Cultural Resource Management Studies

CULTURAL RESOURCES EVALUATION OF THE NORTHERN GULF OF MEXICO CONTINENTAL SHELF

Volume I
Prehistoric Cultural Resource Potential

prepared for
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by

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Foreword

One of the basic defects in the implementation of historic preservation programs today is the absence of comprehensive plans which provide frameworks for decisionmaking and conflict resolution. Relatively few efforts have been made to develop prototypes of such frameworks but they are essential because they offer the only real solution to the seemingly endless arguments over significance, inventory priorities and selections of preservation and mitigation options. The Interagency Archeological Services Division has been contributing to the development of such prototypes through the funding of feasibility studies on various aspects of historic preservation planning issues; some of these studies have previously been published in this series.

In 1974, the Division began to deal with the very specialized problems of protection of cultural resources on the outer continental shelf in conjunction with the oil and gas leasing activities of the Bureau of Land Management and the U.S. Geological Survey. Given the fact that lessess were required by the conditions of their leases to conduct archeological surveys, should these be done everwhere on the shelf? Our conclusion was that surveys were not always necessary, especially in consideration of the practical problems of submerged site identification, provided a large-scale review of site occurence probabilities was undertaken. Because the basic problem was identical, although somewhat less complex, to that existing on land, we launched the pilot study reported in this three-volume study prepared by Dr. Sherwood M. Gagliano and his associates at Coastal Environments, Incorporated of Baton Rouge, Louisiana.

The basic premise was that submerged archeological sites were not randomly scattered about the sea bottom. Instead, the prehistoric sites could be expected to occur in a manner related to the paleogeography of the continental shelf and shipwrecks could be expected to occur in relation to present and past ports, sea routes, and hazards to navigation. Dr. Gagliano's first task was to reconstruct the structure of this larger setting and to block out the major regions in which archeological sites could be expected to occur. He then considered the types of sites likely to be found and their discoverability.

This report goes far toward defining regions in which there is concern for site presence and toward defining the objects of search. There should be no illusions however, that this report represents the last word. A great deal must still be accomplished in further refining our knowledge about which areas have archeological potential and which should be the focus of attentions for resource management. We also need much research and development for site discovery methods. Tolerable techniques exist for finding shipwrecks, provided they are used properly, but the available techniques for finding aboriginal sites are primitive.

Nevertheless, we have in Dr. Gagliano's report a first generation decisionmaking framework useful for triggering the implementation of mineral lease archeological survey stipulations in those areas where this seems to be needed and deleting this requirement from other areas resulting in substantial survey cost savings to the oil and gas industry. It also is potentially useful when other types of land management decisions and setting of priorities are made. Many of these concepts are transferable to the terrestrial setting and studies funded by Interagency Archeological Services are presently exploring such applications. Because the conduct of these studies is truly an investment in a significantly more cost-effective future historic preservation program we encourage any comments or suggestions on our efforts.

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ABSTRACT FOR VOLUMES I, II, AND III

This evaluation of the cultural resource potential of the outer continental shelf, Northern Gulf of Mexico, was generated in response to a significant increase in mineral extraction activities in the Gulf and to a growing awareness of the nonrenewable nature of these cultural resources.

The strategy developed for the study basically involved literary research and synthesis of the archeological, historical, geological, and technical parameters related to the identification and management of these resources.

The study and interpretation of Quaternary sea level fluctuations relating to the geomorphology was a central concept utilized in making recommendations for improved accuracy in identifying submerged archeological sites. This concept generated a testable model which helped to decrease the randomness involved in predicting site occurrences on the continental shelf.

Archeological files of coastal states and knowledgeable amateurs in the northern Gulf area were consulted in order to assess the nature and distribution of known sites in the present day coastal zone and to relate them to formerly active processes. This resulted in a graphic representation of these sites by culture period and physiographic context.

A literary search was also conducted to document all known historic shipping lanes, shipwrecks, and ship losses in the study area. Shipping lanes were mapped on four separate plates, reflecting the division of historic shipping in the Gulf into four time periods.

Further formulation of recommendations for underwater site detection came from an evaluation of the present level of development of geophysical surveying techniques, and the effectiveness of these techniques in locating various types of sites.

A summary product of the study was manifest in the development of a zonation map, dividing the OCS into five areas ranked in priority for probability of occurrence of shipwrecks and drowned terrestrial sites.

ABSTRACT FOR VOLUME I

This is a study of the predictability of drowned prehistoric habitation sites in the continental shelf area, northern Gulf of Mexico, from the Rio Grande River to the Florida Keys. Because of the difficulties of obtaining data concerning the location of a submerged site, an indirect approach was formulated incorporating the limitations of the detection devices that are available.

Geometric models for frequently occurring coastal physiographic features are developed in order that forms on the Outer Continental Shelf (OCS) can be identified and classified as relicts of specific, once-active physiographic units. The OCS is explored area by area, west to east, using the published descriptions and maps that are available, in order to map the shelf and to identify important relict forms with the past-active systems that formed them before they were submerged. Sea level in the Late Quaternary Period is traced, considering the eustatic, isostatic, and tectonic changes that make more land available for habitation at some times than others. The sea level determines the coastline - the seaward limit of our study area for any given period of prehistoric time. A geological history is developed of this fluctuating study area.

A method is presented of forming hypotheses about the nature of the archeological possibilities of the OCS - hypotheses that can be tested with the limited sort of data that can presently be gathered from the OCS. The method is this: the OCS will be divided into Eastern, Central, and Western Gulf areas, corresponding to the adjacent areas on land. The archeological literature of the land areas will be reviewed to identify major cultural

manifestations, by time and by type. These can be predicted to have occurred similarly on the OCS in the time periods when and where it was exposed concurrently. These cultural manifestations are examined for the purpose of making tables of index artifacts, environmental-use models, and particularly landforms favored for habitation sites. Then, addressing the problem of increasing one's chances in site propecting on the OCS: the landforms (detectable, as relicts) that are most frequently favored at any period are assigned a list of "signatures" - discrete site indicators that are capable of being detected by the limited sensing tools and techniques available for OCS survey. An inventory is made of the known sites in the Northern Gulf area that were occupied from 55,000 B.P. to 3,500 B.P. Typical sites from three regions, Eastern, Central, and Western Gulf Coast, are selected for Pre-projectile Point, Paleo-Indian, Archaic, and Poverty Point Periods. Age, ecofacts, artifacts, and associated landforms of these typical sites are discussed. The methodology developed in this study is illustrated with a case study of the Mississippi Delta area.

Last, lists of signatures are presented for the types of frequently occurring sites, the effectiveness of remote-sensing in identifying types of sites is discussed, and the most effective sequential approach to prehistoric site discovery is outlined.

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CHAPTER I

INTRODUCTION

Eighteen thousand years ago, during the time of the Woodfordian glacial stage, sea level in the Gulf was 121 meters lower than it is today, making the coastline of the Northern Gulf of Mexico as much as 100 kilometers farther out in some places. At that time, sea level had been making a long and uneven decline from the period of the Ingleside Shoreline, 55,000 B.P., when it was a little higher than its present stand. During every period, oblivious to eustatic change, rivers and streams wound their way to the Gulf, delivered their sediment loads and built their deltas. Cut-bank and swale formed, as did point bars and natural levees, terraces and lagoons. These geomorphic features gradually appeared and gradually disintegrated, sometimes leaving relicts, sometimes not.

Sometime during this 55,000 years, prehistoric man and woman entered the coastal zone. From the landforms available to them, these people chose the places where they lived and worked. Skills gradually evolved. They moved about with the changing coastal zone. Like the geomorphic features, sometimes they left a record of their existence, and sometimes they did not. If they lived on the area of the shelf that is outside the present coastline, the rising water slowly drowned their habitation sites. Sea level reached a stillstand at its present level at about 3,500 B.P. The possibilities for drowned habitation sites on the Gulf shelf, then, is from 55,000 to 3,500 B.P.

When the Europeans arrived in ships in the 1500's, sea level was approximately at its present stand. The Gulf was quickly criss-crossed with shipping lanes as the Spanish, French, English, and then the young United States and other countries used the Gulf as an area of transportation. The shipwrecks that inevitably occurred are a kind of archeological byproduct of all this commerce. Shipwrecks litter the bottom of the Gulf, some of them buried by sediment. By a historical and geological coincidence caused by the rising of sea water, the shipwrecks may overlie the buried and drowned habitation sites.

In the wake of the recent energy crisis has come accelerated exploration and development of the mineral resources of the outer continental shelf (OCS) in the Gulf of Mexico, as has been true along the California coast, Atlantic coast, and the Alaskan coast. This increased extraction of the mineral resources has raised the specter of irreversible damage and loss to the cultural resources of the OCS, the drowned habitation sites of indigenous peoples and shipwrecks from the historical period.

In recognition of possible damage to environmental and cultural resources resulting from the activities of the mineral extraction industries, the U.S. Department of the Interior has initiated several study efforts to inventory and evaluate the OCS environment, and in 1974 it implemented a requirement for marine archeological surveys of all leased drilling sites. The requirement stipulated that all drilling sites and pipeline rights-of-way be surveyed to determine absence or presence of submerged habitation sites and/or shipwrecks. Minimum requirements called for a geophysical survey using a total field intensity magnetometer towed above the sea bed, dual side-scan sonar coverage of the sea floor at a range width of about 500 feet per side, along with depth sounder and sub-bottom profiler runs. It was recommended that the profiler be capable of resolving the upper 50 feet of sediment. Navigation accuracy of $\pm$ 50 feet at 200 miles was also required. Recommended optional tools included cameras, divers, and cores.

It was advised that engineering soil borings be available for archeologists' inspection. Survey line spacing was to follow a prescribed line grid. Although these requirements represented an important initial step in the protection of cultural resources, the surveys proved to be costly and often resulted in delays in drilling and pipeline construction starts. Furthermore, it was not clear whether the surveys would fulfill the desired objective of identifying endangered cultural resources.

It soon became apparent that a broad study was needed to more clearly define the nature and extent of cultural resources on the continental shelf and to outline approaches to their management. Thus, the present study evolved. Its purpose was to determine the archeological potential, to extablish guidelines for survey priorities and level of effort, and to develop a rational framework for continental shelf archeology. The area of interest included the entire continental shelf of the northern Gulf (Figure 1-1), from the Rio Grande to the Florida Keys, and from the mean water line (MGL) on the Gulf beaches to -160 meters, with some preliminary evaluation of bottom conditions and sedimentation patterns affecting discoverability of shipwreck sites for the zone between water depths of -160 and -600 m MGL.

This order of study was followed: first, in geology, a synthesis was made of the literature and data pertaining to Late Quaternary geology of the shelf and coastal zone. The morphology of each coastal system, shelf sedimentation, tectonics, and sea level fluctuations were considered. Second, a study of prehistoric archeology was undertaken. A synthesis was essential of the literature and data pertaining to coastal zone prehistory by culture period for each culture area. Emphasis was placed on site morphology and content,

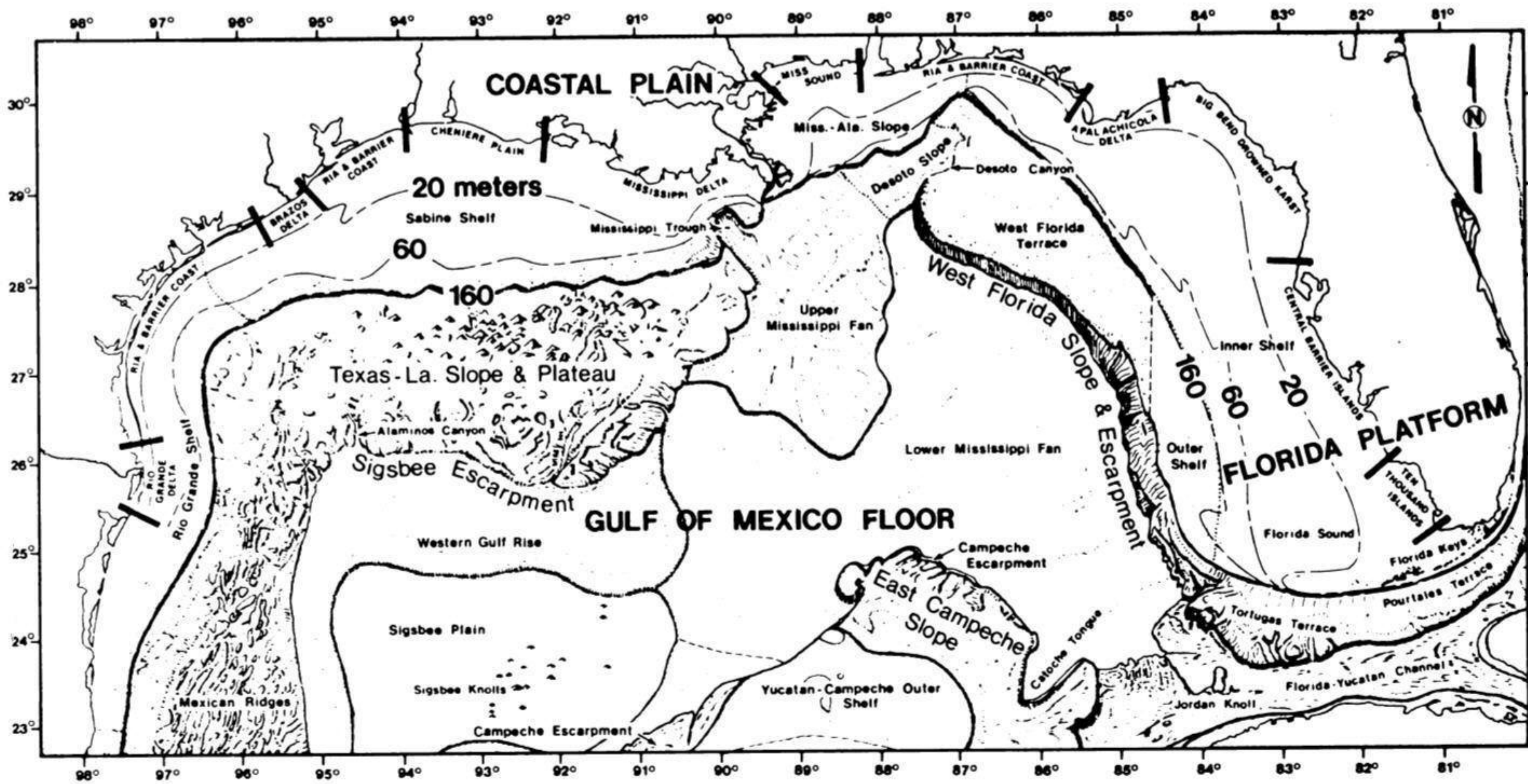


Figure 1-1. Physiographic divisions and bathymetry of the northern Gulf of Mexico (Modified from Bergantino, 1971, and Brooks, 1974).

index artifacts, and characteristic artifact assemblages. Some consideration has been given to the "Pleistocene megafauna" since the remains of these large vertebrates are often associated with early man and provide important environmental indicators.

Third came a study of shipwrecks. A review was made of the literature describing types of ships used in the Gulf from colonial exploration and settlement through World War II (1500 - 1945). Types and characteristics of ships were determined by period as they relate to discoverability. A review was made of charts and maps, literature and archival records, and other data pertaining to sailing routes, along with a systematic analysis of historical reports of shipwrecks for the entire period of interest.

Last in the order of study was the establishment of survey priorities and the identification of pilot study areas. Through evaluation and ranking procedures, a map was developed showing culture resource zones for the continental shelf within the study area. These zones are based on the probability of discoverability and recoverability of shipwrecks and submerged habitation sites. Potential pilot study areas for detailed archeological exploration have been identified, and a review of present survey techniques has been made to provide the basis for recommendations for modification of search and recovery techniques.

This report is presented in three volumes. The first concerns the geologic setting and prehistoric cultural resources. The second deals with historical cultural resources, which consist mainly of shipwrecks. The third volume is an atlas of maps, figures, and tables. The third volume is designed to be used with the text, and in fact is necessary to a reading of the first two volumes.

After the introduction, the first volume proceeds as follows: in Chapter II, "The Relationship of Process to Form in the Coastal Zone," we attempt to develop geometric models for frequently occurring coastal physiographic features so that forms on the OCS can be identified and classified as relicts of specific, once-active physiographic units. In Chapter III, "Late Quaternary Relict Forms," the OCS is explored area by area, west to east, using the published descriptions and maps that are available, in order to map the shelf and to identify important relict forms with the past-active systems that formed them before they were submerged. In Chapter IV, "Sea Level in the Late Quaternary Period," we consider the eustatic, isostatic, and tectonic changes that make more land available for habitation at some times than others. The sea level determines the coastline--the seaward limit of our study area for any given period of prehistoric time. A geological history is developed of this fluctuating study area.

Chapter V, "Archeological Method and Theory," presents a method of forming hypotheses about the nature of the archeological possibilities of the OCS, hypotheses that can be tested with the limited sort of data that can presently be gathered from the OCS. The method is this: the OCS will be divided into Eastern, Central, and Western Gulf areas, corresponding to the adjacent areas on land. The archeological literature of the land areas will be reviewed to identify major cultural manifestations, by time and by type. These can be predicted to have occurred similarly on the OCS in the time periods when and where it was exposed concurrently. These cultural manifestations will be examined for the purpose of developing tables of index artifacts, environmental-use patterns, and particularly landforms favored for habitation sites. Then to the problem of increasing one's chances in site prospecting on the OCS. The landforms (detectable, as relicts) that are most frequently favored at any period can now be assigned a list of "signatures"--discrete site indicators that are capable of being detected by the limited sensing tools and techniques available for OCS survey.

Chapter VI, "Selected Typical Archeological Sites of the Northern Gulf," is an inventory of the known sites in the Northern Gulf area that were occupied from 55,000 B.P. to 3,500 B.P. Typical sites from three regions, Eastern, Central, and Western Gulf Coast are selected for Pre-projectile Point, Paleo-Indian, Archaic, and Poverty Point Periods. Age, ecofacts, artifacts, and associated landforms of these sites are discussed. Chapter VIII is "An Illustration of Methodology: the Mississippi Delta Area." Ideally at this point we should summarize the relationship between the prehistoric occupation sequence and the relict landforms on the OCS. But there have proved to be too many unknowns for this to be possible at the present time. The methodology developed in this study is illustrated, however, with a case study of the Mississippi Delta area. The last chapter, Chapter VIII, "Conclusions and Recommendation for Future Study," presents the lists of signatures for the types of frequently occurring sites, discusses the effectiveness of remote sensing that is available in identifying types of sites, and recommends the most effective sequential approach to prehistoric site discovery.

CHAPTER II

THE RELATIONSHIP OF PROCESS TO FORM IN THE COASTAL ZONE

A major objective of the present study is to evaluate the potential for occurrence of drowned habitation sites on the continental shelf. Since only a handful of sites have been identified, all of which are in shallow water, an indirect approach must be taken. The approach followed is based on the assumption that in the coastal area there is a strong correlation between physiographic units, settlement patterns, and resource use. Furthermore, the distinctive geomorphic form and character of sediment or material of physiographic units may be preserved after the units themselves are no longer active. These relict forms may remain as evidence of past landscapes.

The physiographic unit is the product of the intensity and kinds of processes active in coastal systems. Process is reflected in such measurable variables as sediment characteristics, geomorphic form, vegetation, soil, and human utilization. The simple truth that the form of the feature mirrors the process is the key to interpretation, and prediction depends largely on our understanding of form-process relationships and our effective use of natural analogs.

The physiographic unit, therefore, is the basic element in coastal landscape analysis. While each unit may have a wide distribution throughout the coastal zone, it can be demonstrated that certain assemblages serve to identify major natural systems and subsystems. Figures 2-1 and 2-2 illustrate typical distribution and surface relationships of a deltaic and a coastal bay and barrier system, respectively.

First inspection suggests that coastal systems are hopelessly complex mazes of waterways, bays, sand spits, and swamps; however, there is an orderly arrangement of component parts. Certain major components of

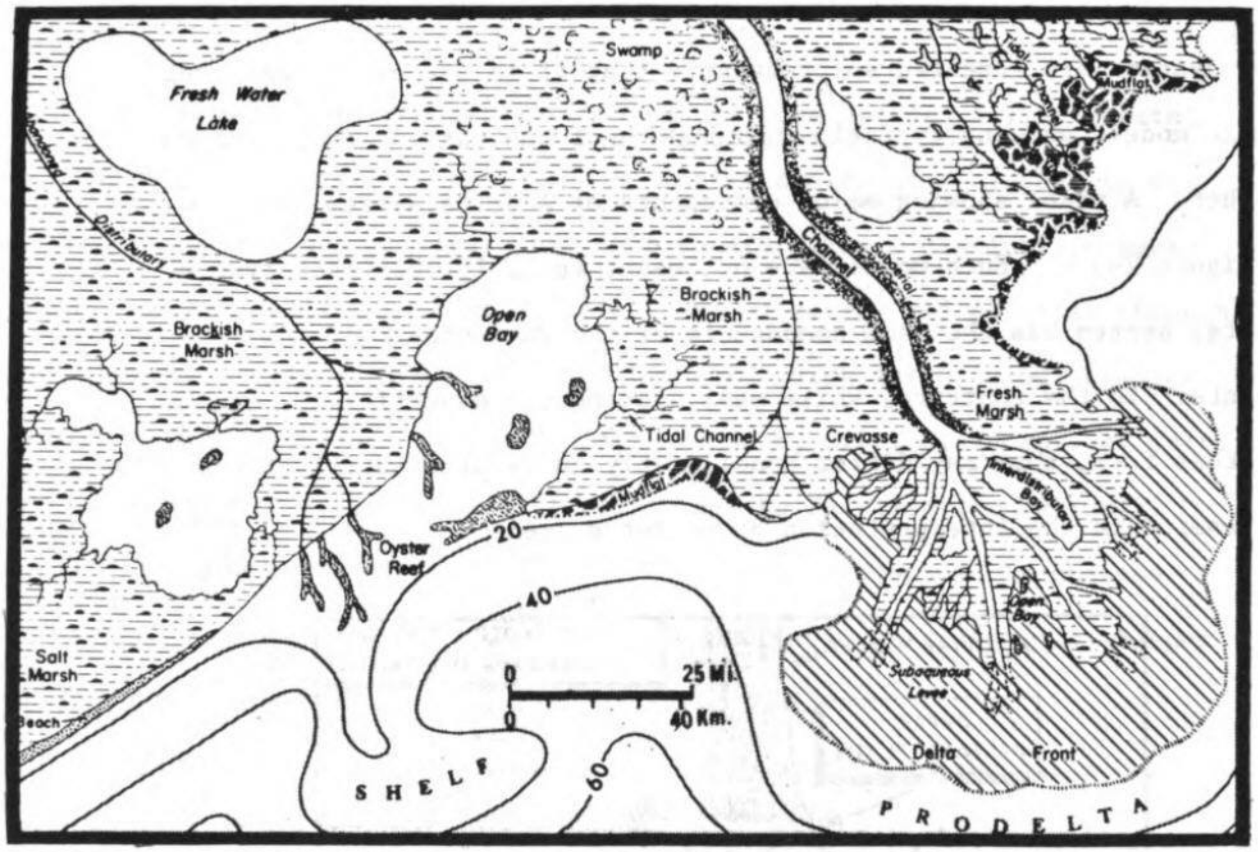


Figure 2-1. Typical distribution and surface relationships of deltaic and related physiographic or environmental units. Scale approximate (after Coleman and Gagliano, 1965).

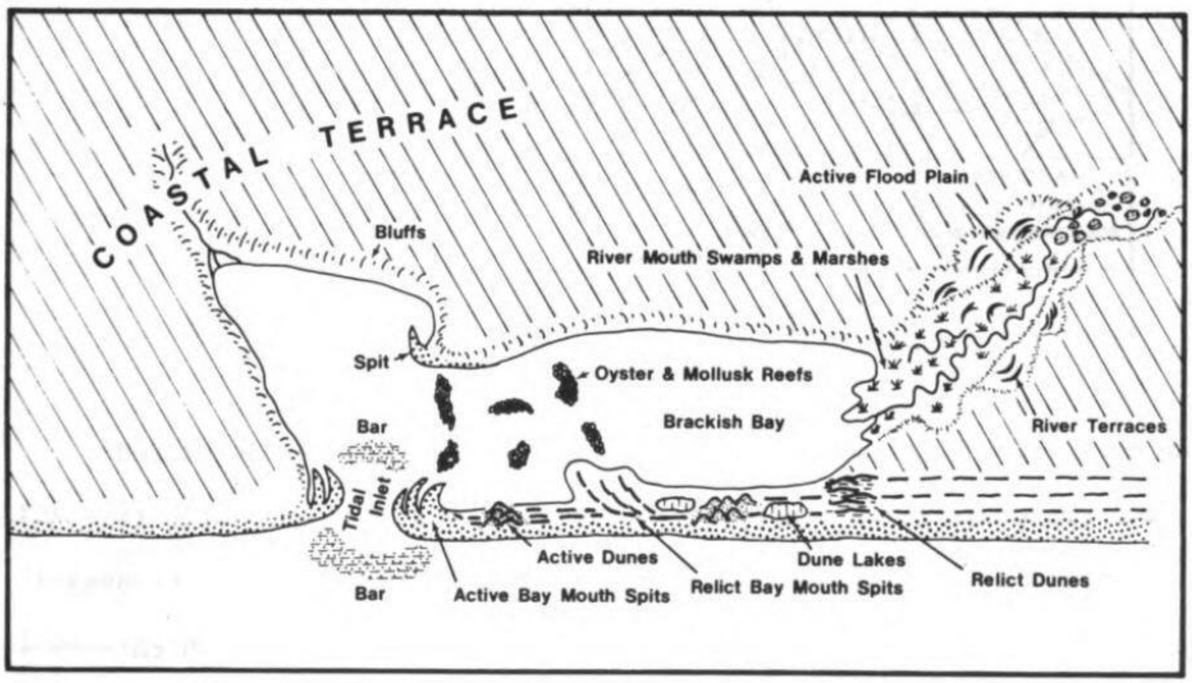


Figure 2-2. Idealized barrier spit and bay system showing typical arrangement of physiographic units.

most systems are repeated so frequently that it is useful to construct simple models showing typical relationships of one part or component to another. A model showing major components of a delta system is shown in Figure 2-3. Such models are not meant to imply that each type of coastal system has the same components or the same proportion of components. To the contrary, while many systems are superficially similar in gross form, they may differ considerably in detail. Still, the models are useful in the interpretation of relict systems.

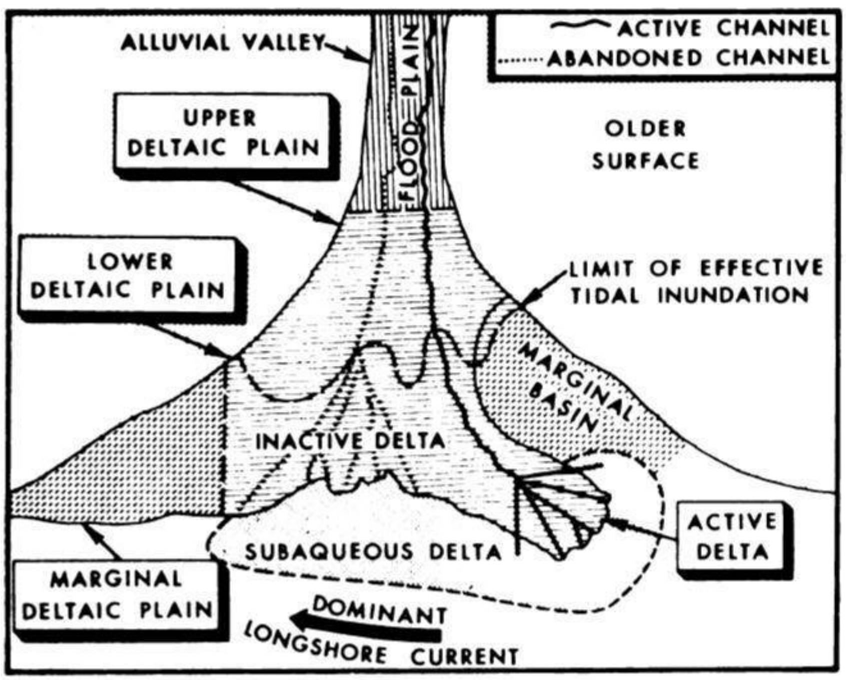


Figure 2-3. Delta model indicating typical arrangement of major components.

An active physiographic unit is one which is presently being acted upon by the processes which shape it and result in its characteristic features. Examples are active sand pits, point bars, and dunes. Relict forms (or features) are no longer being acted upon by the same processes which gave them their distinctive features, but they retain some of the distinguishing characteristics of the physiographic unit.

In the same sense, a distinction can be made between active coastal systems and relict coastal systems. An active system is analogous to a living organism, each physiographic unit constituting a distinctive part of the whole. While active, there are flows of energy and material through the system; the energy flows take the form of moving water, wind, chemical cycles, and food chains. The materials are sand, silt, clay, shells, peat, and others. Such systems may collapse (cease to function), move (shift position), or evolve into other types of systems in response to changes in process regimes. Any of these changes may result in relict assemblages of features which will identify the relict system.

Assemblages of relict features may be thought of as the skeletons of formerly active systems. When found, they tell us that the system functioned in a certain place at some past time. Following the approach of the vertebrate paleontologist, it is not necessary to find all of the bones in order to reconstruct what the body of the dead system was like and how it functioned. Drawing on conceptual models of coastal systems and assemblages of physiographic units, the landscape of a relict system can often be reconstructed from one or two distinctive features.

Distribution of Coastal Systems in the Shore Zone of the Northern Gulf of Mexico

The shore zone can be defined as the band around the perimeter of a large water body in which coastal systems operate. The active shore zone of the northern Gulf of Mexico varies in width from approximately 10 to 40 kilometers. It reaches maximum development in the vicinity of the Mississippi River delta area and narrows along those segments of the coast where long, straight, barrier beaches are developed.

As illustrated in Figure 1-1, the shore zone of the northern Gulf can be divided into 13 segments based on the distribution of active systems and subsystems. Since the northern Gulf area extends over almost 18 degrees of longitude, great variations in process parameters occur. Variations in climate, wave energy, vegetation, tectonics, and sediment type are readily apparent. Figure 2-4 illustrates variation in climate and wave energy.

Landward of the shore zone is the coastal plain. This is a broad area of sedimentary deposits accreted to the continental margin over a long interval of geologic time. The present study includes consideration of the youngest part of the coastal plain, which is made up of Late Quaternary coastal and riverine terraces. These terraces formed initially as lagoons, depositional and erosional features in the shore zone, and adjacent bays, lagoons, and river valleys. Their surfaces are characterized by relict forms which provide clues to their origin.

The continental shelf lies seaward of the present shore zone, extending from approximately 30 to 220 km and to water depths of about 160 meters. Like the Late Quaternary coastal plain terraces, many areas of the continental shelf contain relict terrestrial forms which are believed to indicate positions of formerly active shore zone systems.

The present shore zone, then, can be depicted as a chain of interlocking coastal systems forming a band around the Gulf margin (Figure 2-5). Geological data suggest that the present systems have been active more or less in their same positions for about 3500 years, since sea level reached its present stand. The present shore zone is the latest in a sequence of constantly changing positions that have occurred through geologic time since the origin of the Gulf.

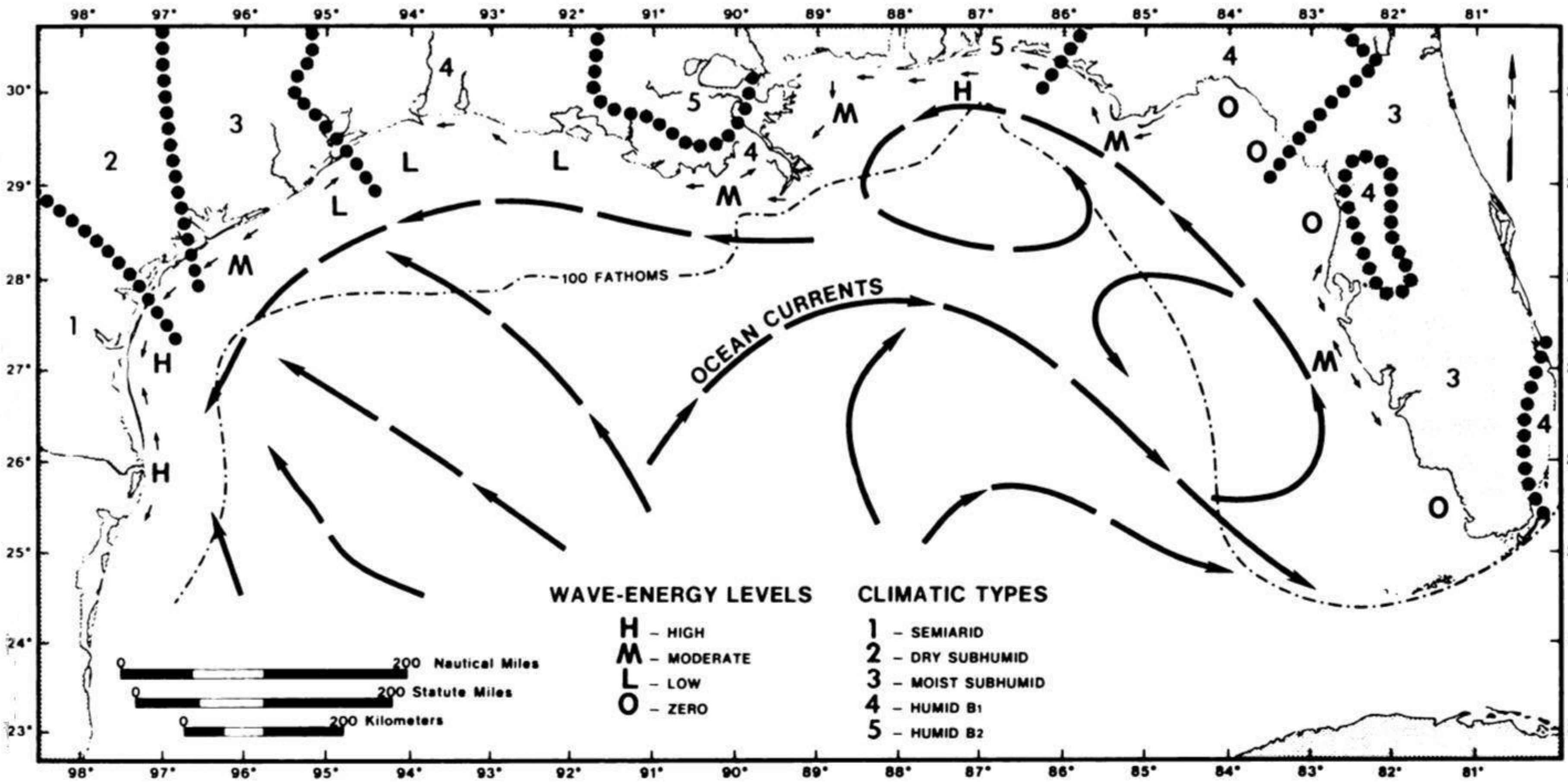


Figure 2-4. Some major process parameters of the northern Gulf of Mexico (after Kwon, 1969).

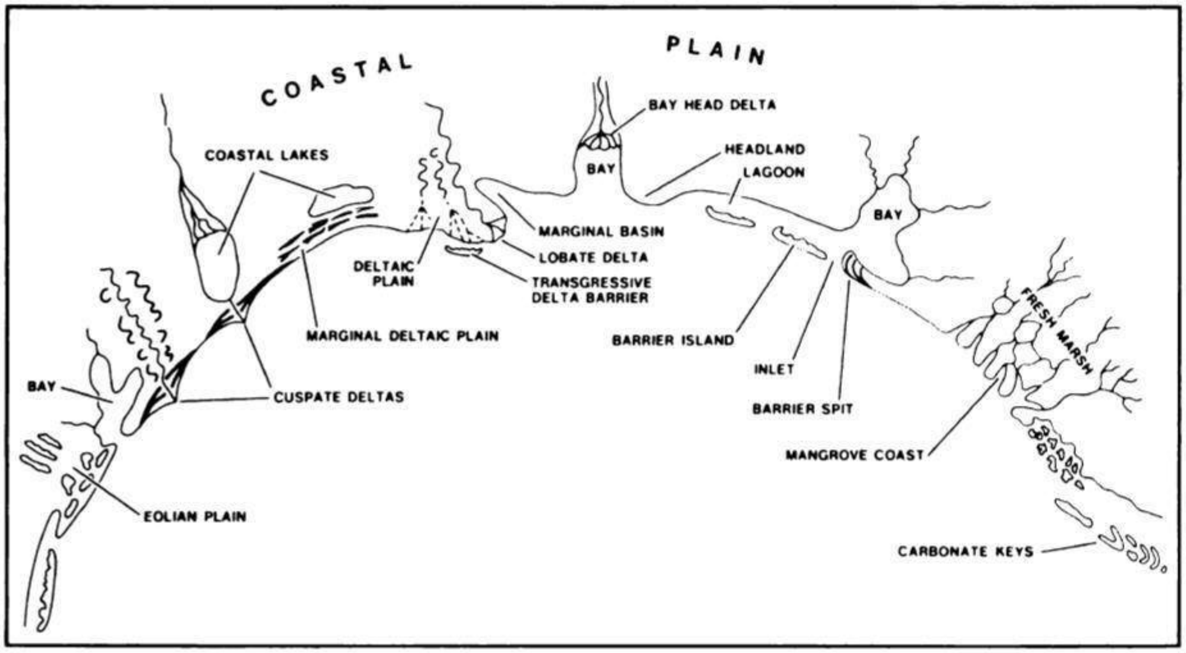


Figure 2-5. Diagrammatic representation of shore zone environments.

This study is interested primarily in the former positions of the shore zone on the continental shelf during Late Quaternary times. However, in order to interpret the forms on the shelf, it is also necessary to consider the later Quaternary coastal and alluvial terraces.

Figure 2-6 is a simple model of the shore zone in the northern Gulf area. The present shore zone is in a quasi-equilibirum condition resulting from the relatively stable sea level and climatic conditions that have persisted for approximately 3500 years. Geological data indicate that in the past, the position of the shore zone has shifted in response to changes in sea level, tectonic movements, changes in sedimentation rates, and/or changes in marine energy conditions. The geological data suggest further that the shore zone has marched back and forth across the coastal plain and the continental shelf in the not-too-distant past.

In many instances, the shifts in position of the shore zone have been parallel (Figure 2-6 B,b and C,b). It is clear, however, that this has not

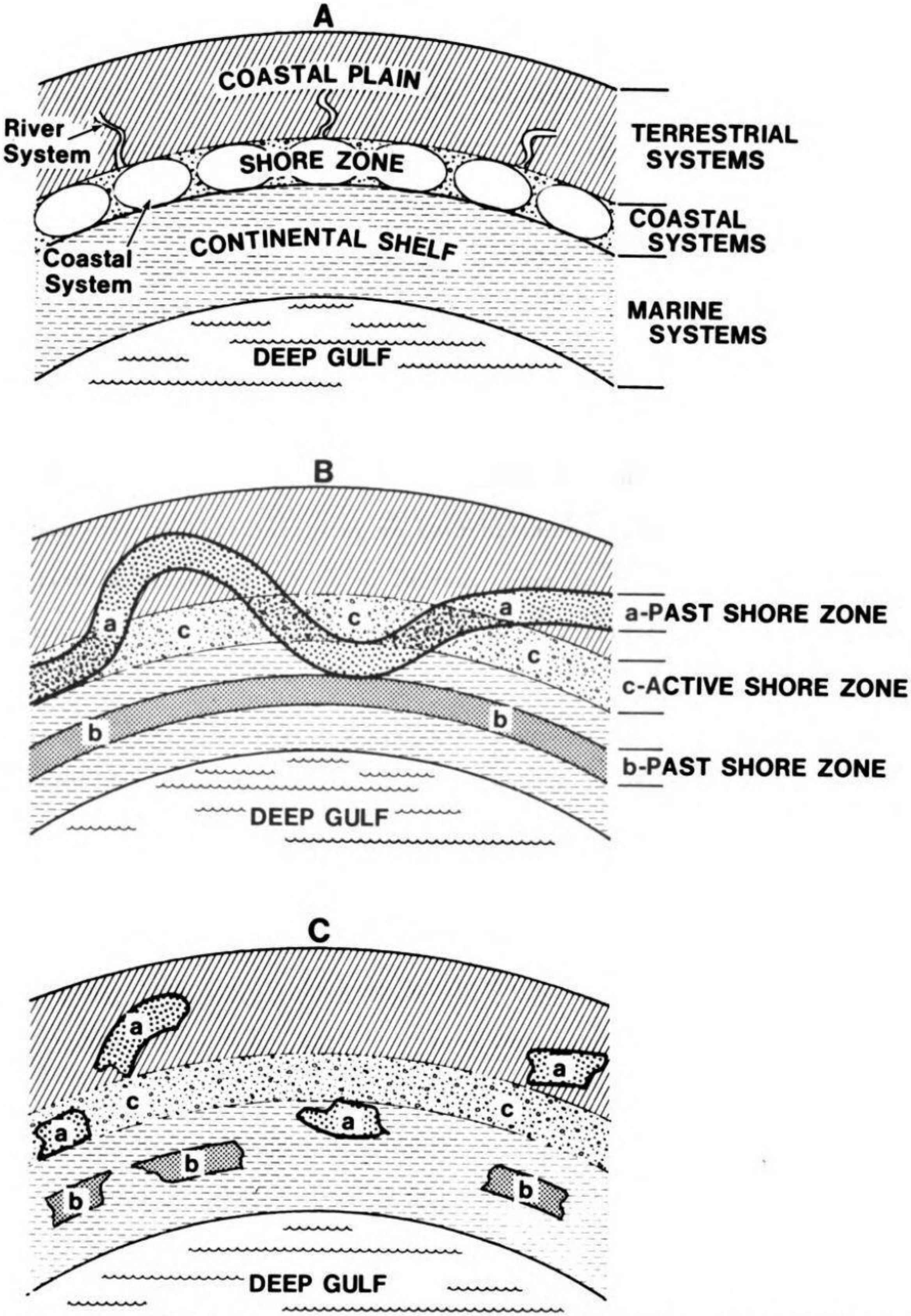


Figure 2-6. Idealized relationships between active and past systems and shore zones. A. The present shore zone consists of a band of interlocking coastal systems around the Gulf margin. B. The present, or active, shore zone is the last in a sequence of constantly changing positions that have occurred through geologic time since the origin of the Gulf of Mexico. C. Only remnants of past shore zones, represented by relict features, are preserved.

always been the case. In some instances, parts of past shore zones lie seaward of the present shore zone; other parts lie landward and now stand raised and drained as terraces on the coastal plain (Figure 2-6 B,a and C, a). In still other instances, the present active shore zone is coincidental with segments of past shore zones (Figure 2-6 B, a and c; C, a and c).

Mappable Geological Features

While each coastal system may consist of an assemblage of physiographic units, the relict forms of these units may be so subtle or modified that they cannot be readily identified. Identification or interpretation is also based to a large extent on the scale of maps, charts, or aerial photographs available for study and on availability of supplemental data, such as bottom sediment types.

Primary data in the form of maps, bathymetric charts, and aerial photographs were used at a variety of scales. Maps at a scale of 1:250,000 were found to be particularly suitable for the regional synthesis. Features were reduced to base maps at a scale of 1:500,000 or 1:1,000,000. Final presentations were prepared at a reduced scale of 1:1,904,762.

Secondary sources consisted of published geological, paleontological, and archeological reports. These often contained detailed descriptions, borings, section radiocarbon dates, and interpretations.

Because of the great size of the area under consideration, only prominent forms could be displayed on the summary maps. Mappable forms are shown in Volume III, Plate 2, and are described below.

Uplands

This is a catch-all category that includes all surfaces inland from and above the lowest well-defined coastal and alluvial terraces. The seaward boundary of the upland surfaces is often marked by well-defined scarps and abrupt changes in lithology. A distinctive belt of Late Pleistocene and/or Early Pleistocene deposits makes up the seaward end of the uplands through much of the region from southwest Texas to southern Alabama. The formations in this belt, known as Goliad, Williams, and Citronelle formations in various areas, are characterized by sand and gravel deposits which apparently represent alluvial valley and upper deltaic plain facies of large river systems. In Florida, these deposits grade into sandy, lime, and chert facies, the surfaces of which often exhibit well-developed karst topography. Inland from this sand and gravel belt, older Tertiary sedimentary deposits outcrop. In contrast to the lower coastal and alluvial terraces, relief in the uplands is relatively high (up to several hundred feet), and the surfaces are deeply weathered and indurated.

Coastal and Riverine Terraces

As the name implies, coastal and riverine terraces consist of raised surfaces that were formerly flood plains and coastal zones active from Late Pleistocene through Middle Holocene times (see Chronology, Volume III, Plate 1). These surfaces are characterized by relict features related to formerly active systems. Subsequent to their abandonment by these systems, the surfaces have been tilted and stand as raised terraces. They are often separated from the uplands above and the active coastal zone systems below by distinctive scarps.

Beaches and Beach Barrier Complexes - This category comprises some of the most prominent and important mappable forms of the study area and consists generally of linear sand bodies and complexes of sand bodies. As the name implies, these features formed along the Gulf shore and were previously shaped by wave and longshore drift actions, producing well-sorted sand deposits. In plan, the geometry is dominated by long, straight ridges which may occur singularly or in parallel to sub-parallel groups (Figure 2-7). The ridge systems may break into fans and combs, marking former "ends" of the islands. Ridge geometry may be accentuated by aligned depressions. Secondary features associated with the complexes may be aeolian (dunes) or tidal (tidal deltas) in origin. Dune features often accentuate the height of the ridges.

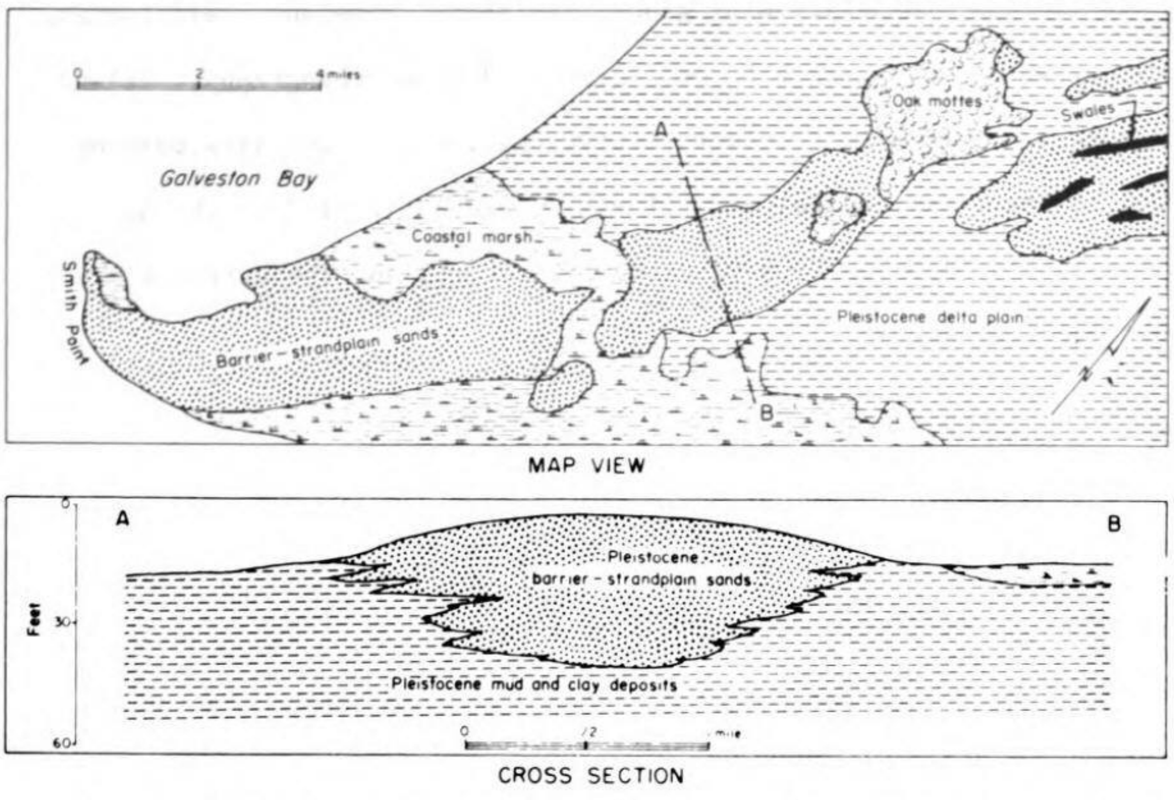


Figure 2-7. Pleistocene barrier island and associated strandplain sands, Smith Point area, Chambers County, southeast Texas (after Fisher et al., 1973).

Meander Plains - The familiar scrolls of bar and swale meander topography serve to distinguish relict meander plains on the surfaces of coastal and riverine terraces (Figure 2-8). While the original relief may be greatly subdued as a result of sediment veneering, colluviation, and erosion, the patterns are readily mappable on aerial photographs and remote-sensing imagery. Point bar complexes with accretion ridges, swales, and cutoff channels are particularly characteristic.

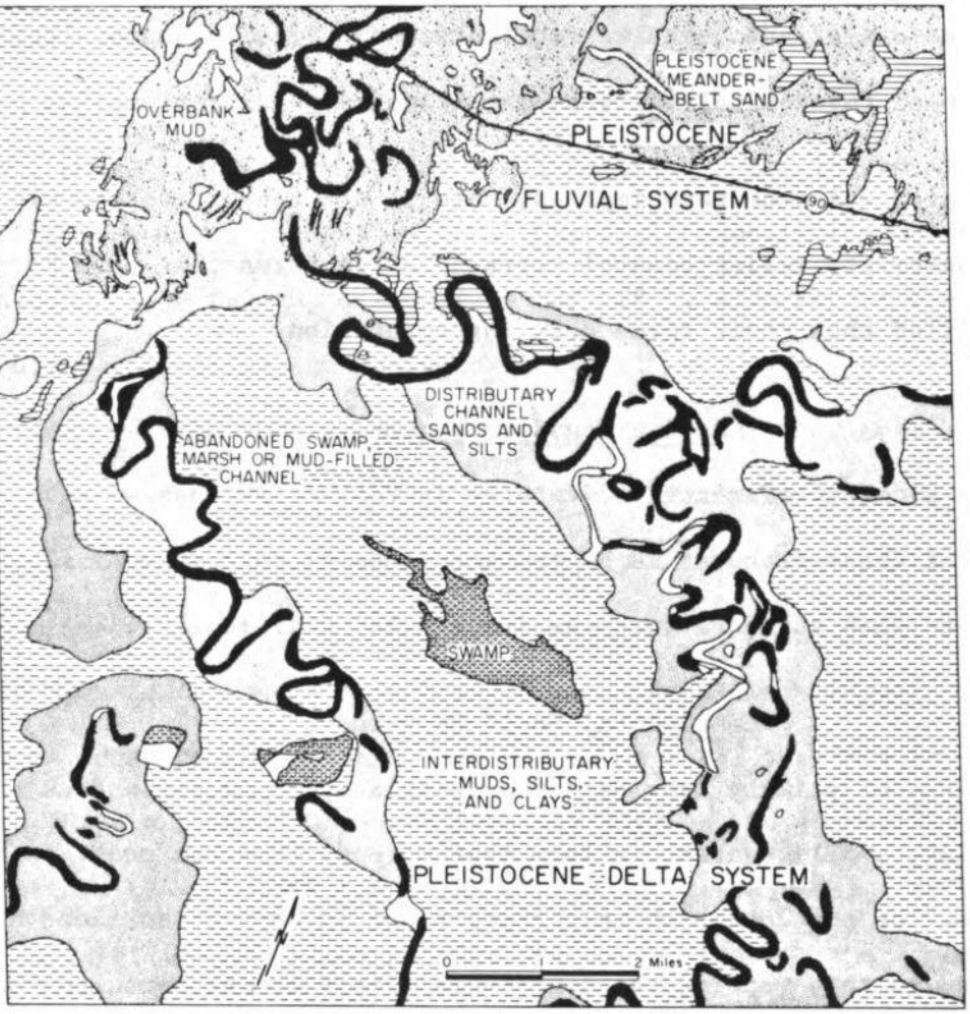


Figure 2-8. Pleistocene meander plain landscape in the vicinity of Devers, Beaumont-Port Arthur area, Texas (after Fisher et al., 1973).

Deltaic Plains - Because initial relief is usually very low and the range of sediment sizes is also restricted, the distinguishing characteristics of relict deltaic plains on coastal and riverine erraces are subtle. Deltaic plains may be distinguished by relict stream scars and natural levees that branch toward the coast. Modern drainage is usually incised into former interdistributary basin areas, and the abandoned distributary-channel levee systems stand as straight ridges in the interfluves of the modern drainage deltaic plains.

In some instances, old beach ridges, lake shores, and lacustrine deltas can be identified on the terrace surfaces. Notably absent from the deltaic plain of the coastal terraces are transgressed features.

Undifferentiated - As the name implies, this is a catch-all category. It may include nondescript, relict coastal terrain, or features that have been so greatly modified that their forms defy interpretation.

Active Coastal Systems

While we make reference to features in the active coastal zone systems, the mapping of these features is beyond the scope of this report. The reader is referred to such standard works as Shepard and Wanless (1971).

Continental Shelf Features

The area of primary consideration in this study is defined as the gently sloping, shallow-water platform that extends from the coast to the shelf "break," or that point where a steep slope to deep ocean floor begins. As emphasized in this report, the continental shelf of the northern Gulf of Mexico is highly variable. The shelf ranges in width from about 30 kilometers in the Mississippi-Alabama-west Florida area to more than 120 kilometers in the south Florida, east Texas, and west Louisiana areas. While the shelf break generally occurs at about 100 meters, features of interest in this study extend to about 200-meter depths in some areas of the Gulf.

Barrier Spit Complexes - Price (1968: 51) defines a barrier as ". . . . a partly emergent barlike ridge of sand or coarser sediment lying off a shore or shoal and usually sub-parallel to the shore, projecting from the flank of a headland or connecting two headlands. A barrier is usually cut by one or more tidal inlets [(Figure 2-9)], forming a barrier chain -- a succession of barrier peninsulas and barrier islands of simple narrow beaches." Further, "barriers are commonly connected below water by tidal deltas. While inlets migrate, the makeup of a chain is changeable. The barrier (coastal) lagoon is a succession of shallow troughs or barriers set off by widening of the islands. There are bay-mouth, midbay, and bayhead barriers."

Barrier and spit complexes tend to be narrow near headlands. The downdrift ends, where they enter bays or migratory inlets, typically become complicated by the formation of recurved spit complexes. While barriers and spits begin as single, water-laid beach ridges, commonly vegetated, they are usually elevated by aeolian sand and become beach-dune ridges. Beach ridges may be added to the seaward side if a sand surplus exists to form a beach plain (Figure 2-10). Washover fans may form on the lagoonal side and are associated with washover flood channels, which often develop during storms. These may be vegetated to become part of the marsh apron on the lagoon side of the barrier.

Dune development may also become complex. Blowout fans form downwind from blowout areas in the foredunes. Dunes may migrate across the island and eventually enter the lagoon over tidal flats. Freshwater ponds are common features in complicated barrier dune areas.

Barrier and spit complexes are among the most common relict features on the continental shelf. This should not be surprising since they are prominent around the Gulf margin in the present active coastal zone and possess a very distinctive geometry.

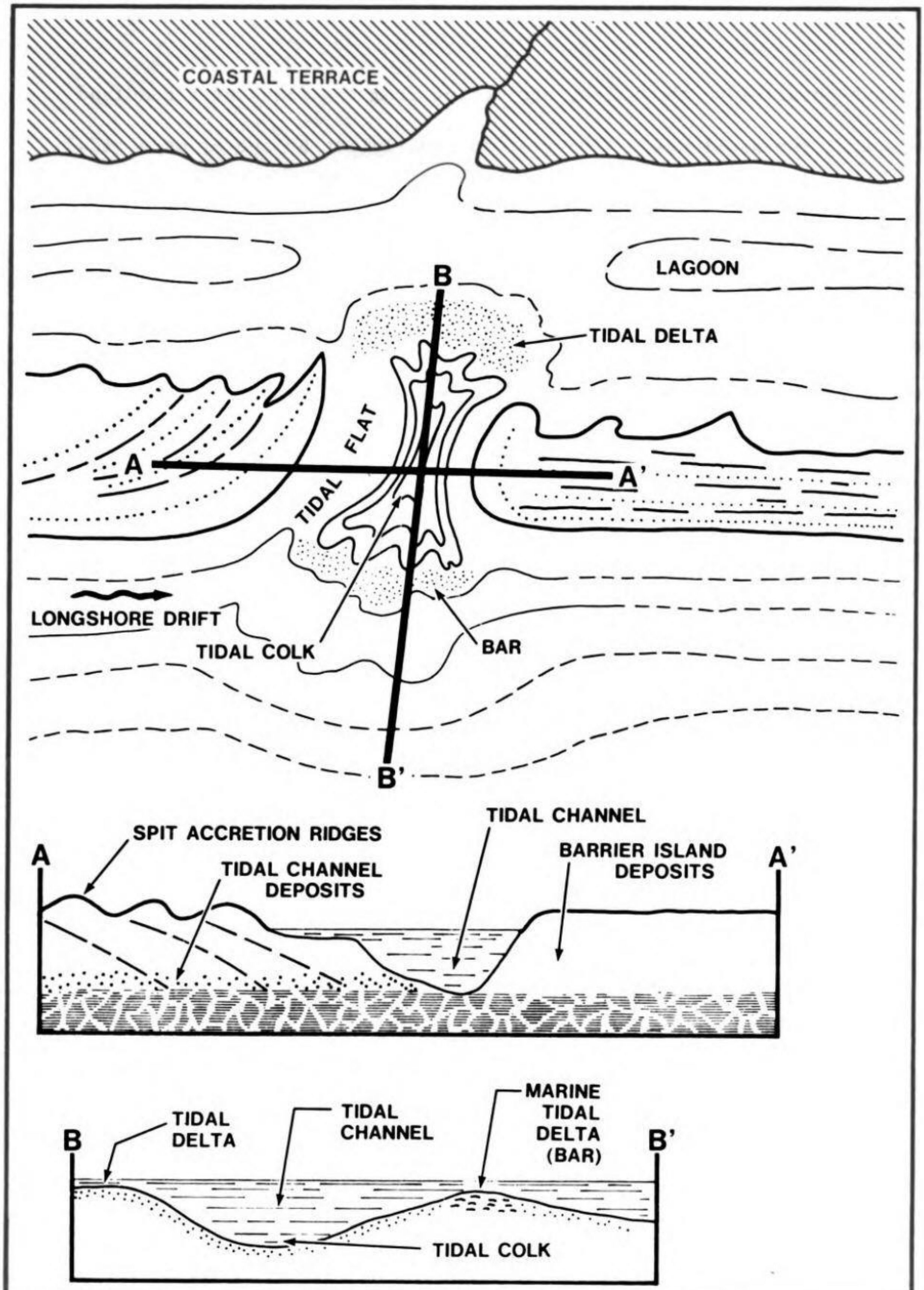


Figure 2-9. Features associated with tidal inlets between barrier islands (after Le Blanc, 1972).

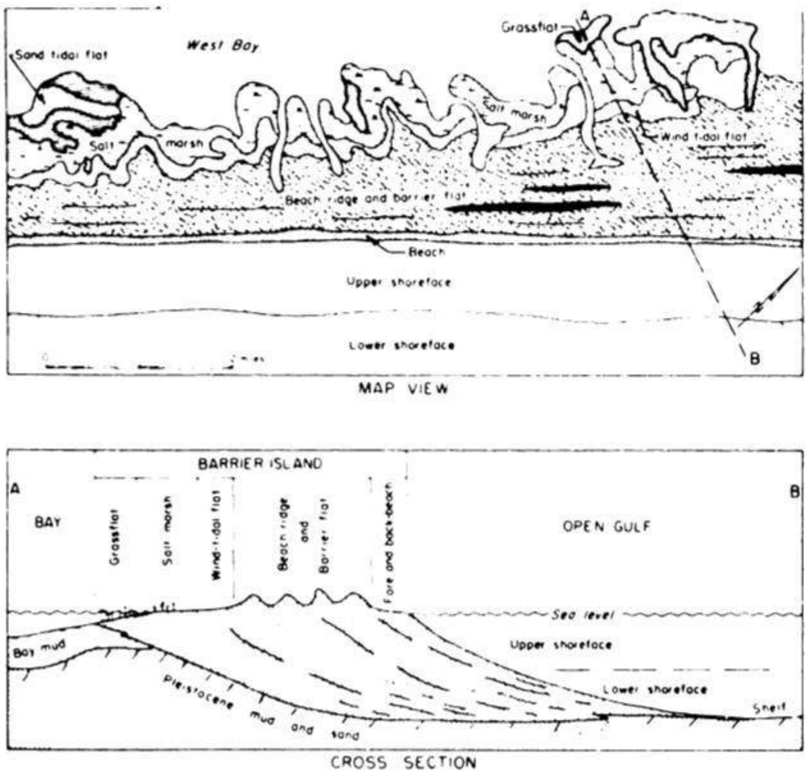


Figure 2-10. Modern barrier island environments and facies, Galveston Island (Cross-section after Bernard et al., 1970; after Fisher et al., 1972).

Beach Ridge Trends - These features appear to be similar to barriers except that they lack the bulbous ends, or noses, that are believed to represent spit complexes. They may best be considered as poorly defined barriers. Their scale suggests multiple, sub-parallel, accretion beach and dune ridges rather than single ridges.

Barrier Accretion Forms - These forms consist of accretion beach-dune ridges developed on the downdrift side of a headland. In plan, the feature is fan-shaped, with the apex of the form on the headland side of the complex and individual ridges pointing downdrift. This type of feature should not be confused with a distributary mouth accretion fan. Although similar in plan geometry, the origin is quite different. Only one barrier accretion fan has been identified on the northern Gulf of Mexico continental shelf, and it is in the Mississppi-Alabama-west Florida area.

Shelf-Edge Bulges - This name has been given to a series of very prominent protuberances along the west-central Florida shelf. They are believed to be relict cuspate forelands, but this interpretation remains to be tested.

Shore Trends - This is another catch-all category of linear features that have been interpreted as relict shoreline trends. In some places, the features are interpreted as relict shoreline trends, and in some places, the features are clearly beach-dune ridges (usually single ridges as opposed to barrier spit complexes and beach ridge trends). On the south Florida shelf, some of the trends are delineated by alignments of relatively small depressions. Zones of branching channels transverse to the shore trends are characteristic in a number of areas.

Escarpments - Escarpments are indicated on the continental shelf by closely spaced contours. Although escarpments may be as much as 11 meters in height, 3.7 meters is nearer to the average. Some of them are remarkably continous. In several instances, they can be traced for more than 100 kilometers, and on the south Florida shelf, one continues for more than 200 kilometers. The most prominent escarpments occur on the outer shelf. Most occur on rocky shelves thinly veneered by unconsolidated sediments.

While some escarpments may be the surface expression of faults, the trends and relationships with other features suggest that most are relict shorelines.

Minor escarpments associated with "seacliffs" are not entirely unknown along the northern Gulf. Modern examples are usually found along the shores of bays rather than on the open Gulf shore. The Silver Bluff shoreline (Late

Pleistocene) of south Florida is characterized by an escarpment and its related features. Figure 2-11 illustrates the cross-section of a low-cliff coast typically developed in limestone coasts. The limestone may be marine or freshwater limestone, aeolian calcarenite or other calcium-cemented sediment. These types of rocks are particularly common around the margin of the northeastern and northwestern Gulf. Associated features include wave-cut notches. In some cases, particularly where tides are developed, a low-tide platform may develop and be bounded by a second escarpment. Encrustations of algae (chiefly Lithothamnion sp.) may be characteristic of the rim of the low-tide platform (Bird, 1967).

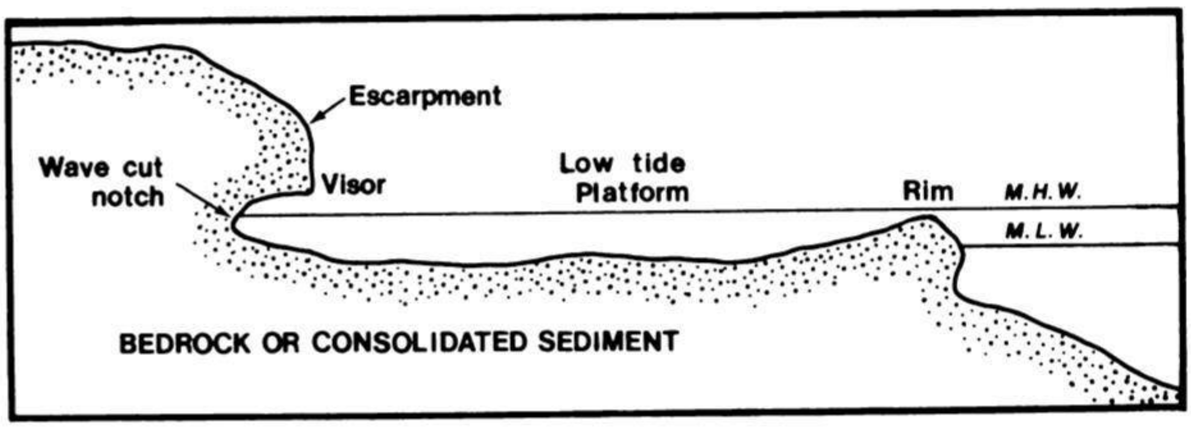


Figure 2-11. Features associated with low-cliff coast developed in limestone.

Tidal Scour Features - This is a group of features whose trend is transverse to related relict shorelines. They are believed to have been formed by tidal scour and related deposition in tidal inlets and at the mouths of bays. Tidal colks, or scour holes, in inlets between barrier islands in the active shore zone, may attain depths of 50 meters and have a distinctive bottom topography (Figure 2-9). Tidal deltas are often associated with such features and may retain their form after the inlets no longer function. While a number of these features have been interpreted from bathymetric maps, it is not certain that they all formed when the associated relict shorelines were active. That is, some may represent submarine erosion and deposition on the continental shelf. W. Armstrong Price (personal communication) reports active bar and trough features in the south and central Texas shelf areas. It is also conceivable that while some of these features were initially associated with active shore zones, submarine erosion and deposition may have continued even after the shore zones became inundated or submerged because of the strong influence of the bottom topography on bottom currents.

Banks, Shoals, and Shelf-Edge Knolls - This category includes: 1) low, shallow, nearshore features of five-meters relief, in water depths of 15-30 meters, 20-40 kilometers offshore; 2) features of moderate relief commonly less than about 70-80 meters in height, but in places as much as 150-200 meters, in water 55-270 meters deep, 200-240 kilometers offshore; 3) those which grade into a class of even larger features, many of which are hundreds of meters in height, in water depths of more than 270 meters, and more than 240 kilometers offshore on the continental slope.

The features have probably originated in a number of different ways. The shallow, nearshore banks may overlie relict coastal forms or salt domes. The larger hills, particularly those near the shelf edge, were probably initiated as diapiric salt and shale structures. The possibility also exists that some of the deeper features may be of igneous origin.

Most prominences on the shelf are distinguished by concentrations of calcareous deposits in the form of shells, coral, algae, etc. Thus, bottom prominences, regardless of their mode of origin, become foundations for bioherms. The remains of the organisms in these reefs and banks depend on specific environmental parameters controlling the growth of marine organisms (depth, temperature, salinity, current, etc.) and the environmental changes which have occurred through time. Thus, the faunal remains from these banks and reefs may record a complex sequence of changes.

The forms of shelf-edge knolls may range from low mounds to steeper hills to slender pinnacles. However, as Ludwick and Walton (1957) have noted, it is the pinnacle that gives the varied topography found along the shelf edge in many areas its distinctive character. The knolls have been of interest to a number of workers. Important publications include those of Edwards (1971), Neumann (1958), Parker and Curray (1956), Poag (1972), Poag and Sweet (1972), Ludwick and Walton (1957), Rezak and Bryant (1973), and Bryant *et al.* (1969).

These factors are of interest to the present study for several reasons. The most important is that some apparently have been exposed as islands or were shallow reefs during intervals of lower sea stand. Poag (1973), for example, suggests that a series of wave-cut terraces, erosional unconformities, and relict reefal assemblages indicates eight earlier sea levels on banks near the edge of the east Texas and west Louisiana shelf areas. Changes in faunal assemblages also indicate changes in water depth and environmental conditions.

Terraces - Drowned terrestrial terraces are probably very widespread on the continental shelf. They are characterized by relatively low relief and gentle slopes. They are bounded by other relict, shore-zone forms which tend to identify them as former terrace surfaces.

Karst Areas - These are areas on the shelf where limestone either crops out or is covered only by a thin veneer of sediment. The bottom topography is characterized by relatively dense patterns of sinkholes. The limestone itself was probably originally deposited in bays and sounds, but was later exposed to subaerial weathering. It was during this subaerial exposure that the sinkholes were formed.

Rocks - There are individual rock occurrences reported on bottom charts. They may be caliche, beachrock, aeolian calcarenite, or freshwater limestone. Rock occurrence has only been noted on the east Texas and west Louisiana shelf areas where distribution seems to be related to a major relict delta lobe and relict barrier-spit complexes.

Channels - There are systems of channels that are sub-parallel to the shelf slope. Many have a dendritic habit, suggesting tributary networks in a shoreward direction. Also they characteristically occur in zones and are often associated with escarpments or shore trends.

Entrenched River Axes - These features have been identified by borings and have been reported in the geological literature. They are believed to represent former entrenched river valleys that have been filled by alluvium. The Mississippi River trench may be the best known of these features (Fisk, 1956; Kolb and van Lopik, 1958; Frazier, 1974). The Pearl River trench (Frazier, 1974), the Sabine (Nelson and Bray, 1970), Galveston (Rehkemper, 1969), and Apalachicola (Schnable and Goodell, 1968) trenches are also reasonably well known.

Delta Lobes - Large, low-relief bulges with arcuate fronts mark the position of relict delta lobes in the south Texas, east Texas, and west Louisiana shelf areas. Linear shoal areas are cutting across a number of these lobes and, sub-parallel to the strike of the present shore zone, are believed to represent transgressive phases of the deltas: the last traces of delta barrier islands that formed during the deterioration stage of the delta cycle. While transgressive features are well developed on some delta lobes, they are apparently absent on others. Perhaps those lobes without transgressive features were formed during periods of falling sea level.

Surface Sediments of the Shelf

Clearly, deposition of marine sediment is presently occurring in many, if not most, areas of the shelf. In order to evaluate the discoverability and recoverability of cultural resources, the kinds and rates of accumulation of these surficial marine sediments must be considered. Although the data in this area is considerable, much of it is in the unpublished files of the petroleum and geophysical service companies. As one might expect, there are presently both erosional areas, where Pleistocene and Tertiary deposits are either exposed or covered by very thin, modern sediment veneers, and depositional areas (central Texas, west-central, central, and south Florida shelf areas). In depositional areas, such as the active delta lobes of the Mississippi River delta, rates of accumulation of hundreds of feet per century have been documented (Frazier, 1974). Rapid and deep burial of either a habitation site or a shipwreck in such areas would affect not only the discoverability and recoverability, but also the preservation. For example, wooden artifacts, cordage, and other perishable materials have recently been recovered from alluvially buried Tchefuncte and Coles Creek Period sites (circa 500 B.C. to 1000 A.D.) in the now abandoned St. Bernard lobe of the Mississippi Delta.

In addition to variation in rates of accumulation, differences in depositional processes and composition are also significant. A map compiled by Holmes (1973) represents a recent attempt to summarize sediment distribution on the continental shelf and slope of the northern Gulf. This map shows the distribution of five major sediment categories: 1) sand, 2) alternating sand, silt, and clay, 3) silt and clay, 4) veneer of sand, silt, and clay over limestone, and 5) carbonate sand and clay. Several important sub-regional studies of sediment distribution patterns have been done based primarily on size and sorting characteristics and mineral content. Important among these are Curray's work in the northwestern Gulf (1960), Frazier's recent paper on the Quaternary stratigraphic framework of the northwestern Gulf (1974), Griffin's studies of clay mineral distributions in the eastern Gulf (1962), and Ludwick's work on calcareous prominences (1964).

A summary map compiled by Curray showing the distribution of surface sediment of the continental shelf in the study area is shown in Figure 2-12.

Changes in Levels of Land and Sea

As our previous discussion has indicated, relict coastal forms marking former shorelines are distributed both above and below the present level of the sea. Clearly, the emerged features owe their present position either to an uplift of the land or a fall in the level of the sea, while submerged coastal features indicate that in former times the sea stood at a lower level relative to the land. Thus, submerged relict shorelines have resulted from either subsidence of the land, a rise of sea level, or a combination of the two. A part of our problem relates to the great difficulty in distinguishing

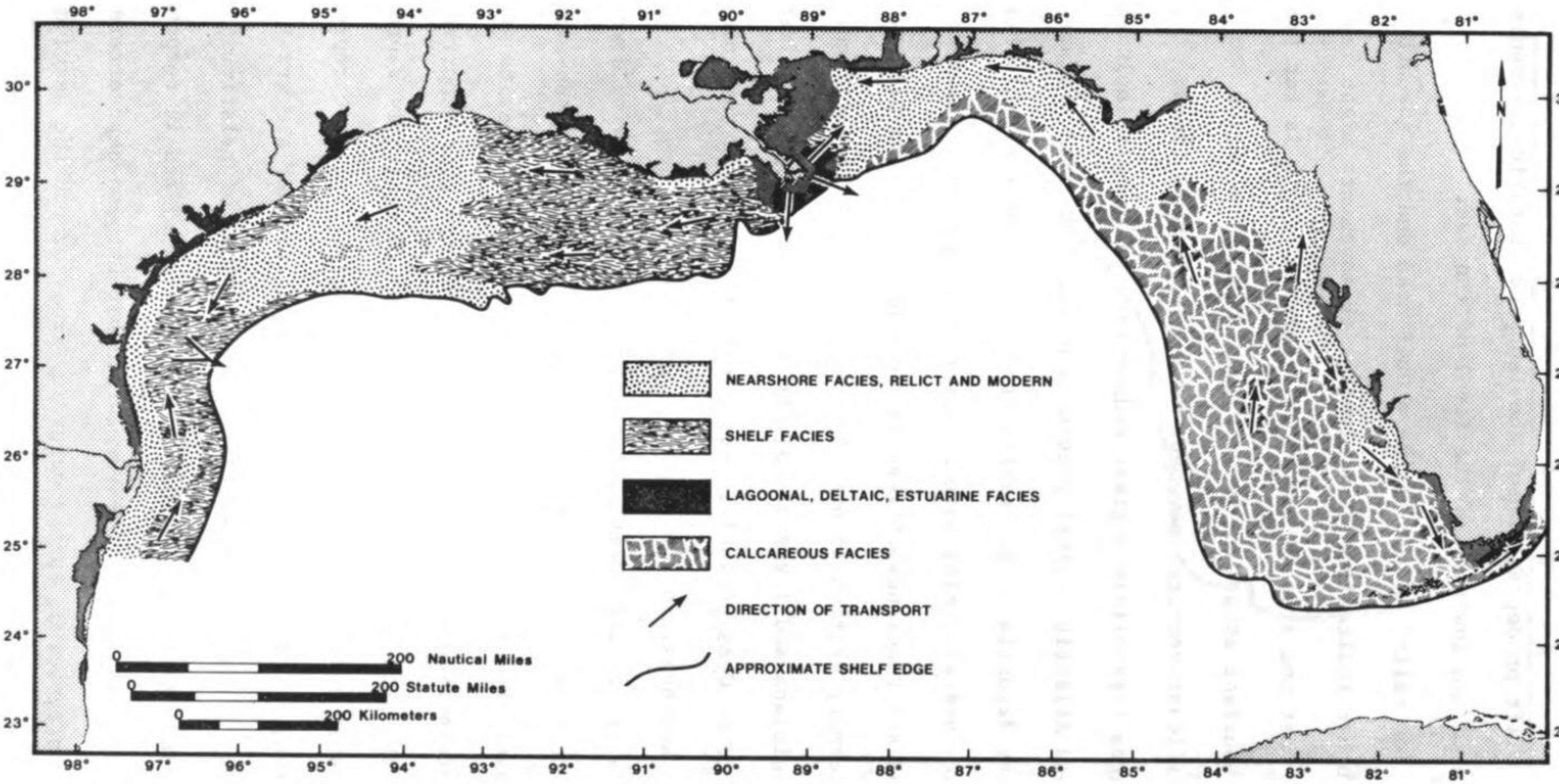


Figure 2-12. Surface sediment distribution of the continental shelf, northern Gulf of Mexico (after Curray, 1975, 1965).

between tectonic uplift or depression of the land, and eustatic movements related to the rising and lowering of the level of the sea.

The general low relief of the northern Gulf area and the absence of igneous rocks or other indications of violent earth movements might lead to the conclusion that the area is tectonically stable. This is far from the case. The subsurface structure is very complex, and the region was subjected to significant vertical movement during Quaternary times.

The study area lies within a great sedimentary basin that includes the entire Gulf and Atlantic coastal provinces of North America (Figure 2-13). Sedimentary deposits in the central and western part of this basin (Louisiana - Texas coastal areas) have been accumulating since Jurassic or Triassic times and are thousands of feet in thickness. In some places, the Tertiary and Quaternary section is over 30,000 feet in thickness (Figure 2-14). In the Louisiana and Texas areas, the axis of this great sedimentary basin (Gulf Coast Geosyncline) is sub-parallel to the present coast extending through southeastern Louisiana.

In this area, there are great systems of growth faults, with downthrown blocks to the south. The strike of these faults is also sub-parallel to the present coast (Figure 2-13). Many of the major growth faults are related to discrete episodes of rapid sediment deposition that occurred at various times in the geologic past. These episodes are generally represented by great ladle-shaped pods of clastic sediment (depocenters) that represent former deltaic areas. Complicating the pattern even further are great diapiric structures of salt and shale. These are spines of relatively light-density plastic material that have been squeezed upward in response to sediment loading. There is a clear relationship between depocenters and zones of diapiric structures; spines occur in arcs around the seaward margins of the depocenters.

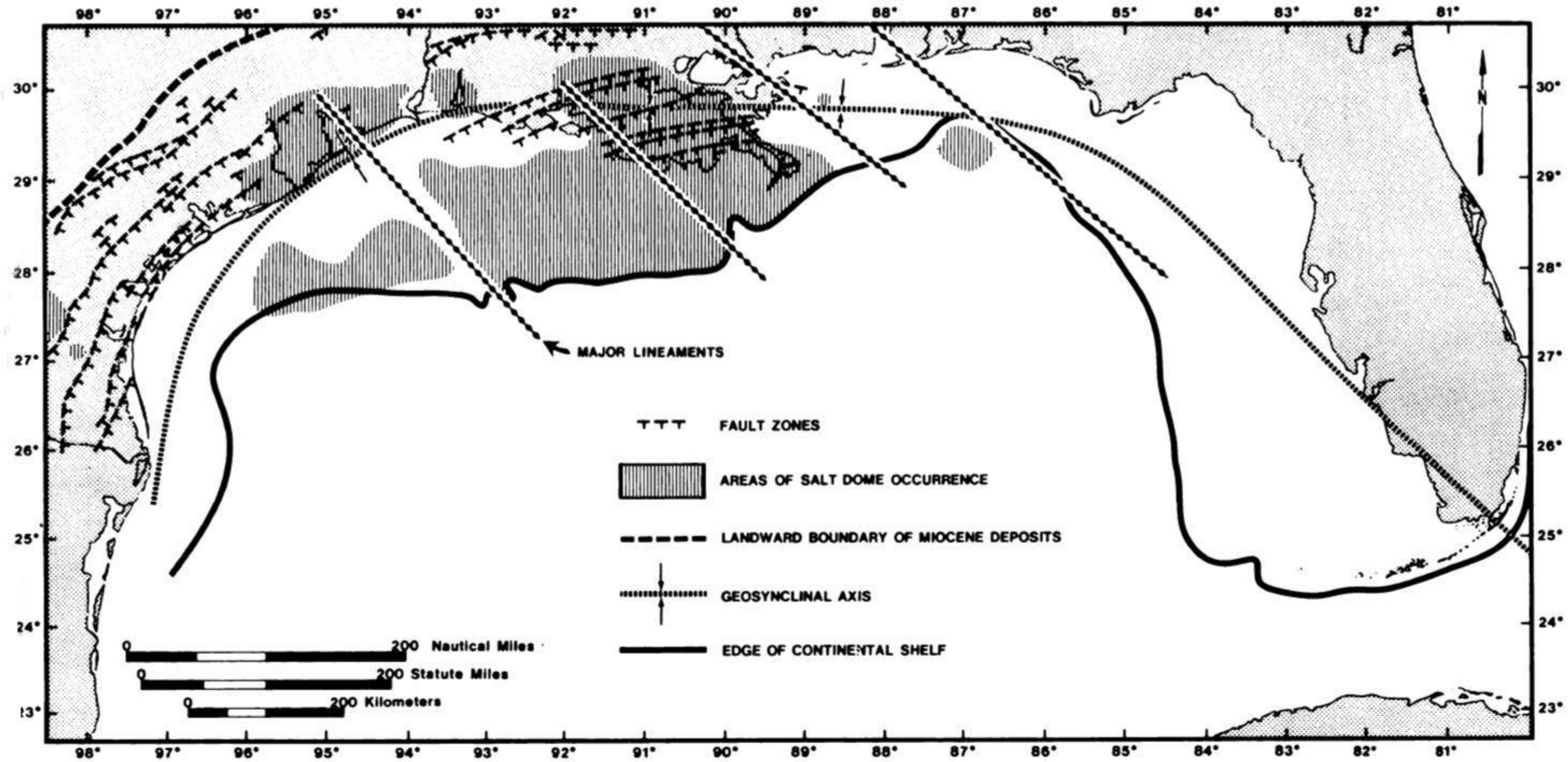


Figure 2-13. Principal faults and areas of salt dome occurrence in the northern Gulf of Mexico. The lineaments seem to mark breaks in the depth thickness of sediment accumulation and the general structural character of the geosyncline.

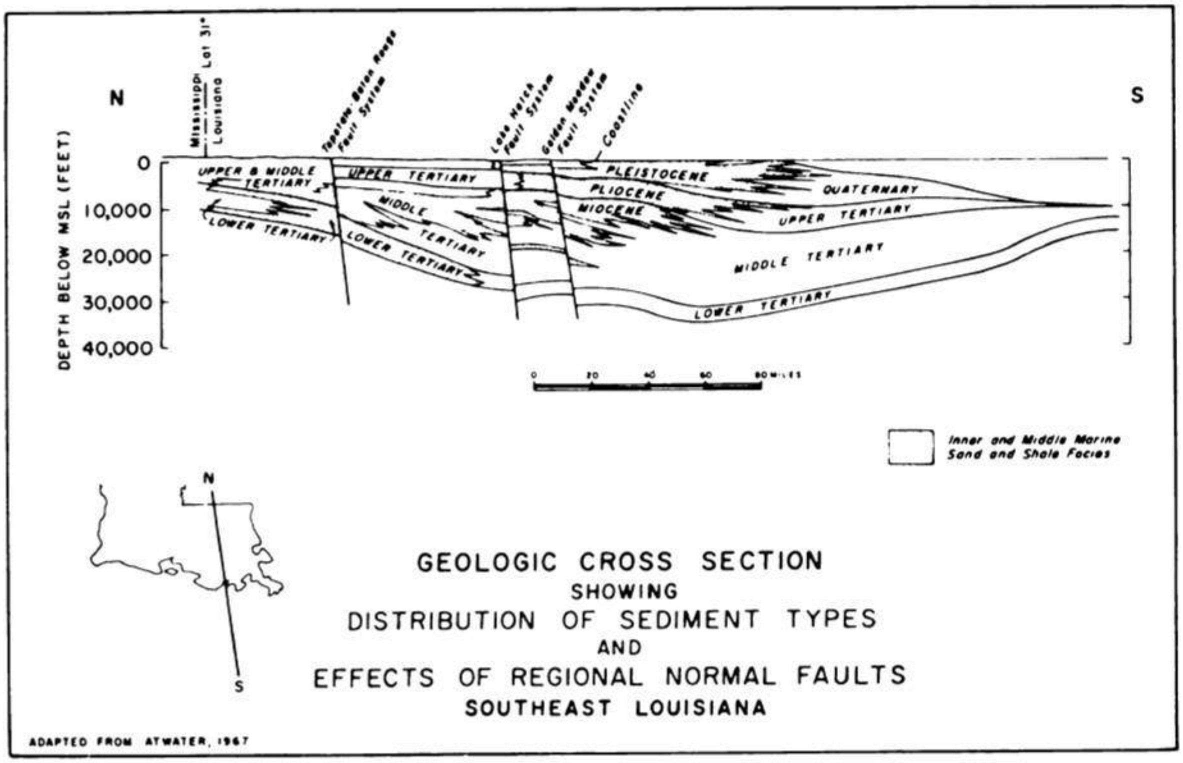


Figure 2-14. Geologic cross-section showing major sedimentary units and effects of normal faulting, southeastern Louisiana (after Jones, 1969).

The parent beds from which the salt diapirs are derived are buried at great depths in the central and western Gulf and are believed to have been deposited in Jurassic or Triassic inland seas. The salt structures are common from central Texas to southeastern Louisiana, and a small cluster has been identified on the Mississippi-Alabama shelf, but they do not occur in the eastern Gulf (see Figure 2-13). Thus, as shown in Figure 2-15, vertical movements within the geosynclinal area may have a number of components and may be very difficult to interpret.

The structural character of the province changes along the coast and shelf areas of Mississippi and Alabama. Here, there is a northwest-southeast trend of major structural elements marking the eastern margin of the Gulf Coast Geosyncline. East of the De Soto Canyon - Florida Escarpment, the character of the province is different, both from the standpoint of structure and the character of the rocks that have filled the sedimentary basin.

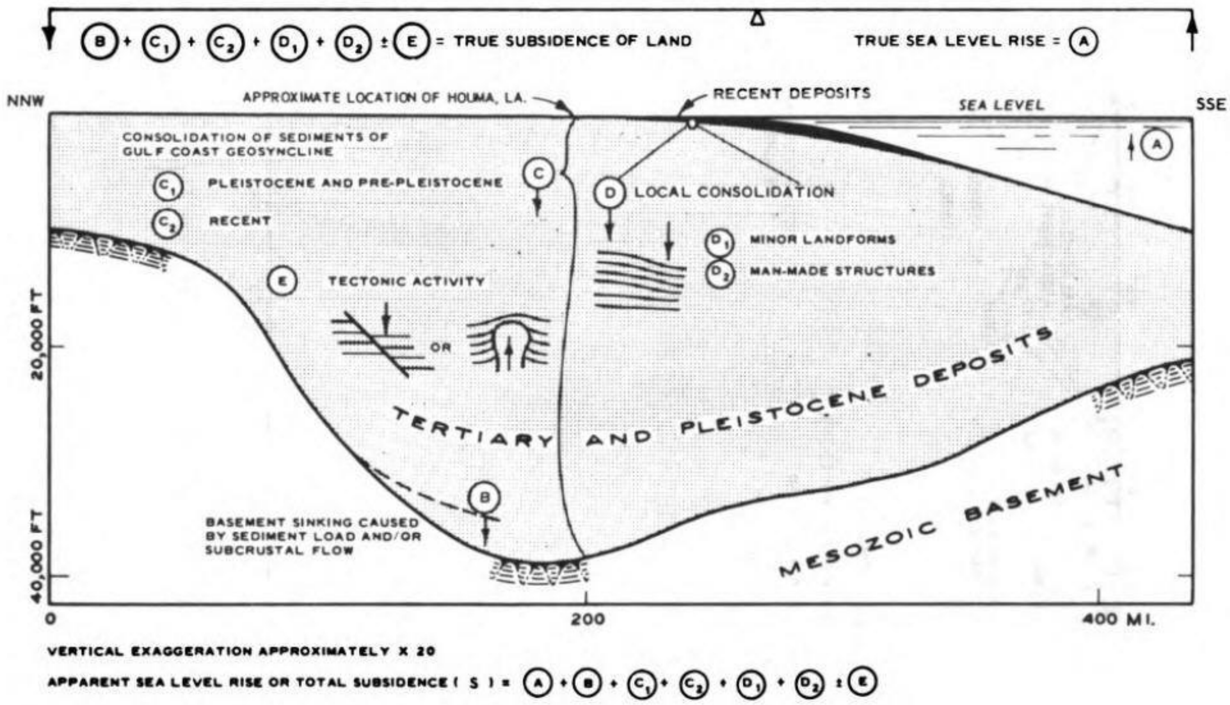


Figure 2-15. Generalized cross-section of Gulf Coast Geosyncline depicting components of apparent sea level rise (after Kolb and van Lopik, 1958).

In the Florida area, the basin rocks are not as thick, and great depocenters with associated growth faults and diapiric structures are absent. From the standpoint of sediment deposition and tectonics, the Florida area is notably "quieter" than the Louisiana - Texas area. It can best be characterized as an area of slow, gentle uplift. However, local areas of subsidence or uplift do occur.

These general patterns have persisted into Late Quaternary times. While indications of some of these movements are subtle, it is nevertheless possible to delineate areas of uplift, subsidence, or relative stability. Data for the map presented in Figure 2-16 is derived in part from the literature and in part from results of the present study.

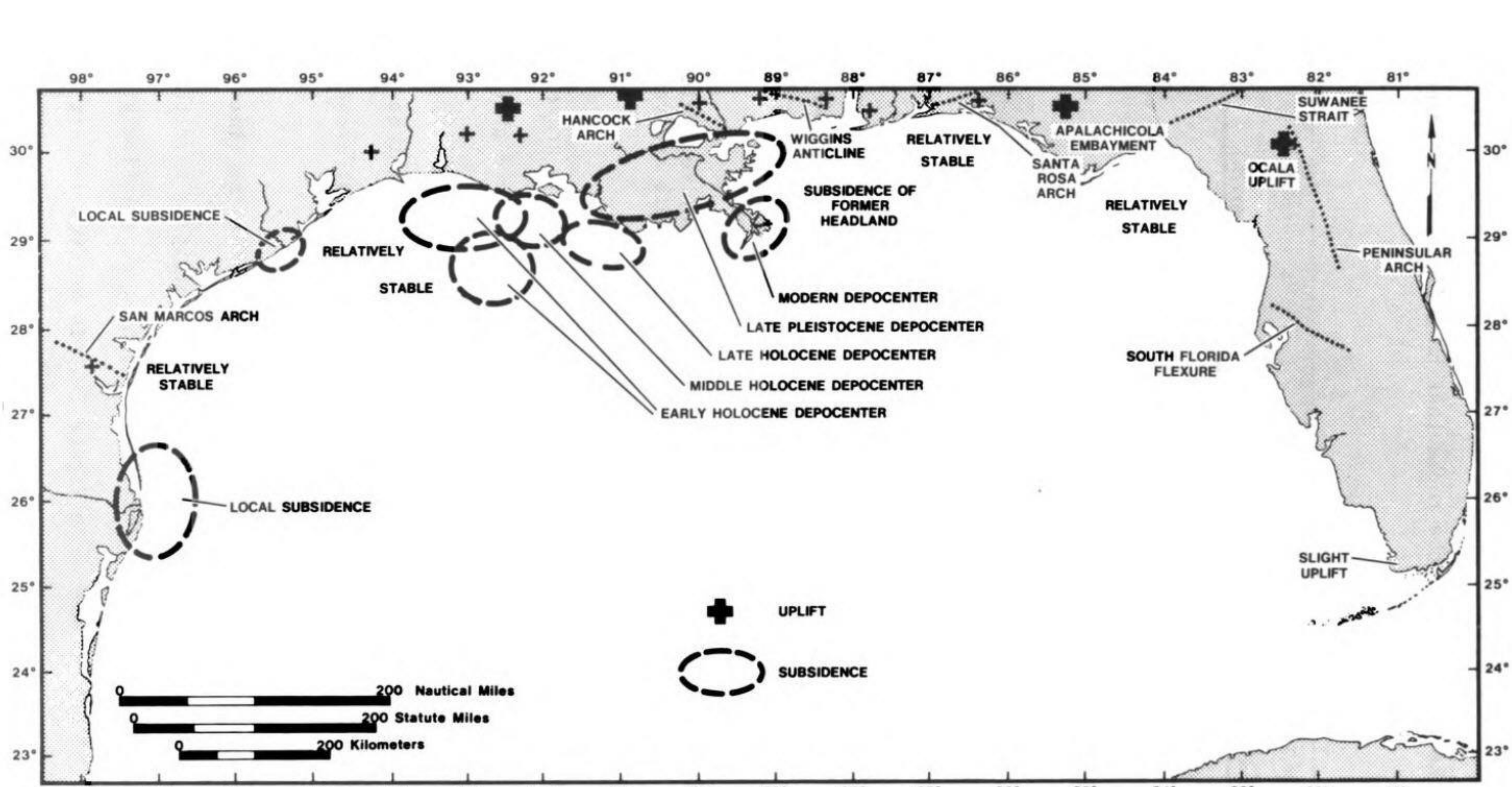


Figure 2-16. Major tectonic features and Late Quaternary movements in the northern Gulf of Mexico.

Eustatic changes in sea level are even more fundamental to our study than tectonic movements. They will be discussed at length in a later section.

CHAPTER III

LATE QUATERNARY RELICT FORMS

Many Late Quaternary relict forms have been identified on the Gulf of Mexico Outer Continental Shelf.

While it is beyond the scope of this work to interpret the history of every relict form, every form should be related to its presumed mode of origin. From this, a framework can be built upon which an interpretive history can be constructed. In order to achieve this, many of the form interpretations made in this study will require some local historical considerations. In the geological history section of this report (Chapter 6), a Gulf-wide synthesis of these local historical indicators (i.e., the forms themselves) will be made.

We freely admit that there are many possibilities which could make the interpretation of submerged relict forms erroneous. For example, the interpretation of channels as the result of terrestrial processes, when they may have been formed by submarine processes, could negate many of the interpretations to be presented.

However, our goal is the identification of areas which possibly were favorable habitats for early indigenous people. To accomplish this as exhaustively as possible, we should not exclude any area for which a reasonably plausible interpretation can be given to indicate that such habitat existed. That some interpretations may later be disproved by new information is inevitable, but in the present state of knowledge, it would be unwise to discount any area simply because the interpretations on which it is judged suitable habitat for people are not definitive or completely documented. There are simply very few, if any, places on the continental shelf, as the following discussion will amply illustrate, for which sufficiently detailed knowledge exists to make such definitive arguments.

The Late Quaternary relict forms will be discussed by area from west to east, beginning in south Texas. A summary of this discussion is on a map in Volume III, Plate 2.

South Texas Area

The single most conspicuous form of the entire south Texas area is the bulge in the shelf. It is the product of long-term Rio Grande River deltaic sedimentation (Vol. III, Plate 2). On the northern side of the deltaic bulge, out near the edge of the shelf, a series of channels of dendritic form is well defined on recent bathymetric charts. These channels terminate at depths no greater than 130 meters. If the -120 m contour is traced southward from this area, it is seen to merge into the face of a marked break in slope in the central area of the delta bulge. For this reason, Plate 2 indicates an escarpment running along this slope break and extending around the distal ends of the dendritic channels on the northern side of the bulge. This escarpment is more or less well defined by the -120 m contour, but is not distinctive enough to be exactly determined. Perhaps 120 to 135 m is a reasonable estimate for its depth. This escarpment is the deepest form that has been identified in the south Texas area.

The deep feature at -120 m to -135 m is interpreted to be a shoreline. It is basically a low escarpment, which suggests a short duration or short period of standstill. The dendritic channels which terminate at this level further suggest that the standstill was preceded by an interval of falling levels. The channels probably remained active as sea level stabilized at the -120 m to -135 m level. Since there are no discernible features at greater depth, we may infer that soon after this standstill, sea level began to rise. That the dendritic channels were not filled or erased by wave planation during this rise suggests that sea level may have risen rapidly by a large amount, submerging these forms to a sufficient degree that they have been less intensively modified by marine processes. As we shall describe later, this rapid submergence may have been of great importance in preservation of archeological areas that may have existed. The channel forms in the southern part of the area may have been covered by later deltaic sediments. A shoreline at the -120 to -135 m level would more than likely exhibit a markedly different set of coastal process conditions than the present shoreline. While the present shoreline is exposed to a sea that overlaps a broad, flat, shelf expanse, the paleo-shoreline at this low level must have directly fronted a rapidly deepening ocean with a consequently greater impingement of wave and tidal energy on the littoral zone. Perhaps this shoreline had the character of a low, cliffed coast with a fronting beach.

The low cliffs may have been cut into relatively unconsolidated, regressive deposits of the falling stage preceding the stillstand and/or into older deposits. These same deposits may have been intensely gullied and channeled inland from the shoreline by small, dendritic stream channels, some of which may have been integrated into the drainage net of the major river system (the Rio Grande), but many of which may have been smaller local basins reaching the coastline independently. The Rio Grande mouth position at this time was probably to the south in waters off of the northern Mexico coast; it was probably of small extent and influence since it was building its delta into much more steeply deepening waters than those into which the deltaic deposits of the present, broad Rio Grande delta are deposited. Sediments from this delta may have contributed to the bulge in contours on the upper slope at about latitude 24.5^{o}N.

The most suitable habitat afforded people who may have existed at the time this shoreline was active was probably the shoreline, especially where drainage systems intersected the coast. (Possibly the area of the Rio Grande delta was most favorable of all.) The channels traversing the coastal uplands may have also been suitable. In the phase of sea level rise over this landscape, the channel valleys must have become ria-type embayments and afforded other valuable habitat locales. It is possible that rising sea level stage could have preserved any dwelling sites through protective burial below bay deposits. If the rise were rapid, wave exposure duration may have been brief, which would be favorable for preservation. It seems quite possible that occupation sites may be discovered in the vicinity of this shoreline or around the associated channels, especially where bay fill deposits thinly cover channel side areas. Shallow cores would be of great importance in such areas in order to determine the suitability of any particular place for early people.

Just inland from this form association is another form which is well outlined by a relatively prominent bulge in the contours at approximately -80 m. This is interpreted as a possible lobe of the Rio Grande delta formed during a stillstand of the sea at approximately that level. This form may be related to what seems to be a minor escarpment which is believed to exist in the northern part of this sector at a similar depth. This feature will be more fully discussed in the following section, which deals with the central Texas shelf.

The delta lobe expressed by the -80 m contour is crossed by a few channels between about -76 m to -86 m. These are possibly equivalent to the dendritic channels that extend to the -130 m depth just to the north, which we described in connection with the -120 m to -135 m paleo-shoreline. If they are equivalent, then there is a possible argument that the delta bulge is older than the escarpment below it.

Next inland from this form is a bulge in the contours at -54 m to -60 m, which is interpreted as another delta bulge. One long channel trends northward across this area. Just to the south is a slightly higher bathymetric feature, which is a bar form expressed prominently by the -50 m contour.

This bar trends NNW in an alignment which is the same as that of the southern flank of the delta bulge. The bar form is interpreted as a beach barrier ridge which represents a stillstand of significant duration following a rising stage. Whether or not it can be regarded as contemporaneous with the somewhat lower delta bulge with which it is aligned is conjectural.

Since this is the first beach barrier ridge form we have described, we will consider briefly the suitability of habitats that may have existed for people at the time of its formation. The beach itself, the dune areas, and older, stranded ridges may have been desirable occupation sites. The lagoon shores behind the ridges and especially any areas of marshy character were probably especially favorable for food gathering. Where higher adjoining grounds bordered lagoon or marsh areas, the probability of occupation sites may be high. In the area of the delta bulge, conditions for occupation must also have been very good. Sites may be related to beach ridges or alluvial ridges if any can be identified in this area. The long, northward-trending channel might be a favorable location for exploration for such sites.

A close depression is outlined below the -50 m contour in the area behind the barrier form. This area may have bay and deltaic sedimentary deposits. Environmental conditions for early people may have been especially favorable in this area.

Proceeding further inland, there are suggestive closures of the -44 m contour which are here interpreted as beach barrier forms, although the interpretation of another deltaic bulge is equally tenable. If these features outlined by the -44 m contour are connected, they form an arcuate outline. It is possible that each of these delta bulges showed such arcuate form, as does the modern Rio Grande delta, and that each had barrier forms fringing the arcuate shoreline.

Shoreward of this form, there is a flattening of the slope of the shelf between the -44 m and -38 m contour, suggesting a terrace that may partly have been a deltaic plain, contemporary with the beach barrier and/or deltaic bulge form that we suggest is outlined by the -44 m contour closures. Two channel features exist that cross this terrace extending from -38 to -48 m. Other evidence of channels is seen at about this same depth in the northern part of the sout Texas shelf, where channel segments are seen extending from -40 to -44 m depths.

Inland from this feature, there are at least two more barriers outlined by prolongated bulges in the contours at -28 to -30 m and -18 to -20 m. The outermost of these two forms extends into the vicinity of the Sebree Bank, where rocks of unknown type occur that are at least partially a result of encrusting organisms (Mattison, 1948). This relief barrier and the Sebree Bank are not necessarily related, but it is possible that the bank represents an outcrop of shelly estuarine facies associated with this shoreline. Some support is given this by a radiocarbon date reported by Curray (1960), taken on samples of oyster shells from a depth of 30.5 m lying between the barrier and the Sebree Bank. The date obtained on this material was 9,530 ± 270 radio carbon years before present (B.P.). As the shoreline was submerged, the shell was exposed and eroded partially by wave planation and became colonized by encrusting organisms that have capped the outcrop of hard substrate. Likewise, the barrier was extensively eroded as it became submerged in the wave zone.

The barrier outlined by the -18 to -20 m contour is a more distinct feature. If the -20 m contour is traced northward from this feature, it indicates an area of rather irregular bottom topography about -15 to -20 km to the north-northeast. The irregular forms at this depth tend to be aligned with similar, shallower features which trend south-southwestwardly in a convex seaward arc toward the present shoreline. This pattern of alignment has led to the suggestion that they were active bottom features of material being moved along the inner shelf floor. Many workers (Swift et al., 1971) consider this to be the dominant bottom topography over wide areas of continental shelves (such as the Atlantic continental shelf off of the U.S.), which are subject to more intense energy regimes than the Gulf of Mexico. An area of such forms is referred to as a shoal retreat massif. This area of irregular bottom topography, with aligned elements sloping over the inner shelf, may indeed be a shoal retreat massif. Even so, since it begins with the -20 m contour, it may originate with materials which outcrop at this depth and provide a source bed for the materials moving in over the shelf in a south-southwest direction (and arising gently to the left to converge with the present shoreline). These reworked materials could be derived from a facies equivalent to the - 18 to -20 m barrier. This might have been a continuation of the form itself or a shelly estuarine deposit. Since the barrier diverges in angle with respect to the present shoreline, our interpretation is that an earlier Rio Grande delta lay to the northward at the time that the barrier was active.

A minor form, lying still farther toward shore and suggested by a north-northwest oriented prolongation of the -16 m contour, is shown on Plate 2 as a relief barrier. This interpretation is readily subject to question since it lies within, and has a common alignment with, the zone of aligned bottom topography discussed just above as a possible shoal retreat massif.

We recognize also that if this small feature is actually part of a shoal retreat massif, then it is also possible to interpret the nearby, similarly oriented bar forms at -18 to -20 m and at -28 to -30 m in the same way. If they originated as shoal retreat massifs under submarine processes, then their potential for archeological resources (shipwrecks aside) is nil or is limited to scattered occurrences of reworked materials which may have become incorporated into the shoal retreat massif.

Rusnak (1960) also recognized these last two types of features. He differentiated them into Type I, which were "low ridges approximately parallel to the present coast line" and which resemble low barrier islands." He further described the Type I ridge of -18 to -20 m as having "a narrow shallow depression shoreward of this ridge (which) suggests a barrier lagoon remnant" (p. 159, parenthesis ours). Rusnak also states that the slight seaward deflection of this ridge is "attributed to the building of the ridge on the flank of the Rio Grande delta." This feature then, was interpreted by him in essentially the same manner that we have interpreted it, including the notion that the deflection of the ridge indicated an adjacent delta.

Type II was described by Rusnak as "parallel ridges" extending outward from Padre Island at a high angle (approximately 60 degrees)." He states that the ridges have a relief of about 1 to 3 m, and that samples from "limited outcrop sampling along-shore" indicate that they are made up of "partially indurated sands or clayey sands." Rusnak interprets these features as "distributary ridges of an earlier, more northerly extension of the Rio Grande."

This information is interesting. Partially indurated sands or clayey sands do not sound like facies of shoal retreat massif. They could, however, be outcrops of scour areas within an overall shoal retreat massif. Regardless of that possibility, such outcrop areas of clayey facies may well indicate some form predating the drift of the shoal retreat massif and associated scour areas. This could well have been a delta, as Rusnak believed. We feel these may be deltaic and/or estuarine beds, but that a delta is nevertheless possibly expressed, if solely by the deflection of the ridges.

Rusnak also regards these deltaic deposits as present in outcrop along the beach of South Padre Island, where he describes them as "in part, of semi-consolidated, weathered, fluvial and fluvial marine clayey sands". He regards their age as uncertain, but feels that "their altitude and character indicate, however, that they are not Holocene and should be tentatively assigned to the Beaumont."

Rusnak also presents a cross-section of Padre Island showing its relationship to onshore strata logged in a water well boring at Port Mansfield (Figure 3-1). The Beaumont formation is shown to underlie the present beach at Padre Island at a depth of little more than -10 m and to outcrop offshore at about -7 m. From the mainland to the outcrop in the shoreface, the Beaumont formation is shown to have a brown clay upper unit, which all borings on the cross-section reached. Two deeper borings penetrated this brown clay, showing it to be thin (-2 to -3 m) and overlying a thicker unit (-7 to -10) of sand with silty clay. At a depth of -11 to -13 m, the two deeper borings encountered "hard shaly clay with shell". Thus, as the cross-section shows, these units extend very nearly horizontally beneath the Laguna Madre and Padre Island, and perhaps all three outcrop within the -20 m contour.

While recognizing this alternative possiblity, we feel that in light of present limited knowledge, it is best to not reject the plausible explanation that these bars are littoral barrier forms, and as such, afforded potentially highly suitable habitat for people before they were flooded by change of sea level. Thus, all three relict bars, as well as potential estuarine

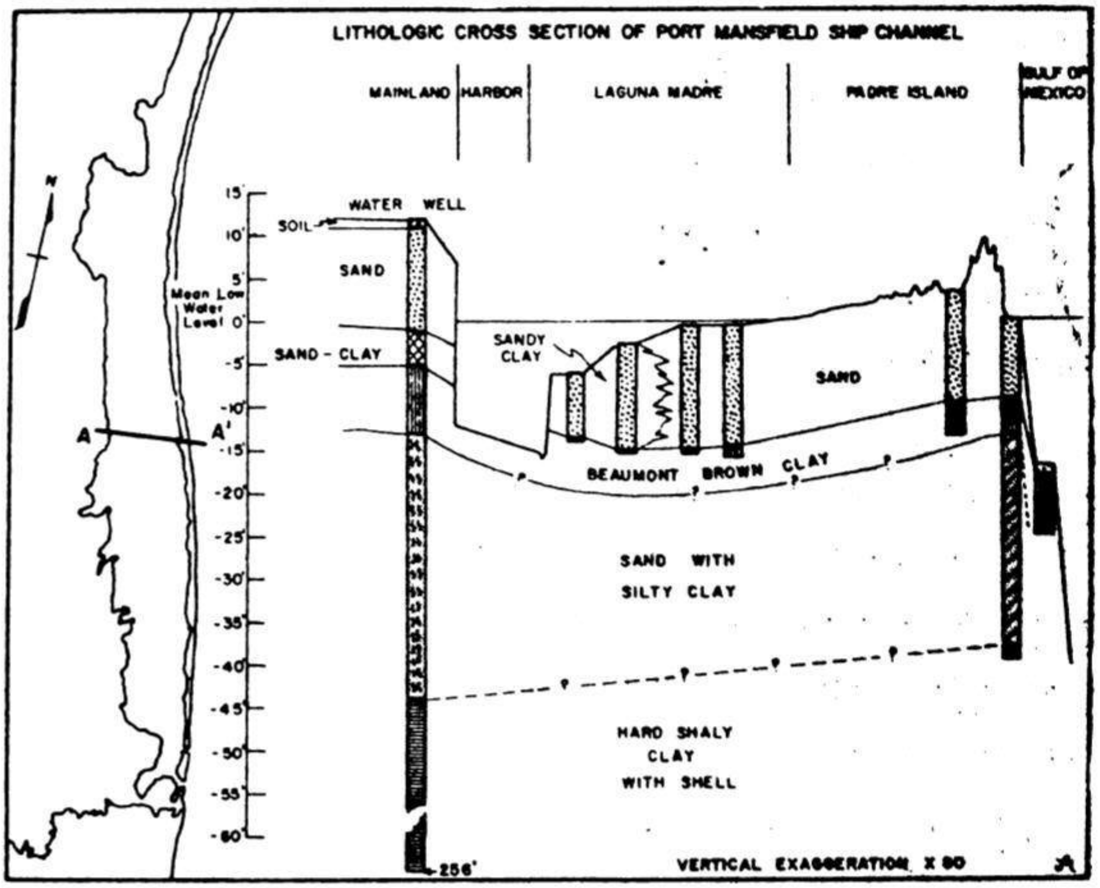


Fig. 3-1. Transverse cross-section from the southern Laguna Madre near Port Mansfield illustrating the pre-Holocene surface as evidenced by shallow borings (From Rusnak, 1960).

or deltaic areas that may be associated with them, may well be excellent potential areas of search for remains of early people.

Having transected the shelf off south Texas up to the present shoreline, let us briefly consider the shape of the present coast. There may be some important differences between the morphology of the present shore zone and many of those that existed at differing levels in the past. Many of the earlier shorelines must have developed during relatively brief still-stands of the sea, while it is clear from numerous lines of evidence discussed elsewhere in this report (see Chapter 4), that the present shoreline has evolved during a very prolonged stillstand. For this reason alone, it may be expected that present coastal forms may differ greatly in scale and geometry when compared with most earlier features. As an example, consider the modern Rio Grande deltaic plain, which is a wide expanse as shown in Plate 2. When it is understood that this plain has been developed over approximately 5,000 years, then it may be realized that a delta plain evolved in only 1,000 years of relatively constant sea level might differ considerably in overall geometry.

The Padre Island barrier likewise may be expected to differ in many ways from earlier barriers for the same reason. Even though it has accumulated over several millenia of relatively constant sea level, its present width of subaerial exposure (which is important in consideration of habitat availability) is generally less than four kilometers and often is only a few hundred meters; but, the overall form, including its subaqueous parts, is more than 4 km wide. This is probably much larger than previous barriers developed during shorter sea level stillstands, although in some cases, barriers may have attained great size in short periods. Rapid barrier formation may have been favored by such factors as: 1) quantity of sand and other coarse fraction material available for barrier growth, 2) relation of factors such as slope of the transgressed surface to varying rates of sea level change, and 3) differences in offshore hydrographic characteristics at the time of formation, which can lead to widely different wave and tidal energy regimes, some sets of which may be ideally favorable for barrier development.

The modern Padre Island has dunes that occasionally rise more than 10 m above present sea level. Older barriers may certainly have differed in respect to dune forms by wide magnitudes, depending on a complex suite of factors such as past climatic characteristics or quantity and type of sediment supply.

The wide Laguna Madre may also be atypical of lagoons of eariler times. The prolonged, relative constancy of sea level may be partly responsible for the great expanse of the present lagoon. The long stillstand may also be reflected by the shallow nature of the lagoon due to filling by local streams and other sediment supplies over a long expanse of time. The wide lagoon grades into the mainland transitionally, in many areas, over wide, saline, barren, wind/tidal flats. Such flats when dry are sources of wind-blown, clay-silt flakes, which aggregate to form the remarkable clay dunes described by Price (1933). At other points, the lagoon abuts the mainland more abruptly, making low, wave-cut bluffs across deltaic and clay dunes.

Much of the older Pleistocene terrain of the south Texas area is mantled by or is part of a terrain of aeolian sand dunes. This terrain shows both presently active, as well as essentially stabilized, dune forms. This sand dune terrain and its relation to other coastal terrains is very poorly understood. In the southern part of the area, the sand features may overlie old, weathered, alluvial sediments of a Pleistocene Rio Grande Delta, which Price (1933) states is evident in the area of Raymondville, Texas.

Central Texas Area

The deepest indentations which can be identified on the central Texas continental shelf are a small number of channels which reach -120 m, with one possible channel fragment reaching -130 m. Above -110 m, channel cuts are more numerous. These extend for the most part to about the -80 m contour. A dendritic pattern is evident in some, and a zone of discontinuity seems to exist between -70 and -80 m across which few of the channels are continuous.

These channels are interpreted as having come into existence at a time when sea level was at -120 m or below, through downcutting of stream valleys. Their present, scattered distribution reflects the fact that this area has subsequently been mantled by marine clay and silt facies which may locally exceed 10 m in thickness (Curray, 1960; Frazier, 1974). The channel segments that are seen are areas where this sedimentary mantle is thin or absent. If the cuts extended to a shoreline at or somewhat below -120 m, then most of the lower parts of this drainage system were masked by later sedimentation.

Many of these stream segments head in the vicinity of calcareous banks at about -70 or -80 m depths, which may have as much as 10 m of relief above the surrounding bottom. The nature of most of these banks is poorly known. They may be similar in some respects to banks at comparable depths that have been described elsewhere, such as the West Flower Garden Bank, (Edwards, 1971) and the shelf knolls of the northeastern Gulf described by Ludwick and Walton (1957). Such banks derive their carbonate sediment cover from a number of reef-building organisms. Calcareous algae of the genus Lithothamnion may be especially important along with a variety of other calcareous algae, encrusting foraminifera, and corals of numerous kinds. While many such calcareous banks in the east Texas and west Louisiana shelf areas are known to be cappings of subsurface salt intrusives, this is not necessarily the case for all such banks.

The positions of the calcareous banks of the central Texas shelf are in part determined by what was possibly an earlier shoreline or an earlier generation of similar banks. The present banks are developed wherever pre-existing substrates were suitable for reef building organisms.

The earlier feature may be evidenced by the suggestive pattern of the stream channels, which frequently appear to have their origin in the area of the banks. Perhaps such topography resulted from a fall in sea level from somewhere above -70 m or so, giving rise to many local dendritic channel patterns originating at about this elevation. Inward from this area, the slope may have been less steep and unfavorable to widespread development of such a channel pattern. The zone of the calcareous prominences may then have been an escarpment formed by a resistant unit separating an inland terrace segment from a more steeply sloping and relatively intensely channeled terrain element which extended to the depth at which the fall of sea level reversed. If the conditions during the higher sea level stand (at or above 70 m) were right, this escarpment might have come about in one of two ways: 1) it may be related to a shoreline form not entirely removed by subsequent erosion, as evidenced by the dendritic channels; or 2) alternatively it could have been a group of algal-coralline banks.

If a shoreline form is considered, what type might it have been? There is no clear way to judge this. It could have been a barrier of high-carbonate type which may have been subject to cementation following the fall of sea level which formed it. Resistant calcarenites of dune and beach origin may be the foundation of hard substrate on which the present calcareous banks developed when the sea later transgressed this area. It could just as well have been some other kind of shoreline, which may well no longer exist, but which left some other hard substrate areas, such as lags of sandy and gravelly units, caliche, or estuarine shell units which developed along the eroding stranded shoreline zone as sea level stood much lower. With later transgression, these lag deposits may have provided hard, current-swept prominences which were favorable to calcareous reef development.

Such ideas can only be speculations without hard evidence from the field concerning the nature of these banks and their stratigraphic relationship to forms which may have preceded them. If they did develop as 1) lag units of gravel, caliche, sand, or shell; 2) older beach or dunes (possibly cemented), or 3) as an earlier generation of algal banks that existed in the same positions as the present ones, then, for all of these cases, they may have constituted relatively permeable prominences at the time when the dendritic channel patterns were evolving. These coarser, permeable units very likely would have springs at their base, which might explain the tendency of the dendritic channels to head near the banks. If any of the banks on the central Texas shelf are over shallow salt dome prominences, then there may have been salt springs as well. Any type of spring may have provided attractive habitat for early people.

The observation that few of the channel segments show continuity between the -70 and -80 m isobath is possibly an indication of a later shoreline which may have occupied this position for an interval that was so brief that its major effect was merely the erasure or masking of the earlier topography. This supposition will require much greater knowledge to detect any evidence of such a shoreline. Perhaps there are other features associated with the banks or buried by later sediments which may confirm or deny such a speculation.

Toward shore from the calcareous bank and dendritic channel forms, the central Texas shelf is remarkably featureless, presumably due to sediment cover. A few channel segments exist between -28 and -42 m depths. As mentioned earlier, these channels are comparable to those at similar depths on the south Texas shelf.

Close to shore, a remarkable bottom feature has been described in some detail by Tunnell and Causey (1969). This feature is known as the 7-1/2 Fathom Bank, which consists of two small outcrops of indurated lime marl with numerous freshwater snails that indicate it was formed in a freshwater environment. Remains of extinct megafauna have been found in association with the rock of the bank, although these have been surficial finds or finds within rock crevices rather than true *in situ* finds.

Tunnell and Causey compare this feature with the marl deposits which are known to occur over the aeolian sand plain onshore. These accumulations collect in depressions in the sand plain, which may have the character of ephemeral lakes. Presumably, the rocks of the 7-1/2 Fathom Bank accumulated in such a lake and became hardened. Later, the old lake bed was transgressed by the sea, and active marine erosion has now exposed the rocks as a bank on the sea floor. Such an outcrop must have considerable potential for occurrence of remains of early people, and conditions for bone preservation are especially good in the calcareous marls. There may be numerous other such features in this and the south Texas continental shelf area.

The present shoreline is similar in character to that described in south Texas, but without a deltaic area of any substantial size. In the central Texas area, there are five published cross-sections which detail the geometry of the modern barriers (Fisk, 1959; Hunter and Dickinson, 1970; and Wilkinson et al., 1975). These provide an idea of the nature of barrier deposits and may be useful as analogies in interpreting a submerged barrier. In the cross-section of Hunter and Dickinson (1970) the sand mass of the barrier exceeds 3 km in width and is generally about 16 m thick. As discussed previously, however, it is by no means clear if any of the submerged barriers on the shelf may have become this large since this modern barrier has developed during a stand of the sea of long duration.

An intriguing feature of the cross-section (Figure 3-2) is the Late Pleistocene shell bed which underlies the barrier island sand. A radiocarbon date of this material has yielded an apparent age of 26,000 radiocarbon years B.P. The validity of dates in this range is subject to question since even minor accounts of younger, carbon-bearing materials mixed with materials much older could result in an apparent age of this magnitude.

The two cross-sections described by Fisk (1959) are a little more than 30 km to the south of that just described. Here, the barrier sand body is somewhat wider (about 5 km) but thinner (about 11 m). Fisk reports dates which suggest that the barrier sands have accumulated over a period of at least 5000 years and that the associated lagoonal deposits have accumulated over approximately 4000 years. A boring made from the modern beach penetrated beach and shoreface sands to about 11 m below present sea level and then penetrated about 2 m of a lighter-colored unfossiliferous sand which Fisk interpreted as comparable to the aeolian plain. Below this were estuarine deposits which rested on a presumed Pleistocene soil surface at -16 m. Mulinia shells from -15 m in this boring were dated at 23,400 $\pm$ 1800 years B.P. This sample was regarded as "anomalous with respect to regional information concerning the level of the sea at that time" (Fisk, 1959, p. 123). The apparent age and the depth of this sample suggest that it may be related to the Late Pleistocene shell bed of the profile shown in Figure 3-2, which lies at about -15 to -17 m. (The faunal composition has not been described in the literature.) It is possible that these occurrences are equivalent and that a bed of estuarine shells underlies a large part of this area. The old, apparent radiocarbon ages are suggestive that it is a Pleistocene unit. If this is the case, then there is nothing to preclude the possibility that the lighter-colored, unfossiliferous sands (above the estuarine bed) described by Fisk is also a Pleistocene unit of beach or dune origin.

The estuarine bed could be regarded as something of the nature of a Mulinia-Anomalocardia biozone, which is perhaps a facies of the Beaumont

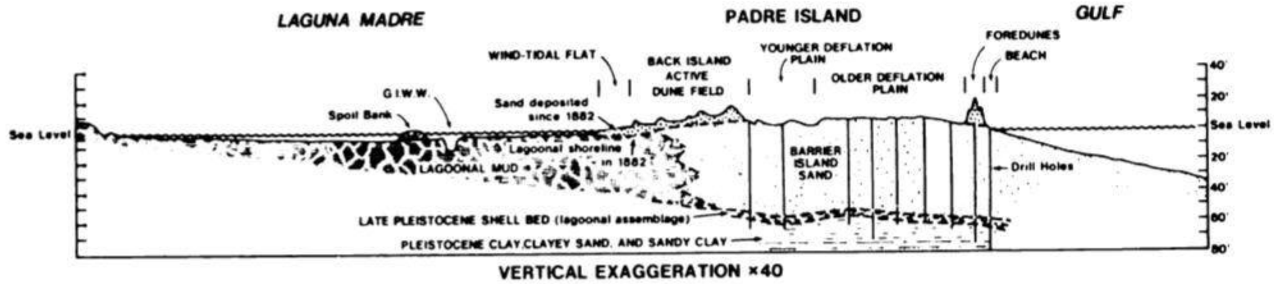


Figure 3-2. Cross-section of Padre Island, South Bird Island, 7.5 Minute Quadrangle (From Hunter and Dickinson, 1970).

formation. In other areas, estuarine and shallow nearshore facies are known in the Beaumont formation (see Pampe, 1971), and its presumed correlatives elsewhere, such as the Prairie formation of Louisiana (Jones et al., 1954) and the Biloxi formation in Mississippi as described to Otvos (1975a).

This unit is not described as indurated or weathered where encountered in borings on Padre Island. The mineralogy of the shells has not been investigated in connection with the reported radiocarbon age dates, so it is not clear to what extent recrystallization may have occurred. Apart from recrystallization, contamination could have occurred by admixture of young and old shell during a time of redeposition by reworking of older units. The shell bed of Figure 3-2, for instance, may have resulted from redeposition of older Mulinia and Anomalocardia during erosion of older deposits fronting a lagoon shoreline. In this way, a mixture of old and new shell may have occurred. Rusnak (1960) described "layered beds up to 1 foot thick along the shoreline of Baffin Bay and the mainland side of the northern lagoon" (p. 166) and observed that "some of these shells appear to be eroded from pre-existing deposits, but the bulk are wave concentrations of dead shell accumulating from living forms." Perhaps in similar facies in the stage of the incipient Laguna Madre, the reworked shell formed a greater percentage of the lagoonal coquina sediment composition, perhaps predominating over the fraction contributed from new production by living molluscs.

A third possibility is that contamination may have occurred during the sampling process. Fisk (1959) was explicit in pointing out that the estuarine Mulinia sample was taken from bit cuttings. If even a few specimens of the Mulinia shells used in the C_{14} assay were derived from the younger beds above, the resulting age could be far lower than the true age of the horizon from which the greater part of the shells were derived.

In the central Texas sector, the Laguna Madre area is similar to the south Texas area, the description of which is given above. The major difference is the existence on the mainland side of several large, ria-type estuaries of hypersaline character due to the limited rainfall and runoff of this area. The Laguna Madre in the central sector is extremely shallow and consists of extensive exposed flats across which sand and clay-silt flake sediments can be moved by wind during times of exposure.

Fisk (1959) interpreted the history of development of the central area of this part of Laguna Madre to follow this sequence: 1) a "clayey-sand estuarine facies" of greenish-gray, sandy clay with "locally abundant shallow water fossils" filled a pre-existing entrenched valley system; 2) at least part of this estuarine unit was covered by the aeolian plain sediment type; 3) gradually, conditions changed in the estuary with accumulation of bay deposits grading laterally into sands with a shallow marine fauna, which were suggested as being analogous to conditions in and around the present-day Mississippi Sound; 4) more general, open lagoon conditions characterized by clay-free sands with shallow marine shells at the base grading to more restricted fauna upward; and 5) closed lagoon conditions comparable to the present.

The interpretation given for this sequence is open to certain criticism. The entrenched valley system which Fisk contoured may be overly exaggerated, as suggested by the sparse distribution of his control borings, particularly within the supposed valley axes (see Fisk 1959, Figure 11, p. 147). The clayey-sand estuarine facies," which supposedly filled the entrenched valley system, was dated (anomalously, according to Fisk) at 23,400 ± 1800 years B.P. by the Mulinia shell sample discussed above. It would seem possible, based on this date, that the entire clayey-sand estuarine facies is perhaps a part of the Beaumont formation. This would imply that where this unit is present, the soil zone which typically marks the Pleistocene contact is perhaps weakly developed or absent. The greenish-gray color of this unit accords well with similar descriptions given by Rusnak (1960) and Shepard and Moore (1955) of stiff, greenish sands, clayey sands, and clays which were thought to represent pre-Holocene nearshore beds due to occurrences of poorly preserved shell. Absence of the soil zone could be due to later removal and exposure of relatively unweathered estuarine facies of the Beaumont formation perhaps at a time just prior to the transgression represented by the latter part of the sequence. Likewise, the lighter-colored, unfossiliferous sands, which are interpreted as aeolian plain deposits that in places overlie the "clayey-sand estuarine facies," also could be a facies of the Beaumont formation. Following clarification of some related features and stratigraphy of the mainland, this problem will be considered further in a discussion of the cross-sections of Wilkinson et al. (1975).

Onshore from the Laguna Madre, there are important elements of the present coastal landscape: 1) in the south, the lagoon adjoins the aeolian sand plain, and 2) in the north, the lagoon adjoins a stranded beach or barrier complex.

The aeolian sand plain of the southern part is described by Fisk (1959: 107) in this way:

> Active and fixed dune fields of the aeolian plain give evidence of long-continued wind activity. The dune fields include both sand deposits and wind-scoured features and have been termed banner complexes by Price (1958). Some dunes in the active complexes rise 30 to 40 feet above wind-scoured blowouts. In fixed dune areas, the blowout depressions form extensive lowlands underlain by sandy clays and by calcareous pond marls. The fact that these deposits attain thicknesses of approximately 10 feet shows how long the local surface has been stable.

On the mainland side of one of his profiles across the Laguna Madre and Padre Island, Fisk shows a boring which penetrates about 6 m of the aeolian sand plain deposits. At about 3 m within this unit (or approximately 1 m below present sea level), pond marl material was dated at 11,490 ± 240 years B.P. Adjacent borings indicated that a weathered soil horizon lay beneath the aeolian sand plain deposits at about 5 m below present sea level. From this information, we might guess that at about 11,500 radiocarbon years B.P., the sea had not yet reached an elevation of -1 m with respect to the present level. Such guesses are obviously subject to a number of difficulties. The reasoning involves certain assumptions, such as that the pond marls did not accumulate below sea level and that the date is not somehow erroneous. We elaborate on this here because it reveals the way that many such isolated facts and similar lines of reasoning provide fragments of information which, after compilation, give insight into past sea level changes.

From the description by Fisk cited earlier, the marl-forming ponds are characteristic of the fixed dune areas of the aeolian plain. If this were true in the past, then fixed dune areas must have existed at the time indicated by the date. The appearance of fixed dunes could be construed to be of importance in paleoclimatic interpretations, as could also the onset of marl-forming conditions; this area, however, remains far too poorly known to make any conclusive judgments.

Inland from the Laguna Madre, to the north of Baffin Bay, there is a remarkable coastal sand ridge of arcuate form which extends discontinuously to the south side of Matagorda Bay. This feature has been termed the Ingleside Barrier by Price (1933). As we shall see, this is the first appearance of an inner barrier form that we have seen in our progression around the Gulf margin, but by no means the last. Such barriers are common around the Gulf, but have been little investigated. Indeed, the extent of our ignorance about these coastal features, which outcrop on dry land where they are readily accessible for geological study, makes it overwhelmingly apparent how difficult geological interpretation of the submerged forms can be.

Just north of the Baffin Bay mouth, the situation described by Rusnak (1960) well illustrates the uncertainties of interpretation that exist. A dense, brown "Pleistocene beach rock" is described cropping in front of the Ingleside barrier (which is known as the Flour Ridge in this local area). Rusnak is vague about composition of the coquina as well as its relationship to the Flour Ridge. He states (pg. 190) that "the attitude of the exposed marine beach rock which flanks the barrier suggests that the nearshore area had a shallow gulf profile very similar to that of the modern barrier." From this, it is apparent that he regards the unit as a nearshore deposit, presumably a beach deposit since he describes it also as a marine beach rock. Elsewhere, he describes the rock as a "coquina beach rock" and a "dense Pleistocene limestone." Limestone gravels derived from this unit are said to consist of "well-cemented shell fragments commonly so completely recrystallized to calcite that individual shells are unrecognizable." Without any additional information, it is impossible to be specific about environment of deposition. While coquinas are characteristic beach deposits, the judgment that this outcrop is a beach rock nevertheless deserves qualification. In the same area today (in fact, in the exact area of the old "beach rock" outcrop), deposition of a coquina is presently occurring in a lagoonal beach environment. This modern coquina is also loosely cemented in places, forming what may truly be described as beach rock.

Beach rock occurrences similar to the above are also known, in association with features that are similar in setting and general character to the Ingleside forms, some 400 km to the south on the Tamaulipas coast of the Laguna Madre near the small village of La Carbajal (Pearson _et al._, 1965). Two dated samples of this material gave ages of roughly 25,000 and 35,000 years B.P. The samples are described as recrystallized, so the results are no doubt only minimal ages.

If we recall the profile of Padre Island by Hunter and Dickinson (1970), which was discussed earlier, the stratigraphic relationship of the barrier to a _Mulinia-Anomalocardia_ bed is striking. The bed, however, yields an old radiocarbon age and might have been exposed near the surface for a prolonged time, then transgressed by the modern Padre Island sediments; but it is not described as weathered, cemented, or obviously recrystallized. It could be assumed that the bed was covered by protective overlying strata, which were removed just prior to the bed being overridden by the transgressing barrier, so that no prolonged period of conditions favorable for weathering or other alterations ever existed. However, no such protective strata are known above the bed, unless they are sands, such as Fisk (1959) considered to be buried occurrences of the aeolian plain sediments. Perhaps the most reasonable interpretation of the lagoonal shell bed is that it is part of the transgressing sequence. That is, it formed in a lagoonal environment behind the early barrier form which evolved into the modern Padre Island. This early lagoon contained a living population of _Mulinia_ and _Anomalocardia_, but, in addition, was supplied with a great abundance of fossil shells of these same types which were derived from the Beaumont formation, thus giving the apparent old radiocarbon age. The fossil shells were derived perhaps in part from equivalents of the old coquina outcropping at the Baffin Bay mouth.

If the shell bed encountered beneath Padre Island is considered to be a part of the transgressive sequence and if we then use the profile shown in Figure 3-2 as a model possibly analogous to Flour Ridge, some interesting suggestions result. The old coquina outcropping in front of Flour Ridge could well be analogous to the conquina beneath Padre Island rather than a marine beach rock. That is, they could both represent the same phase in the sequence of development of the two different barriers. This would suggest (but not necessarily require) that the old coquina may extend inland beneath the Flour Ridge. But we have no knowledge of the validity of this possibility.

Perhaps the following sequence of events is a plausible interpretation, although we by no means suggest a conclusive one. At some time in the past, a transgression of the sea led to the formation of the Flour Ridge (Ingleside) barrier. The geometry of this barrier, we have assumed, was analogous to the Padre Island profile of Figure 3-2. The sequence recorded by both transgressions is estuarine deposits overlain by sandy beach, dune, and shoreface deposits. Since the older coquina unit is approximately at present sea level, and if it were covered by sand as thick as that forming Padre Island, then it would seem possible that sea level at the time that the Flour Ridge feature was active could have been as much as 15 to 18 m above present sea level (assuming there has been no tectonic uplift or subsidence). But, the present elevation of the ridge is seldom greater than 9 m. The original relict of the feature may have been partially reduced by post-depositional changes. The sands of the barrier may have shrunk in volume due to loss of carbonate constitutents and other readily weatherable mineral grains; sand may have been lost by aeolian and other erosional processes; and the sand mass of the beach ridge system may have settled by internal compaction and compaction of underlying layers.

Following a long history of exposure in an area of active aeolian processes that apparently have persisted over a long period continuing to the present, the Flour Ridge stands now as a subdued remnant of its original configuration. A few ridge trends of the relict barrier-strandplain can be differentiated. These may represent late stage depositional topography just prior to the time the complex became stranded, or they may be etched out reflecting internal structure. During the long period of exposure to erosive and weathering processes, carbonate and other unstable minerals were leached. Some of this carbonate may have precipitated out within the form to give the calcareous sandstone concretions which Rusnak (1960) decribes.

The recession of sea level which led to erosion and weathering of Flour Ridge led to downcutting by the streams which enter Baffin Bay. The southern end of the ridge was exposed to strong erosive conditions due to the steeper slope adjacent to the incised valley, which is now drowned beneath the bay. At this point, the coquina became exposed, and its induration may be related to a long period of exposure rather than to formation as beach rock. The large sand body of Flour Ridge can then be envisioned at some indefinite time period in the past as perhaps lying well above present base level on the interfluves between coastal streams. At such times, it probably acted as a reservoir of local ground water with springs around its margin. It was prominently exposed to aeolian forces, perhaps for a significant part of this period of exposure. At this southern end, Flour Ridge is particularly modified by aeolian processes and aeolian deposition. Some resistance to erosion may have initially been offered by cementation effects due to carbonate constituents. In time, however, much of the early cementation may have been lost from prolonged exposure, bringing about dissolution of most carbonate constituents.

However, we need look no further than the northern end of Flour Ridge to find a very different interpretation of its development. Wilkinson et al.(1975) have presented a cross-section of this area (known regionally also by the name of the Encinal Peninsula) which is substantially different from that of Hunter and Dickinson (1970), which lies only 29 km to the south.

This section is reproduced here as Figure 3-3. The section is based on the outcrop where the Ingleside trend is exposed along the shore of Oso Bay and on 15 borings on a traverse extending to southern Mustang Island, although only five of these borings are represented on the published cross-section. The exposed section at Oso Bay is described as "up to 10 ft. of aeolian sand overlying 12 ft. of very fine, yellowish-gray sand, which is very muddy and slightly calichified in the lower 6 ft." This sand overlies a "bright-yellow oxidized mud of unknown thickness."

Wilkinson et al. (1975) interpret that the Ingleside sand unit extends beneath the Laguna Madre and Mustang Island. In their own words (p. 349):

> In the subsurface, Ingleside sand thickens from 12 ft. on the mainland to a maximum of 22 ft. under southern Mustang Island. This interval is fairly homogeneous consisting of very fine, firm, muddy, well-sorted sand. These sands overlie a complex sequence of oxidized sand, greenish-gray micaceous sand, and stiff plastic grayish mud.

These descriptions of the exposed and buried Ingleside sands differ in some important respects: 1) on outcrop, the Ingleside is termed yellowish-gray, while in the subsurface, no color term is applied; 2) on outcrop, the sand is "very muddy"; encountered in the subsurface, it is simply "muddy; and 3) on outcrop, the lower zone is observed to be calichified, while no mention of caliche is made in subsurface occurrences.

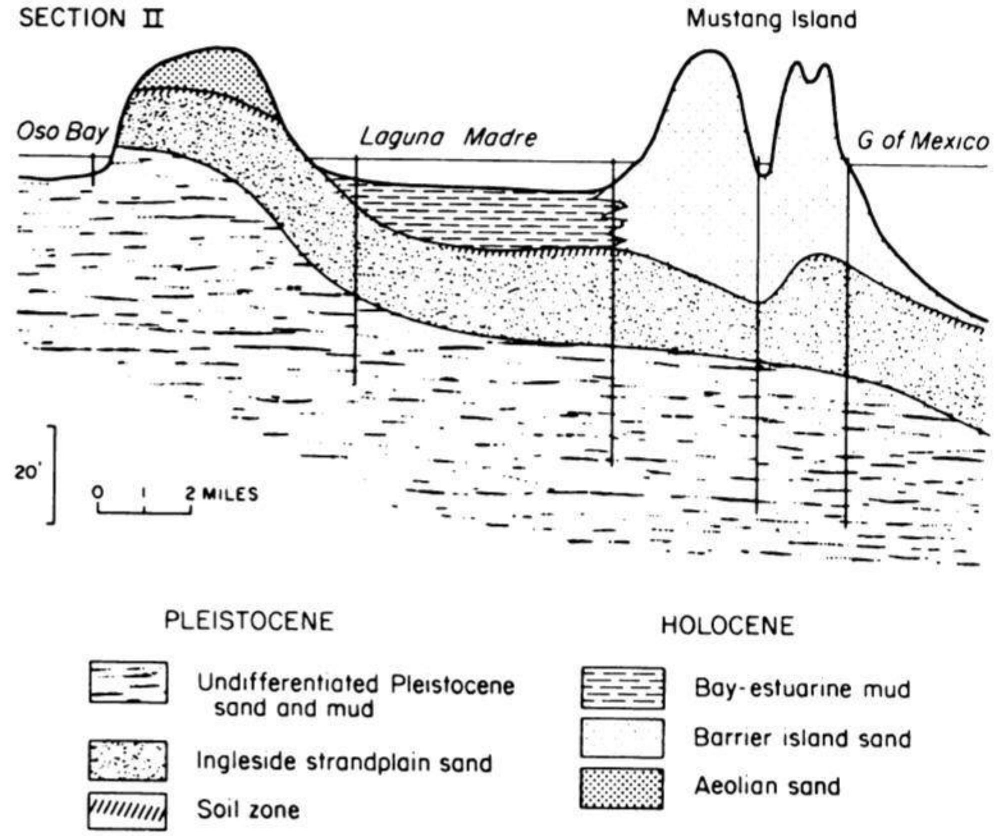


Figure 3-3. Section across Ingleside strandplain sand, Northern Laguna Madre and Southern Mustang Island (From Wilkinson et al., 1975).

If these differences reflect the real situation rather than merely lack of descriptive detail, then it follows that the presumed correlation of the surface and subsurface sand units is questionable. Fisk (1959) encountered a sand beneath Padre Island and the Laguna Madre, as described previously, and interpreted this sand to be of aeolian origin.

Note that a soil zone is indicated in Figure 3-3 at the top of the "Ingleside strandplain sand." A close reading of the text from which the figure was taken (Wilkinson et al., 1975) does not, however, mention any soil zone in this position, so it is possible that the figure as published contains a drafting error. A soil zone which is frequently mentioned in the text is not shown in Figure 3-3 and presumably belongs there instead of the one that is shown. This soil zone occurs at the top of the presumed Pleistocene sands and muds which underlie the sand units. However, this error may admit a partial truth. Since the Ingleside sand at outcrop is described as yellowish-grey muddy sand, which is calichified in its lower part, then it can also be said to show a soil zone. The sand at outcrop overlies a "bright yellow oxidized mud," which apparently represents a widespread soil zone described in the article. Numerous questions arise concerning these bits of evidence, such as: 1) Are there two soil zones or one that perhaps resulted from prolonged or intense soil-forming processes and affected both the sand and the underlying clay? 2) Does the soil affecting the Ingleside sand at outcrop exist in the sand beneath the lagoon and barrier?

As we shall see, these questions will recur as we examine another profile from the Wilkinson et al. (1975) article in the area of San Antonio Bay. Other problems relating to soil zones will recur as we continue our inspection of the evidence concerning the evolution of the Gulf continental shelf. Generally speaking, soil zones are inferred wherever oxidized and somewhat compacted higher strength units are encountered. Caliche and ferruginous nodules may also be features of such soil zones. As persons who are familiar with soils are well aware, they may vary widely in character on a local scale, depending on a wide range of circumstances, such as relief, microrelief, parent materials, climate, etc. For this reason, among others, they are particularly untrustworthy for stratigraphic correlation purposes. As was discussed earlier, Fisk's (1959) profiles, 60 km to the south of this one, possibly illustrate how a discontinuous soil zone can be stratigraphically misleading.

Wilkinson et al. (1975) also present a profile from the San Antonio Bay area which extends from the Ingleside shoreline feature across the lagoon to Matagorda Island. This profile is reproduced here as Figure 3-4. The sands outcropping on the mainland 20 - 40 km north of this profile line are described as light-brown, tan, and brownish-gray sands of very fine size which are regarded as 2 m or less in thickness and overlie an oxidized to highly oxidized paleosoil which at least in part is presumed to have developed on the surface of deltaic interdistributary muds. The paleosoil is referred to as dessicated and calichified.

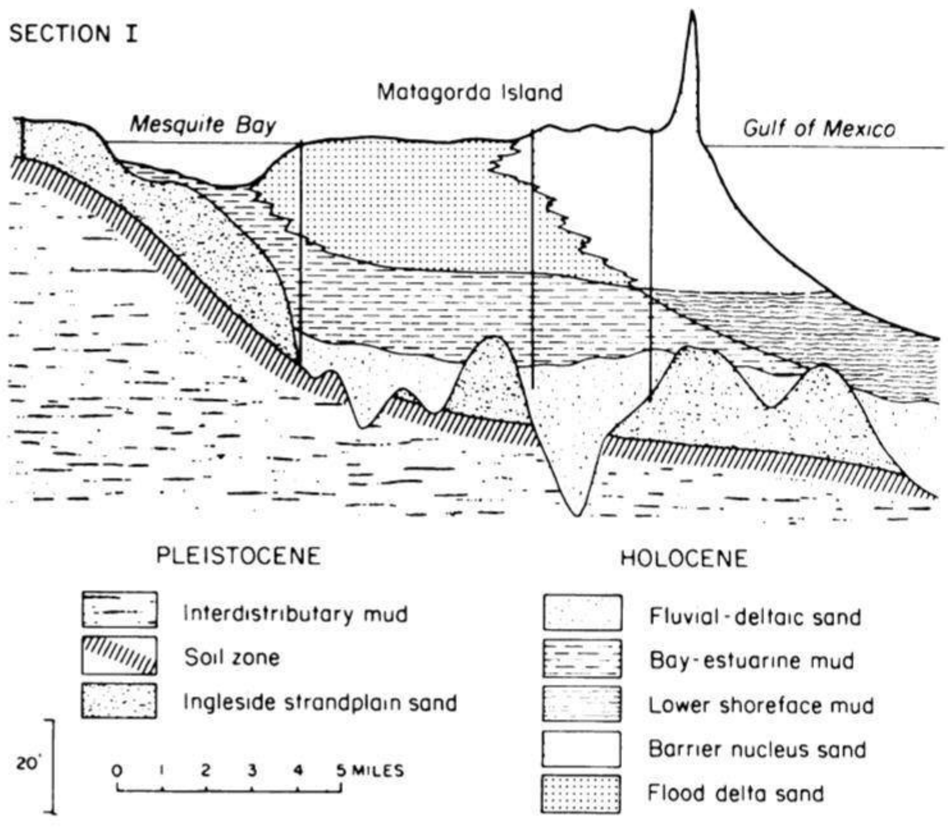


Figure 3-4. Section across Ingleside strandplain sand, Mesquite Bay and Southern Matagorda Island (From Wilkinson et al., 1975).

In subsurface occurrences along the profile of Figure 3-4, the sands which are considered to be equivalent of the outcropping Ingleside sands are described as light-brown to orange and are stated to be homogeneous.

Again, it seems possible to view these descriptions as indicative of there being a paleosoil within the Ingleside sands at outcrop. Other details suggest that the soil is somewhat different here than in the section at Oso Bay. In particular, the soil colors are described in darker hues and the soils to the north were noted to be strongly bioturbated. The thin cover of sand (1 to 2 m) also would not preclude the possibility that the oxidized, dessicated, firm, and sometimes calichified unit beneath is not a distinct paleosoil, but is part of the same profile of weathering.

The presumed Ingleside sand equivalents beneath the Matagorda Island are described as light-brown to orange in color. In this profile, then, it may well be that a soil-forming episode has affected the sand unit, which may be regarded as supportive of the hypothesis that it could be correlative with the Ingleside sand at outcrop. This sand unit beneath Matagorda Island was said to have been encountered in five borings at elevations of 8 - 16 m. The published section only shows two borings through Matagorda Island, and one of these did not encounter the "Ingleside strandplain sand." Neither of the indicated borings is shown to have encountered the soil zone presumably beneath the sand, nor is it indicated in the text of the report how many of the other borings did encounter this soil zone, although it is stated that the soil was encountered as much as 17 m below sea level. The sands are reported to be up to 5 m thick beneath Matagorda Island. However, the reported occurrence of this sand at -8 m somewhere beneath the island would suggest that, at least locally, it may be more than twice this thickness.

This profile again brings to mind the profiles of Fisk (1959) south of Baffin Bay. The tan sands Fisk encountered beneath Padre Island at depths of -11 to -14 m were regarded as aeolian. These differed from modern barrier-island complex sediments, from Fisk's descriptions, solely in lacking shell fragments. Hunter and Dickinson (1970) did not differentiate sands above the lagoonal shell bed which they encountered at 15 - 18 m beneath Padre Island, but considered them to be barrier-island sands of Holocene age throughout. If the "Ingleside strandplain sand" is present here, it was either not recognized by these authors or it lies below the lagoonal shell bed. That it may lie below is not precluded since the unit underlying the estuarine shell bed is at least described partially as clayey sand (Figure 3-2). If it is truly absent, then possibly it was removed in a cycle of valley down-cutting and widening as the sea withdrew from its level at the time the "Ingleside strandplain sand" was deposited.

By this point, it should be obvious that interpretation of the Ingleside shoreline features and their stratigraphic relation to adjoining coastal features is by no means a clear-cut and settled matter. Before attempting a preliminary interpretation of these features, let us consider a few more isolated bits of evidence known from the central Texas area.

Price (1958) reported the occurrence of lagoonal mud beneath the Ingleside sand in a pit near the town of Ingleside, just to the north of Corpus Christi Bay. Although Wilkinson et al. (1975) deny that such a sequence is typical of the area, they do not show that the sequence at this pit is not as described by Price. It is not to be expected that indicators of estuarine conditions (estuarine shells and microfossils, in this case) would everywhere survive the prolonged exposure above sea level which the Ingleside sands and the underlying clayey units have both apparently endured. Conditions for preservation of these materials may have existed only rarely, and Price's locale may well have been one of these rare sites. Wilkinson et al. (1975) argue that the sediments beneath the Ingleside sand represent "older delta-plain sediments" rather than lagoonal fill; however, in common usage at least, "delta-plain sediments" may include lagoonal fill facies with which they may be intergradational in space. After all, the Nayarit littoral accumulative form described by Curray (1961), which these authors regard as a form analogous to the Ingleside strandplain sand (at least in the sense that they are both viewed as progradational), does itself contain intercalated estuarine facies, as acknowledged by Wilkinson and his co-authors. They also consider the Chenier Plain area of southwestern Louisiana to be an analogous progradational form, but one with considerable admixture of muddy estuarine sediments.

The brown, Pleistocene coquina exposed to the north of the Baffin Bay mouth may possibly be associated with the Ingleside shoreline feature, as discussed earlier, but no relevant stratigraphic or paleoecologic information to define the relationship has been published. Rusnak (1960) was of the opinion that it was a marine beach rock and part of the Flour Ridge feature. This is implied in Rusnak's statement that "the attitude of the exposed marine beach rock which flanks the [Flour Ridge] barrier suggests that the nearshore area had a shallow gulf profile very similar to that of the modern barrier" (p. 190). Rusnak apparently regards the beach rock as a nearshore or shoreface deposit. Modern shoreface deposits have attitudes in the order of 20 ft. per mile of slope, which, it is important to note, is steeper than the base of the Ingleside strandplain sand as projected by Wilkinson et al. (1975). Fisk (1959) describes the shoreface sands of this area as gray sands with abundant fossils and wood fragments.

These considerations could be taken to indicate that older sands underlying the lagoon and modern barrier could be at least partially shoreface sand facies of the Ingleside beach deposits. When the sea level fell and the Ingleside shoreline became stranded, these shoreface deposits may have been reworked and modified in form by shoreline processes, and then affected by prolonged weathering and erosion so that they presently resemble the Ingleside sands of the mainland. So far, no fossiliferous evidence of the existence of such a nearshore facies has been reported in this area. Although

Rusnak (1960) believed the indurated coquina to be such a nearshore facies, this is not supported by paleo-environmental evidence. The attitude of the rock itself, which suggested to Rusnak a typical nearshore profile, could possible be otherwise interpreted.

Wilkinson et al. (1975) emphasize that the soil zone, or zone of weathering which lies at the top of the deltaic interdistributary muds, slopes quite steeply (10 ft./mi.), as does their Ingleside strandplain sand. In both of their profiles, the slope is by no means uniform. In Figure 3-4, a break in slope of the weathered surface (the "soil zone") occurs at about 15 m (50 ft.) below sea level; in Figure 3-3, a break exists at about 12 m (40 ft.) below. The corresponding slope-break elevations of the tope surface of the unit, called the Ingleside strandplain sand, are at about 12 m and 6 m below sea level, respectively. Seaward of these slope breaks, the Ingleside strandplain sand unit slopes more gently. The slopes beyond the shoreline shown in the cross-sections are presumably projected since no mention is made of borings or other information utilized beyond the beach. According to Figure 3-3, the earlier formed Ingleside strandplain sands underlie the modern beach at Mustang Island at a depth of only about -7 m. At this point, then, it would clearly seem possible that this sand might outcrop only a short distance offshore. No evidence exists that this is the case, although there are some slightly anomalous irregularities in the -12 to -14 m contours offshore from this area. If these represent the outcropping sand unit, then the projection in Figure 3-3 is more or less accurate.

While considering such a projection, let us recall for a moment the profiles of Fisk south of Baffin Bay. If the Pleistocene soil zone Fisk recognized (or the nearly coincident surface of the buried "aeolian plain" deposits) is projected seaward from the beach, it also would outcrop at about the -14 m contour. In this case, we have a remarkable confirmation to this in the shape of the 7½ Fathom Bank pond-marl bed which lies only about 14 m south from these profiles. Fisk considered pond marls to be typical aeolian plain facies, but as shown by the pond deposits near Ingleside, these may have developed over littoral forms as well.

Fisk's sand, then, could be a littoral sand deposit, and the 7½ Fathom Bank could be related to this deposit as at Ingleside. This interpretation would agree well with that of Wilkinson et al. (1975). On the other hand, Fisk's interpretation could be applied to the data of Wilkinson and coworkers. That is, the sands they encountered in the subsurface could be aeolian plain deposits as Fisk envisioned to have been the case south of Baffin Bay. However, these more northern locales lie outside of the area of greatest development of aeolian forms. Yet, we must confront the possibility that aeolian forms may once have been more widely distributed. After all, there are stabilized dunes on the aeolian plain which indicate that there was formerly perhaps more intense activity. But, if any aeolian features did exist, they did not extend significantly across the present subaerial outcrop of the Ingleside shoreline trend in this area to the north of Baffin Bay.

Recall that in south Texas, Rusnak (1960) described "partially indurated" sands and clayey sands outcropping in areas of irregular bottom topography of narrow, ridge-like form, trending at a sharp angle to the coast. He thought that these ridge-like forms were deltaic distributaries, but it is clear from current bathymetric charts that they may just as well be the result of scour and drift creating what has been called a shoal retreat massif. If that were true, then the indurated sands and clayey sands could possibly be beds of the kind described by Wilkinson et al. (1975). These ridges exist in a depth zone of -12 to -20 m, which is not unlike the zones of outcrop projected to the north.

There are choices beyond these alternatives. The diagrams of Figures 3-3 and 3-4 could also be viewed as two differently aged, littoral accumulations, which would explain the slope breaks. The Ingleside shoreline feature of the mainland may represent one shoreline, and the buried sands may be another, laid down after a significant time interval. The zone of steeper slope could represent shoreface sands. Since it appears from the descriptions of the northernmost profile (Matagorda Island) that the buried sand is also significantly weathered (orange colors are mentioned), then perhaps its age is nevertheless an old one, yet younger than the Ingleside. Fisk's buried sand could be equally old, but also could be Holocene, as he believed, since these localities are far removed and may, not surprisingly, show different sequences. If it is Holocene, it very likely is an aeolian deposit, as Fisk believed, since the bed contains no shell; if it is older, the lack of shell does not preclude that it may be a littoral accumulative form.

At this point, this review has encompassed the important bits of information known to us relative to the Ingleside shoreline and related stratigraphic units, and the published interpretations have been examined and reexamined. While this is not a large amount of information, it is far larger than exists for almost all of the feature submerged on the continental shelf. It is by no means a sufficient amount to yield a clear interpretation, as we have seen. Central Texas is only the first area in which presumed Ingleside shoreline equivalents occur, however, and perhaps clarifying information will yet be found to resolve some of these interpretative difficulties in other areas.

Before concluding this discussion of the Ingleside shoreline features, it may be useful to attempt a larger view. First, let us briefly outline the history implied by Wilkinson et al. (1975). Figure 3-5 was presented by these authors as a diagrammatic representation of this history. A mud-rich lobate delta prograded across the area (Stage A) and was then left exposed by a lowering of sea level. A soil zone formed over the delta mass (Stage B). Sea level rose back across the delta mass (Stage C) and again fell, leaving a sand sheet of progradational, beach-ridge sands essentially draped over the old delta mass.

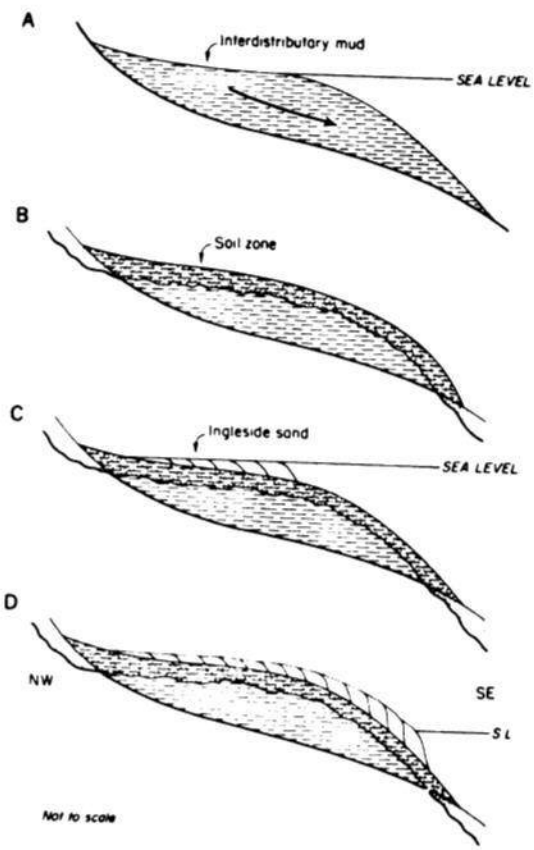


Figure 3-5. Pleistocene sedimentation in Matagorda Island area (After Wilkinson, 1975). A - Deposition of mud-rich lobate delta at sea level near present sea-level position, probably during Sangamon Interglacial. B - Lowering of sea level during renewed glaciation, with subsequent oxidation of interdeltiac muds.

An important element of this interpretation is that the slope of the soil zone and the slope and configuration of the Ingleside sand itself are essentially considered to be inherited from the slope of the pro-delta facies of the original delta mass. Such a prograding delta may have produced a convex seaward bulge (it is described as lobate). If the Ingleside shoreline were merely draped over a large delta lobe, its ridge forms would also be lobate or convex seaward. However, they are concave seaward forms which parallel rather closely the modern barrier-island trend.

Are the convex seaward, sub-parallel trends of the Ingleside shorelines and the modern barrier significant? They may possibly indicate somewhat similar sets of processes and components in the coastal dynamic setting that existed when the two different shorelines were active. As discussed previously, the concave seaward arc of the Ingleside shoreline features would at least seem to deny that the supposed delta progradation produced a convex seaward delta front, or even what we normally might refer to as a lobate form. If such a convex seaward land-sea interface ever existed, by the time the Ingleside shoreline came into being, a curvature reversal had taken place to produce a concave seaward shape. Thus, if the delta front were lobate, convex seaward, or even if it formed a straight shoreline originally, at some time before or during Ingleside shoreline formation, a concave seaward arc was cut into it.

In this central Texas area, the condition today, briefly, consists of a rather large (9 - 20 m thick by 4 - 6 km wide) body of barrier island sand forming the concave seaward, outer coastline; a sub-parallel, 4 – 10 km-wide back-barrier lagoon; and embayed river mouths with deltas well inland from the barrier coastline which, consequently, deliver very little sand to the coast. This situation exists despite the fact that the record of fill in the lagoon and construction of the barrier described by Fisk (1959) indicate that a similar situation has existed for perhaps 4000 years, with a gradual shoaling of the lagoon going on.

If it is assumed that conditions at the time of the Ingleside shoreline were very much like those described for the present, then what facies distribution might be seen? Just as exist today, they would be shoreface, beach and dune, estuarine, fluvial, deltaic, and aeolian facies. Wilkinson et al. (1975) imply in their work that in the Ingleside time there was basically only a single facies of a thin sand sheet deposited in a time of falling sea level over an old delta mass that had previously been exposed and weathered. As shown in Figure 3-5, the lower extensions of this supposed thin sand sheet would be overlying old pro-deltaic beds. Although borings are shown in the cross-sections to presumably penetrate these old marine units, it is not reported that any paleoecological evidence was encountered to indicate support for its interpretation as a pro-deltaic marine deposit. If such evidence did not exist, it would not be surprising considering that these beds must have been exposed to weathering for a considerable time. The lack of evidence for one paleoenvironmental interpretation, however, is no different than the lack of evidence for another.

Thus, it would appear that Price's (1933, 1958) concept must still be tenable, of the Ingleside shoreline as a form analogous to the present barrier. The lack of estuarine fossils is no more of a serious objection than the lack of nearshore marine fossils. If either exist anywhere in this area, they may be rare. The fact that the Ingleside sand extends into the subsurface as a thin unit could easily be due to later erosion, so this does not particularly favor the concept of strandplain progradation during a falling sea level, as Wilkinson et al. (1975) suggest. Their argument was that a prograding strandplain in a time of stable sea level would necessarily thicken seaward. Since the Ingleside sand of their profiles neither markedly thickened seaward nor overlaid estuarine deposits, they argued that it must have developed in a regressive or progradational manner influenced by a falling sea level.

The presence of distinct ridges in the Ingleside shoreline features is, of course, evidence of progradation just as it is evidence of progradation in the modern barrier form. The lack or rarity of estuarine fossils is, as we have shown, not particularly strong evidence. What, then, about the matter of the thickness of the Ingleside sand? First of all, we should note that a field trip guidebook (Corpus Christi Geological Society, 1958) cites two profiles by C. E. Johnson which indicate that the Ingleside sand in the area of Rockport, Texas, is up to 20 m in thickness. Graf (1966) has also cited that the Ingleside sands in segments of the old shoreline between St. Charles Bay and Aransas Bay are 18 m thick, although he describes no borings or other sources of this information. Perhaps these reports of thicker sands represent inlet fillings of greater original thickness. Perhaps the thinner areas have been substantially eroded in addition to undergoing some volume shrinkage from loss of unstable mineral components.

The prograding of delta sediments in this section of the Texas coast deserves further consideration. Wilkinson et al. (1975) believe this occurred before the Ingleside shoreline features were formed. The rivers of this section of the coast (the San Antonio, Nueces, and Guadalupe) presently are not large rivers and have not prograded substantially deltaic areas, for the most part, even into the shallow bays. Was it these same small rivers that made the prograded delta mass? Wilkinson et al. (1975) state that with the fall of seal level following the delta progradation, there was no further delta building in the area of their study. Perhaps then, the drainage basins of the coastal streams entering this central Texas area underwent some change by stream capture, or perhaps there has been no further delta building because the right conditions for it have not since recurred.

A condition favorable for a period of delta progradation could be that of a falling sea level. Consider, for instance, the situation existing at present in central Texas, and then imagine the changes that might occur if sea level began to fall. Suppose that the fall initially would be gradual. The lagoons and bays would become shoaled. Rivers would prograde forward over the fromer bays and lagoons. As these bodies of water became shoaled from falling sea level, the growth rate of deltas would increase because the same volume of added sediment would spread over progressively wider areas. Even a moderate fall could possible occasion a rapid progradation of deltaic deposits across the present lagoons and out to the barrier.

Another condition favorable for progradation of deltaic deposits would be ample amount of time for progradation, such as during a prolonged stillstand. However, the prolonged relative stillstand of recent millenia has not been ample enough for significant progradation of deltas by coastal streams, despite the fact that deltaic sedimentation is taking place in the shelter of a large barrier island system. The largest of the coastal rivers in this area, the Guadalupe, has been slowly and steadily building a small, sheltered delta within the bay, which as been detailed by the investigation of Donaldson _et al_. (1975). These authors predict that given an indefinite continuation of the current conditions into the future, the Guadalupe River will build across the lagoon and barrier island to discharge into the open Gulf, but add that, at that time, "the low load of the Guadalupe River probably would be sufficiently dispersed by longshore currents to prevent appreciable delta development in the open Gulf" (Donaldson _et al_., 1970: 130).

Imagine the situation that must have occurred if the diagram of Figure 3-5 is a correct one. The progradation of a delta mass directly against the opposing forces of the Gulf of Mexico, with no sheltering barrier, would mean that a much larger supply of deltaic sediment was reaching that area than is at present. There are various ways to account for a greater amount of sediment reaching the coast, such as changes in vegetation cover in the watershed or increase in the size of the catchment basin area; but a very large magnitude change in the amount of sediment is difficult to visualize. Let us suppose, for the sake of discussion, that much of the modern Colorado River catchment basin was connected to a basin which flowed to central Texas at the time of the delta progradation. This would have meant a greater sediment input, favoring delta progradation, but it is doubtful that even this would be as strong a progradation as required in the hypothesis of Wilkinson _et al_. (1975). Within the last century, the modern Colorado River has finally prograded to the barrier shoreline (Kanes, 1970) with the assistance of artificial channel clearance. This progradation occurred after a prolonged period of deposition into a sheltered lagoonal situation. Sediment from only a single large catchment is possibly inadequate for any significant amount of delta progradation at the open shoreline of the Gulf. Climatic differences might have added somewhat more sediment yield, but doubling of the amount might still have led to only moderate progradation and then only locally. High-energy Gulf shoreline conditions would have prevented much sedimentation, considering how slow it has been in recent millenia under sheltered conditions.

For these reasons, the delta progradation must have occurred either in a sheltered situation or under conditions of slowly falling sea level. The shelter may have been a barrier, possibly the Ingleside shoreline. The delta may have progaded at the open Gulf shoreline while sea level was falling. In this case, the Ingleside shorelines may represent merely pauses in the fall of sea level.

Perhaps there was a prolonged stage of river-mouth discharge at the Gulf shoreline. At such times, river-transported sands would have reached the coast and may have contributed to the final stages of beach-ridge development, which are the forms that we observe today. In this special case, delta progradation and beach-plain progradation may have been essentially the same thing for some span of time. During such a stage, the subtlety of the distinction between such terms as barrier and strandplain reminds us of the arbitrariness of the terms by which coastal features are described.

Price's interpretation of the Ingleside barrier was no doubt influenced by his well-known concern for the concept that coastal forms are products of equilibrium relationships of particular sets of coastal conditions. The large-scale similarity of the Ingleside shoreline forms and the modern barrier forms clearly suggests a similar equilibrium existed during the formation of both shorelines. Not only is this suggested by the forms, but if we try to suggest that coastal conditions were in some way markedly different in Ingleside times, then it is difficult to demonstrate that any such differences could have been large enough to matter. This was shown earlier in our consideration of how difficult it is to conceive of the small rivers of this central Texas area actively prograding into the open Gulf. Yet, the objection to the period of progradation is diminished if we imagine that it could have taken place behind a sheltering barrier or during a falling sea level period. In either case, the delta mass and the Ingleside shorelines could well represent essentially time-coincident units.

In the final analysis of the thesis of Wilkinson et al. (1975) it is apparent that the crux of the matter lies in their interpretation of a distinct soil zone beneath the Ingleside strandplain sand. In their article, the soil zone is specifically stated to exist only beneath their more northern profile (Figure 3-5), while in the southern profile, the corresponding horizon is not described explicitly as a soil zone, but only as oxidized mud and sand. They also recognize evidence of oxidation and calichification of the Ingleside strandplain sand itself; therefore, it is apparent that either two soil zones exist or that there is really only one soil zone affecting both units. Since their Ingleside strandplain sand as shown in their profiles is rarely more than 7 m in thickness, these soil zones are necessarily so close together in most places that it could well be argued that they are one and the same. If that were the case, the argument that the Ingleside strandplain sand is significantly younger than the underlying deposits would be questionable. Unfortunately, neither of these soil profiles has been described adequately to judge the possible relationships of these units.

With this problem in soil zones, we must let matters rest until further clarification of stratigraphic evidence is made in the literature.

We choose, however, to interpret all of the evidences examined above concerning the Ingleside shorelines in the following manner. At some time in the past, sea level stood higher that its present level, perhaps as high as 16 - 18 m above its present level or perhaps less than half of that. The Ingleside shoreline existed as an active littoral form at this time. It was a progradational feature and may have had partly the character of a barrier island and partly the form of a prograding strandplain, even though no definite estuarine or shoreface deposits have been described from the central Texas area.

Perhaps the form was developed in a cycle of evolution of the following kind: 1) As sea level was rising to a peak level, river mouths were drowned, and erosion of interfluve areas led to barrier-island formation through longshore drift of sand from interfluve headlands across drowned river mouths. 2) A continued, gradually diminishing transgression led to greater development of barriers with greater continuity of lagoon segments, which were still filling too slowly to keep pace with rising sea level. 3) A period of stillstand or near stillstand followed, and some filling of lagoons by both small coastal rivers and some aeolian- and storm-washed sands, which were transported over the barriers, occurred. In many places, the lagoons and bays may have become virtually entirely filled, as in the Laguna Madre Flats of today. 4) A period of slight fall of sea level, during which progradation and bay filling increased rapidly, and progradation to the barrier shoreline probably occurred. 5) A period of occupancy of the barrier-strandplain shoreline followed, with continued accumulation of deltaic deposits in former bay and lagoon lowland areas behind the barrier which was terminated by 6) a period of continuing sea level fall, abandonment of the barrier, exposure of the shoreface, and entrenchment of the coastal streams across the former shoreline.

The Ingleside shoreline features probably began to take on their character as we see them today during a time like that of Stage 5 in the discussion above. If the situation at that time was anything like the present, then this progradation must have been a slow process, possibly accelerated by a falling sea level. The Ingleside features that we see could well be interfingered with deltaic and/or estuarine beds. Their relative prevalence would be a matter of the phase of the transgressive-regressive cycle in which features that we see took their shape.

The streams may have prograded beyond the Ingleside shoreline as sea level fell. This progradation would mainly have been from recession of the shoreline of the falling sea, with advance occasioned by sedimentary progradation somewhat accelerated by falling sea level.

Deltaic progradation during a falling sea level may have led to a regressive sandy deposit, essentially of beach-ridge forms. As the fall of sea level reached the stage at which all coastal rivers began to deliver sands to the mouth, beaches may have slowly accreted forward at progressively lower and lower levels. At some point during such a fall, rivers may have increased in sand trasported to the coast as they began to scour and erode that sand previously stored in more inland deltaic and floodplain units.

The falling sea level may have been interrupted by relative stillstand periods, as suggested by the slope breaks of Figures 3-3 and 3-4. One or more progradational beach-ridge forms at lower levels than the Ingleside features outcropping today could have formed during such pauses. The cross-section could indicate two such separate pauses at perhaps about 10 m and 20 m below present sea level. The approximate 10 m below present sea level stand was recorded by progradation of sand in the southern profile, but was an interval of perhaps non-progradation, or even coastal erosion, in the area of the northern cross section. The approximate 20 m below present sea level stand is possible evidenced by progradational sands in the cross section to the north (Figure 3-4), but these would lie offshore of the southern cross-section, if they existed at all.

Just to the north of Corpus Christi Bay, near the town of Ingleside, an interesting occurrence of vertebrate fossils has been unearthed. Lundelius (1972), in a monograph on the Ingleside fauna, drew several important conclusions: 1) the fauna were preserved in freshwater pond marl and calcareous sand facies which must postdate the barrier-strandplain ridge; 2) "a post-Sangamon age fits the faunal picture better than a Sangamon one" (p. 6); 3) the presence of two large tortoises "probably rules out a late Wisconsin age (p. 6); and 4) certain elements of the fauna suggested that ecological conditions at the time the fauna were living could have been those of a forested area perhaps more humid and with warmer or less extreme winters than at present. Lundelius was careful to stress the somewhat tentative nature of some of these conclusions.

The pond marls of this site bring to mind the similar pond marls of the aeolian plain and the submerged occurrence at 7-1/2 Fathom Bank. As we have cited, Fisk (1959) reported a radiocarbon date of 11,490 ± 240 years B.P. on a deposit of this kind in the aeolian plain.

These various pieces of information give credence to an interpretation that perhaps a warmer and more humid climatic period developed at some time after aeolian processes affecting the Ingleside ridge and adjoining terrains began to diminish. Stabilization of the aeolian sand terrains could have resulted from a more humid local climate. As Lundelius has suggested, the pond marls may have accumulated in a pre-existing blowout depression formed at a time of lower water table. The rise of the water table to form the pond may have been partly due to sea level change and partly due to climatic change. Following this, marl deposition began, accompanied by the accumulation of remains of faunal more diverse than the present.

Lundelius describes fauna with 17 kinds of medium- to large-sized herbivores, as compared to only four in this category today. These include extinct species of camels, horses, elephants, bison, and other animals not so readily analogous to living types, such as other proboscideans, the tapir, and glyptodonts. There were also canids, felids, and other smaller mammals. A small camel or llama-type animal, *Tanupolama mirifica*, which was very well represented in the deposit, showed distinct modes in the height of the third molar of juveniles, suggesting to Lundelius that these animals bred seasonally and were preserved in the pond deposit due to its being intermittently dry during a distinct seasonal dry period.

East Texas Area

The Outer Continental Shelf off the east Texas coast shows a remarkable group of banks, some of which have reefal carbonate deposits. Studies by Edwards (1971), Poag (1973), Rezak and Bryant (1973), and several others have revealed many interesting features and details of these banks which are of the greatest importance in the overall interpretation of the continental shelf.

Many of the banks are known to result from intrusion of diapiric salt into the subsurface. High-resolution, sub-bottom profiles show the structural disturbance of strata in and around the banks. Profiles illustrated by Poag (1973) and Edwards (1971) indicate that structural deformation is episodic in time and shifting in space due to the intrusive salt rising in spine-like projections from the underlying salt plugs.

Because of these characteristics, it has many times been pointed out that structural deformation may be so active that it may cause appreciable change in the elevation of the banks even on a short-term scale. Nevertheless, many workers, even after noting these problems, have apparently regarded this as not a particularly serious impediment for interpretation of features of the banks produced during lower sea level stands. Although Poag (1973) acknowledges this potential instability as a problem, he nevertheless identifies various levels and features on the banks, relates them to former sea level positions, and suggests correlations with features at similar depths from bank to bank and elsewhere. All other workers on the banks in the east Texas area have done the same thing.

Parker and Curray (1956) summarized the bathymetry of shelf banks in a histogram which shows modes of their crests at about -3, -10, and -88 m. Curray (1960) has pointed out that the modes in the bank tops which lie at -3, -10, and -88 m would seem to deny that a long stillstand at -76 m (as suggested by McFarlan, 1961) could have occurred. This ignores, however, the fact that not all of the banks represented in the histogram are surrounded by shelf terrain lower than -88 m. Thus, it is not reasonable to argue that a large proportion of banks should lie at this level when many of the banks in the population described were actually hills rising from the coastal plain rather than islands when sea level was that low.

The idea expressed by Curray (1960) that a very prolonged stillstand (greater than 15,000 years, according to Curray) would lead to widespread and pronounced truncation of banks at the level of the stillstand is not necessarily sound. Islands may persist for long periods of time, depending on the relative balance of destructional and constructional processes that are operative in the particular coastal setting in which they occur.

Edwards (1971) felt that reef-building constructional processes on the West Flower Garden Bank (WFGB) were a late feature in the bank's history, with no important reef facies below -30 m. Further investigations by Rezak and Bryant (1973) have shown that this is incorrect, and that drowned reefs are known to exist at three lower levels: -55 to -58 m, -88 to -89 m, and -128 to -131 m. This is direct evidence of constructional processes at work, which must have compensated for destruction from wave attack.

The recognition of the three levels of drowned reefs in the WFGB leads to many interesting questions about the internal structure of the bank. Edwards' view that the bank has a core of Tertiary rock is somewhat questionable in this light, and the possibility arises that its core is mainly reefal material (coralline and algal). This cannot be substantiated from published descriptions, which are overly vague. Edwards presented photographs of presumed Tertiary rock outcrops at -79 to -82 m, but gave no description of their character. He described lithoclasts, which were a minor component of modern sediment facies, from -50 to -113 m. These were described as "dark in color" and usually with "numerous silt-sized shell fragments surrounded by a muddy matrix." The lithoclasts were said to be derived from biodegradation and erosion of outcropping Cenozoic sediments, such as were illustrated by the photographs. Without additional evidence, it is not possible to decide if the bank is primarily reefal throughout or if it has an older rock core. In either case, reefs have existed in the past at four different levels, at least on the WFGB.

Edwards (1971) concluded in a study of the WFGB that his evidence indicated former shoreline positions at several levels: 1) below -182 m, as indicated by "buried, seaward-dipping erosional surfaces" which extend to this depth, as seen in the sub-bottom profiles; 2) slope breaks and a small terrace at -121 to -134 m; 3) an -89 to -90 m terrace and sub-horizontal, stratified reflectors in the sub-bottom, with some small-scale channel forms; 4) a -73 to -82 m level marked by one wide terrace area and some smaller "erosion surfaces"; and 5) a -46 to -51 m level with terraces on the two main pinnacles.

The argument that Edwards (1971) used to hypothesize that deltaic sediments were deposited in the area of WFGB at the time of his -89 to -90 m sea stand is intriguing. It is based on the sub-bottom profiles which show stratification suggestive to him of topset, bottomset, and foreset structure, such as that associated with deltaic masses. From these structural properties, he infers that a delta existed to the north and east of the bank during the -89 to -90 m shoreline occupancy. This is a plausible argument. Yet an alternative explanation may be that this structural configuration is part of the local tectonic effect of the salt dome. Specifically, it could well be evidence of a rim syncline zone of deformation around the dome, which is an apparent feature in the deeper sub-bottom as shown also by Edwards' one-cubic-inch, air-gun profile (reproduced here as Figure 3-6).

Resolution of these problems will require both samples and, possibly, cores to learn the character of the sediments and a better three-dimensional concept of the structure of the dome from more reflection profiles. With samples and cores, the age and environment of deposition of the sediments can be established, and our paleogeographic information will increase. This, added to increasing structural knowledge from more sub-bottom, structural data acquisition (and increasing skills in storage, retrieval, and display of these data), should permit more definite interpretation of paleogeography in the near future.

Poag (1973) stated that "wave cut terraces, erosional unconformities, and relict reefal assemblages" on the east Texas banks indicated eight past sea level stands at depths of -60, -78, -82, -100, -126, -135, -194, and -223 meters. Poag states that features at these levels are present "at equivalent depths on several banks," but actually presents evidence only in the form of four sub-bottom profiles over four banks. Some of the features shown on these profiles are relatively minor and are not particularly convincing (such as the -223 m feature), but others (such as a shelf at -78 to -85 m) seem real and significant.

Clearly, detailed interpretations of this group of banks, where tectonic effects are probably significant, will require highly detailed investigation of each separate bank. For our purposes in this report, however, the banks clearly show evidences (as cited in the works reviewed above) of having existed at various times and different positions of sea level as submerged banks, reefs, islands, headlands, and hills rising from the coastal plain. For all cases of subaerial exposure, their suitability as habitat for early people was likely to have been excellent.

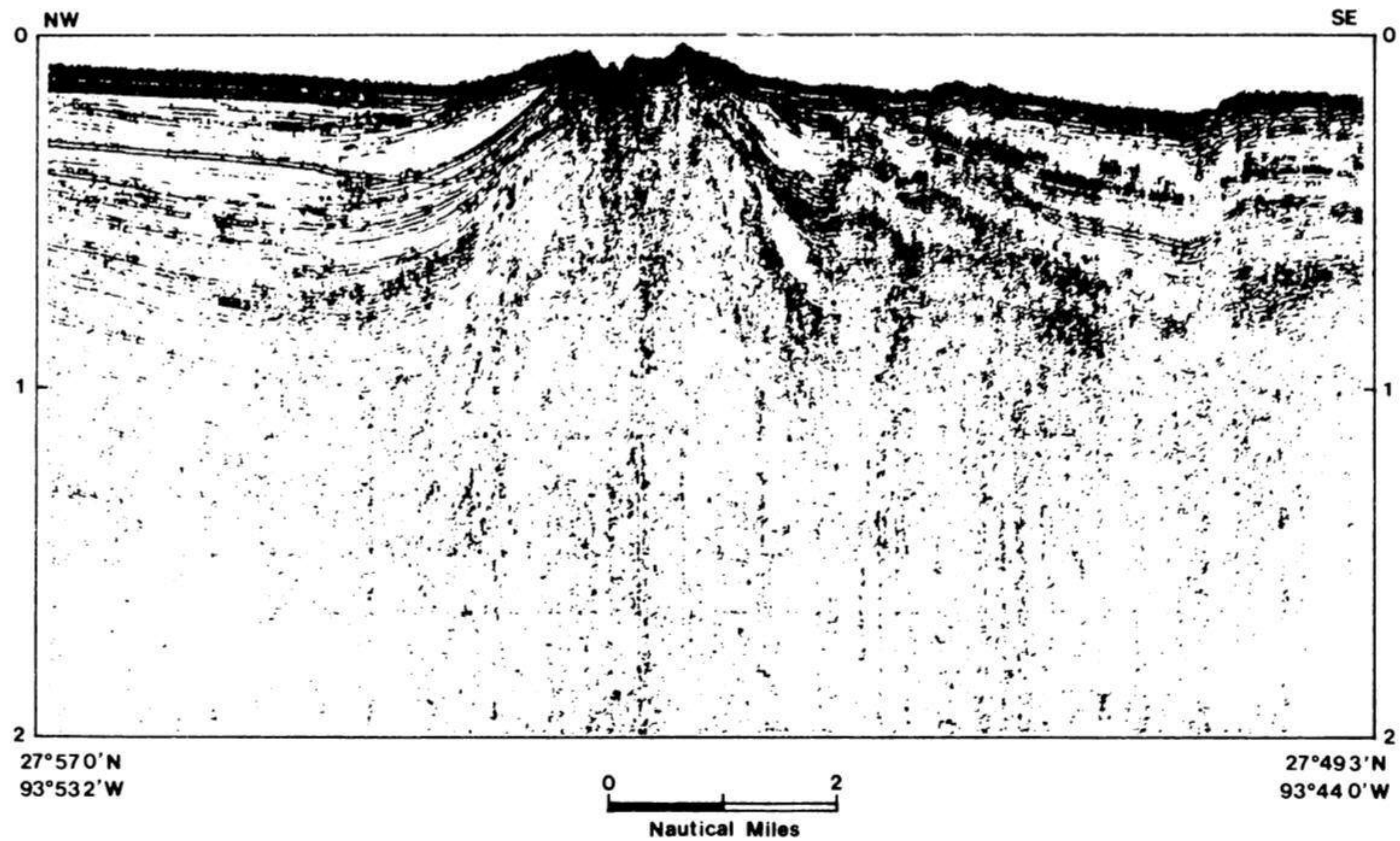


Figure 3-6. One-cubic-inch, air-gun profile of the West Flower Garden Bank (WFGB) (After Edwards, 1971).

Edwards has presented an illustration of this interpretation of the appearance of the WFGB at the time sea level was about 121 to 134 m below the present level (with which we concur in general) (Figure 3-7). The illustration is an oblique aerial view looking landward (northward) of the WFGB dome structure, rising as a hill at the coast much as other salt domes (such as High Island) do today. The various potential habitats can be readily visualized. Barrier froms are interpreted to have existed flanking the dome in the foreground.

Besides the banks, there are other indications of relict forms on the Outer Continental Shelf. Minor excarpments or slope breaks are indicated on Volume 3, Plate 2, in water depths of -130 to -140 m and -80 to -90 m. These compare with similar features on the banks.

One of the most prominent features of the east Texas shelf sector lies on the far western side, where the -80 to -100 m contour reveals a large, arcuate bulge which we interpret here as a submerged delta. There is a steepening of the slope associated with this bulge ar about 84 m. At present, this is still an area of limited bathymetric detail, but generally it seems that contours are rather regular, without indications of complex topography. The regularity of the contours probably reflects the smoothing over of relief features by Holocene marine sedimentation which, by obscuring the details, makes interpretations difficult at this time. Curray (1960) referred to this form as the Colorado delta, but did not elaborate on this interpretation. He did show that surface sediments in the area of the bulge were of a subarkosic nature similar to those of the present Colorado-Brazos and Rio Grande deltaic sediments.

In the eastern half of the east Texas sector of the shelf, there are two ridge-like forms which both trend into the area of Stetson Bank. On the landward side of each, there is a depression of channel-like configuration. Curray (1960) termed the channel on the western side the Outer Brazos-Colorado channel,

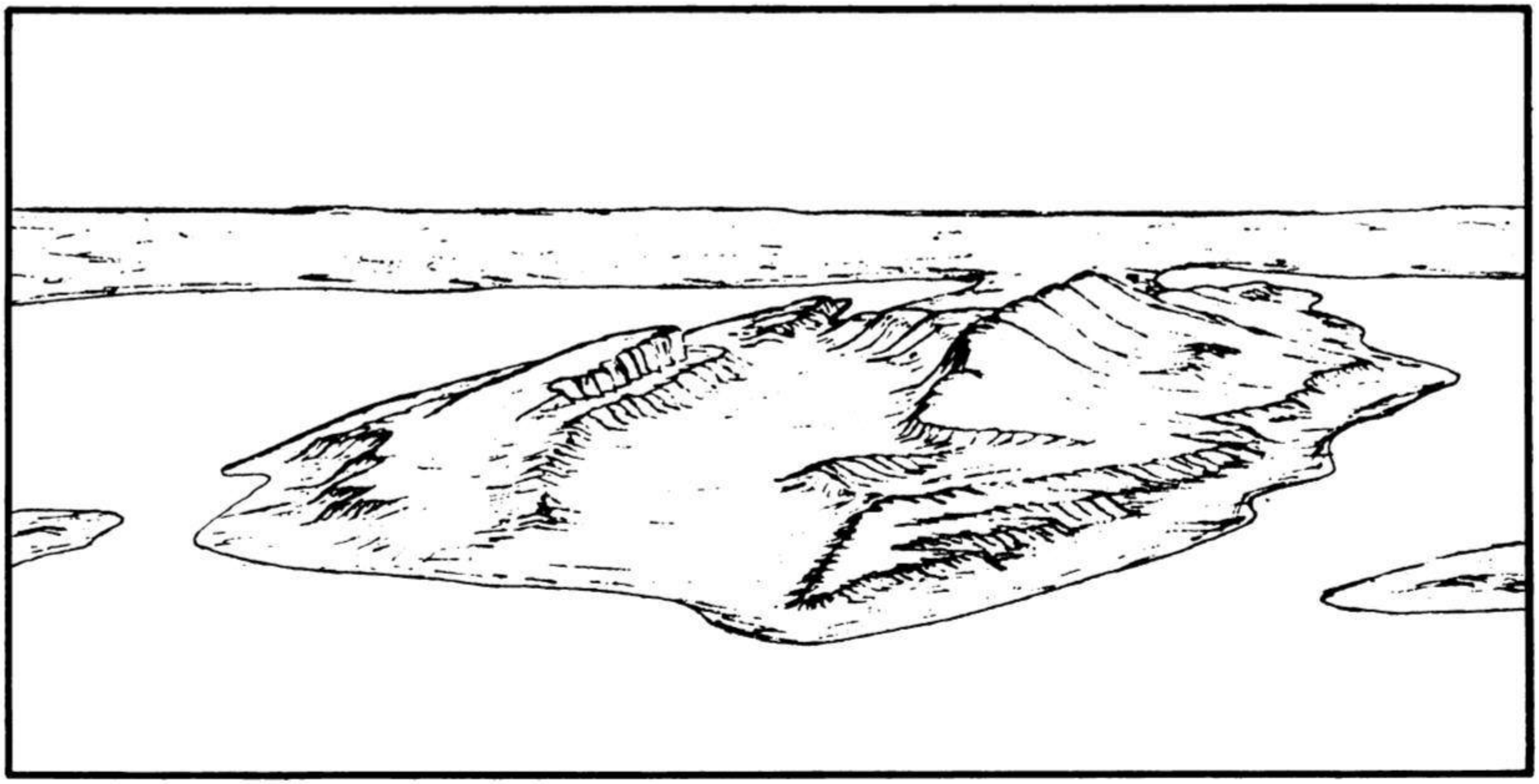


Figure 3-7. Interpretive illustration of the West Flower Garden Bank when sea level was about 121-134 m below present level (After Edwards, 1971).

which he believed to have formed as an actual alluvial channel of these rivers. The ridge south of the channel he regarded as a barrier spit, which developed at the mouth of this river during a falling stage of sea level. This interpretation reflects the fact that the ridge is not a sub-horizontal terrain element, but slopes across the shelf from depths of -53 m to -64 m.

The more eastern ridge form and associated channel was interpreted in an analogous manner. In this case, the channel was termed by Curray the "Louisiana Channel," and the "barrier spit"-shaped ridge slopes from about -57 m to -65 m.

These interpretations seem plausible, but are not completely acceptable. The geometry certainly does suggest coastal barriers or strandplain forms. Their sloping across the shelf conceivably does represent a regression, but can also be a tectonic product or partly a product of erosion. When the two are viewed together, they define an arcuate outline which may well represent a delta lobe with which the forms are contemporaneous.

This arcuate lobe is of large scale, even larger than the present Brazos-Colorado delta area. The meaning of this scale difference is intriguing. It can be interpreted many different ways. The delta perhaps represents the integrated discharge of a much greater catchment area than that of the Brazos-Colorado catchment area of today. Since the coastal rivers and streams which formed the delta bulge flowed across 100 to 150 km of additional exposed terrain at the time when sea level was -60 m or so below its present level, many of the streams which now flow separately to the sea may have then been integrated into one or more major trunk streams. Thus, conceivably, the delta bulge represents the combined flow and sedimentation not just of the Brazos-Colorado, as Curray's name would imply, but also of the Trinity, Sabine, Calcasieu, and several other, lesser, coastal rivers.

The size of the delta lobe could partly represent either an abundant supply of sediment or a long duration of sediment accumulation. Sediment supply during a falling stage could well have been higher because of rivers adjusting to a decreasing base level and may have been higher at other times for other reasons.

The Stetson Bank, which is in the area of the forms just described, is a salt-dome structure which reportedly (Edwards, 1971) has Tertiary rock outcrops at the surface. It is also the area from which one of the most interesting radiocarbon dates reported from the entire Gulf continental shelf comes. This is the articulated Rangia cuneata sample, first reported by Neuman (1958), which gave close age results on replicated samples. The sample elevation was -58 m, and the mean of the age determinations was about 12,900 years B.P. This date is perhaps the best estimate of the age of any of the shoreline features submerged on the shelf that exists. The delta may very well be of that age. On the other hand, it cannot be denied that the estuarine Rangia-bearing deposits are possibly not contemporaneous with the delta bulge.

Similar forms sloping across the shelf exist inland from the form association just described. One of these, shown on Volume 3, Plate 2, was also described by Curray as a relict barrier spit, flanked on the landward side by a channel which he termed the "inner Colorado-Brazos channel." This feature extends from about -26 to -40 m. Smaller, less-extended forms exist in the same depth range in the eastern part of the east Texas sector.

Again, Curray's interpretations of the nature of the larger of these forms is regarded here as plausible. The smaller ones are also interpreted as barrier-strandplain features. Poor bathymetric control and lack of other detail do not permit further interpretation.

The areas known as the Freeport Bank and the Freeport Rocks just offshore of the Brazos-Colorado Delta are part of one of the most interesting associations known on the Outer Continental Shelf. The maps presented by Curray (1960) and Winchester (1971) show that indurated rock outcrops occur at numerous localities which form linear trends.

Winchester has described the rocks which outcrop off of Freeport, Texas, in a depth range of -14 to -20 m. These rocks form a linear trend over a distance of 31 km (Figure 3-8). Four lithologies predominate in samples: 1) orthoquartzite, 2) fine- to medium-grained calcarenite, 3) coarse calcarenite, and 4) caliche nodules. All four rock types are cemeted by low-magnesium, calcite cement. Shell materials are affected by recrystallization. Much of the shell material may have been derived from the Beaumont formation, which is said to underly the rocks.

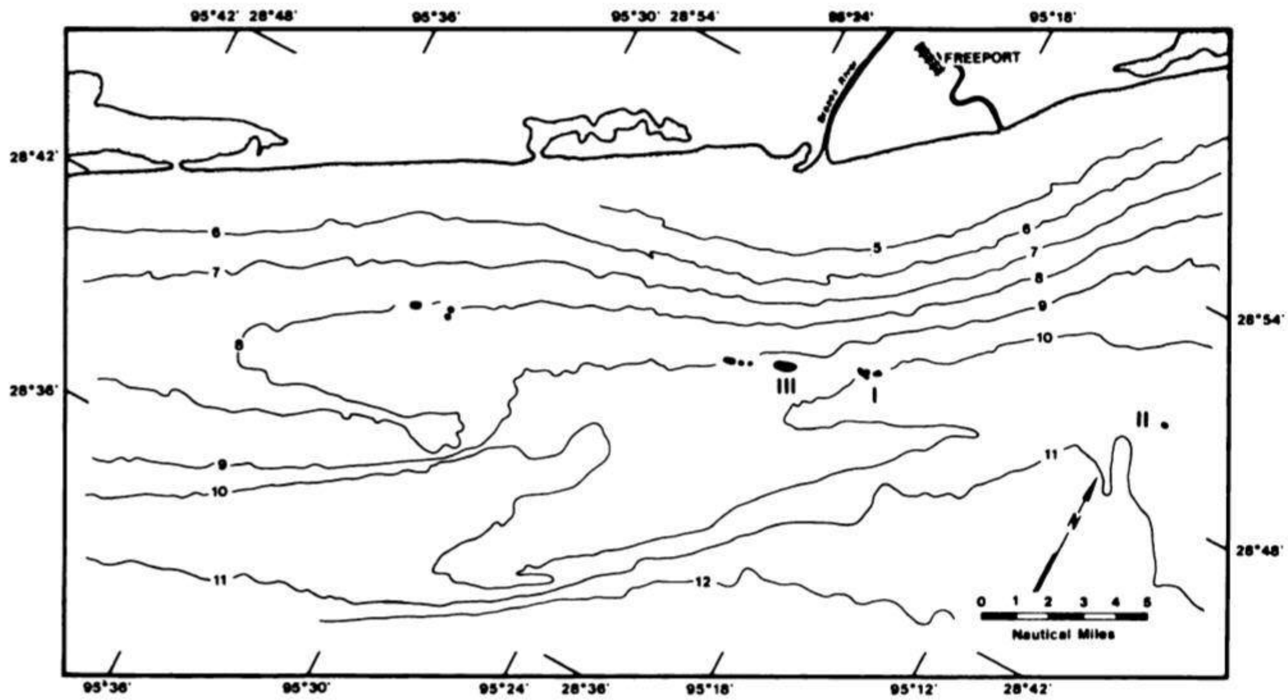


Figure 3-8. Rock outcrops off of Freeport, Texas, at depths ranging from -14 to -20 m below sea level. (After Winchester, 1971).

Winchester makes a comparison of the environment of accumulation of the beds forming the Freeport Rocks with the present-day beach near High Island, Texas. At the High Island beach, much of the coarse, shell fraction is reworked older shell with Rangia cuneata and Crassostrea virginica as common occurrences. Winchester obtained dates ranging from 3800 to 28,000 years B.P. on shells of these forms from High Island beach. He feels that much of this shell is reworked from the Beaumont formation, which outcrops at a shallow depth near High Island beach. For the older specimens, this seems quite probable, although some which give younger ages may be reworked from Holocene deposits as well. Caliche nodules are also abundant at High Island beach, and the stratified beach deposits show the same major lithographic types as at Freeport Rocks.

The preponderance of reworked shells in such deposits makes shell dates suspect. The recrystallization of the shell also casts doubt on the meaning of radiocarbon dates of such shells. Winchester points out, therefore, that the actual age of the Crassostrea virginica shell which Curray (1961) dated from the Freeport Rocks area is possibly older than 50,000 years B.P., although the indicated date was 26,900 ± 1800 years B.P., which may reflect contaminating "new" carbon added at the time of recrystallization.

Winchester goes on to argue that a date of 22,886 ± 431 years B.P. obtained by him on the low-magnesium, calcite cement of the orthoquartzite rock type is probably older than the time of formation of the Freeport Rocks since the source of the cement carbonate must have been shells, many of which were much older. Winchester also dates a caliche nodule and argues that since it formed originally as low-magnesium calcite, it has possibly undergone little or no subsequent recrystallization or uptake of contaminating carbon. Petrographic study of the nodule also revealed no recrystallization. The nodule was dated at 15,857 ± 268 years B.P. Winchester states that "because the caliche formed on the Pleistocene Beaumont surface prior to its incorporation into the sediments of the Freeport Rocks, the age of the Freeport Rocks must be less than 15,857 ± 268 years B.P." (p. 220).

Nelson and Bray (1970) have described and interpreted the sediments of the Sabine and Heald Banks offshore from the easternmost part of the Texas coast. They interpret a history of sea-level rise over an area previously entrenched by the Sabine and Calcasieu Rivers. Cores and marine sonoprobe records allowed reconstruction of paleotopography and paleoenvironments.

The Ingleside shoreline features which were discussed at length in the central Texas sector are believed by many to correlate with similar, old, stranded beach ridges which exist in the east Texas sector. This correlation is not accepted by all, however (Wilkinson et al., 1975). The Ingleside features of central Texas terminate in outcrop at the western side of Matagorda Bay. From this point, there is no evidence of such stranded beach ridges for a distance of about 130 km along the coast. The first occurrence of ridges in the east Texas area is near the Hoskins Mound, a salt dome just northwest of the southwestern tip of Galveston Island. From this point, there are intermittent areas of outcrop of the old littoral features extending all the way into Louisiana.

It is of interest to note that while in the central Texas sector the Igleside trend is concave seaward and nearly parallel to the present shoreline, in east Texas and Louisiana it departs from this pattern. Near Hoskins Mound the trend diverges in orientation from the present shoreline and actually shows a slightly convex seaward curvature. This partly reflects the effect of the Brazos-Colorado River system, which has influenced this area throughout the later Quaternary. Following the old stranded shorelines to the northeast, the concave seaward curvature again becomes apparent.

Graf (1966) has presented borings and a general interpretation of these relict shoreline features. In general, he concludes that they were developed during a phase of deposition of the Beaumont formation. His borings and analysis reveal intense weathering and post-depositional alteration of the shoreline sediments. This and other evidence led him to suppose that an interval of relative aridity followed the period of their formation.

West Louisiana Area

A zone of banks, shoals, and knolls extending across the shelf edge of this area (Volume III, Plate 2) is a continuation of the trend previously discussed in the East Texas area. The most prominent of these features lie at depths of -80 to -200 meters. A smaller group, including Phleger and Sweet Banks, lies seaward of the -200 meter contour. Another cluster occurs in the central part of the West Louisiana shelf at shallower depths, between the -50 and -70 meter contours. Still a fourth group is found around the margins of the Mississippi Trough, between the -50 and -150 meter contours.

Submerged banks in this area have been studied by oceanographers and marine geologists from Texas A&M University. They found that the banks, like their counterparts in the East Texas shelf area, exhibit features interpreted as submerged, wave-cut terraces and escarpments. Figure 3-9 (After Poag, 1973) illustrates 3.5kHz sub-bottom profiles of Sweet Bank and Bank 3. (See Volume III, Plate 2. Bank 3 lies between the -80 and -100 meter contours immediately east of the East Texas-West Louisiana boundary line). Several well-defined terraces can be distinguished on the profiles. While they may be capped with reef-like deposits most if not all of the knolls had their origin as shale or salt diapirs.

The Mississippi Trough, a major feature of this area, is believed to have formed during intervals of low sea stand and, as the name implies, was cut by the Mississippi River. When formed, the river was not building a subaerial delta, but rather was discharging directly into the head of the trough and a great submarine fan formed in the deep waters of the continental rise. This interpretation was developed by Fisk (1956) and has been generally accepted by later researchers. The situation at the mouth of the Mississippi during these low sea stand intervals was comparable to that found at the mouth of the present-day Congo River.

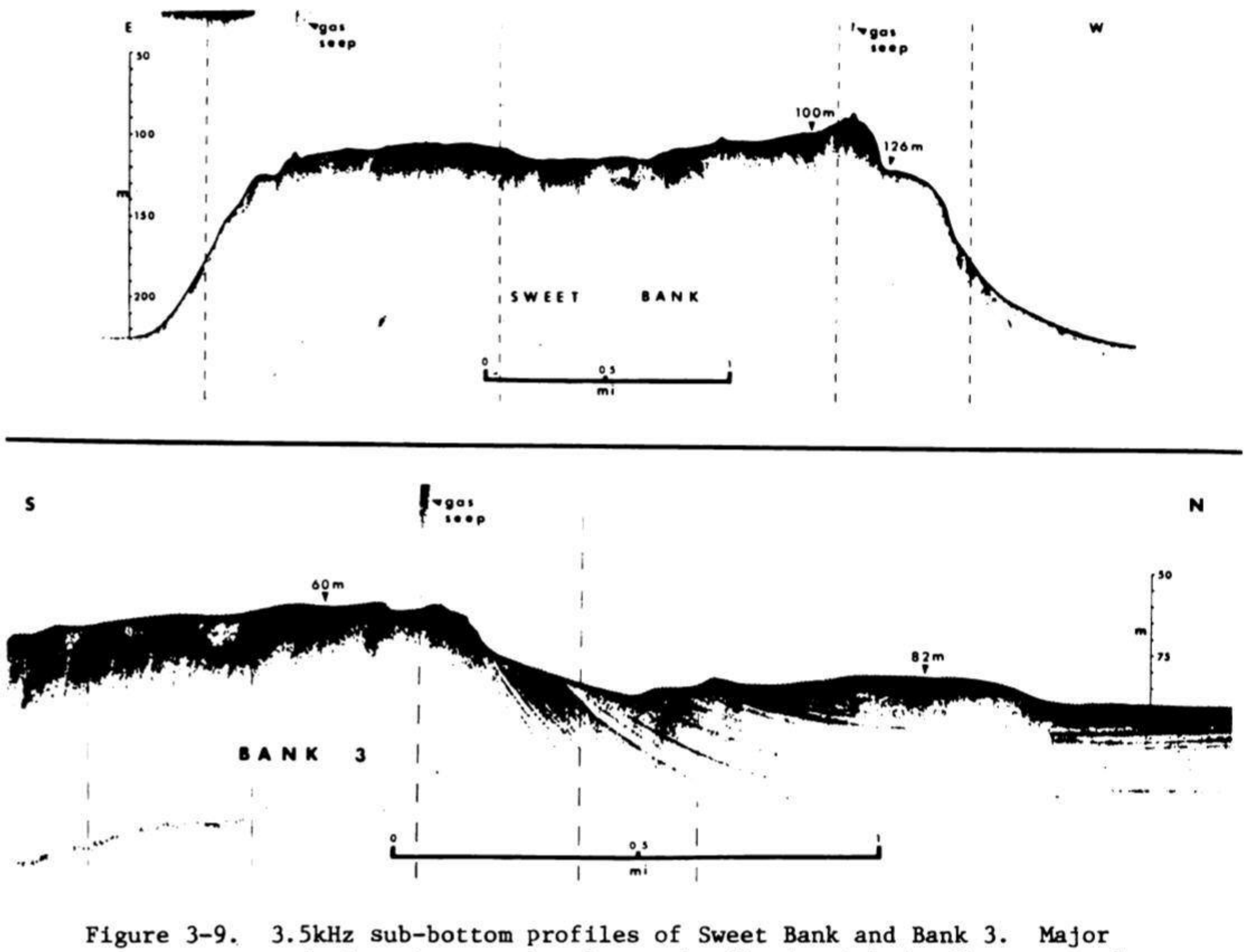


Figure 3-9. 3.5kHz sub-bottom profiles of Sweet Bank and Bank 3. Major and minor terrace levels can be distinguished. Gas seeps along the flanks are believed to be associated with structural activity. (After Poag, 1973.)

There is some evidence that the trough functioned during the interval from 25,000 to 15,000 years B.P. Supporting data come from deep borings in the vicinity of the modern birdfoot delta. Radiocarbon dates from these borings indicate that during this interval clay minerals characteristic of the Mississippi, Alabama, West Florida shelf areas were sweeping to the west (Morgan, Coleman, and Gagliano, 1963). The best explanation for this condition is that Mississippi River sediment was being funneled into the deep Gulf.

The middle and inner areas of the very broad West Louisiana shelf are dominated by six large delta bulges or lobes. One of the lobes is located south of Cameron, Louisiana, and lies largely landward of the -20 meter contour. At least three prominent, transgressive sand complexes help to distinguish this lobe.

A pair of smaller, but very well defined delta lobes lies inside of the -20 meter contour south of Vermilion and Cote Blanche Bays. They are capped by transgressive sand complexes, the most distinctive of which is Trinity Shoal. Tiger Shoal, which is also part of this lobe, is a curious "Y"-shaped feature which may represent the bifurcated, relict natural levee ridges of a major distriburary channel.

Two overlapping lobes lie south of Houma, Louisiana. They are landward of the -20 meter contour and are capped by multiple transgressive complexes. The transgressive complexes on the inner lobe are known collectively as Ship Shoal.

The sixth lobe is found between the -20 and -40 meter contour south of Grand Lake and White Lake. Not only does it occur in deeper water than the other five, but it also lacks the transgressive complexes. Numerous reports of "rocks" from this area of the shelf may be calcium carbonate nodules, ferrous nodules, or possibly slabs of cemented beach sand. The first two instances could indicate a subaerially weathered surface; the third, erosion of transgressive sands.

It is interesting to note that relict delta lobes on the low coastal terraces of Texas and Louisiana formed by the Brazos, Trinity, Sabine, and other coastal plain rivers also lack transgressive sand complexes. Such lobes may be characteristic of intervals of falling sea level, while those with transgressive sand complexes form during stillstands or periods of rising sea level. Thus, we may speculate that the first five deltas discussed above formed during relative stillstands or periods of slow rise, while the sixth formed under falling sea level conditions.

Even though this area of the shelf has been extensively investigated by coring, geophysical, and remote-sensing techniques, the lobes are not well described in the literature. Fisk (1955) showed in illustrations how deltas formed south of Houma, Louisiana, after the Mississippi River abandoned the trough (following the Wisconsin glacial maximum). Curray (1960) and others have followed this interpretation. Curray (1960) shows the lower of this pair of lobes forming around 12,000 years B.P. and remaining active until at least 9,000 years B.P. According to Curray, the inner delta, the ship shoal delta, became active around 8,000 years B.P.

The lobes south of Vermilion and Cote Blanche Bays have been referred to as the Maringouin Delta Complex. Dates for this complex are given as 8,000 to 6,000 years B.P. (Coleman, 1966; Saucier, 1974; Frazier, 1974).

Several authors (Jones et al., 1974; Saucier, 1977) have shown that relict Mississippi River channels are associated with the Prairie Terrace of southwestern Louisiana. Jones interprets Mississippi River scars as far west as Mud Lake (west of Cameron, Louisiana). At least by inference then, the two western lobes may be related to the Mississippi River and their age equivalent to the onshore Prairie Terrace.

The West Louisiana shelf area has been subjected to both rapid subsidence and estensive diapiric movements as a result of sediment loading. Major fault zones occur, in predominately east-west trends. The boundary between this unit and the East Texas unit, marked by an alignment of large diapiric structures, may also be a major zone of structural weakness. Uplifted diapiric structures have formed both true islands and prominent relief features in the otherwise flat coastal terrain. Onshore salt-dome prominences are known to have important archeological sites. We can assume that the same is true for at least some of those on the continental shelf.

East Louisiana Area

This area encompasses the Late Holocene deltaic plain and subaqueous deltaic area of the Mississippi River system (Figure 3-10). Surface features and surficial sediments are generally less than 4,000 years old.

The Holocene history is very complex but has been well described in the literature. For summaries the reader is referred to the works of Fisk and McFarlan, 1955; Kolb and van Lopik, 1958; Bernard and LeBlanc, 1965; Gould, 1970; and Frazier, 1967, 1974 . Deltaic processes and the earlier sequence of delta lobes are discussed in Chapter 7 of this volume.

As shown in Figure 3-10, the landmass of southeastern Louisiana is composed of overlapping delta lobes. The distal ends of the older lobes have eroded and subsided, so that former land areas now lie below the shallow inshore waters of the continental shelf. For example, the landmass of the St. Bernard delta (Figure 3-10) once extended beyond the present position of the Chandeleur Island. Marksville Period archeological sites (circa 2,000 years B.P.) are known to have existed along distributaries of this former delta (McIntire, 1959; Saucier, 1963). Occupation continued through historic times. Thus, prehistoric terrestrial sites inhabited during active buildout

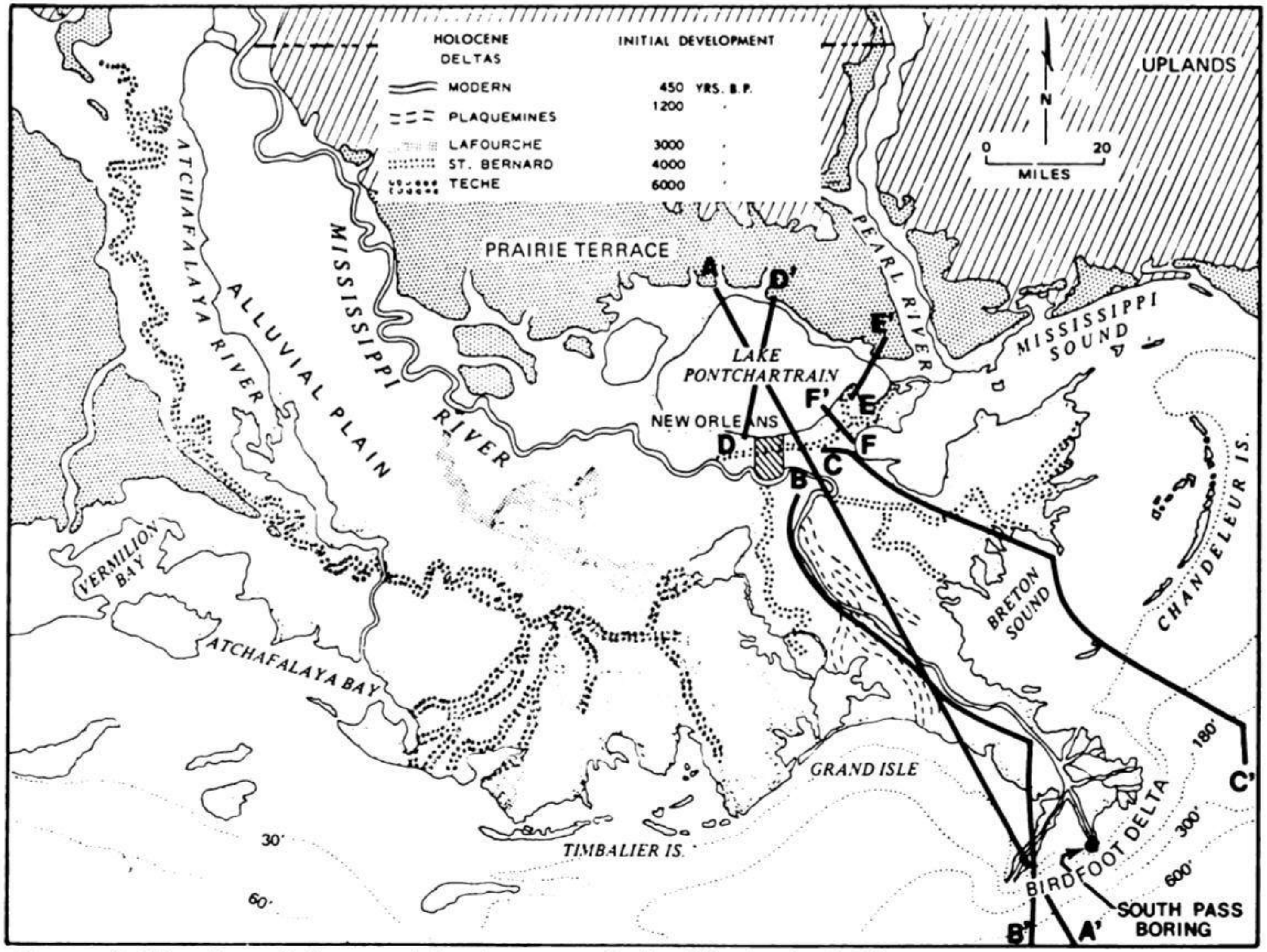


Figure 3-10. Late Holocene deltaic area of the Mississippi River system. (Modified from Gould and Morgan, 1962.)

of the old deltas and during early stages of their deterioration can be anticipated in shallow shelf areas.

The Modern Birdfoot Delta (Figure 3-10) has been constructed by sedimentation in the vicinity of the active outlets of the Mississippi largely during historic times. Old light houses, port towns, and other historic buildings and archeological sites are known in the Modern delta area. A number of these, such as the port town of Balize (1734-1888 A.D.) have subsided and been covered with silts and clays, to be incorporated within the sedimentary deposits of the delta mass.

We can reasonably anticipate that a large number of prehistoric terrestrial sites have also been encapsulated in the alluvial deposits of older delta lobes. Figure 3-11 illustrates a geological section through southeastern Louisiana and shows the great thicknesses of sediment that has accumulated during late Quaternary times. Because of the combination of high subsidence rates and rapid deposition, surface features of older delta are typically buried. This situation contrasts with conditions found in more stable shelf areas, where relict terrestrial features may retain their form on the bottom or be reworked by marine processes after they have been drowned.

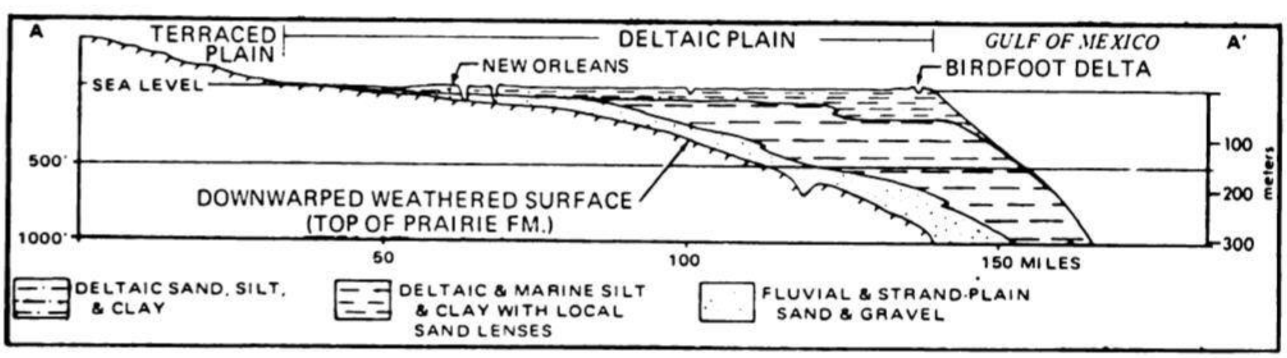


Figure 3-11. Generalized cross-section through Late Holocene deltaic plain of the Mississippi River. Note thick wedge of deltaic sediments and buried surface of the Prairie Formation. Location of section shown in Figure 3-10 (After Fisk and McFarlan, 1955).

Figure 3-12 shows downwarping of the Prairie Terrace surface which has resulted primarily from rapid Holocene sediment deposition in this area. It should be noted that the map datum is a buried weathered surface of soil zone that has been traced through innumerable borings in the deltaic plain and continental shelf areas. Until recently most geologists have correlated the upper buried soil horizon with the surface of the Prairie Terrace and considered it to be the top of the Pleistocene. As illustrated in the section shown in Figure 3-13, this simple model is no longer valid. Boring data indicate that there are several distinctive buried soil zones within the Late Pleistocene-Middle Holocene section. These are related to the complex interplay of depositional events and sea level fluctuations (see Frazier, 1974; Saucier, 1977).

Another feature of special interest in the section shown in Figure 3-13 is the filled and buried trench of the Pearl River. The section suggests that the trench was cut some considerable time after 32,000 years ago and was in the process of being filled 17,000 years ago. By about 9,000 years B.P. the trench had been completely filled and was no longer an active feature at the place where it is crossed by the line of section. In fact, Frazier (1974) indicates that there is a significant hiatal surface across the top of the trench surface and at the base of the Recent (i.e., post 8,400 years B.P.).

Part of this same section has been encountered in borings at South Pass in the Birdfoot Delta area. The modern delta has extended seaward beyond the former edge of the continental shelf and provides a natural platform for drilling into now-buried shelf deposits. Detailed studies of samples from borings at South Pass have been made (Morgan, Coleman, and Gagliano, 1968). Figure 3-14 illustrates the reconstructed section. Sediments associated with the modern delta extend to depths of -76 to -107 meters. These are directly

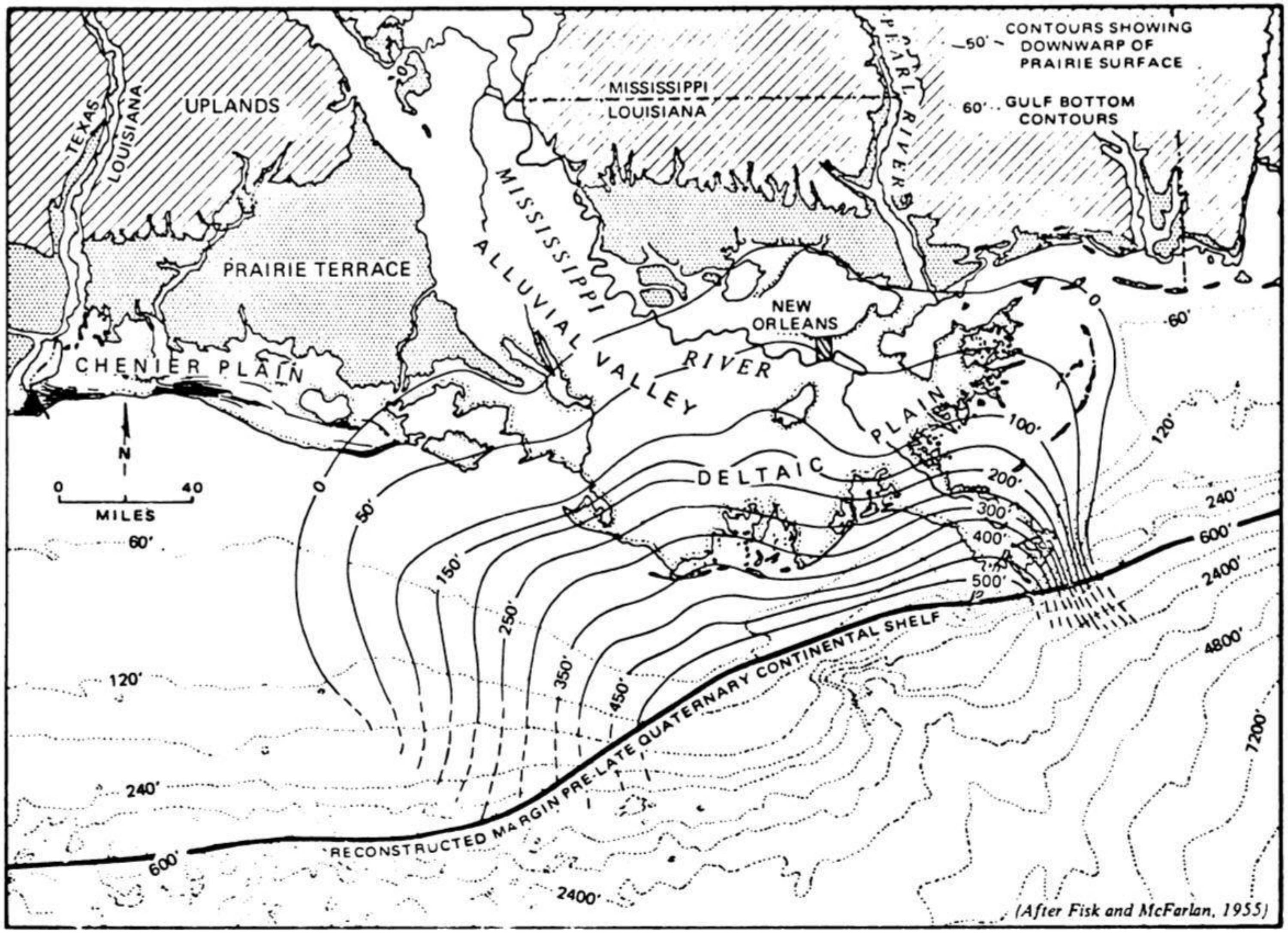


Figure 3-12. Downwarp of Prairie surface beneath Late Quaternary Mississippi deltaic mass as determined from bore-hole data. (After Fisk and McFarlan, 1955.)

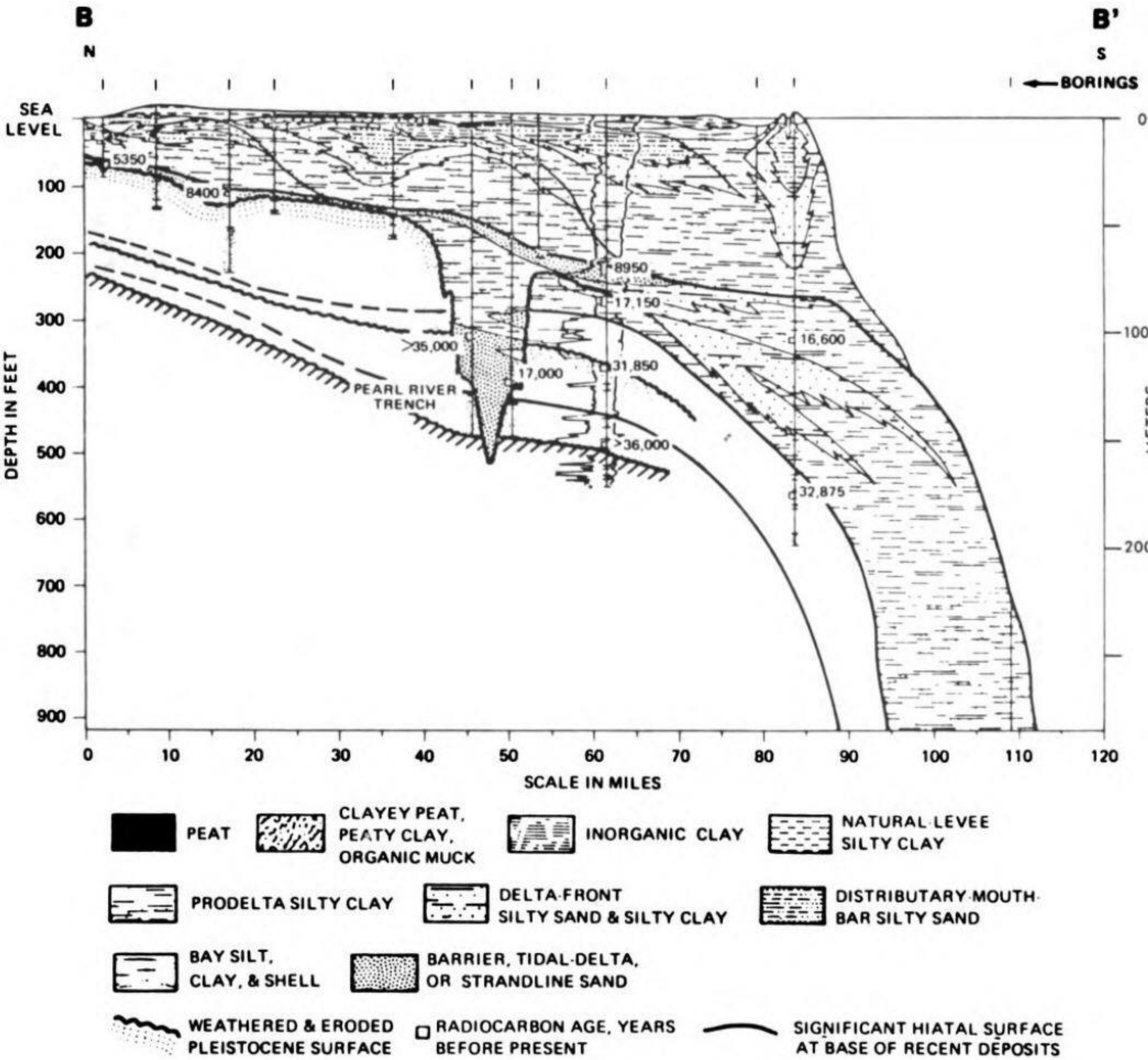


Figure 3-13. Section through southeastern Louisiana illustrating offlapping pools of coastal and deltaic sediment. Note multiple weathered zones and hiatal surfaces. Location of section shown in Figure 3-10. (After Frazier, 1974.)

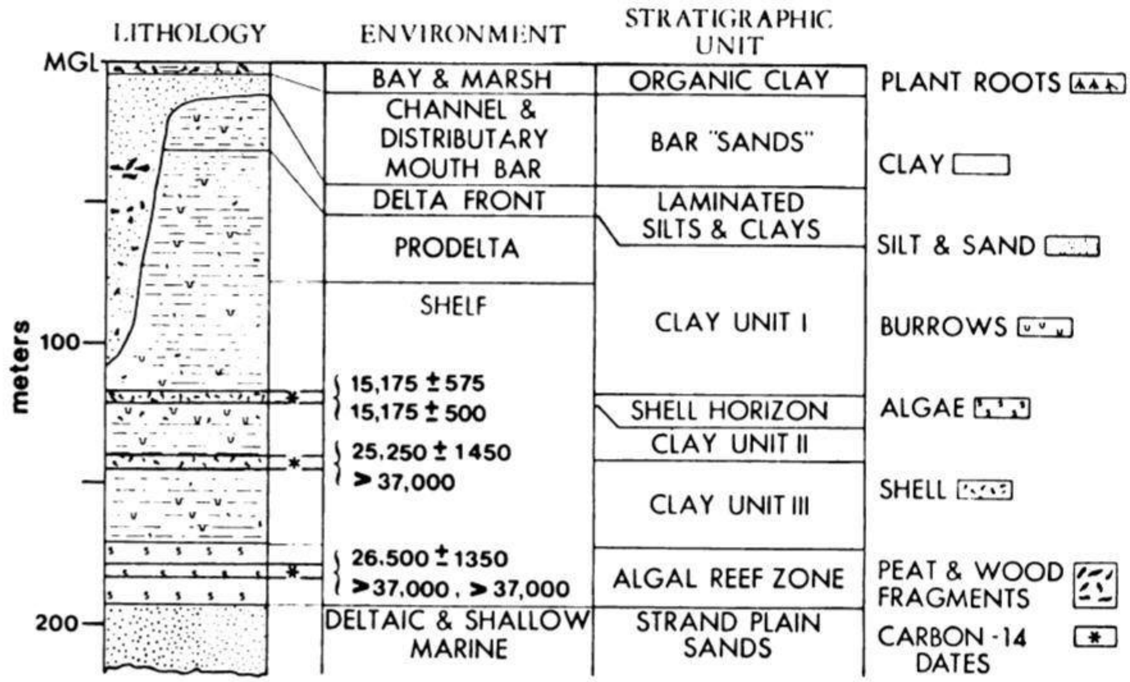


Figure 3-14. Depositional sequence shown by borings at South Pass. Shallow continental shelf deposits dated at approximately 15,000-15,500 years B.P. are overlain by Late Holocene Mississippi River deltaic deposits. Location shown in Figure 3-10. (After Morgan, Coleman, and Gagliano, 1968a and 1968b).

underlain by older shelf deposits introduced by the St. Bernard delta system. At depths of approximately -119 to -122 meters is a very distinctive shell horizon representing a hiatus at the top of the Pleistocene. This shell horizon, dated at 15,175 ± 575 and 15,575 ± 500 years B.P., has been encountered in numerous other borings throughout the Birdfoot Delta area. Within the shell horizon, and below to a depth of approximately -141 meters, is a distinctive clay mineral suite. The clays in this part of the section (Clay Unit II) are higher in kaolonite than the montmorolonite-illite-rich Mississippi River clays of the sections above (Clay Unit I) and below (Clay Unit III). These kaolonite rich clays represent an eastern Gulf suite and are believed to have accumulated during a time when Mississippi sediments were being diverted into deep waters through the trough.

A minor hiatus is represented by a thin shell bed and a change in clay mineralogy at a depth of approximately -145 meters. Radiocarbon dates from this shell bed are 25,250 ± 1,450 and > 37,000 years B.P.

Still lower in the section (-177 meters) is a third hiatus represented by an algae reef zone consisting largely of the genus Lithothamnion overlying sandplain sands. Radiocarbon dates from this zone are 26,500 ± 1,350 and > 37,000 years B.P.

The three hiatal surfaces in the lower part of this section are the most significant to the present study.

Figure 3-15 shows a section through the St. Bernard delta complex. The slope of the weathered surface of the Pleistocene has been mapped in this area, as has the trench of the Pearl River. Of particular interest is a sand body associated with a relict shoreline at a depth of approximately -76 meters.

Saucier (1977) and Kolb *et al.* (1975) have identified two weathered zones within the upper Pleistocene of the Lake Pontchartrain area (Figure 3-16). Saucier indicates that radiocarbon assays of marine deposits between the two weathered horizons include dates of 27,000 ± 1,200 and 29,300 ± 2,000 years B.P., plus at least one date > 30,000 years B.P. While conceding that dates in this time range are questionable because of possible contamination, Saucier believes that designation of the deposits between the two weathered horizons as Farmdalian is justifiable on the basis of stratigraphic position. Kolb suggests the same interpretation but is more cautious and concludes that many more radiocarbon dates are needed and much more boring data must be analyzed before the matter is resolved. The two weathered Pleistocene horizons from the Lake Pontchartrain area seem consistent with Frazier's section illustrated in Figure 3-13.

Figure 3-17 shows a section through an area on the south side of Lake Pontchartrain. Here a Late Holocene barrier-island complex rests on a weathered

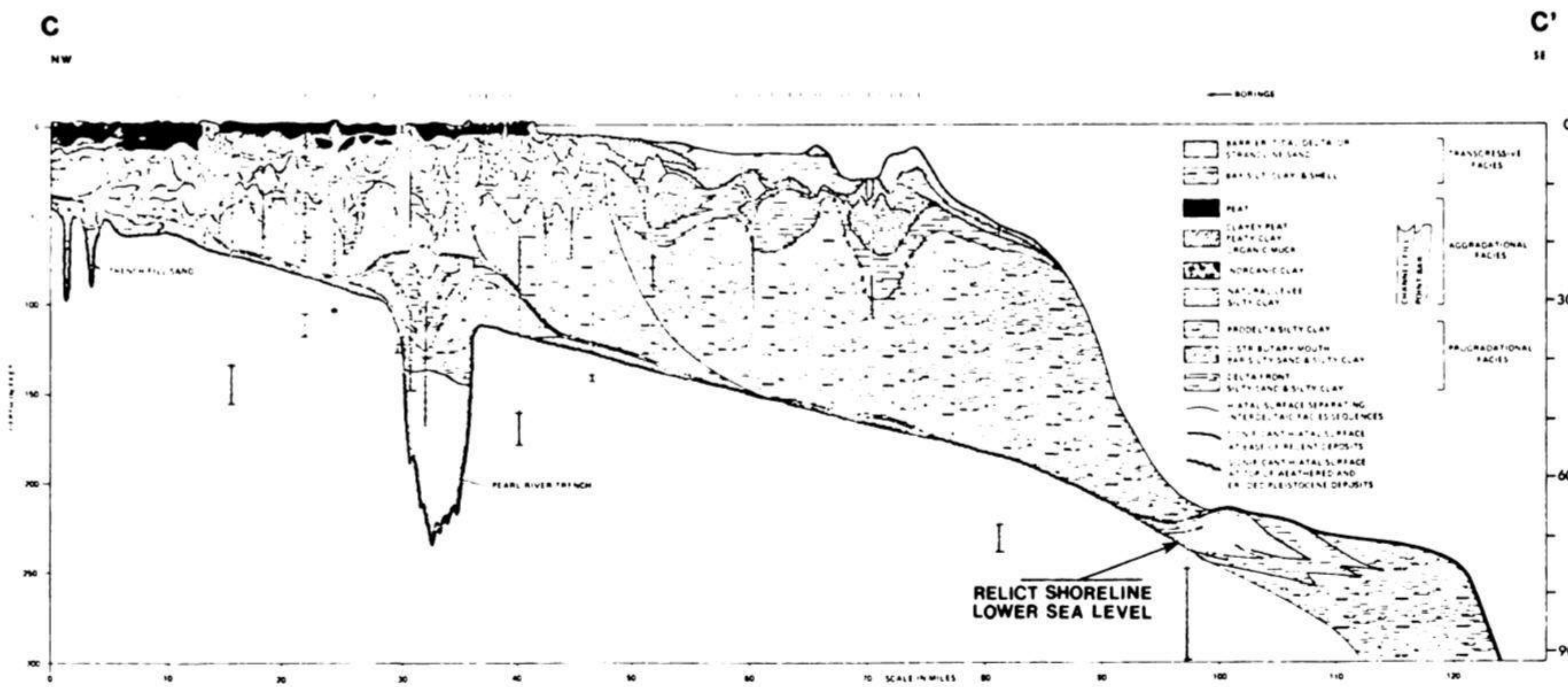
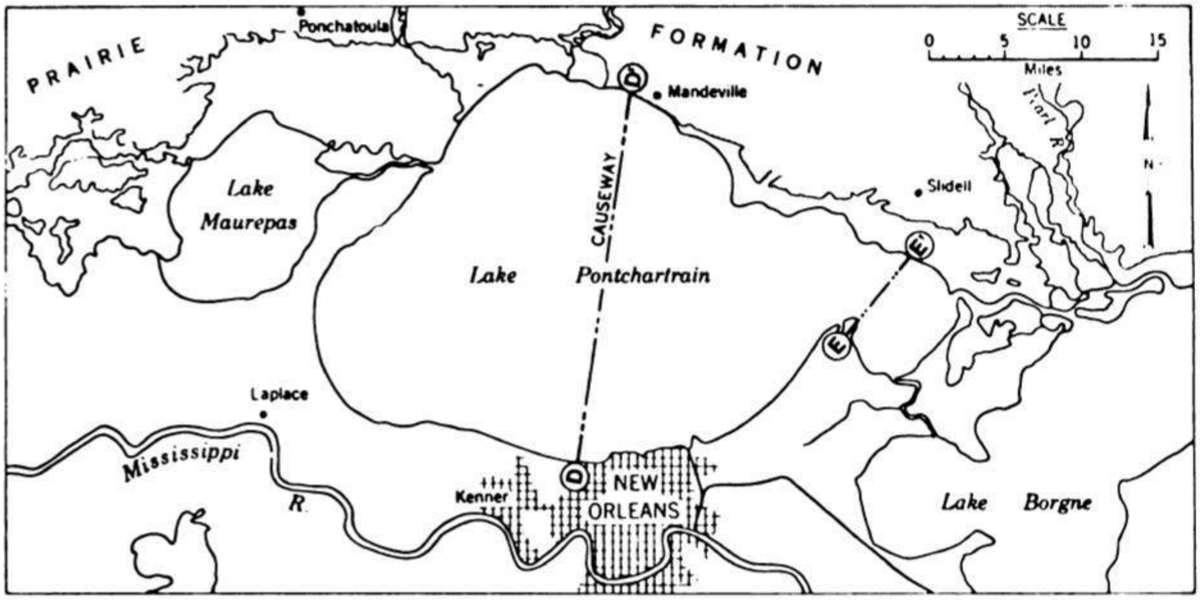


Figure 3-15. Section through St. Bernard delta complex. Note the thick burial of weathered surface and the distinctive character of the Pearl River trench. Location of Section shown in Figure 3-10. (After Frazier, 1974.)



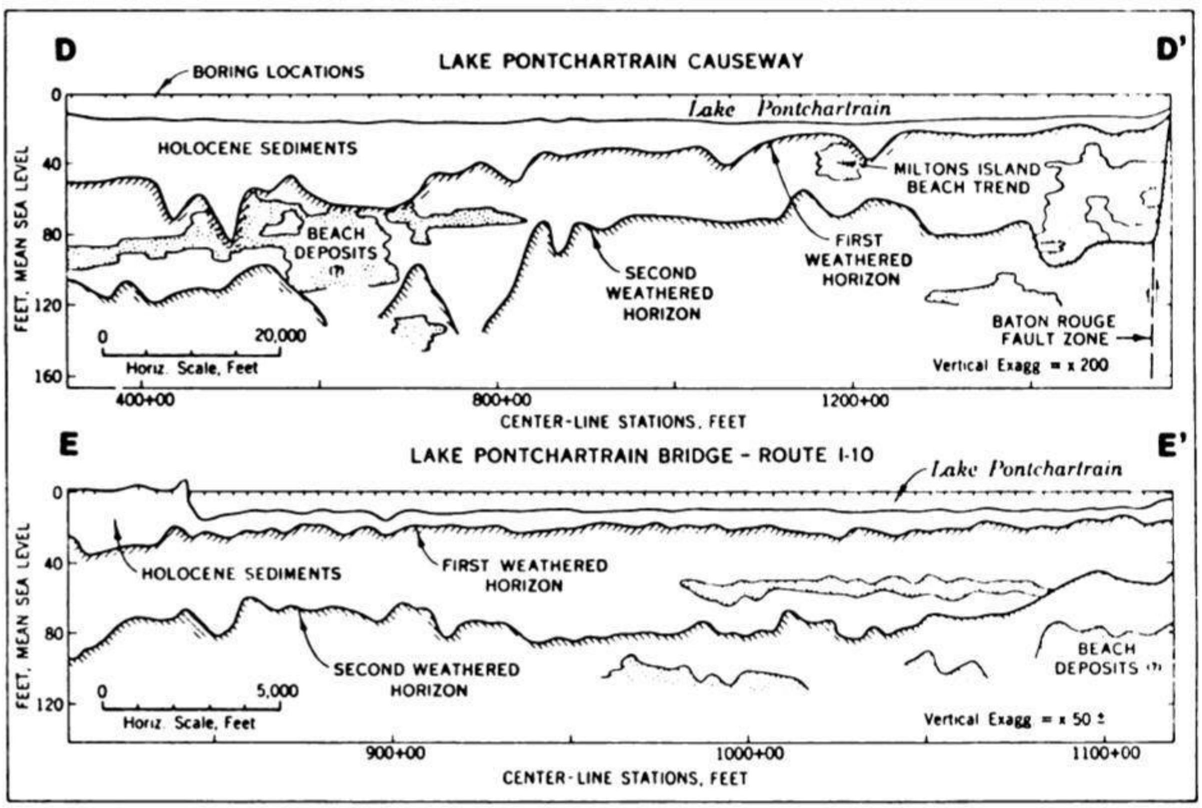


Figure 3-16. Pontchartrain Basin area cross-sections showing weathered horizons (After Saucier, 1977).

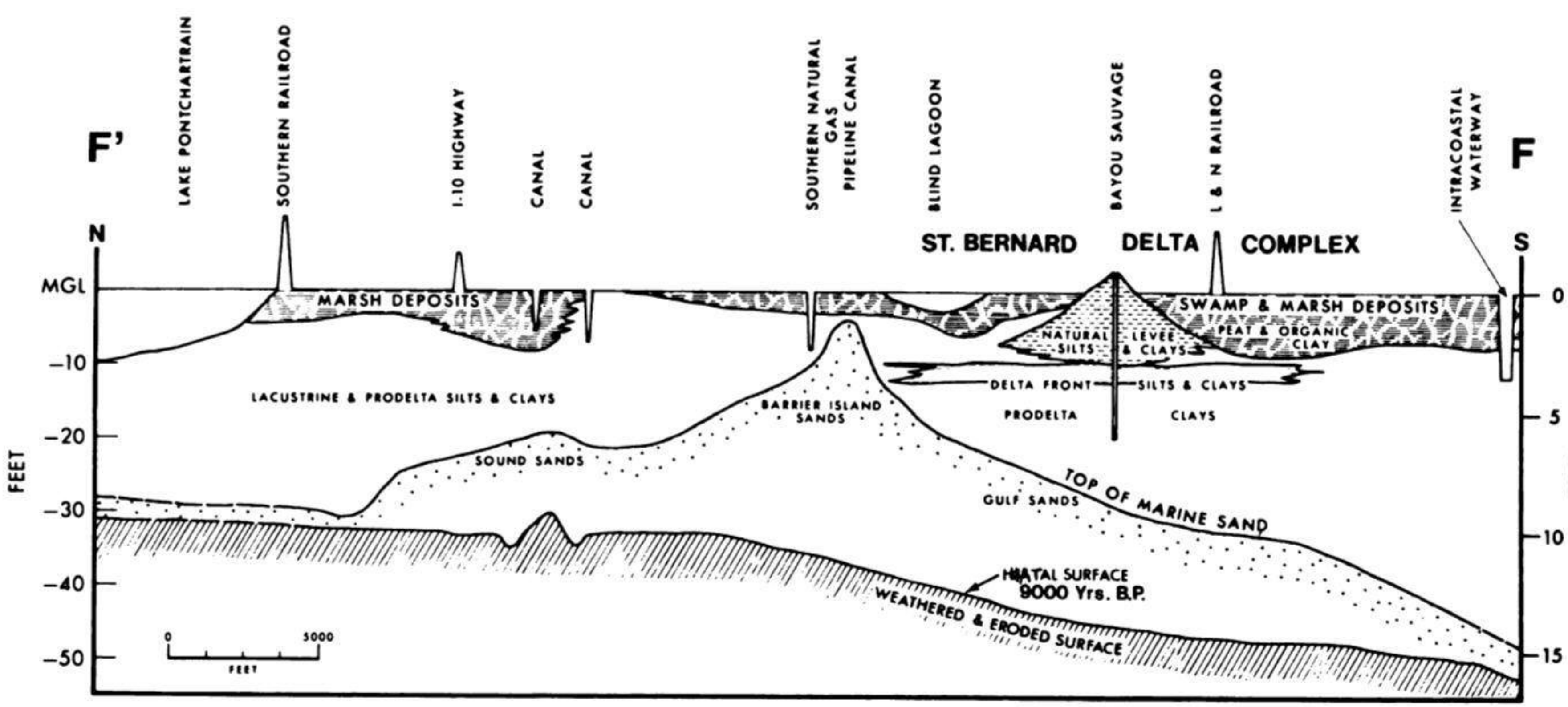


Figure 3-17. North-south cross-section through the New Orleans East area showing near-surface stratigraphy. Location shown in Figure 3-10.

and eroded surface. The barrier island is believed to have been active circa 5,000 years B.P. This feature was subsequently covered by sediment as the early St. Bernard Delta built out into the area.

Mississippi - Alabama - West Florida Area

This shelf area displays remarkably well-preserved relict topography. There are several factors related to its occurrence. The area is one of relatively high wave energy. Through much of Late Quaternary history it has been characterized by sandy coasts with relatively low input of fine-grained sediment. The combination of high energy and a good sand supply has resulted in the development of prominent barrier beach complexes. Another distinctive feature is a major re-entrant in the shelf. In the vicinity of Choctawhatchee Bay the shelf break lies only 40 kilometers from the present shore.

During the course of the present study, newly compiled bathymetric maps (Outer Continental Shelf Resource Management Maps) at a scale of 1:125,000 were published by the National Oceanic and Atmospheric Administration, National Ocean Survey. Using these maps, an interpretation of the large-scale relict topography of the shelf was made. The interpretative map along with profiles is presented in Figures 3-18 and 3-19.

There are several prominent deep-water features. The most important of these is the DeSoto Canyon, which is evident from the bowing of contours from depths of approximately -1,000 m to the canyon head at approximately -450 m. Immediately west of the DeSoto, three other canyon-like features occur in water depths from -1,250 to approximately -300 m. Of more immediate interest to the present study is a trough, or canyon-like feature, in shallower water depths near the edge of the continental shelf extending from approximately -250 m to -80 m. Lying due south of the present city of Pensacola, it is intimately related to a pronounced zone of carbonate knolls, relict shelf-

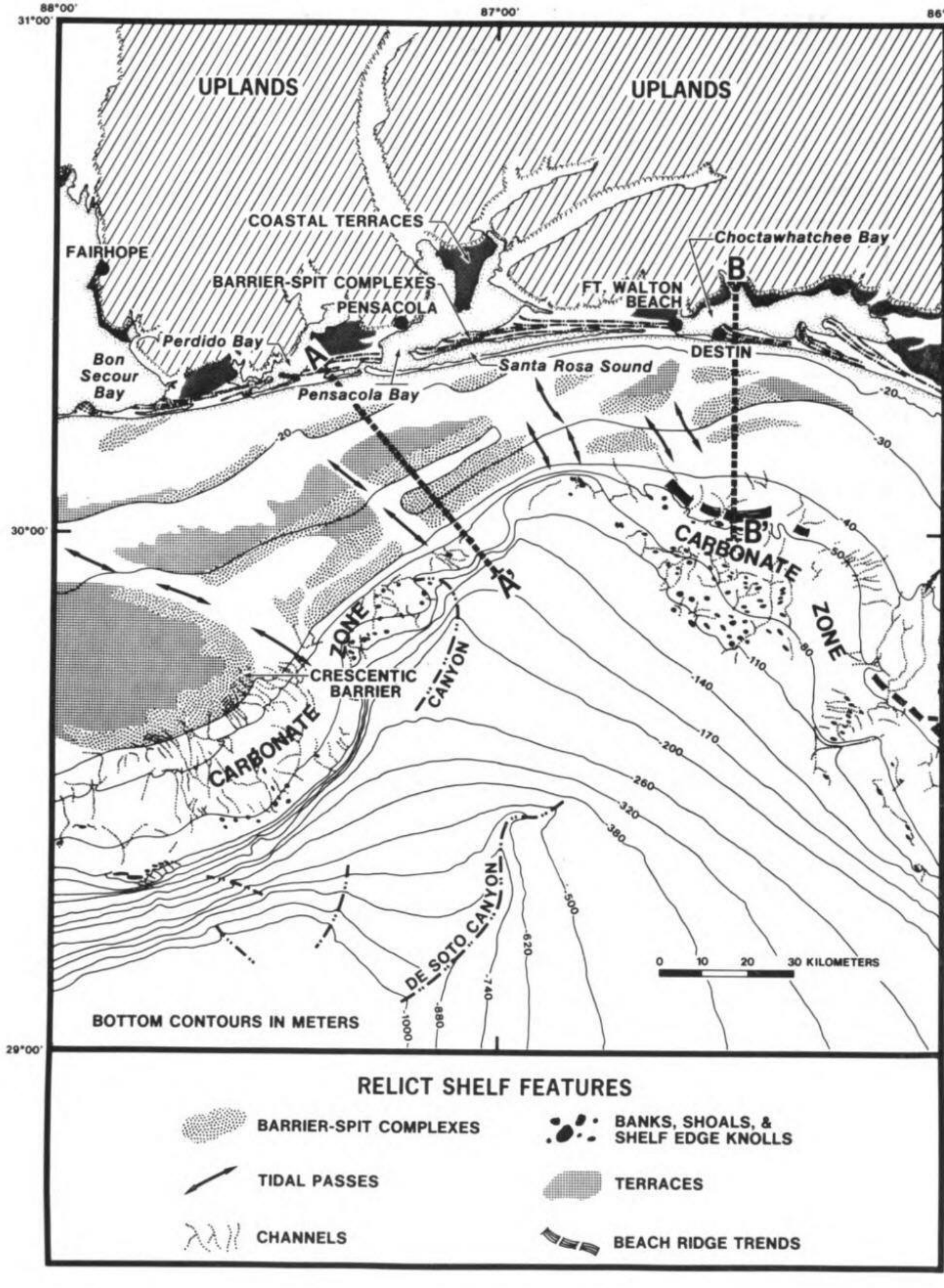


Figure 3-18. Interpretation of relict topography in the Alabama-West Florida area.

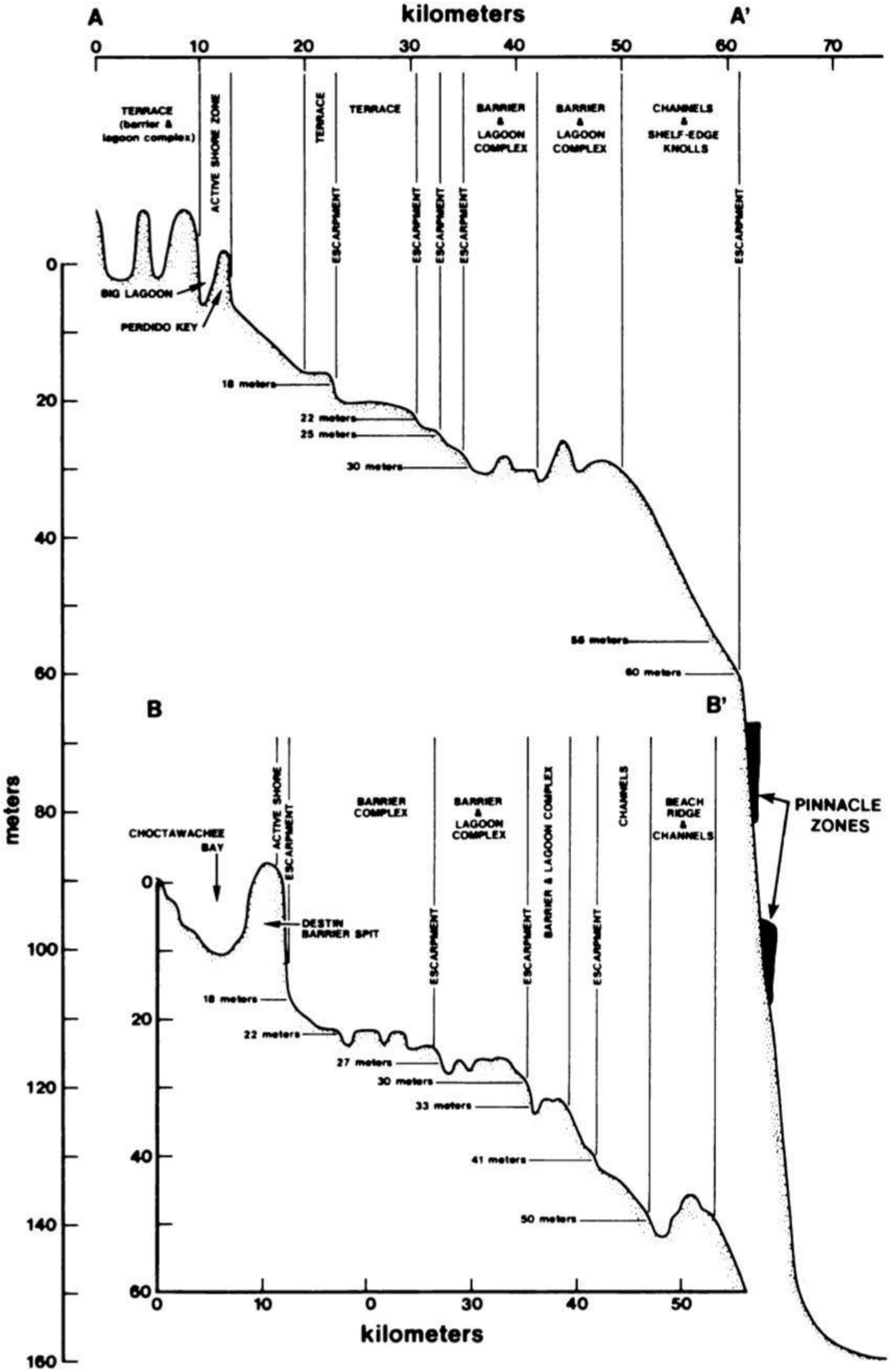


Figure 3-19. Profiles and interpretation of relict topography in the Alabama-West Florida area. Profile locations shown in Figure 3-17.

edge channels, and escarpments. Within this broad zone there are at least three distinctive sub-zones. The seaward terminus of the deepest channels lie in depths of approximately -120 to -130 m. Some of these channels tend to be branched or dendritic, their upper ends extending to about -80 m.

In between the channels are carbonate knolls, or pinnacles. These features have been previously described by Ludwick (1964) and Ludwick and Walton (1957). The reefs are clustered in zones approximately 1.5 km wide with an average relict of 9 m. Ludwick and Walton studied the pinnacles in the area from 85° to 88° west longitude. They found that where the pinnacles were present they were found usually at one or both of two depth zones, -68 m to -84 m, and -97 to -110 m (Figure 3-20). In the eastern part of the study area pinnacles were

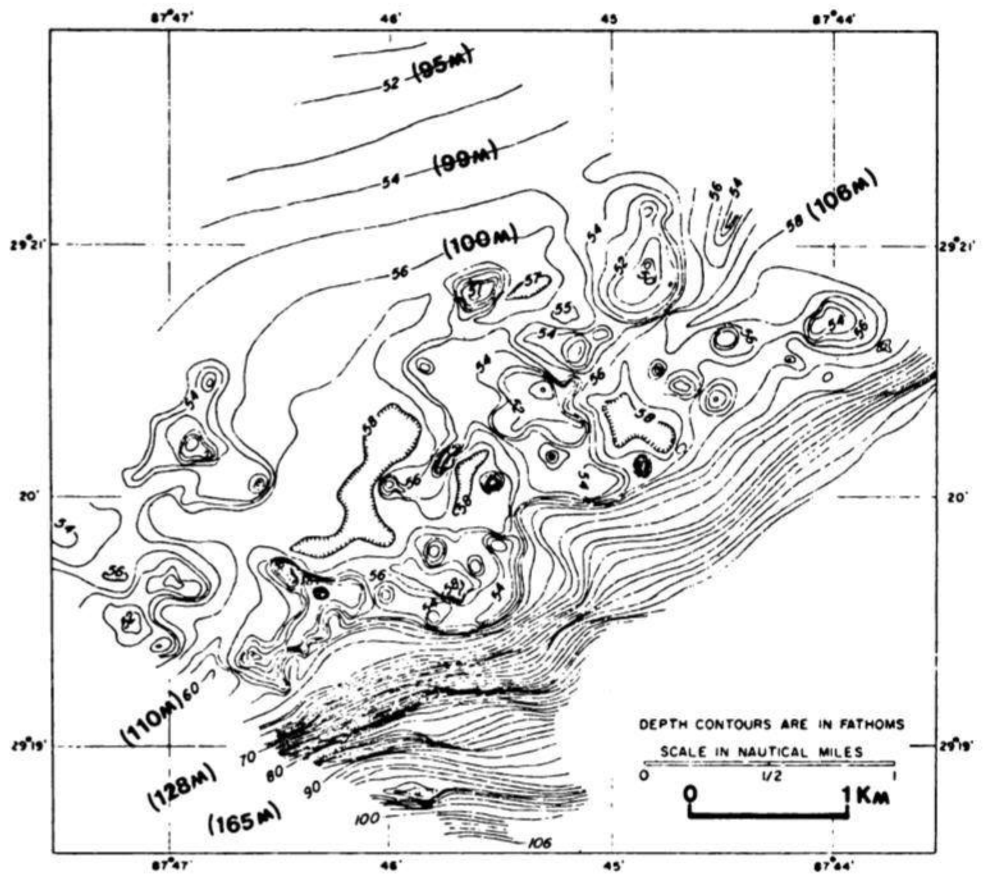


Figure 3-20. Bathymetric chart of lower pinnacle zone south of Mobile Bay, Alabama. Depth contours in fathoms. Supplemental notations in meters. (After Ludwick and Walton, 1957.)

found to be well developed and almost continuous. To the east, pinnacle development was found to be poor, replaced by humps and domes. Samples taken from the reef were found to be composed predominantly of calcareous organic structures such as worm tubes, encrusting Bryozoa and calcareous algae, solitary corals and Foraminifera. Among the most common constituents were calcareous algae of the genus Lithothamnion.

The reefs were found to be neither thriving or living reefs, nor wholly fossil, but rather an intermediate stage. They are believed to have become established as reefs during a period of lowered sea level. Ludwick and Walton (1957:2097) state that the depth of the water at the living reefs probably did not exceed -46 m and the shoreline was near the present day -55 m contour or about 15 km north of the reef. Reef growth in this area occurred simultaneously with reef development at similar depths found elsewhere in the Gulf of Mexico. The non-living "West Indian" foraminiferal fauna that occur in significant concentrations in the reef area are believed to represent conditions not unlike those existing at present in shallow areas off the coast of south Florida or in the Florida reefs.

The second sub-zone of escarpments, dendritic channels, and reef-like structures occurs in depths from -80 m to approximately -60 m. The escarpment is at approximately -80 m, and the dendritic channels extend inland from this. There are fewer knolls in this zone; their tops are at approximately -60 m.

A third sub-zone of branching, dendritic channels extends inland from about the -50 m contour to approximately the -40 m contour. South of Destin, barrier-spit complexes appear to be associated with this sub-zone and occur at depths of -46 to -48 m.

At depths between -30 and -36 m is the first in a series of continuous and very well defined barrier complexes. Traced laterally, this has the configuration of a double barrier. There is a barrier with a dune complex on the landward side that rises to elevations of approximately -27 m, giving the overall feature from 6 to 10 m of relief, falling off to depressions which probably represent an old bay. It then rises again to a second barrier and dune complex behind which is a second depression suggesting a former lagoon. Along strike, the smooth, well-defined form of the barrier is broken periodically by what are believed to be tidal scour features representing old tidal passes or inlets. Here the trend of the ridge and trough topography is transverse to that of the general shoreline. No doubt, submarine erosion has continued in these depressions or tidal scour areas even after inundation of the barrier lagoon shoreline.

Perhaps the most remarkable feature in this area, and among the most striking on the shelf of the northern Gulf, is a very large relict, barrier complex lying south of Bonsecour Bay. The barrier is more than 50 km long, crescent or barchan shaped. The distance between the horns of the crescent is some 45 km. Bathymetric contours indicate a more or less continuous ridge extending around the crescent with a crest at depths of -30 to -38 m. These are probably remnants of coastal dunes that were formed when the feature was active and that have been subsequently modified by submarine erosion. Lying landward of this "dune ridge" is an area of highly irregular bottom topography characterized by hills and troughs. Some enclosed depressions have depths ranging from -42 to -36 m. This may have once been an extensive coastal dune field.

Connected to the southwestern horn of the crescent-shaped barrier is an accretion fan of relict beach ridges. The ridges and bars of the fan branch out toward the west.

Inland from the double barrier, at depths from -26 to -36 m, is another barrier-lagoon complex at depths between -25 and -27 m. Another set of escarpments and barriers occurs at a depth of approximately -22 m. A final set lies at a depth of approximately -18 m. The -18, -22, and -27 m shorelines trend into the present shoreline and intersect the present shoreline at an acute angle.

It appears that the shoreline area east of Destin has been coincident or reoccupied at several times during the Late Quaternary. A number of high-probability areas for site occurrence should be found in this area of the continental shelf related to the relict features just discussed.

Hyne and Goodell (1967) have previously described the innermost submerged barrier complex off Choctawhatchee Bay. In their paper, they noted the trends of submerged barrier complexes at -18 m and -27 m.

Still another feature that should be noted in this area is the reported occurrence of a submerged pine forest west of Panama City. Here, divers have found _in situ_ tree stumps at a depth of -18 m. Radiocarbon dates of 36,500 and > 35,700 years B.P. have been obtained from wood samples, while a peat sample after thorough leaching of humic acids yielded a date of > 40,000 years B.P. (Shumway _et al._, 1962).

Relict shorelines trend at an angle across Mississippi Sound and are truncated and reworked by the present active barriers forming the outer margin of Mississippi Sound. The sands of these modern barriers have been derived from the reworking of older, now-drowned trends. A remnant of one such trend can be seen on Ship Island. This reworking of barrier trends of different age also accounts for the notable difference in heavy mineral suites found on each of the Mississippi islands as reported by Foxworth _et al._, 1962. In the onshore area of Mississippi Sound the present coast is characterized by a major relict barrier-island and lagoon system. These have been described in some detail by Otvos (1972) who believes that they are Sangamon in age (Figures 3-21 and 3-22). Similar barrier lagoon features extend along the eastern Alabama and west Florida coasts. A series of pronounced hooks or recurve spit complexes

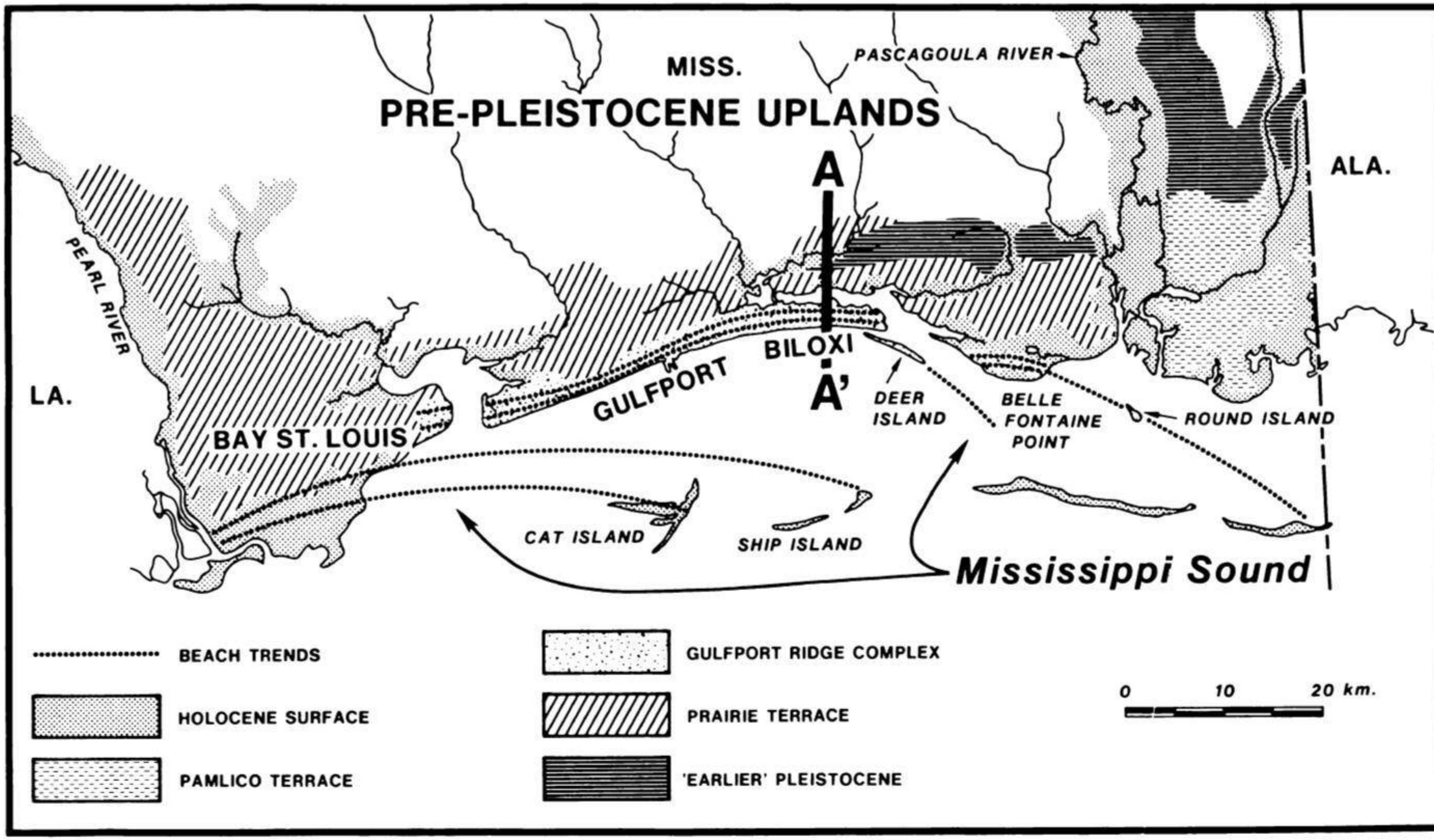


Figure 3-21. Quaternary geological features of the Mississippi Gulf Coast area.

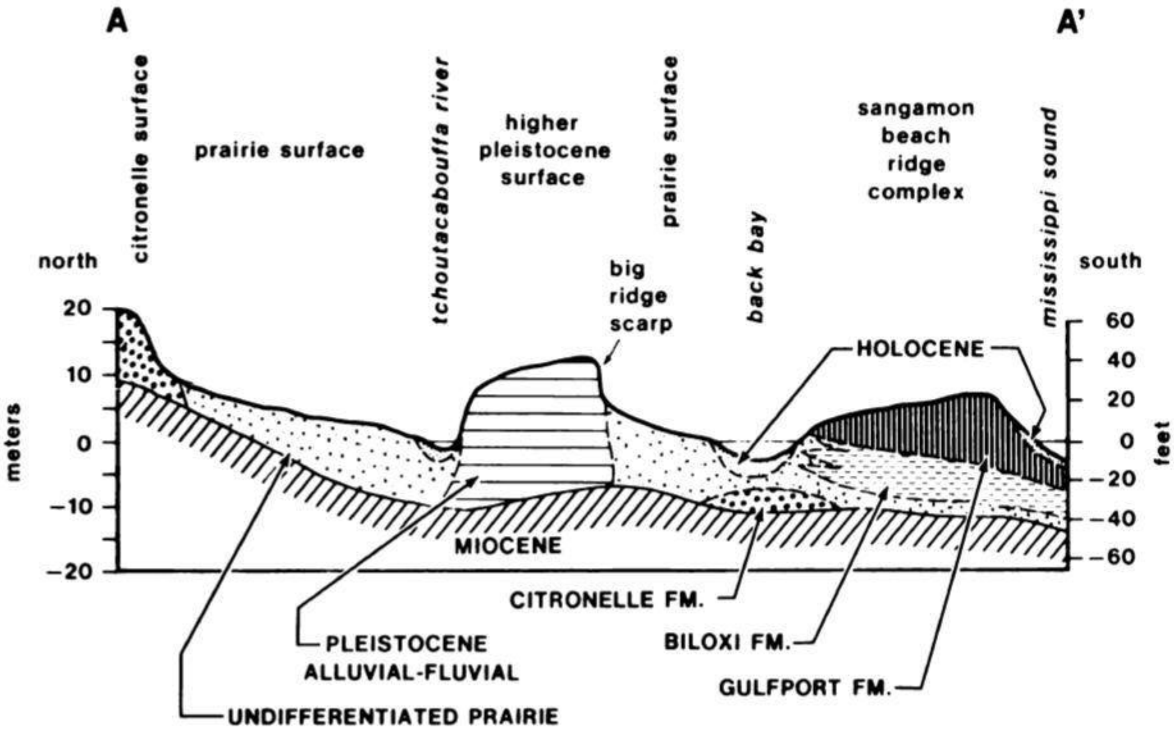


Figure 3-22. Generalized cross-section through the central Mississippi Gulf Coast area. Location of section shown in Figure 3-20. (Modified from Otvos, 1972.)

on these old barriers in Choctawhatchee Bay suggests that this water level has been at this shoreline at least three times.

To the east of the present floodplain of the Pascagoula River is a well defined relict floodplain of the same river. As shown in Figure 3-22, the area is morphologically well defined. From oldest to youngest they consist of the Prairie Terrace, a slightly lower surface distinguished by relict floodplain features called the Pamlico Terrace (Harvey and Nichols, 1960), the Deweyville Terrace, distinguished by relict meander and scars of large radius; and the Holocene floodplain and coastal marshes. Saucier (1977) suggests that the relict Pascagoula floodplain is a Farmdalian feature (Figure 3-23). While there are no radiocarbon dates from the terrace deposits of this area, the morphologic relationships of the various terraces identify it as a key for unraveling the Late Quaternary sequence.

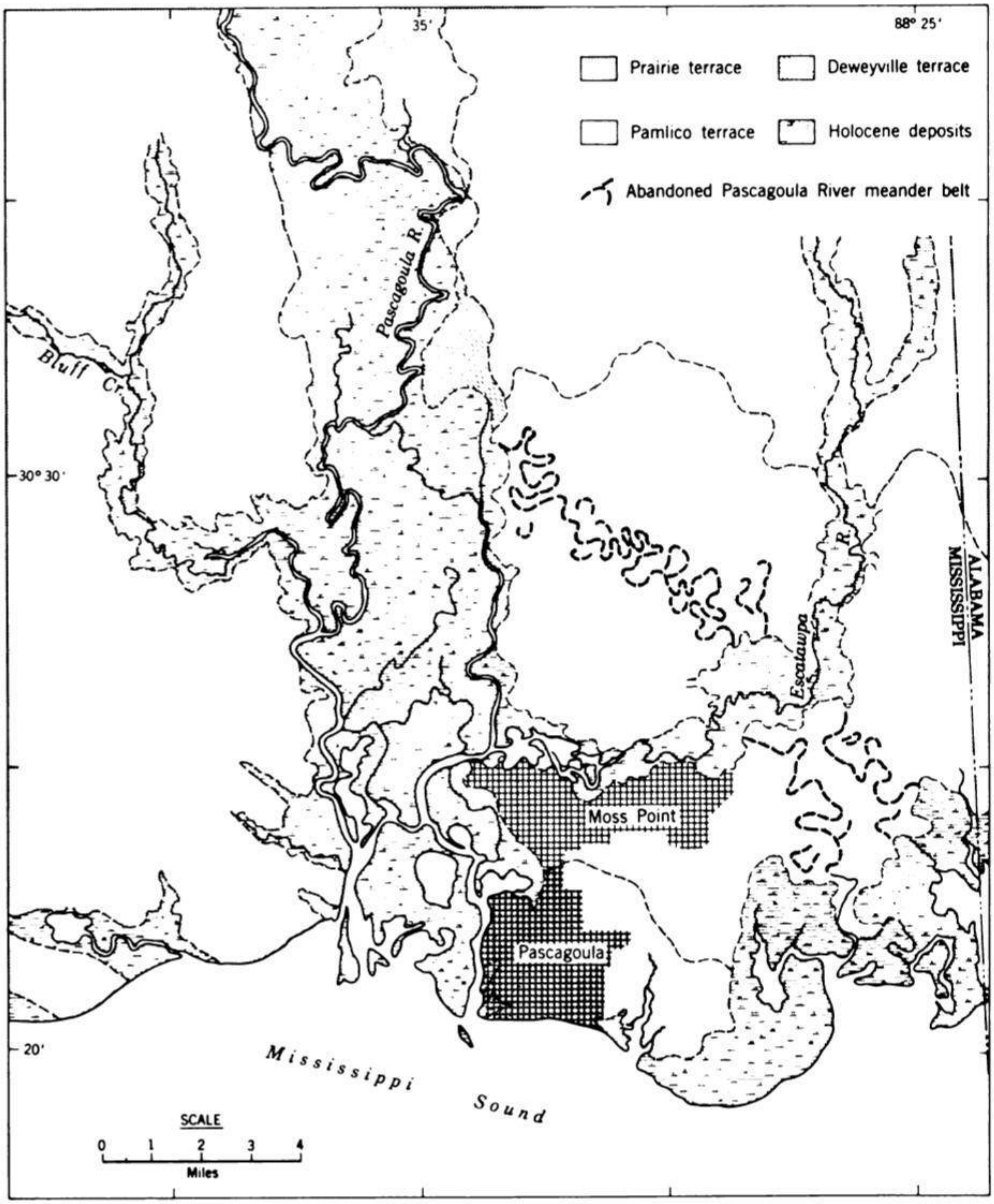


Figure 3-23. Terraces of the Pascagoula River area. (After Saucier, 1977.)

West-Central Florida Area

Beginning at water depths of -145 and -135 m is the first of a series of bulges that characterize the shelf edge in west-central Florida. At least six of these shelf-edge bulges occur; the uppermost lies at a depth of about -70 m. Jordan describes these features in a 1951 article and illustrates fathometer profiles showing surface form. From the configuration of the contour lines and the fathometer profiles it is not too difficult to interpret these features as a special type of barrier-spit complex. They are interpreted here as relict cuspate-foreland islands similar to the present-day complex which exists in the vicinity of the Apalachicola Delta (St. Joseph Spit, Cape San Blas, St. Vincent Island, Cape St. George, St. George Island, and Dog Island - see Figure 3-24. Figure 3-25 is a location map for Figures 3-26 and 3-27. Profiles A and B of Figure 3-26 provide examples of barrier islands separated from an inner shore by a shallow relict bay or sound. On Profiles A the ridge and swale topography above -95 m probably represents an accretion ridge set on the shore side of the former bay.

Profiles C and D of Figure 3-26 appear to represent a beach or barrier ridge directly against the shore (bay-sound absent). Examples of barriers, accretion topography and pronounced escarpments can also be seen in Profiles E-G of Figure 3-27. Depths of sea levels suggested by the profiles are as follows: Profile A, -95 to -105 m; Profile B, -117; Profiles C and D, -120 m; Profile E, -134 m; Profiles F and H, -75 m; and Profile G, -70 m.

Schnable and Goodell (1968) have interpreted the Late Quaternary history of the area in the vicinity of the Apalachicola River (Figure 3-24). Deltaic sedimentation has resulted in pulses of progradation. Because of an abundant supply of sand and relatively high wave-energy conditions, major cuspate barrier complexes have formed in the vicinity of the river. The deltaic sedimentation has created the fortunate situation where the sandy deposits of older Pleistocene beach complexes are preserved and separated by fine-grained

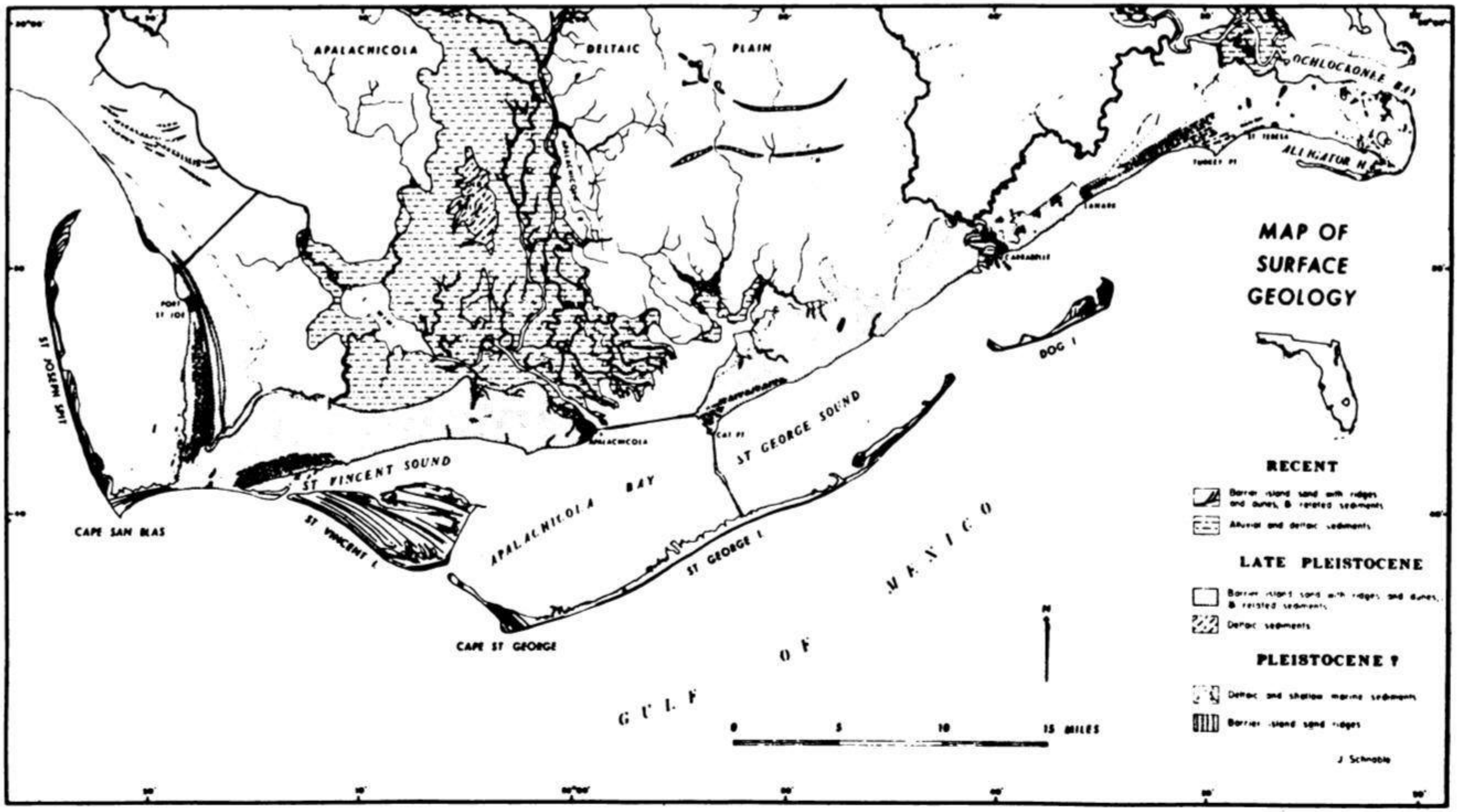


Figure 3-24. Surface geology of the Cape San Blas to Alligator Harbor area, Florida. (After Schnabel and Goodell, 1968.)

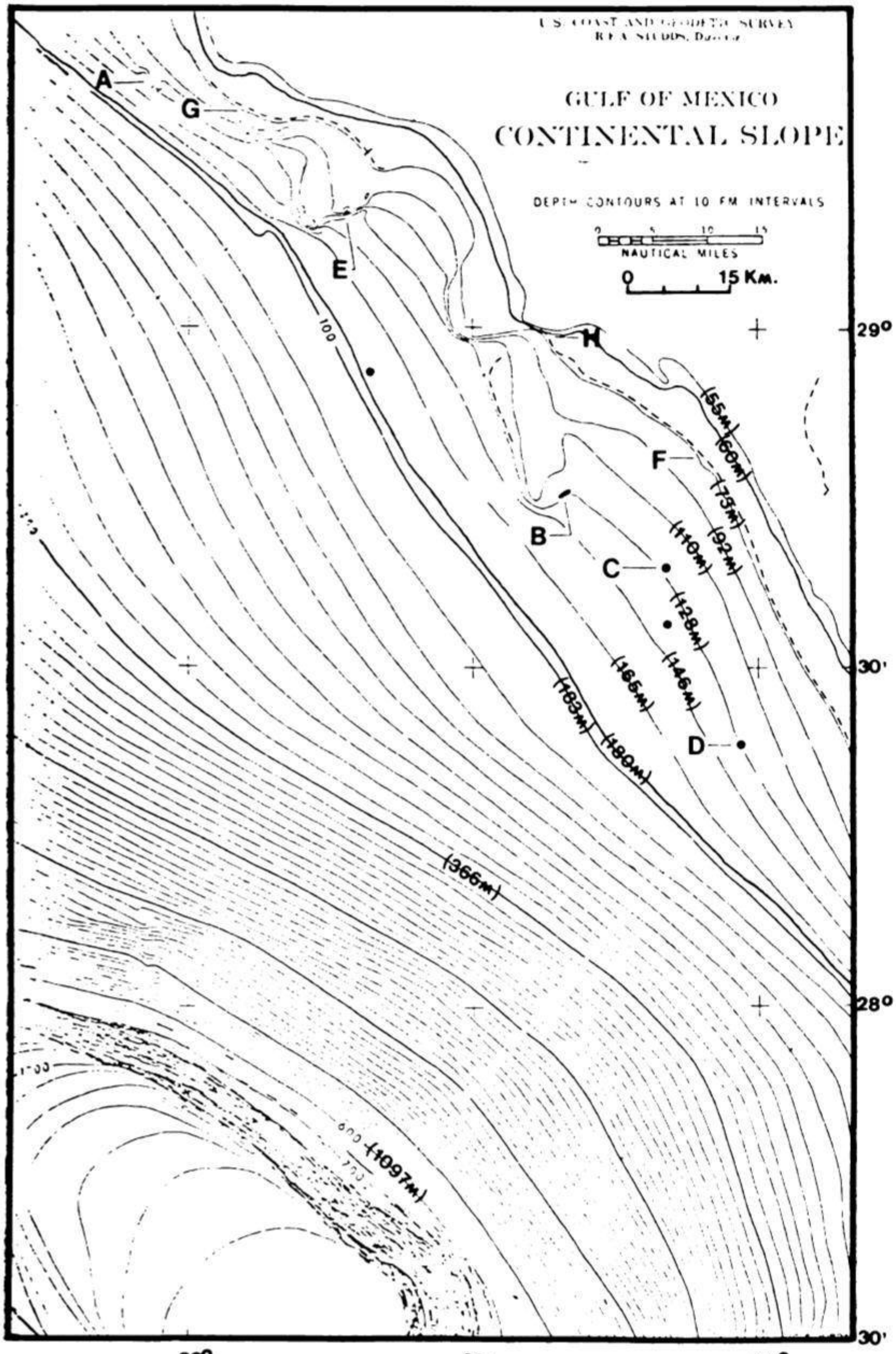


Figure 3-25. Bathymetric chart of shelf-edge bulge and related features south of Panama City, Florida. Depth contours in fathoms. Supplemental notations in meters. (After Jordan, 1951).

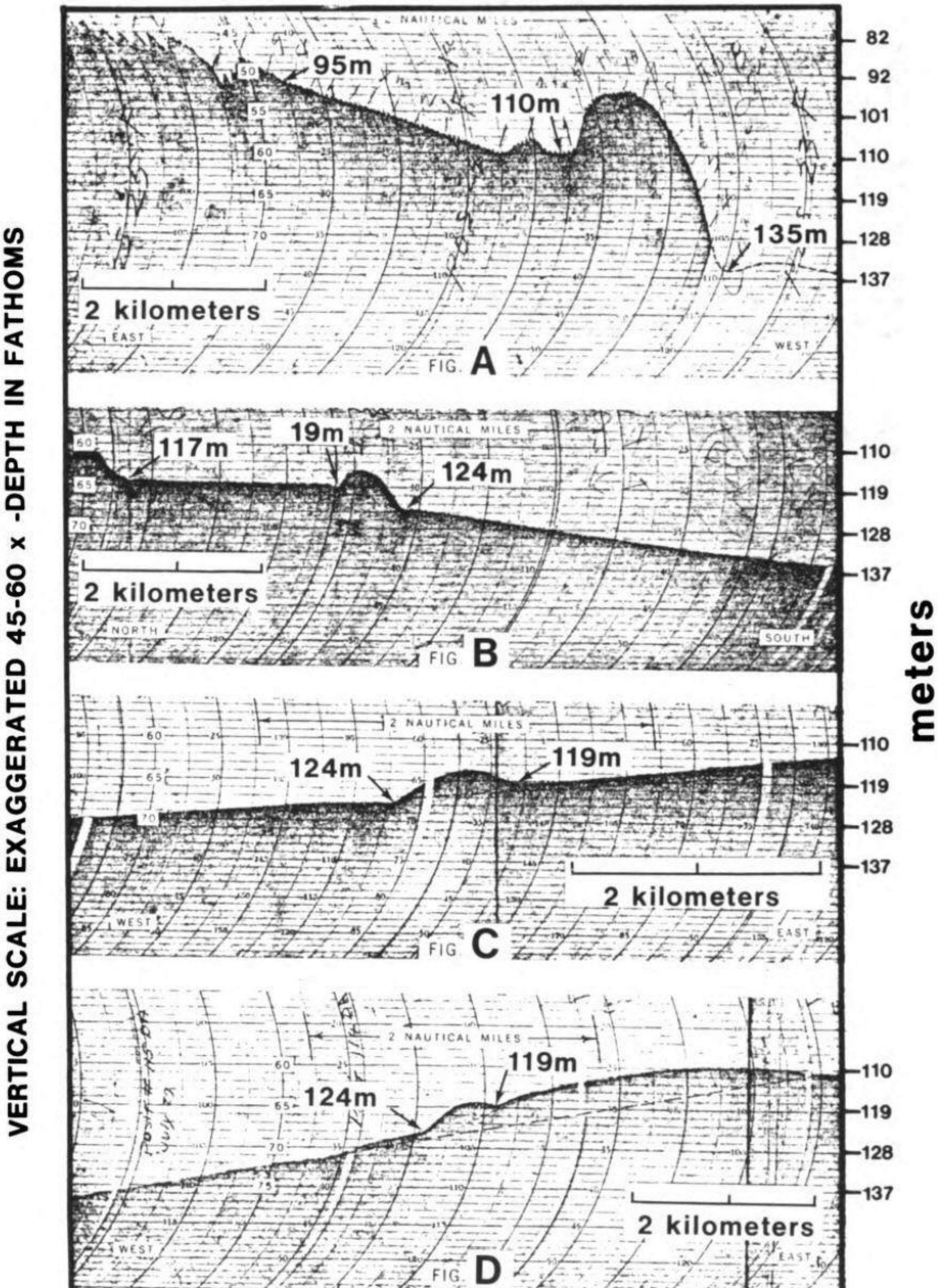


Figure 3-26. Bathymetric profiles of shelf-edge bulges and related features. For locations see Figure 3-24. (After Jordan, 1951.)

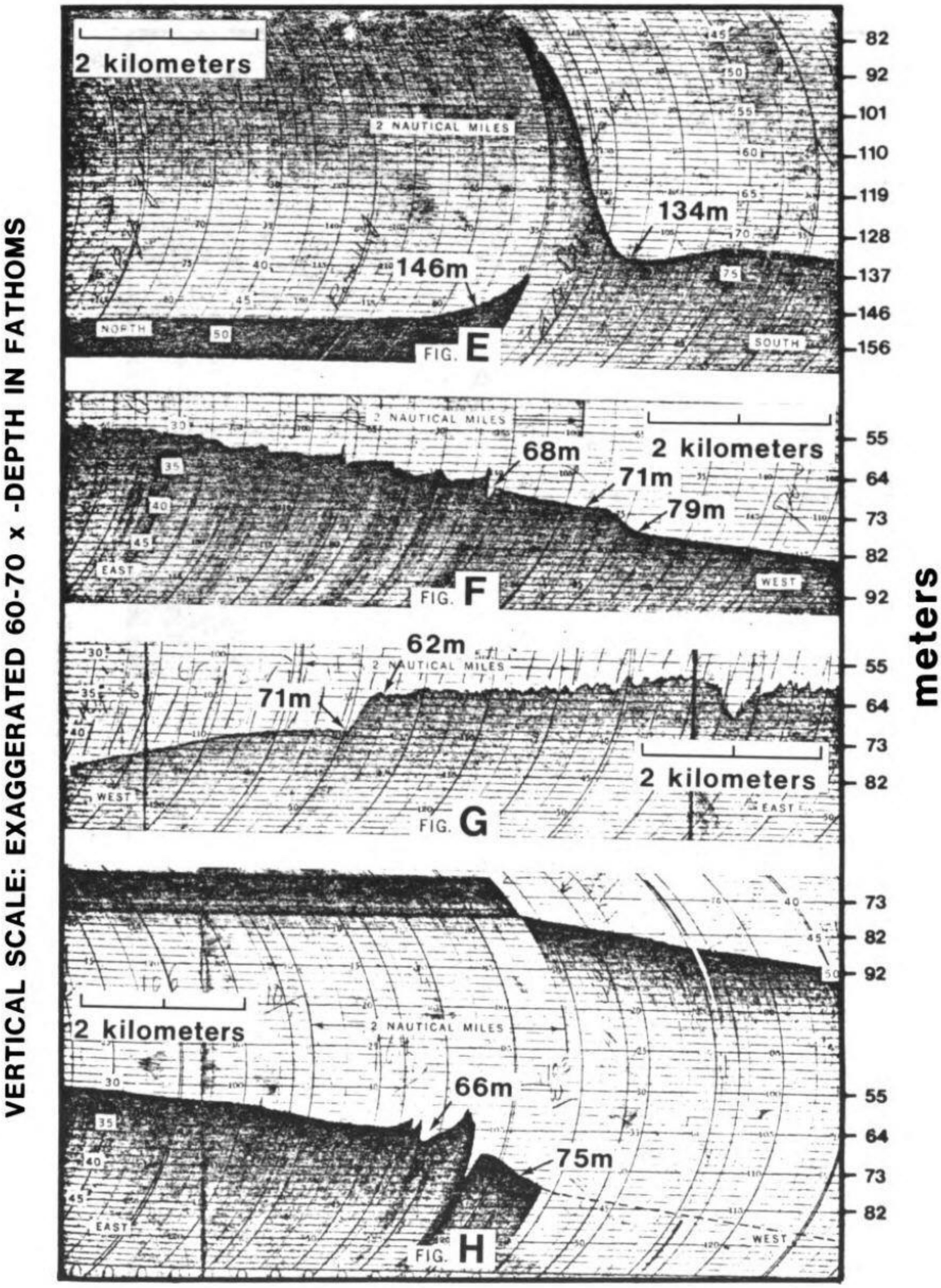


Figure 3-27. Bathymetric profiles of shelf-edge bulges and related features. For locations see Figure 3-24. (After Jordan, 1951.)

deposits. As shown in Figure 3-24, at least three sequences of beach complexes have been identified. Numerous undisturbed cores have been taken through the sequence. Radiocarbon dates, stratigraphic relationships, and environmental interpretation suggest that the large "middle" complex of beaches was formed during a relatively high stand of the sea that was near, or slightly higher than, the present sea level between 24,000 and 40,000 years B.P. Schnable and Goodell believe that the middle beaches correspond to the Silver Bluff shoreline of Florida and Georgia. Saucier (1977) cites these features in support of a relatively high sea level stand during the mid-Wisconsin Farmdalian substage. However, as discussed in Chapter 4 of this volume radiocarbon dates from this time interval have been questioned by other researchers.

The borings also reveal the position of a filled trench of the Apalachicola River. As shown in Figure 3-28, the base of the trench is cut into lithified limestone of Miocene age. Rangia cuneata shell samples collected just above the Miocene-Recent unconformity at the base of the beach (-22 m) yielded a radiocarbon date of 9,950 $\pm$ 180 years B.P.

Landward of the Farmdalian beach complex are remnants of one or more older complexes of beach ridges (Figure 3-24). These are considered to be Pleistocene by Schnable and Goodell.

Central Florida Area

This area forms the northern part of the Florida Plateau, a broad, flat area underlain by relatively stable limestone. The outer shelf consists of what Price (1954) has termed the downwarped shelf (Figure 3-29). This is a terrace-like feature lying between the -200 and -100 m contours. According to Gould and Stewart (1955), the landward margin of this outer shelf is marked by a set of terraces at -100 to -120 m. Local relief on the terrace is 2 to 6 m. Apparently the -120 m terrace is wave-cut and marks the lowest Pleistocene

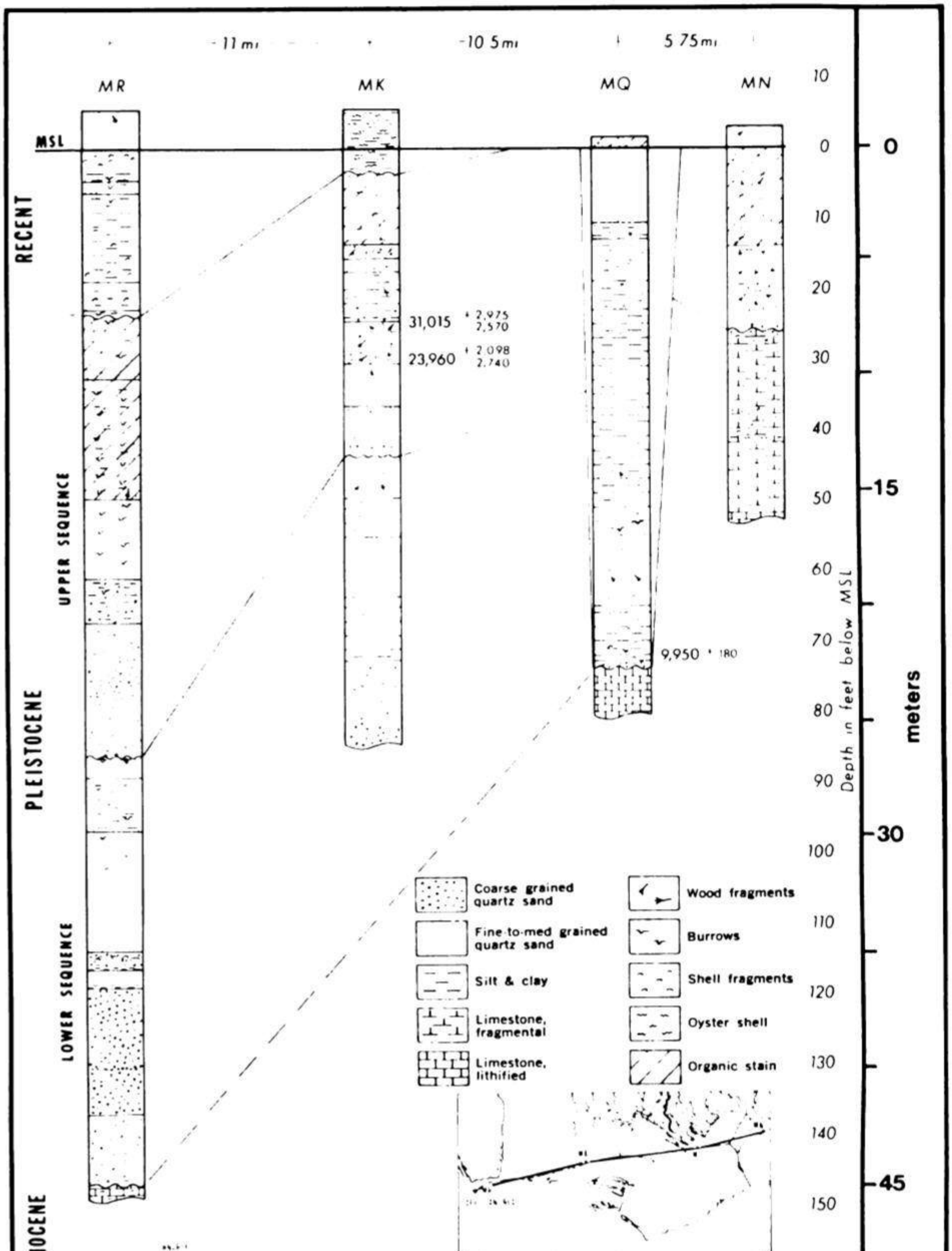


Figure 3-28. Cross-section from Cape San Blas to Cat Point, Florida. (After Schnabel and Goodell, 1968.)

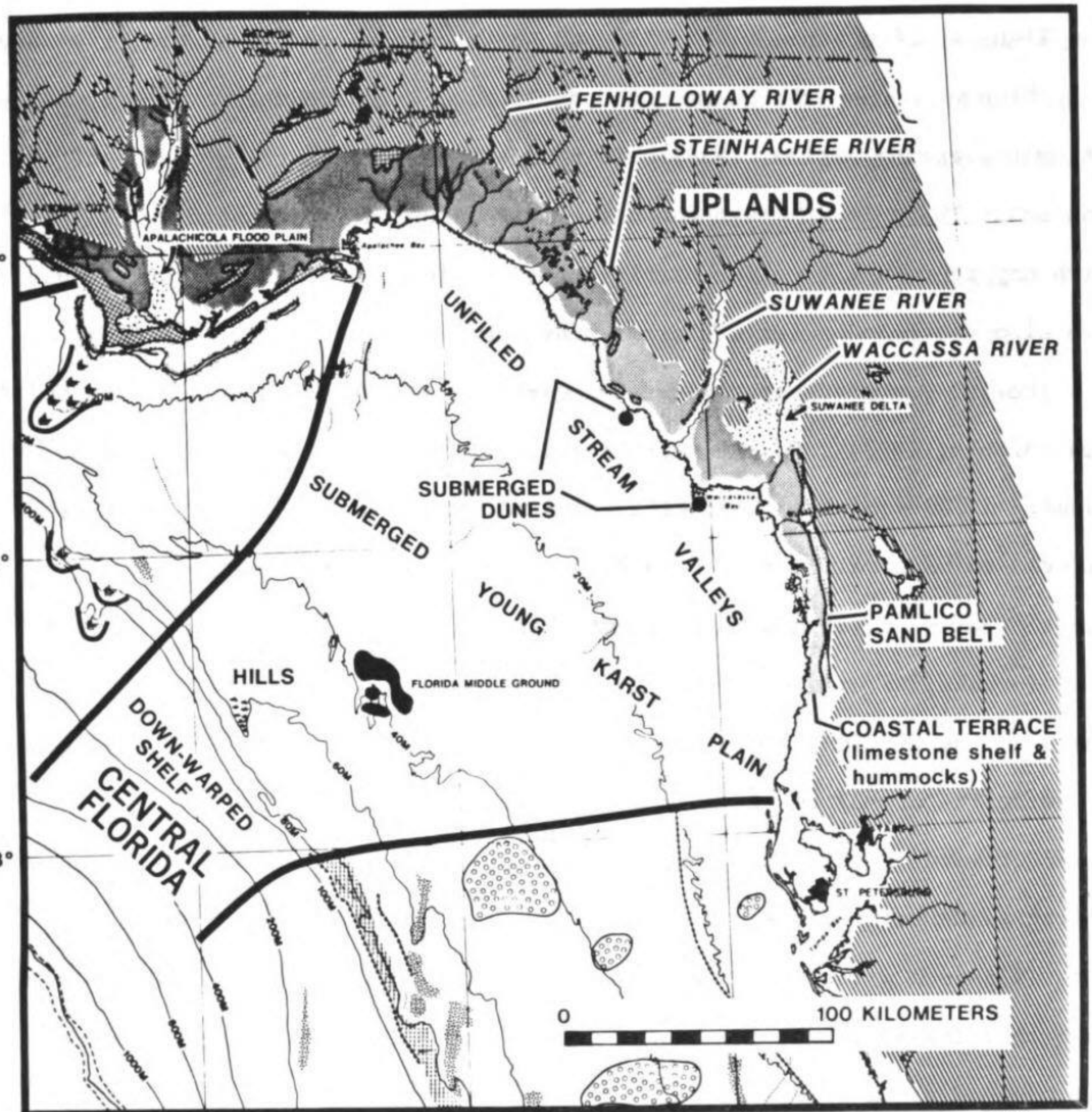


Figure 3-29. Major geomorphic features of the Central Florida area.

sea level (Bergantino, 1971). In the central Florida area, the outer shelf is relatively narrow, but it broadens and has more complex surface topography to the south.

Tight spacing between the -100 and -85 m contours defines a major escarpment which separates the downwarped shelf from a zone characterized by hilly bottom topography (Price, 1954). This zone lies between the -80 and -40 m contours. There is at least one nose-like protuberance at approximately -60 m, which may represent a relict barrier-spit complex. Gould and Stewart (1955) have also described a set of terraces at the -65 to -85 m level.

The -40 m contour approximates the outer edge of the Middle Ground Uplift area (Brooks, 1973). On the edge of this uplift area is the Florida Middle Ground, an 800-square km reef with local relief up to 10 m. This feature is believed to be a relict reef from Pleistocene time upon which two or more meters of worm algal and coral growth has developed during the past 7,000 years (Brooks, 1974:302). Reefs have been described by Jordan (1953) and others in the Florida Middle Ground area. Many isolated reefs rise from general bottom depths of -37 to -44 m to a common depth of -26 m.

Shoreward of the -40 m contour, the shelf can be described as a gently sloping, submerged young karst plain. This part of the shelf, for the most part, is smooth with relief of as little as 5 to 6 m being rare. Karst topography characterizes the bottom within 50 km of shore, and it is here that maximum local relief occurs.

The coast in the vicinity of Homosassa Bay, about 80 km north of Tarpon Springs, Florida, consists of flat limestone, extensively pitted with sinkholes and lacking sandy barriers. The sinkholes apparently developed during intervals of lower sea level (Shepard and Wanless, 1971).

To the northwest the Suwanee River and the Fenholloway River also pass through flat limestone terrain and discharge onto a very gently sloping limestone shelf with exceptionally low wave-energy conditions. Tanner (1960) has classified this as a zero energy coast. This general area has well-developed oyster reefs. The streams are all entrenched into the carbonate rocks; some can be traced for about 6.5 km, where it is about 5 m deep. At this distance offshore, water depths on either side of the channel are only about 1.2 m deep. Erosion of the shallow marine bottom is so negligible that even micro-scale tidal current channels in the more shallow (less than 2 m) embayments have been maintained as enduring features of the bottom (Shepard and Wanless, 1970).

There are no areas in the marine environment of the karst where sedimentation has occurred during Late Holocene times. This of course is the result of the sediment starvation of the area. First, there is a lack of quartzose rock or clayey deposits within the drainage basins which empty into the area. Second, although there is a relatively high level of precipitation, the gradient of the streams is very slight, minimizing flow velocities and erosion capacity. Finally, the predominant rock formations, composed of limestone, are soluble in water.

Erosion of the shoreline itself is also negligible. The limestone formation presents a hard surface to any physical effects, and there is an absence of sand and sediment to be transported. The shoreline is eroded, however, during drastic changes such as a hurricane storm surge which both raises the water level in the Gulf and creates higher-energy waves to impinge upon the shore. This increased level of wave energy can cross the shelf and be focused upon a level of the shoreline seldom exposed to wave energy.

The coastal terraces in this area are simply an onshore continuation of the offshore, low-relief young karst plain. These terraces are virtually flat with innumerable sinkholes. A few hummocks represent inactive dunes. On the east side of the area there is a distinctive boundary between the low coastal terrace and older uplands (some of which are undifferentiated Pleistocene coastal terraces). The boundary is marked by the Pamlico Sand

Belt, interpreted to be a beach-dune shoreline feature possibly equivalent to the Igleside shoreline.

In the central part of the area, between the Waccassa and Fenholloway Rivers, this old shoreline loses definition where it merges into a riverine coast. In this segment a relict delta of the Suwannee River has been identified by previous researchers.

The Uplands surface is also characterized by numerous well developed sinkholes.

Sinkholes are of three general types: the collapse sinkhole, the solution sinkhole, and the aquifer sinkhole. The collapse sinkhole (Jon et al., 1972) occurs where the limestone roff has caved into a void created by the solution of limestone. A solution sinkhole (or doline) occurs where a soil mantle settles into the sinkhole at the same rate that the limestone is dissolved away at the bottom. The most prevalent in Florida is the aquifer sinkhole where the water table is high and erodes the overlying sediment and surrounding soil into the sinkhole. This results in sediment becoming trapped in the aquifer system, and none being supplied to the Gulf for marine deposition.

Paleo-Indian projectile points and bones of extinct Pleistocene vertebrates have been found in many of the sinkholes and at numerous locales within the bottoms of rivers and from river margins both within the uplands and coastal terrace of this area (Neil, 1964).

North of Tampa there are many sand dunes which occur as isolated features, in groups, and as extensive dune fields. The more isolated forms are usually giant U-shaped or parabolic dunes, which reach widths of as much as 3 km and for the most part lie seaward of the Pamlico scarp (approximately 8 m). Some are partially drowned, being wholly or partially surrounded by sea water. Examples of drowned dunes are the Cedar Keys in Levy County and Horseshoe Beach in Dixie County.

The dunes are now largely inactive. All seem to have been nourished by beach-derived sands. Beaches are generally absent from this part of the Florida coast at present, and it is characterized by a marshy, poorly defined shoreline developed over shallow carbonate rocks. The submerged dunes were probably supplied by a pre-modern beach built at a lower sea level.

These drowned parabolic dunes must have formed after the Silver Bluff shoreline. Had they been present during Silver Bluff times, they would have been destroyed by marine erosion or covered by marine sediment during that period.

Dunes on the coastal terrace obsecure the Pamlico scarp north of Tarpon Springs and are believed to have formed during the time of a shore lower and later than the Pamlico. Orientation of the dunes suggests that they were formed by a southwest wind.

South Florida Area

The outer shelf of South Florida consists of an extensive terrace-like area, which is believed to be a downwarped part of the continental shelf (Figure 3-30). The downwarped shelf lies between the -200 and -100 m contours.

Beginning at about -120 m, it has a series of intermittent ridges along its outermost edge. These ridges may have a relief of as much as 18 m. Perhaps the best known of the ridges is Howell Hook, which has been described by Jordan and Stewart (1959) as a residual barrier-spit complex formed when Pleistocene sea level was at its lowest stand (Figure 3-31). The other ridges have been interpreted as barriers and bars from approximately this same time (Bergantino, 1971).

Jordan and Stewart (1959:980-1) describe Howell Hook as ". . . an arcuate ridge 65 miles (105 km) long impounding a 'lagoon' with a pronounced 'lagoon channel'. . . The ridge crest and the bottom of the 'lagoon' are generally

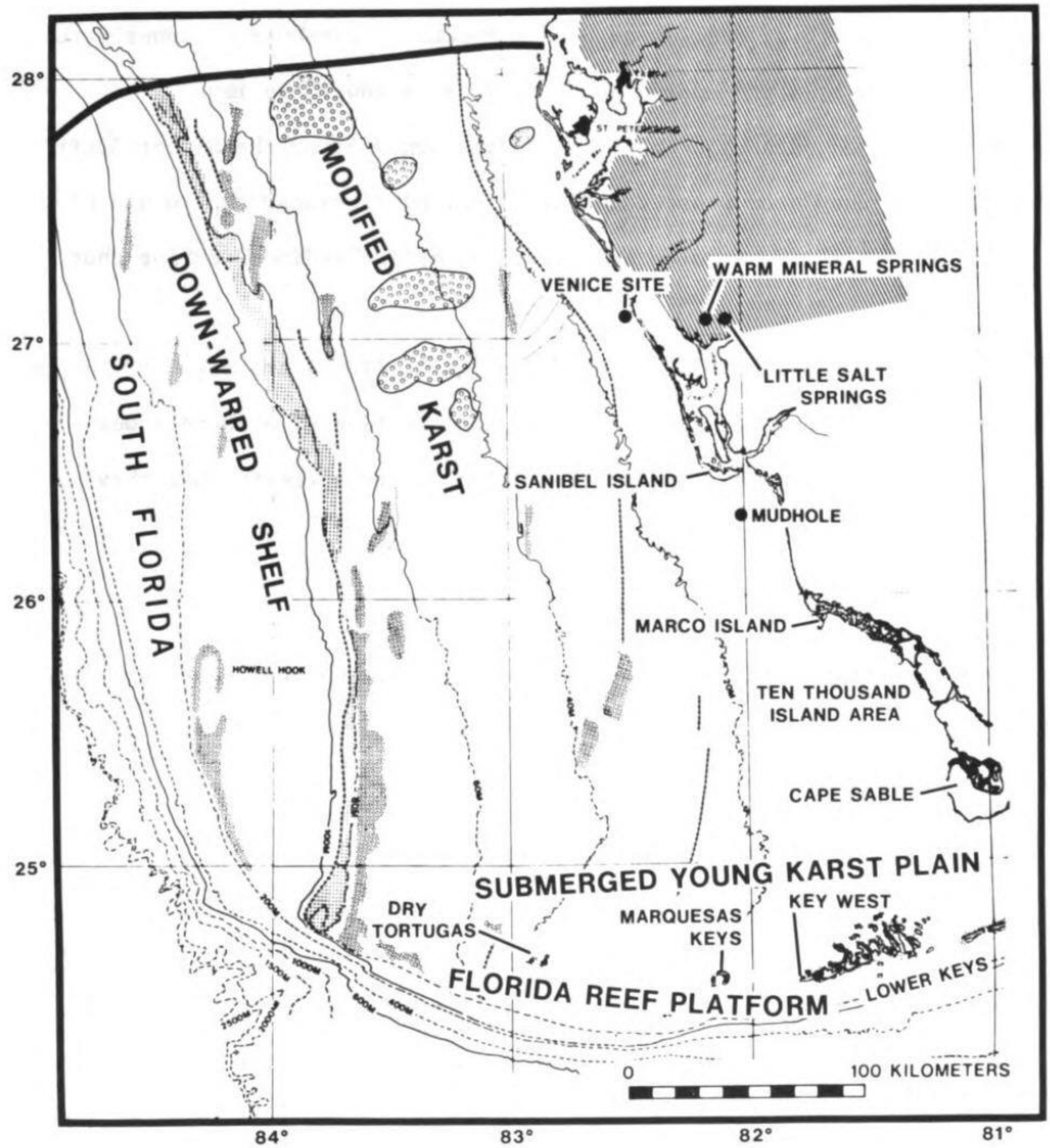


Figure 3-30. Major geomorphic features of the south Florida area.

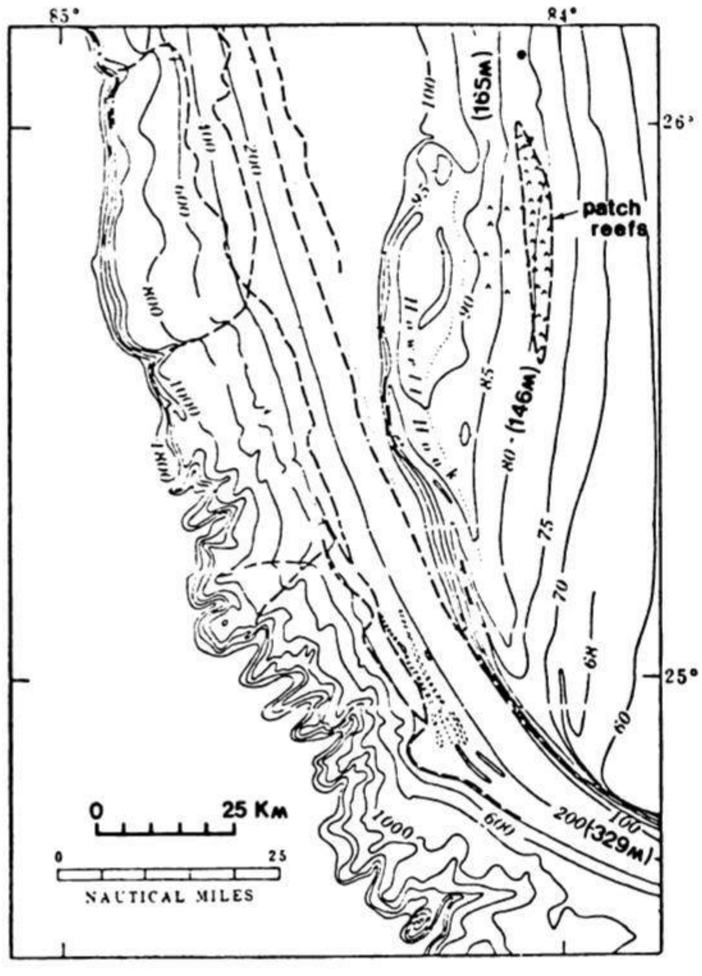


Figure 3-31. Bathymetric chart of the Howell Hook area, south Florida. Depth contours in fathoms. Supplemental notations in meters. (After Jordan and Stewart, 1959.)

smooth, but there are some isolated rises. The deepest section of the 'lagoon channel' is 30 feet (9 m) deep . . . a channel is also indicated by an embayment in the 100-fathom (183 m) contour ."

East of Howell Hook is an elongate 130 sq. km area of reef patches (Jordan and Stewart, 1959). There are also isolated patches near the "lagoon" feature. The large reef area lies in water depths of -137 to -156 m. Local relief of the reefs is 3 to 5 m. A similar patch-reef zone occurs 160 km to the north at -110 to -128 m.

As in the Central Florida area, the outer continental shelf is separated from the middle modified karst shelf by a zone of very well-defined escarpments and terraces. One of the most continuous and best-defined escarpments on the shelf occurs at about -85 m in this area. It can be traced continuously for some 240 km. A second, but less continuous, escarpment occurs between -75 and -70 m. Lying between the two escarpments is a flat, terrace-like feature.

At about -80 m are several nose-like protuberances at the northern end of the area. Toward the south at the same depth is a pronounced ridge-like feature. Both the nose-like features and the ridge are interpreted as barrier-beach complexes. Two additional nose-shaped features occur at about -70 m. The northernmost of these "climbs" contours to -60 m. North of this contour-climbing feature are two additional nose-shaped features associated with the -60 m contour. It will be recalled that Curray (1960) noted similar contour-climbing features in the Texas area. All of these nose-shaped features are interpreted as barrier-spit complexes. The configuration of these features indicates a dominant longshore drift pattern from north to south.

The middle shelf, between about -55 and -30 m, is characterized by what Price (1954) has called modified karst topography. Areas of most distinctive karst are indicated in Figure 3-30. These areas may correspond to the of former bays where coquinas and other lime sediments particularly susceptible to differential solution may have been deposited.

Between -40 and -18 m are a number of features which suggest barrier-spit complexes and shore trends.

Sinkholes are known to exist in the middle and inner shelf, though they are not thought to be extensively developed. Evidence suggests that sinkholes and caverns become more frequent closer to the shore (Brooks, 1974:302).

There is a submarine spring located off Fort Meyers Beach. This feature, known as the Mud Hole, is reported to be saline (chlorinates of 19-20 o/oo), hot (97° F), and apparently rich in trace metals. Pyle, Bryant, and Antoine (1974:298) note that the Mud Hole and several "deep holes" reported by fishermen all lie within a belt 16 to 65 km offshore.

A number of onshore springs in this area have produced Paleo-Indian artifacts and bones of extinct Pleistocene animals (Neil, 1964). Among the most important of these are Warm Mineral Springs and Little Salt Spring, where systematic underwater excavations have been conducted (see Chapter 6).

In the Venice-Naples area prehistoric sites have been reported in shallow offshore areas. Local collectors have found chert debitage, scrapers and projectile points in shoals near Naples, Florida. Ruppe (personal communication) has conducted systematic excavations in a submerged site in 2 to 3 m of water offshore from Venice, Florida. The site is a shell midden and, among other things, has produced pottery from the early ceramic Orange Period.

Numerous artifacts and fossil bones have been dredged up in Tampa Bay. The artifacts range from Paleo-Indian projectile points to ceramics. Bones of extinct animals have also been reported from the dredge spoils.

The southwestern part of penisular Florida between the Florida Keys and Cape Romano is one of the most complex coastal areas in the United States. This is an area of tidal channels and mangrove swamps, but there are open lagoons.

In the western portion, a series of quartz and islands and shoals protected by vermetid reefs (Shier, 1969) has developed seaward of the mangroves. The most unusual feature of the area is a series of large islands composed of oyster shells that lie more or less in a straight line within the mangroves from Goodland Island to Chokoloskee Island. These islands are the only habitable land. Their relief is the product of Indian midden accumulations upon oyster bars subsequent to 1,200 A.D.

The record of the Late Holecene transgression is particularly good in the western margin of the Everglades. According to Scholl (1964) the sedimentary succession from the mangrove swamps of southwestern Florida attests to a 3 meter rise in sea level during the last 4,000 years. The sequence of transgressive sediments (Figure 3-32) consists of calcitic mud and freshwater peat deposited on bedrock. On top of this layer is a unit of basal

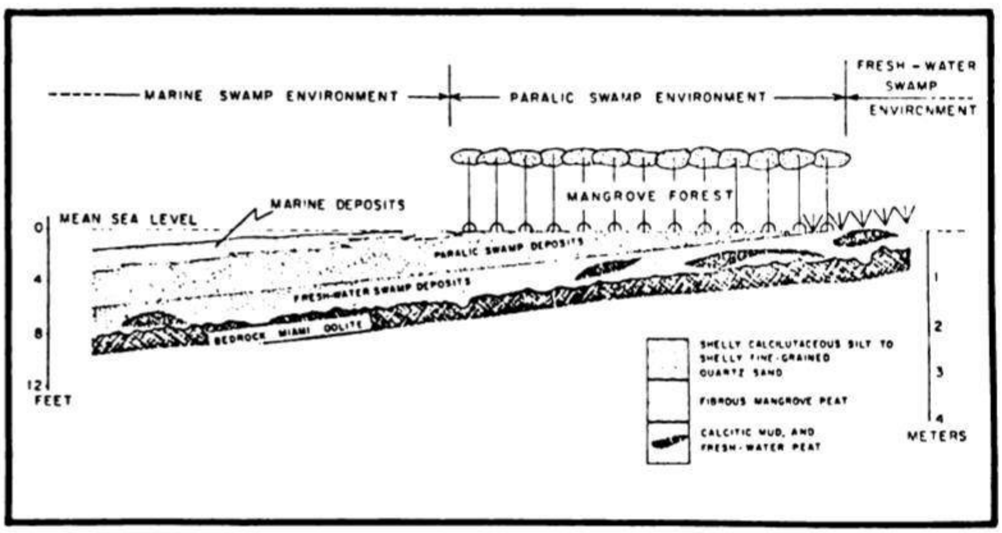


Figure 3-32. Idealized cross-section of coastal mangrove swamps in the Ten Thousand Island area of the south Florida coast. The transgressive sequence consists of freshwater deposits overlying bedrock which, in turn, are overlain by paralic swamps and marine deposits. Mangrove peat begins to form over freshwater calcite mud essentially at mean sea level. (After Sholl and Stuvier, 1967).

fibrous peat, largely derived from mangrove and other rooted plants, and an overlying marine unit of peaty and calcareous shell debris (Whitewater Bay) or shelly, quartz-rich sand and silt (Ten Thousand Islands ~rea). Judging from radiocarbon dates (Scholl, 1964a), the mangrove peat unit began to form 3,000-3,400 years ago after cessation of calcitic mud formation. Within a period of a few hundred to a thousand years, formation of mangrove fibrous peat in areas which are now waterways and intra-forest bays gave way to the deposition of shelly brackish-water and marine sediments of the upper member of the transgressive sequence. The environmental shift from freshwater to brackish-water and marine milieus came about in response to a more or less steady rise in sea level and marine inundation of former mainland swamps. Because a considerable body of evidence points to the probable tectonic stability of southern Florida in Recent time, the recorded submergence is regarded as a measure of an eustatic change in sea level (Scholl and Stuiver, 1967). Based on the age and elevation of fibrous peat overlying bedrock and freshwater calcitic sediment, the rise in sea level across southwestern Florida 4,400 - 3,500 B.P. was 30 cm /100 years. About 3,500 B.P., when sea level stood 1.6 m below its contemporary position, the rate of rise diminished by a factor of five; since 1,700 B.P., the rate of rise has averaged only about 3 cm /100 years.

Figure 3-33 illustrates the positions of relict shorelines on Cape Sable. Note that Shoreline Z has been dated at 4,950 ± 120 years B.P. The shoreline has apparently prograded seaward since that time and the three capes have developed on the island. The ages of relict Shorelines W, X and Y remain to be established.

The Florida peninsula represents just part of a much larger geological feature known as the Floridian Plateau. The southeastern part of this plateau has long been an area of deposition which shows evidence of subsidence.

Between Miami and Key West, bottom contours indicate the existence of a crescent-shaped plateau, the Pourtales Plateau, the surface of which slopes gently from a depth of about -180 m to -550 m. Off Key West, at the outer edge of the plateau, large sinkholes have been discovered at a depth of -250 m.

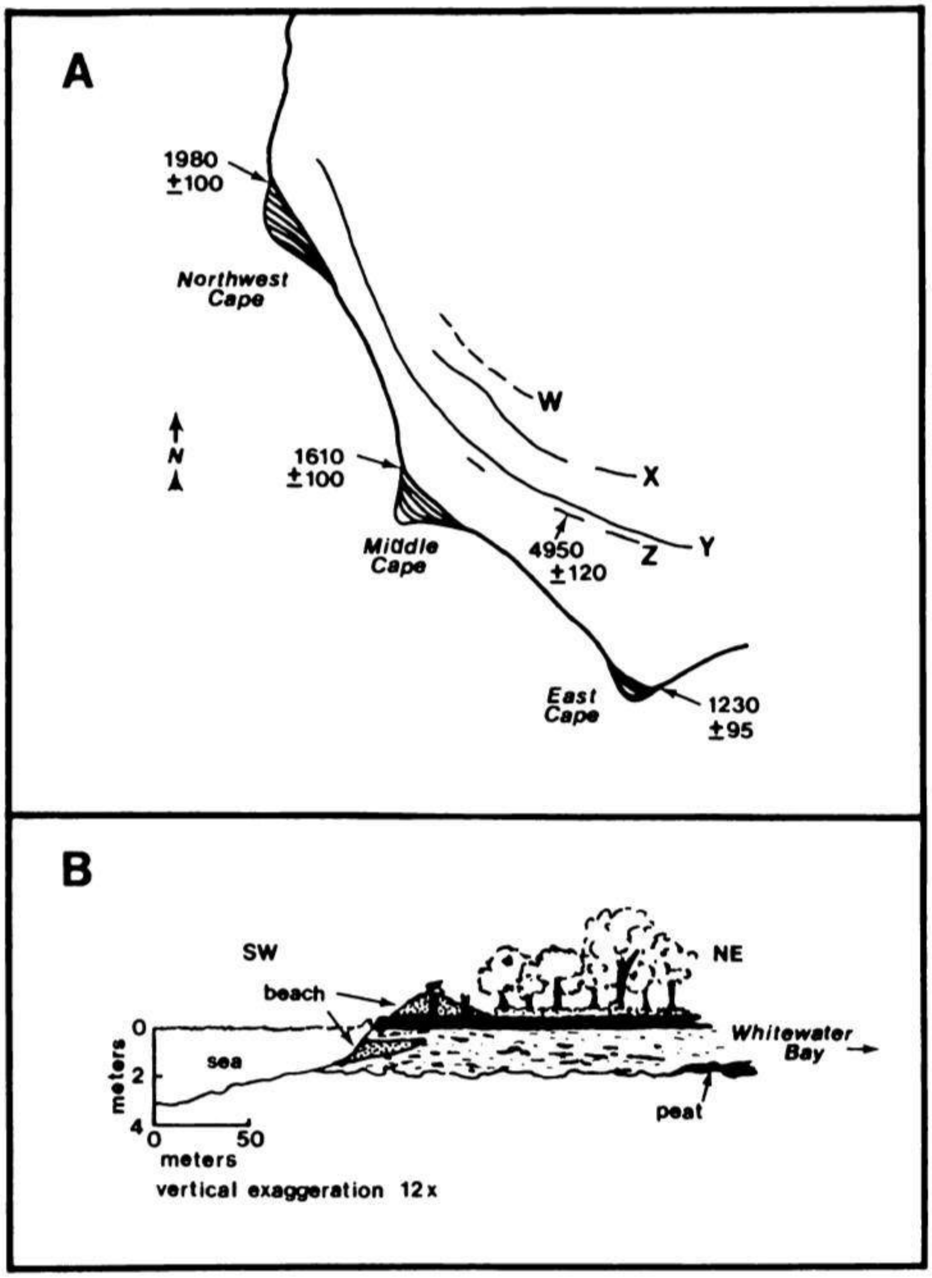


Figure 3-33. Cape Sable beach and relict shoreline features. A. Relict shorelines with radiocarbon dates in years B.P. associated with features. Shorelines W-Z are low-carbonate mud ridges. Shorelines of individual capes are shell beach ridges. (After Smith, 1968). B. Typical cross-section showing modern and buried peat deposits. (After Spackman et al., 1964).

These holes, averaging 1 km in diameter and 140 to 170 m in depth, are evidence that the Pourtales Plateau was once subaerially exposed and that therefore the plateau is more likely due to subsidence and downfaulting than to erosion by the Florida Current which runs along the plateau (Hoffmeister *et al*., 1964; Jordan *et al*., 1964).

The Florida Keys form an arcuate, discontinuous band which follows the shape of the Pourtales Plateau (Figure 3-34). They are composed of two distinct lithologic units, the Key Largo Limestone and the Miami Oölite (Hoffmeister and Multer, 1964). At the northern end of Miami the two diverge. The more inland feature, the Miami Oölite ridge, was a marine limestone bank which was lithified during the last interglacial about 100,000 years B.P. The ridge curves to the southwest for 50 km and then westward to Cape Sable, the southwest point of the Florida mainland. It then overlies the Lower Keys from Big Pine Key to Key West.

The Key Largo Limestone is an elevated, fossilized Pleistocene coral reef of about the same age as the Oölite, being eastward and in slightly deeper water. At Miami Beach, it is found 3 m below sea level. The ridge extends 25 km south from Miami as a shoal which separates Biscayne Bay from the Atlantic Ocean. It then surfaces at Soldier Key and is exposed in the Florida Keys for 200 km to Big Pine Key. From Big Pine Key to Key West, the limestone is submerged below the Miami Oölite. The Key Largo formation is also found in shallow water along the eastern shore of the Florida mainland extending southward from Miami for about 65 km.

At the southwestern extremity of the Keys are ring-shaped reefs called the Marquesas and Dry Tortugas. These are coral reefs which have been incorrectly called atolls. They are formed on shallow sediment banks and, unlike atolls, are not associated with subsidence, nor are they fringed by deep water (Smith, 1971).

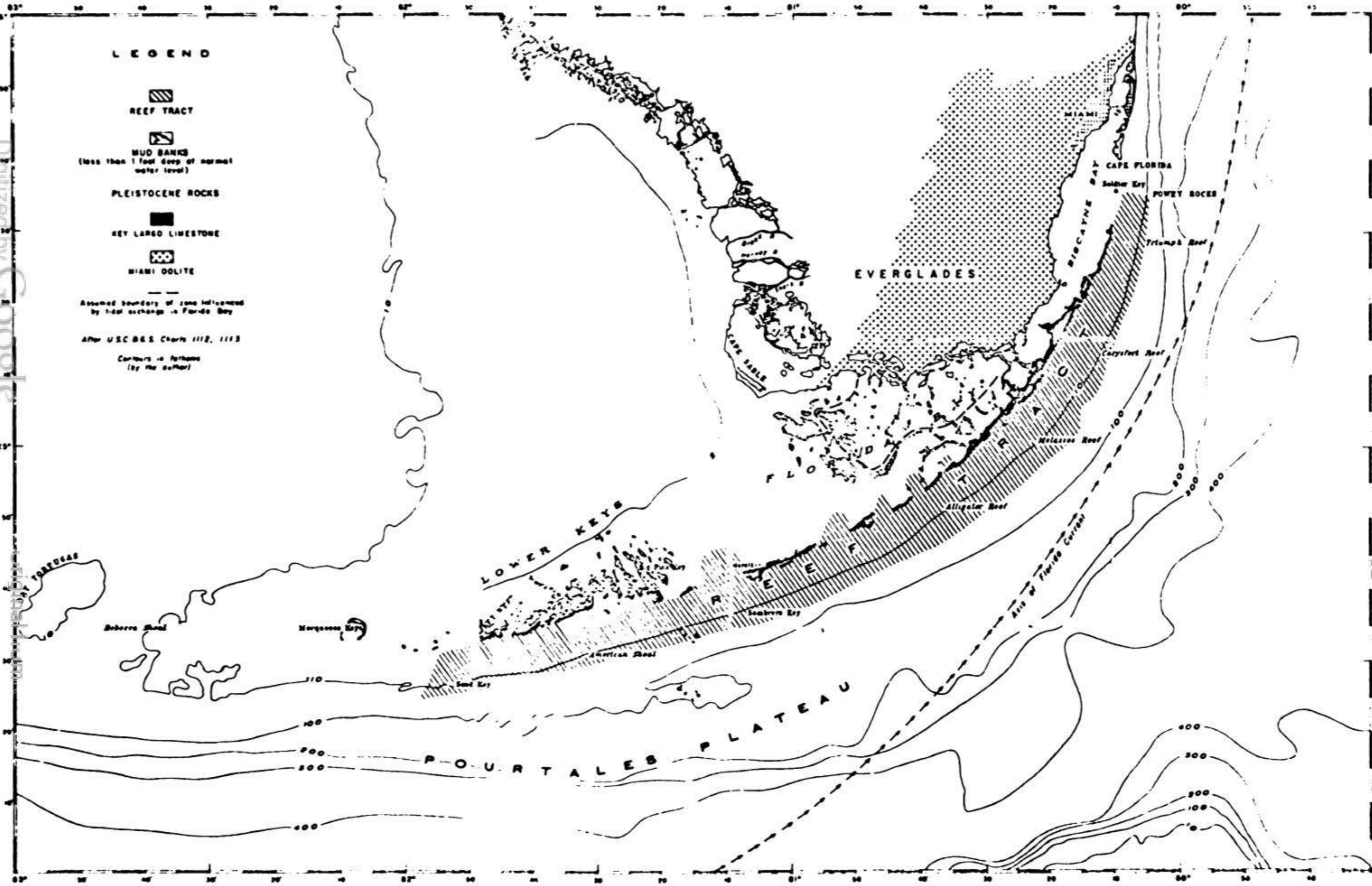


Figure 3-34. The Florida Keys and their environment. (After Hoffmeister et al., 1964.)

While quartz is by far the major constituent of the beaches of Florida, it represents only a small percentage of the beach material on the Keys. On both the east and west coasts of the state, the percentage of quartz decreases until just south of Miami Beach it comprises much less than 50% of the material. On Key Biscayne, quartz ceases to be an important beach constituent. Still farther south, as well as at Cape Sable on the mainland, the beach is almost entirely calcium carbonate in the form of coral, shell fragment, and remains of foraminifera. As an example, Martens (1936) cites a figure of 97.52% calcium carbonate for Upper Matecumbe Key.

The Florida Keys and the modern reefs represent a special case of fringing reef (Smith, 1971). Fringing reefs are formed by corals close to land and in shallow water. Their growth is directed toward the water's surface and outward toward the open ocean. This is a direct result of favorable conditions seaward and upward and unfavorable conditions of increased temperatures, salinity changes, and sediment deposition landward. The result is the configuration shown in Figure 3-35. A broad platform of coral rock is formed extending horizontally in a seaward direction. The platform continues to grow until its base reaches a depth of about -27 m (Smith, 1971), the depth

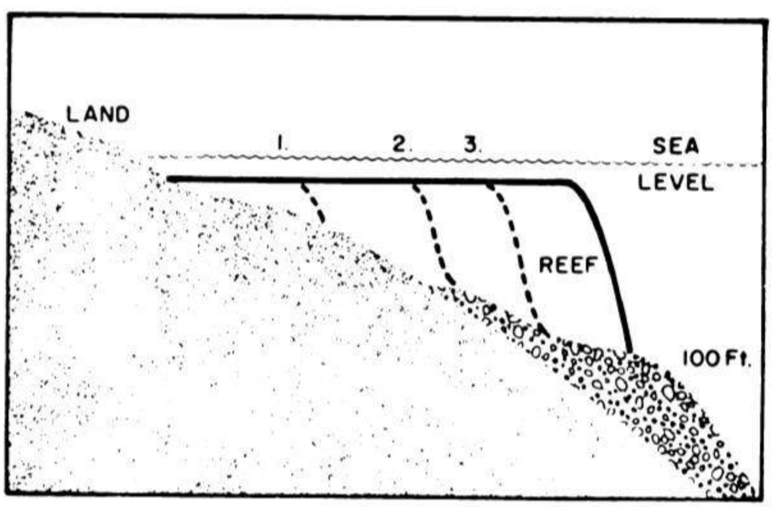


Figure 3-35. Development of a fringing reef. Broken lines indicate stages of growth. Rubble at the edge of the reef forms a base for farther extension in deeper waters. (From Smith, 1971)

beyond which corals can no longer flourish. Farther seaward extension may take place as a result of broken coral forming a base of dead rock upon which more coral may grow. In addition, large-scale movement of land or sea level can create conditions for farther extension of the platform.

The reefs of Florida, both the Keys and the modern reefs, are bank reefs which differ somewhat from the usual fringing variety in that they were formed farther from the shore (Smith, 1971). This area lies within a marginal belt between lower and higher latitudes which, as a result, was greatly affected by the glacial ages. During the glacial ages, the low latitudes remained relatively warm and were able to support coral growth. In the marginal areas, however, corals died, leaving the shore unprotected. Waves wore away the coast, creating a platform just below sea level and adding debris to the offshore region.

Both the Keys and the living reefs are located upon a platform which was once covered by a shallow sea. During the past million years, the platform has been subjected to periodic exposure and flooding as a result of withdrawal of water during glacial periods and its release during interglacial times. Pleistocene reefs which grew over extensive parts of this platform formed a thick layer of rock. During the last glacial age, when sea level was low, a platform was cut into the land. When the ice caps melted for the last time, the platform was flooded. It now forms the base for the modern reefs growing off the Keys.

A north-south section from the Florida mainland reveals the environment described below (Figure 3-36). The southern coast of Florida is a curving ridge rising 3 to 5 m above sea level. This ridge encloses the Everglades, a freshwater swamp the surface of which is about 1 m above sea level. Beyond the southern border of the Florida coast are the Keys, ranging 8 to 50 km from the shore and extending westward beyond the western shore of the mainland

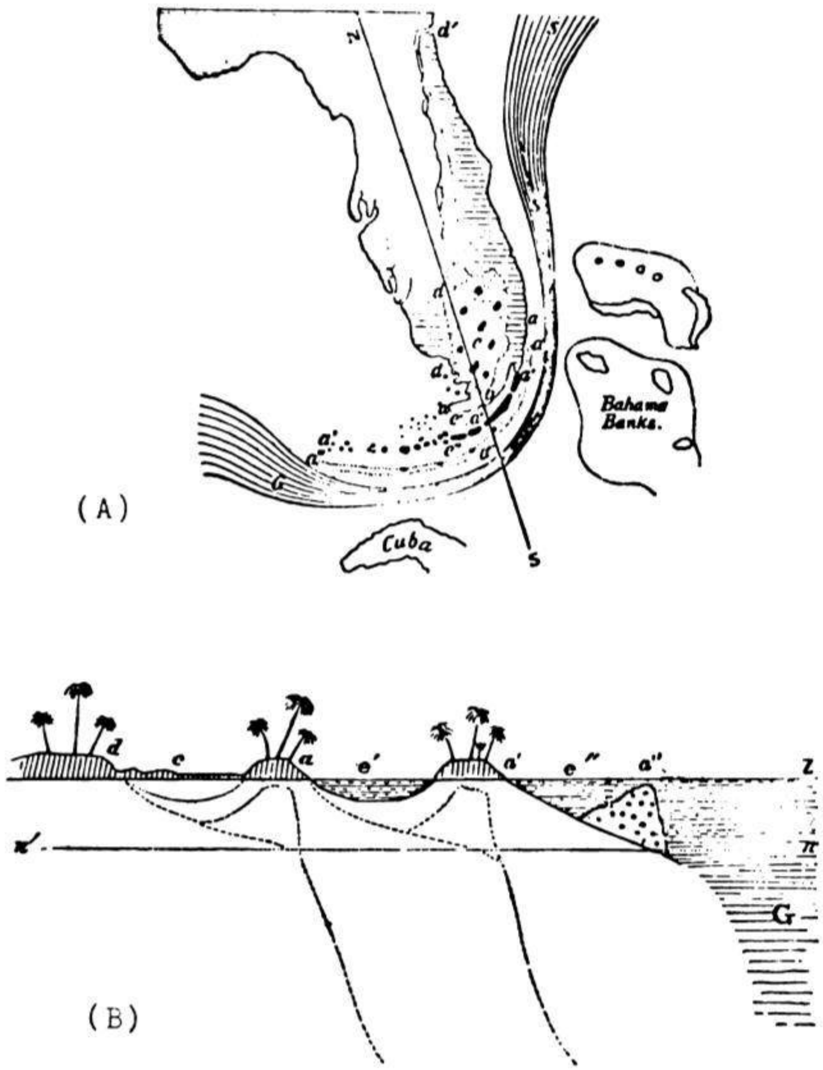


Figure 3-36. (A) Map of Florida. a - southern coast, a' - Keys, a" - living reef; d-d' - bryozoan and oölitic facies; e - Everglades, e' - shoal water, e" - ship channel; GSS - Gulf Stream and Florida Current.

(B) Cross-section of Florida along the north-south line of (A). Lettering is the same as in (A). Dotted lines indicate hypothetical former conditions. (Modified from Grabau, 1960.)

(Ginsburg, 1964). The bay is dotted with small, low mangrove islands. The roots of the mangrove trees trap large amounts of sediment carried by currents. Sedimentation has progressed to such an extent that a large portion of Florida Bay forms mud flats at low tide.

Seaward of the Keys, at a distance ranging from 5 to 25 km, lies a line of living coral reefs consisting largely of the branching coral *Porites* and the calcareous red alga *Lithothamnion*. These reefs are submerged, rising out of the water in a few places. Between them and the Keys is a narrow channel 9 to 10 m deep. The channel represents an area of sedimentation of coral debris, shells, and other calcareous material. Seaward of this living reef, the bottom slopes rapidly into the abyssal depths of the Florida Straits.

The Pleistocene coral reef called the Key Largo Limestone shows a large variation in thickness. At Key West, it is about 55 m thick; at Grassy Key, 52 m; at middle Key Largo, 21 m; and at the northern tip of Key Large, 44 m.

The composition of the Key Largo Limestone is typical of coral reefs (Hoffmeister and Multer, 1964). It is made up of massive coral heads many of which are surrounded by smaller coral colonies, shells and shell fragments. Reef-building corals are found in the formation from top to bottom but are most prolific in the upper two-thirds of the structure.

Although the Key Largo Limestone represents an elevated coral reef, probably less than one-fourth of its total mass is derived from coral (Cooke and Mossom, 1929). A large contribution to its structure was made by calcareous algae. The great bulk of the material was derived from sea water by a variety of organisms.

Since the solidification of the rock, solution and redeposition has taken place. In some places, the rock contains heads of coral replaced by calcite that shows the structure of the original head. In other places, the rock is a breccia composed of angular fragments in a lime cement. The breccias represent loose material that has fallen into solution cavities and has been recemented.

The surface of the Key Largo Limestone (and the Miami Oölite as well) is protected by a laminated crust averaging 3 cm in thickness and in places, up to 13 cm. It is believed to have been formed largely in the intertidal zone, but the same condition has been reproduced in the laboratory under subaerial conditions (Hoffmeister and Multer, 1964). In general, the limestone is found to be harder within 50 to 60 cm of the surface than below (Cooke and Mossom, 1929).

Changes in salinity and other ecologic conditions were at times responsible for the encroachment of corals westward upon the bryozoan community. When conditions were reversed, the bryozoans dominated again and forced the corals to retreat eastward. This process is evident in several intrusions of Key Largo Limestone into the bryozoan facies (ibid).

As the bryozoan facies increased in thickness, oölites formed in ever-increasing amounts in the area which is now the Atlantic Coastal Ridge, a ridge extending in a northeast-southwest direction. While this mound was being formed, bryozoans flourished to the west where they laid down thick deposits.

During a subsequent glacial period, sea level was lowered and these deposits were exposed to the atmosphere. Rain water flowing through the interstices of rock precipitated calcite around the grains and formed indurated rock seen there today. During this period, the eastern side of the oölitic mound was considerably eroded by wave action.

The Lower Keys from Big Pine Key to Key West show some features strikingly different from the Upper Keys. The Upper Keys form essentially an arcuate thin line and are oriented in a northeast-southwest direction. The Lower Keys, on the other hand, form roughly a triangle with Key West at the apex and Big Pine

Key at the base (Figure 3-37). Their orientation is in a northwest direction and they lie parallel to each other, increasing in length from west to east.

The Upper and Lower Keys also differ in composition. The Upper Keys are composed of Key Largo coral reef limestone while Big Pine Key and those westward are made up of oölite. However, all of these Lower Keys with surface deposits of Miami Oölite are believed to be underlain by Key Largo Limestone (Hoffmeister et al., 1967). The relationship in stratigraphy of the two formations is seen at a contact at the southeastern end of Big Pine Key (ibid). Here the oolite overlaps the old coral reef to the south. The oölite cover is a relatively thin layer. For example, at the southern end of Boca Chica Key it is 2 m thick, and 2-1/2 km to the north it becomes 10 m thick (Hoffmeister et al., 1967).

An explanation for the northwest orientation and the shallow channels of the Lower Keys is offered by Hoffmeister et al. 1967 The Upper Keys, which are made up of coral reef limestone, parallel the edge of a reef platform. The Lower Keys, which are made up of different rocks, have a different orientation. Oölites probably formed on a platform just north of the coral reefs which are now overlain by oölite. An east-west mound of unstable oölite at least 10 m thick was formed behind the reef and extending the entire length of the Lower Keys. As the layer became higher than the reefs, the oölite tended to encroach over them and to eventually cover them. Tidal currents then cut channels in the oölite normal to the orientation of the mound. During the subsequent glacial period, the mound was exposed and the rock became indurated. When sea level rose again, the oölite was exposed to waves and currents. The erosional effects of the waves and currents were concentrated on channels so as to create the geomorphologic product which exists today.

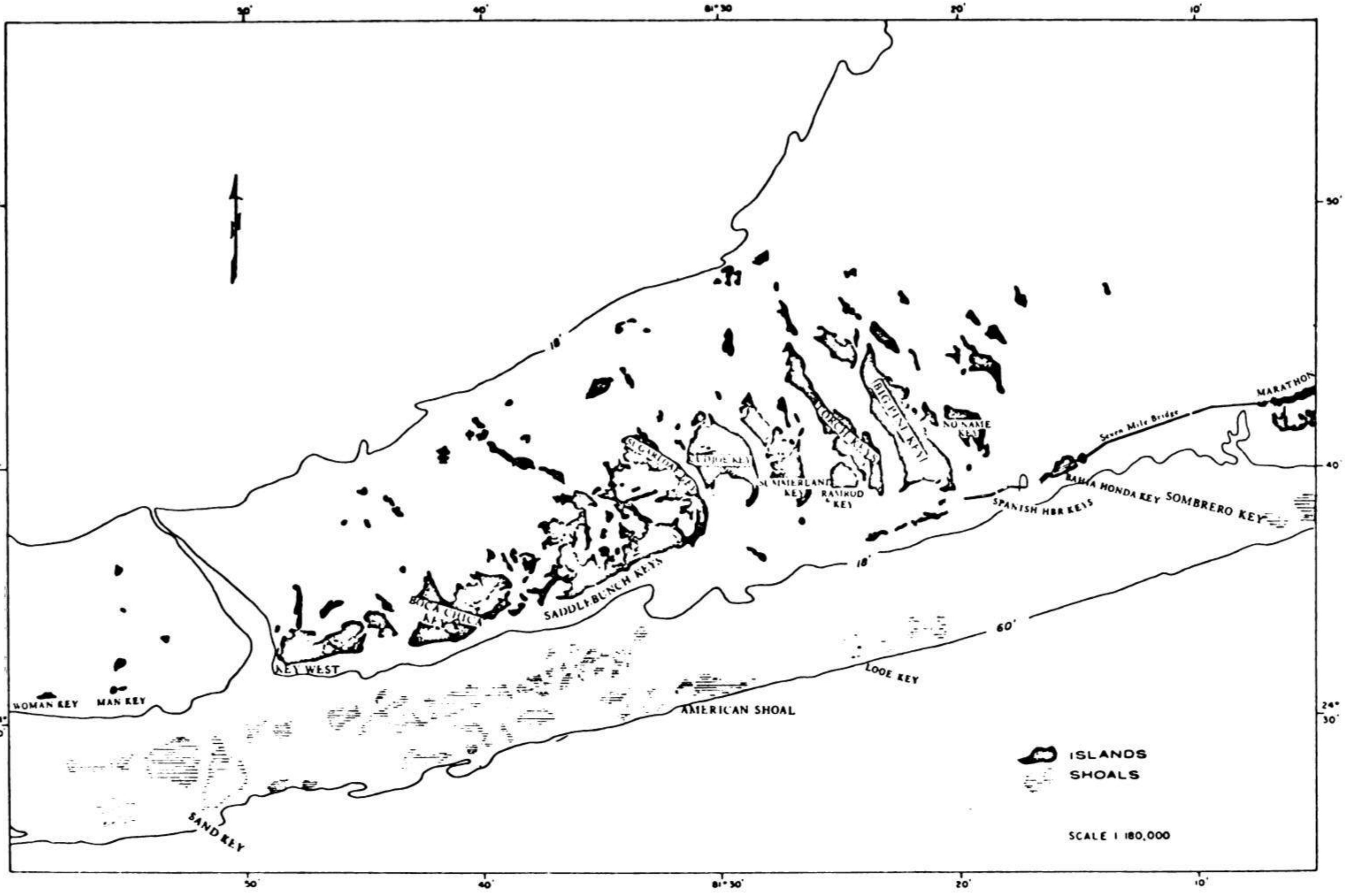


Figure 3-37. The Lower Keys. (From Ginsburg, 1964.)

CHAPTER IV

SEA LEVEL IN THE LATE QUATERNARY PERIOD

Introduction

The rise and fall of sea level during the Quaternary has fascinated geologists for decades. This is an area of investigation which is very poorly understood due to the numerous difficulties and problems that remain unsolved and also due to the comparatively small amount of study given to the problem. The thousands of wells that have been drilled on the Outer Continental Shelf have contributed virtually no information on surficial deposits, and investigations pursued for purely theoretical science are rare.

Nevertheless, a generalized view of the latest cycle of glacial lowering and subsequent rising of sea level has begun to emerge. In this study, we have attempted to synthesize from all the available extant information a history of sea level change which we can relate to observed relict features now submerged on the shelf. In recognition of the importance of glacial control on sea level changes, we have also attempted to relate the sea level changes to well-documented episodes of glacial advance or retreat.

Fluctuations of Sea Level

A chronology table and a correlation map treating fluctuations of sea level are given in Volume III, Plates 1 and 3. Plate 1 is a chronology of Late Quaternary Events and presents an interpretative history of the relative fluctuations of the land-sea boundary (with respect to present-day sea level as a datum). A curve of the relative change of land-sea level is correlated with the Intervals A-K discussed later in this chapter, with glacial periods, with physiographic units, and with corresponding events in faunal evolution, artifact traditions, and cultural sequences. Plate 3 is a map correlating the sea level changes with some of the relict features discussed in Chapter 3. It is important to stress the relativity of the sea level to land fluctuation, since it is compounded of changes in sea level and changes in land level (both with respect to some arbitrary datum, e.g., present sea level as used here) and must therefore be expressed as a algebraic sum.

As Bloom (1967) has stressed, change in sea level may in fact lead to opposing changes in land level due to isostatic effects. Therefore, the record of fluctuation we see at the present time may indicate a somewhat amplified curve with respect to a curve of true or absolute change of sea level.

Besides being amplified, the curve of relative land-sea level must be in various ways distorted (again, with respect to a true or absolute curve of sea level fluctuation). Such distortion may result partly from a lag in isostatic response to sea level change. Other distortions are tectonic subsidence or uplift and subsidence from compaction. Tectonic effects may be of regional scale or of local scale (as seen around salt domes). Changes in the configuration of the geoid as a result of a sudden shift in position of the earth's axis or in variations in the rate of rotation have also been offered as explanations for sea level change (Newman, 1968).

The latest part of the curve is taken from a published version by Scholl et al. (1969), which in turn is based on numerous dates of various coastal deposits of southern Florida. The earlier, partly overlapping segment (about 4000 - 9000 radiocarbon years ago) is constructed in part from published dates of Rehkemper (1969) from Galveston Bay and Coleman and Smith (1964) from the Chenier Plain of Louisiana. The displacement of this curve with respect to the curve of Scholl et al. (1969) may partially represent a distortion such as described above, perhaps a regional tectonic distortion, or geoid changes. The dip in the curve at about 8,000 years is based on geomorphic evidence discussed later.

The curve from about 9000 years to about 10,000 years is based on two dates from the northwest Florida area, one from Jervey (1974) and one from Schnable and Goodell (1968). Again, the shift in geographic area is associated with a discontinuity which may well represent a distortion, possibly from regional tectonic effects.

Beyond this time, only one possibly useful radiocarbon date is known. This was reported by Curray (1960). The sample is an excellent one, but it was collected from near the Stetson Bank which, according to Edwards (1971), is underlain by a salt dome structure; therefore, the possibility of some local tectonic effect exists.

The remainder of the curve is largely inferred from the forms identified on the shelf, Chapter 3, and from knowledge developed elsewhere which indicates the history of glacial conditions (Geological History, below).

Paleoclimatology and the Deep-Sea Period

Some general considerations on Late Quaternary paleoclimatology are important in a study of this kind, but in this area we are faced with the fact that little attention has been paid to paleoclimate in past works. Consequently, there is little available evidence from which inferences can be made.

Perhaps the most authoritative work of concern here is that of Watts (1975). Watts' pollen studies of cores from a lake basin in south-central Florida showed a dry climate characterized by dune vegetation appeared, which, in turn, was replaced about 4700 years ago by vegetation similar to that of the present.

Graf (1966) has made some interesting paleoclimatic speculations regarding the northwestern Gulf coast area. He considers the soil zones in the Beaumont formation, which are associated with the Ingleside shoreline features with their characteristic caliche zones, to be evidence of a former, relatively more arid time. He further believes the characteristic micro-relief features (the pimple mounds) of the Beaumont and older surfaces in the area to be aeolian forms developed during a time of aridity post-dating the Beaumont surface (and the Ingleside shoreline features).

Lundelius (1972), in his faunal analysis of the pit at Ingleside, considers the paleoenvironment to have been warmer and more humid than that of the present. His treatment of the age of this unit is noncommital, but he suggests the possibility that it is younger than Late Wisconsin. This fauna, in our opinion, may well represent an early Holocene deposit in the order of 8500 - 12,000 years in age. The faunal material associated with fresh-water dune ponds may have originated at this time when warming, possibly induced by a surface layer of meltwater which covered much of the Gulf of Mexico in a time of rapid glacial waning, brought to an end a cycle of relative aridity that existed through much of the period of glaciation. The dune pond formed under these wetter conditions.

At about this same time, there may have been partial stabilization of the south Texas sand sheet and deposition of pond marls in the stabilized dune areas as discussed earlier.

In Louisiana, Otvos (1975b) has provided some paleoclimatic interpretations in his recent review of loess stratigraphy and distribution. He states that "the fact of loess accumulation in itself indicates a drier climate." He also notes that caliche is well-developed far to the south and east of the loess localities in the Prairie formation, indicating even more widespread dryness. He states, "calcareous concretions do not accumulate in soils under the present humid-subtropical climate of south Louisiana." However, it should be noted that calcareous concretions do develop in marsh and swamp deposits, raising some questions as to an arid interpretation of their origin.* While probably Late Pleistocene or Early Holocene, the specific date of these features has not been established.

Part of the aridity of the Gulf coast may have been due to a reduced frequency of tropical storms because of lower ocean temperature (Moran, 1975; Adams, 1975a).

Hammond (1976) has presented in preliminary fashion some conclusions of the Climap project, a major inter-institutional study of sea-floor sediments, the results of which will shortly be published (McIntyre et al., 1976; and Gater, 1976). Some conclusions are that at about 18,000 years B.P.: 1) the Gulf Stream may have followed a southerly course toward Spain rather than England; 2) equatorial oceans were as much as 6°C lower in surface temperature, and the world ocean average was about 2.3°C lower; 3) sea level was at least 85 m lower than present; 4) July surface temperatures on land were as much as 15°C lower than present in areas close to the ice sheets and, on the average, about 5°C lower over the continents; and 5) climate was generally drier than now, especially in the northern hemisphere.

Emiliani et al. (1975) have recently presented results of an analysis of the two deep-sea cores marginal to the DeSoto Canyon that are of the greatest importance in interpretation of the Late Quaternary history of the Gulf of Mexico. The cores were investigated in several ways, including foraminiferal studies, radiocarbon dating, and determination of oxygen isotope ratios.

The foraminiferal studies showed several interesting trends: 1) warm-water forms (Spaeroidinella dehiscens, Pulleniatina obliquiloculata, Globorotalia menardii and G. tumida) were very scarce or absent throughout the cores but increased in the uppermost core layers; 2) "temperate-warm" species

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* Otvos (1975b) cites aeolian dune trends associated with the Prairie formation in southeastern Louisiana as further indications of drier conditions.

(Globigerinoides sacculifera-triloba and Globequadrina eggeri) were present in varying abundances throughout the cores; and 3) the "temperate-cold" species Globoratalia inflata is rare in the uppermost zones but common in most of the lower zones of the cores.

Radiocarbon dating of the cores was done on bulk carbonate samples and for this reason probably overestimated their ages since clastic carbonate contribution that is reworked from older deposits is inevitable. Emiliani et al. (1975) estimated that dates in their core on the northwest flank of DeSoto Canyon were about 5000 years older than dates on equivalent horizons in the core from the southwest flank. They considered this to be due to greater amounts of reworked carbonate in the former. They judged the more basinward core to give accurate radiocarbon ages even though bulk samples were used through a presumed correlation with the y/z boundary of Ericson et al. (1964).

The difficulty of interpreting the many oxygen isotope and planktonic foraminiferal studies is that there may be regional variations that lead to confused correlation. Few such studies present adequately considered absolute age determinations, and too often bulk samples of sediment have been the basis of dating. Samples may also be integrated concentrates of calcium carbonate skeletal materials accumulated over so broad a time interval that the resulting age is suspect. It is quite apparent that a generalized review of this entire methodology, clarifying both its weak and strong points, is badly needed, but beyond the scope of the present study.

The foraminiferal studies in particular seem to present many methodological difficulties. The underlying assumption that assemblage variations can be interpreted to yield temperature variations through time is only weakly substantiated by studies of modern assemblages. The variation of factors other than temperature and the potential effect of these on the nature of the assemblages deserve more emphasis. Sea level changes of the magnitude described herein could well have impact on the broad-scale structure and function of marine ecosystems, causing considerable shifts in the relative balance of populations of many marine species. The ways that this might be expressed in the planktonic foraminiferal populations (which collectively are merely one component of the larger marine ecosystem) are by no means simple. Lacking knowledge of such ecosystem response, it is clear that relating variations of planktonic populations solely to temperature change is certainly an oversimplification.

Vergnaud Grazzini (1975) has published one of the more interesting examples of the oxygen isotope method of study of deep-sea cores. His cores from the Mediterranean Sea show particularly pronounced fluctuations, probably due to the restricted nature of this sea and its location with respect to the glacier. Briefly, his interpretation of the cores is that they show peaks indicative of cold water and a large glacial mass about 17,000 years ago, and warm water and a smaller glacial mass at about 55,000 years ago.

By way of explanation of the significance of oxygen isotope variations, Grazzini states that they "are caused both by changes in the ocean surface temperature and by glacially-controlled changes in the isotope composition of the ocean water." He further points out that "most workers believe now that the last is the dominant factor and have even suggested that the existence of any residual temperature effect remains to be demonstrated."

Grazzini postulates that the magnitude of isotope fluctuations in the Mediterranean is exaggerated (with respect to the ocean generally) to a degree by "a 'dry effect' resulting from lower precipitation or higher evaporation, or both" which may have increased isotope and salinity concentrations in the water. He observes that in cold winter weather this occurs presently in the Mediterranean, and "one may observe a sinking to the bottom of the denser surface waters that have undergone extreme evaporation."

This is interesting because in the Gulf of Mexico, sometimes called the "American Mediterranean," Emiliani et al. (1975) have noted that isotope variations are greater than in Caribbean cores and that this "may represent an excess of evaporation in the Gulf of Mexico (which was closer to the Laurentide Ice Sheet)."

Geological History

We have chosen the inner barrier features, which are comparable to and perhaps correlative with the Ingleside shoreline forms, as the oldest forms of concern in this study. It is believed that their antiquity is perhaps of a similar magnitude to that of known evidences of the presence of people in North America.

Our correlations of the forms identified on the shelf with time intervals in which they may have been created is presented in Volume III, Plate 3. The correlations are admittedly provisional due to the rarity of any absolute basis for the chronology. For the most part, the correlations are based on the sea level curve, but the forms have obviously influenced the construction of the curve and the two are not independent.

In a few cases, absolute dating adds to the information used. Jervey (1974) has provided a date which is possibly related to a barrier form which trends into the nearshore zone just east of Destin, Florida. The indicated age is 9070 ± 320 years B.P. The date was on *Chione cancellata* shells from a facies interpreted by Jervey as estuarine. Since this species has a characteristic shell sculpture of cross-hatched ridges (forming a cancellate pattern from which its name is derived), it is possible to recognize evidence of abrasion readily. Jervey states that the shells used for dating were "well preserved," indicating that abrasion was slight and that the shells were not transported from elsewhere. Without such valuable observations, this dated sample would be of little worth, but since Jervey is particularly concerned with transport, dispersal, and abrasion of such biogenic materials in his work, we regard this sample to be of primary importance.

Another potentially useful but less credible date is that of Curray (1960), which comes from between a submerged ridge form and the Sebree Bank off of the Rio Grande delta. This is the ridge assigned to the H_1 interval on Plate 3. In this case, the sample was dredged oyster shell. As we have discussed previously, there is much possibility of contamination in such samples from inclusion of transported older shell. The date obtained was 9530 ± 270 years B.P. The sample was dredged from 30 m of water, and while this sample was not used in constructing the sea level curve, it does not plot off the curve too badly, especially if some allowance is made for depth of water in which the oysters initially lived.

The only other radiocarbon date associated with a submerged shoreline is that of Winchester (1971) on a caliche nodule which was believed to have formed in a soil zone developed in the Beaumont formation through subaerial weathering at a time of lower sea level. The date, then, indicates age of the nodule, not of the beach, and implies that the beach is younger than the nodule. The age obtained from analysis of the nodule was 15,857 ± 269 years B.P.

Interval A - There is by no means any general agreement about the early history of the Wisconsin glaciation and even less concerning the interglacial preceding it. Barry *et al*. (1975) have recently reviewed the thought expressed by some researchers that the initiation of the last glaciation was possibly quite rapid. The various authors cited have reported sudden cooling trends at 115,000 - 120,000, 90,000 and 70,000 years B.P. Attempts by Barry *et al*. (1975) to model physical processes that might produce such rapid changes have so far been unsuccessful, although a degree of cooling of the right order can be achieved after 10,000 years if some assumptions (which the authors admit are dubious assumptions) are made concerning circulation regimes and energy requirements.

As the level of the sea declined from its maximum high stand during the Sangamon interglacial, there may have been one or more prolonged stillstands or secondary maxima. This is an area that remains very unclear due to problems in absolute age determination, particularly radiocarbon dating, that have produced much misinformation in the literature. Nevertheless, there exists some probability that proposed interstadials, such as the St. Pierre interstadial (ca. 60,000 years ago), may yet prove to have validity as significant post-Sangamon interstadials which may have been related to sea levels equal to or higher than the present. Given this possibility, its relevance to the Ingleside shoreline features is obvious.

The Sangamon features of the Gulf coast area are best understood on the peninsula of Florida. Perhaps the most interesting and well-known example of these features is seen in the landscape of south Florida. The paleogeographic and stratigraphic interpretations of Hoffmeister et al. (1967) and Brooks (1968) indicate a shallow sea bank over much of present south Florida, with öolite-characterized shoals, an extensive bryozoal limestone-forming environment, and algal and coralline reefs. Th/U dates indicate such a landscape existed approximately 125,000 years ago. Strong supporting evidence of similar shoreline features at this time exists in the Bahamas (Neumann and Moore, 1975) and in Barbados, where evidence also exists of even higher levels, earlier in the Sangamon.

The inner beach ridges of the Cape Kennedy littoral accumulative form are apparently of comparable age to the south Florida features just described (Osmond et al., 1970).

These features cause us to wonder if there may not be Sangamon-aged features around the entire Gulf rim. Indeed, many have correlated inner relict shoreline forms elsewhere on the Gulf with the forms in Florida and others have suggested Sangamon ages for such forms for other reasons (e.g., Otvos, 1975a).

If Sangamon forms do exist in Florida and if we assume their absence elsewhere, then certain problems of interpretation arise. One is that their absence elsewhere most probably would indicate a tectonic differential, particularly a downward subsidence of the northern Gulf rim since Sangamon times, with respect to peninsular Florida. The other is that if the inner beach ridge forms of the northern Gulf area (such as the Ingleside features) are truly younger than Sangamon, then why did the later high stand of sea level which produced them leave no important record of forms or deposits in the area of the old Sangamon terrace of south Florida? Some workers believe that the Silver Bluff shoreline forms of that area possibly represent a weakly developed, later, brief period of shoreline occupancy slightly above the present level and are true correlates of the features of the northern Gulf. However, other workers believe that the Silver Bluff shoreline is considerably older. Brooks (1973), for example, has stated that:

> There is topographic evidence of a 6 to 8 foot stand of sea level in most coastal areas of peninsular Florida and the Gulf Coast, but for the most part, fossiliferous beach and lagoonal deposits are lacking. This stand of sea level is not Holocene as many have thought (MacNeil, 1949). In the area of Marineland south of St. Augustine, Florida, excellent lagoonal deposits are associated with a coquina barrier. This highly fossiliferous deposit is too old to date by the carbon-14 method. It is herein suggested that the deposit is about 90,000 years old and correlates with a late Sangamon event (p. II E-7).

To say that Sangamon features which seem to exist in south Florida are absent along the northern Gulf rim through a net downward subsidence of that area with respect to Florida is in conflict with much published opinion concerning the tectonic character of the northern Gulf. Fisk (1939), Bernard (1950), Graf (1966), and many others have held that the western part of the northern rim of the Gulf may actually be subject to tectonic uplift, which is generally believed to be the response of more landward locales to subsidence occurring on the shelf.

Since a variety of forms suggesting older Sangamon and Pre-Sangamon shorelines exists in Florida (Alt and Brooks, 1965) and along the Atlantic coastal plain, their absence in the northwestern Gulf has been far too generally ignored. Upwarping inland from a hinge line should have elevated these shorelines, but if this has occurred, they have been totally eroded away, which seems improbable. An alternative is that the shorelines are covered by younger deposits as a result of subsidence or downfaulting.

Consider for instance a hypothetical case. Suppose a sea level stand of 20 m above present sea level occurred about 125,000 years ago. Relict shoreline forms of this stand could have subsided to the modern sea level by 62,500 years ago if they were subject merely to a rate of subsidence of 0.32 m/century, which is less than many other estimates of subsidence rates along the Gulf coast.

If we then consider a hypothesis that at about that time (62,500 years ago) the Ingleside shoreline came into existence at a time when sea level again stood at about 15 m above its present level, then it is probable that the older (125,000 years) shoreline was already either submerged, buried, or possibly washed away by marine erosion.

These are, of course, only hypotheses, and there is no particular evidence for them. However, they are important in order to show that there could have been such a sequence of events. The careful reader will note, however, another dilemma in this hypothetical argument. If the same rate of subsidence we postulate for the first 62,500 years was continued through the second 62,500 years, then the Ingleside shoreline should also have subsided to below present sea level. This is, of course, not the case, although as Graf (1966) shows, this shoreline is virtually at present sea level in the segments near the Brazos-Colorado delta and perhaps is below present sea level in the Freeport Rocks area, as we have described in the section on forms. This dilemma, however, may result from the simplistic assumption that subsidence proceeds at some continuous, linear rate, when actually it is more likely to be episodic and quite variable in time and space. Thus, the high-standing Houston ridge segment of western Louisiana has experienced little subsidence, and the segments near the Brazos-Colorado delta have subsided approximately at the rates assumed above.

Such speculation may seem idle but it does serve to point out an area of truly basic importance where there is great ignorance in consideration of Gulf coast geomorphic problems. This is the subject of active deformational processes (or neotectonics, as some term it). It is clear that much can be gained from more intensive study in this field.

Interval B - The remainder of the falling stage accompanying the early Wisconsin glacial increase is assigned to Interval B. This was an interval of rapidly falling sea level. Coastal streams and larger rivers continued to entrench during this interval. Older fluvial and marine deposits were exposed to weathering and erosion over greater and greater areas as the shoreline receded. This regressive unit was composed of reworked earlier materials and materials in transport over the shelf and along shore. Much of these may have been quickly removed as they became stranded.

The exposed terrain may have responded rather quickly to isostatic compensation leading to relative uplift. This adjustment was probably slight and may not have occurred instantaneously. Other things also happened to affect the relative level of the exposed terrain with respect to the sea. The exposure of fluvial and marine beds during an interval of low sea level must have had some rather important effects, especially if that exposure persisted over a prolonged interval of time. Among some of the effects are: 1) volumetric change effects resulting from dewatering, consolidation, oxidation of organic matter, leaching of soluble constituents, etc., all of which are changes which may lead to varying degrees of local deformation (mainly subsidence); 2) erosive effects which were highly variable - where these were most intense, there may have been further isostatic compensation; and 3) other effects such as mass movement, colluviation, cementation and calichification.

As sea level was falling, streams extended directly to the shoreline and contributed the bulk of their sediment loads directly to the shelf. Inland from the shore, entrenchment led to remobilization of sediment deposited as valley fills in previous periods of valley aggradation. For these reasons, sediment reaching the shelf possibly increased in amount during at least part of such a falling stage, even if streams were possibly diminished in volume due to net addition to glacial snow and ice storage. Much of this remobilized sediment was of coarser-grade size which was redeposited, for the most part, in the nearshore zone after a period of entrainment by coastal current and drift systems. After deposition in the nearshore zone, continued fall of sea level led to re-exposure of the beds. In this way, a thin, probably discontinuous, regressive unit of nearshore deposits came into existence. Wherever this persisted, its importance, as we will see, must have been great at a later time when the sea again rose across this terrain, and these materials were again incorporated into the nearshore zone and into transgressive deposits.

Interval C - A prolonged period of relative constancy of sea level at 60 to 90 m below its present level is believed to have existed throughout the interval of 28 - 46 thousand years before the present. During this period, rivers and streams continued in their profile adjustments to the great base level change of the previous falling sea level interval.

Sediment delivery to the coast was probably still rapid, at least in the earlier part of this period, and coastal progradation may have continued as sea level stabilized, especially in the deltaic areas. Some isostatic compensation may have continued into this time, leading to slight coastal rise.

Away from deltas, slower coastal progradation or even long-term net erosion by nearshore processes may have prevailed. Both would lead, over a long period, to a coastal terrace at or about the sea level of the time.

A prolonged interval of relatively stable sea level may mean that no net glacial snow and ice buildup was occurring and that world climate patterns apparently existed in a more or less stable state of this kind for some time. We are aware of no particular explanation for such an event. In the view of Adam (1975b), an ice sheet once initiated will grow until the heat stored in the surface waters of the ocean is used up and the energy gradient to transfer water from the oceans to glaciers thereby diminishes. Perhaps a steady-state situation existed for some time thereafter in which each yearly increment of solar energy led to sufficient transfer of moisture to the ice sheets to more or less compensate for melting, but not to produce net growth.

In Adam's (1975b) view, after the heat stored above the thermocline in the world ocean has declined in amount (and surface zone temperatures decline correspondingly), less energy transfer as latent heat and more as sensible heat occurs. This would perhaps signify somewhat drier climates in many continental areas since further warming of the air as it flowed from the sea over the land would cause more water uptake.

Adam thought that a glacial episode would involve rapid growth of glaciers while "heat of glaciation" derived from ocean storage was great, then a sudden reversal and decline as this store declined and triggered a decline in latent heat transfer. The suddenness of the decline he felt was also a result of a tendency of the glaciers to over-develop or over-extend. Because of the over-extension, rapid melting ensued. In an extremely interesting argument, Adam shows that rapid melting creates a surface water layer which leads to high heat loss with no potential for storage to drive winter latent heat transfers. This also contributes to glacial disintegration by further cutting off nourishment.

However, it could be argued that other factors may operate that could perpetuate a steady-state glacial condition for a long period. While less water is available from the cooler ocean, perhaps some compensation occurs from evaporation over land areas. An increased aridity over most unglaciated land areas might then be seen, leading to still further reduction of albedo over the unglaciated areas, which might also act to maintain the glaciers.

Emiliani et al. (1975) have recently elaborated a hypothesis of conditions during Stage 3 of the Emiliani interpretation of deep-sea core stratigraphy. They state that all micropaleontological evidence presently available "... indicates that Stage 3 was 'cool' with temperatures closer to those of a glacial age than those of an interglacial one" (Emiliani et al., 1975, p. 1087). They also state, without offering evidence or cited work, that "sea level during Stage 3 apparently stood not much below the present" (ibid). This comment perhaps is influenced by published curves such as Milliman and Emery (1968) presented, but these curves have few data points in the interval of Stage 3 (and even these few are highly suspect according to Thom, 1971).

With their unsupported statement that sea level during Stage 3 was not much below the present, combined with their evidence that the Gulf was comparatively cool at the surface, Emiliani <u>et al</u>. (1975) go on to an interesting interpretation. They suggest these tendencies "can be explained concurrently if a large but thin ice cap had persisted over northern North America during Stage 3, with an unusually rapid rate of accumulation and ablation." They further state that "... continued rapid ablation under equilibrium conditions would supply the Gulf of Mexico with a continued abundant influx of ice meltwater while low temperatures would be maintained."

As Adam (1975b) has emphasized, the lower temperature of the Gulf and an abundant influx of ice meltwater are somewhat mutually exclusive situations, or at least would not likely be stable over the long term. Adam says that fall of temperature of the sea surface leads to reduced glacial nourishment, then to surface layer formation by increased runoff, which further reduces glacial nourishment.

Lindsay <u>et al</u>. (1975) have reported a large (15 km-wide) form which they regard as a submerged barrier reef at 100 - 110 m depth on the Campeche Shelf. This form is illustrated well by its profile which is reproduced here as Figure 4-1. This form possibly began to develop in Interval C and continued its growth in Interval D.

In the southern part of the west Florida shelf, there is a narrow terrace at about 80 - 90 m which broadens at both its northern and southern ends, where there is some suggestion of barrier forms. There is little or no published information on the nature of the bottom in this area, and the bathymetry is also poorly known. The terrace is broadest in an area about 169 km due west of Charlotte Harbor and in an area about 100 km west by northwest from the Dry Tortugas.

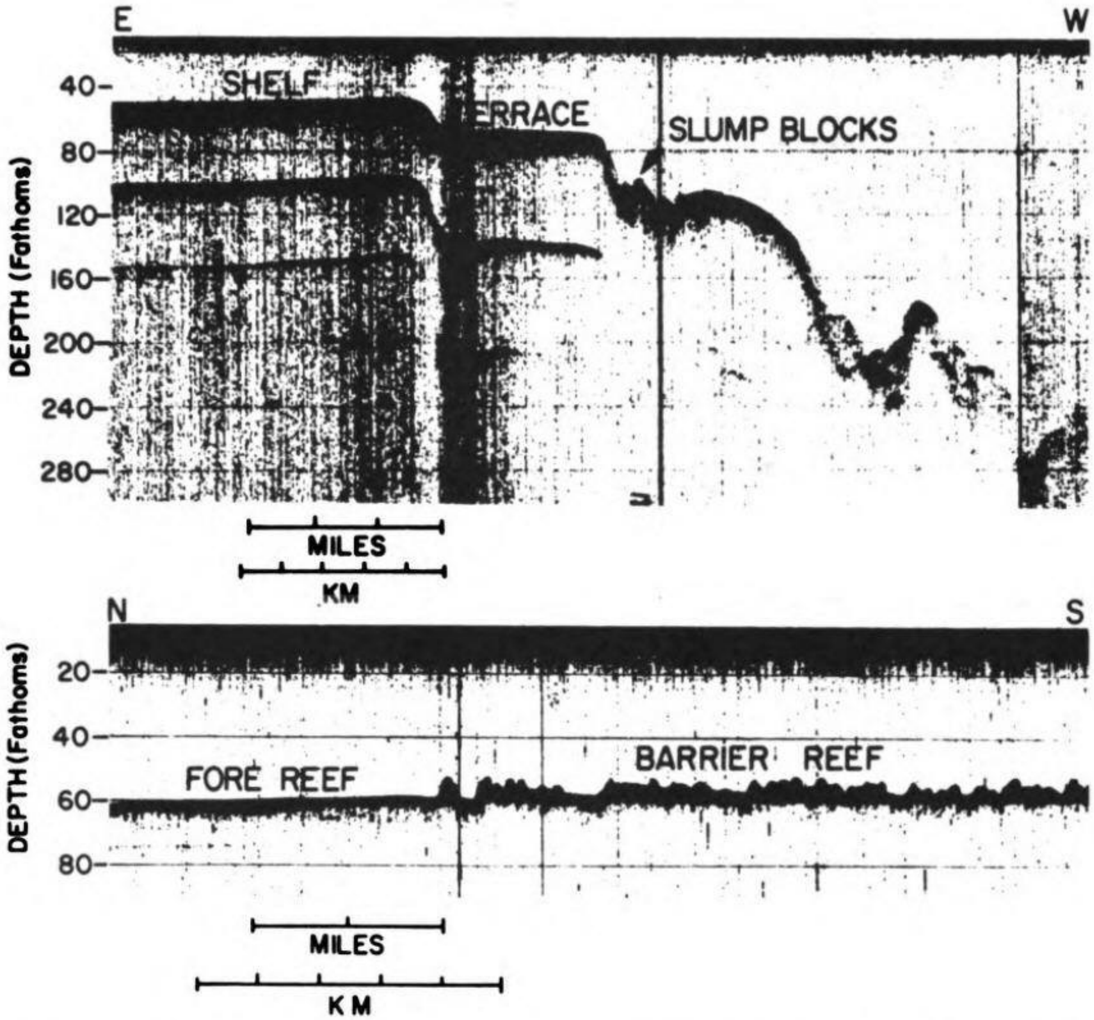


Figure 4-1. 100 - 110 m terrace and drowned barrier reef on Campeche Shelf (From Lindsay et al., 1975).

We tentatively identify this feature as evidence of a prolonged low stand of sea level and suggest that it correlates with the similar terrace of the Campeche Shelf.

Logan et al. (1969) also suggested that there was a "prolonged stillstand" at about 91 m. They felt this occurred prior to 17,710 ± 50 years B.P. from a dated sample of "pelagic shells" from a formation related to this level, but there is little reason to accept this date except possibly as giving a minimal age.

Interval D - The time of the Farmdalian interstade has often been suggested as an interval in which a significant rise of sea level occurred. Many workers feel that the level reached at that time may have nearly equalled or exceeded the present level.

Thom (1971) has extensively reviewed the radiometric evidence of the numerous Mid-Wisconsin high sea level stands that have been proposed and finds that none of the dates are satisfactory. Since this review, the situation has changed very little with the possible exception of a date reported by Neumann and Moore (1975) from a cavern in the Bahamas. This date meets some of Thom's criteria for satisfactory dates, but since it is not a marine sample, the other criteria he proposes are not applicable.

The date was on a sample of a stalagmite, and both the radiocarbon and Th/U methods were applied. The radiocarbon age was 21,900 $\pm$ 900 years B.P. and the Th/U age was 22,000 $\pm$ 350 years B.P. The close agreement tends to support a viewpoint that there has been no recrystallization of the sample. This date indicates that at about 22,000 years ago, sea level was at least 11 m below its present level. There is no way of knowing from this limited information how much lower it may have been, but this work suggests a methodology which may eventually substantially add to our knowledge of past sea levels.

We suggest herein that the Farmdalian Interval did not lead to substantial rise of sea level and is represented in the Gulf of Mexico by a prominent barrier-strandplain form at a depth of 72 - 80 m. This form is evident only in the area of slow deposition off of southern Florida.

Intervals E and F - These two intervals of time represent the resurgence and maximum growth of the Late Wisconsin glacier. On the shelf, sea level fell at a relatively rapid rate. The forms recording this are the dendritic channel forms seen in the areas of more detailed bathymetric coverage in the south and central Texas sectors and on the shelf off of west Florida, some slope breaks in the south Texas and east Texas sectors, and the Mississippi trough. The banks of the east Texas and west Louisiana sectors also show platforms, notches, and submerged reefs which appeared at about the time of maximum low sea stand.

Interval G - The rapid rise of sea level in the latter part of Interval F, reflecting rapid glacial decline, continued in the early part of Interval G. Sea level rose rapidly by about 70 m from its maximum low stand, which led to generation of shoreline forms at approximately the same level as forms which had been created earlier in Interval D. Algal and coralline banks which had been exposed to weathering during the lower sea level became newly active. Many previous forms were obliterated by coastal erosion and new deposition. The size of some of the G-Interval forms may reflect their having been laid over a base of prior forms and the contribution of materials reworked from these prior forms.

Interval H - The onset of Interval H was marked by what perhaps was the most rapid rise of sea level and the most rapid period of deglaciation of the entire period under investigation. This occurred roughly 12,000 years ago and makes a convenient boundary for dividing the Pleistocene from the Holocene, as has been done in this report.

Emiliani et al. (1975) find the lowest ^{18}O concentration in their core near the DeSoto Canyon to occur in an interval bracketed by dates of about 12,000 and 11,000 years. This, then, indicates in their view the time of maximum return of ^{16}O concentrated water from the glaciers. They estimate from the bracketing dates that this occurred about 11,600 years ago and point out that this closely coincides with Plato's estimate of the time of the legendary Atlantean deluge. The coincidence is indeed striking, but perhaps more than it should be since the dates are probably in error (through presence of detrital carbonate as we have discussed elsewhere) and also since it is not clear whether these ages are cited in radiocarbon years or actual historical years. The effect of detrital carbonate would most likely be that the apparent ages would be older than the true age. The effect of not correcting radiocarbon years to actual historic years is that the ages are too old, thus it is possible that the estimate of Emiliani et al (1975) closely coincides with Plato's flood stories only by chance.

We make no reference here to the problematic Valders glacial episode since Mickelson and Evenson (1975) have questioned its existence and maintained that the tills from which this interval was named are actually older than the Two Creeks forest bed. They point out that the till above the forest bed at Two Creeks may be evidence of a glacial episode after the warm interval, and there is some possibility that some decline of sea level accompanied this renewed glaciation.

Geomorphic and archeological data from the coastal zone suggest a relative stillstand during subintervals H_2 and H_3, terminating about 8500 years ago. Extensive swamp development in the west Louisiana area suggests that conditions may have been somewhat wetter than those which prevail at present. The extinction of the Pleistocene megafauna had not yet occurred, and mastodon, mammoth, horse, and other forms were abundant.

There are several lines of evidence which suggest that subinterval H_4 may have been a time of catastrophic events. Geomorphic evidence suggests a reversal of the trend of gradual rise or even relative stillstand of sea level that had occurred for several thousand years prior to this period. Gagliano and Thom (1967) tentatively place the Deweyville alluvial terrace in this time interval. It was also during this period that the extinction of the Pleistocene megafauna probably occurred. It is also noteworthy that during this period of climatic and environmental instability, Archaic culture emerged in the northern Gulf area.

Intervals I, J, and K - These intervals represent a period of about 7000 years of more or less continuous rise of sea level from about -15 m at the beginning of the period to the present level at the present time. This is the best documented interval of time with respect to useful radiocarbon dates. Nevertheless, there is still a wide range of controversy concerning the nature of this last phase of history. Particularly, there is much argument concerning whether the sea formerly may have been higher than at present in the last few thousand years, as Fairbridge (1961, 1974) has repeatedly maintained.

Fortunately, this argument has little importance in the present study since it appears amply evident that regardless of when the sea reached its present level or whether it ever stood higher than present, there still remain many possibilities of cultural resources over most regions of the shelf from earlier times of lower sea level.

CHAPTER V

ARCHEOLOGICAL METHOD AND THEORY

Culture Areas

The archeological literature related to the coastal zone of the northern Gulf is considerable. Important sources of unpublished data exist, in addition, primarily within the anthropology departments and museums of universities and in the files of amateur archeologists in the coastal states bordering the Gulf. Although there are numerous important summaries of the archeology both at the continental and regional levels, no single work satisfies the requirements of the present study.

As a point of departure, the broad cultural areas and subareas defined by Willey (1966) can be used (Figure 5-1). For the purposes of the present study, the northern Gulf will be divided into western, central, and eastern areas. As shown in Figure 5-1, the Western Gulf area corresponds to the Northeast Mexico - Texas culture area of Willey. The Central Gulf is equivalent to Willey's Lower Mississippi Valley Subarea, and the Eastern Gulf area embraces both the Southeast Subarea and the Glades Subarea.

Although it is beyond the scope of the present report, it should be noted that the subareas have also been segmented. Willey (1949) defined three segments of the Florida Gulf Coast within the Southeastern Subarea as the Manatee Region, Central Coast, and Northwest Coast. The work of Trickey (1958) would suggest that Mobile Bay deserves special treatment. In Louisiana, Gagliano (1967) and Phillips (1970) have both defined smaller cultural units. The Texas coast has likewise been segmented (Suhm, Krieger, and Jelks, 1954). Summary treatments exist for a number of these archeological units as well as for a few of the subareas. For example, Phillips' (1970) work on the Lower Mississippi Valley contains a comprehensive summary of coastal Louisiana archeology.

Figure 5-1. Culture areas and subareas of the northern Gulf region (After Willey, 1966).

Although the archeological literature of the coastal zone is generally voluminous, those intervals beyond the Late Archaic (older than about 2,000 B.C.) are poorly known (see Volume III, Plate 1). The explanation probably lies in the fact that much of the record is contained in drowned sites.

When the region is viewed through time, a waxing and waning of distinctive cultural manifestations at various places becomes apparent. Although the complete picture is a complex mosaic of moving peoples and culture traits, certain patterns and clusters of distinctive traits provide the basis for systematic study. From the standpoint of this study, important traits to be considered include patterns of settlement and environmental use, site morphology and content, and index artifacts and characteristic assemblages.

Thus for each cultural manifestation we should strive to develop settlement pattern - environmental use models. The models should indicate the relationship between site location and environmental setting (with emphasis on geomorphic features). Such models increase predictability of high probability areas for site occurrence in reference to landforms. The models become useful when relict features are identified on the continental shelf. They provide an important basis for the prediction of high probability areas for occurrence of drowned sites.

The size and shape of the site (geometry), probable content (shells, animal bones, black earth, burned rock, etc.), and the kinds and abundance of artifacts that are likely to be found, serve to identify archeological sites and to distinguish them from natural deposits or features. The search for drowned terrestrial sites involves testing for these distinguishing features of archeological sites. These distinguishing features can be thought of as "cultural signatures" (in analogy to electronic signatures) in the identification of underwater sites. These signatures might be detected by remote sensing and sampling techniques from the water surface or by direct underwater examination and testing.

Thus, two major objectives of the study that are to be accomplished through the review of coastal area archeology are: 1) the development of settlement pattern - environmental-use models, and 2) the development of lists of distinguishing characteristics or "cultural signatures" which serve to distinguish archeological sites from natural deposits and features, and to distinguish them from each other.

Early Man

One of the most interesting aspects of this study is the evaluation of the nature and extent of the earliest occupations of the region. This indeed touches on one of the least known and possibly the most controversial topic of New World archeology. Because so-called "Early Man" sites are widely scattered, it is important to place the northern Gulf region in proper perspective.

There is abundant evidence, largely in the form of fluted projectile points, that the entire region had been occupied, or at least visited, by 11,000 to 12,000 years before present (B.P.). Large numbers of fluted projectile points have been reported from the eastern as well as the western Gulf area (see Williams and Stoltman, 1965; Neil, 1964; Gagliano and Gregory, 1965).

There is a growing body of evidence that man has been a resident in the area for considerably longer. In Texas, the Lewisville, Malakoff, and Friesenhahn Cave sites have all been assigned to a "pre-projectile point" stage by Krieger (1964). The Avery Island site in coastal Louisiana, the "Natchez Pelvis Find" in Mississippi, the so-called "pebble tool industries" of Alabama, and certain artifacts from sinkholes in Florida also have "pre-projectile point" implications. Radiocarbon dates and geological associations at some of these locales suggest a minimum of 20,000 to 25,000 years B.P. for man's entry into the Gulf coast region.

While some researchers have presented evidence to demonstrate that man has been in the New World for 50,000 to 100,000 years or more, other scholars are highly critical of the validity of the evidence. Although this controversy cannot be resolved by the proposed study, the possibility of these early occupations should at least be considered, and the kinds of sites and artifacts that might be associated with them should be identified.

Richard S. MacNeish in two recent articles (1972, 1976) has effectively summarized the evidence for early man in the New World. Citing evidence from South, Middle, and North America, he defines four prehistoric stages and traditions. As shown in Figure 5-2, the three earliest traditions are attributed to Old World sources. The fourth and most recent tradition, marked by the appearance of well-made projectile points for big-game hunting, seems to be indigenous to the New World. The following is a summary of the four stages described by MacNeish.

Stage I: Core Tool Tradition. This is the most tentative stage dating to more than 20,000 years ago in South America and possibly to more than 40,000 years ago in North America. The difference in ages is attributed to slow southerly dispersal of the tradition. It is proposed that migrating bands crossed the Bering Strait land bridge some 70,000 $\pm$ 30,000 years ago and migrated slowly southward. These early people were unspecialized hunters and gatherers. They utilized a wide range of plants and animals including big game when the opportunity presented itself. The artifact assemblage includes crude, large, bifacial and slab choppers, cleavers, hammers, scraping planes, and crude concave- and convex-sided. unifacial scrapers or spokeshave-like objects.

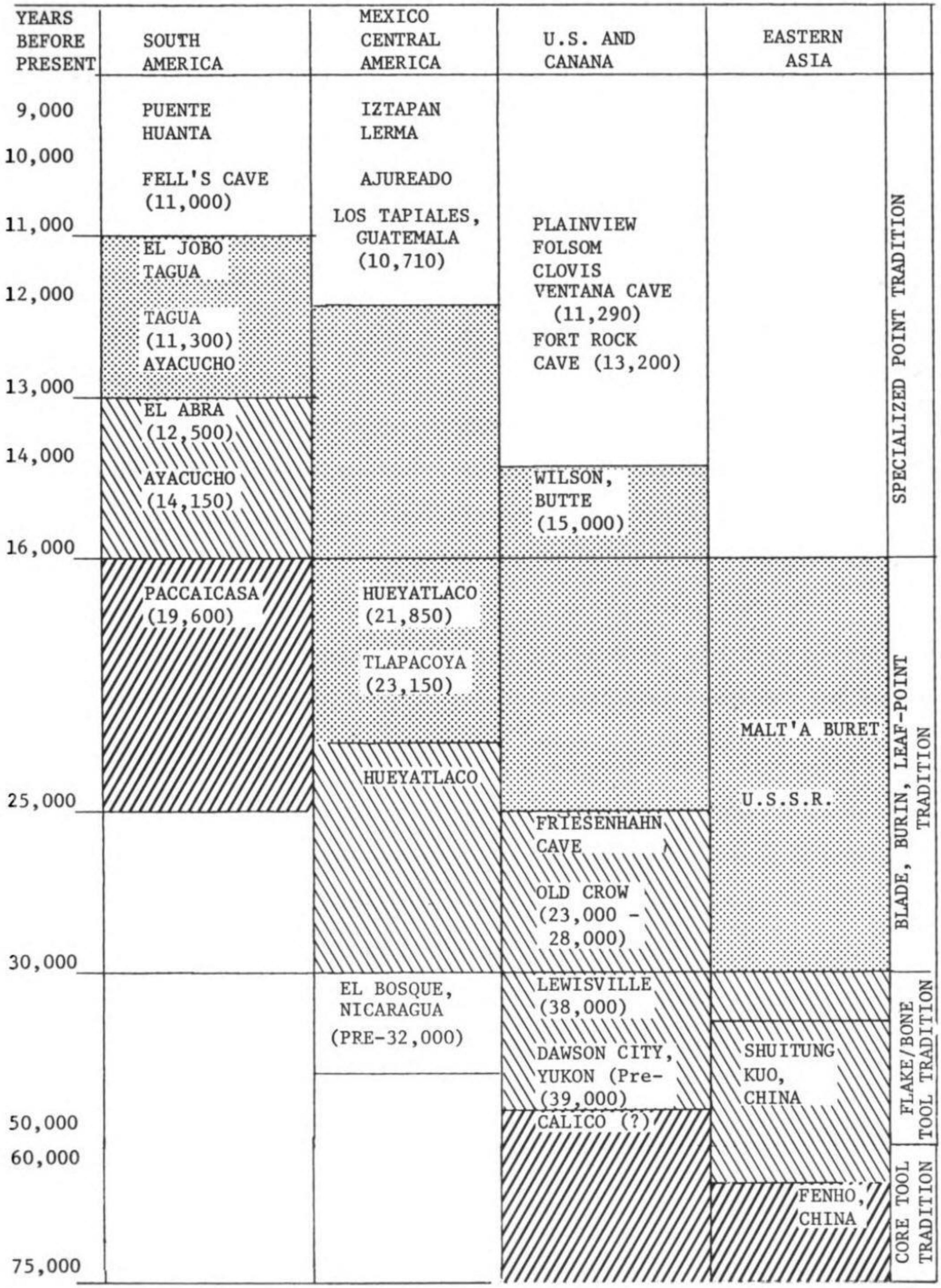


Figure 5-2. Chronology of early man sites and traditions. Note the time lag between major continental areas and the implied Old World origin for the three earliest traditions. The specialized point tradition is thought to be indigenous to the New World (After MacNeish, 1972; 1976).

Pointed flakes may have served as simple projectile points. Burned bone in hearths and simple pebble tools may also be included.

Stage II: Flake/Bone Tool Tradition. Dated sites in South America range from 12,000 to as much as 16,000 years old. In Central America, the dates are from 15,000 to 25,000 years, and in North America from 25,000 to 40,000 years. People of this stage could either have entered the New World via the land bridge from Asia some 40,000 ± 10,000 years ago or developed in northern North America. New concepts appear in the technology which emphasize stone flake tools, produced by percussion and pressure, as well as the manufacure and use of bone tools. Although meager, the faunal and artifact evidence indicates a relatively unspecialized hunting subsistence.

The artifact assemblage includes flake projectile points or knives, bone projectile points, pebble choppers, plano-convex denticulate scrapers, burins, and rib-bone fleshers.

Stage III: Blade, Burin, and Leaf-Point Tradition. This stage is represented by complexes in the 11,000 to 15,000 year range in South America and Middle America. In North America, they do not appear to be greatly older, falling into the 13,000 to 25,000 year range. Although data are sketchy, these people are believed to have been specialized hunters of big game or herd animals in a wide variety of environments. There is a marked advance in tool technology over the previous stage. Fine, leaf-shaped, bifacial projectile points, blades, and skillfully made flint burins appear in the assemblage. The burins suggest a comparable advance in the bone tool technology.

Stage IV: Specialized Point Tradition. This stage covers the period from 13,000 to 8,500 years ago throughout the New World. It is believed to be characterized by highly specialized hunting techniques. These people not only had a number of different hunting techniques, but the wide variety of chipped artifacts and foodstuffs found at the sites suggests that they had begun to collect a number of kinds of plants and to hunt and trap smaller animals. In some areas, there is evidence of systematic collection of nuts, seeds, fruits, and other plant materials. Evidence for occupations during this interval is widespread throughout the New World. Many different kinds of environmental settings were utilized, with a corresponding diversity of subsistence patterns. It should be noted that present concepts of Stages IV as well as III come from inland or interior site exploration. Coastal sites from these intervals in the Northern Gulf area remain virtually unexplored.

Characteristic artifact assemblages show much greater diversity than in earlier stages. Projectile point types include, but are not limited to, Lind Coulee, Lerma, Hardaway, Plainview, Folsom, Clovis, Fell's Cave, Lauricocha, and stemmed points. Unifacial end scrapers, denticulates, spokeshaves, knives, burins, and many other specialized tools occur. Basic tools include pins, projectile points, and shaft straighteners.

Landform Associations

The principles of stratigraphy are well known to the archeologist. A less-formalized and less-used set of concepts is the relationship between site distribution and geomorphic features.

Coastal zone sites in favorable locales that are geologically stable or where there is appreciable relief may be continuously occupied, or periodically re-occupied, for long periods of time. For example, certain cave sites along the South African coast were occupied for many thousands of years. Sites associated with ephemeral features of low-gradient coasts are more often characterized by occupations of shorter duration. Such conditions obtained throughout much of the Northern Gulf area. Further, the periods of occupation are likely to be associated with favorable ecological conditions in the vicinity of the site.

In dynamic coastal situations, where changes in the positions of shorelines and streams are accompanied by shifts in settlement pattern and land use, the occupation pattern is dictated by active and relict landforms, such as stream banks, beaches, margins of estuaries, and important ecotones.

Studies of the distribution of sites by age or culture period in coastal areas have also demonstrated the relationships between occupation patterns and the evolution of the coastal landscape. Simple but effective demonstrations of this are found in places where progradation has occurred over a considerable period of time and a series of relict shorelines has developed.

The basic relationships of this frequently occurring situation are shown diagrammatically in Figure 5-3. Note in the figure that the mouth of the stream has been a favored habitation place through time, and sites are found not only at the present mouth of the stream, but also at former stream mouth locations. In this kind of situation, some of the site occupations may have continued even after the position of the stream mouth shifted as a result of shoreline progradation. However, in such instances, it is the initial occupation that most closely approximates the age of the feature upon which the site is located. For this reason, sequential maps showing initial occupations of sites are very useful in the interpretation of the geological history. Another example of this principle can be found in lobate delta areas, where areas of delta building have shifted periodically as a result of upstream diversion. Figure 5-4 illustrates diagrammatically the relationships which may exist in such a case. Sites are located primarily along the natural levee ridges of trunk channels and distributaries. While the period of initial occupation of the sites associated with an abandoned river course or delta lobe may approximate the time when it was active, habitation may have continued after the system

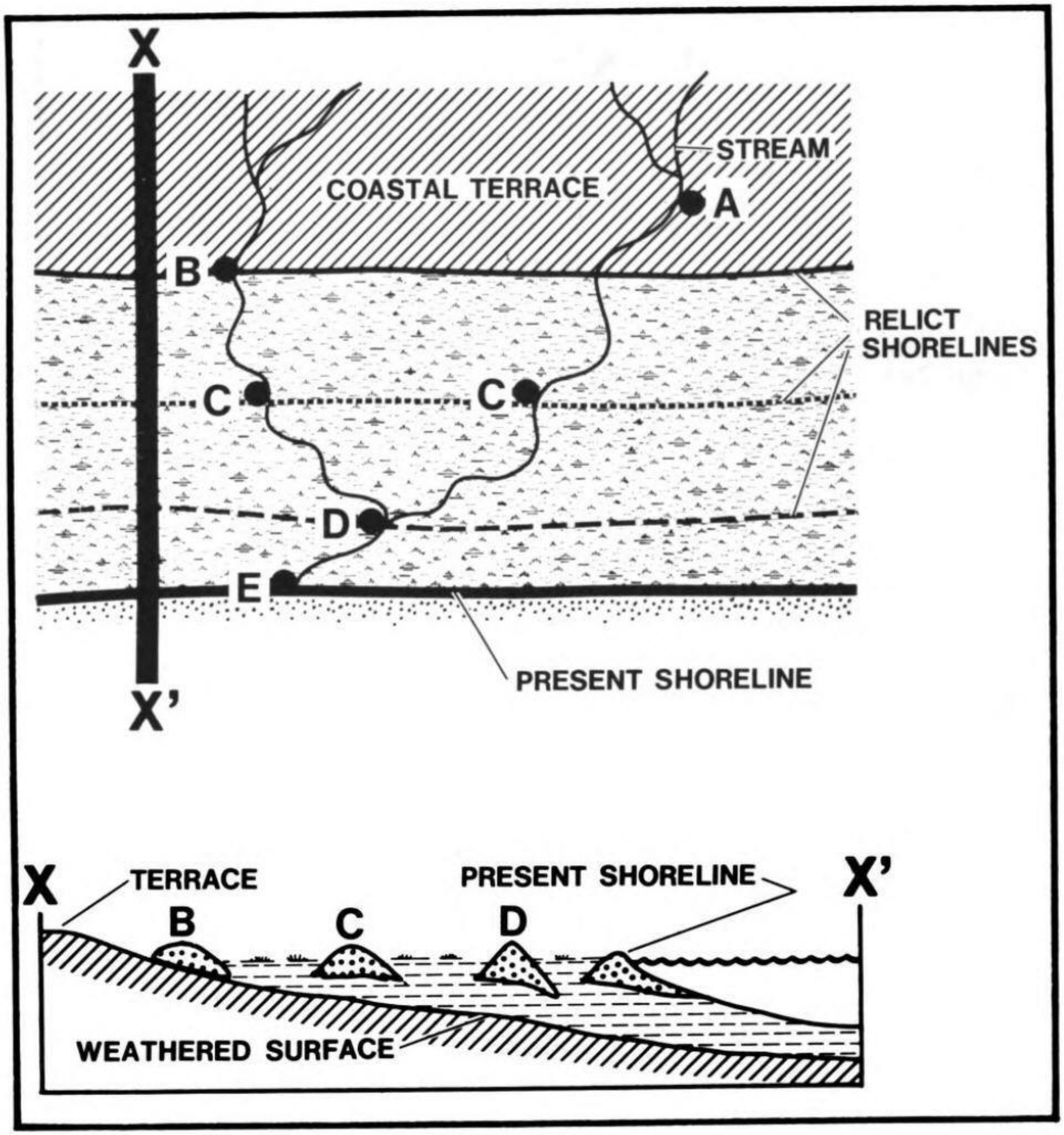


Figure 5-3. Distribution of initial occupation sites in a prograding beach sequence. A - oldest; E - youngest.

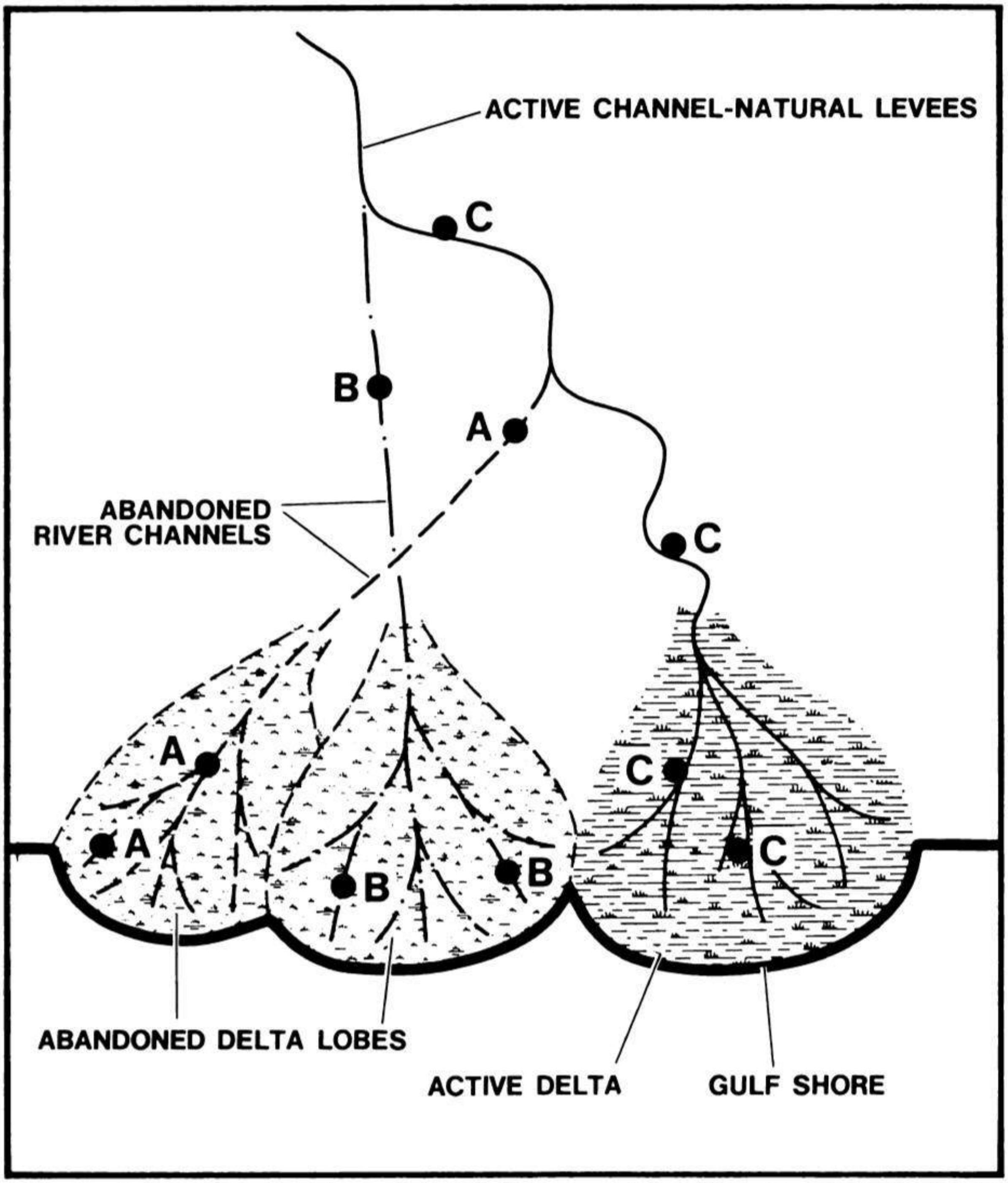


Figure 5-4. Distribution of initial occupation sites in a lobate delta. A - oldest; C - youngest.

ceased to function as an active delta lobe. In some instances the habitation sequence may be out of phase with the delta sequence. An explanation for these relationships is found in the cyclic nature of delta building and the environmental succession which unfolds as the cycle progresses.

Upstream diversions of the river result in an influx of fresh water and sediment along the coast in the vicinity of active distributaries.

Sediment deposition results in delta building and shoreline progradation. Natural upstream closure of a major distributary cuts off the freshwater and sediment influx, marine processes gradually become dominant, and the delta lobe may retreat or deteriorate. Thus, the delta lobe evolves through a cycle. The stages of an idealized delta cycle and associated environmental changes are shown in Figure 5-5. As indicated in the figure, initial human occupation is often associated with the early stages of subaerial development. However, it should be noted that biological productivity is highest during the early stages of deterioration. It is during these stages that utilization of delta lobes by hunting-gathering peoples is usually the greatest.

Another kind of situation is found in places where smaller, coastal plain streams enter the Gulf. Many favorable habitation sites are associated with such streams. As shown in Figure 5-6 (occupation "C" sites), sites can be anticipated along the banks of the stream itself, along the margins of the floodplain or valley wall, in the deltaic area of the stream system, and along the margin of the estuary near the mouth of the stream.

The morphology of such systems may be complicated by fluctuations in the base level of the stream, resulting in alluvial and coastal terraces. Relict stream courses are associated with the alluvial terraces, while relict beaches and other shoreline features are found on the coastal terrace. Figure 5-6 shows a characteristic pattern of initial occupation that might occur in a typical system of this type.

Figure 5-7 illustrates still another pattern of initial occupation sites that might be found in association with sequentially developed, recurved spit complexes and beach accretion on a major barrier-spit complex. Note that the spit builds in a downdrift direction with a minor seaward growth component. The distribution of initial occupation sites reflects

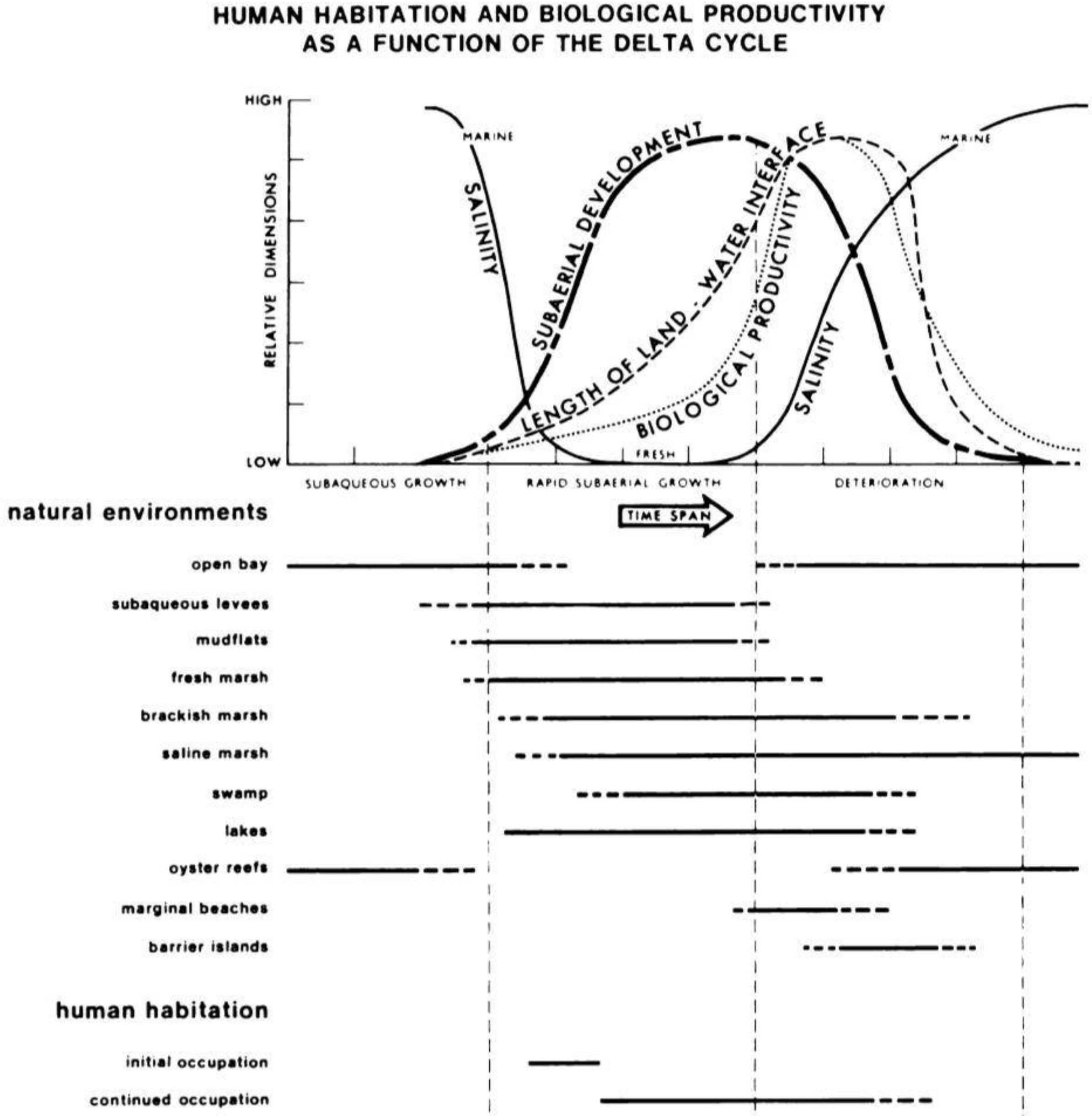


Figure 5-5. Environmental succession of an idealized delta cycle. The time required for completion of a cycle varies from decades to thousands of years, depending on the size and complexity of the lobe. Associated with the cyclic character of delta building is a sequence of environmental changes. These changes in turn influence the character of human utilization and exploitation. (Modified from Gagliano and van Beek, 1975.)

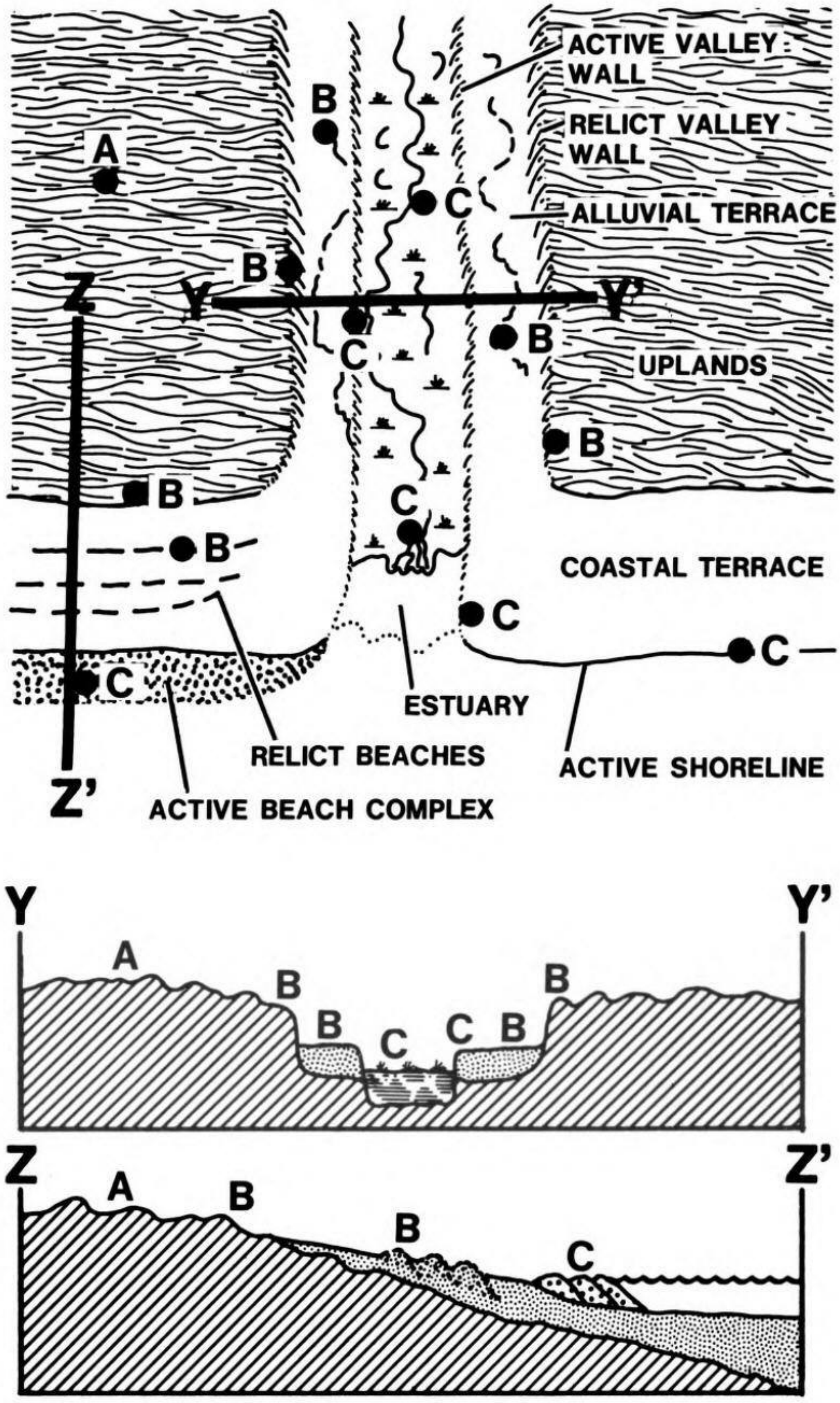


Figure 5-6. Distribution of initial occupation sites associated with a coastal plain stream system. A - oldest; C - youngest.

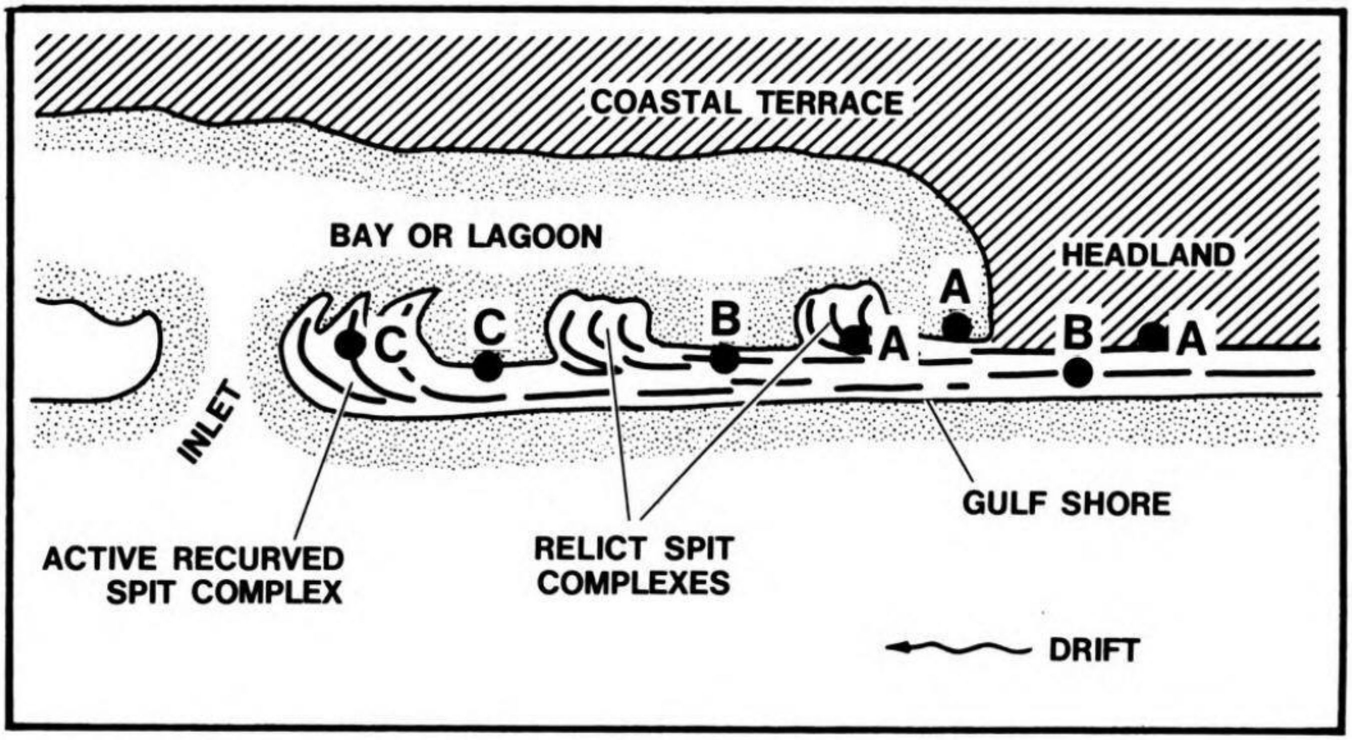


Figure 5-7. Initial occupation sites associated with sequentially developed, recurved spit complexes. This pattern could be produced either by downdrift migration of the tidal inlet or re-occupation of the same shoreline position following a fall and rise of sea level. A - oldest; C - youngest.

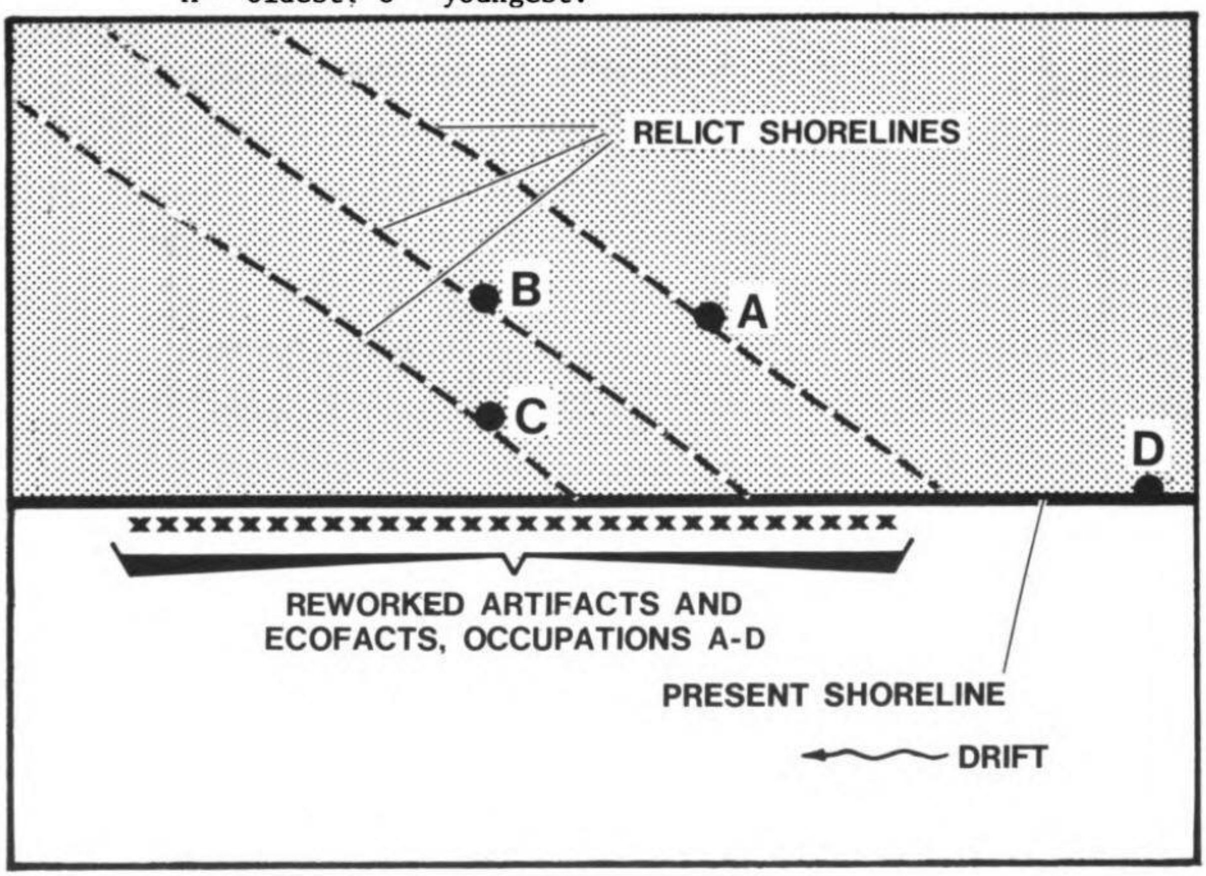


Figure 5-8. Initial occupation sites and reworked material on truncated shorelines. A - oldest; D - youngest.

this growth pattern. This type of spit pattern may develop in two ways. During periods of relative stillstand, inlet migration in a downdrift direction may result in this geometry. In such instances, the time intervals involved may be a few hundred to a maximum of a few thousand years. The pattern can also result from re-occupation of the same shoreline after an interval of sea level fall and rise. In this instance, the time interval between occupations may be thousands or tens of thousands of years.

Figure 5-8 depicts a situation where a set of prograded relict shorelines (A-C) has been truncated at an angle by a later shoreline (D). Artifacts and ecofacts from sites associated with the initial relict shorelines may be winnowed out of eroded sites and redistributed along the later shoreline. In such an instance, a considerable hiatus may occur between occupations C and D.

When shore sites are eroded by waves or wind action along a shoreline or in a dune field, the coarse lag deposits left behind usually contain many valuable data. Artifacts of durable materials (bone, stone, pottery, etc.) may be worn and rounded by abrasion and reposited along with shell and other coarse inclusions. Although the geometry of the site is destroyed, the lag deposits contain identifiable artifacts and ecofacts and are of archeological value. They indicate the presence of a site. They contain artifacts which may be datable and indicative of site activities. Ecofacts give clues to environmental conditions at the time of site occupation.

Eroded and reworked sites may be found in the distal end of delta lobes (Figure 5-9). Artifacts and ecofacts from eroded sites that were once on natural levee ridges of distributaries may be redistributed along the fronts of, and incorporated within the sands of, the transgressive barrier islands that develop during the deterioration stage of the delta cycle.

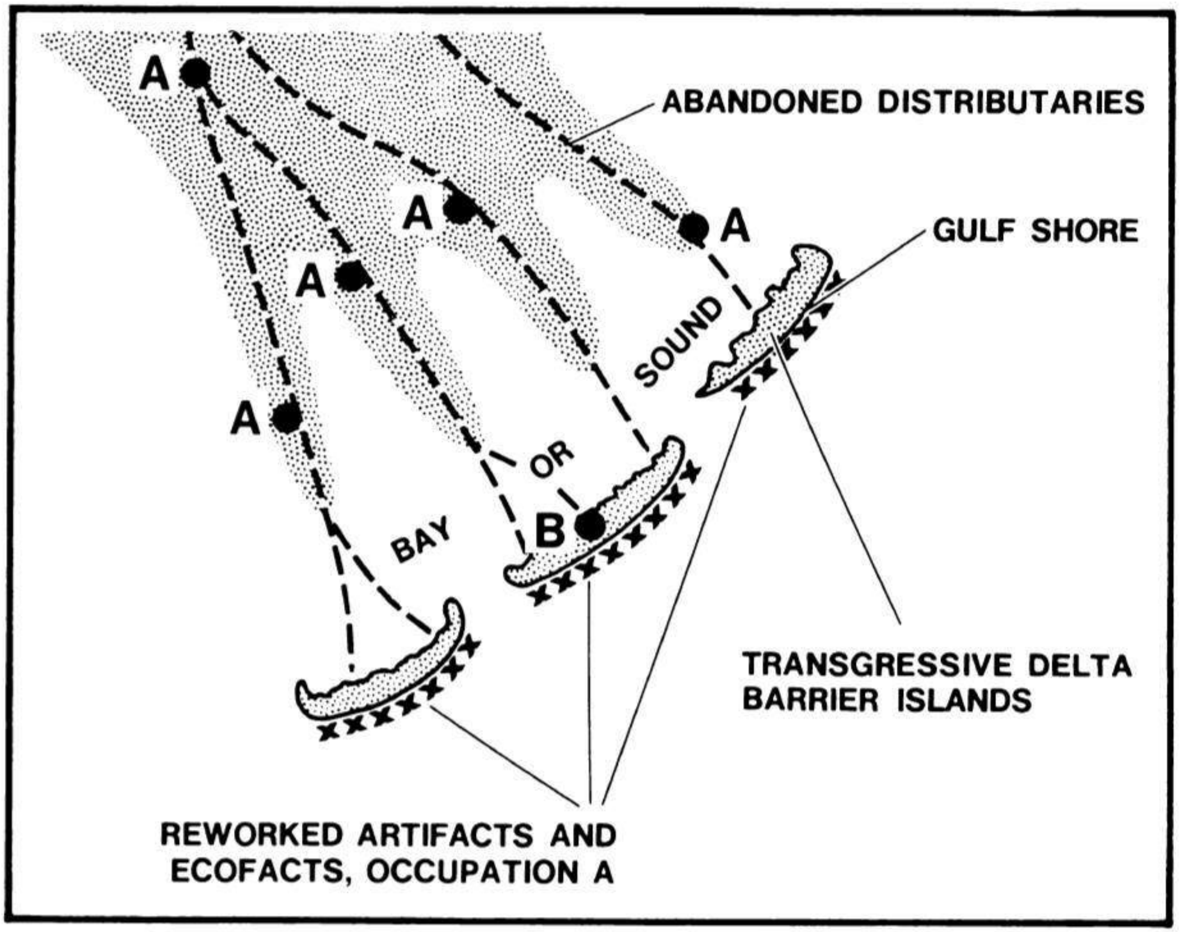


Figure 5-9. Initial occupation sites and reworked material in a transgressive delta. A - oldest; B - youngest.

<u>Ecofacts</u>

The remains of plants and animals occur commonly in archeological sites and may be particularly abundant and well preserved in coastal sites. They include shells of pelecypods, gastropods, and other marine organisms, bones, seeds, wood, peat, foraminifera, pollen, spores, etc. They may constitute the bulk of the archeological deposit, which may be hundreds of meters in length and ten or more meters thick. They may be confined to individual strata, such as bone beds or organically rich deposits. They may also occur as inclusions within a site matrix of sand, silt, clay, or other sedimentary deposits.

If the ecofacts represent remains of fauna or flora that constituted a part of the diet or were otherwise utilized by the site inhabitants, they may contribute significantly to an understanding of past economic activities. Calculations of population size have been made for coastal shell middens, and seasonality of occupation has been determined from studies of annual growth rings of shellfish, deer antler, and seed remains. Ecofacts are also of primary importance in providing samples for radiometric dating.

In addition to their use in dating and cultural interpretation, ecofacts are also of exceptional value in establishing the environmental conditions in the vicinity of the site during its occupation. Archeological sites often contain concentrated samples of ecofacts gleaned from neighboring environemtns by inhabitants of the site. Shellfish remains from coastal sites provide an excellent illustration of the use of faunal remains and environmental interpretation. Shellfish are sensitive indicators of salinity, water temperature, turbidity, and other process factors that define environments and subenvironments. (For an example illustrating characteristic shellfish assemblages from the western and central Gulf, see Parker, 1960.) Consider three molluscs commonly found in archeological sites of the northern Gulf and their environmental implications:

Molluscs	*Salinity*
Unio sp.	Fresh
Rangia cuneata	Brackish
Crassostrea virginica	Saline

Figure 5-10 depicts a hypothetical coastal estuary which has become fresher through time as a result of blockage of its mouth by barrier spits and

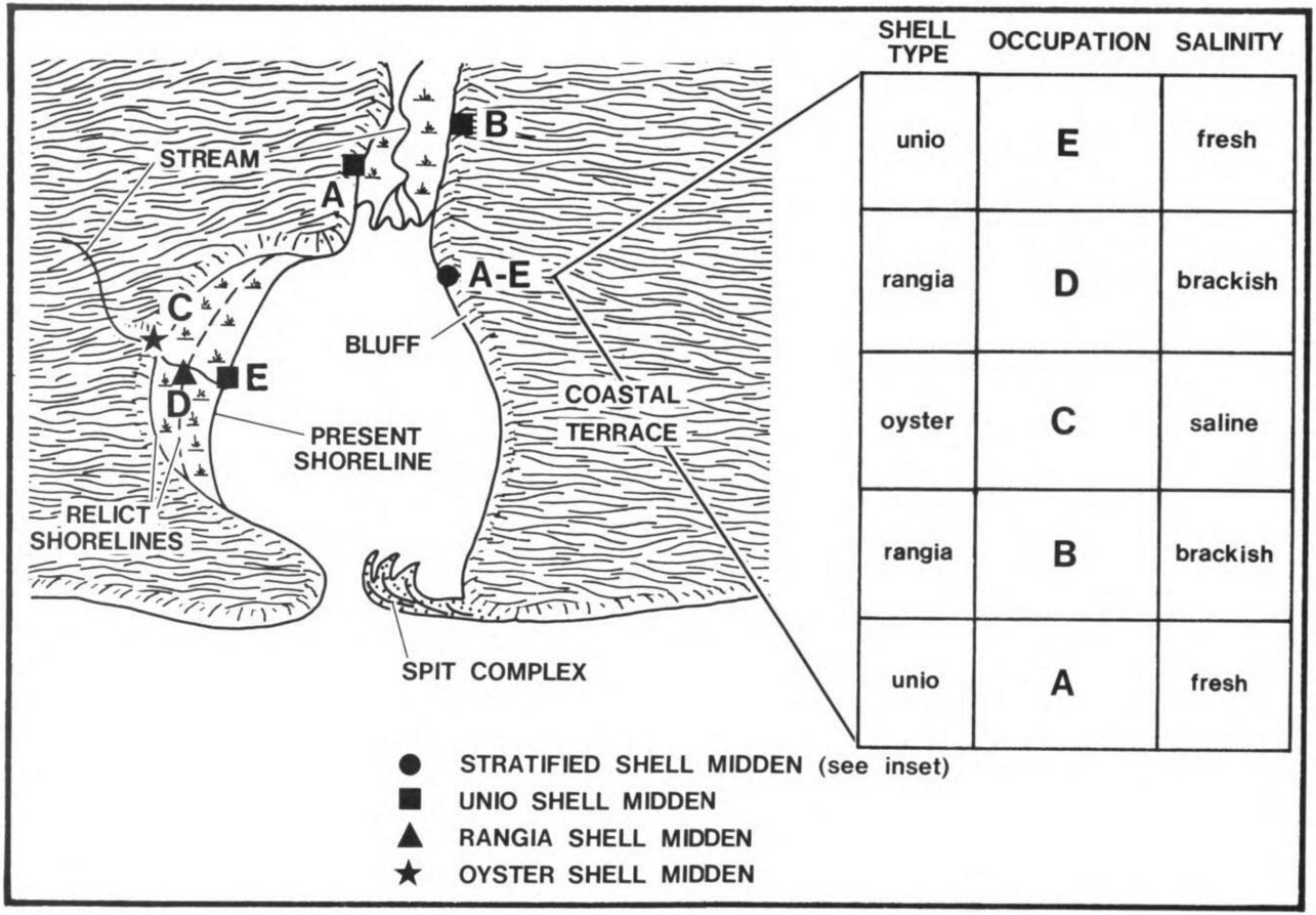


Figure 5-10. Changes in shell content of middens in a hypothetical coastal estuary resulting from sea level fluctuations. Reversal in apparent salinity within the stratified site results from a rise in sea level (A-C), followed by stream progradation (D-E). A - oldest occupation; E - youngest occupation.

outgrowth of streams emptying into the embayment. Middens located around the estuary reflect this environmental change through changes in shell content. Shell middens located on prograding beaches may be composed of different shell types, while a site on a bluff with a long sequence of occupation shows a vertical change in shell types.

Because of the dynamic processes associated with shore zone environments, archeological materials frequently become incorporated into sedimentary environments. Common examples are sites on the banks or on point bars of meandering streams, on actively prograding beaches, on coastal dunes, and around ponds, bogs, or sinkholes.

In subsiding areas or in certain situations during intervals of rising sea level, entire sites may be slowly covered with sediment. Gradual sediment burial of entire mound groups, preserving the entire geometry of the sites, is a rather common occurrence in the Mississippi delta area (Figure 5-11).

Archeological Sequence and Sea Level Fluctuation: The Ria Cycle

Clearly, a major fluctuation of sea level will bring about great changes in coastal environments, landforms, and settlement patterns, which will be reflected in the archeological record. An often-repeated sequence of events in the Late Quaternary history of the northern Gulf area is related to a fall and subsequent rise of sea level. Such a sequence can be called a "ria cycle," since it produces drowned river valleys, or rias.

The ria cycle has been chosen to illustrate archeological relationships related to sea level fluctuations because ria cycles have occurred on several scales during the past 55,000 years and left a distinctive record

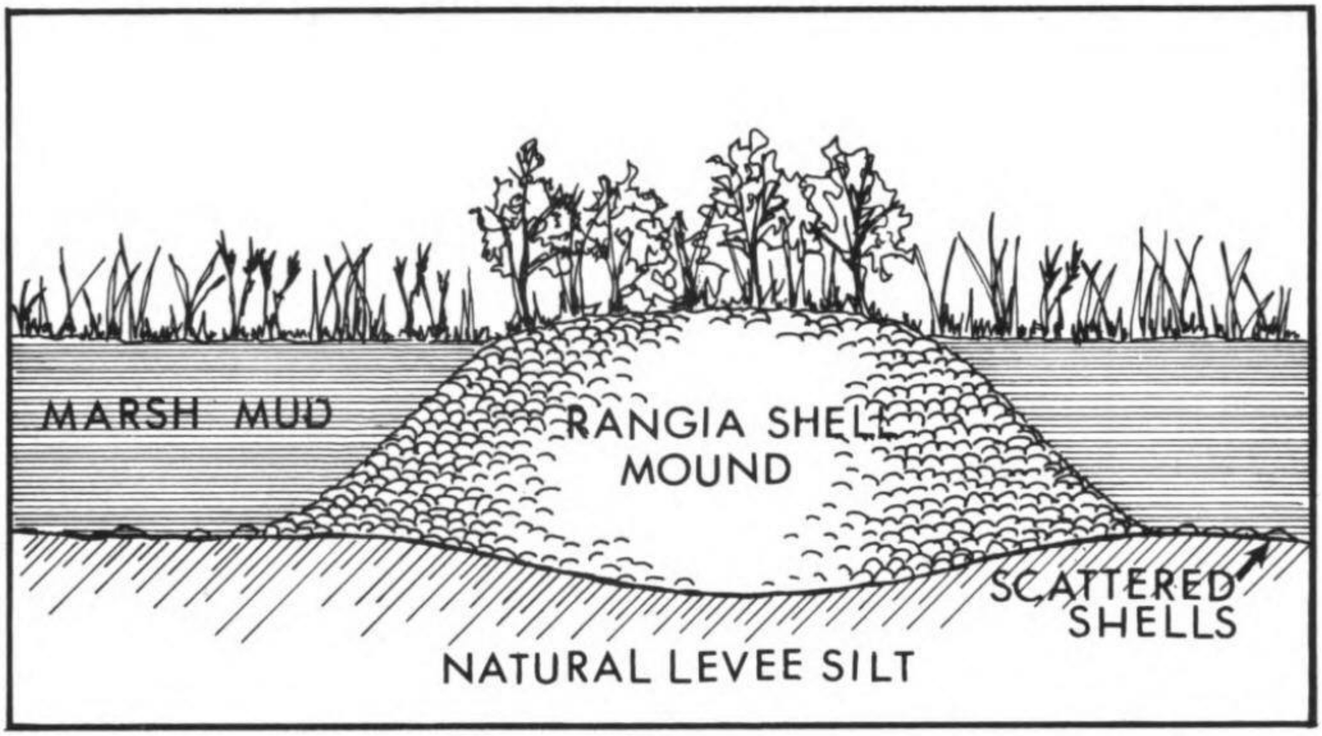


Figure 5-11. Shell mound on a subsided natural levee ridge enveloped by marsh mud (After Russell, 1967).

within the study area. Figures 5-12 and 5-13 illustrate a hypothetical ria cycle and its effects on coastal landforms and the archeological record.

The ria cycle is especially important in the interpretation of continental shelf archeology. As indicated in Chapter 2 a number of ria cycles have unfolded within the time interval under consideration in this study. As illustrated in Volume III, Plate 3, one major, and three minor ria cycles have occurred during the past 25,000 years. Each of these cycles presumably had a major influence on the distribution of landform and associated habitation sites within the study area.

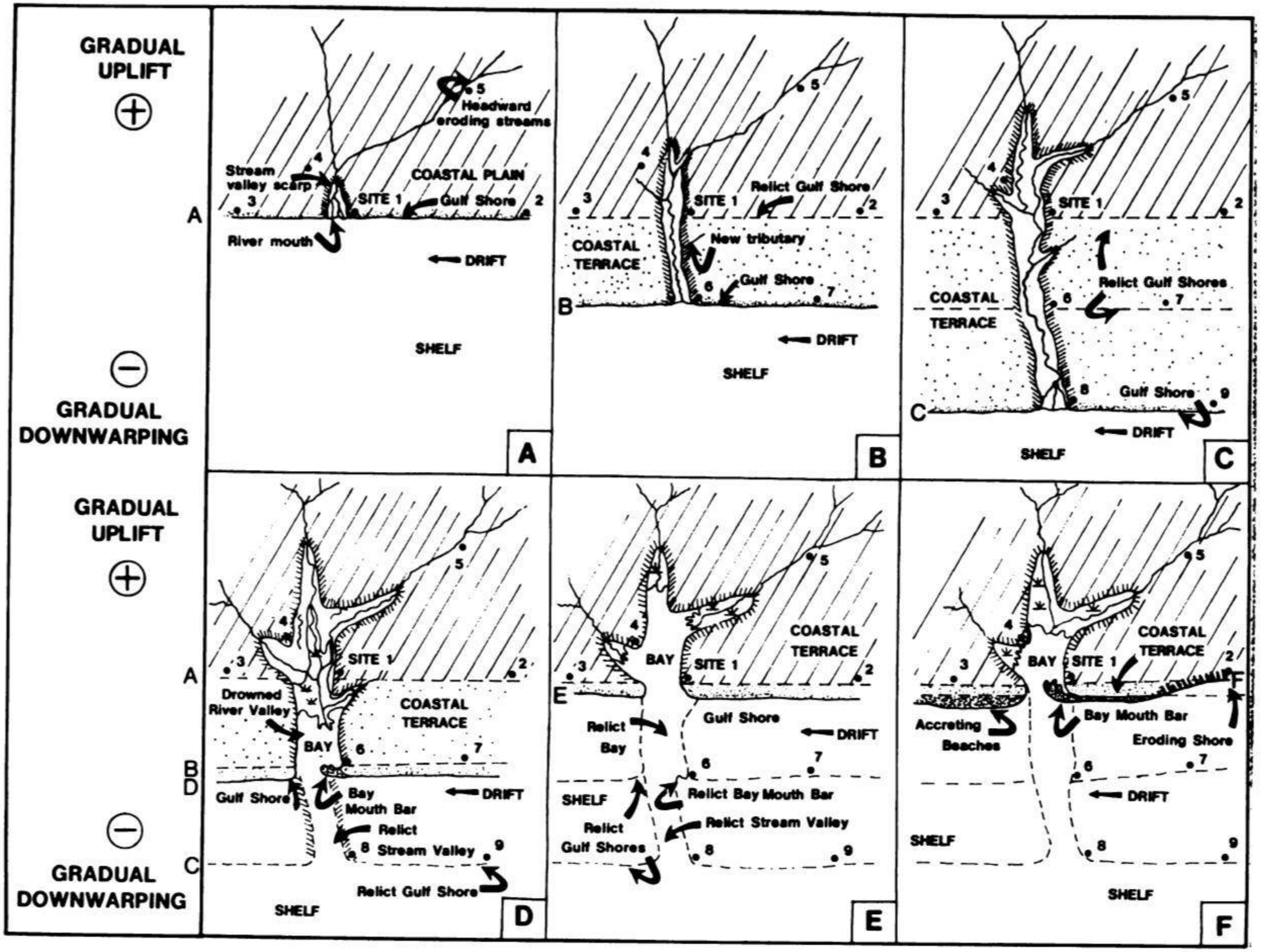
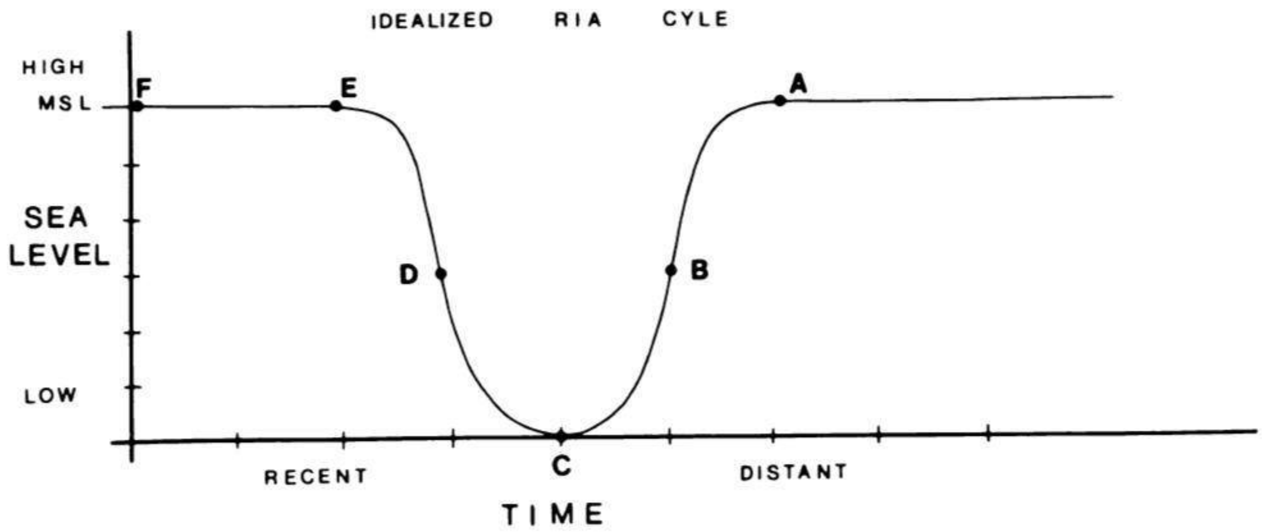


Figure 5-12. Hypothetical sequence of landform development during a "ria cycle." Sea level fluctuations associated with the cycle shown in Figure 5-12. Typical site locations indicated by numbers.



STAGE	SITES								
	1	2	3	4	5	6	7	8	9
A	MEU	MU	MU	U	RU	—	—	—	—
B	RU	U	U	U	RU	MEU	MU	—	—
C	RU	U	U	RU	RU	RU	U	MEU	MU
D	EU	U	U	RU	RU	MEU	MU	—	—
E	MU	U	U	EU	RU	—	—	—	—
F	MEU	MU	U	EU	RU	—	—	—	—

ENVIRONMENTS

M-marine shore-beach-dune-bay mouth

E-estuarine-brackish

R-riverine-gravel-fresh mollusks

U-uplands-flora fauna

Figure 5-13. Idealized sea level fluctuations of a "ria cycle" (top). For associated changes in coastal landforms, see Figure 5-11. The matrix (bottom) indicates changes in environments at sites shown in Figure 5-11, as the "ria cycle" unfolds.

CHAPTER VI

SELECTED TYPICAL ARCHEOLOGICAL SITES OF THE NORTHERN GULF

Site Inventory and Dating

An attempt was made to compile an inventory of known sites in the northern Gulf area that may have been occupied from the time of formation of the Ingleside shoreline (A_2 interval circa 55,000 years B.P.) until sea level was stabilized at approximately its present stand (the end of Interval J, 3,500 years B.P.).

Site data was obtained from various sources, such as the Texas Archeological Research Laboratory, at The University of Texas at Austin, the Department of Geography and Anthropology at Louisiana State University in Baton Rouge, and the Department of Sociology and Anthropology at the University of Southwestern Louisiana in Lafayette. The Louisiana Archeological Survey and Antiquities Commission, the Department of Archives, History, and Records Management of the Florida Department of State, and the Temple Mound Museum, Fort Walton Beach, Florida, added significant site information. In addition to the institutional sources, site information came from selected amateur archeologists throughout Texas, Louisiana, Mississippi, Alabama, and Florida.

A review of the literature on northern Gulf archeology also yielded a long list of sites. The use of such a literature search has its inherent problems, however. We are forced to base our site locations and occupation dates on information which, at times, is fragmentary, poorly reported, poorly analyzed, and sometimes entirely erroneous. Relying on secondary sources is always risky, especially when data is poorly described and illustrated, making a critical review of the interpretations most difficult. In some cases, published reports are so vague that it is impossible to locate sites, even by county.

In dealing with unpublished site reports, another problem was frequently encountered. The file cards often contain very cryptic descriptions, such as "Archaic (?) flint chips found." Such locations were considered on the assumption that most were, indeed, Archaic Period, initial occupation sites.

The site locations resulting from the inventory are presented on the map in Volume III, Plate 4, entitled "Archeological Sites, Initial Occupation." As indicated by the title of the plate, an attempt was also made to establish the time of initial site occupation. The locations of the sites are indicated on a map of the area by a symbol which denotes the initial occupation period. Tabular listings of initial and subsequent site occupations are given in Volume III, Plate 5, "Projectile Points and Site Chronologies." These tables are divided by area, Western Gulf, Central Gulf, and Eastern Gulf. For each area there is a listing of the time span of the projectile points found there, and also a listing of the time period of the site discovered there.

Although it was deemed important to present the occupational sequence to the greatest extent possible, there are many pitfalls in establishing absolute and even relative dates. The shortcomings of radiometric dating are well-known and will not be discussed at length in this section other than to note that the problems increase as the age of the material increases.

The value of utilizing artifact assemblages and "index" artifacts for establishing relative chronology is a well-established tool. The technique becomes shaky, however, when correlations are made far from the place where the chronological position of the artifacts has been established through controlled excavation and absolute dating techniques. Other limitations in the methodology are time lags related to diffusion, the possibility of independent invention of the same form in widely separated areas or at different times, and the many other difficulties related to using artifacts as indicators of culture.

In spite of all these difficulties, the validity of the methodology as applied to a regional problem can be demonstrated. For example, radiocarbon assays of organic samples associated with fluted projectile point forms at sites widely dispersed across the continent indicate that they were in vogue during a relatively narrow time interval, and thus are valuable index forms.

For the period from 11,500 to 3,000 years B.P., chipped stone projectile points are the most universal and distinctive artifact type and are the basis for estimating the chronological position of sites. The term projectile point is something of a misnomer, as many were clearly utilized as knives or other special-purpose hafted tools. Nevertheless, each artifact included in this broad category is usually distinguished by a particular set of attributes which is the basis for classification. In some cases, such as the Clovis points in the Plains area, the age of the points has been established. When points with similar attributes are found in Florida, it is generally assumed that they are the same age as those from the Plains, but at this time they have not been securely dated. Depending upon the area of origin of the fluted point tradition, of which the Clovis point is an early form, and the routes of dispersal from the area of origin, the fluted points of Florida could be older or younger than those of the Plains area. "Culture lag" plays an important role in such instances.

For the period from 11,500 to 3,000 years B.P., chipped-stone projectile points are the most universal and distinctive artifact type for estimating the chronological position of sites. In some cases, such as the Clovis and Folsom points in the Plains area, the age of the points is well established. However, in many instances, either the absolute age of the point has been poorly established or it may vary greatly across the study area. The projectile point chronologies listed in Volumes III, Plate 5, reflect these problems.

For instance, the San Patrice point in Texas (see Volume III, Plate 5) is seen as beginning approximately 5,000 B.P. and lasting well into the first millenium A.D. In Louisiana, the time estimates are considerably different. Data from that state suggest that the San Patrice point has a time range of 10,000 B.P. to 8,000 B.P., a difference in initial dates of 5,000 years! "Culture lag" can play an important part in such instances. Clovis points, for example, which have been dated quite accurately in west Texas, may have taken longer to disperse eastward to Florida, where such precise dates are lacking. Thus, one cannot reliably fix the initial, and even terminal, dates on the point as being the same for the different areas.

That certain points are thought to have longer time spans in one place than another is illustrated by the Lerma point, which in Texas has an estimated range of 10,000 to 2,000 B.P., and in Louisiana of 9,500 B.P. to 6,500 B.P., a difference of 5,000 years. Since the charts shown in Plate 5 are compilations of data listed in various publications dealing with regional chronologies, and are subject to margins of error and assumptions in each publication, the charts should be viewed, in most cases, only as a compromise among several publications. When a projectile point's time span is the same for two or even all three of the Gulf regions, then a more trustworthy chronology can be based upon it. The reader should be warned, though, that in a few cases, the publications dealing with point chronologies copy dates from each other, so that it can appear as if the point has the same exact age and time span in two separate areas.

Point typology is another factor in regional projectile point comparisons. Similar, if not identical, points are given different appellations in different regions throughout the Gulf, although technologically they have the same characteristics. Big Sandy points from Alabama and Bolen points from Florida are an example of this problem.

Certain point names, like Gary, have been used as catch-all terms to include several varieties of points which have no really common attribute except being crudely chipped and having a contracting stem. Garys can be shouldered or non-shouldered, range from 10 cm to 3 cm in length, and can have been either knives, projectile points, or lance tips.

If the data base for projectile point tradition sites appears to be thin, then that for earlier sites can be described as very meager indeed. We are limited to a mere half-dozen sites in the entire region that are reported to have preprojectile point characteristics and descriptions and illustrations of cultural materials from these few sites are virtually nonexistent. The chronological position of these earlier sites is based on a few radiocarbon dates and stone tool assemblages.

One final word should be mentioned about Plates 4 and 5. All sites were listed by number rather than by name, since it was a less cumbersome method. However, in many cases, the responsible state agencies have not assigned numbers to all sites, even when the name and exact location of the site is known. In such instances, letters have been temporarily substituted in the hope that eventually a number will be assigned. 16 EV "A" for the Tate Cove Site is a good example. Its location, artifacts, and age are known, but a number has not yet been assigned.

In retrospect, the task of compiling an inventory of all known sites in the Gulf coastal area dating older than 3,500 B.P. is not an impossible one. As one might expect, relatively few sites are known from the early time intervals.

Selected Sites

From the published and unpublished data reviewed during the course of this study, summaries of selected sites are presented. For each of the three regions into which this report is divided, a significant site, or sites, is described in relation to its age, ecofacts, artifacts, associated landforms, and other pertinent data. Each of the three regions is subdivided into Preprojectile Point, Paleo-Indian, Archaic, and Poverty Point Periods. Except for Texas, where no Poverty Point site has been reported, all three regions contain descriptions of sites of each period.

Although this section presents only a summary of existent terrestrial site data, it does point out the great diversity of site geometry, landform association, and cultural content, and is believed to be representative of the prehistoric cultural resources of the continental shelf.

Western Gulf Pre-projectile Point

In the western sector Gulf area, as in most places in North America, the evidence for human occupation beyond approximately 12,000 years B.P. is fragmentary and scattered. Accumulating evidence gathered over the years, however, cannot be ignored, and Pre-projectile Point sites certainly warrant strong attention. Two sites in particular have played important roles in the establishment of Pre-projectile Point or "chopper-scraper " complex traits in the northern Gulf area. These are Lewisville and Friesenhahn Cave.

Lewisville, except for a problematical Clovis Point discovered in Hearth No. 1, has for many years been one of the pillars on which the whole Pre-projectile Point theory rests. The site was located in a large borrow pit excavated by draglines of the U.S. Army Corps of Engineers in 1949-51 (Crook and Harris, 1958:233). It was situated on the west bank of Elm Fork of the Trinity River, just north of Lewisville, Texas. Subsequent inundation by water backing up behind the dam for which the borrow pit was originally excavated has since sealed off the site.

Before this modern inundation, a series of 21 hearths was discovered in the lower levels of the Upper Shuler geological formation (Wormington, 1957:58; Crook and Harris, 1958:234). This formation of yellow, sandy clay is believed to be of Lake Wisconsin age, and the range of fauna present at the site would seem to bear this out.

Two radiocarbon dates, derived from burned vegetable fiber and solid wood charcoal recovered form two of the hearths, measured in excess of 38,000 years. Aside from the controversial Clovis Point, three other manmade artifacts were located in close proximity to the hearths. These were a crude pebble chopper, a scraper, and a hammerstone. The possibility that these three other artifacts were introduced onto the site in the same manner as the Clovis Point (possibly a "plant," or by mixture of later material caused by the dragline), and that the hearths are really natural burned areas or woodrat nests and are not manmade, has caused skeptical reactions among some archeologists. According to the excavators, however, no such possibilities occurred and the site was not affected by an over-zealous artifact "planter."

If one accepts the age and authenticity of the artifacts (excluding the Clovis point), then a picture of an ancient Pleistocene campsite emerges. From analysis of both the flora and fauna, Crook and Harris (1958) detailed a climate that was warmer and wetter than present. The evidence of pond-deposited clays also argues for this climate difference. Crook and Harris also hypothesized a repeated, seasonal occupation of the site by small groups or bands of migratory peoples. These peoples were "hunters of opportunity," not relying on one specific animal as the basis of their economy, but rather on whatever they could catch. The remains of larger fauna (mammoth, horse, bison) found at Lewisville are believed to be animals killed and butchered away from the site, with only selected portions of the carcass brought back to camp. There were no complete skeletons of these large herbivores found at Lewisville. In any event, the site may well serve to illustrate an open campsite, similar to possible sites of the same vintage located out on the continental shelf.

The other Pre-projectile Point site that has received considerable attention is Friesenhahn Cave, located on the Friesenhahn Ranch, 21 miles north of San Antonio, Texas. Evans (1961), in his summary article on the cave, states that Sellards (1919) was the first to mention the wealth of Pleistocene fossils being found by local collectors. It was not until 1949 however, that systematic excavation of the cave revealed its true importance. Over thirty genera of mammals, birds, reptiles, and amphibians were discovered (Evans, 1961:7). However, the most striking find was that of over forty "flints that show a crude but nonetheless definite pattern of chipping, resulting in steep, almost vertical edges with small, protruding 'beaks.' These artifacts are plano-convex and cannot be accidental..." (Krieger, 1964:45-6). One such artifact, discovered beneath the articulated skeleton of a large saber-tooth cat (Dinobastis serus) is illustrated in Figure 6-1.

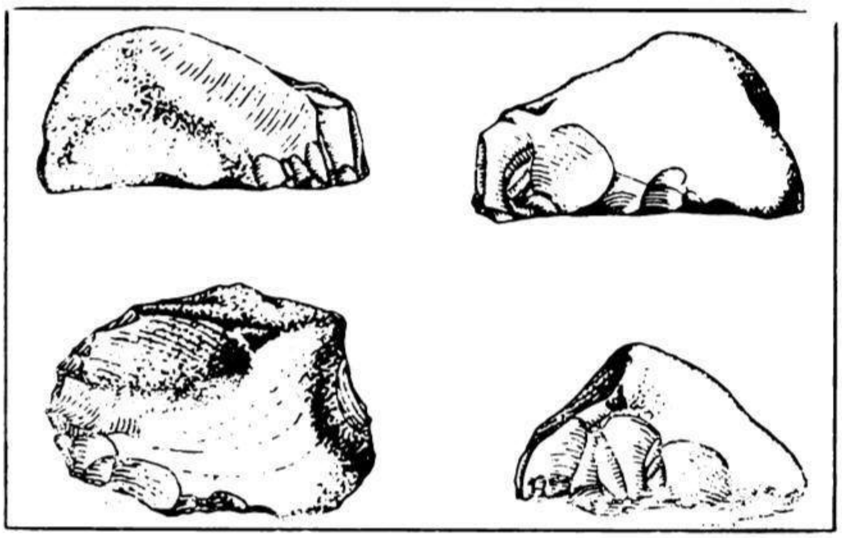


Figure 6-1. Steep, end-retouched artifact found beneath saber-tooth cat at Friesenhahn Cave (After Sellards, 1952).

Aside from these artifacts, a series of small bones was recovered which showed cut and polished ends. It is possible that these cuts were made by a carnivorous animal, and the polishing resulted from the bones passing through the creature's intestinal tract. Whatever their true nature, the bones, if taken under consideration with the artifacts, would seem to mark Friesenhahn as a significant site.

The cave itself (Figure 6-2) was formed as a solution cavern in the limestone bed underlying the southeastern part of Edwards Plateau (Evans, 1961:7). The original entrance, through which the fauna traveled, opened towards the northwest, but was eventually filled with debris so that all

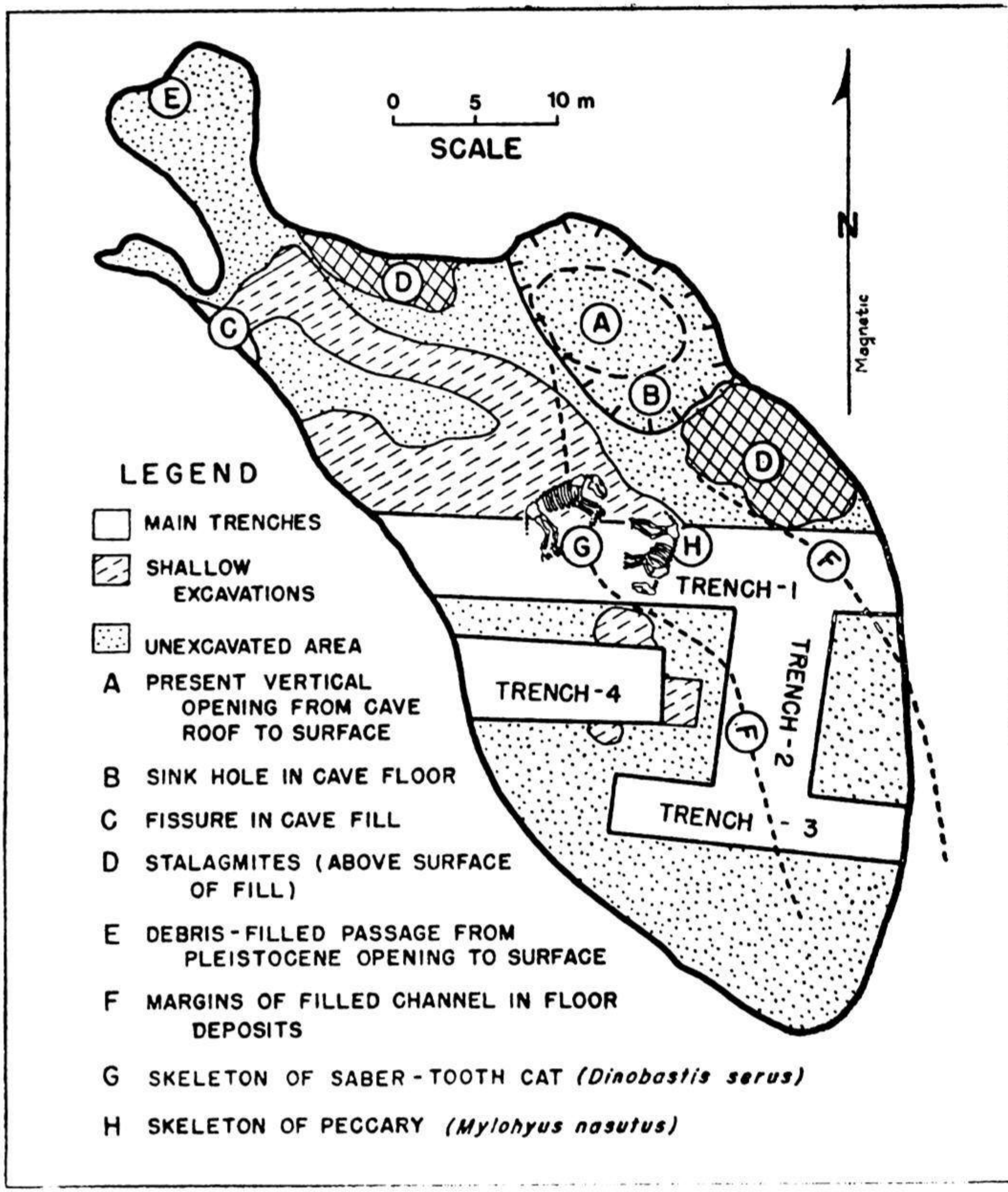


Figure 6-2. Floor plan of Friesenhahn Cave, showing trenches and articulated skeletons (After Evans, 1961).

outside traces of it vanished. Present entrance to the cavern is obtained by a vertical shaft approximately nine meters deep, through which the excavators had to descend.

Four main trenches (Figure 6-2) were dug through the floor of the cave, exposing four distinct zones of fill (Figure 6-3). Zone 1, the deepest, was composed of limestone blocks, gravels, and red clay. Only a few small mammal bones and some turtle shell fragments were recovered.

Zone 2 consisted of water-deposited clays in which were found carbonaceous vegetable remains, limestone grit, and coarse rock debris. The zone also contained the articulated remains of an adult and an infant saber-toothed cat, and a skeleton of a peccary (Mylophus masutrus). Under the adult cat was found the scraper in Figure 6-1.

Zone 3 consisted of "banded, concordally-fractured, gritty clay with inter-bedded thin layers of small limestone and flint gravels" (Evans, 1961: 15). The clays were deposited in ponds, and carbonaceous material was present in the entire zone. This zone also possessed the greatest quantity of fossil vertebrates. Included were Dinobastis and another saber-toothed cat (Smilodan sp.), a large number of juvenile elephant bones (Elephas sp.), young American mastodon (Mammut americanum), a relatively large number of turtle carapace fragments, bison bones (Bison sp.), and the bones of horse (Equus sp.), camels (Camelops sp.), deer (Odocoileus sp.), dire wolf (Canis dirus), bear, and coyote. The diversity of fauna suggests that extinctions had not begun to be evident.

Zone 4 is fill of a once-flowing stream channel on the cave's floor. The channel fill is a mixture of older deposits reworked from below, fragmentary fossil finds, and rocks and clay. Also occurring in this channel was a large freshwater clam shell that could only have come from a stream several kilometers away. Either it was washed in from that distance or carried into

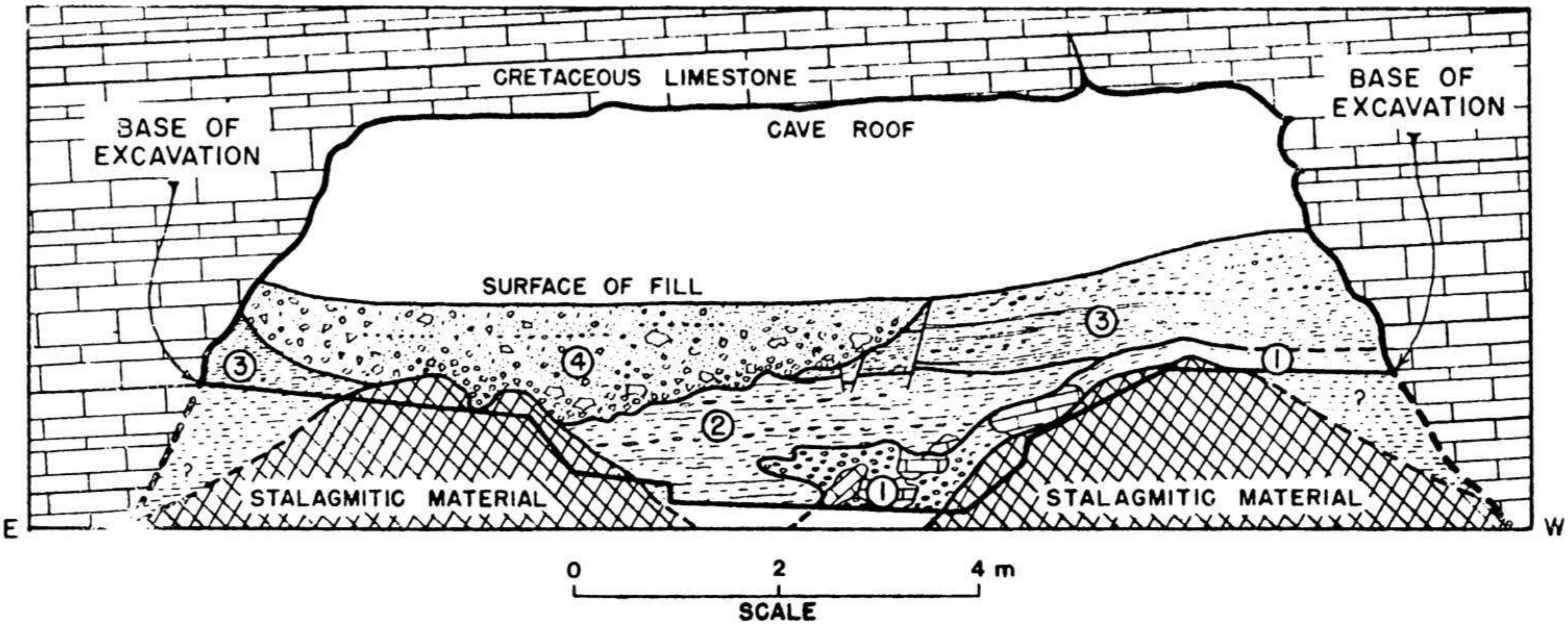


Figure 6-3. Cross-section along south wall of Trench 1, Friesenhahn Cave, showing stratigraphic relation of the several units of fill (After Evans, 1961).

the cave by man. Although this is slim evidence for the occurrence of man, it becomes more significant if one considers the scrapers and the possibility of the polished bones as man's work.

According to Evans, the faunal analysis leads one to conclude that the cats were catching the juvenile elephants and mastodons and dragging them back to the cave. The adults of the other species were probably brought to the cavern in a similar manner.

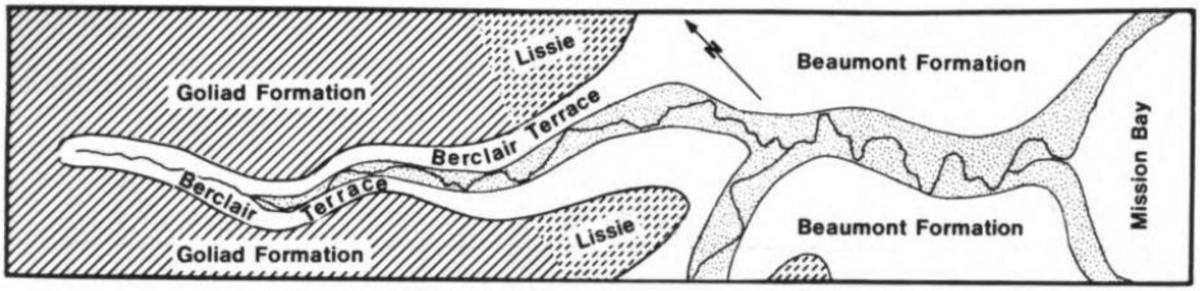
This raises the possibility that if man were present at the cave during the Late Pleistocene, as evidenced by the choppers and scrapers, then he may have likewise played a part in accumulating the bones of the fauna.

Western Gulf Paleo-Indian

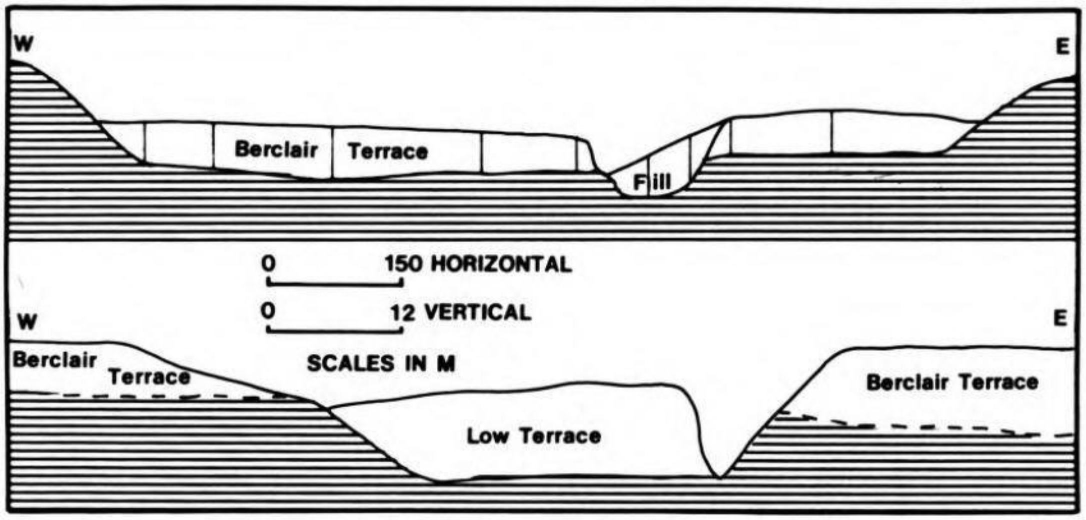
In a 1940 paper, E.H. Sellards described artifacts and vertebrate fossils from a series of sites in the Mission River drainage of Bee and Goliad Counties, Texas. The sites (41 BE 2, 3, 4, 5, and 41 GD 5, 6) were associated with the Berclair terrace, interpreted by Sellards as a riverine equivalent of the coastal Beaumont (Figure 6-4).

Material was recovered along Blanco and Medicine Creeks, and controlled excavations at the Buckner locality (41 BE 2) yielded both artifacts and fossilized faunal remains. Artifact finds at the other sites, although never excavated to any major degree as at the Buckner Site, serve to illustrate that this whole drainage area is a prime location for early man sites.

At the Buckner Site, the Berclair terrace is the surface of a sequence of alluvial fill deposited in a stream valley cut into the Goliad formation (Pliocene) (Figure 6-5). Since deposition of the Berclair sediments, a second interval of entrenchment has occurred, and a sequence of fill is in progress. In the lower reaches of this younger valley, which is entrenched into the Beaumont formation, the stream is now aggrading its channels.



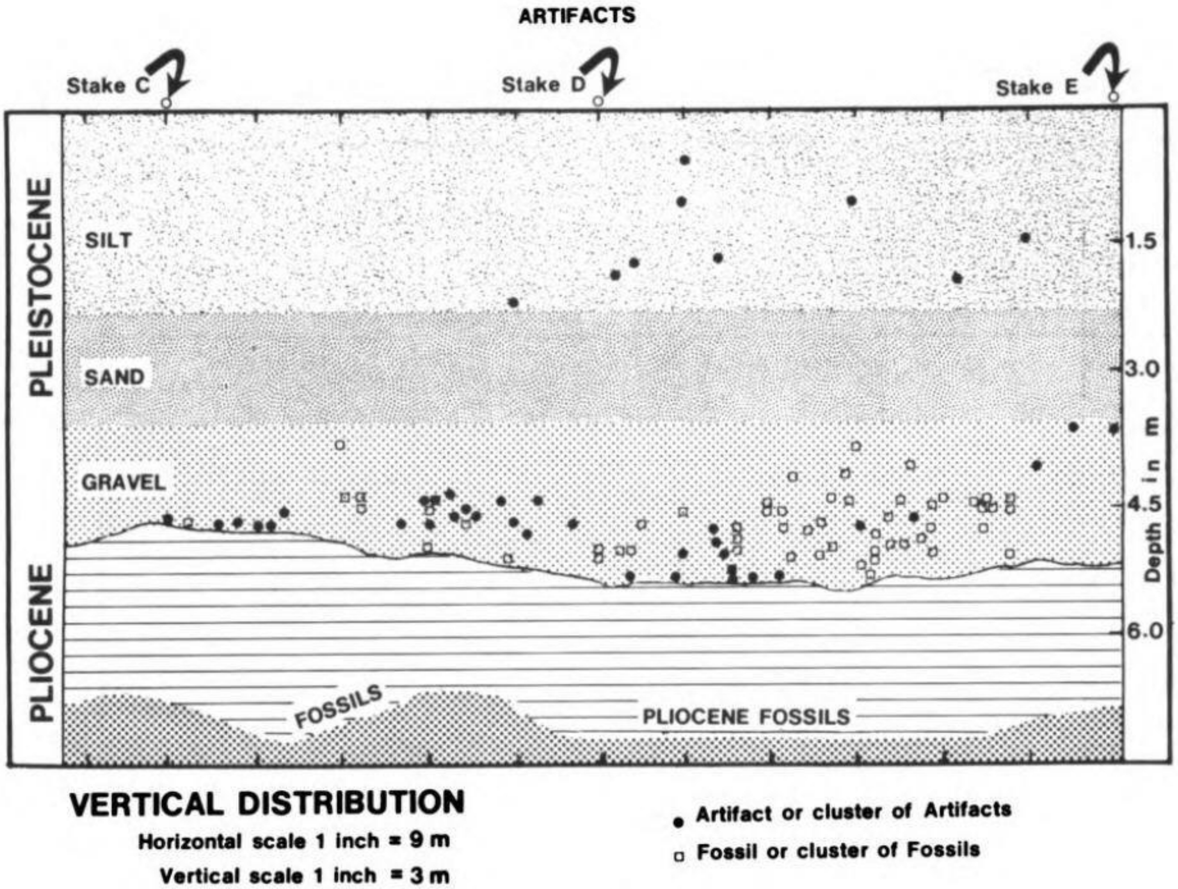
A.



B.

Figure 6-4. Relationship of Berclair Terrace to older Tertiary Goliad Formation, Pleistocene Lissie Formation, Beaumont Formation and the Late Holocene floodplain deposits. The upper section of B is through the confined valley, not the upper reaches of the stream. The lower section is in the vicinity of the Lissie Formation. The "fill" and "low terrace" deposits are considered to be Late Holocene (After Sellards, 1940).

Deposits of the Berclair formation range from light-gray to dark-gray sand, gravel, silt, and alluvial clay derived from Tertiary rocks of the region, particularly the Goliad formation. A typical section consists of cross-bedded gravels at the base, poorly stratified sands in the middle, and silts and clays at the top (Figure 6-5). The percentage of gravel and coarse sand decreases in the lower reaches of the valley, and secondary calcium carbonate in the form of caliche, in varying concentrations, is everywhere present.



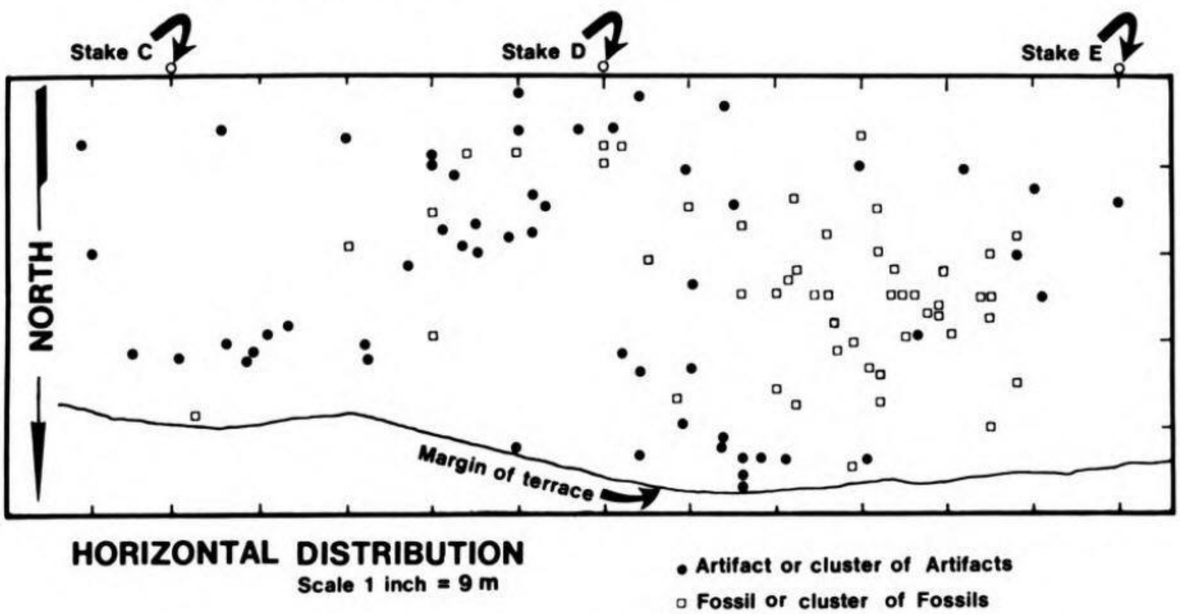


Figure 6-5. Horizontal and vertical distribution of artifacts at the Buckner Site (41 BE 2), showing stratified zones of gravel, sand, and silt (After Sellards, 1940).

The excavations at 41 BE 2 were carried out in massive degrees along the edge of the terrace. Two distinct horizons came to light. The silty upper horizon (0.6 - 2.3 m) yielded about 200 flint chips, burnt rocks, and hearths (Figure 6-5). Among the artifacts were a Clear Fork gouge, a leaf-shaped knife, crude, leaf-shaped blades, a hand axe, and a Morhiss, or Pedernales point. Also in this upper horizon were areas where mud-dauber nests had been hardened by fire. No fossils occurred in this horizon.

Below the upper horizon was a sand stratum void of artifactual content. This extended from 2.3 to 4 m below the surface.

The lower horizon of gravel was found to underlie this sterile, sandy level and extended down from 4 - 5.8 m in depth. In this horizon, Sellards discovered points which appear to be (from published photographs) a Folsom, a Yuma, two unfluted Clovis bases, and a possible Big Sandy type. Associated with these were Clear Fork gouges, oval knives and blades, circular scrapers, scrapers with denticulate spokeshaves, an axe or adz, fire-hardened mud-dauber nests, and assorted Pleistocene vertebrate fossils. It is this lower horizon which shows clear Paleo-Indian traits, and its separation by sterile sand from the upper Archaic horizon which helps support the belief in the antiquity of the site.

This series of sites is significant for several reasons. First, it provides a model for sites associated with alluvial terraces along small, coastal plain river systems. Similar relict features appear to be quite common on the continental shelf.

The second reason for their importance relates to the relative dating of the late Quaternary features in the study area. For some reason, this important work by Sellards has been lost in the literature, and its implications have escaped the attention of recent investigators of the region's Quaternary geology. Putting Sellard's well-described findings in the terminology used in this study, we arrive at the following interpretations:

Formation	Culture Period	Interval	Period
Low terrace and fill	-	Late Holocene	I-K
Upper Berclair	Archaic	Middle Holocene	H
Lower Berclair	Paleo-Indian	Early Holocene	$H_1 - H_3$
Lissie	-	-	Pleistocene (?)
Goliad	-	-	Pliocene (?)

Since Sellard correlates the Berclair terrace with the Beaumont terrace, these data present a serious challenge to the generally accepted age estimates of the Beaumont terrace and its equivalent across the Gulf coast. Most geologists would estimate the Beaumont to be 25,000 to 120,000 years old.

Two additional locales should be mentioned in our consideration of possible relationships between Paleo-Indian occupations and the Beaumont terrace in the western Gulf area. Both are beach deposits where the present shore is eroding into deltaic facies of the Beaumont Formation. At both places artifacts and bones of extinct Pleistocene vertebrates have been collected along the beach.

The first of these locales, the Sargent Beach Site (41 MG 4), is located between the mouth of the Brazos River and Matagorda Bay. In 1957 James Searcy reported that the site consisted of a low,black clay bank approximately 45 cm high, fronting on the Gulf (Files of the Texas Archeological Research Laboratory, University of Texas at Austin). Searcy reported finding bison bones, fossil shells, "elephant" bone fragments and tusks, slivers of mastodon teeth and several flint artifacts. In 1970 W. B. Neyland reported that the locus of the black clay bank had completely eroded away, but that mastodon teeth were still found along the beach. This locale is significant because it is situated upon relict natural levees associated with a late Pleistocene or Early Holocene delta of the Colorado River.

A similar situation is found at McFaddin Beach (41 JF "A") located between the mouth of the Sabine River and the High Island salt dome (Figure 6-6). Here the modern beach is being nourished by material derived from the Beaumont formation, which is eroding offshore. Relict distributary channels and natural levees of an old Trinity River delta exposed on the surface of the Beaumont terrace just north of a narrow belt of Late Holocene marsh presumably extend to the offshore area beyond the beach.

It is from the surface of, or within these, Beaumont deposits that artifacts and bones are being eroded. Projectile points from the beach include Eden, San Patrice and Clovis-like fluted forms. Bones of mammoth (Mammut sp.), giant tortoise (Geochelone sp.), camel (Camlops sp.), and horse (Equus sp.) have also been found.

A neighboring Rangia shell midden, the Willow Lake Site (41 JF 28), also associated with a relict distributary levee of the Trinity River, has produced a single Scottsbluff Point along with pottery sherds and other artifacts.

Western Gulf Archaic

One major problem which confronts archeologists studying the Texas coastal region is the fact that the Archaic of this area is believed to be an extremely long-lived tradition. The Aransas Culture of the south and central Texas coast, for example, has an estimated time-span ranging from 5,000 years B.C. to 1,000 A.D. It is very difficult to place a site of the Aransas Culture in an accurate time frame without absolute dating controls, such as C-14 dates. The Johnson Site (41 AS 1; Campbell, 1947), the type-site of the Aransas Culture, is a case in point. The site was excavated and reported on before the advent of radiocarbon dating. Thus, its position in the 6,000 year history of the Aransas Culture is difficult to determine from the published data.

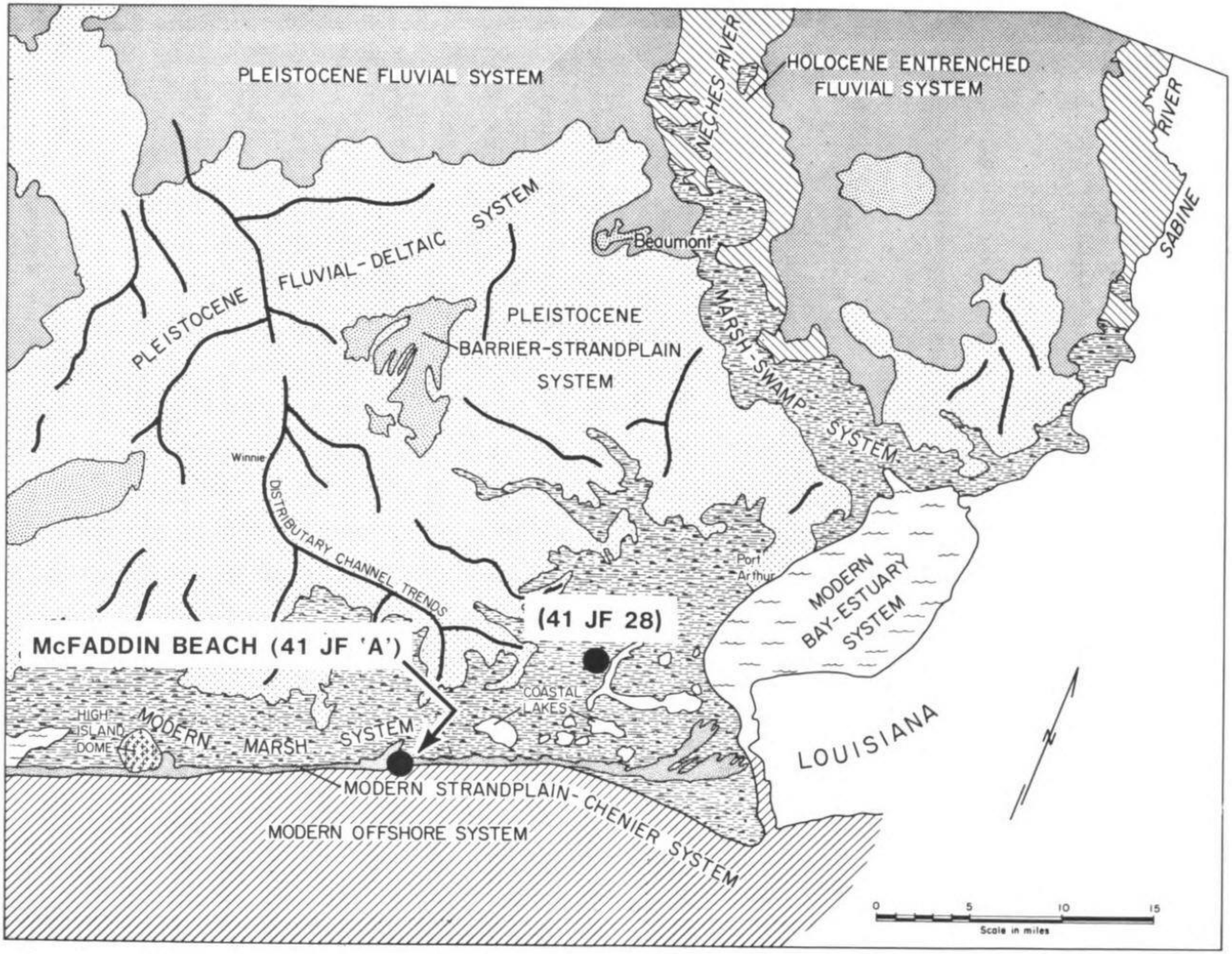


Figure 6-6. The McFaddin Beach site , a beach deposit that has produced Paleo - Indian projectile points and bones from extinct Pleistocene vertebrates. The site is on the surface of, or associated with, relict distributary natural levees of an old course of the Trinity Rivers (Base map after Fisher et al., 1973).

For that reason, we have chosen an Archaic site from the northern Texas coast and have avoided the problem of exactly how old an Aransas Culture Site really is.

The introduction of pottery into the Galveston Bay area has been securely dated through the efforts of a number of workers at about 100 A.D. (Ambler, 1967; 1973; Aten and Bollich, 1969; Aten, 1971; and others). The early ceramic periods of this area are generally thought of as "ceramic Archaic," that is, the continuation of the coastal Archaic tradition with the addition of ceramics to the artifact assemblage. Thus an Archaic site (i.e., pre-pottery) of this northern coast area would be at least 1800 years old, and probably older. It would then have been occupied during a period of slightly lower sea level, and sites of similar nature may be expected to be located on the continental shelf.

The Jamison Site (41 LB 2) in Liberty County, Texas (Aten, 1967), is just such a site. Although the upper levels are rich in pottery, the lower stratigraphic levels of the site contain artifacts, which are probably Late Archaic.

The site itself is located on an outcrop of the Deweyville terrace at the western margin of the Trinity River floodplain (Figure 6-7). This location would have afforded the occupants of the site both the uplands of the terrace and the lowlands of the floodplain in which to carry on food procurement activities (Aten, 1967: 1).

Excavations carried out by members of the Houston Archeological Society from 1959 to 1961 revealed the site to be an earth midden. Four analysis units were therefore established. Aten concluded that these lower two units represent a preceramic occupation of the site. Included in these units were dart points of the Ellis, Gary, Neches River, Palmillas, and Williams types. Williams points have a time range beginning approximately at 4,000 B.C. and lasting well into the time of pottery. Palmillas, Gary,

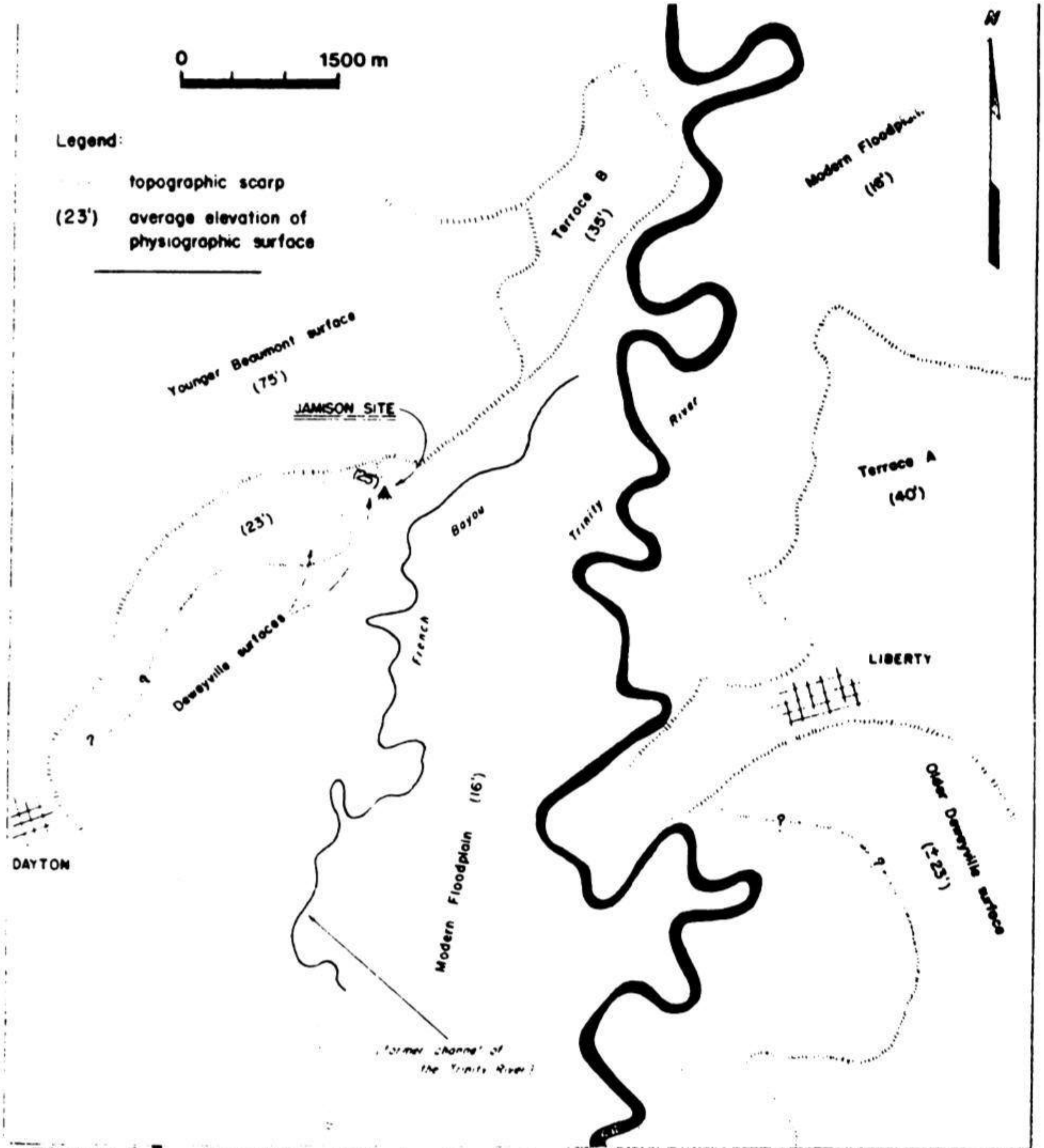


Figure 6-7. Location and physiography of the Jamison Site, 41 LB 2 (After Aten, 1967).

and Ellis points have dates assumed to range from about 2,000 or 1,000 B.C. into pottery times. It can then be inferred, if we disregard the earliest dates for Williams points, that these two units would have been occupied sometime between 2,000 B.C. and 100 A.D.

Similar Late Archaic tool and point assemblages have been found at sites in Texas and Louisiana, although no detailed comparisons have been attempted as yet. These sites could conceivably be contemporaneous with the lowest levels at the Jamison Site. It can also be assumed that some sites having such Late Archaic manifestations at one time existed at locales which are now beneath the surface of the Gulf of Mexico. Although wave action would have altered them in some instances, it is possible that they would exhibit features similar to the Jamison site.

The exact relationship between the site and the Deweyville scar has not been established, but it is not unlikely that the Deweyville scar was active during the period of initial occupation. In any case, the site is located at an important ecotone -- the escarpment between the Beaumont surface and the Trinity River floodplain. Such valley wall escarpments are likely locales for Archaic sites. Similar drowned locales on the continental shelf represent high-probability areas for site occurrence.

Central Gulf Pre-projectile Point

We will be concerned here with two important discoveries believed to be of Pre-projectile Point age: the Natchez Pelvis find in Mississippi and the Salt Mine Valley Site on Avery Island, Louisiana.

In 1846, a Natchez physician by the name of M.W. Dickeson published a short account of some fossilized bones he had collected during the period from 1837 to 1844 (Dickeson, 1846). He described the remains as coming from a gulley overlain by 9.1 meters of sediment. In addition, these remains were said to have been located some 60 cm to 90 cm below the skeletons of three Megalonyx in a stratum of blue clay. Among these fossils was a black-stained human pelvis. The pelvis has since been lost, but its stratigraphic position and relation to extinct Pleistocene fauna have made it one of the most famous of all early man finds in the New World.

In 1889, Joseph Leidy presented a listing of the fauna found by Dickeson to be associated with the pelvis. These were Megalonyx jeffersoni, Megalonyx dissimilis, Ereptodon priscus, Mylodon harlani, Mastodon americanus, Equus major, and Bison latifrons (Leidy, 1889:9; cited in Ouimby, 1956:77).

In 1895, Dr. M. T. Wilson reported the bones of a Mylodon and the Natchez Pelvis to be of the same age after analyzing them by the fluorine dating method (Wilson, 1895:725). The Natchez Pelvis data then lay dormant and practically unknown until 1951 when T.D. Stewart rediscovered the significance of the find (Stewart, 1951).

Finally, in 1956, George I. Quimby, Jr., pursued the Natchez Pelvis problem all the way to the actual creek bottom from which the bone had emerged over 100 years before. His concise summary of the situation surrounding the find and the exact creek location of the pelvis are adequately reported, and there is no need to review all of his findings here. Suffice it to say that any attempt to locate more portions of the skeleton of which the pelvis was a part would prove futile due to the intense eroding of Mammoth Bayou, the creek in which the pelvis was originally discovered. However, the loess bluffs surrounding Natchez are prime locations for more finds of this nature.

These loess bluffs are deposits of wind-blown silts derived from exposed channels and bars of the Mississippi Valley, located immediately to the west (Figure 6-8, 6-9, and 6-10). The fossiliferous blue clay at the bottom of the loess deposits has been interpreted as an eroded surface of the Montgomery terrace (Quimby, 1956:78).

The geology of the Lower Mississippi Valley loess deposits has been studied by a number of recent workers. Among the most important recent work is that of Snowden and Priddy (1968) and Otvos (1975). These authors have described the distribution and stratigraphy and cite radiocarbon dates from two locales. Dates from a roadcut along U.S. Highway 61 near Vicksburg, Mississippi, are shown in Table 6-1. The stratified loess at this locale was deposited between 24,000 and 18,000 years ago during the Farmdalian and

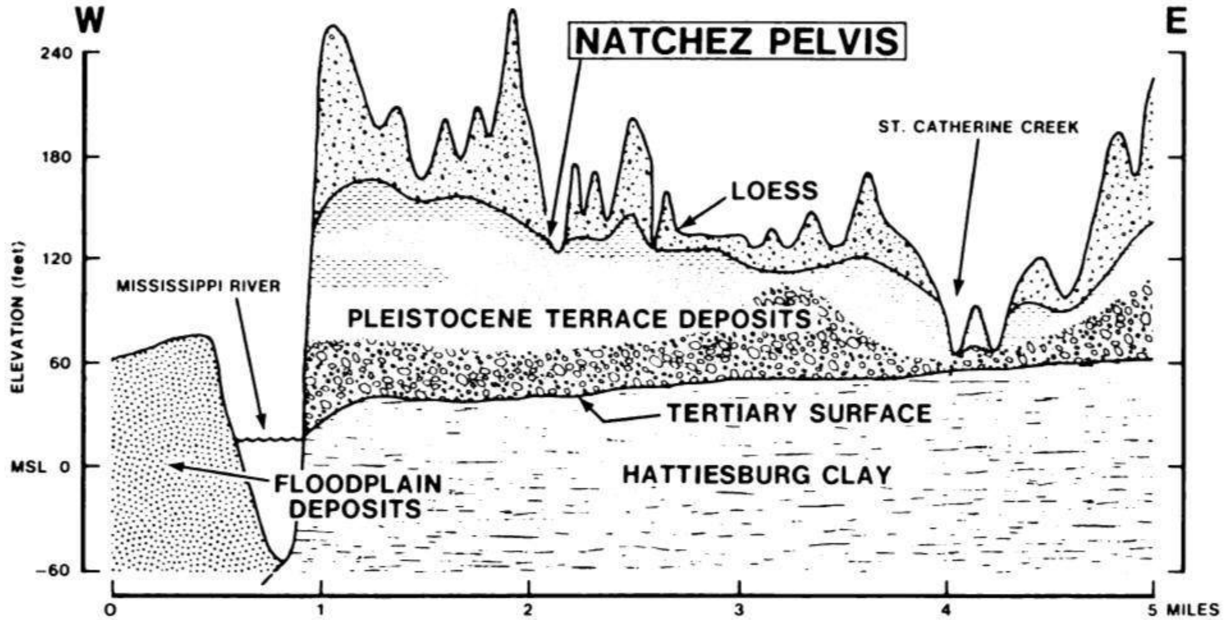


Figure 6-8. Idealized geologic section in vicinity of Natchez, Mississippi, showing setting of Natchez Pelvis find (Geology modified from Saucier, 1967).

Figure 6-9. Fossil locale on Tunica Bayou, West Feliciana Parish, Louisiana. The situation here is believed to be somewhat similar to the Natchez Pelvis locale. Fossil bones of Mastodon deposited on an erosion surface on Miocene marine clays are exposed by stream erosion.

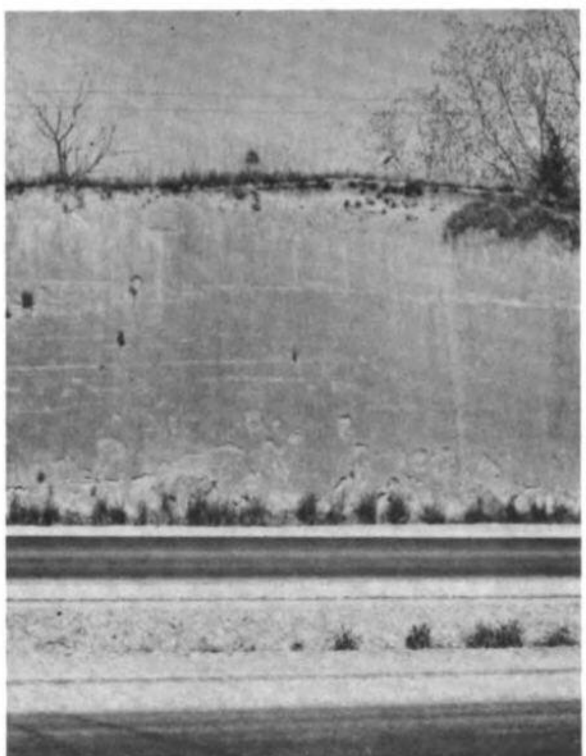


Figure 6-10. Loess deposits in roadcut along U.S. Highway 61 near Vicksburg, Mississippi.

RADIOCARBON AGE (YRS. B.P.)	STRATIGRAPHIC UNIT
17,850 ± 380*	WOODFORDIAN LOESS (INTERVAL "F")
18,200 ± 500*	
18,640 ± 380*	
19,200 ± 420*	
19,250 ± 350*	
20,500 ± 600*	
21,270 ± 440*	
21,800 ± 500*	WOODFORDIAN LOESS (INTERVAL "E")
22,600 ± 700*	FARMDALE LOESS (INTERVAL "D")
22,600 ± 800*	
23,550 ± 750*	
23,550 ± 1000*	
25,600 ± 1000$^{\Delta}$	FARMDALE SOIL?

*FOSSIL PULMONATE GASTROPOD SHELLS
$^{\Delta}$FOSSIL WOOD

Table 6-1. Radiocarbon ages of Vicksburg, Mississippi, loess deposits (After Snowden and Priddy, 1968).

Woodfordian substages of the Wisconsin. Only the upper Woodfordian loess unit, believed to be correlative with the Peorian loess of Illinois, is present at Natchez. South of Natchez, Otvos (1975) has dated this upper unit at Tunica Bayou in West Feliciana Parish, Louisiana. He reports radiocarbon dates on snail shells of 20,690 ± 250 years B.P. and 21,750 ± 310 years B.P.

The Natchez Pelvis, then, would appear to have a minimum age of about 18,000 years, when loess deposition is believed to have terminated. The age could be more than 22,000 years old, when deposition of the Woodfordian loess began. The Natchez find is important because it provides evidence that man was in the central Gulf coast area during Interval E or F, before or during the maximum Wisconsin low stand of the sea. Thus, we do have some basis, however tentative, for the hypothesis that archeological sites may be associated with features on the continental shelf formed during the Late Pleistocene - Early Holocene rise. This coincidence can be seen clearly on the chronology plate, Volume III, Plate 1.

In the southern portion of Louisiana, five major salt domes protrude above the surrounding low-lying terrain (Figure 6-11). On one of these, Avery Island, some of the earliest evidence of man in the central Gulf area has been recorded.

Gagliano (1967) published results of the work he had been conducting on Avery Island since 1962. He also reviewed all previous explorations at the island carried out by Owen (1863), Leidy (1866; 1889), Joor (1895), Veatch (1899), and others in which the presence of Pleistocene fauna and artifacts were revealed from what was termed the "bond bed" (1967:32).

The Salt Mine Valley Site (16 IB 23), the actual location on the island where evidence of early man Pleistocene vertebrate fossils became apparent, seems to have been formed by a repeated process of stream valley cutting and filling (Figure 6-12).

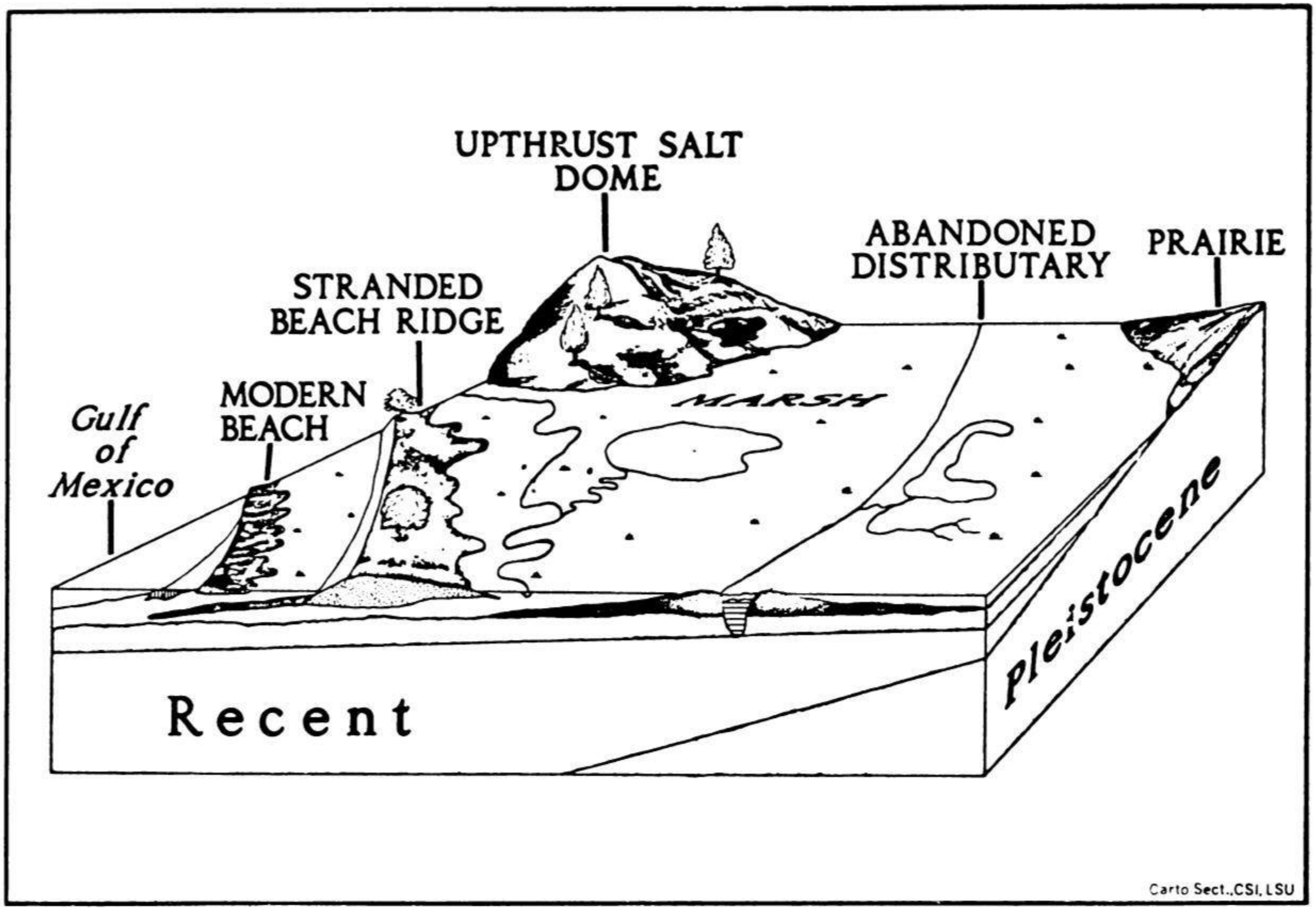


Figure 6-11. Block diagram illustrating major physiographic features of south-central Louisiana. (After van Lopik, 1955.)

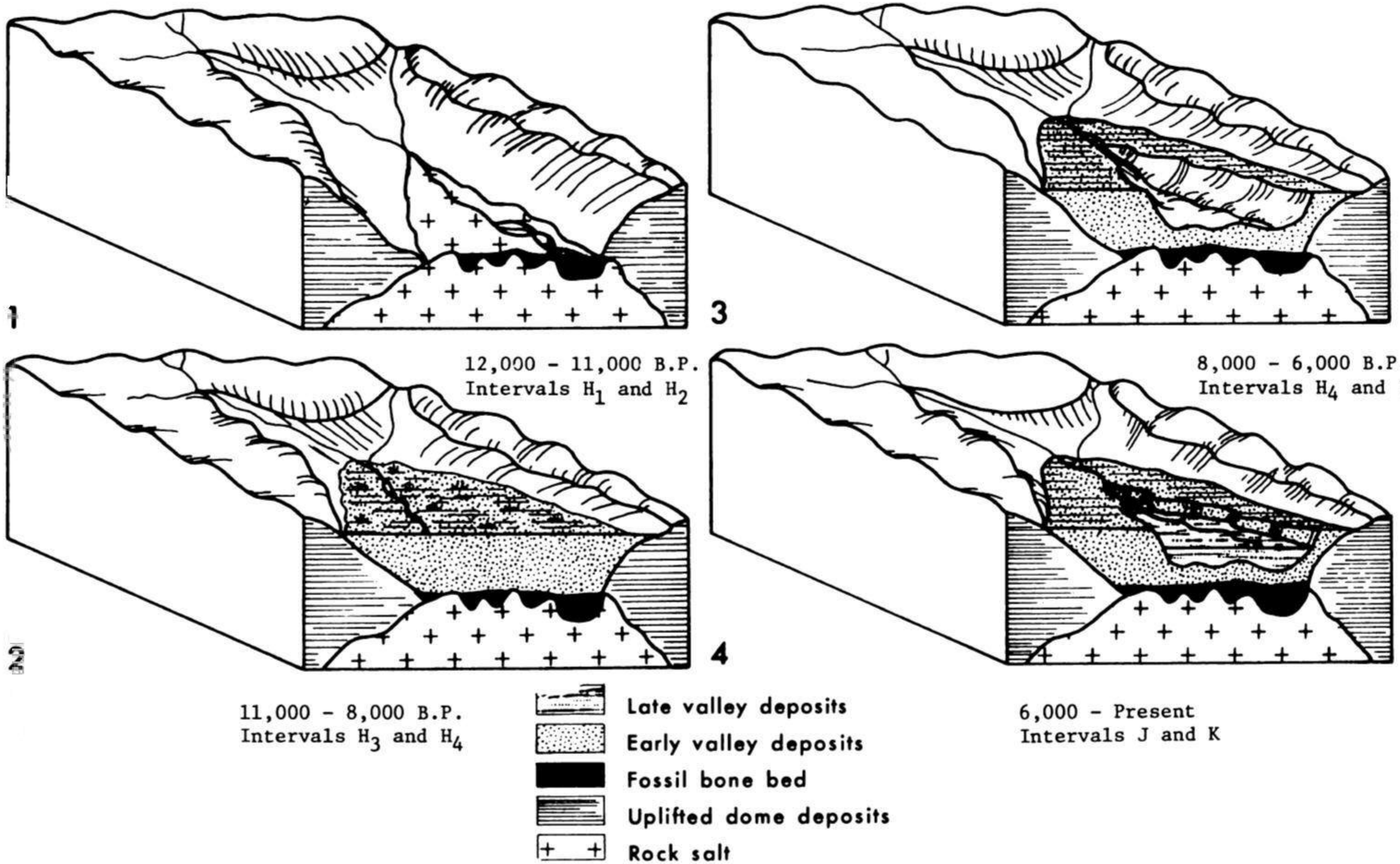


Figure 6-12. Four idealized phases of the geological history of the Salt Mine Valley Site (16 IB 23) showing stream cutting and valley filling. (After Gagliano, 1970.)

Gagliano (1970: 16) hypothesized that in the first stage of this process, 12,000 - 11,000 B.P. (Intervals H_1 and H_2), "Stream erosion exposed upthrust rock salt. The surface of the rock salt was very irregular, and there were deep solution pits. Channel sands and gravels and organic debris collected in solution holes and over shallow pits."

During the second phase (11,000 - 8,000 B.P., Intervals H_3 and H_4) of these geological changes, the valley began to fill with sediments carried by Iron Mine Run, the stream draining much of the island surface and traversing Salt Mine Valley. This stream and others like it shifted back and forth across the valley, depositing an interbedded sequence of channel sands and gravels and overbank silts and clays (Gagliano, 1970: 16).

Phase 3 (8,000 - 6,000 B.P., Intervals H_4 and I) of the valley was marked by erosion and/or solution of the lower salt deposits, which resulted in a new, smaller valley within the older valley walls.

The final phase (6,000 B.P. - Present, Intervals I and K) was marked by another period of stream sediment deposition. Erosion of the banks of the older valley walls has also added to the fill.

In the initial excavations at Salt Mine Valley by Gagliano, begun in 1962, the key bed, from which Joor, Veatch, and others had recovered fossil bones, was exposed at a depth of approximately six meters and continued down to about seven meters.

In 1968 the work in Salt Mine Valley was continued with a program of core drilling and excavating. During this study, the bone bed was dated and tied into the same bed exposed in Pit V, which up until then had not been accurately dated. The dates and a description of the fauna and artifacts recovered from the fossiliferous layer are reported below.

During 1969, the International Salt Company began excavating a new mine shaft in the valley (see Figures 6-13 and 6-14). A pit twelve meters in diameter was excavated down to the basal rock salt. This was accomplished by the use of a clam-bucket working with a steel casing. The material was removed by levels and transported to another part of the island where it was systematically arranged for screening and analysis. Material was removed from a total of four levels, reaching a depth of 9.6 meters below the surface (-2.8 meters MGL) (Gagliano, 1970:7-8). In 1970, part of the fill from the lowest levels (-.46 meters to -2.80 meters MGL) was screened.

Again, it was clear that the bone bed was the prominent feature in which numerous fossil Pleistocene vertebrate bones and human artifacts were found. The artifact assemblage consisted of chipping debitage, anvil stones, hammerstones, bipolar core tools, steep-edge chipped tools, vegetable cordage, cane basketry, and a single bone projectile point (Gagliano, 1970:11). In the levels from -2.5 to -2.8 meters MGL, shells of Rangia cuneata, a brackish-water clam, were found in remnants of a possible hearth, thus pointing to the likelihood of a marsh environment relatively nearby at the time of occupation.

Man's early presence at Salt Mine Valley is marked, as just stated, by a rather diversified assemblage of artifacts within the fossil bone bed, which itself was deposited in the lowest levels of the site, atop the basal salt. This bone bed has been dated (Gagliano, 1970) at 10,900 B.P. (8,950 B.C.) $\pm$ 300 years and 11,950 B.P. (10,000 B.C.) $\pm$ 300 years.

In this stone bed, and thus assumed to be in association with the artifacts, Joor (1895) reported the remains of several extinct species. These included: dire wolf (Canis dirus), saber-toothed cat (Smilodon Floridanus), giant, big-horned bison (Bison gigantobison latifrons), eastern horse (Equus complicatus), plains horse (Equus scottii), ground sloth (Mylodon harlani), mammoth (Mammut sp.), mastodon (Mastodon sp.), ground sloth (Megalonyx sp.), capybara (Hydrochoerus), and giant tortoise (Geochelone crossiscutata) (Galiano, 1967:40). A radiocarbon date on some fossil ground sloth

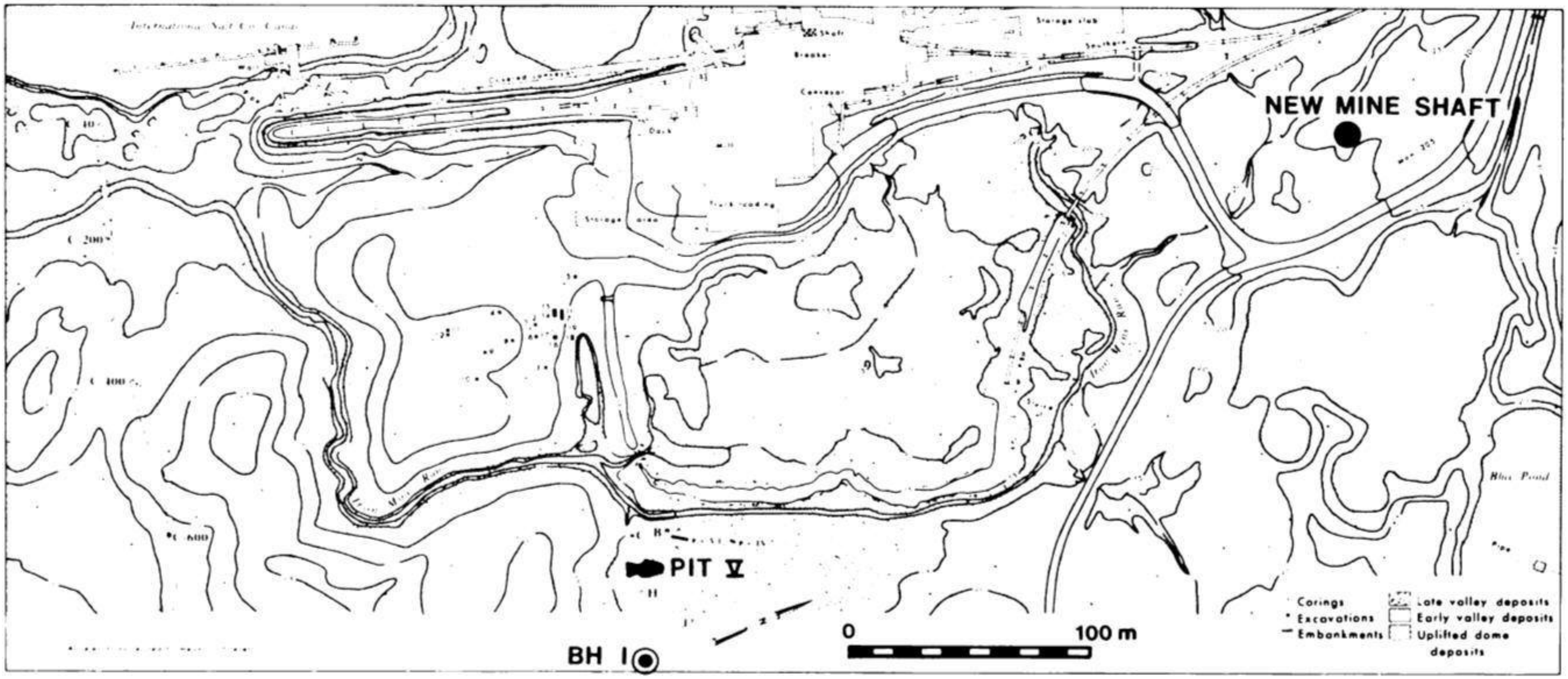


Figure 6-13. Salt Mine Valley (16 IB 23), showing locations of core holes, excavations, and relative age of surface features (After Gagliano, 1970).

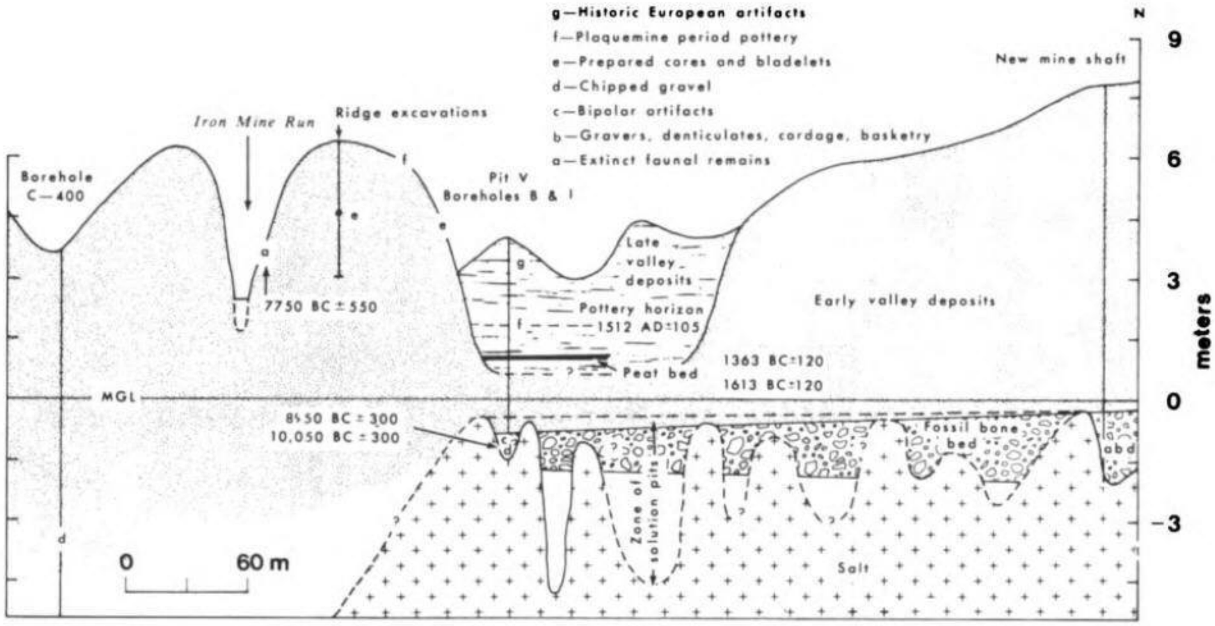


Figure 6-14. Idealized cross-section through Salt Mine Valley (16 IB 23). MGL reference datum equals mean gulf level. For locations of control sections, see Figure 6-13 (After Gagliano, 1970).

vertebrae, originally found by Joor in 1890, yielded the age of 8,390 B.P. (6,440 B.C.) ± 140 years (Gagliano, 1967:34). However, the vertebrae used for this date lacked precise stratigraphic location within the bone bed.

Two distinctive lithic assemblages have now been identified from the fossil bone bed. The first, recovered from Pit V in the 1962 excavation, has been described as a bipolar assemblage (Gagliano, 1967). MacDonald (1968) reported a similar industry from the Debert Site in central Nova Scotia, where the material was associated with fluted projectile points. An excellent sequence of radiocarbon dates obtained from hearth charcoal at Debert yielded an average date of 10,600 ± 47 years B.P. MacDonald groups the products of the bipolar technique into a class of artifacts called <u>pieces esquilles</u>.

These artifacts, first recognized in Upper Paleolithic assemblages of the Old World, are believed to have been used as wedging and slotting tools associated with the groove and splinter technique of working bone, antler, ivory, and hard wood.

MacDonald (1968:89) makes a basic distinction between pieces esquilles and bipolar pebble cores, the former being incidental products of the use of small pebble fragments in splitting and grooving bone and related materials. In contrast, bipolar cores may produce similar forms, but were probably designed to yield usable flakes. Following this reasoning, MacDonald describes five types of pieces esquilles from Debert: 1) rectangular (small wedge forms); 2) "pseudo-cores" (multiple columnar fractures resembling remnants of polyhedral or cylindrical flint cores from which lamellar flakes were struck); 3) "pseudo-burins" (lack negative bulk characteristic of true burins, thus believed to be incidental to bone-splitting function of the artifact class); 4) on-end scrapers (resulting, again, from splitting use); and 5) on-other artifacts. It should be noted that at Debert, both hammerstones and anvil stones are associated with pieces esquilles.

While the possible splitting and grooving functions of the bipolar artifacts from Salt Mine Valley were recognized, their classification rested on the assumption that the basic forms were produced by direct hammerstone blows directed to pebbles placed on anvil stones. This conclusion was based not only on the occurrence of anvil stones and hammerstones, but also by experiments which produced comparable forms. Characteristics of the bipolar types described from Salt Mine Valley are illustrated in Figures 6-15 and 6-16. The types include longitudinally split pebbles, side-split pebbles, split, pebble-core fragments, cores with flat striking platforms, trianguloid cores, fusiform cores, irregular blocky cores, core scrapers, cortex flakes, multiple-scar flakes, and beaked forms. More recently, burin forms have been recognized on bipolar cores from Salt Mine Valley.

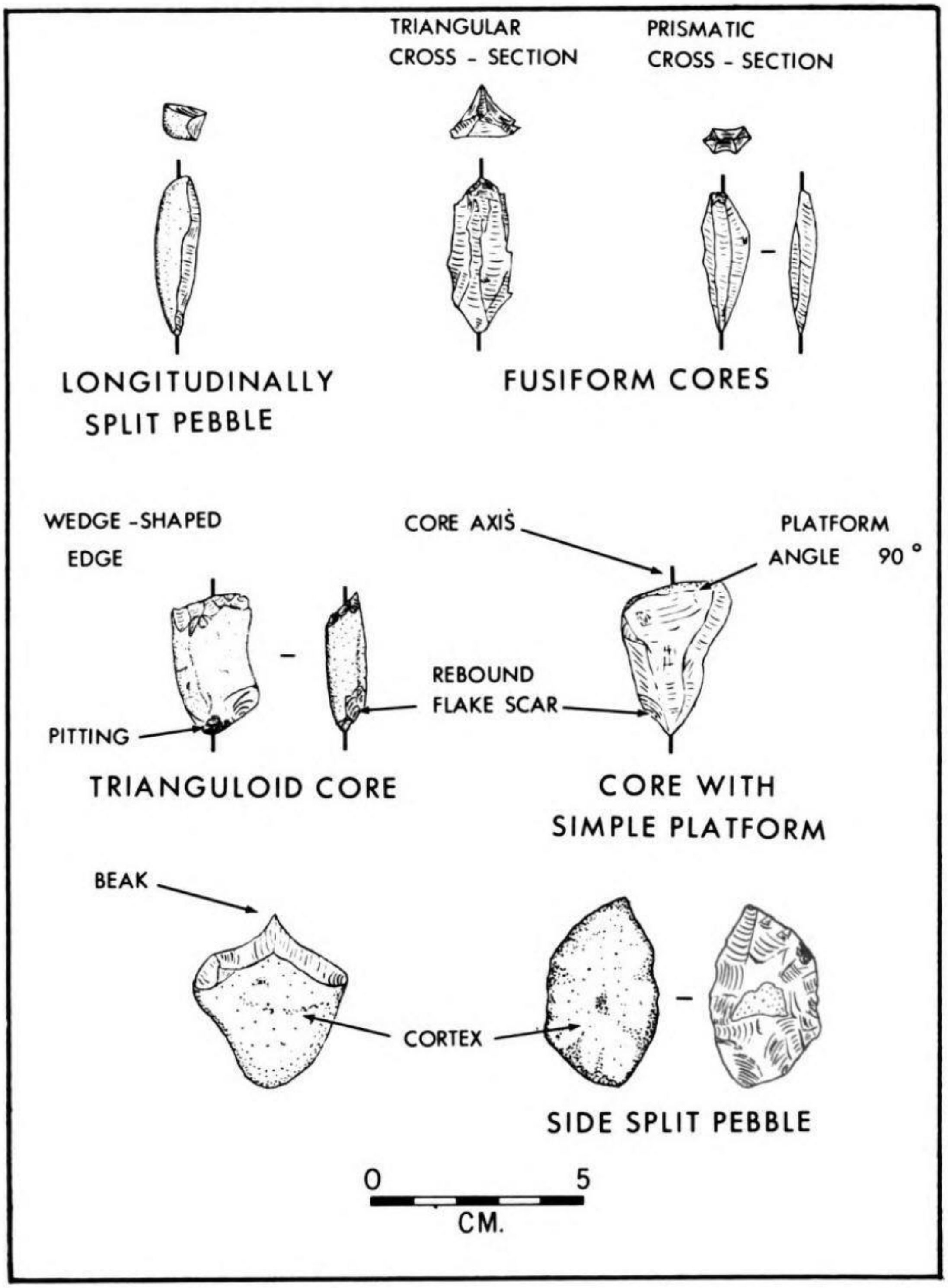


Figure 6-15. Characteristics of bipolar cores from Pit V, Salt Mine Valley (16 IB 23) (After Gagliano, 1967).

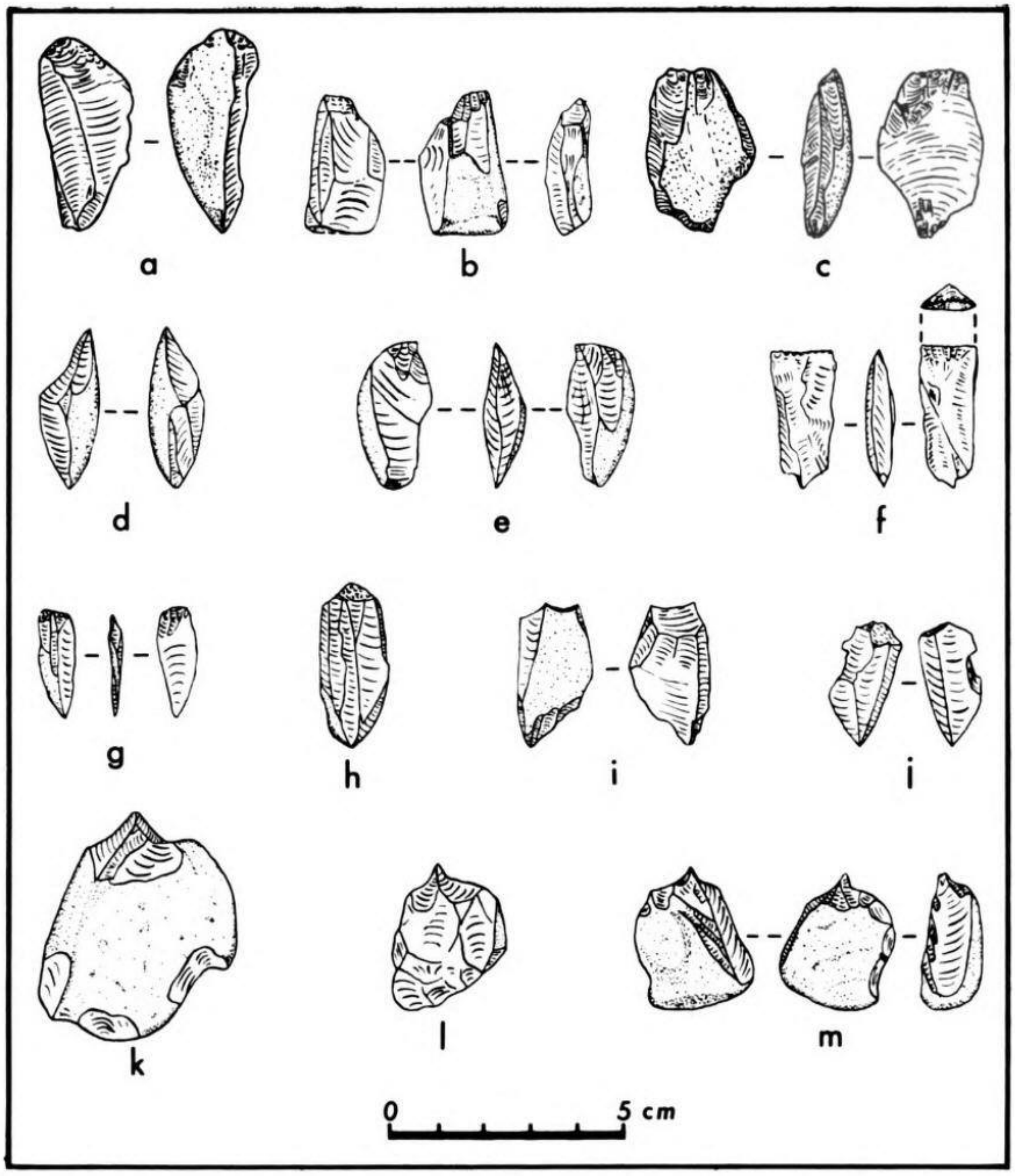


Figure 6-16. Bipolar artifacts from Pit V, Salt Mine Valley Site (16 IB 23). A-C, Longitudinally Spilt Cores; D, I, J, Core Fragments; E-G, Multiple-Scar Flakes; H, Fusiform Core; K, L, Side Split Pebbles; K, L, M, Beaked Forms (After Gagliano, 1967).

This typological discussion has been introduced here because the general class of artifacts is believed to be broadly distributed in the northern Gulf area and highly indicative of Paleo-Indian and earlier Lithic-stage occupations.

A second, highly significant lithic assemblage came to light from Salt Mine Valley as a result of the 1969 excavations in the new mine shaft. The artifacts were manufactured by steep-edge chipping on relatively flat stream pebbles (Figure 6-17 and 6-18). The resulting scalloped edges were utilized as gravers and burins. Some have been worked down or rounded from use. These artifacts are reminiscent of those described by Krieger (1964:46) from Friesenhahn Cave (see Figure 6-1).

As previously noted, the bone bed is remarkable not only for the stone tools which it has produced, but particularly for the quantities of bone and perishable artifacts. The excavations in the new mine shaft yielded a number of perishable artifacts. A small fragment of basketry or matting made from split cane was found in lumps of sand. Although the piece is small (Figure 6-19), the plaiting is unmistakable. Cordage occurred both as short, individual strands (Figure 6-20) and as interwoven bundles. The bundles suggest sandals or fragments of larger, loosely plaited fabric.

A socketed, bone projectile point fashioned from the long bone of a small animal or bird was found partially encased in a grass bundle in the lowest level of the excavation (Figure 6-21). Distinctive grooves or cutting marks and polishing are evident.

Several small pieces of wood that appeared to be cut or intentionally burned on one end were recovered. A small stick with a distinctive flat cone on one end is illustrated in Figure 6-22.

It should be noted that while the bone bed in the new mine shaft has been stratigraphically correlated, where dates have been obtained with Pit

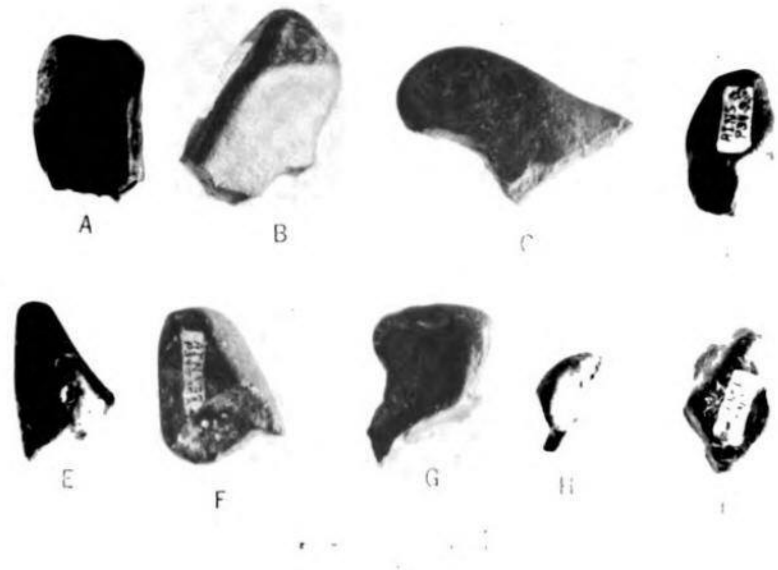


Figure 6-17. Steep, edge-chipped artifacts from the New Mine Shaft, Salt Mine Valley.

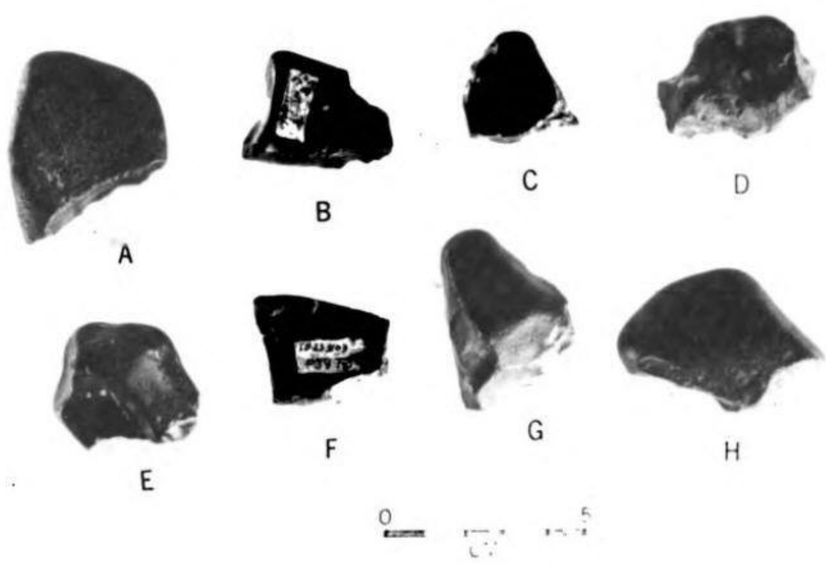


Figure 6-18. Steep, edge-chipped artifacts from the New Mine Shaft, Salt Mine Valley.

Figure 6-19. Fragment of split-cane basketry from New Mine Shaft, -2.5 to -2.8 meters MGL, Salt Mine Valley Site, (16 IB 23).

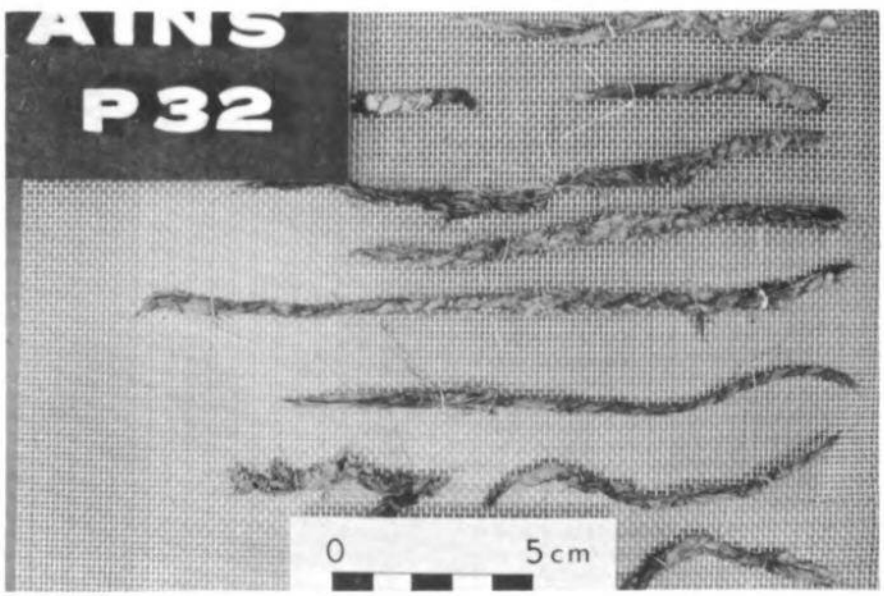


Figure 6-20. Pieces of three-strand cordage from New Mine Shaft, -1.89 to -2.23 meters MGL, Salt Mine Valley Site.

Figure 6-21. Socketed bone projectile point from New Mine Shaft, -2.5 to -2.8 meters MGL, Salt Mine Valley Site.

Figure 6-22. Cut wood from New Mine Shaft, -2.5 to -2.8 meters MGL, Salt Mine Valley Site.

V and Boreholes "B" and "I", organic material from the new shaft has not been satisfactorily dated. There remains the possibility that the two assemblages from the valley are somewhat different in age. An alternative explanation is that they represent different activity areas that were more-or-less contemporaneous.

The pre-projectile point component at Salt Mine Valley can be summarized as follows:

1) During phase 1 of the valley's geological history, while the valley was forming and the rock salt was exposed, wandering hunting-gathering peoples left artifacts in stream and solution pit deposits. Associated with these artifacts are bones of a diversified assemblage of extinct Pleistocene vertebrates. Whether these animals were killed at the site or killed elsewhere and brought to the site has not been established, but the latter explanation seems most likely.

2) Following this, while Iron Mine Run was slowly filling the valley with sediment, artifacts and bones were again incorporated within the deposits, this time along the margins of small streams.

3) Radiocarbon assays have tentatively fixed the pre-projectile component at approximately 12,000 years B.P.

4) Salt domes with surface expression may have provided attractive habitats for early inhabitants of the region. It follows that submerged salt domes on the continental shelf should be regarded as high-probability areas for site occurrence.

Central Gulf Paleo-Indian

As with the preceeding section on the Pre-projectile Point Period, Avery Island will again serve as our principal Paleo-Indian site.

From an area to the northeast of Salt Mine Valley, around the fringes of De Vance's Pond, Gagliano (1967:96) reports the surface findings of San

Patrice, Lerma, and "Lanceolate-type" projectile points. This would seem to indicate the pond area as a favored stopping spot during the Late Paleo-Indian Period.

Additional evidence comes from Pit VI and the surface area to its northeast (Analysis Unit 2) where prepared cores and bladelets have been found (Gagliano, 1967:51-52) (Figure 6-23). These artifacts have been classified as cores with prepared striking platforms, cores with natural striking platforms, blocky cores, cortex flakes, flakes with multiple scars, flake and scrapers, flake side scrapers, and bifacial artifacts.

During the 1969 excavations, several pits were excavated into the ridge deposits of Salt Mine Valley (see Figures 6-13 and 6-14). These ridges are believed to have been formed during Phase 2 of the proposed valley sequence (ca. 11,000 - 8,000 B.P.) and are composed of stream-deposited sands and gravels. In these ridge deposits were located various artifacts conforming to those described previously for prepared cores and bladelets.

Although no true projectile points were located in stratigraphic context, the similarity of the prepared core and bladelet artifacts to Paleo-Indian tool assemblages from elsewhere warrants the inclusion of this component in that time frame. The projectile points from around De Vance's Pond help support the belief that Paleo-Indians did inhabit Avery Island, and most likely Salt Mine Valley, conceivably while following a seasonally based, migratory, hunting and gathering pattern.

Aside from Avery Island, surface collections from two Late Paleo-Indian - Early Archaic sites serve to illustrate projectile point types and other characteristics of the period in the central Gulf area. The Bayou Grand Louis Site (16 EV 4) is associated with a relict, crevasse distributary channel on the Prairie Terrace surface of south-central Louisiana. The old crevasse channel, which once led into an extensive backswamp area, can be identified only by relict channel scars and poorly defined natural levee

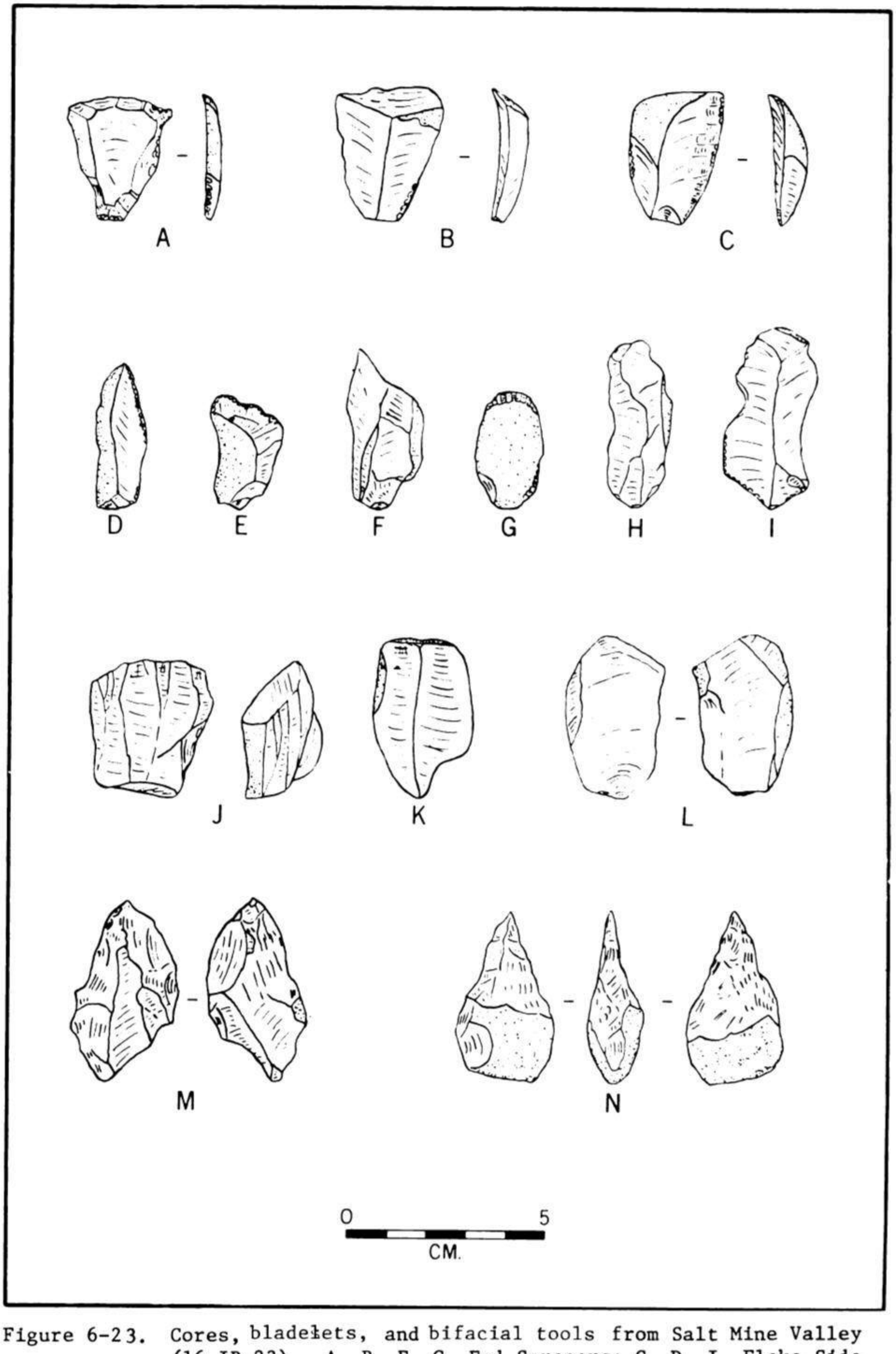


Figure 6-23. Cores, bladelets, and bifacial tools from Salt Mine Valley (16 IB 23). A, B, E, G, End Scrapers; C, D, I, Flake Side Scrapers; J, K, Cores; F. H, L, Multiple Scar Flakes; M, Scraper or Knife; N, Drill or Awl (After Gagliano, 1967).

ridges. The site is distinguished by artifacts scattered over several acres in cultivated fields along the crest of an old natural levee.

The artifact assemblage (Figure 6-24) is distinguished by projectile point forms including Cumberland, Angostora, Merserve, San Patrice, Palmer, Ellis, Gary, and Williams. Hammerstones, pitted anvil stones, unifacial scrapers, and bladelet tools also occur. Debitage and some unworked pebbles are also found. There is no apparent local source of stone from which the artifacts were manufactured. The Prairie Formation with which the site is associated consists of alluvial deposits of silts and clays. While the artifacts are thinly scattered, they are distinctive because they represent the only material coarser than silt that is present. It is a relatively common situation in coastal and alluvial sites to find that stone artifacts represent the coarsest sediment or rock particles present, representing coarse inclusions well beyond the size range of the natural sediments present.

The Palmer Site (16 EBR 13) exhibits some similarities. It, too, consists only of scattered surface finds on an old alluvial terrace, although the paleogeography is somewhat different. The Palmer Site is situated on the margin of a poorly defined scarp marking the margin of the Amite River valley in southeastern Louisiana. When the site was occupied, the reaches of the river in its vicinity are believed to have been estuaries.

The projectile point assemblage from the Palmer Site (Figure 6-25) is distinguished by San Patrice points, Kirk Serrated points, a Plainview, and broad, simple-stemmed forms. Unifacial scrapers and use-polished, gouge-like tools (probably digging stick or "hoe" blades) are also present.

While Bayou Grand Louis and Palmer are typical of Late Paleo-Indian - Early Archaic sites, and similar sites are likely to occur on the continental shelf, their discovery will be extremely difficult. The artifacts are limited in number and scattered over a relatively large area. The surface

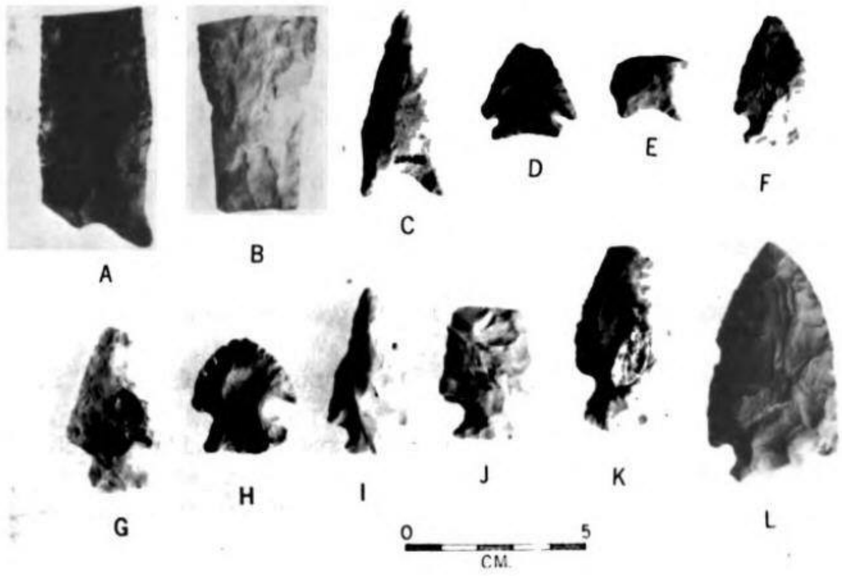


Figure 6-24. Projectile points from Bayou Grand Louis (16 EV 4). A, Cumberland; B, Angostura; C, Meserve; D, Palmer; E, San Patrice; F-L, Unclassified.

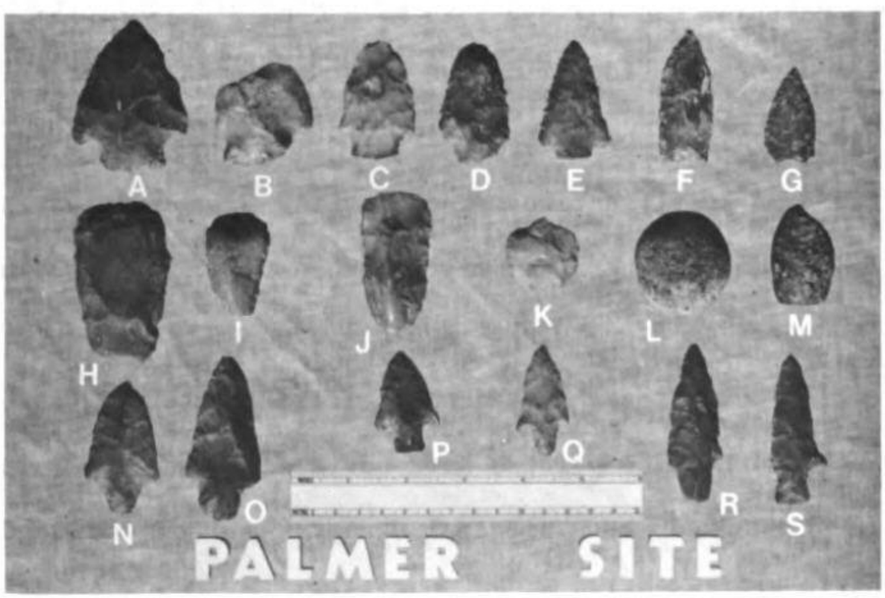


Figure 6-25. Artifacts from the Palmer Site (16 EBR 13). A-C, Unclassified broad-stemmed projectile points; D-E, Kirk Serrated; F, Plainview; G, San Patrice; H-I, Unifacial end scrapers; J, "Digging" celt or adze; K, Circular biface with graver burr; L, Granite hammerstone; M, Ground hematite (plummet?); N-Q, S, Unclassified; R, Kent.

expression of the relict features is subtle, and there does not appear to be a distinctive geometry or internal structure. Such characteristics are too subtle for positive interpretation through present remote sensing techniques. They are likely to be found only through chance artifact recovery in a bottom dredge or some other fortuitous discovery.

Central Gulf Archaic

One of the least known periods in the prehistory of the northern Gulf area is the so-called Middle Archaic. The paucity of specific site data makes this interval difficult to discuss except in very speculative terms.

Centain assemblages of projectile points and stone artifact types have been tentatively assigned to the Middle Archaic, but this is largely through inference and comparison with sequences established in other areas. For example, mixed projectile point assemblages that include Kirk Serrated, Eva, Palmer, Morrow Mountain, Tortugas, Williams, and Marshall might be assigned to an Early-to-Middle Archaic interval.

In Louisiana, at least part of the Amite River Phase may be assigned to the Middle Archaic. The phase has been defined entirely on surface collections from what are in all probability multi-component Archaic sites along the middle Amite River.

Amite River Phase sites most typically are found on riverine terrace surfaces in close proximity to scarps marking the alluvial valley margin of the river (Figures 6-26 and 6-27). They are located along those reaches of the stream where chert gravel is a common component of the bed load. Sites are identified by a profusion of debitage and chipped tools.

At the Williams Gravel Pit (Figures 6-26, 6-27, and 6-28), a chipped adz and a large sandstone mortar were recovered from sand and gravel deposits, indicating active use of the bars by Archaic peoples.

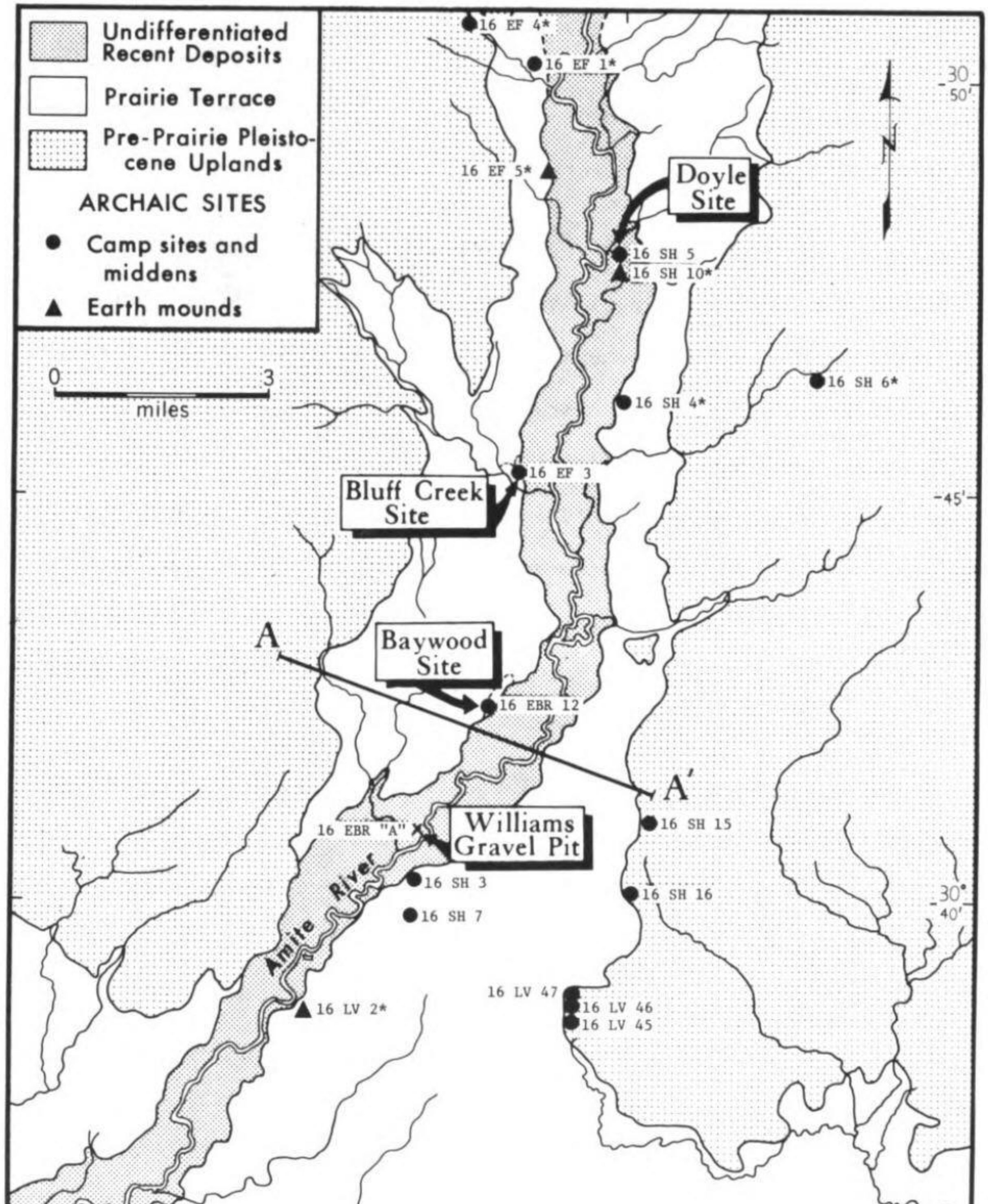


Figure 6-26. Site distribution and morphological relationship in the middle Amite River area. An "*" signifies a site not shown on Plate 4 of Vol. III (After Gagliano, 1963).

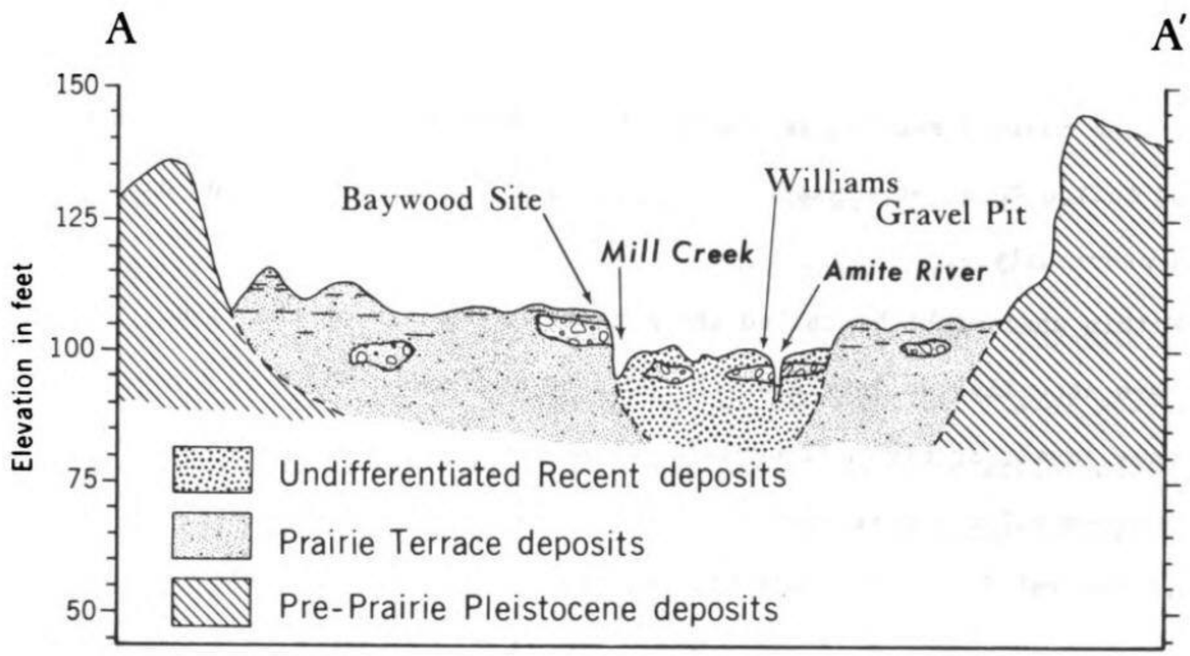


Figure 6-27. Generalized cross-section of the Amite River Valley, showing site-terrace relationships. Location shown in Figure 6-26 (After Gagliano, 1963).

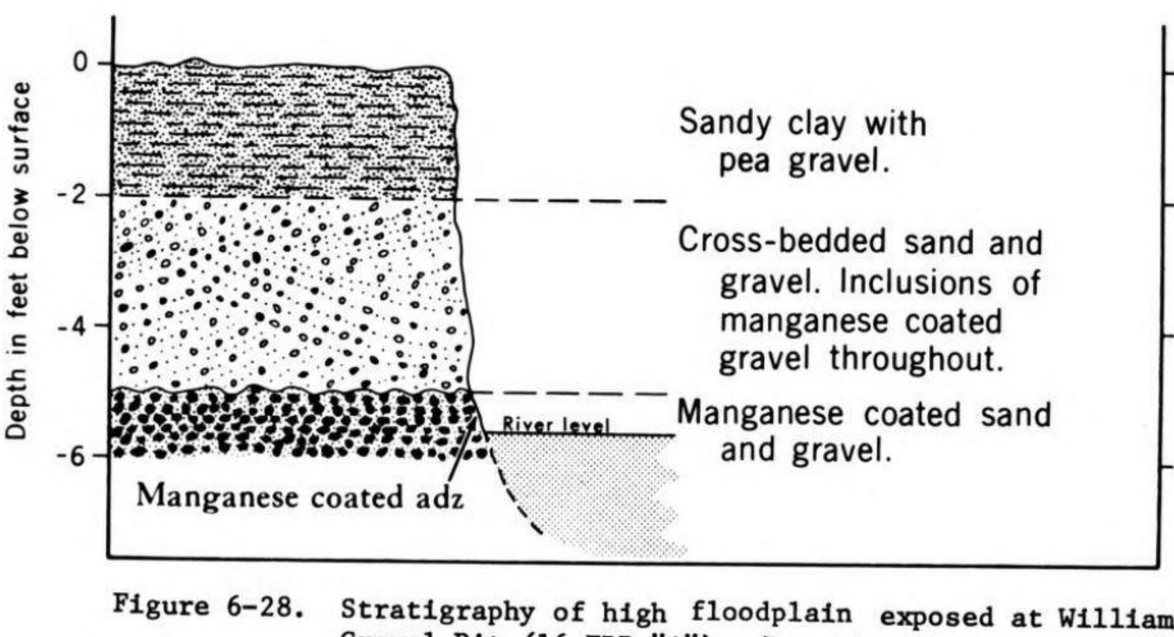


Figure 6-28. Stratigraphy of high floodplain exposed at Williams Gravel Pit (16 EBR "A"). Location shown in Figure 6-26 (After Gagliano, 1963).

The geologic context of the Williams Gravel Pit finds and the morphologic relationships of sites in the area are significant in the present study. The overall setting is similar to the Mission River drainage in Bee and Goliad Counties, Texas, as described by Sellards(1940) and discussed previously.

Within what might be called the present floodplain of the river, there are actually two levels which indicate surfaces of stream deposition. The upper level, or high floodplain is somewhat dissected, has a moderately well-developed soil profile, and is covered with water only during flood. Several feet below this high floodplain is a level of active and abandoned point bars. At first inspection, it might appear that the upper surface was formed during floodstage, and the sandy bars represent stage features. However, deposition by the river seldom exceeds the height of the highest river bar, and only clays are deposited above the bar crests during flood. In the segment of the Amite River under consideration, the stream is still adjusting its gradient by downcutting. Active deposition is presently restricted to sandbars and channel deposits in and below the low level.

In their studies of river systems, Wolman and Leopold (1957:105) have found that a channel has an associated floodplain whether stable and flowing on bedrock, gradually eroding a valley, or gradually depositing a fill. Furthermore, when the aggraded valley fill of a floodplain is incised after its deposition, the original level becomes a terrace. They define an alluvial terrace as "....an abandoned floodplain whose surface no longer bears the normal relationship to the stream bed" (1957:105). The true terrace, by its definition, must not be overtopped by the annual flood. The upper floodplain of the middle Amite River area is occasionally flooded, but does not "....bear the normal relationship to the stream bed." The upper surface, then, might be interpreted as a poorly-defined terrace. It is the deposits of this upper surface that have yielded Archaic artifacts in the Williams Gravel Pit.

The slope relationships between the upper level and the Prairie terrace are such that the two surfaces merge immediately north of the area depicted in Figure 6-26. Like the Prairie, the high floodplain deposits are coarse and presently supply much of the sand and gravel needs of Baton Rouge and adjacent communities. Because of the very slight differences in elevation between "high" and "low" surfaces, the deposits are undifferentiated in Figures 6-26 and 6-27.

Gravel deposits, which are shown schematically in Figure 6-27, are formed by concentration of the coarsest particles eroded from the older deposits. Gravel is abundant in channels and on point bars immediately downstream of tributaries and in places where streams cut and rework older concentrations. The gravel consists predominantly of tan, brown, red, and black chert of varying degrees of purity, with occasional quartzite pebbles and small slabs of ferruginous sandstone.

Extensive site areas are found on the Prairie terrace along the scarp separating Prairie and Recent floodplain surfaces, i.e., the Baywood Site. A few middens, such as the Doyle site, have been found on abandoned point bar ridges within the active floodplain. All of these sites are associated with gravel accumulations, the largest complexes being located on the Prairie surface near the junctions of tributary streams and the river valley, i.e., the Bluff Creek Site. The occupants simply selected spots where streams were actively eroding and depositing gravels, resulting in a readily available supply of raw material for tools and weapons. The Bluff Creek, Doyle, and Baywood Sites typify the settlement patterns of the Amite River Phase.

Recent work in the area has disclosed a series of sites along the escarpment separating the Prairie and pre-Prairie Pleistocene uplands. While the sites thus far found are characterized by chipped stone tools, their age and relationship to the geologic history of the river and terrace sequence remain to be established.

Putting the geological and archeological sequences of the middle Amite River into the terminology of the present study, it can be summarized as follows:

FORMATION	CULTURE PERIOD	INTERVAL	PERIOD
Low floodplain and fill		Late Holocene	J-K
High floodplain (terrace) and fill	Middle Archaic	Middle Holocene	I
Prairie Terrace	Possible associated sites	?	?
Pre-Prairie Pleistocene			Early to Middle Pleistocene

In one sense, the middle Amite River sites can be considered as quarries whose locations were dictated by the availability of stream gravel. However, the diversity of the artifact assemblage suggests a much broader range of activities and has led to the conclusion that the principal sites were at least seasonally occupied and that during these periods, the occupants were engaged in a full range of economic and social activities largely unrelated to the manufacture of stone tools (Figure 6-29 and Figure 6-30).

Small, chipped, gouge-like tools often exhibiting polished bits are now believed to have functioned as hoes or digging-stick tips and may have been used in "root gathering" or "early agriculture . Distinctive projectile point forms are indicative of specialized hunting activity. Bifacial knives and blades are related to these activities. Another suggestion of at least semi-sedentary activities is the occurrence of small, low, circular earth mounds. The specific function of the mounds has not been established. They are usually solitary, but occur sometimes in pairs.

In addition to Amite River sites, there are other suggestions of a Middle Archaic age for the introduction of mound building in the central Gulf coast area. The most important of these is the Monte Sano Bayou Site in southeastern Louisiana (16 EBR 17). Here Haag, Ford, and Gagliano (unpublished manuscript), in a salvage archeological project in 1967, established that two large conical earth mounds located on an alluvial terrace at the valley escarpment of the Mississippi River were mounds constructed over cremation platforms (Figure 6-31 and Figure 6-32). A charcoal sample from the cremation platform within one of the mounds yielded a date of 6,220 B.P. ± 140 years (4,240 B.C.). Poverty Point traits occur at the site, including a stylized grasshopper bead of red jasper, Poverty Point-type microflints, and the similarity in construction techniques of the mounds with those at the Poverty Point Site. This casts some doubt on the validity of this surprisingly early date for mound building. However, another relatively early date from the Banana Bayou Mound (16 IB 24), a small conical cremation mound on the Avery Island salt dome, gives some credibility to the date. Charcoal from the cremation platform within the Banana Bayou Mound was dated at 4.440 B.P. ± 260 years (2,490 B.C.).

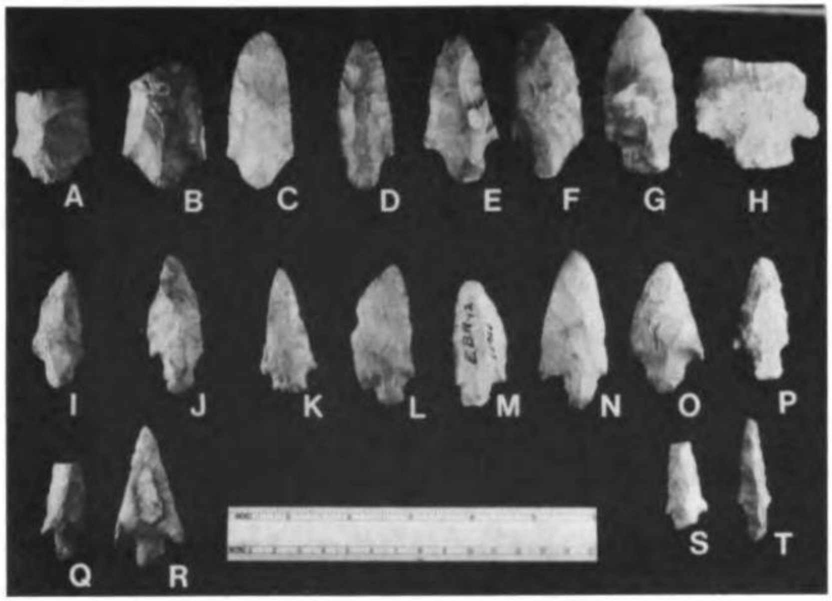


Figure 6-29. Amite River Phase Projectile Points. A-C, Almagre; D-F, unclassified; G, Morhiss; H, Webb (?); I-K, O-P, Kent; L-N, Assymetrical; Q-R, Shumla; S-T, Wells.

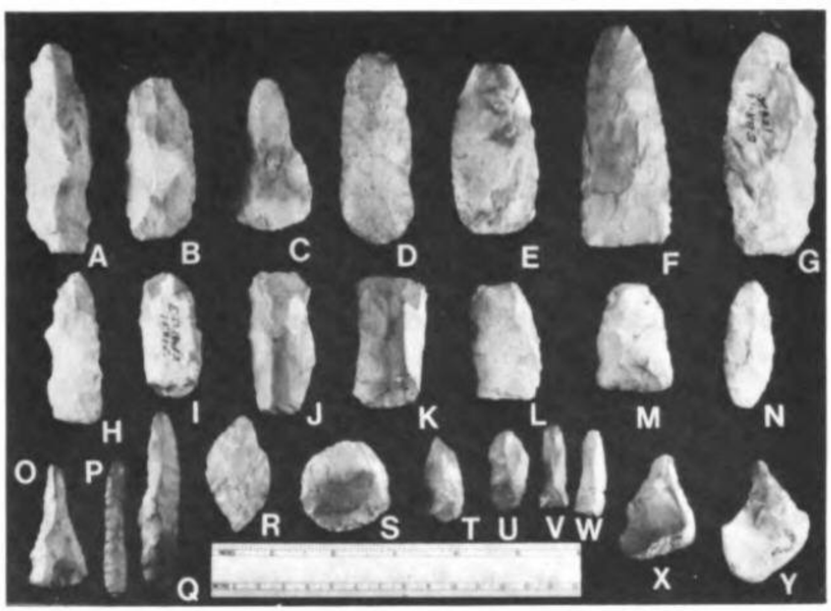


Figure 6-30. Amite River Phase Artifacts. A-D, Ovate and triangular blades; E-G, chipped celts; H, unclassified; I, "turtle-back"; J-K, double-ended gouges; L-M, gouges; N, "leaf-shaped" point or blade; O, notched drill; P-Q, straight drills; R, double-ended graver; S, oval knife; T-U, "petal-shaped" flakes; V-W, lamellar flakes; X-Y, pointed hammerstones.

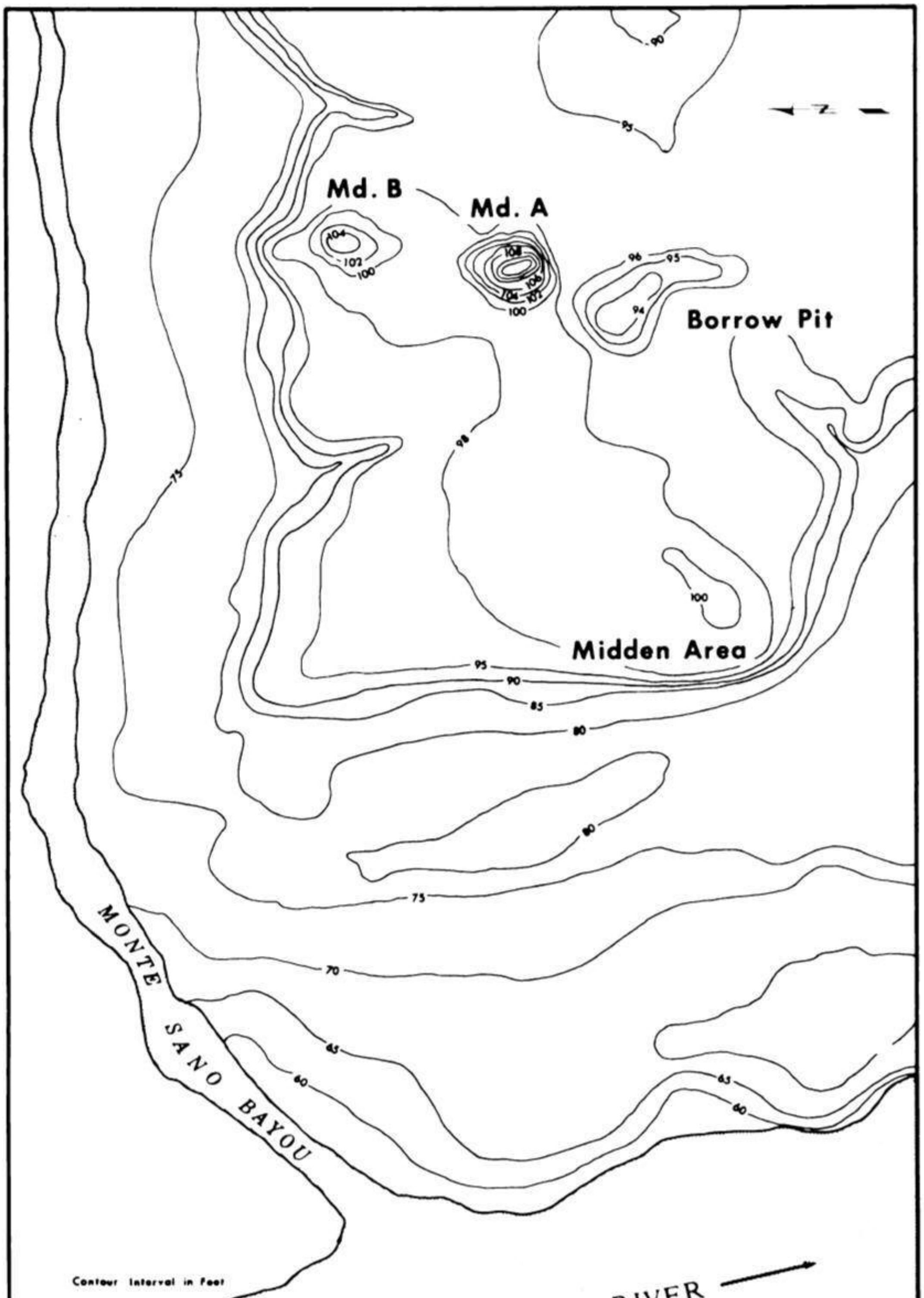


Figure 6-31. Map of Monte Sano Mounds (16 EBR 17). The mounds are situated on the Prairie Terrace surface near the escarpment marking the eastern valley wall of the active floodplain of the Mississippi River.

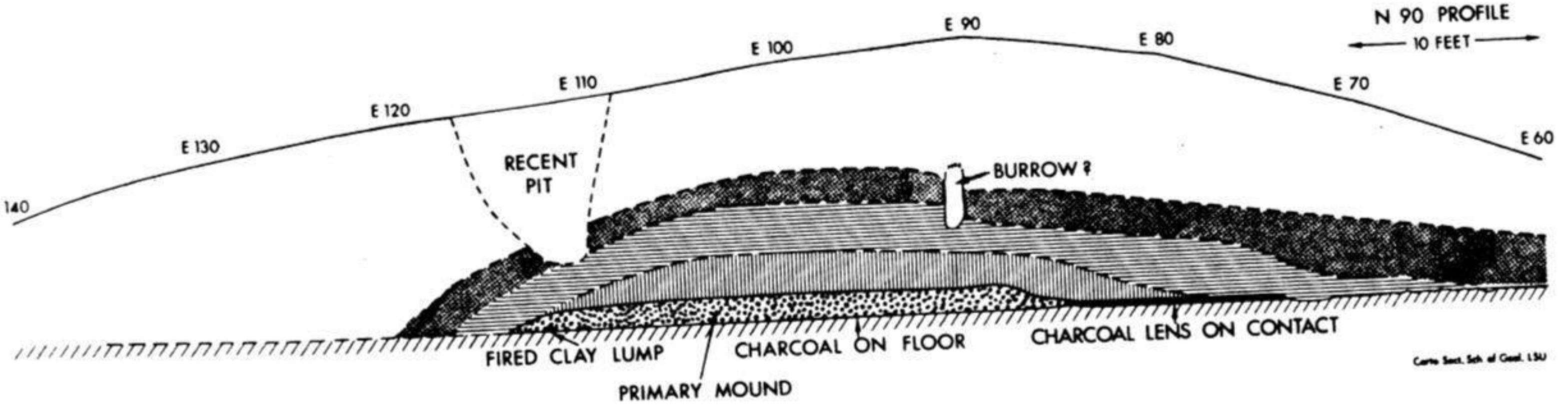


Figure 6-32. Cross-section through Mound A of the Monte Sano Site. Note the primary mound and the charcoal lenses.

Thus, our highly speculative model for the Middle Archaic of the central Gulf coast area includes the trait of mound building. Until disproved, conical earth mounds, occurring singularly or in small groups, should be considered as a possible element of the Middle Archaic.

We have indulged in some speculation regarding the Middle Archaic, as inspection of the sea level curve (Vol. 3, Plate 1) will indicate, because drowned Middle Archaic sites can be anticipated on the continental shelf. In fact, the postulated sea level reversal during interval H_4 may have continued during the Middle Archaic, providing an explanation for the paucity of coastal area sites related to the period.

The settlement and land-use pattern along the middle Amite River provides another model for predicting high probability areas associated with relict alluvial features on the continental shelf.

As previously mentioned, there are currently few published reports dealing with central Gulf coastal Archaic sites. One of the exceptions, however, is the Copell Site (16 VM 102), located in an orange grove on Pecan Island, Louisiana (Figure 6-33). This site was first brought to the attention of archeologists through two short reports compiled by Henry B. Collins (Collins, 1927; 1941). Later, Ford and Quimby (1945) gave considerable review to the site and its artifactual assemblage in their report on the Tchefuncte Culture. In this report, Ford and Quimby placed the Copell Site in the same cultural context as Tchefuncte. They did recognize, though, that the lack of pottery at Copell probably meant the site was earlier than the typical Tchefuncte Culture sites. In 1947, Martin, Quimby, and Collier placed the Copell Site in the Archaic Period. However, in later studies (McIntire, 1958; Haag, 1961), Copell was still considered as Tchefuncte, although some doubt was expressed. It is

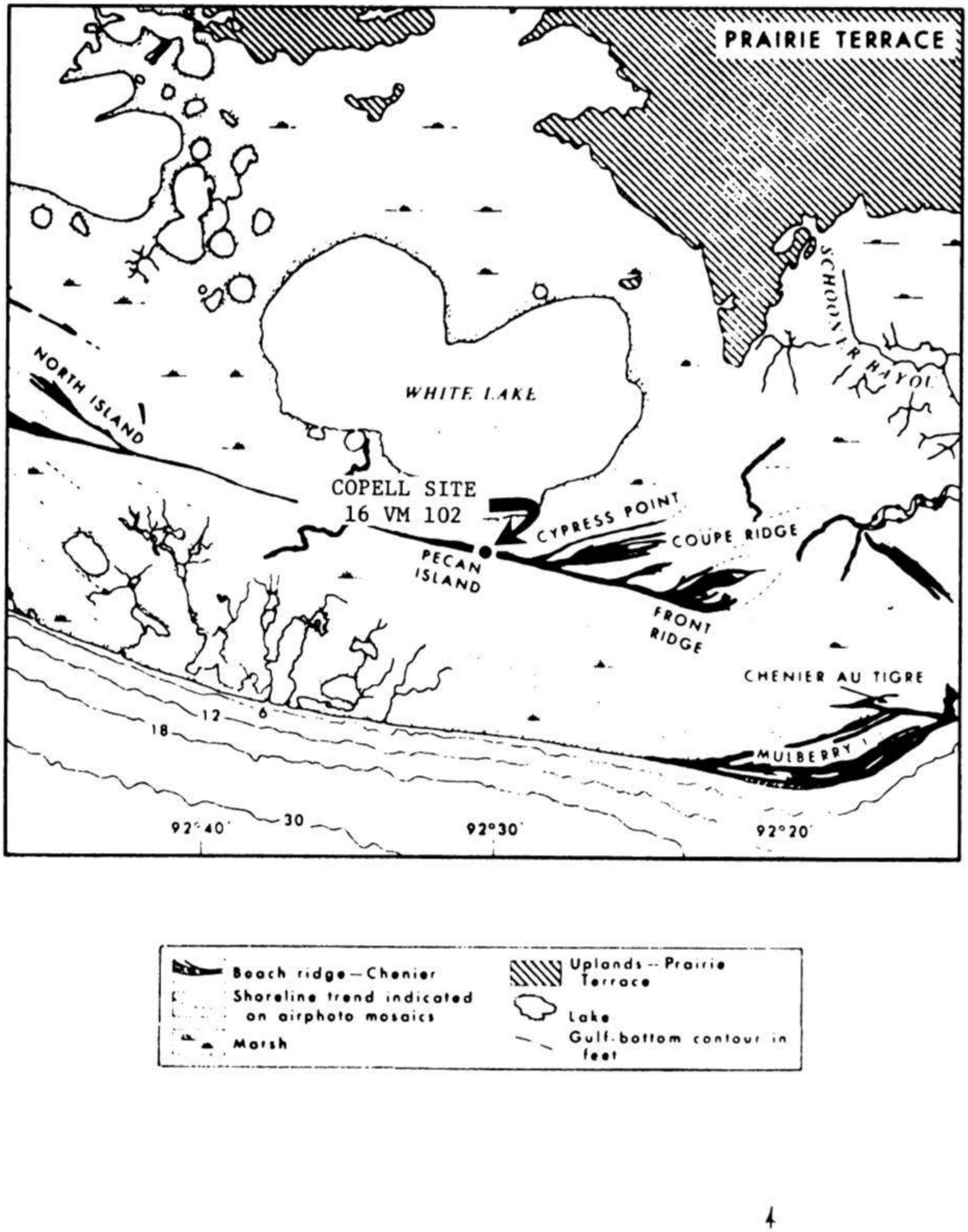


Figure 6-33. The Copell Site (16 VM 102) on Pecan Island, Louisiana. Pecan Island is one of a series of relict beach ridges, or cheniers, along the Louisiana coast.

now generally assumed that the Copell Site is not a Tchefuncte Period site, but rather a Late Archaic Period occupation. Two recent reports (Gagliano, 1967; Gagliano et al., 1975) have suggested that the name Copell be applied to a Late Archaic phase for the area of southwest Louisiana.

The site itself is situated on Pecan Island, a relict Gulf beach ridge, or chenier, rising out of the Louisiana marshes. Such cheniers offered the Indians stable, high ground throughout the centuries and can be considered as prime locations for the discovery of Archaic and Paleo-Indian sites in the continually subsiding Louisiana marsh area. Indeed, scattered Paleo-Indian points have been reported from Pecan Island.

Since we are here concerned with the Late Archaic Copell Site, a trait list may be in order as a summary of the artifacts collected by Collins and analyzed by Ford and Quimby. These artifacts are stemmed, ovate-triangular projectile points, knives, retouched blades, a boatstone, a bar weight, socketed points manufactured from the bones of a variety of mammals and birds, an atlatl hook, bone perforators, cut and drilled bones, and various unworked animal bones (Ford and Quimby, 1945:17). All of these objects were associated with the Copell burials. Indeed the site is unique in that it was a burial site rather than a habitation area. The burials themselves were sometimes laid upon layers of red and yellow pigment and were placed in the ground in tightly flexed positions. They probably also occurred in pits, although Collins could not discern their outlines in the excavations (Ford and Quimby, 1945:16). There were 20 males and 13 females, with the mean age at time of death being 55 years for the males and 46.2 years for the females (Snow, 1945:Table XVII) buried at the site.

The only description of the depth or areal extent of the site is that the burials were unearthed from several feet below the ground surface.

One other interesting item associated with the burials was asphaltum, a commonly occurring item along the Texas coast. This may possibly illustrate ties to the west with the Aransas Phase and other Archaic peoples of the Texas coast.

Another Late Archaic Period site in the central Gulf area is the Cedarland Plantation Site (22 HC 30), located near the mouth of the Pearl River in Hancock County, Mississippi (Figure 6-34).

The site, located in 1957, is a semi-circular, stratified, oyster shell and earth midden (Figure 6-35), situated on a low bluff overlooking the Pearl River estuary (Gagliano, 1963; Gagliano and Webb, 1970). Immediately across a swampy depression to the south-southeast of the site is another Indian habitation locale, the Poverty Point-age Claiborne Site (22 HC 35), which is discussed in the following section.

The Cedarland midden material, as illustrated in the cross-section in Figure 6-35, is basically composed of two strata. The lower stratum is made up "predominantly of oyster shell (Crassostrea virginica) with bones of small animals, deer, bear, fish and waterfowl, and with charcoal and artifacts intermixed (Figure 6-36). Remnants of small, clay-lined hearths (Figure 6-37) are scattered throughout the shell" (Gagliano and Webb, 1970:47). The upper stratum is a black, organic sand containing the remains of animals, charcoal, artifacts, and clay lumps. An increase in the numbers of hearths was also noticed in this upper stratum.

The artifacts recovered at Cedarland (Figure 6-38) became the basis for defining the Late Archaic Pearl River Phase (Gagliano, 1963). Most commonly occurring artifacts and raw materials were marine shells, terrace and stream gravel, ferruginous sandstone, red jasper pebbles, limonite, orthoquartzite from southern Alabama, pink and white meta-quartzite from Arkansas, sandstone

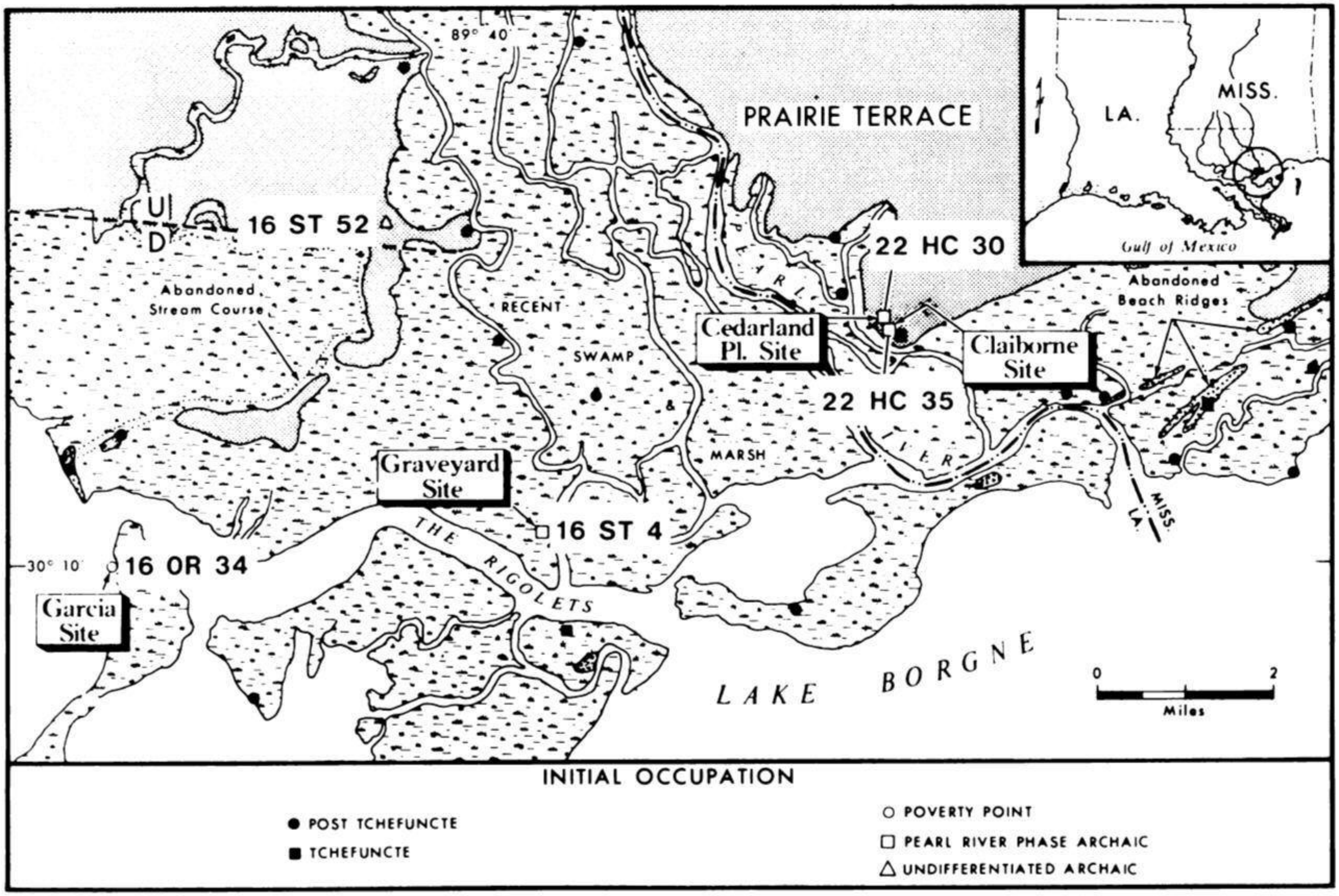


Figure 6-34. Site distributions and morphological relationships in the Pearl River mouth area (Modified from Gagliano, 1963).

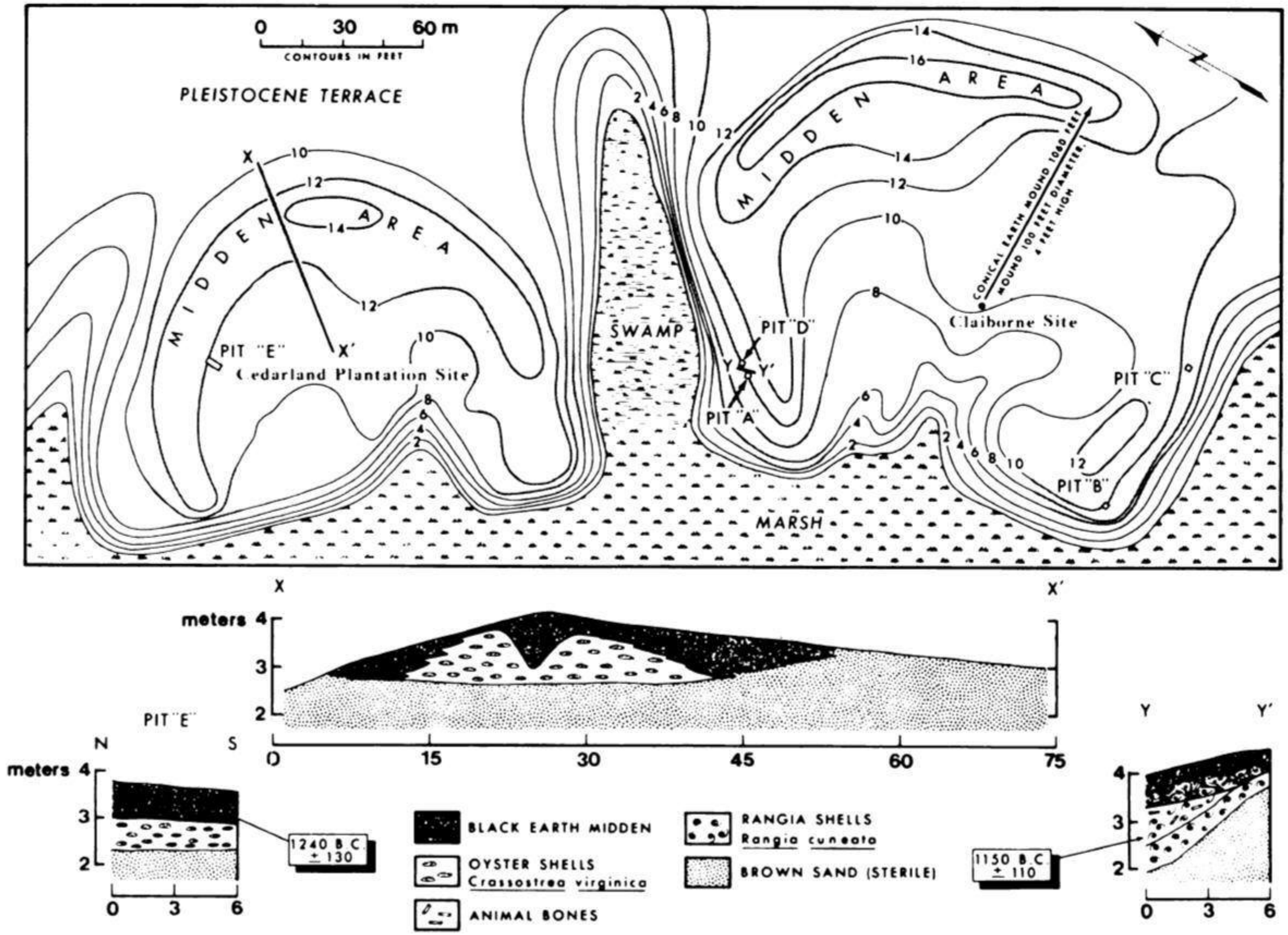


Figure 6-35. The Cedarland Plantation (22 HC 30) and Claiborne (22 HC 35) sites, showing midden concentrations, test pits, and stratigraphy and radiocarbon dates as revealed by cross-sections and profile of the east wall of Pit E (After Gagliano and Webb, 1970).

Figure 6-36. Stratigraphic view of Cedarland Site. Lower portion of site is an oyster shell midden, upper portion is black earth midden.
Date: 12/27/65

Figure 6-37. Cross-sectional exposure of clay-lined hearth in black earth midden in Late Archaic Cedarland Site (22 HC 30), Hancock Co., Mississippi.
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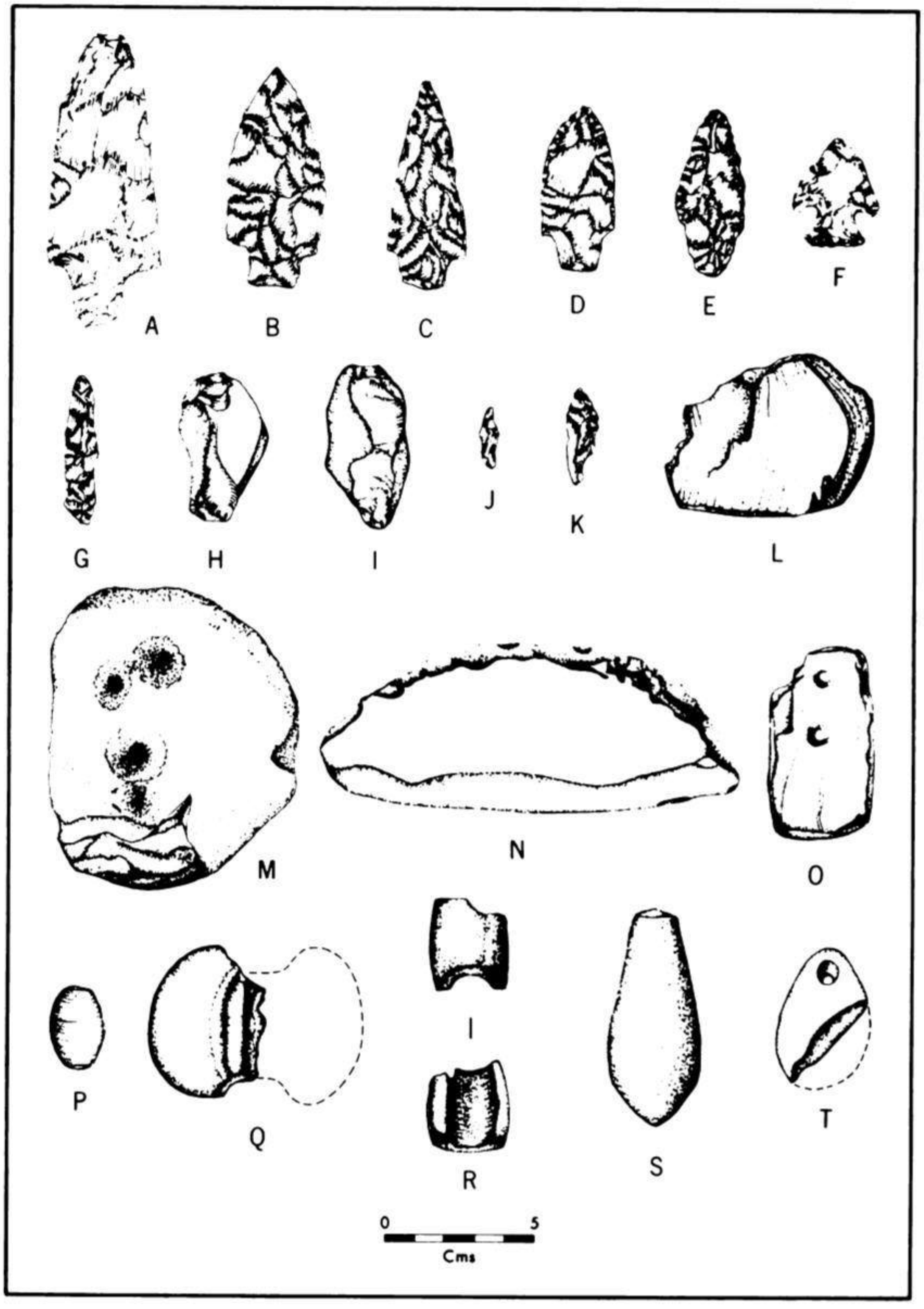


Figure 6-38. Artifacts from the Cedarland Site. A - Hale Point; B - Macon Point; C - Macon Point ; D - Pontchartrain Point; E - Gary Medium Point; F - Ellis Point ; G - drill; H,I - bipolar cores; J,K - microflints; L - Busicon shell scraper or gouge; M - nutting stone or anvil; N - sandstone saw; O - gorget; P - quartzite bead; Q - quartzite winged atlatl weight; R - sandstone cylindrical atlatl weight; S,T - plummets. (M is from Graveyard Site, 16 ST 4). (After Gagliano and Webb 1970).

hones and saws, hammerstones, deer ulna awls, shell scrapers (Busycon perversum), and choppers (Mercenaria mercenaria campechiensis). Winged atlatl weights, red jasper beads, and straight drills were also common. The most common point types consisted of Gary typical, Pontchartrain, Maçon, Hale, and Palmillas, with Ken, Yarbrough, and Gary large and small appearing in lesser numbers.

Another interesting characteristic was the occurrence of bipolar cores. Bipolar cores are also reported from Archaic sites in Texas (Honea, 1965), suggesting that this technique, identified with Paleo-Indian levels of Avery Island, may have persisted for long periods or have been revived for special purposes. The burin-like forms on bipolar cores of the Avery Island assemblage have not been identified at Cedarland.

A single radiocarbon assay from the upper level of the site gave a date of 3,190 B.P. $\pm$ 130 years (Gagliano and Webb, 1970:69). It can be assumed, however, that the site was occupied before that. A relationship between Cedarland and other Pearl River Phase sites has been noted by Gagliano and Webb, especially for the Cedar Point (16 ST "A") and Graveyard (16 ST 4) sites. The transition from the Archaic occupation at Cedarland to the Poverty Point at the neighboring Claiborne Site will be considered in the following section.

Central Gulf Poverty Point

Recognition of the Poverty Point Culture, one of the most interesting phenomena of North American archeology, can be traced to an article by Clarence H. Webb (1944) which describes certain traits from the type site in West Carroll Parish, Louisiana. The real importance of Poverty Point Culture unfolded as a result of the excavations at the Jaketown Site in Mississippi (Ford, Phillips, and Haag, 1955), followed by those at the Poverty Point Site (Ford and Webb, 1956).

Although the Poverty Point culture had been identified at the Jaketown, Poverty Point, and other sites in the Mississippi Alluvial Valley, as late as 1963, the earliest established component in the Louisiana coastal area was Tchefuncte. Various researchers had postulated pre-Tchefuncte occupations, but had no substantial proof upon which to base this supposition. Ford and Quimby (1945) reported Poverty Point Objects from the Tchefuncte Site (16 ST 1), the Little Woods Middens (16 OR 1-5), and Big Oak Island (16 OR 6), all basically Tchefuncte Period (500 B.C. - 100 B.C.) sites. They attributed the presence of the objects to their being hold-overs incorporated in the Tchefuncte cultural milieu.

Earlier, C. B. Moore, in his early reconnaissance surveys of the lower valley's archeological remains, reported Poverty Point Objects from the Bayou Sorrel Site (16 IV 4), the Schwing Site (16 IV 13), and the Miller Site (16 SM 6) (Moore, 1913:12-16).

In a 1963 article in *American Antiquity*, Gagliano and Saucier reported three new Poverty Point sites, two of which, Bayou Jasmine (16 SJB 2) and Linsley (16 OR 40), had been revealed by dredging operations. The third site, Garcia (16 OR 34), had been recorded along a heavily wave-washed beach. In that same year, the Pearl River Phase of the Late Archaic Period was reported (Gagliano, 1963). Situated across a swampy area from the Cedarland Site, the type site for the Pearl River Phase, was the Claiborne Site (22 HC 35), a Poverty Point Period locale. In this section, we will first discuss the Claiborne Site and then Bayou Jasmine, Linsley, and Garcia.

The Claiborne Site (Figure 6-35) is located only about 45 mi from Cedarland. The site itself is almost identical in shape and orientation to Cedarland, containing a semi-circular midden deposit of black earth and shells. In contrast to Cedarland, however, the dominant shellfish forming the midden was the clam *Rangia cuneata*. This suggests a decline in the salinity of the water in the Pearl River's estuary from Late Archaic to Poverty Point times.

Poverty Point Objects were exceptionally abundant (Figure 6-39). These clay balls are believed to have been used as cooking stones in roasting pits or boiling stones in skin-lined and water-filled boiling holes. The most common type of Poverty Point Object was the melon-shaped variety, followed in frequency by biconical types (Gagliano and Webb, 1970:52). This statistic, plus the counts on the other types of objects of Claiborne, shows a marked similarity to the percentages of various types of objects from the Poverty Point Site (16 WC 5) itself and the Linsley Site (16 OR 40), to be discussed below. Only minor differences in size and color and amount of sand present, show up among objects from the sites (Gagliano and Webb, 1970:52-57).

Virtually the entire Poverty Point assemblage is represented, leading to the conclusion that Claiborne was a regional center participating fully in the Poverty Point trade network and cultural organization (Gagliano and Webb, 1970:57).

A small conical earth mound was also associated with the Claiborne Site, 323 meters east of the midden, but was totally destroyed before any data could be obtained from it.

Other artifacts and ecofacts described as being abundant at Claiborne are animal bone, terrace and stream gravel, and Pontchartrain-type projectile points. Gary large, Gary typical, Macon, Hale, Kent, Shumla, Williams, Morhiss, and Carrollton are the other common points at Claiborne. The typical Poverty Point-type microflints, marine shells, red jasper, ferruginous sandstone, limonite, steatite, orthoquartzite, crystal quartz, magnetite and hematite, sandstone hones and saws, hammerstones, socketed bone points and antler tine points, antler flakers, antler scrapers or wedges, bone pins (Figure 6-40), steatite vessels and sherds, fiber-tempered pottery, untempered pottery, two- or three-hole gorgets and sandstone

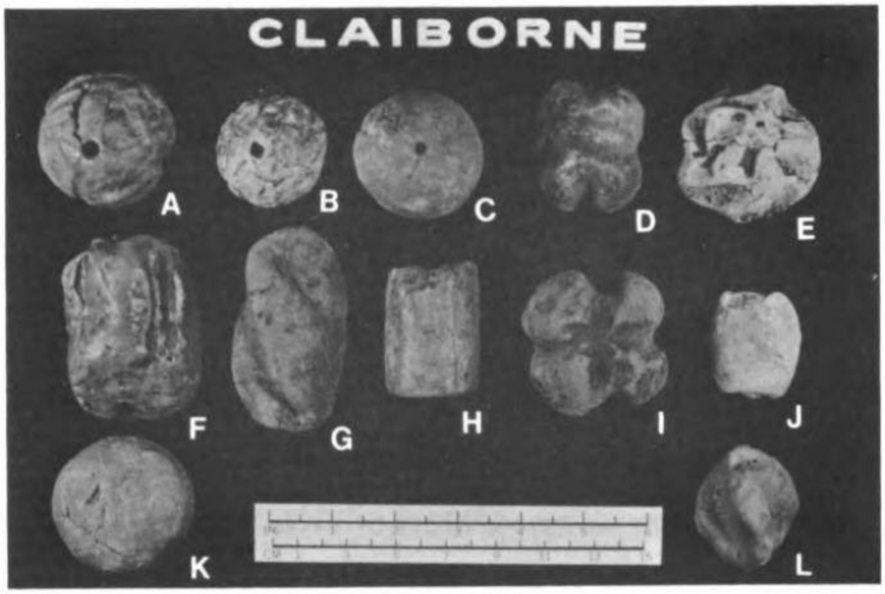


Figure 6-39. Poverty Point Objects from the Claiborne Site (22 HC 35), Hancock County, Mississippi. A - B, "Mulberry roughened" spheroid (perforated); C, Spheroidal perforated; D, Cylindrical, horizontal grooved; E, Cross-grooved; F, Cylindrical, horizontal grooved (perforated); G, Cylindrical, spiral grooved; H, Cylindrical; I, Melon-shaped grooved; J, Melon-shaped; K, Biscuit-shaped; L, Melon-shaped, spiral grooved.

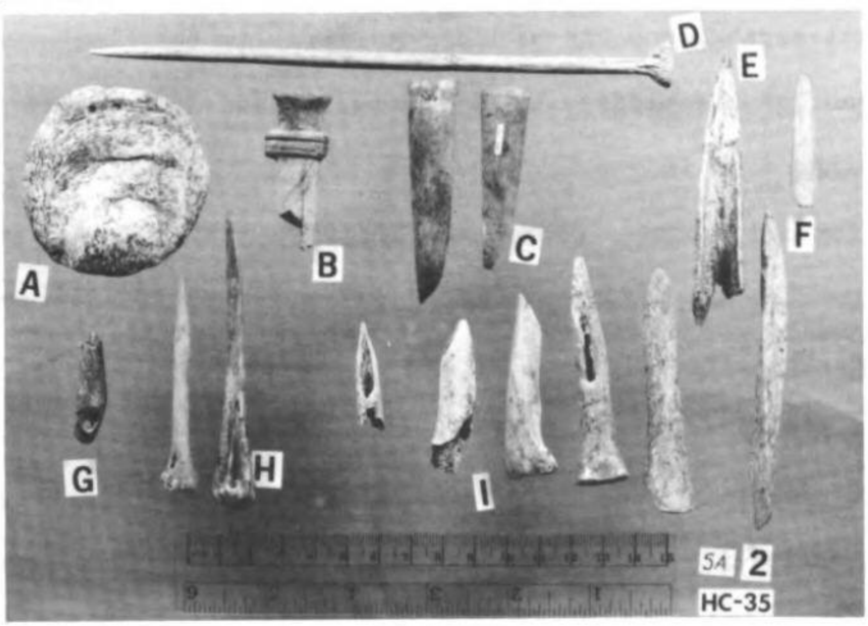


Figure 6-40. Selected artifacts from the Claiborne Site. A , Perforated, shell gorget; B and D, Bone hairpins; C, E, and F, Bone projectile points and fragments; G, Drilled canine tooth; H, Bone awls or pins; I, Bone points and flakers.

gorgets, grooved and perforated plummets, tubular beads, and three female figurines round out the majority of artifacts of the typical Poverty Point assemblage at Claiborne (Gagliano and Webb, 1970: 66-69).

Of particular interest is the fact that Claiborne has produced more fiber-tempered pottery than any other site in the central Gulf region. Approximately 200 sherds of such kind were found. All were classified as either Wheeler Plain or Wheeler Punctated (Figure 6-41).

Steatite sherds and a cache of ten complete steatite vessels (Figure 6-42) were found in sterile soil below the midden.

In summation, Claiborne can be viewed as a site of the Poverty Point Period, having been occupied, most likely, by the same population type that had lived at Cedarland during Late Archaic times. Both sites are so similar in plan and face the estuary in such a like manner that it is hard to conceive of another hypothesis. The population shifted from Cedarland to Claiborne, for whatever reasons, with the advent of the incorporation of the Poverty Point cultural milieu.

Further evidence of this shift in locales is seen in the radiocarbon determinations. A charcoal sample from the upper level of the Cedarland midden yielded a date of 3,190 B.P., while a charcoal from the base of the Claiborne midden was determined to be 3,100 years old (Gagliano and Webb, 1970). Thus, the shift occurred approximately 3,150 years ago.

Claiborne was most likely the major trading or ceremonial center of the area during Poverty Point times, while lesser satellite villages or special activity sites were situated in the marsh and swamp of the surrounding coastal region. The Garcia, Bayou Jasmine, and Linsley Site were just such locales.

Based on bore-holes and radiocarbon dates (Figure 6-43) and the artifacts recovered, Gagliano and Saucier (1963:326) established the Bayou

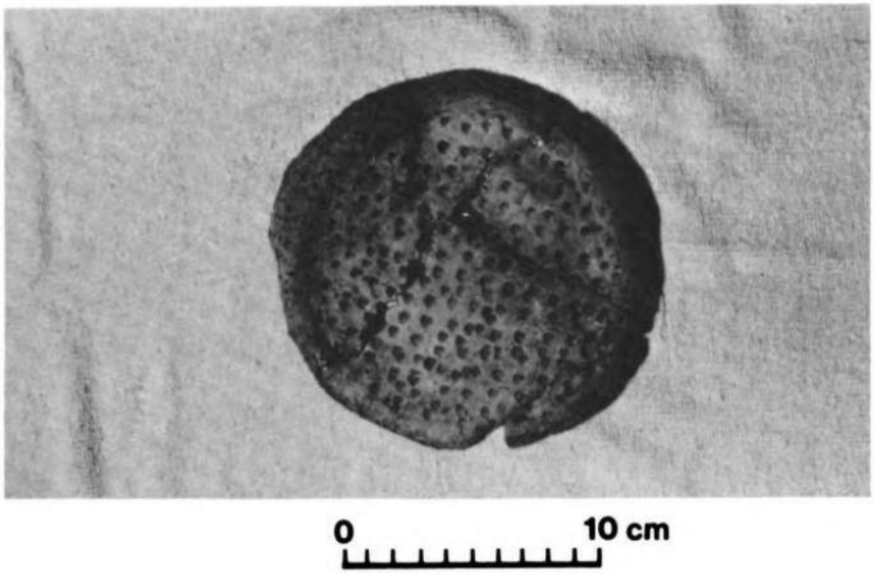


Figure 6-41. Base of a Wheeler Punctated, fiber-tempered vessel from Claiborne.

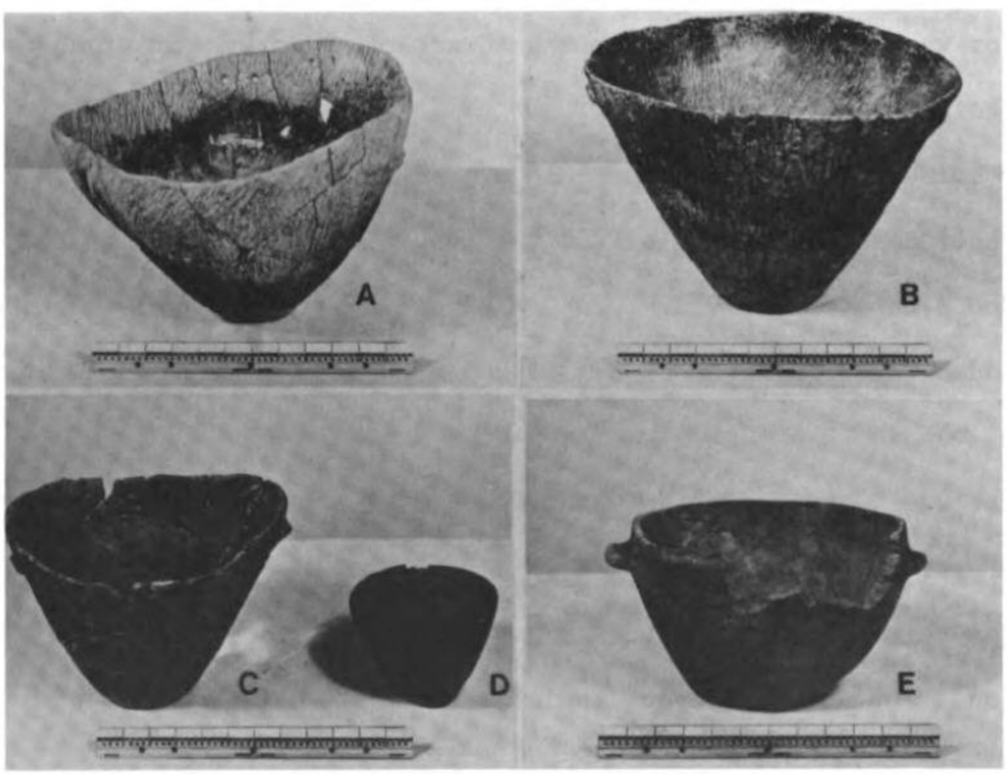


Figure 6-42. Figure of the five steatite bowls, found as a group, at the Claiborne Site. A and B show the gouge marks left from shaping of the vessels, while C, D, and E have been ground to smoothness. Photos courtesy of Mr. Norvell Roberts, Winchester, Ohio.

Jasmine Phase of the Poverty Point Period for the Linsley and Bayou Jasmine Site. Similarly, the Garcia Phase was established for the Garcia Site (location shown in Figure 6-34).

Basically, the phases are distinguished by age. The older, Bayou Jasmine Phase is characterized by larger amounts of typical Poverty Point Objects (Figure 6-44), Rangia cuneata shell middens, abundant faunal remains, bone artifacts, and three radiocarbon dates averaging 3,690 B.P. At the Linsley Site, Poverty Point Objects were even encountered clustered in fire pits, brought up whole in the dragline bucket spoil. It may be noted that these spoil loads were taken from depths of approximately 2-7 meters below mean gulf level, and from what is believed to be the top of an old buried Mississippi River natural levee (Gagliano, 1963:16).

The Bayou Jasmine Site spoil was though to have come from a similar ridge at a depth of 1.8-2.3 meters. Recent excavations by Louisiana State University have revealed, however, that midden material and peat deposits extend down to at least 5.5 meters below the surrounding marsh and swamp.

The Garcia Phase is assumed to be the younger of the two phases based on the similarity between the microlithic assemblages (Figure 6-45) at Garcia and the famous Poverty Point and Jaketown Sites. Radiocarbon dates are lacking from Garcia.

The Garcia Site itself is described (Gagliano and Saucier, 1963:326) as "a victim of rapid shoreline retreat which consists of a heavily wave-washed beach accumulation plus a possibly undisturbed shell deposit lying in 3 to 4 feet of water up to 1,000 feet from the shore." Hints of earlier Paleo-Indian and Archaic Period occupations at the site are revealed by Dalton, Meserve, Lanceolate, and Archaic-type points. The stone assemblage, including the microflints, reveals a trading network with the north and east, since much of the lithic material came from northern

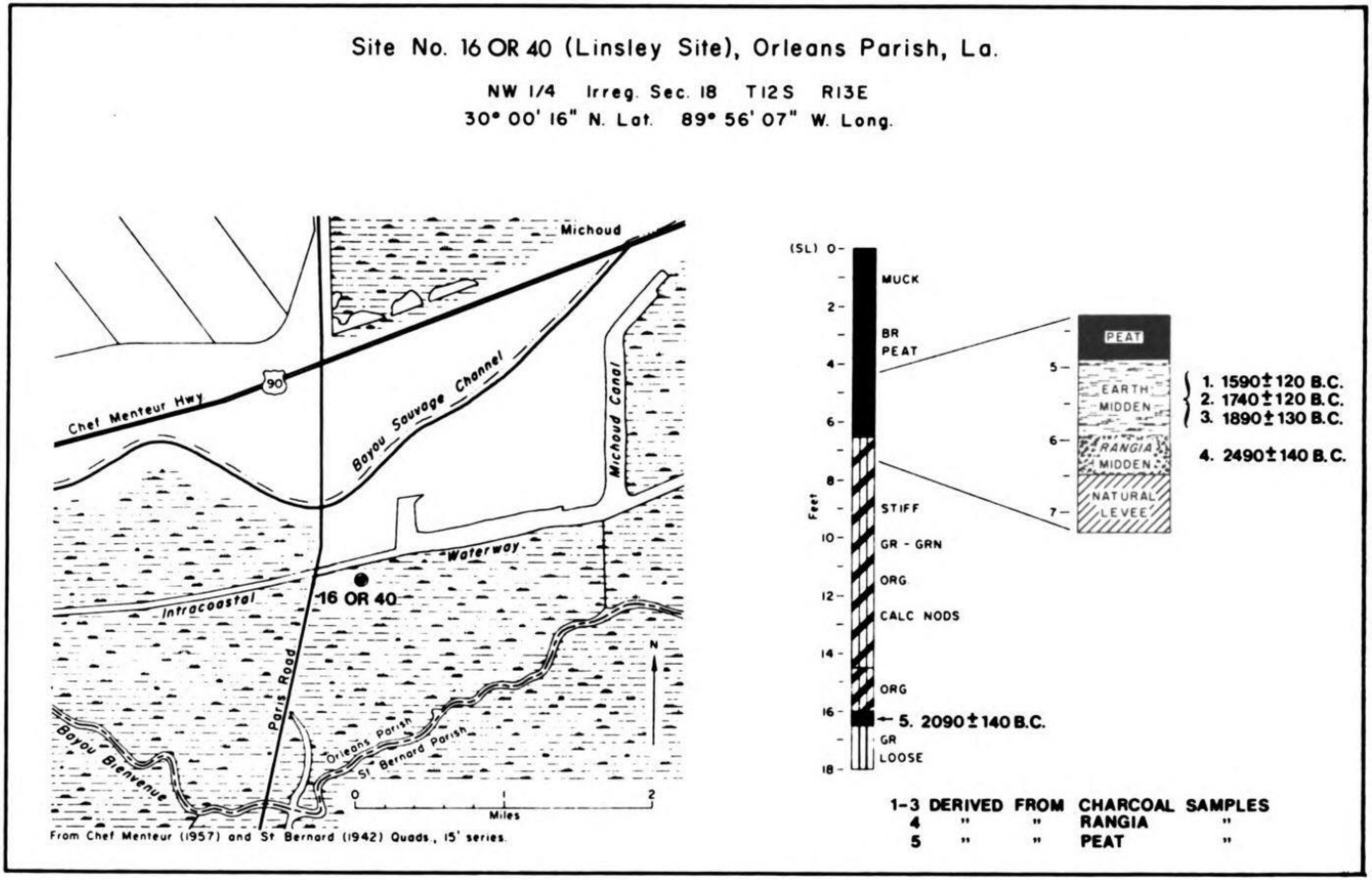


Figure 6-43. Location, borehole stratigraphy, and radiocarbon assays of the Linsley Site (16 OR 40), a site of the Bayou Jasmine Phase of the Poverty Point Period.

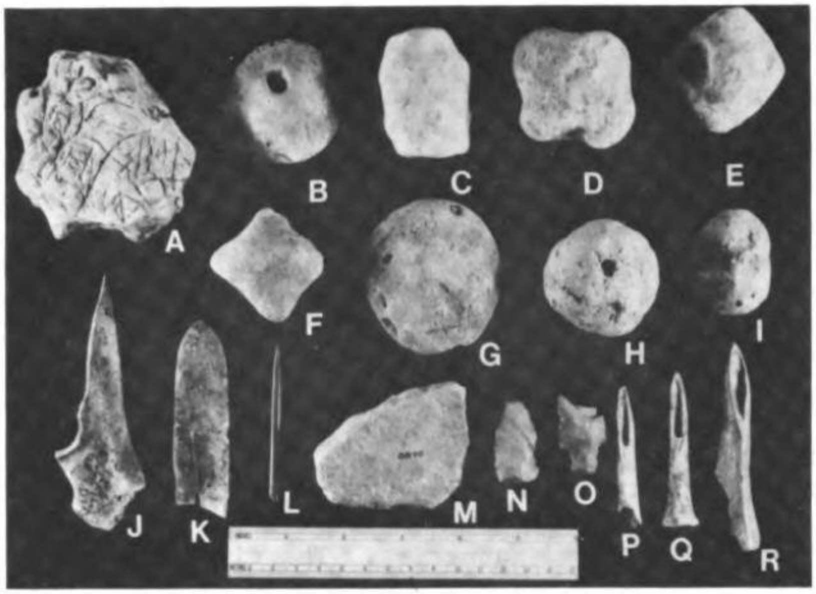


Figure 6-44. Bayou Jasmine Phase artifacts from the Linsley Site (16 OR 40). A - net impressions on baked clay; B-I - Poverty Point Objects; J - deer ulna awl; K - bone net spacer (?); L - bone pin; M - sandstone hone; N,O - unclassified projectile points; P- R - socketed bone points.

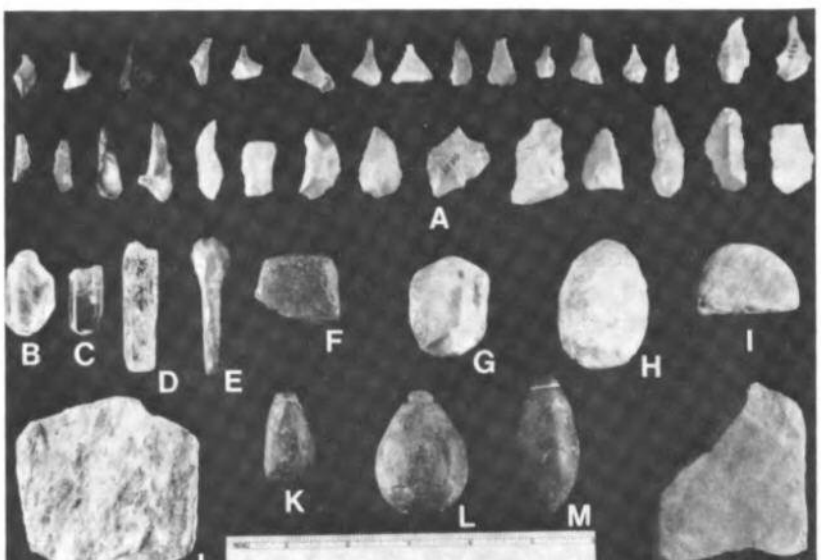


Figure 6-45. Microliths and other artifacts from the Garcia Site (16 OR 34). A - "Poverty Point-type" microliths; B - quartz fragment; C,D - quartz crystals; E - expanded-base drill; F - celt fragment; G,H - hammerstones; I - sandstone disk saw; J - schist slab; K-M - grooved plummets; N - sandstone hone.

Mississippi, Arkansas, Missouri, southern Alabama, and the Appalachian and Piedmont regions of the southeastern United States.

The area in the vicinity of the mouth of Pearl River (Figure 6-34) provides another important model of settlement and environmental use for prehistoric peoples whose economy was based primarily on hunting-fishing-gathering. The area offered a wide variety of ecological conditions, including river bottom swamplands, pine hills, coastal beaches, and brackish and salt marshes, all of which converge in the vicinity. Each of these environments supported a characteristic fauna and flora, and each offered a unique situation for hunting and gathering. The river itself provided a natural avenue of travel giving access to upland products and raw materials. In view of these many attractions, it is not surprising that the area reveals a long occupational history pattern that is repeated at most river mouths throughout the study area.

As illustrated by the number of sites shown on the map (Figure 6-34) the ceramic history is well known. Ceramic materials ranging in age from Plaquemine to Tchefuncte are represented, and there are good correlations between human occupations and geomorphic development. For example, the Tchefuncte Period is the earliest occupation found on the beach-ridge complex at the mouth of the river. This suggests development prior to, or during, Tchefuncte times. The three sites shown near the upper margin of the map represent the northernmost Rangia shell middens on Pearl River and probably approximate the maximum extent of brackish-water encroachment during their occupation.

In contrast to the many Rangia shell middens, the Cedarland Plantation and Graveyard Sites are composed almost entirely of oyster shells (Crassostrea virginica). During the Pearl River Phase, when both were inhabited, the mouth of the Pearl was probably more estuarine and local salinities were somewhat higher, permitting oyster growth. Conditions changed, and by Poverty Point times, when the Claiborne Site was occupied, the brackish water clam Rangia had replaced the oyster as the dominant shell type in the midden, indicating that the estuary was being filled by a growing delta in the vicinity of the site and that the saline zone of the estuary had shifted seaward. It is also interesting to note that in the Poverty Point midden, shell is generally less abundant, and the midden consists largely of black earth with very abundant remains of mammals, birds, and fish. In the middens of the Tchefuncte and subsequent periods, brackish water Rangia shells predominate, making up the bulk of the middens.

Other physical changes in the area have resulted from recent fault movement. The Prairie Terrace, marking the western margin of the stream valley, has been downfaulted, and the Graveyard midden, once on the valley margin, is now partially below sea level.

The Garcia beach deposit, as mentioned previously, contains Poverty Point elements and is believed to be related to an early Mississippi River Delta development. The site was probably a satellite to the major village at Claiborne. The earliest evidence of occupation thus far found in the area comes from the innermost of the abandoned beach ridges (at Ansley, Mississippi) and from the Garcia beach deposit. From the beach ridge, a single side-split quartz pebble with a graver spur produced by steep-edge chipping has been found. At the Garcia Site the evidence consists of an unfluted Clovis Point and a number of Dalton points.

The McKeen Site (16 ST 52), a camp located on a knoll overlooking the valley scarp, is unlike any other in the vicinity of the river mouth. The assemblage is typically Early Archaic, composed exclusively of chipped artifacts, and includes a Kirk point. This Early Archaic occupation is believed to have been contemporaneous with the development of a series of large Deweyville stream scars impinging on the valley wall. Immediately north of the area shown on the map, these scars emerge from beneath a wedge of alluvium to form part of the Deweyville Terrace complex.

By studying the settlement pattern and refuse of habitation sites in the Pearl River mouth area, it is possible to reconstruct a significant part of the Holocene geological history and ecological succession. The following sequence of events is suggested.

CULTURAL PHASE & PERIOD	EVENTS	INTERVAL	PERIOD
Post Tchefuncte	Development of coastal marshes continued.	Late Holocene	K
Pontchartrain Phase Tchefuncte Period	The lower estuary of the Pearl was essentially filled and accretion beaches near the mouth of the river were fully developed.	Late Holocene	K
Bayou Jasmine - Garcia Phase Poverty Point Period	The Pearl River delta advanced within the embayed valley. Mississippi River distributaries approached the area from the west modifying environments from Gulf Sound to marginal deltaic.	Late Holocene	K
Pearl River Phase - Late Archaic Period	The shoreline was re-established along the innermost of the accretion beach ridges and the river valley was embayed as a result of rising sea level. Sea level reached its present stand.	Late Holocene	J
Early Archaic Period (McKeen Site)	Deweyville streams were active and ecological conditions somewhat different. The McKeen site was a number of miles upstream from the existing coast; sea level was approximately 20 meters below its present position.	Middle Holocene	H4-I
Paleo-Indian Period	Late Paleo-Indian occupation on shoreline or near-shoreline features at Garcia site and innermost of abandoned beach ridges.	Early Holocene	H3

Eastern Gulf Pre-Projectile Point

One Pre-projectile Point Period site, Skelly, will be described from the eastern Gulf. The Skelly Site is one of a number of important quarry sites located in the vicinity of Dothan, in south Alabama. The Dothan area is one of subdued karst topography with numerous sinkholes and residual outcrops of more resistant chert and cherty limestone. Mr. William H. Emanuel, formerly of Dothan, and other local collectors reported the sites and described them as containing a profusion of lithic material. Emanuel (personal communication, 1975) was impressed by several features of the sites. First, archeological sites are numerous in the general area. Examination of large surface collections from neighboring sites revealed characteristic artifacts from all documented culture periods thus far recognized in the region, ranging from Paleo-Indian to late Prehistoric. Second, much of the material is heavily patinated. Third, Emanuel found and reported hand axes very similar to Acheulian-type hand axes which he had collected and studied from the Grand-Pressigny area of France.

The Skelly Site is situated on rolling hills around a small dry lake bed. While the total extent of the site is not known, it is so large that it was brought to Emanuel's attention by an Army pilot who reported its aerial appearance as a curious "speckled area." The speckles turned out to be lithic artifacts, patinated white, that litter the cultivated fields and pastures (Figure 6-46). Important features of the site are old quarry pits on the hills. The margins of these pits are paved with workshop debris. Where exposed by a roadcut, several levels of chipping floors can be seen to dip into the old pits and are interbedded with red lateritic sands (Figure 6-47).

After visiting the site with Emanuel, the senior author initiated a preliminary survey of the area. The survey was conducted by Mr.

Figure 6-46. Debitage in cultivated field at Skelly Site near Dothan, Alabama.

Figure 6-47. Stratified chipping floors sloping into old quarry pits at Skelly Site near Dothan, Alabama.

Tom Ryan, then a student at Louisiana State University, during the summer of 1967. Ryan located about 20 sites and examined a number of large collections accumulated by members of a local amateur archeological society. Characteristic artifacts from all periods ranging from Paleo-Indian to late Prehistoric were identified in the surface collections; that is, evidence of all documented culture periods thus far recognized in the region could be found. A number of sites were found where lithic material occurred with associated index artifacts and assemblages from various periods of the established sequence of the area.

Although surface collections suggest a Pre-projectile Point age for much of the occupation (Figures 6-48 and 6-49), because the site remains to be systematically worked, surface-collected material has important implications for this study. The following types appear in the assemblage:

Ovate and trianguloid hand axes - frequently rhomboid in cross-section and with tool edges on the margins produced by secondary chipping

Heavy choppers - crude percussion chipping

Bifacial discs

Plano-convex scrapers - (scraper planes)

Large ovate-to-trianguloid biface blades

Levallois-like cores and blades

Flakes and blades with denticulate and graver spurs - (one or more)

Sandstone hammers and abraders

Heavy polyhedral chert hammerstones

Sandstone anvils

Bipolar cores - (infrequent)

Burins

The possibilities for occurrence of similar sites on the continental shelf or the eastern Gulf are reasonably good. The chances of detection of this type of site by remote-sensing and bottom-sampling techniques are

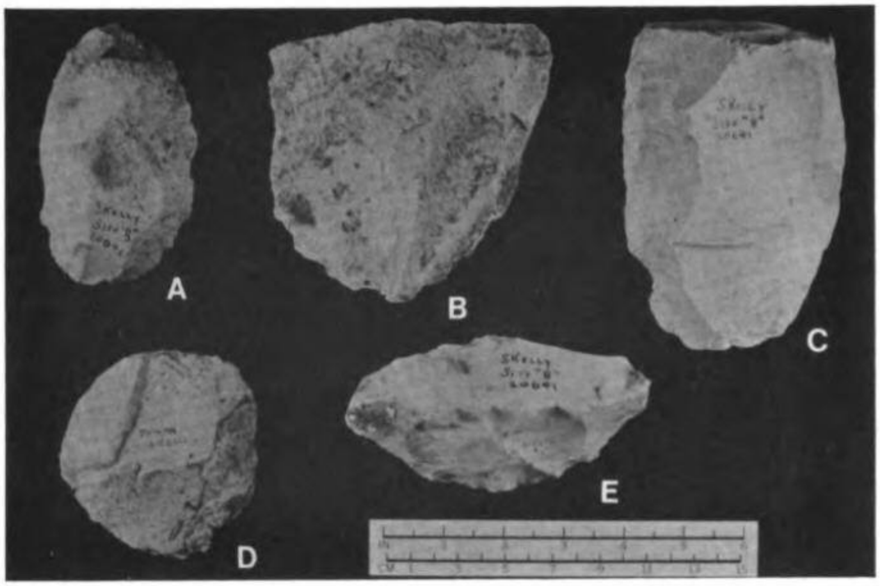


Figure 6-48. Skelly Site Artifacts. A, D, Ovate bifaces; B-C, E, choppers or cleavers.

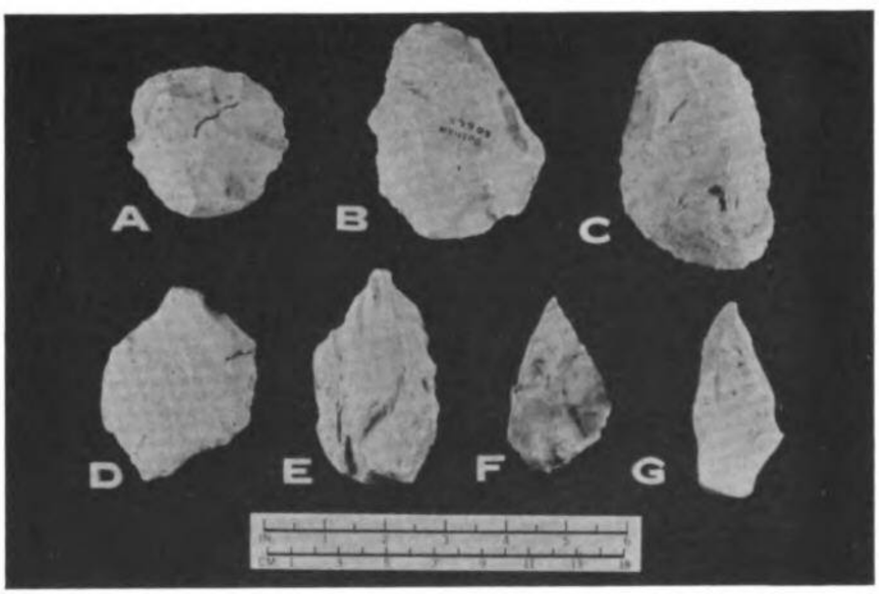


Figure 6-49. Skelly Site Artifacts. A-C, Ovate to rectanguloid bifaces; D-E, Bifaces with denticulates and graver burr on margins; F-G, Trianguloid blades (possibly projectile points or knives).

also reasonably good because of the abundance and density of worked stone and the extensive surface area.

Eastern Gulf Paleo-Indian

The discovery of human fossil remains and extinct Pleistocene fossils in an old stream bed near Vero, Florida, (Sellards, 1916) represents a rare, albeit controversial, situation relative to Paleo-Indian occupation in the eastern Gulf area. Geographically, the Vero Site lies beyond the boundaries of the Gulf coast study area, but its coastal setting and significance warrant inclusion.

The construction of a drainage canal between Vero and Gifford, Florida, in 1913 revealed the presence of vertebrate fossils in a cut through an old stream bed (Figure 6-50). This cut displayed three zones of deposition, which eventually were given temporal estimates on the basis of geological and

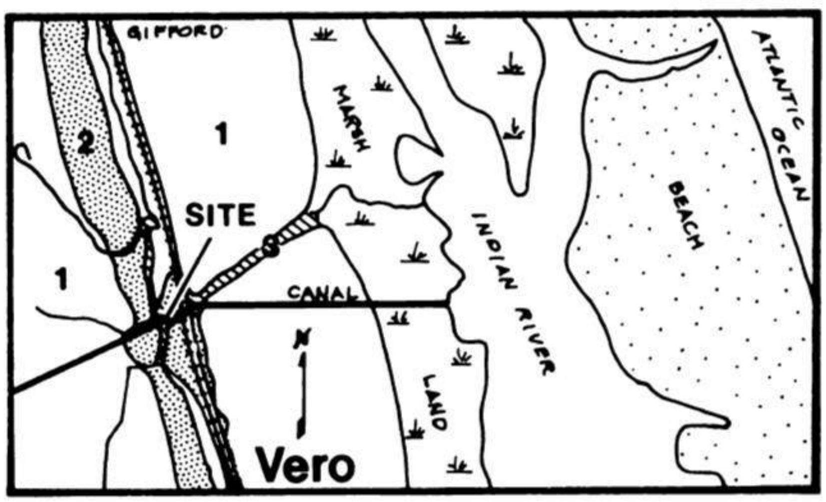


Figure 6-50. Map of Vero area showing canal from which human fossil remains have been found. 1" = 4000'. 1 - Pine lands; 2 - Pleistocene Beach; 3 - Stream valley. Human remains came from this valley, west of the railroad and public highway crossing (From Sellards, 1917a).

biological data, and will be described subsequently. The valley of the stream at the fossil locale is relatively limited, varying in width from 107 to 152 meters.

The stream system, which has been greatly modified by modern channeliation, passes through a pan-shaped depression lying west of a sequence of Pleistocene dune deposits believed to be related to the Silver Bluff shoreline (see Figures 6-50 and 6-51). The depression may have originally formed as a shallow lagoon behind the Silver Bluff beach-dune complex, or it may have resulted from the buildup of the dunes parallel to an old escarpment against the Pamlico Terrace. In either event, the depression evolved into a perched freshwater dune lake, and it is in the deposits of this dune lake (Figure 6-51, Bed 2) that fossil human bones have been found with bones of extinct Pleistocene vertebrates.

Of the three strata revealed by the cut (Figure 6-51), the lowest and oldest deposit has been related in time to the Sangamon interglacial stage (Weigel, 1962) and is basically composed of a marine marl. Fossils from

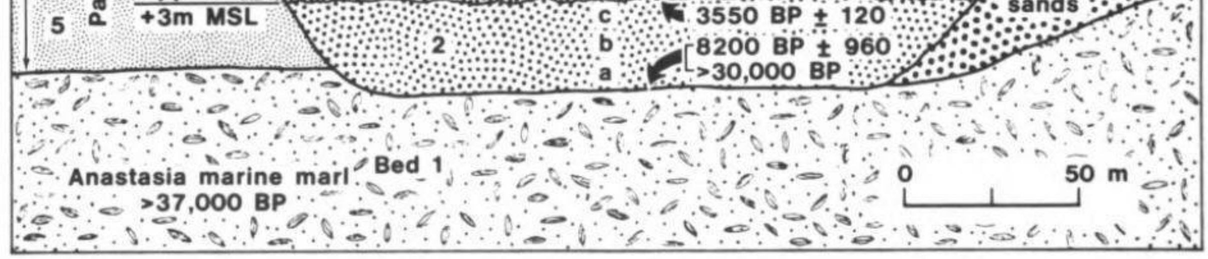


Figure 6-51. East-west cross-section through fossil deposits at Vero. Section is diagrammatic and scales approximate. (Modified from Weigel, 1962.)

this deposit are exclusively invertebrate species characteristic of a marine habitat. Analysis of the molluscan faunal remains shows no major morphological difference from present-day species, indicating the persistence of invertebrate forms through time.

The second stratum is composed of cross-bedded sand at the bottom. The appearance of a freshwater marl at the top of this layer represents a shift to freshwater conditions. All fossils of extinct vertebrates from the site have come from Bed 2, supporting the assumption that it is a Pleistocene-aged deposit. The vertebrate fossils were located in close proximity to human remains as well as flint spalls. Analysis of the fossils shows a predominance of freshwater species, most of which were warm-climate animals. Of the 122 vertebrate species found in Bed 2, four were fish, seven were amphibians, 27 were reptiles, 37 were birds, and 47 were mammals. Forty percent of the mammalian forms are now extinct, as are three percent of the reptiles and amphibians and eight percent of the birds. The 28 identifiable land and freshwater invertebrates found do not differ from modern species.

A checklist of fossil vertebrates from the locale prepared by Weigel (1962) contains the following extinct forms.

Extinct land tortoise	Geochelone sellardsi
Extinct stork	Ciconia maltha
Passenger pigeon	Ectopistes migratorius
Harlan's ground sloth	Paramylodon harlani
Jeffersonian ground sloth	Megalonyx jeffersonii
Extinct armadillo	Dasypus bellus
Extinct armadillo	Holmesina septentrionalis
Extinct bog lemming	Synaptomys australis
Capybara	Hydrochoerus sp.
Extinct wolf	Canis ayersi
Extinct fox	Vulpis palmaria
Extinct jaguar	Panthera augusta
Saber-tooth cat	Smilodon sp.
Mastodon	Mammut sp.
Mammoth	Mammuthus sp.
Peccary	Mylohyus sp.
Extinct horse	Equus sp.
Extinct camel	cf. Tanulpoloma mirifica
Extinct bison	Bison sp. (probably Bison latifrons)

The first human bones discovered in Bed 2 were found 100 m west of the bridge in the south bank of the canal beneath 45 - 60 cm of marl rock. A second discovery of human bones was made in June, 1916 (Sellards, 1917), and included an astragalus, a cuneiform, part of an ilium, two phalanges, a limb bone section, and other bone fragments. A deer scapula was found at the same level as, and between, the astragalus and the cuneiform in Zone 2. All of the bones from this zone were randomly distributed throughout the zone and were usually found in an imperfect state of preservation. A strong case has been made (Sellards, 1917) for the contemporaneity of the human and Pleistocene fossils, based on their aforementioned similar manners of occurrence (scattered and poorly preserved), on their proximity within the strata, on their location in and beneath undisturbed geological formations, and on their equal degrees of mineralization. The absence of any nearby fossil-bearing deposits reinforces the assumption that the deposits are primary. Bed 2 also contained a thin, sharp-edged flint, a small worked spall, two small spalls, and part of a bone implement, which may possibly have been engraved. The sharpness of the spall's edges helps to negate a theory of water travel to explain their appearance in the deposit, and since the closest flint outcrop is 160 km northwest of the site, the original source has yet to be determined.

An abrupt erosional non-conformity marks the transition from Bed 2 to the uppermost stratum (Bed 3), which is composed largely of muck and loose sand, averaging 60 cm in thickness and frequently overridden by freshwater marl. Human skeletal remains, bone implements, pottery, chipped stone projectile points, and ornaments have been collected from this stratum. The vertebrates from this third zone represent extant forms only. Studies of Zone 3 fossil plants reveal a former abundance of hydrophytic plants, with the resulting interpretation of Bed 3 as having been a pond-marsh habitat during its period of deposition.

Further indications of the age of the deposits and their aquatic associations during deposition are gleaned from radiocarbon dating and geological data, especially pertaining to Bed 2. Weigel (1962:11) summarizes some of the relationships as follows:

> The difficulties involved in establishing correlations of Florida Pleistocene fossil deposits with stages of the Pleistocene were reviewed by Bader (1957). The age of the Vero bone beds is relevant to these problems and to the chronology of Florida Pleistocene shorelines. Two of the shorelines, the Pamlico and Silver Bluff, are closely associated with the Vero beds. The Pamlico shoreline lies about 25 miles west of Vero and its terrace surrounds the bone beds. The Silver Bluff Shoreline lies a few feet east of the railway at Vero and shoreline features indicate a sea level about 10 feet higher than present (MacNeil, 1950). The contact between beds 2 and 3 is somewhat less than 10 feet above present sea level; thus the deposit area was subject to tidal action of the Silver Bluff sea.

At approximately +3 m MSL, the Silver Bluff was the only shoreline to approximate, or exceed, the level of the existing shoreline since the Pamlico (Sangamon Interglacial). Since the fossil bed (Bed 2) seems to be intimately related to deposition of the Silver Bluff dune sands, the age of this shoreline is of considerable importance to our problem. There has long been considerable divergence of opinion regarding the age of this feature, which is very well defined along the south Atlantic coast. One school of thought regards the Silver Bluff as post-Wisconsin in age and relates it to the hypsothermal interval (post-glacial maximum) which began, according to Deevey and Flint (1957), about 9,000 years ago. However, the concept of a hypsothermal high stand has been largely disregarded by more recent workers.

A second interpretation might relate the Silver Bluff shoreline to a Farmdalian (Mid-Wisconsin) sea level high stand of 25,000 to 30,000 years ago. As we have discussed in Chapters 3 and 4 of this report, the evidence for the Farmdalian high stand is suspect.

Still a third interpretation, and the one that would probably be favored by most contemporary Quaternary geologists, would relate the Silver

Bluff to the Sangamon Interglacial (see Chapter 4). Following this correlation, the Silver Bluff shoreline might be anywhere from 90,000 to 55,000 years old.

While the age of the Silver Bluff remains to be established, radiocarbon dates shed considerable light on the age of the fossil-bearing bed (Bed 2) at the Vero site. As shown in Figure 6-51, three radiocarbon dates were obtained on samples from Bed 2. A charcoal sample taken from the very bottom of the bed yielded a date of >30,000 years. The date of 8,200 ± 900 years was obtained from carbonaceous material collected from the lower one-third of the bed near the limits of the basin. Weigel (1962:10) does not believe that this sample represents the oldest part of Bed 2, since the older portions thin out at the edge of the basin and are absent at its extreme limits. The 3,550 ± 120 years date is from charcoal collected from the top part of Bed 2. Weigel (1962:10) states, "This bed clearly appears to represent a period of continuous deposition from something over 30,000 years ago until about 3,500 years ago and embraces that period during which many Pleistocene forms became extinct in Florida."

In view of the nonconformity at the base of the bed and the considerable hiatus which it implies, the degree to which the >30,000-year-old date is representative of Bed 2 and its contents is somewhat questionable. Persistence of a dune lake for a period of 30,000 years, during which great fluctuations of sea level and variations in climate are known to have occurred, also raises questions concerning Weigel's interpretation. The two younger dates seem to be more consistent with the faunal and archeological record as we presently understand them.

It is significant to note that the fauna and flora indicate warm, moderate climate during deposition of Bed 2. The nonconformity between Beds 2 and 3 represents a hiatus of unknown duration, but apparently not of great length. The faunal and floral record of Bed 2 indicates Late Holocene conditions not significantly different from those which are obtained at present.

From the published descriptions of the site, the following summary interpretation can be made:

Bed	Events	Interval and Stage	Period
3*	Deposition of sand and muck with bones of extant fauna, pottery and other artifacts. Conditions similar to those at present. Boggy, ponded conditions.	Late Holocene	K
Erosional Non-conformity	Erosion implies reduction of standing water level through reduced ground water level, improved drainage of pond or reduced base level of pond drainage system. Final extinction of Pleistocene fauna.	Middle Holocene	H4-J
2*	Development of perched dune lake. Deposition of sands with fresh-water vertebrates. Fauna and flora indicate warm, moderate conditions. Extinct Pleistocene vertebrate fauna abundant. Human bones and chipped stone indicate presence of man.	Early Holocene	H3 (possibly H1-H3)
4*	Silver Bluff shoreline active, creation of tidal lagoon (?). Deposition of coastal dune deposits. Creation of pan-shaped depression in which Beds 2 and 3 were deposited.	Late Pleistocene or Early Holocene	?
Non-conformity	Major hiatus of tens of thousands of years.	Pleistocene Wisconsin Glacial	
5 - 7*	Deposition of Pamlico sands. Shoreline approximately 25 miles to the west. Sands probably deposited under shallow marine conditions as strand plain.	Pleistocene	A
1*	Deposition of shallow marine marl, Anastasia Formation.	Pleistocene Sangamon Interglacial	A or Pre-A

* Numbers after Weigel, 1962.

One of the most exciting and scientifically rich archeological sites to be located in recent years is the Warm Mineral Springs Site (8 SO 19) in Sarasota County, Florida. Both it and neighboring Little Salt Springs Site (8 SO "A") have afforded the opportunity to study well-preserved organic material in stratigraphic levels, employing underwater archeological techniques. The information gained, and yet to be gained from these sites, should contribute substantially to our understanding of Late Quaternary geology, climate, archeology, flora, fauna, and hydrology of Florida.

Another site, the Fish Creek Site (8 HI 105), in Hillsborough County, does not have the archeological or scientific potential present at Warm Mineral Springs, but it does offer the reader an example of the ordinary, as opposed to the extraordinary Warm Mineral Springs, Paleo-Indian site situated along Florida's bay margins. We will begin our discussion at Warm Mineral Springs and then turn our attention to the Fish Creek Site.

A short paper appearing in American Antiquity (Royal and Clark, 1960) first brought attention to the Warm Mineral Springs sinkhole. In that publication, Royal and Clark discussed and illustrated a remarkably well-preserved human skull and brain, along with various artifacts obtained from the sinkhole. They also mentioned the now well-known ledge, at a depth of approximately 13 m below the water's surface, from which the skull came, and the three distinct stratigraphic zones of the ledge (Royal and Clark, 1960: 285-6). A single radiocarbon date of 10,000 ± 200 years B.P. was obtained from a burned log taken from Zone 3, the lowest on the ledge. The skull was thought to be somewhat younger since it came from the base of Zone 2, the intermediate zone. Royal and Clark did feel, though, that an Early Archaic age for the skull was a strong possibility (Royal and Clark, 1960:285).

It was not until 1973, however, that substantial, stratigraphic evidence emerged during the excavation of a small test pit on the "13 meter" ledge by Carl Clausen, then of the Florida Bureau of Historic Sites and Properties (Clausen, 1972). In a more recent report, Clausen, Brooks, and Wesolowsky (1975) present a detailed account of the test pit and the implications of the data recovered from the excavation.

Warm Mineral Springs originated when a subterranean cavern in the Tampa Limestone collapsed (Figure 6-52). This caused the formation of the present sinkhole, approximately 73 m in diameter and averaging about 38 m in depth (Clausen, Brooks, and Wesolowsky, 1975:193).

At a depth of about 13 m, a small ledge rings most of the sinkhole (Figure 6-53). This ledge, ranging from 1 to 6 m in width, was formed as softer rock and clay materials both above and below it eroded it away. Along the northern side of the spring, the ledge forms a relatively wide platform upon which sediments and organic deposits have accumulated. Here it was possible to carefully examine the ledge's three sedimentary zones and excavate the test pit. These zones, 0.9 to 2 m in thickness, are described by Clausen, Brooks, and Wesolowsky (1975:96-7) as:

> Zone 1 - An algal slime, the stratigraphically superior layer, ranges from 0.20 to 0.50 m in thickness. It is composed of a soft, aqueous, black algal ooze with shells of the same small snails still prevalent in the spring, *Heleobops docima* and *Pyrogophorus platyrhachis*. The bones of alligator, tarpon, and turtle are occasionally found in this layer.
>
> Zone 2 - Calcitic mud, the middle layer, ranges in thickness from 0.15 to 0.50 m. It is predominantly a gray, unconsolidated calcitic silt. There is some pine bark, oak leaves and other plant debris in this layer. Two distinct layers of wall *tufa* represent periods of spalling. Snail shells are common, especially *Physa cubense*, *Heleobops docima* and *Helisoma trivolvis*. Vertebrate remains are uncommon and are those of frogs and mice. Radiocarbon dates on charcoal from the upper and lower portions of this zone are 8,520 ± 400 years: 6570 B.C. (W-1243) and 8,600 ± 400 years: 6650 B.C. (W-1241).
>
> Zone 3 - A leaf bed, the bottom deposit, varying in thickness from 0.10 to 0.80 m. This is the most variable of all the strata, consisting of alternate bands of terrestrial plant debris, predominantly leaves, twigs and small logs, seeds and charcoal intercalated with calcitic mud layers that contain

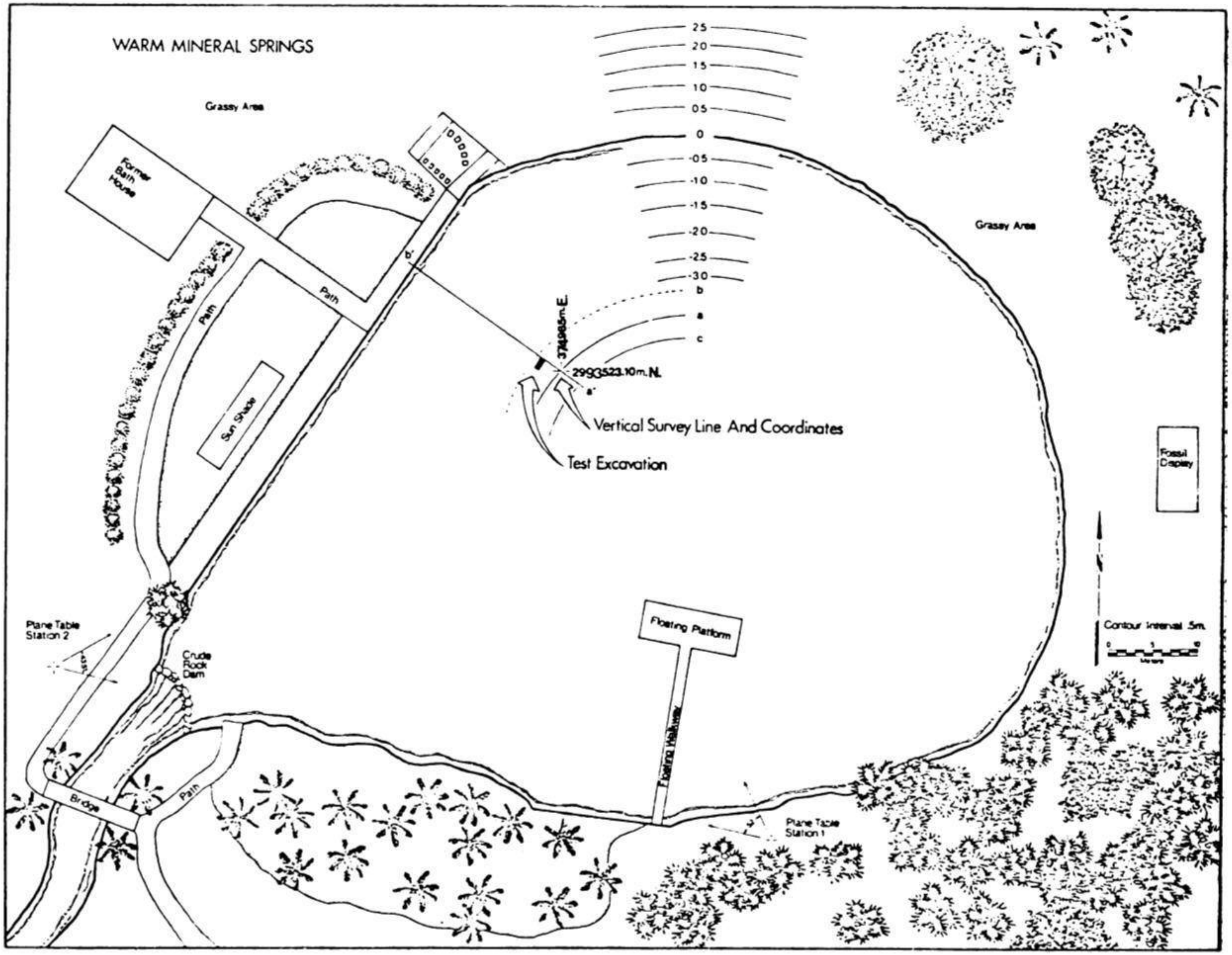


Figure 6-52. Map of Warm Mineral Springs, showing position of Clausen's test pit in relation to surrounding sinkhole walls and modern buildings (After Clausen, Brooks, and Wesolowsky, 1975).

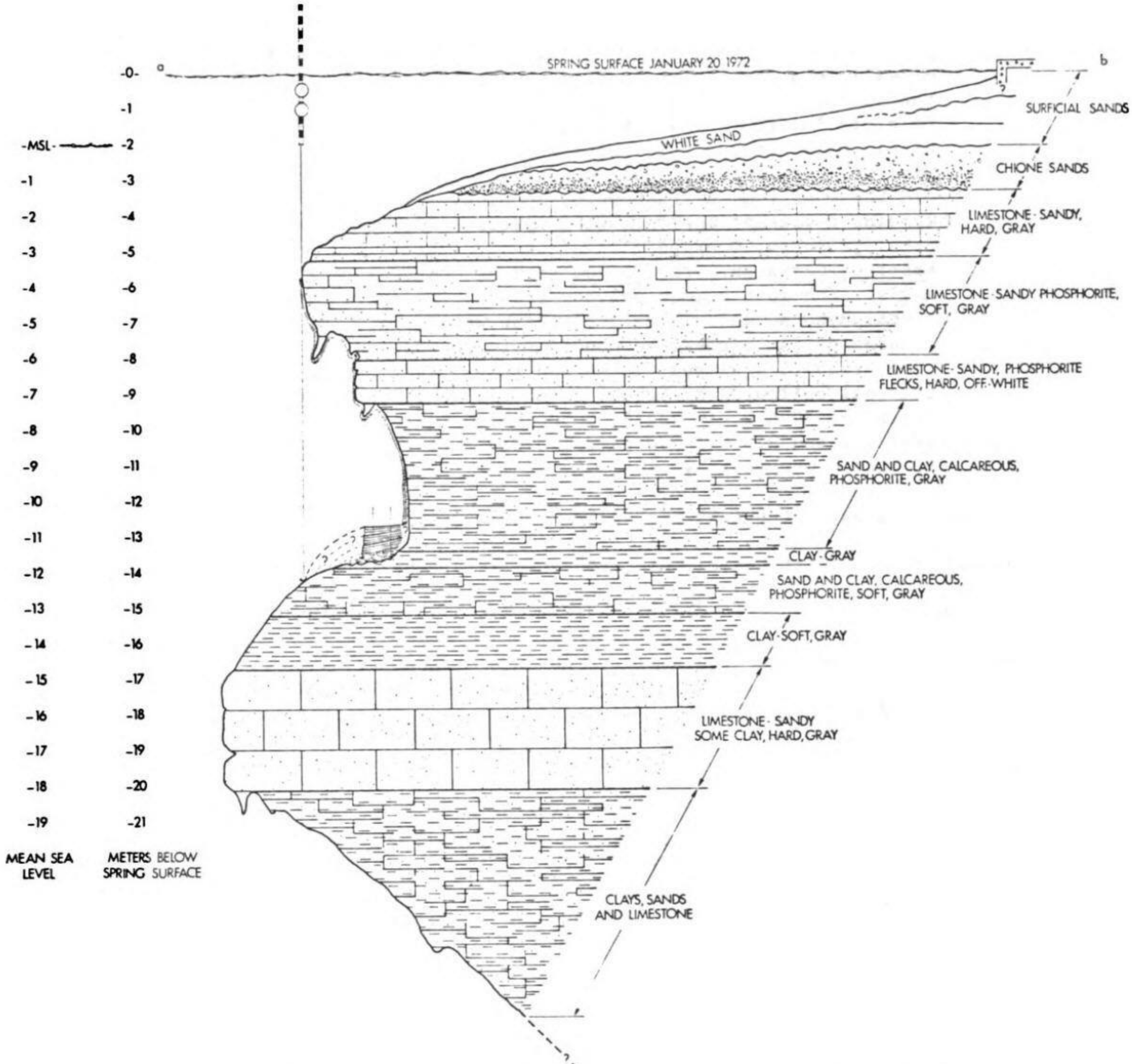


Figure 6-53. Generalized cross-section through the wall of Warm Mineral Springs. Note the ledge at the approximate depth of 13 m, and the three zones of sediment on the ledge. The two pins shown standing vertically out of the three zones mark the location of Clausen's test pit (After Clausen, Brooks, and Wesolowsky, 1975).

fresh-water and terrestrial snail shells as well as fragments of wall tufa. Fallen stalactites occur as well as fronds of the sinkhole fern Thelypteris normalis encrusted with a heavy calcitic layer. A small stalagmite has been found in situ within this stratum. Terrestrial snails are more abundant and diverse in this zone. Helisoma trivolvis and Physa cubense are the most common fresh-water species. Identified plant remains represent the following species: Pinus elliotii, Sabal palmetto, Quercus virginiana, Z. laurifolia, Ampelopsis arborea, Carya sp., Phylolacca rigida, and Thelypteris normalis. The most common polynomorph is a pyospore of a species of Chlamydo monas or a related fresh-water algae. Vertebrate remains so far identified consist of man, deer, opossum, raccoon, rabbit, squirrel, mouse and frog. Radiocarbon dates on charcoal collected by Brooks from this zone are 9,370 ± 400 years: 7420 B.C. (W-1245), 9,500 ± 400 years: 7550 B.C. (W-1212) and 9,870 ± 370 years: 7920 B.C. (W-1153), from top to bottom respecively.

In the area of the test pit, only Zone 3 remained completely intact, however, since relict-hunters had removed most of the first two zones earlier. Three radiocarbon samples were taken from this zone in order to pin down its time of deposition more accurately. The Zone 3 deposit was 70 cm thick at this point, and the radiocarbon dates, in descending order in the zone, were 8,920 ± 190 years, 9,350 ± 190 years, and 9,220 ± 180 years before present, respectively. The bottom radiocarbon date came from the 70 cm level of Zone 3 (Clausen, Brooks, and Wesolowsky, 1975: 198). The test pit was then established near the sinkhole's sloping wall and measured one meter by one-half meter, a rather small pit, but one which yielded considerable data.

While preparing the area for systematic excavation, it was necessary to clear away a portion of Zone 3, so an approach giving easy access to the actual pit could be facilitated. During this clearing process, at a depth of 25 cm into Zone 3, a fragmentary left ilium of a human juvenile was discovered. Based on the size of the ilium fragments and comparison with modern pelves, it was determined that the ilium belonged to a child about six years of age at time of death (Clausen, Brooks, and Wesolowsky, 1975:205).

Following this encounter, the test pit was excavated by removal of 10 cm levels. At a depth of 35 cm into the Zone 3 deposit, an almost complete first sacral vertebra of a human juvenile was uncovered (Clausen, Brooks, and Wesolowsky, 1975:201-202). The degree of synotosis occurring in the vertebra indicated an age of six years when the individual died (Clausen, Brooks, and Wesolowsky, 1975:204). There was no evidence to conclusively state that both the ilium and the vertebra came from the same individual, but such a possibility is indeed high. One radiocarbon sample taken from the same level of Zone 3 as the vertebra yielded a date of 10,260 $\pm$ 190 years before present (Clausen, Brooks, and Wesolowsky, 1975:203).

In addition to the two human bones encountered in a controlled excavation, which by themselves are extremely important finds, Clausen and his associates have interpreted the sediments of the three zones with regard to sea level rise and fluctuations over the past 10,000 years.

As determined by Clausen, Brooks, and Wesolowsky (1975), then, we can make the following summary comments (see also Table 6-2). The zones, including Zone 3, were deposited in a submerged situation. For this to have occurred, the water level in the sinkhole had to remain within the range of -9.5 to -13 m. Combined information on each zone and its data are presented in the tabulation on the following page.

Zone 2 and 3 analyses follow currently held beliefs in post-Wisconsin sea level rise. As sea level gradually rose, water levels also increased in the sinkhole during a corresponding period of time. However, when one looks at Zone 1, some revealing interpretations can be drawn. Due to Zone 1's composition of algal sludge, Clausen, Brooks, and Wesolowsky (1975) have determined that the sinkhole must have changed from a stagnant-water pond to a free-flowing spring, approximating its present-day condition. This could have occurred only if the water level in the spring had increased to a level equivalent to the present level. That, likewise, implies a rise in mean sea level, which ultimately controls the potentiometric level of the spring. As

Table 6-2. Possible relationships of the three zones, located on the 13 meter ledge at Warm Mineral Springs, and their age of deposition, period and interval.

Zone	Required Lower Depth, Below Present Spring Surface, for Deposition of Zone	Depth Below MSL	Postulated Age of Deposition	Period	Interval
1 Algae slime	2 m	0.0 m	8,500 to ?	Early Holocene	H3
2 Calcite mud	7 - 10 m	5 - 8 m	9,000 to 8,500 years B.P.	Early Holocene	H3
3 Peat bed	9.5 - 13 m	7.5 - 11 m	10,500 to 9,000 years B.P.	Early Holocene	H2-H3

the researchers have stated, "The simplest explanation for the transformation ... is that post-Wisconsin sea level ... had reached a point closely approximating present MSL, and that the springs, responding to a potentiometric water level similar to that existing at present, began to flow" (Clausen, Brooks, and Wesolowsky, 1975:206). The authors, however, do not rule out other less likely causes for the water increase in the spring. A higher precipitation rate is one such possibility. Work is continuing at this important site under the direction of Wilburn A. Cockrell of the Florida Department of Archives and History.

Due in part to its marine setting, the Fish Creek Site in Hillsborough County (8 HI 105) is representative of eastern Gulf Paleo-Indian sites (Karkins, 1970). A large portion of Florida Paleo-Indian point finds, especially Suwanee points, are associated with aquatic situations, and the Tampa Bay area has been a frequent source for many such finds. The Fish Creek Site is also typical in that it is devoid of any stratigraphic reference which could be used to determine occupational sequences; therefore, the assignment of age must depend on the time spans assumed for the projectile point. Although habitation at the site persisted beyond the Paleo-Indian Period into late pre-ceramic Archaic, Orange, and Transitional Periods, its significance as a Paleo site is foremost in this review.

Lying in a mangrove swamp which borders Old Tampa Bay, the Fish Creek Site is totally submerged at high tide. The muck along the western edge of the mangrove and fill beside the creek mark the most productive locales for artifact occurrence.

Known surface collections over the years have yielded totals of 183 potsherds and 304 stone tools. The sherds are indicative of more recent occupations. The stone tools collected represent the earlier occupations and are predominatly ovate and trianguloid knives (52%), while points and scrapers together compose 34% of the total assemblage. The frequencies of the point types represented include 12 Suwanees, one Bolen Plain, 10 Archaic Stemmed, one Florida Morrow Mountain, two Newnans, eight Culbreaths, three Lafayettes, one Westo, none Citruses, one Hernando, two Bradfords, one Pinellas, and two Fish Creek points.

The remainder of the lithic assemblages consists of plano-convex end-scrapers, bifacially flaked end-scrapers and side-scrapers, drills, picks, hammerstones, sandstone abraders and "horse's hoof" cores. Shell artifacts include perforated Melongena shell hammers, a possible conch-shell gouge, and a columella pendant.

Paleo-Indian and Early Archaic Projectile points along with large chipped bifacial tools and bones of extinct Pleistocene vertebrates have been reported also from deeper submarine oyster shell deposits of Tampa Bay (Warren, 1964; Goodyear and Warren, 1972). The material has been collected from shell piles that were dredged from the submerged deposits.

The shell deposits themselves are huge; there has been continuous dredging for some 40 years. The reefs are reported to be as much as 16 km long and 15 m thick. They are composed predominately of Crassostrea virginica (greater than 99 percent) with minor inclusions of conch (Busycon caricum), clay (Venus mercenaria), sea pen (Atrina rigida), olive (Oliva sayana), Florida conch (Strombus alatus), and others. Pieces of water-worn wood, cypress knees, concretions of sandstone or limestone, cobbles of cemented oyster shell (sometimes smoothly polished) and clay lumps also occur in the dredged material.

Shells showing a higher degree of mineralization have been dredged from depths of -12 to -15 m below a limestone or marly cap of about 45 cm in thickness (Goodyear and Warren, 1972:55).

Chipped artifacts predominate which are manufactured from local limestone cherts and silicified coral. Although a few pottery sherds have been found, neither shell nor ground stone objects have been noted. The most common types are crude bifacial choppers, roughly chipped unifacial scrapers of small size, large unifacial core planes (about the size and shape of a horse's hoof), a spheroidal hammerstone, and projectile points. Paleo-Indian and Early Archaic points include Suwanee, Nucknolls Dalton, Greenbriar Dalton, and Bolen points (or Big Sandy I variants). Nine Putnam and Newnan points have been recovered from the dredged shell. These are believed to represent the Middle and Late Archaic.

Pottery is present in small quantities though less common than the stone tools. Only five sherds were reported by Goodyear and Warren in 1972.

Pleistocene bones from depths of -12 to -15 m include Alligator mississipiensis, Geochelone sp., Proboscidea, Equus sp., Lamine Camelid, and Odocoileus sp.

Goodyear and Warren present several lines of evidence which lead them to believe that the oyster shell deposits are middens, at least in part. If so, they represent the oldest reported shell middens in the Northern Gulf area.

Another area of Florida which is noted for recurring surface finds of Paleo-Indian projectile points is around Choctawhatchee Bay in the Florida panhandle. Mrs. Yulee Lazarus, Director of the Temple Mound Museum of Fort Walton Beach, and her late husband, William Lazarus, started keeping records of Paleo-Indian projectile point finds in the area over 15 years ago. The result is the map shown in Figure 6-54. While interpretation of single surface finds must be made with caution, the pattern of finds in the Choctawhatchee Bay area is believed to be very significant.

With few exceptions, only projectile points have been reported from most of the locales. Three have later components: 8 OK 53, 8 WS 8 (Lazarus, 1965b) and 8 WL 29 (not identified in Figure 6-54; see Vol. 3, Plate 5, reported by Lazarus, 1965a). The bayshore in the vicinity of 8 WL 31 has produced three chipped-stone tools which also appear to be related to early occupations. As illustrated in Figure 6-55, A-C, these tools are steep edge-chipped gravers of the Friesenhahn Cave and Salt Mine Valley type.

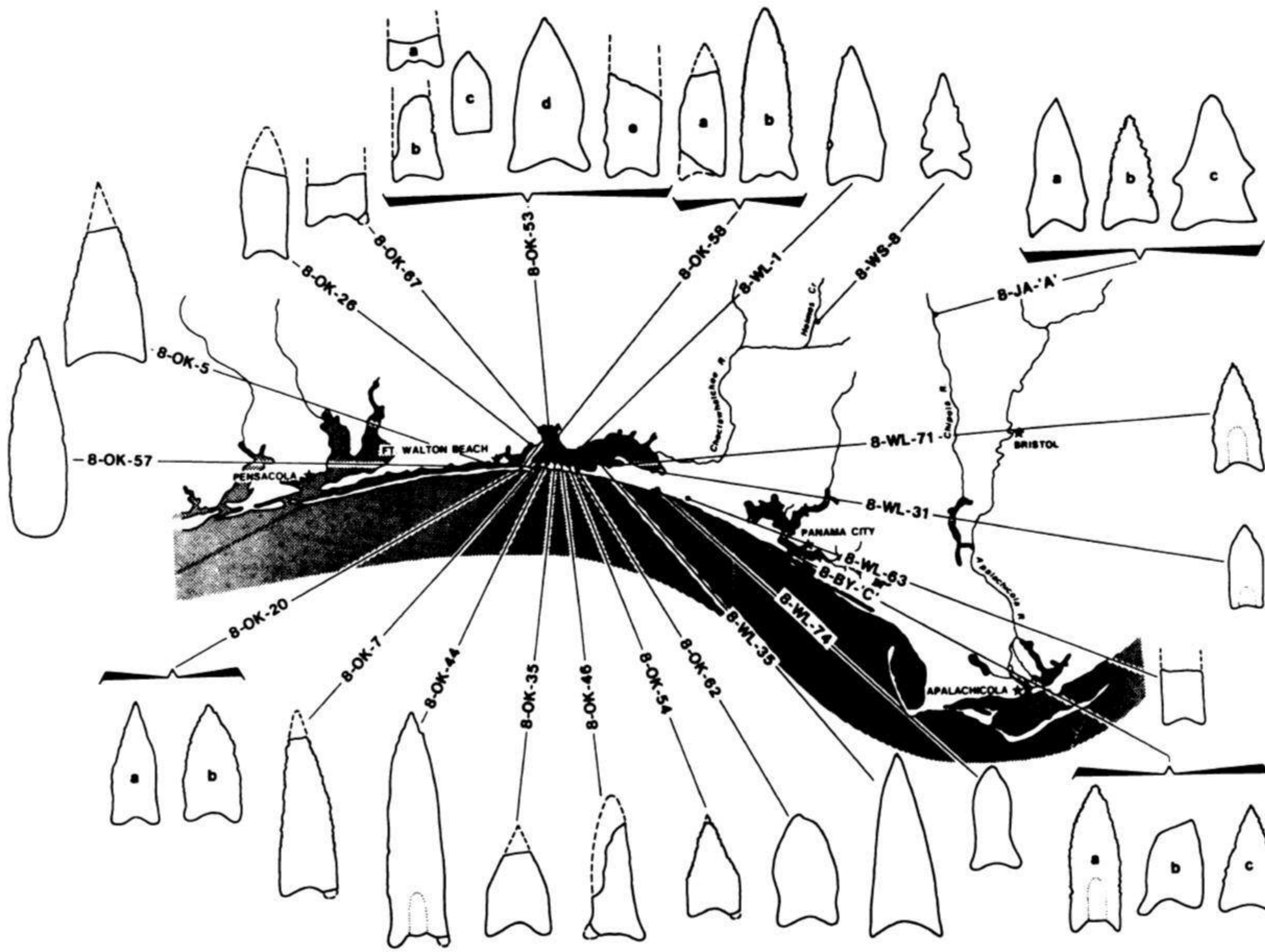
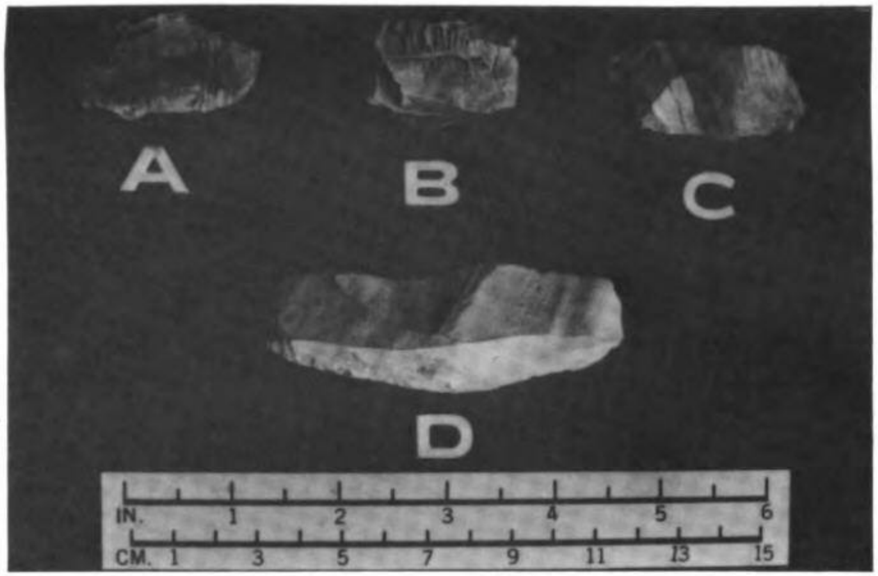
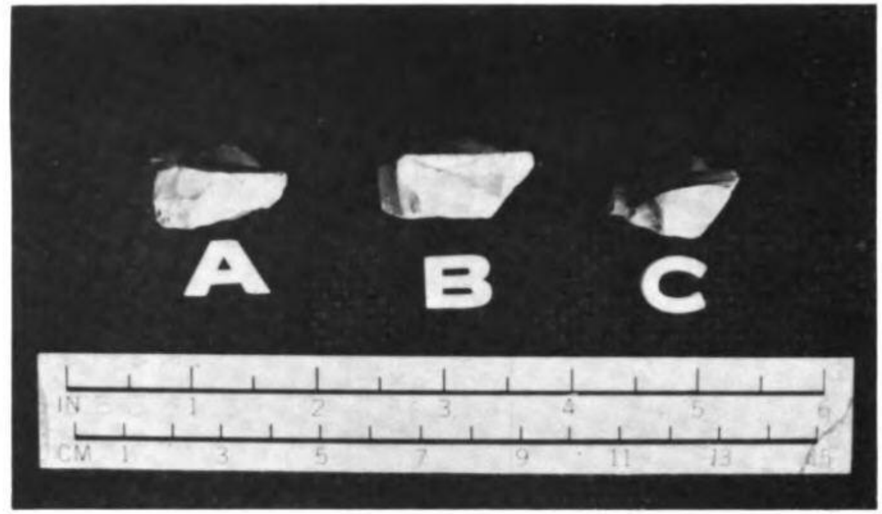


Figure 6-54. Paleo-Indian projectile point finds around Choctawhatchee Bay, Florida, and vicinity. Data from Fort Walton Beach Temple Mound Museum, courtesy of Mrs. Yulee W. Lazarus.





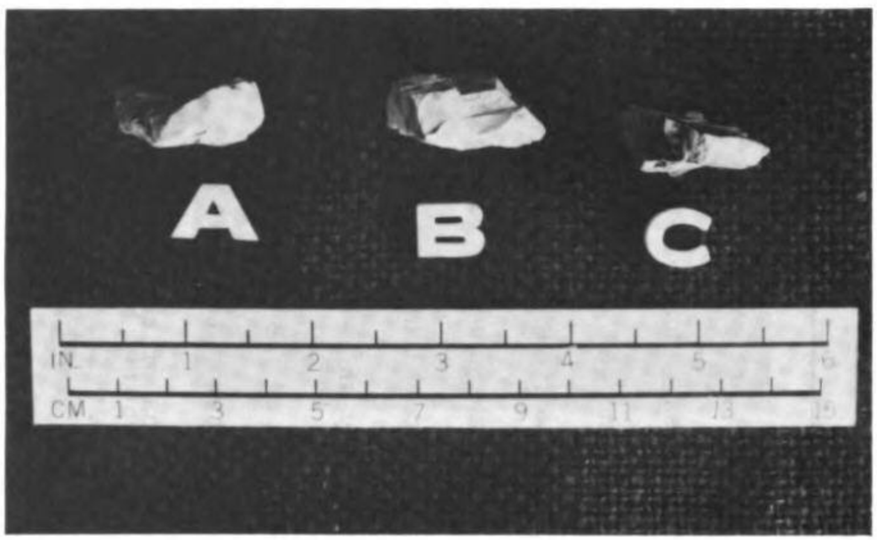


Figure 6-55. Artifacts from Point Washington 8 WL "B" (near 8 WL 31, Figure 6-54), Choctawhatchee Bay, Florida. A-C, steep edge-chipped gravers of the Salt Mine Valley, D, flake blade from the Camp Creek Site, located near 8 WS 8.

The entire Paleo-Indian Interval is well represented by the projectile points from the Choctawhatchee Bay area. In addition, the steep edge-chipped gravers may represent a pre-fluted point horizon.

In this area, we again find evidence of Paleo-Indian occupations in a coastal setting. The locales fall into four ecological settings as shown in the following list:

	TERRACES AND UPLANDS		BARRIER SPIT COMPLEX	
	Upland Stream	Bay Margin	Back Barrier	Gulf Shore-Dune Lake
Total	2	6	9	5
%	9	27	41	23
	8 WS 8 8 JA "A"	8 OK 26 8 OK 67 8 OK 20 8 OK 53 8 OK 58 8 WL 1	8 OK 7 8 OK 44 8 OK 35 8 OK 46 8 OK 54 8 OK 62 8 WL 35 8 WL 71 8 WL 31	8 OK 57 8 OK 5 8 OK 74 8 OK 63 8 BY "C"

No data are available regarding the specific settings of the upland stream locales. Most of the bay-margin finds have been made in situations where old terraces around the inner bay shores are eroding back. The artifacts, winnowed out of eroding sites, are commonly found along the active beach or in the shallow waters of the bay.

The site situation at back barrier sites is very similar to that along the inner bay shores. Artifacts are usually exposed by erosion and found along the beach or in the bay shallows (Figure 6-56). However, a distinction has been made between the two types of settings because of differences in origin, age, and fauna of the geomorphic features upon which the sites may have been located.

Gulf shore-dune lake sites are also associated with barrier spit complexes. Two of these locales presently occupy what might be considered bay

Figure 6-56. The Alligator Point Site (8 BY "C"), located along the entrance to St. Andrews Bay. View to the southwest. Date: 8/12/75.

Figure 6-57. Freshwater pond in coastal dune field between Choctawhatchee and St. Andrews Bays, Florida. This is also the location of 8 WL 63. View to the west-northwest. Date: 8/15/75.

margin locales (8 OK 57 and 8 OK 5). However, the barrier island (Santa Rosa Island) that presently separates them from the open Gulf is believed to have formed subsequent to the time when the points were made. That is, Santa Rosa Island is a product of the Late Holocene transgression and post-dates the projectile points. While these two point-find locales are related to modern beach erosion, the sites from which they were presumably derived were either on the open Gulf beaches or more likely in dune fields behind the beaches. Locales 8 WL 74 and 8 WL 63 are associated with freshwater ponds or lakes in dune fields on the barrier spit complex (see Figure 6-57).

The distribution of Paleo-Indian projectile points in this area implies that the barrier spit complexes with which they are associated were active during the Paleo-Indian Period (Subintervals H_1 - H_3). The distribution also provides an indication of the kinds of coastal geomorphic situations where Paleo-Indian materials might be found. From the standpoint of negative evidence, it is significant that in spite of substantial evidence of Paleo-Indian use of the area, concentrated accumulations of artifacts or other site indicators have not been found. Nor have Paleo-Indian shell middens been identified in this area. Detailed studies of this key area would undoubtedly contribute substantially to our understanding of both Paleo-Indian culture and Late Quaternary geological history.

Eastern Gulf Archaic

The Lake Kanapaha Site in Alachua County (8 AL 172) provides an excellent example of a Florida Archaic, upland site because it contains mainly scattered concentrations of lithic tools and tool-making remains (Hemmings and Kohler, 1974). Located on the western shore of the 200-acre (800,000 m^2) Lake Kanapaha, the site encompasses approximately 500 acres (2 million m^2) of mostly pasture-land and lies generally within the 80-foot (24.4 m) contour line, representing an environmentally suitable location for habitation today, as it probably did 7,000 years ago.

The site lies at the junction of three geomorphic divisions of the Alachua County highlands: plateau zone to the north and east, a karst plain to the west, and a lake and prairie zone to the south and southeast (Figure 6-58). These divisions indicate distinct landforms and drainage patterns which reflect different underlying structural formations, chiefly Hawthorne sediments and Ocala limestones. The subsequent diversity in biotic exploitation potential was strongly influential in the selection of this locale for habitation and camping activities since Archaic times. Exposed Arrendondo limestone quarries within 1.6 km of the site present another geologic unit that would have favored early settlement.

Excavations at this site took place at five separate areas and revealed three distinct occupational zones, extending down 2.4 m through recent aeolian sand layers. Below the aeolian sand lies a sandy-clay substrate with relict chert boulders at its uppermost surface (Plio-Pleistocene?). These boulders not only provided raw material for making tools, but also contributed to the selection of this site for Archaic occupation, indicating the strong interrelationship of environment and settlement patterns.

A total of 142 square meters and 56 trenches were involved in the excavations, and the resulting three-fold stratigraphic division was based on the occurrence of diagnostic ceramics and projectile points. Areas 1 and 2 proved to be the most productive archeologically and are the basis for generalizations about the site.

The uppermost ceramic zone was usually about 35 cm thick and yielded 39 sherds, 10 stone-cutting and scraping tools, and a charred turtle carapace, the only evidence of food remains found. This level indicates a Deptford Period occupation of small temporary campsites along the Lake Kanapaha shoreline.

The middle, or pre-ceramic Levy Zone (named for a recurring projectile point type found at the site), extended from 30 cm to 71 cm and was well

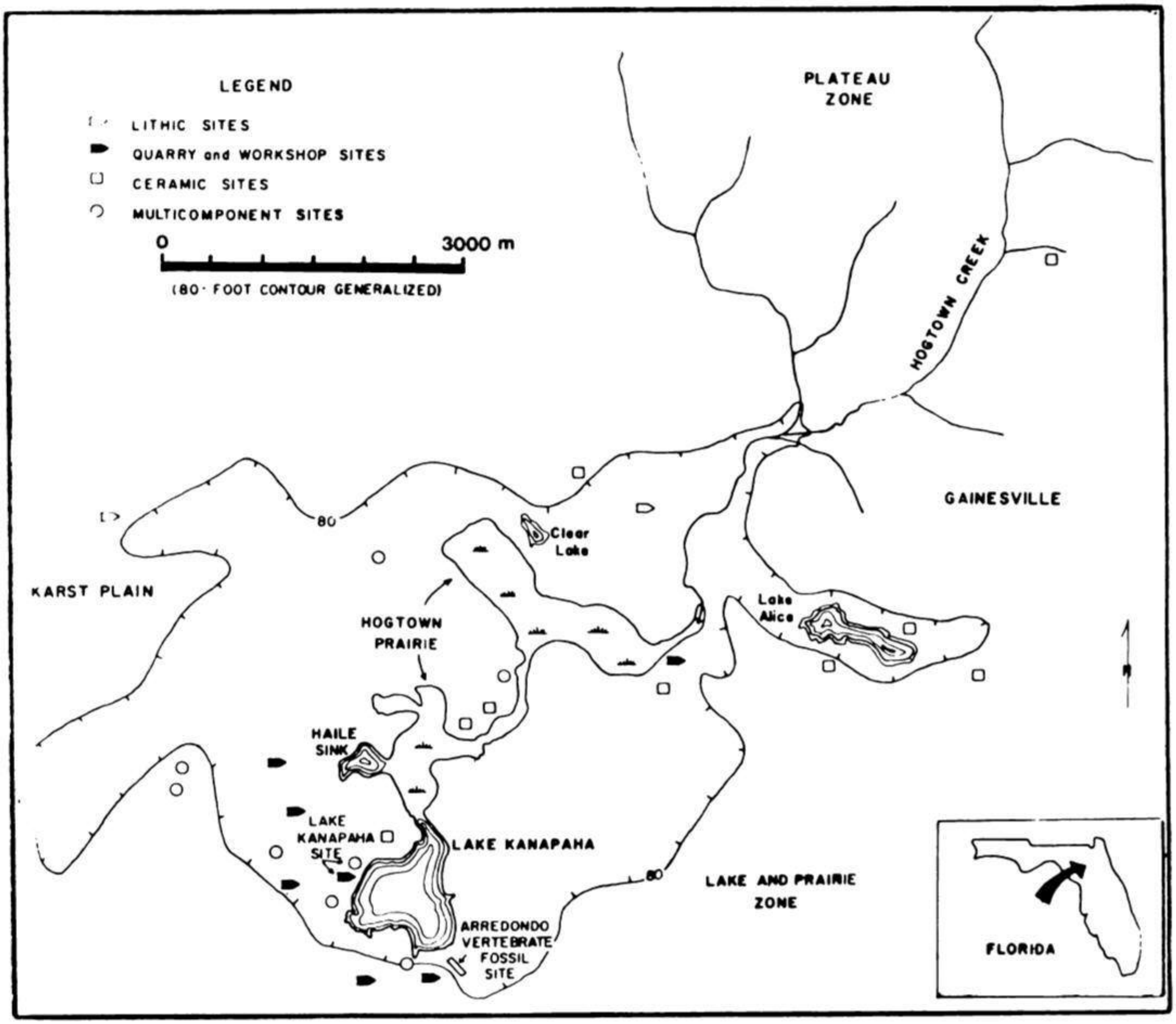


Figure 6-58. Location of the Lake Kanapaha Site (8 AL 172) and surrounding lithic and ceramic sites. Note also the location of the Arredondo Fossil locale (After Hemmings and Kohler, 1974).

represented in Areas 1 and 2 by 54 stone tools, including 14 Florida Archaic Stemmed projectile points, seven scrapers, nine bifaces, six cores or planes, six irregular cores, one hammerstone, and 8,000 flakes and fragments, usually associated with flintknapping activities. The stone was of a local source and often displayed heat treatment.

Throughout Areas 1 and 2, over 7,000 pieces of stone debitage were differentially distributed. Their distribution reflects the settlement and use patterns for at least these areas of the site. Areas with a large percentage of debitage from cores, preforms, and hammerstones were presumably used as flintknapping locales, whereas tools such as projectile points and scraping and cutting tools were found in areas of low flake density. This suggests an aboriginal areal division between living and working areas.

A third pre-Levy zone, located from 0.8 to 2 m below the surface, was poorly represented by seven stone tools: three end or side scrapers, one "horse's hoof" core or plane, one small bifacial fragment, and two utilized flakes. All bifaces, cores, and flakes were from local chert. An absolute date has not been assigned to this level.

Excavations in Area 3 did not exhibit the same stratigraphic divisions as Areas 1 and 2, but a single Late Archaic component (equivalent to the Levy Zone in Areas 1 and 2) was indicated by the tools and debitage found in the topmost 61 cm of sand. The appearance of 26 stone tools and a multitude of heat-modified chert flakes helped define Area 3 as a focal point for heat treatment and related knapping activity.

The stratigraphy and artifacts at the Lake Kanapaha Site allow an interpretation of the functional and temporal placement of this site. Similar flint tool kits and debitage and, frequently, similar environmental conditions characterize many of the upland Archaic sites in the eastern Gulf area.

The aeolian origin of the sand bed from which all artifacts were excavated is of more than passing interest. Characteristically, it is a tan, homogenous sand locally reaching 2.44 m in thickness, masking the corrugated surface of the underlying Plio-Pleistocene (?) clay.

Hemmings and Kohler (1974:48) note that, "The Lake Kanapaha aeolian sand is not an isolated phenomenon, as the artifact-bearing deposits at Bolen Bluff (8 AL 439) in Alachua County and Silver Springs (8 MR 92), Johnson Lake (8 MR 63), and the Senator Edwards Site (8 MR 122) in Marion County are all essentially identical (Bullen 1958; Neil 1958; Bullen and Dolan 1959; Hemmings 1973; Purdy 1973). This sand can also be seen at the surface in many roadcuts and borrow pits in the Central Highland area." The archeological data indicate that the aeolian sand was deposited during the interval from 7,000 to 4,000 years B.P. (Intervals I and J).

Eastern Gulf Poverty Point

The cultural transformations marking the termination of the Archaic Period in the eastern Gulf area are evidenced in sites of the Orange, Transitional, and Elliot's Point Complex culture periods. In the Choctawhatchee Bay area of Florida, these changes are discernable in a cluster of sites which comprises what is considered to be the temporal and artifactual equivalent of the Poverty Point Period in the central Gulf area. This Florida site cluster was randomly represented by surface finds of fired-clay objects (Figure 6-59) until excavations at the Elliot's Point site (8 OK 10) (Lazarus, 1958) permitted the inference of stratigraphic sequences and resulted in a definition of the "Elliot's Point complex." There are presently 18 sites in northwest Florida that exhibit Elliot's Point traits.

Elliot's Point is a bay-margin site on the margin of 3.7 m above sea level in Fort Walton Beach, Florida. The stratigraphy of the Elliot's Point site as revealed in excavations of three 24-square foot (2.2-square meter) sections presents an upper zone of coarse yellow sand, extending down to the maximum excavation depth of 90 cm. The only discontinuities in this twofold division are a brown sand pocket intruding into the yellow sand in Section III and a layer of black sand occurring in the upper layers of Section I.

Stratigraphy and analysis of the 418 artifacts recovered during the excavation yielded chronological data relevant to the Florida clay-object complex. The top 51 cm of the three sections produced a total of 362 sherds, along with coral fragments, fire-blackened quartz pebbles, charcoal, and shells of the eastern oyster, southern quahog, Florida arith, and snails. The underlying yellow sand was the matrix for almost all of the baked clay objects, which are, at 8 OK 10, typically peach-shaped spheroids with shallow longitudinal grooves. The clay objects were usually found with flint chips and flakes below the pottery zones, and less frequently, with sherds from the Deptford Period, which as an approximate time span of 500 B.C. - 200 A.D. The repetitive association of baked clay objects with flint chips and tools exposes this as a basically pre-ceramic clayball assemblage, which is so far represented in Florida by the Choctawhatchee Bay area almost exclusively.

Most of the sites in the Choctawhatchee Bay area having an initial occupation during the Elliot's Point Period (about 3,500 B.P.) also have components from later culture periods. Many sites in this same area have also yielded projectile points (mostly from undetermined contexts) which date back 10,000 years (see Figure 6-60). As previously discussed, these points are sometimes found in sites assumed to be of Elliot's Point age. Three explanations for their occurrence can be offered. They may have been antiques collected by Elliot's Point people; or the sites, most of which are in environmentally favorable situations, may have been initially occupied

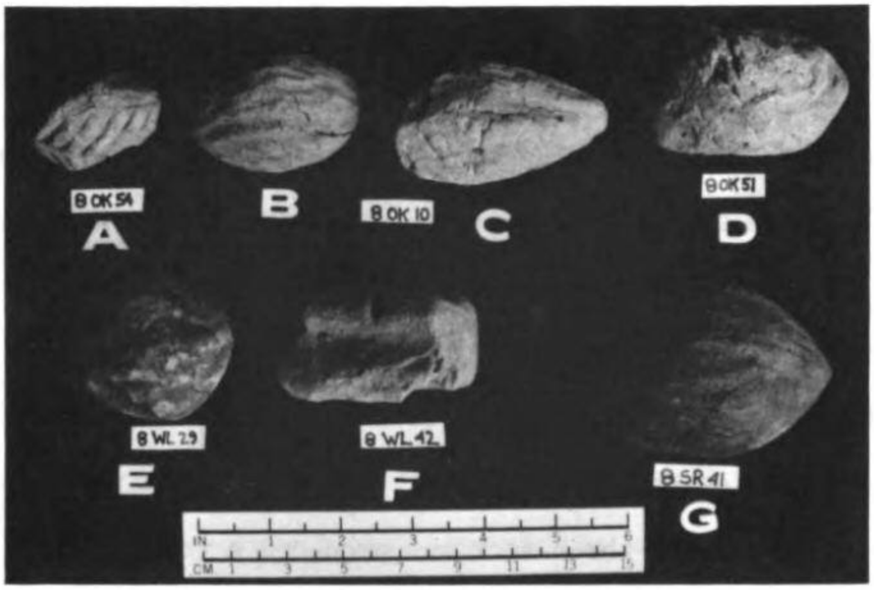


Figure 6-59. Elliot's Point Complex clay balls, similar to Poverty Point objects found in Louisiana and Mississippi.

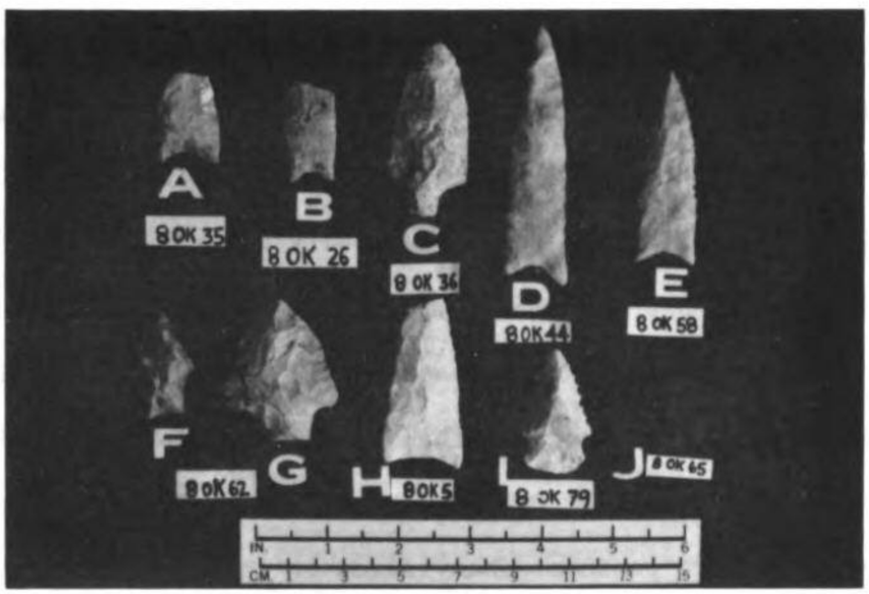


Figure 6-60. Paleo-Indian and Archaic projectile points from Choctawhatchee Bay area. Sites 8 OK 35 and 8 OK 5 have also yielded artifacts of Elliot's Point age. A,B, "Paleo point" bases; C, Westo; D, Suwanee; E, Tallahassee; F, Late Archaic "limestone" point; G, Alora; H, Dalton; I, Bolen (?), J, Archaic "hematite" point.

during Paleo-Indian times and then reoccupied during Elliot's Point time; or the points may have a long time-span dating from Paleo times through to Elliot's Point times. The second explanation seems the most favorable.

CHAPTER VII

AN ILLUSTRATION OF METHODOLOGY: THE MISSISSIPPI DELTA AREA

Introduction

Ideally, this section of the report should summarize chronologically the relationship between the prehistoric occupation sequence and the relict landforms on the continental shelf and in the coastal zone for each major area. However, it was reluctantly concluded to be an impossible task within the scope of the present study. Major problems encountered in such a summary include: 1) Archaic, Paleo-Indian, and Early Man archeology is still very poorly known in most of the study area; 2) the relationship between human occupation and geologic events is not well understood, particularly in the time period of concern; 3) the Late Quaternary geology beyond the past 5,000 years is still very poorly understood; 4) there are large unresolved discrepancies in published geologic interpretations within areas and between areas; and 5) there are large discrepancies in interpretation of Late Quaternary dating between a purely geological approach to the problem and an archeological-geological approach.

The fact that many of these problems remain unresolved does not indicate lack of interest from the scientific community. The scientific literature treating these topics is indeed voluminous. The difficulties lie in the magnitude and complexities of the problems themselves.

In spite of these difficulties, it is felt that an attempt to further illustrate the methodology is in order. This will be done through a case study of a single large area, the Mississippi Delta, which combines the east and west Louisiana shelf areas and the related coastal zone (Volume III, Plate 2).

The Mississippi River Delta

The Louisiana coast is dominated by a 300-mile lowland consisting of large tracts of marshes and swamps and innumerable lakes and bays. This extensive near-sea-level area makes up the Late Quaternary deltaic plain of the Mississippi River and has resulted from deposition of river sediment (Figure 7-1). The Mississippi River Delta, like all deltas, is a zone of interactions between fluvial and marine processes and constitutes one of the most dynamic situations in nature. The balance between the rates of sediment deposition and the combined effects of subsidence and erosion by the sea cause shorelines in deltas alternately to advance and retreat. Seaward growth occurs at the mouths of active streams, whereas erosion results near the mouths of inactive streams which no longer transport sufficient sediment to sustain their positions or advance seaward. Delta building can be thought of as a contest between the river and sea. If the river deposits sediment faster than the sea is able to remove it, new land is added to the shore and the delta builds seaward (Figure 7-2). As the delta is extended, it gradually builds upward, or aggrades, by processes associated with lateral shifting of channels, by sediment deposited during overbank flooding, and by accumulation of plant and animal remains (Figure 7-3). Deterioration of the delta occurs if all or part of it is deprived of the supply of river-borne sediment necessary for its continued growth. This results in removal of the seaward edge by wave attack and the settling or subsiding below sea level of the surface (Coleman and Gagliano, 1964; Frazier, 1976; Gagliano and van Beek, 1970).

In a low coastal plain where plant and animal communities are delicately adjusted to minor differences in elevation and salinity,

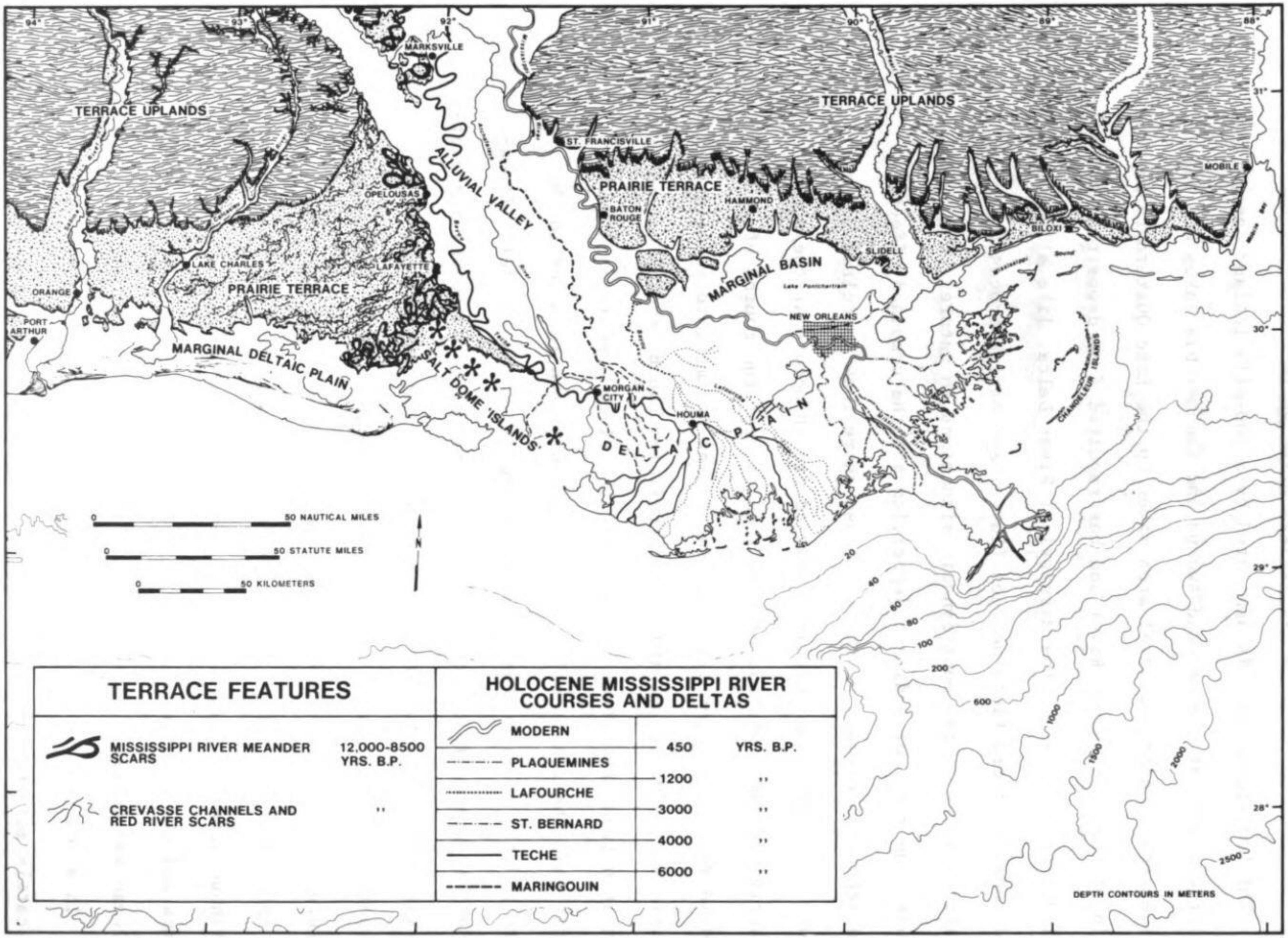


Figure 7-1. Major features of south Louisiana and south Mississippi area and the regional setting of the Mississippi Delta System.

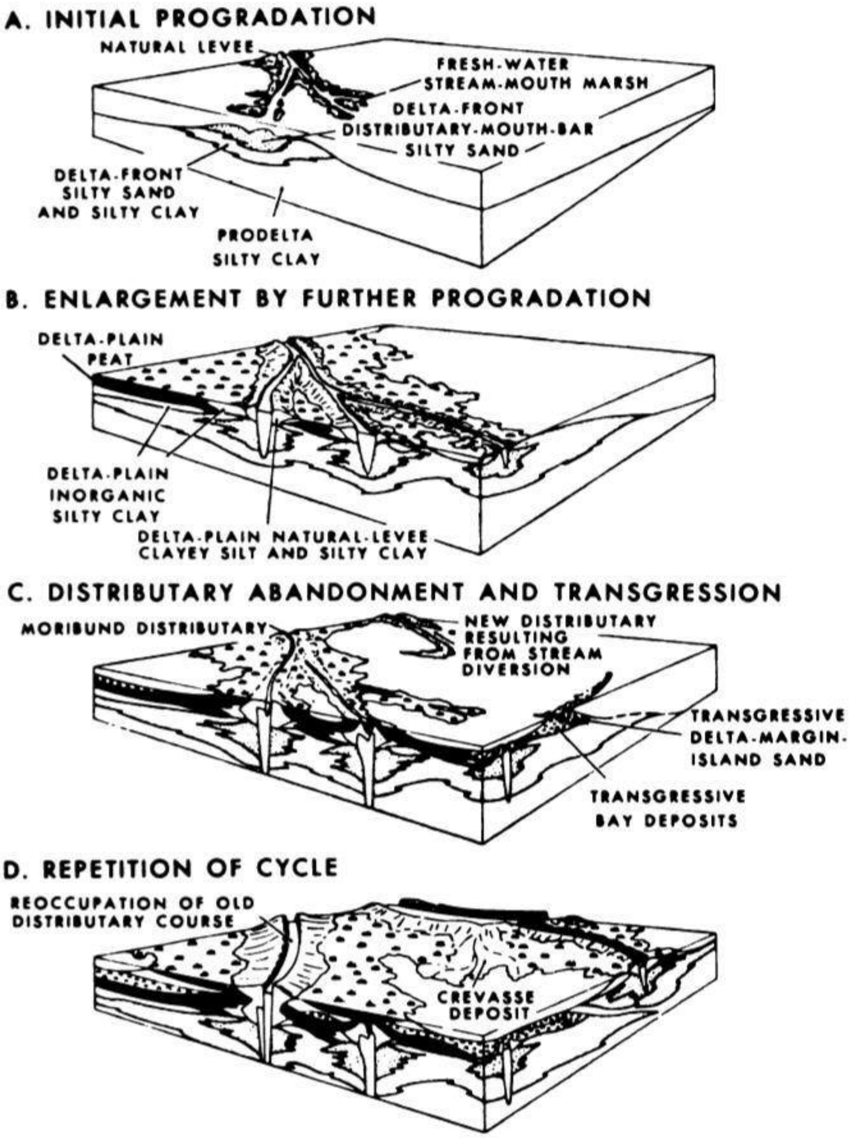


Figure 7-2. Block diagrams illustrating progradation and transgression in a delta with a bifurcating branching habit, such as the Mississippi (After Frazier, 1967).

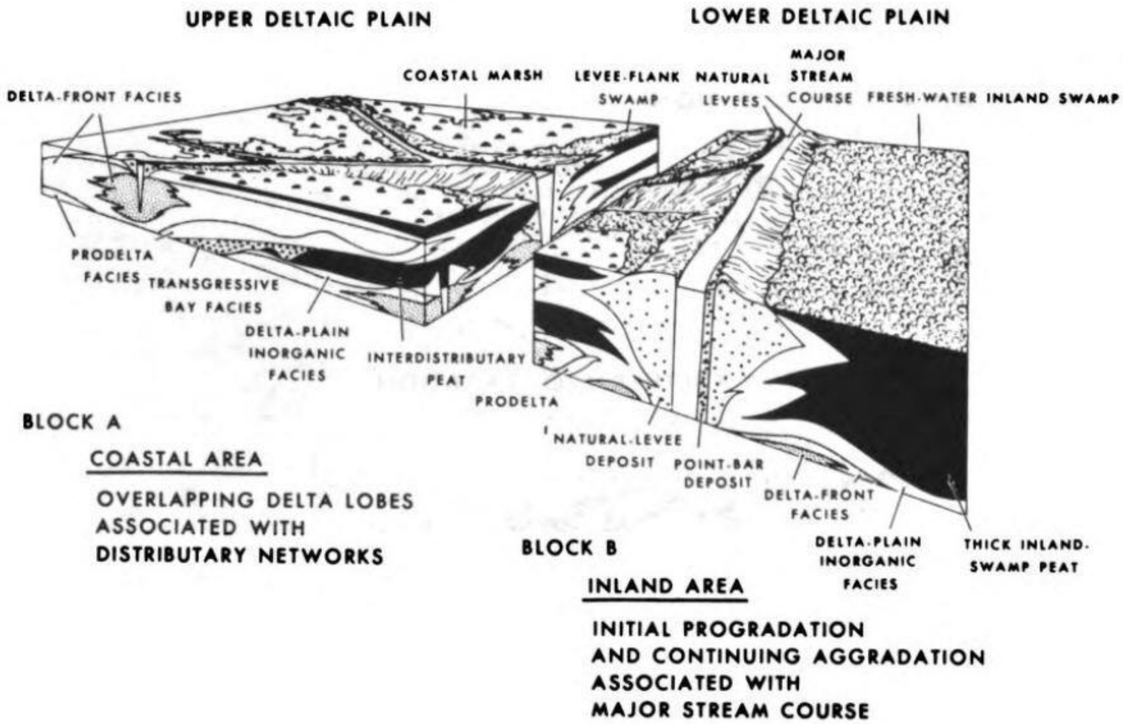


Figure 7-3. Diagrammatic representation of the relationship between major morphologic features and sedimentary facies in an advanced stage of delta building (After Frazier, 1967).

shifting of streams and changing of shorelines are accompanied by changes in ecology and environment. Therefore, during the long evolution of the deltaic plain, not only has the morphology changed through time, but at any given place a gradual environmental succession has also occurred.

Deltaic areas have been important to man since earliest prehistoric times. They usually abound in wildlife and edible plants, and the many waterways provide natural routes of transportation. From the biological standpoint, marshlands which make up a major part of the deltaic surface have the highest primary production of any continental habitat. One measure of this productivity comes from modern commercial fisheries records. The deltaic coast of Louisiana consistently accounts for approximately 25 percent of the nation's fish harvest (exclusive of Alaska) (Lindall _et al._, 1971). It is no accident that early civilizations flourished in the deltaic lowlands of the Nile and the Tigris-Euphrates. Alluvial soils are usually fertile, and irrigation and soil replenishment result from annual flooding. Man's utilization of deltas, however, has not been an entirely happy experience since these areas often are subject to floods, harbor diseases, and the adverse effects of coastal storms. As shown in Figure 7-4, the area of the Mississippi Delta was no exception. More than 600 known archeological sites attest to the attractiveness of the deltaic plain to prehistoric peoples whose economies were based on hunting and gathering or primitive agriculture.

It should be noted that the known sites represent only a sample of the total number of archeological sites. Systematic survey of even high-probability areas has never been completed in the entire area. Intensive ground survey has been done in only a few relatively small areas. Innumerable sites are believed to be buried or veneered by natural sedimentary deposits. A very large number of sites has been lost to erosion and modern destruction. There is an important need to undertake a carefully designed intensive survey in a portion of the Louisiana coastal area to test the concepts of high-probability areas and to determine what percentage of the total population of archeological sites is represented by the known sample.

Archeologists in south Louisiana have emphasized the close relationship between prehistoric habitation and changing morphology and environment. Effects of the dynamics of delta building and change on both the environment and man's activities have received particular attention. This approach and viewpoint have resulted from the work of

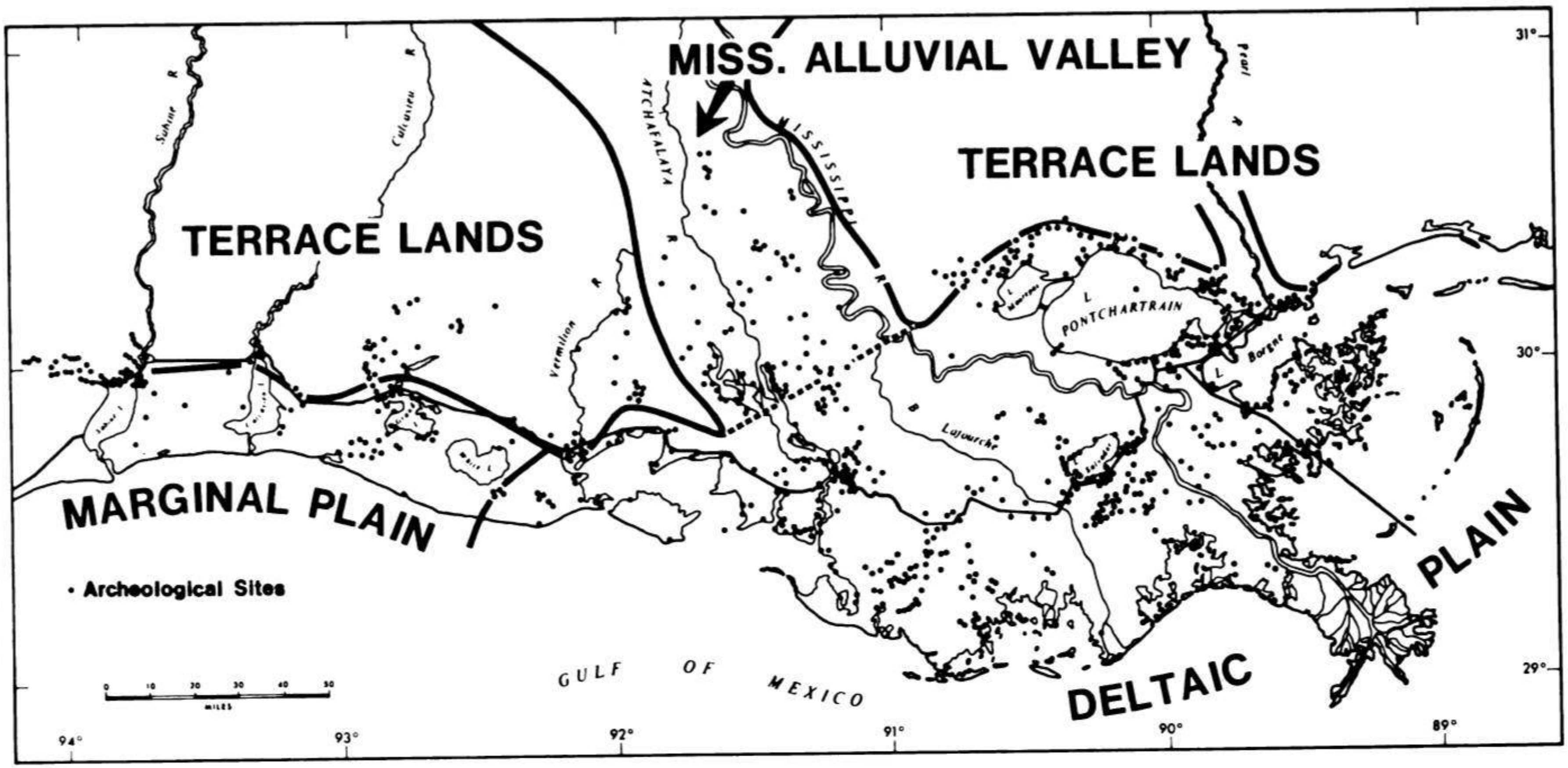


Figure 7-4. Distribution of known archeological sites in coastal Louisiana.

Kniffen (1936), McIntire (1958), Saucier (1963), Gagliano (1963), and others. South Louisiana can be considered as a distinctive area which was subject to cultural influences from adjacent regions as well as to developments which appear to be more or less indigenous.

Thus, in the deltaic setting there is a unique situation in that the morphology and environment have been subjected to continuous and rapid changes through time, and primitive peoples inhabiting the area were forced to adjust to these changes, at the same time experiencing gradual and meaningful evolution in culture and technology. The unraveling of this complex story of interactions between primitive man and his environment has resulted in a unique interdisciplinary approach to archeology and the study of coastal environments and has produced a method and theory that is particularly useful in the present study. For this reason, natural processes and forms and related cultural associations are considered in some depth.

The geomorphic and environmental framework of the delta exerts strong influence on such things as settlement pattern and economy. In the coastal portion, the distribution of habitation sites is dictated by the location of Gulf and lake beach ridges and Mississippi River natural levees (Figure 7-5). These features provide virtually all of the firm, relatively high places suitable for even periodic occupancy.

Deltaic Plain

The deltaic plain consists mainly of near-sea-level lakes, former stream courses, marshlands, and swamps. The main streams which presently flow through this area are the Mississippi River and its major distributary, the Atchafalaya River. The Mississippi flows across the eastern side of the plain and discharges its sediments through several active distributaries, forming the present birdfoot delta. Evidence of

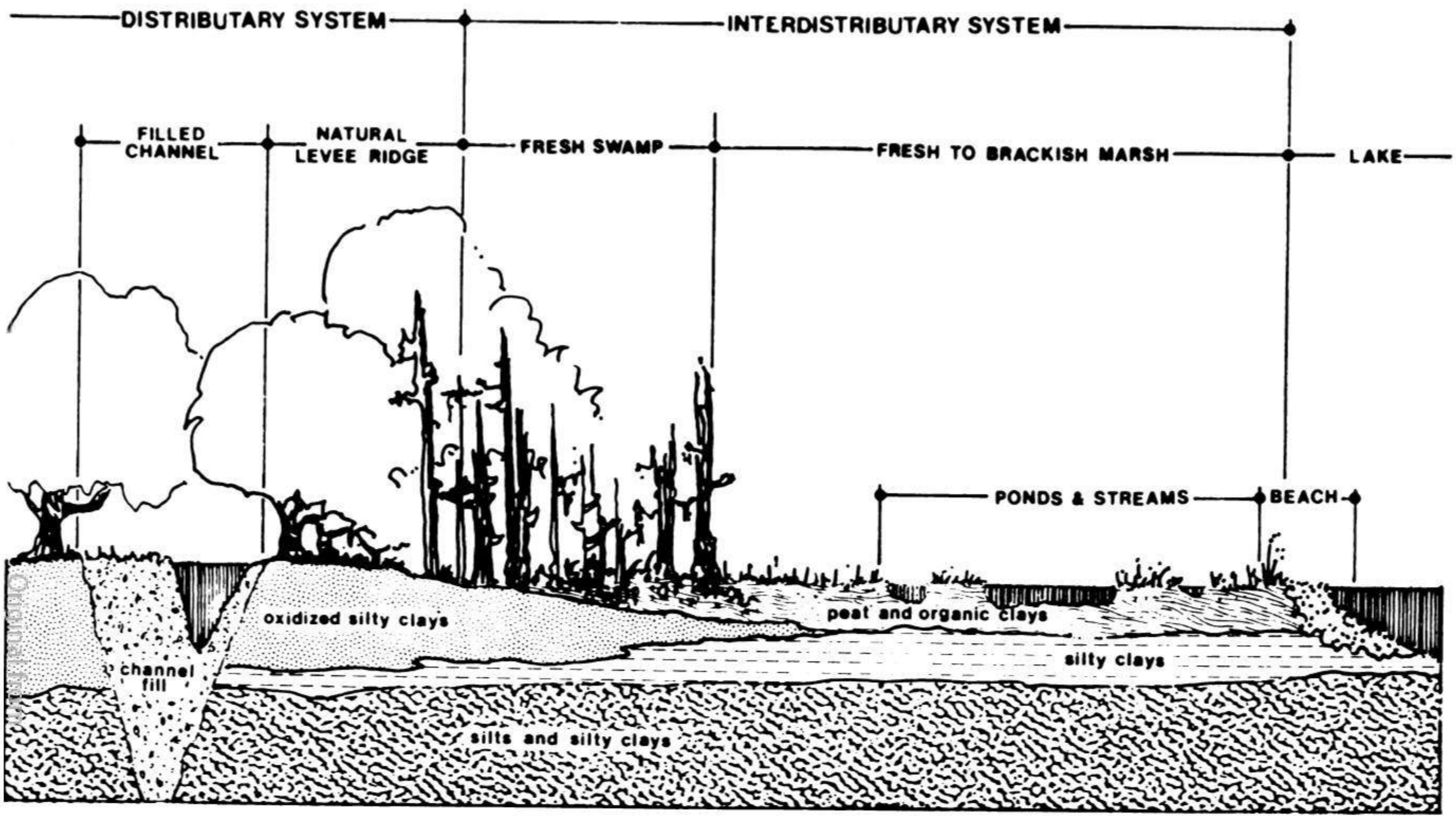


Figure 7-5. Cross-section of natural levee and backswamp. Many Indian sites were located on the relatively firm, high ground of natural levee ridges.

abandoned stream courses comes from numerous minor drainage lines and topographically high natural levees of former streams which vein the coastal marshes.

Marginal Plain

Almost one-third of the Louisiana coastal area lies west of the deltaic plain proper and is termed the marginal deltaic plain, or chenier plain. This marginal plain, which developed during the Holocene, owes its origin primarily to sedimentation accompanying westward-flowing littoral currents when the river mouth was located toward the western Pleistocene boundary. When the river shifted eastward, sedimentation ceased, and concurrently with coastal retreat, beaches were formed. The relict beach ridges, or cheniers, mark progressive positions of the Gulf shoreline during minor retreats in a general progradation that has taken place during the past 3,500 to 4,000 years since sea level reached its present stand. The beach ridges have provided habitation places in the otherwise marshy coastal environments. It has been demonstrated that initial human occupation on a ridge approximates the time when it was an active Gulf beach. Thus, the oldest sites in the marginal deltaic plain are found on relict beaches farthest removed from the present shoreline. In another section of this report (Chaper VI), the Copell Site (16 VM 102), which is located on one of the oldest beach-ridge complexes in the marginal plain, is discussed.

It is also important to note that the marginal plain is the surface of a prism of Holocene deposits which overlaps a Late Pleistocene deltaic surface. This older deltaic surface has been tilted so that it stands as a terrace north of the marginal plain and is submerged on the continental shelf to the south.

Marginal Basin

In reference to the dominant longshore currents, the marginal basin lies updrift of the Holocene deltaic plain of the Mississippi River. For this reason, it has received less sediment from the river system than either the deltaic plain or the marginal plain and has developed into an extensive basin area as the deltaic plain prograded seaward. The basin is dominated by three large, shallow fresh-to-brackish lakes (Lakes Maurepas, Pontchartrain, and Borgne). These lakes, along with bordering swamps and marshes, lie between the natural levee ridges of the modern Mississippi River on the south and on the Prairie Terrace to the north. The Late Quaternary history of the basin is complex. Included in the area are Pleistocene and Early Holocene barrier-island complexes, old delta lobes of the Mississippi River, and complex estuarine areas of smaller streams draining parts of the coastal plain east of the Mississippi (i.e., the Amite, Tickfaw, Tangipahoa, Tchefuncte, and Pearl Rivers).

Alluvial Valley

The boundary of the Late Holocene deltaic plain, which merges inland with the alluvial plain of the lower Mississippi Valley, is arbitrarily placed where the valley begins to widen toward the Gulf of Mexico. Inland in Louisiana, the Late Holocene alluvial valley is incised into Pleistocene terraces and Tertiary material. These older surfaces heighten from near sea level at the contact between the Prairie Terrace and Late Holocene coastal wetlands to several hundred feet in the northern part of Louisiana.

The valley is occupied by active and relict meander belts of the Mississippi and Red River. At times, the Red has been tributary to the

Mississippi; at other times, it has had an independent course to the Gulf. There are also extensive freshwater swamp and lake areas, some of which have persisted for thousands of years.

Terraces and Uplands West of the Alluvial Valley

Included in this category is the Prairie Terrace, extending from the west wall of the Late Holocene alluvial valley of the Mississippi River to the Sabine River. Relict features on the terrace surface include remnants of a major meander belt of the Mississippi River and a large freshwater swamp laced with crevasse distributary channels and an independent course of the Red River which terminated in lacustrine deltas. Salt dome islands in the southeastern part of the area stood as prominent topographic features when the delta was active. Subsequent events have tilted the old delta surface upward and resulted in its drainage, so that it now stands as a terrace.

Geologists have long regarded the Prairie Terrace and relict features on its surface as Pleistocene in age (Fisk, 1944, 1956; Kolb and van Lopik, 1958; Bernard and LeBlanc, 1965, and others), with age estimates of from 80,000 to more than 100,000 years. While this concept is deeply entrenched in the geological literature, it is basically incompatible with archeological data and some newly developed geological data. An alternate hypothesis is presented here in which relict features on the Prairie surface are considered to have formed during Early and Middle Holocene times.

The Prairie Terrace is bordered on the northwest by older, more deeply dissected and weathered Pleistocene terraces. Distinctive escarpments mark the contact between the Prairie surface and these older terraces. In places, valleys of streams draining these uplands and extending onto the Prairie surface have alluvial terrace equivalents of the Prairie extending for some distance into the uplands.

Terraces and Uplands East of the Alluvial Valley

The area from the east wall of the Late Holocene alluvial valley and northern rim of the marginal basin of the Mississippi Delta to Mobile Bay in Alabama is divisible into the Prairie Terrace unit bounded on the north by dissected and weathered Pleistocene Terraces (Uplands). The Prairie Terrace in Louisiana is relatively flat, but does exhibit a number of rather subtle relict features. These include delta lobes of coastal plain streams (Amite, Tangipahoa, and Pearl Rivers), relict beaches, and dunes derived from point bar sands of coastal plain streams.

The Prairie Terrace along the coast of Mississippi is dominated by relict barrier islands and lagoons. The Amite, Pearl, and Pascagoula Rivers exhibit a series of sub-Prairie alluvial terraces that have been termed Deweyville and related to Early to Middle Holocene (Gagliano and Thom, 1967).

Prehistoric Land Use

The Indian chose the sanctuary of the natural levees, salt domes, cheniers, and beaches of the delta as the locations for his campsites and villages. While this area had its disadvantages in the form of ever-present insects and the constant threat of flooding, it balanced these with several advantages. Perhaps the most important was the abundant food supply provided by the natural landscape. The waters were rich in fish, molluscs, and edible plants. Animals and fowl were plentiful as well as fruits, berries, and nuts. This plentiful food supply attracted man to this deltaic area for thousand of years. Physical evidence found in the numerous middens, mounds, and quarries attests to the long, continuous sequence of human occupation.

Of the more than 600 known sites in the area, more than half are coastal shell middens. Middens are refuse heaps composed mainly of the shells of molluscs, which provided a basic element of the diet, but include ash, bones, shell, soil, pottery fragments, and other debris of daily living. The midden is one of the most desirable places for the collection of cultural remains because it provides the best cross-section of the daily habits of prehistoric life styles. But the cultural materials represent only a part of the resource value of these sites. Since the inhabitants gleaned food from neighboring environments, the midden matrix contains a concentrated sample -- usually in a stratified sequence -- of environmental indicators (ecofacts), such as shell, bones of a wide variety of animals, seeds and pollen. Shells of the brackish-water clam Rangia cuneata make up the greatest portion of the midden material and attest to the importance of these animals in the economy of the coastal inhabitants. Crassostrea and Unio are also often found in the midden and reflect different environmental situations. While the vast majority of these coastal shell middens are less than 3,000 years old, and thus by our earlier definition are too recent for consideration in this study, they are mentioned here to emphasize the attractiveness of a deltaic environment to early peoples and because they provide essential models for prospecting for drowned sites on the continental shelf.

Relationships between delta development and human habitation have now been extended back some 12,000 years in the coastal Louisiana area (Gagliano, Weinstein, and Burden, 1975). Although many of the details are still very sketchy, the overall pattern is reasonably well established and provides an important conceptual framework for students of archeology and Quaternary geology. A sequence of nine delta complexes and lobes is shown in Figures 7-6, 7-7, and 7-8, spanning the time from about 12,000 years ago in historic times. Archeological sites related to development of the first nine lobes are shown. An approximate chronology of the complexes and lobes is given in Figure 7-9.

1) Lafayette Complex: Paleo-Indian to Early Archaic. Based on habitation pattern and fossil vertebrate associations, boring logs, surface morphology, and radiocarbon datings, we now have a picture of the Paleo-Indian deltaic landscape. The most prominent feature of that landscape was a well-developed meander course of the Mississippi River trending through what is now the Avoyelles Parish area near Marksville, Louisiana, and continuing south through Opelousas and Lafayette, Louisiana (Figure 7-10). The complexity of meandering and cutoff suggests that this course was active for 1,000 to 2,000 years. South of the present location of Lafayette, Louisiana, the trunk channel branched into three separate deltaic lobes extending into the Gulf of Mexico. One of these is identified as the Sabine Bank Delta Lobes, the second is unnamed and the third is called the Tiger Shoal Lobe. Collectively they make up the Lafayette Delta Complex. These have been down-dropped by faulting and subsidence and now lie drowned on the continental shelf.

Landward of the deltaic lobes was a vast overflow swamp (Eunice Swamp). Lacing the swamp were crevasse distributaries from the Mississippi as well as an inland delta of the Red River.

While many freshwater swamps are not as productive as marshlands, overflow swamps receiving a large annual supply of river water and sediment do tend to be highly productive from the biological standpoint.

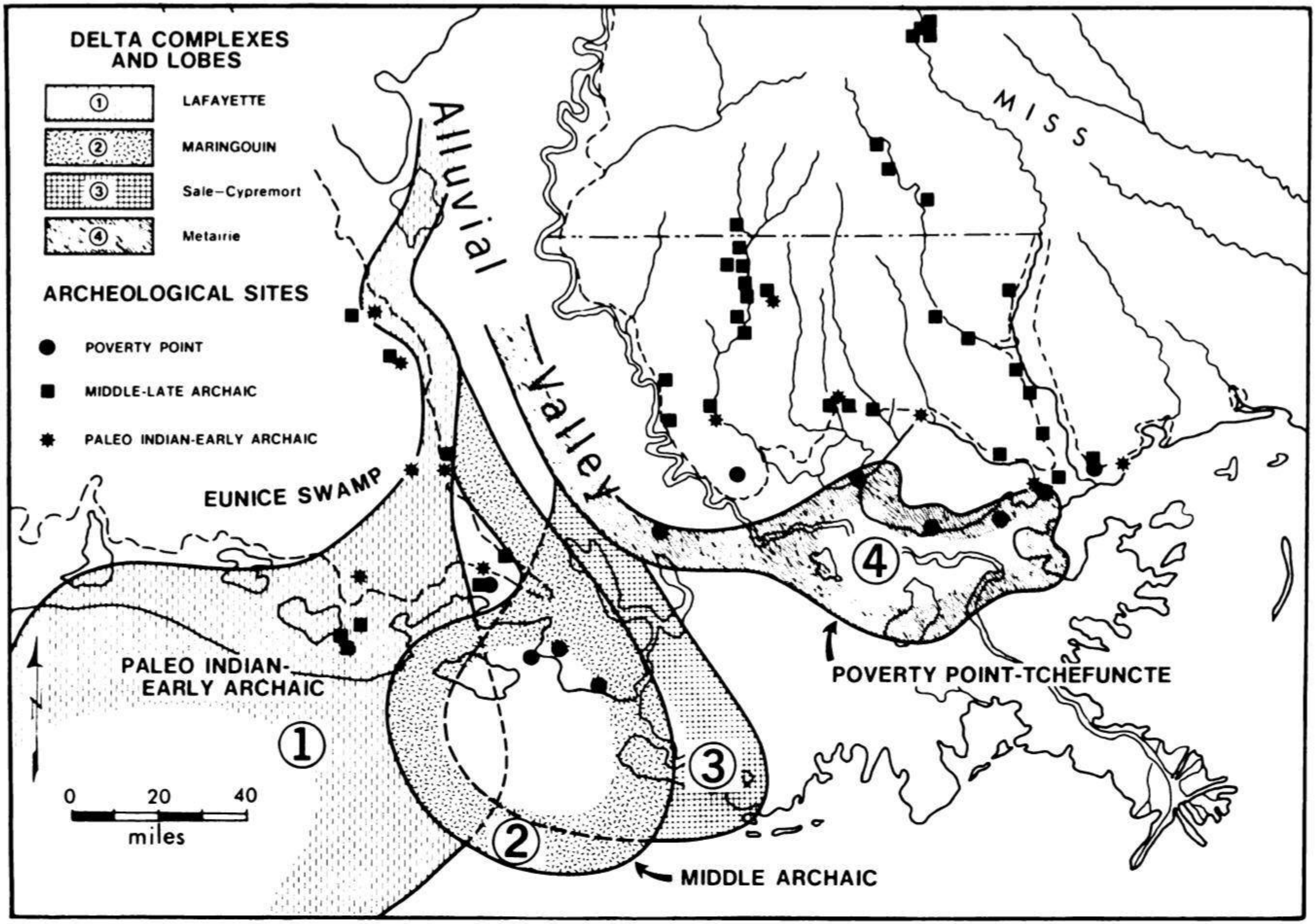


Figure 7-6. Major delta complexes (upper case) and lobes (lower case) of the Mississippi River and prehistoric archeological sites for the interval 12,000 to 2,100 years before present. (After Gagliano, Weinstein, and Burden, 1975).

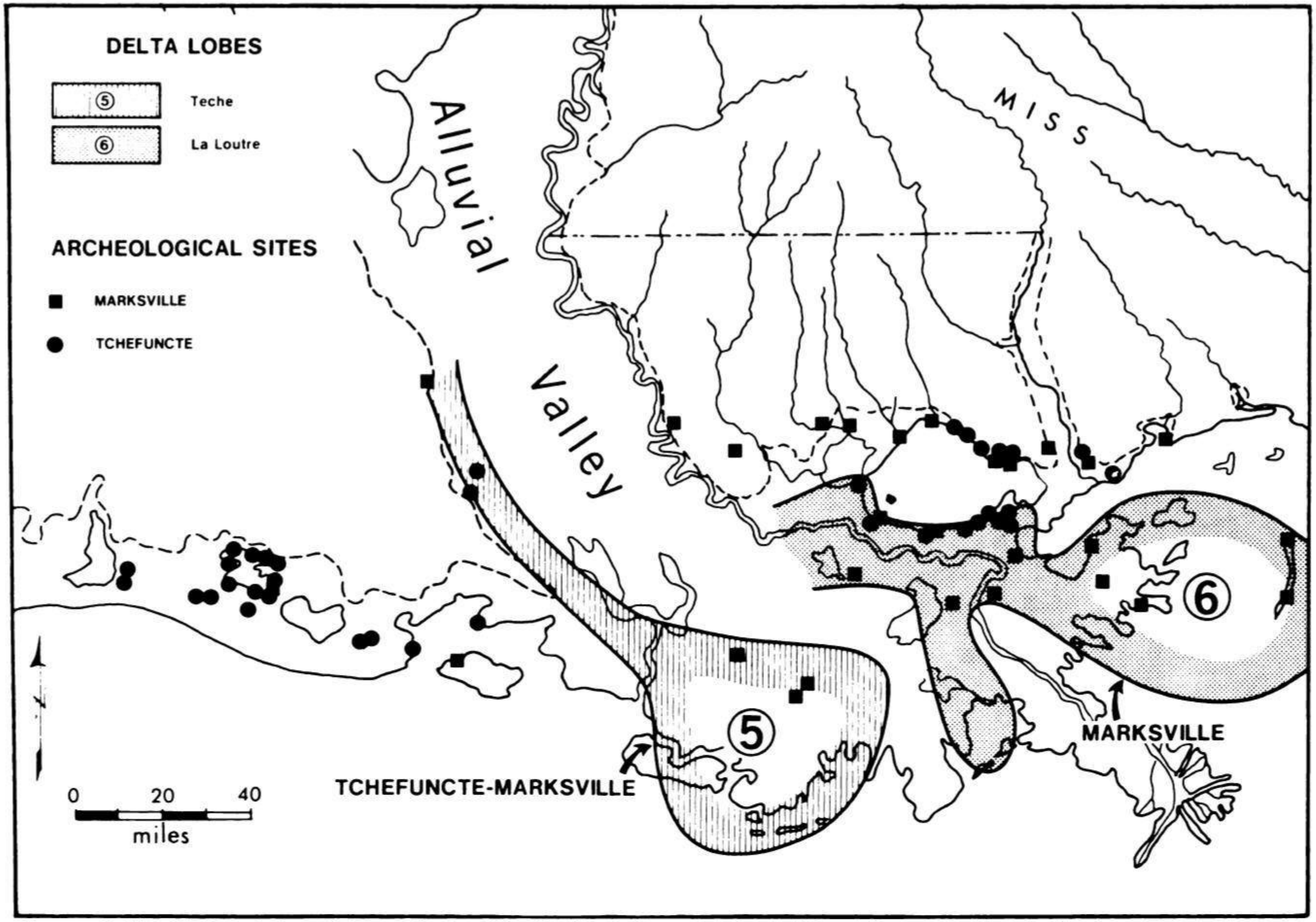


Figure 7-7. Major delta lobes of the Mississippi River and prehistoric archeological sites, for the interval from 2,500 to 1,700 years ago (After Gagliano, Weinstein, and Burden, 1975).

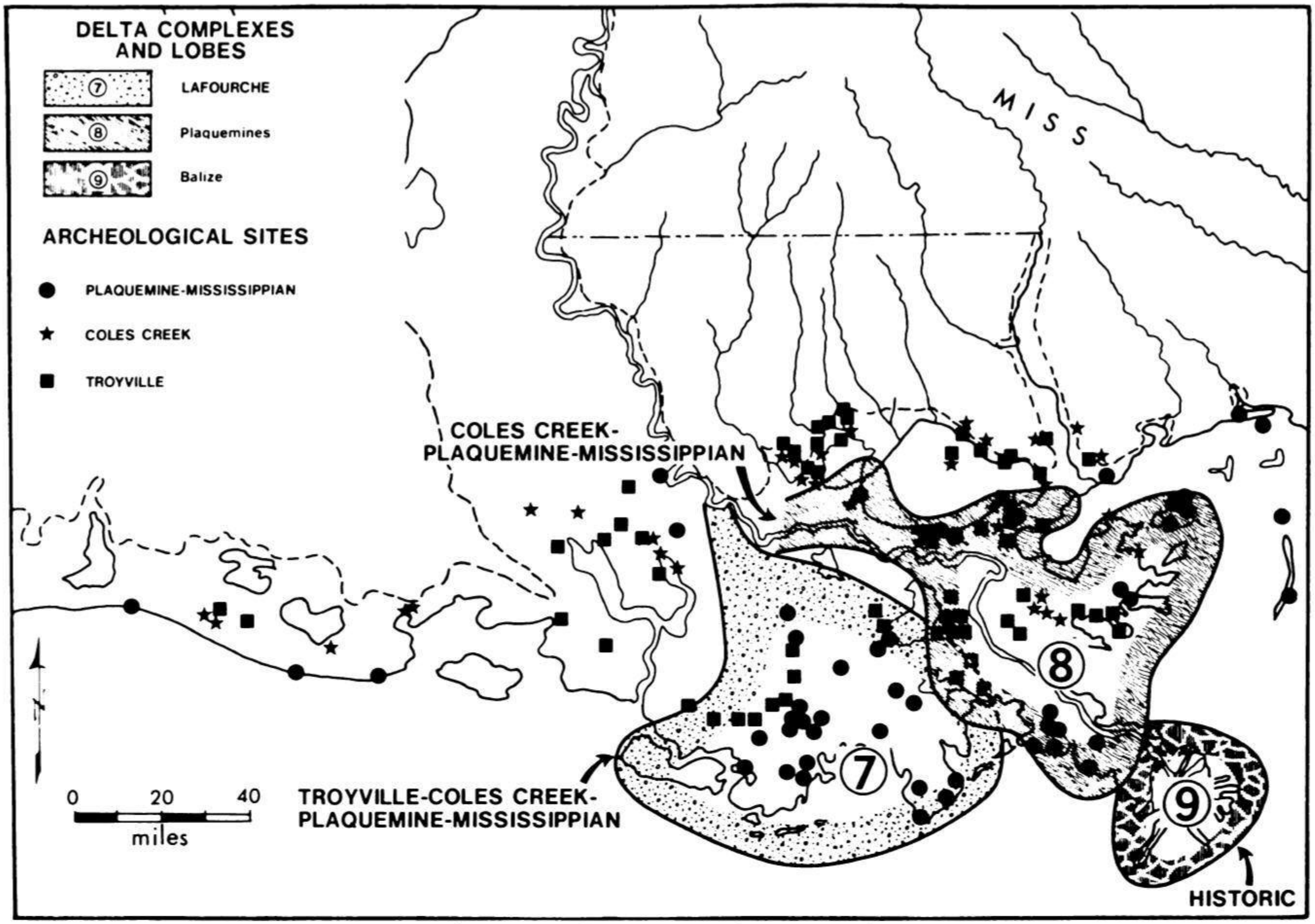


Figure 7-8. Major delta complexes (upper case) and lobes (lower case) of the Mississippi River and archeological sites for the interval from 1,700 years ago to present (After Gagliano, Weinstein, and Burden, 1975).

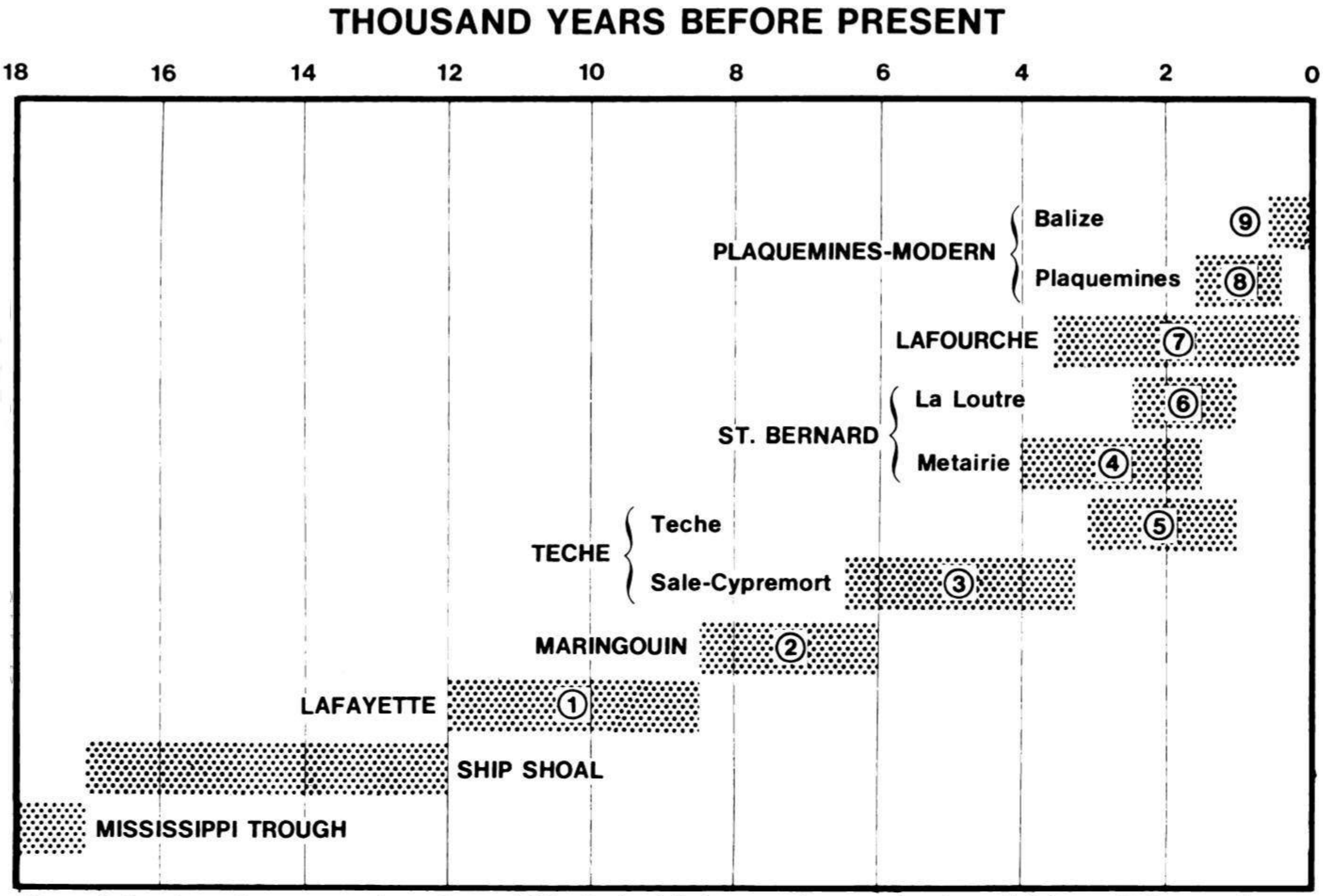


Figure 7-9. Late Quaternary chronology of Mississippi Delta complexes and selected lobes. Prior to about 17,000 years B.P., the river is believed to have been discharging directly into the head of a submarine canyon or trough and was not building a subaerial delta.

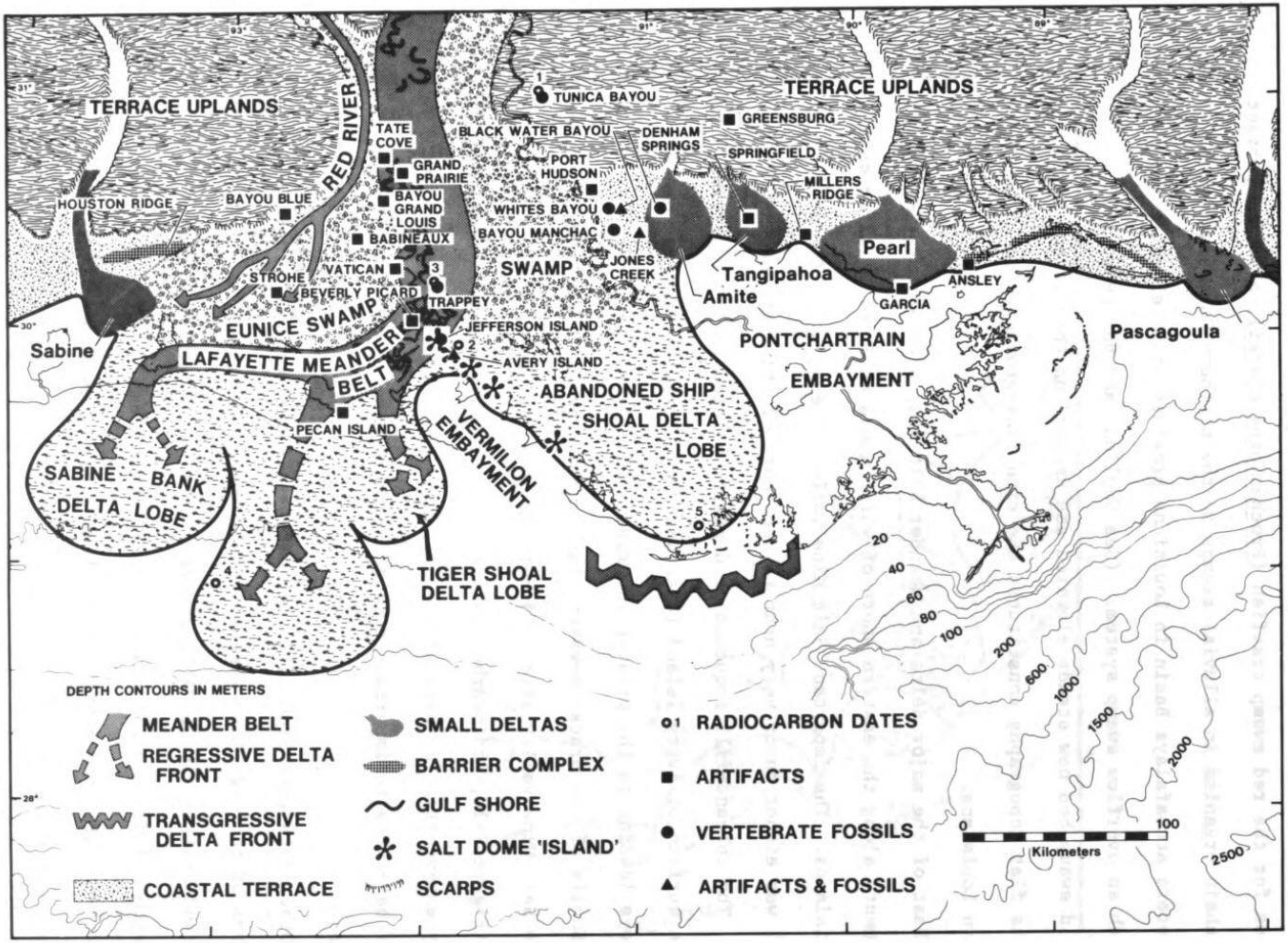


Figure 7-10. Lafayette Delta Complex - 12,000 to 8,500 years B.P. Paleogeography of the Mississippi Delta area during Paleo-Indian - Early Archaic time.

The annual overflow replenishes nutrients and creates ideal habitat conditions for the red swamp crawfish (Prochambarus clarki), a very important food-chain organism in alluvial swamps in the northern Gulf coast area. The modern Atchafalaya Basin in Louisiana provides an excellent example of such an overflow swamp system. (See Gagliano and van Beek, 1975.) The old swamp bed now stands elevated and drained on the terrace surface, but its flat topography constitutes the rich rice-growing area of southwestern Louisiana.

East of the major delta and meander belt was an embayment (Vermilion Embayment) along the eastern shore of which was a chain of uplifted salt dome islands. The important Salt Mine Valley site at Avery Island (16 IB 23) was either on or very near to the shore of this embayment at this time. The cut-and-fill sequence of deposits related to local streams on the surface of Avery Island (discussed in Chapter 4) provided one of the keys leading to the present interpretation.

Shells of the brackish-water clam Rangia cuneata in the lower levels of the Salt Mine Valley site in a horizon dated at about 12,000 years B.P. (Figure 7-10, Radiocarbon Date 2) were probably obtained from the nearby embayment. The size of the Salt Mine Valley site suggests that it may have been an important seasonal gathering place for Paleo-Indian peoples.

Other data come from sites intimately associated with alluvial features of the old river system. For example, at Tate Cove (16 EV "A") and Grand Prairie (16 SL "A"), a series of sites occurs in association with old Mississippi meander scars (Figure 7-11). Over one hundred Late Paleo-Indian projectile points from these sites have been examined. Although not systematically worked, the sites have also produced tools and debitage. The Bayou Grand Louis site (16 EV 4) has yielded Late

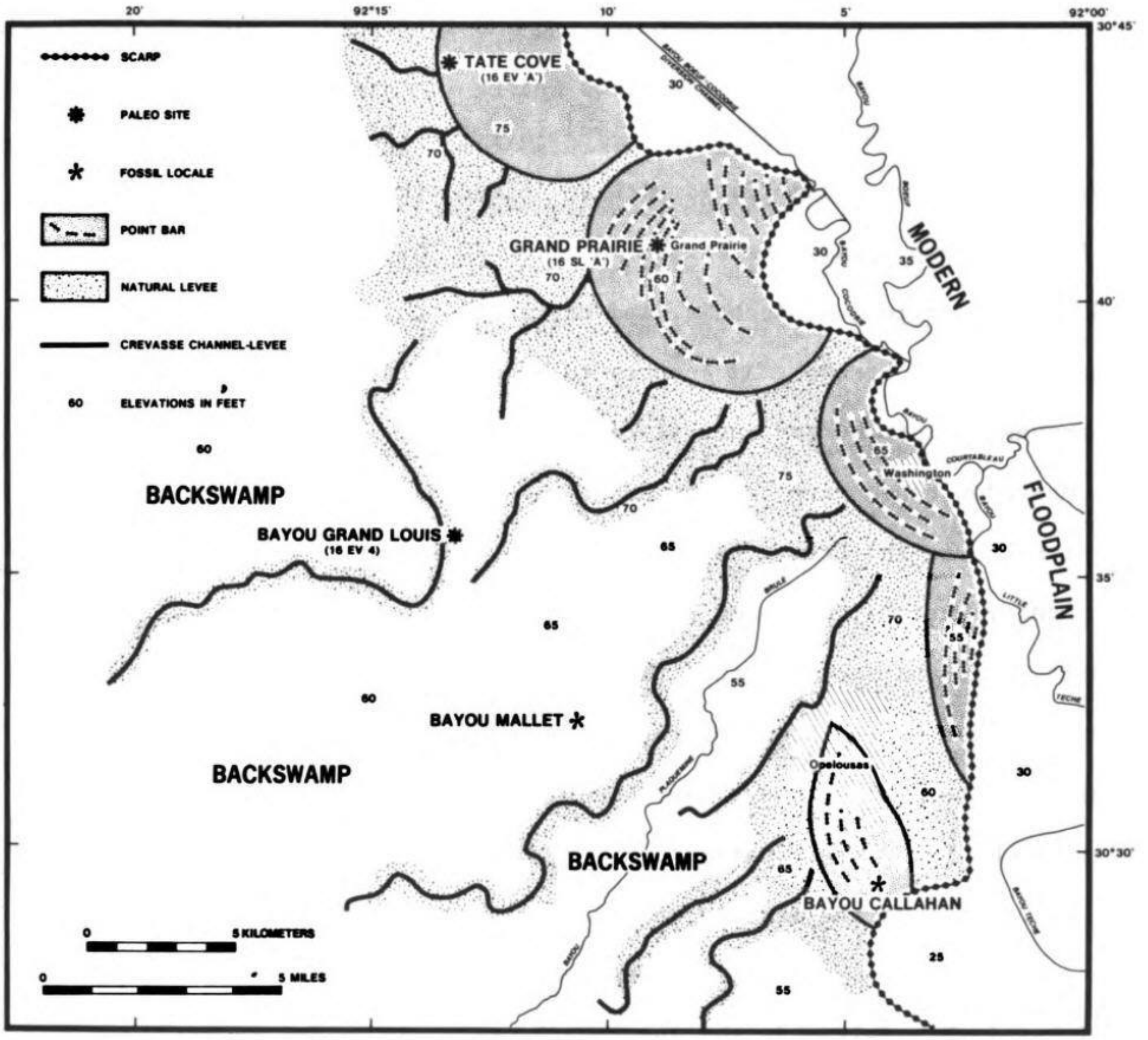


Figure 7-11. Reconstructed paleogeography of a part of the Lafayette meander belt (circa 8,500 years B.P.) showing related Paleo-Indian sites and vertebrate fossil locales. Late Paleo-Indian projectile points and artifacts have been recovered from the Tate Cove (16 EV "A"), Grand Prairie (16 SL "A"), and Bayou Grand Louis (16 EV 4) sites. Mastodon remains have been found in backswamp deposits at the Bayou Mallet locale and in point-bar deposits at Bayou Callahan.

Paleo-Indian fluted and plano points as well as tools and debitage. This site and the Vatican site (Lafayette Parish) are located on natural levee ridges of old crevasse distributaries that emptied into the swamp. Bayou Grand Louis also has an Archaic component believed to be related to some later ecological changes that will be discussed in another section.

The Bayou Blue site (Allen Parish) is a stratified Paleo-Indian through Archaic site associated with an upland stream that entered the Eunice Swamp area. The Strohe site (16 JD 10) is also stratified with Paleo-Indian, Archaic, and Marksville through Plaquemine components. The Strohe site appears to be on the distal end of an old crevasse distributary natural levee ridge.

Mastodon bones have been recovered at the Bayou Mallet locale (St. Landry Parish) from a backswamp facies, while at Bayou Callahan (St. Landry Parish), mastodon remains have been found in point-bar deposits. To the south at the Trappey location (Lafayette Parish), mastodon remains have been recovered from a soil horizon below natural levee deposits. These bones have been dated at about 12,000 B.P. (Figure 7-10, Radiocarbon Date 3).

Lying east of the meander belt was an abandoned delta complex that is known only from borings. Radiocarbon datings suggest that the lobe of this delta, in the Ship Shoal area, was active about 13,000 years ago and at a lower sea level. By Paleo-Indian times, it was abandoned by the river, and by 12,000 B.P., it was partially submerged and in a condition of transgression or retreat.

In what is now southeastern Louisiana, there appears to have been another large embayment (Pontchartrain Embayment). Scattered Paleo-Indian finds have been made on remnants of beach ridges that were once active at the north shore of this embayment.

While the dating is still tentative, streams draining the uplands such as the Sabine, Amite, Tangipahoa, and Pearl Rivers appear to have been building deltas during this interval. Late Paleo-Indian sites and locales in the general vicinity of the present-day city of Baton Rouge are associated with areas marginal to the Amite Delta. At Jones Creek (16 EBR 13) mastodon remains and late Paleo-Indian artifacts have been found and the Denham Springs locale has produced mastodon bones.

Two isolated finds of Paleo-Indian projectile points, a Clovis and a Quad, have been made within the old delta area of the Tangipahoa River, but specific geologic associations remain to be established.

Several other bits of geological data contribute to an understanding of the overall picture. At Tunica Bayou, for example, organic deposits associated with mastodon remains at the base of an alluvial terrace on an upland stream have been dated at 11,000 to 12,000 years B.P. (Figure 7-10, Radiocarbon Date 1). The cut-and-fill sequence at Tunica Bayou and along many of the upland streams of the surrounding area matches the sequence of events at the Salt Mine Valley site on Avery Island (see Chapter VI, Figure 6-12).

Two important bits of data come from core samples. In his important 1974 paper, David E. Frazier lists a date from a wood and brackish-marsh peat immediately beneath transgressive deposits obtained at a depth of 35 meters below present sea level (Figure 7-10, Radiocarbon Date 4). The sample yielded a date of 10,525 $\pm$ 215 years B.P. The sample may be associated with the distal end of one of the delta lobes of the Lafayette Delta Complex.

Another important radiocarbon date published by Frazier in the same paper (1974) comes from the abandoned Ship Shoal Delta Lobe

(Figure 7-10, Radiocarbon Date 5). Here, brackish marsh peat was obtained at a depth of-43 meters and dated at 10,700 ± 150 years B.P. This date probably relates to a transgressive phase of the Ship Shoal Delta Lobe.

The reconstructed paleogeography leads to the conclusion that sea level was relatively stable during the interval from about 12,000 to 8,500 years B.P. Furthermore, the level of the sea may not have been as low as many workers have reported (20 to 45 meters). In fact, the extensive freshwater swamp surface suggests a level near that of the present stillstand. The level subsequent to the time of the Layfayette Delta Lobe and associated features is not easily recognizable, however, since the surface has been tilted and displaced by faulting. Part of the surface now stands as a well-drained terrace (Prairie Terrace), while the delta lobes have been subsided and are submerged on the continental shelf.

2) Maringouin Complex: Early to Middle Archaic. About 8,500 years ago sea level started to fall from the high stand which occurred during Paleo-Indian times. Following a short reversal a slow rise resumed. By 7,000 years ago, it was approximately 10 to 15 meters below its present level. During this reversal, a series of stepped terraces east of Lafayette was formed and meanders of the Mississippi cut into the now-elevated and abandoned Lafayette meander belt. A pronounced erosional scarp was formed and became the western wall of the Late Holocene or modern alluvial valley. A delta lobe developed in the vicinity of present day Marsh Island, Vermilion, and Atchafalaya Bays (Figure 7-12). Shoals in the Gulf remain as remnants of the

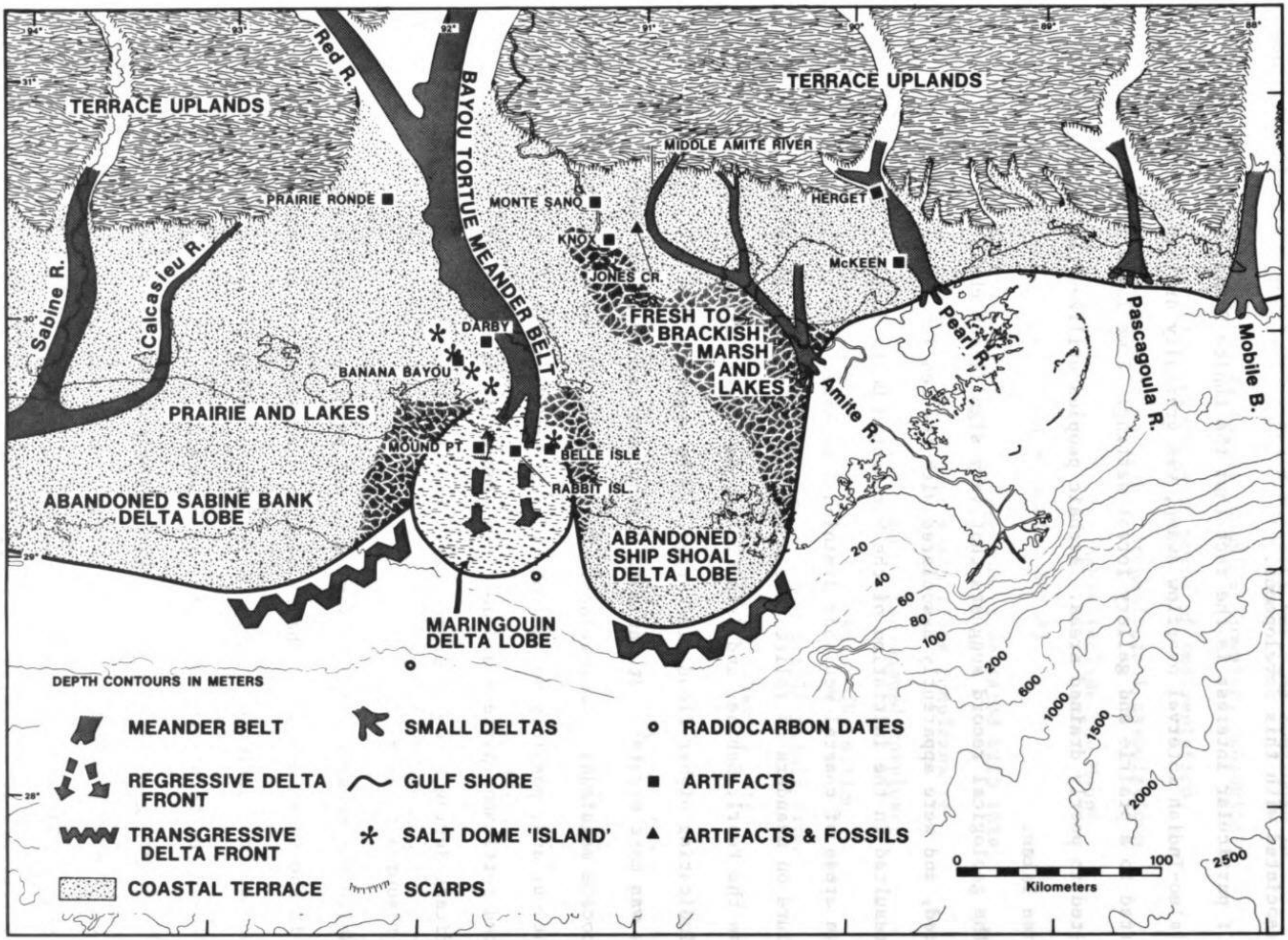


Figure 7-12. Maringouin Delta Complex - 8,500 to 6,000 years B.P. Paleogeography of the Mississippi Delta area during Early to Middle Archaic times when the Maringouin Complex was active

now-submerged delta lobe. A number of Early to Middle Archaic sites are associated with this development.

Of particular interest is the fact that the Eunice Swamp, the vast Paleo-Indian interval overflow swamp, was gradually drained and converted to a prairie and gallery forest setting. Some lakes may have persisted in poorly drained areas. Archaic peoples utilized the margins of these lakes.

The geological record suggests that very significant changes occurred, and were apparently associated with the sea level reversal that resulted in the initiation of the Maringouin Delta Complex. Extensive areas of coastal wetlands diminished in size. The radius of curvature on meanders of relict stream scars along coastal plain streams, such as the Pearl, Sabine, and Trinity, became larger during this interval, indicating higher flood discharges. This suggests that the flow regime was more erratic. It was also during this interval that the Pleistocene megafauna became extinct. This interval is one of the least understood, and, possibly because of climatic implications which in turn affected settlement pattern and absolute population size, one of the most significant during Late Quaternary times from the standpoint of continental shelf resource management.

While the present scope of work will not permit an in-depth treatment, it should be mentioned that a combined archeological-geological approach could contribute greatly to our understanding of events that occurred during this rather obscure time period.

3) <u>Sale-Cypremort Lobe of the Teche Complex: Middle to Late Archaic</u>. The most recent or Late Holocene rise of sea level, beginning about 6,000 years ago, drowned the Maringouin Delta Complex and led into the modern succession of lobes. During the interval between

approximately 6,000 and 4,000 years B.P., delta building continued in the general area of the old Maringouin Complex. However, geological data suggest a distinctive new cycle or pulse of sedimentation, probably related to a major delta lobe. Archeological associations with this lobe are poorly defined, but probably include the Mound Point (16 IB 14) and Rabbit Island sites (16 SMY 8).

A number of other important features was associated with this rise. Among these was the formation of beach-ridge complexes reworked from channel and natural levee sands. Fan-shaped complexes at Pecan Island (Vermilion Parish) and Little Chenier (Vermilion Parish) are particularly prominent. Archaic projectile points from the Pecan Island area are related to occupation of these features when they were active.

4) *Metairie Lobe of the St. Bernard Complex: Poverty Point and Tchefuncte Period*. As sea level approached and reached its present stand (4,000 to 3,000 years ago), a major delta lobe began to develop in what is presently the eastern part of the deltaic plain (Figure 7-13). By Poverty Point times, the growing deltaic land mass had created a marginal deltaic basin in the areas now occupied by Lakes Maurepas and Pontchartrain. Poverty Point peoples began utilizing the highly productive environments associated with the growing delta lobe. Four Poverty Point sites have been found that were associated with the lobe, two of which were located on natural levees of active distributaries. The delta lobe sites were all specialized fishing-hunting-gathering camps and villages. A major village or ceremonial center was located on the eastern side of the Pearl River estuary (Claiborne 22 HC 35, Hancock County, Mississippi). During this interval, Poverty Point peoples continued to use environments associated with abandoned and deteriorating lobes of earlier deltaic developments.

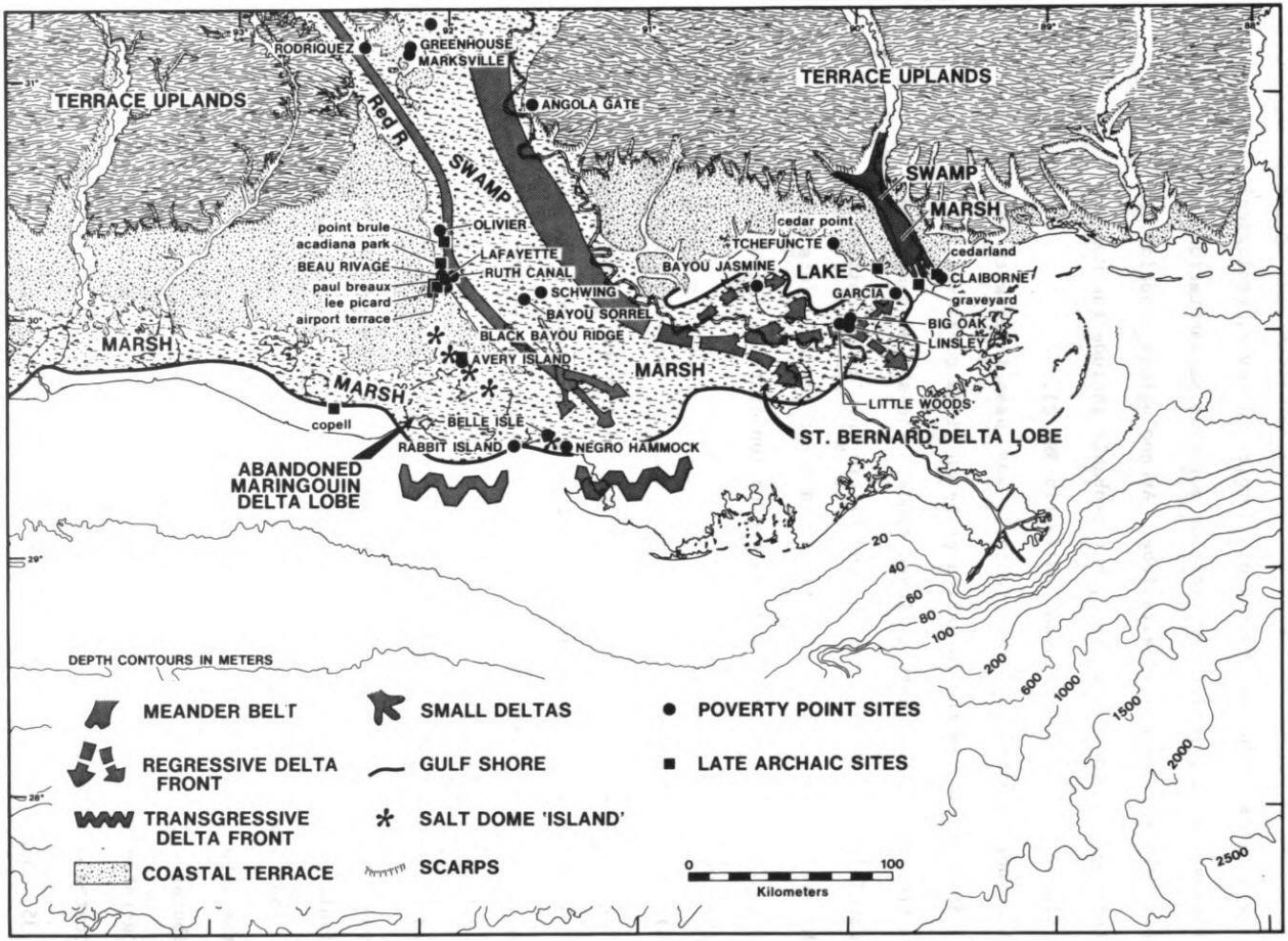


Figure 7-13. Metairie lobe of the St. Bernard Delta Complex - 4,000 to 2,000 B.P. Paleogeography of the Mississippi Delta area during Late Archaic, Poverty Point and Tchefuncte times.

Summary and Conclusions

Application of an archeological-geological approach to the Mississippi Delta area of the central Gulf coast has resulted in the interpretation of the prehistoric landscape and settlement patterns presented in this chapter. While to some extent the hypothesis presented varies from previous interpretations, suggesting that many features of the area are considerably younger than generally believed, its value to the continental shelf problem is largely as a model. Clearly, many continental shelf features in this central Gulf area are of deltaic origin and the known relationships which can be worked out in the onshore parts of the coastal zone can be projected offshore.

There is clearly a continuity of features and presumably of related archeological sites between the coastal zone and the continental shelf. To a great extent, interpretation of the coastal zone is the key to interpretation of the continental shelf. The importance of additional research in key coastal areas is self-evident.

Major vertical movements have differentially displaced relict features of the central Gulf area during at least the past 12,000 years. Surfaces deposited at or near the level of the sea have been tilted, warped, and faulted subsequent to their formation. Differential vertical movements of 50 meters or more may have influenced the surface of the Lafayette Alluvial Valley and Deltaic Plain since its abandonment approximately 8,500 years ago.

During the period from approximately 12,000 to 8,500 years B.P. (Intervals H1 to H3) there was a very slow rise or relative stillstand of the sea. Major coastal progradation occurred with associated development of extensive coastal wetlands (swamps and marshes). Pleistocene megafauna flourished and there is abundant evidence of man throughout the area, particularly during the closing interval.

The climatic implications of the hypothesis for the period from approximately 8,500 to 6,500 years B.P. (Intervals H_4 and I) are particularly significant. Major geomorphic and ecological changes occurred, including a reversal of the long-term trend of sea level rise and stability. This reversal caused a ria cycle and a general displacement of the shore zone. The extent of coastal wetlands was greatly diminished and the Pleistocene megafauna became extinct. Great fluctuations in runoff conditions and stream discharge occurred. There were effects on settlement pattern and population size. The impacts of these changes are recorded in the archeological and geological record throughout the study area.

During the past 6,000 years (Interval J to K), sea level has risen slowly and attained a relative stillstand. Conditions have been relatively stable and not greatly different from those of the present. There is a continuity of the geological and archeological record during this time.

CHAPTER VIII

CONCLUSIONS AND RECOMMENDATIONS FOR FURTHER STUDY

Summary

Cultural resources are not evenly or randomly distributed across the earth's surface, but are clustered or concentrated in areas of human activity. This is true not only for terrestrial areas, but also for the continental shelf. We have tried to demonstrate that there is a relationship between prehistoric human activity and landforms. While it is not possible to predict specific site locales, certain landforms were clearly favored for habitation and other activities. These preferred locations in respect to landform geometry can be defined as areas of high probability of site occurrence.

We have also tried to demonstrate that relict landforms can be identified on the Gulf bottom. The distribution of these relict landforms is related to former natural systems and has an orderly and predictable arrangement. A relict landform can be shown to be not submerged during a particular period, and favored for habitation by prehistoric peoples flourishing in nearby areas during that period. But although this gives us an area of high probability for the occurrence of a site, it may be a rather large area that contains a few rather small sites.

Discovery of sites on the continental shelf therefore becomes a matter of prospecting. Two general approaches to prospecting for sites are available. The first involves underwater search by divers or archeologists in underwater vehicles of some type. While direct underwater search techniques may be preferable in some cases, there are strict limitations imposed by water depth, visibility, costs, and time factors. The second general category involves searching with remote-sensing tools from surface vessels. For site discovery and verification, remote-sensing techniques seem far more efficient and promising. Once high-probability areas have been defined, the next obvious question is "what do we look for?"

Cultural Signatures

Our survey of the literature of the northern Gulf area, as presented in Chapters 5 and 6, indicates that there are eleven site situations and types of sites that occur frequently enough within the time intervals of concern that they may be anticipated in the OCS area. Table 8-1 presents these eleven types and the probable periods of occurrence of each. A summary of the basic characteristics of each of the eleven site types follows. These basic characteristics are called "signatures" in analogy to the use of the phrase "electronic signatures" in computer interpretation. The totality of a site can not be explored when it is on the ocean floor, and site determination must be made on the basis of a few isolated and always limited indicators. As is true of electronic signatures, these cultural signatures can be positive or negative. They are discrete site indicators, capable of being detected by presently available instrumentation. A few signatures of each type site situation are offered below.

Quarry Sites

1) Outcrops of chert, quartzite, or other rocks that are suitable for chipping or grinding.

2) Scattered debitage and chipped tools. Concentrations occur over areas from approximately 1,000 to 200,000 m^2 (1/4 acre to 50 acres).

3) Most material occurs as surface lag. Some stratification of chipping floors may occur, particularly in the vicinity of rock outcrops. Stratification may also occur if there are ponds near the rock outcrops.

4) Perishable materials are generally absent unless a pond or depression is associated with the rock outcrop.

Salt Dome Sites

1) Around depressions (solution ponds) on dome surface or associated with small streams on dome, on margin of dome adjacent to stream, lake, or bay.

Table 8-1. Occurrence of site types by culture period or stage.

CULTURE PERIOD OR STAGE / TYPE OF SITE	Poverty Point	Late Archaic	Middle Archaic	Early Archaic	Paleo-Indian	Pre-Fluted Point
Quarry Sites	P	X	X	X	X	P
Salt Dome Sites	X	X	X	X	X	P
Spring (Sinkholes) Sites	P	P	X	X	X	P
Valley Margin Sites	X	X	X	X	P	P
Natural Levee Sites	X	X	X	X	X	P
Point Bar Sites	P	P	X	X	X	P
Bay Margin Sites	X	X	P	X	X	P
Coastal Dune Lake Sites	P	X	P	X	X	P
Shell Middens	X	X	P	?	?	?
Conical Earth Mounds	X	X	X			
Crescentic and Circular Villages	X	X				

X - Known occurrence

P - Probable occurrence

2) Scattered debitage and stone tools, particularly if gravel or rock is available on dome. Artifacts may be locally concentrated in areas of 9 m^2 (100 square feet) to 40,000 m^2 (10 acres).

3) Stratified deposits, including bone beds and organic deposits, may occur in sinkholes or other depressions on the dome surface.

4) Perishable material may be preserved if sinkholes or depressions are present.

Spring Sites

1) Around the margins and within sinkholes in karst areas.

2) Scattered debitage and stone tools may occur in the vicinity of the sinkhole rim.

3) Artifacts and bone may be incorporated in deposits in the bottom of the sinkhole. Mineralized bone may be anticipated. All material was dropped in from the surface and is randomly distributed.

4) Stratified deposits may be found on ledges around the inside walls of the sinkhole. These ledges may have served as shelters or burial places. Preservation of bone and vegetable matter may be excellent due to the high mineral content of the spring waters. In addition to stone tools, artifacts and ecofacts of bone, shell, wood, fiber and other perishables may be found.

Valley Margin Sites

1) Found near the escarpment marking the boundary of a floodplain or stream valley. Distinguished by the escarpment and/or change in the nature of deposits. Stream valleys may often be identified by bathymetry, sub-bottom profiles, and/or cores. Sites may occur in close proximity (within 100 meters) of the valley wall scarp.

2) Types of sites may be variable, including small campsites, gravel quarry sites, crescentic villages, shell middens, or earth mounds. Most typically, the sites may be marked by stone artifacts and debitage scattered

over the surface. Most artifacts are manufactured from stream gravel. Where gravel was readily available in nearby streams, the site may take on characteristics of a quarry site.

3) Stratification is poorly developed and poorly preserved.

4) Preservation is usually poor. Only materials highly resistant to chemical weathering can be expected to survive.

Natural Levee Sites

1) Located near the crests of natural levee ridges. Preferred locations include the cut bank side of meander loop cutoffs, junctions of tributaries and distributaries, and/or crevasse distributaries. Natural levees are distinguishable by bathymetry and/or sub-bottom profiles.

2) Sites may include camps, shell middens, conical earth mounds, and crescentic villages. Distributary levees are prime locations for shell middens.

3) Sites may be stratified and interbedded with overbank sediment deposits.

4) Preservation may be poor to moderate. Some bone and shell may survive, but usually only chemical-resistant materials.

Point Bar Sites

1) Habitation of actively accreting point bars of a meandering stream results in archeological materials being incorporated in the point bar deposits along sloping depositional surfaces. Materials may remain exposed on the crests of accretion ridges in a point bar sequence.

2) If the stream was transporting gravel during habitation, the site may have the characteristics of a quarry, with abundant debitage and artifacts produced for gravel. Hearths may be present in the point bar.

3) Lateral stratification is related primarily to active sedimentary processes of point bar accretion.

4) Preservation of perishable materials will probably be very poor. Usually only stone will be preserved.

Bay Margin Sites

1) The margins of bays and estuaries may be typically marked by low escarpments defined by bathymetry (if well preserved). It can be anticipated that sites will frequently be located near such escarpments, particularly along sheltered parts of the bay. Sites may range from small camps or shell middens to very large mounds, shell middens, or crescentic villages.

2) Shell middens are likely to be well represented around bay margins.

3) Preservation is likely to be poor to moderate. Preservation of bone, shell, and seeds may be good in shell middens.

Coastal Dune Lake Sites

1) Sites may be located around the margins of lakes and ponds in dune fields. Artifacts and ecofacts may be incorporated in the sedimentary deposits within such shallow water bodies. In some instances, these depressions may be identified from bathymetry, sub-bottom profiles, or cores. Humic and calcified organic sands often form in the freshwater ponds and lakes of coastal dune fields. Such deposits may be more resistant to erosion than surrounding, unconsolidated dune fields and may produce inverted topographic features on the sea bottom. Site area may be a few acres in extent. Deposits should rarely be more than 2 meters thick.

2) Scattered stone tools and hearth stones may occur, but will rarely be abundant. Small shell middens may be associated.

3) Stone beds and plant materials may be associated with the humic deposits or cemented pond deposits. In such instances, preservation of perishable materials may be very good.

Shell Middens

1) Sites may be associated with a variety of coastal landforms, especially around margins of estuaries, lakes, bays, flood plains, on natural levee crests, on relict beach ridges, salt domes, etc. Shell middens may be identified on bathymetric charts and sub-bottom profiler records and with coring or dredging samplers. Side-scan sonar may have limited effectiveness as well.

2) Although scattered artifacts are possible, they are probably not abundant unless midden material has been redistributed along the bottom. *Rangia cuneata* and *Crassostrea virginica* are the most common shells, but often other molluscs are present in lesser numbers. Midden geometry may range from large, crescentic or circular villages covering over 40,000 m^2 (10 acres) to small piles only 2 m in diameter and 30 cm in height. The most common geometry is likely to be linear, cigar-shaped ridges.

3) Stratigraphy is probably good if the midden is not scattered.

4) Preservation is probably good if the site is *in situ*. Midden material may be locally or entirely cemented. Calcium carbonate forms the cementing agent, and shells, bone, and artifacts may be contained in the aggregate.

Conical Earth Mounds

1) Sites may be located in any of the areas described for shell middens (see above). If mounds should be preserved on the Gulf bottom, they may be located through bathymetry, sub-bottom profiles, and side-scan sonar.

2) Mounds generally occur in groups of two. Height may vary between 50 cm or less to over 5 meters. Some mounds may be over 30 m in diameter. Artifacts will probably be very scarce on an *in situ* mound, but may be located among the remains of eroded or scattered mounds. Typically early

mounds of Poverty Point, Late Archaic, and Middle Archaic times exhibit a paucity of accompanying artifacts. Possible village or shell midden areas may be anticipated nearby.

3) Stratigraphy is most likely excellent in a well-preserved mound.

4) Preservation should be fair with usually only stone, baked clay, and poorly preserved burials found.

Crescentic and Circular Villages

1) Located along terrace margins overlooking a flood plain or marine estuary, along the bay side of barrier islands, and on natural levee crests of relict streams. Terrace margins can usually be located by bathymetry and/or sub-bottom profiles.

2) Crescentic sites are located in the coastal Gulf area, while circular villages are found along the Atlantic coast, with the possibility that they can occur in the eastern Gulf. Sites are composed of oyster and/or Rangia shells or black midden areas. They range in size from 1000 m in diameter and covering 2 km^2 (500 acres) (Poverty Point Site) to as small as 0.03-0.06 km^2 (8-15 acres) with diameters of about 75-90 m (Cedarland, Claiborne). The central area of the village is void of shell or midden accumulation, with a shell "ring" from 1 m to 3 m high. Commonly, there are more than one or two villages close together (i.e., Cedarland and Claiborne, and Sapelo Island shell rings).

3) There is a good possibility that village areas also have an outlying conical earth mound or mounds associated with them. Artifacts exhibit evidence of wide trade network and mostly appear as chipped stone points, steatite bowls, ground-stone plummets, exotic lithics, such as quartz crystals, and fiber-tempered pottery. Baked clay, Poverty Point objects are usually associated. Artifacts are likely to be abundant.

4) Stratification will probably be fair to good. Lithification of midden material may occur with bone, shell, and artifacts in the matrix.

5) Preservation of organic matter is probably fair to good in shell middens, poor in earth middens.

Remote Sensing Techniques

The characteristics presented above are, in effect, signatures which must be identified by remote-sensing or surface-testing techniques in order to discover and confirm a site. At this point, we really do not know how effective presently available remote-sensing techniques are in identifying these signatures. However, based on a working knowledge of the remote-sensing techniques and the site characteristics, we can evaluate the techniques from the standpoint of relative effectiveness. Such an evaluation is presented in Table 8-2. As indicated in the table, good bathymetry and sub-bottom profiles are basic tools for identifying characteristic geometry of landforms and large or conspicuous sites. Side-scan sonar may be of some value in defining the geometry of a conspicuous site or conspicuous landform. Various types of sampling devices, specifically grab samples, cores, and box samplers, may assist in verifying the interpretation of the form by providing material from which the landform is composed, or the matrix material of the site. The recovery of artifacts or ecofacts can be accomplished by direct sampling approaches. These include drag samples, bucket samples, cores, and box samples.

Only a very few sites in the continental shelf areas of the United States have been found and investigated by direct diver inspection. However, if we review the reports on artifacts, sites, and ecofacts that have been found, several interesting things appear. Most notable is the work of Ruppe in west Florida (personal communication). One shell bank, possible a midden, has been reported in deeper

Table 8-2. Effectiveness of remote sensing survey and testing tools.

REMOTE SENSING TECHNIQUE / TYPE OF SITE	Bathymetry	Sub-bottom Profiler	Side Scan Sonar	Magnetometer	Piston Corer	Box Corer	Bottom Dredge	Clam Bucket Dredge on Sampler
Quarry Sites	1	1	2	0	0	2	3	2
Salt Dome Sites	3	3	2	0	2	3	2	2
Spring (Sinkhole) Sites	3	3	2	0	2	3	2	2
Valley Margin Sites	2	1	1	0	0-1	2	3	2
Natural Levee Sites	2	3	1	0	0-1	2	3	2
Point Bar Sites	2	3	1	0	0-1	3	3	2
Bay Margin Sites	2	1	1	0	0-1	1	2	2
Coastal Dune Lake Sites	2	3	1	0	2	3	2	2
Shell Middens	3	3	2	0	0	3	3	3
Conical Earth Mounds	3	3	1	0	1	3	0	0
Crescentic and Circular Villages	2	3	1	0	2	3	2	2

EFFECTIVENESS:

0 - Virtually useless

1 - Occasionally effective

2 - Limited effectiveness

3 - Highly effective

water off the Atlantic coast by Emery (1969). A number of artifacts and fossil bones has been recovered in fishing nets and geological bottom-sampling devices, usually drag samplers. This leads one to conclude that drag and bulk sampling devices may be the most effective way of sampling and testing drowned or submerged sites. Given the present state of the art of OCS cultural resource methodology and underwater remote-sensing and diving technology, the most effective sequential approach to prehistoric site discovery seems to be as follows:

1) Interpretation of relict landforms and relict systems from large-scale bathymetry, identification of high-probability areas from these bathymetric maps, interpretation of the age of the features and associated high-probability areas, development of models for site types most likely to be associated with the high-probability areas.

2) Sampling and testing with remote-sensing techniques. This can be done either through a specific research project in a specific area or through the present OCS survey requirement. A hierachical or step approach to testing should be employed. The first array of instruments at Step 1 should include small-scale bathymetry (fathometer), sub-bottom profile to 30 feet or to define the upper 30 feet, and a drag sample or grab sample. If this first-step survey indicates an anomaly or probable site, Step 2 testing might include side-scan sonar, bottom core or cores, additional grab samples and drag samples. Step 3 inspection would include underwater photography or television viewing, box core sampling, and/or direct inspection by divers.

Zone Map

We have attempted to apply the findings of this study to the problem of survey requirements for the northern Gulf OCS area. Based on the distribution of relict landforms and our interpretation of the age of these landforms, the northern Gulf OCS area has been zoned. The zone boundaries were combined with those developed for shipwreck occurrence and evaluation (see Volume II). Plate 11 of Volume III presents the combined zonation showing probable cultural resource occurrence for prehistoric sites and historic shipwrecks. Zone 1 on Plate 11 is predicted to have high productivity for prehistoric cultural remains dating back to and including Paleo-Indian, Early Archaic, Middle Archaic, and Late Archaic periods 12,000 - 3,000 B.P. In the Chandeleur Sound area of southeastern Louisiana, sites as recent as 800 years B.P. may be submerged. The seaward limit of Zone 2 indicates the extent of Paleo-Indian habitation sites. The seaward limit of Zone 3a approximates the maximum low stand of sea level during the Wisconsin glacial stage. The zone contains relict shore features ranging in age from approximately 19,000 to 12,000 years B.P. Habitation sites within the same time range can be anticipated. Zone 3b is a zone of banks which were probably exposed as islands during the maximum Wisconsin low stand. Prehistoric sites within the age range of 19,000 to 17,000 years B.P. may occur. Zone 4 exhibits apparent shoreline features in water depths of 90 to 200 m. Little is known of the nature or age of these features at present. They may be related to Illinoisian glacial stage.

While these zonations and recommendations were not arrived at lightly, it should be emphasized that the map was developed through qualitative, graphic approaches and should be characterized as a "best judgment" map. Clearly, the methodology developed in this volume is untested in the OCS area. We do believe, however, that the rationale is sound and can be demonstrated in the coastal plain of the northern Gulf, and that the methodology is amenable to testing.

Recommendations For Further Study

The methodology should be tested in pilot-study areas both onshore and offshore. Major objectives of the onshore work should be to: 1) better understand Late Quaternary geologic events and landforms; 2) test the "high-probability area" methodology and compare with random sampling, transects, and other sampling designs, 3) better define early cultures which may be represented in the OCS area; 4) better understand site-landform geometry relationships, and 5) better define site signatures. These objectives can best be achieved in a terrestrial situation.

The OCS pilot study that is needed now is simply a more detailed application of the methodology developed in this paper. The objectives would be: 1) study the bathymetry and available geological data at a scale and level of detail that was not possible in the present study; 2) map relict features and paleogeography and identify high-probability areas of site occurrences; 3) using remote-sensing techniques, systematically survey high-probability areas; 4) using the step approach discussed above, attempt to verify and test possible sites; 5) if feasible, inspect and test sites using divers. Such a program should result in a significant improvement in defining the survey requirements from the standpoints of both efficiency and effectiveness. In addition, the fascinating study of the prehistoric archeology of the outer continental shelf would be advanced.

REFERENCES

Adam, D. P.

1975a. The Tropical Cyclone as a Global Stabilizing Mechanism. Geology, Volume 3, pp. 625-626.

1975b. Ice Ages and the Thermal Equilibrium of the Earth, III. Quarternary Research, Volume 5, pp. 161-171.

Alt, D. and H. K. Brooks

1965. Age of Florida Marine Terraces. Journal of Geology, Volume 73, pp. 406-411.

Ambler, R. J.

1967. Three Prehistoric Sites near Cedar Bayou, Galveston Bay Area, Texas. State Building Commission Archeology Program, Report No. 8.

1973. The Lost River Phase of the Lower Trinity River Delta. Manuscript submitted to the National Park Service, Southwestern Region, by Texas Archeological Survey. Austin: University of Texas.

Aten, L. E.

1967. Excavations at the Jamison Site (41 LB 2), Liberty County, Texas. Houston: Houston Archeological Society Report No. 1.

1971. Archeological Excavations at the Dow-Cleaver Site, Brazoria County Texas. Texas Archeological Salvage Project, Bulletin No. 1.

Aten, L. E. and C. N. Bollich

1969. A Preliminary Report on the Development of a Ceramic Chronology for the Sabine Lake Area of Texas and Louisiana. Texas Archeological Society Bulletin, Volume 40, pp. 241-258.

Bader, R. S.

1957. Two Pleistocene Mammalian Faunas from Alachua County, Florida. Florida State Museum Bulletin, Volume 2, pp. 52-75.

Bergantino, R. N.

1971. Submarine Regional Geomorphology of the Gulf of Mexico. Bulletin of the Geological Society of America, Volume 82, pp. 741-752.

Bernard, H. A.

1950. Quaternary Geology of Southeast Texas. Unpublished Ph.D. dissertation on file at Louisiana State University at Baton Rouge. 165 pp.

REFERENCES

Adam, D. P.

1975a. The Tropical Cyclone as a Global Stabilizing Mechanism. Geology, Volume 3, pp. 625-626.

1975b. Ice Ages and the Thermal Equilibrium of the Earth, III. Quarternary Research, Volume 5, pp. 161-171.

Alt, D. and H. K. Brooks

1965. Age of Florida Marine Terraces. Journal of Geology, Volume 73, pp. 406-411.

Ambler, R. J.

1967. Three Prehistoric Sites near Cedar Bayou, Galveston Bay Area, Texas. State Building Commission Archeology Program, Report No. 8.

1973. The Lost River Phase of the Lower Trinity River Delta. Manuscript submitted to the National Park Service, Southwestern Region, by Texas Archeological Survey. Austin: University of Texas.

Aten, L. E.

1967. Excavations at the Jamison Site (41 LB 2), Liberty County, Texas. Houston: Houston Archeological Society Report No. 1.

1971. Archeological Excavations at the Dow-Cleaver Site, Brazoria County Texas. Texas Archeological Salvage Project, Bulletin No. 1.

Aten, L. E. and C. N. Bollich

1969. A Preliminary Report on the Development of a Ceramic Chronology for the Sabine Lake Area of Texas and Louisiana. Texas Archeological Society Bulletin, Volume 40, pp. 241-258.

Bader, R. S.

1957. Two Pleistocene Mammalian Faunas from Alachua County, Florida. Florida State Museum Bulletin, Volume 2, pp. 52-75.

Bergantino, R. N.

1971. Submarine Regional Geomorphology of the Gulf of Mexico. Bulletin of the Geological Society of America, Volume 82, pp. 741-752.

Bernard, H. A.

1950. Quaternary Geology of Southeast Texas. Unpublished Ph.D. dissertation on file at Louisiana State University at Baton Rouge. 165 pp.

REFERENCES

Adam, D. P.
1975a. The Tropical Cyclone as a Global Stabilizing Mechanism. Geology, Volume 3, pp. 625-626.

1975b. Ice Ages and the Thermal Equilibrium of the Earth, III. Quarternary Research, Volume 5, pp. 161-171.

Alt, D. and H. K. Brooks
1965. Age of Florida Marine Terraces. Journal of Geology, Volume 73, pp. 406-411.

Ambler, R. J.
1967. Three Prehistoric Sites near Cedar Bayou, Galveston Bay Area, Texas. State Building Commission Archeology Program, Report No. 8.

1973. The Lost River Phase of the Lower Trinity River Delta. Manuscript submitted to the National Park Service, Southwestern Region, by Texas Archeological Survey. Austin: University of Texas.

Aten, L. E.
1967. Excavations at the Jamison Site (41 LB 2), Liberty County, Texas. Houston: Houston Archeological Society Report No. 1.

1971. Archeological Excavations at the Dow-Cleaver Site, Brazoria County Texas. Texas Archeological Salvage Project, Bulletin No. 1.

Aten, L. E. and C. N. Bollich
1969. A Preliminary Report on the Development of a Ceramic Chronology for the Sabine Lake Area of Texas and Louisiana. Texas Archeological Society Bulletin, Volume 40, pp. 241-258.

Bader, R. S.
1957. Two Pleistocene Mammalian Faunas from Alachua County, Florida. Florida State Museum Bulletin, Volume 2, pp. 52-75.

Bergantino, R. N.
1971. Submarine Regional Geomorphology of the Gulf of Mexico. Bulletin of the Geological Society of America, Volume 82, pp. 741-752.

Bernard, H. A.
1950. Quaternary Geology of Southeast Texas. Unpublished Ph.D. dissertation on file at Louisiana State University at Baton Rouge. 165 pp.

1961. Late Quaternary Sea Level: A Discussion. Bulletin of the Geological Society of America, Volume 17, pp. 1707-1712.

1965. Late Quaternary History, Continental Shelves of the United States. In, H. E. Wright and D. G. Frey (eds.), The Quaternary History of the United States. Princeton: Princeton University Press, pp. 723-736. 11 figures.

Dickerson, M. W.
1846. Report at Meeting of October 6, 1846. Philadelphia: Proceedings of the Academy of Natural Sciences of Philadelphia, Volume 3, No. 5, pp. 106-107.

Donaldson, A. C., R. H. Martin, and W. H. Kanes
1970. Holocene Guadalupe Delta of Texas Gulf Coast. In, J. P. Morgan and R. H. Shaver (eds.), Deltaic Sedimentation, Modern and Ancient. Society of Economic Paleontologists and Mineralogists Publication No. 15, pp. 107-137.

Edwards, G. Serpell
1971. The Geology of West Flower Garden Bank. TAMU Sea Grant Program, Publication 71-215, 199 pp., 47 figures, 6 tables.

Fairbridge, R. W.
1961. Eustatic Changes in Sea Level. In, L. H. Ahrens et al. (eds), Physics and Chemistry of the Earth, Volume 4. New York: Pergamon Press, Inc., pp. 99-185.

1974. The Holocene Sea Level Record in South Florida. In, P. J. Gleason (ed.), Environments of South Florida: Past and Present. Miami Geological Society Memoir No. 2, pp. 223-231.

Fisher, W. L., L. F. Brown, Jr., J. H. McGowen, and C. G. Groat
1973. Environmental Geologic Atlas of the Texas Coastal Zone: Beaumont - Port Arthur Area. Austin: Bureau of Economic Geology, University of Texas.

Fisher, W. L., J. H. McGowen, L. F. Brown, Jr., and C. G. Groat
1972. Environmental Geologic Atlas of the Texas Coastal Zone: Galveston - Houston Area. Austin: Bureau of Economic Geology, University of Texas.

Fisk, H. N.
1939. Depositional Terrace Slopes in Louisiana. Journal of Geomorphology, Volume 2, pp. 181-199.

1944. Geological Investigation of the Alluvial Valley of the Lower Mississippi River. Vicksburg: U. S. Army Corps of Engineers Mississippi River Commission.

1955. Sand Facies of Recent Mississippi Delta Deposits. Rome: Proceedings of the Fourth World Petroleum Congress, Section 1, pp. 377-398.

1956. Nearsurface Sediments of the Continental Shelf off Louisiana. Austin: Proceedings of the Eighth Texas Conference on Soil Mechanics and Foundation Engineering, September 14 and 15.

1959. Padre Island and the Laguna Madre Flats, Coastal South Texas. Baton Rouge: Second Coastal Geography Conference, Coastal Studies Institute, University State University, pp. 103-151.

Fisk, H. N. and E. McFarlan, Jr.
1955. Late Quaternary Deltaic Deposits of the Mississippi River. Special paper of the Geological Society of America, Paper No. 62, pp. 279-302.

Ford, J. A. and G. I. Quimby
1945. The Tchefuncte Culture, An Early Occupation of the Lower Mississippi Valley. Menasha: Memoir of the Society for American Archaeology No. 2.

Foxworth, R. D., R. R. Priddy, W. B. Johnson, and W. S. Moore
1962. Heavy Minerals of Sand from Recent Beaches of the Gulf Coast of Mississippi and Associated Islands. Mississippi State Geological Survey Bulletin No. 93. 92 p.

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

1974. Depositional Episodes: Their Relationship to the Quaternary Stratigraphic Framework in the Northwestern Portion of the Gulf Basin. Bureau of Economic Geology, Geology Circular, Volume 74, No. 1. 28 p.

Gagliano, S. M.
1963. A Survey of Preceramic Occupations in Portions of South Louisiana and South Mississippi. Florida Anthropologist, Volume 16, No. 4, pp. 105-132.

1967. Occupation Sequence at Avery Island. Coastal Studies Institute Report No. 22. Baton Rouge: Louisiana State University.

1969. Evidence of Early Man in the Central Gulf Coast. Paper presented at the annual meeting of the Society of American Archaeology, May 1, 1969. Milwaukee.

1970. Archaeological and Geological Studies at Avery Island, 1968-1970. Baton Rouge: Coastal Studies Institute, Louisiana State University.

Gagliano, S. M. and H. Gregory
1965. Paleo-Indian Projectile Points in Louisiana. Louisiana Studies Service, Volume 4, pp. 62-67.

Gagliano, S. M. and Roger T. Saucier
1963. Poverty Point Sites in Southeastern Louisiana. American Antiquity, Volume 28, pp. 320-327.

Gagliano, S. M. and B. G. Thom
1967. Deweyville Terrace, Gulf and Atlantic Coasts. Coastal Studies Institute, Bulletin No. 1. Baton Rouge: Louisiana State University, pp. 23-41.

Gagliano, S. M. and J. L. van Beek
1970. Geologic and Geomorphic Aspects of Deltaic Processes, Mississippi Delta System. In, Hydrologic and Geologic Studies of Coastal Louisiana, Report No. 1. Baton Rouge: Center for Wetland Resources, Louisiana State University. 140 p.

1975. An Approach to Multi-Use Management in the Mississippi Delta System. In, M. L. Broussard (ed.), Deltas, Models for Exploration. Houston: Houston Geological Society, pp. 223-228.

Gagliano, S. M. and C. H. Webb
1970. Archaic-Poverty Point Transition at the Pearl River Mouth. Paper presented at the 26th annual meeting of the Southeastern Archaeological Conference, November 15, 1969. Macon, Georgia.

Gagliano, S. M., R. A. Weinstein, and E. K. Burden
1975. Archeological Investigations along the Gulf Intracoastal Waterway: Coastal Louisiana Area. Report submitted to the New Orleans District, U. S. Army Corps of Engineers.

Gater, W. L.
1976. Science. (In press.)

Ginsburg, R. N.
1964. Introduction to Recent Sedimentation. In, R. N. Ginsburg (ed.), South Florida Carbonate Sediments. Coral Gables: Institute of Marine Science, University of Florida, pp. 4-11.

Gould, H. R.
1970. The Mississippi Delta Complex. In, J. P. Morgan and R. H. Shaver (eds.), Deltaic Sedimentation, Modern and Ancient. Society of Economic Paleontologists and Mineralogists, Special Publication No. 15, pp. 3-30.

Gould, H. R. and J. P. Morgan
1962. Field Trip No. 9, Coastal Louisiana Swamps and Marshlands. In, E. H. Rainwater and R. P. Zingula (eds.), Geology of the Gulf Coast and Central Texas and Guidebook Excursions. Houston: Houston Geological Society, pp. 287-341.

Gould, H. R. and R. H. Stewart, Jr.
1955. Continental Terrace Sediments in the Northeastern Gulf of Mexico. In, J. L. Hough and H. W. Menard (eds.), Finding Ancient Shorlines. Society of Economic Paleontologists and Mineralogists, Special Publication No. 3, pp. 2-20.

Grabau, A. W.
1960. Principles of Stratigraphy. New York: Dover Publications, pp. 384-466.

Graf, C. H.
1966. The Late Pleistocene Ingleside Barrier Trend, Texas and Louisiana. Unpublished thesis on file at Rice University.

Griffin, G. M.
1962. Regional Clay-Mineral Facies - Products of Weathering Intensity and Current Distribution in the Northeastern Gulf of Mexico. Bulletin of the Geological Society of America, Volume 73, No. 2, pp. 737-768.

Haag, W. G.
1961. The Archaic of the Lower Mississippi Valley. American Antiquity, Volume 26, No. 3, pp. 317-323.

Hammond, A. L.
1976. Paleoclimate: Ice Age Earth Was Cool and Dry. Science, p. 455.

Harvey, E. J. and J. L. Nichols
1960. Stratigraphy of the Quaternary and Upper Tertiary of the Pascagoula Valley, Mississippi. In, Guidebook, Cenozoic Field Trips. Biloxi: Gulf Coast Association of Geological Societies, pp. 9-22.

Haynes, C. V., Jr.
1964. Fluted Projectile Points: Their Age and Dispersion. Science, Volume 145, (September 25).

Hemmings, E. T.
1973. Recent Excavations at Silver Springs, Marion County, Florida. Paper presented at the 25th annual meeting of the Florida Anthropological Society. Jacksonville.

Hemmings, E. T. and Kohler
1974. The Lake Kanapaha Site in North Central Florida. Tallahassee: Bureau of Historic Sites and Properties, Bulletin No. 4, pp. 45-64. Division of Archives, History, and Records Management.

Hoffmeister, J. E., J. I. Jones, J. D. Milliman, D. R. Moore, and H. G. Multer
1964. Living and Fossil Reef Types of South Florida. Coral Gables: Institute of Marine Science, University of Miami.

Hoffmeister, J. E. and H. G. Multer
1964. Pleistocene Limestones of the Florida Keys. In, R. N. Ginsburg (ed.), South Florida Carbonate Sediments. Coral Gables: Institute of Marine Science, University of Miami.

Hoffmeister, J. E., K. W. Stockmein, and H. G. Multer
1967. Miami Limestone of Florida and Its Recent Bahamian Counterpart. Bulletin of the Geological Society of America, Volume 72, pp. 1051-1058.

Holmes, Charles W.
1973. Distribution of Selected Elements in Surficial Marine Sediments of the Northern Gulf of Mexico Continental Shelf and Slope. Geological Survey Professional Paper 814, Washington, 7 p., 4 plates.

Honea, K. H.
1965. The Bipolar Flaking Technique in Texas and New Mexico. Bulletin of the Texas Archeological Society, Volume 36, pp. 259-267.

Hunter, R. E. and K. A. Dickenson
1970. Map Showing Landforms and Sedimentary Deposits of the Padre Island Portion of the South Bird Island, 7-1/2-Minute Quadrangle, Texas. U. S. Geological Survey, Miscellaneous Inventory Map I-659.

Hyne, N. J. and H. G. Goodell
1967. Submarine Geomorphology of the Inner Continental Shelf off Choctawhatchee Bay, Florida. Marine Geology, Volume 5, pp. 299-313.

Jervey, M. T.
1974. Transportation and Dispersal of Biogenic Material in the Nearshore Marine Environment. Ph.D. dissertation on file at Louisiana State University at Baton Rouge. 205 p.

Jon, J. W., Jr., et al.
1972. Environmental Geology and Hydrology, Tallahassee Area, Florida. Special Publication No. 16, State of Florida, Department of Natural Resources.

Jones, P. H.
1969. Hydrology of Neogene Deposits in the Northern Gulf of Mexico Basin. Louisiana Water Resources Research Institute Bulletin GT-2. Baton Rouge: Louisiana State University. 105 p.

Jones, P. H., A. N. Turcan, and H. E. Skibitzke
1954. Geology and Groundwater Resources of Southwestern Louisiana. Louisiana Geological Survey Bulletin No. 30. Baton Rouge: Department of Conservation.

Joor, J. F., M.D.
1895. Notes on a Collection of Archaeological and Geological Specimens Collected on a Trip to Avery Island (Petit Anse), February 1, 1890. American Naturalist, Volume 29, pp. 394-398.

Jordan, G. F.
1951. Continental Slope off Apalachicola River, Florida. Bulletin of the American Association of Petroleum Geologists, Volume 35, No. 9, pp. 1979-1993.

1952. Reef Formation in the Gulf of Mexico off Apalachicola Bay, Florida. Bulletin of the Geological Society of America, Volume 63, No. 7, pp. 741-744.

REFERENCES

Adam, D. P.

1975a. The Tropical Cyclone as a Global Stabilizing Mechanism. Geology, Volume 3, pp. 625-626.

1975b. Ice Ages and the Thermal Equilibrium of the Earth, III. Quarternary Research, Volume 5, pp. 161-171.

Alt, D. and H. K. Brooks

1965. Age of Florida Marine Terraces. Journal of Geology, Volume 73, pp. 406-411.

Ambler, R. J.

1967. Three Prehistoric Sites near Cedar Bayou, Galveston Bay Area, Texas. State Building Commission Archeology Program, Report No. 8.

1973. The Lost River Phase of the Lower Trinity River Delta. Manuscript submitted to the National Park Service, Southwestern Region, by Texas Archeological Survey. Austin: University of Texas.

Aten, L. E.

1967. Excavations at the Jamison Site (41 LB 2), Liberty County, Texas. Houston: Houston Archeological Society Report No. 1.

1971. Archeological Excavations at the Dow-Cleaver Site, Brazoria County Texas. Texas Archeological Salvage Project, Bulletin No. 1.

Aten, L. E. and C. N. Bollich

1969. A Preliminary Report on the Development of a Ceramic Chronology for the Sabine Lake Area of Texas and Louisiana. Texas Archeological Society Bulletin, Volume 40, pp. 241-258.

Bader, R. S.

1957. Two Pleistocene Mammalian Faunas from Alachua County, Florida. Florida State Museum Bulletin, Volume 2, pp. 52-75.

Bergantino, R. N.

1971. Submarine Regional Geomorphology of the Gulf of Mexico. Bulletin of the Geological Society of America, Volume 82, pp. 741-752.

Bernard, H. A.

1950. Quaternary Geology of Southeast Texas. Unpublished Ph.D. dissertation on file at Louisiana State University at Baton Rouge. 165 pp.

1965b. Significance of Dimensions of Big Sandy I-Like Projectile Points in Northwest Florida. Florida Anthropologist, Volume 18, No. 3, pp. 187-199.

LeBlanc, R. J.
1972. Geometry of Sandstone Reservoir Bodies in Underground Waste Management and Environmental Implications. American Association of Petroleum Geologists Memoir No. 18, pp. 133-190.

Leidy, J.
1866. Remarks. Philadelphia: Proceedings of the Academy of Natural Sciences of Philadelphia, p. 109.

1899a. Notice of Some Fossil Human Bones. Transactions of the Wagner Free Institute of Science of Philadelphia, Volume 2, pp. 9-12.

1899b. Notice of Some Mammalian Remains from the Salt Mines of Petit Anse, Louisiana. Transactions of the Wagner Free Institute of Science of Philadelphia, Volume 2, pp. 33-40.

Lindall, W. L. et al.
1971. Louisiana Coastal Zone: Analysis of Resources and Resource Management in Connection with Estuarine Ecology. Florida National Marine Fisheries Service. 323 p.

Lindsay, J. F., T. H. Shipley, and J. L. Worzel
1975. Role of Canyons in the Growth of the Campeche Escarpment. Geology, Volume 3, pp. 533-36.

Logan, B. W. et al.
1969. Carbonate Sediments and Reefs, Yucatan Shelf, Mexico. American Association of Petroleum Geologists Memoir No. 11, pp. 1-198.

Ludwick, J. C.
1964. Sediments of Northeastern Gulf of Mexico. In, R. L. Miller (ed.), Papers in Marine Geology, Shepard Commemorative Volume. New York: Macmillan Co., pp 204-238.

Ludwick, J. C. and W. R. Walton
1957. Shelf Edge Calcareous Prominences in Northeastern Gulf of Mexico. Bulletin of the American Association of Petroleum Geologists, Volume 41, No. 9, pp. 2054-2101.

Lundelius, E. L., Jr.
1972. Fossil Vertebrates from the Late Pleistocene Ingleside Fauna San Patricio County, Texas. Austin: Bureau of Economic Geology, Report of Investigation No. 77, University of Texas.

McFarlan, E., Jr.
1961. Radiocarbon Dating of Late Quaternary Deposits, South Louisiana. Bulletin of the American Association of Petroleum Geologists, Volume 72, No. 1, pp. 129-158. 9 figures.

McIntire, W. G.
1958. Prehistoric Indian Settlements of the Changing Mississippi River Delta. Coastal Studies Series Report No. 1. Baton Rouge: Louisiana State University.

1959. Methods of Correlating Cultural Remains with Stages of Coastal Development. In, R. J. Russell (ed.), Second Coastal Geography Conference, pp. 341-359.

McIntyre, A. and Members of the Climat Project
1976. Surface of the Ice Age Earth, Science 191, pp. 1131-37.

MacDonald, G. F.
1968. Debert: A Paleo-Indian Site in Central Nova Scotia. Anthropology Papers No. 16, Museums of Canada. 207 p.

MacNeil, S.
1950. Pleistocene Shorelines in Florida and Georgia. U. S. Geological Survey Professional Paper 221-F, pp. 95-107.

MacNeish, R. S.
1976. Early Man in the New World. American Scientist, Volume 64, No. 3 (May and June).

Macintyre, I. G., B. W. Blackwelder, L. S. Land, and R. Stuckenrath
1975. North Carolina Shelf Edge Sandstone: Age, Environment of Origin, and Relationship to Pre-Existing Sea Levels. Bulletin of the Geological Society of America, Volume 86, pp. 1073-1078.

Martens, J. H. C.
1936. Beaches of Florida. Florida State Geological Survey, 21st and 22nd annual reports, pp. 67-119.

Martin, P. S., G. I. Quimby, and D. Collier
1947. Indians Before Columbus: Twenty Thousand Years of North American History Revealed by Archaeology. Chicago: University of Chicago Press.

Mason, R. J.
1962. The Paleo-Indian Tradition in Eastern North America. Current Anthropology, Volume 3, No. 3, pp. 227-246.

Mattison, G. C.
1948. Bottom Configuration in the Gulf of Mexico. Journal of Coastal and Geodetic Survey, Volume 1, pp. 78-82.

Moore, C. B.
1913. Some Aboriginal Sites in Louisiana and Arkansas. Journal of Natural Sciences of Philadelphia, Volume 16, pp. 7-99.

Mickelson, D. M. and E. B. Evenson
1975. Pre-Two Creekan Age of the Type Valders Till, Wisconsin. Geology, Volume 3, pp. 587-590.

Milliman, J. D. and K. O. Emery
1968. Sea Levels during the Past 35,000 Years. Science, Volume 162, pp. 1121-1123.

Moran, J. M.
1975. Return of the Ice Age and Drought in Peninsular Florida. Geology, Volume 3, pp. 695-696.

Morgan, J. P., J. M. Coleman, and S. M. Gagliano
1968a. Mudlumps at the Mouth of South Pass, Mississippi River: Sedimentology, Origin, and Relation to Deltaic Processes. Coastal Studies Series No. 10. Baton Rouge: Louisiana State University. 190 p.

1968b. Mudlumps: Diapiric Structures in Mississippi Delta Sediments. American Association of Petroleum Geologists Memoir No. 8.

Muller-Beck, H.
1966. Paleohunters in America: Origins and Diffusion. Science, Volume 152 (May 27).

Neil, W. T.
1958. A Stratified Early Site at Silver Springs, Florida. Florida Anthropologist, Volume 16, No. 4, pp. 99-104.

1964. The Association of Suwanee Points and Extinct Animals in Florida. Florida Anthropologist, Volume 17, No. 1, p. 17.

Nelson, H. T., and E. T. Bray
1970. Stratigraphy and History of the Holocene Sediments in the Sabine-High Island Area, Gulf of Mexico. In, J. P. Morgan and R. H. Shaver (eds.), Deltaic Sedimentation, Modern and Ancient. Society of Economic Paleontologists and Mineralogists, Special Publication No. 15, pp. 48-77. 13 figures, 5 pl.

Neumann, A. C.
1958. The Configuration and Sediments of Stetson Bank, Northwestern Gulf of Mexico. Project 24, Section VII, Res. Rept. Texas A & M University, Department of Oceanography and Meteorology. 125 p., 18 figs., 5 tbs.

Neumann, A. C. and W. S. Moore
1975. Sea Level Events and Pleistocene Coral Ages in the Northern Bahamas. Quaternary Research, Volume 5, pp. 215-224.

Newman, W. S.
1968. Coastal Processes. In, R. W. Fairbridge (ed.), The Encyclopedia of Geomorphology. New York: Reinhold Book Corp., pp. 150-155.

Osmond, J. K., J. P. May, and W. F. Tanner
1970. Age of the Cape Kennedy Barrier-and-Lagoon Complex. Journal of Geophysical Research, Volume 75, pp. 469-479.

Otvos, E. G.
1972a. Pre-Sangamon Beach Ridges along the Northeastern Gulf Coast - Fact or Fiction? Transactions of the Gulf Coast Association of Geologic Societies, Volume 22, pp. 223-228.

1972b. Mississippi Gulf Coast Pleistocene Beach Barriers and the Age Problem of the Atlantic-Gulf Coast "Pamlico"-"Ingleside" Beach Ridge System. Southeastern Geology, Volume 14, No. 4, pp. 241-250.

1973. Geology of the Mississippi-Alabama Coastal Area and Nearshore Zone. New Orleans Geological Society Field Trip Guidebook. 67 p.

1975a. Ingleside Strandplain Sand of Central Texas Coast: Discussion. Bulletin of the American Association of Petroleum Geologists, Volume 59, No. 12 (December).

1975b. Southern Limits of Pleistocene Loess, Mississippi Valley. Southeastern Geology, Volume 17, No. 1 (September).

Owen, R.
1863. On a Quarternary Rock Salt Deposit in Louisiana. Transactions of the St. Louis Academy of Sciences, Volume 2, pp. 250-252.

Pampe, W. R.
1971. A New Pleistocene Marine Fossil Locality in Chambers County, Texas. Bulletin of the Gulf Coast Association of Geological Societies, Volume 21, pp. 395-410.

Parker, R. H.
1960. Ecology and Distributional Patterns of Marine Macroinvertebrates, Northern Gulf of Mexico. In, E. P. Shepard et al. (eds.), Recent Sediments, Northwest Gulf of Mexico. Bulletin of the American Association of Petroleum Geologists, pp. 302-337.

Parker, R. H. and J. R. Curray
1956. Fauna and Bathymetry of Banks on Continental Shelf, Northwest Gulf of Mexico. Bulletin of the American Association of Petroleum Geologists, Volume 40, No. 10, pp. 2428-2439. 6 figs., 1 pl.

Pearson, F. J., E. M. Davis, M. A. Famere, and R. W. Johnstone
1965. University of Texas Radiocarbon Dates, III. Radiocarbon Volume 7, pp. 296-314.

Phillips, Philip
1970. Archaeological Survey in the Lower Yazoo Basin, Mississippi, 1949-1955. Papers of the Peabody Museum of Archaeology and Ethnology, Volume 60. Cambridge: Harvard University Press. 2 Volumes.

Poag, C. W.
1972. Shelf-Edge Submarine Banks in the Gulf of Mexico: Paleoecology and Biostratigraphy. Transactions of the Gulf Coast Association of Geological Societies, Volume 22, pp. 267-287. 19 figs., 2 pls.

1973. Late Quaternary Sea Levels in the Gulf of Mexico. Transactions of the Gulf Coast Association of Geological Societies, Volume 23, pp. 394-400.

Poag, W. C. and W. E. Sweet
1972. Geology of Claypile Bank, Texas Continental Shelf. In, V. J. Henry and R. Rezak (eds.), Contributions on the Geological and Geophysical Oceanography of the Gulf of Mexico. Texas A & M University Oceanographic Studies, Volume 3, pp. 223-261. 20 figs.

Price, W. A.
1933. The Role of Diastrophism in the Topography of the Corpus Christi Area, South Texas. Bulletin of the American Association of Petroleum Geologists, Volume 17, pp. 907-962.

1954. Dynamic Environments: Reconnaissance Mapping, Geologic and Geomorphic, of Continental Shelf of Gulf of Mexico. Transactions of the Gulf Coast Association of Geological Societies, Volume 4, pp. 75-107.

1958. Sedimentology and Quaternary Geomorphology of South Texas. Transactions of the Gulf Coast Association of Geological Societies, Volume 8, pp. 41-75.

1968. Barriers - Beaches and Islands. In, R. W. Fairbridge (ed.), The Encyclopedia of Geomorphology, III. New York: Reinhold Book Corp., pp. 51-53.

Purdy, B. A.
1973. The Senator Edwards Chipped Stone Workshop Site (Mr 122), Marion County, Florida: A Preliminary Report of Investigations. Paper presented at the 38th annual meeting of the Society for American Archaeology. San Francisco.

Pyle, T. E., W. R. Bryant, and J. W. Antoine
1974. Structural Framework of the West Florida Continental Shelf and Recommendations for Further Research. Proceedings of Marine Implications of Offshore Drilling, Eastern Gulf of Mexico: 1974. University of Southern Florida and Florida Department of Natural Resources, pp. 295-300.

Quimby, G. I., Jr.
1956. The Locus of the Natchez Pelvis Find. American Antiquity, Volume 22, No. 1, pp. 77-79.

Rehkemper, L. J.
1969. Sedimentology of Holocene Estuarine Deposits, Galveston Bay. In, R. R. Lankford and J. J. W. Rofers (eds.), Holocene Geology of the Galveston Bay Area. Houston: Houston Geological Society, pp. 12-52.

Rezak, R. and W. R. Bryant
1973. West Flower Gardens Bank. Transactions of the Gulf Coast Association of Geological Societies, Volume 23, pp. 377-382.

Rolingson, M. A. and D. W. Schwartz
1966. Late Paleo-Indian and Early Archaic Manifestations in Western Kentucky. Lexington: University of Kentucky Press.

Royal, W. and E. Clark
1960. Natural Preservation of Human Brain, Warm Mineral Springs, Florida. American Antiquity, Volume 26, No. 2, pp. 285-287.

Ruppe, Reynold.
Personal communication.

Rusnak, G. A.
1960. Sediments of Laguna Madre, Texas. In Recent Sediments, Northwest Gulf of Mexico, 1951-1958. American Association of Petroleum Geologists, pp. 153-196.

Russell, R. J.
1967. Plains and Sea Coasts. Berkeley and Los Angeles: University of California Press. 173 p.

Saucier, Roger T.
1963. Recent Geomorphic History of the Lake Pontchartrain Basin, Louisiana. Coastal Studies Institute Series, No. 9. Baton Rouge: Louisiana State University.

1967. Geological Investigations of the Boeuf-Tensas Basin, Lower Mississippi Valley. U. S. Army Waterways Experiment Station, Technical Report No. 3-757.

1974. Quaternary Geology of the Lower Mississippi Valley. Arkansas Archeological Survey, Research Series No. 6.

1977. The Northern Gulf Coast during the Farmdalian Substage: A Search for Evidence. Environmental Effects Laboratory, U. S. Army Engineer Waterways Experiment Station, Miscellaneous Paper No. Y-77-1. 39 p.

Schnable, J. E. and H. G. Goodell
1968. Pleistocene Recent Stratigraphy, Evolution, and Development of the Apalachicola Coast, Florida. Geological Societies of America Special Paper No. 112. 72 p.

Scholl, D. W.
1964. Recent Sedimentary Record in Mangrove Swamps and Rise in Sea Level Over the Southwestern Coast of Florida. Marine Geology, Volume 1, pp. 334-466; Volume 2, pp. 343-364. In two parts.

Scholl, D. W. and M. Stuiver
1967. Recent Submergence of Southern Florida: A Comparison with Adjacent Coasts and Other Eustatic Data. Bulletin of the Geologic Society of America, Volume 78, pp. 437-454.

Scholl, D. W., F. C. Craighead, and M. Stuiver.
1969. Florida Submergence Curve Revised: Its Relation to Coastal Sedimentation Rates. Science, Volume 163, pp. 562-564.

Sellards, E. H.
1916. Human Remains and Associated Fossils from the Pleistocene of Florida. Florida Geological Survey, Eighth Annual Report, pp. 121-160.

1917. On the Association of Human Remains and Extinct Vertebrates at Vero, Florida. Journal of Geology, Volume 25, pp. 4-24.

1919. The Geology and Mineral Resources of Bexar County. Austin: University of Texas Bulletin, 1932.

1940. Pleistocene Artifacts and Associated Fossils from Bee County, Texas. Bulletin of the Geological Society of America, Volume 51, pp. 1627-1658.

1952. Early Man in America: A Study in Prehistory. Austin: University of Texas Press.

Shepard, F. P. and D. G. Moore
1955. Central Texas Coast Sedimentation: Characteristics of Sedimentary Environment, Recent History, and Deagenesis. Bulletin of the American Association of Petroleum Geologists, Volume 39, Part 2, No. 8, pp. 1463-1493.

Shepard, F. P. and H. R. Wanless
1971. Our Changing Coastalines. New York: MacGraw-Hill. 563 p.

Shier, D. E.
1969. Vermetid reefs and Coastal Development in the Ten Thousand Islands, Southwest Florida. Geological Society of America Bulletin, Volume 80, p. 485-508.

Shumway, G., G. B. Dowling, G. Slasman, and R. H. Payne
1962. Submerged Forest of Mid-Wisconsin Age on the Continental Shelf off Panama City, Florida. Geological Society of America, Special Paper No. 68, p. 271.

Smith, F. G. W.
1971. Atlantic Coral Reefs. Coral Gables : University of Miami.

Smith, W. G.
1968. Sedimentary Environments and Environmental Change in the Peat-Forming Area of South Florida. Ph.D. dissertation on file at Pennsylvania State University. 254 p.

Snow, C. E.
1945. The Skeletal Remains. In, The Tchefuncte Culture, An Early Occupation of the Lower Mississippi Valley. Memoir of the Society for American Archaeology, No. 2.

Snowden, J. O. and R. R. Priddy
1968. Loess Investigations in Mississippi. Mississippi Geologic, Economic and Topographic Survey, Bulletin III.

Spackman, W., D. W. Scholl, and W. H. Taft
1964. Field Guidebook to Environments of Coal Formation in Southern Florida. Preconvention field trip guide of the Geological Society of America.

Stewart, T. D.
1951. Antiquity of Man in America Demonstrated by the Fluorine Test. Science, Volume 113, pp. 391-392.

Suhm, D. A. and E. B. Jelks
1962. Handbook of Texas Archeology: Type Descriptions. Texas Archeological Society, Special Publication No. 1, and Texas Memorial Museum Bulletin No. 4.

Swift, D. J. P., D. J. Stanley, and J. R. Curray
1971. Relict Sediments on Continental Shelves: A Reconsideration. Journal of Geology, Volume 79, pp. 322-346.

Tanner, W. F.
1960. Florida Coastal Classification. Transactions of the Gulf Coast Association of Geological Societies, Volume 10, pp. 259-266.

Thom, B. G.
1971. The Dilemma of High Interstadial Sea Levels during the Last Glaciation. Progress in Geography, Volume 5, pp. 170-246.

Trickey, E. B. and N. H. Holmes, Jr.
1971. A Chronological Framework for the Mobile Bay Region, Revised, 1970. Journal of Alabama Archeology, Volume 17, No. 2.

Tunnell, J. W. and B. D. Causey
1969. Vertebrate Pleistocene Fossils from the Continental Shelf, Northwestern Gulf of Mexico. Texas A & M University Studies, Volume 2, pp. 193-203.

van Lopik, J. R.
1955. Recent Geology and Geomorphic History of Central Coastal Louisiana. Coastal Studies Institute, Technical Report No. 7. Baton Rouge: Louisiana State University. 89 p.

Veatch, A. C.
1899. The Five Islands. In, G. D. Harris and A. C. Veatch (eds.), A Preliminary Report on the Geology of Louisiana. Special Report No. 3, pp. 213-262.

Vergnaud Grazzini, C.
1975. ^{18}O Changes in Foraminifera Carbonates during the Last 10^5 Years in the Mediterranean Sea. Science, Volume 190, pp. 272-274.

Watts, W. A.
1975. A Late Quaternary Record of Vegetation from Lake Annie, South-Central Florida. Geology, Volume 3, pp. 344-347.

Webb, C. H.
1948. Evidence of Pre-Pottery Cultures in Louisiana. American Antiquity, Volume 9, pp. 386-394.

Weigel, R. D.
1962. Fossil Vertebrates of Vero, Florida. Tallahassee: Florida Geological Survey, Special Publication No. 10.

Willey, G. R.
1949. Archeology of the Florida Gulf Coast. Smithsonian Miscellaneous Collections, Volume 113. 599 p., 60 pls.

1966. An Introduction to American Archeology, Volume I - North and Middle America. Englewood Cliffs: Prentice Hall. 526 p.

Williams, S. and J. B. Stoltman
1965. An Outline of Southeastern United States Prehistory, with Particular Emphasis on the Paleo-Indian Era. In, H. E. Wright and D. G. Frey (eds.), The Quaternary of the United States. Princeton: Princeton University Press, pp. 669-684.

Wilkinson, J. H. McGowan, and C. N. Lewis
1975. Geologic Notes. In, Bulletin of the Geological Society of America, Volume 59, No. 2 (February), pp. 349-350.

Wilson, M. T.
1895. On the Presence of Fluorine as a Test for the Fossilization of Animal Bones. American Naturalist, Volume 29, pp. 301-317, 439-456, and 719-725.

Winchester, P. D.
1971. Geology of the Freeport Rocks, Offshore Texas. Transactions of the Gulf Coast Association of Geological Societies, Volume 21, pp. 211-222.

Wolman, M. G. and L. B. Leopold
1957. River Flood Plains: Some Observations on Their Formation. U. S. Geological Survey, Professional Paper No. 282-C.

Wormington, H. M.
1957. Ancient Man in North America. Denver Museum of Natural History, Popular Series No. 4.