bioclasts for Little Chenier probably were derived from older transgressive deposits (see Discussion).

Because biostratigraphic alteration is related to reworking, it also has a rough correspondence with the direction of shoreline movement. Most regressive deposits [Front Ridge (samples 6a–c), Oak Grove Ridge (samples 7–8), Holly Beach (sample 1)] have low biostratigraphic alteration. Rutherford Beach (sample 2) is an exception. However, erosion of an updrift ridge (relict spit complex at Hackberry Beach) with highly biostratigraphically altered bioclasts (i.e., samples 5a–b) is a primary sediment source for Rutherford Beach (McBride et al., 1997). Transgressive deposits of Little Chenier (samples 10a–b), and two modern shoreline sites (samples 3–4), show high biostratigraphic alteration, although those of Chenier Perdue (samples 9a–b) do not. Laterally accreted deposits [relict spit complex at Hackberry Beach (samples 5a–b), and Lit-

tle Pecan Island (samples 11, 12a–b)], however, do not have a consistent relationship with biostratigraphic alteration.

In summary, taxonomic composition and, to a lesser extent, pedogenic alteration vary with ridge age. In contrast, the degree of biostratigraphic alteration reflects the prevalence of reworked bioclasts, which generally are more abundant in transgressive than in regressive deposits.

DISCUSSION

The temporal trend in composition of molluscan assemblages has several potential causes, including: (1) progressive effects of pedogenic processes, (2) changes in depositional environment, (3) changes in the source of reworked bioclasts, or (4) replacement of nearshore biotic communities caused by environmental change. Combined taxonomic and taphonomic evidence outlined below indicate that both community replacement and changes in the source of reworked bioclasts contributed to the trend observed. Moreover, both factors operated in response to chenier-plain progradation.

Although pedogenic alteration generally increases with age, pedogenesis is not the primary process affecting assemblage composition. The relationship between pedogenic alteration and ridge age is not strong, and aragonitic

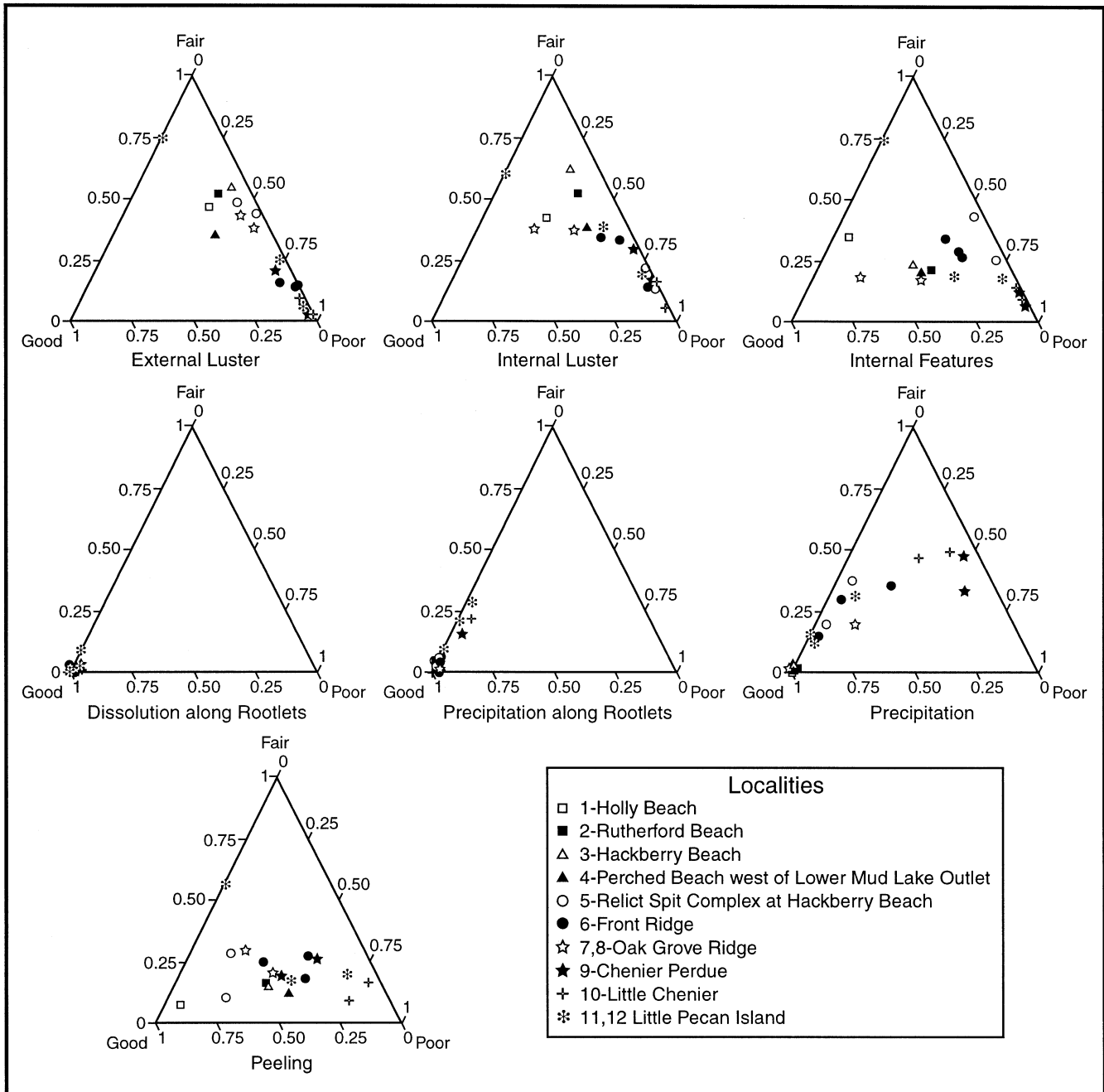


FIGURE 8—Ternary taphograms (see Kowalewski et al., 1995) illustrating preservation of *Mulinia lateralis* according to seven pedogenic features. See Table 1 for locality descriptions and Table 2 for taphonomic feature descriptions.

species (e.g., *Mulinia lateralis*) are common in all ridges. In addition, the volumetric loss of aragonitic bioclasts that would occur in transforming an assemblage from one similar to that of the relict spit complex at Hackberry Beach into that of Chenier Perdue would require an unreasonably large original shoreline deposit.

The depositional environment of ridges does not vary systematically with age and, therefore, changes in depositional setting did not cause the community trend. Stratigraphic and geomorphic evidence indicate that all ridges and beaches sampled for this study represent deposits of

outer shorelines (Taylor et al., 1996). In addition, no relation exists between the direction of shoreline movement and ridge age: transgressive, regressive, and laterally-accreted shorelines existed simultaneously throughout chenier-plain history (Byrnes et al., 1995a; McBride et al., 1997).

For those ridges with abundant reworked shells, a change in the source of these bioclasts is one cause of the taxonomic differences between the oyster-rich assemblages of older ridges (particularly Little Chenier) and the *Mulinia*- and *Anadara*-rich assemblages of younger ridges

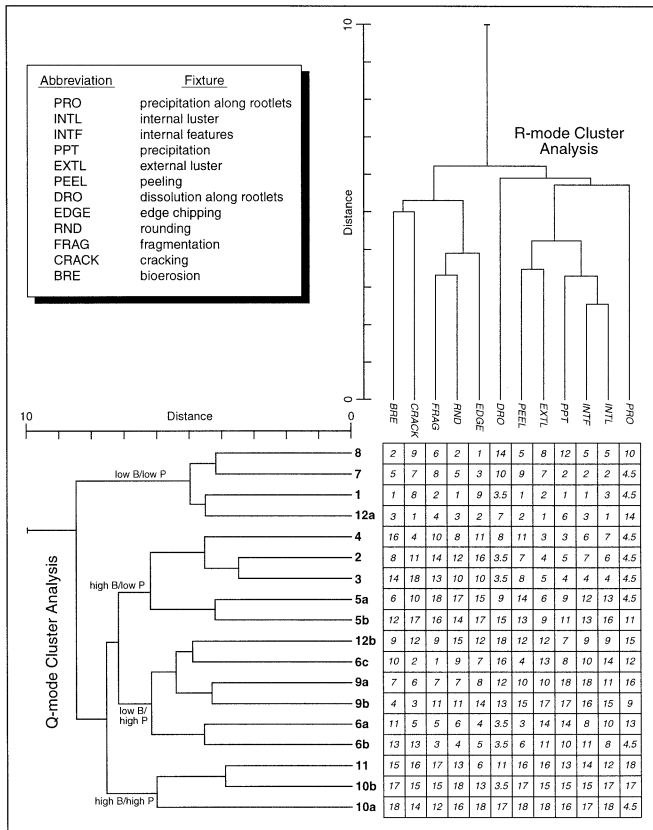


FIGURE 9—Two-way cluster diagram showing groupings of samples and preservational features for *Mulinia lateralis*. Ranks of average taxonomic scores for each feature in each sample are illustrated. Low ranks signify low alteration. See Table 1 for sample information.

es. Before extensive progradation, older deposits of the preceding Holocene transgression probably were eroded and reworked. Coarse sediments from these deposits were incorporated into the earliest-formed ridges, such as Little Chenier (samples 10a–b). These older sediments included estuarine (possibly back barrier) oyster-reef detritus, which is reported from the subsurface in the vicinity of Little Chenier (Byrne et al., 1959). Old bioclasts continued to be incorporated into younger ridges via multiple episodes of reworking (Fig. 5), but because the chenier plain is net progradational, most reworked bioclasts for later generations of ridges were from marine foreshore and shoreface deposits. This environmental transition also is observed in deposits immediately underlying ridges. The coarse foreshore sediments of Little Chenier unconformably overlay fine-grained low-salinity bay deposits, whereas the foreshore sands of Front Ridge conformably overlay interbedded shoreface sand and mud (Kaczorowski and Gernant, 1980; Byrnes et al., 1995b; McBride et al., 1997).

In addition to a change in the source of reworked bioclasts, community replacement within the regional macrofauna inhabiting the chenier plain affected the taxonomic composition of ridges. Community replacement was caused by environmental changes, specifically changes in substrate stability, associated with chenier-plain progradation. Older ridges (sample 9–12), whether or not reworked bioclasts predominate, are oyster-rich and appar-

ently are derived from oyster-reef and inter-reef areas. Early in chenier-plain development (at least until the formation of Chenier Perdue about 2,100 yr B.P.), the outer coastline may have resembled the present-day seaward shoreline of Marsh Island, LA, immediately east of the chenier plain. Oyster reefs are well developed in the Gulf of Mexico on the shoreface of Marsh Island and beaches in the vicinity also are oyster rich (Coleman, 1966). Because of high freshwater influx from the Mississippi Delta, salinity can be significantly depressed (<30 % at 7 m below water surface; Murray and Donley, 1996), allowing species typically found in bays and estuaries (i.e., *Crassostrea virginica*) to inhabit the shoreface. Oyster-reef distribution along Marsh Island is said to be controlled by antecedent topography with reefs located on the firm substrates of drowned natural levees of former distributary channels (Coleman, 1966; although see Hedgpeth, 1953). Similar substrates favorable for oyster-reef growth apparently were available in the early stages of chenier-plain development. Progradation of the chenier plain, however, primarily proceeds by deposition of fluid mud derived from the Mississippi and Atchafalaya rivers (Wells and Kemp, 1981; Kemp, 1986; Roberts et al., 1989). Deposition of this mud would have fouled oyster-reef communities and buried the firmgrounds necessary for establishment of new oyster-reef habitats. Chenier-plain progradation also would favor more extensive development of infaunal near-shore communities, which become prevalent by the time Oak Grove Ridge (samples 7–8) and Front Ridge (samples 6a–c) were deposited about 1,100 yr B.P.

Growth of the Louisiana chenier plain both caused and preserved an episode of community replacement that occurred over several millennia as transgression ended and regression began. Community replacement is of a regional scale, and extensive oyster-reef communities that were lost along the chenier plain still occur in adjacent coastal areas and bays. Therefore, because of net progradation and the episodic nature of time averaging, spatial and temporal resolution is sufficient to track community trends in these deposits.

CONCLUSIONS

Relict beach deposits of the Louisiana chenier plain preserve an episode of community replacement in the molluscan fauna. Chenier-plain progradation caused and preserved this record of community change. Replacement of the macrofaunal community inhabiting the chenier plain occurred in response to changes in substrate stability caused by deposition of chenier-plain mud. Older ridges are oyster rich, whereas younger ridges are dominated by infaunal bivalves. The temporal trend in assemblage composition was also affected by a change in the source of reworked bioclasts. Early in chenier-plain development, older brackish-water (possibly back barrier) deposits of the Holocene transgression were readily reworked, but as progradation proceeded, younger sediments deposited under marine conditions were the source of most reworked bioclasts. Because time averaging was episodic, this millennial-scale community trend was preserved in these shallow-marine deposits.

ACKNOWLEDGMENTS

We thank The Nature Conservancy of Louisiana and Raphael Richard for transportation and access to Little Pecan Island. Julie Doucet and Mary Hobbs were able field assistants. Clifford Duplech and Mary Lee Eggart drafted the figures. Charles McGimsey is especially thanked for assisting in field efforts and for reviewing several drafts of this work. Thanks also to an anonymous reviewer, Karl Flessa, John Kruger, Wayne Henderson, and Brett Fitzgerald for their constructive comments on the manuscript. Research was funded in part by the USGS Coastal and Marine Geology Program and the Louisiana Department of Natural Resources, Coastal Restoration Division.

REFERENCES

- ALBERTZART, L.S., and WILKINSON, B.H., 1990, Barrier backbeach shell assemblages from the central Texas Gulf Coast: *PALAIOS*, v. 5, p. 346–355.
- ALLEY, R.B., MAYEWSKI, P.A., SOWERS, T., STUIVER, M., TAYLOR, K.C., and CLARK, P.U., 1997, Holocene climatic instability: A prominent, widespread event 8200 yr ago: *Geology*, v. 25, p. 483–486.
- ANDERSON, L.C., BYRNES, M.R., and MCBRIDE, R.A., 1995, Paleoenvironmental and taphonomic evidence of diverse bioclast sources and their implications for the depositional settings of southwestern Louisiana cheniers: *Transactions, Gulf Coast Association of Geological Societies*, v. 45, p. 21–29.
- ARONSON, R.B., and PRECHT, W.F., 1997, Stasis, biological disturbance, and community structure of a Holocene coral reef: *Paleobiology*, v. 23, p. 326–346.
- BARRY, J.P., BAXTER, C.H., SAGARIN, R.D., and GILMAN, S.E., 1995, Climate-related, long-term faunal changes in a California rocky intertidal community: *Science*, v. 267, p. 672–675.
- BRANNON, H.R., JR., SIMONS, L.H., PERRY, D., DAUGHTRY, A.C., and MCFARLAN, E., JR., 1957, Humble Oil Company radiocarbon dates II: *Science*, v. 125, p. 919–923.
- BYRNE, J.V., LEROY, D.O., and RILEY, C.M., 1959, The chenier plain and its stratigraphy, southwestern Louisiana: *Transactions, Gulf Coast Association of Geological Societies*, v. 9, p. 237–259.
- BYRNES, M.R., MCBRIDE, R.A., TAO, Q., and DUVIC, L., 1995a, Historical shoreline dynamics along the chenier plain of southwestern Louisiana: *Transactions, Gulf Coast Association of Geological Societies*, v. 45, p. 113–122.
- BYRNES, M.R., MCBRIDE, R.A., ANDERSON, L.C., TAYLOR, M.J., and ZENERO, R.R., 1995b, Sedimentary processes, geologic framework, and coastal erosion issues of the chenier plain in southwestern Louisiana: *Gulf Coast Association of Geological Societies and Gulf Coast Section SEPM Field Guide*, 100 p.
- COLEMAN, J.M., 1966, Recent Coastal Sedimentation: Central Louisiana Coast: Coastal Studies Series No. 17, Louisiana State University Press, Baton Rouge, Louisiana, 73 p.
- DEAN, W.E., 1997, Rates, timing, and cyclicity of Holocene eolian activity in north-central United States: Evidence from varved lake sediments: *Geology*, v. 25, p. 331–334.
- DICKINSON, W.R., 1995, The times are always changing: The Holocene saga: *Geological Society of America Bulletin*, v. 107, p. 1–7.
- FÜRSICH, F.T., and ABERHAN, M., 1990, Significance of time-averaging for palaeocommunity analysis: *Lethaia*, v. 23, p. 143–152.
- GOULD, H.R., and MCFARLAN, E., JR., 1959, Geologic history of the chenier plain, southwestern Louisiana: *Transactions, Gulf Coast Association of Geological Societies*, v. 9, p. 261–270.
- HEDGPETH, J.W., 1953, An introduction to the zoogeography of the northwestern Gulf of Mexico with reference to the invertebrate fauna: *Publication of the Institute of Marine Science*, v. 3, p. 111–224.
- HOWE, H.V., RUSSELL, R.J., MCGUIRT, J.H., CRAFT, B.C., and STEPHENSON, M.B., 1935, Reports on the geology of Cameron and Vermilion Parishes: Louisiana Geological Survey Geological Bulletin, no. 6, 216 p.
- HOYT, J.H., 1969, Chenier versus barrier, genetic and stratigraphic distinction: *American Association of Petroleum Geologists Bulletin*, v. 53, p. 299–306.
- JABLONSKI, D., and SEPKOSKI, J.J., JR., 1996, Paleobiology, community ecology, and scales of ecological pattern: *Ecology*, v. 77, p. 1367–1378.
- JACKSON, J.B.C., 1992, Pleistocene perspectives on coral reef community structure: *American Zoologist*, v. 32, p. 719–731.
- JACKSON, J.B.C., 1994, Community unity?: *Science*, v. 264, p. 1412–1413.
- KACZOROWSKI, R.T., and GERNANT, R.E., 1980, Stratigraphy and coastal processes of the Louisiana chenier plain and Louisiana chenier plain microfossil associations: *The Sedimentary Environments of the Louisiana Coastal Plain, Gulf Coast Association of Geological Societies Field Guide*, 72 p.
- KEIGWIN, L.D., 1996, The Little Ice Age and Medieval warm period in the Sargasso Sea: *Science*, v. 274, p. 1504–1508.
- KEMP, G.P., 1986, Mud deposition at the shoreface: Wave and sediment dynamics on the chenier plain of Louisiana: Unpublished Ph.D. dissertation, Louisiana State University, Baton Rouge, 148 p.
- KIDWELL, S.M., and BOSENCE, D.W.J., 1991, Taphonomy and time-averaging of marine shelly faunas: in ALLISON, P.A., and BRIGGS, D.E.G., eds., *Taphonomy: Releasing the Data Locked in the Fossil Record*: Plenum Press, New York, p. 115–209.
- KIDWELL, S.M., and FLESSA, K.W., 1995, The quality of the fossil record: Populations, species, and communities: *Annual Review of Ecology and Systematics*, v. 26, p. 269–299.
- KOWALEWSKI, M., 1996, Time-averaging, overcompleteness, and the geological record: *Journal of Geology*, v. 104, p. 317–326.
- KOWALEWSKI, M., FLESSA, K.W., and AGGEN, J.A., 1994, Taphofacies analysis of Recent shelly cheniers (beach ridges), northeastern Baja California, Mexico: *Facies*, v. 31, p. 209–242.
- KOWALEWSKI, M., FLESSA, K.W., and HALLMAN, D.P., 1995, Ternary taphograms: Triangular diagrams applied to taphonomic analysis: *Palaaios*, v. 10, p. 478–483.
- MCBRIDE, R.A., ANDERSON, L.C., TAYLOR, M.J., MCGIMSEY, C., and BYRNES, M.R., 1997, Linear sand bodies in muddy environments: Geologic framework, sedimentary processes, and geoarchaeology of the southwestern Louisiana Chenier Plain: *Friends of the Pleistocene South Central Cell, Field Guide*, 151 p.
- MCFARLAN, E., JR., 1961, Radiocarbon dating of Late Quaternary deposits, south Louisiana: *Geological Society of America Bulletin*, v. 72, p. 129–158.
- MURRAY, S.P., and DONLEY, J., 1996, Mississippi River plume hydrography: Second annual report: OCA Study MMS 96–0022, U.S. Department of Interior, Minerals Management Service, Gulf of Mexico OCS Region, New Orleans, LA, 175 p.
- O'BRIEN, S.R., MAYEWSKI, P.A., MEEKER, L.D., MEESE, D.A., TWICKLER, M.S., and WHITLOW, S.I., 1995, Complexity of Holocene climate as reconstructed from a Greenland ice core: *Science*, v. 270, p. 1962–1964.
- PANDOLFI, J.M., 1996, Limited membership in Pleistocene reef coral assemblages from the Huon Peninsula, Papua New Guinea: Constancy during global change: *Paleobiology*, v. 22, p. 152–176.
- ROBERTS, H.H., HUH, O.K., HSU, S.A., ROUSE, L.J., JR., and RICKMAN, D.A., 1989, Winter storm impacts on the chenier plain coast of southwestern Louisiana: *Transactions, Gulf Coast Association of Geological Societies*, v. 39, p. 515–522.
- ROY, P.S., 1991, Shell hash dating and mixing models for palimpsest marine sediments: *Radiocarbon*, v. 33, p. 283–289.
- SOUTHWARD, A.J., 1995, The importance of long time-series in understanding the variability of natural systems: *Helgoländer Meeresuntersuchungen*, v. 49, p. 329–333.
- SOUTHWARD, A.J., BUTLER, E.I., and PENNYCUICK, L., 1975, Recent cyclic changes in climate and in abundance of marine life: *Nature*, v. 253, p. 714–717.
- SOUTHWARD, A.J., HAWKINS, S.J., and BURROWS, M.T., 1995, Seventy years' observations of changes in distribution and abundance of zooplankton and intertidal organisms in the western English Channel in relation to rising sea temperature: *Journal of Thermal Biology*, v. 20, p. 127–155.

- STONER, A.W., and RAY, M., 1996, Shell remains provide clues to historical distribution and abundance patterns in a large seagrass-associated gastropod (*Strombus gigas*): Marine Ecology Progress Series, v. 135, p. 101–108.
- TAYLOR, M.J., 1996, Geomorphology and Sedimentology of Southwestern Louisiana Cheniers: Unpublished M. S. thesis, Louisiana State University, Baton Rouge, 133 p.
- TAYLOR, M.J., BYRNES, M.R., and MCBRIDE, R.A., 1996, Form/process relationships and geomorphic evolution of the southwestern Louisiana chenier plain: Transactions, Gulf Coast Association of Geological Societies, v. 46, p. 413–422.
- VAN VALKENBURGH, B., 1995, Tracking ecology over geological time: Evolution within guilds of vertebrates: Trends in Ecology and Evolution, v. 10, p. 71–76.
- WELLS, J.T., and KEMP, G.P., 1981, Atchafalaya mud stream and recent mudflat progradation: Louisiana chenier plain: Transactions, Gulf Coast Association of Geological Societies, v. 31, p. 409–416.

ACCEPTED APRIL 29, 1998

