Pleistocene Shore Lines in Florida and Georgia

GEOLOGICAL SURVEY PROFESSIONAL PAPER 221-F

Correction, pl. 19, Professional Paper 221-F

The fractional scale of the original map (1:500,000) was inadvertently copied on the final map on the reduced copy as printed. The correct scale is 1:750,000.

Pleistocene Shore Lines in Florida and Georgia

By F. STEARNS MACNEIL

SHORTER CONTRIBUTIONS TO GENERAL GEOLOGY, 1949

GEOLOGICAL SURVEY PROFESSIONAL PAPER 221-F

A report and accompanying map prepared in connection with investigations of the land pebble phosphate deposits of southern Florida

UNITED STATES GOVERNMENT PRINTING OFFICE, WASHINGTON : 1950

UNITED STATES DEPARTMENT OF THE INTERIOR

Oscar L. Chapman, *Secretary*

GEOLOGICAL SURVEY

W. E. Wrather, *Director*

For sale by the Superintendent of Documents, U. S. Government Printing Office
Washington 25, D. C. - Price $1.00 (paper cover)

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PLEISTOCENE SHORE LINES IN FLORIDA AND GEORGIA

By F. Stearns MacNeil

ABSTRACT

Each of the shore lines recognized is marked by a variety of features, including cliffs, lagoons, bars, and bays. Shore lines adjacent to previously dissected terrain show cliffs that characterize shore lines of submergence, whereas shore lines adjacent to preexisting terraces exhibit elongate lagoons and bars that generally are taken to indicate early to youthful stages of shore lines of emergence. It is postulated that the subsidence of an undissected terrace simulates the nearly plane shore profile of an emerged shallow ocean floor and, inasmuch as the nearly plane shore profile is the only prerequisite for the development of the features characterizing shore lines of emergence, that identical features would result in both cases. All the shore lines recognized, therefore, represent maximum rises of sea level, which are ascribed to glacial oscillation.

Four marine terraces and shore lines are recognized between present sea level and an altitude of 150 feet. The two highest, the Okefenokee and Wicomico, are correlated with the Yarmouth and Sangamon interglacial stages, respectively. The next lower, the Pamlico, is correlated with a mid-Wisconsin ice recession. The lowest, the Silver Bluff, is regarded as post-Wisconsin. The widespread fluvial deposits of the Citronelle formation and terraces above 150 feet, whether fluvial or marine, are referred to the early Pleistocene or Pliocene.

No basis for the correlation of shore lines with glacial events is known in Florida and Georgia. The correlation here accepted is based on the discovery by Leverett that a gravel train derived from Illinoian till passes into Wicomico terrace sediments along the Susquehanna River.

This study, undertaken to show any possible relationship between the Pleistocene terraces and the land pebble phosphate deposits of Florida, indicates that no such relationship exists. An early Pleistocene age for the phosphate beds is possible, but the evidence of fossil land mammals indicating Pliocene age is considered stronger.

INTRODUCTION

PURPOSE OF INVESTIGATION

This paper and the accompanying map were prepared in connection with investigations of the land pebble phosphate deposits of southern Florida. In order to discover any possible relationship between the phosphate beds and the Pleistocene terraces, it seemed necessary to determine what terraces and shore lines exist and to map the shore lines in the phosphate area more accurately than has been done in the past. Inasmuch as some of the Pleistocene shore lines are preserved only locally, and because the evidence for some of them lies far afield, the Coastal Plain of Georgia and western Florida was studied in addition to the peninsula of Florida.

The map may prove to be a valuable guide in prospecting for heavy mineral deposits in both Florida and Georgia. The coast of the Pamlico sea in particular is known to carry large amounts of heavy minerals in Florida, and possibly deposits of equal value may be found in Georgia. Likewise, the coastal bars of the Okefenokee sea (Trail Ridge) have been prospected recently and found to contain concentrations of heavy minerals. The outer shores of the coastal bars of all sea-level stages are regarded as more favorable locations for heavy-mineral prospecting than the inner lagoonal shores. Deposits now being worked and areas blocked out for future mining lie along the shore lines of coastal bars.

ACKNOWLEDGMENT

The writer wishes to express his sincerest thanks to Dr. Richard F. Flint, of Yale University, for a long series of correspondence dating from the time the writer first started work on the coastal terraces. Dr. Flint offered many ideas and much helpful criticism.

PREVIOUS WORK

An excellent account of the study of Pleistocene sediments along the Atlantic Coastal Plain up to 1940 has been given by Flint (1940). Reviewing early work by McGee, Darton, Shattuck, Salisbury and Knapp, Wentworth, Campbell, and Cooke, Flint pointed out that three hypotheses had emerged from these studies: one favoring a marine origin, another favoring a fluvial origin, and a third favoring a combination of fluvial and marine origins. He stated, in summary, that "the hypothesis of dominantly fluvial deposition in New Jersey" had been "unchallenged"; that "serious objections to a hypothesis of chiefly marine deposition in Maryland" existed, that there was "evidence of both marine and fluvial deposition in Virginia," and finally that "widespread evidence (chiefly morphologic) of marine deposition" had been reported from Georgia, South Carolina, and Florida.

Flint cast doubt on the marine origin of certain higher features, while supporting the marine hypothesis for at least the lower scarps and terraces along the Atlantic seaboard from southern Virginia to Florida, and challenged C. W. Cooke, an important contributor on the subject of marine terraces, to show evidence for all the seven terraces he recognized. Flint stated that in his opinion only two marine scarps had been proved to exist in the central Atlantic region, but that there was a possible third and higher scarp in Georgia and Florida. Cooke (1941) replied that Flint's requirement of high seaward-facing scarps for the recognition of marine shores was entirely too rigorous, for there was no such feature (other than dunes) along the present seashore of the Coastal Plain.

In his latest published discussion of the Pleistocene terraces, Cooke (1945, p. 248) recognizes seven shore lines and the possibility of an eighth. He regards the highest shore line, where more than one is referred to a single interglacial stage, as the culmination of the interglacial stage; the lower shore lines he considers to be pauses during the ensuing emergence of land. The names of these shore lines, with their altitudes, age, and correlation, are as follows:

Shore line	*Altitude (feet)*	*Age*
Brandywine	270	Aftonian interglacial stage.
Coharie	215	Yarmouth interglacial stage.
Sunderland	170	
Wicomico	100	Sangamon interglacial stage.
Penholoway	70	
Talbot	42	
Pamlico	25	"Mid-Wisconsin recession."
Silver Bluff(?)	5	

Cooke believes that sea level was progressively lowered throughout Pleistocene time, possibly due to the sinking of some large, unstable part of the earth in, for example, the North Atlantic Ocean or a part of the Pacific Ocean. The same amount of water may have been abstracted from the hydrosphere during successive glacial stages and restored during the interglacial stages, but the successive interglacial rises in sea level were progressively lower along tectonically stable coasts.

Sufficient topographic or sedimentary evidence is not available at present to evaluate properly the two highest shore lines recognized by Cooke. The existence of a Brandywine shore line appears to be based mainly on a general widening of present river valleys at about 270 feet, which widening Cooke interprets as marking the heads of former estuaries; however, the line formed by the "heads" of these "estuaries" coincides with the boundary between the Coastal Plain and the crystalline rocks in Georgia, so that other explanations for the widening of the river valleys are possible. A slight break in the slope of the high terrace at about 220 feet is indicated on topographic maps in western Florida, but the surface where this break occurs is a narrow remnant and the feature cannot be traced for any distance.

Cooke's 170-foot shore line is not definitely the Okefenokee shore line of this paper. (See p. 101.) His 100-, 25-, and 5-foot shore lines, however, are well founded and correspond with the altitudes of 100 feet, 25 to 35 feet, and 8 to 10 feet given for three of the shore lines here recognized. The shore line at 70 feet is well preserved locally, but the one at 42 feet is obscure. Both the 70- and 42-foot shore lines were regarded by Cooke as formed during pauses in the retreat of the sea from the 100-foot level in late Sangamon time.

Cooke's terrace chronology, in which the highest shore line is the oldest and the lowest shore line is the youngest, is followed in this paper. His interpretation seems inescapable in view of the softness of the sediments that compose the former shore features and the probability that any subsequent marine transgression to the same altitude would almost certainly have effaced them. The only alternative to assigning the shore lines to different interglacial stages is to assume that they represent successive stages in a single regression, which seems unlikely. Cooke's correlation of the Wicomico terrace with the Sangamon interglacial stage is taken from Leverett (1934, pp. 32–34), who has shown that a gravel train along the Susquehanna River is derived from Illinoian till and passes into Wicomico terrace sediments.

Flint declined to refer to terraces in his discussion, inasmuch as any sea floor is irregular and a wide range of altitudes might be concurrent. He based his shore lines on remnants of seaward-facing scarps and mapped such remnants as he could find from the James River in Virginia to southern South Carolina. He recognized two such scarps: the Suffolk scarp, having a toe at an altitude of 20 to 30 feet, and the Surry scarp, with a toe at 90 to 100 feet. He stated that he could recognize no marine features higher than the Suffolk scarp in this area. In Georgia, however, Flint recognized Trail Ridge as a marine feature, rising from a maximum altitude of 180 feet in the southern part of that State to a maximum of 240 feet in north-central Florida. Moreover, Flint told the writer in June 1945 that he thought marine features were present between altitudes of 200 and 250 feet in western Florida. These features, he believed, might correlate with the southern part of Trail Ridge. The terrace remnants in western Florida are part of the high terrace as here mapped.

The relationship of the Surry scarp to the high southern end of Trail Ridge was considered by Flint (1940, p. 777) to be obscure. Later, however, he pointed out that, whereas the Suffolk and Surry scarps maintain horizontality, the discrepant elevations along Trail Ridge suggest tilting to the north (Flint, 1947, p. 440). This would indicate that coastal stability has existed since the formation of the Surry scarp, but that coastwise tilting probably followed the epoch of the sea that formed Trail Ridge. Flint did not recognize a definite shore line above 90 (or 100) feet, but interpreted Trail Ridge as merely a bar, probably of marine origin and probably tilted.

Flint's shore lines are summarized as follows:

Shore line	*Altitude (feet)*	*Age*
Trail Ridge (?)	140–240	
Surry	90–100	Yarmouth interglacial stage.
Suffolk	20– 30	Sangamon interglacial stage.

Flint emphasized the fact that the assigned correlations were pure speculation. Earlier (1942, p. 237) he had referred the Suffolk scarp to the "Peorian interglacial sub-age" and the Surry scarp tentatively to the Sangamon interglacial age.

Substitution of the names Suffolk and Surry for Pamlico and Wicomico was made, apparently, because of the feeling that terraces and scarps should have a different nomenclature.

The latest interpretation of the coastal terraces of Georgia appears on a geologic map by MacNeil (1947). The terraces are divided into "older terraced surfaces" of fluvial or marine origin and "younger terraced surfaces" of marine origin. The older terraced surfaces are referred to in this paper as the high terrace; it comprises some large terraced areas but nevertheless is greatly dissected in comparison with the lower marine terraces. The high terrace differs from the lower terraces, also, in that it is not bounded on the landward side by a scarp. The lower terraces are all terminated on the landward side by a seaward-facing scarp, presumably an abandoned sea cliff. Not only is no seaward-facing scarp found at the innermost edge of the high terrace, but in most places its inner edge stands higher than the adjacent landward terrain. This proves, not that the high terrace is of nonmarine origin, but merely that it is unquestionably the oldest of the terraces and that its shore line, if one ever existed, has been completely destroyed.

Workers who have studied the coastal terraces of the western Gulf region have been more universally in favor of a nonmarine origin for the terraces in that area. In 1930 Barton explained the coastal prairies of Texas as a deltaic plain formed by the coalescing fans of the Pleistocene master streams. Doering (1935) later recognized three "surface formations," the Willis, Lissie, and Beaumont, which he attributed to fluvial aggradation during three periods of rejuvenation. Doering believed the Willis to be the oldest and showed how the materials of the Lissie and Beaumont formations reached their present position by being transported through gaps in the Willis. Fisk (1940, p. 175) subsequently described the coastal prairies of Louisiana as the work of streams. After the publication of Flint's paper (1940) on the Atlantic Coastal Plain, a paper by Price (1947) appeared, supplementing earlier work by Barton and others and showing that the coastal prairies of Texas were formed by subaerial deposition. Price stated that "supposedly emerged coastal Quaternary surfaces were [believed in early studies to be] composed of different elements termed terraces and these were expected to have seaward-facing erosional scarps at their inner margins." He thus implied the nonexistence of the abandoned sea cliffs that led early geologists to regard the coastal terraces as marine in origin.

Considerable difference of opinion therefore exists among geologists as to whether the Atlantic and Gulf terraces are of marine or subaerial origin. Moreover, there is disagreement among the principal exponents of marine origin as to how many sea levels there were and how many resultant scarps and terraces are present. Those who explain the coastal terraces as being of nonmarine origin regard them as the work of aggrading streams during periods of glaciation, whereas those who believe they are marine features attribute them to high sea levels during interglacial stages. It would seem possible that the features that are obvious in any area might depend largely on which set of features predominates and on how destructive each stage was of the features of the preceding stage.

METHODS OF PRESENT STUDY

The accompanying shore-line map (pl. 19) is based chiefly on a study of topographic maps and is intended primarily to show to what extent the available maps contribute data to the problem of Pleistocene sea levels. The shore-line scarps can be recognized easily where good topographic maps on a 10-foot contour interval are available, but the scarps are not well shown in areas mapped on a 20-foot interval and their exact position can be only estimated. Points at which scarps have been checked in the field are widely scattered and comparatively few, considering the size of the area. Contours shown on the topographic maps of the United States Engineers, at scales of 1:250,000 and 1:500,000, are only approximately located and indicate merely the general position of the former shore lines.

The high terrace on the accompanying map is taken, with some modification, partly from the writer's previous work on the Tertiary and Quaternary formations of Georgia (MacNeil, 1947) and partly from the topographic maps of western Florida. The 150-foot shore line in parts of Polk and Highlands Counties, Fla., was taken from aerial photos and over most of the area is without vertical control.

The map shows terraced surfaces above 150 feet. At 150 feet and lower it shows parts of contours that best locate the features of the several sea levels: shore lines, bars, intracoastal water, and the like. The contours used are those at 10, 30, 80, 90, 100, and 150 feet. The two highest recognizable shore lines are close to the 100- and 150-foot contours. The two lowest shore lines are placed at 8 feet and 25 to 35 feet, for which the closest available contours are 10 and 30 feet, respectively. The 30-foot contour was estimated on maps having a 20-foot contour interval. Submarine bars of the 100-foot level, some of which assumed the position of coastal bars during the ensuing land emergence, are well shown by the 80- and 90-foot contours. The 90-foot contour was used only on the maps with a 10-foot contour interval.

Former shore lines are not shown exactly by contours. In areas where scarps are little dissected, the contours closely approximate the shore lines, but in areas where the scarps are dissected the former shore lines are indicated mainly by a general concordance of points. The map here presented thus gives a good impression of the preservation of the former shore lines.

For most parts of Florida contours were transferred from quadrangle sheets by template, but those for certain quadrangles lacking a land net were reproduced by photographic reduction. All the Georgia quadrangles are slightly generalized photographic reductions. Small-scale maps prepared by the United States Engineers either were traced directly or were photographically reduced.

FLUVIAL DEPOSITS OLDER THAN THE MARINE TERRACES

A blanket fluvial deposit of highly cross-bedded sands, clays, and gravels exists in Mississippi, Alabama, and western Florida. This fluvial deposit was named the Citronelle formation by Matson (1916, p. 168). The Citronelle formation extends from present sea level to altitudes of over 400 feet in Alabama and over 500 feet in Mississippi. It has a thickness of about 150 feet in western Alabama. It lies beneath the Pleistocene terraces at a low altitude, but a terraced surface on the fluvial deposits rises higher than the highest estimated Pleistocene sea levels. It is necessary, therefore, that a distinction be made both between the fluvial deposits of the Citronelle formation and the Pleistocene marine deposits and between the high terraced surface, which may be the constructed surface of the Citronelle formation, and the Pleistocene marine terraces.

The Citronelle formation was referred to the Pliocene by Matson on the evidence of plants, studied by Berry (1916), which were supposed to have come from the formation. More recently, Roy (1939) has showed that the plants came from a clay that lies unconformably below the Citronelle formation and cannot, therefore, be used to date the formation. Still more recently, Fisk (1945) has correlated the Citronelle with one of the glacial stages, stating that it "falls within the terrain of the two highest terraces" of the Mississippi River. No direct evidence has been presented for determining the exact age of the Citronelle. If it is younger than the clay containing Pliocene (?) leaves, it can be shown, also, to be older than the middle and late Pleistocene marine terraces, so that an early Pleistocene age is possible. A Pliocene age cannot definitely be ruled out, however.

The distribution and character of the Citronelle sediments suggest that they are coalescent deposits of several early rivers that emptied into the Gulf of Mexico. Where the fluvial deposits merge with marine deposits has not been demonstrated, but it may be below present sea level.

THE HIGH TERRACE

The high terrace is the dissected surface lying entirely above an altitude of 150 feet. Many remnants of a terraced surface, believed to have been continuous at one time, are found in Georgia, western Florida, Alabama, and Mississippi. The surface rises to an altitude of about 250 feet in Georgia, to about 280 feet in western Florida, and to over 340 feet at Citronelle, Ala. (pl. 20), where it forms the upper surface of the Citronelle formation. Parts of this terrace, therefore, are higher than the highest shore line, at an elevation of 270 feet, recognized by Cooke.

The identification of marine terraces in this paper is based on the coexistence of shore-line scarps, which are presumably wave-cut cliffs. All terraces up to an altitude of 150 feet are bounded on the landward side by seaward-facing scarps, but there is no scarp at the upper edge of the high terrace. Cooke (1941, p. 457) points out that the absence of a scarp does not preclude the existence of a shore line, inasmuch as few scarps are found along the Atlantic and Gulf coasts today. Without the evidence of a scarp, however, and until study of the soils and sediments yields some definite evidence, there seems to be little way of determining what part, if any, of the terraced surface above 150 feet is marine and what part is fluvial.

In western Florida the high terrace is greatly dissected, and its remnants terminate on the gulfward side at an altitude of about 200 feet. The seaward edge thus lies about 50 feet above the Okefenokee shore line.

Along the Atlantic side, in eastern Georgia, the high terrace is less dissected. Its seaward edge rises from an altitude of 150 feet in the south, where it passes beneath the Okefenokee terrace, to approximately 180 feet near Claxton, in the Claxton quadrangle (7),[1] where its seaward edge is again about 30 feet above the Okefenokee shore line. North of Claxton the high terrace has been destroyed.

Any interpretation of the structure of the high terrace would be unreliable until more of it has been mapped topographically. It appears to rise both to the west and to the north from southeastern Georgia.

On purely speculative grounds, if the Citronelle formation is the result of fluvial aggradation by rivers during the Pliocene or during the melting of the first ice cap, the high terrace—or a part of it—is the constructed top of the formation. With the rise of sea level during the Aftonian interglacial stage, the Citronelle formation was partly inundated and a part of its surface became a subaqueous platform. If the hypothesis of the progressive lowering of sea level during the Pleistocene is correct, the boundary between the subaqueous terrace and the fluvial terrace might be sought at a high altitude, but the figure of 270 feet given by Cooke is regarded as far from proved. During the Kansan stage of glaciation rivers cut gaps in the high terrace. In the ensuing Yarmouth interglacial stage sea level rose to an altitude of 150 feet, and at that level river-borne materials reached the sea through gaps in the high terrace and were distributed coastwise by oceanic waves and longshore currents.

The high terrace, therefore, is believed to be of subaerial origin. Subsequent to its formation a part of it may have been inundated by the sea and possibly modified, but no conclusive evidence to indicate that the sea ever transgressed it to an altitude higher than 150 feet has been put forth. The terraces below 150 feet are believed to be entirely of marine origin.

THE MARINE SHORE LINES

GENERAL FEATURES

The shore lines here recognized are as follows:

Shore line	*Altitude (feet)*	*Age*
Okefenokee	150	Yarmouth interglacial stage.
Wicomico	100	Sangamon interglacial stage.
Pamlico	25–35	Mid-Wisconsin glacial recession.
Silver Bluff	8–10	Post-Wisconsin.

All these shore lines are regarded as peaks of marine transgression. Minor shore lines believed to have been formed during pauses in the following regression, such as Cooke's Penholoway and Talbot shore lines, either have not been dealt with or are referred to as "late stages."

The shore lines of this report are characterized from place to place both by open, steeply cliffed mainland and by more complex coasts combining embayments, lagoons, and offshore bars. Where offshore bars are developed, there are really two shore lines, an inner shore line facing the lagoon and an outer shore line facing the open sea.

The *coastal shore* is here defined as the shore facing the open sea—the shore of the mainland, where it is unobscured, and the outer shores of offshore bars where they are developed. The *coastal shore line* is the outline of the coastal shore; the *intracoastal shore* is the shore of lagoons or bays partly enclosed by bay-mouth or offshore bars; and the *intracoastal shore line* is the outline of the intracoastal shore.

The precise altitude of the high-tide mark along an abandoned shore probably cannot be determined without a study of all the coastal features. The shore line has been variously located at the toe of the scarps and on or above the scarps. This is apparently due to the fact that the scarps have been interpreted as sea cliffs by some geologists, as steep beaches by others, and as scour zones at the line of breakers by still others. Probably scarps representing all conditions exist within any one set of coastal features, so that the problem is to determine which part of the coast will indicate the true sea level most accurately. Probably the toe of the scarp off a coastal bar is the least likely indicator, because this scarp is being carved by the undertow of breakers and is well below water level. The bars themselves may be submerged. A steep, unindented coast is unreliable, so far as indicating the high-water mark is concerned, because the water off such coasts is naturally deeper at some places than others and also because erosion of such a coast might produce an even profile from the top of the cliff to the scour zone at the line of breakers. The nips cut along the landward side of shallow lagoons by comparatively small waves should most nearly approximate the high-water mark. Even these may be a few feet too high, however, owing to the fact that the base of lagoonal and estuarine bluffs usually is cut by storm waves.

The Silver Bluff shore line is sharply defined, but the 10-foot contour, the only contour that is available to show its features, is probably the upper limit of possibility for its high-water stage. An altitude of 8 feet for the Silver Bluff sea level is probably correct within 2 feet. The Pamlico shore line also is well preserved. The toe of the scarp along certain intracoastal shores is close to 40 feet, but the high-water mark was probably a little lower than the toe. The 30-foot contour was

[1] Numbers in parentheses are quadrangle numbers on index map of plate 19.

selected to show the coastal features of the Pamlico coast and is probably correct within 7 or 8 feet for the Pamlico sea level. An altitude higher than 30 feet is more likely than a lower altitude. Both the Wicomico and Okefenokee shore lines are approximate, and the 100- and 150-foot contours used to outline their features are probably correct within 10 feet for the altitude of their shore lines.

Spits and capes are frequently found along the abandoned coasts opposite features similar in size and shape on the Recent coast. The concordance of the bars and spits of the Pamlico coast with similar features along the present-day coast may be noted—for example, the alinement of a point near Medart in the Arran quadrangle (90) in western Florida with the Recent Lighthouse Point in Franklin County and the similarity of bars developed around the north end of Lake Butler in Pinellas County and the Recent Anclote Keys. This concordance illustrates to what extent these features were dependent then as now on bedrock formations and a source of sand. Both the old and the new features approximate the edge along which the sandy Miocene formations crop out, whereas the coast line between them is underlain by older limestones on the eroded Ocala uplift. The limestones furnish no sand, and the shore is mainly muddy.

Another feature on the Pamlico coast is the small festoon of islands shown in the Tates Hell Swamp quadrangle (111) in Franklin County, Fla. These islands may be evidence that a large river, probably the Apalachicola, emptied in this area in Pamlico time. They compare favorably with the islands now found at the mouth of the Suwannee River.

Some peculiarities of the Recent coast are due to the coexistence of Silver Bluff and Recent lagoons, which may have resulted both from the depth of the Silver Bluff lagoons and from the comparatively slight drop in sea level since Silver Bluff time. This is especially well shown by the Indian River, a Silver Bluff lagoon that is still inundated, and by Mosquito Lagoon and the Banana River, Recent lagoons, in Brevard County, Fla.

Where Silver Bluff lagoons have been filled in, Silver Bluff and Recent coastal bars have a double structure. This is illustrated by the Sea Islands. Amelia Island (pl. 21) in northeastern Florida and Cumberland Island in southeastern Georgia both have an inner ridge, built as a dune-covered bar during Silver Bluff time, and a high outer dune-covered bar built by the Recent sea. The two dune areas are separated by a swamp, formerly a narrow lagoon.

The terrace deposits below altitudes of 150 feet in peninsular Florida and in Georgia in no way resemble the highly cross-bedded sands, clays, and gravels of the Citronelle formation. There is no apparent difference in the appearance of the sand on the various lower terraces. The materials are well sorted and consist of fine- to medium-sized sand grains. Histogram studies of a few samples from central peninsular Florida, carried out by J. B. Cathcart, Jr., in connection with phosphate studies, indicate that they most nearly resemble beach sands.

The general land gradient has much to do with the preservation of both scarps and terraces, as can be seen by a comparison of the Okefenokee shore line and terrace in the Brooklet quadrangle (4) in Bulloch County, Ga., an area of low gradient, with the same shore line in Walton and Okaloosa Counties in western Florida, an area of steep gradient. A shore-line scarp is always sharper and steeper where it adjoins an area that was previously dissected, such as that in the Brooklet quadrangle (4). It may be practically indistinguishable, however, where superimposed on a previously existing terrace such as the Okefenokee shore line, where it transgressed the high terrace along the western edge of the present Okefenokee Swamp, or the Pamlico shore line, where it transgressed the Wicomico terrace in the Owens Bridge (98) and Thousand Yard Bay (99) quadrangles in western Florida.

Strikingly shown by this map is the high degree of duplication of compound coastal features on each of the four abandoned shore lines along the Atlantic Coast, as well as the location of later and lower features completely outside the coastal shore line of the next higher sea level. The coastal features of the Wicomico sea lie wholly outside the coastal shore line of the Okefenokee sea, the Pamlico coastal features outside the coastal shore line of the Wicomico sea, the Silver Bluff coastal features outside the coastal shoreline of the Pamlico sea, and the Recent lagoons and coastal bars outside the coastal shore line of the Silver Bluff sea.

The open, steeply cliffed shore line, of which the Okefenokee shore line in Bulloch County, Ga., is a well-developed example, is the type that normally, according to Johnson (1919) and Lobeck (1939), indicates subsidence; in this instance, it is believed to be due to inundation caused by a rise of sea level. In southern Georgia and northern Florida, however, the Okefenokee shore line, as well as the lower shore lines, shows a good development of offshore bars enclosing lagoons of greater or lesser size. This type of shore line is taken by both Johnson and Lobeck to indicate the emergence of land. According to them, when a shallow ocean floor is elevated above water level so as to produce a nearly plane shore profile, an offshore bar is immediately built up by the scouring of the bottom by the undertow along the line of breakers offshore, and the material dislodged is deposited as a bar in front of the line of breakers. Although this process was postulated to follow the emergence of a nearly flat ocean floor, the only physical requirement for the operation of the process is the existence of a nearly plane shore profile. It is here postulated that, where a preexisting undissected terrace is submerged, the same process will occur.

OKEFENOKEE SHORE LINE

The term "Okefenokee" was introduced by Veatch and Stephenson (1911, pp. 60, 424–434) as a formation name and was later used by Cooke (1925, p. 35) as the name of a terrace constructed on deposits of that age. Cooke defined the terrace as lying between the altitudes of 100 and 160 feet. Later he abandoned the name in favor of "Sunderland terrace," fixing the upper limit at 160 feet. Still later he defined the Sunderland terrace as having an upper limit of 170 feet. Cooke informed the writer in March 1949 that he now believes there is a "lower Sunderland terrace" with a shore line at 140 feet. Inasmuch as there is some doubt that the highest shore line in Georgia here recognized is equivalent to the Sunderland shore line of Maryland, the name "Okefenokee" is revived for the terrace.

The Okefenokee shore line is well developed in Bulloch County, Ga., and is well shown by a scarp in the Brooklet quadrangle (4). The scarp, which apparently was a cliff facing the open sea, is poorly developed or destroyed to the north of this area. In Bulloch County the cliff borders a highly dissected Miocene terrain (pl. 22), but farther south in Tattnall and Long Counties it borders remnants of the high terrace. The altitude of the edge of the high terrace drops to the south, and a slightly projecting cape near Redland in Wayne County may mark the point at which it passed below the level of the Okefenokee sea. From here southward the coastal shore line passed from the mainland to a narrow elongate bar (Trail Ridge), and the sea transgressed the high terrace for some distance to form a shallow intracoastal bay or sound (the present Okefenokee Swamp). In Brantley and northern Charlton Counties, Trail Ridge was mostly submerged (pl. 23), but in southern Charlton County parts of it extended 20 to 30 feet above water. The Okefenokee lagoon had a maximum depth of about 30 feet.

Trail Ridge widens in Bradford and Clay Counties, Fla., to a large pear-shaped promontory; the southern end probably is an island of older terrain rather than a bar. The lagoon west of Trail Ridge apparently shallowed to the south and was about 20 feet shallower in southern Baker and northern Bradford Counties than in southern Georgia.

Three irregular, roughly parallel ridges stood as islands in the Okefenokee sea in Polk and Highlands Counties in central peninsular Florida. The one farthest east is known as the Lake Wales ridge. Terraced surfaces surrounding these ridges terminate abruptly at 150 feet, and aprons of white sand extend outward from the actual shore line for a short distance. These aprons were presumably submarine extensions of the beaches, the sand having been derived from the erosion of nips in the central highland ridges. Smaller promontories were reduced by marine abrasion to wave-washed bars (pl. 24). An irregular thin white sand dune is occasionally found above 150 feet, but seldom above 225 feet. The terrain above the 150-foot contour is hilly, with many characteristic round lakes. Except where these lakes are now being drained and their altitude has been lowered to a level below 150 feet, no lakes of this type are present below the 150-foot contour, and presumably any that existed were filled in by the Okefenokee sea. Inasmuch as the lakes, which are probably sinkholes, are present in the sandy hills but have been effaced on the adjoining terrace, the ridges could hardly be bars formed by the Okefenokee sea. The central highlands undoubtedly represent a topography older than the Okefenokee terrace.

High hills between Dade City and Brooksville, in Pasco and Hernando Counties, also stood as islands during the Okefenokee transgression. They are believed to be composed of beds of the Hawthorn formation (middle Miocene), leached in place. To the north, in Citrus, Levy, and Marion Counties, numerous small hills stand above an altitude of 150 feet. Islands existed here, but their exact shape can hardly be inferred on the basis of topography in an area where Recent sinkholes are so abundant.

Another large area, composed of rocks of the Hawthorn formation, formed an island farther north in Alachua County. This area and the blunt southern end of Trail Ridge comprised the largest group of islands in the Okefenokee sea in Florida. Other large islands existed in southern Baker, Columbia, Suwannee, and Hamilton Counties; with the island in Alachua County, they mark the irregular upturned edge of the Hawthorn formation around the east and north sides of the Ocala uplift. These islands enclosed the intracoastal water of southeastern Georgia on the south. The intracoastal shore line of the Okefenokee sea entered Florida in northern Hamilton County, but its location from there to the vicinity of Tallahassee is indefinite.

A fairly straight shore line with several small, submerged offshore bars extended from Tallahassee to the Bristol quadrangle (60) on the Apalachicola River.

It is poorly preserved or not mapped topographically from there to eastern Walton County. From T. 1 N., R. 18 W., in Walton County to T. 1 S., R. 25 W., in Okaloosa County, however, the Okefenokee shore line is fairly well defined by a series of concordant points arranged in a gentle arc, although the general terrain is highly dissected. No uniformity exists from this region to the Alabama line.

The Okefenokee shore line does not appear to deviate appreciably from an altitude of 150 feet anywhere along its visible extent. It is well preserved in Georgia, in northern Florida, and along both sides of the Lake Wales ridge and two smaller ridges that make up the central highlands of peninsular Florida. Yet altitudes along the crest of Trail Ridge rise to the south. The Lake Wales ridge is coaxially alined with Trail Ridge. The highest point in Florida, the hill on which the Bok Tower stands, at an altitude of 325 feet, is located on the Lake Wales ridge. If the Lake Wales ridge is a continuation of Trail Ridge on the other side of the Ocala uplift, then altitudes along its crest increase from about 140 feet in Georgia to 280 feet in northern Florida and 325 feet in central Florida. If these discrepant altitudes indicate coastwise tilting, as suggested by Flint (1947, p. 440), it is of pre-Okefenokee age and may indicate that the Florida peninsula was raised slightly in late Pliocene or early Pleistocene time. The apparent continuity of Trail Ridge with the Lake Wales ridge is due largely to the fact that they both lie along the broadly arcuate Okefenokee coast line, some parts having been constructed and other parts carved to conform with it. If the large southern end of Trail Ridge and the Lake Wales ridge are part of an older terrain, they might well reflect pre-Okefenokee tilting, but there is little to indicate tilting of the Okefenokee bar that forms the northern part of Trail Ridge.

WICOMICO SHORE LINE

The Wicomico shore line is the least sharply defined of the shore lines recognized, which might indicate that the sea stood at this level for a comparatively short time. Fairly well developed marine features are shown by the 100-, 90-, 80-, and 70-foot contours. In some areas the 70- and 80-foot contours mark the top of the Pamlico scarp, so that any lower features formed during the withdrawal of the sea from the 100-foot stage were effaced. Theoretically the sea stood at every altitude during a withdrawal from its maximum rise to its lowest fall, and it is possible that some of the offshore bars associated with this shore line represent several minor pauses in the withdrawal of the sea from a maximum rise of 90 to 100 feet. References to the Wicomico shore line will be made in terms of early and late stages, which are comparable to differences between the Silver Bluff and Recent shores.

The highest shore line Flint could recognize north of Georgia he named the Surry scarp, and he determined the altitude of its toe as being between 90 and 100 feet. This is undoubtedly the shore line that had been known previously as the Wicomico. The scarp was traced by Flint from the James River to a point in the north-central part of the Pineland quadrangle (3) of South Carolina and Georgia. The Pineland quadrangle is shown in its proper position on the map, and the southernmost extension of the Wicomico scarp as traced by Flint is indicated by an arrow. The Wicomico scarp at this point appears to have been an intracoastal shore line, at least in its late stages, judging from the way a series of offshore bars appears to diverge from it to the north. Between the Savannah River and the Altamaha River, the Wicomico shore line is very irregular, but a good alinement of bars offshore is shown by the 80- and 90-foot contours in the Egypt (5), Meldrim (9), Pembroke (8), and Hinesville (13) quadrangles. This indicates that in late Wicomico time at least a good deal of intracoastal water existed in this area. There appears to have been a weakly projecting cape just north of the present Altamaha River in early Wicomico time, but a sharp cape projected southeastward into the northern part of the Ludowici quadrangle (18) in late Wicomico time. South of the Altamaha River the Wicomico scarp merges with Trail Ridge and is congruent with the Okefenokee scarp as far south as western Duval County, Fla. Well-defined bars were present in late Wicomico time both north and south of the St. Marys River.

The features of the Wicomico shore line attributed to late stages, particularly for the part of the coast north of the Altamaha River in Georgia, strongly recall the present compound coast of North Carolina. This type of coast probably resulted from the inundation of preexisting drainage systems for a short period—not long enough for the sea to have completely destroyed coastal promontories of soft rocks, but long enough for the deposition of flat, terracelike estuarine and adjacent sea floors. With subsequent withdrawal of water, the newly formed shallow floors emerged, and coastal bars typical of shore lines of emergence were constructed.

In Clay, Putnam, and Alachua Counties, Fla., the Wicomico shore line was very irregular; the sea probably inundated valleys in a prominent terrain of weathered Miocene rocks.

The Wicomico shore line follows the east side of a ridge in Marion, Lake, and Orange Counties that is here designated the Orlando ridge. One island was located on this ridge in northern Marion County. From southern Marion County the shore line extended to south-central Orange County, where it formed a pronounced cape southeast of Orlando. From this point the shore line cut back sharply to the west as far as southeastern Lake County and then turned abruptly southward, following the east side of the Lake Wales ridge to a point south of Lake Childs. A narrow bar east of Lake Arbuckle in southeastern Polk County forms the present divide between the Kissimmee River and the drainage into Lake Istokpoga.

The Orlando ridge, passing below the 100-foot contour in southern Orange County, continues with decreasing altitude through eastern Osceola County, northeastern Okeechobee County, and western St. Lucie County into western Martin County. During late Wicomico time a long, narrow peninsula extended as far as southeastern Osceola County. It is probable that the low southern end of the Orlando ridge is younger than the part from Orange County northward and that it grew southward during the retreat of the Wicomico sea. The southern limit of all coastal bars along the eastern coast of Florida probably was and is being extended by slow movement of sand by southward-moving longshore currents.

The Wicomico shore extended from a point south of Lake Childs northward to a point northwest of Sebring and thence irregularly around the uplands of central Florida. Throughout this area it is expressed as a low scarp cut in the older Okefenokee terrace. It extended along the west side of the Orlando ridge from Lake Apopka to central Marion County, where it rejoined the eastern shore line. Large islands were present in Pasco, Hernando, Citrus, Sumter, and Marion Counties. From the vicinity of Gainesville, the Wicomico shore line roughly paralleled the strike of the Miocene beds around the Ocala uplift to Tallahassee.

The Wicomico shore line was irregular in western Florida. A general concordance of points indicates that it extended in a gentle arc north of Choctawhatchee Bay, paralleling the older Okefenokee shore line. In late Wicomico time some well-defined bars were constructed east of the Ochlockonee River in the Smith Creek (88) and Bradwell Bar (89) quadrangles.

PAMLICO SHORE LINE

The Pamlico is the best preserved of the Pleistocene shore lines. It represents an advance of the sea to an altitude of about 25 to 35 feet following the retreat of the Wicomico sea to an unknown depth.

A series of large bars, similar to the present Sea Islands, was present all the way across the Coastal Plain of Georgia. These bars may have impounded a great deal of intracoastal water during early Pamlico time, but it is possible that in late Pamlico time this area was silted in and was largely salt-marsh savannah, similar to the Recent savannahs. At least it is certain that the sharp scarp (pl. 25) extending from southeastern Effingham County to western Camden County, Ga., was an intracoastal shore line and that the coastal shore line was located along bars well to the east in early Pamlico time.

The coastal shore line is very well preserved along the east side of large bars, not far from the present coast, from the St. Marys River to central Flagler County, Fla. Narrow coastal bars extended from southern Brevard County. The long St. Johns River valley was a large intracoastal bay in which there were several large islands. No contour maps are available to show the Pamlico bars south of Brevard County; possibly the intracoastal water joined the open sea in this area.

The shore line of the lagoon in southern Brevard County continued southward through Indian River and St. Lucie Counties and extended around a sharp cape, in southwestern Martin County, that marks the low southernmost end of the Orlando ridge.

From this sharp cape the Pamlico shore line extended around the north side of Lake Okeechobee; it then trended southwestward nearly to the Caloosahatchee River and from that point northwestward toward Sarasota Bay. It is marked by a low scarp cut in the Wicomico terrace in this area. A large, low island existed south of the Caloosahatchee River.

A larger and more open estuary occupied the region of present Tampa Bay. Several islands existed at the time, the largest of which are in Pinellas County, one about on the site of St. Petersburg and two others to the northwest between Seminole and Tarpon Springs. A strait apparently existed across the present site of Lake Butler, and a strong, curved spit extended around the lake's north end. This spit, the Pamlico counterpart of the Recent Anclote Keys, is the last sandy feature along the stretch from southern Pasco County to Lighthouse Point in Franklin County.

During Pamlico time, as now, the shore from Pasco County to Wakulla County was probably muddy or had comparatively small amounts of sand derived from older terraces. The bedrock in this area consists of early Tertiary limestones, exposed by weathering of the Ocala uplift, and was not a source of sand.

Apalachee Bay in Pamlico time extended as far north as southern Leon County, but its shore line swung abruptly southward southwest of Tallahassee along the scarp of the middle Miocene beds on the west side of the Ocala uplift. The west side of Apalachee Bay in Pamlico time thus falls in line with the west side of the Recent bay, and a hooked cape near Medart in the Arran quadrangle (90) corresponds to a similar feature in eastern Franklin County. From this cape, the Pamlico shore line cut across the older Wicomico terrace in a more or less westerly direction. A small arcuate group of islands in the Tates Hell Swamp quadrangle (111) in Franklin County is comparable to islands off the mouth of the Suwannee River and suggests that possibly the Apalachicola River emptied at this locality in Pamlico time. Several high bars along the north side of St. George Sound may or may not have been formed during Pamlico time.

West of the Apalachicola River the Pamlico shore line extended across the Wicomico terrace to a cape at Panama City, and from there westward the coastal shore line can be followed along a series of bars concordant with the present coast. West Bay and Choctawhatchee Bay were large embayments. West of Choctawhatchee Bay the Pamlico bars were along the north side of the Recent Santa Rosa Sound, and intracoastal water was present in the East Bay River inlet and an enlarged Pensacola Bay. West of Pensacola Bay was a series of bars and spits.

SILVER BLUFF SHORE LINE

The name "Silver Bluff" is of comparatively recent usage (Parker and Cooke, 1944). Cooke first used it definitely for the name of a shore line in 1945 (Cooke, 1945, p. 248). Reports of a very late drop in sea level of about 6 to 8 feet, however, have come from worldwide sources. Probably one reason it has not been mapped before is the lack of accurate small-interval topographic maps along the coast. Although the 6- or 8-foot contour would more accurately locate the toe of its scarp, the 10-foot contour brings out its features in sufficient detail for mapping.

The Silver Bluff intracoastal shore line in Georgia is very well marked by the inner edge of the coastal savannahs. The Sea Islands lying outside have a double structure consisting of a higher inner ridge and a lower outer ridge, generally separated by a narrow swamp (pl. 21). The higher inner ridge represents the Sea Islands of Silver Bluff time; the coastal shore line lay along the outer margin of these islands. The strip from 6 to 8 miles wide between these islands and the present inner edge of the savannahs was intracoastal water. The intracoastal zone narrowed in Florida and followed the present course of the Amelia River, the South Amelia River, Sisters Creek, Pablo Creek, Cabbage Swamp, and the Tolomoto River north of its junction with the Guano River. Coastal bars of the Silver Bluff sea are again preserved south of the middle of the Matanzas quadrangle (142) and are present in the northern and also in the southern part of the Ormond quadrangle (145). A few small bars were present near Port Orange and New Smyrna in the Port Orange quadrangle (148). Silver Bluff intracoastal lagoons between the Matanzas quadrangle (142) and New Smyrna occupied narrow, unnamed depressions. South of New Smyrna no accurate topographic maps are available. A part of Merritt Island in Brevard County rises above an altitude of 10 feet, and apparently the Indian River in this area was a lagoon during Silver Bluff time. A cape corresponding to the Recent Cape Canaveral was located on Merritt Island.

The 10-foot contour is shown, also, on topographic maps in western Florida. In this area the Silver Bluff coastal shore line was located along the present intracoastal shore line in places and along the present coastal shore line in others. A large bay existed in southern Gulf and western Franklin Counties, and it appears that the Apalachicola River shifted its course to empty into this depression after having silted up its mouth a little to the east in late Pamlico time. Some well-defined bars are found east of St. Joseph Bay; they curve, curiously, in a direction opposite to Recent St. Joseph Spit. All the present bays in western Florida—St. Andrews Bay, West Bay, Choctawhatchee Bay, and Pensacola Bay—were larger in Silver Bluff time.

The Silver Bluff age might be tentatively correlated with the so-called "climatic optimum" of glacial geologists, botanists, and zoologists, a period about 6,000 to 4,000 years ago when the climate was appreciably warmer than now. For many reasons it is regarded as the peak of the Recent interglacial stage.

RECENT COAST LINE

The closely spaced, often concentric, arrangement of Silver Bluff and Recent features makes it highly probable that present sea level is merely a retreat from the Silver Bluff level. This change, if true, makes an adequate standard for comparing the early and late stages of former retreats of sea level.

The coast line on the Atlantic side in Georgia and Florida is being built up, probably because of the local occurrence of soft reworkable sediments and the large volume of fresh sediments carried to the sea by the Georgia rivers and on southward by longshore currents. In this region practically every Silver Bluff feature has a Recent analog. There is little indication that Recent features mimic Silver Bluff features on the Gulf side, however, and around St. Joseph Bay in western Florida the Recent features depart radically from Silver Bluff forms. At least along the interval from Anclote Keys to the western edge of Apalachee Bay the coast appears to be undergoing destruction, probably because of solution of the clastic-free limestones on the Ocala uplift and the absence of clastic residues.

EVIDENCE OF COASTAL STABILITY DURING THE PLEISTOCENE

Extreme caution has been urged by some physiographers in the correlation of Pleistocene shore lines from place to place, and it is argued that shore lines at the same altitude at widely separated points do not necessarily indicate the continuity of a shore line at that altitude. Most of this caution, at least as far as the Atlantic coastal region is concerned, appears to stem from a foregone conclusion that the coast has been tilted recently and that therefore the terraces and shore lines must be tilted. The basis for this conclusion is probably the concept, now almost classical, that coastwise tilting along an axis close to Cape Hatteras has drowned the coast to the north and elevated the coast to the south.

The study of former shore lines along the Atlantic coast has advanced to the stage where it is no longer dependent on observations at scattered points. These shore lines can be traced for miles on topographic maps with only local gaps, which obviously are made by streams. Furthermore, these maps were prepared by men whose only interest was topography and who were not especially concerned with the significance of the features they were mapping. Not only are the nips and sea cliffs preserved, but it can also be shown that many other coastal features, such as bars, lagoons, spits, and capes, are present and that these are all a part of the abandoned coasts. It is entirely possible that simple scarps might be miscorrelated from place to place, but it is unlikely that one related set of coastal features could be confused with another set that lies wholly separated from it.

The Pamlico (Suffolk) and Wicomico (Surry) scarps were found by Flint to maintain their altitudes from the James River in Virginia to the Savannah River. The present writer has found that the shore-line scarps in Georgia and Florida do not appear to deviate from their altitudes in any significant degree and that any possible coastal warping involving the middle and late Pleistocene shore lines must be a matter of inches or a few feet, never enough to make one shore line indistinguishable from another.

It seems to this writer that continental tilting does not imply that Pleistocene shore lines have been tilted and that the only bearing the altitude of the shore lines might have on the continental tilting would be to date it tentatively. Continental warping or tilting is certainly indicated by the distribution of the Cretaceous to Miocene sediments of the Atlantic Coastal Plain, which extend to altitudes high above present sea level in the south but are known to lie below sea level off the coast of New England. The Pleistocene shore lines from Maryland southward are not tilted, however, so that the continental tilting does not appear to be of Recent date.

Some of the bays that indent the coasts of North Carolina, Virginia, and Maryland are carved in late Tertiary sediments and were excavated subsequent to the deposition of the high-terrace gravels, which are of Pliocene or early Pleistocene age. It is suggested that these bays are drainage systems that were excavated during the Pleistocene glacial stages when the sea stood far below present sea level. The lack of deep embayments along the south Atlantic coast suggests that the rivers of the south were aggrading their beds while the rivers of the north were cutting theirs. The drainage systems of the North Carolina, Virginia, and Maryland coasts are now inundated simply because of the rise of sea level due to the melting of glacial ice.

The large embayments of western Florida (Pensacola Bay, Choctawhatchee Bay, St. Andrews Bay, and others) and of southwestern peninsular Florida (such as Tampa Bay and Charlotte Harbor) have likewise been considered evidence of Recent subsidence of the land. Stumps standing a few feet off shore in western Florida have been taken to indicate that the land is being inundated. If, however, the Recent shore line is a retreat from the Silver Bluff level, another explanation is needed. Stumps could be left standing in water by the cutting back of a forested shore without land subsidence and even with land emergence, if the rate of cutting was greater than the rate of emergence. It seems more likely that these embayments also are middle and late Pleistocene drainage systems and that they were drowned more than once during Pleistocene time, not as a result of land subsidence, but as a result of the oscillation of sea level. During Wisconsin glaciation streams flowed through them and they were probably cut deeper, whereas during Silver Bluff time the water in them was deeper than now.

PLEISTOCENE SHORE LINES AND PHOSPHATE DEPOSITS

This investigation was undertaken to determine whether any part of the land pebble phosphate deposits of Florida is of Pleistocene age. The main body of the phosphate deposits, together with subsidiary sand and clay, constitutes the Bone Valley formation, now known to extend over southern and western Polk County, eastern Hillsborough County, and northern Hardee and Manatee Counties, Fla. Leached areas of the underlying Hawthorn formation, here a limestone, also are mined for phosphate. Owing to erosion, the Bone Valley formation terminates in a feather edge to the west and to the north but, according to information obtained by drilling, passes into less phosphatic beds to the east and to the south. The Bone Valley formation has been assigned to the Pliocene on the basis of land and marine mammals contained in it. It has been correlated with the Caloosahatchee marl of southern Florida, and the Caloosahatchee marl contains a large molluscan fauna that has been the standard for the Pliocene in the eastern United States for many years.

Vernon (1943, p. 156) states that the phosphate deposits are confined beneath terraces, "one with flats developed near 100 feet above sea level, one with flats near 150 feet, and possibly a third in the land pebble field, that are approximately 212 feet above sea level. * * * These terraces are separated by escarpments and have been described in detail by Cooke, who believed them to be remnants of former marine plains." Vernon states further that "the fact that phosphate occurs in at least two different beds indicates that the accumulation of Florida phosphate rock was not during one phase, as believed by most writers, but during at least two, and probably more."

Although no geologic age is mentioned, this is clearly an assignment of the Bone Valley formation to the Pleistocene and an assertion that, instead of being a single deposit, it consists of separate formations deposited during different interglacial periods.

Work on the phosphate deposits by the United States Geological Survey began in 1948 under the direction of the writer and continued under J. B. Cathcart, Jr. Isopach maps and cross sections were prepared from information supplied by mining companies, current drilling was observed, and pits were examined, but the existence of several phosphate-bearing terrace deposits has not been verified. Instead, the phosphate gravels appear to be a continuous beach placer deposit resting disconformably on a very irregular limestone surface. The underlying limestone also contains phosphate nodules; where leached, it forms a deposit of high commercial value, rich in flotation-sized particles. No breaks in the extent or altitude of the phosphate gravels were detected at either the 100- or the 150-foot contour, and the phosphate was found to extend under the high hills above 150 feet as well as under the adjacent Okefenokee terrace. The phosphate gravels terminate abruptly at the Pamlico shore line, however, apparently because of destruction by the Pamlico sea, and the Pamlico terrace deposit contains at its base a thin conglomerate of reworked phosphate, washed clean, which is of no commercial value.

The oldest shore line, at 150 feet, is correlated with the Yarmouth interglacial stage. It is possible that deposits of the Aftonian interglacial stage are present in central peninsular Florida but that they have no physiographic expression. If so, the phosphate gravel could be of early Pleistocene age, but all of it must be of this age. Evidence of fossil mammals indicating a Pliocene age for the marine deposits is considered stronger than the mere possibility of early Pleistocene age. A few alluvial phosphate deposits, no longer of commercial importance, contain a mixture of Pleistocene and reworked Pliocene fossils and presumably were reworked by Pleistocene streams.

REFERENCES CITED

Barton, D. C., 1930, Deltaic coastal plain of southeastern Texas: Geol. Soc. America Bull., vol. 41, no. 3, pp. 359–382.

Berry, E. W., 1916, The flora of the Citronelle formation: U. S. Geol. Survey Prof. Paper 98–M, pp. 193–208.

Cooke, C. W., 1925, Physical geography of Georgia: Georgia Geol. Survey Bull. 42.

———, 1941, Two shore lines or seven?: Am. Jour. Sci., vol. 239, no. 6, pp. 457–458.

———, 1945, Geology of Florida: Florida Geol. Survey Bull. 29.

Doering, John, 1935, Post-Fleming surface formations of coastal southeast Texas and south Louisiana: Am. Assoc. Petroleum Geologists Bull., vol. 19, no. 5, pp. 651–688.

Fisk, H. N., 1940, Geology of Avoyelles and Rapides Parishes: Louisiana Dept. Cons. Geol. Bull. 18.

———, 1945, Pleistocene age of the "Citronelle" [abstract]: Geol. Soc. America Bull., vol. 56, no. 12, pt. 2, pp. 1158–1159.

Flint, R. F., 1940, Pleistocene features of the Atlantic Coastal Plain: Am. Jour. Sci., vol. 238, no. 11, pp. 757–787.

———, 1942, Atlantic coastal "terraces": Washington Acad. Sci. Jour., vol. 32, no. 8, pp. 235–237.

———, 1947, Glacial geology and the Pleistocene epoch, New York, John Wiley & Sons.

Johnson, D. W., 1919, Shore processes and shore-line development, New York, John Wiley & Sons.

Leverett, Frank, 1934, Glacial deposits outside the Wisconsin terminal moraine in Pennsylvania: Pennsylvania Geol. Survey, 4th ser., Bull. G–7.

Lobeck, A. K., 1939, Geomorphology, New York, McGraw-Hill Book Co.

MacNeil, F. S., 1947, Geologic map of the Tertiary and Quaternary formations of Georgia: U. S. Geol. Survey Oil and Gas Investigations Preliminary Map 72.

Matson, G. G., 1916, The Pliocene Citronelle formation of the Gulf Coastal Plain: U. S. Geol. Survey Prof. Paper 98–L, pp. 167–192.

Parker, G. G., and Cooke, C. W., 1944, Late Cenozoic geology of southern Florida: Florida Geol. Survey Bull. 27.

Price, W. A., 1947, Geomorphology of depositional surfaces: Am. Assoc. Petroleum Geologists Bull., vol. 31, no. 10, pp. 1784–1800.

Roy, C. J., 1939, Type locality of the Citronelle formation, Citronelle, Ala.: Am. Assoc. Petroleum Geologists Bull., vol. 23, no. 10, pp. 1553–1559.

Veatch, J. O., and Stephenson, L. W., 1911, Geology of the Coastal Plain of Georgia: Georgia Geol. Survey Bull. 26.

Vernon, R. O., 1943, Florida Minerals Industry: Florida Geol. Survey Bull. 24.

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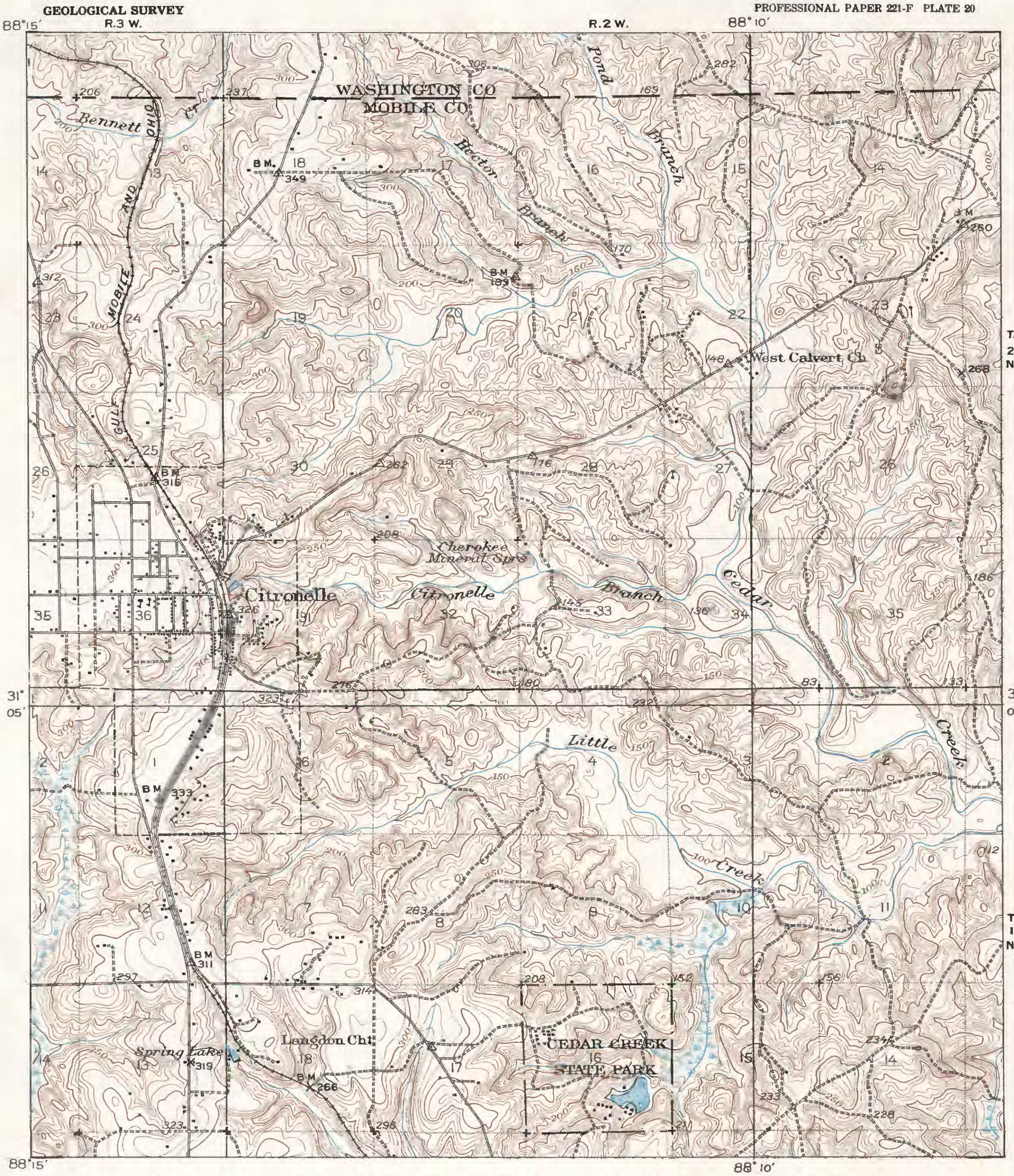


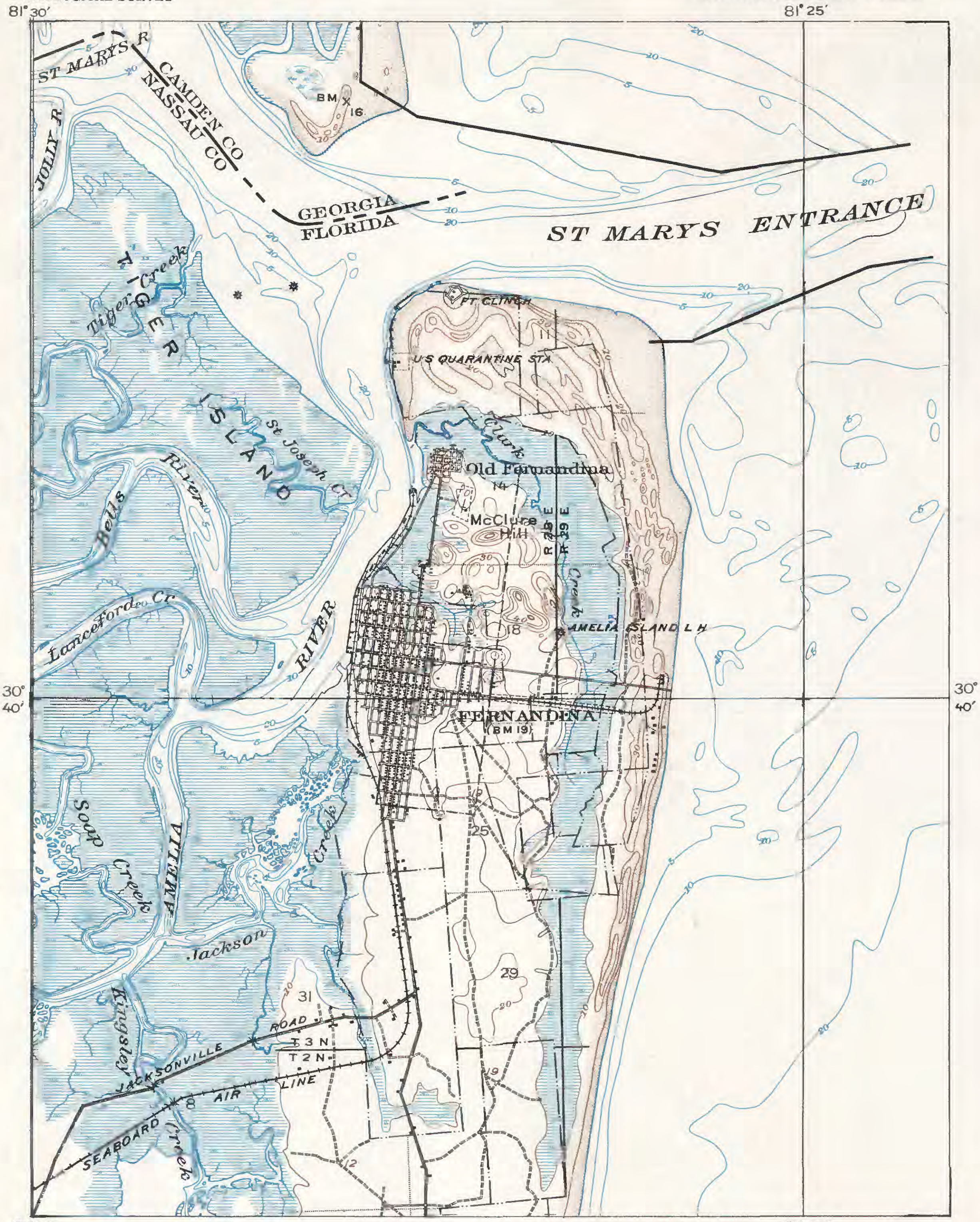
PART OF CITRONELLE QUADRANGLE SHOWING REMNANTS OF HIGH TERRACE.

Scale $\frac{1}{62500}$

1 ½ 0 1 2 3 4 Miles

Contour interval 10 feet

Datum is mean sea level



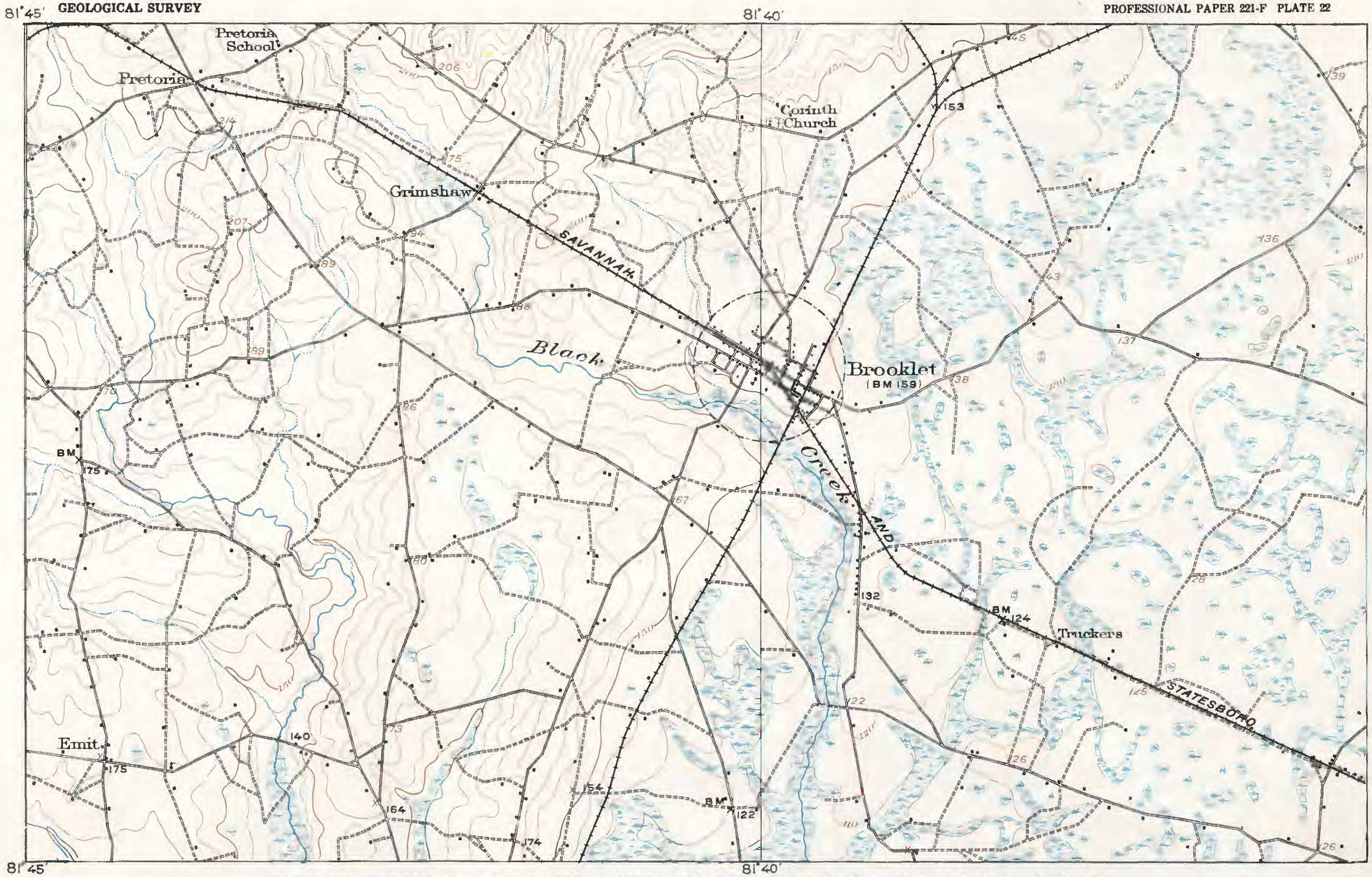
PART OF FERNANDINA QUADRANGLE SHOWING SILVER BLUFF LAGOON AND BAR (BROAD SAVANNAH AND INNER RIDGE) AND THE RECENT LAGOON AND BAR (NOW FILLED IN).

Scale $\frac{1}{62500}$

1 ½ 0 1 2 3 4 Miles

Contour interval 10 feet

Datum is mean sea level



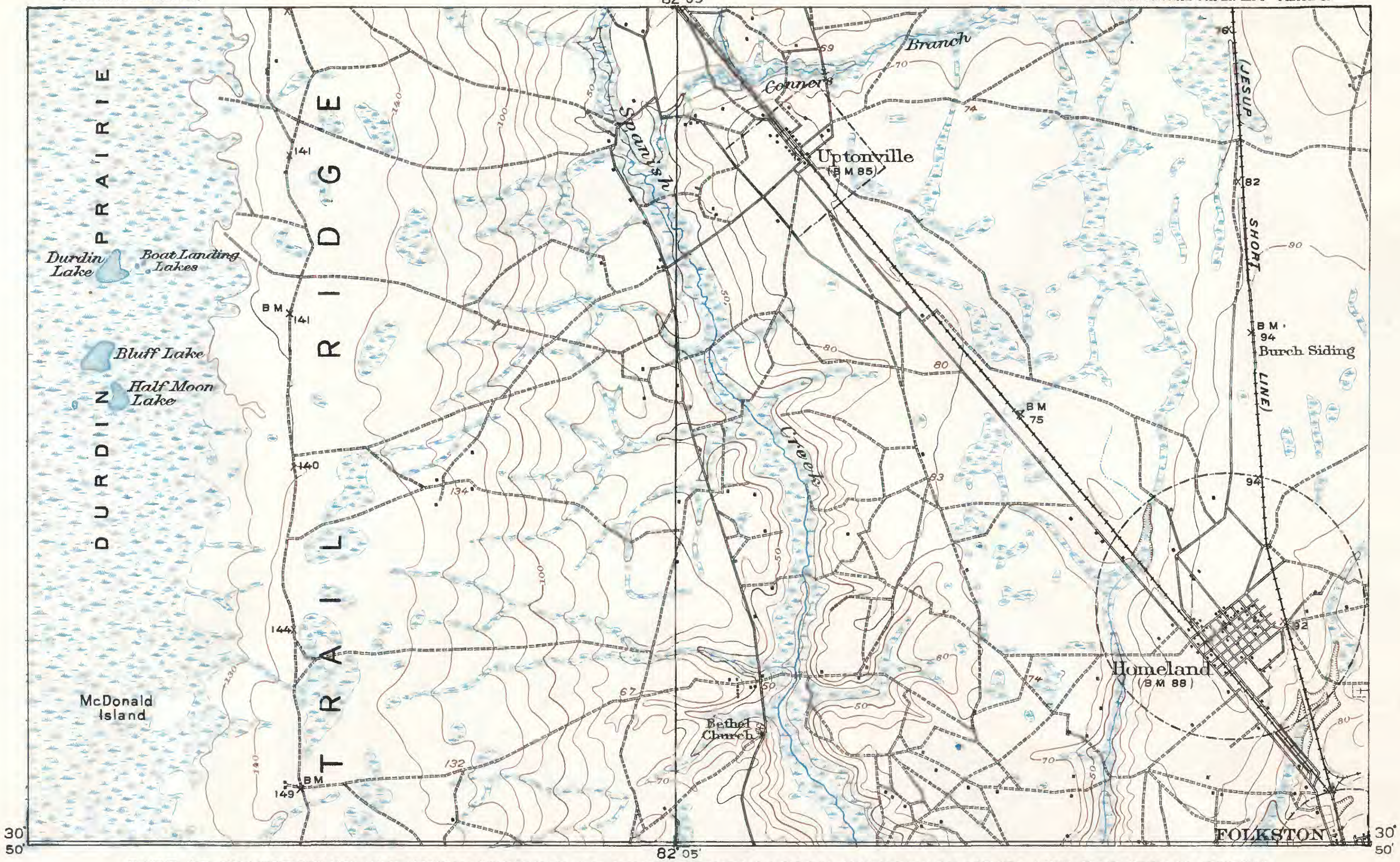
PART OF BROOKLET QUADRANGLE SHOWING UPPER PART OF OKEFENOKEE TERRACE AND OKEFENOKEE SHORE LINE ALONG DISSECTED MIOCENE TERRAIN.

Scale $\frac{1}{62500}$

1 ½ 0 1 2 3 4 Miles

Contour interval 10 feet.

Datum is mean sea level.



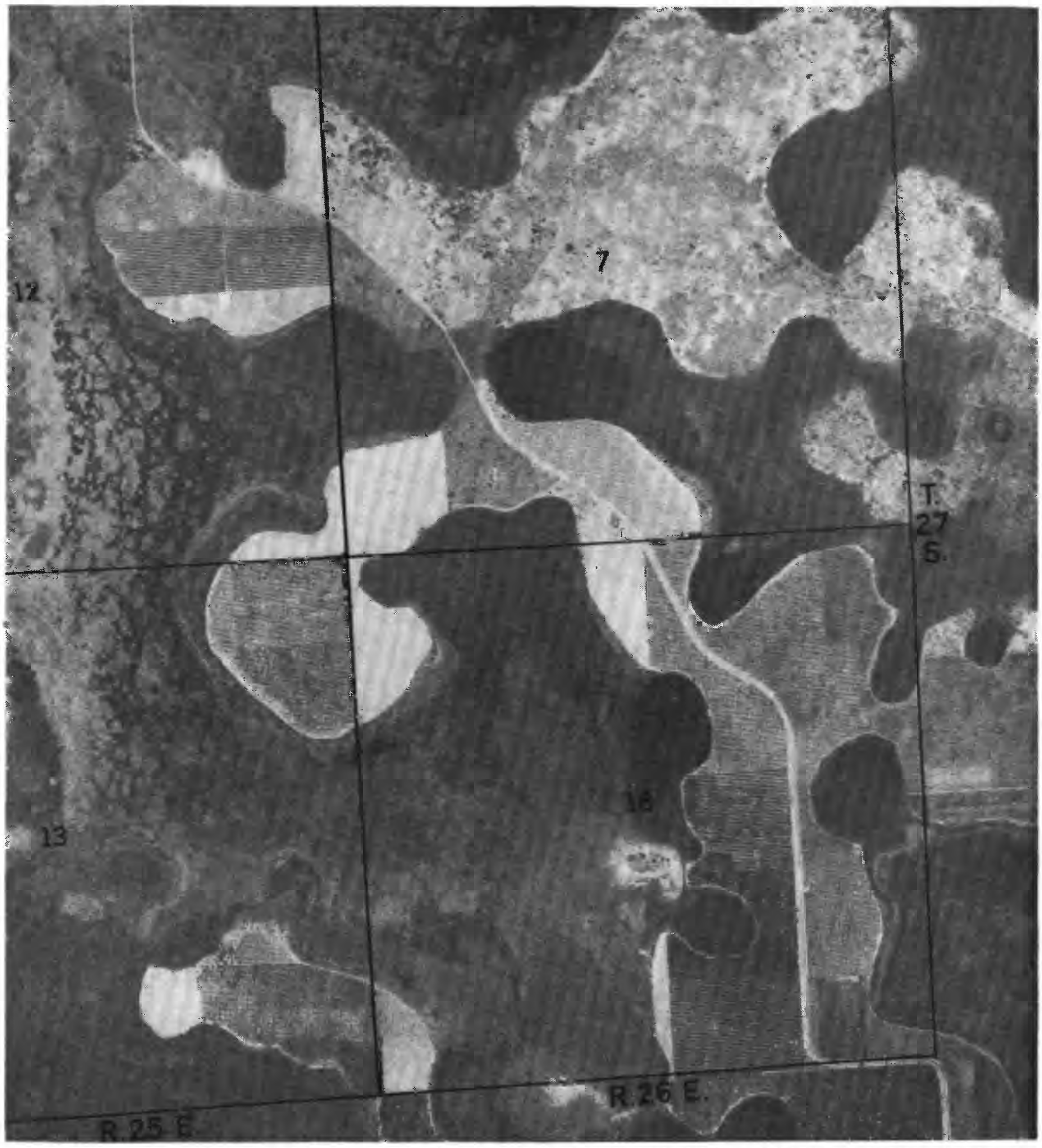
PART OF FOLKSTON QUADRANGLE SHOWING AN OKEFENOKEE LAGOON (DURDIN PRAIRIE) AND BAR (TRAIL RIDGE), PROBABLY SUBMERGED IN THIS AREA, AND A WICOMICO LAGOON AND BAR TO THE EAST.

Scale $\frac{1}{62500}$

1 ½ 0 1 2 3 4 Miles

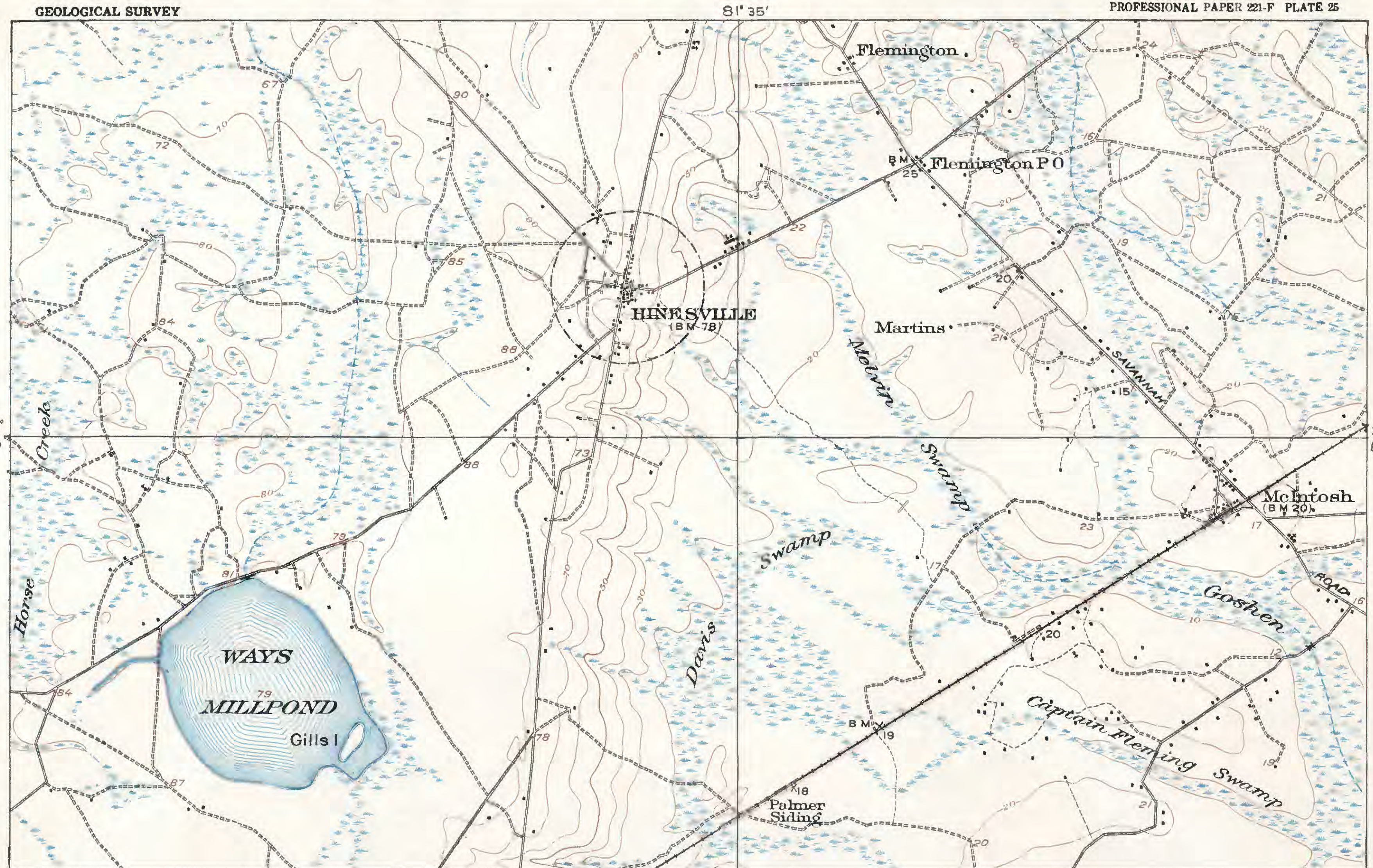
Contour interval 10 feet.

Datum is mean sea level.



AERIAL PHOTOGRAPH SHOWING WAVE-WASHED BARS ON THE OKEFENOKEE TERRACE, POLK COUNTY, FLA.

These bars were formed by marine abrasion of small promontories of older terrain.



PART OF HINESVILLE QUADRANGLE SHOWING UPPER PART OF PAMLICO TERRACE, PAMLICO SHORE LINE SCARP, AND LOWER PART OF WICOMICO TERRACE.

Scale $\frac{1}{62500}$

1 ½ 0 1 2 3 4 Miles

Contour interval 10 feet

Datum is mean sea level