Recent Geomorphic History of the Pontchartrain Basin

BY

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INTRODUCTION

The Pontchartrain Basin is a large, nearly enclosed, lowland area located on the margin of the deltaic plain of southeastern Louisiana. Over one-half of the total area is occupied by two shallow lakes; the larger, Lake Pontchartrain, and the smaller, Lake Maurepas (Fig. 1). Since the surrounding lowlands are environmentally closely related to the lakes, the basin is a relatively homogeneous physiographic unit. To the north and west are a geologically older and different formation and environment. Along the southern margin, the Mississippi River and its abandoned distributaries separate the basin from similar ones to the south (Fig. 1).

The Recent geomorphic history of the Pontchartrain Basin involves the relationship between an embayment of the Gulf of Mexico and shifting courses and distributaries of the Mississippi River. Deltaic sedimentation initially transformed the area from a marine to a lacustrine environment as it is today. The physiography of the area depends upon the degree of balance maintained between deposition and accretion on one hand, and subsidence, erosion, and redistribution of sediments on the other. An attempt is made to reconstruct the degree of balance throughout the history of the basin in sequential order.

During the past several decades, extensive work by Russell (1936, 1940), Fisk (1944, 1947, 1955), and others has helped establish a firm foundation for an understanding of deltaic processes and regional deltaic patterns. This background has helped subsequent workers to make detailed studies of specific problems or areas in the deltaic plain. Studies of this type have been made for parts of the Pontchartrain Basin (Fisk, 1947a, 1947b, 1955), but this is the first attempt at a detailed study of the entire area.

In the reconstruction of the geomorphic history of the basin, frequent references are made to information obtained from a study of Indian sites. Kniffen (1936) was one of the first to point out the significance of Indian occupational patterns and chronology in interpreting deltaic sequences in Louisiana. Later, McIntire (1954) successfully employed this type of data in establishing a chronological check for the deltaic sequences of coastal Louisiana.

Field work for this study was conducted mainly during the summers of 1957, 1958, and 1959. After a careful study of maps and aerial photographs, a general reconnaissance was made to familiarize the writer with the area as a unit. Subsequent work focused on identifying, describing, and interpreting the origin of landforms. Particular attention was placed on establishing the relationship between landforms in producing the over-all pattern.

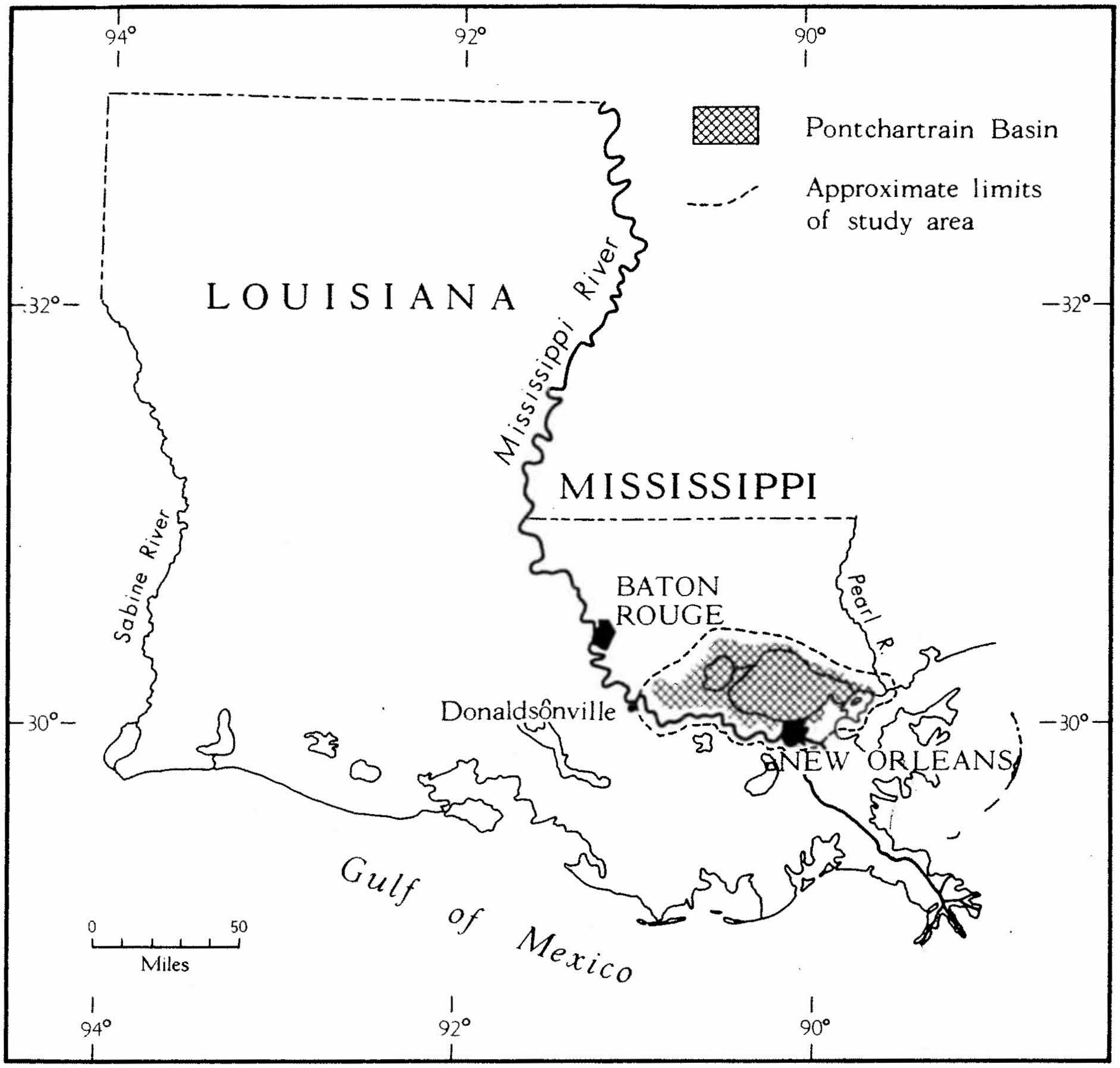


Fig. 1. Map showing the location of the Pontchartrain Basin and approximate limits of the study area.

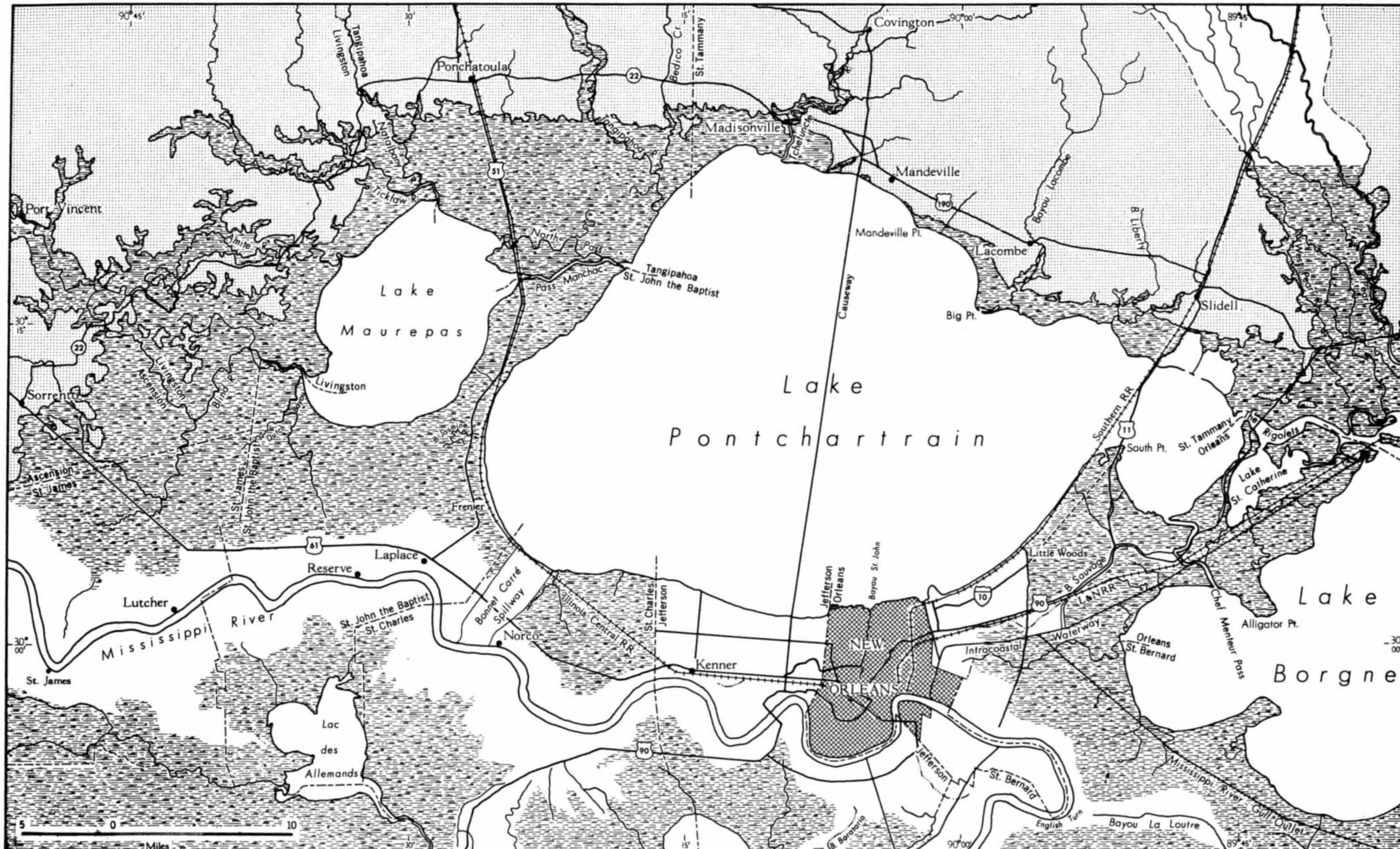


Fig. 2. Index map of the Pontchartrain Basin.

In studies of alluvial morphology, it is necessary to consider the entire area in three dimensions as well as individual landforms. To gather subsurface data, numerous shallow borings were made with a powered drilling rig in accessible areas and with a hand auger in the marsh and swamp. To supplement these, logs of many additional borings were obtained from other sources. A total of over 5000 borings were used in the study to determine the extent and sedimentary structure of both the visible and buried landforms.

Throughout the field investigation, attention was devoted to locating sites of Indian occupancy, collecting artifacts whenever possible, and determining the relationships between the sites and the underlying landforms. In the laboratory, collections were analysed and classified to determine the relative age and duration of occupancy of the sites. During the survey, a total of 140 sites were located and collections totalling approximately 20,000 sherds of pottery and other artifacts were obtained from 57 sites (Fig. 10).

When zones of peat or organic materials were encountered in borings or in archaeological sites, samples were taken for possible radiocarbon datings. Eighteen samples were considered significant enough to be dated. In addition, 39 other radiocarbon datings on materials from the area were available. These were used to supplement the archaeological data and to help establish a chronological framework for the basin.

After a discussion of the present physiography, the basin's geomorphic history is reconstructed, centering around a series of maps showing the postulated conditions for selected dates in the past. Both geomorphological and archaeological evidence is given in support of the establishment of several stages in the development of the Pontchartrain Basin.

GENERAL SETTING

The Pontchartrain Basin is located in the Mississippi River deltaic plain of southeastern Louisiana between 29°55' and 30°25' North Latitude and 89°40' and 90°50' West Longitude. The present course of the Mississippi River between Donaldsonville on the west and New Orleans on the east marks the southern boundary of the basin (Fig. 2). A line extending east from Baton Rouge marks the maximum northern limit.

The basin is roughly oval in shape with its major axis extending about 75 miles in an east-west direction from a point about 8 miles east of Donaldsonville to the mouth of Pearl River (Fig. 2). The minor axis is about 35 miles long (Madisonville to New Orleans) and the basin includes approximately 1600 square miles. Of this total area, about 45 per cent is occupied by Lakes Pontchartrain and Maurepas (630 and 93 square miles, respectively).

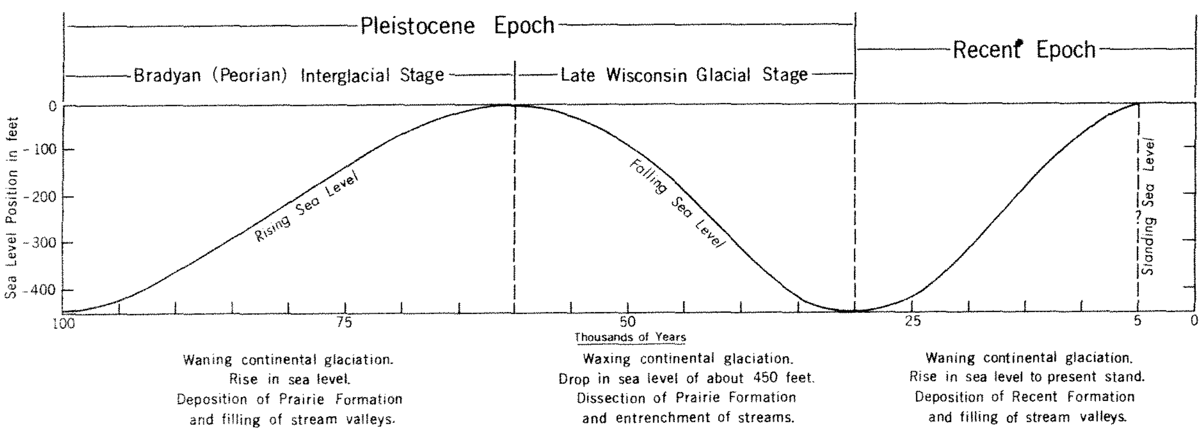
Numerous small towns and settlements flank the basin on the terrace lands to the north and along the Mississippi River to the south (Fig. 2). New Orleans, located largely between the Mississippi River and Lake Pontchartrain, is the largest urban center. The population of the basin proper is quite low, largely because of the extensive areas of swamp and marsh. A few settlements are present, however, largely in Orleans Parish, and consist of hunting and fishing camps, services, and recreational facilities.

GEOLOGY AND TOPOGRAPHY

The sediments in the Pontchartrain Basin consist largely of alluvium deposited by the Mississippi River and to a minor extent by streams entering from the north. Following Russell's definition of Recent (1940, p. 1201) as being that period during which the last major eustatic rise in sea level has occurred, all sediments in the basin were deposited during Recent times. Estimates of the length of the Recent Epoch vary from 15,000 years (Trowbridge, 1954) to more than 35,000 years (McFarlan, 1961). This report will be basically concerned, however, with approximately the last 5000 years of the epoch during which time the seas had reached their approximate present level (Fig. 3).

The slightly higher Prairie terrace surface north and west of the basin is the youngest of four generally recognized Pleistocene terraces in Louisiana (Fisk, 1939, p. 186). Each is a depositional formation dating from Pleistocene interglacial periods. The Prairie formation dips southward and underlies the Recent deposits of the Pontchartrain Basin as well as the entire Mississippi deltaic plain (Fisk and McFarlan, 1955, p. 290). Influences exerted by the buried formation on events in the basin's history are discussed in detail later.

Similar to most deltaic plain environments, the Pontchartrain Basin is one of low elevation, low relief, and gentle slopes. The highest elevations and greatest relief in the area occur on the Prairie terrace surface. In the basin proper, the natural levees of the



Adapted from Fisk and McFarlan (1955) and Van Lopik (1955).

Fig. 3. Late Quaternary events and chronology, Louisiana Gulf Coast.

Mississippi River and its abandoned distributaries form the most conspicuous topographic features. Along the present river course, levee crests reach a maximum elevation of about 23 feet above mean Gulf level (MGL) and average from 12 to 15 feet. Distributary natural levee crests usually do not exceed 10 feet in elevation. At least 40 per cent of the basin area consists of relatively flat swamps and marshes. These closely approximate mean Gulf level and even in inland positions, rarely stand more than three feet above MGL.

A considerable area in the vicinity of New Orleans lies well below mean Gulf level, but this is not a natural condition. These are former swamp and marsh areas that were ringed with levees and artificially drained to produce habitable land. Dehydration of the sediments has resulted in considerable compaction, in some cases as much as nine feet.

SEDIMENTS

The landforms of the Pontchartrain Basin are composed of fine-grained and rather unconsolidated sediments. Silts and silty clays predominate in the landforms of alluvial origin while those of marine origin consist largely of sand.[1] Coarse sand and fine gravel are the maximum grain sizes encountered in the area. Sediments vary appreciably from one landform type and environment of deposition to another, but each has an identifiable and distinguishing range of sedimentary characteristics. In general, nearly all types are characterized by a relatively high organic and water content.

Prior to the beginning of Mississippi River activity in the basin, sediments were derived from two main sources. Streams draining the Pleistocene terraces to the north introduced varying quantities of silts, sands, and fine gravels to the basin area. Additional sediments were eroded from Pleistocene and Recent deposits of the continental shelf during the last major sea level rise. Materials from both sources were reworked by marine processes and deposited as a distinct zone overlying the buried Prairie surface during the early history of the basin.

The greatest portion of the basin's history, approximately the last 4000 years, was characterized by active sedimentation by the Mississippi River. The resulting sedimentary unit is in the form of a seaward-thickening wedge which overlies and almost completely covers all features of the previous marine zone. Active deposition of clays, silty clays, silts, and small quantities of very fine sand by the Mississippi River occurred as a result of at least three major shifts in the course of the river. The first two shifts resulted in the development of deltas largely marginal to but partially within the present area of the basin. These are evidenced by systems of abandoned distributaries and large areas of organic clays and peats deposited in inter-levee basins. The third shift resulted in the

[1] All grain-size designations are from the U.S. Bureau of Soils Classification.

establishment of the river along its present course and introduced a somewhat less significant quantity of sediments to the basin area.

CLIMATE

The Pontchartrain Basin has a pronounced humid subtropical climate which reflects the proximity of the Gulf of Mexico. Precipitation, almost exclusively in the form of rain, is moderate and well distributed throughout the year. Summer temperatures are warm to hot and winters are relatively mild, but not without occasional frost.

During the warm season (May to September), moist air from the Gulf causes almost daily scattered afternoon and evening thundershowers. The mean annual rainfall for the basin varies from about 59 inches in the western portion to about 64 inches in the eastern portion.[2] Of this amount, about 18 inches occurs during the months of June, July, and August with July being the wettest month (U. S. Weather Bureau, 1959). Maximum summer temperatures, although uncomfortable because of high humidity, rarely exceed 95°F.

During the winter months, cold fronts periodically move across the area and bring several days of cold dry air, high atmospheric pressure, and clear skies. As this condition slowly deteriorates (the cold continental air is replaced by tropical air), temperatures rise and frequently light but widespread rainfall occurs. The mean January temperature is 55°F. and is relatively uniform across the area. Spring and fall months represent transitional stages between summer and winter weather types. In general, fall months resemble the summers, especially in rainfall patterns, and spring months resemble the winters.

Hurricanes and less severe tropical storms occasionally strike the basin area during the summer and fall months, especially during September. The storms, although greatly variable in size and intensity, are normally accompanied by high winds (storms with winds of 74 miles per hour or greater are designated as hurricanes) and may produce 10 or more inches of rainfall in a 48- to 72-hour period. Strong

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[2]Until several years ago, all weather stations in the basin area were located around the margins of the lakes. No actual recorded data were available to indicate weather conditions over Lakes Pontchartrain and Maurepas. Observations by the U. S. Weather Bureau at New Orleans, including the plotting of thundershowers by radar, indicated noticeably less summer rainfall over the lakes (Personal communication, 1960).

With the completion of the Lake Pontchartrain Causeway in 1957, a weather station was established about eight miles south of the north shore of the lake. An incomplete 30-month record indicates an appreciable rainfall deficit in all months of the year, especially during the summer. A much longer period of record is needed, however, before any conclusions can be reached regarding average rainfall amounts.

winds are normally restricted to a small area near the storm center and rarely are severe effects felt beyond a 100-mile radius.

Since 1900, the Pontchartrain Basin area has directly experienced eight tropical storms and six hurricanes (Tannehill, 1956). Of the latter, the storms of 1909, 1915, and 1947 are considered as truly major hurricanes. Each of these was accompanied by heavy rainfall, winds in excess of 100 miles per hour, and widespread flooding of lowland areas.

In terms of morphological changes, hurricane-created storm tides are by far the most significant factor. These develop in widely varying degrees depending upon such factors as the direction of storm movement, storm intensity, slope of the ocean bed, and configuration of the coastline (Tannehill, 1956, p. 34). In the cases of the three above-mentioned hurricanes, the Pontchartrain Basin was ideally situated for the development of exceptional storm tides. Steinmayer (1939, p. 10) summarizes the effects of the September 1915 hurricane on Lake Pontchartrain.

> The normal elevation of the lake is about 0.3 foot above mean Gulf level, but during this storm it rose to a height of 13 feet near the woods of Frenier (southwestern corner of the lake), and 6 feet above that level in the open spaces near Pass Manchac (see Fig. 2). In addition to battering a high railroad bed on the west side of the lake, other changes, both in the configuration of its shore line and in the character of its sediments, were brought about by the violent agitation and tremendous shoreward sweep of the lake waters.

Judging from the descriptions of hurricane-induced morphological changes which have occurred in similar environments (Morgan, *et al.*, 1958), several types of change may occur during a major storm. These include shoreline retreat, destruction of beaches, deposition of a thin veneer of silt in swamp and marsh areas, destruction or modification of vegetation, and either scouring or filling of tidal channels. Since neither a hurricane nor a tropical storm of significant intensity occurred in the basin area during the writer's field observations and since the descriptions of past storms contain little or no reference to precise morphological changes, no accurate evaluations of such modifications can be made.

HYDROGRAPHY

Lakes Pontchartrain and Maurepas are shallow, relatively flat-bottomed, fresh to brackish water bodies indirectly connected to the Gulf of Mexico. The maximum natural depths of the lakes, which occur toward their southeastern corners, are 16 feet and 12 feet, respectively. About 75 per cent of the area of Lake Pontchartrain, however, is 10 feet or greater in depth (Steinmayer, 1939, p. 2). Numerous small lakes and lagoons are present, especially in Orleans Parish (Fig. 2), and these are not more than four to six feet deep.

Lake Maurepas is connected to Lake Pontchartrain by two channels or passes, Pass Manchac and North Pass (Fig. 2). During hictoric times, Pass Manchac has been straightening its course and enlargening its channel at the expense of North Pass which is filling in and accentuating its meandering pattern. Frequently reversing currents in Pass Manchac have scoured it to considerable depths, greater than 50 feet at several points along its course.

At its eastern end, Lake Pontchartrain is connected to Lake Borgne (which in turn is connected to the Gulf of Mexico by way of Mississippi Sound) by two major and several minor passes (Fig. 2). The largest pass, The Rigolets, has an average width of about 2500 feet and a maximum depth of 88 feet (U. S. Army Engineer Quadrangle "Rigolets," 1957 ed.). Chef Menteur Pass, although narrower and more sinuous, is deeper.

In the basin area, no streams are tributary to the Mississippi River. All precipitation falling in the basin area eventually enters Lake Pontchartrain and thence the Gulf. In addition, the lakes are analogous to an estuary of several small rivers which drain the Pleistocene terraces and older formations to the north. From west to east, the more important streams are the Amite, Tickfaw, Natalbany, Tangipahoa, and Tchefuncte rivers (Fig. 2). The discharge of these streams is not great, the average being 3740-cubic-feet-per-second (U. S. Geological Survey, 1958). This is less than one per cent of the normal stage discharge of the Mississippi River. Even the combined maximum discharge of the streams is appreciably less than the mean low water discharge of the Mississippi River. During low water stages, the discharge of these streams may drop so low that their lower stretches come under the direct influence of tidal variations in the lakes and may experience a reversal in flow.

The marsh and swamp areas contain numerous small sluggish drainage channels commonly called bayous (Fig. 4a). They usually have a tightly meandering pattern and numerous branching tributaries. The frequently changing direction and volume of flow in the streams depends upon local rainfall and changes in the level of the lakes. Blind River is the largest stream of this type in the basin area (Fig. 2). In eastern Orleans Parish, the drainage channels are more complexly interwoven with numerous small lakes and ponds, a partial reflection of active subsidence.

Tides and Currents

The frequent and often appreciable changes in the water levels of Lakes Pontchartrain and Maurepas are not primarily caused by periodic tidal variations. Nearly all changes are the result of variations in the direction, force, and duration of the wind. The periodic tidal range in Lake Pontchartrain is about 0.2 feet (Marmer, 1954, p. 109).

During the winter, when the wind is frequently from the north or northwest, lake levels may average one to two feet lower than during the summer. This is the result of a net movement of water from the lakes into the Gulf. Abrupt changes in wind direction, such as those which often accompany the passage of a cold front, may cause a rapid change in lake level. A rise or fall of six inches in an hour has been observed on the shore of Lake Pontchartrain on several occasions. The effects which hurricanes can have on water levels has already been pointed out. Strong winds and heavy rainfall which occasionally accompany convectional thundershowers normally create localized turbulence but have little effect on over-all lake levels.

As a result of frequently changing lake levels, strong and irregular currents often characterize the major passes, particularly The Rigolets. The ordinary maximum velocity in this pass is 0.6 knots but extreme velocities of 3.75 knots have been observed (U. S. Coast and Geodetic Survey, 1949, p. 297). At present, little is known about currents in the lakes proper. Observations by the writer suggest that a slight counter-clockwise circulation may be present in both lakes.

The salinity of Lake Pontchartrain averages less than six parts per thousand but varies widely with location and season. Least salinity occurs in the northwestern portion of the lake during the winter and spring months. Values as low as 1.2 parts per thousand (following a heavy January rainfall) and as high as 18.6 parts per thousand (following a September tropical storm) have been observed in the lake (Darnell, 1958, p. 357). Although specific salinity values for Lake Maurepas are not available, the lake is undoubtedly much fresher than Lake Pontchartrain and experiences less pronounced variations.

Fig. 4a. Dutch Bayou, a typical swamp drainage channel near Lake Maurepas.

Fig. 4b. Hinge line or contact between the pine-covered Prairie terrace and the Recent marsh near Slidell.

Fig. 4c. Dead trees surviving as the only indication of an essentially buried natural levee system in eastern Orleans Parish.

Fig. 4d. Live oaks and mixed-hardwoods on a natural levee of the Bayou Sauvage distributary.

Fig. 4e. Cypress and water tupelo trees in a swamp near Laplace.

Fig. 4f. Severely cut-over cypress swamp near Pass Manchac.

Fig. 4a.

Fig. 4b.

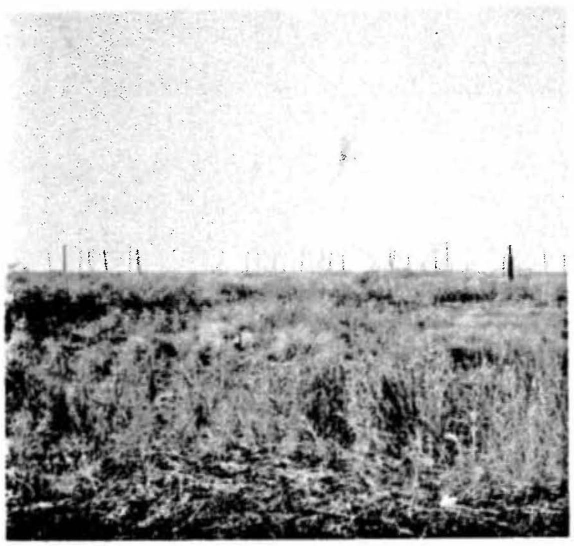

Fig. 4c.

Fig. 4d.

Fig. 4e.

Fig. 4f.

SUBSIDENCE AND SEA LEVEL RISE

Throughout the entire basin area and during all stages in its development, subsidence, faulting, and sea level fluctuations have occurred. A recognition and understanding of these factors is necessary in order to explain both present and past physiography. Normal depositional and erosional processes alone do not fully explain such changes as the burial of landforms and erosional surfaces, shoreline retreat, changes in drainage patterns, stream diversions, and thick accumulations of swamp and marsh deposits. Similarly, vegetation as well as sites of human occupancy have experienced change due to these factors.

Subsidence has been defined as the relative lowering of the land surface with respect to sea level (U. S. Army Engineer Waterways Experiment Station, 1958, vol. 1, p. 93).[3] This may involve an actual movement of the land, a sea level rise, or a combination of the two. During the last 5000 years, actual movement of the land is considered to have been the most significant factor in the Pontchartrain Basin area. Several factors must be considered in this respect.

For tens of thousands of years, the Mississippi River has been depositing large quantities of sediment in the central Gulf Coast area, probably at a decreasing rate during Recent times (Fisk and McFarlan, 1955, p. 299) which now averages about 500 million tons per year (Holle, 1952, p. 123). The resulting mass of sediment, hundreds of feet thick, is believed by some to be slowly but appreciably downwarping the older underlying strata in the vicinity of the deltaic mass (Russell, 1940, p. 1227; Fisk and McFarlan, 1955, p. 301). At the same time, the mass of Recent sediment is itself compacting as a result of sedimentary loading (U. S. Army Engineer Waterways Experiment station, 1958, vol. 1, p. 99).

On a smaller scale, the processes of downwarping and compaction are acting on individual landforms and small areas. Landforms such as natural levees and beaches experience a certain amount of internal compaction while slowly depressing the underlying deposits because of their weight. Local subsidence is much more variable in area and intensity than regional subsidence.

Faulting has been not only an important determining factor in the geologic history of the Pontchartrain Basin, but is also considered to be an important component of subsidence. Most faults in the area are normal, are downthrown toward the coast, and exhibit progressive displacement with depth. The fault pattern present in

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[3]This report contains a full discussion of the problem of subsidence in coastal Louisiana.

the basin area (Fig. 5) is similar to that of the Lower Mississippi Valley and other parts of the world (Russell, 1958, p. 12) and, in this case, seems to be an indication of structural adjustment during deposition and subsidence (Storm, 1945, p. 1329).

It is frequently difficult to locate faults in the poorly consolidated Recent deposits of the basin because of the small amounts of displacement near the surface and the tendency for the deposits to warp rather than to shear. Physiographic criteria such as changes in vegetation and soils, abnormal drainage patterns, the orientation of lake outlines, and sharp changes in the course of meandering streams rather than the presence of actual fault scarps must be frequently relied upon when mapping faults.

In the basin area, the buried Prairie surface was chosen as the most suitable near-surface formation to use in measuring fault displacements. Figure 5 shows estimated minimum amounts of displacement at various points along the major fault zones where closely spaced borings are available.

In spite of the ability to estimate roughly the amount of fault displacement, these values cannot be used to calculate the percentage of total subsidence due to faulting. Cross sections of the basin (drawn at right angles to the faults) suggest that a certain amount of rotational movement has occurred on some of the downthrown blocks, hence the displacement measured at the fault plane is not indicative of the entire block. In addition, it could not be determined whether the fault movement has occurred intermittently or progressively at a uniform rate.

In the recent report on subsidence in coastal Louisiana, values were ascribed to several of the component factors causing subsidence (U. S. Army Engineer Waterways Experiment Station, 1958, vol. 1, p. 104). An average regional subsidence rate of 0.78-feet-per-century was obtained for southeastern Louisiana at the present time. The rate is appreciably greater in the present Mississippi River Delta and decreases with distance inland. The figure also includes an estimated 0.32-feet-per-century value for true sea level rise occurring at the present time and an undetermined amount of subsidence due to faulting.

Through the use of 28 radiocarbon datings of peat deposits, an average subsidence rate of 0.39-feet-per-century was calculated for the Pontchartrain Basin area for approximately the last 4400 years (Fig. 6).[4] This figure does not include the estimated rate of present sea level rise. The distribution of the datings on the chart suggests a maximum variation of about 10 feet due to differential local subsidence and variation from one part of the basin to another. Additional variations can undoubtedly be attributed to faulting, shifts in location and intensity of deltaic deposition, and possibly

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[4]In the calculation, the statistical errors of the datings were ignored and it was assumed that the organic materials accumulated at or very close to sea level.

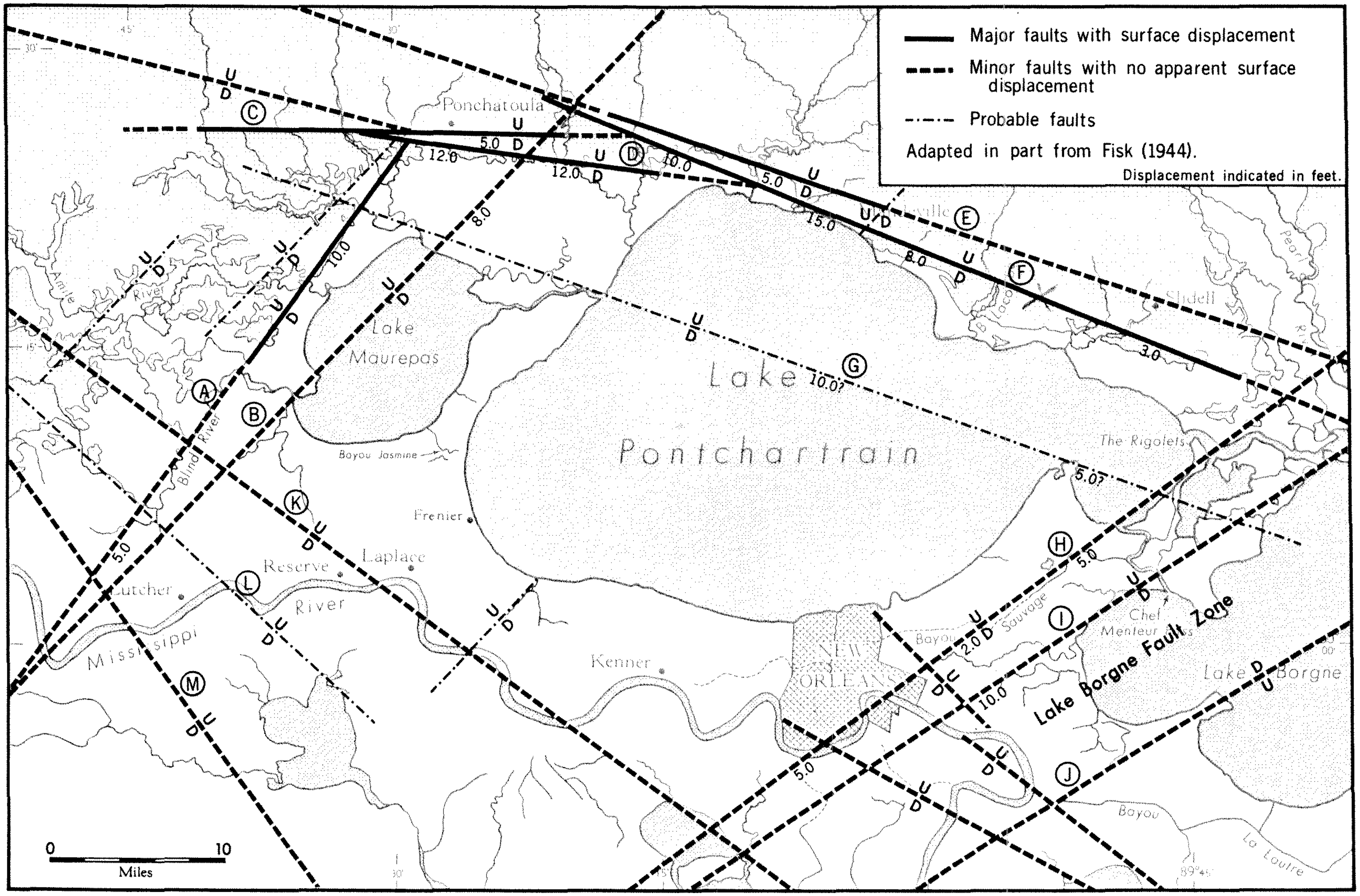

Fig. 5. Fault zones in the Pontchartrain Basin, including estimated minimum amounts of displacement on the Prairie surface.

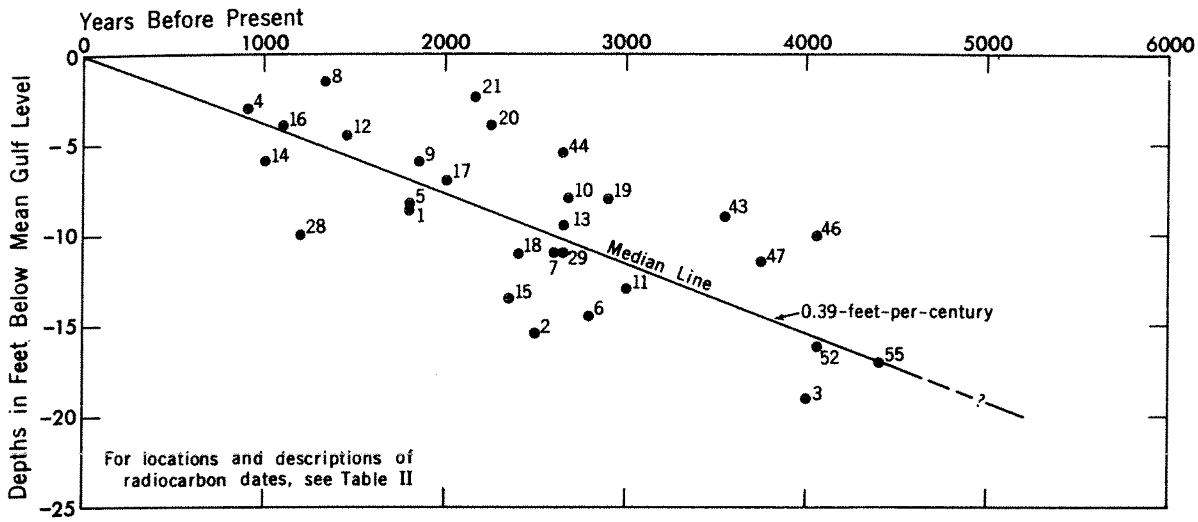

Fig. 6. Average subsidence rate for the Pontchartrain Basin calculated from radio carbon dates on peat and organic clay deposits.

to slight sea level fluctuations during the 4400-year period. Since a majority of the dated samples are from the vicinity of New Orleans, the calculated subsidence rate is most nearly correct for that particular area and may be excessive for the more inland portions of the basin.

The Recent postglacial sea level rise, although widely accepted in principle, is still quite controversial in regard to age, duration, and magnitude. In spite of a wealth of radiocarbon datings, workers in the Gulf Coast area still significantly disagree on certain aspects of the problem, especially regarding the date at which sea level reached its present stand. Largely because of the complicating factor of subsidence, the radiocarbon datings in coastal Louisiana are not conclusive and provide numerous possible interpretations.

Primarily as a result of investigations of the buried entrenched valley of the Mississippi River (formed during the last glacial advance), Fisk and McFarlan (1955) estimate the level of the sea at the glacial maximum to have been about 450 feet lower than at present. The most recent estimate of the date of this stage, based on an analysis of 122 radiocarbon datings, is more than 35,000 years ago (McFarlan, 1961). Russell (1957), who places the date at about 18,000 years ago, states that sea level probably rose rapidly after this low stand (with probable reversals in trend and quiescent periods) at a rate which may have approximated 3.5-feet-per-century. Data are still insufficient to permit accurate estimates of sea level positions for given dates during the rising sea level stage.

Many of the present workers in the area conclude that sea level reached its present level approximately 5000 years ago (Fisk and McClelland, 1959; Russell, 1957; LeBlanc and Bernard, 1954).

Recently, Gould and McFarlan (1959)[5], working with radiocarbon datings of peat deposits from southwestern Louisiana, have presented a more-recent date of 3000 years. Regardless of the exact date, there is wide agreement in this area that once present sea level was reached there were no further significant changes in level.

The sea level rise which is occurring at the present time, although proceeding at a considerable rate (0.32-feet-per-century), has been observed only during the past several decades (U. S. Army Engineer Waterways Experiment Station, 1958, vol. 1, pp. 94-96). Provided this trend reverses itself in the near future, the resultant sea level fluctuation would be minor and could possibly be considered as typical of minor variations which undoubtedly occurred during the last 3000 to 5000 years.

Investigations in the Pontchartrain Basin area have not uncovered any conclusive evidence that would accurately establish the date at which present sea level was attained. Radiocarbon dates do, however, provide an indication that this event occurred approximately 4500 to 5000 years ago.

In the early stages of the formation of the Pontchartrain Basin, the area was invaded by a shallow arm of the Gulf (the Pontchartrain Embayment). The extent to which Gulf waters spread inland and the locations of the shorelines implies that sea level must have been very close to its present level. Radiocarbon dates on the embayment stage vary from 5600±140 to 4800±130 years before present; the later date is interpreted as being the most indicative.

The radiocarbon dates used to calculate the average subsidence rate for the basin area provide an additional clue to possible sea level variations (Fig. 6). If sea level did not reach its present stand until 3000 years ago, as Gould and McFarlan (1959) have stated, the six radiocarbon dates greater than 3000 years old should lie below the line indicating the average subsidence rate. This is not the case; the median point of these six dates actually lies above the line. It must be considered, however, that this might be an erroneous impression created by an unknown change in the subsidence rate.

[5]This article, although published earlier than the 1961 study, contains McFarlan's latest conclusions regarding sea level rise.

PHYSIOGRAPHY

Both the Pleistocene and Recent sediments in the basin area were deposited under widely differing environments and in different types of landforms. The depositional history of the Prairie formation, complicated by a long period of subsequent erosion and modification, is poorly known and beyond the scope of this report. It is thus considered as a unit and discussed in gross terms. The Recent sediments, however, are distinguishable into numerous separate landforms, each with certain identifiable characteristics and ranges of variation.

THE PRAIRIE TERRACE

The origin of the Prairie terrace is concisely summarized by Fisk and McFarlan (1955, pp. 289-290) who state,

> A broad deltaic plain, bordered by a continental shelf similar in width and slope to the modern one, developed in the late phase of the cycle immediately preceding the late Quaternary - i.e., between Early and Late Wisconsin glaciation in the interglacial stage originally termed Peorian and now referred to as Bradyan (Frye, 1951). Since then the inland portion of the plain has been uplifted and tilted seaward to form the low coastwise Prairie terrace, and its seaward margin has been downwarped in the area of late Quaternary deltaic deposition. Inland along the margins of the Mississippi alluvial valley, regional uplift has raised the terrace surface 40 feet above the modern alluvial plain. The surface is tilted seaward in a 100-mile-wide zone in central Louisiana and slopes beneath the coastal marshlands. The line of intersection of the terrace and marshlands can be considered a hinge line marking the position of no structural movement relative to present-day sea level.

Figure 7 shows the position of the hinge line in the Pontchartrain Basin area. Between the Natalbany River and Pearl River, the configuration of the hinge line has been strongly influenced by faulting. In the vicinity of the Tangipahoa River, the Prairie-Recent contact is a well-defined east-west trending fault scarp. West of Lake Maurepas, the contact is more irregular; a single contact line is replaced by isolated segments or "islands" of terrace surrounded by swamp. The islands are the highest parts of the generally buried irregular Prairie surface. Along all major streams, fingers of Recent sediments extend inland and largely fill the entrenched valleys created during the Late Wisconsin glacial stage. Valley walls of Prairie terrace are usually well defined and increase in height inland from the coastwise contact.

The Prairie terrace slopes in a generally southerly direction at rates varying from about 2.0- to 10.0-feet-per-mile (average slope of 5.0-feet-per-mile). Elevations at the hinge line vary from several inches to about two feet above mean Gulf level. Just north of the hinge line, however, there are several narrow elongated zones with appreciably steeper slopes which are the result of faulting. The terrace surface is more highly dissected than any portion of the Recent deltaic plain. Interfluve areas are broad and relatively flat, but local relief of 15 feet occurs along streams near the contact. Drainage patterns are typically dendritic with the larger streams following routes established during Pleistocene times.

The sediments of the Prairie terrace, although similar in composition to the present deltaic plain, are much more consolidated and form the largest expanse of firm ground in the area. This is clearly indicated by the widespread presence of agricultural land, dense road networks, and numerous small settlements and towns. The near-surface sediments are composed largely of well-oxidized silty to sandy clays ranging in color from red and yellow-browns to buffs and light grays. Excluding a few natural depressions, the organic and water contents are low.

In the early part of the 18th century, the part of the Prairie terrace under consideration was described as being forested in open stands of longleaf and slash pine[6] with mixed pine-hardwoods along the streams (St. Amant, 1959, p. 30). At the present time, forest lands are generally restricted to the western portion of the area (Livingston Parish) (Fig. 2) and to a narrow strip along the margin of the terrace north of Lake Pontchartrain. These are composed largely of natural and reforested stands of loblolly or slash pine (Fig. 4b) with scattered hardwoods such as magnolia, pecan, hickory, and a variety of oaks (Table Ia). More inland portions of the terrace are cultivated in a variety of crops or consist of denuded pine barrens and pasture land. The characteristic species of the stream bottoms and more poorly drained areas are listed in Table Ib. Since the swamp and marsh areas south of the terrace contact are virtually devoid of pines, the presence of these trees is a significant factor in delimiting and identifying small isolated remnants of terrace in the northern and western portion of the basin. In general, pines are absent from all parts of the Recent deltaic plain.

NATURAL LEVEES

Near Donaldsonville, each Mississippi River natural levee, typically wedge-shaped in cross section, is from two to three miles wide (river bank to backswamp) and has an elevation of about 20 feet at the crest. Maximum thickness is from 15 to 17 feet. Levee dimensions progressively diminish downstream so that at New Orleans each levee is about 1.5 miles wide, 8 to 12 feet thick, and reaches an elevation of

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[6]Table I lists the common and scientific names of all plants mentioned in the text.

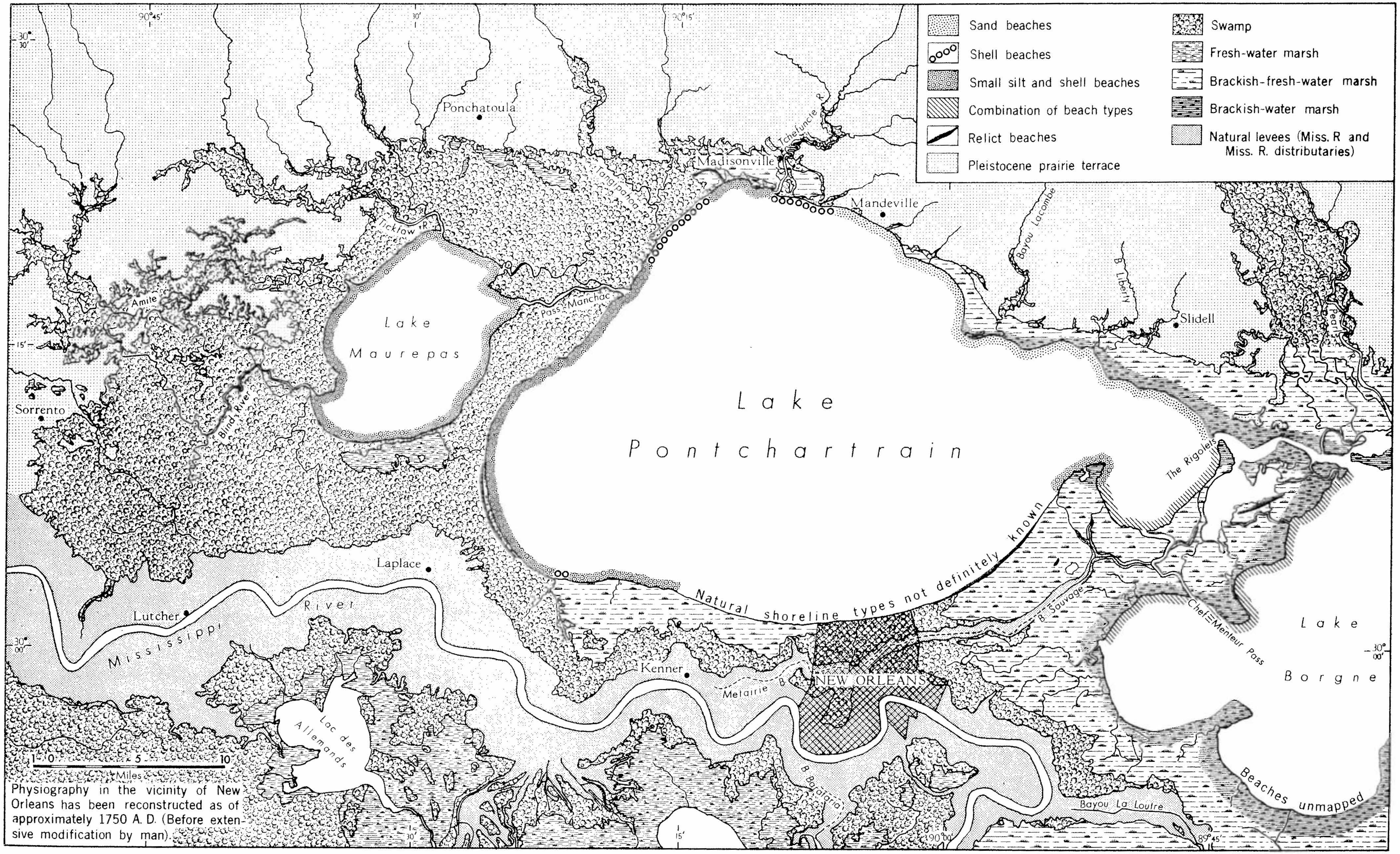

Fig. 7. Present physiography of the Portchartrain Basin.

about 12 feet. The average downstream slope of the levee crest is about 0.15-feet-per-mile.

Near the levee crest where the coarsest materials are normally encountered, the sediments consist of firm to stiff silty clays with scattered thin lenses of silt. Toward the backswamp, the clay content increases, silt layers become less numerous, and the amount of fragmented wood and organic matter increases. Levee sediments are well oxidized and contain numerous small iron and manganese nodules. The typical color is a tan or light gray-brown with fine red, yellow, and black mottling. Oxidation diminishes with depth and disappears near the base of the levee. Sediments beneath the levees are varied and are discussed later.

Natural levees of abandoned Mississippi River distributaries are similar in origin and composition to those of the parent stream, but smaller and steeper. This is a direct reflection of the size of the parent channel (Russell, 1939, p. 1210). In general, the sediments are more compacted due to their greater age. The lower portions of the levees which have subsided beneath marsh or swamp deposits have frequently lost their oxidation and are being reduced. These sediments often lack yellow, brown, or red coloration and instead are gray in color with green and olive mottling. Calcareous nodules are commonly abundant.

The Metairie Bayou-Bayou Sauvage system is the most conspicous abandoned distributary in the basin area (Fig. 7). Its natural levees can be traced eastward from Kenner, constantly narrowing, to the vicinity of Chef Menteur Pass where they finally lose surface expression and proceed as completely buried features (Fig. 4c). Near Kenner, the levees are about one mile wide, 12 feet thick, and have a maximum elevation of about seven feet (MGL). The original main channel of the system was until recently occupied by remnant and underfit streams (above-mentioned bayous) along most of its length. These have been either artificially filled or enlarged by dredging in recent years. Bayou Barataria and Bayou La Loutre follow the courses of other Mississippi River distributaries in the area (Fig. 7).

Small natural levees are present on the lower courses of the larger streams which drain the Prairie terrace north of the basin. These average about two to three hundred feet wide, two to four feet in elevation and thickness, and are composed of well oxidized very silty to sandy clay. The largest levees are those of the Amite and Tangipahoa rivers.

Since the passes between the lakes and to a lesser extent the marsh and swamp drainage channels experience occasional flooding of their banks, they exhibit small but noticeable levees. As a reflection of the small amounts of fine sediment available, the levees are composed of firm and slightly oxidized clays and silty clays with a high organic content. Rarely do these levees rise more than six to twelve inches above the adjacent marsh or swamp levels.

Under natural conditions, the levees of the Mississippi River and its distributaries supported a dense growth of hardwoods with a thick under-story of switch cane and palmetto (St. Amant, 1959,p. 31).

Judging from historical accounts (Darby, 1817, p. 73) and a few remaining areas of forest (Fig. 4d), former vegetation probably consisted of cottonwood, sycamore, sweet gum, hackberry, magnolia, pecan, and a variety of oaks, especially live oak (Table Ie). Throughout most of the area, the hardwood levee forests graded laterally to cypress-gum swamps along the levee flanks. The vegetation on the natural levees of the passes and swamp drainage channels, although closely related to the adjacent swamps and marshes, can be distinguished as separate associations. The characteristic species are listed in Table Id and Ih.

For many years, the natural levees of the Mississippi River and the larger distributaries have been the focal point of intensive agricultural activity. The maximum extent of cultivated land normally corresponds closely to the outer limits of levee deposits. Numerous closely spaced settlements, connected by major road and railroad routes, are located near the levee crests on both sides of the Mississippi River. Recently, urbanization and industrialization have been spreading at the expense of agriculture.

INTER-LEVEE BASINS

Inter-levee basins or depressions are near-sea level lowlands between distributary channels. In a deltaic plain environment, these vary greatly in size and distribution depending on the density of the distributary network. Normally, about 75 per cent of the total area is occupied by inter-levee basins.

Streams flanking the basins are their major source of inorganic sediments. Since the coarsest sediments and greatest quantity of sediments are deposited on the natural levees, only restricted amounts of clay and silt reach the basin areas. Should the flanking streams become inactive (e.g., abandoned distributaries), the basins would receive virtually no inorganic sediments. A large percentage of the deposits is therefore organic, derived from marsh and swamp vegetation. As the basin areas slowly subside, the marshes and swamps grow vertically, striving to maintain a constant elevation. The presence of dense drainage networks and numerous shallow lakes and ponds indicates a general deficiency of either organic or inorganic sediments.

Lakes in inter-levee basins may be formed in two general ways. First, they may be remnants of a once larger body of water that has been partially or fully closed off by distributary growth and/or areas that have never been filled with sediments. Second, they may originate through the destruction of former swamp and marsh areas. This occurs in such ways as bank erosion along streams, exhumation of swamp and marsh deposits during storms, and marsh fires. Lakes formed in both ways are present in the basin area.

Physiographically, the Pontchartrain Basin may be considered as a large inter-levee basin. The Mississippi River and the Metairie Bayou-Bayou Sauvage distributary flank the basin on the south and although no similar system is present to the north, the Prairie terrace serves much the same purpose. In genesis, however, the resemblance is much more remote.

Swamps

The terms swamp and marsh, although synonymous in meaning a low area of wet and spongy sediments, are distinguishable in terms of vegetation. A swamp is an area dominated by tree growth while a marsh is composed primarily of grasses, sedges, and rushes. The soils of both are usually saturated or covered with surface water for one or more months of the growing season (Penfound, 1952, p. 415). The swamps in the basin area are strictly fresh-water communities. Brackish water invasions during storms are too infrequent to be significant.

Swamp vegetation is dominated by two trees, cypress and water tupelo (locally called tupelo gum) (Fig. 4e). Drummond red maple, water ash, sweetgum, black willow, and palmetto are numerous, particularly on higher ground (Table Ic). As a result of many years of intensive logging operations, very little mature cypress now remains (Fig. 4f). Some areas have been almost denuded of their original vegetation which has frequently been replaced by dense thickets of black willow and buttonbush mixed with scrub cypress and tupelo. Wetter areas of the swamp more closely resemble marshes and consist of scattered trees mixed with alligator weed, water hyacinth, sawgrass, and cattail.

The largest expanse of swamp in the basin occurs west of Madisonville and Laplace (Fig. 7). It is interrupted only by several small and isolated areas of fresh-water marsh south of Ponchatoula and south of Lake Maurepas. In addition, a narrow strip of swamp follows the edge of the Prairie terrace and extends up stream valleys on the north side of the basin. Similar but wider strips flank the margins of the natural levees of the Mississippi River and its abandoned distributaries east of Laplace (Fig. 7).

Much of the swamp area has a surface elevation of not more than one foot above mean Gulf level. Maximum elevations (two to three feet) occur in the western portion of the basin near the Prairie terrace. Local relief usually does not exceed one foot.

Swamp deposits typically consist of organic to highly organic clays with scattered lenses of silt and peat layers. The deposits are soft, range in color from grayish-brown to reddish-brown, and have a high water content. Actual organic content is normally less than 30 per cent (U. S. Army Engineer Waterways Experiment Station, 1958, vol. 1, p. 61).

Continued subsidence has enabled swamp deposits to accumulate to considerable thicknesses in parts of the basin. Areas that have remained marginal to active stream deposition have continuous accumulations to a maximum known thickness of 22 feet (northwest of Kenner). Thicknesses from five to ten feet are common throughout the basin area. Swamp deposits encountered in borings beneath natural levees and marsh deposits in various parts of the basin indicate different distributions of swamps existed at various times in the past.

Fig. 8a. "Ghost forest" of dead cypress trees in a marsh area near Bayou Sauvage.

Fig. 8b. Isolated area of fresh-water marsh south of Ponchatoula.

Fig. 8c. Brackish-fresh water marsh near The Rigolets in St. Tammany Parish.

Fig. 8d. Bayou Jasmine, a swamp drainage channel choked with alligator weed and water hyacinth.

Fig. 8e. Deposit of "coffee grounds" along the shore of Lake Pontchartrain.

Fig. 8f. Small sand beach along the northeastern shore of Lake Pontchartrain.

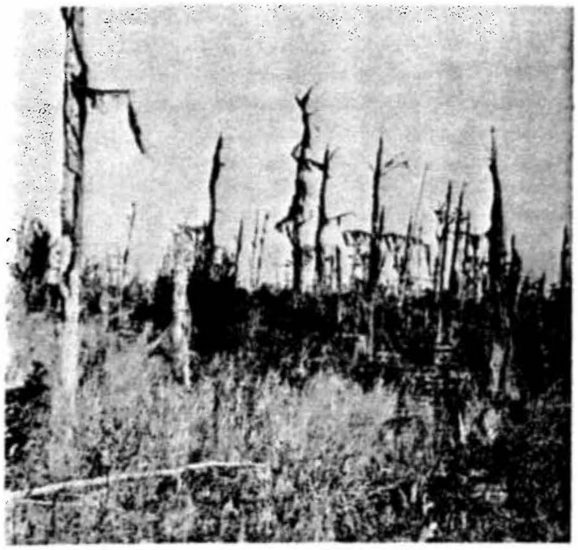

Fig. 8a.

Fig. 8b.

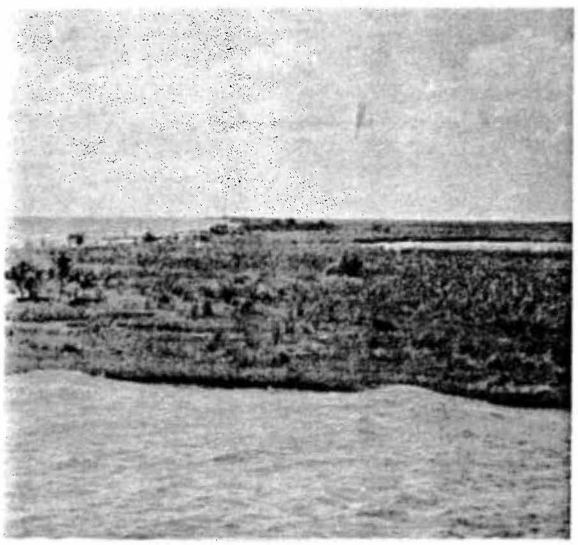

Fig. 8c.

Fig. 8d.

Fig. 8e.

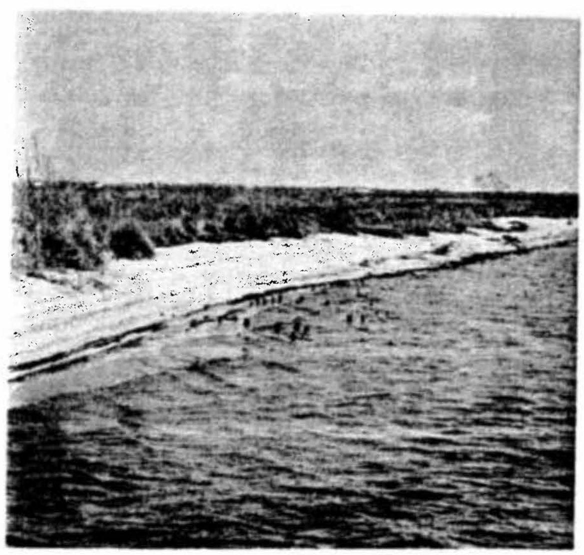

Fig. 8f.

At the present time, swamps are slowly overriding the subsiding margins of the Prairie terrace and various natural levees in the western portion of the basin. Farther to the east, where subsidence is permitting a slow invasion of brackish water, more salt-tolerant marsh vegetation is replacing the swamps. "Ghost forests" of dead cypress trees and stumps in the marsh flanking Bayou Sauvage in eastern Orleans Parish are striking evidence that this is occurring (Fig. 8a).

Marshes

The composition and distribution of marsh vegetation is primarily determined by edaphic factors (Penfound and Hathaway, 1938, p. 36). Largely on the basis of the most important edaphic factor, soil salinity, marshes are commonly classified as fresh-water, brackish-water, or saline types (plus intermediate types). Marshes in the Pontchartrain Basin vary from nearly fresh to strongly brackish. Highest salinities probably do not greatly exceed 20 parts per thousand.

The isolated patches south of Ponchatoula and Lake Maurepas are the only areas of essentially fresh-water marsh (Fig. 8b). The characteristic plants are cattail, paddle weed, and paille fine (Table If). The marsh grasses have formed a thin but uniform root-mat located below several inches of standing water. Below this and extending to the base of the deposit (five to ten feet) is a zone of dark gray to black watery ooze composed mainly of very fine granular and fibrous organic matter with varying amounts of clay. Thin layers of dark brown to black fibrous peat are scattered throughout the deposit. The organic content is normally quite high (20 to 50 per cent) and the water content frequently exceeds five times the dry weight of the sample (U. S. Army Engineer Waterways Experiment Station, 1958, v. 1, p. 53).

Flanking the shores of Lake Pontchartrain in St. Charles and St. Tammany parishes (Fig. 8c) and over most of eastern Orleans Parish are extensive areas of brackish-fresh water marsh (Fig. 7). This type, comprising over 75 per cent of the total marsh area, consists mainly of three-cornered grass, cattail, salt grass, black rush, couch grass, roseau, and oyster grass (Table Ig). Distribution of plants within the zone is complex and is controlled by slight changes in such factors as elevation, drainage, and salinity.

Brackish-fresh water marshes are generally firmer, have a denser root-mat, and contain more inorganic sediments than fresh-water marshes. Layers of peat are more numerous, although the over-all organic content is not as high. The organic material varies from light brown to black in color while the inorganic zones are usually a light bluish-gray.

Brackish-water marshes are limited to narrow strips (one to three miles wide) along the shore of Lake Borgne and along the northeastern shore of Lake Pontchartrain from the vicinity of Bayou Liberty to Pearl River (Fig. 7). The vegetation consists of salt grass, black rush, couch grass, and oyster grass (Table I). This marsh type is the firmest in the area and has the lowest organic content. Storm tides have introduced significant quantities of clay and silt, producing a very gentle slope of the marsh surface toward the interior.

In the fresh to slightly brackish marsh areas and in the cypress-tupelo swamps, water hyacinth and alligator weed have dominated most of the small drainage channels and the smaller lakes and ponds. Both plants are exotics, having been introduced since 1900 (O'Neil, 1949, p. 11). Figure 8d shows that some channels have been so effectively choked that navigation is impossible. In addition, the exotics are threatening to kill off and replace natural marsh vegetation where they have managed to gain a foothold. So far, most attempts to eradicate the plants have failed.

A set of aerial photographs covering most of the marsh areas of the basin taken in the period from 1931 to 1933 was compared with a second set taken in the period from 1952 to 1954. Almost without exception, all types of marsh showed a sharp increase in extent of open water, a general thinning of marsh vegetation, and a definite increase in the drainage network, during this approximately 20-year period. Factors that are contributing to these rapid changes undoubtedly include increasing and uncontrolled burning, invasion of brackish water into fresh water areas, contamination and/or poisoning of various plant types by man, and subsidence. The increase in extent of open water in the marshes near the lakeshores is greatly facilitating rapid shoreline retreat.

BEACHES

The beaches around Lakes Pontchartrain and Maurepas are generally small, discontinuous, fine grained, and contain varying amounts of shell. With one possible exception, they are located along actively retreating shorelines. Beach variations are due primarily to the configuration of the shoreline and the abundance and types of sediment available. Wave intensity and frequency, when calculated over a period of years, does not appreciably vary from one portion of the lakes to another. Primarily on the basis of shape and composition, beaches are divided into three general types.

The first and most widespread beach type is a small, discontinuous, and irregular strip of fine to very fine sand, silt, and shell. Most frequently associated with a cypress swamp shoreline, it occurs around most of Lake Maurepas and the western shore of Lake Pontchartrain (Fig. 7). The sediments are moderately well sorted, contain numerous shells and shell fragments (predominately the clam Rangia cuneata), and are littered with plant remains and large pieces of wood. The entire beach is often not more than 25 feet wide, seldom exceeds two feet in height, and generally has a cuspate form. The small size and general character of this type of beach reflect the paucity of inorganic sediments present in the eroding swamp deposits.

Cypress stumps and living cypress trees occur in shallow water up to several hundred feet offshore from this type of beach along long stretches of shoreline. These serve as natural breakwaters, dampening wave activity along the beach. During calm periods, deposits of brown to black granular organic matter and wood fragments accumulate in the nearshore zone. This material, derived primarily from eroding swamp deposits, closely resembles and is often called "coffee grounds" (Fig. 8e). Deposits may reach a thickness of 12 to

Fig. 9a. Ledge of marsh deposits exposed in a retreating sand beach along the northeastern shore of Lake Pontchartrain.

Fig. 9b. Rangia shells and sherds from a destroyed shell midden concentrated on a beach along the shore of Lake Pontchartrain.

Fig. 9c. Small shell midden, gutted by dredging, in the marsh just east of New Orleans.

Fig. 9d. Big Oak Island, a conspicuous shell midden in eastern Orleans Parish.

Fig. 9e. Highly eroded shell midden at the mouth of the Tchefuncte River.

Fig. 9f. Rapidly eroding washover deposits along the shoreline of Lake Pontchartrain at Frenier.

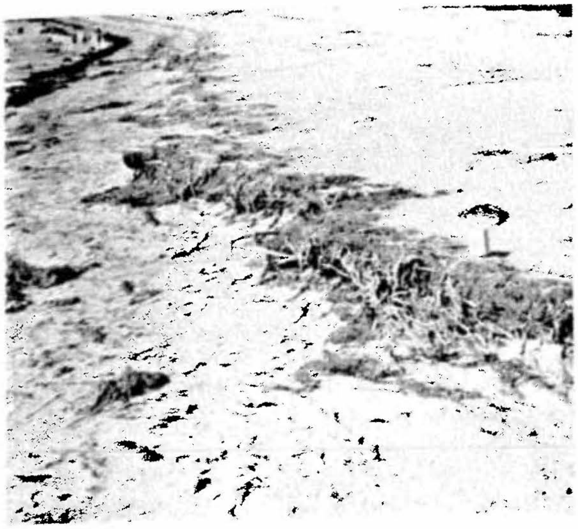

Fig. 9a.

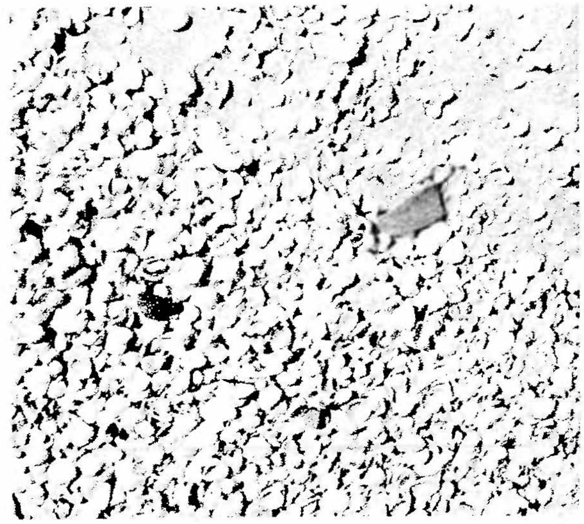

Fig. 9b.

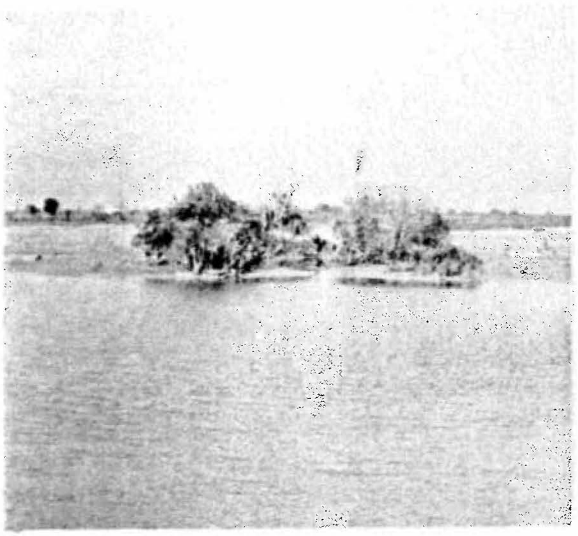

Fig. 9c.

Fig. 9d.

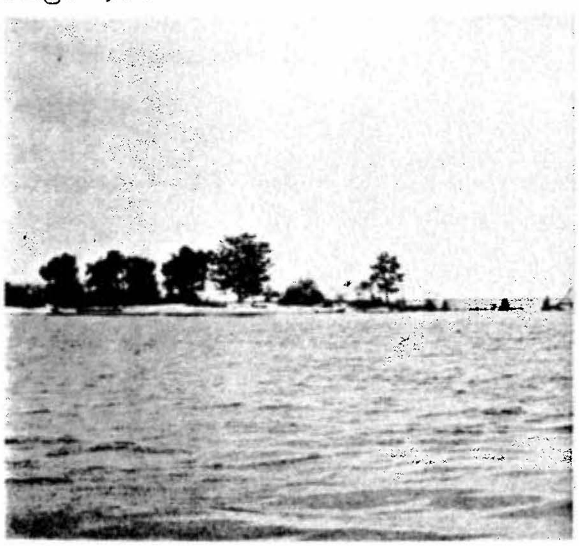

Fig. 9e.

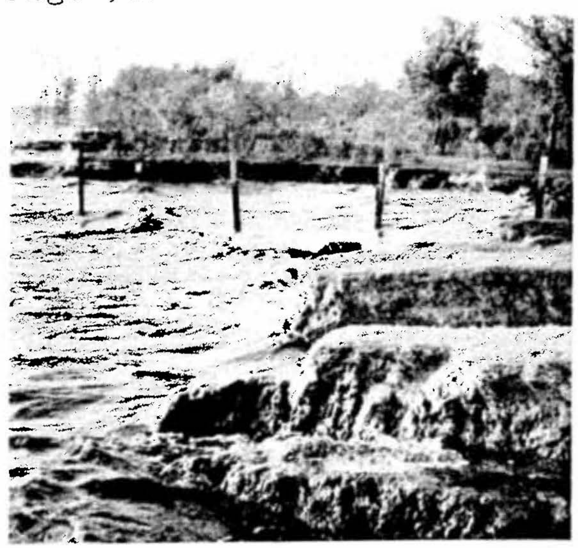

Fig. 9f.

18 inches and extend offshore for 25 to 50 feet. During stormy conditions, the organic matter is put into suspension and either carried offshore or thrown back into the swamp.

The second beach type is slightly larger, more continuous and regular, and is composed of very fine to fine sand with a low shell content (Fig. 8f). These average 25 to 50 feet wide and occasionally exhibit small dunes. The greatest development occurs along the northeastern shore of Lake Pontchartrain between Mandeville and The Rigolets (Fig. 7). Elsewhere along marshy shorelines, the beaches are smaller and are transitional between the two types. Eroding marsh deposits are seldom the primary source of sediments. In most cases, beach size and composition are a direct reflection of the type of sedimentary unit or landform which the retreating shoreline encountered and destroyed at some point offshore.

Along the foreshore, these beaches frequently exhibit an irregular ledge of marsh deposits protruding through several inches of sand veneer (Fig. 9a). As the ledge is eroded, the finer materials are carried offshore while the small amount of coarser material is added to the existing sand. At the same time, the entire beach is slowly being pushed back across the marsh.

The third beach type, constituting those composed almost entirely of Rangia shells, has a limited distribution at the present time. The largest shell beaches are located along the shore of Lake Pontchartrain for several miles on both sides of the Tangipahoa River, east of the Tchefuncte River, and at a locality several miles south of Frenier (Fig. 7). The shells have been naturally concentrated by wave action from deposits on the lake bottoms or from destroyed Indian shell middens. Stretches of shell beach several hundred feet long, isolated in the midst of another beach type,usually indicate the latter condition. The larger shell beaches are generally regular in plan, average about 25 feet wide, have steep slopes, and may develop to elevations of four to six feet.

About 50 per cent of the shoreline of the two lakes is characterized by the above-mentioned beach types. An additional 25 per cent is characterized by a combination of types, transitional stages between types, or completely lacks a beach. The remainder of the shoreline, essentially the south shore of Lake Pontchartrain has been artificially modified by man.

Nearly all beaches in the basin area are accompanied by a small washover fan behind the beach. The sediments, primarily carried inland to marsh and swamp areas during storms, consist of thin layers of silts and clays separated by organic deposits. Coarsest sediments, which occasionally include fine sand and scattered small shell fragments, are found closest to the beach. The largest washover fans occur at the extreme western end of Lake Pontchartrain, along the southern shore of Lake Maurepas, and along the shore of Lake Borgne. From an elevation of 12 to 18 inches (MGL) at the crest, the relatively firm surfaces gradually slope inland to marsh or swamp level over a distance of several hundred feet.

Throughout the Pontchartrain Basin, relict or stranded beaches stand as evidence of shoreline changes in both the present lakes and former bodies of water. These vary in size from large barrier spits more than 20 miles long and several miles wide to thin strips of sand or shell 25 feet wide. Some are completely buried features while others are prominent topographic features (commonly called "ridges" or "islands"). Certain relict beaches are significant clues to the basin's geologic history and are discussed in detail later.

PREHISTORIC OCCUPANCE

Archaeological evidence indicates that Indians were present in the Pontchartrain Basin by approximately 1800 B.C. They continued their occupance until finally driven out by spreading European settlements and culture about 1780 A.D. During this period of more than 3500 years, numerous small groups of Indians occupied permanent or semi-permanent villages near streams and lakes. The permanent population in the basin at any given time, however, was apparently quite small. Many sites were undoubtedly occupied by groups which seasonally migrated to the basin in search of a more abundant food supply.

All Indian groups practiced a simple hunting, fishing, and gathering economy. A knowledge of agriculture, although probably present at an early date, apparently remained secondary to wild life as a source of food in this bountiful coastal area. Judging from archaeological remains and a knowledge of historic tribes, the Indians utilized deer, bears, otters, muskrats, alligators, turtles, fish, waterfowl, wild turkeys, fruits, nuts, tubers, wild grains, and a variety of other foods.[7] Numerous shell heaps throughout the area testify that mollusks formed a basic part of their diet. Depending upon the environment, the most widely utilized mollusks were a freshwater clam (*Unio*), a brackish-water clam (*Rangia cuneata*), or the oyster (*Crassostrea virginica*). *Rangia* is by far the most abundant of all types found in sites (Fig. 9b).

TYPES OF SITES

At the present time, 143 Indian sites have been located in the basin area (Fig. 10). Many others have undoubtedly been totally destroyed by erosion or buried as a result of subsidence. At least 30 sites are known to have been destroyed in recent years, most of these in the New Orleans area, and many others severely damaged. Only 39 sites remain more or less in their original condition.

By far the most numerous type of site is the shell midden (Fig. 9c). These sites, which comprise about 80 per cent of the total number, are irregular and unintentionally accumulated refuse heaps. Aside from their large percentage of shell, they contain numerous animal bones, pottery fragments (sherds), human burials, and a wide variety of weapons and implements of everyday life. Middens vary in size from thin lenses of shell a few inches thick and 20 or so feet long to large mound-like accumulations 10 to 15 feet high and several

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[7]For a detailed discussion of the food habits of Louisiana Indians, see McIntire (1958, pp. 31-50).

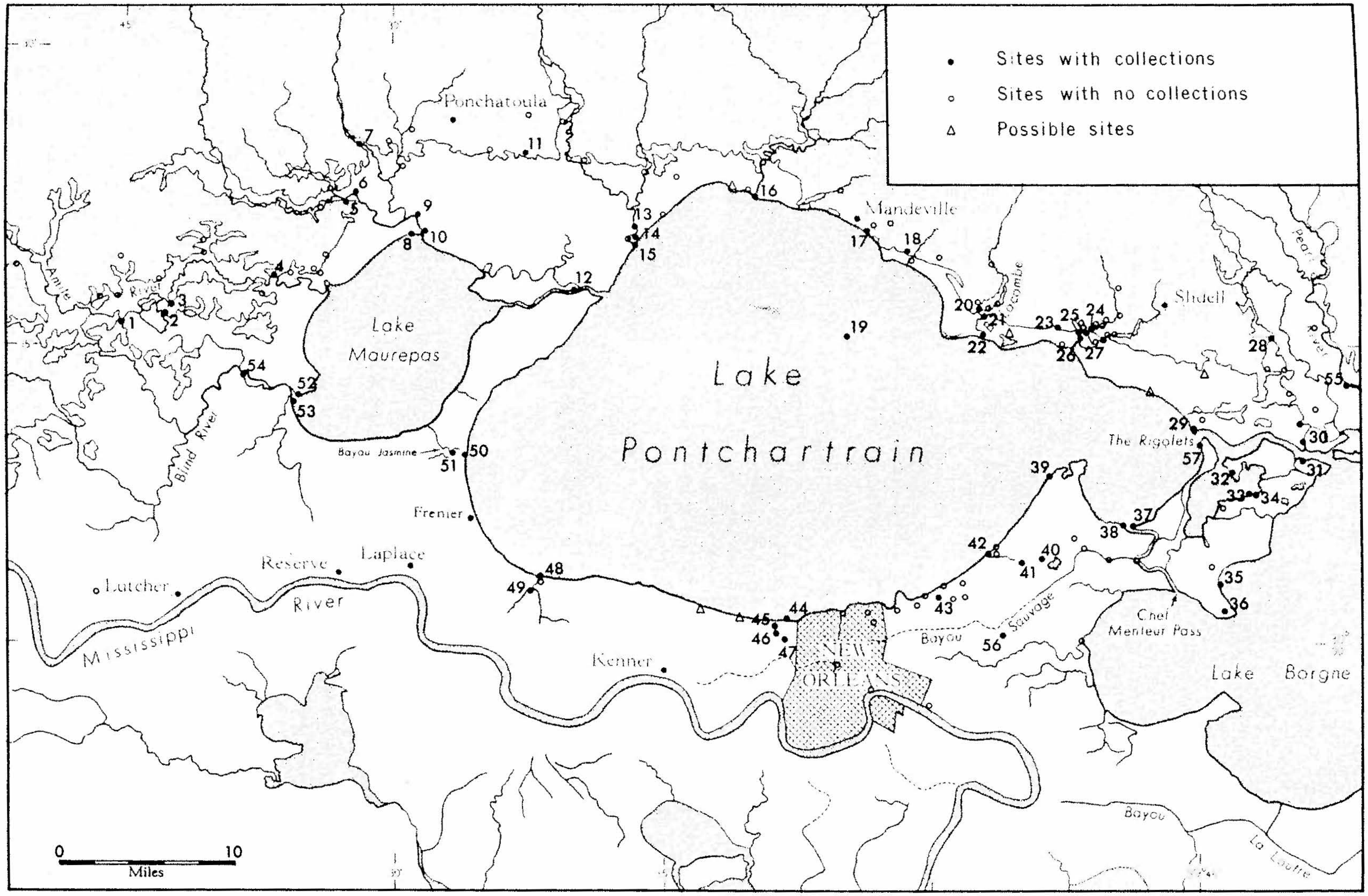

Fig. 10. Indian site distribution map.

hundred feet long. They occur most frequently as a single site, but some are found in an irregular string of small knolls or ridges.

Most middens are conspicuous features in this low coastal environment. With the exception of a few natural beaches, they are the only surficial concentrations of shell. Largely because of their greater height, middens normally support a dense growth of woody vegetation, most characteristically large live oak trees (Fig. 9d). The distinctive vegetation is of great help in locating middens, especially in the case of those sites which occur within treeless marshes.

Middens exposed to wave attack along shorelines or stream banks usually exhibit damage or truncation (Fig. 9e). In some cases sites have been completely destroyed, but usually the shell and the more durable artifacts remain, concentrated by wave action along the nearby shoreline (Fig. 9b). Sites of this type, where none of the materials remain in their original location, are referred to as beach deposits.

To the archaeologist, eroded middens and beach deposits often provide an opportunity to make large collections of artifacts without excavation. Since the collections include materials from all parts of the site and possibly several sites, there is a complete loss of stratigraphy. In some cases, abrasion has so severely damaged the artifacts, particularly the pottery, that identification is impossible.

Village sites are irregular accumulations of debris and artifacts, similar to middens in origin, but differing mainly in size and in the absence of shell. Twenty-one sites of this type have been located, largely limited to the Prairie terrace. The average village site is several acres in extent and normally lacks any obvious surface expression.

Nearly all such sites have been located only as a result of farmers reporting the presence of projectile points and other artifacts in their plowed fields. The absence of shell in sites may indicate either a cultural difference (i.e., mollusks were not included in their diet) or that the sites were occupied during the seasons when emphasis was placed on obtaining wild life other than mollusks. Both situations probably existed in the basin area.

Perhaps the most popularized but least rewarding sites in the area are the mounds. They are intentionally built and definitely shaped hillocks of earth, shell, and occasionally a combination of both. Mounds are normally associated with a village site and occur both singly and in groups. They were built either as a burial ground or a temple base. Most of the 15 mounds found in the area are low dome or cone-shaped structures about 40 feet in diameter at the base and about four to six feet high. At least one mound, however, exceeds 150 feet in diameter and 30 feet in height.

With few exceptions, mounds contain appreciably fewer artifacts than middens or village sites. Since they were constructed for a specific purpose, the incorporated cultural remains do not represent so typical a cross section of everyday life as do the middens and village sites.

LOCATION OF SITES

The Indians had to take several important factors into consideration when choosing a place to live. First, it was necessary to find high ground which would remain relatively dry throughout the year. Second, the village had to be located near a flowing stream or other dependable source of fresh water. The streams also must have served as a means of transportation and communication. Third, an adequate supply of food had to be obtainable within relatively short distances of the village.

The Pontchartrain Basin area offered the Indians three basic choices of a place to satisfy the needs: the margins of the Prairie terrace, relict beaches or perhaps active beaches, and the natural levees of the larger streams. Exact sites selected for villages depended upon variations in the distribution of the choice sites through time and in the cultural background of the Indians.

Judging from the actual site distribution (Fig. 10), one of the most favored locations throughout the period of prehistoric occupance was on the Prairie terrace, either along the sides of stream valleys or along the terrace-Recent contact. About 40 per cent of the sites in the area occur in this milieu. Traces of Indian occupancy are most frequently found where streams such as the Amite or Tangipahoa have impinged against the valley wall. Shell middens characterize these points on the lower stretches of the streams while village sites prevail farther inland. This difference may be a reflection of the relative availability of mollusks.

Shell middens associated with relict beaches are most numerous in Orleans Parish but occur in all parts of the basin. At least 12 sites near New Orleans are located on a large buried barrier spit and smaller beaches closely associated with it. When the Indians occupied the ridge, portions of it stood several feet above mean Gulf level and were at least partially surrounded by marsh. In this case, fresh water was obtainable from a nearby Mississippi River distributary or from ground water in the beach itself.

Along the northern margin of the basin, a relict beach paralleling the terrace-Recent contact was extensively occupied, especially where intersected by small streams. Figure 11 illustrates the relationship between sites and physiography for the Bayou Liberty-Bayou Bonfouca area. Three sites are associated with the relict beach adjacent to the Prairie terrace while another marks the location of a smaller buried beach near the present shore of the lake.

Whether or not the Indians extensively occupied active beaches during prehistoric times has not been determined. It seems unlikely that permanent villages would have been located in such exposed places. In historic times, however, sites along the shorelines of both Lakes Maurepas and Pontchartrain were occupied temporarily during the summer months. There is no reason to believe that seasonal migrations were not a common practice in prehistoric times.

Fifteen sites in the area are known to be associated with natural levees of Mississippi River courses and eight sites with the

Fig. 11. Relationships between sites and physiography in the Bayou Liberty-Bayou Bonfouca area.

levees of smaller streams. Nearly all are located near the levee-crest adjacent to the channel.

An examination of the site distribution map (Fig. 10) reveals a striking deficit of sites along the present course of the Mississippi River. This cannot be explained by the fact that this course became established relatively late in the period of Indian occupancy or that sites existed and have subsequently been destroyed. The first European explorers encountered only four small groups of Indians living along the river in the area under consideration. These groups lived near the river only in winter and spent their summers on the shores of Lake Pontchartrain.

The occurrence of similar situations in other parts of the deltaic plain suggests that the Indians preferred to live along those streams which had already reached maximum development. The lower reaches of partially abandoned distributaries seem to have been the most desired localities. In these cases, there was still a sufficient flow of fresh water but not enough to cause frequent flooding of the banks. Perhaps most important was the close proximity of swamps, marshes, and fresh- to brackish-water lakes, i.e., sources of wild life and particularly mollusks. It appears that the Indians preferred to live as close to the lakes as possible during at least six months of the year.

CHRONOLOGY

During the past 20 to 30 years, archaeological investigations in the Lower Mississippi Valley have resulted in the development of a workable chronological framework. As a result of work by Ford, Phillips, Quimby, Webb, and others, there are eight recognized periods or horizons in the area (Fig. 12). Six of the eight periods, Tchefuncte through Historic, are characterized by a presence of pottery. The Poverty Point horizon, although generally considered as Late Archaic, represents a transition from the Archaic to the ceramic periods. Each period is characterized by a distinctive assemblage of artifacts and each has a definable time span in a given area.

Throughout the Pontchartrain Basin investigation, an attempt was made to use this Lower Mississippi Valley chronology as a guide. As McIntire (1954, p. 26) discovered, however, it is not completely adaptable to the coastal area. All of the above cultures are represented in the basin, but some are either poorly defined or occur during different periods of time than customarily assigned to them. Furthermore, radiocarbon dates support the belief that there is an appreciable time overlap between horizons. For these reasons, it was necessary to establish a modified chronology for the basin area (Fig. 12).

Investigation at six shell middens in the basin definitely revealed for the first time that both the Archaic and Poverty Point horizons are represented in the coastal area. Radiocarbon dates from one of the Poverty Point sites (Fig. 21, No. 56) suggest a greater antiquity for this culture in the coastal area than in the Lower Mississippi Valley (Ford and Webb, 1956, pp. 116-124) and an

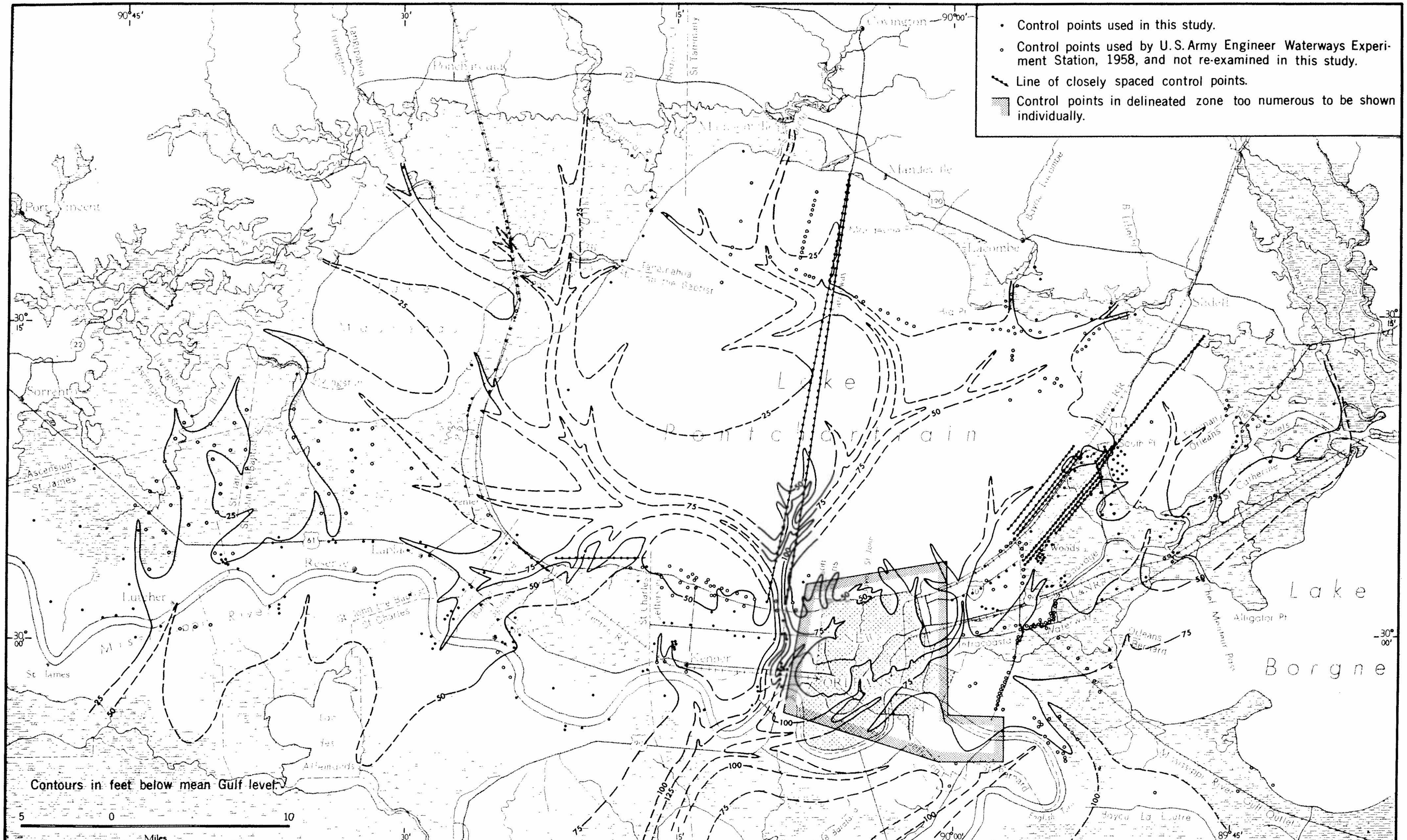

Fig. 14. Contours on the surface of the buried Pleistocene Prairie terrace.

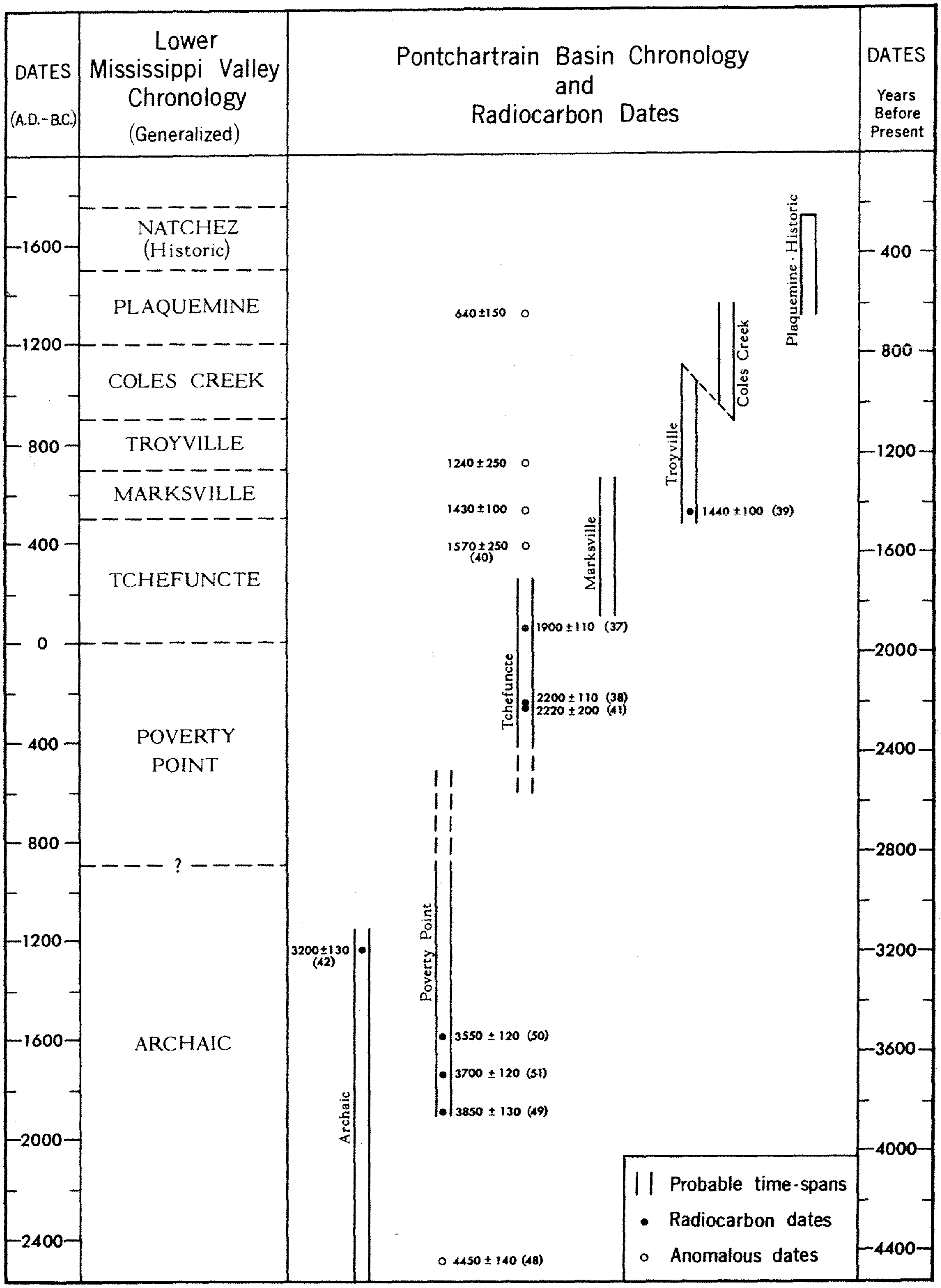

Fig. 12. Comparative Chronology Chart.

appreciable overlap with the Archaic.

The Troyville and Coles Creek horizons, although readily separable in other parts of the Mississippi Valley, are generally indistinguishable on the basis of pottery types in the basin area. Pottery types of one horizon were invariably found to be closely associated with types of the other. Because of a lack of suitable stratigraphic control, they are considered essentially as a single unit in this report.

The latest of the prehistoric periods, the Natchez, is poorly represented in the basin area. There are indications that the Plaquemine culture continued up to and persisted during early historic times. The represented time span is thus referred to as the Plaquemine-Historic period, a single unit (Fig. 12). This period is more characterized and definable in the basin by an introduction of a distinctive shell-tempered pottery rather than by the typical Plaquemine types. Shell-tempered pottery, which shows strong influences from Alabama and Florida, apparently moved into the area from the east during the Plaquemine-Historic period.

In most cases, the age-determination of sites was based entirely on surface collections of pottery. With the exception of some of the older sites, only negligible quantities of stone, shell, or bone artifacts were encountered. A total of about 19,000 sherds were collected from 57 sites in the area. Since plain ware is frequently difficult to identify, actual classification was based primarily on 2000 decorated sherds. The survey materials were supplemented by the published data on artifacts from nine Tchefuncte period sites (Ford and Quimby, 1945) and the collections of McIntire (1954) from sites in the area.

SITES AND PHYSIOGRAPHY

The primary purpose of the archaeological investigations was to use the cultural remains as a means of relatively dating landforms and land areas. In this regard, the oldest or initial occupation of a site is one of the most significant factors (McIntire, 1954, p. 12). This immediately establishes a minimum date for the landform on which the site is located, for it is obvious that the landform could not have formed after the site was inhabited.

On the Mississippi River or its distributary courses, the oldest occupation of a site apparently did not occur before the natural levees had attained maximum size and frequent flooding had ceased. The oldest site on a levee, however, may not have been occupied until appreciably after maximum development. For example, the oldest known site associated with the natural levees of the Metairie Bayou-Bayou Sauvage distributary is of Marksville age (Fig. 10, No. 46). Radiocarbon dates, on the other hand, indicate that this course had attained maximum development in that area in pre-Tchefuncte times. Possible explanations are that the levees were either not occupied before Marksville times for an unknown reason or that older sites did exist but have been destroyed or were not located during the survey. In either event, Indian sites sometimes give an abnormally young minimum date.

The duration of occupancy of a site sometimes reflects environmental conditions. The presence of sites in an area which has a long and continuous record of occupance indicates that living conditions must have remained relatively favorable during a long period. Similarly, a sudden abandonment of a site or group of sites suggest a possible deterioration of living conditions. The abandonment of a distributary, i.e., a cessation in the fresh-water supply, or the subsidence of a natural levee beneath marsh or swamp deposits could bring about the necessary adverse conditions.

In addition to indicating that subsidence has occurred, Indian sites also provide one of the best methods for measuring actual rates of subsidence. Assuming that the bases of all sites were at least at mean Gulf level and probably several feet above when occupied, borings can be made to locate the present base of a site in reference to this datum. For example, a Tchefuncte period site (Fig. 10, No. 18) located near the northern margin of the basin is resting on a buried relict beach. The base of the midden was encountered in borings at an average depth of six feet below mean Gulf level. Since the site was first occupied approximately 2000 years ago, the minimum calculated subsidence rate at this location is 0.3-feet-per-century.

Occasionally sites stand as the only visible indications of a buried landform. Since they are the highest features on the landforms, they are the last to be completely encompassed by encroaching marsh or swamp. Sites with no obvious physiographic relationship on the surface were explored by borings to reveal their possible relationship to buried features. Several of the oldest distributaries in the basin were first located by investigations of this type.

The shell content of middens is perhaps one of the best indicators of large-scale environmental conditions and changes. A predominance of oyster shell in the oldest (Archaic) sites in the basin area is a strong indication that marine conditions were prevailing in the vicinity at that time. By Tchefuncte times, however, brackish-water conditions had become prevalent, as evidenced by a predominance of *Rangia* and a general lack of oyster. It seems quite unlikely that this represents a major change in the food habits of the Indians rather than a change in environmental conditions.

Rangia continued to be the basic mollusk utilized throughout the remainder of prehistoric times. Significant quantities of *Unio* are found only in the farthest inland sites along the Amite River. The presence of approximately equal quantities of *Rangia* at these same sites suggests that they were in the transition zone between fresh- and brackish-water environments.

With the advent of radiocarbon dating, Indian sites have assumed a new importance as sources of datable materials. With careful small-scale excavations, adequate samples of charcoal, ash, bone, or shell can be obtained from most sites. An ideal situation is to find datable materials from Indian sites above a given landform and from peat or organic clays below the landform, thus achieving both maximum and minimum dates for the landform's age.

GEOMORPHIC HISTORY

THE BURIED PRAIRIE SURFACE

As previously mentioned, the Pleistocene Prairie terrace forms the northern and western limits of the Pontchartrain Basin and related deposits underlie the Recent sediments of the basin at varying depths. Modifications of this surface, caused by several different processes, have had a direct influence on the shape and extent of the basin, particularly in its earlier stages.

Original Characteristics

By the end of the Bradyan (Peorian) interglacial stage (Fig. 3), the Prairie deltaic plain and its bordering continental shelf had attained maximum development (Fisk and McFarlan, 1955, p. 289). Faunal evidence from scattered deep borings suggests that the Prairie coastline roughly bisects the Pontchartrain Basin; the western and northern portions of the basin are located over the deltaic plain and the eastern and southern portions are located over the shallow continental shelf (ibid., p. 291).

Borings in the basin area make possible the delineation of a probable sand beach deposit several miles wide and over 40 feet thick along this former coastline. The beach deposit has been traced from a point about five miles south of Slidell northwestward to the north central portion of Lake Pontchartrain (about three miles south of Mandeville) and then southwestward to a point about midway between Laplace and Kenner. The highest portions of the beach deposit apparently occur in the northern portion of the basin where sand has been encountered in borings at a minimum depth of 25 feet below mean Gulf level.

South of the probable former coastline, the Prairie surface sloped toward the southeast at an estimated gradient of 1.3-feet-per-mile. As illustrated on Figure 13, water depths in the vicinity of New Orleans probably did not exceed 20 to 30 feet (ibid., p. 291).

Downwarping and Faulting

During the Late Wisconsin glacial stage and the Recent Epoch, a considerable portion of the Prairie deltaic plain and continental shelf has experienced appreciable downwarping. A maximum downwarping of about 500 feet is estimated for an elongated zone near the shelf edge about 80 miles south of New Orleans (Fisk and McFarlan, 1955, p. 300).

The amount of downwarping of the Prairie surface in the

Pontchartrain Basin area increases in a seaward direction from zero along the hinge line to about 40 feet in the vicinity of New Orleans. If it is assumed that the downwarping has been a uniform warping of the deposits, the resultant seaward slope of the surface in the vicinity of New Orleans would be on the order of 2.5-feet-per-mile. There is strong evidence, however, that a considerable amount of faulting has been coincident with downwarping and probably a major means by which downwarping has been accomplished. Consequently, the buried Prairie surface actually has a steplike configuration rather than a uniform seaward slope (Fig. 13.) Because of greater fault displacements in the northern part of the basin than in the southern part, the average slope of the Prairie surface is only slightly greater (1.6-feet-per-mile) at the present time than it was originally.

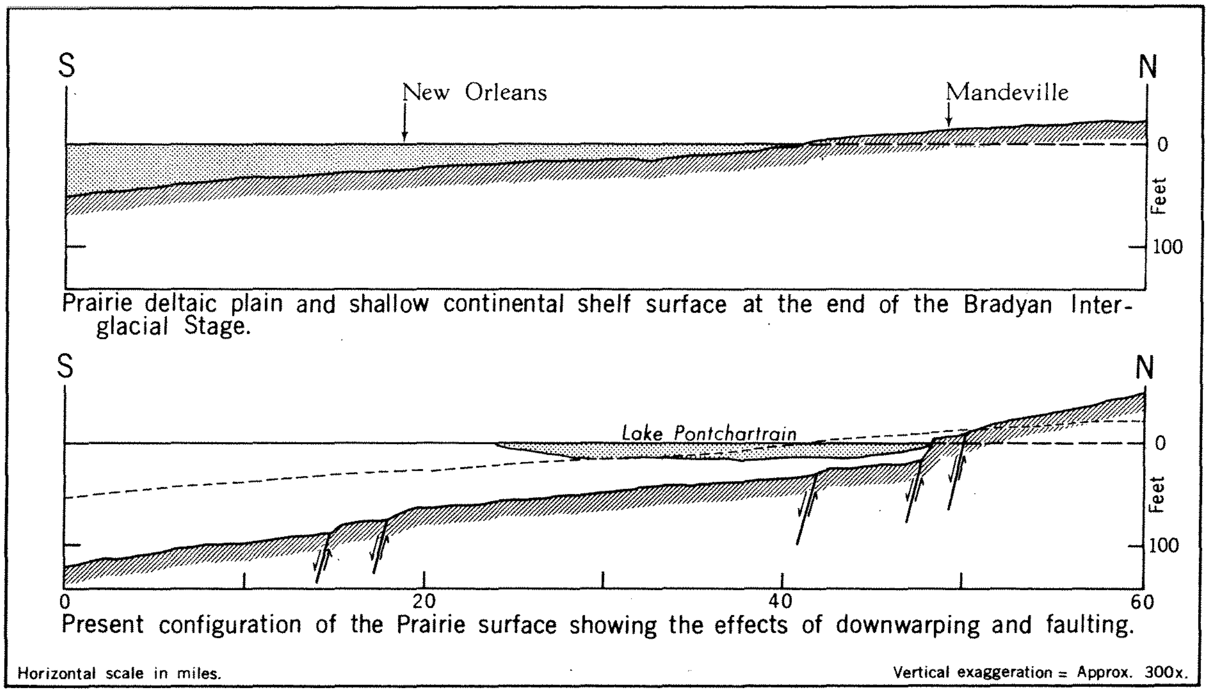

Fig. 13. Generalized cross sections through the Pontchartrain Basin showing the results of downwarping and faulting of the Prairie surface.

The major faults along the northeastern, northern, and northwestern margins of the basin (Fig. 5, A-F) have played an important role in determining its shape and extent. Several of these faults (Fig. 5, C-F) are undoubtedly part of a large fault zone which trends east-west across central Louisiana (through Baton Rouge). This system, active since Miocene times, exhibits local displacement of over 2000 feet at depth (Fisk, 1944, p. 32). The faults' greatest near-surface effect has been to lower appreciably a large area of Prairie terrace south of the faults to a position below present sea level (Fig. 13). Had the faulting not occurred, the northern and western limits of the basin would be located at least five miles farther seaward than their present position. In addition, the Prairie-

Recent contact has been strongly accentuated and angulated by the faulting.

Entrenchment

When sea level began to fall in the early part of the Late Wisconsin glacial stage, the Mississippi River and the smaller streams draining the Prairie surface were forced to erode trenches in order to adjust to the falling base level. The entrenchment continued, with the streams lengthening seaward across the continental shelf, until the lowstand of sea level was reached at the glacial maximum (Fisk and McFarlan, 1955, p. 292).

The first mapping of the entrenched valley system beneath the Pontchartrain Basin was done by Fisk (1944, p. 34). Working with a limited number of borings, he indicated a probable east-west trending system, the main valley of which extended eastward from the Amite River (called the Amite Trench). All other streams in the basin area became tributary to this main course. Fisk showed the entire system then draining to the southeast and passing below eastern Orleans Parish near Chef Menteur Pass.

With the benefit of many additional borings, the buried entrenched surface beneath the basin was re-mapped in 1958 for a geologic study of the Mississippi deltaic plain (U. S. Army Engineer Waterways Experiment Station, 1958, vol. 2, Pl. 4). It became evident at this time that the main trench trended north-south rather than east-west and that the Prairie surface was not nearly so dissected as was previously believed.

Using the 1958 map as a guide, the Prairie surface was remapped in detail using an additional several hundred borings (Fig. 14). These data suggest that several tributaries converge in a single major trench near the south center of the basin. Just west of New Orleans, the trench is about 1.3 miles wide and reaches a maximum depth in excess of 75 feet below the adjacent Prairie surface (125 feet below mean Gulf level). The trench proceeds to the south with a gradient of about 3.0-feet-per-mile and eventually joins the major Mississippi River trench near the coast of Louisiana south of New Orleans.

Because of a complete lack of subsurface data over much of the area of Lake Pontchartrain, the positions of the trenches in this area are necessarily largely inferred. It becomes increasingly apparent with additional information, however, that the trenches throughout the entire area are relatively narrow and occupy only a very small part of the total area. Large areas, such as below the southwestern portion of the basin, are relatively undissected and compare closely to areas on the exposed Prairie terrace north of the basin.

Along most of its present course, the Mississippi River has scoured deeply (up to 100 feet) into the buried Prairie formation. The base of the scoured channel (below both the present channel and point bar areas) averages about 100 feet below mean Gulf level and usually does not exceed two miles in width. The characteristically steep sides of this scoured channel and similar ones beneath the major passes (e.g., The Rigolets) do not lend themselves to contouring on a small scale map such as Figure 14 and consequently are not shown.

Physical Characteristics

During the period when sea level was 75 feet or more below its present level, the Prairie surface beneath the basin was subjected to erosion, oxidation, and consolidation. By the time that postglacial rising seas began to cover this surface, it must have had many of the same characteristics as the presently exposed terrace. The usual marked contrast between these characteristics and those of the overlying Recent deposits greatly facilitates the identification of the Prairie surface when encountered in borings.

The sediments typically consist of well-oxidized firm to stiff silty and sandy clays. In general, the silty clays are more common in the western portion of the basin area while the sandy to very sandy clays are more common in the eastern portion. This is probably a reflection of both the environment of deposition (deltaic plain to the west and north, continental shelf to the east and south) and reworking during the postglacial invasion by the sea. In both cases, the sediments have a distinctively lower water and organic content than most Recent sediments.

The upper 5 to 20 feet of the Prairie formation typically exhibit a mottled tan, yellow or orange, gray, and olive coloration. The tan and yellow oxidized coloring gradually diminishes with depth and is replaced by a green, gray, and white mottling. The latter coloring is occasionally present at the contact in the deeper portions of the trenches where the formation has been heavily eroded and has been exposed to a reducing environment for a longer period. In the portions of the formation where clays and silty clays predominate, the upper several feet are characterized by numerous and frequently large (up to one or two inches) calcareous nodules.

POSTGLACIAL SEA LEVEL RISE

Recent evidence based on an analysis of radiocarbon dates suggests that sea level rose from its maximum lowest glacial stand of about -450 feet to about -250 feet before 35,000 years ago (McFarlan, 1961, p. 129). Following a long stillstand which lasted until about 18,500 years ago, sea level continued its rise to its present level (ibid.). Except during the stillstand and possible short quiescent periods, the Gulf shoreline was forced to retreat inland accross the continental shelf before the transgressing sea. Shoreline retreat was probably more rapid during the second stage of sea level rise because of gentler inner-shelf slopes above the -250-foot level (Fisk and McFarlan, 1955, p. 296).

As the exposed continental shelf became submerged beneath Gulf waters, areas away from the zone of active deltaic deposition by the Mississippi River were subjected to appreciable amounts of marine planation. The most active erosion undoubtedly occurred on the interfluves between stream trenches. In most cases, stream deposition was not rapid enough to prevent the Gulf waters from flooding well inland into the stream trenches, thus producing estuarine conditions.

Sediments reworked from the Prairie surface, including some reworked from materials introduced onto the shelf by the Mississippi River, were either deposited along the shorelines as beaches or deposited offshore in a thin veneer. These latter deposits, called strand plain deposits by Fisk and McFarlan (1955, p. 296), accumulated in a nearshore marine environment and vary considerably from one area to another.

Toward the close of the rising sea level stage, the continental shelf south of the Pontchartrain Basin was marginal to and received little influence from the area of active deposition by the Mississippi River. Most of the fluviatile materials incorporated in the strand plain deposits in the basin area appear to have been derived from Pearl River or other streams farther to the east (either sediments deposited on the shelf during Pleistocene times or during the Recent sea level rise). A predominant westward drift, believed to have been present along the northern Gulf Coast when sea level had risen to within 60 feet of its present stand, helps to explain this occurrence (Van Andel and Poole, 1960, p. 110).

When sea level was from 75 to 100 feet below its present stand, Gulf waters invaded the seaward portions of the stream trenches in the basin area. Sediments introduced from offshore combined with those being deposited by the streams and filled the basal portions of the trenches. This material consists of soft to firm gray clays (slightly silty to sandy) with numerous thin zones of silt and sand and scattered shell fragments.

After sea level rose to within 50 feet of its present level, interfluve areas beneath the basin were submerged and subjected to a certain amount of planation. The basal Recent deposits in these areas, although highly variable, consist primarily of silts and sands with numerous zones of clay and scattered shell fragments. Near the base of the deposits, there are occasional fragments of reworked yet typically oxidized and multi-colored Prairie terrace materials.

A study of the fauna was made of cores taken from sediments of this type deposited in a shallow trench in the New Orleans area (Oakes, 1947). Oakes (p. 23) states that,

> There is clear evidence in the lithology of the sediments, and in the included fauna and flora, that sea level was actively rising during the period when the lower sands and silty sands of Unit G were deposited (deposits directly overlying the Pleistocene). The poorly sorted texture and fine size of individual grains of the sediments and their mottled light-brown color clearly indicate that they were locally derived as the sea spread landward across the irregular surface developed on the oxidized Pleistocene sediments.
>
> The first 5 feet of sediments above Unit G are clays with sand lenses which contain an abundant fauna that lived in deeper water than any successive fauna. Their

preserved shells and tests indicate that sea level was still rising and that sedimentation did not keep pace with the rate of rise. However, the fauna in the next 7 feet of sediments show a gradual decrease in depth of deposition of sediments.

Oakes then describes a beach sand overlying this latter zone and interprets it as being deposited when sea level reached its present stand. This sand is part of the Pine Island beach trend which is discussed in detail later in this report.

Radiocarbon dates of samples of shell taken from these marine sediments in the New Orleans area vary from 7870±300 to 8940±190 years before present and represent materials taken from 65 to 95 feet below mean Gulf level (Table II, samples 23, 24, and 27). Assuming that these are most likely maximum dates[8], they indicate that sea level had probably risen to within 50 feet of its present stand at least by about 7000 years ago.

THE PONTCHARTRAIN EMBAYMENT

The presence of marine shells at a shallow depth (30 to 50 feet) below New Orleans was recognized as early as the middle of the 19th century (Hilgard, 1870). Several writers have advanced the idea that Lake Pontchartrain was once a westward extension of Mississippi Sound and later cut off as a result of delta growth (Russell, 1936, p. 163), hence the source of the marine deposits. In 1947, Fisk (p. 27) recognized the presence of an arm of the sea in the basin area and called it the Pontchartrain Embayment. At maximum extent, it was mapped as extending inland as far as Donaldsonville and closely following the northern margin of the basin (ibid., p. 24).

Extent and Age

For the most part, relict shorelines of the Pontchartrain Embayment are well preserved in the basin area and consist of large buried sand beaches (Fig. 15). The related bay-sound and/or nearshore gulf deposits (U. S. Army Engineer Waterways Experiment Station, 1958, vol. 1, p. 71) are widespread and easily discernable.

West of the basin area the exact locations of the shorelines are largely unknown. There are a few borings, however, which have encountered shallow bay-bottom deposits that can be correlated with the embayment. Rangia shells have been encountered at shallow depths at two localities southwest of Baton Rouge (Fig. 15) and have yielded

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[8]Most laboratories making radiocarbon assays have found that, in general, shells give somewhat inconsistent and unreliable dates as compared to those on charcoal or peat. In addition to this inherent quality, a sample of shell from a bay-bottom or similar deposit most likely contains some reworked material. In all cases, this would produce a date older than the true age of the sample.

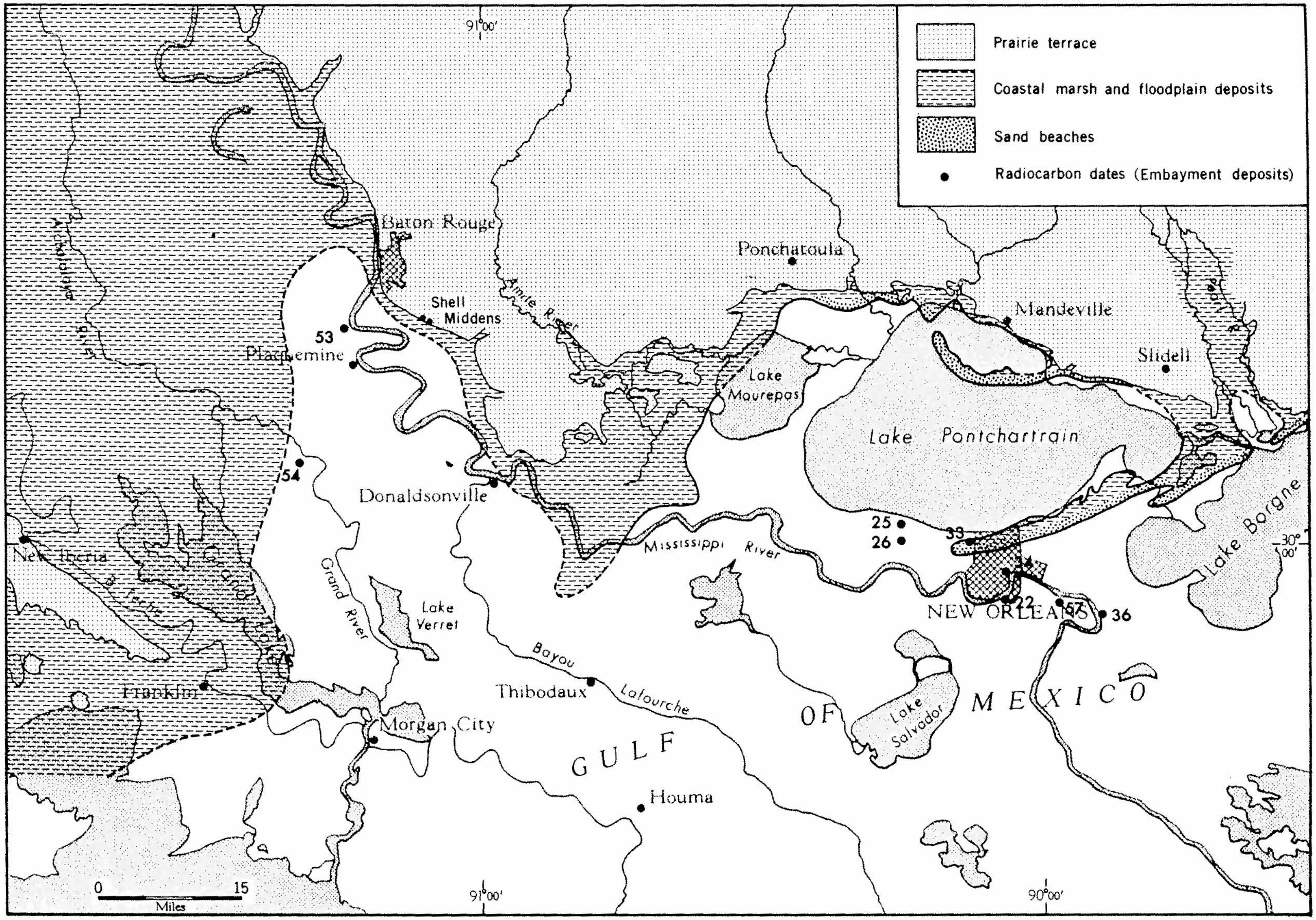

Fig. 15. Postulated maximum extent and shoreline features of the Pontchartrain Embayment.

radiocarbon dates of 5500±140 and 5600±140 years ago (Table II, samples 53 and 54). Assuming that these are quite likely maximum dates, they indicate that the maximum inland extent of the embayment in this area probably occurred between 5000 and 5600 years ago or possibly later. In this portion of the embayment, fresh water from the Mississippi River mixed with Gulf waters to form a brackish-water environment.

Additional evidence for brackish-water conditions exists in the form of two Indian sites located near the edge of the Prairie terrace southeast of Baton Rouge (Fig. 15). The sites, composed primarily of Unio and Rangia shells, are by far the farthest inland shell middens known to exist in the area. Investigations at the northernmost midden (the southernmost one was recently destroyed) revealed typical midden materials such as charcoal, animal bone, and rich black earth, but no artifacts of any type.

Primarily on the basis of the conspicuous absence of artifacts, the sites were initially considered to be of Archaic age. This tenuous age determination was not verified until a radiocarbon date of 5475±135 years ago (Table II, sample 58) was obtained on a sample of Rangia shell from near the base of the existing site (known as the Knox Site). Since this date accords so well with others of the embayment stage, there can be little doubt that the Indians were living on or near the eastern shoreline of the Pontchartrain Embayment and were obtaining Rangia from the brackish-water body.

In the Pontchartrain Basin area, where more marine conditions prevailed, samples of marine shell have yielded the following radiocarbon dates (Fig. 15),

Dating	Depth	Sample No.
4800±130	-49	25
4840±130	-50	26
5200±135	-57.8	57
5350±350	-68	36

On the basis of these dates, the fully developed stage of the embayment in the basin area is interpreted as being about 4800 to 5000 years ago.

The maximum extent of the embayment must have occurred at or shortly after the time that sea level reached its present level. Because of the shallow slope of the Prairie surface beneath the basin area, a sea level stand only several feet below its present level would have resulted in a shoreline appreciably farther seaward than is indicated. In addition, the rate of sea level rise from the -25-foot or -50-foot stage to the present level must have been rather rapid in order to shift the site of Mississippi River sedimentation inland into its alluvial valley and permit an invasion of the Gulf. Shortly after this, during the early part of the standing sea level stage, the Mississippi River quickly filled the shallow embayment and began building a delta seaward from the mouth of the alluvial valley[9].

[9]The commonly accepted division between the alluvial valley and

The Miltons Island Beach Trend

The mainland shoreline of the Pontchartrain Embayment has been traced with a moderate degree of accuracy from the vicinity of Slidell westward to the vicinity of Ponchatoula (Fig. 16). With the exception of a 2.5-mile long ridge southwest of Madisonville, the entire relict shoreline is buried beneath marsh and swamp deposits or lies beneath Lake Pontchartrain. The entire system will be referred to as the Miltons Island beach trend or system after the name of the exposed ridge (U. S. Geological Survey Quadrangle "Covington", 1935 ed.). The ridge has also been named Miller's Island and Martin's Ridge on various other maps.

Between Slidell and Bayou Lacombe, the former shoreline is characterized by a low, broad, and thin sand beach resting on the Prairie surface (Fig. 16, section C-C'). The beach deposit consists of a moderately well sorted and well oxidized very fine to medium quartz sand with very few shell fragments. Toward the base of the beach, the clay content increases until it grades into the very sandy clay of the Prairie surface. Since the sandy clay is limited to the upper few feet of the Prairie formation, this probably represents reworking by wave action.

The position of the shoreline between Bayou Lacombe and Miltons Island has been traced using several criteria. The best evidence is in the form of a series of deep and well-logged borings along a proposed route of the Lake Pontchartrain Causeway (Fig. 16, section A-A'). At this location, a large sand beach deposit overlies both a filled entrenched valley in the Prairie surface and a portion of the surface itself and consists of a coarse gray sand with some fine gravel and shell fragments.

Although there are no additional borings in the northern part of the lake which have encountered the beach, some indication of its location appears on the bottom of the lake in the form of several shoals. The shoals, which are interpreted as being remnants of the higher portions of the beach, become particularly apparent when the relatively flat lake bottom is contoured using a one-foot interval (Fig. 16). The presence of nearly pure sand along the trend projected between the shoals is confirmed by bottom samples analysed by Steinmayer (1939, pp. 4-5).

In 1934, a barge load of Rangia shells containing human and animal bones, charcoal, and pottery of Coles Creek age was reported as having been dredged from the bottom of Lake Pontchartrain south of Mandeville (Russell, 1940, pp. 1210-1211). Best estimates place the location of the dredged Indian site (Fig. 10, No. 19) as being about

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the deltaic plain of the Mississippi River is a line drawn between Donaldsonville and Franklin (Fig. 15).

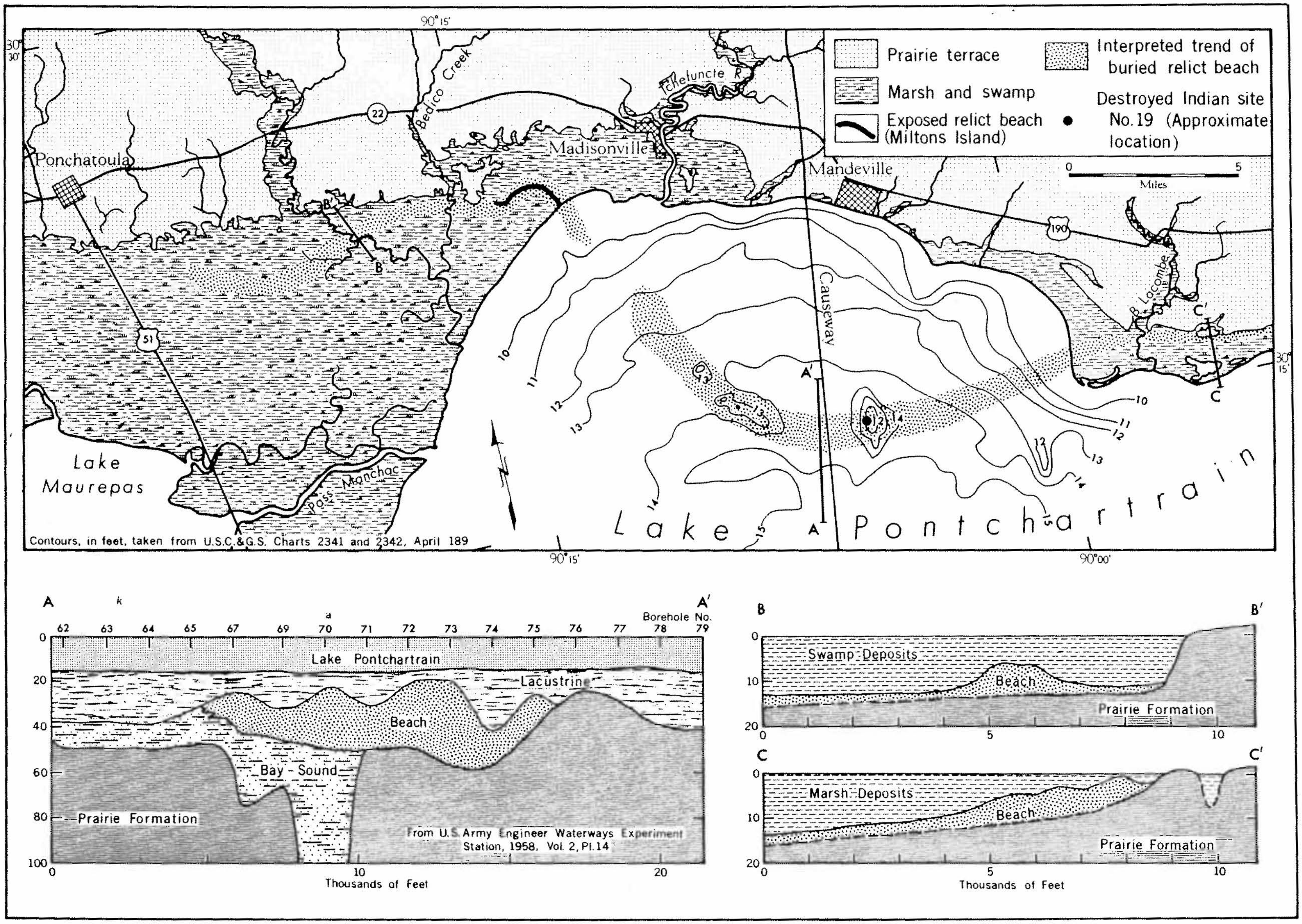

Fig. 16. Central and western portions of the Miltons Island beach trend.

five miles southwest of Mandeville Point[10]. This location lies on or very close to the most prominent shoal on the bottom of the lake in about 12 feet of water (Fig. 16). Assuming that such a site existed at this location (to be discussed more fully later), it most probably was located on what was then a surviving portion of this beach trend.

Miltons Island itself is an arcuate ridge about 2.5 miles long, 300 to 500 feet wide, and about 5 feet high (Fig. 17). Borings to a depth of 13 feet near the center of the ridge encountered well oxidized very fine to medium sand with a small percentage of coarse sand and fine gravel. In comparison to most beaches, the material is poorly sorted; it does compare favorably, however, with samples taken by means of hand-auger borings (disturbed and possibly contaminated) in other relict beaches of the same age. The ridge, a prominent feature because of its stands of pines and mixed hardwoods, has been truncated at right angles by Lake Pontchartrain on the south and gradually loses elevation until it disappears beneath swamp deposits on the west (Fig. 17).

Between the western end of Miltons Island and U. S. Hwy. 51, the beach is very similar in shape and composition to the ridge near Bayou Lacombe (Fig. 16, section B-B'). Along the highway south of Ponchatoula, the Prairie surface is overlain by a thin veneer of sand and sandy clay deposits reworked from the materials below rather than a well defined beach. Exactly how far to the east of the highway the actual beach ends is not known.

Southwest of Ponchatoula and as far as the Mississippi River, no indication of a well defined shoreline has been found. The sand and sandy clay bay-bottom deposits overlying the Prairie surface at depths of 20 to 30 feet in the vicinity of Lake Maurepas gradually thin and shallow toward the west and eventually pinch out. Their maximum inland extent is taken to be a close approximation of the former shoreline (Fig. 15).

Bay-bottom deposits overlying the Prairie surface north of the central portion of the Miltons Island system strongly suggest that this section (Fig. 15) was in the form of a barrier spit (terminology as defined by Shepard, 1952, p. 1906) rather than a mainland shoreline. There is no reason to believe that the Prairie surface was not at sufficient depth to allow Gulf waters to spread inland behind the barrier. No shorelines around this shallow bay or sound have been located, however.

The Pine Island Beach Trend

The largest and most widely known feature associated with the Pontchartrain Embayment is a large barrier spit located beneath Orleans Parish and extreme northeastern Jefferson Parish. The name of the system is derived from one of only two localities where the

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[10] F. B. Kniffen and R. J. Russell, personal communication, 1959.

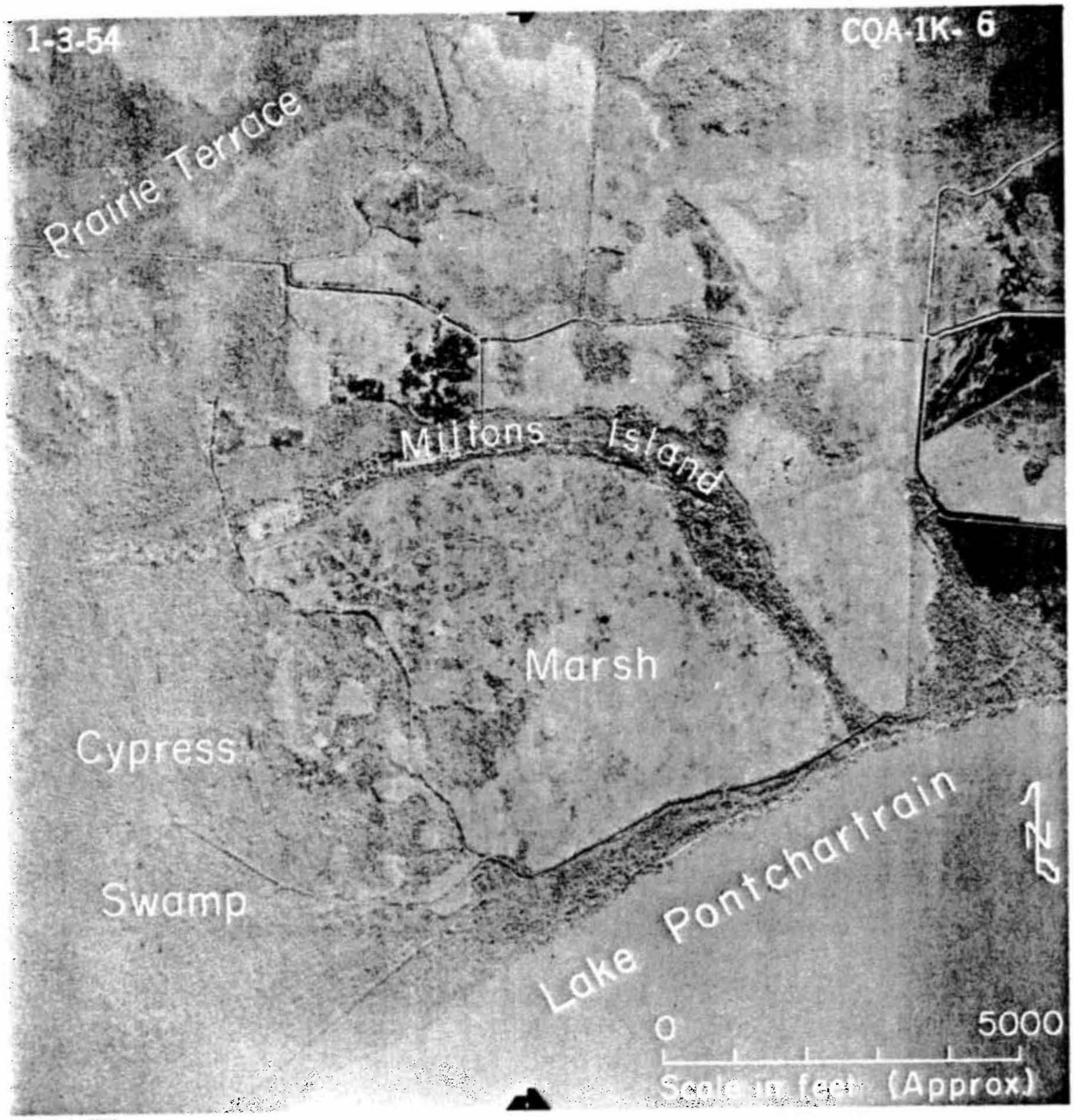

Fig. 17. Miltons Island.

ridge rises a few feet above mean Gulf level (Fig. 7). Figure 18 illustrates the physiography of the buried ridge as determined by approximately 850 borings.

Throughout a total distance of about 35 miles, the south or Gulf side of the ridge is relatively steep and fairly uniform in plan. When the ridge was an active coastal feature, the irregular northern or sound side probably consisted of a series of ridges, swales, sand flats, and sandy shoals in shallow water. No evidence of a strip of marsh along the sound side of the barrier has been found, although such quite likely existed in places. Closely spaced borings at several localities in the New Orleans area have encountered well-defined accretion ridges and possible dunes near the crest of the ridge. Readily discernable accretion ridges are present on the outcrop of the ridge located just south of Lake St. Catherine (Fig. 18).

In a fully developed stage, the system was probably one continuous ridge from the mouth of Pearl River to the vicinity of New Orleans, i.e., there were no major inlets or passes. Although no evidence has been found, it was probably connected to the mainland (Prairie terrace) at its eastern end and served as a mainland shoreline for a distance of at least five miles. Slow growth on its western end (due to a prevailing westward drift) lengthened the ridge appreciably during its life as an active beach (estimated to be a period of at least 500 years). Late in the ridge's history, an inlet or pass developed in the vicinity of The Rigolets, thus separating it from the mainland. The two passes shown on Figure 18 and a possible third one located just west of Chef Menteur Pass are also believed to date from the latter stages of the ridge's history, but were probably inactive by the time the one at The Rigolets developed.

The entire beach ridge is characteristically composed of fine sand (median grain-size) with large quantities of shells and shell fragments. The normal range of grain-sizes is from very fine sand to coarse sand. The sand is usually well sorted and with the exception of the lower northern portions of the ridge, contains very few lenses of clay or silt. Composed primarily of quartz, the sand is typically a light gray or tan color but bleaches to a brilliant white upon exposure at the surface. Beach sediments grade both laterally (north and south) and vertically (downward) into silty sand and sandy clay nearshore gulf and bay-sound deposits. In general, only the eastern half of the sand beach deposit lies directly on the Prairie surface.

During the construction of a new highway (U. S. Interstate Hwy. 10) in the Little Woods area of Orleans Parish (Fig. 2), large quantities of shell and sand were dredged from the buried ridge and used as fill. An abundant molluscan assemblage in the material was analysed by Rowett (1957, p. 153) primarily to determine the environmental conditions prevailing at the time of deposition. Based on an identification of 87 species of Mollusca (ibid., pp. 154-155), he shows the fauna to be representative of the shallow continental shelf assemblage listed by Parker (1956). Rowett further concludes that (p. 153),

> . . . The fauna is interpreted as having lived on the gulf side of a barrier island similar to those now

existing off the Mississippi Sound. It is believed to be of late Pleistocene or early Post-Pleistocene age.

Two radiocarbon dates, 5400±140 and 4300±200 years before present (Table II, samples 34 and 22), were obtained from shells from bay-sound deposits which appear to be closely related to the beach deposit. A third date, 4800±140 years ago (Table II, sample 33), was obtained from marine shells located in the center of the beach ridge near its western end (Fig. 15) at a depth of -20 to -25 feet. These dates are in accord with others of the Pontchartrain Embayment stage.

Origin of the Beach Trends

As previously stated, the maximum extent of the Pontchartrain Embayment occurred at or shortly after the time that sea level reached its present stand. The Miltons Island and Pine Island systems, however, are believed to have begun forming when sea level was somewhat below its present level. It is quite likely that the final rapid sea level rise was a major factor contributing to the formation of the beach trends, especially the Pine Island trend.

The origin of the beach trends is illustrated in Figure 19 by a series of maps showing postulated conditions for several stages of the Recent sea level rise. When sea level was about 40 feet below present level, Gulf waters were just beginning to overlap the Prairie surface in the latitude of New Orleans (Fig. 19A) but extended much farther inland along the major stream trenches in the form of narrow estuaries. During this stage, sediments from Pearl River were probably combining with others reworked from the Prairie formation in sufficient quantities to form relatively large sand beaches along the shoreline in the eastern portion of the basin area.

As sea level continued to rise, the Gulf shoreline moved rapidly inland over most of the basin area but not in the vicinity of Orleans Parish. In this latter area, the transgressing shoreline encountered a zone of relatively steep slopes (a partial result of activity along the Lake Borgne Fault Zone (Fig. 5)) on the Prairie surface. The consequent slowing of the rate of transgression is believed to have been the impetus that originated the Pine Island system. By the time that sea level had reached the -20-foot stage (Fig. 19B), an incipient barrier spit had probably already formed.

During the succeeding 10 or so feet of sea level rise, the Pine Island barrier spit became finally stabilized in position, it actively lengthened toward the southwest, and it grew vertically to keep pace with the rising sea level (Fig. 19C). It was during this stage that the central portion of the Miltons Island system became well established. Its initiation facilitated by irregularities on the Prairie surface (Fig. 16, A-A'), it remained relatively fixed in position and accreted rapidly. The eastern and western segments of the system, however, were still transgressing swiftly across the gently sloping Prairie surface. Gulf waters were also spreading eastward in back of the Pine Island system, thus narrowing its connection to the mainland.

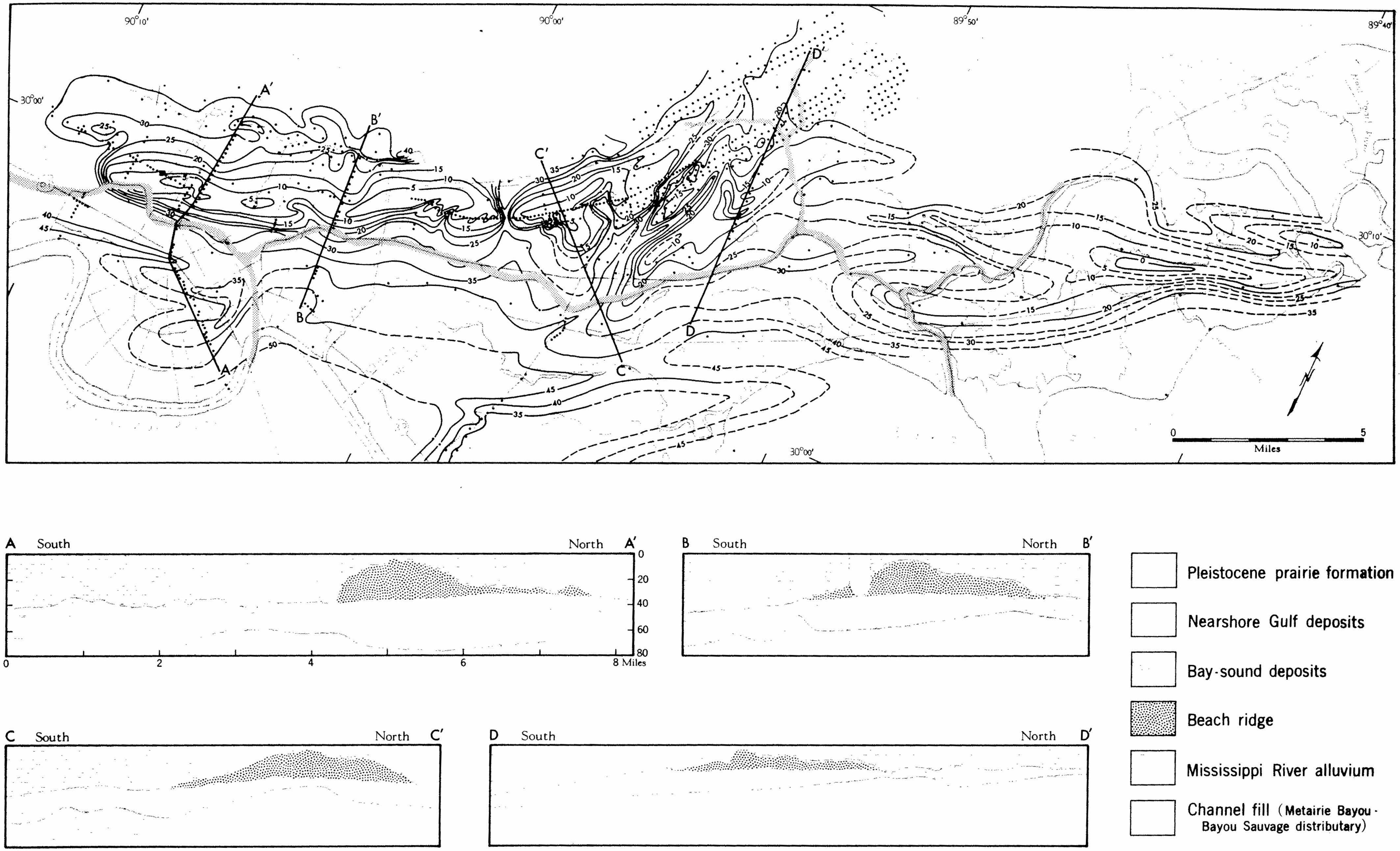

Fig. 18. Contours on the surface of the buried Pine Island beach trend.

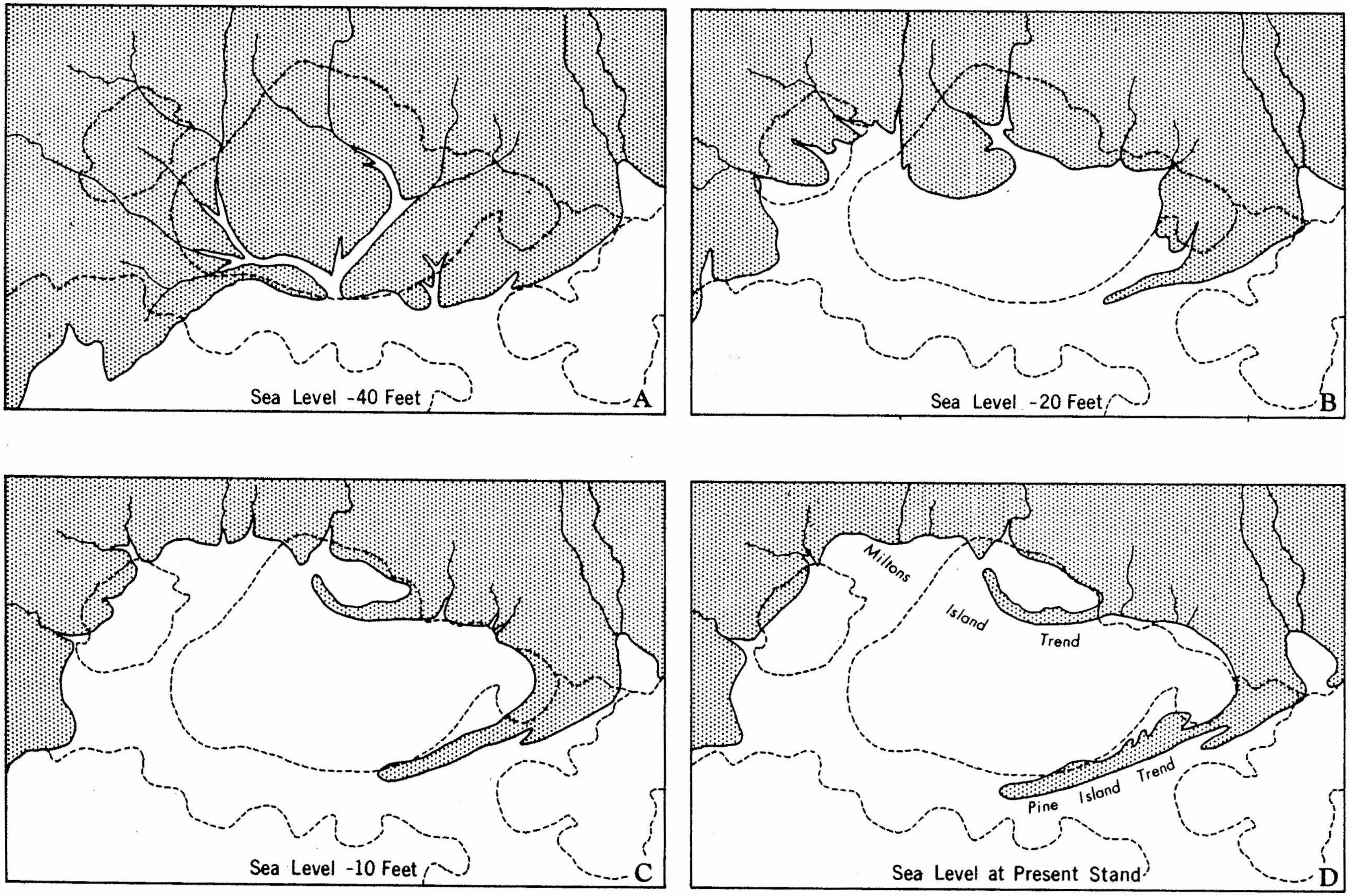

Fig. 19. Origin of the Miltons Island and Pine Island beach trends.

Figure 19D shows that the final 10 feet of sea level rise resulted in an increase in size of both beach trends and, in general, the establishment of the shorelines in the position in which they now remain. Additional changes after this stage were probably in the form of accretion along the shorelines rather than erosion and a gradual filling of the shallow sounds in back of the barriers.

INITIAL MISSISSIPPI RIVER SEDIMENTATION

When the Pontchartrain Embayment was at its maximum extent, the site of active Mississippi River sedimentation was probably in the alluvial valley at approximately the latitude of Baton Rouge (Fig. 15). Shortly after this stage, with sea level remaining relatively stationary at about its present level, the Mississippi River began building its delta seaward beyond the mouth of the alluvial valley. As Van Lopik (1955, p. 83) states,

> . . . This gulfward growth was accompanied by many shifts both in course and location of the active delta. Thus, a front of fine alluvium was pushed gulfward over the previously deposited sediments in the troughs (consisting of coarse basal fluviatile deposits, overlain by estuarine and marine sediments) and the inter-trough older deposits.

The oldest recognized delta of the Mississippi River formed during the last 5000 years is located in central coastal Louisiana south of Franklin (Fig. 24). Named the Salé-Cypremort system (Van Lopik, 1955) after two of its major distributaries, the delta is believed to have been active from about 4500 to 5500 years ago (U. S. Army Engineer Waterways Experiment Station, 1958, vol. 1, p. 7).

By 4500 years ago, the Mississippi River was beginning to introduce sediments into the western portion of the Pontchartrain Basin. The rate of sedimentation increased over the next several hundred years until the river finally diverted a large percentage of its flow toward the east into the basin area.

Sediments

The initial Mississippi River sediments consist of a wedge of soft to firm gray clays and silty clays with scattered thin layers of silt and silty sand. Faunal remains, found scattered throughout the deposits in varying quantities but generally more abundant in the silt and sand layers, indicate prevailing brackish-water conditions. Throughout the area, the fine deltaic deposits may be either transitional into or sharply distinct from the underlying nearshore gulf deposits.

As the Mississippi River extended its delta eastward, the clays and silty clays gradually filled large areas of the Pontchartrain Embayment beneath the western and central portions of the basin. In the eastern and southern portions of the area, the deposits are transitional into, interfinger with, and are not readily distinguishable from lacustrine, bay-sound, and nearshore gulf deposits. The shallower of the fluviatile deposits, those laid down near the delta front,

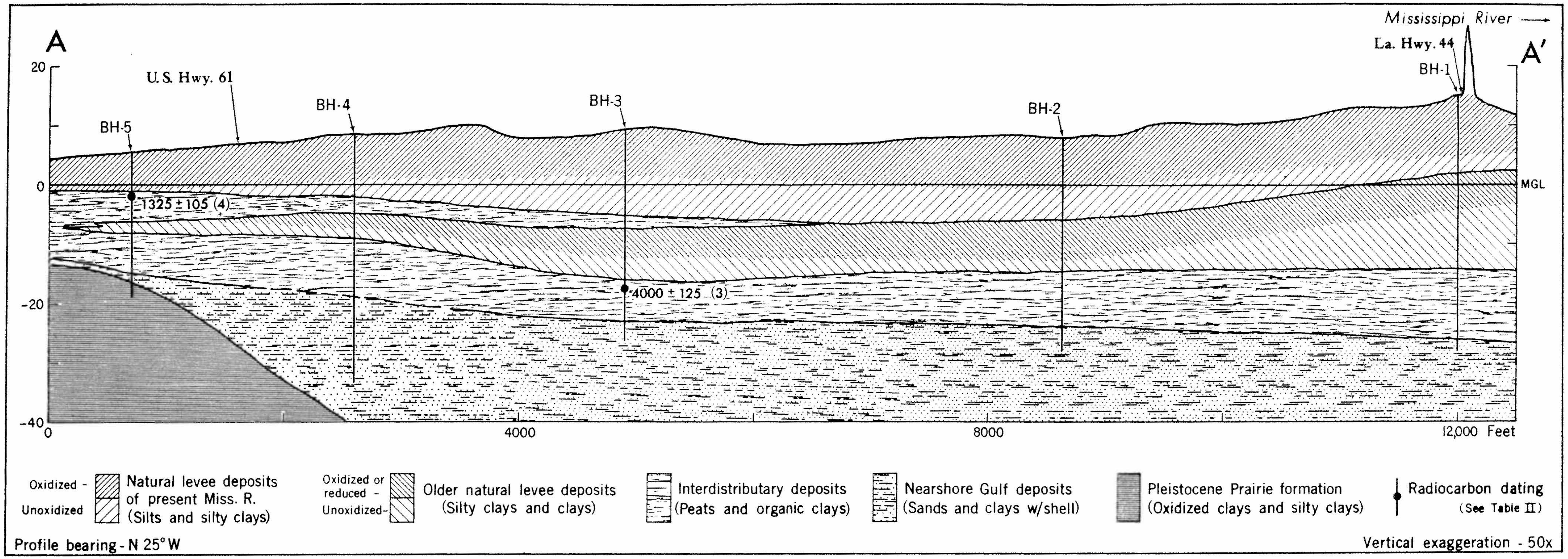

Fig. 20. Cross section through a Mississippi River natural levee near Reserve, La.

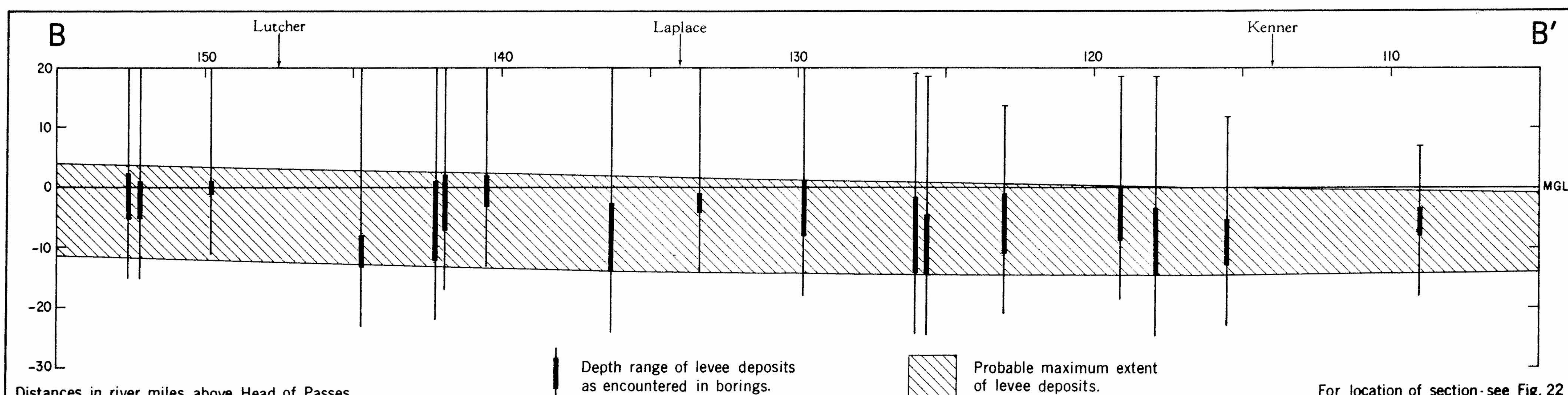

Fig. 21. Downstream cross section showing older natural levee deposits beneath the present Mississippi River natural levees.

are more variable and consist of silts and very fine sands near the mouths of advancing distributaries and clays and silty clays deposited on mud flats, in marsh areas, and in shallow lakes and bays.

Levee Systems

Early in the Pontchartrain Basin investigation, the presence of an older deltaic mass (more than 3000 years old) was suspected, but actual stream channels and their associated natural levees and inter-levee deposits were unknown. As a result of several detailed borings along the Mississippi River near Reserve (Fig. 2) and investigations at a shell midden on Bayou Jasmine (Fig. 10, No. 51), natural levee deposits of an older system were first recognized. Subsequent borings enabled the writer to trace the levee systems over a considerable portion of the area once the levee characteristics were known and it was realized that everywhere the levees lie below mean Gulf level or are buried by the present Mississippi River levees.

Characteristics.-- The natural levees consist of firm to stiff silty clays and slightly silty clays. Red, yellow, and brown oxidized coloration, so typical of exposed natural levees, is usually absent except in the upper several feet of the levees. Instead, the sediments are generally a mottled light gray and green or olive with only occasional specks of brown. This is thought to be the result of chemical reduction because of burial but may also indicate less initial oxidation. Cream colored calcareous concentrations and well indurated nodules are usually quite abundant while organic remains are generally absent. The green coloration and nodules disappear toward the base of the levees and the material becomes noticeably softer.

Borings through a buried levee of the probable trunk channel of the river system near Reserve indicate a definite decrease in grain size and increase in organic content toward the backswamp. Oxidation and reduction characteristics decrease in intensity and extent both with depth and distance away from the levee crest. The size and configuration of the buried levee and its relation to the present levee are shown on Figure 20. The levee width of about 12,000 feet may be excessive since it is not known if the line of section is perpendicular to the channel (Boring No. 1 is thought to be within 500 to 1000 feet of the channel). The anomalous warping of the levee between Borings 3 and 4 is believed to be due to differential subsidence caused by the configuration of the underlying Prairie surface or perhaps due to faulting.

A somewhat better idea of the elevation, thickness, and downstream slope of the buried levees of the major channel can be obtained from Figure 21. Since the borings indicated in the section have penetrated the levees at varying points between their crests and backswamp margins, there is considerable variation in elevation and thickness. A line connecting the highest and lowest points, however, should give a reasonable indication of the maximum values. The suggested downstream slope of about 0.1-feet-per-mile is comparable to that of the present levees in the same area.

Distribution.-- The locations of borings which have encountered buried natural levee deposits and the inferred location of the stream channel are shown in Figure 22. The position of the former river course appears to correspond well with that of the present course except in the vicinity of Laplace. Levee deposits, lying below a complicating and partially obliterating cover of recent crevasse deposits, were located north and east of the present river course at this point. A slight surface expression of the older levees appears to have strongly influenced the route of the crevasse channels which formed during four Bonnet Carré crevasses from 1849 to 1882 (Gunter, 1953, p. 23).

A portion of the original channel of a major distributary which trends north and northeast from the vicinity of Laplace is occupied near Lake Pontchartrain by Bayou Jasmine, an underfit swamp drainage channel. Borings along U. S. Hwy. 51 at this location (Fig. 22) show a maximum levee thickness of about eight feet and a total levee width of about 10,000 feet. About six miles northeast of Bayou Jasmine, borings encountered levees about half the size of those at the latter location, thus suggesting at least one major bifurcation between the two points. At both locations, the levee crests lie four to six feet below mean Gulf level.

Of the three distributaries which apparently formed in the vicinity of Kenner (Fig. 22), the one following the trend of the present river was probably the largest. Natural levees thought to be related to this distributary have been found at only one locality east of New Orleans. Borings through a buried shell midden (Fig. 10, No. 56) near Bayou Sauvage yielded natural levee deposits similar to those at Reserve from a depth of 6.5 to 14.5 feet below mean Gulf level. The maximum thickness and width of the levees at this point have not been determined. With the exception of this one location, the route of the buried distributary through Orleans Parish is unknown. The channel location indicated on Figure 22 is largely speculative and is based primarily on marsh drainage patterns and the routes of subsequent distributaries. It is suspected that large portions of the older system have been completely destroyed by erosion, particularly in the vicinity of Lake Borgne.

Paleogeography

It is difficult to come to many valid conclusions regarding the maximum extent of this old river system because of the paucity of subsurface data and because many of its levees have undoubtedly been modified by erosion. It is possible to reconstruct with a fair degree of accuracy, however, the conditions that must have existed in several portions of the basin area. The postulated conditions as they existed between approximately 3500 and 4000 years before present are summarized in Figure 23.

It is reasonable to assume that enough fluviatile sediments were introduced to convert much of the western and southern portions of the former embayment into swamp or marsh environments and to isolate the beach trends. By this time, subsidence, if occurring at approximately the rate of 0.39-feet-per-century, had sufficiently

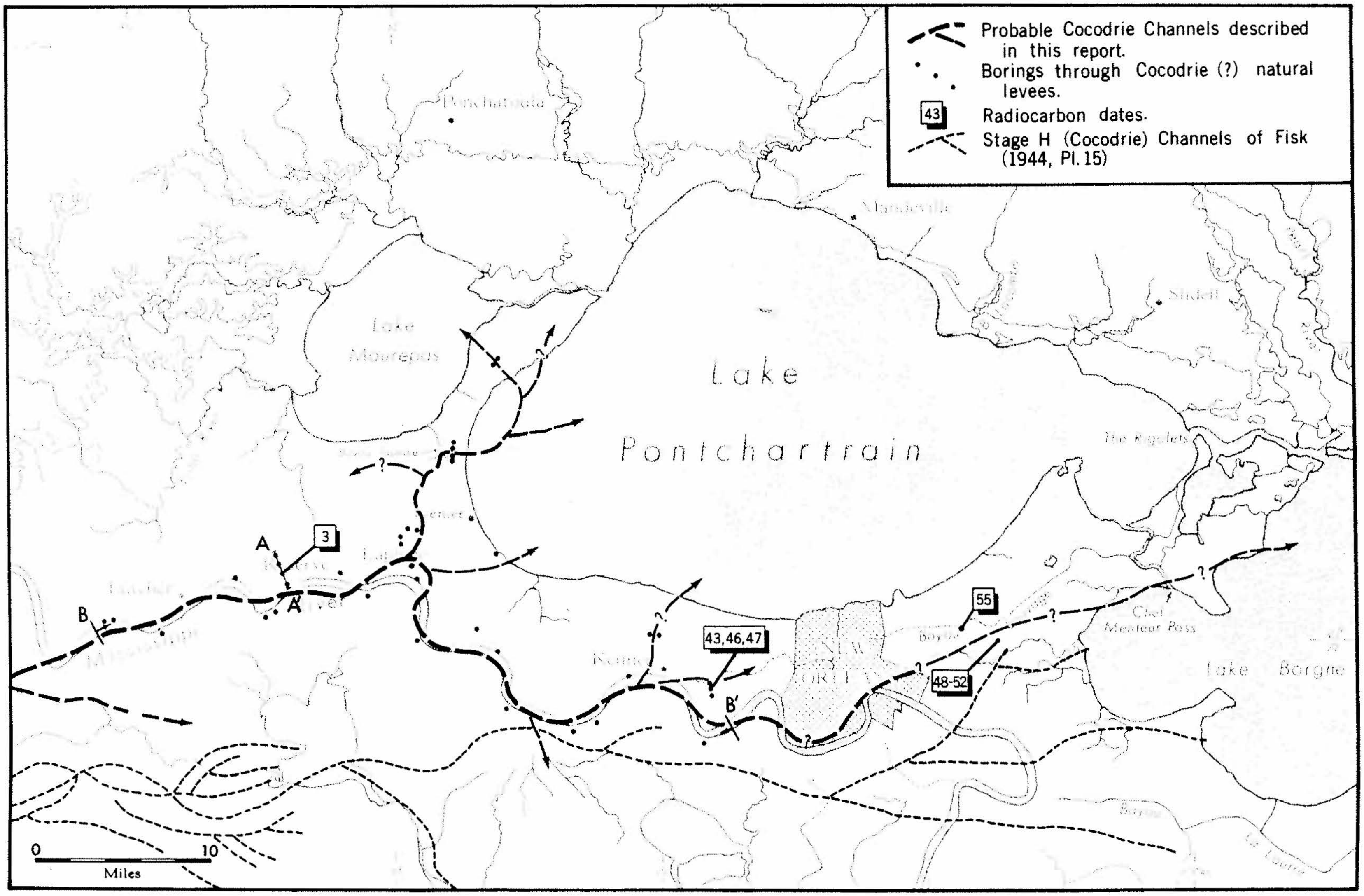

Fig. 22. Trunk stream and distributaries of the initial Mississippi River (Cocodrie?) Delta.

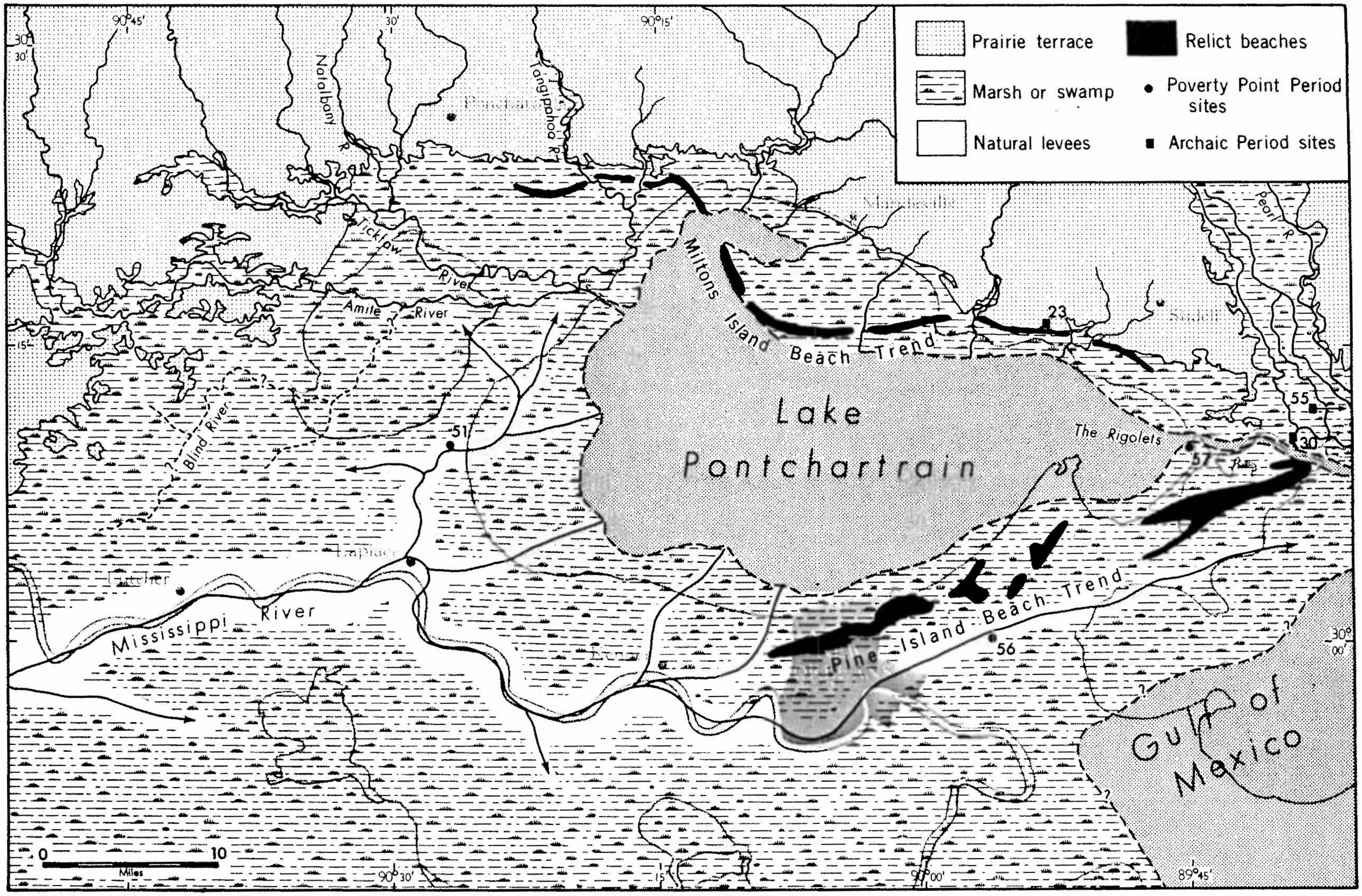

Fig. 23. Paleogeography of the Pontchartrain Basin, about 3500 to 4000 years before present, showing maximum extent of the Cocodrie Delta and locations of Poverty Point and Archaic period sites.

lowered the beach trends so that they existed as isolated islands rather than continuous ridges. Assuming that the location of the easternmost distributary of the river system is correct, the Pine Island ridge certainly appears to have exerted a strong influence on its route and prevented it from following a more northerly route into the basin area.

With the deltaic area at its maximum extent, the open body or bodies of water in the basin area were separated from the Gulf of Mexico on the south. This marked the end of marine conditions in the basin and the beginning of a lacustrine environment. The ancestral Lake Pontchartrain that resulted was not a fresh-water environment, however. Streams draining the Prairie terrace north of the basin introduced water to the basin which had to eventually find its way into the Gulf. The necessary pass or channel that formed the outlet was probably located in the approximate present position of The Rigolets. It is highly unlikely that any of the streams became tributary to the river system in the basin area. Thus connected with the Gulf, the open water in the basin was tidal and assumed to be brackish.

Since there was probably no open water in the area of present Lake Maurepas, channels draining the inter-levee basins and streams draining the Prairie terrace in the western portion of the area continued eastward through marsh and swamp to the vicinity of Lake Pontchartrain. The present Pass Manchac quite likely occupies the eastern portion of what was an old Amite River channel and North Pass occupies the eastern portion of what was an old Tickfaw-Natalbany River channel (Fig. 23). Traces of an abandoned stream channel, readily visible on aerial photos, suggest that the Tangipahoa River joined the Amite River near the present Pass Manchac-North Pass junction during this same period.

Indian Sites

During the Pontchartrain Basin investigation, six shell middens were located which are among the oldest known sites in coastal Louisiana and which are closely related to the initial deltaic area. Three of the sites (Fig. 23, Nos. 23, 30, and 55), composed predominately of oyster shell, are considered to be Archaic in age, while the remaining three sites (Fig. 23, Nos. 51, 56, and 57) are composed of Rangia shell and are of Poverty Point age[11] (Fig. 12).

The ecologic implications of the sites are significant. The three Archaic middens, located on or in close association with the edge of the Prairie terrace, strongly imply occupation during the latter stages of the Pontchartrain Embayment. Assuming that the Indians obtained their oyster supply locally, the area in the northeastern portion of the basin and/or the western end of Mississippi Sound

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[11] Two Poverty Point period sites were investigated and collected by the writer during the survey. The third site (Fig. 23, No. 57) was recently investigated and reported to the writer by Sherwood M. Gagliano.

must have been more exposed to the Gulf (hence more marine) during the period of occupation than it would have been at any time during the latter stages of the development of the river system. The oyster is an estuarine animal which flourishes best in a mixture of fresh water and sea water but is definitely known to be killed by excessive amounts of fresh water and/or fine sediment (Gunter, 1953). Oyster growth is believed to have ceased when the eastward-building delta reached the vicinity of the western end of the Pine Island beach trend.

Two of the three Poverty Point period Rangia shell middens are directly associated with the buried natural levees of the river system (Fig. 23, Nos. 51 and 56). The presence of Rangia shell supports the belief that there were brackish-water bodies in the area in the latter stages of delta growth. It must be assumed, or course, that the Indians during Poverty Point times would have utilized oysters had they been available locally. The precise association of the third site is unknown but it was quite likely situated on or near the pass connecting the lake with Mississippi Sound.

As shown in Figure 12, there are four radiocarbon dates representing materials of Poverty Point age (obtained from Site No. 56) and one date on materials from an Archaic period site (No. 55). The 3200±130-year-date (Table II, sample 42) represents charcoal taken from a black earth midden accumulation overlying the older oyster shell midden and is not considered to be indicative of the true age of the shell deposit. Evidence suggests that Indians with Archaic culture continued to inhabit the site and formed the earth midden after the period of extensive oyster availability and utilization.

Of the four dates representing Poverty Point remains, the 4450±140-year-date (Table II, sample 48) definitely appears to be anomalous. A date of 3700 years before present, the average of the three remaining dates (Table II, samples 49, 50, and 51), conforms well with the geomorphic evidence, but is considerably older than previous dates on Poverty Point remains in the Lower Mississippi Valley (Ford and Webb, 1956, pp. 121-122). The reason for this appreciable difference in age cannot be explained at the present time.

Age and Correlation

Age determination of the old river system has been facilitated by six radiocarbon datings on peat or highly organic clay deposits from beneath the natural levees of the system. The datings are as follows:

Location	Dating	Sample No.
Reserve area	4000±125	3
Metairie Bayou area	3550±125	43
	3750±120	47
	4050±125	46
Bayou Sauvage area	4050±140	52
	4400±130	55

Samples 3, 43, and 52 appear to represent some of the last organic materials deposited in marsh or swamp environments before they were encroached upon by advancing distributaries. Samples 46 and 47 represent materials from a marsh deposit lying several feet below the actual base of the distributary levees and may be separated by a greater period of time from the date of distributary development. In all cases, however, the organic deposits are believed to be a direct result of alluviation by this river system and do not represent an appreciably older land mass[12].

The radiocarbon dates thus indicate that the river system had advanced well into the area by 4000 years ago and that the youngest of the known distributaries formed not much later than 3550 years ago. In the case of the easternmost distributary, dates at the Poverty Point site (Fig. 23, No. 56) indicate that it had reached maximum development by 3700 years ago. On the basis of these dates, it appears safe to assume that the period of maximum discharge in the system occurred about 3800 to 4000 years ago.

Thus far, no attempt has been made to establish the exact source of the system or to correlate it with any of the previously identified deltas of the Mississippi River. Since field investigation was limited to the Pontchartrain Basin area, any statements in this context would be largely conjectural. Evidence gathered in the basin area, however, does suggest two alternative explanations.

The third oldest delta of the Mississippi River named by Fisk in his 1944 study (p. 36) was the Cocodrie Delta which he characterized as follows:

> The Cocodrie Delta is named for its trunk stream, Bayou Cocodrie, which follows a meander belt within the Tenses Basin. The meander belt has been traced southward through the Atchafalaya Basin to the Lafourche Ridge near Labadieville. East of the Lafourche Ridge, the trunk course divides into a series of poorly defined distributaries which trend west-east across the upper end of the Barataria Depression. The eastward traces of the Cocodrie Delta system are located near New Orleans.

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[12]Sample No. 55 (Table II) was originally described by McFarlan (1961, p. 151, sample 30) as being associated with "an east-trending offshore bar deposit at the margin of the Maringouin delta." This is the Pine Island beach trend as defined in this study. On the basis of the data presented in Fig. 18, the writer feels that the dated sample is definitely not associated with the beach trend but rather with the old river system. The location of the sample as given by McFarlan lies in an area where the beach deposit is interpreted as being about 35 feet below mean Gulf level; this is 18 feet below the indicated depth of the sample. On the other hand, the depth and age of the sample as well as the type of material are very similar to Sample No. 52 (located 2.2 miles to the southeast) which lies directly below the levees of a distributary of the river system.

The distributaries mapped by Fisk (<u>ibid</u>., Pl. 15) are shown on Figure 22. The Cocodrie Delta has not been mentioned again by Fisk since the 1944 publication; he has apparently eliminated it from his delta sequence because of a lack of confirming evidence.

In the 1958 publication by the U. S. Army Engineer Waterways Experiment Station, the concept of a Cocodrie Delta was revived but not elaborated upon. In this report (vol. 1, p. 4), the trunk stream is shown to be located in the same position as originally defined but its deltaic area is extended only as far east as New Orleans. The approximate duration of significant flow in the system is indicated as having occurred from 3600 to 4600 years ago (vol. 1, p. 7).

On the basis of the age ascribed to the system and the eastward trend of the Cocodrie trunk stream (toward the Pontchartrain Basin) to the point where it disappears (Fig. 24), the writer is inclined to believe that the old river system in the basin area represents at least a major portion of the Cocodrie Delta if not the entire delta.

A second possible upstream correlation was suggested in a study of the Atchafalaya Basin by Fisk (1952). When the Mississippi River was flowing in the central or western portion of the valley, as it would have been during the Cocodrie stage, the Yazoo River[13] may have occupied a separate course along the eastern side of the valley and built a delta into the western part of the Pontchartrain Basin. The Yazoo Delta would have been located north of the Cocodrie Delta or a possible earlier Maringouin Delta (<u>ibid</u>., p. 59) and the stream would have contributed sediments very similar in composition to those of the Mississippi River.

The writer does not believe, however, that the Yazoo River was ever capable of extending a delta as far eastward as eastern Orleans Parish. The width and thickness of the natural levees, the amount of fluviatile sediments introduced to the basin, and the apparent rapidity at which the river system developed certainly suggest a Mississippi River origin.

DETERIORATION OF THE DELTA

The period of significant flow in the river system apparently ended no later than 3500 years ago. Assuming that the system is Cocodrie, the Mississippi River was abandoning the course in favor of one along the western side of the valley and was already forming the Teche Delta (Fig. 24) by this time. Upon abandonment, sedimentation no longer was able to keep pace with subsidence and the Cocodrie Delta began to deteriorate.

Judging from more recently abandoned deltas such as the St. Bernard and Lafourche (Fig. 24), deterioration occurs in several ways.

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[13]The Yazoo River, 188 miles long, flows southwestward through the west central portion of the State of Mississippi and joins the Mississippi River near Vicksburg, Miss.

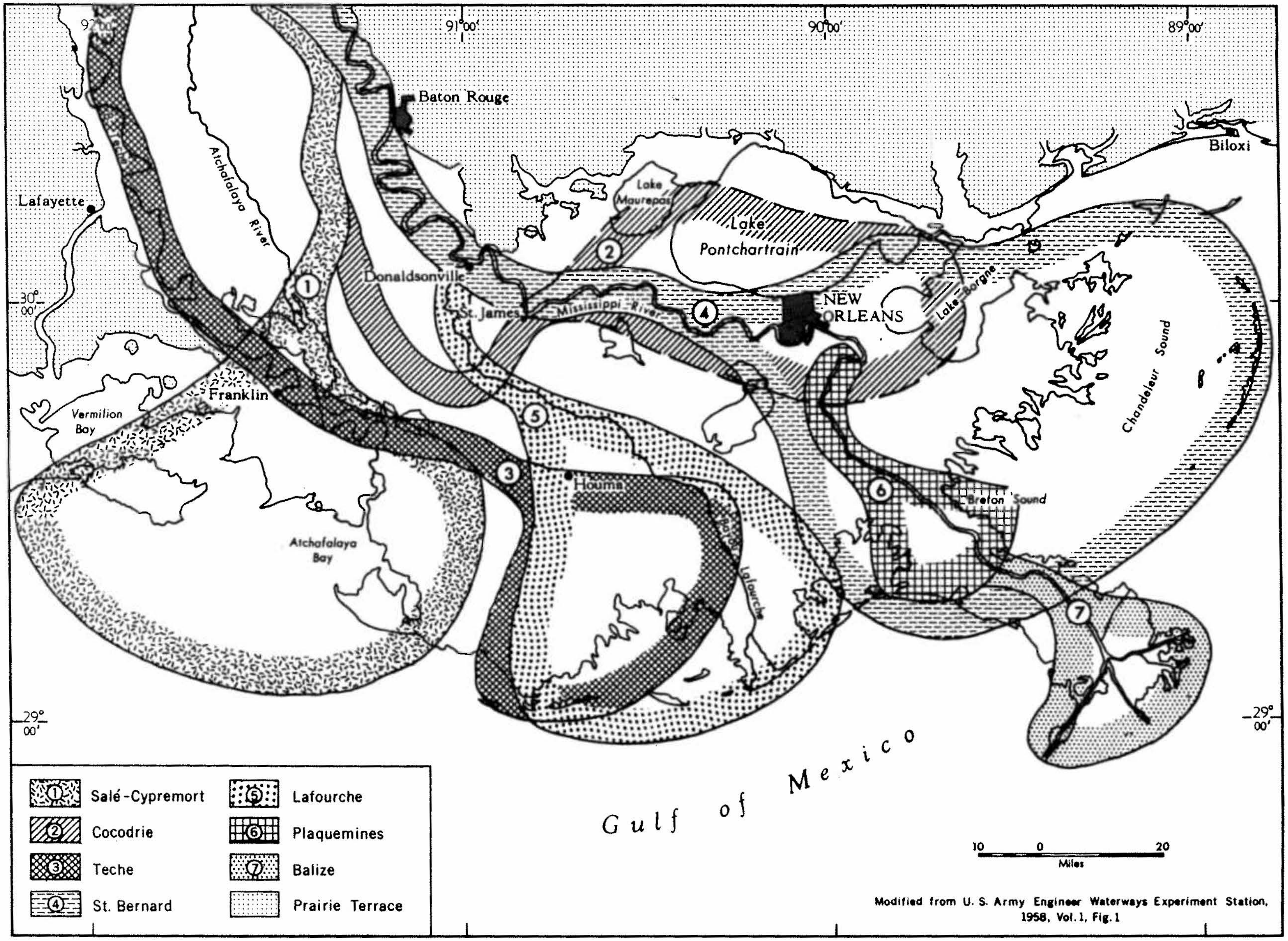

Fig. 24. Deltas of the Mississippi River.

Natural levees, no longer able to grow vertically by the addition of new sediments, gradually subside beneath encroaching marshes or swamps while the lower courses of abandoned distributaries become tidal. Fresh-water marshes and swamps are displaced inland by encroaching brackish water. Brackish-water marshes around the margins of the delta become highly dissected by expanding drainage networks and are constantly under attack by erosion along the Gulf margin. Relatively continuous beaches, composed of coarser sediments and shell reworked from deltaic deposits, often characterize the retreating deltaic margin.

Beaches which formed around the margins of the deteriorating Cocodrie Delta provide the best evidence for reconstructing the paleogeography of the basin area as of about 2600 to 2800 years ago. The beaches shown in Figure 25 indicate the maximum extent of open water areas that existed in the basin area just prior to the formation of the St. Bernard Delta.

The most continuous relict beach, over 14 miles long, roughly parallels the present lakeshore in Orleans Parish (Fig. 25). Lying four to five feet below mean Gulf level along most of its length, the beach is composed primarily of whole and broken Rangia shells with a small amount of gray silt and very fine sand. Where encountered in borings, the shell ridge varies from two to seven feet in thickness and 50 to 200 feet in width.

The trend of the relict beach indicates that the Pine Island beach trend, although generally buried by deltaic deposition with only isolated "islands" exposed, exerted a strong influence on the configuration of the shoreline. The shell beach lies either directly against the Pine Island ridge or is separated from it vertically by several feet of gray organic sandy clay which suggests deposition in a marshy swale or shallow body of water near a shoreline.

Near the present mouth of the Tangipahoa River there are two large borrow pits from which Rangia shells were dredged in the early part of this century. Although Indian artifacts are present at both locations (Fig. 10, Nos. 13 and 14), the southern pit appears to be basically a natural beach accumulation rather than a midden. Traces of a probable continuation of the shell deposit can be followed to the east of the pit for a distance of about one mile before it is truncated by Lake Pontchartrain. The shell accumulation is believed to be of the same general age as the one in Orleans Parish.

The small isolated segments of relict beaches in the northeastern portion of the basin (Fig. 25) may also have formed during this stage. These are generally composed of very fine sand or silty sand, contain only small quantities of shell, and lie one to two feet below marsh level. In size, they are similar to the shell ridge near New Orleans.

The interpreted locations of these shorelines indicate that the enclosed body of water was comparable in size and shape to present Lake Pontchartrain. Unfortunately no evidence has been found that accurately indicates the depth of the lake. If the relationship between average width and depth of the larger water bodies of the Gulf

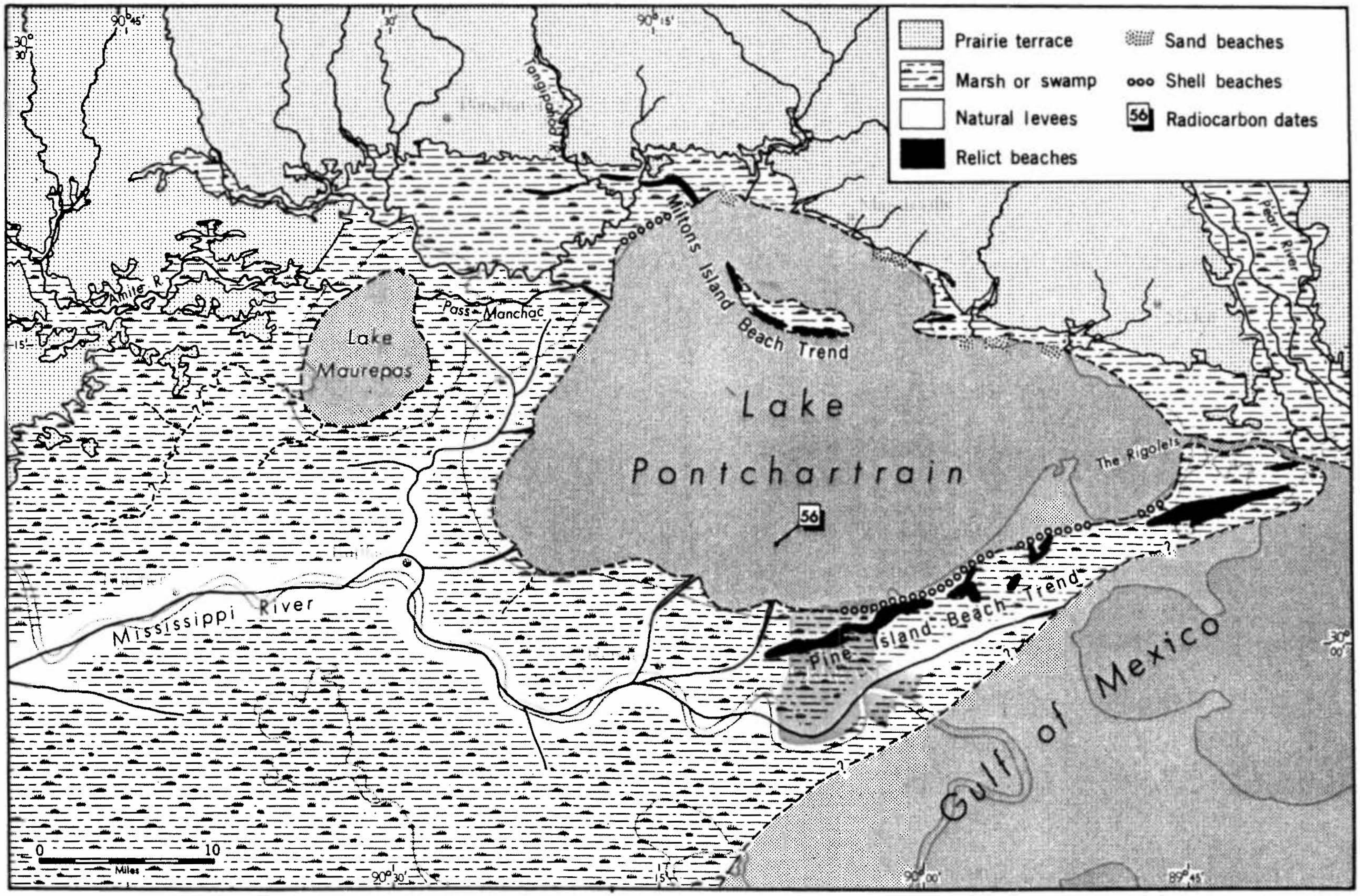

Fig. 25. Paleogeography of the Pontchartrain Basin, about 2600 to 2800 years before present, showing maximum deterioration of the Cocodrie Delta.

Coast area as stated by Price (1947) is valid, however, the depth of the older lake should have been quite similar to that of the present lake. A radiocarbon dating of 3350±120 years before present (Table II, sample 56) on Rangia shells from below Lake Pontchartrain (Fig. 25) does suggest a water depth of 5 to 10 feet for this location (corrected for subsidence) during the period of delta deterioration.

Similarly, there is no evidence to indicate the precise nature and extent of the central portion of the Miltons Island beach trend during this stage. It is postulated that portions of the barrier spit remained exposed as sand ridges on a low marshy island in the northern part of the lake. The configuration of the mainland shoreline north of the beach trend can be interpreted as indicating that it was no longer connected to the mainland on the east.

The Gulf shoreline is believed to have retreated northward to within a short distance of the Pine Island beach trend, but no beaches have been found that mark the exact shoreline position (Fig. 25). Remnants of the delta, preserved as buried natural levees or marsh deposits, have not been recognized east or south of the Poverty Point site near Bayou Sauvage (Fig. 23, No. 56). It is possible that the deltaic margin was located just seaward of this locality and just seaward of additional localities near New Orleans where preserved natural levees have been found.

On the basis of present configuration and later geomorphic history, it is suspected that Lake Maurepas originated during this stage in a large depression between natural levees of Cocodrie distributaries and the Prairie terrace. The possibility also exists, however, that the Cocodrie stage sedimentation was not sufficiently great to completely fill the depression and that the lake represents an isolated remnant of the Pontchartrain Embayment.

THE ST. BERNARD DELTA

Radiating to the east, southeast, and south of New Orleans are several prominent natural levee systems which mark the courses of abandoned Mississippi River distributaries (Fig. 26). During his initial investigation of the deltaic plain, Fisk (1944, pp. 34-35) included them as part of the large Plaquemines-St. Bernard Delta and designated various sections as subdeltas (e.g., Barataria Subdelta, St. Bernard Subdelta, Metairie Subdelta). Because of relatively great differences in age (to be discussed later), the Plaquemines-St. Bernard Delta is now commonly considered as two distinctive units, i.e., a younger Plaquemines Delta and an older St. Bernard Delta (U. S. Army Engineer Waterways Experiment Station, 1958).

Levee Systems

Distributaries. -- Figure 26 shows the locations of 15 distributaries which are considered to be part of the St. Bernard Delta. The portions indicated by solid lines have definite topographic expression while probable extensions and connections between distributaries which have been buried by more recent levee deposits are shown by dashed lines.

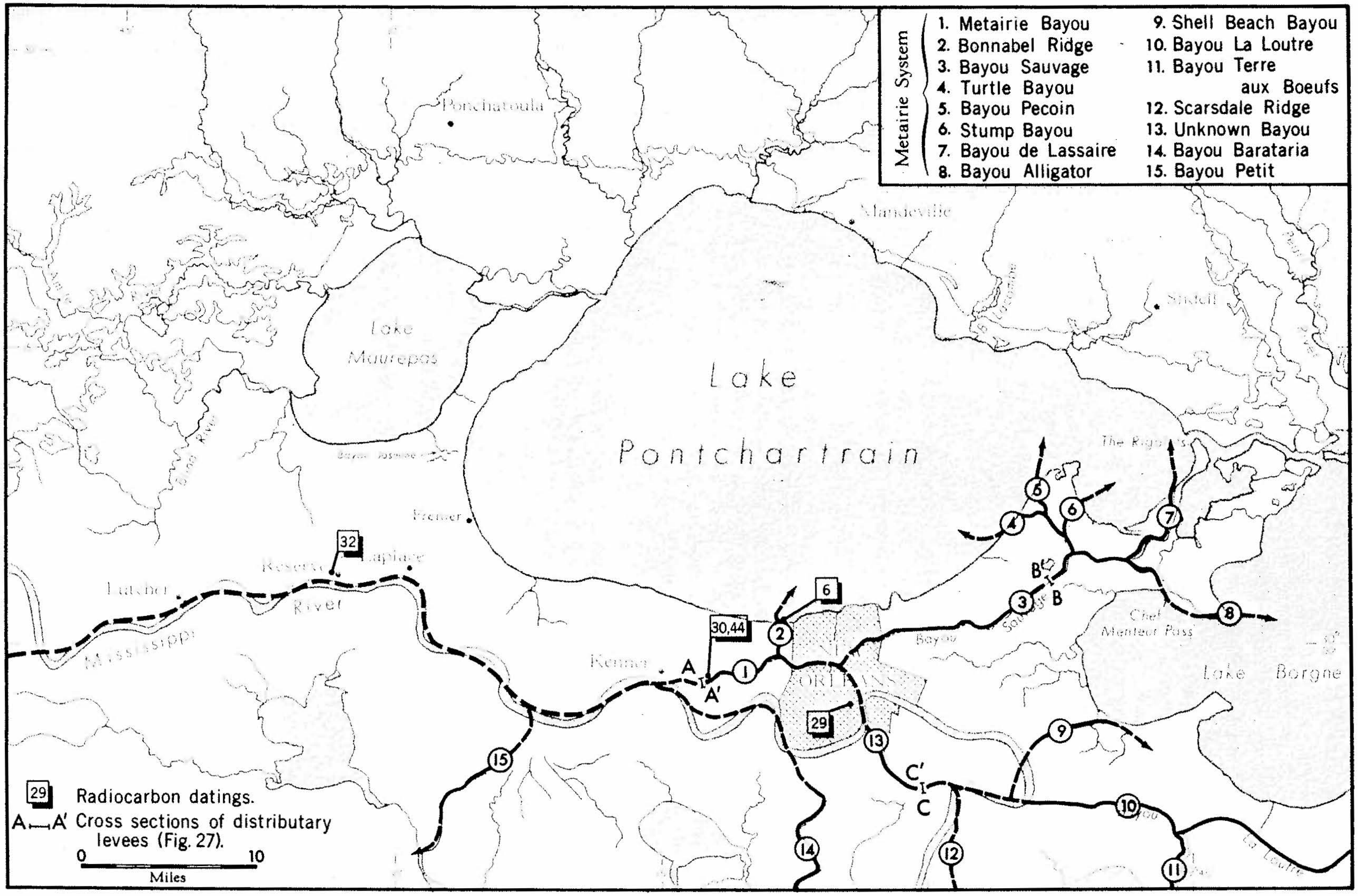

Fig. 26. Locations and names of St. Bernard Delta distributaries.

The cross sections in Figure 27 show that the distributary natural levees have a thickness (10 to 12 feet) comparable to the Mississippi River levees (15 feet). The distributary levees, however, are generally only one fourth to one half the width of the Mississippi levees, hence they are appreciably steeper from levee crest to backswamp. The average downstream slopes of the levee crests are approximately 0.2- to 0.25-feet-per-mile. Although levee crest elevations and levee widths steadily decrease downstream, levee thicknesses remain relatively uniform for long distances.

The Metairie system[14] is the most significant portion of the St. Bernard Delta in reference to the Pontchartrain Basin. The Metairie Bayou distributary (Fig. 26, No. 1) flowed eastward from the vicinity of Kenner to near the center of the city of New Orleans at which point it bifurcated into approximately equal-sized channels now occupied by Bayou Sauvage and Unknown Bayou (Fig. 26, Nos. 3 and 13). The Bayou Sauvage distributary flowed east-northeast through Orleans Parish bifurcating several times. The principal channel appears to have flowed southeastward from Chef Menteur Pass across the tip of Alligator Point and eastward into Lake Borgne (Fig. 26, No. 8). A possible further extension of this course is present on the eastern shore of Lake Borgne (Treadwell, 1955, p. 5).

During the period of maximum discharge, the Metairie Bayou distributary probably had a channel width of about 1000 feet and a maximum channel depth of about 50 feet near Kenner. The Bayou Sauvage channel near Chef Menteur Pass had a maximum width of about 500 feet and a depth of 25 to 30 feet. The smaller distributaries branching northward from Bayou Sauvage (Fig. 26, Nos 4 to 7) average 200 feet in width and 15 to 20 feet in depth.

Trunk Stream. -- Between Kenner on the east and Donaldsonville on the west, natural levees of the trunk stream of the St. Bernard Delta are buried by more recent levee deposits and are nowhere known to be exposed at the surface. The course of the river established during this stage has continuously served as a significant channel of the river to the present time. Even during the period of maximum discharge in the later Lafourche distributary (Fig. 24), a sufficient amount of flow was probably present to keep the channel open.

In reality, therefore, the natural levees of the St. Bernard stage cannot be truly separated from those of the present river. During the occupation of the Metairie system, a large portion of Mississippi River flow is believed to have been directed into the Grand River Basin area (Fig. 15) north of the Teche ridge (U. S. Army

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[14] A certain amount of confusion exists in regard to the usage of the name Metairie distributary. In this report, the name "Metairie Bayou Distributary" is used for that portion of the system located between Kenner and the central portion of New Orleans while the name "Bayou Sauvage distributary" refers to that portion of the system located east of New Orleans in Orleans Parish. The name "Metairie system" is a more inclusive term and refers to both segments as a unit.

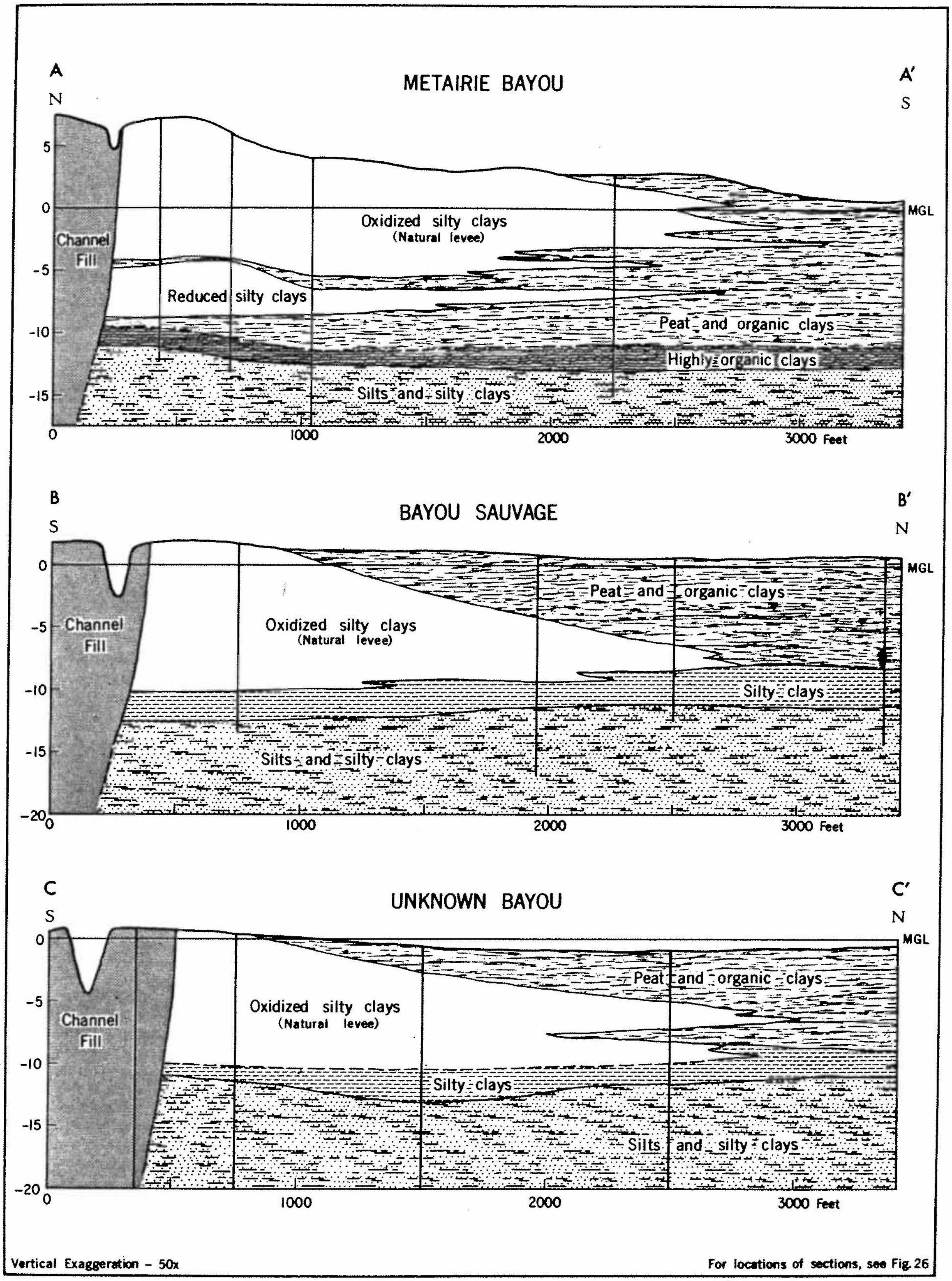

Fig. 27. Cross sections of St. Bernard Delta distributary natural levees.

Engineer Waterways Experiment Station, 1958, vol. 1, p. 6). The trunk stream levees formed at this time consequently should be smaller in size than those formed subsequently when greater discharge occurred in the channel. The levees along the present river course may therefore be considered as having been built at varying rates (depending upon volume of flow) over a relatively long period of time. Borings through the Mississippi River levees, however, fail to show any significant differences which could be attributable to the different stages of formation.

The position of the trunk stream as shown in Figure 26 does not correspond exactly with the present course of the river. An attempt has been made to allow for the meandering in the channel which has occurred since formation. In general, meandering has been slight; point bar deposits are normally less than one mile wide and decrease in size downstream.

Influence of Existing Physiography. -- Abandonment of the Teche Delta occurred when the Mississippi River diverted upstream to a course along the eastern side of the alluvial valley. The new course (St. Bernard stage trunk stream) closely followed the valley wall southeastward past Baton Rouge to St. James and then turned eastward toward New Orleans (Fig. 24).

The abnormally sharp bend and change in the general trend of the river at St. James (Fig. 24) strongly suggest that this was the point at which the newly forming river channel encountered the abandoned Cocodrie course and was forced to turn toward the east. Between St. James and New Orleans, the St. Bernard stage channel is definitely known to have reoccupied the older channel and to have constructed its natural levees over the basically subsided older levees. Most or all of the channel fill that accumulated in the Cocodrie channel was scoured out to accomodate the renewed flow.

East of Kenner, the Bayou Barataria distributary (Fig. 26, No. 14) may have continued in the Cocodrie channel as far as New Orleans where it then turned southward away from the older course. It is possible that the Cocodrie levees at this point had either subsided beneath marsh or swamp deposits to such a degree that they no longer had any influence on the new distributary or that they had been removed completely by wave erosion along the margin of the deteriorating delta.

Several factors appear to have played a part in determining the route of the Metairie system. At Kenner, a small eastward trending Cocodrie distributary (Fig. 22) is believed to have influenced the course of the upstream segment of the Metairie system and perhaps even initiated its development. Farther downstream, the Metairie system apparently occupied the long, narrow depression that probably existed between the Pine Island beach trend and the partially subsided levees of the easternmost Cocodrie distributary (Fig. 25). An examination of the route of the Bayou Sauvage segment of the Metairie system in reference to the Pine Island ridge (Fig. 18, contour map and cross sections) strongly suggests that the distributary was striving to divert or flow northward throughout its length but was able to do so only where there were breaks in the Pine Island ridge.

Between Kenner and a point about eight miles west of Chef Menteur Pass (Fig. 26), levees of the Metairie system overlie remnants of the Cocodrie deltaic plain, i.e., natural levees and inter-levee basin deposits. East of this zone, levees of the Metairie system (Bayou Sauvage and the minor distributaries shown on Figure 26) are apparently underlain by intradelta deposits. These are defined as the relatively coarse deposits associated with the advance of a distributary into a body of water (U. S. Army Engineer Waterways Experiment Station, 1958, vol. 1, p. 40). Since the intradelta deposits are underlain by lacustrine deposits at a shallow depth (10 to 20 feet), there can be little doubt that the Cocodrie delta had been destroyed by wave erosion in this area and consequently had no effect on the route of the advancing distributaries.

Age and Correlation

In his original work, Fisk (1944, pp. 43-44) postulated that the Lafourche Delta was the first delta to form after the Mississippi River shifted to the eastern side of its valley and that it immediately succeeded the Teche Delta. This work was a modification of and an elaboration on a deltaic chronology introduced earlier by Russell (1940, pp. 1201-1211). As a result of a major diversion at Donaldsonville, the Lafourche Delta was abandoned and the Plaquemines-St. Bernard Delta then developed to the east. Fisk (1952, p. 64) dated the diversion at about 1200 A.D. (760 years ago) and stated that, by 1400 A.D. (560 years ago), it had become well established in its new course.

More recently, archaeological investigations by McIntire (1954, pp. 42-43) showed that there was a definite conflict between pottery periods and the accepted ages of the deltaic areas concerned. The oldest sites found to be associated with distributaries of the Lafourche Delta are of Plaquemine age whereas at least seven sites of Marksville age (Fig. 30) are associated with distributaries of the Plaquemines-St. Bernard Delta (ibid., p. 64). Since there is also a complex of Plaquemine period sites in St. Bernard Parish, McIntire (ibid.,p. 34) suggested a division of the delta into an Early St. Bernard subdelta (Marksville) and a Late St. Bernard subdelta (Plaquemine). All of the courses described in this report are considered as belonging to the Early St. Bernard Delta stage.

Since 1954, several radiocarbon dates have been obtained on peat and organic materials taken from beneath the natural levees of distributaries of both deltaic areas. These dates confirm McIntire's findings and form more conclusive proof that the Lafourche Delta is appreciably younger than the St. Bernard Delta. It is now commonly accepted that the river diverted from the St. Bernard course to the Lafourche course rather than from the Lafourche course to the St. Bernard course (McFarlan, 1961, p. 139).

On the basis of these data, the Plaquemines portion of the Plaquemines-St. Bernard Delta, although recognized by Fisk as being the latest part of the system, needs to be shifted to a still younger position in the chronology. It now appears certain that the Plaquemines Delta formed after the Lafourche Delta and was not a direct outgrowth of the St. Bernard Delta (Fig. 24). The age duration now assigned to the delta is approximately 500 to 1200 years ago (U. S. Army Engineer Waterways Experiment Station, 1958, vol. 1, p. 7).

The following radiocarbon dates are considered to be significant indicators of the ages of various St. Bernard Delta distributaries. In all cases, the materials dated were organic remains located in close proximity to the bases of the levees, thus providing maximum dates for the courses.

Distributary	Dating	Sample No.
Metairie Bayou	2320±110 2650±110 2650±120	30 29 44
Bonnabel Ridge (Fig. 26)	2800±115	6
Trunk Stream (Reserve)	2750±110	32
Bayou La Loutre	2200±110	--[15]
Bayou Barataria	2400±110	--[15]

Ever since the original work of Russell (1940), the Metairie system has been considered to be the earliest of the St. Bernard Delta distributaries. Additional work in the area plus the radiocarbon datings appear to substantiate this. The datings also indicate that the entire delta formed rapidly during a relatively short period of probably not over 600 years. It is quite possible that the earliest (Metairie) distributary was still receiving some flow at the time that the latest (La Loutre?) distributary was experiencing maximum flow. The writer believes that the Metairie system originated about 2600 years ago and reached its maximum development between 2000 and 2400 years ago. These dates are appreciably older than those first mentioned by Fisk.

In the center of the city of New Orleans, an anomalous situation exists in regard to the precise connection between the Metairie Bayou, the Bayou Sauvage, and the Unknown Bayou segments of the system. Although the precise junction of the segments is now completely obscured, trends projected from the nearest traces of the old channels suggest that an abnormally sharp angle of diversion or an exceptionally sharp bend existed (Fig. 26). This has led to some doubt as to whether the three segments, particularly the Metairie Bayou and the Bayou Sauvage distributaries, are indeed part of the same system and of the same approximate age.

Although no accurate dating has been obtained on the Bayou Sauvage distributary, it is the writer's belief that both the Metairie Bayou and the Bayou Sauvage distributaries can be considered as one

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[15]For locations and descriptions of these datings, see U. S. Army Engineer Waterways Experiment Station, 1958, vol. 2, Pl. 9A, Nos. 23 and 24.

continuous system and that the Unknown Bayou distributary formed as a result of a diversion at a slightly later date. The anomalous angle of diversion is thought to be the result of normal channel abandonment (Welder, 1959, p. 72) plus modifications experienced when the Mississippi River adopted its present route through New Orleans (crevassing and/or a short re-occupation of Bayou Sauvage).

Paleogeography

In general, the St. Bernard Delta had a less direct influence on the Pontchartrain Basin as a whole than did the Cocodrie Delta and contributed a much smaller supply of sediment. The greatest quantity of deltaic sediment was deposited south and southeast of the basin area in Jefferson, Plaquemines, and St. Bernard parishes. In the basin area, actual deltaic sedimentation occurred only in Jefferson and Orleans parishes.

In the southwestern part of the basin area, the St. Bernard stage trunk stream utilized an existing older channel which had the effect of directing the greatest portion of the discharge (and sediments) directly to the east into the New Orleans area. Nearly all of the coarser sediments which left the stream channel in this area were deposited immediately on the natural levees. Only a small quantity of fine sediments, mostly clays, reached the backswamps and the adjacent lakes.

During the apparently short period of maximum discharge, the Metairie system probably did not carry more than 30 or 35 per cent of the total discharge of the Mississippi River. The system grew rapidly and covered a rather large area because of the shallow water into which it developed rather than any great quantity of sediment. It should be remembered that it was the Cocodrie system rather than the St. Bernard system which was responsible for essentially filling the Pontchartrain Embayment.

This new wave of sediments, regardless of its exact quantity, was evidently sufficient to cause progradation of the shorelines around most of Lake Pontchartrain. The most significant shoreline advance (by distributary growth and mudflat development) occurred in the southeastern portion of the lake as a result of several branches of the bayou Sauvage distributary (Fig. 26, Nos. 4-7). In the northern and western portions of the lake, enough fine sediments were probably introduced to cause the average shoreline position to remain relatively stationary over a period of several hundred years rather than to appreciably retreat (Fig. 28). The average depth of the lake was probably slightly reduced, especially in the quiet water north of the surviving remnant of the Miltons Island beach trend.

The maximum extent of cypress swamp in the basin appears to have been coincident with the maximum development of the St. Bernard Delta. A change from a swamp to a marsh environment over large areas of Orleans Parish is evidenced by extensive zones of buried cypress and water tupelo stumps and wood fragments. The spoil banks along miles of canals in the marsh areas of the basin are littered with wood from zones of this type. There can be little doubt that swamp conditions

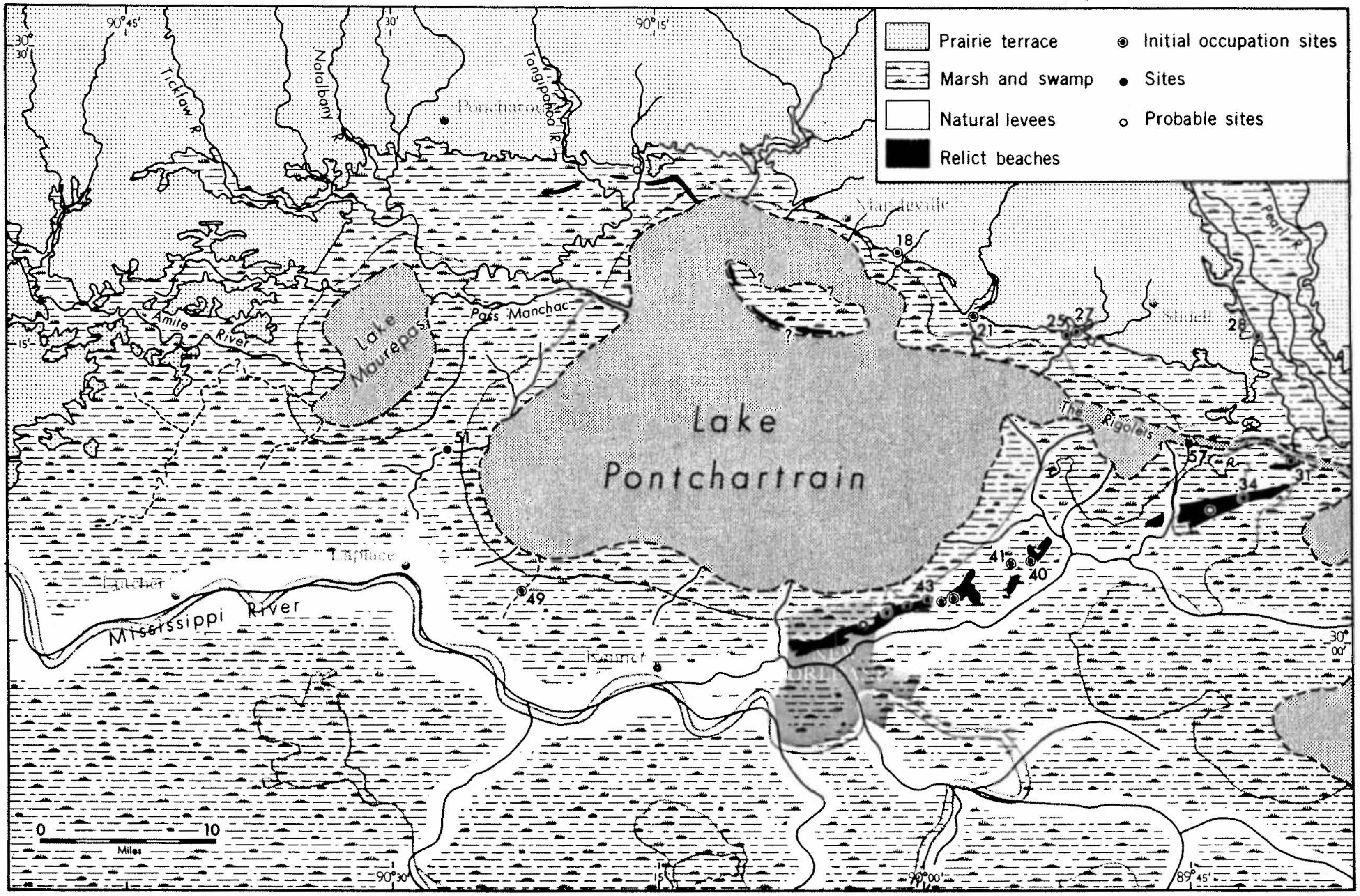

Fig. 28. Paleogeography of the Pontchartrain Basin, about 2000 to 2400 years before present, showing maximum extent of the St. Bernard Delta and locations of Tchefuncte period sites.

existed much closer to the shores of the lake during the St. Bernard Delta stage than at present and occupied a greater extent than did brackish-water marsh.

Since the St. Bernard Delta stage marked the last major period of active sedimentation in the basin area, all shorelines have been primarily retreating since that time. Consequently, the lakeshores must have everywhere been located beyond (lakeward of) their present position during the optimum St. Bernard Delta stage. There is no accurate means, therefore, of reconstructing the shape and extent of the lakes at this time. The configuration of the lakes shown on Figure 28 is at best an approximation based largely on the present and projected rates of shoreline retreat and the present shoreline configuration.

As was the case when the Cocodrie Delta was at its maximum extent, a tidal connection had to be maintained between Lake Pontchartrain and Lake Borgne, i.e., a connection with the Gulf. Again, such a connection could only have existed at or very close to the present location of The Rigolets. During the period of maximum discharge in the Metairie system, a constant struggle must have occurred between distributaries striving to build northward (Fig. 28), particularly the Bayou de Lassaire distributary, and the necessary discharge of water from the lake. The configuration of the Prairie terrace suggests that the western end of The Rigolets may have been forced to migrate about one half mile to the north because of the Bayou de Lassaire distributary.

Indian Sites. -- A comparison of the age assigned to the Metairie system with the archaeological chronology (Fig. 12) shows that the system began forming during the latter part of the Poverty Point period and had reached maximum development by the early part of the Tchefuncte period. As pointed out earlier, however, the oldest sites known to be associated with natural levees of St. Bernard Delta distributaries are of Marksville age. Perhaps because the distributaries were still relatively active (their levees subject to periodic flooding), the Tchefuncte period Indians chose sites marginal to the streams when they moved into the area (Fig. 28).

At the present time, there are 12 known and 2 questionable Tchefuncte period sites in Orleans Parish which are believed to be associated with the Pine Island beach trend or with the shell beach that formed just prior to the development of the Metairie system. Although most of the sites have been destroyed or severely damaged, they were described as having been large Rangia shell middens, elongated oval in shape, 300 to 400 feet in length, 80 to 100 feet in width, and resting on water-laid sands at an average depth of about eight feet below mean Gulf level (Ford and Quimby, 1945, pp. 8-10). These sites, plus four or possibly five others in the northeastern portion of the basin, are the largest, most significant, and apparently longest occupied Tchefuncte sites (Fig. 28). The other sites in the basin area (Fig. 28, Nos. 49, 51, and 28), although they contain small quantities of Tchefuncte period artifacts, are more truly indicative of other periods.

There are several factors which suggest a conflict between the age of the complex of Tchefuncte sites and the age assigned to the development of the Metairie system. In the first place, most Tchefuncte sites, composed primarily of the brackish-water clam Rangia, are located in the eastern portion of the basin where relatively large quantities of fresh water and fine sediment were being introduced by the various distributaries. A question therefore arises as to whether or not the clams could have existed in this portion of the basin in the abundance in which they apparently did during or shortly after the full-flow stage of the system. In the second place, there are sites in both Orleans and St. Tammany parishes which seem to have been initially occupied on active beaches rather than relict beaches (ibid., p. 10). There can be no doubt that at least the beaches in Orleans Parish were completely isolated by sediments by the final stage of the Metairie system. Both of these factors suggest that the Tchefuncte sites were occupied before the development of the distributary system.

The writer believes that an actual conflict exists only if the entire Bayou Sauvage distributary system is considered as a single unit of one specific age. While the Bayou Sauvage distributary was flowing in its primary channel (Bayou Sauvage-Bayou Alligator), very little discharge was probably finding its way across the Pine Island ridge to the Lake Pontchartrain side. This is believed to be the time (probably 2200 to 2400 years ago) when the Tchefuncte sites were first being occupied. Beaches along the north side of the Pine Island ridge and elsewhere in the basin should have been active at this time and Rangia growth in the lake perhaps even more abundant than previously because of the slight influx of nutrient-bearing fresh water.

The conflict can be resolved if the four northward trending branches of the Bayou Sauvage distributary are considered to be a final stage of the system which formed slightly later than 2200 years ago. These branches were the primary source of the fresh water and sediment in the southeastern portion of the lake. The development of the branches about 2200 years ago may also explain an abrupt and uniform abandonment of the sites at the end of Tchefuncte times.

THE BAYOU MANCHAC-NEW RIVER DISTRIBUTARIES

Bayou Manchac and New River are remnant streams which occupy former Mississippi River distributaries. As shown in Figure 29, both distributaries formed on the left (east) bank of the river between Baton Rouge and Donaldsonville and flowed eastward into the western end of the Pontchartrain Basin. Although the period of significant flow in both channels occurred many centuries ago, Bayou Manchac received some flow during high water on the Mississippi River until 1814 at which time it was artificially closed (Russell, 1938, p. 11). New River is not known to have been active during historic times.

The somewhat disproportionate attention that has been given to these distributaries has partially been because of certain peculiarities of the streams themselves rather than their importance as Mississippi River distributaries, i.e., both encountered and managed to cut directly across an area of appreciably higher Prairie terrace before re-entering a lower floodplain level. In the case of Bayou Manchac, this occurrence has been explained in detail by Kniffen

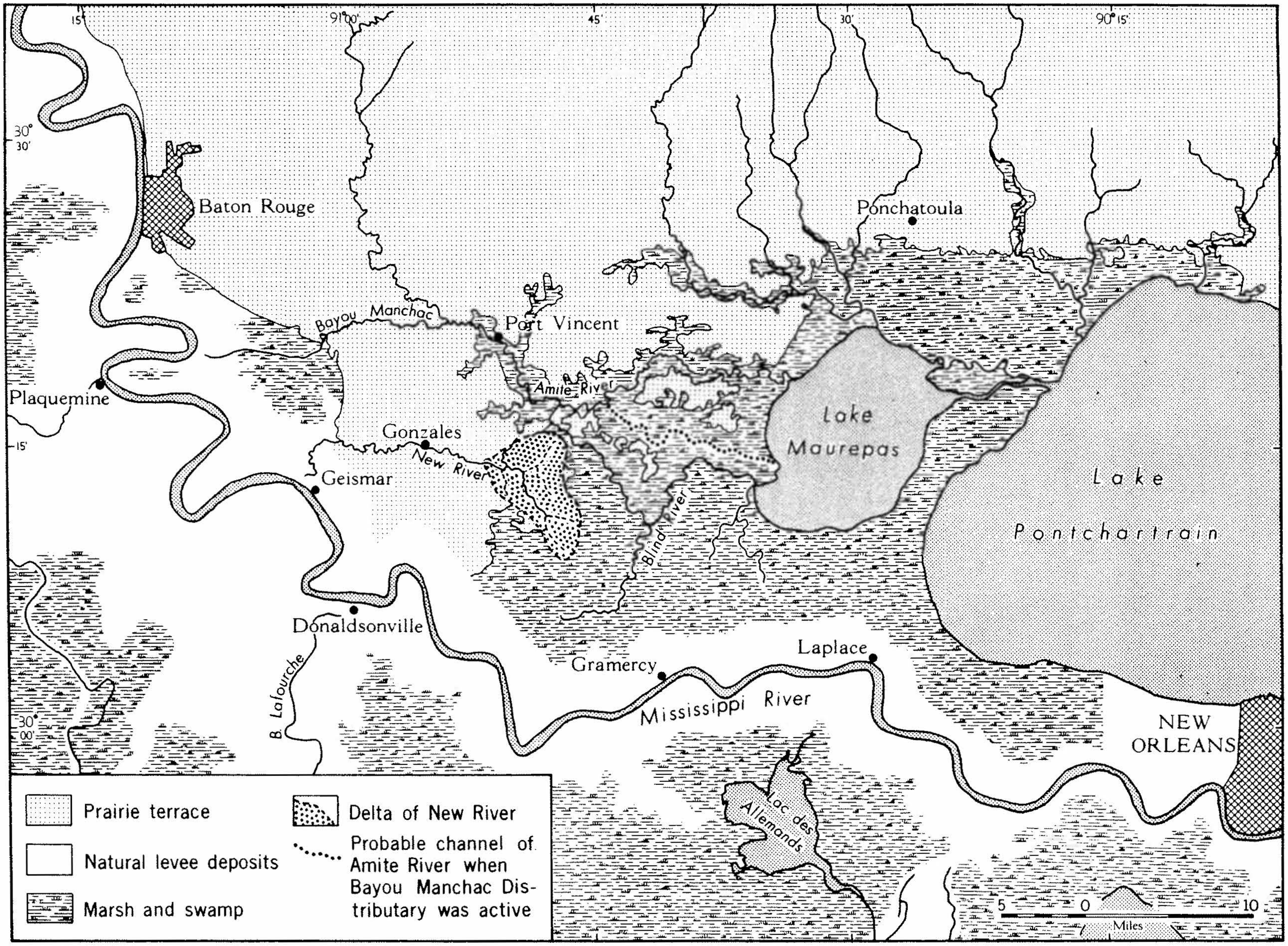

Fig. 29. Western portion of the Pontchartrain Basin showing the locations of Bayou Manchac and New River.

(1935, pp. 465-466).

The significance of Bayou Manchac as an active Mississippi River distributary has been concisely summarized by Russell (1938, pp. 10-11) who states,

> The incision through the terrace is so narrow that the possibility of its (Bayou Manchac) having at any time carried a significant portion of the Mississippi discharge is absolutely precluded. It is doubtful whether five percent of an ordinary Mississippi flood could pass between the walls through the terrace.

On the basis of natural levee size and coarseness of meander pattern, Russell (ibid., p. 44) considered New River to have had a more significant period of distributary flow but still that of a relatively minor distributary.

Whatever discharge that Bayou Manchac carried entered the Amite River and was conducted by this stream into the southwestern portion of Lake Maurepas. The channel shown on Figure 29 by a dashed line is considered as probably having been the main course of the Amite River at the time that Bayou Manchac was active.

East of Gonzales (Fig. 29), New River ceased flowing across the surface of the terrace in a single channel and split into several small distributaries. The area enclosing the distributaries may be considered as the actual delta of the system and probably consists of a thin veneer of deltaic sediments overlying both Prairie terrace and swamp deposits. The very close resemblance of the oxidized deltaic deposits to the terrace deposits makes delimitation of the former extremely difficult.

Neither Bayou Manchac nor New River are believed to have contributed enough sediments to have appreciably altered the characteristics or extent of the swamp area west of Lake Maurepas, the Amite River, or Lake Maurepas itself. They probably did little more than shallow Lake Maurepas, slow or halt the rate of shoreline retreat in the lake, or possibly build a small delta as shown in Figure 28.

So far, the exact ages of the distributaries have not been accurately determined. It is logical to assume, however, that they are of the same approximate age and that neither formed until the Mississippi River had shifted to the eastern side of its valley (St. Bernard Delta stage). A midden initially occupied during the Marksville period, located on a natural levee of Bayou Manchac about eight miles east of the Mississippi River, does provide a minimum date for this distributary. Furthermore, the Marksville period site suggests an age relationship between this distributary and similarly occupied distributaries of the St. Bernard Delta stage.

DEVELOPMENT OF THE MODERN LAKES

By the time of the abandonment of the St. Bernard Delta, nearly all of the significant landforms in the Pontchartrain Basin area had already been formed. Those formed after this stage and changes which occurred in existing ones were primarily due to erosion and/or subsidence. Both Lakes Pontchartrain and Maurepas were in existence at this time and had a configuration similar to what they have now, but were smaller in size. Numerous archaeological sites provide some of the best evidence for interpreting basin characteristics during the subsequent stages of progressive lake enlargement.

Marksville Period Conditions

The presence of Marksville period sites on four St. Bernard Delta distributaries (Fig. 30) prove that the streams had reached maximum development by this time (1400 to 1800 years ago) and were probably already abandoned. The absence of sites on the other distributaries suggests that one or more of these courses (excluding the Metairie system) may have still been active. Although this is the time at which the Mississippi River is believed to have begun diverting a large percentage of its flow into the Lafourche course (U. S. Army Engineer Waterways Experiment Station, 1958, vol. 1, p. 7), some flow was still being directed eastward into the St. Bernard Delta area. Bayou Barataria and Bayou La Loutre were most likely receiving this flow.

The Bayou Sauvage distributary system may have been partially active during the early part of the Marksville period but was certainly abandoned by the latter part. The widespread presence of Marksville period *Rangia* shell middens, including initial occupation sites located west and northwest of Lake Maurepas (Fig. 30), indicates that both lakes in the basin must have been at least moderately brackish. All brackish water that entered the lakes was still being conducted only by The Rigolets since Chef Menteur Pass had not yet formed.

In all probability, Lake Maurepas had expanded to the point where it tapped the drainage of the Tickfaw and Natalbany rivers (Fig. 30), thus transforming the lower course of the channel into a tidal pass. The presence of two passes undoubtedly facilitated the removal of sediments from Lake Maurepas into Lake Pontchartrain. The discharge of sediment into Lake Pontchartrain probably helped retard erosion along the lakeshore in the vicinity of Pass Manchac as it appears to be doing today.

During the Marksville period, the shoreline in the southwestern corner of Lake Pontchartrain was located slightly farther inland than at present and was characterized by Freniere Ridge, now a relict beach composed of firm, well oxidized silts and very fine sands with widely scattered shell fragments (Fig. 30). Although most of the ridge's surface is now obscured by the roadbed of the Illinois Central Railroad, it appears to stand about three feet above mean Gulf level and average about 200 feet in width along most of its known length of about seven miles.

In the eastern portion of the basin, Indians occupied relict beaches as they did in Tchefuncte times. In the case of the sites in Orleans Parish, however, the Marksville period occupational horizons are thin and rather poorly developed, indicating that either the

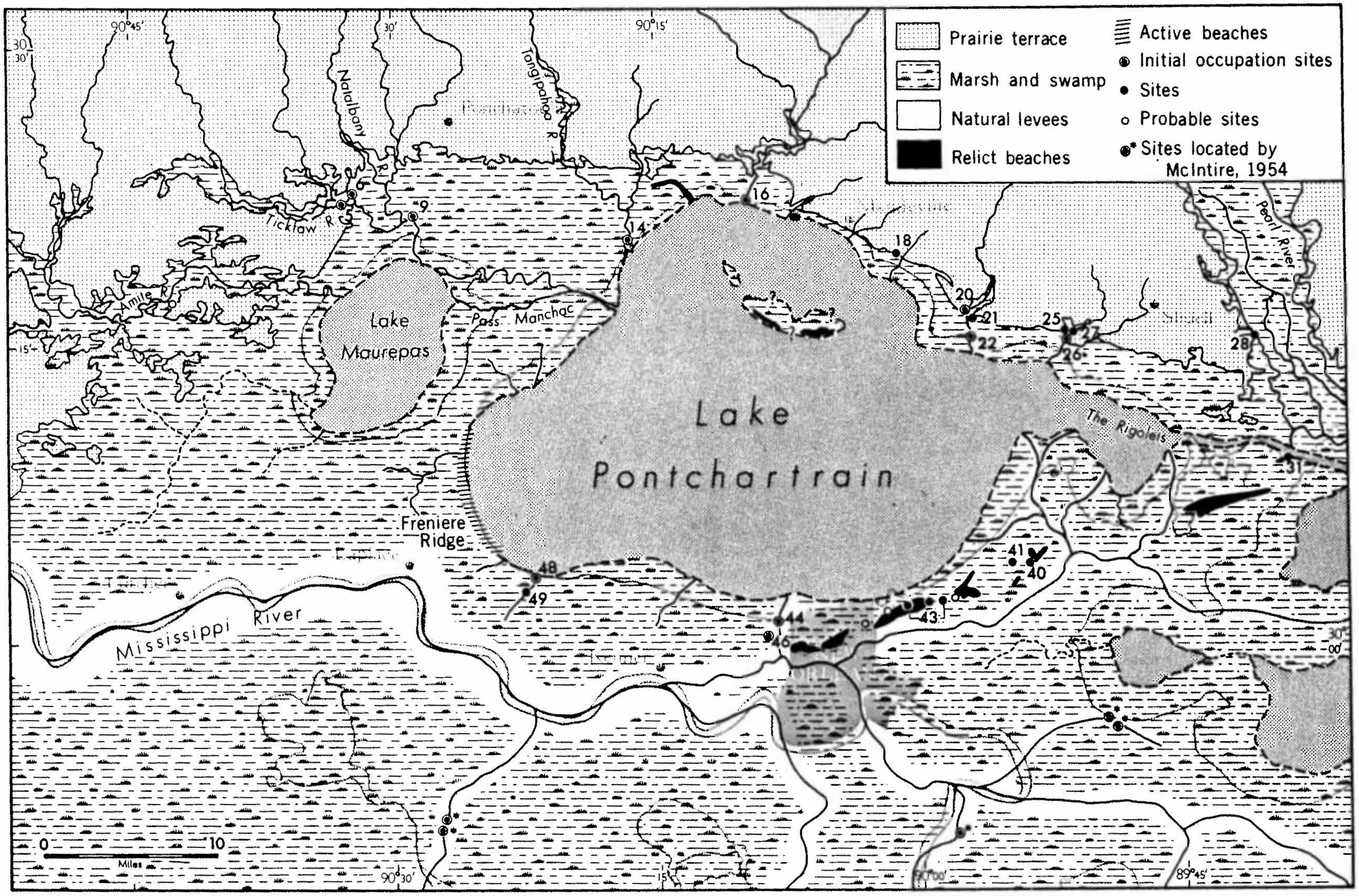

Fig. 30. Paleogeography of the Pontchartrain Basin, about 1400 to 1800 years before present, including locations of Marksville period sites.

period of occupation was relatively short or that the number of inhabitants was small. In either case, there are suggestions that living conditions seriously deteriorated after Tchefuncte times. Such a deterioration could have been brought about by the period of active sedimentation by the Bayou Sauvage system distributaries or by subsidence of the Pine Island ridge to a point where it was no longer habitable.

As a result of some continued flow in the St. Bernard stage trunk stream, natural levees probably maintained their size and were not narrowed or lowered by subsidence. The levees of the abandoned distributaries, however, were being actively eroded by wave action at their mouths and were subsiding beneath the marsh or swamp. East of New. Orleans, small shallow lakes, which were to eventually coalesce and form Lake Borgne, began forming in inter-levee depressions (Fig. 30).

Troyville-Coles Creek Period Conditions

Judging from the number and distribution of sites, the basin area supported the highest prehistoric population during this period. Over 75 per cent of the sites from which collections were obtained yielded pottery types characteristic of this period. The Indians, who almost exclusively built Rangia shell middens, occupied all parts of the basin except along the present course of the Mississippi River and occupied a wide variety of landforms (Fig. 31).

For reasons previously mentioned, it is necessary to consider the Troyville period and the Coles Creek period as one period rather than two. During the relatively long period of time involved (ca. 600 to 1400 years before present), several significant events occurred in the basin area. Radiocarbon datings and physiographic evidence together with archaeological evidence has enabled a precise dating of some of the events within the period.

Development of the Modern River Channel. -- Following the period of major discharge in the Lafourche distributary, significant Mississippi River flow was again directed toward the east into the St. bernard stage trunk stream. As this occurred, the Bayou Barataria and Bayou La Loutre distributaries were abandoned, the river adopted a new course through New Orleans, and the Plaquemines Delta began to form. The new course of the river is shown in Figure 31.

A portion of the new course below New Orleans, an anomalous bend called English Turn (Fig. 31), has aroused interest on the part of several investigators. Russell (1935, p. 115) investigated this bend and two others in the deltaic area and came to the following conclusion:

> English Turn lies just at the dividing point between the St. Bernard subdelta, as a whole, and the Plaquemines subdelta, as a whole. It thus appears pretty certain that these bends are not meanders in the ordinary sense of the word but mark upper subdelta

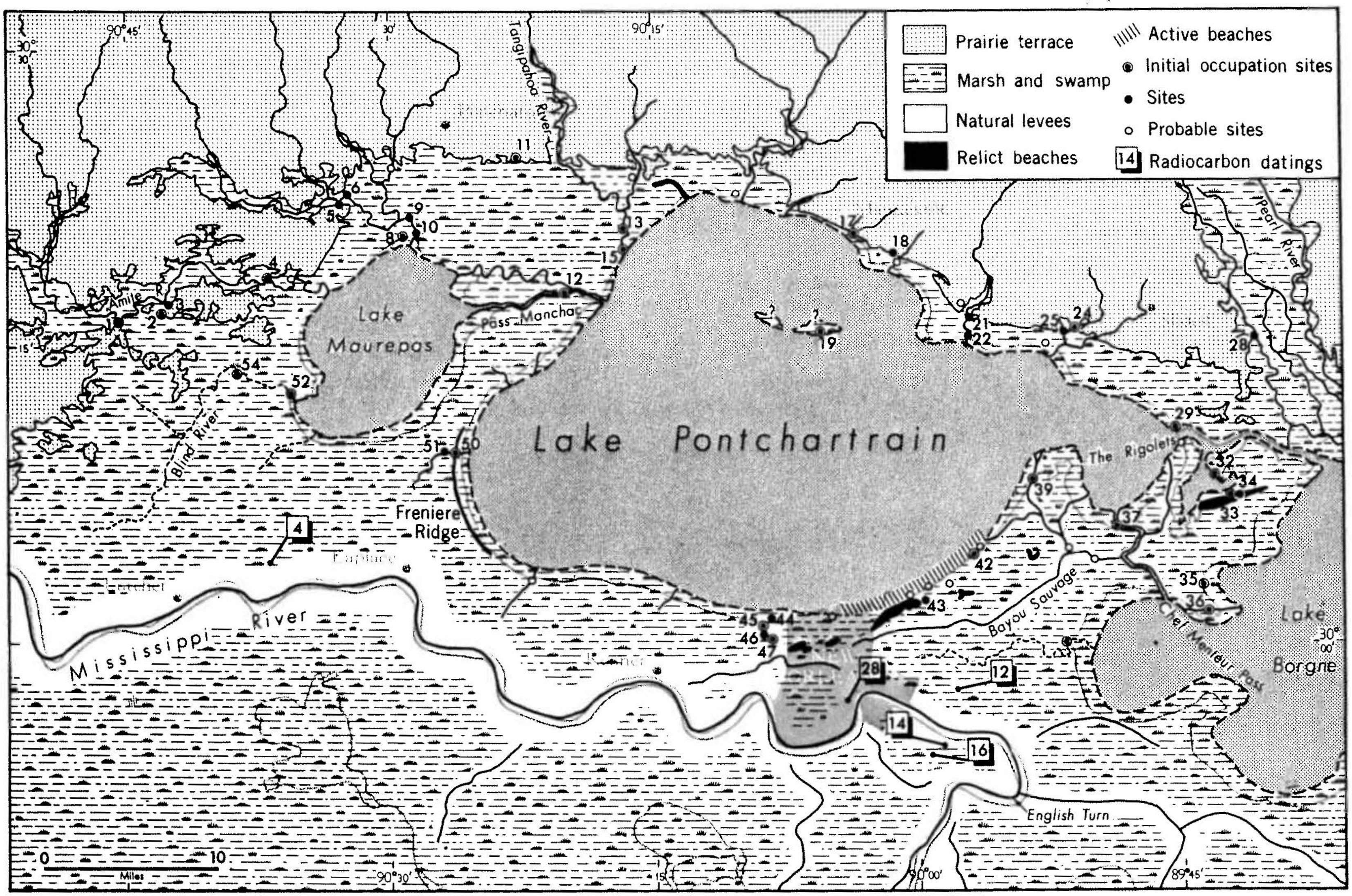

Fig. 31. Paleogeography of the Pontchartrain Basin, about 600 to 1400 years before present, including locations of Troyville-Coles Creek period sites.

> boundaries. Possibly they are relict from branching at passes or are in some way determined by shores; more probably from old crevasse locations in which the crevasse channels permanently diverted the channel flow.

Fisk (1944, pp. 33-35) later observed that English Turn is located in the Lake Borgne fault zone (Fig. 5) and stated that faulting may be the explanation for the anomalous bend.

Provided that the known and projected locations of the St. Bernard Delta distributaries are correct (Fig. 26), a third solution to the problem is immediately apparent. The Mississippi River diverted eastward from the Bayou Barataria distributary at the southwestern corner of the city of New Orleans (Fig. 31), encountered and flowed northward in the Unknown Bayou distributary for a short distance, and then flowed southeastward in a new channel. In the vicinity of English Turn, the river again encountered the Unknown Bayou distributary and flowed in a reverse (westward) direction for a short distance before breaking away to establish a new course to the south. It certainly appears that the St. Bernard Delta distributaries had more direct control over establishing the new river course than did the two factors previously mentioned.

The following radiocarbon datings are considered to be indicative of the age of this final course of the river in the basin area:

Location	Dating	Sample No.
New Orleans	1000±100	14
	1100±105	16
	1200±100	28
	1450±105	12
Reserve	1325±105	4

The datings represent either peat or organic deposits closely associated with the bases of the natural levees (hence maximum dates) or, in the case of sample No. 28, wood fragments from within the levee itself. The average of the five dates, approximately 1200 years ago, occurs during the early part of the Troyville-Coles creek period and is believed to accurately date the establishment of the river course.

Paleogeography.-- The diversion of the river to a new course in the vicinity of New Orleans had very little effect on Lakes Pontchartrain and Maurepas. While natural levees were actively forming on the new course, all fine sediment not deposited on the levees were deflected by older natural levee ridges into Lake Borgne or adjacent swamp and marsh areas. The Metairie Bayou-Bayou Sauvage distributary ridge effectively prevented any of this material from entering Lake Pontchartrain (Fig. 31).

The only major exception to general shoreline retreat during the period occurred in the southwestern corner of Lake Pontchartrain and resulted in the isolation of Freniere Ridge. Crevasses along the

Mississippi River near Laplace may have introduced enough fine sediment to cause the shoreline advance. There are no indications that even minor distributaries formed along the river in this area.

Small relict beaches in Orleans Parish (Fig. 31) indicate a period of relative shoreline stability but probably no major shoreline advance. The relict beaches, composed primarily of well oxidized silt and very fine sand with scattered Rangia shells and shell fragments, are in the form of closely spaced and poorly defined accretion ridges. Borings through the ridges indicate a lakeward thickening and lakeward rising wedge of beach material having a maximum width of about 1500 feet and a maximum elevation of about two feet (MGL).

The entire beach complex lies north of the Rangia shell beach that formed during the deterioration of the Cocodrie Delta (Fig. 25). Borings indicate that the complex lies on either lacustrine deposits associated with the former shoreline or on subsequent marsh deposits (formed during the advance of the northernmost branches of the Bayou Sauvage distributary). A radiocarbon dating of 1800±105 years ago (Table II, sample 5) was obtained on a sample of these marsh deposits located beneath the southernmost (oldest) ridge at a depth of eight to nine feet below mean Gulf level. This is, or course, a maximum date for the entire group of ridges.

A minimum date for the beach complex is provided by remnants of what appears to have been an almost continuous string of small Rangia shell middens (now largely destroyed because of the activities of man). Collections from the best preserved site (Fig. 31, No. 42) indicate that the most widespread occupation occurred during the Plaquemine-Historic period and the initial occupation occurred during the Coles Creek period[16].

The presence of a zone of accretion rather than a single well-defined beach suggests a much greater supply of silt and sand than is present along the typical stable or retreating shoreline. Erosion of St. Bernard deltaic deposits introduced by the Turtle Bayou and Bayou Pecoin distributaries (Fig. 26, Nos. 4 and 5) undoubtedly accounted for most of the beach sediments. Additional sediments could have been derived from older lacustrine deposits and perhaps even the Pine Island ridge.

By the early part of the Troyville-Coles Creek period, Lakes Pontchartrain and Borgne are believed to have enlarged sufficiently and the natural levees of the Bayou Sauvage distributary to have subsided enough to permit the formation of Chef Menteur Pass. The pass was apparently created when a small marsh drainage channel, located just south of the eastern lobe of Lake Pontchartrain, managed to breach the northern natural levee of the Bayou de Lassaire distributary (Fig. 26, No. 7) and connect with the distributary channel which in turn was connected to Lake Borgne. Once through flow was initiated

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[16]This is one of the few instances in which Coles Creek pottery types were found without Troyville types being closely associated with them.

the pass began enlarging through channel scouring and bank erosion. At present, only remnants of the original distributary levees remain along the pass.

A Troyville-Coles Creek shell midden located at the northern end of Chef Menteur Pass (Fig. 31, No. 37) suggests but does not necessarily prove the existence of a pass at this time. It can only be assumed that a village located at the mouth of a major pass would have had certain decided advantages over one located on a small marsh drainage channel.

The only evidence for indicating a persisting remnant of the Miltons Island beach trend during this and preceeding periods (Figures 30 and 31) is the previously mentioned Troyville-Coles Creek and Plaquemine-Historic period site shown on Figure 31 (No. 19). As pointed out earlier, however, there are several reasons for suspecting the accuracy of this reported site data. In the first place, the exact location from which the materials were dredged has never been positively established and furthermore, it cannot be proven that the artifacts were definitely associated with the dredging operations in the lake. It is possible that the artifacts were left in the barge from a previous dredging elsewhere in the basin area. In the second place, the pottery that was recovered (unfortunately no longer available for study) has been described as being well preserved and not exhibiting wave-washed characteristics[17]. This, plus the fact that fragile and floatable charcoal is reported to have been present (Russell, 1940, p. 1211) does not appear to be possible for a site located in more than 10 feet of water. In the writer's opinion, it is possible but not probable that habitable remnants of the beach ridge could have remained in such an exposed position up until historic times as the site tends to indicate. If such had occurred, either an island or shoal would have been observed by early explorers or a more prominent shoal would still exist on the bottom of the lake. On the other hand, if such a site did exist, it almost certainly had to have been located on a surviving remnant of the beach trend.

Plaquemine-Historic Period to the Present

Approximately the last 600 years of the basin's history is included in the essentially prehistoric Plaquemine-Historic period and the historic European or modern period. In sharp contrast to the cultural landscape, the physical landscape remained relatively uniform during this period. Processes operating during the last 50 years probably operated at very much the same rate and with the same distribution throughout the 600-year period. Accurate historic records and precise measurements have made an evaluation of some of these processes more feasible than at any other time in the basin's history.

Indian Sites.-- The number of sites and the quantity of pottery recovered indicate that the basin's population during this period was

[17] F. B. Kniffen, personal communication, 1959.

appreciably smaller than during the preceeding period (Fig. 32). Only one site (Fig. 32, No. 38) is an initial occupation site; all the rest represent continued occupation or re-occupation of pre-existing sites.

Maps and historic records contain references to only 16 sites which were occupied after 1650 A.D. Only nine of these were actually located during this survey. It is interesting to note that historic sites are the only ones known to exist along the present course of the Mississippi River. Although all of these sites are now destroyed, historical records indicate that they were seasonally occupied earth middens with possibly one or more earth mounds associated. There is no evidence that shell middens ever existed along the Mississippi River natural levees.

In the basin proper, shell middens stand as evidence of a continued and widespread utilization of Rangia. The presence of these shells in middens located well inland along the Amite River (Fig. 32) strongly suggest continued brackish-water conditions in Lake Maurepas as well as Lake Pontchartrain.

In eastern Orleans Parish, prehistoric occupation was apparently limited to the shores or near-shore areas of the major lakes. With the exception of a small area near Lake St. Catherine, the Pine Island ridge had subsided to a point where it was no longer habitable.

Mississippi River Crevasses.-- The end of the period of significant discharge through the Lafourche distributary and the consequent development of an essentially full-flow Mississippi River channel past New Orleans is estimated to have occurred about 700 years ago (U. S. Army Engineer Waterways Experiment Station, 1958, vol. 1, p. 7). Four high-water distributaries such as Bayou Manchac probably did not divert more than 25 per cent of any given flood on the river.

As a result of increased flow, Mississippi River natural levees east of Donaldsonville must have grown in height and width through the addition of new sediments during floods. This process occurred in much the same way as it had countless times in the past along the river and its distributaries; i.e., the frequent topping of long stretches of levee by a relatively thin sheet of sediment-carrying flood water. During any given flood, the amount of fine sediment reaching the backswamp was small and an even smaller amount reached the lakes in the inter-levee basins. Rarely did flood waters become restricted to a well-defined crevasse channel and/or scour enough to create a permanent or semi-permanent breach in the levees.

The more violent floods on the river are probably represented by the numerous thin layers of soft gray clay which characterize the accumulations of swamp and marsh deposits adjacent to the natural levees. The clay layers decrease in number away from the levees and in no cases do they exceed organic accumulation as the primary type of deposition. During the last several hundred years, the amount of fine sediment that reached the lakes in the basin apparently was not sufficient to cause any noticeable shallowing or shoreline accretion.

Construction of artificial levees along the Mississippi River

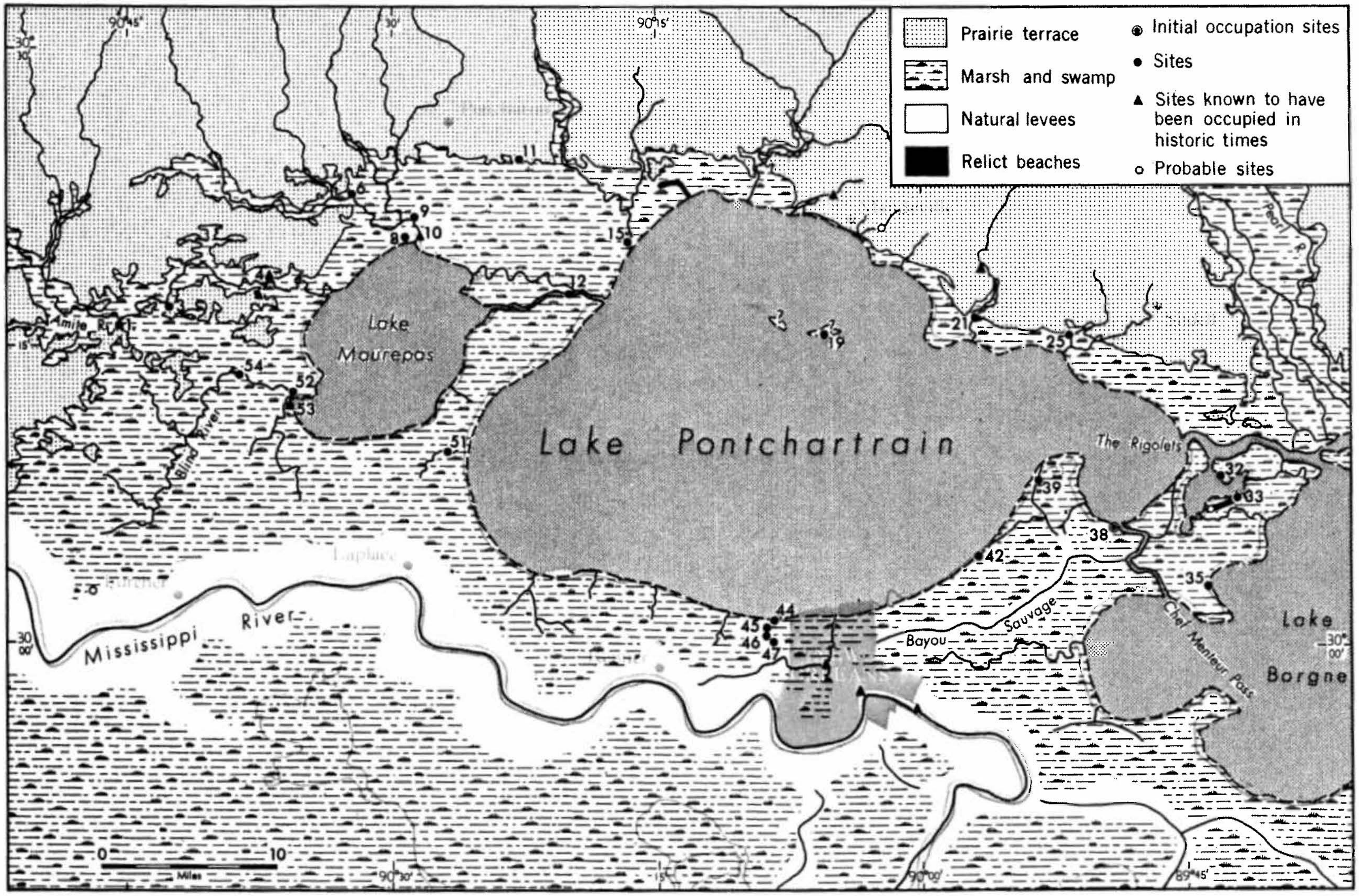

Fig. 32. Paleogeography of the Pontchartrain Basin, about 300 to 600 years before present, including locations of Plaquemine-Historic period sites.

resulted in a decrease in the number of crevasses but greatly increased their intensity and altered their characteristics. Levee construction, which began at New Orleans in 1727 and had spread continuously upstream as far as Baton Rouge by 1812 (Elliott, 1932, vol. 2, pp. 159-160), appreciably raised the height of the average flood crest on the river. Flood crest elevations rose approximately five feet at New Orleans between the 1830's and the 1920's (ibid., p. 83), for example. Crevasses consequently became much more violent because of the greatly increased gradient between levee crest and backswamp level as compared to the main channel (Russell, 1938, p. 20).

In general, the crevasse period in the Pontchartrain Basin area is considered as having extended from about 1750 to 1927 (Gunter, 1953, p. 22) but accurate records are available only for the period 1849 to 1927 (U. S. Army, Chief of Engineers, 1931, pp. 125-137). The locations of the crevasses which occurred during this period are shown in Figure 33.

The average crevasse along the river during this period breached the artificial levees for a distance of 500 to 1000 feet, scoured to a depth of about 12 feet, and discharged at an average maximum velocity of about 65,000-cubic-feet-per-second (c.f.s.) At least four crevasses (Bonnet Carré, 1849; Nita, 1890; Belmont, 1892; Sarpy, 1892) flowed at a rate in excess of 100,000 c.f.s., a rate approximating 10 per cent of the normal stage discharge of the Mississippi River at New Orleans.

One of the largest crevasses ever to form in this area occurred on the Nita Plantation on March 13, 1890 (Fig. 33). The break in the levees reached a width of almost 3000 feet and the maximum discharge has been variably calculated as being from 385,000 to 402,556 c.f.s. (U. S. Army, Chief of Engineers, 1931, pp. 125-137). Concerning the inundation attending the crevasse, Johnson (1891, p. 20) states,

> The first break began March 13, 1890; yet it was not until March 22, nine days later, that the water came through the south pass of Manchac (the bayou or strait connecting Lake Maurepas with Lake Pontchartrain), and two weeks more passed before Lake Maurepas overflowed the lowlands to the northeastward sufficiently to threaten the track of the Illinois Central railway; and it was not until April 13, or a month after the break, that this railway was covered so deeply as to stop the running of trains. The water now quickly spread over the whole of the flat country from the 28-mile post north of New Orleans (near Frenier) to the 46-mile post, or to within one and a half miles of Ponchatoula station, and trains ceased to pass over this line till June 23. The greatest height attained here by the river water was only eight and a half feet above mean tide, or the ordinary low-water stage of Manchac.

According to the New Orleans Daily-Picayune newspaper at this time, strong easterly winds developed on April 22 and the level of Lake Pontchartrain rapidly rose. This had the additional effect of flooding the swamps north of New Orleans with muddy water, flooding

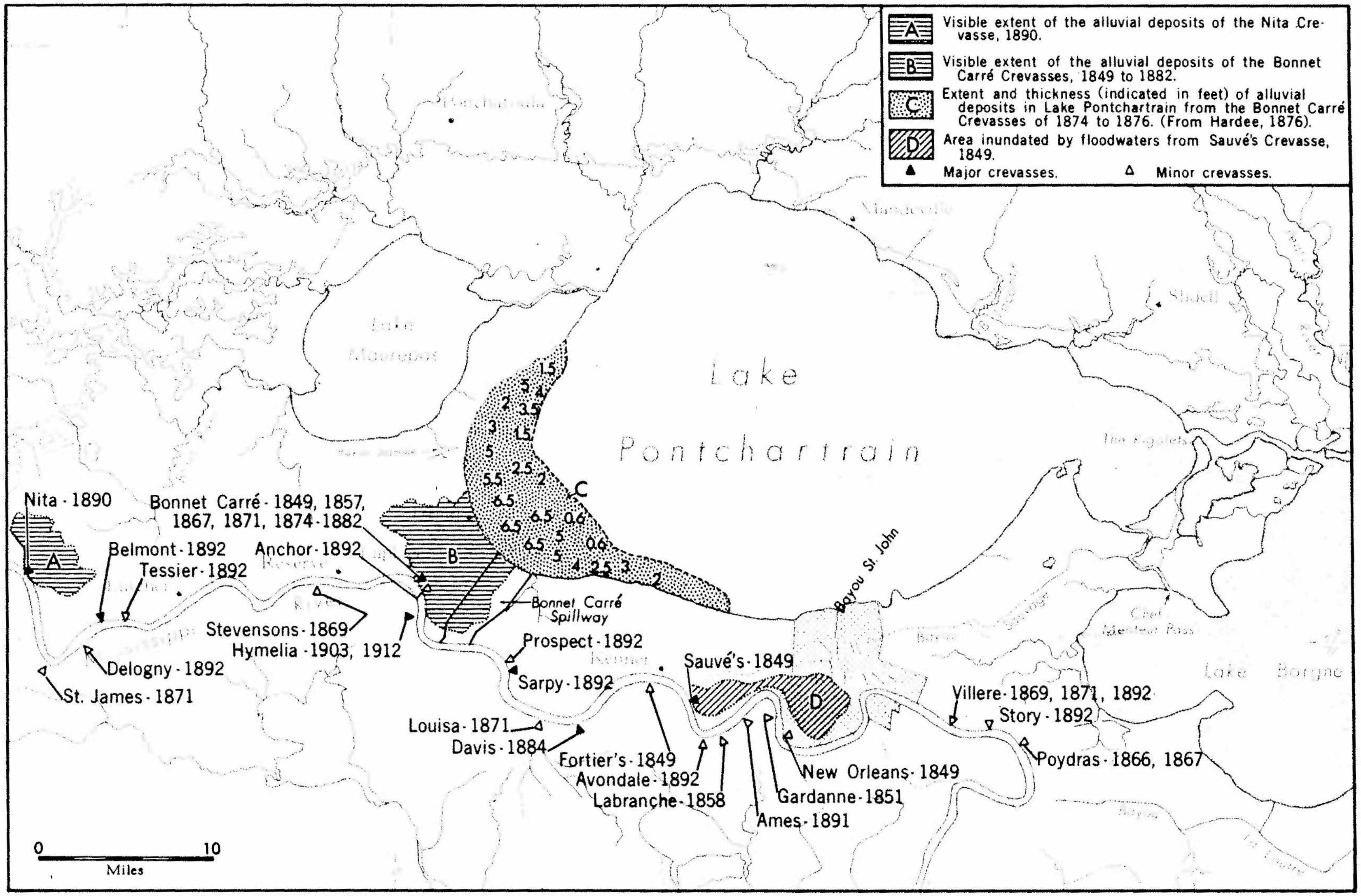

Fig. 33. Locations of crevasses along the Mississippi River from 1849 to 1927 including areas affected by three major crevasses.

the railroad tracks and surrounding areas near Bayou Sauvage (to about 10 miles west of Chef Menteur Pass), and even inundating part of Metairie Ridge. Thus very little of the Pontchartrain Basin escaped effects of the crevasse.

Most of the coarser sediments (silts and very fine sands) resulting from the crevasse are visible in a fan-shaped area of about 11 square miles radiating from the point of the crevasse (Fig. 33). Concerning additional sediments, Johnson (1891, p. 23) states;

> A part of this silty sediment, but with less and less of sand, was deposited eastward along the bayous and timbered bottoms between the crevasse and Lake Maurepas. On the large flat prairie or pine meadow towards Ponchatoula (marsh areas south of Ponchatoula), the water, deep as it was, left no sand, but only a fine, impalpable, yellowish or bluish-brown clay... .

Undoubtedly similar deposits occurred over most of the inundated area, including the lakes themselves, but decreasing in amount eastward. Whatever quantity of sediment was deposited, however, probably greatly exceeded the amount that was introduced by a crevasse that occurred before artificial levees were constructed.

One of the most favorable locations for crevassing was on the left bank of the river just east of Laplace (Fig. 33). The 12 crevasses that occurred at this point flowed at rates varying from 70,000 to 225,000 c.f.s. (Gunter, 1953, p. 23) and scoured to a maximum width of 5,300 feet (1849) and a maximum depth of 52.7 feet (1874).

As shown in Figure 33, the visible extent of silty and sandy crevasse deposits covers an area of about 35 square miles. Surface topography in the area is characterized by numerous ridges and swales radiating from the point of crevassing and by similarly radiating braided crevasse channels.

Shortly after the crevasse of 1874, a survey was made to determine the effects that this crevasse and preceeding ones at Bonnet Carré Bend had on Lake Pontchartrain (Hardee, 1876). Hardee describes the crevasse as follows,

> The present crevasse, which was caused in the spring of 1874 by a breach in the levee at Bonnet Carré bend, about 35 miles above the city (New Orleans), is now 1370 feet in width, in a direct line across the gap, and as the discharge of water courses towards Lake Pontchartrain, 5 miles distant, it widens in a fan-like shape so that by the time it reaches the shore of the lake the flow of water has attained a breadth of more than 22 miles...

A special survey was made in Lake Pontchartrain to determine the amount and distribution of sediment introduced into the lake (Fig. 33). In reference to this, Hardee states,

> A very large proportion of sediment is of course

> precipitated before reaching the lake shore, but enough is still held in suspension to produce marked effects when the flow of water is at last checked by debouching into the lake.
>
> It will be perceived that the greatest width and depth of deposit has been made opposite Frenier Station, on the Jackson Railroad (Illinois Central), or where the main crevasse water pours into the lake. At this point the cross section from the shore outward shows the deposit to have been made over a distance exceeding 5 miles, and the greatest thickness in that section to be about 6 and a half feet. The whole area of deposit embraces a compact mass, some 22 miles in length by an average of 4 miles in width, and contains by calculation about two hundred million cubic yards of sedimentary matter.

According to Hardee's calculations, Lake Pontchartrain, if entirely filled, could hold about 10,000 million cubic yards of sedimentary matter. The amount of sediment introduced by the crevasse, therefore, filled approximately two per cent of the volume of the lake.

Following deposition, the sediments were redistributed over the bottom of the lake by waves and currents and probably reduced considerably in volume by winnowing. During storms, much of the sediment was carried inland and re-deposited as washover deposits. The importance of this process is evidenced by the unusually thick and well-developed washover deposit in the vicinity of Frenier (Fig. 9f). Enough sediments have remained in the western portion of the lake, however, to keep the slope of the lake bottom (from the shoreline outward) shallower than it is in any other portion of the lake (excepting the small eastern lobe).

Sauvé's crevasse of 1849 (Fig. 33) is considered to be more typical of the numerous smaller crevasses which occurred in the basin area. Flood waters from this crevasse discharged into the narrow inter-levee basin between the Mississippi River and the Metairie Bayou distributary and spread as far east as the central portion of the city of New Orleans. According to a map of the inundated district dated 1849 (surveyer unknown), the water accumulated to a maximum depth of six feet. All of the water not removed by evaporation or seepage eventually found its way into Lake Pontchartrain by several artificial canals cutting through Metairie Ridge but primarily via Bayou St. John (Fig. 33). The impounding of flood water in the depression south of the ridge during prehistoric times may have been largely responsible for the formation of this bayou.

The construction (1931) and operation (1937, 1945, and 1950) of the Bonnet Carré Spillway (Fig. 33) has provided an excellent opportunity for studying the effects of crevassing along the river. The spillway was designed to protect New Orleans by diverting portions of major Mississippi River floods into Lake Pontchartrain, thereby actually being an artificial and controllable crevasse.

The following statistics are available on the operation of the spillway (Gunter, 1953, p. 25),

Year	Total days in operation	Maximum discharge (c.f.s.)	Average discharge (c.f.s.)
1937	48	211,000	129,000
1945	57	318,000	215,000
1950	38	222,800	143,000

During the 1950 opening, samples of flood water were collected at various points in the spillway and in Lake Pontchartrain to determine the amount of sediment being carried. It was found that about 63 per cent (five million cubic yards of fill) was dropped in the spillway itself (ibid., p. 48). In reference to the flood water entering Lake Pontchartrain, Gunter (1953, pp. 48-49) states,

> Velocities of flood water drop almost to zero a few miles out in Lake Pontchartrain and all of the load but the finest particles, which remain in suspension indefinitely, fall out. Such a sediment load change, however, leaves the appearance of the water largely unchanged. The water still has a brown or muddy appearance, but it cannot deposit large quantities of mud anywhere. It does not muddy or cover the whole lake bottom, which is 640 square miles in extent. Instead, the sediment settles out in an underwater delta fan at the mouth of the floodway, a section of about 30 square miles or about 5 per cent of the lake bottom.

The effects of the spillway openings on the lake were determined by comparing two hydrographic surveys made by the U. S. Army Corps of Engineers. The first survey (1935-36) predates the first opening of the spillway while the second (1950) postdates by one month the last opening of the spillway. Total accretion on the lakebottom resulting from the three spillway openings, over the area of about 30 square miles, was found to average less than one foot. Greatest accretion, occurring immediately adjacent to the mouth of the spillway, generally did not exceed two feet.

This data indicates that the total effects of the spillway openings were appreciably less than those of the Bonnet Carré crevasses. The primary reason for the difference in volume of sediment was most probably the duration of discharge since the volume of discharge, the type of sediment introduced, and the character and size of area through which the discharge flowed before reaching the lake were comparable.

As great as the volume of sediment from either the crevasses or the spillway appears to be, it nevertheless had little effect on modifying or reversing the processes of subsidence and erosion. The Turtle Bayou and Bayou Pecoin distributaries in Orleans Parish (Fig. 26) obviously had a much greater long-term effect on the basin area. These distributaries not only discharged for a much longer period of time, but also deposited vastly larger quantities of silt and very fine sand. Considered in gross terms, this material is probably much more resistant to erosion and winnowing in this environment of deposition than is a layer of soft silty clay or gelatinous clay resulting from the crevasses or spillway. This is, of course, assuming that the clay would be reworked before it had a chance to become well consolidated.

The deposition of small quantities of clay over extensive areas of marsh and swamp throughout the basin, such as occurred after the Nita crevasse (1890), must have been duplicated many times during unrecorded crevasses and during the development of the major distributaries. However, this would occur extensively only during the right combinations of hydraulic and climatic conditions and would vary in intensity depending upon the location of the introduction of sediment (western portion of basin versus eastern portion).

Modern Shoreline Retreat.-- Through the use of topographic maps and aerial photographs, comparisons were made of various shoreline positions over the last 100 years to accurately determine recent shoreline changes. Because of degree of accuracy and large scale, best results were obtained by comparing aerial photos of the period 1931 to 1937 (Scale - 1:10,000) with aerial photos of the period 1950 to 1954 (Scale - 1:20,000). The calculated values for Lakes Pontchartrain and Maurepas are shown on Figure 34. The values indicated along the shore of Lake Borgne were calculated using topographic surveys of 1858 and 1955 and are considered to be less accurate than those for the other lakes.

Averages of the values shown on Figure 48 are as follows: Lake Maurepas, less than two feet-per-year; Lake Pontchartrain, 5.4 feet-per-year; Lake Borgne, 4.5 feet-per-year. In the case of Lake Pontchartrain, this means an increase in water area of about one-eighth square mile per year (three million square feet).

The appreciably varying rates of retreat in each of the lakes show definite relationships to the physiography. Although it is not obvious because of variations in other factors, brackish-water marsh areas appear generally to be more resistant to erosion than swamp and fresh-water marsh areas. As one would expect, exposed points or capes erode faster than cove areas and the steeper the offshore profile, the faster the rate of shoreline retreat.

Throughout most of the basin, however, there are other factors which more strongly effect shoreline changes. Taking such factors as variations in water depth, prevailing wind direction, and length of fetch into consideration, areas formed by the Bayou Sauvage distributary system appear to be eroding faster than any other area in the eastern portion of the basin. In general, this is the youngest mass of deltaic sediments and consequently, is less compacted and more easily eroded. The relationship between ages of deltaic areas and rates of shoreline retreat along the Louisiana coast has been discussed by Morgan and Larimore (1957).

The lowest rates of retreat in Lake Pontchartrain occur along the northeastern shore between Mandeville and The Rigolets. The

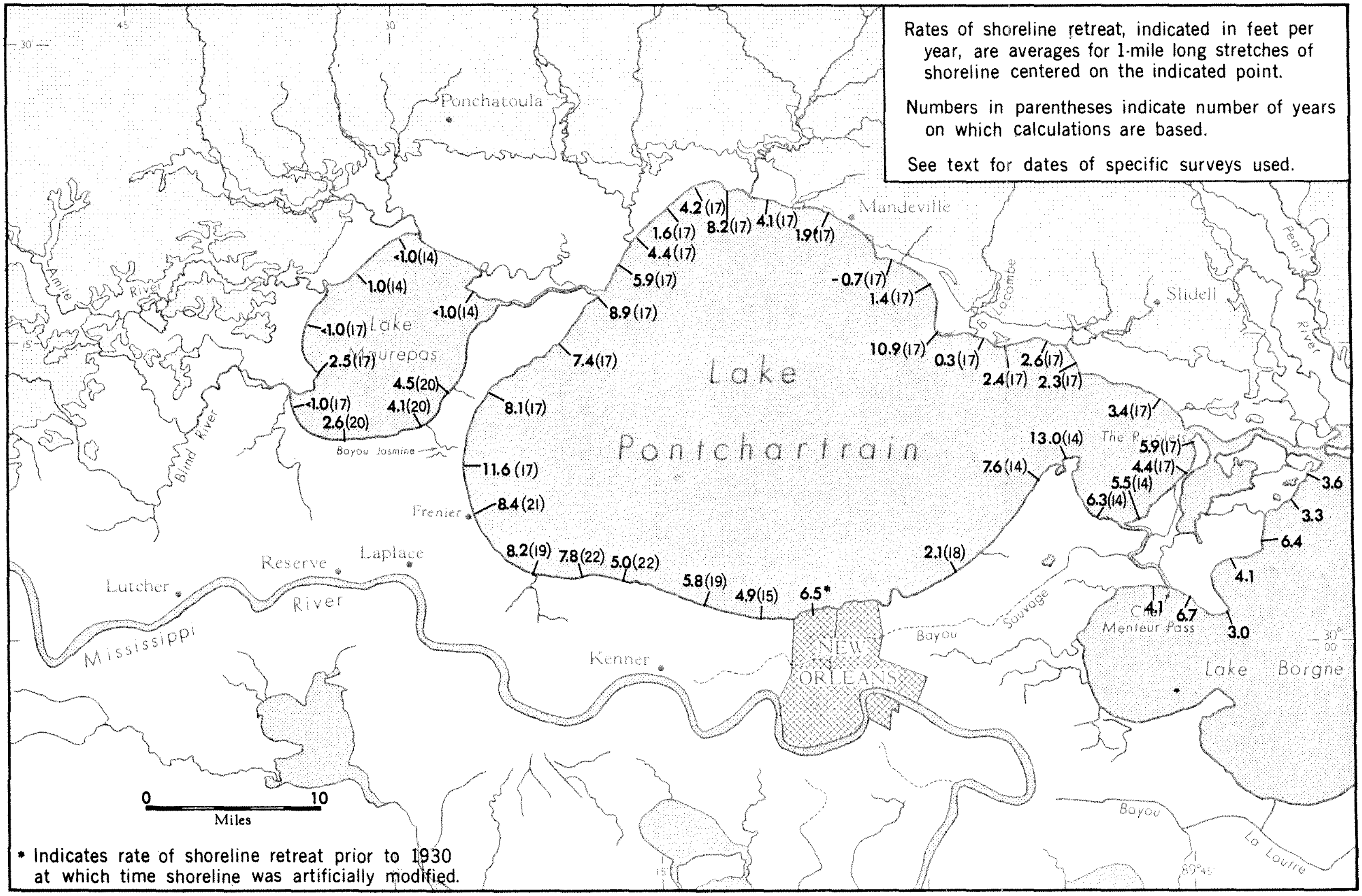

Fig. 34. Rates of modern shoreline retreat as calculated from maps and aerial photos.

significant factors which have influenced this stretch of shoreline are the shallow depth (6 to 10 feet) at which the resistant Prairie formation underlies the area, the presence of moderately well developed sand beaches, and a relatively resistant brackish-water marsh with firm washover deposits. Perhaps most important is the fact that the present shoreline is encountering relict silt and sand beaches at several localities. The available energy remains the same in these areas but the supply of sediment is greatly increased. The best examples of this situation occur near the mouth of Bayou Lacombe and just east of Mandeville (Fig. 34).

A more detailed evaluation of shoreline changes in the vicinity of Frenier was possible because of four sets of aerial photos and a 1897 topographic survey. The following changes were found to have occurred,

1897 to 1931	Total shoreline advance	-	112.0 feet
	Average advance per year	-	3.2
1931 to 1937	Total shoreline retreat	-	67.5
	Average retreat per year	-	11.2
1937 to 1940	Total shoreline retreat	-	27.4
	Average retreat per year	-	9.1
1940 to 1952	Total shoreline retreat	-	73.7
	Average retreat per year	-	6.1

The 1897 shoreline was very similar to the present shoreline in configuration (Fig. 9f), i.e., highly irregular and eroding rather rapidly. Between 1897 and 1931, however, the shoreline advanced through the development of a long, straight, silt or sand beach. By 1937, the beach had been completely removed and the shoreline had adopted its present irregular configuration.

The origin of the silt and sand beach (silt undoubtedly was the predominant grain size) is believed to have been the thin mass of silt and clay deposited in Lake Pontchartrain by the Bonnet Carré crevasses. Although a reduction in volume of the mass by winnowing of the clay undoubtedly occurred, necessary energy to drive the sediment shoreward was probably lacking until the 1915 hurricane. If this storm was responsible for the formation of the beach, it had likely reached its maximum development before 1931 and had already started to retreat by this time.

An obvious explanation for the progressively slower rates of shoreline retreat since 1931 is the sediments deposited in the lake during operations of the Bonnet Carré Spillway. If this was the case, the rate of shoreline retreat should be increasing at the present time (the last spillway operation was 11 years ago). General observations in the area, but no precise measurements, seem to indicate that this is happening.

Whenever possible, shoreline positions of the 1930's and the 1950's were compared with those of the 1850's. Allowing for a considerable error in the early surveys, the comparisons showed that shoreline retreat was occurring at a more rapid rate during the more recent period at fully 75 per cent of the locations. The instances in which the shorelines were not found to be retreating faster have no discernable pattern of distribution and suggest errors in measurement rather than actual trends in processes.

If only the balance between subsidence and sedimentation is considered to be a controlling factor in shoreline movement, the lakeshores should be eroding more rapidly at the present time. To this factor, however, must be added the facts that as the lake (or lakes) increase in size, the length of fetch increases and the depth of the lake proportionately increases. Both of these would have the effect of accelerating shoreline retreat. The slight rise in sea level which is apparently occurring at the present time is another factor which must be considered in this respect.

In regards to subsidence, there can be no doubt that it is a prevalent process in the Pontchartrain Basin today. Since the last opening of the Bonnet Carré Spillway in 1950, there have been no Mississippi River sediments reaching the basin. The only other sources of sediment are the streams which drain the Prairie terrace to the north and west and it is evident that these contribute only insignificant quantities of alluvium.

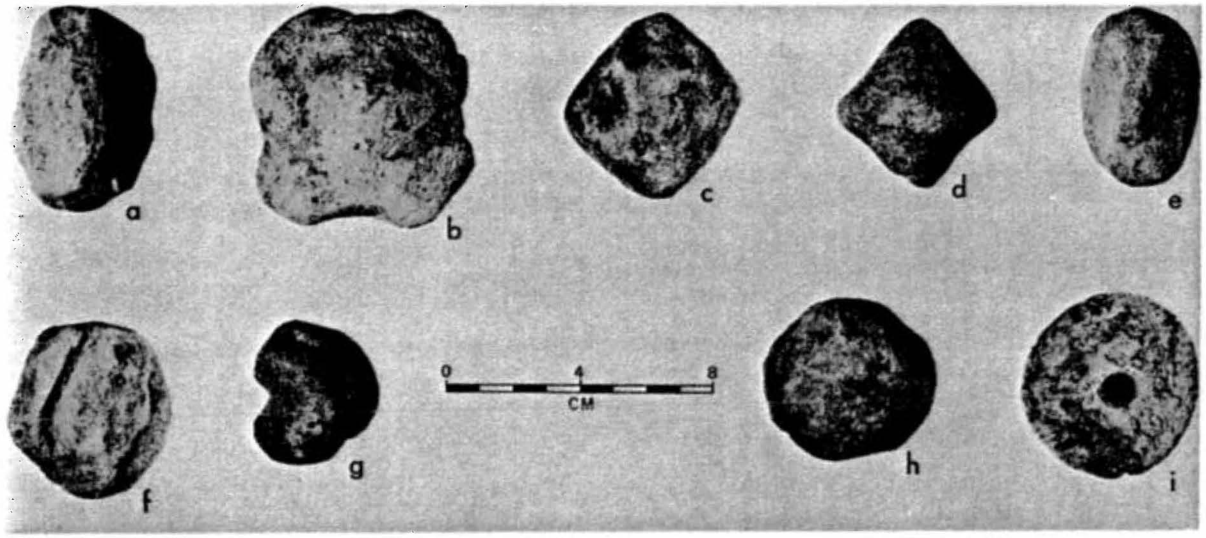

Fig. 35. Poverty Point objects from Site No. 56: a, cylindrical with lateral grooves; b, biconical, grooved (top view); c, biconical, grooved (side view); d, biconical, plain; e, f, melon-shaped· g, cross-grooved; h, spheroidal; i, unusual variety.

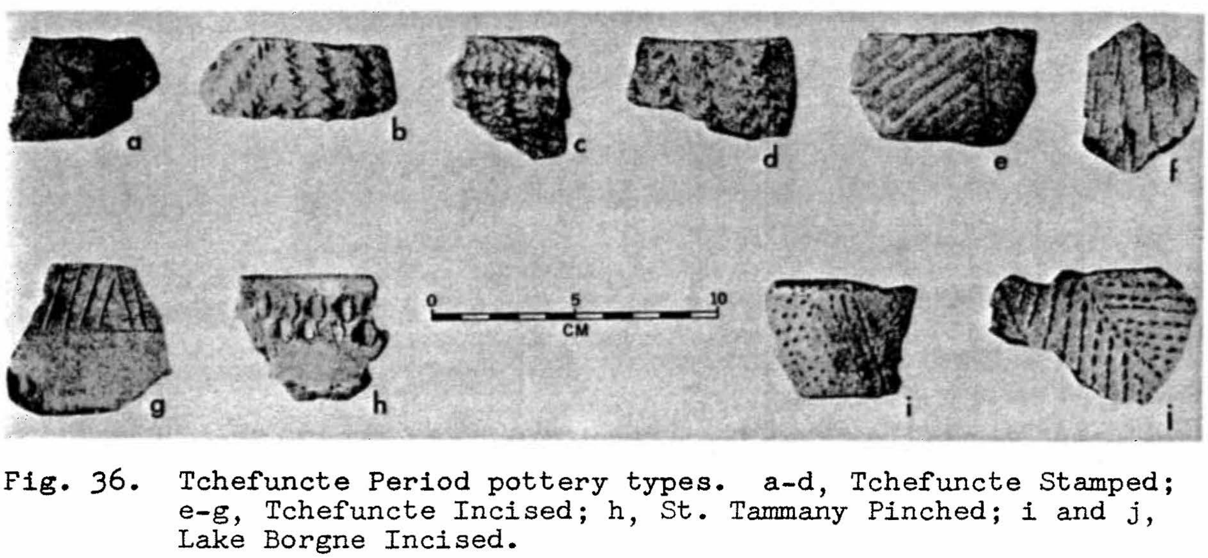

Fig. 36. Tchefuncte Period pottery types. a-d, Tchefuncte Stamped; e-g, Tchefuncte Incised; h, St. Tammany Pinched; i and j, Lake Borgne Incised.

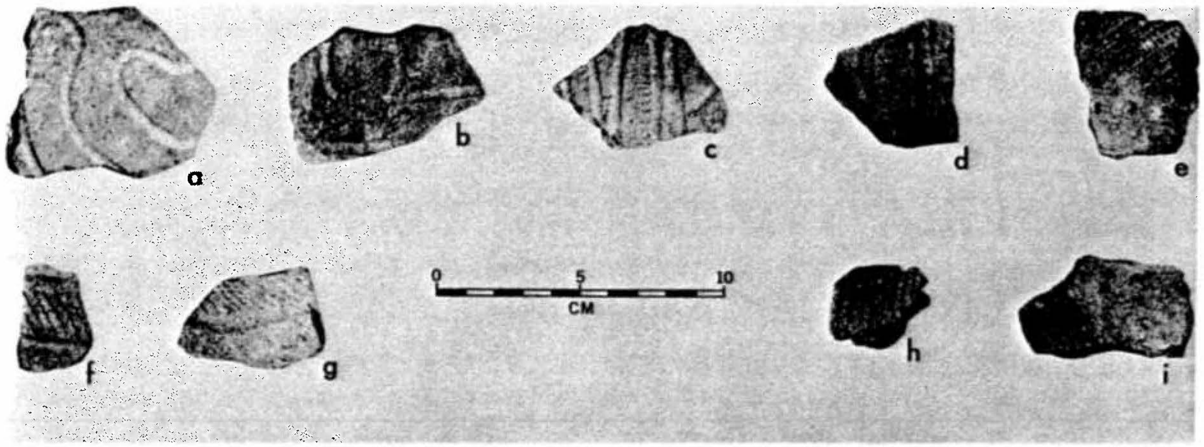

Fig. 37. Marksville Period pottery types. a and b, Marksville Incised; c and d, Marksville Stamped; e, Marksville Period Rim; f-i, Crooks Stamped.

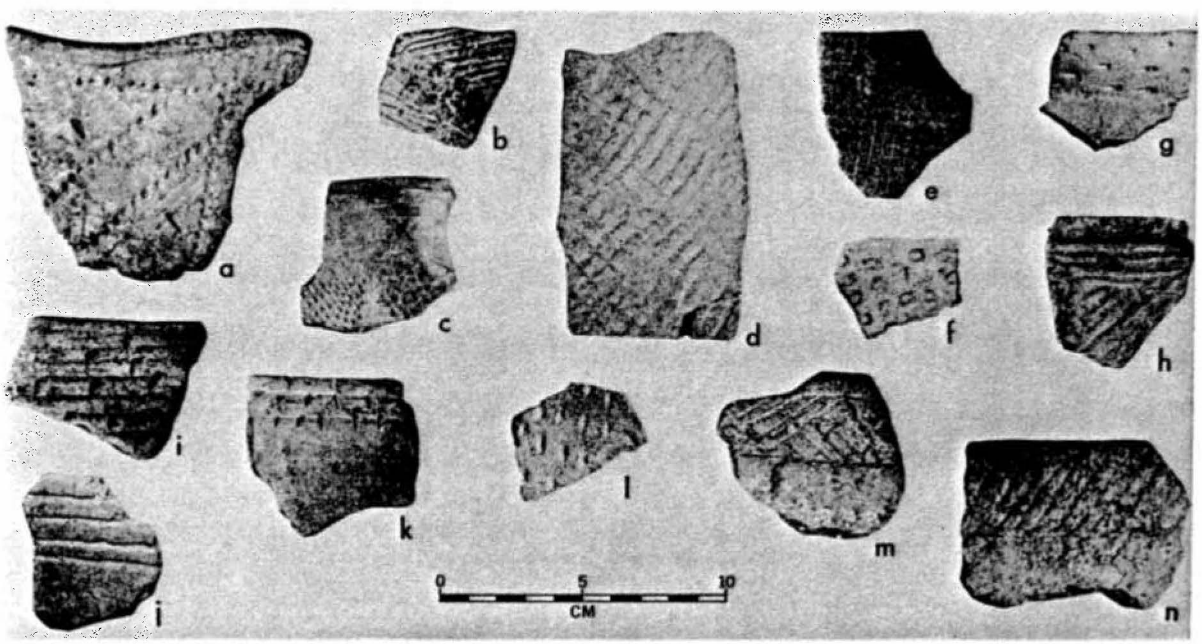

Fig. 38. Troyville-Coles Creek Period pottery types. a-c, French Fork Incised; d and e, Pontchartrain Check Stamped; f and g, Rhinehart Punctated; h, Yokena Incised; i-k, Coles Creek Incised Rims; l, Churupa Punctated; m and n, Mazique Incised.

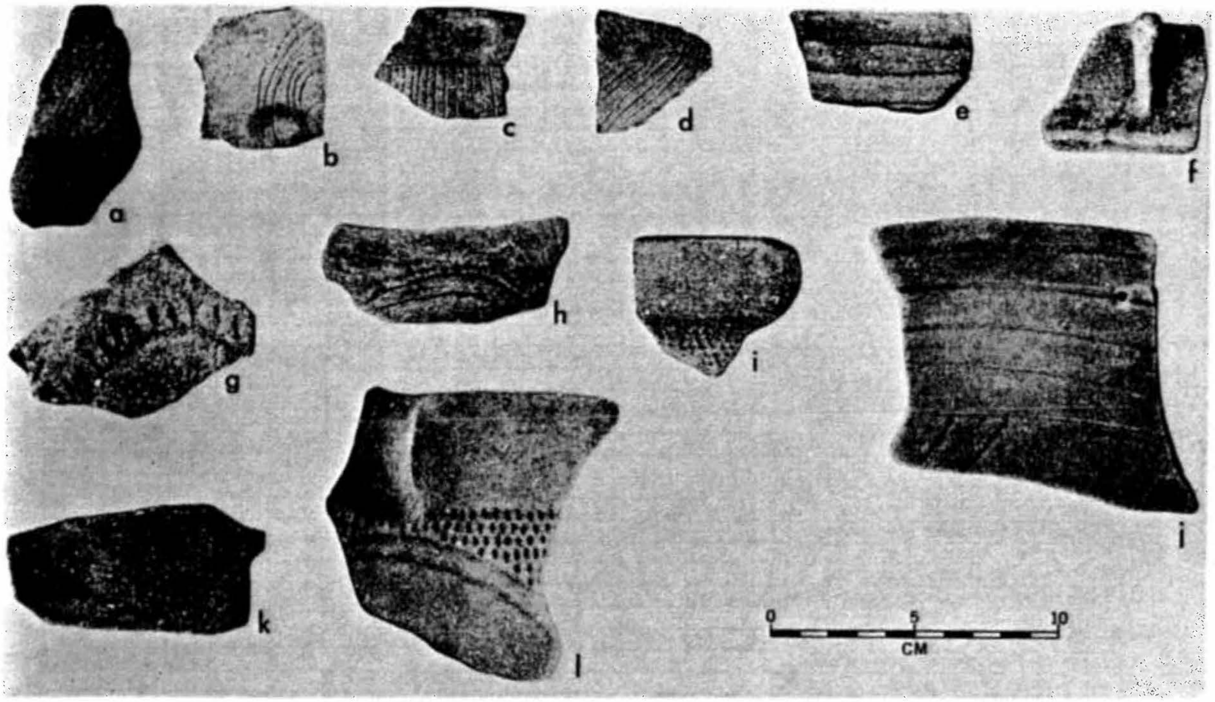

Fig. 39. Plaquemine-Historic Period pottery types. a, Dupre Incised; b, Fatherland Incised; c and d, Manchac Incised; e-l, shell-tempered sherds similar to Moundville types.

	A	B	C	D	E	F	G	H
Drummond red maple - *Acer drummondii* Hook. & Arn.		■	■	■				
Alligator weed - *Alternanthera philoxeroides*			■			■		
Switch cane - *Arundinaria tecta* (Walt.) Muhl				■	■			
Buckbrush - *Baccharis hamlimifolia* L.			■					▒
Water hickory - *Carya aquatica* (Michx.) Nutt.		■		■				
Pecan - *Carya illinoensis* (Wang.) Koch	■				■			
Shagbark hickory - *Carya ovata* (Mill.) Koch	■							
Chinquapin - *Castanea pumila* Mill		■						
Hackberry - *Celtis laevigata* Willd.					■			
Buttonbush - *Cephalanthus occidentalis* L.			■		■			■
Salt grass - *Distichlis spicata*							■	
Water hyacinth - *Eichornia crassipes*			■			■		
Beech - *Fagus grandifolia* var. *caroliniana* (Loud.) Fern. & Rehd.		■						
Water ash - *Fraxinus caroliniana* Mill.			■					
Green ash - *Fraxinus pennsylvanica* Marsh.				■				
Honeylocust - *Gleditsia triacanthos* L.				■				
Marsh-elder - *Iva fructescens* L.				■				■
Black rush - *Juncus roemerianus*							■	
Sweetgum - *Liquidambar styraciflua* L.	■	■	■	■	■			
Yellow-poplar - *Liriodendron tulipifera* L.		■						
Southern magnolia - *Magnolia grandiflora* L.	■	■			■			
Sweetbay - *Magnolia virginiana* L.		■						
Sawgrass - *Mariscus jamaicensis*			■			▒		
Waxmyrtle - *Myrica cerifera* L.					▒			▒
Water tupelo - *Nyssa aquatica* L.			■					
Swamp tupelo - *Nyssa sylvatica* var. *biflora* (Walt.) Sarg.		■		■				
Paille fine - *Panicum hemitomon*						■		
Redbay - *Persea borbonia* (L.) Spreng.		▒		▒				
Roseau - *Phragmites communis*						■		■
Slash pine - *Pinus elliotti* Engelm.	■	■						
Longleaf pine - *Pinus palustris* Mill.	■							
Loblolly pine - *Pinus taeda* L.	■	■						
Sycamore - *Platanus occidentalis* L.		■			■			
Cottonwood - *Populus deltoides* Bartr.				■	■			
Southern red oak - *Quercus falcata* Michx.	■	■						
Overcup oak - *Quercus lyrata* Walt.				▒	▒			
Blackjack oak - *Quercus marilandica* Muenchh.	■							
Water oak - *Quercus nigra* L.	■	■			■			
Nuttall oak - *Quercus nuttallii* Palmer				■	■			
Cherrybark oak - *Quercus pagoda* Raf.		■		■				
Post oak - *Quercus stellata* Wang.	■							
Live oak - *Quercus virginiana* Mill.	■	■		■	■			
Blackberry - *Rubus* spp.				■				
Palmetto - *Sabal minor* (Jacq.) Pers.	■	■	■	■	■			■
Paddle weed - *Sagittaria lancifolia*						■		
Arrowhead - *Sagittaria latifolia*						■		
Black willow - *Salix nigra* Marsh.		■	■	■	■			■
Giant bulrush - *Scirpus californicus*						■		
Three-cornered grass - *Scirpus olneyi*							■	
Oyster grass - *Spartina alterniflora*							■	
Couch grass - *Spartina patens*							■	
Cypress - *Taxodium distichum* (L.) Rich.			■					
Cattail, lance leaf - *Typha angustifolia*			■			■		
Cattail, broad leaf - *Typha latifolia*			■			■		
American elm - *Ulmus americana* L.	■			■				
Cut grass - *Zizaniopsis miliacea*						■		

Compiled from Brown (1956); St. Amant (1959); O'Neil (1949); and others.

A. Pleistocene Prairie terrace.

B. Stream bottoms & depressions on the Prairie terrace inland from cypress swamp areas.

C. Cypress swamps.

D. Spoil banks, natural levees of small streams, & relict beach ridges in cypress swamp areas.

E. Natural levees of Mississippi River & Mississippi River distributaries.

F. Fresh-water marshes.

G. Brackish-water marshes.

H. Spoil banks, low natural levees, & small relict beach ridges in marsh areas.

Table I. Vegetation Types of the Pontchartrain Basin.

TABLE II

RADIOCARBON DATES

Sample No.	Location	Sample Type and Depth (MSL)	Age (B.P.)	Source	Lab. No.
1.	Ponchatoula Quad. 30°20'45" N. Lat 90°24'50" W. Long	Peat -8 to -9	1800±105	1.	G-294
2.	Bonnet Carré Quad. 30°04'35" N. Lat. 90°24'20" W. Long.	Peat -15 to -16	2500±115	1.	G-295
3.	Mount Airy Quad. 30°04'00" N. Lat. 90°36'40" W. Long.	Peat -18.5 to -19.5	4000±125	1.	G-296
4.	Mount Airy Quad. 30°04'40" N. Lat. 90°36'55" W. Long.	Peat -1 to -2	1325±105	1.	G-297
5.	Chef Menteur Quad. 30°03'20" N. Lat. 89°57'50" W. Long.	Peat -8 to -9	1800±105	1.	G-298
6.	Spanish Fort Quad. 30°00'30" N. Lat. 90°08'45" W. Long.	Peat -14 to -15	2800±115	1.	G-299
7.	St. Bernard Quad. 29°59'42" N. Lat. 89°56'31" W. Long.	Peat -10.5	2600±115	2.	-
8.	St. Bernard Quad. 29°58'45" N. Lat. 89°56'46" W. Long.	Peat -3	900±100	2.	-
9.	St. Bernard Quad. 29°58'45" N. Lat. 89°56'46" W. Long.	Peat -6	1850±200	2.	-
10.	St. Bernard Quad. 29°58'45" N. Lat. 89°56'46" W. Long.	Peat -8	2675±115	2.	-
11.	St. Bernard Quad. 29°58'45" N. Lat. 89°56'46" W. Long.	Peat -13	3000±240	2.	-

Sample No.	Location	Sample Type and Depth (MSL)	Age (B.P.)	Source	Lab. No.
12.	St. Bernard Quad. 29°57'28" N. Lat. 89°57'21" W. Long.	Peat -4.5	1450±105	2.	-
13.	St. Bernard Quad. 29°57'28" N. Lat. 89°57'21" W. Long.	Peat -9.5	2650±115	2.	-
14.	St. Bernard Quad. 29°54'49" N. Lat. 89°58'25" W. Long.	Peat -6	1000±100	2.	-
15.	St. Bernard Quad. 29°54'49" N. Lat. 89°58'25" W. Long.	Peat -13.5	2350±110	2.	-
16.	St. Bernard Quad. 29°54'27" N. Lat. 89°58'56" W. Long.	Peat -4	1100±105	2.	-
17.	St. Bernard Quad. 29°54'27" N. Lat. 89°58'56" W. Long.	Peat -7	2000±105	2.	-
18.	St. Bernard Quad. 29°54'27" N. Lat. 89°58'56" W. Long.	Peat -11	2400±110	2.	-
19.	St. Bernard Quad. 29°53'22" N. Lat. 89°59'52" W. Long.	Peat -8	2900±115	2.	-
20.	New Orleans Quad. 29°53'04" N. Lat. 90°00'05" W. Long.	Peat -4	2250±110	2.	-
21.	New Orleans Quad. 29°51'52" N. Lat. 90°00'48" W. Long.	Peat -2.5	2150±110	2.	-
22.	New Orleans Quad. 29°55'18" N. Lat. 90°03'43" W. Long.	Shells -60	4300±200	3.	-
23.	New Orleans Quad. 29°55'18" N. Lat. 90°03'43" W. Long.	Shells -90	7870±300	3.	-
24.	New Orleans Quad. 29°55'18" N. Lat. 90°03'43" W. Long.	Shells -95	8940±190	3.	0-225

Sample No.	Location	Sample Type and Depth (MSL)	Age (B.P.)	Source	Lab. No.
25.	Bonnet Carré Quad. 30°02'14" N. Lat. 90°16'45" W. Long.	Shells -49	4800±130	3.	0-270
26.	Bonnet Carré Quad. 30°01'34" N. Lat. 90°16'45" W. Long.	Shells -50	4840±130	3.	0-226
27.	Bonnet Carré Quad. 30°01'34" N. Lat. 90°16'45" W. Long.	Shells -65	8100±170	3.	0-228
28.	New Orleans Quad. 29°56'50" N. Lat. 90°04'35" W. Long.	Wood -10	1200±100	4.	0-62
29.	New Orleans Quad. 29°56'50" N. Lat. 90°04'35" W. Long.	Peat -11	2650±110	4.	0-64
30.	New Orleans Quad. 29°58'18" N. Lat. 90°12'35" W. Long.	Peat -2	2320±110	4.	0-90
31.	Chef Menteur Quad. 30°02'26" N. Lat. 89°59'26" W. Long.	Shells 1	2200±110	4.	0-97
32.	Mount Airy Quad. 30°03'03" N. Lat. 90°32'17" W. Long.	Wood 4	2750±110	4.	0-124
33.	Spanish Fort Quad. 30°00'15" N. Lat. 90°07'23" W. Long.	Shells -20 to -25	4800±140	4.	0-119
34.	New Orleans Quad. 29°57'28" N. Lat. 90°03'40" W. Long.	Shells -48 to -51	5400±140	4.	0-75
35.	St. Bernard Quad. 29°53' N. Lat. 89°54' W. Long.	Shells -13	1400±350	5.	L-175D
36.	St. Bernard Quad. 29°53' N. Lat. 89°54' W. Long.	Shells -68	5350±350	5.	L-175E
37.	Slidell Quad. 30°15'43" N. Lat. 89°51'35" W. Long.	Shells (Midden)	1900±110	6.	0-28

Sample No.	Location	Sample Type and Depth (MSL)	Age (B.P.)	Source	Lab. No.
38.	Covington Quad. 30°19'40" N. Lat. 90°01'30" W. Long.	Organic carbon (Midden)	2200±110	6.	O-30
39.	Spanish Fort Quad. 30°01'00" N. Lat. 90°08'45" W. Long.	Charcoal (Midden)	1440±100	6.	O-102
40.	Chef Menteur Quad. 30°04'26" N. Lat. 89°56'25" W. Long.	Shells (Midden)	1570±250	7.	M-218
41.	Chef Menteur Quad. 30°04'10" N. Lat. 89°54'58" W. Long.	Shells (Midden)	2220±200	7.	M-243
42.	Rigolets Quad. 30°13'12" N. Lat. 89°34'56" W. Long.	Charcoal (Midden)	3200±130	8.	G-561
43.	New Orleans Quad. 29°57'52" N. Lat. 90°12'19" W. Long.	Peat -8.5 to -9.5	3550±125	8.	G-558
44.	New Orleans Quad. 29°57'40" N. Lat. 90°12'16" W. Long.	Peat -5 to -6	2650±120	8.	G-559
45.	New Orleans Quad. 29°57'40" N. Lat. 90°12'16" W. Long.	Peat -11.5 to -12.5	8700±160 (Anomalous)	8.	G-560
46.	New Orleans Quad. 29°57'57" N. Lat. 90°12'23" W. Long.	Peat -9.5 to -10.5	4050±125	9.	G-574
47.	New Orleans Quad. 29°57'32" N. Lat. 90°12'13" W. Long.	Peat -11.0 to -12.0	3750±120	9.	G-575
48.	Chef Menteur Quad. 30°00'16" N. Lat. 89°56'07" W. Long.	Charcoal (Midden)	4450±140	9.	G-577
49.	Chef Menteur Quad. 30°00'16" N. Lat. 89°56'07" W. Long.	Charcoal (Midden)	3850±130	9.	G-578
50.	Chef Menteur Quad. 30°00'16" N. Lat. 89°56'07" W. Long.	Charcoal (Midden)	3550±120	9.	G-579

Sample No.	Location	Sample Type and Depth (MSL)	Age (B.P.)	Source	Lab. No.
51.	Chef Menteur Quad. 30°00'16" N. Lat. 89°56'07" W. Long.	Shells (Midden)	3700±120	9.	G-580
52.	Chef Menteur Quad. 30°00'16" N. Lat. 89°56'07" W. Long.	Peat -16.0 to -16.5	4050±140	9.	G-581
53.	Grosse Tete Quad. 30°20'18" N. Lat. 91°15'40" W. Long.	Shells -10.0	5500±140	3.	0-279
54.	Chicot Lake Quad. 30°08'00" N. Lat. 91°19'20" W. Long.	Shells -23.0	5600±140	3.	0-72
55.	Chef Menteur Quad. 30°00'39" N. Lat. 89°58'12" W. Long.	Peat -17	4400±130	10.	0-339
56.	Spanish Fort Quad. 30°05'00" N. Lat. 90°08'16" W. Long.	Shells -20	3350±120	10.	0-337
57.	St. Bernard Quad. 29°54'56" N. Lat. 89°58'15" W. Long.	Shells -57.8	5200±135	10.	0-242
58.	Baton Rouge Quad. 30°21'24" N. Lat. 91°06'26" W. Long.	Shells (Midden)	5475±135	11.	1480

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PARISH SITE NO. (La. State Univ. Files)	Lv.-5	Lv.-25	Lv.-19	Lv.-15	Lv.-8	Lv.-6	Lv.-23	Ta.-10	Ta.-11	Ta.-5	Ta.-16	Ta.-15	Ta.-14	Ta.-12	ST.-24	ST.-26	ST.-1	ST.-8	ST.-29	ST.-30
POTTERY TYPE — SITE NO.	1	2	3	4	5	6	8	9	10	11	12	13	14	15	16	17	18*	19	20	21
FORT WALTON INCISED																				
PENSACOLA INCISED																				
MOUNDVILLE TYPES											13.3		50.0					42.8		2.0
MADDOX INCISED																				
CROCKETT CURVILINEAR INCISED																				
AUSTRALIA INTERIOR INCISED																				
PLAQUEMINE BRUSHED							25.0													
L'EAU NOIRE INCISED																				
HARRISON BAYOU INCISED						1.7														
NEILD INCISED	4.0		0.8																	
SWIFT CREEK COMPLICATED STAMP											6.7									
NATCHEZ INCISED																				
PENNINGTON PUNCTATED																				
EVANGELINE INTERIOR INCISED																				
DUPRE INCISED																				
WILKINSON PUNCTATED			6.0					1.6												
FATHERLAND INCISED						5.1														
MANCHAC INCISED										33.3										
HARDY INCISED			0.8			5.1			14.3											
GREENHOUSE INCISED						1.7														
BELDEAU INCISED			0.8																	
CHASE INCISED																				
CHEVALIER STAMPED			4.3																	
RHINEHART PUNCTATED								1.6									0.1	14.3		
COLES CREEK INCISED	16.0		6.0			10.2		3.2						50.0			0.1			4.1
PONTCHARTRAIN CHECK STAMPED	28.0	58.0	33.3		25.0	40.7	25.0	10.0	28.6	12.2	73.3	40.0		50.0			0.1	28.6		4.1
WOODVILLE RED FILMED			3.4																	
LARTO RED FILMED		10.5	5.1			6.8						40.0								
TROYVILLE STAMPED			7.7			1.7		1.6	14.3											
CHURUPA PUNCTATED	4.0		1.7			3.4		3.2	14.3											
YOKENA INCISED	12.0	10.5	11.1			5.1		19.3												
MAZIQUE INCISED	24.0		9.4	100.				6.5								100.				
FRENCH FORK INCISED	4.0	10.5	8.5			1.7		3.2									0.1			2.0
CROOKS STAMPED						1.7											0.2			
MARKSVILLE INCISED			0.8			3.4		19.3					50.0				0.1			4.1
MARKSVILLE STAMPED					50.0	6.8		14.5							100.		0.1		100.	4.1
CHINCHUBA BRUSHED																	0.3			
MANDEVILLE STAMPED																				
ALEXANDER PINCHED																	0.8			2.0
TAMMANY PINCHED																	1.6			6.1
ALEXANDER INCISED																	0.6			
ORLEANS PUNCTATED																	1.0			2.0
LAKE BORGNE INCISED																	2.0			
TCHEFUNCTE STAMPED																	62.7			32.6
TCHEFUNCTE INCISED																	28.6			32.6
UNIDENTIFIED	8.0	10.5	17.9		25.0	5.1	50.5	16.2	28.6	44.5	6.7	20.0					1.9	14.3		4.1

* Collections and analyses of Ford and Quimby (1945). For locations of sites, see Fig. 10

Table III. Summary of Pottery Collection Analyses.

S.T.-44	S.T.-34	S.T.-12	S.T.-36	S.T.-37	S.T.-6	S.T.-5	Or.-16	Or.-31	Or.-14	Or.-22	Or.-18	Or.-33	Or.-29	Or.-12	Or.-7	Or.-6	Or.-15	Or.-1-5	Je.-4	Je.-5	Je.-6	Je.-39	SCh.-11	SCh.-10	SJB.-3	SJB.-2	Lv.-24	SJB.-4	An.-8
22	24	25	26	27	28	29	31	32	33	34	35	36	38	39	40	41	42	43*	44	45	46	47	48	49	50	51	52	53	54
													42.9	3.4					0.4										
									4.3		50.0								1.3										
		0.8							13.1				42.9	13.8					15.7	4.3	1.8							60.0	
																			0.4										
																			0.4										
																											7.1		
									4.3										0.4										
																			0.4	4.3									
																			0.4										
													14.3	3.4															
																			1.3										
									4.3										0.8										
																	20.0		0.8	8.7	0.7								
																			0.8								7.1		
																			0.8			11.8				29.4		20.0	
																	60.0		2.5	8.7		17.6					21.4		16.7
																			5.1			17.6				29.4			
									4.3																				
								33.3						6.9							0.4								
																			0.4		1.5								
																			6.4		2.2				50.0				
	100.	1.9							21.7		50.0						20.0		15.7	13.0	1.1						21.4		
28.6		5.9			4.0	100.			21.7			100.		24.2				7.1	13.1	47.8	56.8	47.0			50.0	17.6	35.7		
																					0.4								
					4.0														0.4		0.7								
														3.4					1.3		1.1								
														6.9					1.7	4.3	1.5								16.7
					8.0				8.7										0.8	4.3	3.3								
14.3					8.0									6.9					7.2		1.1								33.3
					4.0			33.3	13.1	33.3				13.8					6.4	4.3	5.9								16.7
		0.4	22.2													16.7		1.2					23.8						
14.3		0.8	22.2	33.3	16.0		2.7								4.2	16.7		0.2	0.8		1.5		28.6	20.0					
28.6		1.6	33.3	33.3	32.0										2.8	13.3			0.8		3.3		33.3	30.0					
		0.4					0.9																						
		1.2																											
		1.6																											
		1.9																0.6											
		3.1					0.9								2.8	3.3		3.8											
		3.1			4.0		11.8								7.0			4.8											
		35.5			4.0		39.1			33.3					69.1	30.0		31.3						20.0		11.8			
		37.9		33.3			43.6								14.1	20.0		50.9											
14.3		2.5	22.2		16.0			33.3	4.3	33.3				13.8					13.1		16.6	5.9	14.3	30.0		11.8	7.1	20.0	16.7

Figures represent percentages of all decorated sherds at each site.

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