SEA-LEVEL RISE AND SUBSIDENCE EFFECTS ON GULF COAST ARCHAEOLOGICAL SITE DISTRIBUTIONS

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This article examines the archaeological effects of two major geologic factors, eustatic sea-level rise and land subsidence, on the archaeological site distributions of low-energy coastlines. It describes an inexpensive, quick approach to identify these effects, which exploits the interpretive value of state-maintained archaeological site location files. The application of this approach to the Mississippi Gulf Coast suggests that coastal sites older than roughly 3500 B.P. were submerged or destroyed by eustatic sea-level rise; more recent sites were affected little by this process. Among subsidence factors, endogenic or deep-earth subsidence has had little impact on local site distributions. Exogenic or surficial subsidence processes, however, are sufficient to explain the temporal gradient of tidally inundated marsh sites.

Este artículo examina los efectos arqueológicos de dos factores geológicos mayores—la subida eustática del nivel del mar y el hundimiento de la tierra—en la distribución de los sitios arqueológicos en un litoral de baja energía. El artículo describe una manera barata y rápida de identificar estos efectos. El método explota el valor interpretativo de las fichas de ubicación de sitio que mantienen las oficinas estatales. La aplicación de este método a la costa del Golfo de misisipí sugiere que los sitios costeños mayores a aproximadamente 3500 A.C. de antiguedad fueron sumergidos o destruídos por la subida eustática del nivel del mar mientras que los sitios más recientes no fueron muy afectados por este proceso. Entre los factores de hundimiento, el hundimiento de tierra profunda o de endogénesis tiene poco impacto en las distribuciones de los sitios locales. No obstante, los procesos de hundimiento exógenos o de la superficie sí son suficientes como para explicar la gradiente temporal de los sitios de pantano que son inundados por las mareas.

My objective is to estimate the general effects of sea-level rise and land subsidence on the archaeological site distributions of low-energy coasts, which are characterized by minimal wave and current action and are common on every continent (Bird 1993).[1]

The main combined effect of sea-level rise and land subsidence on such coasts often is to bury archaeological sites more or less intact beneath muck, sand, and water rather than to erode them away or redeposit them (Blanton 1996; Haag 1978). Buried sites offer essentially the same research potential as unburied sites (Coastal Environments Inc. 1977:I:29–30; Gagliano 1984:28); they are simply harder to study. The low-energy coast, because it can act as an agent of preservation rather than destruction, is therefore interesting from the archaeological perspective.

I describe methods to assess the archaeological impacts of coastal subsidence using site reconnaissance information such as that found in most state-maintained site files. The main strengths of the latter data are that they are readily available for most regions, typically encompass larger areas than that addressed by field reconnaissance projects, and represent the most comprehensive site record database available for most states. They also have many weaknesses. They represent a grab-bag sample of the archaeological sites in a region, as reported by professional and amateur archaeologists and the public. Analyses of such data yield approximate answers to be corroborated by independent evidence, generally field survey.

The test case for this study is the Mississippi Gulf Coast, a region for which archaeological and geophysical data are readily available. The details of the Mississippi coast example are of local significance, but they offer general implications for site burial in similar environments. The results are directly applicable to much of the Gulf of Mexico and Atlantic

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coasts of the United States and, given comparable data, to subsiding coastal lowlands elsewhere (e.g., the Amazon and Orinoco deltas and the Gulf of LaPlata in South America; southeastern England; the southern Baltic; northwestern Europe; the Nile, Niger, and Zambezi deltas in Africa; the Rann of Kutch, the Coromandel coast and the Ganges-Brahmaputra delta in India; the Bangkok coast; the Hwang-Ho delta in northern China; and southeastern Australia, among others [Bird 1993:4–5]).

Sea-Level Rise and Subsidence

Perhaps the greatest challenge of coastal archaeology is dealing effectively with the interface between the terrestrial and marine worlds. That the challenge exists is due partly to the dynamic nature of this interface and partly to our view of the oceans as agents of change. The nature of the interface can be explained by dealing with the last point first.

Most people see the oceans as experiencing continuous change and the land as a stable, nearly passive entity that responds to these changes. Nevertheless, the land is stable to our eyes mostly because its changes, especially significant vertical displacements, usually take place at rates that are imperceptible when measured in human life spans (Pirazzoli 1996:1). For this reason, rapid land changes, such as the 9.5-m subsidence of Long Beach, California (Bird 1993:103–104), and the 20–160 cm land subsidence of Bangkok, Thailand (Nutalaya et al. 1996), both of which were caused by twentieth-century fluid extraction, are seen as novel events by the general public and specialists in the earth sciences alike.

To put most coasts into an archaeologically meaningful interpretive framework, the shore also must be viewed as a dynamic environment, in which many of the key geomorphological processes simply take place at different rates than those of the oceans (Bailey and Parkington 1988:3). Only after the land *and* the sea are both treated as agents of coastal changes can one begin to understand and explain long-term archaeological site distributions in coastal environments.

The major factors of natural coastal land loss are submergence, erosion, sediment reduction, and wetlands deterioration (Table 1) (Morton 1996:208), of which the latter two can be viewed as special cases of submergence or erosion. Of the four factors, only submergence by sea-level rise and land subsidence offers the possibility of significant de facto preservation of archaeological information by site burial. As the following sections describe, coastal land loss due to submergence is patterned temporally and spatially. The identification and explanation of these patterns are important aspects of the interpretation of coastal archaeological site distributions.

Table 1. Common Natural Causes of Worldwide Coastal Land Loss (adapted from Morton 1996:Figure 1).

Process	Primary Causes
Submergence	Land subsidence Sea-level rise
Erosion	Waves & currents Storms Landslides
Sediment reduction	Stream avulsion Source depletion
Wetlands deterioration	Herbivory Freezes Fires Saltwater intrusion

Sea-Level Rise

Sea-level rise can be eustatic or isostatic. Eustatic sea-level rise is the global component of sea-level change that moves in relation to an effectively stable land surface. Isostatic sea-level change, on the other hand, is localized and represents vertical displacements of the land surface with respect to a stable sea level (Penland and Boyd 1985:100–101). The former responds to major climatic changes, the latter to load compaction, fluid extraction, and similar kinds of local and point conditions. Both forms of sea-level rise act differently on archaeological site distributions. This section addresses archaeological effects of eustatic sea-level rise. Isostatic changes are covered in the section on subsidence.

Most geologists and oceanographers now question the validity of a global sea-level rise concept and reconstructions based on the assumption of uniform global sea-level changes (Emery and Aubrey 1991; Pirazzoli 1996). The changes are not only far more complex than once believed, but also tend to manifest themselves differently along otherwise similar stretches of the same coastlines. For archaeologists, this means that the interpretation of coastal site distribution patterns is most usefully framed on a local or regional basis rather than encompassing thousands of kilometers of a coastline (e.g., the portion of the Gulf of Mexico coast that borders the Mississippi Sound rather than the entire northern Gulf Coast).

With these cautions in mind, at least three generalizations can be drawn about eustatic sea-level changes that hold important implications for the reconstruction of human adaptations on submerging coastlines in the continental United States. First, late Pleistocene sea-level curves show that sea level at 20,000 B.P. may have been more than 100 m below its present level in mid-latitudes (Pirazzoli 1996:64–68; Wells 1996). Second, most drowned terrestrial sites between the nearshore zone and the continental shelf date to late glacial and postglacial times, or roughly the past 10,000–15,000 years. Third, sea level approached its present stand roughly 2,000–5,000 years ago (Pirazzoli 1991).

The primary archaeological implications of the 5000-20,000 B.P. eustatic sea-level rise pattern are, first, many Archaic and Paleoindian sites lie buried offshore (Russo 1996; Stright 1990). Second, most of the dry land, pre-Late Archaic period sites recorded by field reconnaissance projects on submerging coasts can tell us little about coastal adaptations because 1) they were not coastal sites at the time they were occupied, or 2) they do not represent the entire range of site types created during seasonal rounds. Blanton (1996:210–211), for example, found that many of the submerged mid-Holocene sites in Chesapeake Bay that he recorded from interviews with local "watermen" appear to be base camp sites that are poorly represented among the dry land sites that border the Bay.

Given the late Pleistocene and early Holocene geological evidence, it is reasonable to infer that the distribution of dry-land archaeological sites on subsiding United States coastlines should be biased, on a temporal gradient, against archaeological evidence of coastal adaptations older than approximately 2000–5000 years B.P.[2] This inference assumes implicitly that 1) the resource "pull" of coasts on a human population tends to be greater than the interstream uplands that form the hinterland of a coast, and 2) the prehistoric human population density in coastal environments tended to increase over time. The inference also is testable in the field, at least in principle, by underwater survey (Gagliano et al. 1982; Stright 1986), which is out of the reach of most archaeological research project budgets.

A low-cost alternative, available for most regions, is to make a rough estimate of the archaeological effects of eustatic sea-level rise by analyzing existing dry-land site reconnaissance information. To do this for a given region of interest, compare relative site frequencies per period between the active coastline (defined, say, as that portion of the coast between 0–5 m above modern mean sea level) and farther inland (e.g., the portion of the region that lies more than 5 m above modern mean sea level). This approach uses the inland subregion as a control against which to measure archaeological effects; it assumes that eustatic sea-level rise has had little direct impact on inland archaeological patterns.[3] The result is a delineation of general site distribution trends, especially temporal bias, in the modern coastal zone, which can be attributed to eustatic sea-level rise.

In summary, the main geoarchaeological aspect of sea-level rise is that attributable to global or eustatic changes. Its archaeological effects are most accurately assessed by direct or indirect underwater surveys, which are not feasible for most archaeological projects due to their great expense. A low-cost alternative uses existing dry-land site information to compare the relative frequencies of components, broken down by archaeological period, between a coastal zone and a nearby stable landform that was unaffected (or at least less affected) by this geologic factor. The result is a rough estimate of the general archaeological effects of eustatic sea-level rise in a given region.

Subsidence

To the archaeologist, isostatic sea-level rise is subsumed within the general concept of subsidence, of which there are two kinds. Exogenic subsidence is caused by surficial processes, such as load compaction, while endogenic subsidence refers to fundamental geological processes, such as faulting, that happen deep within the earth (Prokopovich 1978). The main analytical problem with exogenic and endogenic subsidence is to separate their archaeological effects. To do so, one must focus on those aspects of regional site distributions that can only be explained by one or the other process.

To estimate exogenic subsidence effects using dry-land site file information, the simplest comparison to make is between two groups of sites, one comprised of sites subject to tidal inundation, the other of sites unaffected by tides, controlling for the archaeological periods during which each site is reported to have been occupied. If the frequencies of tidally inundated sites increase on a temporal gradient, with the most recent archaeological periods showing the highest frequencies of tidally inundated components, then local site distribution patterns may exhibit exogenic subsidence effects. This pattern should be evident because the exogenic subsidence of archaeological sites stems largely from the sinking of individual loads, like village middens and natural levees, in the soft, unconsolidated muck that makes up river mouths and coastal marsh deposits (McIntire 1958:26). On a subsiding coastline, these exogenic factors tend to bury a larger proportion of old components than recent ones (McIntire 1958:24).[4]

To estimate endogenic effects, compare the frequencies of tidally inundated and "not submerged" dry-land sites along the directional gradient indicated by the main endogenic force. Archaeological site distributions affected by endogenic forces should show increasing frequencies of tidally inundated sites on this gradient, with the greatest relative frequencies closest to the center of the endogenic force. If, for example, the trend of a geosyncline is to the east across a given region, then one should expect to find more tidally inundated sites relative to "not submerged" sites as one moves eastward. The directional nature of endogenic subsidence distinguishes it from exogenic forces, with the notable exception of the edges of regions affected by extraordinary subsidence events such as those mentioned earlier at Long Beach, California, and Bangkok, Thailand, the latter of which affected a 4,550 km^2 area (Nutalaya et al. 1996). Such exceptions, however, are usually both noticeable and readily explicable by local causes (large-scale oil and water extraction in the above-cited examples, respectively).

In summary, exogenic subsidence is caused by geologic processes near the earth's surface; endogenic subsidence is caused by processes that take place deep within the earth. Their archaeological effects can be estimated from existing dry land site file records by comparing the frequencies of tidally inundated and “not submerged” sites and components in a coastal zone. If the archeological record shows important exogenic effects, then the frequencies of tidally inundated sites will increase on a temporal gradient, with the most recent archeological periods showing the greatest numbers of tidally inundated sites. Endogenic effects can be estimated by comparing the frequencies of tidally inundated and “not submerged” sites along the directional gradient indicated by the main endogenic force. Archaeological site distributions affected by endogenic forces will show increasing frequencies of tidally inundated sites on this gradient, with the greatest relative frequencies closest to the center of the endogenic force.

Mississippi Coast Case Study

Having outlined the main effects of eustatic sea-level rise and land subsidence on coastal site distribution patterns, let us turn now to an example. The six southernmost Mississippi counties (Hancock, Harrison, Jackson, Pearl River, Stone, and George) form a region of low-lying "flatwoods," extensive marshes, rolling hills, and forested beach ridges (Figure 1). The offshore barrier islands protect the Mississippi Sound and the mainland from all but the most severe weather events in the Gulf of Mexco.

This large region is divisible into the *Coast* and *Pine Hills* zones for the purpose of analysis. Following Bahr et al. (1983), the coast is defined as that portion of south Mississippi that lies at or below the 5-m (approximately 15-ft) contour line (i.e., where the 15-ft contour can be traced in an unbroken line across the state). The Pine Hills comprise the rest of the 6-county region above the 5-m (15-ft) contour line (Figure 1). These pine-covered hills stretch far inland and are bracketed between the hardwood forests of the Pearl and the Pascagoula river valleys, which drain southern and central Mississippi and empty into the Gulf (Cross et al. 1974).

The earliest archaeological surveys of coastal Mississippi were those of Moore (1905) and Brown (1992), who reported the largest, most visible, and most accessible sites along the margins of the Mississippi Sound. After nearly a 40-year gap in which little was published, Gagliano (1963; 1967; Gagliano and Saucier 1963; Gagliano and Webb 1970) began investigating Archaic and Poverty Point period sites around the Pearl River mouth in the 1960s. Most of the subsequent published research has focused on the Pearl River locality (e.g., Bruseth 1991; Lowry 1969; Neumaier 1985; Williams 1987). In 1980 the University of Illinois began an archaeological research project on human adaptations to estuarine environments in St. Louis Bay (Aleto 1981; Lewis 1981, 1982, 1988, 1994); this project also included field surveys in the Pearl River drainage and eastward as far as Long Beach, Mississippi. The most recent research in the region is a new project begun by Blitz

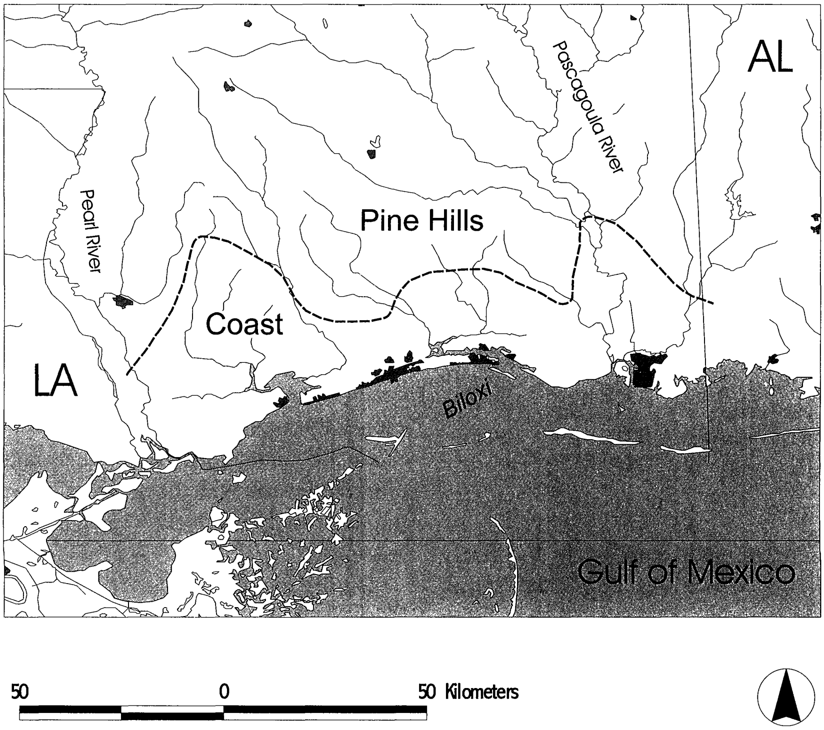

Figure 1. The Mississippi coast, showing the coast and Pine Hills zones. The heavy dashed line marks the approximate location of the 5-m contour.

and Mann (1993) in Harrison and Jackson counties.

The data used in this study were compiled from the site files maintained by the Mississippi Department of Archives and History (MDAH). For the 6-county area of southern Mississippi, these files contain records for 567 site locations, representing 756 discrete components (Table 2). Additional topographical information for each site was recorded from the U.S.G.S. quadrangle maps for the region. Digital geophysical data on soils, streams and other water bodies, and topography were provided by the Mississippi Automated Resource Information System (MARIS), a state-sponsored GIS resource center. The archaeological and geophysical data were analyzed using the ESRI ArcView GIS 3.0a system, Microsoft Excel 97, and Stata 6.0 statistical software. Copies of all data sets and the ArcView GIS are on file in the Department of Anthropology, University of Illinois, Urbana.

Regional Chronology

Lewis (1988), Blitz (1982, 1983), Blitz and Mann (1993), and Sears (1977) outline the prehistoric portion of the regional chronology. Davis (1984:224–229) and Usner (1992) provide comprehensive discussions of the Historic period archaeology of this and adjacent regions. Although the data set analyzed here includes 126 more components than that examined by Lewis (1988), the general temporal patterns are essentially the same as those previously described.

Table 3 lists the components by archaeological period reported on the MDAH site form.[5] The most common classified components date to the Tchula

Table 2. South Mississippi Sites by Study Region Zone.

	Count		Percent	
Study area zone	Sites	Components	Sites	Components
Coast	312	396	55.0	52.4
Pine Hills	255	360	45.0	47.6
Totals	567	756	100.0	100.0

Table 3. South Mississippi Sites by Archaeological Period.

Period	Count	Percent
Paleoindian	7	.9
Archaic, Period Undetermined	16	2.1
Early Archaic	15	2.0
Middle Archaic	15	2.0
Late Archaic	39	5.2
Poverty Point	9	1.2
Woodland, Period Undetermined	108	14.3
Tchula	87	11.5
Marksville	58	7.7
Baytown, Coles Creek	44	5.8
Mississippi	76	10.0
Historic, Native American	5	.7
Historic, Other Ethnic Group	54	7.1
Prehistoric, Age Undetermined	223	29.5
Totals	756	100.0

period, which corresponds roughly to the Early Woodland in the rest of the Eastern United States, and the Mississippi period. The relative abundance of Tchula components may be a methodological artifact in the MDAH site forms rather than one that reflects a regional settlement pattern shift. Given the classificatory imprecision that attended the current lack of a detailed chronology for the region until the 1980s, the Tchula through Baytown/Coles Creek periods were the most difficult parts of the sequence to identify accurately and precisely on the basis of surface collections, which is the most common source of the temporal information reported on the MDAH site forms.

Most (292 or 89 percent) of the 327 prehistoric sites that can be classified by site use or function are reported on the MDAH forms as camps or villages. Of the 17 mounds and 6 habitation sites with associated mounds, all but 4 are present in the coast zone. Other recognized prehistoric site types include 2 cemeteries and 7 eroded sites described simply as beach deposits in the MDAH site files.

To summarize the main points of the chronology, little is known about the human use of the region before the Late Archaic period (i.e., before 5000 B.P.). Pre-Late Archaic coastal sites are assumed to lie buried offshore, having been covered by the sea. This inference is supported by several lines of evidence, including the temporal distribution of coast and Pine Hills sites, as discussed in the next section.

Late Archaic and Poverty Point period (5000–2500 B.P.) sites tend to be found along creeks and rivers of the Pine Hills and on high ground in the coast zone. This portion of the archaeological record is well known only at the Cedarland Plantation (22HA506) and the Claiborne (22HA501) sites in the Pearl River mouth locality (Bruseth 1991; Gagliano and Webb 1970).

Tchula period (2500–2000 B.P.) sites are present across the region and the typical component appears to be a seasonally occupied campsite. Most Marksville (2000–1600 B.P.) and Baytown/Coles Creek (1600–1000 B.P.) components are known from the coast zone (Figure 2). These sites often are marsh clam (*Rangia cuneata*) middens situated on beach ridges or abandoned natural levees. They are especially common in the lower reaches of the coastal rivers. Such locations offered their inhabitants easy communication with the interior and ready access to potable water, marsh clam beds, and other estuarine resources.

During the Mississippi period (1000–300 B.P.), Pensacola complex assemblages are found across the Mississippi coast and into eastern St. Bernard Parish, Louisiana. These sites could be classified as Bayou Petre or Bottle Creek phase components depending on whether one looks at the Mississippi coast from the Louisiana Delta or the Mobile Bay chronologies.

Early Historic Native American sites follow much the same pattern as the prehistoric ones. An Acolapissa village has been tentatively identified on a Pleistocene terrace at the Pearl River mouth (Williams 1987). A late prehistoric village yielding abundant Fatherland Incised sherds is situated along the marsh edge at the mouth of Bayou Portage in St. Louis Bay. Beads and other small bits of early Historic debris are surface-collected occasionally on the large middens of the region (MDAH site file information).

Mississippi Coast Sea-Level Rise

During the late Pleistocene at 20,000 B.P., the Mississippi coastline was as much as 80–100 km to the south of its present position (Saucier 1994:49). The general Holocene trend was for sea level to increase gradually until about 3500–4000 B.P., when it approached within a few meters of the modern stand and the rate of increase decreased significantly.

Penland and Boyd (1985:101) estimate that for much of the twentieth century "a comparison of the relative sea-level rise between Louisiana and Florida suggests that eustatic factors can account for no more

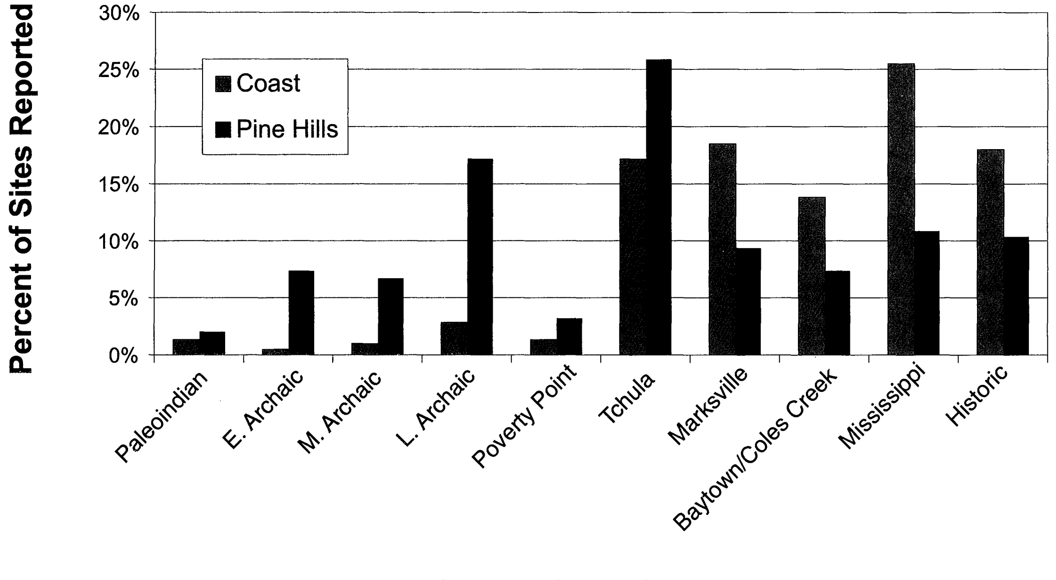

Figure 2. Temporal distribution of components in the coast and Pine Hills zones. The data are given by period in Table 3. Prehistoric sites of undetermined age and Archaic and Woodland sites of undetermined period are omitted from this figure. Historic components are the combined total of both Native American and non-Native American sites.

than 20 percent of the relative sea-level rise along the Mississippi delta coastline." Wetland loss research by Turner and Cahoon (1988:I:40-41; 187–202) yields a similar inference that the major threat to existing marshes (and, by direct implication, many archaeological sites), is subsidence, not eustatic sea-level rise. That Holocene sea-level rise is sufficient to account for site submergence in some nearby Gulf Coast regions was demonstrated by Barber (1983) at the Bryant's Landing site in Mobile Bay, Alabama. Barber's regression of ground-level depth against ^{14}C age estimates for the Bryant's Landing stratigraphy shows that sea-level rise was a continuing gradual process throughout the prehistoric occupation of this site. Colquhoun and Brooks (1986), in a somewhat similar analysis of marsh stratigraphy and radiocarbon-dated archaeological contexts in coastal South Carolina, found that small fluctuations in the late Holocene sea level also can be explained by eustatic changes.

The primary archaeological implications of the late Pleistocene and early Holocene eustatic sea-level rise pattern are, first, many Archaic and Paleoindian sites may lie buried offshore. Although some of these sites were undoubtedly lost to erosion by the sea transgression, eustatic sea-level rise would have tended to submerge rather than rework archaeological deposits due to the low gradient of the Gulf Coast (Stright 1986:350; Williams et al. 1990:8–9). Testing this implication awaits new methodological developments in continental shelf archaeology (Coastal Environments Inc. 1977; Gagliano et al. 1982; Johnson 1992; Stright 1986, 1990).

Second, most pre-Late Archaic sites discovered in the coast zone can tell us little about coastal adaptations because they were not coastal sites at the time of occupation. The pre-Late Archaic *coastal* contexts are either out in the Gulf, buried deep beneath the modern floodplains of the lower reaches of the Pearl and Pascagoula rivers, or destroyed by erosion. As Gagliano (1984:15) notes, a true coastal site of the Paleoindian or Early Archaic periods has yet to be found on the Gulf Coast.

Given the late Pleistocene and early Holocene geological evidence, it is reasonable to infer that the distribution of archaeological sites in southern Mississippi should be biased, on a temporal gradient, against archaeological evidence of coastal adaptations older than approximately 3500 years B.P. This can be tested by comparing the temporal patterns of site frequencies between the Pine Hills and coast zones. The Pine Hills zone is a geologically stable surface relative to the coast and it offers a useful control against which to measure coastal site distribu-

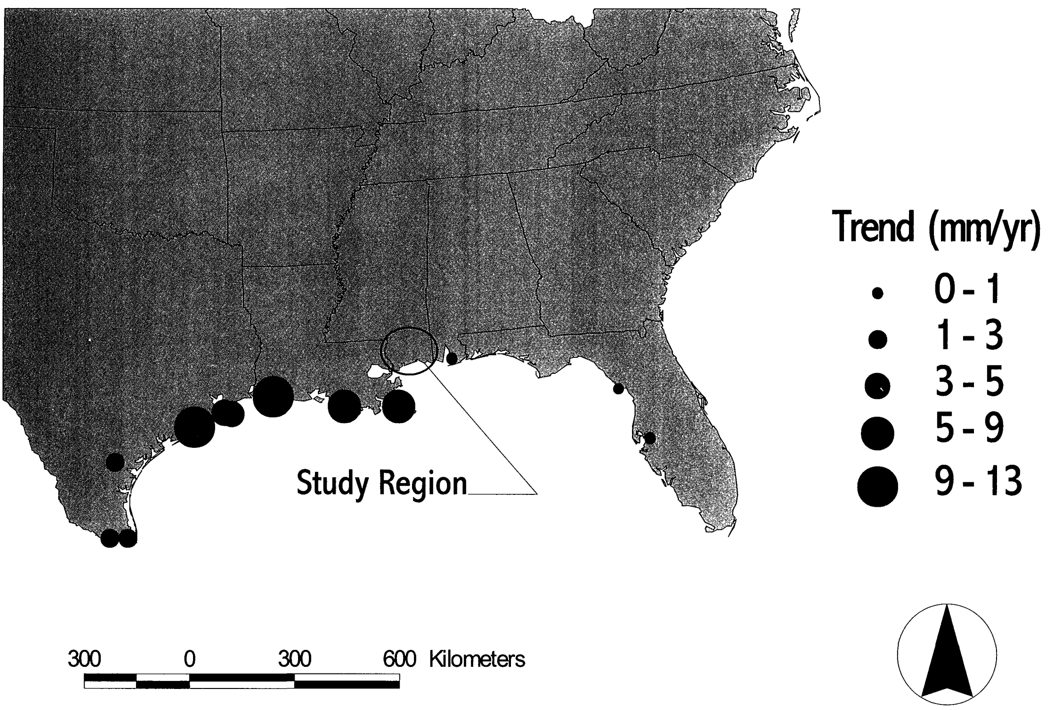

Figure 3. Gulf Coast local subsidence trend, corrected for an estimated regional eustatic sea-level rise rate of 1.25 mm/yr. Each graduated symbol is scaled to sea-level trend data for local tide gauge stations. The highest subsidence rates are found along the eastern Texas coast and southern Louisiana, in part due to the effects of fluid extraction. The Mississippi coast lies on the edge of this extreme subsidence region and is experiencing a relative sea-level trend of <3 mm/yr. Data are from Gornitz and White (1993).

tion effects attributable to eustatic sea-level rise.

Comparison of site frequencies shows a greater proportion of Tchula period and older sites in the Pine Hills than in the coast zone (Figure 2). The latter has a much higher proportion of post-Tchula components. This site distribution pattern is hypothesized to be at least partly an artifact of eustatic sea-level rise before 3500 B.P. and the relatively low rate of eustatic sea-level rise since that time.

Why is this pattern a function of sea-level rise and not wholly some other process, including cultural changes? Essentially because eustatic sea-level rise is the only process that is both sufficient and necessary to account for both the documented geomorphological evidence of increased postglacial sea-level rise *and* the low frequencies of pre-Tchula sites in the coast zone. Cultural changes alone cannot explain these patterns. The Cedarland Plantation and Claiborne sites, two of the most widely cited examples of Late Archaic and Poverty Point period sites on the northern Gulf Coast, help to make the point. Both of these coast-zone sites are located on a Pleistocene terrace remnant near the mouth of Pearl River in Hancock County. These large sites are unequivocal evidence that pre-Tchula peoples not only lived on the coast, they also left large sites with thick middens, few of which are reported from the Pine Hills, where the typical pre-Tchula component is smaller and shows less evidence of sustained occupations. Comparable older Coast components at lower elevations or on less stable landforms have been lost to sea-level changes, land subsidence, and erosion, much as has been documented in Chesapeake Bay (Blanton 1996), the Georgia Coast (DePratter and Howard 1980), and for North America generally by Stright (1990).[6]

In summary, the comparison of MDAH site file records for the Pine Hills and coast zones shows that the spatial distribution of Coast components is biased against locations older than roughly the Tchula period. This archaeological pattern is interpreted as an effect of eustatic sea-level rise.

Mississippi Coast Land Subsidence

It has long been known that the coast between Texas and Alabama is experiencing both endogenic and

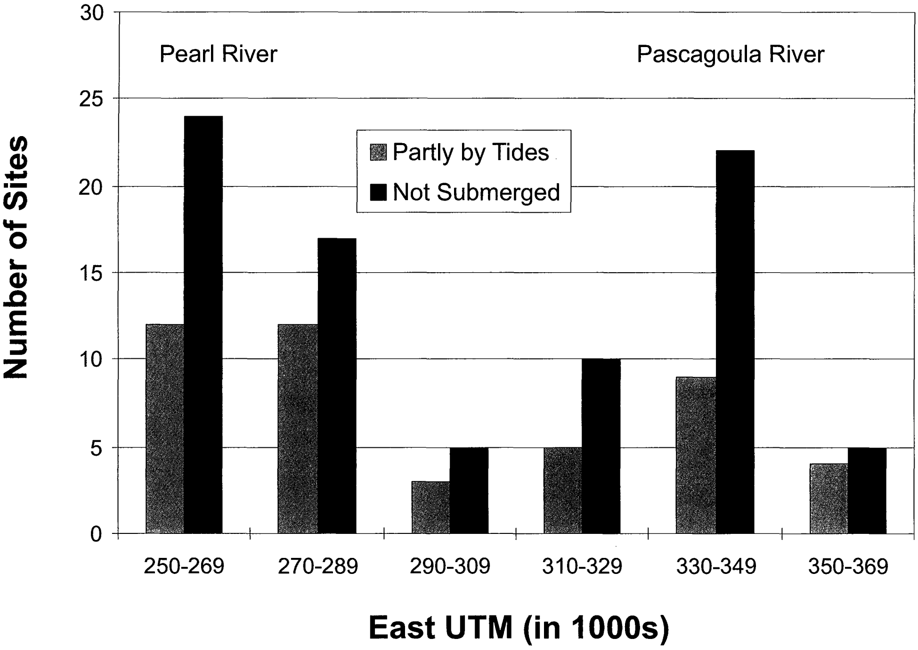

Figure 4. East-West distribution of 291 archaeological sites in the Coast zone.

exogenic subsidence (Barry A. Vittor & Associates Inc. 1985; Christmas 1973:14; McIntire 1958:24–28; Russell 1936, 1978; Saucier 1994:53–54; Smith et al. 1894; Turner and Cahoon 1988). Data on tide gauge subsidence trends for the Gulf Coast are unequivocal on this point (Figure 3). The high subsidence rates in southeastern Texas and southern Louisiana reflect the endogenic forces of the Gulf Coast geosyncline (Saucier 1994:51–53) and the exogenic effects of oil, water, and gas extraction in these regions (Dolan and Goodell 1986). These rates also show considerable local variation. Penland and Boyd (1985:102), for example, estimate that Louisiana's delta plain is subsiding at an average rate of 5.5 mm/yr. The Houston-Galveston-Freeport region of Texas, on the other hand, is sinking at 6.4–14.0 mm/yr, with local maximum rates exceeding 75.0 mm/yr also reported (Emery and Aubrey 1991:39).

James A. Cuevas, writing of the Mississippi coast before the 1860s, felt that the city of Biloxi and Cat Island, one of the barrier islands, had subsided noticeably during his lifetime (McGinnis 1977:31). Recent assessments, however, conclude that the subsidence rate in this region is insignificant by comparison with southern Texas and Louisiana (Van Beek et al. 1981:28), due largely to the proximity of stable landforms close to the Mississippi coast and a low rate of recent sedimentation. What this means in archaeological terms is that the Mississippi coast is less subject to the kinds of endogenic and exogenic processes that reshaped the southern Texas coastline in the twentieth century.

The main analytical problem with endogenic and exogenic subsidence processes is to separate their archaeological effects. As noted earlier, the focus must be on those aspects of regional site distributions that can only be explained by one or the other subsidence process. In the Mississippi coast case, the major potential endogenic factor is the Gulf Coast geosyncline, the main effects of which are found to the west of the study region. The region's proximity to the Mississippi Delta depocenter, or area of maximum deposition, is demonstrated geologically by the greater depth of the Biloxi and Prairie Formation beds in Hancock County than eastward along the Mississippi coast (Otvos 1982:19, 23). This stratigraphic fact implies that endogenic effects on local archaeological resources, if present, also should manifest themselves in an increasing east-to-west trend in the frequencies of sites subject to tidal inundation. The latter are of greatest relevance because they are demonstrably affected by subsidence processes.

Figure 4 shows the east-west site distribution of 128 tidally inundated sites and coast zone sites not

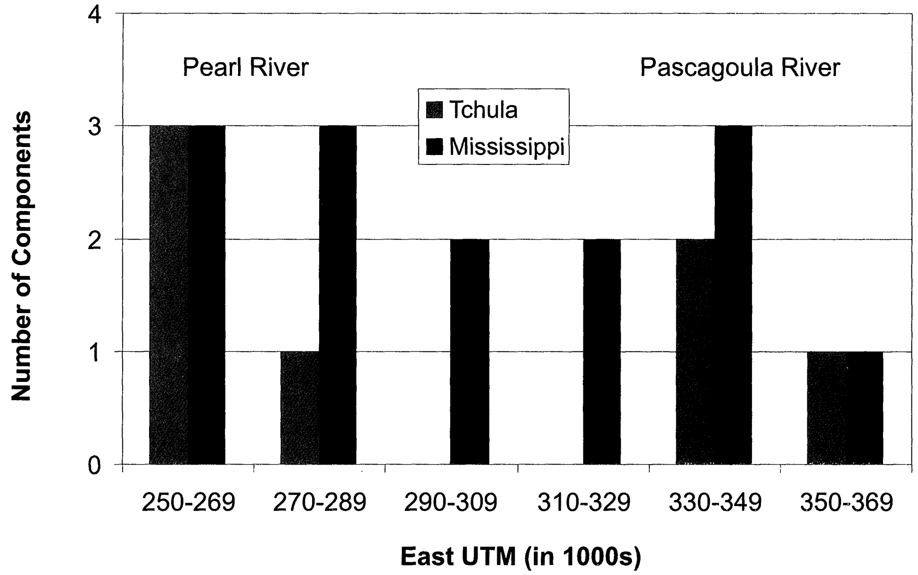

Figure 5. East-West distribution of Tchula and Mississippi period sites in the coast zone.

subject to submergence. The bimodal pattern indicates that these sites were conditioned more by the proximity of major river mouths than by the Gulf Coast geosyncline. A comparison of the general pattern of tidally inundated sites by period, using the Tchula and Mississippi periods as examples, shows similar site inundation frequencies across the Mississippi coast (Figure 5). The subsidence patterns described by Figures 4 and 5 support the interpretation that the frequency of tidally inundated sites owes more to exogenic than endogenic forces.

Figure 6 compares by archaeological period the frequencies of 36 tidally inundated components and 81 "not submerged" components in the Coast zone. The plot makes several important points. First, most of the identified MDAH components in the coast zone date to the Tchula through Mississippi periods.[7] Second, even if one assumes increased coastal population densities in the more recent periods, the absence of pre-Tchula period components is striking. The one pre-Tchula tidally inundated site reported in the study region is a Late Archaic beach deposit (22JA611), which represents the remains of a site destroyed by erosion on the coast west of the mouth of the Pascagoula River.

Just as eustatic sea-level rise is sufficient to account for the low frequencies of tidally inundated sites older than the Tchula period, exogenic subsidence processes are sufficient to explain the frequencies of more recent tidally inundated components. By this reasoning, there are relatively fewer middens in the marshes older than the Mississippi period because these older components simply sank beneath the surface. Writing about a comparable site pattern in southern Louisiana, McIntire (1958:54) notes that, "sites with the greatest antiquity would have the least chance of survival above the ground. Any site that did survive is probably associated with more stable ground."

The empirical evidence needed to test this interpretation lies deep in the marshes, on the bottom of the bays and inlets that dot the region, in the Mississippi Sound, and on the continental shelf out in the Gulf. Little is known about Mississippi coast drowned sites. A few of the known middens are exposed only by the lowest winter tides. Local professional fishermen, who worked the St. Louis Bay oyster beds before pollution forced them to be closed to fishing, also report that they occasionally tonged up artifacts rather than oysters from some of these beds. At least some Mississippi coast oyster reefs, therefore, appear to cap drowned terrestrial sites. Similar phenomena are reported from Mobile Bay (Curren 1976:64), Tampa Bay (Goodyear and Warren 1972; Warren 1964, 1972), and Chesapeake Bay (Blanton 1996).

In summary, exogenic subsidence is caused by geologic processes near the earth's surface; endo-

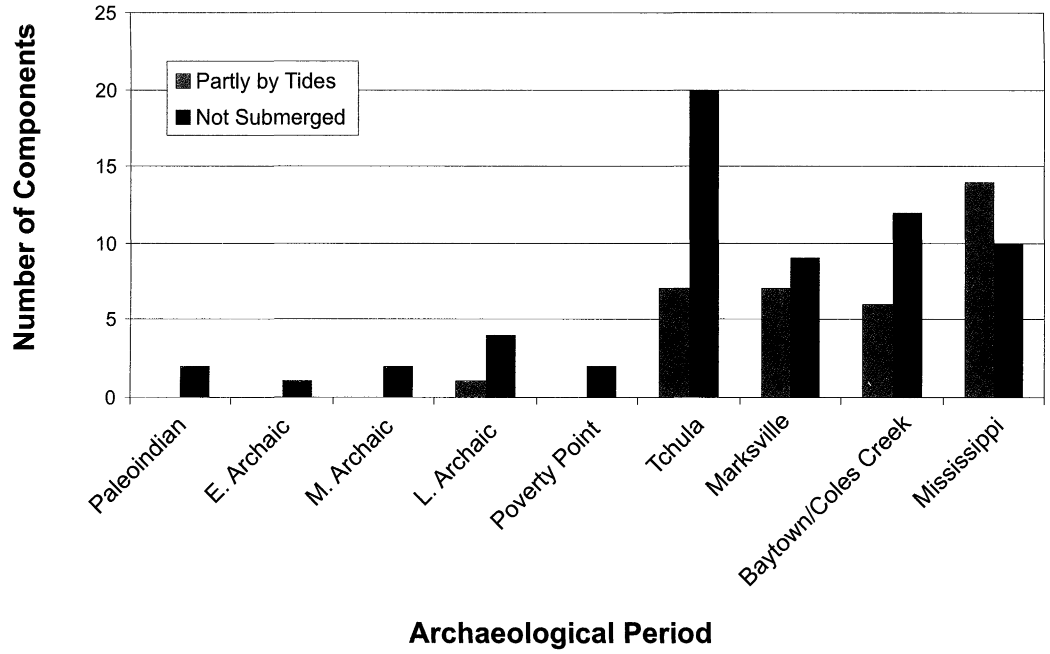

Figure 6. Frequencies of 35 tidally inundated components and 62 "not submerged" components by archaeological period in the coast zone. Eustatic sea-level rise accounts for the low frequencies of tidally indundated sites older than the Tchula period. Exogenic subsidence processes are sufficient to explain the frequencies of more recent tidally inundated components.

genic subsidence is caused by processes that take place deep within the earth. Their archaeological effects can be estimated from existing dry-land site-record information by comparing the frequencies of tidally inundated and "not submerged" sites and components. Such comparisons for components broken down by archaeological period in a coastal zone reflect exogenic subsidence effects. If the archeological record shows important exogenic effects, then the frequencies of tidally inundated sites will tend to increase on a temporal gradient, with the most recent archeological periods showing the greatest number of tidally inundated sites. To estimate endogenic effects, compare tidally inundated and "not submerged" site frequencies along the directional gradient indicated by the main endogenic force. Archaeological site distributions affected by endogenic forces will show increasing frequencies of tidally inundated sites on this gradient, with the greatest relative frequencies closest to the center of the endogenic force. In the Mississippi case study, tidally inundated sites show a strong temporal pattern of exogenic subsidence and little evidence of endogenic subsidence.

Other Factors Affecting Coastal Site Distributions

The analysis of site file records provides one indirect measure of the effects of eustatic sea-level rise and land subsidence on archaeological site distribution patterns. Like many indirect measures, its reliability is uncertain and is strengthened greatly from corroboration by independent data (Webb et al. 1981). Archaeological site files maintained by governmental agencies are not systematic collections; they typically contain information that has been gleaned from any source judged to be valid and reliable by the staff who manages the files. There is seldom a direct way to assess the archaeological representativeness of these data.

The tests described in the preceding sections enable the researcher to make initial estimates of the archaeological effects of eustatic sea-level rise and land subsidence. Given these estimates, one also must weigh the possible effects of other factors that could bias the state site file records and coastal site distributions. Chief among these factors are prehistoric cultural patterns, erosion, and modern land-use practices. This section briefly considers these factors in relation to the case study.

Prehistoric cultural patterns, or a combination of natural and cultural factors, explain aspects of the site distributions discussed above. They are an essential dimension to any archaeological investigation of the effects of land subsidence on prehistoric populations. In the Mississippi case study, for example, the clustering of sites along the major river valleys (Figure 4) can be explained only in cultural terms–these resource-rich localities held far greater attraction for human populations than did interstream uplands. What cannot be explained by cultural factors alone are those patterns in which geomorphological processes are clearly at work. For example, the absence of Paleoindian and pre-Late Archaic coastal sites from the Mississippi archaeological record and the general temporal gradient evident in the frequencies of tidally submerged components by period (Figure 6) is explicable by reference to geologic processes alone. This is not to deny that there could be more Tchula period than Mississippi period middens in the marshes simply because the Tchula population density was greater than that of Mississippi times. The key point, however, is that, until the beginning of large-scale oil and ground water extraction in the twentieth century, there existed no *cultural* mechanism by which one could explain land subsidence.

Erosion affects all reconstructions of the archaeological record, not just those based on aggregate site data. Currents, changes in sedimentation rates, stream-channel movements, storm waves, and other erosion factors destroy or hide sites so they either cannot be or are unlikely to be identified and studied by archaeologists. While erosion is everywhere the enemy of archaeological sites, its effects can be particularly severe in coastal environments, which are dynamic landscapes relative to many other kinds of landforms (Williams et al. 1990:1). Isles Dernieres, Louisiana, for example, is eroding at a rate of roughly 20 m per year (Williams et al. 1990:22–23; Williams et al. 1992). Archaeological surveys in Jefferson Parish, Louisiana, also show that as many as 40 percent of the recorded sites in this parish have been lost to the combined effects of erosion and subsidence (Barry A. Vittor & Associates Inc. 1985:421). In Plaquemines Parish, the 186,156 ha (460,000 acres) of marsh that remained in 1980 are expected to be destroyed by subsidence and erosion by AD 2032 (Gagliano et al. 1981). The archaeological implication of these rates of destruction are profound—most of the sites now visible in the Louisiana marshes will sink out of sight or be eroded away in the twenty-first century.

Along the Atlantic and Gulf of Mexico coasts, storm surges, also known as storm tides (Murty 1984:1,4), are probably the most significant agent of widespread coastal site erosion.[8] Storm surges are short-term changes in sea level that show their greatest range in shallow coastal waters like the Gulf of Mexico (Dunn 1958:27; Murty 1984:510–511, 647). During catastrophic storm events, such as Hurricane Camille, which was one of only three Saffir-Simpson rank-5 storms (Simpson and Riehl 1981) to strike the U.S. coast in the twentieth century, storm surge on the western Mississippi coast exceeded 7 m (approximately 23 ft) (Murty 1984:511). A surge great enough to deposit ocean-going vessels on 4-lane highways and cut barrier islands in half, both of which Camille did, can easily erase all evidence of a shell midden in an exposed location. Although the surge that accompanies most storms is less than 2 m (approximately 6.6 ft), it accelerates the erosion of coastal sites. Like all forms of erosion, it destroys the archaeological record.

Modern land-use practices can both destroy sites and cover them so they are hard to discover, regardless of the effects of geologic factors. For example, the MDAH records are biased against prehistoric sites covered by cities and towns. Urban archaeological surveys at Bay St. Louis and Pass Christian (Lewis 1981, 1982; Lewis and Murphy 1982) demonstrate that remnants of prehistoric sites are preserved under the streets and buildings of these towns. Archaeological reconnaissance at Bay St. Louis, for example, demonstrated that one site, the Ramsey Mound (22HA528), formerly estimated to consist only of a midden mound in a yard fronting on the mouth of the bay, actually extends for nearly 2 km along the bay shoreline under houses and streets (Lewis 1982). Similar sites undoubtedly lie under Gulfport, Biloxi, and the other towns of the region.

Another land-use practice that has significant implications for coastal archaeology is shell mining and dredging. The shell industry has been an important factor in worldwide shell-midden destruction, systematically removing this portion of the archaeological record from many coasts (Ceci 1984; Neuman 1976:2; Sanger and Sanger 1997).

On the northern Gulf Coast, oyster (*Crassostrea virginica*) and marsh clam shells have been used for more than a century as road gravel, poultry feed grit, oyster culch, and, after being burned, for field lime (Gunter and Demoran 1976:386). While some of the raw material is dead reef shell (Gunter and Demoran 1976), shell middens have historically proven to be an excellent source. Eugene W. Hilgard, state geologist, promoted the exploitation of "shell banks" (i.e., shell middens) as a lime source for Mississippi farmers as early as the mid-1800s (Hilgard 1860). Many of the middens situated in the marsh or near its edge and accessible by truck or schooner were mined and sold for the value of the shell. This activity alone probably accounts for the early disappearance of huge middens noted by early nineteenth-century travelers (e.g., Hutchins 1968:65). Lang (1936) reports that "thousands of barrels of these shells have been taken away [from Harrison County shell middens] to surface the streets and roads of this section."

The selective destruction of shell middens is a major factor that biases reconstructions of coastal adaptations and is a problem for which no available data sources can compensate directly, whether in Mississippi, the rest of America's coastlines, or throughout the world. Exploitation typically began decades if not centuries ago, well before archaeological sites had begun to be recorded. Official site files, therefore, often have little to tell us about the major shell middens of a given region. The most important potential information source is the indirect one afforded by historical accounts, oral histories, and travel narratives in which local topographical features are described. Such accounts can, at least, help to pinpoint the locations of such features and provide varying levels of detail about their archaeological structure.

Conclusions

The objective of this report has been to examine the major geologic factors that bias site distributions along a low-energy coastline, as these patterns can be reconstructed from the records contained in official site files. The results, although framed in a case study, offer an inexpensive and quick approach that exploits the interpretive value of existing site information. As demonstrated by the Mississippi case study, these results also offer general archaeological and methodological implications for coastal archaeological site reconnaissance and the reconstruction of human coastal adaptive patterns.

This study offers two main conclusions. First, many coastal sites older than the Late Archaic period either lie buried offshore or were reworked by the sea during postglacial eustatic sea-level rise. A rough estimate of the extent to which sea-level rise was a factor in a given region can be assessed by comparing the frequencies of components between a coastal zone and an adjacent stable landform. In the Mississippi case, the MDAH site records show fewer Tchula period and older sites in the Coast zone than in the Pine Hills. I have argued that eustatic sea-level rise is sufficient to account for the observed temporal distribution of components, but that other factors, including cultural changes, erosion, and modern land use practices, may be part of the overall explanation of the archaeological patterning.

Second, exogenic subsidence effects, or those due primarily to load compaction and oxidation, can be separated, at least partly, from endogenic effects, which are due to more fundamental geological changes. To estimate exogenic effects from aggregate site file data, compare the frequencies of tidally inundated and "not submerged" components by archaeological period in a coastal zone. Regions subject to the effects of exogenic forces should show a generally increasing temporal gradient in the relative frequency of tidally inundated components. Many endogenic subsidence effects, on the other hand, are effectively independent of exogenic forces and can be estimated by comparing frequencies of tidally inundated and "not submerged" sites along a directional gradient predicted by endogenic forces. If these forces are a major factor in the pattern of modern site densities, then the relative frequency of tidally submerged sites should increase in the direction of the endogenic force. Comparisons between tidally inundated and "not submerged" coastal Mississippi sites show a strong pattern of exogenic subsidence and little evidence of endogenic subsidence.

In conclusion, although relative sea-level rise will become more common in the twenty-first century, the sinking of archaeological sites beneath the surfaces of marshes and oceans is not necessarily the end of their research value. Gagliano (1984:28) describes subsiding sites in the marshes as the "deltaic equivalent of Pompeii" because of the preservation environments enjoyed by submerged sites. Such sites are no longer subject to storm waves, weekend boaters who cannot comprehend the concept of a "no wake" zone, relic hunters, shell miners, builders of fishing camps, and so on. The abiotic environment of marsh muck also facilitates the preservation of organic remains (Coastal Environments Inc. 1977:I:29–30). Ultimately, sea-level changes and land subsidence along low-energy coastlines may prove to be less destructive to archaeological sites than erosion and modern land uses.

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Notes

1. Geologists, oceanographers, and environmentalists predict that land subsidence will become even more widespread in the twenty-first century with global warming and worldwide sea-level rise (Milliman and Haq 1996; Titus and Narayanan 1995; Tooley and Jelgersma 1993).

2. Greater temporal specificity is possible when this inference is framed on a regional basis, as demonstrated below in the discussion of the Mississippi coast case study.

3. The degree to which this assumption is warranted must be assessed for the given case. Depending on the nature of the inland terrain, eustatic sea-level rise can change stream gradients and exert other direct and indirect environmental effects on local human cultural adaptations. In the Mississippi coast case, the Pine Hills subregion is relatively homogenous topographically, with average elevations between 16–64 m above mean sea level. Eustatic sea-level rise appears to have had little effect on the Pine Hills, except for the lower stream gradients and increased sedimentation of the Pearl and Pascagoula valleys.

4. Emery and Edwards (1966:735) use a similar approach to infer the presence of submerged sites on the Atlantic continental shelf.

5. As is common with state-maintained site file records, which represent unsystematic accumulations of records over decades, one often encounters obsolete temporal units and archaeological culture names and considerable range in the specificity with which information is recorded on the forms (e.g., a site may simply be reported as "Woodland" rather than Early, Middle, or Late Woodland period). The temporal information given on each MDAH site form had to be assessed and the site classified in one regional chronology for the purpose of analysis. Following Lewis (1988), I use the temporal units

defined by Phillips (1970). A total of 223 sites, representing 40 percent of the 567 MDAH site records for the 6-county Mississippi coastal region, cannot be classified by age. The remaining 344 sites include 124 sites that cannot be classified more precisely than "Archaic" or "Woodland" (Table 2).

6. The Cedarland Plantation and Claiborne sites are unusual among pre-Tchula sites in the coast zone because they are situated on a terrace remnant that is not only higher than much of the surrounding terrain but is also more stable than the marsh and flatwoods (Prairie Formation surface) around it. Given the geological characteristics of their locations, these sites have been essentially unaffected by sea-level rise or subsidence. They were, therefore, preserved to the present century, where less advantageous placed sites were buried by sea-level rise and subsidence or destroyed by erosion.

7. Most Historic period components are Euroamerican. They are omitted from this figure because Euroamerican settlement patterns in this region differ greatly in some aspects (e.g., Euroamericans seldom selected marsh locations for their habitation sites) from those of their Native American predecessors. The MDAH archaeological site files also tend to be biased against Euroamerican sites.

8. Boat and ship wakes are far less dramatic than storm surges, but can be just as destructive to archaeological sites in the coastal marshes of bayous, bays, and river mouths.

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