

FLORIDA STATE GEOLOGICAL SURVEY

HERMAN GUNTER, *State Geologist.*

BULLETIN No. 7

THE PENSACOLA TERRACE AND ASSOCIATED BEACHES AND BARS IN FLORIDA

By FRANK LEVERETT

TALLAHASSEE, FLORIDA,
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LETTER OF TRANSMITTAL

*To His Excellency, Hon. Doyle E. Carlton,
Governor of Florida.*

SIR: I have the honor to submit herewith for publication as Bulletin 7 of this Department a report entitled "The Pensacola Terrace and Associated Beaches and Bars in Florida" by Dr. Frank Leverett, of Ann Arbor, Michigan. Dr. Leverett was a member of the staff of the United States Geological Survey from 1886 to his retirement in 1929, and during that time became recognized as an authority on the glacial geology of the northeastern United States. Among his leading studies was that of tracing ancient shore-lines and terraces in the vicinity of the Great Lakes, and he has published many papers on the subject.

Since his retirement he has spent his winters in Florida, and studied the marine terraces which can be seen a few to several miles back from the present shore-line at a number of localities, indicating that the ocean level was higher than now in comparatively recent times. The present bulletin, which Dr. Leverett has kindly prepared for us without remuneration except for necessary traveling expenses, deals with the lowest and most clearly marked of these terraces, which has been named the Pensacola terrace.

Although the location of this terrace is still indefinite in places, owing to the lack of topographic data and the inaccessibility of portions of the country traversed by it, the results already obtained are deemed of sufficient interest to be presented at this time for the benefit of students of physiographic problems.

This terrace is of more than academic interest. On it are located all our seaport cities, and on account of its level nature it is peculiarly adapted to intensive scientific farming, and agricultural practices there are quite different from those prevailing on the uplands of the State. At Dr. Leverett's suggestion a chapter has been appended showing some of the ways in which the Pensacola terrace differs from the rest of the State in population, agriculture, etc. This chapter was prepared by Dr. R. M. Harper, Geographer, whose intimate knowledge of such facts peculiarly fits him for making such a contribution.

Respectfully,

HERMAN GUNTER,
State Geologist.

Tallahassee, Florida,
June 9, 1931.



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THE PENSACOLA TERRACE AND ASSOCIATED BEACHES AND BARS IN FLORIDA

By FRANK LEVERETT, Senior Geologist (Retired),
U. S. Geological Survey.

INTRODUCTORY STATEMENT

The writer's studies in Florida, and in parts of the Gulf Coast farther west, have been undertaken for the purpose of determining whether one of the best-defined raised beaches, that bordering the Pensacola terrace, has been subjected to differential uplift, or instead holds a uniform altitude above sea level throughout the district examined. The determination of the probable length of time since the Pensacola terrace became exposed has also been a leading object, for on this terrace have been found remains of several extinct species of animals closely associated with human remains. The state of preservation of the Pensacola shore-line and the degree of erosion of the Pensacola terrace have received close attention. In such study the writer has drawn comparisons with results of work on the shore-lines and terraces around the Laurentian Great Lakes, the approximate ages of which have been determined.

Concentration of study on the Pensacola terrace and associated beaches and bars is due partly to the brief period of time available for the investigation, and partly to the fact that higher terraces and shore-lines have become so broken down and toned down by erosion and solution in much of the region covered as to make continuous tracing and correlation difficult and uncertain. This was found to be the case even where excellent topographic maps are available.

No attempt is made here to review the literature pertaining to the Pleistocene features and deposits of the Atlantic and Gulf coastal plains. Much of it is fragmentary, as the studies were usually taken up incidentally in connection with studies of underlying older formations. The literature pertaining to the Pensacola terrace and shore-line is embraced in a few references. The name Pensacola was applied to the terrace by Matson in 1913, and is interpreted by him to merge with the Satilla formation in Georgia.¹ Both are said to be below 40 feet above present sea level. The Pensacola terrace and Satilla formation are discussed by Cooke in recent papers on the Pleistocene Sea

¹George C. Matson, Water Supply Paper 319, U. S. Geol. Survey, 1913, pp. 34-35. For discussion of the Satilla formation see Veatch and Stephenson, Bull. Geol. Survey of Georgia No. 26, 1912, pp. 334-445.

Shores.² These papers deal mainly with features on the Atlantic coastal plain from Georgia northward, but the interpretation of terraces given, namely, that they show no tilting, or deformation, is inferred to have application in Florida, and on the Gulf coast farther west.

Two important papers on features of the Gulf coast in eastern Texas, recently brought out by Barton,³ have an important bearing on the extension of the Pensacola terrace and shore-line.

In determining the altitude of the Pensacola shore-line several sources of information have been drawn upon. For northeastern Florida the topographic maps of the U. S. Geological Survey with 10-foot contours have been used. For western Florida around Pensacola Bay the Fire Control maps of the U. S. Army Engineers with 10-foot contours have been found useful. For the St. Johns River drainage, maps and profiles by the U. S. Army Engineers, and for the region around Lake Okeechobee maps by the U. S. Army Engineers and lines of levels by the Commissioners of the Everglades District have been very useful. Data on Collier and Hendry Counties have been supplied by D. Graham Copeland of Everglades, Engineer of the Florida Development Company. In many cases state and county highway profiles have furnished data, and in Tampa and St. Petersburg bench marks given by city engineers. In some cases soil maps by the Bureau of Soils, U. S. Department of Agriculture, have been found to denote the position of the shore by a peculiar class of soil. These sources of information when combined with field observations have served to give a fairly accurate knowledge of the position and altitude of the old shore-line.*

The Pensacola shore-line or scarp is easily traced where it has been cut into a slope sufficiently steep to permit strong wave action. There are, however, parts of Florida in which roads are so few that considerable sections have not been accessible. In places where the land has a very gentle seaward slope it has been found difficult to determine the limits of the Pensacola sea, as scarps are indefinite or wanting. Where altitudes are available its theoretical position can be fixed, but elsewhere in these flat areas the position of this old sea shore can only

²C. Wythe Cooke, *Pleistocene Sea Shores*, Jour. Wash. Acad. Sci. Vol. 20, 1930, pp. 389-395. Correlation of Coastal terraces, Jour. Geol. Vol. 38, 1930, pp. 577-589.

³Donald C. Barton, *Deltaic Coastal Plain of Southeastern Texas*, Bull. Geol. Soc. America, Vol. 41, 1930, pp. 359-382. *Surface Geology of Coastal Southeast Texas*, Bull. Am. Assoc. Petroleum Geologists, Vol. 14, 1930, pp. 1301-1320.

*Since this report was submitted for publication I have had the privilege of a trip with Prof. D. W. Johnson, of Columbia University, over part of the Pensacola terrace and shore-line in Florida and in neighboring states. He thinks the attempt to fix the sea level so definitely as is done in this report may not be warranted, for in many places it is a difficult matter to determine so exactly where it stood. The altitudes given should thus be taken as tentative and approximate.

be conjectured. But in spite of this indefiniteness of the coastal features in some places, the position as indicated on the map is likely to be within a very few miles of the actual extent of this former sea.

The stage of the sea at the time it covered the Pensacola terrace seems appropriately called the Pensacola stage, and the beach and scarp on its border the Pensacola shore-line.

THE PENSACOLA SHORE-LINE

POSITION ON ATLANTIC COAST OF FLORIDA.

Before beginning the description of this shore-line a few remarks seem necessary concerning the difficulty in some places of distinguishing between bluffs or scarps cut by waves and those cut by streams. In places the scarp cut by the sea has been modified by subsequent stream action. In other cases, of which there are notable instances near Palatka and along the borders of the St. Johns River between Palatka and Sanford, the stream action appears to have preceded marine action and cut into a plain in such a way as to leave island-like remnants. The wide spaces between such remnants were probably cut out by stream action rather than by marine, the marine action being restricted to a moderate notching of the borders of these higher tracts, causing steeper scarps. No attempt has been made to work out the fluvial history that preceded the occupancy of the area by the Pensacola Sea.

In Nassau County, the northeasternmost county of Florida, a bay of the Pensacola sea extended up the St. Marys valley some 25 miles, but it was only one to two miles in general width, and the bluffs clear down to Boulogne rose considerably above the level of the sea, which at that locality appears to have been about 40 feet above present sea level. This valley no doubt has had considerable modification by the river since the sea withdrew. About 3 miles below Boulogne the shore turns away from the St. Marys valley and bears southward across Nassau County, passing east of Hilliard and west of Callahan and entering Duval County near Plummer. It continues a course east of south across Duval County, passing near Cambon and Marietta and entering Clay County about 6 miles west of the St. Johns River. There was, however, an island in the northeastern part of Clay County, 2 to 3½ miles west of the St. Johns River, and another bordering Doctor's Lake, which occupies a recess of the St. Johns valley. This island lies west of the Atlantic Coast Line Railroad near Peoria station. These islands probably were developed by river action prior to the marine occupancy. Back of these islands, as may be seen by reference to the Middleburg topographic map of the U. S. Geological Survey, there

were extensions of the sea some miles up tributaries of Black Creek, covering areas below the 40-foot contour. South of Black Creek the shore bears eastward and crosses the southwest corner of the Orange Park quadrangle.

The part of the shore thus far traced, down to latitude 30° , is covered by the Boulogne, Hilliard, Cambon, Middleburg and Orange Park topographic maps of the U. S. Geological Survey, and the limits are quite definitely fixed, as they fall near the 40-foot contour on these maps.

The part of the shore between latitude 30° and latitude $29^{\circ} 45'$ is not covered by topographic maps, but it lies just west of the Atlantic Coast Line Railroad from Green Cove Springs about to Bostwick station. Between Bostwick and Rice Creek stations the railway crosses a cape-like spur which extended out to the edge of the St. Johns valley. A part of this spur appears in the north part of the Palatka topographic map. A large island directly west of Palatka is also shown on this map, as well as an island east of the St. Johns River at San Mateo, and a large area east of the river between it and Crescent Lake. All of these seem to be residual of a plain that had been eroded by river action. The extent of the Pensacola sea westward from the St. Johns River from latitude $29^{\circ} 30'$ to $29^{\circ} 45'$ is shown on the Interlachen topographic map. There were bays extending some miles up the Ocklawaha valley and some of its tributaries, but high land borders the river closely on the south in the Ocala National Forest.

In Figure 1 the Pensacola shore-line is near the 40-foot contour. The map shows the youthful condition of drainage on the Pensacola terrace below the shore-line, drainage lines being few and the surface wet although there is a descent of 20 feet on the terrace within a space of only a mile. A higher Pleistocene shore-line, the Newberry, probably follows the base of the ridge below the 110-foot contour.

The limit of the Pensacola Sea appears to be near the west bank of the St. Johns River and Lake George throughout the length of the Ocala National Forest, though the sea probably extended back over the basin of Lake Kerr and up Juniper (Sweetwater) valley. The extent of the sea in northern Lake County is fairly well marked by a change in soil and drainage conditions. Referring to the soil map, the "Portsmouth fine sand" seems to have been covered almost entirely by the sea, while the areas of "Lakewood fine sand" and "St. Lucie sand" west of it were mainly above its limits. This places the shore from 1 to 4 miles west of the St. Johns River from the northern end of the county as far south as the Wekiva River. There seem to have been narrow bays extending up Blackwater Creek as far at least as Lake Norris, and up the Wekiva River as far as Wekiva Springs in Seminole

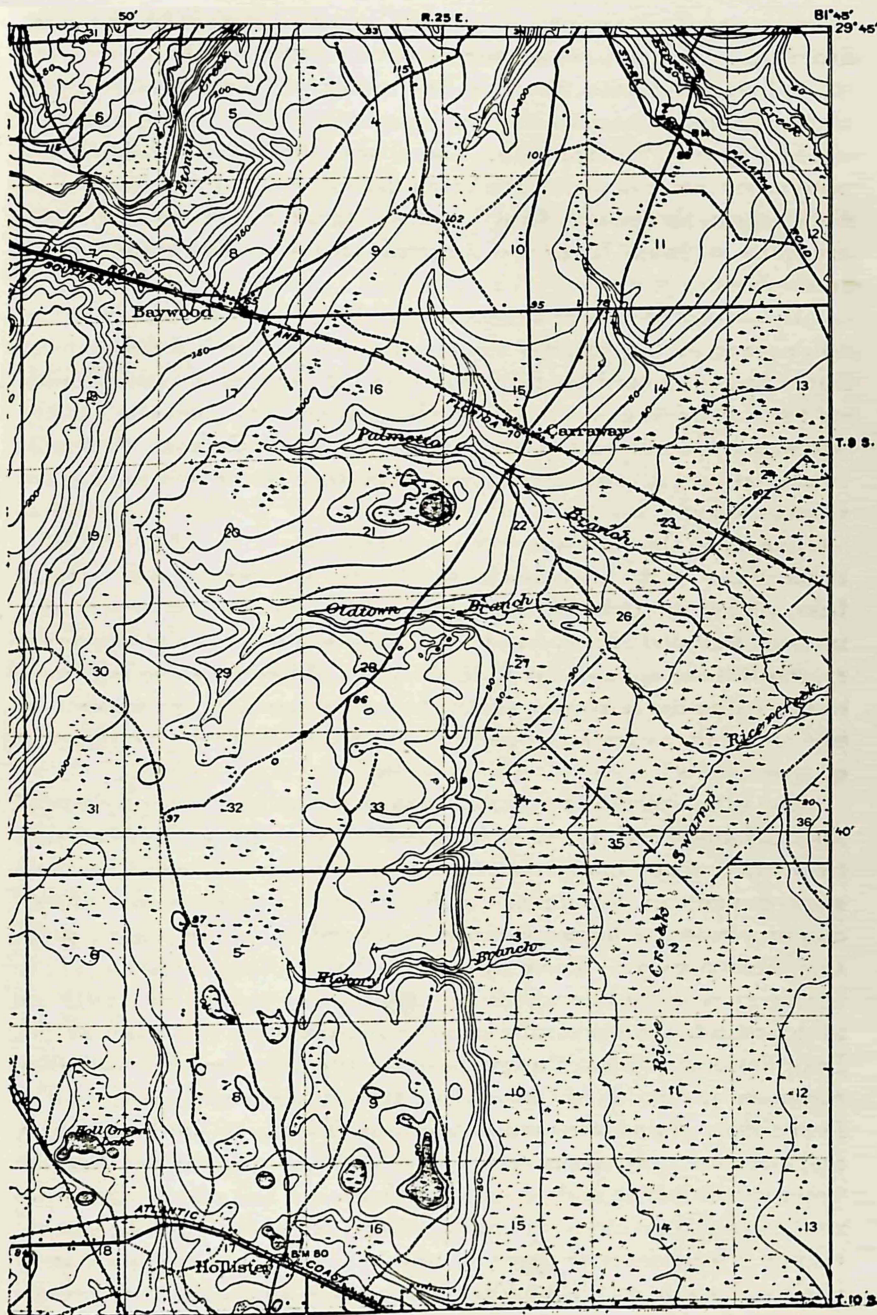


FIGURE 1. Topographic map of part of the Interlachen quadrangle, U. S. Geol. Survey, showing the Pensacola shore-line running about north and south near the center, (Putnam County.)

County, and Rock Springs in Orange County, with an extension north from Rock Springs into southern Lake County.

In Seminole County the shore had rather large bays between which were prominent extensions. These perhaps are old stream meanders antedating the Pensacola Sea. There was a bay around Lake Jessup with an extension of about 8 miles south from the St. Johns River and a width of similar amount. West of it at a distance of only about two miles from the St. Johns River was a prominence extending from Sanford to the Wekiva River, while east of it was a cape-like projection terminating at Lake Harney and the St. Johns River near Osceola. South of this cape was a long narrow bay now drained by the Econlockhatchee River (locally known as Econ River) which extended fully 30 miles up the Econlockhatchee valley across southeastern Seminole County, and at least 15 miles into Orange County. A branch from it extended southwestward up the Little Econlockhatchee River into the edge of Orange County.

In eastern Orange County the Pensacola sea extended 6 to 10 miles or more west of the St. Johns River. There are what seem to be small bars, classed as "Orlando fine sand" on the Orange County soil map, immediately west of the wet plain of "Bladen fine sand" bordering the river. But the sea appears to have extended beyond these bars some distance into the level area of "St. Johns fine sand." The water there was probably too shallow for effective wave action, or the development of a distinct scarp.

The extent of the Pensacola sea west of the headwater portion of the St. Johns River is fairly well indicated on an unpublished map by the U. S. Army Engineers of the part above Lake Monroe, based on a survey made in 1903 under the direction of Capt. Francis R. Shunk, and supplemented by maps of the U. S. Land Survey and charts of the U. S. Coast Survey.⁴ The border of the Pensacola sea appears to have been very near the line where the map shows a change from wet land to drier land. The line runs into Osceola County 7 or 8 miles west of Lake Poinsett and takes a south-southeast course for about 20 miles, coming near the line of Osceola and Brevard counties directly east of Deer Park. It then runs southward near this county line for 10 miles, and passes east of south across the southwest township of Brevard County. Its course is then southward through the middle of the two westernmost townships of Indian River County into Okeechobee County. It passes near the southwest corner of Indian River County north of Fort Drum. From there its course is south-southeast through eastern Okeechobee, and southwestern St. Lucie County nearly to

⁴This map was prepared to accompany a report of June 22, 1904, to the Chief Engineers, U. S. Army. With it are several profiles across this part of the river basin.

Indiantown in Martin County. In the last 20 miles it forms the east border of a narrow peninsula that lay east of the north part of the Lake Okeechobee basin. Before continuing the description of its course across from the Atlantic to the Gulf coast, the islands east of the St. Johns River will be taken up.

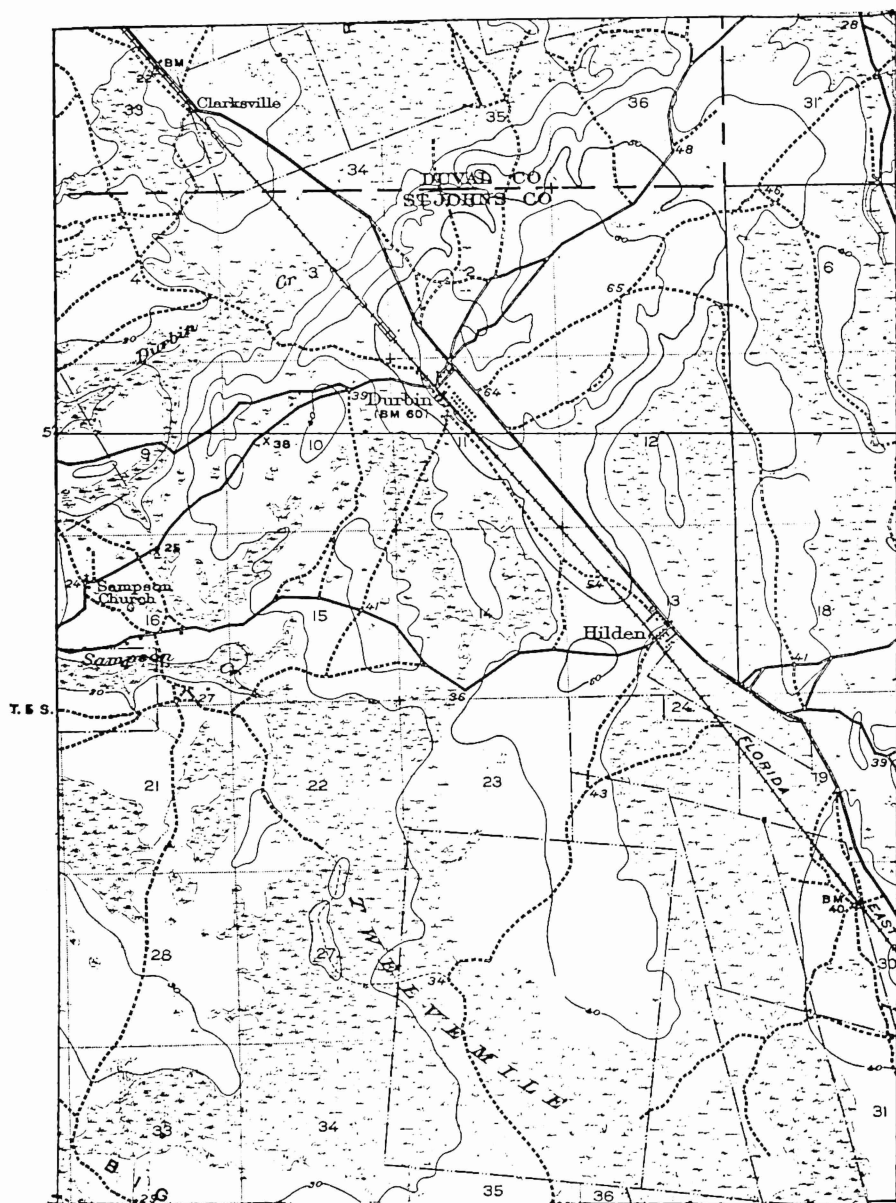


FIGURE 2. Part of the Palm Valley quadrangle, U. S. Geol. Survey, showing an island in the Pensacola sea near Durbin, and neighboring Pensacola bars.

ISLANDS AND OFF-SHORE BARS ON THE ATLANTIC COAST.

There are a number of places shown on the topographic maps of the St. Marys, Jacksonville, Mayport, Palm Valley, and Orange Park quadrangles where slender ridges about parallel with the present coast rise above the 40-foot contour, while the swales separating them are usually below that contour. These are interpreted to be off-shore bars on shoals of the Pensacola sea, formed by its waves. There are in these quadrangles small areas that rise above 50 feet and one near Durbin in the Palm Valley quadrangle shown in Figure 2 reaches 70 feet. Some of those which reach 50 feet are dunes, or sand ridges formed by wind action, as is evident from their form as well as structure, but they are probably on bars of the Pensacola sea. There are other areas with plain or smooth surface which appear to have been islands that were not covered by the Pensacola waters. The most conspicuous within the quadrangle mentioned is the area around Durbin, which embraces 3 or 4 square miles of which about 3 square miles stand above 50 feet.

Directly east of Jacksonville, on the east side of the St. Johns River, is an area of several square miles with points rising above 50 feet, which appears to have been an island. Its surface does not have pronounced dune topography and it may have been slightly raised by wind deposit. A long narrow strip, a part of which is shown in Figure 3, runs north and south through the southeast part of the Jacksonville and northeast part of the Orange Park quadrangles. This is generally above 50 feet and at one place reaches 80 feet. This has the topography of a strip of dunes, but as the base of the sand ridges is generally above 50 feet, this strip appears to have been a slender island standing above the Pensacola sea. East of it are several bars standing near the 40-foot contour, as shown in Figure 3, which appear referable to the Pensacola Sea.

There is a small area of old dunes near Jacksonville of still greater prominence. It is located east of the Prison Farm north of the St. Johns River and has points above 100 feet. This may have been heaped up after the withdrawal of the Pensacola waters, and perhaps there was no island there in Pensacola time. The same is the case with old dunes near Riverview in the western part of the Jacksonville quadrangle and of some old dunes forming "St. Johns Bluff" near the mouth of the St. Johns River in the Jacksonville and Mayport quadrangles, also of old and modern dunes near Fernandina. A small strip of land near Evergreen School in northern Nassau County in the northwest part of the St. Marys quadrangle, which has points above 60 feet, may have been an island whose altitude has been increased somewhat by sand deposits due to wind action.

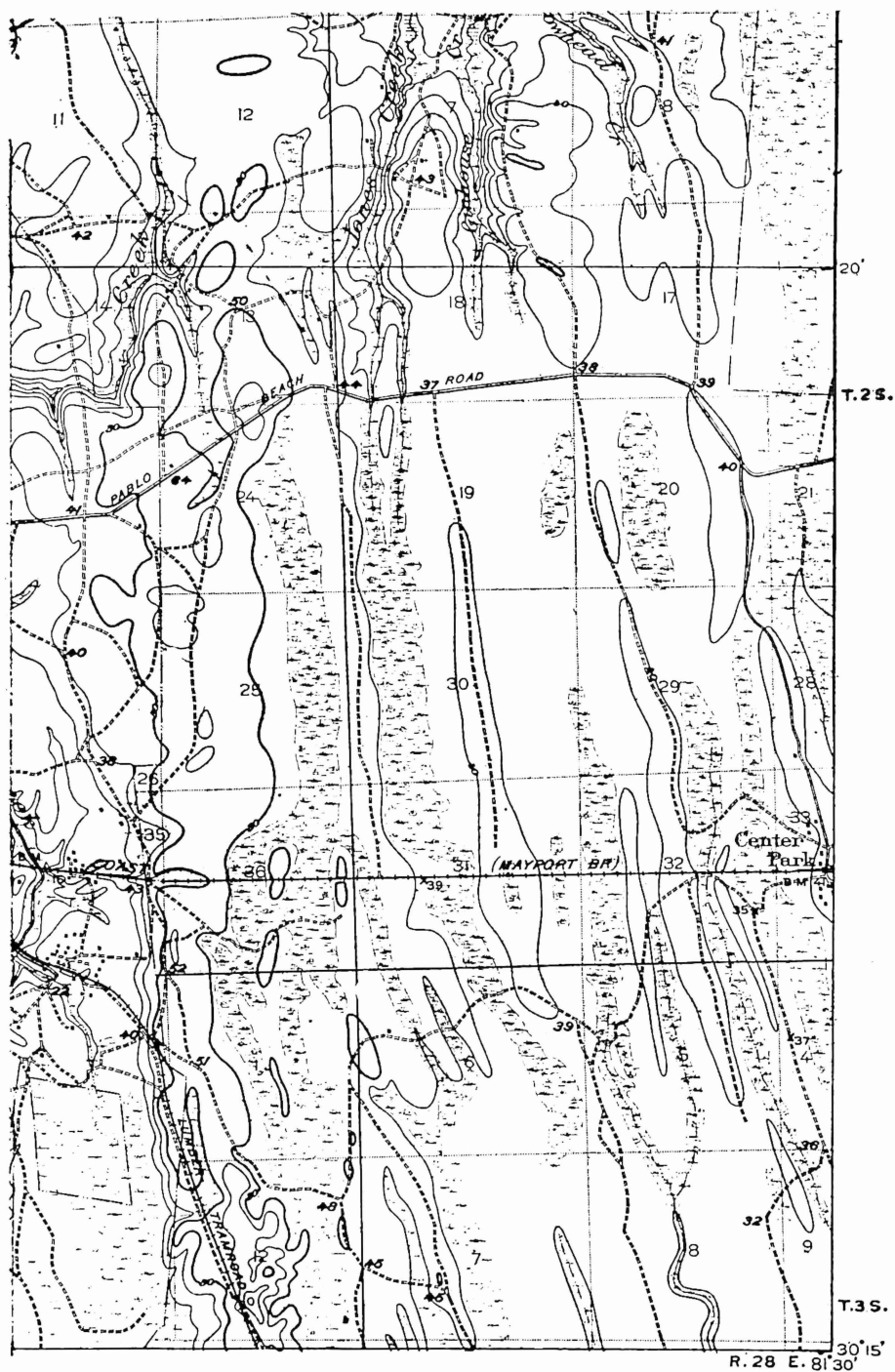


FIGURE 3. Part of the Jacksonville quadrangle, U. S. Geol. Survey, showing a dune-covered island in the Pensacola sea, and neighboring Pensacola bars.

Aside from the island near Durbin St. Johns County seems to have been below the Pensacola sea except perhaps an off-shore bar which at Hurds, on the Florida East Coast Railway southwest from St. Augustine, has an altitude of 44 feet. It is probable that this altitude is maintained for some distance north and south from Hurds, perhaps southward past Gopher Ridge into Flagler County, but data as to altitude are not available. The degree of continuity as well as the altitude of the bar in these counties has not been determined. The soil map of Flagler County shows only scattered patches of dry sandy land there.

In Putnam and Volusia counties there are large areas with the lake region topography and suitable conditions for orchards of citrus fruits which had been cut off from the main district probably by fluvial action prior to the invasion of the surrounding lower areas by this Pensacola sea. They rise to a moderate elevation of 30 to 40 feet above the level reached by the sea. One of these extends from Satsuma Heights to Barberville, a distance of 30 miles, with a width of 3 to 5 miles or more, and height up to 80 feet or about 40 feet above the Pensacola sea. There appears to have been a gap of 4 or 5 miles between this island and one setting in at De Leon Springs and running south and east as far as Osteen, a distance of fully 25 miles, with a width ranging from 2 miles or less up to about 8 miles. Much of this land stood scarcely 20 feet above the Pensacola sea. These lands are indicated on the State soil map, 17th Ann. Rept. Florida Geol. Survey, 1925. In Volusia County, as in Flagler and St. Johns counties, an off-shore bar was formed some miles east of the large island strips just noted. The altitude appears to be about 40 feet above present sea-level where well developed. The degree of continuity has not been ascertained. It lies within 5 or 6 miles of the present shore in much of its course.

In northern Brevard County a sandy ridge of old dunes 35 feet or more in height lies only 1 to 3 miles back from Indian River, but bears farther inland near Cocoa. Its course and degree of continuity have not been determined farther south. The highway leading west from Melbourne crosses a summit about midway between Melbourne and the St. Johns River at a place where ridging is not so pronounced as farther north. There is a sandy dune ridge near the present sea-coast for much of the way from Oslo, in southeastern Indian River County, across St. Lucie and Martin counties to the vicinity of West Palm Beach, whose height ranges from 35 to 40 feet up to about 70 feet, the latter height being attained in dunes near Olympia. To what degree this sandy ridge was developed as an off-shore bar in Pensacola time, and to what degree in later times has not been determined. The wind evidently has been an important agent in places where the dune topog-

raphy has been developed, but where the ridge takes the form of a regular even-crested bar it may prove to be largely the product of waves at the Pensacola stage.

SOUTHERN LIMIT OF THE FLORIDA PENINSULA IN PENSACOLA TIME.

As already indicated, a narrow strip of land extends southeastward from near Okeechobee City nearly to Indiantown, on the east side of the northern part of the Lake Okeechobee Basin. Its western shore runs westward from a little north of Okeechobee City to the Kissimmee River opposite Fort Bassenger. There may have been a narrow bay extending some miles up the river, but the main shore had a westward continuation to near the south end of Lake Istokpoga. It there turned abruptly southward and passed through the eastern part of townships 37, 38, 39 and 40 S., R. 30 E. to Fisheating Creek near Palmdale, the land to the east being flat and wet while that to the west has fairly well drained slopes. From a map by the U. S. Army Engineers of a district bordering the Caloosahatchee River⁵ it appears that the land has a rather rapid slope from 40 down to 30 feet in a strip running southwest from Hall City nearly to La Belle, from which place the contours bear north of west and are more widely spaced. The shore thus seems to pass about 2 to 2½ miles north of La Belle. The slopes are so gentle in southern Charlotte County that there were very unfavorable conditions for the development of a definite scarp, but the limits of the sea were probably 4 to 6 miles north of the south line of Charlotte County across Ranges 24, 25, 26, and 27 E., T. 42 S. There probably was a bay extending up Prairie Creek into southern De Soto County, north of which the shore ran westward to the valley of Peace River near Fort Ogden. A narrow bay extended many miles up this river probably into Hardee County. Surveys by the Army Engineers, and by D. G. Copeland, Engineer of the Florida Development Company, show that two sandy ridges rise above 40 feet in the district south of the Caloosahatchee River, and these probably were built by the Pensacola sea and raised slightly by wind action.

POSITION ON THE GULF COAST OF FLORIDA.

The description of the Pensacola shore on the Gulf coast naturally starts at the Peace River valley, for this is where it begins to run about parallel with the present coast. The shore seems to bear away from the Peace River bay about west of Fort Ogden. Here as in the district east of Peace River the slope is very gentle and conditions unfavorable for development of a definite scarp. The profile of the Atlantic Coast Line Railroad shows scarcely 5 feet variation in altitude in a distance

⁵House Doc. 215, 70th Congress 1st Session, Sheet No. 2, April, 1928.

of 15 miles, across southern Manatee and eastern Sarasota counties, and for several miles it is at about 42 feet. This is slightly higher than the Pensacola sea, whose altitude in this longitude appears to have been about 35 feet; so the limits of the sea are theoretically placed 2 or 3 miles southwest of the railroad. The county line east of Honore is 37 feet while Honore station is 30 feet, so the railroad seems to pass to the Pensacola terrace near the line of Manatee and Sarasota counties. It crosses sandy bars between there and Sarasota, but the limits of the sea appear to be north of the railroad. A bar near Utopia is 39 feet and one near East Sarasota 33.6 feet. There is also a bar at Bee Ridge south of East Sarasota at 36 feet. The bars at East Sarasota and Bee Ridge are surrounded by lower land and do not connect with the old shore-line.

The shore-line appears to bear northwestward from northern Sarasota County about to the Seaboard Air Line Railway in Manatee County, which it crosses near the township corners of townships 34 and 35 S., ranges 18 and 19 E. From there a narrow bay extended eastward up the Manatee River valley for many miles, perhaps well toward the east side of Manatee County. North of the river the shore-line runs northwest and crosses the Seaboard Air Line about 3 miles west of Parrish station. Its course is then northeastward to the Little Manatee River in southern Hillsborough County, about $1\frac{1}{2}$ miles below Willow station. There was an embayment up the valley of this stream for several miles. From the Little Manatee valley the coast line had a northward course to Riverview on the Alafia River, running near the line between ranges 19 and 20 E. across townships 32 and 31 S. There was a bay north of the Alafia River extending into the northeast part of T. 30 S., R. 20 E. The water also extended some miles up the Alafia valley as a narrow bay. The features near Tampa are represented in Figure 4, as they are exceptionally complex.

The shore-line followed the east and north sides of the drainage basin of Six Mile Creek (Palm River) around a large swamp lying east of Harney. West of this drainage basin and south of the Hillsborough River there was a large island covering the northern part of Tampa, known as "Tampa Heights," and the district between Tampa and Harney as indicated in Figure 4. There was a narrow bay less than a mile wide along the Hillsborough River above Florida Avenue and about $1\frac{1}{2}$ miles wide below Florida Avenue in Tampa, the east border being near Florida Avenue and the west near Armenia Avenue. In Temple Terrace, above Harney, the Hillsborough River has a very narrow valley which opens into a swamp above Temple Terrace whose level is slightly lower than that of the Pensacola sea and which extends up Cypress Creek as well as the Hillsborough River. It is likely to

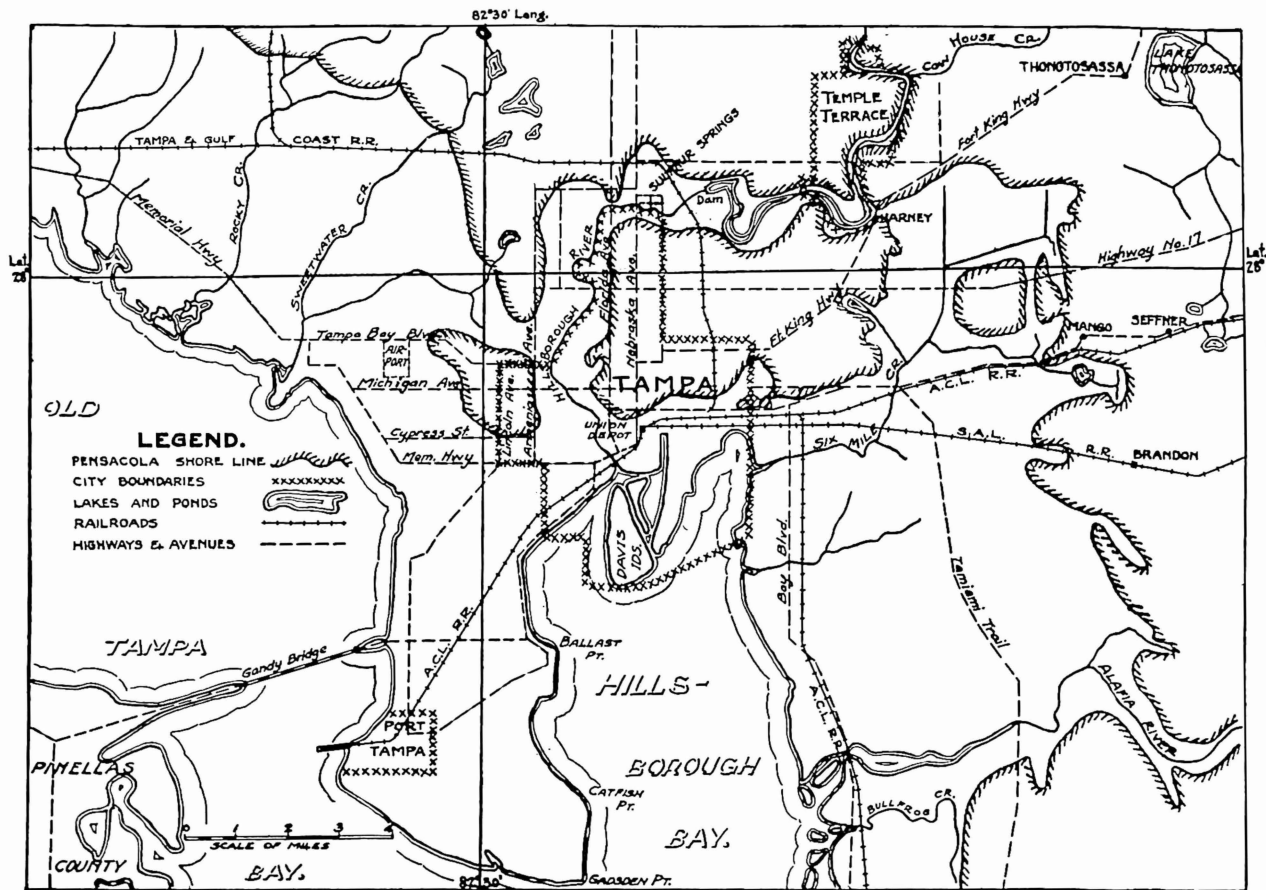


FIGURE 4. Map of the Pensacola shore-line in the vicinity of Tampa.

have been submerged in Pensacola time and the sea may have extended into it through the narrow passage occupied by the Hillsborough River in Temple Terrace.

There was a small island west of the Hillsborough River extending from near Tampa Bay Boulevard southward about to Cypress Street in Tampa and covering an area of about 3 square miles. This was separated from the mainland on the north by a passage less than a mile wide. This island rose less than 10 feet above the level of the Pensacola sea, its highest point being about 40 feet above present sea-level.

The mainland had a narrow peninsula along and west of Armenia Avenue, terminating on the south in Sections 2 and 3, T. 29 S., R. 18 E. From the end of this peninsula the shore-line bore northwestward into the northwest corner of Hillsborough County, passing about a mile south of Citrus Park and coming to the west line of the county about 2 miles south of its northwest corner. It there turned to the northeast into Pasco County and crossed the Atlantic Coast Line Railroad about a mile west of Odessa. In the absence of roads in this part of Pasco County, north of Odessa, the course of the shore-line has not been traced, but it comes westward to the state highway near Port Richey and probably turns from a northward to a westward course near the Anclote River in the central part of T. 26 S., R. 17 E.

Before outlining the course of the shore-line farther north, some important islands in Pinellas County will be taken up. The southernmost island is largely within the limits of St. Petersburg and covers about 20 square miles. Its highest points stood 20 to 25 feet above the level of the Pensacola sea, but the rise to them is so gentle as to be scarcely perceptible. The St. Petersburg island was separated by a space of several miles from a much larger island in the western part of Pinellas County whose length was nearly 20 miles and general width about 3 miles. Its southern terminus is in Sections 33 and 34, T. 30 S., R. 15 E. and northern in Section 36, T. 27 S., R. 15 E. Its west border is close to the present coast line from near Indian Rocks to Clearwater, and less than 2 miles east of the present coast from there northward. This island reaches an altitude of nearly 100 feet above present sea level directly east of Dunedin, but its general altitude is from 60 to 75 feet. On its east side in Safety Harbor there were a couple of small islands separated from it by narrow passages, which gives diversity to the topography of that village. Another island in northern Pinellas County covered 4 or 5 square miles on the east side of Lake Butler. Its easternmost point is less than 3 miles from the main coast line in northwestern Hillsborough County.

From near Tarpon Springs a chain of bars extends northward along

or near the present paved highway to connect with the shore-line near Port Richey. One of these bars from Elfers southward causes the Anclote River to be deflected from a westward to a southward course along its east side. One north of the Pithlachascotee River passes just east of New Port Richey and connects with the old shore-line a short distance northeast of Port Richey. These bars are undulating strips of sandy land that have had considerable modification by wind action. There are dunes at various heights in southwestern Pasco and northern Pinellas counties, some of which derive material from the present coast. It becomes difficult to separate some of them from the sandy bars that rise above the level of the Pensacola sea and which may date from Pensacola time. There is an exceptionally regular shore-line from near Port Richey northward across Pasco, Hernando and Citrus counties. It is marked by a change from wet land to drier land standing well above the level of the Pensacola sea. In Pasco County the shore-line was scarcely 3 miles back from the present coast, and in Hernando County only 4 to 5 miles. In Citrus County the border lies near the Atlantic Coast Line Railroad from Homosassa Springs northward to the Withlacoochee River. There was a very narrow embayment up the valley of this stream past Dunnellon. Tide-water of Pensacola time may have extended up this valley about to the Tsala Apopka Lakes and had some influence in their development. The level of the lakes, as determined by the U. S. Geological Survey, is 38 to 39 feet, and the 30-foot contour crosses the river about $1\frac{1}{2}$ miles below the lake outlet. A narrow bay may also have extended up to Blue Springs north of Dunnellon.

The Pensacola shore-line is well defined for only a few miles north from the Withlacoochee valley, as there is a wide exposure of flat land in Levy County on which the slope is so gentle as to prevent strong wave action. There is some undulating land south of Lebanon station which it is thought may have been an island in Pensacola time. The station is in a plain about 30 feet above sea-level, and 10 to 15 feet lower than this undulating land. The shore-line is run theoretically across the plain a short distance north of the Atlantic Coast Line Railroad from Lebanon to Otter Creek. The profile of the highway from Bronson past Otter Creek shows the plain to drop below 30 feet about 3 miles northeast of Otter Creek, thus indicating submergence as far as that point in Pensacola time. The level at the crossing of the Atlantic Coast Line Railroad in Otter Creek is only 3 feet lower, thus showing a remarkably slight slope in the plain.

In the district west from Otter Creek as far south as the vicinity of Ellzey there is more undulation than to the east, and the altitude seems to range from 30 feet or less up to over 40 feet in passing from

basins to bordering higher land. The shore-line may have been 2 to 4 miles west of the Atlantic Coast Line Railroad from near Otter Creek to Chiefland. From Chiefland to the Suwannee River near Oldtown there is an undulating surface ranging from 42 feet down to 24 feet, thus indicating that small bays extended east to this line. The Suwannee River bluff is 25 feet. Between Oldtown and Cross City the surface is below 30 feet for about 7 miles, and but one ridge rises above 40 feet between there and the eastern limits of Cross City. The surface however in this interval appears to have been slightly above the Pensacola sea, so the shore-line is given a theoretical course 1 to 2 miles south of the railroad and highway from near Eugene to Cross City. It probably holds a similar distance south of the highway nearly to the Steinhatchee River, but extends to the highway and railroad at this stream, for it is below 30 feet at this crossing. In the vicinity of Carbur and Athena the surface is a few feet higher and the land drier; so the Pensacola shore-line probably departs somewhat farther from the railroad there.

From near the meridian of Perry westward about to the meridian of Tallahassee lines of levels for a proposed ship canal across Florida run by the U. S. Army Engineers about 1879 under the direction of Lieut. Colonel Q. A. Gillmore traverse a district so near the level reached by the Pensacola sea that they can be used in determining somewhat closely the extent of the sea in that section. The level of the sea there being about 30 feet above present sea-level, a line connecting points at or near this altitude will show its extent. This line crosses the Fenholloway River near the bend 5 miles south of Perry, where it turns northwest, and follows the river to Pershing. The river there turns southwest while the old shore-line continues northwestward across the southwest part of T. 4 S., R. 7 E. and the east and north parts of T. 4 S., R. 6 E. to the northeast corner of T. 4 S., R. 5 E. near which it turns northward across Econfinia River. It then runs northwest to the border of the Aucilla valley about 2 miles below Covington. A narrow bay extended up this valley about to the southwest corner of Madison County. West of the Aucilla River the old shore-line seems to run near the Seaboard Air Line Railway as far as Wacissa and is but 1 to 2 miles south of it from Wacissa westward to the St. Marks River in southeastern Leon County. It appears to run near the west bank of the river in a southwest course across T. 2 S., R. 2 E. and then bear westward to Woodville, about 9 miles south of Tallahassee. There is a solution basin 2 to 3 miles north of Woodville that is below 30 feet, thus bringing possible submergence to within 6 miles of Tallahassee, but it is not certain that it opened into the Pensacola sea. There are likely also to be small areas south of the shore-line, as here given, which stood

as islands in that sea. The village of Fanlew in Jefferson County stands on one of these islands at 10 to 12 feet above the surrounding lower plain.

In Wakulla County and also in southeastern Leon County the shore-line appears to have been more irregular than in the district to the east, because of prominences and depressions in the surface of the underlying Tampa limestone, there being recesses at some of the depressions and salients at the prominences. Where the surface of the limestone stands near 30 feet and at lower levels it has been extensively laid bare by the waves of the Pensacola sea, but at a higher altitude than 30 feet it generally carries a covering of sand several feet thick. This change from bare rock to sand-covered rock at about 30 feet thus gives an indication of the altitude as well as extent of the sea. In places there are sandy bars up to about 35 feet which are likely to have been formed to some degree by wave action at the shore. These are numerous both east and south of Crawfordville and between Medart and Sopchoppy. The sand near Crawfordville and Medart is exceptional in that it carries very coarse quartz and feldspar grains or fragments in some cases $\frac{1}{2}$ inch in diameter. These are not usually very well rounded, but in bars west of Medart standing about 30 to 35 feet the largest ones, $\frac{1}{4}$ to $\frac{1}{2}$ inch in diameter, are well rounded as if worked over by waves on the Pensacola shore.

The shore-line, which has a general southwest course from Woodville to Crawfordville, seems to round a cape-like projection near Medart, on which an altitude of 40 to 45 feet is shown by the highway profile crossing it. Near Medart the shore-line turns from a course east of south to a westward course which it maintains to Sopchoppy. From such data as are available the shore-line has a westward course from Sopchoppy to the Ocklocknee River and also westward across the entire width of Liberty County, probably within the southern tier of townships. The Apalachicola Northern Railway from the Gulf coast northward to about 2 miles beyond the Franklin and Liberty county line is below 30 feet.

There was a notable extension as a narrow bay up the valley of the Apalachicola River on the border of Liberty and Calhoun counties, but the shore-line on the west side swings westward in southern Calhoun County to the Chipola valley and follows the west side of the Dead Lakes southward into Gulf County. From near Wewahitchka it runs westward to Panama City with a somewhat irregular border on the north side of East Bay. It has considerable extension northward from North Bay into the Econfinia valley and its tributaries in northeastern Bay County. Farther west it lies only a short distance back from the north shore of St. Andrews Bay. There was an embayment extending

far up the valley of the Choctawhatchee River, but the Pensacola shore-line lies but a short distance north of Choctawhatchee Bay and the lower west-flowing part of the Choctawhatchee River. It runs through the southern part of the Choctawhatchee National Forest to Pensacola Bay.

There were narrow embayments up Yellow River and Blackwater River and its tributaries from the head of Pensacola Bay. The position of the shore on the borders of Pensacola and Escambia Bays is clearly shown on the Fire Control maps of the U. S. Army Engineers, the coast line being near the 30-foot contour. Directly west of Pensacola there is a fine display of bars standing between the 20 and 30-foot contours, with an occasional point above 30 feet. The Pensacola sea appears to have stood at about 25 feet above present sea-level in the vicinity of that city. The city of Pensacola stands partly on a prominent part of the old shore-line with points 50 feet or more above it. Northeast of Pensacola the west bluff of Escambia Bay attains an altitude of nearly 100 feet, and points within a mile back 110 to 120 feet above present sea-level.

OFF-SHORE BARS OF THE PENSACOLA SEA IN WESTERN FLORIDA.

St. James Island in eastern Franklin County, bordered by the Ocklocknee River and its distributary channel, Crooked Creek, is the easternmost strip in middle northern Florida that seems likely to have been developed as an off-shore feature of the Pensacola sea. Most of this island is less than 20 feet above sea-level, but parts of it have a nearly level crest at about 30 feet, while dunes on it reach 50 feet or more. Such is the case directly northwest of Lanark station, while a smooth ridge east from there is about 30 feet.

The strip of sandy land bordering St. George's Sound from Carrabelle to East Point may have started as an off-shore bar in Pensacola time and been given additions by wind action later. The same is true of the strip bordering St. Vincent Sound from Apalachicola westward to Indian Pass, and along the present coast northwestward past St. Andrews and Choctawhatchee Bays and between East River and Santa Rosa Sound, and between Pensacola Bay and this Sound. The topographic map of the strip between Santa Rosa Sound and Pensacola Bay shows dune ridges up to 40 feet above present sea-level. A ridge over 30 feet high lies along the south side of East River in southeastern Santa Rosa County, as shown by the profile of a highway leading westward from the Okaloosa-Santa Rosa County line. The western part of Escambia County south of the latitude of Pensacola is made up of diverging bars extending from the high land in Pensacola westward to Perdido Bay. The majority of them have a height consistent

with the level of the Pensacola sea. Some of the lower ones farthest south, which are at or below 20 feet, may have been developed later. The bars leading west from the Navy Yard past Fort Barrancas are largely below 20 feet, and where higher the sand seems to have been heaped up by wind action.

Although the bluffs at Pensacola are composed largely of the pebbly Citronelle formation the bars that trail away from them are composed of rather fine sand, carrying scarcely any pebbly material. This is the common condition of all the strips along the present mainland coast to the eastward that seem likely to have been formed as off-shore bars of the Pensacola sea. It is also a matter worthy of note that in places where limestone has been washed by the Pensacola sea the bars contain very few limestone pebbles, and not many flakes or broken bits of limestone. The material is usually quartz sand brought in from the Piedmont region to the north.

BURIED PEAT NEAR MILTON

It is a matter of some interest to determine whether the sea rose continuously to the level of the Pensacola shore-line from some lower stage or had halts at certain levels as it rose. On the northern outskirts of Milton, a peat bed about 3 feet thick is exposed for a distance of 50 to 60 yards in the west bank of Blackwater River at 13 to 16 feet above present sea-level.* It rests on a fine sandy gravel and is overlain by about 10 feet of sand carrying minute pebbles. This sand forms a terrace 26 to 28 feet A. T. which is in harmony with the level of the Pensacola sea. The peat seems to have been covered up in the course of stream aggradation of the Pensacola stage and to antedate that aggradation. That this relation is a certain indication of a rise in sea-level is not fully established. It is a very exceptional feature not noted generally in the sections of valley deposits connected with the Pensacola sea, and hence one that needs to be carefully considered before drawing a conclusion as to a halt in the rise of the sea. Tests should be made to determine whether the peat is *in situ* where the vegetation grew or has been washed in from some higher level and buried beneath the valley deposits. There are also cases where peat has formed as a growth of floating vegetation on the border of a water body. If this is encroached upon by the advance of a delta deposit it would be pressed down to the bed of the water-body and thus be given the appearance of having been formed at the lower level. The significance of this buried peat at Milton thus remains to be determined.

An independent set of features suggesting a similar rise of sea-level

*For descriptions of this locality see J. Kost, First Report of the Geological Survey of Florida, p. 28, 1887; R. M. Harper, 3rd Ann. Rept. Florida Geol. Survey, pp. 295-297, 1910.

following a halt is found in the somewhat discordant altitudes of the base of scarps and the upper limit of the Pensacola sea, as shown by bars and other coastal features in northeastern Florida and northward on the borders of the Atlantic. The base of the scarp is down to about 25 feet for long distances, but the bars of the Pensacola sea are high enough to take the 40-foot contour, while the youthful condition of drainage, such as is represented in Figure 1, extends up to the same contour. These differences may have come as the result of a rise of the Pensacola sea from about 25 feet up to 40 feet. This would correspond to the rise at Milton from the base of the peat at 13 feet to the top of the Pensacola terrace at 26 to 28 feet.

TILTING OF THE PENSACOLA SHORE-LINE.

One of the main objects of the present study has been to determine whether the Pensacola shore-line shows evidence of tilting, or instead maintains the same altitude through its course through the region examined. It was aimed to test out an assumption by C. Wythe Cooke in his recent papers, previously cited, that the Gulf Coast as well as the Atlantic Coast lacks evidence of deformation of Pleistocene shore-lines.

This study has shown that the altitude of the Pensacola shore-line has a somewhat steady decrease from east to west, but whether there is a north to south change in altitude has not been determined. It is found that the altitude of the Pensacola shore on the east side of Florida is between 40 and 45 feet above present sea-level. As noted above and shown in Figs. 2 and 3, the bars near Jacksonville in northeastern Florida stand above 40 feet, while the swales between the bars are in places below that contour. The topographic maps of quadrangles in northeastern Florida show a general change at about 40 feet from a lower rather flat surface to a higher more steeply inclined surface. Topographic maps are not available for the east part of Florida farthest south, but the profile of a highway running west from Melbourne into Osceola County shows the change from flat to more steeply inclined surface near Deer Park to be at 43 feet above present sea-level. It seems to be at about 45 feet east of Lake Okeechobee in Martin County, but exact figures are not available. The Pensacola shore-line is here at its easternmost position in Florida. In about the same latitude on the west coast, on the borders of Tampa Bay, the altitude is found to be 10 feet lower than on the east coast, or about 33 feet above the present sea-level, while at intermediate points it appears to be between 33 and 43 feet, the altitude near La Belle being just about the 35-foot contour. On turning westward on the borders of the Gulf the altitude declines to about 30 feet on the meridian of

Tallahassee, while at the western end of Florida around Pensacola, it is about 25 feet. Farther west, on the border of Mobile Bay, it is about 22 feet, and in the vicinity of Baton Rouge, on the east side of the Mississippi, the base of a scarp which seems referable to the Pensacola sea is down to about 15 feet. The valleys of small streams in that part of Louisiana fall below 20 feet as they approach this scarp. They are broadly excavated down to this low level, thus indicating a corresponding sea-level datum of considerable duration or sufficient to equal the time required to develop the Pensacola shore-line.

The decline in altitude of the Pensacola shore in passing toward the delta of the Mississippi River seems to strongly favor the interpretation that the weight of the sediments of the delta may have had influence in producing the downward westward slope of the shore-line. The effect may be more pronounced near the Mississippi than farther east. This is suggested by certain drainage features of a small stream near the east border of the delta. As these features possess exceptional interest they will be described in some detail. Reference may be made to Figure 5, taken from the topographic map of the Baton Rouge quadrangle, for the location of the places mentioned. Dawson Creek, which heads near the southern limits of the city of Baton Rouge, has a rather broad, swampy valley below the 20-foot contour from near its head down about to Trajers Bridge. Below this bridge there is, for a couple of miles, to the junction with Ward Creek, a broad valley bottom standing about 20 feet, into which a very narrow valley has been cut below that contour. This seems to indicate that the swampy part above the bridge has been depressed, or instead that the higher part of the valley bottom below the bridge has been uplifted since the stream had formed the broad valley. That the former has been the case seems favored by the features of the neighboring part of Ward's Creek valley in which there is no evidence of a bulge. Although Ward's Creek is a larger stream its broad bottom remains above 20 feet about down to the mouth of Dawson Creek and shows a steady decline down stream. It thus appears that the headwater part of Dawson Creek, being nearer the border of the Mississippi delta, is reflecting more clearly the effect of the weighting down or depression occasioned by the delta accumulation. Inasmuch as the headwater part of Dawson Creek is closely adjacent to the Mississippi valley it may be thought that the waters of part of the river were turned through it temporarily and scoured it to an exceptionally low gradient. Were this the case the creek valley should show a deepening below that of its tributaries which did not carry such a flow, but it will be seen that the northern tributaries of this creek are down to a level to correspond to that of the broad bottom of the creek, and their lower courses are

swampy. It thus appears probable that the low altitude is due to a downward movement of land that is adjacent to the heavy load of the Mississippi delta.

Delta growth in much of southern Louisiana and in eastern Texas seems to have been rapid enough in Pensacola time, as well as in earlier times, to obscure or obliterate the effect of shore currents and wave attack, in consequence of which distinct scarps are not traceable through that region. It is at present a matter of uncertainty whether the Pensacola sea stood above the present level of the Gulf on that part of the coast. But farther south in the vicinity of Corpus Christi, Texas, topographic maps show clearly a shore-line and attendant off-shore bar at about 20 feet above sea-level. These may have been formed in Pensacola time. Recent papers by Dr. Donald C. Barton, previously cited, have shown that in eastern Texas the deltas of such rivers as the Trinity and Brazos have had a dominance over wave attack on that part of the Gulf coast, thus making it difficult to determine the level of the sea there in Pensacola time, or at any of the Pleistocene stages of the sea.

The determination that the Pensacola shore-line is tilted in the region examined by the writer, from the Mississippi valley eastward across Florida, naturally raises the question whether the interpretation by C. Wythe Cooke that it owes its altitude above present sea-level on the Atlantic coast entirely to a lowering of the sea-level is likely to be sustained. The fact that the shore holds a uniform level there while departing from horizontality in this region does not make certain that there has been no uplift of that part of the Atlantic coast. It is conceivable that a shore-line may run for a long distance along an isobase of uplift, and thus exhibit marked horizontality. The trend of this part of the Atlantic coast is so nearly parallel with that of the neighboring Appalachian mountain system as to lead one to expect any uplift of the mountain system to carry isobases on its slope that will trend in harmony with the trend of the mountain axis. There is clear evidence from the comparatively recent deep trenching of the valleys of the western slope of the Appalachians from Pennsylvania southward that the mountains have become more elevated in late Tertiary and early Quaternary time. On that slope there is no complication involving fluctuations of sea-level to consider, such as affects the eastern slope. An established uplift of the mountain axis, however, carries with it the natural inference that the eastern slope has been elevated, unless some such factor as faulting can be demonstrated to have had influence on the eastern slope to offset the effect of the rise of the mountains.

The degree to which the ice sheets on the Antarctic continent and

Greenland were melted in interglacial stages, is not known, nor is the amount of water locked up in the present ice-sheets. The latter question may be settled in the near future by soundings of the thickness of the ice. It will then be feasible to calculate whether, as suggested by Cooke, a complete disappearance of the ice-sheets in interglacial stages would have given a sea-level approximating that of the highest of the Pleistocene shore-lines.

The reference by Cooke of the Pensacola stage to mid-Wisconsin time seems to carry with it the assumption that there was less water locked up in ice-sheets at that time, so that the sea-level stood higher than at present. But there really was very little reduction of the extent of the ice-sheets between the time of forming of the Early Wisconsin and the Middle Wisconsin series of moraines, or between the Middle Wisconsin and Late Wisconsin series. So the sea-level of mid-Wisconsin time is likely to have been considerably below the present level, instead of being up to the level of the Pensacola sea.

PROBABLE AGE OF THE PENSACOLA SHORE-LINE.

There are several ways in which the age of such a feature as the Pensacola shore-line may be estimated. One of these is the degree of weathering and toning down by rain wash which it has experienced since the sea ceased operating on it. Another and more widespread basis for estimate is found in the degree of erosion of the plain terrace, standing just below the shore-line, which became exposed to the action of streams on the withdrawal of the sea. A third means of determining the age, only applicable if the shore-line under consideration is the latest one standing above the present sea-level, is the estimate of time required to form the present shore-line. In case the sea shrank to a lower level than the present and then came up to the present, the time involved in this stage would need to be estimated. Some paleontologists have used the extinction of certain species of animals as a time measure, it being inferred that their extinction was widely effective at a given time.

It is evident that the duration of faint scarps or notches cut in sand or clay, as is the case with those of the Pensacola sea, must be rather brief as expressed in geological reckonings. Every heavy rain in this region of high precipitation may have a perceptible modifying influence on them. For this reason it is not surprising that shore-lines older than the Pensacola have become so obscure that connected tracing seems scarcely feasible. The fact that the Pensacola shore-line exhibits a distinct scarp easily traceable for long distances is interpreted to indicate a very moderate age. The notch made in the slope by the waves, and the bank back of it, are generally still preserved in places

where conditions for effective wave action were present. Where they are not present it is doubtful if they ever were formed, as conditions generally may have been such as to prevent effective wave action.

On the Pensacola terrace the development of drainage lines has been so slight that much of the rainfall over a large part of its surface is disposed of in slowly moving widespread currents rather than definitely confined in stream channels. The main streams, however, cut across this terrace from the higher lands in sharply outlined valleys. These are usually cut to considerable depth below present sea-level, thus indicating a lower stand of the sea than the present, and consequently better condition for drainage development. But in spite of this the Pensacola terrace does not show a good development of tributary channels, and there are very few small independent streams running directly to the coast. The lower stage of the sea thus appears to have been of brief duration. The rise to present sea-level tends of course to slacken the fall and to cause the lower courses of the rivers to become estuaries. It also has submerged the lowest part of the Pensacola terrace producing an extension of the sea coast and enlargement of the bays. While it has no measurable effect on the slope of the part of the terrace standing above present sea-level, the rise of the sea probably is partly responsible for the slow escape of the water. But there are large areas still poorly drained in which the slope of the terrace is rapid enough to lead one to anticipate that in time there will be a better development of definite drainage channels. This feature is well illustrated in Fig. 1. Slopes fully as gentle on the bed of a late Pleistocene glacial lake in northwestern Ohio have reached such a state of drainage development, thus indicating a greater age than that of the Pensacola terrace. It is estimated from Niagara Falls history that the lake bed there is not over 25,000 years old.

The size of the system of bars along the present coast is such as to seem to require a considerable period of time for its development. Those on the Atlantic coast are especially bulky. Those on the Gulf coast of the peninsula are more slender. Those on the northern Gulf coast are so largely combined with the off-shore bars of Pensacola time as to be difficult to evaluate. Studies of the rate of growth of the modern coastal bars appear to be entirely inadequate for basing an estimate. The rate of development of the shore features bordering the Great Lakes has been given some attention, enough to show that features of great strength may be produced in a few thousand years. It is found by connecting the Glacial Lake stages with the succession of events shown in the Niagara gorge that a period of less than 25,000 years is embraced in the Algonquin, Nipissing, and present stages of lakes in the Huron, Michigan and Superior basins. The Algonquin

and Nipissing stages probably cover at least 80 percent of this time. There thus remains only 4,000 to 5,000 years for the work of these lakes at about their present stage. But in that time it is estimated from a study of the Lake Survey charts that the shore of Lake Michigan has been cut back over a mile on much of its west coast and probably still more around the islands of the northern part and the adjoining mainland. Such being the case the great coastal bars on the east side of Florida, the largest being those east of the Indian River in Brevard County, may prove to have been developed in a much shorter period than 25,000 years. Shore currents, as well as wave work, seem to have contributed to the growth of the broad system of bars in Brevard County.

It thus appears probable that the period of exposure of the Pensacola terrace may be not more than 15,000 to 20,000 years. This would make the Pensacola shore-line a near correlative of the shore of the glacial Lake Algonquin. It appears to be fully as well preserved as the Algonquin beach, and may prove to be somewhat younger. The amount of deformation it has suffered is very slight compared with that of the Algonquin beach. The Algonquin beach has suffered a deformation of about 410 feet in the interval of 340 miles between Port Huron, Michigan, and Sault Ste. Marie, or a distance similar to that between Pensacola and Jacksonville, Florida, where the tilting amounts to only 15 feet. Of the deformation in Michigan about 100 feet appears to have taken place within the last 4,000 years, that being the estimated time since the drainage of the upper Great Lakes was turned to the Erie Basin and the enlarged flow over Niagara Falls has formed the upper Great Gorge.

FOSSIL MAN AND PLEISTOCENE VERTEBRATES ON THE PENSACOLA TERRACE

For the past 15 years there has been much interest in scientific circles in the occurrence of human remains in close association with those of vertebrates and other fossils, partly of extinct species, near the Florida coast, on the lower part of the Pensacola terrace. An early locality to attract notice is near Vero (now called Vero Beach). Subsequently important finds were made near Melbourne, both places being on the Atlantic coast. Remains of extinct vertebrates have been found at several other places, especially near St. Petersburg, Bradenton and Sarasota on the Gulf coast. The literature is quite voluminous, as will appear from the subjoined list of papers, embracing and supplementing the list published by Dr. Sellards in 1919.

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There is wide diversity of opinion expressed in these papers as to the presence of man as far back as the time when certain extinct species of vertebrates, such as the mastodon, camel, and giant sloths were living in this region.* There is, however, general agreement that these remains are in the valley bottoms of small streams that had opened shallow trenches in the Pensacola terrace, and which extend across the littoral formation that borders the present coast.

The fragmentary and scattered condition of the human remains has led nearly all the persons who have had opportunity to excavate them to conclude that they were washed into the valley along with the remains of the extinct species of vertebrates. But Hrdlicka maintains it is more probable that they have been buried at a much later time, and urges the importance of more definite evidence of the time relations in forming judgments on so far-reaching a question as the antiquity of man in America.

The present writer has had no opportunity to study these remains in place, but he has examined into the topographic and drainage relations of the burial sites and will accordingly deal only with this phase of the question.

The remains at Vero and Melbourne are found in shallow valleys that come to the coast across the Pensacola terrace. The floor of these valleys is the Anastasia formation, described by Cooke as "a coarse sandy coquina composed of rather firmly cemented broken shells and sand." This occupies a narrow strip along the coast and is found in the interstream spaces as well as in the floors of the shallow valleys. It thus appears to antedate the cutting of these valleys or at least of their lower ends. This would naturally be inferred, since it is a marine deposit. But in the valleys there are deposits of fluvial character, which have caused a slight aggradation, or filling. The lower part is

*Papers by Hay, Simpson, Berry and Wickham, noted in the Bibliography, list these fossils.

generally largely of sand with but little associated muck, but the upper part has mucky beds associated with pockets and strips of sandy material. The remains of man in the Vero locality, as well as those of the fossil vertebrates, were found in the lower, more sandy, part of the filling. There is shown a confidence in the minds of those who have given the deposits the most careful attention that the remains were found beneath an undisturbed overlying deposit of mucky character. It also appears that Dr. Sellards and Mr. Gunter, who have done most of the work of excavation and sifting, have found that the human bones were frequently widely scattered, as indicated in Fig. 6.

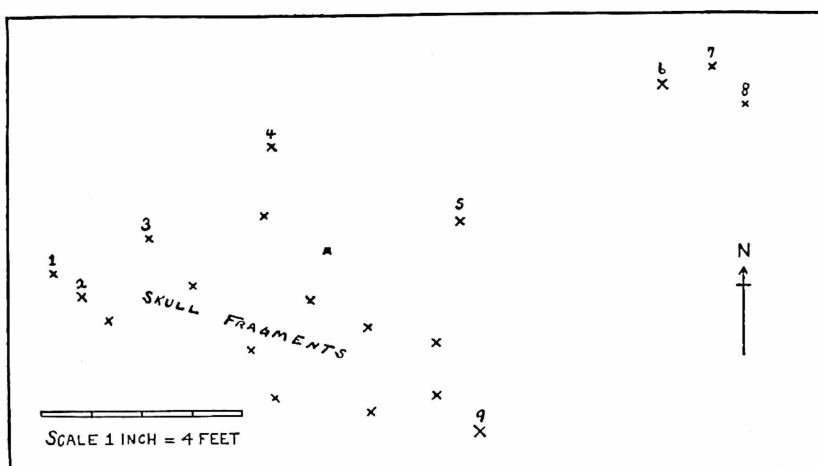


FIGURE 6. Ground plan showing the location of human bones found in the canal bank at Vero, in April and June, 1916. Reproduced from an illustration in a paper by Dr. Sellards, published in *Journal of Geology*, vol. 25, p. 12, 1917; and in *Ninth Annual Report, Fla. Geol. Survey*, p. 73.

The manner of occurrence of the skull fragments is peculiarly significant. Scarcely one-half of the skull was obtained, and the pieces that were secured were distributed over an area of about seven by three feet. This condition, as well as the widely separated parts of the femur, can be explained on the basis of distribution by a stream, but seems inconsistent with the hypothesis of an intrusive burial in a grave. Combined with this evidence against an intrusive burial is the unbroken continuity of the overlying deposit.

The human remains as well as those of the fossil vertebrates appear to have been washed in from the land adjacent to the stream that flowed in this valley. This border district, upstream from this locality, is part of the Pensacola terrace. Whether the human remains on that terrace are as ancient as those of the extinct species of vertebrates remains unsettled, for any surface material of whatever age may have

been washed in. But the time of deposition of these remains in the valley seems to have been within a limited range. It is likely also to have been considerably later than the time when the sea withdrew from the Pensacola terrace. This statement is applicable to the Melbourne deposits as well as those at Vero. The Melbourne deposits are in the bed of Crane Creek. The filling with sand and muck lacks several feet of reaching the level of the bordering part of the Pensacola terrace.

The question of the relation of the coming of man to that of the disappearance of the extinct species of vertebrates seems to resolve itself into a matter of probabilities. If the sea withdrew from the Pensacola terrace within the past 25,000 years, as seems probable from the slight change effected in the shore-line, and the very youthful state of drainage lines across the terrace, the time of occupancy of the terrace by these vertebrates appears not unlikely to have overlapped the peopling of the region by man. The abundance of game in this southern region would seem likely to have led to its early peopling by tribes fond of the chase. As finds increase the relation may be more fully cleared up.

At my request Dr. Roland M. Harper, of the Florida Geological Survey, who has been in all the counties involved, and has published reports on their natural features, has kindly prepared the discussion of some economic features of the Pensacola terrace in Florida, and the statistical comparisons with other parts of the State which follow.

SOME ECONOMIC FEATURES OF THE PENSACOLA TERRACE IN FLORIDA.

By ROLAND M. HARPER.

GEOGRAPHY

The Pensacola terrace, as described by Dr. Leverett in the foregoing pages, together with some coastal beaches and dunes which rise above its level, and the Florida Keys which have had a different history, corresponds approximately with that part of Florida mapped by Dr. Eugene A. Smith in his geological and agricultural description of Florida, nearly fifty years ago, as the "pitch pine, treeless and alluvial region."^{*} It covers approximately 44% of the land area of the state. The greater part of it is sandy, but the Everglades and other muck lands constitute about one-fourth of the terrace area, and there are also several hundred square miles where limestone lies at or near the surface.

On account of its low elevation, the ground-water is within a few feet of the surface everywhere, which makes the soil rather damp and sour, so that not much farming is possible without drainage or fertilization, or both.[†] The original vegetation was about half slash pine forest (long-leaf pine being scarce near sea-level), with an undergrowth of saw-palmetto and various other low shrubs and herbs, and the rest mostly swamp, marsh and prairie.

All the seaports of the State are of course on this terrace, though it is so narrow at places on the Gulf coast that the residential sections of Tampa, St. Petersburg and Pensacola lie partly or mostly above it. The early settlers, finding little in the back country to encourage agricultural developments, congregated mostly around the seaports and engaged in commerce, fishing, and other activities characteristic of coast settlements. The pine forests near by became important sources of lumber and turpentine, and many cattle and hogs were raised at slight expense on free range in the pine woods and prairies, though much of the area was too marshy or rocky for grazing. The shipment of beef on the hoof from the lowlands of Florida to Cuba was an important industry 30 or 40 years ago, and perhaps has not entirely ceased yet.

When Florida became connected with the North by railroads, and the prosperity of the nation enabled many people to take long winter vacations, these same seaports became important winter resorts, on account of their proximity to ocean beaches, their climate a little

^{*}E. A. Smith, Tenth Census U. S., vol. 6, pp. 205-208, 240-243, 1884. (Map opposite p. 187.)

[†]There is, however, much poor soil on the uplands as well. See Florida Geol. Survey Seventeenth Ann. Rep., pp. 33-34, 40.

milder than in the interior, and their hotel facilities. Many coast towns that are not seaports have also been developed by the tourist business.

Many tourists became permanent residents, and from the beginning of the winter resort business to the present, the Pensacola terrace has had a very progressive and cosmopolitan population, contrasting in many ways with the agricultural population on the fertile uplands of the state. Of course there are many delightful resorts on the uplands too, especially in the lake region, but farming is the principal business there, and that makes a difference in the population, as will be shown by several kinds of statistics farther on.

In the last fifty years or so large quantities of fertilizers from the world's potash, phosphate* and nitrate mines have been put on the market, and at the same time machinery for digging drainage ditches has been gradually developed, and all this has greatly stimulated agriculture in the formerly unappreciated sandy and marshy lowlands.† Farming on the terrace has long been more intensive and specialized than on the more fertile uplands, as will be shown farther on by the expenditures and receipts per acre. Throughout the country truck farming is chiefly concentrated on level lands, probably because the water supply can be more closely controlled there than on slopes. And in this respect the Pensacola terrace is ideal, for its average slope is only a few feet to the mile.

Florida's peninsular position gives it almost a monopoly of the winter vegetable business of the United States, and these crops are marketed at a time when they command a high price on account of their scarcity. In this respect the southern third of the state, which is nearly all on the Pensacola terrace, has an advantage over the rest, and the value of crops per acre is decidedly greater there than on the more northerly portions of the same terrace; though these local differences are not here brought out in the statistics. The mere fact that successful farming on the terrace requires more knowledge of engineering and chemistry and greater expenditures per unit area than on the fertile uplands, calls for a more intelligent and hence more prosperous class of farmers than the average.

STATISTICAL COMPARISONS.

The following comparisons have been made by picking out on a state map the counties and parts of counties included in the Pensacola terrace, and fitting the statistics of population, agriculture, etc., to them.

*Much of the phosphate is mined in Florida, but not on the Pensacola terrace.

†For a study of the influence of commercial fertilizers on the agricultural development of the coastal plain see *Journal of Geography*, vol. 15, pp. 42-48, Oct., 1916. Also *Geog. Review*, vol. 2, pp. 366-367, Nov., 1916. Some statistics of drainage in different parts of Florida are given farther on.

Some statistics of 1880 have been used, to show the great changes in the last fifty years, but most of them are the latest available. The 1930 figures available for single counties at this writing are rather few, so some for 1920 or 1925 have been used instead for certain features. Most of the statistics have been taken from United States census reports, but some additional ones have been obtained from the state census of 1925, and from John M. Hager's "Commercial Survey of the Southeast," published by the U. S. Department of Commerce early in 1928. The statistics of families and radio sets in 1930 are taken from a press bulletin of the U. S. Census Bureau, dated March 23, 1931, and those of gasoline consumption from a report of the inspection division of the state agricultural department covering 1929 and the first half of 1930.

POPULATION

In 1880, which is perhaps as far back as it is worth while to carry the comparisons, the Pensacola terrace had only about one-fourth of the population of the state; but by 1930 it had almost exactly half, so that it is now more thickly settled than the rest of the state. It has always had most of the state's urban population (using the arbitrary census definition of urban population, as that in incorporated places with 2500 inhabitants or more). In 1880 there were only four "census cities" in Florida, namely, Key West, Jacksonville, Pensacola and Fernandina; and all of those are below the Pensacola shore line except that Pensacola is partly above it.

People from other states and countries seem to have always been more numerous on the terrace than on the uplands, but that is probably not so much on account of the topography as on account of the seaports. In 1880 about 30% and in 1925 about 60% of the natives of other states living in Florida were on the terrace; and the difference is still greater when foreigners are considered. Both in 1880 and in 1925 over 80% of the foreigners in the state were on the terrace and other lowlands. And even if we leave out the Keys (Monroe County), which had over half the foreigners in the state in 1880 (but much fewer in 1925), there were over twice as many on the terrace proper as on the uplands.

In ante-bellum days the large plantations with their many slaves were on the fertile uplands, and some of the upland counties had more negroes than whites, which has never been true of any of the terrace counties. This condition continued to within the present century, but now there is very little difference between uplands and lowlands in the racial composition of the population.

The terrace, with about half the total population of the state, has about 60% of the adult population, and this has an important bearing on education and wealth, as will be shown farther on.

There are naturally some marked differences in occupations in the two areas, but the census figures on this point for single counties are rather meager, dividing all occupations into only nine groups (with distinction of sex but not of race or age).^{*} And in these forestry and fishing are combined with farming, thus obscuring what might otherwise be some significant contrasts. The terrace has a larger proportion of manufacturers and merchants than the uplands, and fewer miners and farmers; but some of this difference is of course due to the proportion of urban population, and not directly to the topography.

FARMING.

In 1880, when drainage ditches and commercial fertilizers were almost unknown, the terrace had less than half of one percent of its area cultivated, as compared with over four percent in the rest of the State. At present it is about two percent cultivated, and the rest of the State ten percent. Only about one-fourth of the farms, one-fifth of the farm population, and one-eighth of the cultivated land in the State are on the terrace, but these farms produce about one-third of the State's crop values.

Over half the farmers reporting drainage ditches, and two-thirds of the mileage of such ditches, in Florida in 1920 were on the terrace.

The farms on the terrace average only about half as large as on the uplands, and this permits (or may be a result of) more intensive cultivation. The expenditure for fertilizer per improved acre was over four times as much on the terrace as on the uplands in 1880, and in 1920 over six times as much. The relative value of crops per acre was not quite 2 to 1 in 1880, and nearly 4 to 1 in 1920. In value of crops per farm the terrace was a little below the uplands in 1880, but nearly double it in 1920.

This intensive farming seems to set too fast a pace for the average negro, and although the racial composition of the aggregate population is now about the same on terrace and upland, the ratio of white to negro farmers is about 10 to 1 on the terrace as compared with 2½ to 1 in the rest of the state. The terrace has more foreign white than negro farmers, and nearly half the State's foreign-born farmers. There is doubtless some correlation between this and the fact that farming is much more intensive in most European countries than in the United States.

WEALTH AND EDUCATION.

There seems to be no satisfactory direct measure of wealth for single counties, on account of variations in the rate of assessed to true valuations, and the amount of property that escapes taxation, rightly

^{*}There are no statistics of occupations by counties in any U. S. census report between 1840 and 1930, but some previously unpublished data of this sort from the census of 1920 are included in Hager's Commercial Survey.

or wrongly, in different counties; but some indirect indications of differences of wealth are available. One of the simplest is the proportion of adults in the population; for most adults are producers of wealth and most children are not. The ratio of adults to children is now about 3 to 2 on the terrace, and this makes possible better public school facilities than on the uplands, where the number of adults and children was nearly equal in 1920. (Corresponding figures for counties in 1930 are not yet available.) And this makes the percentage of illiteracy, among both races, much less on the terrace than inland.

Another indication of wealth is the number of income-tax-payers, which is available by counties for 1924 (in Hager's Commercial Survey previously referred to). At that time over 75% of such tax-payers in the State, and a still larger proportion of those with incomes above \$10,000, lived on the terrace. The statistics of radio sets and gasoline consumption show differences of the same sort.

EXPLANATION OF TABLE.

The following table shows some of the contrasts between those parts of Florida above and below the Pensacola shore-line, by means of percentages and other ratios, in parallel columns. Some of the figures include some fractional parts of counties, while some are based on whole counties.* Many other kinds of statistics could have been used for the same purpose, if space had been unlimited.

A third column of figures, for State averages, is added, for the benefit of any one who may wish to make comparisons between Florida and other states. Florida has long ranked ahead of other southern states in various measures of wealth and culture, and it is the first and only southeastern state to have more than half its population urban.

*The area below the shore-line can be estimated with reasonable accuracy, but there is more uncertainty about the population and farms, which are very unevenly distributed in some of the counties that lie partly above and partly below the line as mapped by Dr. Leverett. Generally the densest population is on the coastward side of the line, but this relation is reversed in some of the counties bordering the Gulf between Tampa and Apalachicola, where the coast is rather marshy. The fact that the line passes through several large cities complicates matters still further, for there it would be necessary to know the population of single blocks to apportion it accurately.

The statistics of density of population, urban population, racial composition, improved land, and farm expenditures and receipts have been adjusted as closely as possible to the terrace area, making allowance for known inequalities of distribution in the divided counties. But that is a rather tedious undertaking, and the other statistics are based on whole counties (13 in 1880, 24 at the beginning of 1925), some of which lie partly above the Pensacola shore-line. And while accuracy cannot be guaranteed in either case, the percentage of error may be no greater than in the original census data, which can never be perfect. At any rate, wherever the figures show a great contrast it is certain that a real difference exists; and even where the difference is small it may be significant.

STATISTICAL COMPARISONS OF PENSACOLA TERRACE WITH
REST OF FLORIDA.

POPULATION STATISTICS	Terrace	Rest of State	Whole State
Inhabitants per square mile, 1880.....	3.0	6.4	4.9
1920.....	17.2	17.8	17.6
1930.....	30.6	23.7	26.6
Percent urban, 1880.....	33.8	1.4	10.0
1920.....	58.3	20.5	37.8
1930.....	68.0	35.8	51.7
Percent white, 1880.....	62.5	49.5	53.0
1920.....	63.5	68.0	66.0
1925.....	69.0	67.0	67.8
Percent native of other states, 1880.....	35.8	31.8	32.0
1925, white.....	51.6	39.7	46.2
" negro	40.4	27.8	33.9
Percent foreign-born, 1880.....	10.9	0.7	3.68
1925, white.....	8.5	2.1	5.55
" negro	6.9	0.4	3.36
Percent of adults, 1880 (male)	50.5	43.0	45.2
1920 (white).....	59.5	52.2	54.9
" (negro)	61.1	50.9	53.3
Persons per family, 1920.....	3.95	4.30	4.14
1930	3.73	4.10	3.89
Percent of persons over 10 illiterate, 1920 (white) ..	1.95	4.41	3.22
" (negro) ..	13.3	27.5	21.7
Occupations, 1920:			
Percent of workers engaged in			
Mining	0.3	1.2	0.8
Agriculture, etc.	16.9	45.9	32.2
Manufacturing, etc.	33.1	19.9	26.1
Transportation, etc.	9.6	5.9	7.6
Trade	12.3	6.5	9.2
Professional service	5.4	3.8	4.5
Percent of population paying income tax, 1924-5....	7.9	2.1	5.1
Percent of families having radio sets, 1930.....	19.8	9.7	15.5
Per capita consumption of gasoline, first half of			
1930 (gals.)	98.9	62.3	82.4

AGRICULTURAL STATISTICS

Percent of land improved, 1880.....	0.5	4.4	2.7
1920.....	1.8	10.2	6.5
Improved acres per farm, 1880.....	20.4	44.1	40.5
1920.....	24.5	47.1	42.5
Percent of farmers in 1920: Native white.....	81.4	69.6	71.9
Foreign white.....	10.2	2.6	4.1
Negro	8.4	27.8	24.0
Percent of population on farms, 1925.....	9.2	33.8	20.8
Percent of farm population, white.....	81.6	69.1	72.0
Percent of farms reporting drainage ditches, 1920..	27.0	4.0	8.5
Percent of farm area drained.....	7.9	1.4	2.4
Expenditure for fertilizers, per improved acre,			
1879-80 (\$)	0.26	0.06	0.08
1919-20 (\$)	17.90	2.70	4.50
Value of products, 1879 (\$) Per farm.....	262	327	318
Per improved acre..	12.90	7.40	7.85
Value of crops, 1920 (\$) Per farm.....	2390	1240	1490
Per improved acre.....	97	26	35

Whether or not the principle that areas lying below the latest Pleistocene shore-line are always more prosperous than those farther inland is of nation-wide application cannot be asserted until similar studies have been made in other states. But it is quite probable that some such relation exists, for large cities tend to grow up along the coast, and farming in the lowlands of other states is rather intensive, for much the same reasons as in Florida.

General Francis A. Walker, who directed the 1880 census, investigated the distribution of the population of the United States according to altitude, and found 18.3% of the total population, 28.3% of the foreign born population and 22.3% of the colored population in that year living within 100 feet of sea-level. But in the absence of any indication of the areas of the different altitudinal belts, it is impossible to say just how much the lowlands differed from the highlands in density of population. And no statistics of the composition of the population, except as to color and nativity, in the different belts were given in that census.

In a special report of the U. S. Census Bureau, "Supplementary Analysis and Derivative Tables," published in 1906, Dr. Henry Gannett divided the country into 19 physiographic divisions, one of which, the "coast lowlands," includes the Pensacola terrace and a little additional area in Florida (following county lines). It was found to contain 2.8% of the area and 2.4% of the population of the United States in 1900, and had 22.5 inhabitants per square mile, as compared with a national average of 25.6. Its population increased 28.1% between 1890 and 1900, as compared with 20.7% in the whole United States.

