GEOMORPHOLOGY

By Gerald G. Parker

FACTORS AFFECTING LAND FORMS

The factors that have most to do with shaping land forms in southern Florida are: (1) Materials comprising the land, (2) fluctuating sea level, (3) shoreline processes, (4) climate and vegetation, (5) solution, and (6) erosion.

No attempt has been made to list these factors in the order of their importance; obviously that would be difficult to decide. In the following account they are discussed separately but, as will be noticed, it is impossible to separate them entirely. In nature they are mutually operative and effective.

MATERIALS COMPOSING THE LAND

The principal geologic materials in southern Florida are limestones, calcareous sandstones, marls, shell marls, sands, silts, and clays. All these are rocks that offer comparatively weak resistance to degradational forces acting in a warm, moist climate such as that of southern Florida.

Figure 21.—Natural limestone bridge over Arch Creek.

The calcareous materials are especially likely to be attacked by percolating ground waters charged with humic or other acids occurring in nature. A terrain developed on calcareous materials is characterized by solution forms, and southern Florida is no exception; solution holes and sinks are common, even a natural bridge is found (fig. 21), and a drowned karst topography is largely responsible for the topographic expression of the Ten Thousand Islands area. Solutional features predominate over erosional features. (See figs. 22 and 25.)

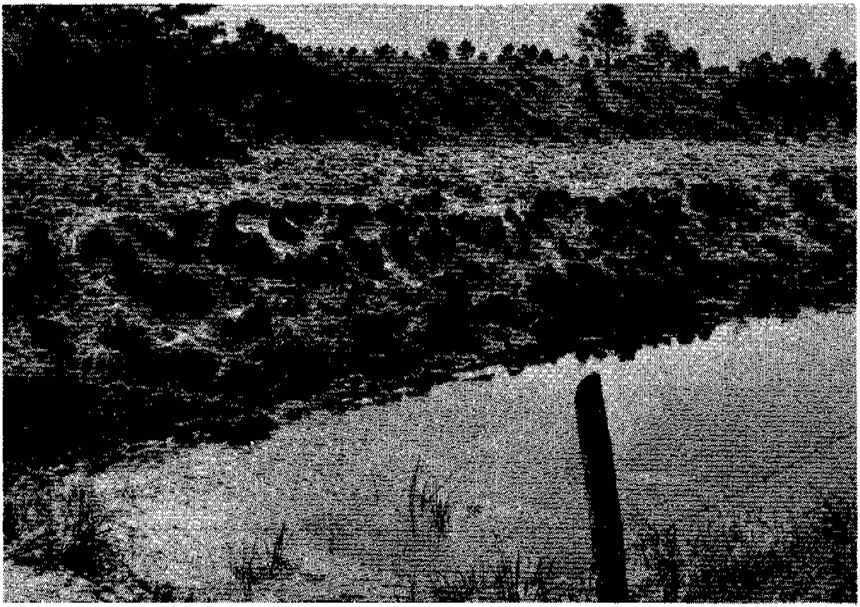

Figure 22. —Rock pinnacles resulting from solution of the Miami oolite.

The sands of southern Florida are principally siliceous (quartz), but present-day beach sands are quite shelly and calcareous. Sand is an excellent absorbent of rainfall, and in areas mantled with fairly thick deposits of sand there is comparatively little surface runoff following storms. This lack of runoff tends to prevent erosion and thus to preserve land forms, such as ancient beaches, beach ridges, or dunes; at the present time, their identity is fairly well preserved in many places.

Where sands are uncemented and unaffected by vegetation they tend to drift and to form dunes in areas where wind action is strong. Loose sand will not stand in steep banks, but instead it tends to maintain slopes of low angle with subdued, rounded outlines. The effect of the weathering agents (wind and rain), combined with gravity and animal activities, is to round off and reduce the once steep beach bars, ridges, or dunes to low, flattish heaps.

The permeable sand of southern Florida permits large amounts of rainfall to be stored as ground water; this water reacts chemically upon the underlying rocks and produces great changes over a long period of time.

Marls are variously defined, both by geologist and laymen. Common usage in southern Florida designates a marl as any unconsolidated rock that contains considerable amounts of carbonate. Most common, perhaps, are the "shell marls" of the Caloosahatchee marl and the Tamiami formation. These are usually sandy shell deposits and may contain little or no silt or clay. However, silty and clayey marls are common in southeastern Florida, although they seldom are found very near the surface and therefore exert little topographic control.

Shell marls are much more permeable than clayey marls, and where exposed to rainfall they are attacked by solution, which increases their permeability and reduces surface runoff. On the other hand, clay marls are relatively impermeable, and where they lie near the surface they prevent absorption of rainfall and promote surface runoff.

FLUCTUATING SEA LEVEL

A fluctuating sea level has been an important factor in shaping the topography of southern Florida. (See p. 111–125.) The principal topographic effects of the fluctuating sea over the Floridan Plateau were the terracing of the landscape with a veneer of marine sands, the alternate cutting and filling of shallow river valleys, and the development in the underlying calcareous rocks of a system of deep solution passages and sinkholes, many of which later became filled with sediment when the sea rose high enough to cover them. Also, marine features were left, such as spits, bay bars, offshore bars, lagoons, beaches, beach ridges, and flat shallow sea bottoms. These features abound on the marine terraces at the present time, especially on the younger terraces which have not yet been destroyed by solution and erosion. They may be readily observed from the air or studied on aerial photographs. Primarily, they control the natural drainage, and therefore they are important factors in water-resources studies.

SHORELINE PROCESSES

Waves, tides, and currents along the shoreline are actively engaged in modifying the adjacent land and the shallow sea bottom, and wind-blown spray etches rocks, especially the calcareous ones, beyond the reach of the waves.

In southern Florida, as the sea has fluctuated over the relatively flat surface of the Floridan Plateau, the shoreline has migrated many miles; each time that the sea halted long enough, it left some present land features as marks of its stand. These features are

Figure 23. —Silver Bluff, a late Pleistocene sea cliff.

usually beach ridges, inner lagoons, and offshore bars, but they may be wave-cut notches in sea cliffs or wave-cut benches at the bases of sea cliffs. (See figs. 23 and 24.) Because consolidated rocks are rare in southern Florida, sea cliffs are scarce, but old beaches, with their associated bars, ridges, and dunes, are common and widely scattered.

One of the principal effects of shoreline processes in southern Florida has been the building up of the land along the coast. Sand is constantly being fed to the ocean by streams of the Piedmont Region of Alabama, Georgia, the Carolinas, and Virginia, and some of it eventually finds its way along the shore to Florida. Ancient sand deposits formed along the coast in the geologic past are now attacked by waves, and the newly released sand is dragged south by longshore currents and diagonally striking waves, to be incorporated later in new deposits still farther south.

Since the close of Miocene time, sand has not worked very far south of Miami. Calcareous rocks contain progressively less sand as they are traced southward. Today, the southern part of Biscayne Bay has much less sand in it than the northern end. In fact,

Figure 24.—Sea undercutting coralline limestone of Key Vaca.

Cape Florida, the extreme southern tip of Key Biscayne, off Miami, is now the principal southern terminus of the siliceous sands that wash down the coast.

This lateral movement of sand along the beaches tends to fill in, on the north side, tidal runways that cut through the offshore bar; but the sweep of tides and tidal currents in and out tends to keep the cuts open. The result of these two actions is the down-beach (southward) migration of the tidal inlets, a phenomenon with which all coastal residents are familiar.

Hurricanes may cause storm tides of as much as 16 or 18 feet (Congressional documents, p. 8–9). Waves of tremendous eroding power, which accompany hurricanes, are prime movers of loose materials along the shoreline and may accomplish greater changes during the course of one hurricane than normal shoreline processes would accomplish in many years. Sand bars, spits, and even small islands may be entirely washed away; new tidal cuts may appear across bars that formerly excluded the sea from direct access to inner lagoons; and a new set of bars, spits, and beaches may appear—all these changes are subsequently modified by the usual shoreline processes.

On a land as flat as southern Florida, these shoreline processes and the features they produce have a marked effect on subsequent drainage which, in turn, has a direct effect upon storage of ground water, upon the vegetation, and consequently upon the use that man makes of the land.

CLIMATE AND VEGETATION

Climate is an important factor and has a profound effect on both organic and inorganic materials. Southern Florida has a semi-tropical climate. Rainfall is plentiful (50 to 60 inches per year), humidity is usually high, winds blow most of the time, and an occasional hurricane roars in from the tropical seas. (See section on Climate, p. 15-56.)

The principal effects of climate upon topography in southern Florida are brought about by the plentiful supply of rain that flows over or enters the rocks and attacks them both chemically and mechanically. Solution, a result of chemical attack on carbonate rocks, produces the characteristic karst topography of a limestone terrain.

Running water has carved valleys but in southern Florida its principal effect is solution. (Note on the hypsometric map, pl. 10, the indentations partly brought about by streams working on the marine terraces.)

On the flat terrace lands streams are sluggish and drainage is imperfect. The combination of physical conditions mentioned above has developed one of the largest areas of principally organic soils in the world—the Everglades. Outside the main body of the Everglades—extending up Kissimmee River, Fisheating Creek, and in old lagoons and swales between ancient beach ridges—other smaller deposits of peat and muck have developed.

These organic deposits would continue to build up even today, but they are prevented from doing so by drainage operations. This problem has been discussed by Evans and Allison (1942, p. 34-46).

Not only is the climate favorable to the growth of swamp plants, but it enables bunch grasses, pines, palmettos, and other semi-tropical-to-tropical vegetation to grow on the old beach sands and dunes. This vegetation helps to prevent continuous drifting of the sands before prevailing winds and, by preserving their forms, helps the immature drainage pattern to become better established.

SOLUTION

Southern Florida is underlain by limestone and other calcareous deposits and, because surface waters usually contain natural acids, solution plays a more important role than abrasion in the development of topographic features. At times in the past, when the Floridan Plateau stood high above the sea, few, if any, deep gorges were carved by running water. Instead, both surface and underground rocks were etched and made cavernous by the lateral

Figure 25. --Close-up view of one o. the larger solution holes in Dade County.

and downward movement of corrosive waters. (See figs. 15, 25 and 26.)

Apparently, no original cavity is needed to start a solution hole, though the existence of a ready-made hole hastens the process. It has been suggested that many vertical solution holes begin to be dissolved along taproots of trees, and possibly some holes do originate in this fashion, but it is not the most common way. On the surface of hard limestone or soft calcareous clayey marl the first effects of solution appear as small surficial pits resembling raindrop marks in mud. These pits gradually deepen, many retaining their rounded outlines. Without visible outlet along the sides or bottom, they later become tubes which enlarge into holes of various shapes and sizes, but generally they develop vertically.

The work of solution is evident wherever outcrops of rock occur, as on the bare limestone surface south of Miami or in the Big Cypress Swamp, in canals and street cuts, in borrow ditches and rock quarries, or in river and creek banks. In large areas of southern Florida it is evident that at least one-fourth of the total volume of limestone, once more or less solid rock, is now occupied by solution holes, generally filled with sand. (See fig. 26.) Trees blown over by hurricanes rip up rock with their roots, thus leaving a new and localized depression for concentration of rain water and the start of active solution holes. Adjacent holes enlarge, coalesce, and become increasingly effective in draining surface water underground. Many solution depressions of this kind,

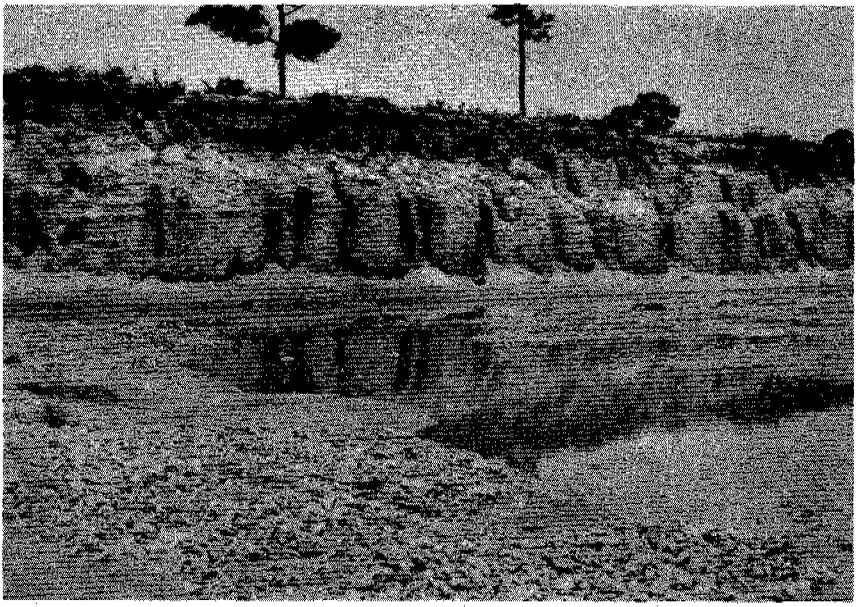

Figure 26. —Borrow pit in Miami oolite at Fort Lauderdale.

some as much as 150 feet in diameter, can be seen in the pineland and wet prairies south and west of Miami.

EROSION

Erosion by running water has been more effective in the area north of Lake Okeechobee (especially on the higher terrace lands) than it has been to the south of the lake and on the lower terraces, partly because of difference in underlying materials and partly because stream erosion has had a longer time to work on the older terraces.

The very flatness of the marine terraces, their mantle of relatively permeable sands, the soluble underlying rocks, and the rank growth of vegetation, all play important roles in inhibiting surface flow. During glacial ages, when the surface of the Floridan Plateau stood relatively high above sea level, the water level in the ground dropped accordingly, and the principal flow of water was downward to the water table, where it moved laterally to the seas. As a result, shallow valleys usually were carved.

On the higher sandy terraces with underlying shell marls and clayey marls, small streams developed and meandered in their lower courses across the flat land, causing little abrasion. Of low gradient, they carried relatively clear water, but during seasonal floods they probably moved considerable quantities of loose sand seaward, as Fisheating Creek, the Kissimmee River, and other streams are doing today. Characteristically, they developed broad, shallow valleys.

During subsequent interglacial ages the lower reaches of these valleys were flooded by the sea to a lesser height with each successive age and the valleys then became embayments whose margins were modified by wave action and whose bottoms were leveled by planation and aggradation.

During subsequent glacial ages these lower parts of the former stream courses were partly reexcavated, and the upper reaches continued to work headward, though very slowly and rather ineffectually.

The net result has been the indented terrace pattern shown on the accompanying hypsometric map (pl. 10). Generally speaking, the inner boundaries of the terraces coincide with the shoreline of the sea at the time the terrace was developed, and the almost flat, gradually sloping surface of the terrace was the shallow sea bottom. But these features have been modified by subsequent erosion and solution so that the old shorelines have been changed; the older the shoreline, the more it is modified. However, some of these old shorelines with associated offshore bars and inland dunes are remarkably well preserved and are readily recognized.

Wind erosion, very effective in southern Florida during the Pleistocene glacial (low sea level) ages, has ceased to be a prominent factor. During the later glacial ages, prominent dunes were built in present southern Florida, especially in Palm Beach, Martin, and St. Lucie Counties, atop old beach ridges, and along the Gulf shore near Marco in an area of prominent karst topography; many of the Ten Thousand Islands owe their origin to these Pleistocene dunes, now partly drowned by rise of the sea to its present level.

The old dunes are now held down by vegetation and are quiescent, and even when vegetation is cleared off they remain fixed. They were formed under climatic and sea level conditions that do not now prevail.

MARINE TERRACES

GENERAL STATEMENT

Marine terraces are the former bottoms of shallow seas, usually floored with deposits of sand, clay, silt, and shells, and are bounded along their inner margin by shoreline features such as beach ridges, swales, offshore and bay bars, or, in rare instances, by low rocky sea cliffs notched by wave action. Landward, these

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deposits merge with estuarine and fluviatile deposits that were laid down in bays and in rivers emptying into the sea.

The surfaces of the terraces are generally almost featureless, flat, gently sloping plains with an occasional old sand bar or island remaining as very slightly higher land. Old tidal runways are now the sites of rivers, creeks, or swamps, and the land surface is dissected by moving water or pocked by solution holes in underlying calcareous rocks. The wash of small waves, in the water of the shallow ponds that fill these depressions, or the circulation of currents due to prevailing winds tend to produce evenly curved shorelines. Swamps and lakes develop in the lower lying, poorly drained areas of the terraces. (See p. 113-114 for a discussion of the effect of glacial control of sea level.)

Table 15 lists eight Pleistocene terraces in southeastern United States. No description is given in this report for terraces higher than 100 feet. (See pl. 10.)

WICOMICO TERRACE

The inner boundary and shore of the Wicomico terrace today stands approximately 100 feet above sea level, and its outer margin is bounded by the 70-foot shoreline of the next younger terrace.

The Wicomico terrace forms a narrow fringing band surrounding the higher terrace lands that extend southward between the valleys of Fisheating Creek and the Kissimmee River. In Wicomico time, this high land was a long, comparatively narrow peninsula, called Highlands Peninsula in this report, after Highlands County in which it occurs. (See pl. 10.)

The greater part of Kissimmee River valley is developed on the Penholoway terrace (the next terrace lower than the Wicomico), which supports two islands of Wicomico deposits. The smaller of these islands called Kissimmee Island in this report, is approximately 27 miles long and 8 miles wide. It separates the larger Kissimmee River valley from the smaller Arbuckle Creek valley, which drains southward into Lake Istokpoga and from there into the Kissimmee River. In Wicomico time, Kissimmee Island was separated from the mainland by a salt-water narrows, called Istokpoga Strait in this report, which is about 27 miles long and averages about 3 miles in width.

The larger of the two islands of Wicomico deposits, called Osceola Island in this report, was an offshore bar during Wicomico time, and its highest parts probably were slightly submerged at high tide. It lay between deep water of the Atlantic Ocean and the shallow body of shoal water that extended about 20 miles west to the mainland. For this great Pleistocene shoal area the name "Kissimmee Sound" is here proposed. Osceola Island may have gained much of its modern shape during succeeding Penholoway time when it stood as an island about 70 miles long with an average width of about 6 miles. A long narrow spit, about 23 miles long and a mile wide, extended almost due north from the main body of Osceola Island to a point that is now almost midway between Orlando and Titusville. Osceola Island is important today as the drainage divide that separates the upper St. Johns River basin from the Kissimmee River basin.

PENHOLOWAY TERRACE

The 70-foot shoreline of the Penholoway terrace is fairly well preserved in many places and is usually marked by a scarp, or wave-steepened slope, at its inner boundary. The terrace itself is relatively broad, flat, little dissected, and slopes gently to its outer margin, where another terrace, the Talbot, with a shoreline at approximately 42 feet, borders it.

A tongue of the Penholoway terrace extends northward along the west side of Highlands Peninsula in an embayment (called Fisheating Bay in this report), which in Penholoway time was about 20 miles long and 7 miles wide. It is now occupied by the upper reaches of Fisheating Creek.

During Penholoway time, Highlands Peninsula was lengthened by longshore currents sweeping sand southward as far as Palmdale, in Glades County. Fisheating Creek now turns abruptly eastward around the southern terminus of this extensive Pleistocene sand spit.

The Penholoway terrace narrowly fringes the east side of Highlands Peninsula as far north as the north shore of Lake Istokpoga; the southern boundary then turns eastward across Kissimmee River basin, with deep indentations along Kissimmee River and Taylor Creek. To the south of Osceola Island, the Penholoway terrace extends as a long peninsula (here called Okeechobee Peninsula), northeast of Lake Okeechobee.

From Okeechobee Peninsula the Penholoway terrace extends northward and fringes Osceola Island in a band about 7 miles wide and generally parallel to the modern Atlantic shore. Small headward-working streams, tributary to the upper St. Johns River basin, scallop its outer margin.

KISSIMMEE RIVER BASIN

The present drainage system of the Kissimmee River, with its numerous large and small lakes, meandering connecting channels and swampy lowlands, occupies Pleistocene Kissimmee Sound.

Rainfall that becomes ground-water storage in the adjacent higher terrace lands eventually reappears as ground-water discharge into Kissimmee River. The time lag is such that the flow of the river is maintained even during times of drought. (For details on the flow and the drainage-area characteristics of Kissimmee River, the principal tributary of Lake Okeechobee, see p. 301-314 .)

Four large consequent lakes, Kissimmee, Hatchineha, Tohopekaliga, and East Tohopekaliga, occupy shallow basins that apparently were original depressions on the floor of old Kissimmee Sound. To what extent they may be impounded because of shallow sand bars is not known, owing to lack of detailed topographic work. Some of the smaller lakes in the Kissimmee River valley result from the damming of the sluggish drainage ways by Recent organic material.

At the extreme northern end of Kissimmee Sound there is a narrow strait connecting with the part of St. Johns drainage system that lies between the northern extremity of Osceola Island and the mainland. At present, surficial flow in this area is unpredictable.

FISHEATING CREEK VALLEY

Fisheating Creek heads on the Penholoway terrace and occupies Pleistocene Fisheating Bay, which lies just west of Highlands Peninsula; its valley is broad and flat. The stream, like the Kissimmee River, carries highly colored water with little sediment. Reeds, sedges, water hyacinths, and other aquatic and semiaquatic plants choke its channel and reduce abrasion to a minimum. During extended droughts, streamflow in Fisheating Creek, especially along the upper reaches, dwindles to nothing.

TALBOT TERRACE

Following the stand of the sea at 70 feet and the formation of the Penholoway terrace, the sea level dropped to 42 feet and stayed at that level long enough to establish a definite terrace, which is named the Talbot. Its outer limit is the generally poorly marked 25-foot shoreline of the next lower terrace, the Pamlico.

The inner shoreline of the Talbot terrace is marvelously well preserved in some places and may be viewed to good advantage

3 miles east of Childs on Florida Route 70. At that place, it lies at the foot of a noticeable scarp that separates it from the Penholoway terrace. A series of quiescent sand dunes lie inland from the old shore. Just east of the shoreline is a shallow offshore trench, and beyond the trench lies an offshore bar; both of these formations are comparable to those now being formed at the present time off Miami Beach and elsewhere along the Atlantic and Gulf coasts. The old offshore trench is now filled with a woody-peat deposit, and dense swamp vegetation grows there. The old offshore bar is not continuous, but like most offshore bars, it has the higher and lower parts separated by tidal scour channels. It is known locally as the Parker Sand Islands.

The Talbot terrace is usually a narrow fringing area around the wider Penholoway terrace. South of DeSoto County it flares out into a wide lobe, called Glades Peninsula in this report, and a long tongue extends to form the floor of the southern part of Fisheating Bay. North of Lake Okeechobee a wide embayment, called Seminole Bay in this report, is largely floored with Talbot deposits. Seminole Bay lies between Highlands Peninsula on the west and Okeechobee Peninsula on the east. It was a very shallow bay, open to the ocean on the south, and it received the flow of ancestral Kissimmee River in its northern end when that river first came into existence. Lake Istokpoga appears to occupy an original depression on the floor of Seminole Bay.

East and northeast of Lake Okeechobee is the wide projection of the Okeechobee Peninsula, with a long narrow strip of Penholoway terrace as its core. Okeechobee Peninsula seems to have been formed in the same manner as the rest of these old peninsulas; that is, by longshore currents dropping their load of sand in the form of a broad spit.

Across Caloosahatchee Strait from the broad lobe of Glades Peninsula is roughly pear-shaped Immokalee Island, which is surmounted by a very small area that may possibly belong to the Penholoway formation. Immokalee Island still bears noticeable beach ridges in its southwestern quarter. These old beach ridges and intervening swales trend roughly west-northwest to east-southeast and parallel the southwestern shoreline of the island. See the map showing directions of surficial flow (pl. 11).

In addition to these old shorelines features, the long north-south-trending drainageway of the Okaloacoochee Slough and the east-west-trending extension known as the Devil's Garden occur on Immokalee Island. They are probably inherited from old tidal runways and are largely original features on the bottom of the Talbot sea. They have been modified by subsequent erosion and possibly by solution in the underlying shell marl. In places they may be partly blocked by old sand bars.

The Talbot terrace is remarkably flat, and drainage on it is very sluggish. Sloughs, shallow ponds, and swamps abound, and there are wide grassy plains with bunch grasses, palmettos, and pines.

PAMLICO TERRACE

All the land of southern Florida lying below the 25-foot contour, where it skirts the outer boundary of the Talbot terrace, and above the 5-foot contour which marks the inner boundary of the Silver Bluff terrace (p. 146-147), is a part of the Pamlico terrace. The Pamlico shoreline is generally very difficult to trace because of the nature of the materials and the slope of the land surface upon which the Pamlico sea encroached.

In some places, notably west of the St. Lucie River in St. Lucie County, the shoreline becomes markedly steeper; probably this was caused by wave erosion. In others, southwest of Immokalee, Collier County, for example, the shoreline is marked by fringing swamps developed in the shallow offshore trench, and the shoreline itself can be plainly seen from high in the air. Lake Trafford lies in a re-entrant in the shoreline in this area.

The shoreline of the Pamlico sea is roughly indicated on the hypsometric map, plate 10. It followed up river valleys developed in previous low stands (glacial stages) of the sea, especially up such streams as Myakka River, Peace Creek, Kissimmee River, and Caloosahatchee River. The Caloosahatchee valley was flooded by 10 to 15 feet of marine water and formed a strait about 7 to 10 miles wide connecting the Gulf of Mexico with Pleistocene Okeechobee Bay (which was then a shallow shoal area similar to the present Bay of Florida)—this strait was deepest in the area now occupied by Lake Okeechobee.

The Pamlico terrace is remarkably flat and even, except in certain areas where it was made uneven by beach-ridge, swale, and dune deposits. Over most of southern Florida it is so flat lying that the eye can detect no change in slope.

The Pamlico terrace is poorly drained. Few well-established drainage courses cross it, and these are sluggish streams usually choked with aquatic weeds. Most important of these rivers is the northward-flowing St. Johns, lying in an old inner lagoon and separated from the present ocean by beach ridges. Its headwaters lie on the wet prairies and in the marshes at about the latitude of Lake Kissimmee.

Many small streams and canals drain water from the higher terrace lands surrounding Lake Okeechobee. Among them are Fisheating Creek, Harney Pond Canal, Indian Prairie Canal and

Taylor Creek. The lower courses of both Kissimmee River and Fisheating Creek cross the Pamlico terrace as extended consequent streams.

The largest stream flowing oceanward from the Lake Okeechobee area is the Caloosahatchee River on the west. The St. Lucie River on the east drains an area of beach ridge and swale topography through an old lagoon separated from the ocean by high beach ridges. North of the estuary of the Caloosahatchee River are the estuaries of Peace Creek and Myakka River emptying into Charlotte Harbor.

Numerous small rivers or creeks are on both the east and west sides of the State. Rivers such as the Estero and Imperial flow from the higher parts of the terrace to the Gulf of Mexico. Streams such as the Jupiter, New, and Miami Rivers flow to the Atlantic Ocean. All these streams carry highly colored swamp waters and accomplish little mechanical erosion.

Regions of special mention developed entirely or mainly on the Pamlico terrace of southern Florida are the sandy flatlands, the Big Cypress Swamp and the Atlantic Coastal Ridge.

THE SANDY FLATLANDS

The sandy flatlands are developed over most of southern Florida and include deposits of all the Pleistocene marine terraces having shorelines of 100 feet or less above sea level. Most of this area is lower than 25 feet and generally is very flat; the remainder may be slightly rolling, and it is called by Sanford (1909, p. 185–186) the "Rolling Sand Plains."

The sandy flatlands floor most of the lowlands along the Atlantic coast and extend west around the north side of Lake Okeechobee, fringing the central highlands (developed mainly on Wicomico and higher terraces), to the Gulf coast. (See pl. 12.)

They continue south in this western area beyond Naples, where coastal marshes begin. Along the Atlantic coast they are limited on the east by the narrow coastal ridge with its Pleistocene dunes, and on the southwest and west by the eastern border of the Everglades. This strip continues southward between the Everglades and the coastal ridge to Coral Gables, in the Miami area, with an occasional break through the ridge north of Miami, where they form the floor of old drainageways and tidal channels.

Rainfall on the sandy flatlands either sinks directly into the surficial sand or is stored in shallow pools from which evapotranspiration removes most or all of it. The whole flatlands area is dotted with these circular intermittent ponds, generally only a foot or so deep and rarely over 4 feet deep. Diameters of the ponds may reach several hundred feet. Many of these ponds, as seen in aerial photographs, look remarkably like the Carolina bays. The ponds appear over areas of deep sand as well as over areas where only a thin layer of sand mantles underlying limestones and shell marls. These ponds may be a result of solution of the underlying calcareous rocks, thus creating a local subsidence, or they may result from original inequalities on the sand floor, which were left when the sea withdrew, modified now by the wash of small waves and wind-impelled currents. Many definitely are in alinement, which was caused by underground solution along either horizontal passages or old bars and ridges.

Transpiration and evaporation probably account for the disposal of almost all the rainfall on the sandy flatlands, as they do in the Everglades. Studies described in the section on Surface water (Quantitative studies) and material by Clayton, Neller, and Allison (1942, p. 27–35), have shown that for limited areas transpiration and evaporation may exceed rainfall, the deficiency being accounted for by seepage and runoff from contiguous areas.

Drainage of the flatlands is sluggish and there is generally little or no surface flow, except in the rainy season when lower parts are inundated. Although the surficial sands are permeable, the movement of ground water is very slow because the gradient is almost flat and because the immediately underlying shell marls, calcareous marls, and clayey marls are of low permeability.

In some of the rather well marked areas on the sandy flatlands, drainageways inherited from the past and modified by present conditions are still used by surface waters. Most important of these are the Okaloacoochee Slough and Devil's Garden, the Loxahatchee Marsh, and the Allapattah Marsh. (See pl. 12.)

THE OKALOACOOCHEE SLOUGH AND DEVIL'S GARDEN

The Okaloacoochee Slough and Devil's Garden (pl. 12) form a marshy drainageway on the sandy flatlands south of the Caloosahatchee River, west of the Everglades, and in general, north of the Big Cypress Swamp. The Okaloacoochee Slough extends southward about 50 miles from the vicinity of La Belle into the Big Cypress Swamp. Its average width is little more than 2 miles, but a wide prong, called the Devil's Garden, extends northeastward from Immokalee.

The northern end of the Okaloacoochee Slough has a number of branches, most of which discharge into little creeks flowing into the Caloosahatchee River. The southern end branches out in a similar manner, but it is lost in the maze of intertwining courses in the Big Cypress Swamp. Fahkahatchee Slough is the southwestern branch of the Okaloacoochee Slough.

The Okaloacoochee Slough drains both northward and southward from about the latitude of the Devil's Garden. The Devil's Garden itself drains westward most of the time to Okaloacoochee Slough, but in times of high water it may overflow in all directions—into the flatlands on the north, the Everglades on the east, and into the Big Cypress Swamp on the south. (See pl. 12; arrows indicate directions of surficial flow.)

The Okaloacoochee Slough and Devil's Garden occupy poorly drained depressions on the former Pamlico and Talbot sea bottom. The depressions may have been inherited from an earlier age and are now partly obstructed by old beach bars. When the Pamlico sea was withdrawing from its high-water shoreline, 25 feet above present mean sea level, it left many low beach ridges and bars. These have since been modified by erosion, but many are still noticeable and show plainly on aerial photographs.

Drainage from the Okaloacoochee Slough and Devil's Garden and from the Allapattah and Loxahatchee Marshes is retarded by a rank growth of vegetation and by an accumulation of organic peat and muck that clogs the channels; therefore, at times the movement of water is difficult to discern. Moreover, the direction of flow in the channels may be changed by local rains. "Spot showers," which typify the rainfall in southern Florida, may cover only a fraction of a square mile or several square miles, but they may be so intense that surface-water gradients are temporarily reversed in the sluggish drainageways.

ALLAPATTAH MARSH, LOXAHATCHEE MARSH, AND HUNGRYLAND SLOUGH

The Allapattah Marsh occupies a poorly drained depression on the sandy flatlands east and northeast of Lake Okeechobee. To the south it splits into two prongs, one that discharges its water to Lake Okeechobee north and west of Indian Town, and another that drains almost due south of that city into the Everglades.

The Loxahatchee Marsh and Hungryland Slough together form a wishbone-shaped marshy area with the apex pointed toward Jupiter Inlet and with prongs leading to the Everglades. Drainage is in both directions from a low divide in the middle of Hungryland Slough, and from a divide in Loxahatchee Marsh west of Kelsey City. Part of Loxahatchee Marsh drains directly into the Hillsboro Lakes Marsh at a point a few miles southeast of Loxahatchee. (See pl. 12.)

SANDY FLATLANDS SOUTH OF LOXAHATCHEE MARSH

Southward from the Loxahatchee Marsh the sandy flatlands extend just past Coral Gables, where they abut against the coastal ridge of oolitic limestone and are overlapped by Everglades soils. Apparently the sand never extended farther south because the currents that swept the sand southward became ineffective there.

Between Fort Lauderdale and Miami are several low, shallow valleys, floored with Pamlico sand, that reach to the present shore. These valleys are called transverse glades because of their orientation and their characteristic soils and vegetation. They occupy old drainage courses cut through the Miami oolite, probably in early Wisconsin time, and subsequently partly filled with sand during later Wisconsin and Recent time.

Outside the Atlantic Coastal Ridge, a strip of Recent sand extends southward to Miami as beach, beach-bar, and lagoon areas.

THE BIG CYPRESS SWAMP

The Big Cypress Swamp (pl. 12) is an indefinitely defined area. In general, it is bounded on the east and southeast by the Everglades, a region distinguished by its organic soils, sedges, and lower lying area. The sandy flatlands adjoin it on the north (where they are higher) and on the west (where they are lower). On the southwest and south, the Big Cypress Swamp merges into the low-lying coastal marshes and mangrove swamps. In marked contrast to the surrounding areas of mucky, sandy, and marly soils with no outcropping rocks, the Big Cypress Swamp has large areas with solution-riddled limestone at the surface, or with thin marly soil lying in shallow pockets in the rock. This marly soil in old drainageways is suitable for truck farming if the water table is adequately controlled by ditches, dikes, dams, and pumps.

Natural drainage is very defective, and in the rainy season the larger part of the Big Cypress Swamp usually is flooded; but even under flood conditions the only discernible movement of water is in shallow, poorly defined drainage courses, locally called sloughs, rivers, or creeks. Near the Gulf of Mexico these courses are better defined; however, they are so intricate that the service of a guide is required by a stranger traversing them.

The Big Cypress Swamp is not a vast morass of huge moss-shrouded cypress trees, as is supposed by many people unfamiliar with the area. Instead, it is an area of alternating swampy and higher land (hammocks), with the former prevailing. Davis (1943) describes these relationships and lists the principal components of the flora. The differences in the heights of aerated ground above the water table cause a marked diversification in the distribution of plants. The higher areas support bunch grasses, palmettos, and pines, whereas the lower areas are covered with cypress, much of it stunted, and with willow, bay, reeds, sedges, and other marsh plants. This relationship is especially noticeable near the borders, where strips of coastal marsh, of sandy flatland, or of Everglades may invade the Big Cypress Swamp for several miles. In general, there is no sharp line of demarcation between areas; instead, they merge into each other.

THE ATLANTIC COASTAL RIDGE

The Atlantic Coastal Ridge extends along the Atlantic shore as an irregularly shaped higher strip between the sandy flatlands and the Everglades on the west, and the ocean on the east. It has no sharp crest and appears to rise almost imperceptibly from the Everglades and descend gently to the ocean. Along several short stretches of shore (the most notable at Silver Bluff in Miami), there are several low sea cliffs. Silver Bluff is notched by wave action at a former higher stand of the sea, 5 feet above present mean sea level (fig. 23).

The greatest altitudes on the coastal ridge (about 50 feet) are found on the summits of sand dunes formed during the Pleistocene epoch. These dunes lie in a series of nearly parallel and broken rows inland from the present shoreline. The most southern dunes are found in the region west of Fort Lauderdale[1], but here the dunes are much lower and broader than in the vicinity of West Palm Beach, Jupiter, and Hobe Sound. Northward from Hobe Sound and extending into St. Lucie County, the belt of dunes surmounts old beach ridges and is better developed. These dunes are now quiescent and largely overgrown with bunch grasses, low shrubs, pines, and palmettos.

South of the Fort Lauderdale area there are no dunes on the coastal ridge, although large amounts of sand are present as far south as Coral Gables. This veneer of Pamlico sand was spread out over the limestone bedrock by ocean currents during mid-Wisconsin time.

The coastal ridge almost everywhere has a rock foundation; north of Boca Raton it consists of sandy limestone and calcareous sandstone of the Anastasia formation, and south of Baca Raton it is the Miami oolite. The oolite lies at or near the surface almost everywhere from Miami southward to the point where the ridge finally dies out on the mainland southwest of Florida City. The height of the coastal ridge south of Fort Lauderdale averages about 8 feet above sea level; maximum altitudes of about 21 feet occur on the western shore of Biscayne Bay at Coconut Grove, Miami.

The coastal ridge disappears southwest of Florida City in a series of low "islands," often called "Everglades Keys," sur-

[1] Pine Island, so called from the fact that prior to drainage of the glades this large, pine-covered dune was entirely surrounded by water, is the best developed of these ice-age dunes.

rounded by lowlands of Everglades soils. The coastal ridge reappears once again in the lower Florida Keys, from Big Pine Key to Key West, where Miami oolite is again the bedrock. Maximum altitude measured on Big Pine Key is less than 7 feet, and on Key West it is about 13 feet.

Marly or mucky strips, called by Harper (1927, p. 176) "transverse glades," cut across the coastal ridge in several places. The plants of these glades are unlike those of the higher ridge land and are very distinctive. Some of the transverse glades, especially south of Miami, head on the ridge itself and merge seaward with the coastal prairie developed on the Silver Bluff terrace. They are generally floored with gray marl soils, and when the water table is properly controlled they form excellent agricultural lands.

SILVER BLUFF TERRACE

The Silver Bluff terrace has not previously been described in detail, although the shoreline that borders it has been partly described (Parker and Cooke, 1944, p. 22–44; Parker, 1945b, p. 130, 138–139) and the terrace adjacent to Silver Bluff (a wave-cut bench) was called the "Miami bench."

Since then, this wave-cut bench and its bordering shoreline have been found to be quite extensive. They have been traced and mapped with considerable accuracy in Dade County, but with less accuracy in adjoining counties. The Silver Bluff terrace has been found to underlie most of the Everglades and the coastal marshes. A map, plate 13, shows the Silver Bluff terrace in Dade County, the approximate location of the old shoreline, and the areas that were dry land, mostly islands, in the time of Silver Bluff deposition.

Not only are the islands and surrounding terraces now distinguishable by physiographic means; they support an entirely different assemblage of plants (reeds, sedges, willows, wax myrtle, on the terrace, and pines, bunchgrasses, and saw palmetto, on the islands) and thus aid field mapping. The area shown in plate 13 has been mapped by leveling and by studying aerial photographs.

Modern shorelines are not uniformly level throughout their distribution, nor was that of the Silver Bluff in Pleistocene time. In Florida, along the open ocean this Pleistocene shoreline now averages about 5 feet above sea level, but in protected places and areas where the oolite is harder it may be several feet higher. Thus, it does not everywhere coincide with the 5-foot contour line.

Nor does the terrace have a perfectly smooth surface. It shows shallow undulations, trenches, and low ridges caused by differential erosion of oolite varying in hardness and whose original depositional surface was not level. However, as a whole it is fairly uniform. It slopes gently seaward along the Atlantic Ocean; and inland, between the islands and the mainland that existed in the time of Silver Bluff deposition, the terrace slopes gently toward a broad, shallow groove that is oriented in a northeast–southwest direction and connects with outlets on the northeast at Miami and Fort Lauderdale, and on the southwest with the Bay of Florida.

Most of the Everglades and coastal marshes in Dade County are developed on the Silver Bluff terrace. The shoreline is traceable in Broward County (northward from Dade County on the eastern side of the Atlantic Coastal Ridge), but it loses its identity near Pompano where the geologic materials that compose the Atlantic Coastal Ridge are not consolidated—sand, not limestone, occurs there. On the western side of the Coastal Ridge the Silver Bluff shoreline follows a sinuous path beneath the Everglades soils and connects with the Lake Okeechobee basin. From here, the shoreline follows southward in a line roughly parallel to the Everglades–Big Cypress Swamp border.

MacNeil (1950, p. 104) has recognized the Silver Bluff shoreline in northern Florida and Georgia. However, the fact that the Silver Bluff shoreline and terrace are easily traceable only in southeastern Florida is not at all surprising. Elsewhere along the Atlantic and Gulf coasts there are few areas of consolidated rocks in which the record of this latest Pleistocene shoreline could be either developed or preserved.

Sands and other unconsolidated materials soon weather, creep, and slump, reducing a once-prominent sea-cut scarp to a mild change in slope of the land surface. Although very hard rocks may not even be noticeably cut in a relatively short stand of the sea at a given level, soft limestones develop a noticeable and lasting cut.

At the present time, southeastern Florida presents an outstanding example of the development and preservation of the modern shoreline. If present sea level starts to recede, it would not be long, geologically speaking, until most recognizable features of the present shore elsewhere along the Atlantic and Gulf coasts would be so nearly obliterated that they would be recognizable only to the trained eye.

THE EVERGLADES

The Everglades, a region of organic soils (pl. 12), occupies an irregularly defined area of about 4,000 square miles, lying between slightly higher areas on all sides, except on the south and southwest, and developed principally on the Silver Bluff terrace. (See p. 118–125 for the geologic history of the Everglades.)

An arm of the Everglades borders the western side of Lake Okeechobee, and a narrow tapering arm extends northward along the eastern side, where it merges with the Allapattah Marsh and cypress swamps. The Everglades extends southward and southwestward from the lake in a vast sweep about 40 miles wide and 100 miles long, merging near the Bay of Florida and the Gulf of Mexico into salt-water marshes and mangrove swamps. The boundary between the Everglades and surrounding areas is very indefinite. It may be regarded as the place where the sedges of the Everglades give way to true grasses and pines or cypress, or to salt-marsh plants and mangroves.

Large areas in the northern and eastern parts of the Everglades are almost treeless expanses of sawgrass (*Mariscus jamaicensis*) —a sedge, growing as tall as 10 or 12 feet. Low shrubs of wax myrtle, willow, bay, and custard apple appear on slightly higher areas, generally in isolated clumps called tree islands, which are generally in alinement with the general drainage pattern (fig. 27).

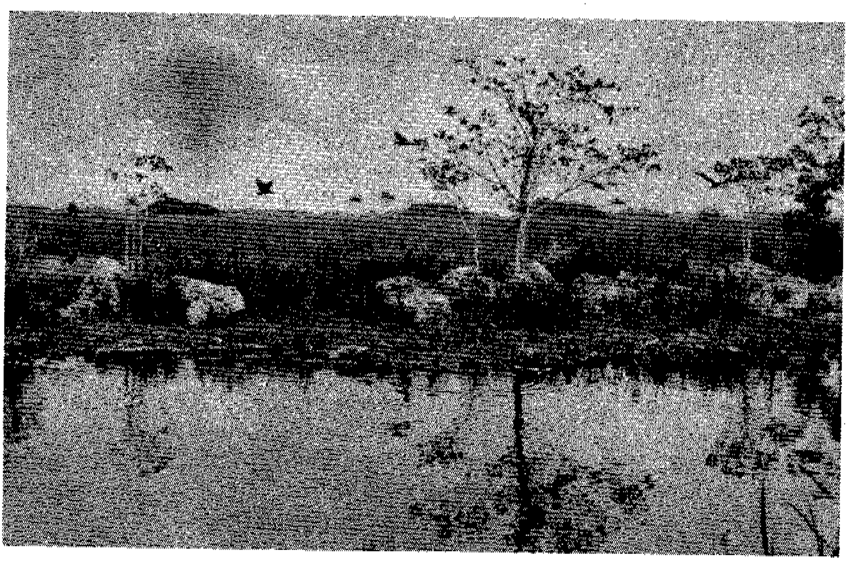

Figure 27. —Typical view of western part of the Everglades showing tree islands.

Trees grow in the Everglades where there is enough height above the perennial water table to allow aeration of the soil. Conditions are very favorable along spoil banks, and trees and shrubs grow there in rank profusion.

The accumulation of peat and muck is still continuing in certain undeveloped areas of the Everglades where each year's growth of plants dies and sinks below the surface of the shallow water and is incorporated in the organic mass below. And it would continue at a much faster rate except for man's interference by drainage and farming.

FLOOR OF THE EVERGLADES

The floor of the Everglades is chiefly comprised of rocks of the Fort Thompson formation, except in the south where the Miami oolite is prevalent. A thin gray blanket of relatively impermeable Lake Flirt marl covers vast areas of the rocky floor, and along the west and east margins of the Everglades (as far south as the latitude of Miami) a thin mantle of Pamlico sand occurs. Over these materials are several kinds of peat and muck (Evans and Allison, 1942, p. 34—46).

Sanford (1909, p. 192—193) thought that the rock floor in the northern part of the Everglades slopes to the west more steeply than in the southern part, that depth to bedrock 5 miles west of the eastern rim back of Fort Lauderdale is probably not less than 20 feet, and that the Everglades probably occupies a series of comparatively shallow rock hollows. He states, "Whether these hollows were as deep when the Everglades first occupied them as they now are, that is, whether they have been deepened by solution through underground drainage, whether they represent original inequalities of deposition of the lime rock, or whether they are buried shallow valleys cannot be determined from the evidence at hand. It is probable, however, that the deepening and enlarging effect of underground solution has been exaggerated."

Subsequent writers have added little to this concept because of lack of specific information. Of the rock floor, Fenneman (1938, p. 63) writes: "Under it (the organic soils) is a floor of limestone believed to be nearly level. Rarely, if ever, does it fall below sea level, and nowhere in the Everglades proper does it reach the surface. The fact that it reaches the surface on all margins, except along the shore to the southwest, suggests that the Everglades may owe their existence to an original rock basin. The rock floor is slightly more uneven in the north than in the south, and various explanations have been offered, based on erosion, solution, and deformation."

Data gathered by the U. S. Geological Survey while drilling numerous exploratory test wells, and by the Soil Conservation Service while making soil surveys in the Everglades, show that Sanford's and Fenneman's observations were fairly accurate. Beginning along the eastern rim of the Everglades (fig. 28), from Lake Okeechobee to the latitude of the Palm Beach—Broward County boundary, there is a rapid descent from the Atlantic Coastal Ridge to the shallow basin that contains the Hillsboro Lakes Marsh in its southern end (pl. 12 and fig. 28). Elevations drop from about 10 feet to about 3 feet (mean sea level, U. S.

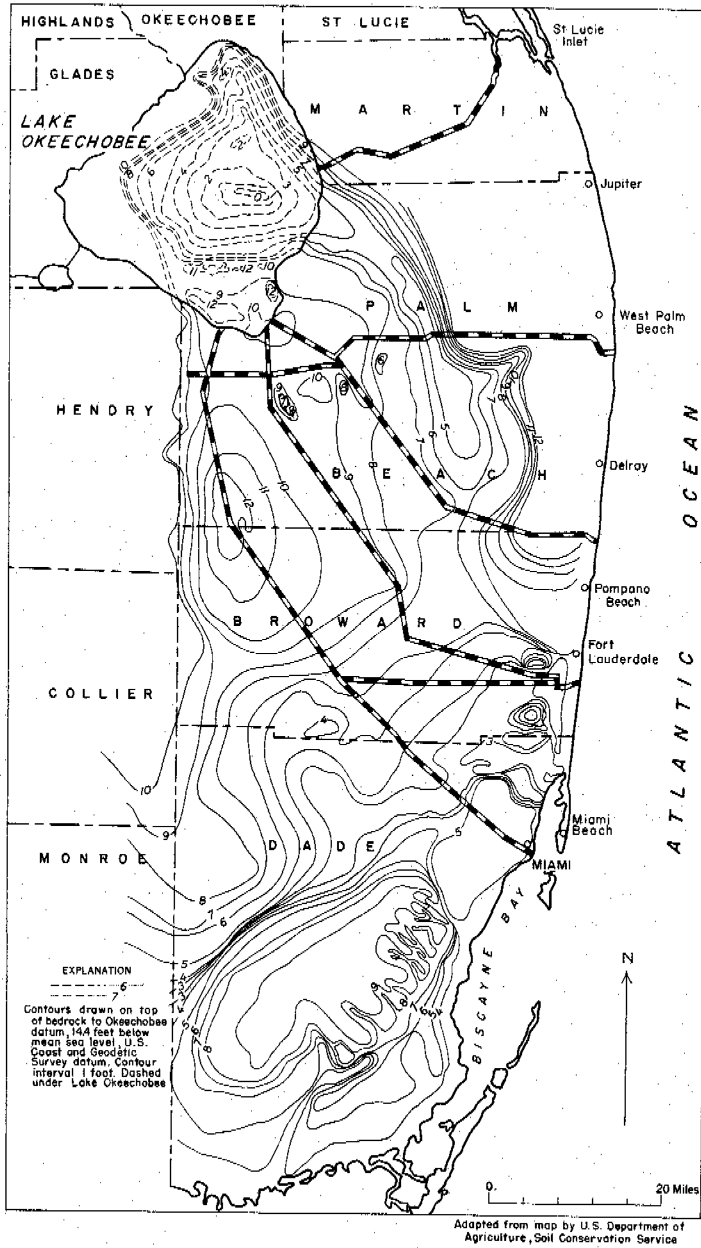

Figure 28. —Contour map of rock floor of Everglades.

Coast and Geodetic Survey datum) within a distance of about 1 mile—a change in elevation that is distinctly scarplike. There is a shallow trough leading into the shallow basin of the Hillsboro Lake Marsh from the southeastern side of Lake Okeechobee. Southward from the Hillsboro Lakes Marsh this trough continues to connect with old spillways and tidal channels emptying into the Atlantic Ocean between Fort Lauderdale and Miami. Some of these old channels have been deeply eroded in the rock and later filled with sand; Sanford referred to these sand-filled channels when he said that depth to bedrock west of Fort Lauderdale is not less than 20 feet. However, he did not know that these depths exist only in channels, because sufficient data were not available to him.

West of this trough, which lies along the eastern margin of the Everglades, the rock floor forms a domelike surface (an erosion remnant) with its top about 10 feet above mean sea level. This "high" centers on the Palm Beach—Broward County line about 6 or 7 miles east of the Palm Beach—Hendry County line, and due south of Lake Okeechobee. From the top of this low dome the floor slopes gently northward and southward. To the north the slope is quite gentle until the basin of Lake Okeechobee is reached; then the drop is abrupt. To the south, also, the slope is slight. To the west the slope increases and the floor drops about 3 feet in 4 miles to where a narrow trough (with floor elevation about 8 feet above mean sea level) lies along the eastern margin of the Big Cypress Swamp and the sandy flatlands north of the Big Cypress. (See pl. 12 and fig. 28.)

Farther south, beyond the domelike area and between the Big Cypress Swamp on the west and the Atlantic Coastal Ridge on the east, the floor of the Everglades slopes gently from the sides toward the center where a low, broad, flat valley swings gently to the southwest.

These major features of the floor of the Everglades are locally marked by smaller basins and higher areas. In general, the floor slopes from the Silver Bluff shorelines at the sides toward the middle, but the slope is interrupted by local ridges and basins, none higher than the lands surrounding the Everglades and few deeper than sea level.

Solution is actively engaged in etching out the floor of the Everglades at the present time, deepening the hollows and roughening the ridges. Deposition, too, is taking place in some parts, especially in the soils of the hammocks where calcium carbonate is being deposited, making a carbonaceous marl that locally hardens to friable, impure limestone.

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DRAINAGE PATTERN OF THE EVERGLADES

In the Everglades there are many elongate tree islands, arranged more or less in parallel rows and separated from one another by shallow "swales," "runs," "sloughs," or "lakes," as they are variously called locally. These tree islands and swales trend northwest–southeast in the upper part of the Everglades as far south as the old spillways through the coastal ridge between Miami and Fort Lauderdale, then they begin to bend to the south, and finally, about 18 miles south of Miami, they swing abruptly to the southwest.

The linear arrangement of this pattern is most noticeable from the air, from which, as Dickerson (1942, p. 136–139) says, "They reveal a decided 'grain' to a broad sweep of country * * * as if a great coarse broom had been rudely brushed over the low-lying Everglades region." Such an arrangement of alternate strips of tree islands and sawgrass is developed best toward the western side of the Everglades in the vicinity of the Tamiami Trail (fig. 27).

Dickerson postulates that this "grain" may be the result of ocean currents during Pamlico time when this whole area was a shallow sea bottom. He notes, "Off the east coast of Florida a strong south-flowing inshore current prevails, and this current drags the quartz sands from the north and mixes them with the coral sands of the Florida Keys as it sweeps westward in a great arc. The marked parallelism between these Everglades groovings and the present east and south shorelines of Florida suggests that the same agents—ocean currents—shaped both."

Dickerson's hypothesis, which is based entirely on photographs taken from an altitude of 14,000 feet, fails on closer examination. The "grain" of the Everglades, interpreted by him as traces of ocean current, is believed to be developed entirely on fresh-water peat and muck and apparently does not reflect an underlying pattern of marine bars. It merely represents a drainage pattern produced on a very gentle sloping surface of organic deposits. The "grain" is composed of tree islands and swales that trend parallel to the regional slope, just as one would expect in an area of consequent drainage. Streams flowing across the Sunderland terrace into Okefenokee Swamp in Clinch and Warren Counties, Ga., show a similar pattern of parallel lines. On certain parts of the Pamlico terrace, especially in St. Lucie and Martin Counties, a parallel arrangement of old dunes, beach ridges, bars, and lagoons is noticeable. This pattern is a direct product of the lowering of a sea level in a shoreline environment but is not the same as that of the organic Everglades soils.

The drainage pattern in the Everglades is gradually being changed by man's operations. "Subsidence valleys", according to

Evans and Allison (1942, p. 38), have developed along the principal drainage canals, and the flow in the northern end of the Everglades at certain times of the year is northward into the lake, exactly opposite to the original condition.

LAKE OKEECHOBEE

Lake Okeechobee occupies the northermost and largest of the interconnected series of basins and shallow troughs that comprise the Lake Okeechobee—Everglades lobe of the Silver Bluff terrace (fig. 28). The lake basin is an original hollow in the Pliocene sea floor that has been modified by solution, erosion, and deposition of sediments during the Pleistocene and Recent epochs.

The lake averages a little less than 30 miles in diameter, and its area usually varies between 650 and 725 square miles, depending on the stage. (See section on Surface water for detailed information on the lake.)

The lake is very shallow; the deepest parts are approximately at sea level (fig. 28). It is saucer-shaped, and because of its physical characteristics it is subject to violent wind tides and wave action during storms. According to House Document 469, 76th Congress, 1st session, pages 8–9: "The hurricane of 1933, with a maximum wind velocity of about 80 mph, caused a hurricane tide of approximately 5.6 feet. The hurricane of 1926, with a maximum wind velocity of about 90 mph, caused a hurricane tide of 6.8 feet. The hurricane of 1928, with a maximum wind velocity of 135 to 150 mph, caused a hurricane tide of 13.2 feet. This hurricane caused such great loss of life and property damage that it was the primary cause of the Federal Government undertaking the present flood-control project. Past records show that hurricanes with much greater wind velocity than that of 1928 have occurred, notably that of the Florida Keys in 1935, which had an estimated wind velocity of approximately 200 mph and a maximum hurricane tide of 16 to 18 feet."

From these data it is easily understood that the bottom of the lake is rather thoroughly scoured by the action of storm waves, and because these waves effectively cast out detrital material, loose sand is scarce on the bottom. Around portions of the lake, especially on the northeastern, eastern, and southeastern borders, a definite sand ridge has been built up. This is a beach ridge, probably built by storm waves, and it lies outside the hurricane levee. It is the dwelling place of most of the rural families who live around the eastern margin of the lake. Shallow sand-point wells driven into this deposit furnish domestic water supplies. For information on ground-water inflow into the lake see p. 106–107.

HILLSBORO LAKES MARSH

Hillsboro Lakes Marsh (pl. 12) is a boggy area of about 55 square miles in Palm Beach County. It lies north of the Hillsboro Canal, south of the West Palm Beach Canal, west of the strip of sandy flatlands that borders the Atlantic Coastal Ridge, and, in general, east of a north-south line through the junction of the Cross Canal and the West Palm Beach Canal.

It occupies one of the large and deeper basins in the floor of the Everglades—a basin now nearly filled with peat and muck. These organic soils are being constantly built up over the greater part of this area by aquatic and semiaquatic vegetation. Expanses of open water, dotted with small tree islands on peat and muck and flotant masses of "floating islands," exist over large areas. In shallower parts, sawgrass grows thickly; in deeper water, pond lilies and pickerel weed are the commonest plants.

Since the excavation of the Hillsboro Canal and the resultant lowering of the water table, rejuvenation of the better-established drainage courses has occurred, and at the present time, some of them have become small streams in which the underlying organic deposit has been stripped away in their channels and the bedrock exposed. Indian Run is a good example.

COASTAL MARSHES AND MANGROVE SWAMPS

The coastal marshes and mangrove swamps are developed on the seaward margin of the Silver Bluff terrace and along the border of the present seashore. In southeastern Florida their greatest development is in southern and eastern Dade County, but they continue as an irregular narrow band along much of the Atlantic coast behind the sandy beach ridge.

The mangrove swamps are generally floored with a black peaty deposit, often with considerable inorganic material (quartz sand, chiefly) admixed. The coastal marshes are characterized by marly soils mixed locally with sand and muck. In the area bordering salt water the vegetation consists of the usual salt-marsh subtropical assemblage, which gives way to fresh-water marsh plants at the outer edge of the sandy flatlands, the Everglades, or the Atlantic Coastal Ridge. The general relationship of these plants has recently been presented by Davis (1943). The coastal marshes have yielded excellent truck crops in areas where a properly controlled water table has been maintained.

THE FLORIDA KEYS

The Florida Keys are low-lying islands that extend about 140 miles to the southwest in a gently curving arc from Soldier Key (in Biscayne Bay) to and including Key West.

The keys are divisible into two groups, distinguishable both by their difference in rock characteristics and by their shape. The "upper keys" include the group lying between Soldier Key and Bahia Honda. They are of coral-reef origin and are elongated in a direction parallel to the coastline along which the reef grew during the Pleistocene epoch. They average about a quarter of a mile in width and range in length from a few hundred yards to many miles—Key Largo, the longest, is almost 30 miles long. All are low; land surface in excess of 5 feet above sea level is rare.

The "lower keys" are merely an extension of the oolitic limestone reef or bar on which Miami and other mainland cities of southeastern Florida are built. These lower keys begin with Big Pine Key, and are generally elongated at right angles to the elongation of the upper keys. This northwest-southeast elongation of the lower keys is caused largely by the direction of movement of the tidal scour produced by differences in time and height of the tides in the Gulf of Mexico and the Strait of Florida, but it is also influenced by the original shape and differences in altitude of the surface of the oolitic bar from which the rocks of the lower keys are formed.

The shape of the keys is also modified by agencies other than the tides. The work of the waves along the shorelines (especially during hurricanes) is important, and solution of the limestone by percolating water is another vital factor. The latter is especially noticeable in the so-called potholes or natural wells which occupy a large part of the total volume of the rock. On both Big Pine Key and Key West these open vertical solution holes are commonly called springs, although they do not flow. Some of the larger solution areas, produced by coalescense of a group of small, adjacent potholes, create ponds, or depressed areas reaching near the water table. These latter depressions become centers of extremely lush vegetation.