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Charles D. and Mary Vaux Walcott
Research Fund

EMERGED QUATERNARY SHORE LINES
IN THE MISSISSIPPI EMBAYMENT

By

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U. S. National Museum
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(PUBLICATION 4677)

CITY OF WASHINGTON
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ABSTRACT

Borings through the alluvial deposits of the Mississippi Embayment reveal steep-walled valleys entrenched in the underlying Tertiary and Cretaceous formations. Repeated fluctuations of sea level during the Quaternary Epoch drowned the valleys to a maximum height of 360 feet. Emerged shore lines at this and nine lower levels remain horizontal. They stand at the same heights as horizontal shore lines in Alabama and along the Atlantic seaboard. The altitudes of the shore lines and the names of the terraces bounded by them follow:

<i>terrace</i>	<i>altitude in</i>	
	<i>feet</i>	<i>meters</i>
Morley	360	110
Hazlehurst	275	84
Coharie	215	66
Sunderland	170	52
Okefenokee	145	44
Wicomico	100	30
Penholoway	70	21
Talbot	42	13
Pamlico	25	8
Silver Bluff	6	2

Alluvial deposits accumulated at tidal flats and bayhead deltas during each of these ten stages in tidewater that was kept fresh or only slightly brackish by the inflow of the Mississippi and other great rivers that emptied into the bays. At each stage the rivers meandered across the tidal flats built during the preceding higher stages and laid on them a veneer of floodplain alluvium, obscuring but not completely

obliterating the shore lines of the preceding epochs. Thus arose a very gently sloping alluvial plain bordered on each side by more plainly marked terraces.

INTRODUCTION

The name Mississippi Embayment is applied to a great extension of Cretaceous and younger sediments in the Mississippi Valley and adjacent areas below the vicinity of the mouth of the Ohio River. This includes all of Louisiana, a large part of Alabama, Mississippi, and Arkansas, and smaller areas in Missouri, Tennessee, Kentucky, and Illinois.

The Gulf of Mexico has repeatedly invaded the embayment. The remarkable Upper Cretaceous shells at Coon Creek, Tenn., the Paleocene oysters of the Clayton Limestone, the well-preserved late Eocene shells at Jackson, Miss., and Montgomery, La., the Oligocene fauna at Vicksburg—all give unmistakable evidence of some of those invasions.

Rivers have been flowing into the embayment since Mesozoic time. Their muddy waters played a large part in filling it with sediments. Such formations as the Porters Creek Clay (Paleocene) and the Yazoo Clay (late Eocene) were doubtless built of mud brought down by these rivers.

Quaternary deposits cover a vast area in the Mississippi Embayment. Borings through these sediments prove that before their deposition through-flowing rivers, including the Ohio, the Mississippi, the Ouachita, the White and, the Red, had carved valleys into the older formations of the Coastal Plain, and that these rivers flowed into the Gulf of Mexico somewhere beyond the present coast. The contemporary shore line may have lain not far from the edge of the Continental Shelf (Fisk, 1944, p. 38). Sea level at that time probably lay 400 to 450 feet lower than now (Fisk, 1944, p. 68).

At that early time the Mississippi River flowed west of Crowley Ridge. The Ohio joined it below Natchez, and the Arkansas came in below latitude 30°, near Franklin, La. Later, the Ohio, flowing in a lower valley, captured the Mississippi above Vicksburg, and still later diverted it through Thebes Gap (Fisk, 1944, fig. 45).

These ancient valleys are now buried under a great accumulation of gravel, sand, and silt upon which the rivers now meander with greatly reduced gradients. Fisk (1944, p. 17) estimates that this alluvium "has a volume of approximately 1,000 cubic miles and an average thickness of 132 feet." Krinitzsky (1949, p. 13) increases

the estimate of the volume to 1,200 cubic miles. Fisk (1944, p. 17) assigns all of this alluvium to the Recent Epoch. It seems incredible that this great mass of sediments could have accumulated in the short interval since late Wisconsin time.

Plate 32 and 33 of Fisk's (1944) report place the base of his "Recent Alluvium" in Terrebonne Parish, La., nearly 400 feet below sea level and extend "Quaternary deposits" to approximately -3,500 feet. More recently Druid Wilson (oral communication, 1964) has found well-preserved diagnostic late Miocene marine mollusks in three cuttings from Terrebonne and St. Mary parishes at depths around 2,500 feet. This proves that at least 1,000 feet of Fisk's supposed Pleistocene is really Miocene. The remainder may be Pliocene. His "Recent Alluvium" probably includes the Pleistocene.

Fisk apparently did not include in his estimate of the volume of sediments the terrace deposits bordering the central alluvial plain. He regarded these terrace deposits as fluvial and named them, in ascending order, the Prairie Formation, the Montgomery Formation, the Bentley Formation, and the Williana Formation (Fisk, 1938a, pp. 51, 56, 59, 62). He correlated the four formations with four interglaciations and attributed their present heights above sea level to separate elevations of the land, each of which he conveniently made coincident with a rise of sea level caused by glacial control (Fisk, 1944, p. 69). He supposed that the terraces had been tilted, and he assumed that terraces standing at different heights on the east and west sides of the central plain were of the same age.

Fisk's interpretation of the origin of the terraces in the Mississippi Embayment differs fundamentally from the current interpretation of terraces along the Atlantic seaboard, which explains the terraces as the result of changes of sea level on a stable land.

If the Atlantic Ocean stood higher in past ages, the Gulf of Mexico must have stood at the same height at the same time, and the abandoned shore lines should stand at the same levels in the two regions unless the land has been tilted. If there is a similar sequence of level emerged shore lines in both areas, the assumption is justified that neither has been warped and that there has been no differential change of level between the two areas.

In the present paper an attempt is made to decipher the geologic history of the Mississippi Embayment during the Quaternary Epoch by using the evidence that can be interpreted from topographic maps and to compare it with the results of similar studies along the Atlantic seaboard. Large-scale maps of much of the embayment have been

made by the U. S. Geological Survey, the Mississippi River Commission, and the Corps of Engineers of the U. S. Army. On many of these maps the topography is shown by 5-foot contour lines. On such maps boundaries between terraces can be traced with considerable precision. Because of their great lateral extent and the variation of slope of the land at them, shore lines are much more readily traced on topographic maps than by examination in the field, where the range of view is limited.

FLUCTUATIONS OF SEA LEVEL

A dominant cause of emergence and submergence of the land is changes in sea level. Such changes raise or lower the shore line on all islands and continents to the same extent wherever the land has remained stationary. With each change in level the shore line migrates seaward or landward, the distance depending on the slope of the adjacent sea bottom or on the topography of the land.

The Quaternary Epoch was a time of unstable sea level. There appears to have been an intermittent lowering throughout the epoch, reflecting increases in the capacity of the oceanic basins caused by downwarp of the bottom of the sea. There also were variations in the volume of water in the seas resulting from changes in the size of the continental ice caps. During glaciations there was less water in the seas, and sea level was temporarily lower. The resultant of these two causes—glacial control and increase of capacity—was repeated fluctuations of sea level.

As the number of shore lines recognized exceeds the number of generally accepted interglaciations, which were times of high water, some of the shore lines presumably represent intermediate still stands during the intermittent lowering of sea level from causes other than glacial control. The terrace deposits that accumulated during such intermediate stands should lie conformably on the deposits, if any, of the next older terrace, though there might be local unconformities at the lower shore line caused by coastal erosion. The major discontinuities within a sequence of terrace deposits should mark the advance of the sea across the land after each glaciation.

(It should be noted that terrace deposits may be absent from places distant from sources of sediment. A discontinuity at the base of a terrace deposit may indicate merely the lack of sedimentation during the preceding epoch, not erosion.)

Many attempts, none very convincing, have been made to correlate the emerged shore lines with the chronology of the glaciated regions

(Cooke, 1932, 1935; MacNeil, 1950; and others). It is hoped that investigations now in progress in South Carolina (Colquhoun, 1962, 1964) will yield evidence that may point to more definite conclusions.

THE TRACING OF EMERGED SHORE LINES

Each lowering of sea level, whether caused by expansion of the ice caps or by downwarp of the sea bottom, laid bare a new strip of land; each melting of the ice caps raised the level of the sea and drowned all valleys to the same height. During high stages bayhead deltas accumulated in the drowned valleys; during lower stages trenches were cut by the rejuvenated streams.

The terrace laid bare by the retreat of the sea to a lower stand is not level. It ranges in height from the altitude of the original shore to that of the new. Moreover, it retains all the humps, hollows, and slopes of the original sea bottom except as they may have been modified by the retreat of the sea across them.

The most characteristic feature by which one marine terrace can be distinguished from another is the contemporary shore line. Even that line is not completely level, for it is the mark made on the land by the water, and the location of that mark varies with the force of the waves and the height of the tides. Moreover, the depth of the water at the shore varies from place to place and makes more difficult the recognition of the location of the original surface.

The tracing of an emerged shore line is further complicated by the dissection that it may have suffered since the sea withdrew. In general, the higher, older terraces have suffered more erosion, and their shore lines are the most difficult to trace. However, the relief of the land has more influence on the rate of erosion than its age. A high, wide terrace may be better preserved than a lower, narrower one having greater local relief.

The altitude of an emerged shore line can generally be determined with more precision within an estuary than along the open sea coast, for tidal flats there give a very close approximation to the former sea level. But tidal flats may be restricted to the head of the estuary; farther down the drowned valley the sides may slope steeply into deep water, perhaps even form a vertical bluff. At such places high water may leave little or no mark, or the narrow terrace may later be eroded.

The altitudes assigned to the shore lines in this paper are not precise, but they probably do not differ from the average altitude by more than a few feet, perhaps less than five feet.

The term *marine terrace* as used here includes terraces formed in estuaries as well as those bordering the open sea. A delta built into tidal waters may be considered a marine feature, though it was built by a river, and may rise a few feet above the contemporary sea level. It is the connecting link between a river terrace and a marine terrace.

Shore features and delta deposits may yield the only clues from which the former presence of the sea on the land may be inferred. Clean water drops no clastic sediment. Continuous sedimentation across a large, open bay or far from land in the ocean is not to be expected. Every river and little stream dumps its load of sand or gravel at the shore, from which it is distributed across the bottom by waves and currents. So one need not be surprised to find great areas that must have been submerged beneath the sea completely free from recognizable contemporary sediments or covered by only a thin veneer of sand or silt.

Some geologists deny the marine origin of certain terraces because they find Pliocene or older rocks at the surface within areas claimed to have been flooded during the Pleistocene. They overlook the fact that parts of the Gulf of Mexico off the coast of Florida are floored with bare Eocene limestone (Cooke, 1939, p. 75). Gould and Stewart report outcrops of several other Tertiary limestones in the bed of the Gulf off St. Petersburg and Fort Myers. Dredgings studied by them indicate that ". . . unconsolidated sediments in many places form only a thin veneer on the bedrock surface, whereas in other areas the bedrock is essentially uncovered" (Gould and Stewart, 1955, p. 13). If the Gulf were to withdraw to a lower level, the newly emerged Recent terrace would be free from terrace deposits at such places.

The names of shore lines and terraces should not be applied to the sediments under the terraces unless there is clear evidence that the sediments are contemporaneous with the shore lines. The geologic formation whose upper surface forms a terrace may be much older than the shore line; if so, the use of the name for those older deposits would not be appropriate. Moreover, the shore line and the terrace are much more extensive than the local geologic unit to which a formation name is applied.

SHORE LINES ALONG THE ATLANTIC SEABOARD

Marine terraces were recognized along the Middle Atlantic States as long ago as 1887, when McGee described the Columbia Formation. More detailed work was later done by Shattuck (1901, 1906).

These early workers supposed that the sea had remained stationary while the land rose and tilted. Marine terraces in North Carolina, South Carolina, Georgia, and Florida were later described by B. L. Johnson (1907), Stephenson (1912), Veatch and Stephenson (1911), Matson (1913), Cooke (1924-54), MacNeil (1950), Colquhoun (1962, 1964), and many others. Richards (1962) has reviewed the literature.

A paper on the correlation of coastal terraces (Cooke, 1930b) proposed to define and identify terraces by means of their shore lines. Its abstract (p. 577) states that: "The Pelistocene coastal terraces along the Atlantic Seaboard of the United States are bounded by shore lines that are horizontal south of the glaciated region and that appear to continue unwarped westward along the Gulf coast to Texas." Later work has amply confirmed the essential horizontality of the shore lines along the Atlantic coast; the present work traces the shore lines across the Mississippi Embayment.

Nine terraces have heretofore been recognized along the Atlantic seaboard. To these should be added a tenth, the Morley terrace, herein described. The names of these ten terraces and the altitudes of their shore lines as presently accepted are as follows:

<i>terrace</i>	<i>altitude in</i>	
	<i>feet</i>	<i>meters</i>
Morley	360	110
Hazlehurst	275	84
Coharie	215	66
Sunderland	170	52
Okefenokee	145	44
Wicomico	100	30
Penholoway	70	21
Talbot	42	13
Pamlico	25	8
Silver Bluff	6	2

TERRACES IN ALABAMA

Carlston (1950) has traced the terraces from Florida into Alabama, where the coastal terraces are narrower and hence more subject to erosion than at most places along the Atlantic seaboard. He noted (Carlston, 1950, p. 1125) that the estuarine terraces in Alabama are better preserved than those fronting on the Gulf. He recognized scarps at altitudes corresponding to shore lines of the Coharie, Sunderland, Wicomico, Penholoway, and Pamlico terraces and noted another at 145 feet (Carlston, 1950, pp. 1123, 1124) which he tentatively

referred to the Sunderland. This altitude has since been determined as that of the shore line of the Okefenokee terrace. Besides these, remnants of the Hazlehurst terrace are recognizable in Mobile County, and a large part of western Escambia County is occupied by the Morley terrace. The Silver Bluff and the Talbot are well developed on the Coden quadrangle. Thus all ten of the terraces occur in Alabama at the same altitudes as along the Atlantic seaboard. They form the connecting link with those of the Mississippi Embayment, which adjoins them.

TERRACES IN THE MISSISSIPPI EMBAYMENT

Above Little Rock, Ark., the Mississippi Embayment is floored by Quaternary deposits that abut the Ozark Escarpment on the northwest and the Mississippi Bluff on the east. The foot of the scarp from Little Rock to Cape Girardeau, Mo., forms a nearly level line very close to 360 feet above sea level. The base of the bluff on the east is lower because the river has cut into the Quaternary deposits, but many remnants of a plain abut the bluff at 360 feet above sea level. I interpret this 360-foot margin of the Quaternary deposits as the shore line of a bay when sea level in the Gulf of Mexico stood 360 feet higher than now.

Other horizontal shore lines of smaller bays can be traced at lower levels. They stand at the same heights above sea level as the shore lines in Alabama and along the Atlantic seaboard. At the heads of several of the bays abandoned deltas rise above the general level.

Morley terrace (shore line 360 feet).—The highest inundation reported here backed water in the pre-Pleistocene valleys in the Mississippi Embayment to a height of approximately 360 feet above present sea level. Tidewater then extended up the gorge of the Mississippi probably as far as Gorham, Ill., about 30 miles above Cape Girardeau, which stands at the head of the bay. The valley of the Ohio was flooded for many miles into Illinois and Kentucky. Tidewater may have extended up the Tennessee River to the head of Kentucky Lake (Jeannette, Tenn., quadrangle).

As shown in figure 1, the shore of the bay extended southwestward in a nearly straight line from Cape Girardeau to Little Rock, beyond which it has not been traced. The eastern shore lies high up on the bluff of the Mississippi River and is not so well preserved. It extended past Memphis, Yazoo City, Vicksburg, and Natchez into West Feliciana Parish, La., where the bay opened into the expanded Gulf of Mexico, whose shore extended eastward parallel to the present coast.

Crowley Ridge and other uplands formed a chain of islands from the head of the bay to Helena, Ark.

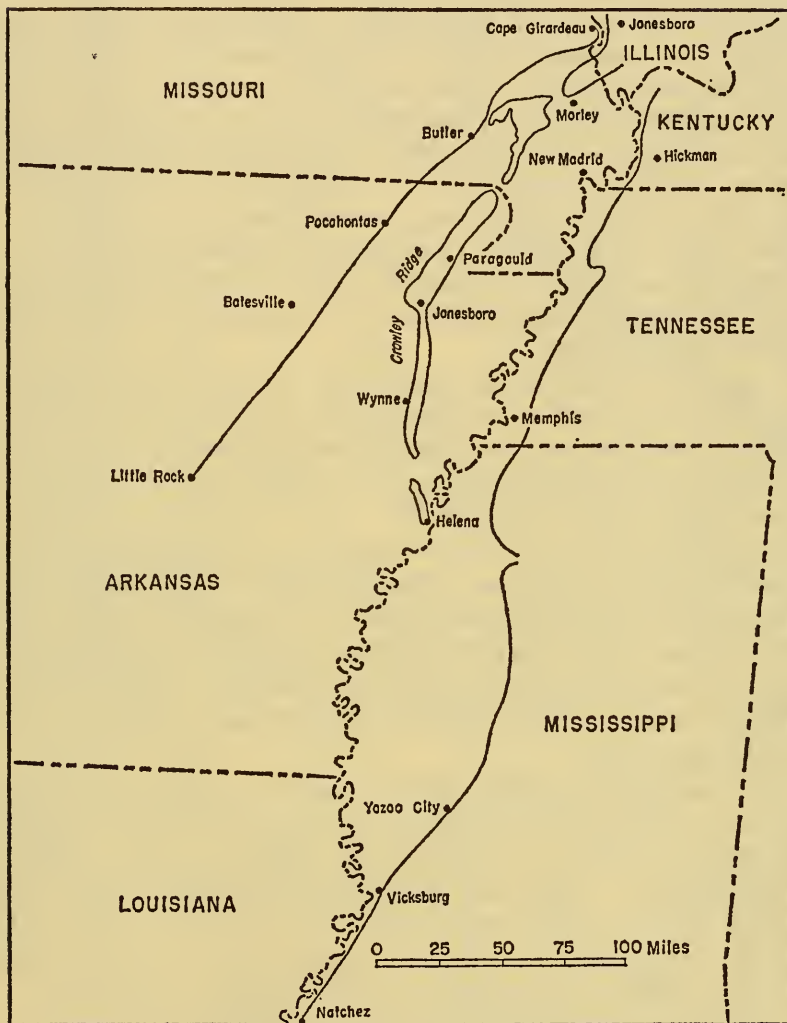


FIG. 1.—Shore line of the Morley bay.

The name Morley is chosen for the terrace having the 360-foot shore line because the town of Morley, in Scott County, Mo., is built on it not far from the shore. As shown on the map of the Morley quadrangle the entire town stands within a foot or two of 344 feet above sea level. Half a mile north of the city limits

the land slopes gently up to 360 feet, beyond which comes a steep climb to 530 feet. Figure 2 shows the Morley terrace near Benton. Profiles a few miles northwest of Morley are shown in figures 3 and 4.

The Morley terrace is well preserved in the southern part of the Puxico, Mo., quadrangle, where it slopes upward from 325 feet at Ash Hill, Fisk, Lakeview School, and Cypress School to 360 feet at the shore line in sections 21 and 22, T. 26 N., R. 8 E., above which the land rises to 447 feet at Asherville, one quarter mile from the shore. The lower parts of this area appear to have been graded in pre-Morley time by a large river, presumably an early course of the Mississippi. Meander scars of this river pass southwest of Edmunson School and east of Cypress Lateral Ditch No. 1. The divide between this ditch and Lick Creek Ditch stands at 355 feet at Wilkerson School and 357 feet at Dudley.

The western shore of an island in the Morley bay lies near the 360-foot contour line on the Puxico quadrangle, passing 1 mile west of Aid, 1 mile west of Greenwood School, and near Howell School. The island stood 140 feet higher west of Garner School, where the present altitude is more than 500 feet.

The Morley shore line has not yet been traced along the Atlantic seaboard although the terrace is represented there. Much of the area where it occurs is highly dissected and still unmapped. The surface of the Brandywine gravel above 275 feet in Maryland probably forms part of this terrace. Flat areas in South Carolina higher than the Hazlehurst terrace (shore line 275 feet) presumably are remnants of the Morley terrace.

In Georgia, the Morley terrace should be sought in the unmapped area between the Okefenokee Swamp and Tifton, where it probably lies somewhere northwest of the railroad connecting Valdosta with Waycross. The terrace also occupies the eastern part of the Dougherty Plain (Cooke, 1925). The Morley shore line, much eroded, forms the boundary between the Dougherty Plain and the Tifton Upland (Cooke, 1925). It passes about 4 miles west of Sylvester.

A well-preserved plateau around 300 feet extending eastward from Mt. Pleasant, Gadsden County, Fla., and northward into Decatur County, Ga., evidently is the lower part of the Morley terrace unless it is bounded by an unrecognized shore line lower than 360 feet.

A broad plain in western Escambia County, Ala., slopes from 360 feet at the northern edge of the Huxford quadrangle southward across the Atmore quadrangle to 280 feet at the Florida line, a distance

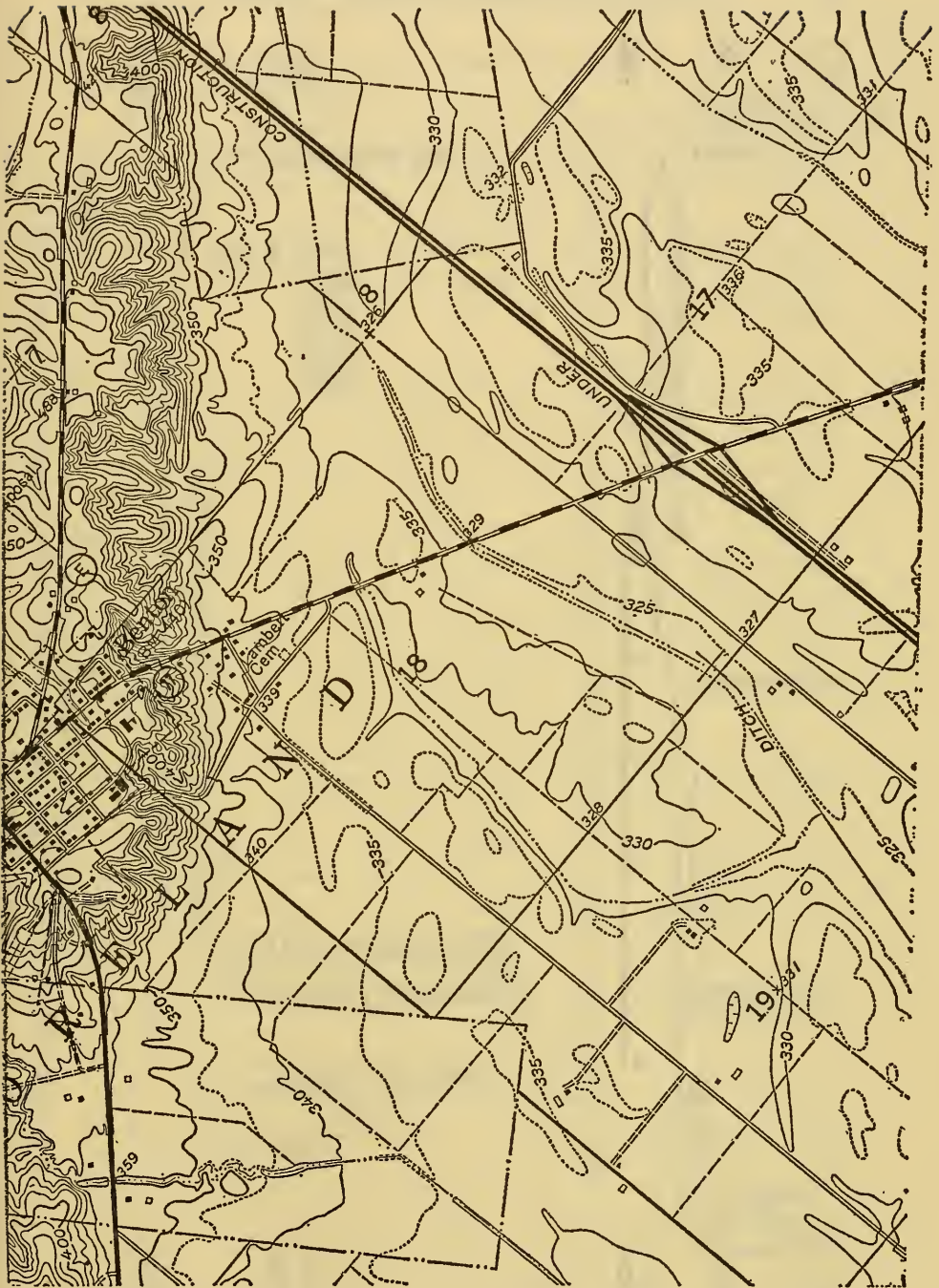


FIG. 2.—Part of the Morley, Mo., quadrangle, 7½-minute series, scale 1:24,000. Contour interval 10 feet. Dotted lines represent 5-foot contours. The shore line of the Morley terrace lies near the 360-foot contour line.



FIG. 3.—Profile on the Advance, Mo., quadrangle from Dongola southeastward to Bird Hill at Perkins.

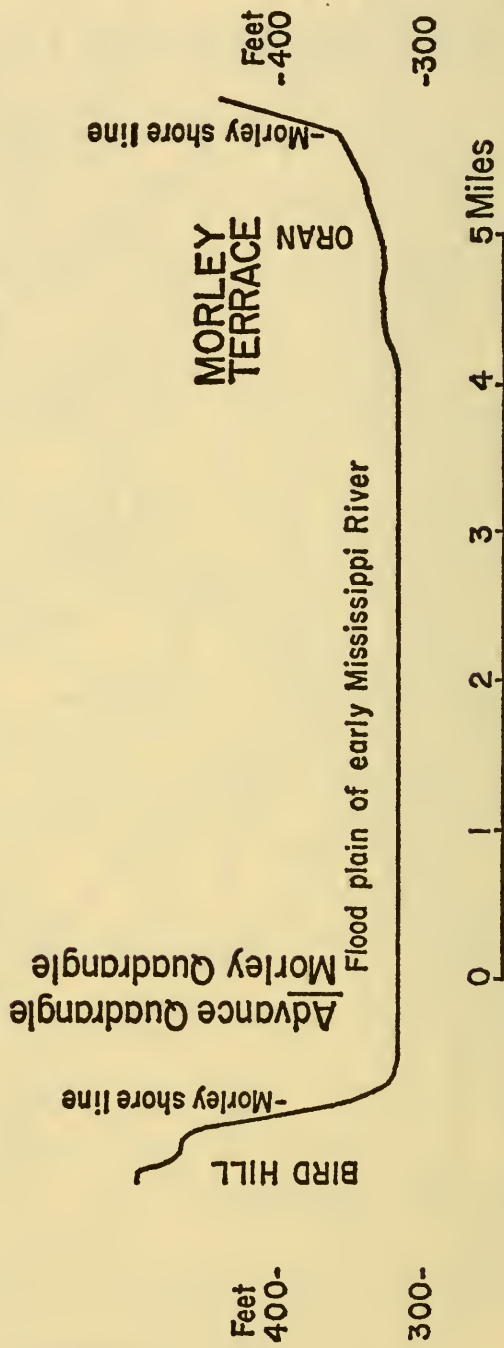


FIG. 4.—Profile from Bird Hill (Advance quadrangle) eastward across the Morley quadrangle to Oran, Mo.

of approximately 18 miles. Dissected remnants occur at least as far east as Murder Creek.

Remnants of a plateau near 340 feet at Citronelle, Mobile County, Ala., extend southward for 5 miles and westward for 4 miles onto the Deer Park quadrangle. The relation of this terrace to the typical Citronelle formation should be investigated.

After a long still stand near 360 feet, sea level receded to about 275 feet above its present location, perhaps without an intermediate drop to a lower level. This caused the emergence of the Morley terrace.

Hazlehurst terrace (shore line 275 feet).—The type area of the Hazlehurst terrace (Cooke, 1925, p. 29) is crossed by the road from Hazlehurst, Jeff Davis County, Ga., to Baxley. This plain slopes from about 260 feet to about 215 feet. As there are still no topographic maps of this area, the limits of the terrace have not been determined.

The name Hazlehurst was discarded (Cooke, 1931, p. 505) in favor of Brandywine because the Hazlehurst terrace appears to be the same as one at Brandywine, Md., which had been casually referred to as the Brandywine terrace by Clark (1915, pp. 499, 505) in his description of the Brandywine Formation, an older deposit. Later Cooke (1954, p. 204) revived the name Hazlehurst because that terrace is younger than the Brandywine Formation.

The altitude usually attributed to the shore line of the Hazlehurst ("Brandywine") terrace (Cooke, 1931, p. 505; 1943, p. 104; 1936, p. 130; 1945, p. 248) is 270 feet. A closer approximation is 275 feet.

The Williana terrace of Fisk (1938a, p. 62) may be equivalent to the Hazlehurst terrace, or its type area may be a reduced remnant of the Morley terrace. Fisk chose as its type area the divide followed by the highway from Alexandria to Winfield in Grant Parish, La., 1 mile south of Williana. The altitude there, as shown on the map of the Colfax quadrangle, is about 270 feet. A profile by Fisk (1944, pl. 26) shows part of his supposed Williana terrace well above 500 feet. The correlation is certainly questionable.

The shore line of the largest Hazlehurst bay in the Mississippi Embayment is shown in figure 5. At the 275-foot stage the area covered by tidewater formed a bay more than 100 miles wide at Memphis (fig. 6). Above Helena, Ark., the bay was divided by Crowley Ridge into two long prongs. The western prong reached as far north as the southern parts of Clay and Randolph Counties, Ark.; the eastern prong extended into New Madrid County, Mo., and Lake County, Tenn.

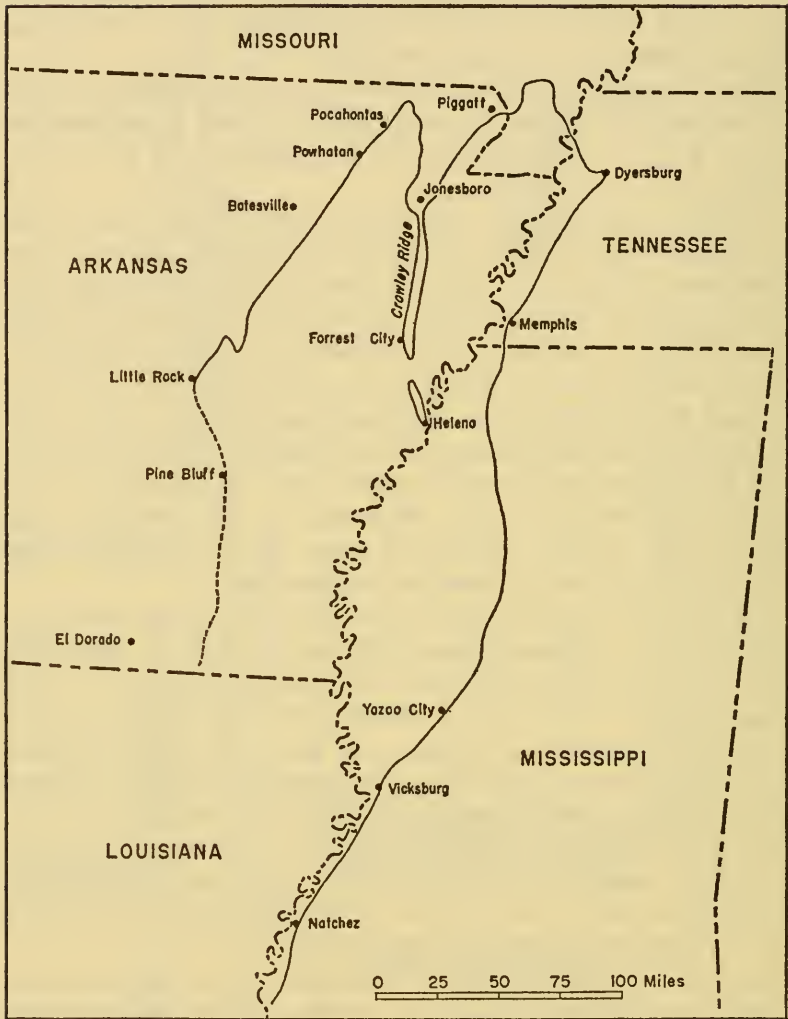


FIG. 5.—Shore line of the Hazlehurst bay.

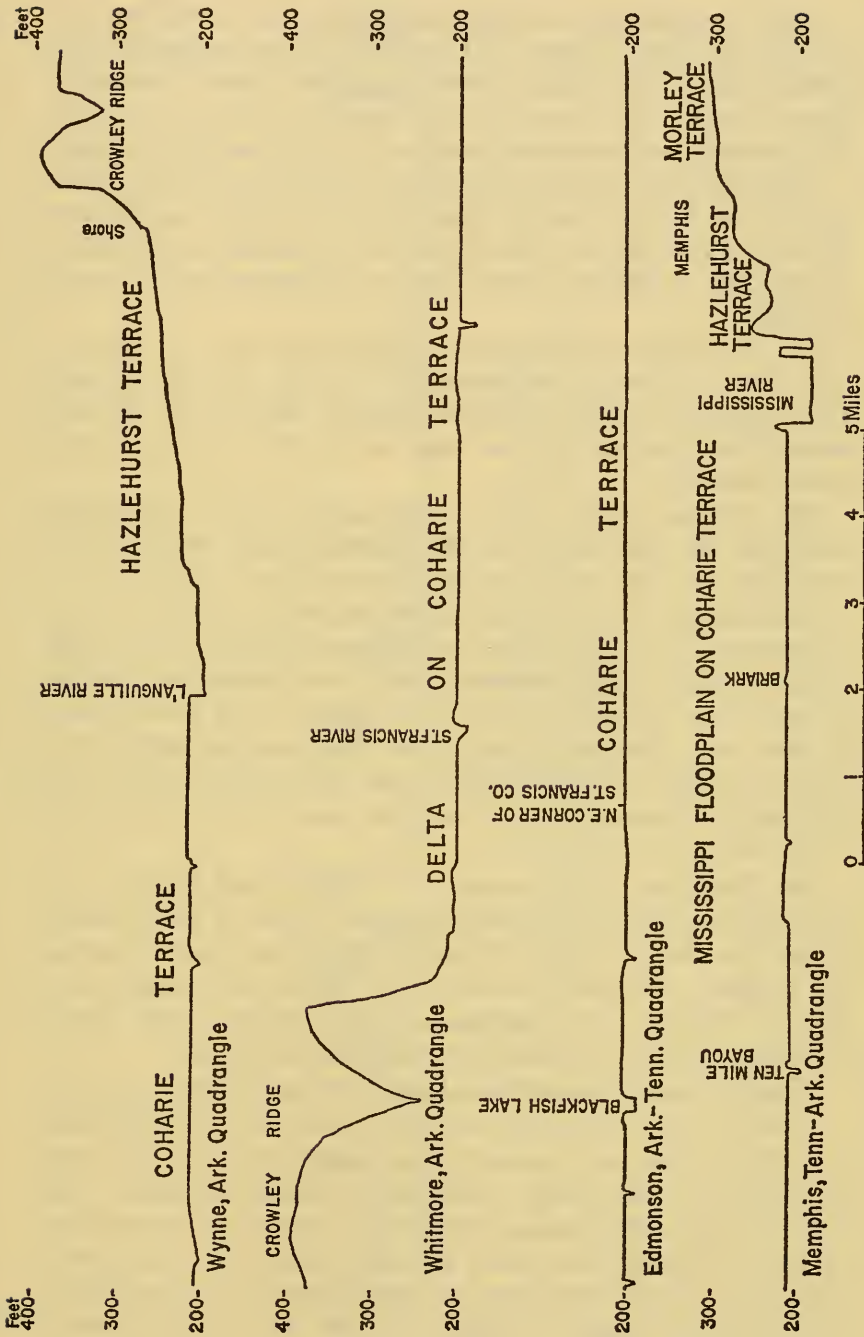


FIG. 6.—Profile from the northwest corner of St. Francis County, Ark., eastward to Memphis, Tenn.

The western shore line followed the bluff as far as Little Rock, not far from the 360-foot shore. It has not been traced in detail beyond Little Rock, but it probably trends southward across Arkansas to Union County, La., thence south-southwestward to Vernon Parish, La., entering Texas somewhere near the thirty-first parallel of latitude.

The eastern shore followed the bluffs across Tennessee and Mississippi to the Gulf of Mexico, whose shore at that stage crossed the northern tier of the West Florida parishes of Louisiana. This shore of the Gulf is difficult to trace because the terrace there is much dissected.

The shore of the Hazlehurst terrace is conspicuous on the Gainesville, Ark., quadrangle. In section 12, T. 18 N., R. 4 E., a broad plain bordering Cache River abuts a steeper slope at the 275-foot contour line. Similar conditions occur on both sides of Jones Ridge, east of Delaplaine.

The 275-foot shore crosses the Marmaduke, Ark., quadrangle, separating the Hazlehurst from the dissected Morley terrace on the northwest. The line passes through Marmaduke and Paragould.

The Hazlehurst shore extends almost due south for 50 miles along the west side of Crowley Ridge, in Craighead County, to Forest Hill in Saint Francis County, following the 275-foot contour line. Part of it near Wynne is shown in figure 6. The opposite shore there is about 50 miles away. That the bay east of the ridge, once the valley of the Ohio, was deeper than the western prong, the original valley of the Mississippi, is shown by figure 7, a profile across the Dee quadrangle in the latitude of Trumann.

The Hazlehurst terrace covers all of the Walnut Ridge, Ark., quadrangle except the northeastern corner, where a short stretch of the shore line is shown. The terrace and the shore extend across the adjoining Powhatan quadrangle, but the terrace slopes gently down to 250 feet at the southern end, following the grade of the drowned valley, and the shore line lies against the bluff.

A drop in sea level caused the emergence of the Hazlehurst terrace.

Coharie terrace (shore line 215 feet).—The shore of the Coharie bay (fig. 8) was more crooked. Two prongs near the head were separated by Crowley Ridge and fringes of Hazlehurst terrace. The entrance to the eastern prong, which extended up the drowned valley of the St. Francis River across Poinsett County, Ark., was partly blocked by a 15-mile-long island, the continuation of Crowley Ridge. This prong was roughly triangular, with one shore trending south-

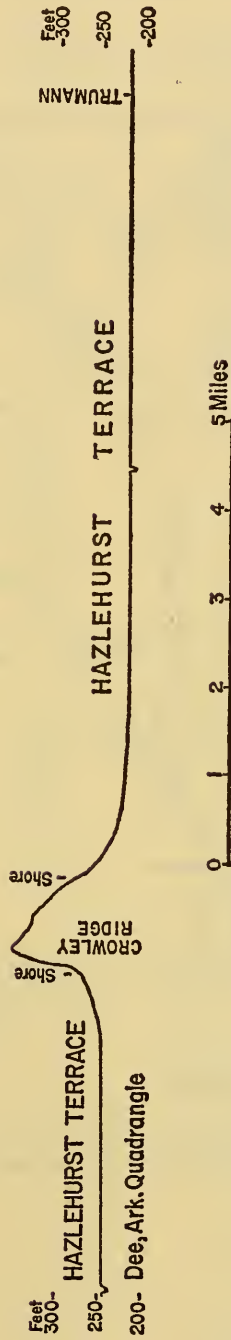


FIG. 7.—Profile across Poinsett County, Ark., from a point 7 miles north of Harrisburg eastward across the Dee quadrangle to Trumann.

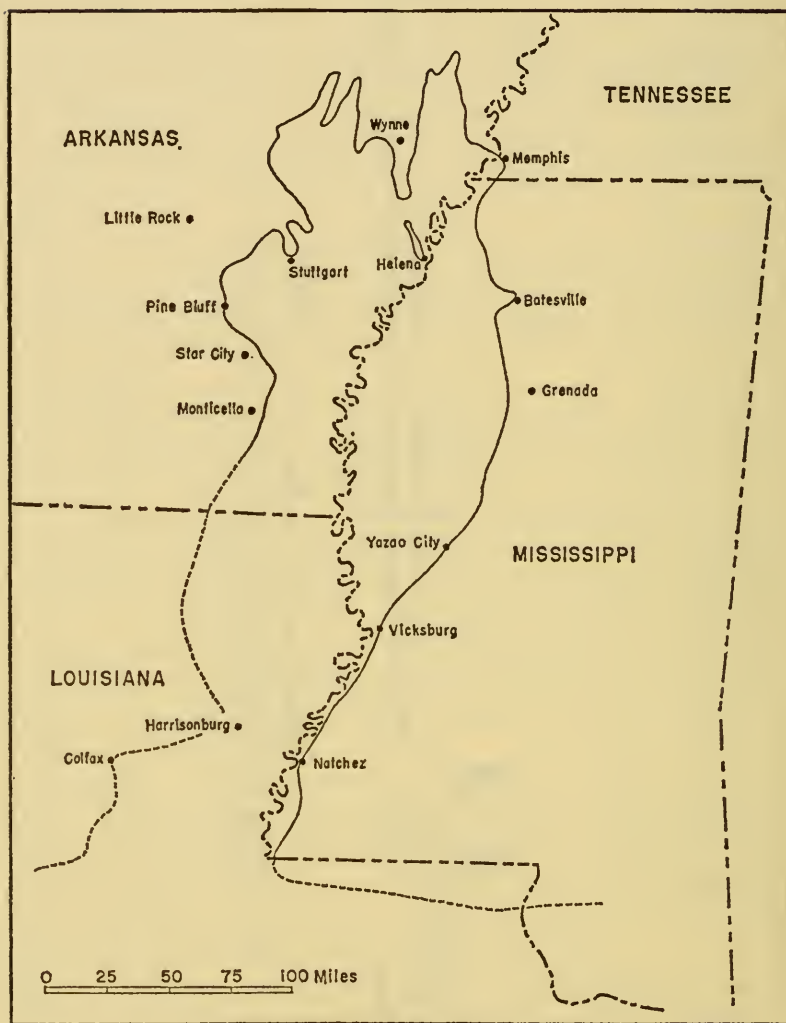


FIG. 8.—Shore line of the Coharie bay.

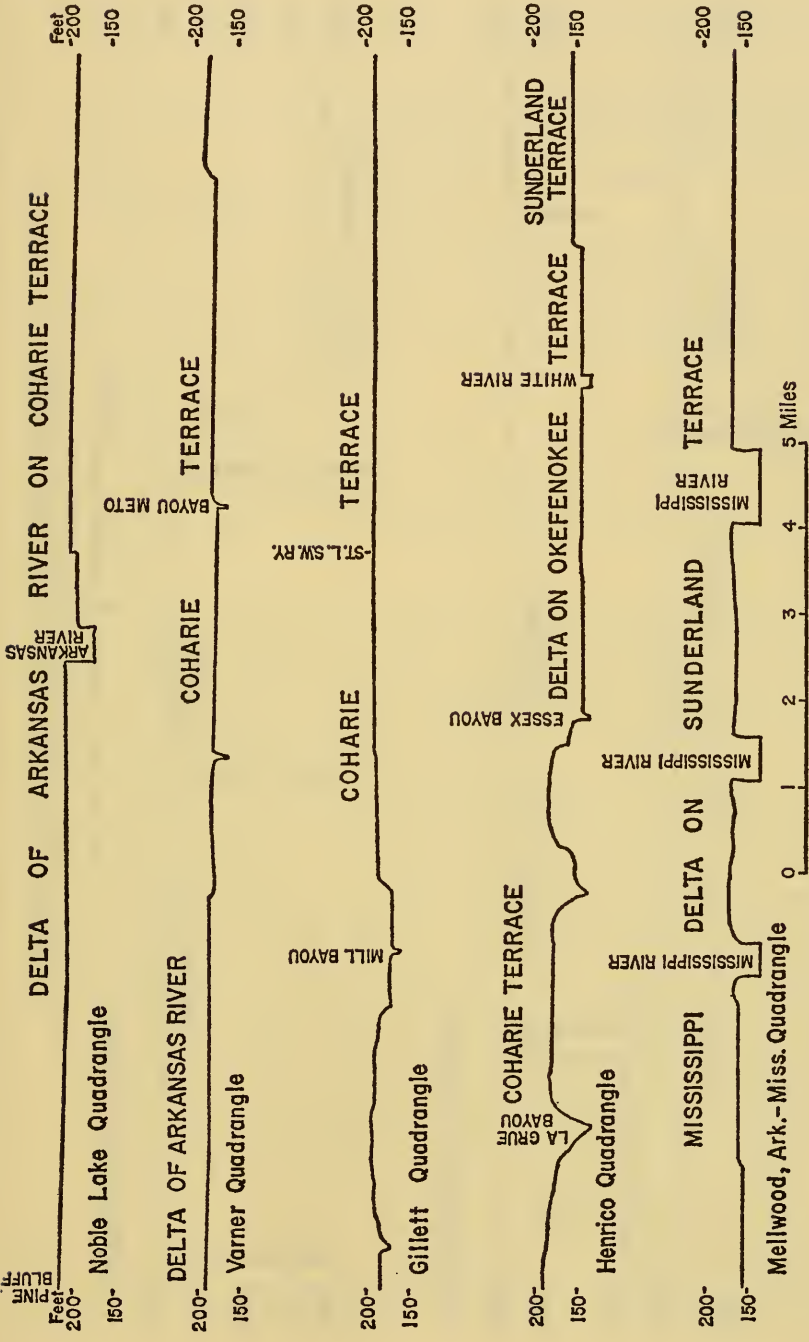


FIG. 9.—Profile extending eastward from Pine Bluff, Ark., into Pinola County, Miss. Part I: Noble Lake, Varner, Gillett, Henrico, and Mellwood quadrangles.

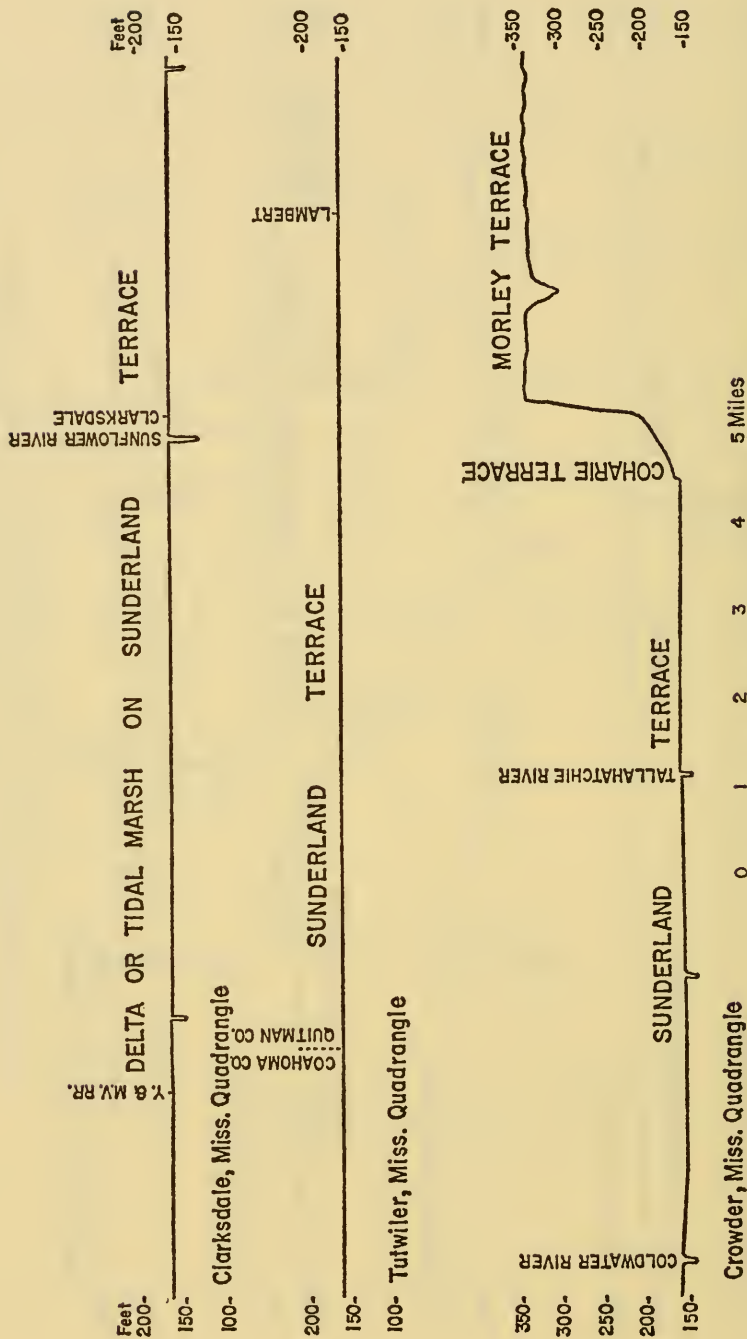


FIG. 10.—Profile extending eastward from Pine Bluff, Ark., into Pinola County, Miss. Part II: Clarksdale, Tutwiler, and Crowder quadrangles.

easterly through Memphis, the other southward almost to Marianna, Ark.

The western prong was roughly rhombic, with one side running from Haynes in Lee County, Ark., to Newport in Jackson County; another side from Newport along the bluff to Higginson, in White County; and another southeastward from Higginson past De Valls Bluff to Monroe County near Roe.

From this cape at the entrance to the western prong, the crooked shore wandered past Stuttgart, Tomberline in Loneoke County, and Pine Bluff. From Pine Bluff the shore of the Coharie bay followed the right bank of Bartholomew Bayou about to Warrenton in Lincoln County and thence southward to Paradise in Drew County, which seems a good place to leave it.

In Louisiana the western shore of the Coharie bay has not been traced in detail. It seems to have lain not far west of the Ouachita River as far as Harrisonburg in Catahoula Parish. Here it met the broad entrance to the combined estuaries of Little River and Red River.

The Coharie bay was widest between Pine Bluff, Ark., and Batesville, Miss., a distance of about 120 miles. A profile across it there is shown in figures 9 and 10. Between Harrisonburg and Natchez, Miss., the bay was less than 30 miles wide. The narrow lower reaches of the bay widened to 50 miles between Catahoula Lake and the opposite cape in West Feliciana Parish, La.

From this cape the eastern shore extended northward and north-eastward along the bluffs past Natchez, Vicksburg, and Yazoo City to Memphis, from which the eastern prong crossed into Arkansas.

The shore line at the head of the east prong was very intricate because the old Ohio River (now the Mississippi) and the old Mississippi (now the St. Francis) built deltas across it. Delta building doubtless began while the bay was still flooded and continued after the Coharie terrace emerged. These younger deposits obscure the original shore line in many places, but not everywhere. For instance, at Walnut Grove Corner, near the center of the Dee quadrangle, Ark., a 10-foot scarp rises above the 215-foot level and extends northward for more than 2 miles. Southeast of Harrisburg on the same map the 215-foot contour line hugs the foot of Crowley Ridge. On the Marked Tree quadrangle a distributary of the delta now followed by Little River rises above the 215-foot contour line.

There was also some delta building at the head of the west prong but on a much smaller scale. The old shore line lies at the foot of the

Ozark Escarpment from Bradford (Augusta quadrangle) to the Jackson-Independence County line (Newport quadrangle). Thence it wanders eastward around delta deposits to Bott Spur, 3 miles west of Wynne in Cross County. From this point southward on the Wynne quadrangle there is a low scarp bordering the Hazlehurst terrace, which separates it from Crowley Ridge (fig. 6).

The name Coharie Formation, derived from Great Coharie Creek, a tributary of Black River in North Carolina, was applied by Stephenson (1912, p. 273) to terrace deposits whose upper surface ". . . forms a terrace plain more or less dissected, which slopes from elevations of about 160 or 170 feet along its southeastern edge to elevations of about 230 or 235 feet along the foot of the escarpment which separates it from the Lafayette belt" (Stephenson, 1912, p. 274). These upper limits are a little too high. The shore line of the Coharie was later placed at 215 feet above sea level by Cooke (1930a, p. 391; 1930b, p. 582; 1935, p. 333; 1936, p. 132), who has traced it through every state from New Jersey to Florida (manuscript maps).

The Coharie terrace is evidently the same as the Bentley terrace of Fisk, which ". . . slopes southward at a rate of 5 feet per mile from 215 feet above sea level, at the foot of the escarpment near Bentley, to 180 feet at the Grant-Rapides Parish line" (Fisk, 1938a, p. 60). This area occupies part of the combined estuaries of Red River and Little River.

After a long still stand at 215 feet, the sea withdrew to an undetermined lower level and came to rest at or near 170 feet, exposing the Coharie terrace.

Sunderland terrace (shore line 170 feet).—At this lower, 170-foot stage of the Gulf, the boundaries (fig. 11) of the lower reaches of the embayment did not differ much in location from the higher stages. Where they had lain near high escarpments only a narrow strip of the Coharie emerged. The greatest changes were in the upper parts of the bay (figs. 9, 10) where the drowned valley was shallower and the drop of 45 feet laid bare a greater width of bay bottom. The shore at the head of the bay became very intricate, for the Mississippi River built a delta, which extended southward from Helena, Ark., almost to Clarksdale, Miss.

An arm of the Sunderland bay extended up the drowned valley of White River to a head above Clarendon, Ark. Its mouth at St. Charles in Arkansas County was about 12 miles wide. Another branch



FIG. 11.—Shore line of the Sunderland bay.

headed in Lincoln County, Ark., between Meroney and South Bend, where the delta of the Arkansas River was 20 miles wide.

Outside of the Mississippi Valley, another long, narrower bay extended up the drowned Red River Valley from Alexandria, La., to a head above Shreveport.

The bayous in western Arkansas County and eastern Jefferson County in Arkansas occupy former tidal marshes whose shore follows the 170-foot contour line on the Gillett quadrangle. A 10-foot scarp 3 miles southwest of Gillett leads up to the Coharie terrace.

The name Sunderland terrace dates from 1901, when it was proposed by Shattuck (1901, p. 102). The name is taken from a hamlet in Calvert County, Md. As described by Shattuck the Sunderland is a marine terrace having a shore line about 170 feet above sea level. In later work Shattuck (1906, p. 68) included parts of several terraces in the Sunderland, which he thought had been warped. According to Cooke (1931, p. 507) "The name Sunderland should be restricted to the terrace that is bounded by the shore line at or near 170 feet above sea level."

The Sunderland appears to be the same as Fisk's (1938a, p. 56) Montgomery terrace, which lies within a former estuary of the Red River. The type locality of this terrace is at the intersection of U. S. Highway 71 and State Highway 162 near Montgomery, Grant Parish, La. The altitude of this intersection as shown on the map of the Montgomery quadrangle is approximately 170 feet above sea level. The 20-foot contour interval on the map is too great to show the exact location of the shore line.

The withdrawal of the Gulf from 170 feet to a lower level drained the flooded valleys and exposed the Sunderland terrace.

Okefenokee terrace (shore line 145 feet).—The approximate location of the shores of the Okefenokee bay is shown in figure 12. At the 145-foot stage the Mississippi Valley was drowned as far north as the thirty-fourth degree of latitude, that is, to Tallahatchee and Bolivar counties in Mississippi. In Arkansas tidewater extended up the White River even farther north, to the vicinity of St. Charles. The western shore of the estuary through Arkansas was fairly straight between St. Charles and the Louisiana border. Below Selma, in Drew County, it lay west of Bartholomew Bayou. In Louisiana it followed the western side of the Ouachita Valley as far as Harrisonburg, beyond which it passed southwestward to the Gulf of Mexico. A profile across the Okefenokee terrace at Bastrop, La., is shown in figure 13.



FIG. 12.—Shore line of the Okefenokee bay.

The Okefenokee shore is very conspicuous on the map of the Collins, Ark., 7½-minute quadrangle, where it is separated from the adjoining Sunderland or Coharie terraces by a 30-foot scarp. It nearly coincides in location with the Sunderland beach, which seems to have been cut away locally by stream erosion.

The contact with the Sunderland terrace, here very narrow, is shown on the Philipp, Miss., quadrangle along the foot of the bluff between Paynes, Tallahatta County, and Oxberry, Grenada County, where it is marked by the 145-foot contour line.

The Okefenokee terrace takes its name from the Okefenokee Swamp in southeastern Georgia and adjoining Florida, which is its most distinctive feature. Otto Veatch (Veatch and Stephenson, 1911, pp. 35, 36) described the "Okefenokee plain" as "a wave-built, marine terrace, recently raised above sea level." "Perhaps 125 feet" is the highest altitude assigned to it by Veatch. MacNeil (1950, pp. 99, 102) referred the terrace to a shore line near 150 feet. A closer approximation is 145 feet.

Wicomico terrace (shore line 100 feet).—The shape of the Wicomico bay is shown in figure 15. At the beginning of the 100-foot stage the Mississippi Valley was flooded for several miles above the Louisiana line into Arkansas. The shallow head of the bay became silted up by the muddy river, and distributaries of a delta pushed southward nearly 30 miles into Louisiana. The delta ended near Epps in Carroll Parish (Mitchiner quadrangle) in water about 20 feet deep.

Along the Ouachita Valley tidewater extended 50 miles beyond the state boundary as far as Camden, Ark., where the present floodplain covers the Wicomico terrace. On the Moro Bay quadrangle a low scarp passing Ebenezer School separates the Wicomico terrace from a low part of the Okefenokee terrace. A much higher scarp adjoins the Wicomico south of the river.

The 100-foot contour line lies near the bottom of a high bluff from Twin Oaks on the Bastrop quadrangle to Collinston on the Collinston quadrangle. The Wicomico terrace extends from this line eastward beyond the limits of the quadrangles (fig. 13). It slopes very gently southward and merges into the Penholoway terrace near Collinston.

In Union Parish, La., patches of Wicomico terrace border the uplands west of the Ouachita, notably at Litroe and Gravel (Haile quadrangle). Farther south, in Ouachita Parish, there are areas west and south of Monroe. Beyond these the Wicomico shore lay close to the Ouachita River to Harrisonburg, where it turned southwestward to the mouth of the Red River estuary below Alexandria.

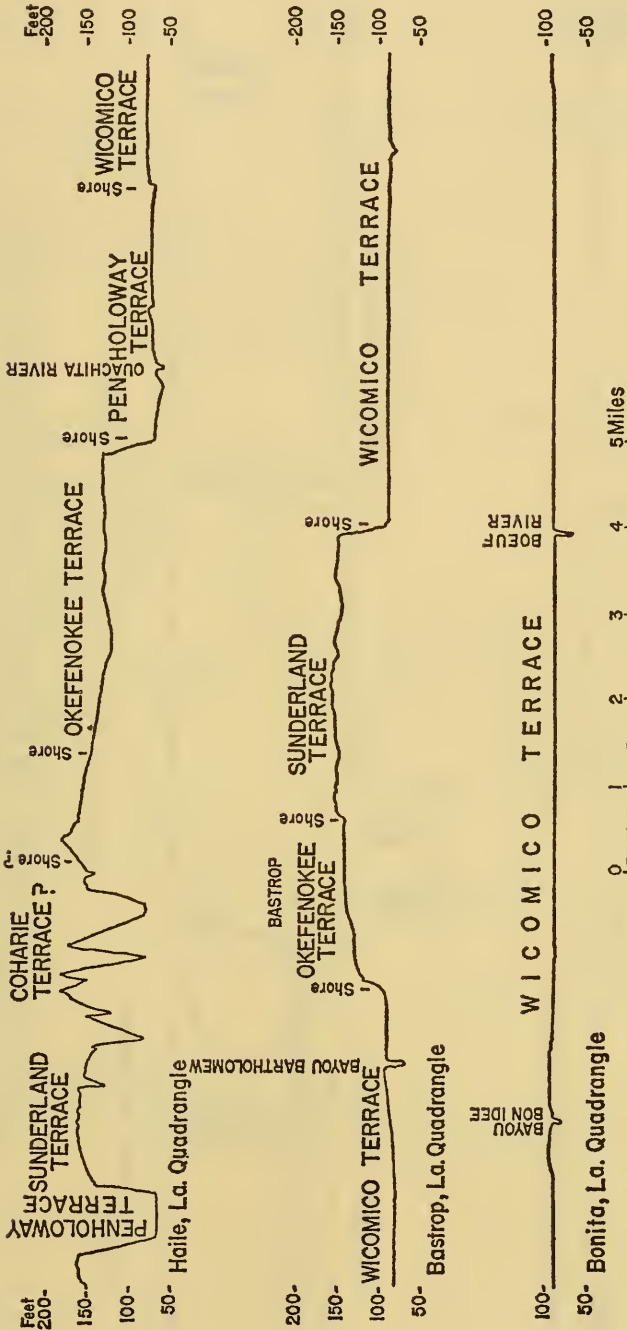


FIG. 13.—Profile from a point 10 miles south of Marion, Union Parish, La., eastward to Yazoo County, Miss. Part I: Haile, Bastrop, and Bonita quadrangles.

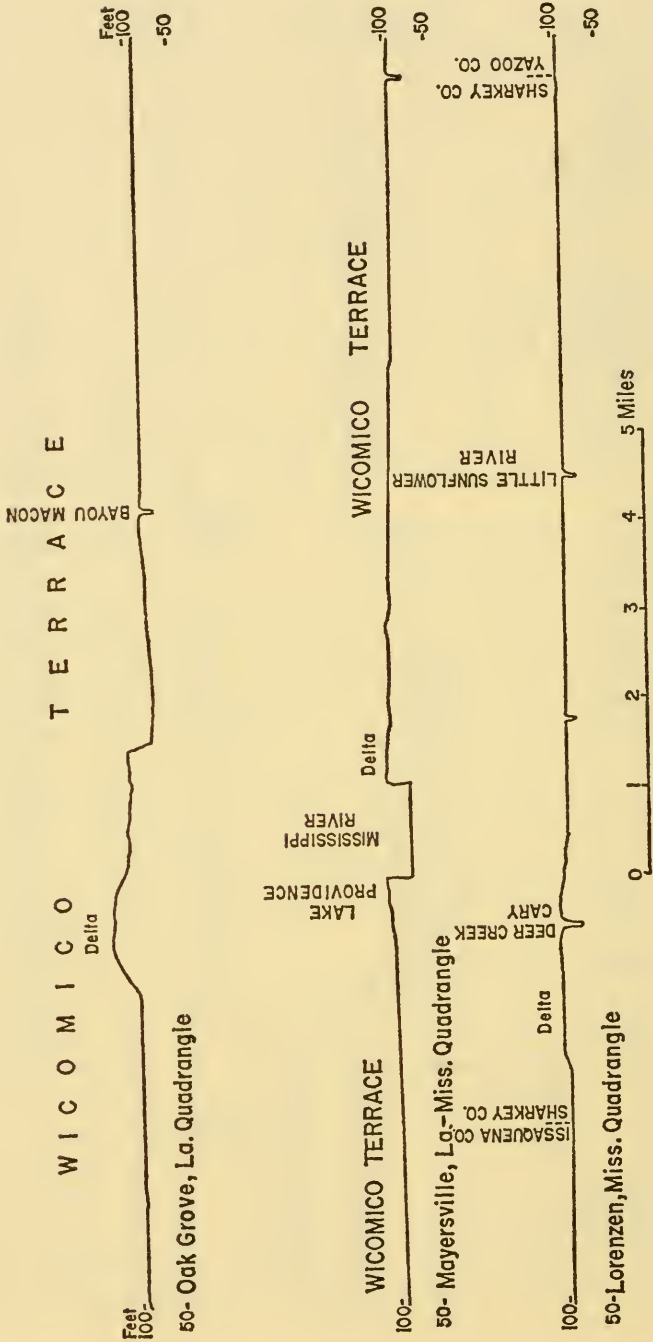


FIG. 14.—Profile from a point 10 miles south of Marion, Union Parish, La., southward to Yazoo County, Miss. Part II: Oak Grove, Mayersville, and Lorenzen quadrangles.



FIG. 15.—Shore line of the Wicomico bay.

Bayou Bartholomew flows upon the Wicomico terrace at Bastrop, where it adjoins the Okefenokee terrace. Four miles east of Bastrop the Wicomico abuts the Sunderland terrace, from which it extends eastward into Mississippi (figs. 13, 14).

In Mississippi the head of the Wicomico embayment is masked by distributaries of the contemporary Mississippi delta. Parts of the terrace occupy the eastern part of the Swan Lake quadrangle and much of the adjoining Auter quadrangle in Washington, Humphreys, and Sharkey counties (fig. 14). From Yazoo City southward the shore followed the bluff into Louisiana. At a low cape 3 miles southeast of Port Hudson, East Baton Rouge Parish, the shore turned eastward along the expanded Gulf of Mexico.

The name Wicomico terrace dates from 1901, when Shattuck (1901, p. 103; 1906, p. 71) applied it to a marine terrace in Maryland whose shore line now stands about 100 feet above sea level. The name has been used repeatedly since then for all the states from Maryland to Florida.

Fisk's (1938a, p. 51) name Prairie terrace evidently is a synonym of Wicomico terrace. The name was "proposed for a terrace typically developed near Aloha, sec. 16, T. 7 N., R. 4 W., Grant Parish, and at Nebo School, irregular sec. 40, T. 7 N., R. 3 E., La Salle Parish" in Louisiana. At Aloha (Montgomery quadrangle) and also at Nebo School (Jena quadrangle) this plain is bounded by the 100-foot contour line. Aloha lies within the Wicomico estuary of the Red River about 6 miles above Colfax; Nebo School stands on the shore of the wide entrance to a larger Wicomico bay about 23 miles southwest of Harrisonburg.

The Port Hickey terrace of Matson (1916, p. 190) as defined by Fisk (1938b, p. 8) is here interpreted as equivalent to the Wicomico. It slopes up from more than 90 feet above sea level at Port Hickey (Port Hudson quadrangle) to 100 feet at Port Hudson, a mile and a half away.

MacNeil (1950, p. 99) regarded the Wicomico as a peak of marine transgression. This assumption seems to be corroborated by Colquhoun (1964, p. 137), who finds the Okefenokee Formation to be overlain unconformably by Wicomico terrace deposits in the Eutawville quadrangle of South Carolina.

At the end of Wicomico time the Gulf withdrew to a lower level and came to rest at 70 feet.

Penholoway terrace (shore line 70 feet).—At the 70-foot stage a bay about as long as Chesapeake Bay and more than twice as wide



FIG. 16.—Shore line of the Penholoway bay.

extended across Louisiana into Arkansas (fig. 16). An eastern prong reached up Tensas Bayou into Madison Parish, La. The upper part was bounded on the east by the delta of the Mississippi, which pushed down below Grand Gulf, Miss. The western shore lay west of Bayou Macon. This eastern prong was separated from the drowned valley of the Ouachita by a low-lying peninsula of Wicomico terrace that extended southward beyond Leland into Catahoula Parish.

The western prong of the Penholoway bay forked near Monroe, La. One wide branch followed Bayou La Fourche almost to Collinston; the other pushed up the Ouachita into Arkansas beyond the mouth of the Saline River, with a narrow place near the town of Ouachita, in Union Parish. Tidewater also reached up Bayou d'Arbonne and Bayou l'Outre.

At Harrisonburg the shore turned southwestward along the highland west of Bushley Creek and Catahoula Lake, where it curved southeastward to the expanded Gulf of Mexico in Avoyelles Parish near Long Bridge.

In the western part of Evangeline Parish the shore of the Gulf followed the boundary line between the "Montgomery Formation" and the "Prairie Formation" as mapped by Varvaro (1957, pl. 1). Presumably, therefore, the "Prairie terrace deltaic surface" of Varvaro (1957, p. 37) is equivalent, at least in part, to the Penholoway terrace.

The eastern shore of the Penholoway bay lay not far east of the Mississippi River from Grand Gulf, Miss., to a projecting cape at Alsen, about 4 miles north of Baton Rouge, where it met the Gulf.

The State Industrial School for Boys at Alsen (Scotlandville, La., quadrangle) is built on the Penholoway terrace near the shore of a cove that curves eastward past Baker, which stands on the Wicomico terrace just above the Penholoway shore (fig. 17). The greater part of the city of Baton Rouge is built on the Penholoway terrace, but the southern part steps down to lower terraces (fig. 18).

The Penholoway terrace was named by Cooke (1925, p. 24) from Penholoway Creek and Penholoway Bay (a swamp) in Georgia. It was further defined by reference to a shore line at 70 feet (Cooke, 1931, pp. 505, 509). It has been mapped in Georgia (Cooke, 1939b, 1943), South Carolina (Cooke, 1936), and Florida (Cooke, 1945).

After the sea withdrew from the 70-foot level it came to rest at 42 feet.

Talbot terrace (shore line 42 feet).—During the 42-foot stage of the Gulf (fig. 19) the mouth of the Talbot bay lay between Baton

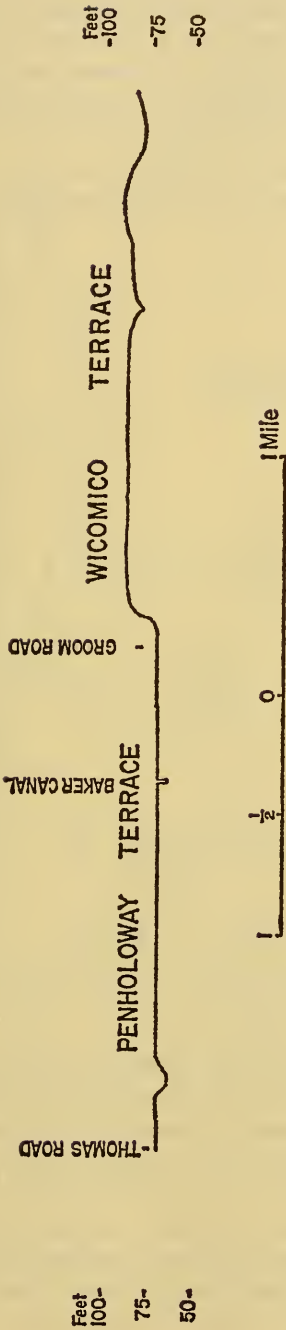


FIG. 17.—Profile on the Scotlandville, La., quadrangle extending northward from the Thomas Road at North Maryland.

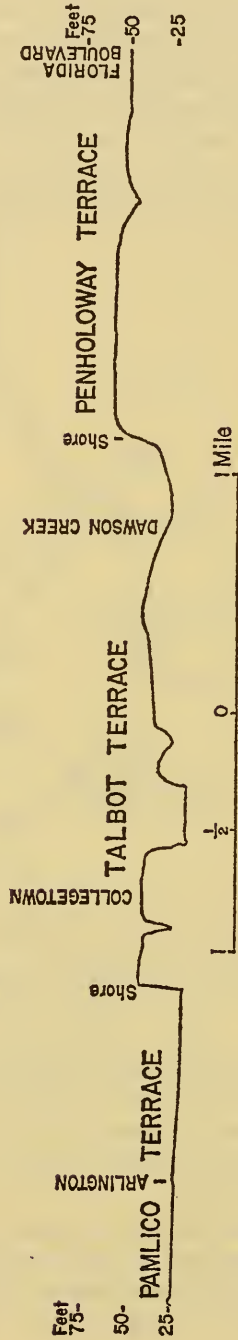


FIG. 18.—Profile on the Baton Rouge West, La., quadrangle extending from Arlington to Florida Boulevard at Foster Drive.

Rouge and Lafayette, La., a width of 40 miles. The shore line at Baton Rouge (fig. 18) crossed the intersection of the Kansas City Southern Railway with the St. Helena Meridian as shown on the Baton Rouge West quadrangle. From this point a 10-foot scarp extends eastward past the Baton Rouge Country Club.



FIG. 19.—Shore line of the Talbot bay.

West of the cape at Lafayette the shore of the Gulf was very low lying; there is no conspicuous scarp separating the Talbot terrace from the Penholoway. The shore line appears to curve northward past Cankton (Carencro quadrangle) to the south corner of Church Point.

Within the bay, whose generalized outlines are shown in figure 19, the shore line is made very intricate by distributaries of the Red River delta now occupied by Bayou Cocodrie, Bayou Boeuf, Bayou Rouge, and other bayous. Traces of the original level can still be

seen at St. Landry (Turkey Creek quadrangle) and at many places within the Bunkie quadrangle.

Water backed up Little River for several miles above Catahoula Lake, which now is blocked by delta deposits. The Talbot bay extended up the Mississippi Valley at least as far as Dismal Swamp (Deer Park quadrangle) in Concordia Parish.

The name Talbot terrace dates from 1901, when Shattuck (1901, p. 103) applied it to a marine and estuarine terrace in Maryland having a shore line near 45 feet above sea level. It is the same as



FIG. 20.—Shore line of the Pamlico terrace in Louisiana.

the terrace in North Carolina later called Chowan by Stephenson (1912, p. 328). The terrace has also been described and mapped in South Carolina (Cooke, 1936a) and Georgia (Cooke, 1939b; 1943). The upper level of the "Pensacola terrace" of Matson (Matson and Sanford, 1913, p. 34; Cooke, 1939a, p. 40) is equivalent to the Talbot terrace.

When the sea withdrew from the Talbot terrace to an undetermined lower level it came to rest at 25 feet.

Pamlico terrace (shore line 25 feet).—The generalized outlines of the Pamlico shore in Louisiana are shown in figure 20. The capes at the mouth of the largest Pamlico bay stood near Hope Villa,

14 miles southeast of Baton Rouge, and at Delacroix, 3 miles southeast of St. Martinville. The entrance to the bay was more than 50 miles wide. The head of the bay lay in St. Landry Parish near Elba and in Pointe Coupee Parish near Morganza.

In the western part of the bay drainage from the Red River built a long delta, now followed by Bayou Teche, from Port Barre past Leonville and Arneaudville to Breaux Bridge. Drainage from the Mississippi built a delta down the middle of the bay along the Atchafalaya past Melville to Krotz Springs. Another distributary followed Bayou Fardoche from Morganza to Frogmore on Bayou Grosse (Fardoche quadrangle), and wider branches bordered the river from Morganza to the southeast corner of the New Roads quadrangle.

The western shore of the Pamlico bay follows the 25-foot contour line on the Carencro quadrangle for 6 miles, passing 3 miles east of Sunset. Here it lies at the foot of a 30-foot bluff leading to the Penholoway terrace.

Most of the bay appears to have been shallow. It probably did not much exceed 25 feet in depth.

The name Pamlico Formation was used by Stephenson (1912, pp. 286, 287) for Pleistocene beds along Pamlico Sound in North Carolina ". . . whose upper surface forms a low, nearly level plain whose elevation nowhere exceeds 25 feet." The plain was called "Pamlico terrace" on an earlier page of the same volume, by William Bullock Clark, whose description was based on Stephenson's field work. The Pamlico terrace has been mapped in all the states from Maryland to Florida.

At the end of the still stand at 25 feet the Gulf withdrew and came to rest about 6 feet above its present level. The Pamlico terrace emerged.

Silver Bluff terrace (shore line 6 feet).—The name Silver Bluff was substituted (Cooke, 1945, p. 248) for the name Miami terrace (Parker and Cooke, 1944, p. 24) to avoid confusion with the Miami Oolite, which is older.

At the 6-foot level the present salt marshes along the Gulf were completely submerged. A bay occupied the drowned drainage system of the Atchafalaya as far north as Catahoula (Loreauville quadrangle), about 10 miles northeast of St. Martinville and Crescent (Chicot Lake quadrangle). At the White Castle Oil field (White Castle quadrangle) it was stopped by the delta of the Mississippi, which formed its eastern boundary.

In many places the shore at the 6-foot stage was so low that it cannot be traced on maps with a 5-foot contour interval. An exception is at Ponchatoula, where a bluff rises about 10 feet above the 5-foot contour line, which bounds the marshes north of Lake Marepas. This bluff continues westward into the Springfield, La., quadrangle.

The shore of the Gulf during Silver Bluff time is marked by a narrow barrier beach, rising 10 feet above the 5-foot line, that curves across the southwestern part of the Lake Charles quadrangle. Grand Lake School, in sec. 16, T. 12 S., R. 8 W., stands on it.

RESUME OF EVENTS

At the beginning of the story, presumably in Pliocene or early Pleistocene time, the shore of the Gulf lay beyond the present seashore, and rivers flowed across the Mississippi Embayment in steep-walled valleys carved in bedrock. Then, perhaps during the first interglaciation, the sea rose and flooded the embayment to a height of 360 feet above its present level.

This inundation produced a great bay extending about 250 miles northeastward from Little Rock and averaging about 100 miles in width. Later, the Gulf established shore lines successively near 275 feet, 215 feet, 170 feet, 145 feet, 100 feet, 70 feet, 42 feet, 25 feet, and 6 feet. There were probably intermediate lower stands whose locations have not been established. At each level the drowned valleys formed successively smaller bays.

In each bay the rivers deposited their load of sediment not far from the shore, filling up the head of the bay and usually extending distributaries of a delta into deeper water. These distributaries were abandoned when sea level fell to a lower level. At the present stage the embayment is completely filled and the Recent delta bulges out into the Gulf.

Thus developed a series of terraces bordering a very gently sloping area across which the once-rapid streams now meander. The old shore lines within the central area are masked by veneers of alluvium except where distributaries of Pleistocene deltas, their channels now occupied by minor streams, stand above the general level.

Objection will doubtless be raised to this theory of the growth of the terraces and the alluvial plain of the Mississippi Embayment because the sediments appear to be fluvial deposits. They have every right to look like fluvial deposits, for they were brought down by rivers, dropped for the most part as tidal flats and deltas in water that

was kept fresh or only slightly brackish by the great volume of river water flowing into the bays.

Even the largest bay must have been nearly fresh, for it received all the drainage from the midcontinent. Into the head of the bay flowed the Tennessee, the Ohio, and the Mississippi. No large streams came in from the east, but the western side received the St. Francis, Spring River, Strawberry River, the White, the Little Red, and the Arkansas. These large streams must have kept the Morley bay nearly fresh as far down as Little Rock. Later, smaller bays were only slightly brackish as far south as Natchez, at which latitude the pre-Pleistocene valleys were narrowed by uplands west of Harrisonburg, La. South of Harrisonburg the sea water was diluted by the Ouachita, Little, and Red Rivers. Clearly, lack of sea shells is no evidence that the Quaternary deposits of the Mississippi Embayment did not accumulate in tidal waters.

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