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Executive Director
ERRATA

Please attach this errata sheet to the inside cover of Bulletin No. 51.

PAGE

III 2nd par., 2nd line - “Florida” not “florida.”
19th line - “lineaments” not “lineamounts.”

V Line 34 - “Lines” not “Liens.”

VI Line 18 - “Aeolian” not “Aeolean.”

VI Line 18 - “Peninsula” not “Peninsual.”
Last line - “Bibliography” not “Biography.”

VIII Titles for figures 32 and 33 should bear the acknowledgement, “After Davis (1946)”.

2 3rd line - “Caloosahatchee” not “Caloosahattchee.”

2 2nd par., 3rd sentence et seq. should read as follows:
“The central or mid-peninsula zone extends northward from this line as far as one which would pass approximately through the cities of St. Augustine, Palatka, Hawthorne and Gainesville. From this last line the northern or proximal zone extends northward to Georgia.”

4 1st par., next to last line - “post-Flandrian” not “post-Floridian.”
Sub-heading - “Peculiarities” not “Pecularities.”

10 1st line - “attested” not “atedested.”

11 Figure 3 should bear this legend - “Contours show elevation above assumed datum in inches.”

12 Figure 4 should bear legend saying that length of line indicates number of observations. Arcs are drawn at distances indicating 6, 9, and 10 observations.
7th line in par. - “Caloosahatchee” not “Caloosahattchee.”

22 2nd par., 3rd line - “their” not “then.”

26 2nd par., 2nd line from bottom - “accretions” not “accretions.”
31 5th line from bottom - “instances of such” not “instances such.”
32 2nd sentence - “lose their coast-perpendicular” not “loose their coast-parallel.”

35 Figure 16 should bear the following legend:

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42 2nd par., 4th line - “is” not “in.”
6th line from bottom of page - “islands” not “inlands.”

43 2nd par., 4th line - “lee” not “Lee.”

51 5th line - delete reference to figure 25.

66 1st par., 4th line - “27” not “28.”

71 Figure 29 should bear this legend: “Contours show elevation above assumed datum in inches.”
ERRATA, cont.

PAGE

73 Figure 30 should bear this legend: “Contours show elevation above assumed datum in inches.”

80 Figure 32 should bear the acknowledgement: “After Davis (1946).”

81 Figure 33 should bear the acknowledgement: “After Davis (1946).”

91 2nd par., 7th line - “coast-parallel” not “coast parallel”.
3rd par., 12th line - sentence should read: “Their pattern on the map suggests that they originally converged to make an early counterpart of the present False Cape.”

4th par., 4th line - “Mayport” not “Maysville.”

94 2nd par., 5th line - “traverse” not “transverse.”

95 4th par., last line - “figure 41” not “figures 40 and 42.”

104 4th par., 5th line - “coast-parallel” not “coast parallel.”

122 Both references to Bishop are to his 1956 publication, not 1959.
3rd line from bottom - “Hawthorn” not “Hawthorne.”

123 3rd line of sub-heading - “Crescent” not “Cresant.”

125 The line of alternate dots and dashes referred to in the next-to-last sentence of the first paragraph under the heading “POSSIBILITY OF A RELIC CAPE AT ORLANDO” was omitted from Plate 1.

127 4th par., 6th line - “gingerly” not “ginerly.”

133 Heading - “WESTERN” not “WESTER.”

4th par., 3rd line - “cross” not “corss.”

4th par., 4th line - “valleys” not “valley.”

135 4th par., 4th line - “juncture” not “junture.”

137 3rd par., 7th line - “southern” not “solution.”

139 3rd par., 5th line - “apophyse” not “apoplyse.”

152 1st par., 12th line - “is” not “in.”

1st par., 14th line - “foreset” not “foresee.”

155 1st par., 1st line - “Miocene” not “miocene.”

156 4th par., last line - “Okefenokee” not “Okefenoke.”

5th par., 5th line - “subterranean” not “subteranean.”

157 4th par., 10th line - “subterranean” not “subteranean.”

158 2nd par., 3rd line - “Okefenokee” not “Okefenoke.”

2nd par., 7th line - “Okefenokee” not “Okefenoke.”

3rd par., 5th line - “Okefenokee” not “Okefenoke.”
Bureau of Geology
Tallahassee
May 7, 1970

The Honorable Claude R. Kirk, Chairman
Department of Natural Resources
Tallahassee, Florida

Dear Governor Kirk:

The Bureau of Geology of the Division of Interior Resources is printing as its Geological Bulletin No. 51 a report prepared by Dr. William A. White, professor of Geology at the University of North Carolina on "The Geomorphology of the Florida Peninsula."

This report was originally started as part of a six volume series on the geology of Florida, but because of budgetary limitations the portion on the panhandle of Florida was not completed in time to be included with this publication. It is planned to subsequently issue the companion report on the Geomorphology of the Florida Panhandle and to combine these two as a volume in a set that will ultimately include under "The Geology of Florida" volumes on the stratigraphy of Florida, the water resources of Florida, the structure of Florida, guide fossils of Florida, and perhaps a volume on geochemistry.

In order to protect the names assigned by Dr. White it was felt desirable to publish his report immediately.

Respectfully yours,

R. O. Vernon, Chief
Bureau of Geology

ROV:ebl
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December 15, 1969
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ACKNOWLEDGEMENTS

Grants numbered GP-1480 and GP-3350 from the National Science Foundation made to the Geology Department of the University of North Carolina at Chapel Hill defrayed much of the cost of the investigation described in this bulletin.

I acknowledge with much appreciation the benefit of discussion with Dr. R. O. Vernon, Mr. W. D. Reves, Mr. J. W. Yon, Jr. and Mr. E. W. Bishop.

Dr. H. S. Puri cooperated with me in establishing the major geomorphic divisions of the Florida Peninsula and consulted with me in the field. His contributions are much appreciated.

Dr. Walter H. Wheeler kindly identified the fossils from South Canal in Indian River County and appraised their ecologic significance.

I was assisted by my students at the University of North Carolina, Mr. J. P. May, Mr. E. L. Phillips, Jr., Mr. L. L. Smith and Mr. L. H. Slorp. I owe much to their work.

Dr. Robert Ginsburg and Dr. J. E. Hoffmeister very kindly gave me helpful information about the Keys and Florida Bay.
MAJOR GEOMORPHIC DIVISIONS
OF THE FLORIDA PENINSULA

by

WILLIAM A. WHITE

DELINEATION OF GEOMORPHIC FEATURES

Some confusion in the delineation of the physiographic features of Florida (pl. 1) results from the generally low relief.

In a region of high relief, there is little equivocation in separating adjacent features. A mountain is recognized as a feature which rises prominently above its immediate surroundings and its edge is defined as the break in slope at its base. There is little concern whether this break in slope forms a level line. Quite generally, it does not. However, a region of very low relief, many significant topographic features are imperceptible to ordinary observation, but are recognized through knowledge gained from surveying or their effects on flora, drainage, culture etc. Under such circumstances, there is a strong tendency to delineate topographic highs by use of delimiting contour lines. This tendency is augmented by the fact that such features are ordinarily defined from a study of topographic maps and it is easy to define them as being the land above certain specific contours.

Also since the low-lying parts of Florida have been repetitively below sea level, a number of relict shoreline features have been commonly recognized. These are ordinarily horizontal. Therefore, there has been a strong tendency to delimit physiographic features by these relict shorelines and hence by individual key contour lines which represent the elevations of sea level at the times these relict shoreline features were made.

To some extent, this tendency is a good one, but it has faults and they increase with elevation and distance from the present coast. The higher the shoreline, the older it is and, therefore, the longer it has been subjected to erosion and sagging because of solution of any limestone which may underlie it. Farther north, in Georgia, the Carolinas, Virginia and Maryland, the lower terraces at least have been little deformed; they are largely based on insoluble rocks. But the Florida peninsula is largely founded on limestone which has been differentially dissolved to allow differential sagging of the overlying surface.
For these reasons, I have avoided the delineation of physiographic features by single contour lines, and have used natural features as much as possible. Thus, I have tried to map scarp bases by breaks in slopes rather than by particular elevations. In certain broad, flat areas of imperceptible dome-shaped form, such as the Immokalee Rise, I have been guided more by the extent of the sand and the delimiting zone of lakes than by a given contour line.

MAJOR GEOMORPHIC DIVISIONS OF THE FLORIDA PENINSULA

The Florida peninsula can be divided into three physiographic zones, separated along trans-peninsular lines, oriented about perpendicular to the length of the peninsula (Fig. 1). The Southern or Distal zone, extends from the southern end of the peninsula to a line that crosses the peninsula from the general vicinity of Stuart on the east coast to that of Fort Myers on the west coast. The central or mid-peninsular zone, extends northward from this line from this last cross-peninsular line. The northern or proximal zone extends northward to Georgia as far as one which would pass approximately through the cities of St. Augustine, Palatka, Hawthorne, and Gainesville. Certain features cross these boundaries from one physiographic zone to another. Thus, the terraced coastal lowland extends along the west coast of the peninsula from the northern to the central zone, as does also the Eastern Valley along the Atlantic side of the peninsula. The Atlantic Coastal Ridge reaches the entire length of the peninsula from the Georgia state boundary to Miami, as does also its insular counterpart the Atlantic Barrier Chain.

The low-lying lands of the southern zone, west of the Atlantic Ridge, did not reach elevations as high as the Atlantic Ridge on their eastern rim because they were not exposed to the high energy processes of the Atlantic shore, which at once carried sand southward from northern sources to build beaches and fed the corals that built the reefs of the Keys.

The northern physiographic zone is distinguished by continuous high ground forming a broad upland which extends eastward to the Eastern Valley, and westward continuously into the western highlands of Florida. The central or mid-peninsular zone is characterized by discontinuous highlands in the form of sub-parallel ridges separated by broad valleys. The southern or distal zone, is characterized by a broad, flat, gently sloping and poorly drained plain, fenced on the east by the Atlantic Ridge.
Figure 1. Map of Florida showing major transpeninsular physiographic divisions

For the most part, the northern zone is high enough to have its surface above the piezometric surface and is therefore characterized by many of the features of dry, highland, or "dead-zone" karst, such as first generation, dry, steep-walled sinks, abandoned spring heads, dry stream courses, intermittent lakes and dry beds of former broad shallow lakes which are now prairies.
In general, the ridges of the central or mid-peninsular zone are above the piezometric surface, but the broad valley floors are below it. Broad shallow lakes are common on the valley floors and smaller deep lakes, apparently of rather complex geomorphic history, pock the ridges. The southern or distal zone, is almost universally below the piezometric surface and has lakes only in its most northerly part. These lakes are apparently a carry-over from the central zone and seem to exist largely because small amounts of sand overlie limestones. Farther to the south there is no sand. Limestone lies bare or is covered by post-Floridian peat and lime mud. There are no lakes but broad swamps dominate the landscape.

THE DISTAL OR SOUTHERN ZONE

MAJOR PECULARITIES OF THE SOUTHERN PART
OF THE FLORIDA PENINSULA

The east coast of the Florida Peninsula changes character at the latitude of Palm Beach because the upper edge of the continental slope intersects the litoral zone there. To the north of Palm Beach the landward edge of the continental slope is farther off shore with distance northward. To the south of Palm Beach it remains a short and rather uniform distance off-shore.

This change comes about through a change in the orientation of the coast line. The outer edge of the Continental Shelf maintains a smoothly concave regional curve southward from Cape Hatteras (in North Carolina several hundred miles to the north) all the way to Miami. In general, the coast line describes a somewhat similar concave curve of slightly smaller radius that intersects the more gentle curve of the outer edge of the shelf at Palm Beach. This intersection accounts for the change in orientation of the coast line at Palm Beach. The curve of the shelf edge is unbroken and it becomes the curve of the coast line south of Palm Beach.

This peculiarity of the distal end of the Florida Peninsula is a major anomaly of the Coastal Plain. It is the only place in the entire Atlantic-Gulf of Mexico coast of the United States where land extends all the way to the outer edge of the Continental Shelf. The reason for this is not wholly clear, but it probably results from the rapid deposition of carbonates from the tropical water of the Florida current.
Carbonate accumulation is not primarily dependent on mechanical transport agents but on the loci of precipitation. Coral reefs establish themselves at the outer edges of shoals and grow up to the surface of the sea forming a sediment trap over the shoal. Calcareous oolite bores or shoals are precipitated from deep marine water as it rises to pass over the edge of a shoal. This also tends to form a platform rim (Newell, Purdie and Imbric, 1960b). Inside such containing barriers or even without their protection other biogenic or inorganic precipitation of carbonates occurs over broad areas indiscriminate of hydraulic or topographic gradient.

Under such conditions of growth, isolate areas of carbonate accumulation build up to sea level and out to the edge of the Continental Shelf. Even where there are no prominent coral reefs, as in the Bahamas, the outer edges of broad carbonate banks tend to be unusually steep. Not infrequently they are submarine cliffs.

There are no such abrupt topographic ends to the edges of either coastal plains or continental shelves where they are dominated by insoluble clastic sediments. Such submarine surfaces change grade gently from shelf to shore. At the coast line the gradient shows little change from coastal plain to continental shelf other than the usual five-fathom drop from the beach to the sea floor some half mile to mile off-shore.

Deformation may be involved in the seaward inclination of the continental shelf. Along a continent’s edge, there may be a continuous isostatic adjustment to the transfer of mass from land to sea. This tends to keep a hinge line near the coast and tilt both the shelf and the coastal plain seaward.

Carbonate banks usually are isolate from sources of terrigenous sediment and have little apparent reason to share such one-way tilting. Many seem to have subsided great distances but have maintained a horizontal top at sea level. Perhaps this is an index to rapid sedimentary growth. They may have been tilted but maintained their tops at sea level despite the tilting. The asymmetric gravity anomaly in the Bahamas may suggest this.

Rates of carbonate deposition as shown by the geologic section of the Bahama Banks have been regarded as spectacular but their gross products are no thicker than insoluble clastic sediments accumulated on continental shelves in comparable amounts of time. However, the maintainance of carbonate lowlands and shallow marine banks at elevations very close to present sea level is not only a matter of rapid
accumulation of carbonate sediment. It is also a matter of equally facile lowering. Tropical carbonate banks, atolls, reefs, and insular and peninsular lowlands like Andros Island and south Florida stand almost alone among areas of late marine sedimentation in having no higher lands extending significantly above present sea level. Virtually all coastal plains that border continental oldlands and are made dominantly of insoluble clastic sediments have flights of broad marine terraces that attain elevations hundreds of feet above present sea level. Such tropical carbonate areas as those described above are usually free of broad terrace flights. Yet the thick Tertiary and Quaternary sections of such places as the Bahama Banks and south Florida offer good evidence that they have been in existence for periods comparable to those of the terraced terrigenous coastal plains of the continents. If their acquisition of new carbonate sediment is fast enough to maintain them constantly at sea level, in the past they should have built themselves up to the several former sea levels reflected in the Terraces of the continental coastal plains.

Since they rarely show relicts of such former higher surfaces, it seems reasonable to assume that such surfaces once existed but have been reduced by denudation or depression. Since extensive remnants of such relict sea-graded surfaces exist not only on coastal plains built of insoluble terrigenous sediment, but also in the karst-riddled, lime-founded terrain of the central zone of the Florida peninsula, it seems plausible to assume that the correlative surfaces of the tropical banks have been lost by subsidence and burial beneath lime deposition rather than by denudation. Such an assumption is supported by the southward dip of strata from their zone of exposure in the Central Zone to their increasing burial with distance southward into the Distal Zone.

The Bahama Islands proper are discrepant to this generalization but they are, I think, a special case. Were they unreduced residuals of formerly higher broad marine banks like the present Bahama Banks but built up to former higher-than-present sea levels, they should be scattered over the surfaces of the present Bahama Banks. Instead they are all peripheral to those banks and are always located where the off-shore slope goes precipitately down to abyssal depths, usually to windward. This assures that deep-water surf is always able to break on their shores regardless of sea level change, and always in the same place geographically. The resulting beaches assure a copious supply of sand which is blown onto the islands' surfaces, where it builds high dunes. Most of these dunes seem always to have been stabilized by dense scrubby vegetation that forms an excellent sand trap. And accumulating under subaerial conditions of agradation such masses of carbonate
sand were probably cemented together progressively as they accumulated. Thus indurated as dune rock they would be constantly subject to accretion by aeolean deposition but would be invulnerable to wind erosion.

Evidence that certain Bahaman islands are not remnants of deposits made by sea levels much higher than the present one can be had from Dall (1905) who noted that these islands contain marine fossils up to an elevation of 15 feet and do not contain any marine fossils at higher elevations. Also, Newell (1960) says, "Many of the best preserved, cemented dunes rest on submerged platforms approximately 3 to 6 meters below sea level." Newell also summarized the age determinations for such Bahaman dune rock. They range from 13,000 to 70,000 years B.P. — much younger than the higher terraces of the Atlantic Coastal Plain, most of which are currently believed to be Tertiary in age.

With the passage of time and multiple changes of sea level, all parts of those coastal plains that are dominated by insoluble clastic sediments have passed through the level of the sea and each in its turn has located a shore line. These many former shore lines are revealed today by relict beach ridges, barriers, dunes and other littoral features which blanket the entire lower part of such coastal plains, as in the Florida peninsula north of Palm Beach.

In the distal zone of the Florida peninsula, such coastal features rarely develop, and most of the terrain is built of limey sediment derived from seawater. This sediment was precipitated in a variety of ways. And these several kinds of precipitation made a variety of depositional sedimentary masses that have emerged largely unchanged to make the present topographic forms. None of these depositional processes resemble those which distributed the insoluble clastic sediments of the terrigenous coastal plain to the north. Some of these limey deposits were accumulations of marine shell, some were oolite, some were limey muds, and some coral. Few were located strictly by line of intersection of sea and land. On coasts dominated by insoluble sand, the temporal succession of beaches causes the shore line to migrate across an emerging off-shore slope. But in a variety of masses of limestone which still retain their original depositional form, the locations of later shorelines at different levels of sea are not arranged in systematic sequence.

In Pamlico time, when the sea seems to have been about thirty feet above its present level, most of the Distal Zone of the Florida peninsula was a shallowly submerged marine bank similar to the present Bahama Banks. Along its eastern edge, an oolite shoal or bore
formed an elongate bar. As the level of sea dropped from the Pamlico level, this bar emerged and localized the relict oceanic shore features now seen in the relict mangrove islands of the Miami Ridge and in the Silver Bluff shorelines. Protected by this energy-absorbing barrier the great shoal area emerged under conditions of very low wave energy to become inland terrane of the distal zone of the peninsula which thus has no relict features of former high energy shore lines; no relict beaches, or reefs. After emergence, during Wisconsin time, the Flan-drian transgression crested at an elevation which allowed sea level to intersect the seaward front of this bar, determining the present main-land shore of Biscayne Bay. However, the present level of sea is some 0 to 8 feet lower than the broad expanse of the relict Pamlico marine bank, which allowed this bank to remain slightly emergent as the present Everglades.

South of the shoreline scarp that passes north of Lake Okeechobee, there are no obvious relict shorelines in the distal zone of the Florida peninsula, aside from the Silver Bluff shoreline along the east side of the Miami Ridge. Apparently the sea receded from these former marine banks under such low energy conditions that they emerged with broad, marshy, coastal fringes and left no recognizable shoreline features behind them. There is, of course, the possibility that such features were formed but destroyed by solution during Wisconsin subaerial emergence.

The topography of the distal end of the Florida peninsula can be divided into areas like the Immokalee Rise, the Big Cypress, the Miami Ridge, and the Keys which have not been appreciably affected by post-Flandrian deposition, and the other areas like the Everglades, and the littoral areas of Florida Bay and the Gulf Coast where post-Flandrian peat, lime mud, shell, or sand has covered and masked the pre-Flandrian surface.

Generally the noncovered areas are the only ones that show any perceptible local relief. Thus the Keys and the Miami Ridge have much more local relief than the peat-covered plains of the Everglades and the mud-covered flats that surround Florida Bay. To a lesser extent the Everglades Keys and the Big Cypress are distinguished from their peat or marl-buried surroundings by demonstrable irregularities of surface.

The areas that have escaped burial beneath post-Flandrian sedi-ment may be subdivided into those whose surfaces are dominated by earlier pre-Wisconsin depositional forms as the higher part of the Miami Ridge, and those dominated by the denudational effects of solution or marine erosion as in the Coral Keys, the Everglades Keys, and the Big Cypress.
Figure 2. Severed boulders of limestone in Everglades near Rock Reef Pass on Flamingo Highway

The drainage of the distal zone of the Florida peninsula shows little consequence to relict coastal features where post-Flandrian deposits make its surface. Because the peat and lime mud of such deposits are the result of swampy conditions, they have built up the ground surface and allowed the water to braid its flow over all parts of the land surface. Also braided drainage has developed in post-Flandrian time on the swampy surfaces of bare pre-Wisconsin limestones as in the Big Cypress and the Everglades Keys. These areas seem to have developed ragged karstic surfaces of small local relief in glacial times of low sea level. Now solution is planing them down to a sub-aerial water table.
This present surface planation is attested by little natural bridges and rock pedestals a foot or two high, and by solution-riddled, severed boulders of comparable stature that lie loose upon the bed rock surfaces, figure 2. In such places small structurally-controlled subsequent features are still evident. They are seen in the structural lineaments, shown on the microtopographic map of an area 10 feet square at Pinelands Trail in Everglades National Park, figure 3. On a larger scale they are shown by the infra-red aerial photographs of an area near the place where the old Ingram Highway intersected the present Flamingo Road, (Florida State Highway 27). These color photographs which show green as red reveal prominent lineation in the exposed limestone. This lineation is shown by its control of the places where pine trees have been able to grow. Most of them seem to be rooted in small sinks that were filled with organic debris by smaller plants that occupied the sinks earlier. The sinks which are revealed by the pine trees seem to be located along structurally controlled lineaments. In the photograph, the pine trees are seen as pink dots which are arranged in parallel or geometrically similar rows.

Farther west where the water table is at the surface of the ground, dwarf cypress trees are rooted in similar small sinks and are also aligned in subparallel rows. Looking through the dwarf cypress forest, such alignment is frequently seen resembling the rows of trees in an orchard. Figure 4 shows the orientation of a number of sightings along such rows of cypress trees.

Occasionally, larger structurally-controlled features are preserved from the karstic dissection of pre-Flandrian times of lower sea level. Rock Reef in the Everglades Keys, figure 5, is one of these. It is an assemblage of structural lineaments that stand a little higher than the surrounding land because they have resisted solution better.

Somewhat similar is the major structural lineament in the Everglades Sloughs that located the Shark River, figure 6, and confined it to a remarkably straight course as it passes through the plexus of associated streams that share its job of draining the Everglades to the Gulf of Mexico. Unlike the structures that made Rock Reef, the one that made the Shark River lineament seems to have been an avenue of easy movement for ground water. Instead of making a ridge like Rock Reef, it made a linear depression to which the Shark River became consequent as the Flandrian transgression crested and the water table rose to the surface of the ground.

The Shark River lineament is a major one. It is long and straight. On the assembled photo-index sheets of the distal end of the Florida peninsula, it can be traced from the Gulf coast immediately north of
Figure 3. Contours on exposed surface of oolitic limestone 100 yards east of Pinelands Trail in Everglades National Park
Figure 4. Compass direction of open avenues through dwarf cypress forest on Flamingo Highway

Cape Sable to the Atlantic Coastal Ridge near Fort Lauderdale. It is one of the major structural lineaments along which the several contemporaneous Pleistocene formations are juxtaposed. (df., the section of this report called the Everglades Trough). It is parallel with the trend of the Low Coral Keys and the Oolite Keys, with the postulated fault that bounds the Pourtales Scarp southeast of the Keys (Jordan, Malloy, and Kofoed, 1964), and with the Caloosahattchee-Okeechobee fault-founded lineament that bounds the Distal zone of the Florida peninsula at the north (Tanner, 1966).
Figure 5. Rock Reef in Everglades, a structural lineament, photograph after Craighead (1964)
Figure 6. Air photos showing Shark River lineament
Beaches are made where waves spend their energy on bottoms that can produce sand. Such places are so common that oceanic shorelines rarely fail to be dominated by beaches.

There is a southward drift of sand along the Atlantic Coast which extends in diminishing volume as far south as Cape Florida (Key Biscayne), but south of Palm Beach there is little source of sand other than comminuted shell, and the beach is so close to the brink of deep water at the upper edge of the continental slope that sand is probably carried into the abyssal depths of the Florida Straits and lost to the beach. The supply of sand gives out completely at Cape Florida and beyond it there are no beaches. Somewhat similarly on the west coast of the peninsula the supply of sand for making beaches gives out at Cape Romano and the Ten Thousand Islands. From Cape Florida to Cape Romano the dearth of sand prevents this strongest of coast-forming processes from working, and between these two capes lies one of the few parts of the Coastal Plain where oceanic shores are not dominated by beaches.

In the absence of the strong, the weak are able to express themselves, so the character of the oceanic shoreline has been determined by various weaker factors such as relict coral reefs and oolite shoals, the precipitation of lime mud and the growth of mangroves and vermetid gastropods. Thus a variety of low energy coasts have developed along the southern and southwestern shores of the Florida Peninsula, none of which would have been possible had the usual sand been present to be thrown up in beaches by the waves.

**THE FLORIDA KEYS**

**THE HIGH CORAL KEYS**

The High Coral Keys seem to have been an active coral reef at the time the Miami Ridge was an active oolite shoal and possibly also while it was emerging to form mangrove islands. The present surface of the High Coral Keys is a denuded one from which the original surface of the coral reef has been completely removed. In the highest parts of the High Coral Keys (mostly on Key Largo east of the place where U.S. Highway No. 1 enters the Coral Keys from the mainland and on Windley Key near the quarry) there seems to be no evidence of resubmergence since the original emergence. The surface has some considerable local relief and occasionally shows the ragged irregular
surface of micro karst. Also there are local accumulations of residual soil. All these features suggest that these higher parts of the Keys have remained under conditions of subaerial exposure for the greatest part of the 100,000 years (Broecker and Thurber, 1965) since the coral of the reef was formed. There are no topographic maps of the High Coral Keys but there are two places that are said to reach elevations of 18 feet. Both of these are in these higher, rougher, never resubmerged places, one on the eastern part of Key Largo, the other at the quarry on Windley Key.

The remainder of the High Coral Keys have a lower, smoother surface which seems to have been made by marine denudation. Near the outer and inner edges of the relict coral reef this surface slopes gently down toward the present shore (Fig. 7) where it is being cut back
by solution from wave splash (Fig. 8) in the present cycle of shoreline
denudation. In this process a recent surface of the same kind is being
formed immediately offshore. The shore zone that is repetitively wet
by wave splash is intimately dissected to make an extremely ragged,
irregular surface of bare coral rock honeycombed with solution holes.
Most of these are a few inches to a foot or so wide and not greatly
different in depth.

The origin of this sort of surface has been discussed by several
writers. Agassiz (1896), and Ginsburg (1953) have dealt with the
Florida occurrence. There is general agreement that it has been made
by solution but opinion differs as to the immediate mechanism;
whether it be done by boring organisms or by physical-chemical means
without the assistance of living organisms. Ginsburg (1953) made a
good case for the influence of boring animals. But in 1957, Kaye found that limestone exposed to splashing (bursting bubbles) acid dissolved much more rapidly than when immersed in the same acid. In the light of his findings I am inclined to believe that wave splash is the dominant mechanism that facilitates solution along tropical limestone shores. These ragged, differentially dissolved surfaces are found only on shores of some considerable wave energy. Deposition tends to replace them on low energy shores.

On high energy shores the solution seems to be confined to the zone that is commonly wet by wave splash for the ragged surface doesn’t persist below low water level. Instead, a broad, flat, bed-rock surface reaches long distances offshore. This seems to be a newly formed surface leveled at depths of a few inches to a few feet by the shoreward retreat of the ragged zone of active solution above low water level. At the seaward edge of the shore zone of active solution pedestals form, and severed boulders lie about on the landward edge of the newly beveled zone. Much of this newly beveled bed rock surface is exposed under shallow water but probing with a steel rod showed it persisting to distances several hundred yards off shore beneath a few inches to a foot or two of unconsolidated sediment.

This newly cut, sea level-controlled, post-Flandrian bedrock surface is the morphologic counterpart of the surface of the lower, flatter, smoother part of the High Coral Keys. This suggests that the higher, older surface was cut at some earlier Pleistocene time when sea level was about 10 feet higher than present.

The higher, rougher, more soil-covered parts of the High Coral Keys, as in the eastern part of Key Largo and near the old quarry on Windley Key, would have been islands in this sea that were not bitten away by the shoreline solution that beveled the lower, smoother, flatter parts.

The level of sea that did this beveling of the High Coral Keys seems to have been the cresting of a transgression rather than an interval of stability during a regression. Moreover, the span of time between the regression of the sea from its Pamlico level (when the Key Largo Coral Reef seems to have been built) and its rise to the 10 foot level that beveled most of the High Coral Keys seems to have been much longer than the later span of time since the sea regressed from that 10 foot level to leave the lower, smoother parts of the High Coral Keys exposed. This assumption follows from the presence of an appreciable accumulation of residual soil on the higher parts of the High Coral Keys and a virtual absence of residual soil from the lower, smoother, wave-beveled parts.
It is this brown residual soil that attests the transgression that culminated in the 10 foot sea level stand. The walls of two widely separate cuts in the wave-beveled part of the High Coral Keys show old solution pits filled with such brown soil and fragments of limestone. Apparently these pits were dissolved out by fresh ground water before sea level rose to the 10 foot level at which it beveled the surface of the lower, smoother parts of the High Coral Keys.

Such wave-beveled, soil-filled solution pits can be seen in the wall of the canal at Seven Acre Estates on the north shore of Key Largo 3.4 miles from its southwestern end (Fig. 9). They may also be seen in the eastern wall of the Key Largo Waterway (Kids Kut) south of U.S. Highway No. 1.

THE LOW CORAL KEYS AND THE OOLITE KEYS

Between Upper and Lower Matecumbe Keys is the boundary between the High Coral Keys described above, and a lower surface which extends all the way to the southwestern end of the Florida Keys. This surface has about half the elevation of the lower, flatter, beveled parts of the High Coral Keys. Its eastern part from lower Matecumbe
Key to Newfound Harbor Keys is part of the same relict, emerged, coral reef of which the High Coral Keys are made. On the map it is seen as the western distal part of the same long, narrow, smoothly-curved archipelago of which the High Coral Keys form the eastern, proximal part. All these coral keys, both high and low, are elongate in the direction of the length of this arc parallel with the general trend of the coastline. Their lower, western part is the Low Coral Keys.

To the west and north of the Low Coral Keys lie the Oolite Keys. These share the low, eroded surface of the Low Coral Keys and in gross plan as a group of islands, they continue the westward curving coast line of the Coral Keys. However, this western extension of the curving archipelago is set back northward a few miles forming an abrupt break in the trend of the coast line. Also the Oolite Keys overlap the western end of the Low Coral Keys by some 15 miles extending in behind them to the northeast. The general trend of the Oolite Keys as a group is east-west, sharing the same direction of elongation as the Coral Keys, but individually the Oolite Keys tend to be elongate perpendicular to this direction, usually a little west of north.

The surface of the Low Coral Keys closely resembles that of the lower, flatter parts of the High Coral Keys and gives every indication of having been formed in the same way; that is, beveled by solution along the shore line of the sea. It is smooth and flat in the center of an island and near the shore it slopes gently downward. Like the wave beveled parts of the High Coral Keys it bears little if any residual soil. No subaerially made solution pits were observed but there are few cuts that might be expected to reveal them.

The surface of the Low Coral Keys seems to have been beveled by a sea level some four or five feet higher than the present level of sea. But in the absence of relict subaerially made features extending below this surface it is not clear whether the sea rose to this level from a lower stand or dropped to it directly from the higher stand that beveled the lower parts of the High Coral Keys.

In plan the Oolite Keys are a mirror image of the Miami Ridge in that they relate to the southwestern end of the Coral Keys (the Pamlico coral reef of the Key Largo coral limestone) the same way the Miami Ridge relates to its northeastern end. Both the Oolite Keys and the Miami Ridge are relict oolite shoals or bores. Both are set back from the arc of curvature of the seaward front of the Coral Keys. Both overlap an end of the relict reef extending in behind it and gradually losing stature as they pass into its lee. The Miami Ridge extends southwestward behind the northeastern end of the relict reef and loses stature as it does so until it loses its identity a short distance southwest of Homestead
and Florida City. Similarly, the Oolite Keys extend northeastward behind the southwestern end of the old coral reef and become more sporadic and sparse in distribution until they disappear entirely beyond East Bahia Honda Key. Both the Miami Ridge and the Oolite Keys have coast-perpendicular avenues running through them; the transverse glades of the Miami Ridge and the channels of the Oolite Keys.

These similarities leave little doubt that these two relict oolite shoals or bores were made in the same way at opposite ends of the coral reef that now forms the Coral Keys, but their dissimilarity in stature raises the question whether they were formed at the same former time of high sea level or at different sea levels at different times.

The relict oolite shoal that forms the Miami Ridge has stature roughly commensurate with that of the higher part of the High Coral Keys. It seems most plausible to assume they both were made during Pamlico time. The evidence for a Pamlico high sea level is well established and its level was very close to the level of sea at which these two relict features would have been formed.

The Oolite Keys on the other hand have much lower maximal elevations the same as those of the Low Coral Keys. Hence, it would seem possible that they could have been made as an oolite shoal at either of the other two levels of sea recorded in the smooth, beveled surfaces of the Low Coral Keys (3-4 feet) and the High Coral Keys (some 10 feet). But two things suggest that the Oolite Keys were made at the higher Pamlico level of sea.

The age of the oolite of the Oolite Keys is the same as that of the coral of the High Coral Keys. For oolite from Key West Broecker and Thurber (1965) got uranium series ages of 90+9 thousand years and 120+10 thousand years. For coral rock from Windley Key they got an age of 95+9 thousand years and for coral rock from Key Largo they got ages of 130+20, 130+15, and 140+15 thousand years. Two other older ages from Key Largo they considered unreliable.

Although parts of the Coral Keys have been reduced by wave attack twice in post-Pamlico time they seem never to have been resubmerged to a depth great enough to get another growth of coral. Hence, all the coral rock of the Key Largo formation should be Pamlico age or older. And, since the oolite of the Oolite Keys has the same age, it too should have been made during the Pamlico high level of sea.

However, the surface of the Oolite Keys shares the low elevation of the Low Coral Keys which raises the question of whether it was lowered to this level in the same period of shoreline solution that beveled the Low Coral Keys or was a shallowly submerged oolite bank
in the Pamlico Sea. Perhaps the internal structure of the oolite may help answer this question. The oolite of the Miami Ridge is shown to be an unreduced Pamlico shoal by its ring-shaped ridges that have maximal elevations comensurate with those of the High Coral Keys. These ridges contain fossils of mangrove roots that grew in the oolite as it emerged from the Pamlico Sea. The oolite of the Oolite Keys shows few if any fossil mangrove roots. This suggests that the shoreline erosion which beveled the Low Coral Keys also removed the upper part of any relict mangrove islands that formed as this distal oolite shoal emerged from the falling surface of the Pamlico Sea. The fossil mangrove roots would have been contained in this upper part that was removed. Had the oolite shoal formed at one of the lower sea levels that beveled the Keys, the fossil mangrove roots should still remain.

Another confusing matter is the difference between the transverse Glades of the Miami Ridge which are wholly emergent and the transverse channels which are then submerged counterpart in the Oolite Keys. On first thought this suggests down-warping of the Oolite Keys at the southwestern end of the archipelago while the Miami Ridge on the east side of the peninsula remained stable. However, this does not seem to be the case. Instead this discrepancy seems better explained by the presence of water on both sides of the Oolite Keys which let tide rips erode the transverse channels down to lower levels as sea level fell. In the case of the Miami Ridge the transverse glades seem to have been similarly eroded down by tide rips to the level at which the floor of the Everglades emerged from the sea. This emergence stopped the tidal exchange of water and the former transverse channels became the present transverse glades.

FLORIDA BAY

The history of Florida Bay is difficult to decipher. Its general outline suggests a bell-mouthed estuary widening westward from a headwater area at the structure where it passes in to the south end of Biscayne Bay. But there is little to suggest that it ever carried the drainage of any appreciable area outside its present limits despite the repetitive pattern of westward turning peninsular drainage as seen in the Caloosahatchee River and the Everglades Sloughs.

More probable is an origin as a lagoon. However, this is complicated. Lagoons that border coastal plains are usually thought of as creations of the Flandrian transgression; separated from the ocean proper by barriers built since the transgression crested essentially at
present sea level. But, Florida Bay is enclosed by the Coral Keys, a pre-Wisconsin coral reef, and the Oolite Keys, an emerged oolite bore. Furthermore, three different sea levels seem to have been involved in making the present subaerial surface of this containing barrier. A high one beneath which the northeastern part of Key Largo grew up as a reef to elevations greater than those found it its present irregular karstic surface, some 18 feet; a lower and later one at which waves planed the western end of the High Coral Keys to an elevation of some 10 feet, and a still lower and later one during which the Low Coral Keys were planed to their present level of some four feet elevation. The Oolite Keys would seem to have been formed at one of the higher of these sea levels since some six feet is the optimum depth for the top of an oolite bore (Newell 1960). But their equality in elevation with the Low Coral Keys suggests that both Oolite and Low Coral Keys were planed at the same time by a sea level somewhat lower than that at which either was deposited.

Explanation of Florida Bay compatible with these observations demands either that it has been eroded out of a wave-planed surface or that it is a twice-reinundated relict lagoon from an interglacial high sea level. My tendency is to lend some credence to both possibilities, suggesting that an interglacial lagoon has been reinundated after suffering some reduction by solution during glacial low sea levels.

Such reduction by solution would be compatible with other major features of the distal part of the peninsula. The drainage of the Everglades is presently confined by the Miami Ridge, and it would seem plausible that during somewhat lower sea levels the Florida Keys should similarly have confined the drainage of the area now occupied by Florida Bay.

Of course, such confinement would be insecure during sea levels much lower than present because the steep off-shore slope beyond the Keys would promote drainage escape by underground solution avenues or solution-deepened channels between the Keys. Precedent for this last is seen in the 100 feet of fill in the channel of the New River (Parker, Ferguson, Love and others, 1955). Somewhat lesser depths of fill were found in the North New River in explorations made for the tunnel that takes U.S. Highway 1 under it in Fort Lauderdale.

The buried topography of the bedrock (oolite) surface beneath the post-Flandrian lime mud of Florida Bay suggests, a broad low divide extending westward through the center of the bay from its eastern end and curving southward between two broad bedrock swales that would seem to have drained through one of the inlets near the west end of the High Coral Keys.
THE ISLANDS AND SHOALS OF FLORIDA BAY

The islands and shallow banks of Florida Bay are quite discrete from its essential containing bounds and its oolite floor which are pre-Flandrian in origin. The islands and banks are made of post-Flandrian lime mud and their surfaces usually lie within a foot above or below normal water level. The most western of these banks are sandy and extend southeastward from East Cape (the southeasternmost of the three component capes of Cape Sable.) They face deeper, open water of the Gulf of Mexico on their west side. Perhaps for this reason these western banks are somewhat broader and sprawling in plan. But all the other banks to the east of these are made of mud and form a plexus of long narrow, intersecting Thalassia-covered shoals and mangrove-covered islands.

According to Scholl (1966) the mud is some 89 to 90 per cent calcareous and made in the water of the bay or in marine water nearby.

The plan of these elongate mud banks is difficult to explain. I think the attenuate form results from distribution of sediment by a plexus of currents whose present pattern of flow is largely determined by the deflection effected by the banks. Probably this plexus of banks acquires a denser distribution as cumulative sediment is produced with the passing of post-Flandrian time. The currents of this part of Florida Bay are weak and complex in pattern of flow. Gorsline (1963) calculated slow rotational currents in some of the "lakes" between banks and islands. Regardless of what their pattern of flow may originally have been at the crest of the Flandrian transgression when Florida Bay may have been a continuous body of open water, it is now influenced by the arrangement of the banks. The banks in turn seem to have accumulated from deposition of the limey mud distributed by these currents. In effect the banks and the currents seem to have evolved together, mutually affecting each other.

Not infrequently narrow moats of deeper water lie close along the edges of the islands. Usually these are some six to eight feet wide and two to three feet deep. They lie close along the shores of mangrove islands, separating them from thalassia-covered banks, where the water is commonly less than a foot deep. In these moats perceptible currents can be seen on most occasions. Such moats are frequently overhung by the branches of mangrove trees that cover the low islands the moats encircle. The water of the moats is deep enough to float mangrove seeds in the erect position and carry them down-current. I think this helps to distribute the mangrove growth along the drift of the current. In turn the mangrove probably serves as a sediment trap for lime mud carried
by the same current after winds have disturbed the bottom and muddied the water.

Seeds of the red mangrove (rhizophora) are peculiarly designed to be carried by currents rather than by winds. When ripe seeds were picked from the tree and dropped into the water of the inlet between Blackwater Sound and Little Blackwater Sound, they first floated in a horizontal position with their length parallel with the surface of the water. But after two or three minutes of immersion they changed their position and began to float with their length perpendicular to the surface of the water.

At first when these seeds were floating in a horizontal position they were blown across the water surface by the wind gusts of the moment. But after they changed position and began to float in their more permanent, vertical position they moved with the current rather than the wind. Floating in this vertical position they resemble float bottles. Most of their length is submerged and only a small share of it is above water. This preponderant exposure to water rather than air allows the water currents rather than the wind to dominate their direction of travel. Seeds picked from mangrove trees on the west side of Long Sound Pass (between Long Sound and Little Blackwater Sound) floated across the inlet and lodged in shallow water on its eastern side in a place where many mangrove seedlings were beginning to grow despite considerable evidence of shoreline erosion to depths of six inches to a foot or so.

A somewhat similar situation seems to have shaped the tree islands of the Everglades. The plan of these is characteristically tear-drop shaped, with the blunter end facing up-current, and the narrow tail pointing down-current. The tree islands seem to have acquired this tear-drop plan by splitting the flow of the water which used to drift over the surface of the Everglades before the present drainage works lowered the water level and dismembered the natural drainage. The tree islands vary much in ratio of width to length, and grade into linear sub-parallel distributions of different kinds of vegetation which gave the Everglades a striated appearance on early aerial photographs (Davis, 1943). These attenuate forms of the vegetal distributions of the Everglades have a much more uniform orientation than the shallow banks and islands of Florida Bay. This is because they are the product of a uniformly oriented drift of fresh water which flows down a regional topographic slope. The currents of Florida Bay obey no such uniform discipline but are variously affected by winds, tides, and possibly barometric pressure and water density. The result is that they developed a parcelled and variable pattern of flow directions as the forces
which drove them changed direction. The result of the intersection of these variously oriented currents produced an arrangement of sediment which shows little order other than a network of attenuate, intersecting shallow banks and low islands. Once established, this network of deflecting barriers has tended to promote circituous, orbital currents in each partially or completely enclosed "lake". It is my opinion that these currents tend to repair any breaks in the continuity of the linear banks by drifting mangrove seedlings and lime mud into the breach.

Figure 10 shows such a breach at Long Sound Pass between Little Blackwater Sound and Long Sound. At the time the picture was taken, a perceptible current was flowing across this breach from west to east in agreement with the wind direction at the time. As described above, mangrove seeds dropped into the water on the western side of the breach floated with the current across the breach toward its eastern side. The end of the opposing septum of land on the eastern side of the breach was undercut by the current or perhaps more plausibly by the waves made by the same wind that drove the current. Its edge was sharply truncated, and a dense growth of mangrove seedlings covered it. These observations support the idea that the distal ends of such septa of lands are points of geomorphic activity, both erosional and depositional, and I feel that the intersecting network of such attenuate banks maintains and modifies itself by such distal activity. Successive concentric accretions of sediment at the distal end of an island in Florida Bay can be seen on the air photo shown here as figure 11.

Quite generally capes, points of land, distal ends of shoals, beach groins, and similar attenuate protuberances deflect currents that otherwise would flow past them. Thus long-shore currents approaching such protuberances from either direction are deflected in the same offshore direction. In high energy environments the sedimentary efforts of such currents are modified or negated by wave erosion but in quieter waters they seem to be able to extend the protuberances that beget them by cumulative deposition of current-borne sediment at the distal ends of the coastal protuberances. In Florida Bay the low energy of the quiet water assures that such sediment will be mud rather than sand.

Probably there is an alternation between brief occasions of erosion during storms and long periods of sediment accrual during quieter weather. During the high energy conditions of storms, waves in the "lakes" between the banks scour the bottoms of the "lakes" and erode the sides of the banks. Figure 12 shows the eroded edge of such a bank on the east side of Blackwater Sound. Note the undermined mangrove tree overturned in water 5 feet deep. The depth of scour in the "lakes" is generally limited by the upper surface of the Miami oolite which
Figure 10. Long Sound Pass, looking eastward
Figure 11. Distal growth of a lime bank in Florida Bay
everywhere underlies the water of Florida Bay at shallow depths, usually between 5 and 9 feet. Apparently the surface of the oolite was cemented during subaerial exposure in Wisconsin time and it now forms a resistant base to wave scour. Thus the storm waves stir up the post-Flandrian sediment but leave the cemented oolite as a stable floor that tends to be scoured clean. The post-Flandrian sediment is almost wholly mud and, once disturbed by erosion, it lacks the coarse component necessary to make lag gravels and build sand bars. Being almost wholly of particle sizes that can be held in suspension by slowly moving water, much of it stays in suspension until currents carry it to vegetal sediment traps such as the attenuate ones described above.
This process would promote the development of two discrete environments, one of erosion down to bed rock (oolite) in the "lakes", the other of deposition up to water level on the attenuate shoals. And the boundaries between these two environments should be fairly sharp because wave erosion undermining the edges of the depositional areas would move only fine mud that could not be distributed locally in gradational bars but would remain in suspension while it moved through the same routes to the active vegetal sediment traps.

The marine grass thalassia (usually called turtle grass in south Florida) also seems to be an important contributor to the system of vegetal sediment traps. It covers most of the shallow banks that are not dominated by mangrove. It makes a mat of subaqueous vegetation far denser and finer textured than that afforded by mangrove. Furthermore it has been shown (Dr. W. W. Hay personal communication) that it prefers to grow in places where currents are swiftest. The resulting tendency for it to make a dense mat of leaves where currents sweep the bottom should provide good sediment traps where currents carry sediment most voluminously. Plausibly, banks that have been shoaled or distally extended with sediment trapped by thalassia may later be colonized by mangrove as they become too shallow to support thalassia any longer. Moreover the mortality of individual leaves of thalassia seems to be high because many small, sessile, carbonate-secreting organisms attach themselves to the leaves. These probably make a considerable contribution to the accumulated sediment on which the thalassia grows.

To repeat, in summary: The post-Flandrian sediment of Florida Bay is dominantly fine mud which is either protected by vegetation (thalassia or mangrove) or eroded by storm waves. Much of that eroded remains in suspension until currents carry it to vegetal sediment traps whose shape and location are determined by these same currents because the vegetation that forms the sediment trap is localized by the currents that deliver the sediment. The thalassia grows best in currents and the currents carry the mangrove seeds to the places where they root themselves.

DRAINAGE OF THE AREA ADJACENT TO THE NORTH SHORE OF FLORIDA BAY

In southern Dade County, between Homestead at the north and Florida Bay and Barnes Sound at the south, the parallel pattern of drainage on the distal slope of the peninsula is characteristic of agrada-
tion. A sheet of water covers it all, and the darker zones seen in air photos are chains of higher vegetation rather than stream channels. The little spermatazoon-shaped patches of vegetation with tails pointing down slope are tree islands and in many places they can be seen merging in chains to evolve ultimately up or down-stream into more continuous strings of vegetation that become the dark lines seen on the air photos.

The origin of these tree islands is not wholly clear. Some of them may be established in places where pre-Wisconsin solution lowered the surface of the oolite. If this be true it would seem necessary that the coastward drift of shallow ground water had been channeled through a series of such small solution openings and had made connecting openings between the original holes to account for their being connected in coast-perpendicular chains.

Another possibility might be that the higher vegetation of tree islands deflected the surface water drift to control the distribution of floating vegetal matter including seed. Individual tree islands would be consolidated into chains by lodgement of such debris.

Various arrangements of tree islands exist. Figure 13 shows a winding linear group of individual tree islands strung out along the direction of water flow. They seem to be approaching integration and have achieved it at their downstream end where they become a continuous zone of trees. Such a wandering line of tree islands makes little suggestion of structural control. Figure 14 however, shows several short lines of tree islands that are notably straight and parallel. These might be easier to interpret as structurally controlled were it not for their neatly coast-perpendicular orientation. Figure 15 shows a line of tree islands that is straight in its northern part and well integrated. Apparently the water flows along the length of the line of tree islands. In the southern half of the line the tree islands are less well integrated and have a different orientation which seems to be at an angle with the general direction of water flow. Here the individual tree islands are arranged en echelon with their tails pointing in the same direction as the better integrated northern half of the line. However, these en echelon islands seem to be growing together because of their joint effect of deflecting some of the water which approaches their up-stream flank. Apparently the deflected water promotes the vegetal growth that integrates the individual islands into chains.

Price (1967) sees a genetic influence of earlier instances such lines of higher vegetation (his "rill divides") on the elongate shoals and islands of Florida Bay to the south. Certainly they extend southward short distances into the Bay; possibly because they offer greater resistance to shoreline erosion than do the less vegetated areas of lime.
mud between them. However, most of these small peninsulas are truncated a short distance offshore and the few that ramify into the reticulate system of lime shoals and islands loose their coast-parallel orientation and partake the curvilinear form of the shoals and islands of the Bay. Mostly they adopt a coast-parallel elongation.

Craighead (1964) has described storm levees along the north shore of Florida Bay. These have dominantly coast-parallel (east-west) elongation and seem to mark the northern edge of the direct effects of Florida Bay. The sediment transporting capacity of Florida Bay lessens landward and finally the coast-parallel storm levee seems to end the direct influence of the bay in the same place that it effaces the features of the fresh water drainage.
Figure 15. Air photo showing line of tree islands in southern Dade County

THE LOWER WEST COAST OF THE PENINSULA

The differences of the several parts of the western and southern coasts of the peninsula are largely a result of differences in the original
materials encountered by the waves as they attacked the land at the crest of the Flandrian transgression.

It is notable that the sandy coasts (such as those of the west coast beach resorts between Anclote Key at the north and Cape Romano at the south) are at once steep in offshore profile and geographically protuberant in plan. They make a broad, coastal salient between equally broad reentrants to north and south. The salient has ubiquitous sand barriers separated from the mainland by lagoons. By contrast the limestone-floored coastal reentrants have very gentle offshore profiles, little sand and either degenerate barriers, as south of Cape Romano or none at all as in Suwannee Bight north of Anclote Key.

Figure 16 shows this relation between profile and kind of stuff that makes the sea bottom. In the sandy, protuberant part of the coast between Anclote and Marko Keys there are many relict barrier bars and beach ridges to landward and the five-fathom isobath is rarely more than half mile offshore from the oceanic beach on the barrier. By contrast, in the sand-starved coastal reentrants to north and south, relict shoreline features are absent or obscure, the coastline is indeterminate, gradational, and marshy, and the five-fathom isobath lies 20 to 30 miles offshore. For the most part the five-fathom isobath tends to be fairly straight across the three sections of coast, being close to the protuberant sandy section, and remote from the reentrant sand-free sections. This suggests that it marks a contour on a part of the pre-Flandrian subaerial surface which has not been appreciably changed by marine processes of erosion or deposition other than having a barrier thrown up on its landward side where it traverses sandy bottom. The barrier appears immediately landward (shoalward) from this line because five-fathoms is a depth close to the nearly ubiquitous maximum for depth of wave scour on oceanic shores. This straightness of the five-fathom isobath along the west coast of the Florida peninsula suggests that the protuberant, steep-profiled, high-energy, sand-dominated section of the coast has been built out to the five-fathom line rather than the reentrant, gentle-profiled, low-energy, marshy coasts being cut back from it. The high wave energy could more plausibly throw up sand at wave base to build a barrier island than the slow dissipation of wave energy through a 20 or 30 mile zone could account for the gradual off-shore slope of this zone by 20 or 30 miles of shoreline regression from wave erosion. Actually, this latter evolution seems impossible in the face of the existence of subaerially produced peat on the sea bottom offshore from the marshy southwestern coast of the peninsula (Spackman and others, 1964 Shier 1969) because this peat would have been removed by wave erosion had the submarine
Foreshortened Sketch
RELATION OF LITHOLOGY TO OFFSHORE PROFILES
ALONG THE WEST COAST, FLORIDA PENINSULA

Figure 16. Foreshortened sketch showing the relation of lithology to offshore profiles along the west coast of the Florida peninsula
Figure 17. Air photo showing characteristic pattern of Ten Thousand Islands
profile been cut out by wave erosion. Similarly the partly drowned crescentic dunes that form Cedar Keys and Horseshoe Beach in Suwannee Bight at the north would also have been destroyed in shoreline retreat had this broad bight been cut out by wave erosion.

Where quartz sand has been continuously available in preexistent rocks such as the Miocene sediments of the mid-peninsular west coast, seaward migration of shorelines seems to have been going on for a long time through successive transgressions. This seems to explain the broad succession of relict beach ridges and barriers that characterize the protuberant part of the peninsular Gulf coast between Anclote Key and Cape Romano. Apparently transgressions crested at lower sea levels than previous ones or at approximately comensurate ones have added new seaward increments to a coast that has been repetitively progradational.

The Ten Thousand Islands are an interesting transitional section of coast, figure 17. They are founded on the Tamiami Limestone which supplies little sand, but a drift of sand across Gullivan Bay from Cape Romano Shoals supplies enough sand to allow an impersistent barrier to accumulate as the outer islands of the Ten Thousand Islands. But this barrier is not accompanied by the characteristic wave-scoured off-shore profile that brings the five fathom isobath within a mile of the beach.

By contrast with these protuberant sand-dominated coasts, areas floored by rocks that do not readily supply sand to the shore-forming processes tend to maintain shorelines which are less affected by erosional and depositional littoral processes. Such shorelines tend to be located where sea level intersects the previous subaerial slope rather than where waves tear up the bottom and throw up barriers as they do on sandy bottoms. Such shorelines therefore tend to be reentrant rather than protuberant, as south of Cape Romano, and north of Anclote Key in Suwannee Bight.

Since they build few barriers or beach ridges these reentrant shorelines are much more migrant shifting their geographic location markedly with each nuance of sea level change because their profiles are so exceedingly gentle (about one foot per mile seaward slope). Such conditions gradually dissipate wave energy before it reaches the shore. And since every minor change of sea level causes the shoreline to migrate some considerable distance this continually changes the place at which shore processes operate and further thwarts their efforts to cut an erosional shore. However, despite this migration of shore line during a rapid transgression, the coast seems to have gone through a progressive evolution of type in the 4000 years of essentially stable sea level since creting of the Flandrian transgression.
Sandy shores may remain fairly securely localized where a barrier or beach ridge has been built. Because of their steep profile they are not as subject to great migration with minor sea level change if sand supply is adequate to maintain equilibrium.

Since the sand-deficient parts of the Florida peninsular West Coast result from submergence of an extremely gently sloping, and very flat limestone terrain, the resulting shorelines are characteristically marshy, incorporating a wide zone of gradually deepening water in a broadly gradational shore zone that changes slowly over several miles. It begins offshore with open shallow marine water that grades through various kinds of mangrove or other salt marsh, to fresh water swamp, usually with a plexus of more or less open water ways.

The details of this gradation change with the nature of the terrain that has been transgressed. Each of the several geologic formations that outcrop along the southwestern coast of the peninsula can be delineated in the shore zone by the changes its distinctive rock imposes on this general pattern of coastal features. Thus, the nature of the shoreline is to a large extent a matter of indirect lithologic control. The Tamiami formation is associated with the Ten Thousand Islands. The Anastasias formation is coextensive with an area of straighter, more integrate coastline adjacent to the Ten Thousand Islands on the south which is influenced by the debouchure of the Everglades Sloughs. And the coastal prominence that is Cape Sable overlies Miami Oolite.

Although these relations between geologic formations and coastal types are rather well defined, the reasons for the characteristic peculiarities of each of the three coastal segments are difficult to establish. Thus the salient of Cape Sable, although it correlates with and overlies the distal end of the coastal zone where the Miami oolite outcrops, is largely built of post-Flandrian coquinoid beach ridges that are separated from the nearest surface exposures of oolite by broad areas of peat and marl and the lagoon-like Whitewater Bay. The oolite here is a degenerate southwestern extension of the Miami Ridge, which forms the low partial divide between the Everglades Sloughs and Florida Bay. Either it was a very weak feature here to begin with or has been greatly reduced in stature by solution, as buried stream channels in its upper surface suggest (Spackman, Scholl and Taft, 1964). Nonetheless, it seems to have formed a low ridge that localized the coastal salient of Cape Sable. Spackman, Scholl and Taft (1964, figure 58) in a block diagram of this region show the surface of the Miami oolite high under Cape Sable and falling away to lower elevations to north and south. They also present a cross section (their figure 34) which shows a shallow submarine scarp cut into the oolite beneath Cape Sable. Again
their figure 27, "Structural Contours on Miami Oolite", in the vicinity of Whitewater Bay, landward of Cape Sable shows the top of the oolite higher behind the cape and falling to lower elevations both southeastward toward the mouth of Florida Bay and northward toward the edge of the Everglades Sloughs as typified by the Shark River.

Perhaps this shallow, wave-cut notch in the oolite bedrock localized wave-breaking long enough to allow a bar to build up and form a barrier. Apparently the resulting environment of open, clear, sea water and higher wave energy fostered growth of shell fish. Their shells seem to have enabled the barrier to maintain itself, anchored on the notch in the oolite, building up in the same place as sea level rose to its present elevation. Minor changes of shoreline here of both progradation and regression are shown by the pattern of relict beach ridges and micro-lagoons which dominate a narrow zone immediately landward of the present beach (Spackman, Scholl and Taft, 1964: Craighead, 1964).

Adjacent to this area of high, oolite bedrock on the north was the low broad, bedrock swale of the Everglades Sloughs founded on the Anastasia formation. There the waves of the Gulf of Mexico went farther eastward before they felt the bottom enough to break. This seems to have allowed the Cape Sable area to become a broad coastal prominence built on the western end of the Miami Ridge between two reentrant sections of coast, Florida Bay to the south and the area of debouchure of the Everglades Sloughs to the north. This peninsular situation seems to have produced a coast-parallel drainage exemplified by the Joe River which flows northwestward along the southwestern edge of Whitewater Bay. Probably storm levees (Craighead, 1964) built along the north shore of Florida Bay during hurricanes prevented Joe River and Whitewater Bay from draining southeastward to Florida Bay.

However, there are features in Whitewater Bay which suggest that it occupies an area that formerly drained southwestward toward the present cape through many sub-parallel, coast-perpendicular avenues oriented like the Everglades Sloughs adjacent to the northwest. Such an early post-Flandrian drainage pattern may have been inherited from a similarly oriented pre-Flandrian one, relicts of which (Spackman, Scholl and Taft, 1964, figure 27) are preserved in the oolite bed rock beneath the post-Flandrian marls and peats of the present surface. When water tables rose, as the Flandrian transgression neared its crest, these coast-perpendicular drainage ways began to accumulate peat. But they still maintained the coast-perpendicular orientation that is characteristic of mainland drainage ways near the coast all around the low distal part of the Florida peninsula. However, as the bedrock-anchored barrier began to develop at Cape Sable and the resulting lagoon began
to accumulate sediment (mostly peat according to Spackman, Scholl and Taft, 1964) these coast-perpendicular drainage ways not only became over extended in an untenable direction of flow parallel with the axis of a promontory, but they had a barrier athwart their mouths in the person of the beach ridges of Cape Sable. Possibly for this reason either Joe River or a drainageway in the area now occupied by Whitewater Bay initiated a right-angled change of drainage direction letting it escape laterally from the north side of the Cape Sable promontory to the adjacent low area occupied by the Shark River at the Southeastern edge of the Everglades Sloughs.

The relicts of the original coast-perpendicular drainage seem to be manifest in the nearly parallel orientation of long attenuate islands in Whitewater Bay which are elongate in the northeast-southwest direction that is characteristic of all coast-perpendicular drainages of the southwestern coast of the Florida Peninsula between Cape Romano and the Shark River.

Spackman, Scholl and Taft (1964) discussed wave or current erosion of the peaty islands of Whitewater Bay and they also have discussed development of marl levees along waterways in this area. Possibly the erosion they described has produced the present open water of Whitewater Bay through wave erosion induced by cresting of the Flandrian transgression after the bulk of the peat had been deposed. The marl levees may, in large measure, be responsible for the long narrow islands and peninsulas of the southwest side of Whitewater Bay that seem to be relicts of the earlier southwesterly drainage built up on the peat that is now rapidly being destroyed by erosion.

Beyond Whitewater Bay to the southwest between the Joe River and Cape Sable proper, the drainage seems to have become an isolated pocosin for that area is now mostly a peat dome sloping downward in both directions; both northeastward to the Joe River and Southwestward to the micro Lagoons landward of Cape Sable (Spackman, Scholl and Taft, 1964, figure 34).

By contrast with the Cape Sable coastal prominence the area of outcrop of the Anastasia formation adjacent to the oolite on the north, localizes the Everglades Sloughs, the broad zone of braided drainage ways that drain the Everglades to the Gulf of Mexico. Possibly this drainage is located here because it was deflected westward by the oolite ridge rather than because of any peculiarity of the Anastasia formation over which it flows. But, whatever the reason for the Everglades Sloughs being in the zone of outcrop of the Anastasia formation their large discharge of fresh water has probably helped to lower the profile
of this area by solution of the underlying shelly limestone thus accounting for the reentrant character of its coastline.

The features sometimes called Back Bays are lagoon-like bodies of open water that extend more or less continuously from Naples at the north to Whitewater Bay at the south. It seems instructive that they all but disappear in the peat-surfaced area where the voluminous fresh water discharge of the Everglades emerges in the southern part of the area of exposure of the Anastasia formation. There many of the coast-perpendicular drainage ways still preserve their identity across the zone which elsewhere seems to have been dissected by wave and current action to form the open water of the Back Bays. On the flanks of the Everglades Sloughs section of the coast these coast-perpendicular stream channels gradually lose their identity in crossing the Back Bay zone. Thus, Lostmans River to the north has two discrete branches that fork on the seaward or barrier side of the Back Bays, continue eastward across the zone of the Back Bays as widened, lake-like water bodies separated by narrow septa of insular and peninsular land, and persist discretely northeastward into separate headwater areas on the mainland.

Whatever the reason for the lagoon-like Back Bays, it seems fairly clear that the voluminous flow of fresh water from the Everglades has favored the growth of peat to the extent that they have not been able to form (or perhaps have not been able to maintain themselves as bodies of open water) in the area of debouchure of the Everglades Sloughs. Only in this section of the coast does peat extend all the way to the shore of the open Gulf of Mexico giving it a smoother, less ragged shoreline. Elsewhere, to the north and south, a zone of marine marl or shell intervenes between the edge of the peat and the shore of the Gulf of Mexico.

These observations suggest that the area across which Everglades water debouches has progressively narrowed from a wider zone which originally extended both northwestward beyond Lostmans River and southeastward across much of the area now occupied by Whitewater Bay.

Deprived of the voluminous fresh water discharge necessary to maintain peat growth by excluding the salt water, these flank areas seem to have become subject to erosion, producing Whitewater Bay to the southeast and the more southerly of the Back Bays to the northwest. Their lagoon-like form may result from the former juxtaposition of peat to landward and marine marl to seaward. The more resistant marl remained as a pseudo-barrier while the more vulnerable peat was eroded out to form a pseudo-lagoon (Back Bay). Similar juxtaposition
of resistant marl and vulnerable peat may account for the remnant marl levees (Spackman, Scholl and Taft, 1964) that delineate the relicts of the former drainage avenues in Whitewater Bay and where Lostmans River formerly crossed the area of the present Back Bays.

There has been much concern about the conservation problems associated with lowered water tables in the Everglades, and it may be that this apparent narrowing of the area of debouchure of the Everglades in another result of reduced fresh water discharge. Erosion of the shorelines of islands and peninsulas in Whitewater Bay is great enough to show conspicuously on aerial photographs taken at different dates (Spackman, Scholl and Taft, 1964). In a broader sense, this may mean that the present artificially-made drought is undoing the work that a rising water surface began at the crest of the Flandrian transgression.

However, the plan of the Back Bays on the map seems too systematic to be wholly a product of differential erosion as Spackman, Scholl and Taft (1964) thought. It follows the great geometric curve of the coastline between Capes Romano and Sable with more faithfulness than the present oceanic shore does. Moreover, it follows two concentric, similar curves which overlap for a short distance in the northern part of the Ten Thousand Islands (Pl. 1). This suggests that they are differentially derelict remnants of degenerate lagoons. These lagoons were probably enclosed behind barriers of sand at the north in the Ten Thousand Island area (see below), and behind shell bars farther south. With passage of post-Flandrian time the preservation of low-energy, swampy conditions allowed mangrove and fresh water swamp deposits to mask their original character and render them derelict.

It seems instructive that these old lagoons are most degenerate where the regional slope to landward is gentlest. Thus, as the Back Bays, they persist southeastward as far as the steeper slope of the Big Cypress (the area of exposure of the Tamiami sandy limestone) does. But farther south in the virtually horizontal area of the Everglades Sloughs they are wholly occluded by peat because it is through this low flat trough that the Everglades debouched most of their great discharge of fresh water. This broad sweep of fresh water was the maintaining force of the peat and, now that it has been reduced by diverting drainage works, the occluded lagoon seems to be reappearing as the occluding peat is eroded out of it. The attenuate inlands and peninsulas of Lostmans River and Whitewater Bay, and the isolated marl levees are resistant remnants of a once more continuous mass that show the progress of this exhumation of the occluded lagoon. However, one can not think of Whitewater Bay as a feature dominantly made by modern artificially induced erosion. Apparently there have been natural
changes of circumstance that have sometimes helped aggradation and sometimes erosion. Thus, the rock floor of the Everglades Sloughs has an axial valley that seems to have been made during a period of reduction but it was covered by a broad blanket of peat made during times of aggradation.

THE TEN THOUSAND ISLANDS

The coastal area adjacent to the Big Cypress is known as the Ten Thousand Islands. It differs from adjacent sections of the coast to the north and south and seems to be a gradation between them. The Ten Thousand Islands begin at the north in the Lee of Cape Romano at the southern end of the sand-dominated section of the coast. Unlike the coast farther south, quartz-rich sand forms short beaches around the outer shores of the outer islands but it is not available in sufficient quantity to allow these beaches to coalesce and form a continuous barrier like those which prevail along the sand dominated coast to the north of Cape Romano.

Landward of these beach rimmed outer islands are the rest of the many islands that give this intricate archipelago its name. Most of these inner islands are made of oyster shell (Crassostrea virginica) and are surmounted by mangrove. Between the Ten Thousand Islands and the mainland lies the generally open water of the Back Bays (Chokoloskee Bay, etc.).

Shier (1969) found that the outer, beach-rimmed islands were generally defended by cores of vermetid reef rock (Vermetus (Thylaeodus) nigricans). He agreed with Scholl (1964) that the sand of the beaches was transported across greater Gullivans Bay from the Cape Romano shoals. In the lee of these vermetid-reef-founded outer islands he thought the inner oyster-founded islands grew up in the lagoonal waters during late-Flandrian time.

THE SILVER BLUFF RIDGE AND SCARP

The Miami Ridge and associated Silver Bluff Ridge were probably more or less coeval with the Key Largo Reef. Their maximal elevations seem to be about the same, all being about the right height to correlate with Pamlico sea level. The Miami Ridge seems to have been a Pamlico oolite shoal which reached its best development where arterial tidal overwash could pass around the northern end of the Key Largo Reef.
Both the Miami Ridge and the Silver Bluff Ridge lose stature and definition as they extend southwestward behind the Key Largo Reef. The southwestern part of the Miami Ridge may have lost stature from solution by freshwater overflow southward from the Everglades, but it seems to have been best developed as an oolite shoal at the northeast where it was open to surf and tide.

More definite information on the simultaneous growth of the Miami and Silver Bluff Ridges can be had from the plan of the Silver Bluff Ridge which parallels the Miami Ridge on the east and seems to have been its seaward barrier in Pamlico time. Since the Silver Bluff Ridge has the form of a coastal arc or beach crescent (Pl. 2) and is only a few hundred feet wide it is obvious that it has not been greatly modified by post-Flandrian coastal erosion otherwise it would have been transected and dismembered by the erosion. Its relation to the relict mangrove islands of the Miami Ridge shows it to have been extant while they were being built. It turns up the valley of the Miami River in the manner of an inlet ridge (the curved extension of a beach ridge turned landward along the shore of a tidal inlet in a barrier island). And as can be seen on plate 2 this landward-turning extension of the Silver Bluff Ridge merges with and becomes part of the first ring-shaped relict mangrove island south of the Miami River. This establishes the simultaneous origin of the Silver Bluff Ridge and the relict mangrove islands of the Miami Ridge behind it, since they were both built up to the same pre-Wisconsin sea level. And it places this former sea level near the top of the Silver Bluff Ridge during the time the ridge was being built because it is essentially the same height as the adjacent relict mangrove islands to the west which by analogy with modern mangrove islands should have had elevations very close to their contemporary sea level.

The internal construction of the Silver Bluff Ridge also offers evidence that it was largely awash when it was built because it is almost wholly made of cross-bedded oolite sand with most of the crossed beds dipping seaward (east). Only on the gentler, western slope of the Ridge do they occasionally dip landward (west).

The “Silver Bluff shoreline” is a wave-cut berm and scarp on the east side of the Silver Bluff Ridge. The scarp seems to have originated as the seaward edge of the Silver Bluff Ridge when it was built as an oolite shoal in Pamlico time with its crest essentially at the level of the Pamlico stand of sea. But it seems to have been modified by the attack of waves during three different times of sea levels lower than that of the Pamlico stand. One at about 10 feet above present sealevel, one at about half that and lastly, it seems to be under occasional attack by certain hurricane-gotten waves of the present water of Biscayne Bay. It
is probably the most obvious scarp of the Coastal Plain. Named for the community of Silver Bluff in Miami (which in turn seems to have been named for the scarp), it is seen dramatically along the northwest side of South Bay Shore Drive. It crosses South Bay Shore Drive near the west corner of the grounds of Mercy Hospital and a few hundred yards to the northeast it was used to dramatize the entrance to the grounds of Vizcaya, the house of the late John Deering, where a broad stairway descends the scarp just beyond the present ticket-seller’s booth which is situated at its crest.

In several places along South Bay Shore Drive the Silver Bluff Scarp shows the character that seems to have gotten it its name. Here it is an obvious wave-cut cliff of varying stature up to some 15 feet from crest to toe. In a few places the crest of the Silver Bluff Ridge reaches elevations above 20 feet, among the highest natural elevations in south Florida; at least roughly commensurate with the highest parts of presently unmapped Key Largo. The scarp is cut into the Miami oolite of the Silver Bluff Ridge and stands sharp and vertical as a wall of surficially indurated rock showing neither slump nor soil development (Fig. 18). In the coastal plain such an abrupt topographic feature could not fail to become a subject of geologic curiosity, and several geologists have noted its peculiarities, notably Parker and Cooke, (1944), Cooke (1945), Parker and others (1955).

Parker and Cooke, (1944, p. 24) referred to 5 and 8 foot benches and suggested that they were cut by wave erosion during regression of the Pamlico sea. Cooke (1945) regarded the Silver Bluff Scarp as dual, cut by sea levels ten and five feet above present sea level. Evidence for wave erosion at the ten foot level is sparse and if there was a prominent scarp with a toe at ten feet, it has apparently been largely destroyed in the cutting of the younger and lower one. Although in the center of the broad topographic swell between Franjo at the Southwest and Cutler at the northeast (Perrine 7½" sheet) elongate, closed, fifteen-foot contours suggest a relict, low, emergent bar like the present Bahaman cays south of Bimini along the western edge of Andros Bank. This may well have been associated with the upper of the two relict benches noted by Parker and Cooke.

Most of the evidence for an eight or ten foot toe was obtained from the vicinity of the Miami River where the upper part of the Silver Bluff Scarp turns inland up the south valley wall of the river and the lower part ends at Point View, a prominence in the mainland shore at the edge of the flood plain about three quarters of a mile south of the river mouth.
Figure 18. The Silver Bluff Scarp on South Bay Shore Drive where it seems to have been freshened by recent wave erosion during certain hurricanes
Adjacent to the Miami River this floodplain or transverse glade is about a mile wide through the lower two or three miles of the river's valley. Like most of the other transverse glades it widens up-stream toward the Everglades while the adjacent interfluves gradually lose elevation in the same direction until both uplands and lowlands lose topographic distinction and merge to a common low plain where the west flank of the Miami Ridge slopes down to become the Everglades. Most plausibly this stream-side flat is a relict pre-Wisconsin tidal channel. It has two prominent slough-like channels which seem to be relict tidal creeks developed on it as it emerged to become a tide flat. As well as can be determined from the five-foot contour interval of the topographic maps, elevations on the relict tide flat are between five and ten feet. Those of the relict sloughs are between zero and five feet. Plausibly these two surfaces correlate with those of comparable elevation in the Coral and Oolite Keys. At its edges this relict tide flat rises abruptly to the ring-shaped ridges or relict mangrove islands which frequently attain elevations roughly commensurate with those found at the crest of the Silver Bluff Ridge. I believe this abrupt rise is the scarp with the eight to ten foot toe mentioned by Parker and Cooke. But here along the edge of the transverse glade traversed by the Miami River it is the outer edge of a relict mangrove island of Pamlico time and the elevation of its toe may have been determined by the depth of scour of the tidal currents that flowed through this transverse glade when it was a Pamlico tidal sluiceway rather than by a sea level lower than Pamlico. The 8 or 10 foot scarp toe of the Silver Bluff may correlate with the surface of commensurate elevation in the Coral Keys and similarly the five foot toe may be a correlative of the surface of the low Coral Keys and the Oolite Keys. Such a correlation would lend credence to the idea that the Silver Bluff Scarp had been attacked by waves during levels of sea some 5 and 10 feet higher than present sea level. But the alternative idea that the 8 to 10 feet level is a relict of the base of tidal scour in Pamlico time casts some doubt on the idea that the Silver Bluff Scarp was significantly affected by wave erosion during a ten foot sea level. Apparently wave energy was usually rather low here because of the offshore barrier provided by the Coral Keys.

The spectacular sharpness of the Silver Bluff Scarp fades away to the southwestward along the mainland shore of Biscayne Bay. It can be seen very easily along Old Cutler Road east of Perrine but it is a gentle slope rather than a cliff. Little rock is seen and all parts of the profile are soil covered. Still farther to the southwest the scarp becomes so gentle in slope it is hardly discernable on the ground, but can be found on the topographic map of one-foot contour interval made by the Soil
Conservation Service of the United States Department of Agriculture. Apparently the Scarp is sharper and more precipitate at the northeast because it is still exposed to occasional vigorous wave erosion during hurricanes. Farther southwest where it lies in the lee of the Coral Keys it seems completely derelict.

I think this sharper part of the Silver Bluff Scarp is jointly a post-Flandrian product of recent wave erosion at present sea level and of pre-Flandrian wave erosion during the stand of sea level that bevelled the surface of the Low Coral Keys and the Oolite Keys and I believe it is still occasionally an active shoreline. Its superficial appearance as a cliff cut into obdurate consolidated rock is misleading. Most geologists who have worked with the Miami oolite are familiar with its ability to develop an indurated surface where it is subaerially exposed. This ability is seen in Figure 19 which shows two adjacent excavations in the Miami oolite at the crest of the Silver Bluff Scarp near Brickell Avenue in Miami. In the foreground is a vertical surface cut into the oolite to grade the street some years ago. In the background is a new excavation which was being made at the time the photograph was taken. The wall of the older surface in the foreground is now indurated rock, yet earth moving equipment designed for incoherent materials (ditching machines and bulldozers) had no difficulty removing oolite within a few inches of this hardened surface.

Again at the crest of the Silver Bluff Scarp at the intersection of southwest 22nd Avenue and Kirk Street in Silver Bluff I had little difficulty putting a hole down five feet with an ordinary soil auger after spudding through a few inches of hardened crust.

Obviously the Silver Bluff Scarp gives a false impression of durability. It is not a cliff cut into consistently hard rock but a case-hardened bluff cut into incoherent oolite. But if it is subject to only rare attack and only by the big waves of hurricanes its freshly wave-bitten face may have time to develop a hardened protective crust during the intervals between such rare attack by waves.

I think the Silver Bluff Scarp has been cut back in very recent times during certain hurricanes when high on-shore winds and low barometric pressures were forcing water into Biscayne Bay and causing abnormally high tides. Under these circumstances the surf would wash away the debris from the toe of the scarp, undermine the case-hardened part, and erode it back farther. There is little case hardening on the bench at the toe of the scarp because vegetal cover and wet marly fill usually prevent it.
In the summer of 1965 there was extensive ditching along South Bay Shore Drive in Silver Bluff in the area along the toe of the scarp where it is most sharply cut. Excavations to depths of four and five feet showed no identifiable Miami oolite in place. Instead there was a variety of stratified fill including an organic-rich layer at a depth of about three to four feet. Probably this last was a natural subaerial surface. Its overburden may have been largely artificial. However, the organic layer was barely above present sea level at horizontal distances less than 75 feet from the toe of the Silver Bluff Scarp. This argues against the idea that the present face of the scarp here was cut by a sea level appreciably higher than the present one.
The relation between the natural ground surface at the toe of the Silver Bluff Scarp and present sea level can be seen at several other places along the mainland shore of Biscayne Bay. Where the natural ground surface is seen in section it is not more than a foot to eighteen inches above sea level. Figure 20 shows a photograph taken from the shore of Biscayne Bay a few hundred yards south of "Spoil Bank" at the mouth of Cutler Canal. The toe of the Silver Bluff Scarp is seen in the distance where the road slants up the hill near the Palm tree. The water in the ditch alongside the road is sea water. It is no farther below the surface of the ground at the toe of the scarp than it is in the foreground of the photograph.
Again near the Coral Gables Water Way (Fig. 21) the natural ground surface, marked in figure 21 by the top of the darker, finer-textured zone at the bottom of the bank is barely above sea level at a distance of some few tens of feet from the toe of the Silver Bluff Scarp. At the mouth of Cutler canal near “Spoil Bank” the photograph (Fig. 25) shows artificial fill at the toe of the Silver Bluff Scarp. Fifty to one hundred feet to left or right of the canal the natural mangrove swamp lies directly along the toe of the scarp at elevations less than a foot.

Even the most active sea cliffs do not have their toes at sea level. The wave-cut bench characteristically slopes up to the toe of the cliff at elevations several feet above sea level. This elevation is determined not
by sea level alone but by height of tides, size of maximal storm waves, quantity and texture of debris, off-shore slope, etc. With maturation of erosion and establishment of a profile of equilibrium where a cliff is cut out of unconsolidated sediment the ephemeral influence of exceptional high tides and big waves is more effective because equilibrium profiles are temporarily violated by higher water levels and significant erosion can be effected in a very short time. Thus, the Silver Bluff Scarp, cut out of incoherent oolite, should be a good place for such high tides and big waves of hurricanes to effect significant erosion despite their short duration.

The direction of maximum-speed winds in the Miami area is generally from the east; the direction necessary to bring hurricane waves through the mouth of Biscayne Bay and allow them to break along the mainland shore where the Silver Bluff Scarp has its most freshly cut appearance. Before the southward growth of the barrier to form Virginia and Biscayne Keys these high waves would have had more direct access to the scarp.

A few hundred yards southwest of the mouth of Cutler Canal there is good evidence that hurricane seas can reach the Silver Bluff Scarp. Figure 22 shows a twenty-five foot sailboat that Hurricane Donna (1960) washed across some 1,000 feet of what is ordinarily dry land, and dropped within fifty feet of the toe of the Silver Bluff Scarp.

The internal structure of the Silver Bluff Ridge supports the idea that it has largely been formed as a shallowly submerged bar. (Hoffmeister, Stockman and Multer, 1967, p. 185.) Most beach ridges are dominantly made of sand that has been blown landward from a dry beach berm and filtered down into dense, scrubby, spray-stunted vegetation. Although essentially aeolian, such accumulations of sand show little of the crossbedding characteristic of non-vegetated, marching dunes. The Silver Bluff Ridge by contrast is built dominantly of cross-bedded oolitic sand that seems to have been emplaced by water rather than wind and the seaward dip of most of the cross-bedding suggests that the Silver Bluff Ridge was built at a higher sea level when most, if not all, of its present subaerial stature was submerged.

The present mainland lagoonal shore between Pompano Beach and Miami seems to be a relict pre-Wisconsin oceanic shore reactivated at present sea level or at least a recent shore line that closely resembles the last pre-Wisconsin shore line that is still above sea level. Both this present shore line and its relict predecessors have been cast into a series of concentric arcs that are somewhat similar to those between the Carolina Capes farther north (Cape Hatteras, Cape Lookout and Cape
Fear in North Carolina) which also seem to have been shaped under the influence of geometrically similar relicts of earlier shore lines to landward (White, 1966).

The mainland lagoonal shores of the coast of southeastern Florida have been cut off from the waves of the open ocean by a sand barrier as have those of the lagoons between the Carolina Capes, but there is a major difference in the way this occultation was done.

In the Carolinas, from Core Sound southward, the lagoonal mainland shore and the oceanic shore of the barrier are geometrically similar and essentially concentric. The present oceanic shore line of the barrier mimics the older oceanic shore line that forms the present mainland
shore of the lagoon. All parts of the barrier seem to be essentially coeval along its length and the lagoon has a rather uniform width along its length. This tendency for the barrier to mimic the mainland shore is generally characteristic of the coast north of the coastal salient at Palm Beach because shallow shelf waters intervene between the barrier and the edge of the continental slope.

In Southeastern Florida on the other hand the barrier does not simulate the relict coastal arcs of the mainland lagoonal coast. Instead it extends nearly straight southward from Pompano Beach to Cape Florida. Apparently it has been localized by some influence that is quite independent of earlier oceanic shores; possibly the outer edge of shoal water along the crest of the continental slope.

The barrier differs from its Carolinian counterpart in its manner of growth as well as in its shape. All parts of the Carolinian barrier are essentially coeval, but the barrier of southeast Florida seems to have grown southward like a spit; its northern part being the oldest and its southern distal end the youngest so that it cut off the mainland shore from the oceanic surf increasingly later with distance southward.

Thus dereliction of these mainland coastal arcs of southeastern Florida is increasingly older to the north. The original post-Flandrian headland seems to have been near Lettuce Lake near the southeastern corner of the city of Pompano Beach (Pl. 3). The northernmost relict shoreline arc begins there and extends southward along the mainland side of a derelict lagoon curving, at first, abruptly westward and then southward with more gentle curvature to the latitude of the north end of Hugh Taylor Birch State Park in Fort Lauderdale.

Before this shoreline arc had been long exposed to the attack of the surf from the open ocean a spit-like barrier grew southward across it from the original headland at Pompano Beach. This barrier cut off the mainland shore of the lagoon from the open ocean and it became derelict as far south as the barrier-spit reached. Farther south, however, the mainland shore was still open to oceanic surf which continued to maintain a second shoreline arc very similar to the first between the southern end of the first one and the west end of North Lake in eastern Hollywood. Like the first shoreline arc this second one was later cut off from the open ocean by southward growth of the barrier and it in turn became derelict.

This process of occultation of successive arcs along the mainland shore seems to have continued until five such arcs were produced (Pl. 3). The third extended from Hollywood to North Miami Beach, the fourth, from North Miami Beach to Point View, and the fifth or present
one, from Point View to the southern part of Biscayne Bay where the mainland shore has long been protected against erosion by the intervention of the Coral Keys between it and the ocean.

The sequence of events suggested here is supported by differential dereliction of the five parts of the lagoon involved. The part of the lagoon that lay before the first or most northerly of these shoreline arcs is so degenerate that it shows no open water at all and little marsh or swamp. That which lay before the second shoreline arc still shows occasional bodies of open water although most of its eastern part is mangrove, and there is a considerable zone of low dry land adjacent to the original oceanic coastal scarp. Areas of both mangrove and open water increase in the third section of lagoon. The fourth section is the open water of the narrower northern part of Biscayne Bay north of Point View and the mouth of the Miami River. The fifth is the main body of open water of Biscayne Bay itself.

Before the barrier began to grow southward from the first headland at the north near Pompano Beach, the entire reach of mainland shore was subject to oceanic surf. But when the barrier cut the waves off from the northernmost shoreline arc, this arc became derelict while the remainder of the mainland shore to the south was still an active shoreline of the open ocean. As the barrier grew southward by another increment the second shoreline arc was cut off from the oceanic surf, and it too began to degenerate. Similarly the third and fourth shoreline arcs have been successively cut off from the ocean as the barrier added the increments needed to occult them.

The fifth shoreline arc, the Silver Bluff Scarp, adjacent to the main body of Biscayne Bay south of Point View, has not yet been wholly cut off from the ocean since the barrier chain ends at Cape Florida; and the occultation process is not complete.

In the case of the last two shoreline arcs, the fourth and fifth, each one shows that it is younger than the next one to the north by crossing the lagoon. Thus, as the fourth shoreline arc curves more sharply eastward toward its northern end, it truncates the sediments (mangrove swamp) of the more degenerate section of lagoon associated with the adjacent third shoreline arc to the north.

The fifth mainland coastal arc is the Silver Bluff Scarp, and like the other four mainland coastal arcs to the north, the Silver Bluff Scarp curves increasingly eastward as it approaches its northern end near the mouth of the Miami River at Point View. If this curve were extended out into Biscayne Bay it would separate the wide, southern part of the bay from the narrow northern part and would intersect the present
barrier at the southern tip of the island that is occupied by the main part of the city of Miami Beach. The barrier south of that point (mostly Virginia Key and Biscayne Key) seems to be late additions to the barrier chain still following the repetitive pattern of cutting off the mainland coastal arcs from oceanic surf and rendering them derelict. The apparent late dereliction of the Silver Bluff Scarp is probably a product of this latest southward extension of the distal end of the sand barrier. Perhaps with time the barrier will grow southward far enough to close the mouth of Biscayne Bay and completely occult the Silver Bluff Scarp. But the general dearth of sand in the peninsula below this latitude suggests that the barrier has already grown about as far southward as its sand supply will permit. Also the seaward turn of the distal, southern end of Biscayne Key at Cape Florida suggests a seaward-setting current there which shunts the southward drifting sand into the deep water of the Florida straits. If this be true it would seem improbable that the barrier should ever grow much farther southward.

The controlling factor is the major coastal prominence at Palm Beach. Northward from Palm Beach the coastline lies increasingly farther back from the edge of the continental slope. At Palm Beach the edge of the continental slope intersects the land and southward from that point the shoreline can not prograde appreciably because of deep water closely off shore. The five coastal arcs in question occupy most of the Atlantic coastline south of Palm Beach which forms a great coastal prominence similar to that of the North Carolina Coast which seems to have caused the development of the three similar coastal arcs to the south of Cape Hatteras between Cape Hatteras, Cape Lookout, Cape Fear and Cape Romain (White, 1966). In both instances, Florida and the Carolinas, there are southward-setting longshore currents along the segments of coast in question at least in part. In the Carolinas the present barrier is able to mimic the older mainland shore because there is shallow shelf water offshore to allow the off-cape shoals to extend the headlands (capes) seaward and maintain the coastal arcs between the capes. In southeastern Florida on the other hand the present barrier has been built southward essentially at the edge of the deepening water of the continental slope and therefore the headlands between coastal arcs could not maintain off-cape shoals to separate coastal arcs.

In the Carolinas (south of Cedar Island) the coastal arcs are expressed in both the mainland shore and in the barrier as well. But in south Florida they are not expressed in the plan of the barrier but rather in the mainland shore and the contemporaneous southern ends of lagoons as the barrier grew distally southward. This is because in the Carolina Cape zone sand supply is voluminous, the shelf is wide and
slopes gently seaward. Therefore prominent off-cape shoals could maintain themselves and partition the coast into coastal arcs even during rising sea levels following glacial regression (White, 1966).

But in the southeastern coast of Florida sand supply for longshore drift is increasingly small with distance southward and sand is probably lost to transport down the continental slope to the deep Florida straits. For all these reasons off-cape shoals could not maintain themselves far enough eastward to influence the plan of the present barrier which is at the crest of the continental slope at the edge of deep water.

Thus, in the Carolinas, all parts of the mainland lagoonal shorelines were made at the same time. Although the oceanic barrier shores may be younger, they also seem to have been built simultaneously throughout, and both mainland and barrier have similar, concentric, coastal arcs. In southeastern Florida the barrier is increasingly younger with distance southward toward its distal end. The coastal arcs of the mainland lagoonal shores of southeastern Florida although they may have shared a more or less simultaneous inception seem to have differed greatly in their active life. Thus, at the extreme southern end, the coastal arc that fronts the Silver Bluff Ridge along Biscayne Bay seems to have begun as the seaward edge of an arcuate oolite shoal in the Pamlico Sea while at the north the high ridge in the vicinity of Del Ray Beach, Boynton Beach and Lantana (Pl. 3) exceeds 40 feet in elevation and was probably a southward extending spit in the Pamlico Sea. Higher parts of the ridge atop the mainland lagoonal shoreline scarp between these northern and southern extremes probably were partly above and partly below the Pamlico Sea level. In general they seem to have been increasingly below it with distance southward toward the distal shoal that became the present Silver Bluff Ridge. During later times of sea levels lower than Pamlico these shoaly bars, islands and spits were integrated to make shorelines of more continuity which became derelict at higher than present sea levels at the north and at present sea level at the south.

There is a good possibility also that the spit-like southward growth of the barrier was not wholly accomplished in post-Flandrian time either. Perhaps the more northerly coastal arcs were cut off from the open sea during the time when the four foot surface at the low coral keys and the oolite keys was being formed. The lagoons between the first three mainland coastal arcs and the barrier are increasingly emergent toward the north with urban development on natural, dry ground.

Still farther north between Pompano Beach and Boynton Beach in the general vicinity of Deerfield Beach, Boca Raton and Del Ray
Beach the derelict lagoon is a frankly emergent relict with a floor that rises gradually westward from an elevation of about five feet immediately landward of the old barrier to about 25 feet at the toe of the scarp of the relict mainland shore. The present oceanic shore line here seems to be situated in about the same place as its predecessor that was made during the last pre-Flandrian sea level that was higher than present sea level. Complementarily the barrier is higher here also. North of the headland at Pompano Beach it commonly exceeds 20 feet elevation, while south of Pompano Beach it rarely reaches ten feet.

THE MIAMI RIDGE

There is a persistent ridge along the mainland shore of the east coast of Florida. North of Palm Beach it is a prominent relict beach ridge, but south of Palm Beach it changes character. Although ridges persist as far south as Miami; the sand of which they are built gradually changes its composition with distance southward. North of Palm Beach it is almost wholly quartz and other detrital minerals but with distance southward from Palm Beach it acquires steadily increasing percentages of calcareous oolite. More or less coextensive with this change in mineralogic composition is a change in topography. As the sand becomes more oolitic it takes the form of a relict oolite shoal; a broad low swell a few miles wide and some ten to fifteen feet high. Toward the north it is surmounted by several relict beach ridges but their number decreases southward until they disappear somewhat north of Miami.

This change of form with change in composition seems to reflect sedimentary process. To the north where the sand is dominantly detrital quartz it seems to have been moved to its present location by longshore drift, hence, its characteristic repetitive topographic form is that of successive beach ridges and swales. Some of these may have been formed by prograding shorelines. But a general tendency for the land surface to be higher with distance landward suggests that several sea levels have been involved; probably there were several discrete transgressions. These successive beach ridges at different elevations can be seen in plate 3. Their number diminishes southward by disappearance of the higher ones.

While the older shorelines to the north were building the higher beach ridges of detrital quartz and coquina, the more southerly parts of the present Miami Ridge were being deposited as a broad shoal or shallow submerged bore of calcareous oolite which seems to have resembled the present Browns Cay on the western side of Andros Bank.
in the Bahamas. As Newell (1960b) has shown, such oolite banks precipitate on shallowly submerged edges of broad shoal areas where these abut deep water. Tidal overwash fed from the deeper water passes over the edge of the shoal where warming, pressure reduction, and agitation cause it to lose carbon dioxide and precipitate calcium carbonate. The optimum depth for such precipitation seems to be less than six feet at low tide (Newell, 1960b).

These observations seem pertinent to any attempt to explain the Miami Ridge for it is located in a place where the same genetic factors could have worked. It is near the edge of the continental platform at an elevation that in Pamlico time would have been submerged in shallow sea water of about the same depth as that which now covers the Bahaman oolite shoals. It lies to landward from a part of the coast that is impoverished for beach sand. This is seen in the present absence of beaches south of Cape Florida. But in Pamlico time the distal part of the present peninsular mainland was shallowly submerged like the Bahama Banks and mineral sand doesn’t seem to have reached it in sufficient supply to build any beaches at all in the latitude of the Miami Ridge. The Miami area was protected against influx of detrital sand by its remote distal situation just as the Bahama Banks are now protected against it by their oceanic isolation. Thus, there would have been unhindered opportunity for a shallow bank to accumulate a mass of chemical sediment as in the relict oolite shoal of the Miami Ridge or the presently active ones on the Bahama Banks.

The topography would have tended to concentrate tidal flow in the Miami area for tidal flows would have entered jet-like on the east through the relatively narrow opening between the southern end of the Pamlico-aged barrier beach at the north and the Key Largo coral reef at the south. But once through this orifice they could have spread broadly westward across a marine bank (the present Everglades) toward the Gulf of Mexico.

**RE LIC T MANGROVE ISLANDS**

The present topography of the Miami Ridge was acquired during the process of its emergence from the Pamlico (?) sea. As the water above the oolite shoal became shallower, mangroves began to establish themselves tending to form ring-shaped islands like the present ones along the northern edge of Florida Bay. These last usually have no names, so I will identify them by the names of the bodies of water they enclose, as Blackwater sound, Little Blackwater sound, Long Sound, Manatee Bay, Joe Bay, and Madera Bay. Relicts of the ring-shaped
Pamlico islands of the Miami Ridge can be seen in plate 2 which was condensed from the 7½ minute topographic maps of the United States Geological Survey. Despite their inadequate five foot contour interval, these maps show a line of ring-shaped ridges which I believe are emerged relics of mangrove islands somewhat like those of Florida Bay. They have roughly similar shape and size in plan. However, those of the Miami Ridge had tidal channels between them (the present transverse glades) which assured that each ring-shaped island was quite discrete from its neighbors. But the present mangrove islands of Florida Bay run together and branch in a braided pattern.

In most instances where these levee-like ring-shaped hills were examined in exposure they showed external molds of mangrove roots
as their dominant innate structure. Not infrequently these molds are very detailed preserving the form of a plexus of roots over an extensive area. The molds are formed of calcareous oolite grains cemented together. Their characteristic form is that of a hollow tube. The walls of the tubes vary in thickness. As they become thicker the external surfaces of the tubes tend to lose their resemblance to mangrove roots. Differential thickness of cementation makes the outside of the tubes ragged and irregular. But when tubes are broken through, their internal surfaces are usually seen to be smoothly cylindrical, true external molds of the original mangrove roots (Fig. 23).

Where their walls are not unduly thick a plexus of these tubes looks very much like an intimate intergrowth of mangrove roots (Fig. 24). Such intergrowths can be seen very well in the cut on the west side of the Sunshine State Parkway (Florida Turnpike) immediately south of Honey Hill Road (N.W. 199th Street) which is a short distance south of the northern boundary of Dade County and south of the bridge over Snake Creek Canal. These tubes branch in the manner of mangrove roots which have a strong tendency to grow rectangularly in horizontal and vertical directions. Many of the vertically oriented tubes seem to be fossil pneumatophores of black mangrove, Avicennia, resembling those described by Hoffmeister and Multer (1965). Others are fossils of the geotrophic roots that descend from horizontal ones.

The fossil roots of the relict mangrove islands differ from the younger ones described by Hoffmeister and Multer from Key Biscayne which is a part of the present sand barrier. In the instance they describe the root itself has been variously replaced with calcareous materials and a layer of sand grains, largely quartz, has been cemented together around its exterior surface. The resulting entity they refer to as a “rod”. But in the much older, Pamlico (?) deposits of the relict mangrove islands very little quartz was involved. The enclosing material was mostly calcareous oolites which seem to have been more voluminously cemented together to form a thick encrusting layer around the roots. The roots themselves are not usually fossilized. At least I recall seeing little that resembled the inner layers of the “rods” of Hoffmeister and Multer (1965). Apparently conditions were not suitable for replacement of the wood and it rotted out leaving empty tubes rather than solid rods (Fig. 23).

Hoffmeister and Multer refer to the long standing opinion that mangroves are rarely fossilized (Bowman, 1917, p. 666). But they also speculate that “rock structures which are of doubtful origin and which have tentatively been assigned to worm tubes and burrows of various animals may actually have originated in some type of marine vegetation.”
In my opinion the characteristic structure of the Miami oolite where it composes the relict mangrove islands is that of a plexus of fossil mangrove roots; mostly external molds made of agglutinated oolite grains. In some instances the vegetal origin of the form of these tubular structures is patent, as may be seen in figure 24. But in most instances the tubes form such a dense snarl that their relation to any systematic arrangement of the roots of a plant is obscure (Fig. 25). This complexity probably results from the roots of many generations of plants as well as various animal burrows penetrating the same space.

Nonetheless, close examination of most exposures of Miami oolite in the ring-shaped ridges shows rough surfaces with many small holes. Most of these are an inch or so across. They readily fall into two categories: (1) irregular shaped holes that are places where loose grains
of oolite have fallen out from between the external surfaces of the tubular molds of the old mangrove roots, and (2) cylindrical or tubular holes that are the internal space whence the roots rotted from the molds.

This kind of structure was found in the oolite at every exposure I visited in the ring-shaped ridges or relict mangrove islands. Other kinds of structure appear in these areas too, most notably, thin bedding and animal burrows but the external-root-mold structure is the commonest one.

East of the relict mangrove islands, and occasionally truncating them on the east, is a prominent ridge (the Silver Bluff Ridge) built of
oolite along the Silver Bluff. Superficially, it resembles the ring-shaped ridges of the relict mangrove islands but on the map it is seen to have the plan of a high energy oceanic shoreline. The Silver Bluff Scarp is cut into its eastern edge.

In this surficially indurated oolitic ridge I don’t recall seeing any of the mangrove-root structures. All the exposures I recall showed cross bedding like that seen at the type locality of the Silver Bluff shoreline on South Bay Shore Drive in the Silver Bluff section of Miami. This restriction of the mangrove-root structures and associated fossil burrows to the relict low-energy localities of the ring-shaped ridges and their absence from the surf-dominated Silver Bluff Ridge suggests that; the mangrove root external mold is the proper interpretation of the
structure commonly seen in the relict mangrove islands or ring-shaped ridges.

The ring-shaped ridges of the relict mangrove islands and the higher parts of the Silver Bluff Ridge share the highest elevations of greater Miami. The site mentioned above where Honey Hill Road or N.W. 199th Street crosses the Sunshine State Parkway is impressive, although atypical in containing more cross bedding than fossil mangrove root structures. The road cut where the parkway passes through the ring-shaped ridge is deep enough to let Honey Hill Road cross it on an overpass without necessity for fill to maintain clearance in the parkway beneath. Figure 26 shows the stature of the ridge where it is transected by the parkway.
Although this is an extreme instance of the local relief produced by the relict mangrove islands most of the others are steep and high enough to demand cuts in roads or railroads that cross them. Abrupt changes in elevation and slope can be seen in figure 28, a view from a position just east of St. Mary's Cathedral looking eastward along the south side of N.W. 75th Street toward N. Miami Avenue. Mangrove root molds shown in figure 25 are located in the road cut seen on the right in figure 27. Similar structures in another part of the same relict mangrove island can be seen on the south side of N.E. 69th Street between N. Miami Avenue and N.E. 2nd Avenue.

About a quarter mile west of U.S. Highway 441 in the NE quarter of Section 13, Township 50 S.; Range 41 E in the latitude of Fort Lauderdale, a former rock pit (now used as a playground) shows relict mangrove roots to advantage. As can be seen on the Fort Lauderdale South quadrangle, this pit is in an isolated area of continuous high ground rather than a ring-shaped ridge with enclosed lower ground. This hill seems to have been a mangrove island like many of those presently found in Florida Bay that are more or less equidimensional rather than ring-shaped. It held no lagoon-like body of water in its center, nonetheless, like the ring-shaped ridges its dominant structure is that of tubular molds of mangrove roots. Those shown in figure 28 were washed out of incoherent oolite sand from the southeastern wall of this pit.

Southwestward from the center of Miami, mangrove root structures can be seen in a prominent ring-shaped ridge that is bisected along an east-west line by Miller Drive (SW 56th Street). Its eastern edge lies immediately west of the Palmetto Expressway (Florida Highway 826). Root structures can be seen where the Seaboard Airline Railroad transects it both in a low cut at the southwest where it crosses Galloway Road (S.W. 87th Avenue) and, in a deeper cut west of the railroad about 1000 feet northeastward from Miller Road. In this last cut, which is some ten feet deep, cross-bedding dominates the bottom of the exposure and mangrove root structures are common at the top.

Farther to the southwest, toward the end of the zone of ring-shaped ridges, the town of Perrine centers in the area enclosed within a ring that is some two miles in diameter. Near the north edge of Perrine a small roadside park centers on an old borrow pit on the east side of U.S. Highway 1 about 1000 feet north of the place where it becomes a divided highway. The upper two or three feet of the wall of this pit is dominated by fossil root structures. The lower part of the wall shows cross-bedded oolite but no root structures.
Figure 28. Tubular molds of mangrove roots washed out of Miami oolite from walls of playground in old rock pit in Fort Lauderdale.

Southeastward from this old pit the ring follows the land enclosed within the fifteen foot contour as shown on the Perrine 7½ minute quadrangle. There are a number of road cuts on residential streets in this area. Most of them show fossil root structures. A good exposure may be seen on S.W. 176th Street between S.W. 90th and 91st Avenues.

The stature and plan of most of the ring-shaped ridges or relict mangrove islands can be seen on plate 2 where the three intervals between the 10, 15, 20, and 25 foot contours have been shaded. With very few and minor exceptions these are the highest elevations' of the greater Miami area. Their configuration on the maps outlines the
ring-shaped ridges in a general way. But I think a smaller contour interval would show the ridges to have greater continuity.

It is notable (Pl. 2) that no streams transect ring-shaped ridges. The ridges enclose low ground, but no streams flow through it. Instead the drainage is concentrated in the areas between ring-shaped ridges in the valleys that have been known as "Transverse Glades". From north to south these are the valleys of New River, the natural valleys now drained artificially by Snake Creek Canal, Royal Glades Canal, and Biscayne Opaloka Canal, the valleys of Little River and Miami River, and the valleys now occupied by Coral Gables Canal, and Snapper Creek Canal. All these drainages thread their way between ring-shaped ridges and never invade the lowlands enclosed by the ridges.

This supports the idea that the present drainage ways are relicts of tidal channels that separated the original ring-shaped mangrove islands before they were rendered derelict by falling sea level.

THE EVERGLADES

Most of the soluble parts of the surface of south Florida have elevations very close to present sea level. This probably means that either sea level has returned almost exactly to interglacial levels to which solution had lowered and deposition raised the carbonate areas, or solution has lowered these areas to present sea level in post-Flandrian time. Most of this low, solution-levelled surface is the Everglades.

Peat overlies the limestone throughout most of the Everglades. The basal part of the peat has been dated by carbon 14 at about 4,000 years B.P. at a number of places: south of Lake Okeechobee (Schroeder, Klein, and Hoy 1958); along Levee 67 southwest of Andytown (dates obtained for this study); and near the mouth of the Everglades Sloughs (Spackman, Scholl, and Taft, 1964). The uniformity of these dates at about 4,000 years B.P. suggests that the present carbonate lowlands were low enough to bring a water table to the surface of the ground and produce swamp conditions when the Flandrian transgression crested. This suggests that the bedrock surface was already low 4,000 years ago and makes it difficult to assume that it was cut down by post-Flandrian solution engendered by crest-of-Flandrian water table rise.

Another alternative is to assume that the solution took place over a longer period of time and most actively during lower glacial sea levels. This, of course, raises the problem of explaining the absence of solution depressions whose surfaces are lower than present sea level. Perhaps
they may exist in the person of the sub-sea level parts of the low places that hold Florida Bay, Biscayne Bay, and Lake Okeechobee. But such sub-sea level areas are not impressive. They are few and they reach depths only a few feet below sea level. And these low areas are more plausibly explained by other means. Moreover, solution during lower sea levels could not produce a plane surface so nicely adjusted to present sea level as the Everglades. Carbonate deposition could produce a flat surface and undoubtedly has helped to maintain and repair the extant one. But the extant surface of South Florida is dominantly micro-karst which bespeaks an origin by lowering to a base level rather than by building up to one.

The problem suggests the repetitive return of the sea essentially to its present level during several interglacials as suggested by the work of Parker and Cooke, (1944), Alt and Brooks, (1965), and others outside of Florida. The solution produced during each of these repetitively duplicated interglacial high sea levels would help to lower more of the carbonate land surface to elevations little above this recurrent sea level. Meanwhile, peat would grow on already lowered parts of the land surface and preserve them against further lowering. Thus, the Big Cypress, Everglades Keys, and Miami Ridge are now being lowered by solution while the Everglades is protected against further lowering by its covering of peat. However, such protecting peats probably disappear quickly when sea level falls during glacial times.

A critical factor in determining where fibrous peat accumulates in south Florida seems to be the nature of the base on which it rests. It commonly lies on limestone and rarely on silica sand. This association of fibrous peat with a limy base supports the concept of an Everglades Trough cut down by solution. Apparently the fibrous peat accumulates on the limestone because the limestone can be dissolved down to watertable. The resulting pocosin creates the swampy condition necessary for the growth of fibrous swamp plants and their preservation as peat. The surface of silica sand can not be so readily reduced to a pocosin because it is not lowered by solution except for reduction of volume as its shell component is leached out.

A widespread blanket of peat such as that of the Everglades Trough overlying a karst surface induces speculation that the solution was effected by organic acids drained out of the peat. There seems little reason to believe this has happened. Dr. David Alt (personal communication) could find no acid water coming from the peat. Moreover, the topography of the limestone surface buried beneath the peat of the Everglades near levee number 67 of the Central and South Florida Flood Control District is essentially similar to that of the exposed
limestone surface at Pinelands Trail on the Flamingo Highway in the Everglades National Park.

The topographic maps shown in figures 3, 29 and 30, show micro-karst in these two places. The two maps shown in figures 3 and 29 were made by contouring elevations obtained from a one foot grid over areas 10 feet square. Figure 30 used a ten foot grid over an area 100 feet square. The map of the area near Pinelands Trail (Fig. 3) was made directly from the subaerially exposed surface of the limestone. The maps of the limestone floor beneath the peat of the Everglades (Figs. 29 and 30) were made from information obtained by probing to hard rock with a 3/8 inch steel rod at a location about 100 yards south of Levee 67 and about two miles west of U.S. Highway 27.

The topography shown on all three of these maps is so similar it suggests both surfaces were made in the same manner. Since the Pinelands Trail area is dry enough to support an open pine forest, it seems doubtful that it was ever covered by post-Flandrian peat. This in turn, suggests that the similar surface at Levee 67 was made under similar conditions of subaerial exposure before the peat began to accumulate.

The artesian head in the Biscayne aquifer (Schroeder, Klein, and Hoy, 1958) is normally great enough to maintain a piezometric surface higher than the land surface through most of the Everglades. In the absence of a continuous cap rock this also casts doubt on the validity of explaining the karst surface beneath the peat by water that descended through the peat deriving acid from it.

The presence of an artesian aquifer below the Everglades also raises the possibility that the surface has been lowered by solution effected by moving artesian water. This also seems a small possibility for several reasons. The karstic surface is obviously the product of solution at the surface of the limestone, and artesian water would not fit its movement to the contact between the peat and the limestone. It would more plausibly spread its flow through a thick zone of permeable rock. Any solution produced by such a thick zone of flow would cause broad, gently sloping topographic sags or big, steep-walled collapse sinks rather than minutely and intricately etched surficial micro-karst at the interface between limestone and peat.

At the base of cores of the unconsolidated stuff overlying the limestone there is a thin, white stratum a few inches thick that usually is silt and fine sand resting directly on the top of the limestone and overlain directly by the peat. Davis (1946) referred to this as the Lake Flirt Marl, but here, at least, it is mostly insoluble. If the karst surface
Figure 29  Contours on surface of limestone beneath peat in Everglades alongside Levee 67 about one mile west of U. S. Highway 27, one foot grid
of the limestone directly beneath were the product of sagging or collapse caused by solution throughout a thick vertical zone, this insoluble residue should also be distributed throughout the vertical zone in which the solution occurred. On the other hand, its presence as a thin, sharply defined septum between limestone below and peat above suggests that it was originally a soil developed subaerially on the limestone when it was exposed at the surface of the ground under conditions of good drainage in pre-Flandrian time. This idea is supported by the presence of soils formed of similar insoluble residues along the Tamiami Trail on limestone in parts of the Big Cypress where the surface is usually dry.

**DEPOSITION AROUND THE EDGE OF THE EVERGLADES**

Although the limestone surface of the Everglades Trough has been lowered by solution, there is little doubt that deposition along its edges has helped to confine it as an axial drainage way. Quartz sand moved southeastward from both east and west coasts of the peninsula in Pamlico time, but did not enter the Everglades. It built the sandy Immokalee Rise west of the Everglades Trough and much of the Atlantic Coastal Ridge east of the Everglades.

The protection of the Everglades Trough against incursions of southeastward-moving quartz sand is involved with the prior development of the Kissimmee Valley up-peninsula to the northwest. The Okeechobee Scarp extends from the south end of the Indiantown Ridge on the east, around the north side of Lake Okeechobee, to the south end of the Lake Wales Ridge (Pl. 1). It is an erosional scarp with a level base and a crest of differential elevation. This assures that it is younger than the Kissimmee River Valley which it truncates at the south.

The Kissimmee River Valley is a broad, open, gently sloping swale some 20 miles wide which extends in length from the cross-peninsular divide at the head of the Kissimmee River to the Okeechobee Scarp immediately north of Lake Okeechobee, a distance of some 75 miles. This valley was formed by solution-sagging or subsidence of its surface by subterranean solution without complete destruction of its original surface details. Thus, the drainage pattern of the Kissimmee River and Taylor Creek shows their consequence to relict beach ridges that were built along a succession of Atlantic shorelines as the sea regressed eastward across this area. These relict beach ridges are but meagerly suggested in the lower parts of the Kissimmee Valley, but they become clearer with distance up the side slope of the valley toward the east.
Figure 30  Contours on surface of limestone beneath peat in Everglades alongside Levee 67 about one mile west of U. S. Highway 27, 10 foot grid
Since they are relicts of Atlantic Oceanic shorelines and become higher in the direction of the present coast, obviously the more westerly ones must have been lowered since they emerged (White, 1958, and discussion of Osceola Plain in this report). These relict beach ridges are closely parallel with modern Atlantic oceanic shorelines and also with other relict shorelines at elevations both higher and lower and locations both east and west of the present Kissimmee Valley. They assure that the Atlantic regressed eastward across the area now occupied by the Kissimmee Valley leaving a series of relict shorelines that were all essentially straight, and parallel with the present Atlantic beach.

The Atlantic shoreline must have regressed from these relict beach ridges before the Kissimmee Valley acquired its present trough-like character and while its surface was still inclined gently eastward toward the Atlantic with a continuous slope from the eastern toe of the Lake Wales Ridge to the crest of the east-facing scarp that bounds the Osceola Plain on the east. Any quartz sand drifted southward into the area now occupied by the Everglades Trough from these relict beach ridges of the present Kissimmee Valley must have been delivered before the valley was formed by sagging of the original eastward-sloping beach ridge plain. The level toe and differential crest elevation of the Okeechobee scarp assure that the Kissimmee Valley had sagged before the scarp truncated it. There is no trace of such sand on the surface of the Everglades Trough now. Possibly the surface on which it was deposited has been dropped by faulting and buried by younger, lower energy, calcareous sediments such as the Fort Thompson formation.

Faulting is suggested by a number of features along the line that separates the low distal part of the peninsula from its higher central part. A major topographic break occurs here. It includes the narrowing of the peninsula south of Sanibel Island on the west coast, the course of the Caloosahatchee River, and the straight northwest shore of Lake Okeechobee. It terminates the higher ground to the north in the southern end of the DeSoto plain which is some 60 feet high at the crest of the Caloosahatchee Incline north of the Caloosahatchee Valley compared with elevations generally half that high in the Immokalee Rise to the south. It truncates the Lake Wales Ridge. And the Okeechobee scarp seems to have been eroded back to its present location as the shoreline of a sea (Pamlico ?) that once existed to the south submerging the distal part of the peninsula south of the Kissimmee Valley. Also this line generally separates quartzose sandy soils on the north from peats overlying limestone on the south.

Tanner (1965) has suggested a fault here. It would be parallel with the one mapped by Jordan, Malloy, and Kofoed (1964) along the
northern side of the Pourtales submarine terrace south of the Florida Keys and would also be parallel with the fault suggested by Vernon, (1951), and White, (1958), which ends the Kissimmee faulted flexure at its southern end in the latitude of Cape Kennedy.

Both the subsidence that formed the Kissimmee Valley from the former beach ridge plain and any down-faulting of the former extension of this valley must have antedated the sea level (Pamlico ?) at which the Okeechobee scarp was made. Thus, (Pamlico ?) sand could be drifted into positions southeast of the Caloosahatchee River-Lake Okeechobee lineament only in places that were in line with the (Pamlico ?) oceanic beaches of the east and west coasts of the peninsula to the north. These were located near the present east and west coasts of the Peninsula and accordingly the Pamlico quartz sand south of the lineament is all near the edges of the peninsula as seen in the Atlantic Coastal Ridge (northern part of the Miami Ridge) along the east coast and Immokalee Rise on the west coast. Between these two peripheral ridges of quartz sand is the sand-free Everglades Trough.

INFLUENCE OF STRUCTURAL LINEAMENTS ON SOLUTION
IN THE DISTAL ZONE OF THE PENINSULA

Throughout the Florida peninsula confusion arises in recognizing structural lineaments because one of their two principal trends (Vernon, 1951, figure 11) is the same as the relict and present oceanic shorelines of the east coast. This complicates what has been said about the Everglades in the immediately foregoing part of this report because differential solution at depth on opposite sides of structural lineaments may have determined geographic boundaries between overlying, thin Pleistocene formations. The boundaries between the confining Pamlico (?) quartz sands southwest and northeast of the Everglades Trough and the Fort Thompson formation which floors the trough have this dually explicable orientation.

The geologic map of the distal end of the Florida Peninsula presented by Schroeder Klein and Hoy (1958) is reproduced here in simplified form as figure 31. It will be noted that most of the contacts between formations follow lineaments of one or the other of the two main sets. I have added peripheral arrows on the edge of the map to mark these lineament-founded formational contacts. One of these (the one pointed out by the arrows numbered a and a') lies along the northeast-southwest lineament mentioned in the immediately preceding section that locates the southeastern end of the Central Highland
section of the Florida peninsula, the cape at Sanibel Island, the valley of the Caloosahatchee River, and the northwest shore of Lake Okeechobee. It brings the Anastasia formation into contact with the Fort Thompson and Tamiami formations. Parallel with it, farther to the southeast, another major lineament, marked by the peripheral arrows b and b', brings four different formations into contact; the Tamiami formation against the Anastasia, the Fort Thompson against the Miami, and the Miami against the Anastasia. With the exception of the Miocene Tamiami formation these are all Pleistocene formations that are frequently referred to as contemporaneous in part (Parker and Cooke, 1944: Cooke, 1945; Schroeder, Klein, and Hoy, 1958; Puri and Vernon, 1959.) There is little reason to think that most of these young formations were ever buried under any appreciable sedimentary cover, and their common surface is nearly reliefless. Hence it is difficult to think of the structurally controlled boundaries between them as produced either by faulting that broke them or by differential reduction after such fault breaking. More plausible is the possibility that the surface on which these Pleistocene formations were deposited had acquired a fault-controlled topography before they were laid down. This could have been by differential solution of the pre-deposition surface or by differential subsidence of this surface because of solution at greater depth. In this connection it is of interest that Schroeder and Klein (1954) regarded all the contacts of their area of study in the western Everglades and eastern Big Cypress as unconformable.

The difference in sedimentary environment made by different water depths on opposite sides of lineaments that juxtaposed buried formations of different vulnerability to solution would form the boundaries between topographically low areas on the more soluble rocks and higher areas on the less soluble rocks. Submerged shallowly beneath an interglacial sea (Pamlico ?) the topographic relief so produced would affect water depth and therefore the kind of sediment accumulated in it.

Such initial topographic differences may partly account for the distribution of such differing Pleistocene formations as the Anastasia, the Miami and the Fort Thompson, which in turn, are largely responsible for the present topography of the distal end of the Florida peninsula. In a broad, shallow submergence like that now extant on the Bahama Banks, peripheral places produced the Anastasia formation where wave energy was high. Where tidal overwash by straits water was great and wave energy less the oolite was precipitated. And between the peripheral barriers so built, the Fort Thompson formation was deposited in the central (Everglades) trough in water that was sometimes
Figure 31  Geology of the Distal Zone of the Florida Peninsula. After Schroeder, Klein and Hoy (1958)
salt and sometimes fresh depending largely on the depth of sub-
mergence.

Unlike the present situation in the Bahama Banks, voluminous
fresh water enters the central trough of the distal part of the Florida
peninsula from the discharges of south-flowing rivers of the central part
of the peninsula, Fisheating Creek, the Kissimmee River, and Taylor
Creek. This water-freshening influence probably helped to form the
fresh water facies of the Fort Thompson Formation. Much of this
facies may have been deposited where salt water and fresh water
mingled as they do now at the inner edge of the mangrove zone along
the southwestern mainland coast of the peninsula.

**LAKES AROUND THE EDGE
OF THE EVERGLADES TROUGH**

The edge of the Everglades Trough is marked by a zone of extant
and relict lakes. They seem to have come into existence as small lakes
located along the edge of the peripheral quartz sand since the aquatic
peat which accumulated in them reaches its lowest elevations there. As
they became filled with aquatic peat they were increasingly overlapped
by sawgrass fibrous peat.

Along the southwestern edge of the Everglades Trough many
small lakes mark the edge of the bordering higher area of quartz sand
that forms the Immokalee Rise. The large Lake Hicpochee is in an
essentially similar position near the western corner of the Everglades
Trough, and the largest of all Florida lakes, Lake Okeechobee, domi-
nates the northwestern end of the trough extending nearly all the way
across it. In general, the more northwesterly parts of the shoreline of
Lake Okeechobee are founded on quartz sand while the southeastern
parts show peat resting directly on limestone. On the northeastern
flank of the Everglades Trough were the Hillsborough Lakes and
Loxahatchee slough, now largely drained. They were founded on the
southwestern edge of the quartz sand of the Atlantic Coastal Ridge.

The relation between the deepest parts of these lakes and sand-
coated limestone suggests that the lakes first came into existence
through the same process that formed the basins of lakes farther up the
peninsula to the north that occur in similar stratigraphic situations in
which quartz sand overlies limestone; especially along the toes of scarps
(White, 1958).

Apparently these lakes on the periphery of the Everglades Trough
came into existence with the rise of water table that accompanied the
cresting of the Flandrian transgression when the sea rose to its present level, only a few feet lower than the surface of the Everglades. The surface of the limestone was lowered by solution where accelerated discharges of ground water emerged from the sand at the toe of the peripheral scarp of the Everglades. From the nuclei of these small peripheral sag ponds larger lakes developed as the fibrous peat of the Everglades thickened with time to become a rising dam. These widened lakes became additions to the Everglades Trough enabling it to increase in width with the passage of post-Flandrian time. The progress of this surface-lowering and trough-widening is shown by the distribution of aquatic peat (Loxahatchee Peat). Figure 32 after Davis (1946) shows variation in thickness of the peat in the Everglades Trough. It is thickest around the edge of the trough. From the vertical cross section shown in figure 33, also after Davis, it can be seen that this thicker peripheral part of the peat is Loxahatchee aquatic peat, a sapropel accumulated in lakes. Furthermore, it is thickest where the underlying rock floor is lowest, and this lowest zone is at the extreme edge of the peripheral sand. This seems to show that the surface of the limestone was lowered by solution where it was overlain by the sand, which widened both the Everglades Trough and its covering of peat. Apparently the sawgrass peat began to accumulate in the center of the Everglades Trough and spread laterally over the earlier formed Loxahatchee aquatic peat as the peripheral lakes became derelict by being increasingly filled with aquatic peat. Through this process the Everglades Trough seems to have widened itself by invading the solution-lowered edges of the peripheral sand-covered areas.

These peripheral lakes have been enlarged by having their outlets raised. By this process Lake Okeechobee became the largest lake in Florida. If it existed at the crest of the Flandrian transgression 4,000 years ago it was probably much smaller. Under natural conditions, before the present drainage works and dikes were made, it overflowed its southeastern and southwestern banks at an elevation of some 18 feet, to discharge water into the Everglades Trough and the Caloosahatchee Valley. At that time the peat in the Everglades Trough adjacent to the southeastern shore of the lake was about eleven feet thick. As the peat thickened with the passage of post-Flandrian time, the surfaces of both the peat and the lake dammed by it rose until they were eleven feet higher than they were at the crest of the Flandrian transgression when the peat first began to accumulate. It was this rise of surface level that allowed Lake Okeechobee to spread its waters broadly across the surrounding lowlands to become the biggest of Florida’s lakes.

Davis’s profiles of the Everglades Trough (Fig. 33) suggest that the former lakes along its northeast and southwest edges migrated away
LEGEND

OKEECHOBEE MUCK

PEAT THICKNESS FEET

9-11
7-9
5-7
3-5
1-3
0-1

WITHIN LIMITS OF EVERGLADES

MANGROVE PEAT

CAPE SABLE

LAKE OKEECHOBEE

BIG CYPRESS

MIAMI

ISOPACH MAP SHOWING THICKNESS OF PEAT IN THE EVERGLADES

Figure 32  Isopach map of the Everglades region showing thickness of peat and some muck areas
Figure 33  Profile across the Everglades showing layers of peat and some marl, rock, and sand sediments
from the axis of the Everglades Trough, encroaching on the walls of the trough as a rising dam of sawgrass peat in the center of the trough progressively raised the levels of their water surfaces and overlapped the earlier formed aquatic peat. The smaller of these peripheral lakes, as they grew wider, acquired a fill of Loxahatchee aquatic peat and thereby widened the Everglades by enabling both aquatic and fibrous peat to extend across the edge of the peripheral quartz sand of the adjacent Miami Ridge to the northeast and Immokalee Rise to the southwest. The larger Lake Okeechobee acquired less aquatic peat and aquired wider and wider expanses of open water as its surface rose behind a rising dam of fibrous peat.

Further evidence for the idea that the Everglades Trough has been widened by lake-forming solution of limestone beneath a covering blanket of quartz sand may be had from the change in the eastern edge of the Everglades Trough farther south, where the overlying quartz sand is replaced by the Miami oolite. At the north, where the trough is bounded by quartz sand, its peripheral slope is steep, its peat burden thicker, and its sub-peat floor lower. Farther south, and farther down the drainage direction, where the trough is bounded by the soluble calcareous oolite of the Miami Ridge, its peripheral slope is gentler, it has no peripheral lake basins, and its sub-peat floor is higher.

**REASONS FOR DIFFERENT KINDS OF SWAMPY SURFACE IN THE DISTAL ZONE**

The low, swampy, lime-founded areas of the distal part of the Florida peninsula have three kinds of surface whose distribution seems to be determined by the nature of surface drainage.

(1) Where drainage is more or less confined by peripheral areas of higher ground, the surface tends to grow up with peat. This is best seen in the Everglades Trough. It is a great swamp throughout its whole extent. Its drainage is confined between areas of higher ground; the Atlantic Coastal Ridge (Miami Ridge) to the east and southeast, and the Immokalee Rise and Big Cypress to the southwest. In general, the flow of surface water is confluent toward the somewhat restricted outlet of the Everglades Sloughs at the southwest.

(2) Where drainage is more diffluent or centrifugal, the surface has no cover of peat and is mostly bare pre-Flandrian limestone as in the Big Cypress or on the southwestern extension of the Miami Ridge between Homestead and Whitewater Bay. Both of these are places where, under natural conditions, water from the Everglades Trough overtopped the peripheral divide and escaped its confinement to spread
difflently outward toward the sea. In the case of the Big Cypress much of the water came from the Immokalee Rise to the north.

(3) Such low, swampy areas of bare limestone give way to hinter-coastal zones where lime mud accumulates, as on most of the mainland shore of Florida Bay and the Gulf of Mexico between Homestead and Cape Romano except behind Cape Sable and the mouths of the Everglades Sloughs.

The reasons for these three different kinds of low swampy surfaces are not wholly clear; but their relation to the drainage conditions described seems fairly certain.

The growth of peat in areas of convergent drainage may result from the persistence of swampy conditions in such places. By contrast, the diffluent drainage of peripheral divides such as the Big Cypress and the southwestern extension of the Miami Ridge offer less restriction to flow of swamp water and allow it to flow away completely in times of drought. This might be inimical to the growth of the swamp vegetation that builds up the peat. Or, perhaps more plausibly, such dry periods allow peat to oxidize or burn. Davis (1946) describes fires that have removed thin layers of peat from areas peripheral to the Everglades Trough. But the fires he refers to post-date construction of the major drainage canals of the southeastern part of the peninsula, and the drier conditions that enabled the peat to burn may have come from an artificially lowered water table.

The hinter-coastal areas of the third zone where lime mud accumulates are more difficult to explain. Their drainage has been described above in the section entitled Florida Bay. They are continuous from the mainland shore of the sea to the seaward edge of the second zone where bare pre-Flandrian limestone is exposed. This lime mud is usually called marl. Near the sea it has been called marine marl. Toward its landward edge it has been called fresh-water marl. This distinction seems to have been based on differences in the relicts of flora and fauna it contains. But the process which made the marl seems to be the same throughout its whole extent for it is a continuum which stops equally abruptly at the edge of the second zone of bare pre-Flandrian limestone on its landward edge and at the shore of open lagoonal water on its seaward edge. It persists landward as far as scrub mangrove does and no farther. This relation between mangrove and lime mud can be seen along the Flamingo Road (Florida Highway No. 27) in the Everglades National Park. The dwarf cypress and karstic surface of bare pre-Flandrian limestone end together at the extreme landward edge of the scrub mangrove zone where the pre-Flandrian limestone begins to be buried under the feather edge of the lime mud.
Since the mangrove is a littoral plant I tend to think that both the mangrove and the lime mud are dependent upon the influence of salt water, although Davis (1940) says mangrove roots penetrate rock ledges only with difficulty. Possibly precipitation of lime mud in such places may be brought about by mixing lime-laden fresh water with marine salt water in a somewhat similar manner to that described by Russell (1962) in his discussion of beach rock.

Solution pits are everywhere throughout the bare surface of pre-Flandrian limestone as seen in the dwarf cypress area of the diffluent second zone. They stand full of water even during times of drought. They don't fill up with lime mud, but rather are refuge for aquatic animals. They so frequently harbor alligators that they are commonly called alligator holes. A few hundred yards seaward from the outermost of these fresh-water-filled solution pits of the second or bare limestone zone, the most landward outposts of scrub mangrove are rooted in similar solution pits that are filled with lime mud.

“Lime Levees” were described by Spackman, Scholl and Taft (1964). These deposits of lime mud border channels that penetrate the peat-covered areas of the southwestern coast of the peninsula in the area of Whitewater Bay and the Everglades Sloughs. I think they are another instance of the deposition of lime mud where fresh and salt water mingle.

I have found little to suggest the occurrence of true fresh water limestone in south Florida. Most Florida lakes tend to have bottoms foul with carbonaceous matter, sapropel or aquatic peat. Their bottom waters are commonly foul with hydrogen sulfide. They don't provide environments favorable to accumulation of limestone by either biologic or physico-chemical means. The Lake Flirt “marl” has always been mapped as a fresh water marl but elsewhere in this report I offer evidence that where it underlies the Everglades peat it is largely an insoluble residue from pre-Flandrian solution of the limestone that underlies the peat.

**THE IMMOKALEE RISE**

In the northwestern part of the Distal Zone of the Florida Peninsula the Immokalee Rise lies north of the Big Cypress, west of the Everglades and south of the Caloosahatchee Valley. Like the Atlantic Coastal Ridge south of West Palm Beach, it is a southerly extension of Pamlico (?) marine sand invading the Distal Zone from the sand-dominated Central Zone to the north. Unlike the Atlantic Coastal Ridge, however, the Immokalee Rise shows few relicts of Pamlico
shoreline features. It seems to have been built in Pamlico time as a submarine shoal that extended southward from a mainland cape at the south end of the Desoto Plain much in the manner that the present off-cape shoal extends southward from Cape Romano. Fahkahatchee and Ocaloacoochee Sloughs seem to be emergent relicts of Pamlico tidal passages through this shoal. Relict coastal features that may have formed during emergence of the shoal from the Pamlico sea are very weakly developed. Apparently low energy conditions prevailed and prevented the development of prominent shoreline features.

As in other areas where sand overlies limestone, (White, 1958) a line of lakes has developed along the feather edge of the sand-covered area, to the extent that the sandy Immokalee Rise is ringed with small solution lakes. The occurrence of these peripheral lakes is so characteristic that the edge of the sand-covered area can be delineated by drawing a line on the map connecting the lakes.

THE MIDPENINSULAR ZONE
THE ATLANTIC COASTAL LOWLANDS

ATLANTIC COASTAL RIDGE, LAGOONS AND BARRIER CHAIN

With occasional interruptions the Atlantic Coastal Ridge extends along the mainland coast of the Florida Peninsula from the south shore of the St. Mary’s River at the Georgia State boundary to the vicinity of Homestead some 30 miles southwest of Miami in Dade County. It is made of relict beach ridges and bars sometimes single and sometimes multiple.

North of Eau Gallie in Brevard County the ridge is generally wider than it is from Eau Gallie southward, but it widens again to maximal dimension near its southern end in Broward and Dade counties in the vicinity of Fort Lauderdale, Miami, and Homestead. The narrower part of the ridge south of Eau Gallie is generally located closely along the mainland shore with the Indian River or equivalent lagoon directly at its eastern toe, save for the stretch between Sebastian in Indian River County and Fort Pierce in St. Lucie County where lower ground intervenes between the ridge and the shore. This suggests that it involves the last mainland oceanic shore to be formed. North of Eau Gallie on the other hand the ridge is not only broader but usually sits back some mile or so from the mainland shore of the lagoon.
This appearance of greater antiquity is increased north of the Volusia-Brevard county boundary. Here the Indian River ends abruptly as an open water lagoon and becomes a valley with its floor attaining elevations of some 5 to 10 feet. The younger Mosquito Lagoon intervenes between this valley and the active barrier chain to the east. With the exception of Turnbull Bay, (the estuary of Spruce Creek near New Smyrna Beach) the floor of this valley generally remains emergent toward the north until the valley (a relict lagoon) and the present lagoon merge about 5 miles north of Flagler Beach in Flagler County. The emerged floor of this relict lagoon becomes an important part of the urban area of Daytona Beach 30 miles north of the north end of Indian River. A narrow relict barrier lies between this valley and the younger Mosquito Lagoon to seaward. The present lagoon also tends to become increasingly derelict toward the north until the Intra-Coastal Waterway finally has to resort to 10 miles of canal in the northeastern part of St. Johns County for lack of a natural connection between North River at the south and Pablo Creek at the north.

Superficially this increasing dereliction of lagoons to the north might suggest longshore tilting with uplift at the north. However this would seem a small possibility, since these former shorelines and lagoons converge toward the north and differential uplift increasing in that direction would be expected to produce a coastal prominence rather than a reentrant.

The Atlantic Coastal Ridge seems to be almost wholly a product of Pamlico (?) time when sea level was about 30 feet higher than it now is. Except for its southern extremity in the southern part of the Distal Zone of the Peninsula, it seems to have been the mainland shore of the Pamlico sea (see section of this report entitled “The Eastern Valley”).

The eastern slope of the Atlantic Coastal Ridge closely resembles the present submarine slope that is so uniform off-shore from oceanic beaches throughout the length of the Atlantic Coastal Plain. Such off-shore submarine slopes drop off seaward, steeply at first, and ever more gently with distance seaward, until they become sensibly flat at a depth of about 30 feet and a distance of some half mile to mile off-shore from the beach. In the case of the relict, Pamlico, off-shore profile that forms the eastern slope of the Atlantic Coastal Ridge the higher (landward) end of the profile is about 30 feet above present sea level. And in many places (as on the Edgewater and Ariel 7½ minute topographic maps) the straightness and spacing of contours on the subaerial Pamlico relict off-shore slope are practically identical with those of the depth curves on the present submarine slope off-shore from the present oceanic beach.
It is unusual for such an off-shore profile to pass through a changing sea level and emerge nearly intact. Ordinarily it would be masked by the topographic features made by a succession of younger shorelines which occupied its face during the progression of emergence. Quite commonly it would be buried beneath lagoonal sediment or a succession of beach ridges, but the Pamlico off-shore profile seems generally to have emerged rapidly without being masked by such later changes. In part this clean, undamaging emergence may result from the fact that regression of the sea from the Pamlico level seems to have been caused by a rapid onset of glaciation. It may also have been helped by the fact that along most of the Florida east coast it was an erosional shoreline rather than a prograding one. This can be seen in its discordance with earlier shore lines adjacent to landward. Most of these, expressed in relict beach ridges (Fig. 34), are truncated at angles by the shoreline erosion that cut the Pamlico relict off-shore scarp.

The Indian River ends abruptly at the north about a half mile north of the Volusia-Brevard county line. Directly east of this point is the southern end of a relict barrier or long spit that seems to have grown southward cutting off the Pamlico shore from the surf of the open sea. It lies on the landward side of the present Mosquito Lagoon. Perhaps this is the reason for the precipitate ending of the Indian River. Farther north lagoonal sediment accumulated at the toe of the Pamlico Scarp in the lee of this barrier. The southward drift of sand that built this barrier seems to have been deflected seaward by a contemporaneous phase of the coastal prominence that now forms False Cape and Cape Kennedy. This is suggested by a slight seaward turn of the southern, distal end of this old occluding barrier. This seaward shunting of the long-shore drift prevented farther southward extension of the barrier, and south of its distal end the Pamlico shore remained open to oceanic surf until the off-shore slope emerged in full thirty-foot stature. When sea level rose again during later, lesser transgressions including the Flandrian it found the southern part of this relict, Pamlico, off-shore profile low enough to inundate. Farther north, in the lee of the relict barrier, sediment had raised the floor of the old lagoon too high to be inundated by present sea level and it remains a dry valley.

Such occultation of the Pamlico off-shore slope in Pamlico time seems responsible for its better preservation in the lee of the relict barrier-spit north of the north end of the Indian River.

This part of the Atlantic Coastal Ridge is notably free of carbonates, and considering that it still exists essentially in the full stature it acquired when it was made in Pamlico time, it seems never to have had much carbonate content. The relict beach ridges of the Eastern Valley,
immediately landward to the west, have lost the greater part of their stature by solution of an originally dominant shell fraction. But the Atlantic Coastal Ridge is a relict beach ridge that surmounts the crest of the relict Pamlico offshore scarp, and both ridge and scarp seem to be preserved essentially in their original form without noticeable loss of stature.
Where the Atlantic Coastal Ridge is seen in section, as at Oslo Road south of Vero Beach or in the heavy mineral workings a few miles to the north, it shows no visible shell fraction. But the younger beach ridges on the present barrier contain large shell fractions, just as the older ones of the Eastern Valley seem to have had large shell fractions before the shell was dissolved out. This difference seems to be explained by the fact that the Pamlico Scarp was made by an erosional shoreline at the crest of a transgression. Biting into a mainland shore composed of the well-leached sands of the Eastern Valley the surf of the Pamlico sea could obtain large amounts of quartz sand from local mainland sources, and broken fragments of contemporaneous shell should have been a minor component of the beach sands. The rotten shell in the lower part of the section of the older beach ridges of the Eastern Valley would have been comminuted easily by the beating of the Pamlico surf, and reduced to very fine particle sizes would have been washed out of the coarser mineral fraction that remained behind to become the quartzose sand of the Pamlico Scarp along the mainland shores of the Indian River and the Atlantic Coastal Ridge atop the scarp.

By contrast prograding shorelines receive little nourishing sand from sources to landward. Most of it must be brought from the sea either by long shore drift or shoreward transport across the fore beach. In either event there would be a much better opportunity for the sand from such marine sources to have a larger shell fraction.

Apparently for this reason the Atlantic Coastal Ridge is wider and higher than the more common relict progradational beach ridges that have been extensively reduced by leaching of an appreciable shell component. Its resemblance to the older Ten Mile and Green Ridges farther landward suggests that these also were built along the erosional shores of transgressing seas marking the limits of the transgressions. Heretofore these older ridges seem to have been regarded as part of a Pamlico barrier chain. McNeill (1949) showed intracoastal water behind them on his map of Pleistocene shorelines. However in the section of this report entitled the “Southern End of the Eastern Valley” they are shown to lie at the eastern (seaward) edge of a degenerate, solution-flattened sequence of relict beach ridges which are narrower and of lesser stature (plate 4).

I suggest that such atypically high beach ridges are criteria of the crests of transgressions in regions where beach sands are wont to contain large percentages of shell fragments.

These considerations may be significant in attempting to explain the concentration of heavy minerals that has fostered prospecting for
titanium in relict beach deposits of Florida. In the Atlantic Coastal Ridge north of Vero Beach and in Trail Ridge near Starke concentrations of heavy minerals have been great enough to support mining operations. Both these places are in ridges atop erosional scarps cut by mainland shores of the open ocean. This common situation could have worked in the same way at both places to produce unusual concentrations of heavy minerals.

Apparently the ratio of heavy minerals to light minerals stays fairly constant as shell fragments replace the hydraulically equivalent quartz during the southward migration of sand by longshore drift from temperate conditions in the mineral source areas at the north in the Carolinas and Georgia to tropical, carbonate-producing areas at the south along the east coast of the Florida Peninsula.

In such extensive leaching as has been described here for the relict beach deposits of the southern part of the Eastern Valley the shell fragments that displaced the quartz grains are dissolved away and the heavy minerals become a larger fraction of the insoluble residue.

When a vigorously erosional, mainland, oceanic shore cuts into such a concentrate of heavy mineral and quartz sand, the heavy minerals may be further concentrated locally by the commonly recognized mechanisms of wave working and wind winnowing. Perhaps such a sequence of events explains the unusual deposits of heavy minerals near Vero Beach and Starke.

The dereliction and sedimentation of the lagoons north of the end of the Indian River at the Brevard-Volusia county boundary may have been assisted by the fact that there is a considerable group of relict beach ridges to landward of the Atlantic Coastal here and much of the area they occupy drains eastward into the lagoon complex. To the south on the other hand a late cycle of shoreline erosion seems to have cut away an ancestral False Cape, and the resulting, present, mainland shore from Buenaventura to the Brevard-Volusia county boundary was cut into the eastern flank of the St. Johns River Valley. Thus most of the drainage there is westward into the Saint Johns River and little fluvial sediment can enter the Indian River.

Ten Mile Ridge branches off the Atlantic Coastal Ridge a few miles north of Eau Gallie and slowly diverges from it toward the west until the two are some seven miles apart at the southern end of Ten Mile Ridge (five miles south of the St. Lucie-Indian River County boundary.) Ten Mile Ridge tends to lose stature southward, is flatter than the Atlantic Coastal Ridge, and, like the Atlantic Coastal Ridge north of Eau Gallie, considerably broader. Toward its southern end it becomes
indeterminate and the 7½ minute topographic maps show suggestions of its former significant existence east of the St. Johns River Marsh in St. Lucie County where it is now barely distinguishable. This part of it has been shown on the physiographic map (Pl. 1) with a dotted line.

Farther south in Martin County and the southern part of St. Lucie County Loxahatchee Slough and Allapattah marsh cover a large, flat, swampy area which are similar to the St. Johns River Marsh. They show a striped pattern of subparallel zones of more open water which are parallel with the present Atlantic Coast nearby and seem to be derelict relics of swales and beach ridges. Allapattah Marsh is paralleled on the east by Green Ridge, a narrow coast parallel ridge which very closely resembles Ten Mile Ridge whose southern end is some fifteen miles to the north of the northern end of Green Ridge. The two are about parallel, but not quite in line.

Thus Ten Mile Ridge, which is truncated by the present mainland shore of Indian River between Eau Gallie and Bonaventure in Brevard County, would be the southern extremity of the ancestral False Cape which, between Bonaventure and Turnbull seems to have been truncated by the erosion that cut the Pamlico scarp out of a mainland shore. The northern counterpart of Ten Mile Ridge might be found in certain relict beach ridges of Volusia County which converge southward and if projected would intersect the present mainland shore of Indian River at a focal point south of Titusville. Both these ridges and Ten Mile Ridge have crest elevations generally approximating 30 feet, suggesting that they all may have been coeval made during the same pre-Pamlico sea-level. Their pattern on the map suggests that they originally converged to make an early counterpart at the present False Cape. This was eroded back to the present mainland shore of the Indian River in the transgression which cut the Pamlico Scarp. In post-Pamlico time the same engendering structural feature (White, 1958) that located this ancestral False Cape caused it to be rebuilt in its present form but at a lower level.

These relict beach ridges north of the Brevard-Volusia County boundary are part of an extensive area of higher land which extends northward all the way to the south bank of the coast-perpendicular reach of the St. Johns River between Jacksonville and Maysville. This higher land is interrupted near its northern end by a three-mile-wide cross valley near the head of Durbin Creek at the St. Johns-Duval County boundary between the community of Bayard and the Ponce de Leon Raceway. Otherwise it is a continuous area of land higher than adjacent areas to the east. This higher land is bounded on the east by the scarp which, at the south, drops down to the valley which has been
described above as a northward continuation of Indian River. Farther north it drops down to the degenerate lagoons of Halifax, Matanzas and North Rivers. The western edge of this higher area is irregular, and poorly delineated here for lack of adequate topographic maps. It would seem to have been dissected by solution effected by waters flowing into the eastern tributaries of the St. Johns River.

This broad area of higher land takes the place of the Atlantic Coastal Ridge between Turnbull at the south and the coast-perpendicular reach of the St. Johns River at the north. Although for a 25 mile stretch between New Smyrna Beach and National Gardens in Volusia County the eastern scarp is surmounted by a ridge which reaches elevations approaching 60 feet at their maximum. In general this area of higher land lies east of the DeLand and Welaka Ridges which have been described below as outliers of the Central Highlands on the east side of the St. Johns River Reentrant.

In broad generalization it might be said that the Atlantic Coastal Ridge is a relict Pamlico beach ridge which was built at the crest of the Pamlico, offshore erosional scarp. It lies at the seaward edge of a pre-Pamlico plain from the general area of St. Lucie Inlet at the south to the terminal coast-perpendicular reach of the St. Johns River at the north.

It has been argued above in this report and more extensively by White (1958, p. 45 et. seq.) that False Cape and the genetically related Cape Kennedy have been located by exposure of a resistant mass of rock. This argument is further supported by the fact that the relict shore lines of the southern end of Merritts Island extend the trend of Ten Mile Ridge of the mainland despite the truncation of Ten Mile Ridge by the former oceanic shore that forms the west bank of the Indian River. For the relict beach ridges of Merritts Island to reestablish this identical trend after a period of erosion by the shore of the open ocean it would seem necessary that the same factor which caused the north end of Ten Mile Ridge to curve eastward should have been still effective to locate the Beach Ridges of Merritts Island in the same place with the same orientation. This factor would most plausibly have been a securely anchored bed rock feature rather than a matter of imbalance between sediment load and distributing agents.

The seaward deflection of the south end of the relict barrier which occulted the valley that extends northward from the north end of the Indian River Lagoon also suggests such a structural anchor in the same place. And as described in the part of this report entitled “The Central Highlands” a still older relict cape seems to locate the most eastward protrusion of the Central Highlands along this same cross-peninsular
axis. The Pamlico Scarp at the eastern foot of the Atlantic Coastal Ridge seems to stand alone in cutting directly across this axis. It may have been that no resistant rock was felt by the surf of the Pamlico sea at that elevation and longitude. Such inequities of distribution of resistant rocks could readily result from the fortuitous disposition of displaced strata along a fault. However, a more plausible explanation for the absence of a relict counterpart of False Cape in the Pamlico Scarp can be found in the fact that this is an erosional scarp. The classically described sequence of events in an erosional shoreline involves truncation of headlands and promontories and the the straightening of the coast line as erosion proceeds toward equilibrium.

THE EASTERN VALLEY

A persistent scarp lies along the eastern edge of the Osceola Plain from Indiantown at the south to the latitude of Sanford at the north. It appears again farther north extending along the eastern edge of the Crescent City Ridge and the Northern Highlands to the Georgia State boundary line at the St. Mary’s River. It may be present also in the intervening interval, along the eastern foot of the DeLand Ridge, but the poor topographic maps of that area that are available suggest that the foot of the DeLand Ridge is at a higher elevation than the characteristic 25 to 30 feet of the toe of this scarp. A few spot elevations on the maps suggest a 35 to 45 foot toe there but elevations reaching 70 feet are also present.

East of this scarp lies a broad flat valley which extends about 90 miles southward from Geneva Hill east of Sanford in Seminole County to the general latitude of Vero Beach in Indian River County. It reaches an elevation of about 30 feet at its head west of Vero Beach and drops to a general elevation of about 20 to 25 feet near Geneva Hill and Lake Harney. However, certain lower parts of the valley floor near the St. Johns River drop low enough to carry a five foot contour line. This lowland carries the St. Johns River through a large part of its northward course. And since it has elevations which are commonly somewhat less than the level of the Pamlico Sea most workers (Kofoed, 1962) have assumed that the St. Johns River came into existence consequent to a broad Pamlico lagoon that was enclosed by a barrier which now remains in relict form as the Atlantic Coastal Ridge.

I find it difficult to believe this because there are relics of beach ridges throughout much of the length and width of the Eastern Valley (the zone which others have called a Pamlico lagoon). The presence of these beach ridges assures that it was not a lagoon, but rather a regessional or progradational beach ridge plain.
The state of preservation of these beach ridges varies significantly along the length of the Eastern Valley. Toward the southern end in the vicinity of the headwaters of the St. Johns River they are imperceptible on the ground but on the 7½ minute topographic maps their relicts are visible through their control of the drainage pattern which has a strong coast-parallel trend. This is seen in many small swampy draws that are closely parallel with each other. On the aerial photographs, trends of the former beach ridges can frequently be seen in sub-parallel stripes of differing shades of darkness. Much of the southern part of this area has elevations of about 25 feet. These elevations have probably led to the assumption that it is a Pamlico surface.

There is evidence that this surface has been lowered from higher elevation. Throughout the part of this zone of relict beach ridges that is followed by the St. Johns River the maximal elevations remain in the approximate range of 25-30 feet. But in the latitude of Sanford, where the St. Johns River turns west to transverse part of the central highlands, there is an abrupt change in the maximal elevations of these same beach ridges. Although they continue northward with the same geographic trend, they rise to approximately twice the elevation. There is a dearth of adequate topographic maps here, but there are a number of spot elevations which exceed 70 feet. Both the aerial photographs and Army Map Service 1 to 250,000 scale maps show the presence of the beach ridges much more clearly here than south of Sanford.

Since these higher, more northerly ridges are a continuation of the zone of lower ones in the upper (southern) part of the St. Johns River Valley, it seems necessary to conclude that all were coeval at a time much earlier than Pamlico. Plate 4 is a map showing differences in elevation in the southern part of the Eastern Valley. The southern part of this map is generally a divide area. It lies south of the headwaters of the St. Johns River and contains no definitive streams. Before the St. Lucie Canal was dug this area probably drained by a slow drift of water through multiple swampy swales to the St. Lucie River and to the Everglades. This southern area of indifferent drainage shows on the map (plate 4) as a relict beach ridge plain dominated by subparallel ridges and swales. The local relief is nearly insensible on the ground but it shows on the topographic map where the thirty-foot contour happens to fall between the bottoms of the swales and the crests of the ridges, thus the thirty-foot contour shows there as a closely spaced system of subparallel lines oriented essentially parallel with the present Atlantic beach. In other parts of this southern area of indeterminate drainage the elevations of both bottoms of swales and crests of ridges lie within the same interval between two adjacent contours and their
presence is not shown by contours. In such places the inter-beach ridge swales are revealed by the many elongate, closely-spaced, subparallel swamps that dominate the pattern on the map.

The process by which these beach ridges were reduced in stature by solution of constituent shell fraction is described below in the discussion of the section exposed in the banks of South Canal near Vero Beach.

With increasing distance northward along the Eastern Valley the surface drainage becomes more definitive and the St. Johns River begins. Coextensively with this evolution the topographic pattern slowly changes. The relict beach ridges gradually lose identity, and the beach ridge plain that had the same thirty-foot elevation all the way across the southern end of the Eastern Valley grades into a broad shallow regional valley some 15 to 20 miles wide which slowly deepens northward until its thalweg drops below sea level and it becomes the estuary of the St. Johns River.

As this broad shallow valley deepens northward its thalweg acquires great meanders that have an amplitude of some 5 miles and a wavelength of about 15 miles (plate 4). Some of them have the essential form of ingrown meanders with long gentle slopes down the inside of the bend. Along the thalweg of this system of meanders lies the flood plain of the St. Johns River and its included lakes that are described below as a differentially filled estuary (figures 40 and 42).

These peculiarities of the St. Johns River Valley seem to reflect a geomorphic history much more complex than the usual assumption that it occupies a relict Pamlico lagoon. And the gradual dissolution of relict beach ridges with distance northward suggests that the route of the river was determined by consequence to the swales between relict beach ridges rather than consequence to a relict lagoon. The principal process of denudation seems to have been solution of limestone.

The extent to which calcareous beach ridges are lowered by solution can be estimated with some certainty by a study of the section exposed in the banks of South Canal near Vero Beach (Fig. 35). There, in a total vertical distance reduced by leaching to some 4 feet, one can see the shrunked counterpart of the entire section from the tops of relict beach ridges down to the unbroken shells that lay below the reach of the surf. At the top of the present, shrunken section is 1 to 1½ feet of fairly clean sand darkened with organic matter. Below this a finertextured, white, insoluble residue fills the pores of the sand. At a depth of some four feet rotten shells begin to appear. These are of genera that commonly inhabit shallow marine waters close to beaches. Pelecypods
Figure 35  South bank of South Canal showing section of relict beach ridge reduced in stature by solution
commonly found are Trachycardium, Laevicardium, Dosinia, and Anomia. Busycon is a common gastropod. These shells are rarely broken, which suggests that they lived in a zone too deep to be smashed by surf.

Figure 36 shows the surface of the ground looking westward in a view across the length of the derelict beach ridges along the south side of South Canal. The landscape is sensibly level and shows no suggestion of the original relief of the beach ridges. However, the aerial photograph of the same area (Fig. 37) shows the pattern of coast-parallel stripes characteristic of the original beach ridges. The pattern is preserved here by an obscure influence on natural drainage.
Figure 37  Air photo of area adjacent to South Canal in Indian River County about 3 miles southwest of Vero Beach
As seen in active beach ridges along the present shore of the ocean the unreduced counterpart of the section seen in the banks of South Canal would involve a vertical distance of 20-40 feet. Thus one can infer that the present section of the floor of the Eastern Valley as seen in the banks of South Central has suffered vertical shrinkage of some 15 to 35 feet. This is the right amount to account for the difference in elevation between the beach ridges of the northern and southern parts of the Eastern Valley. If 30 feet were added to the general maximal land level of 25 or 30 feet in the southern end of the valley, this would approximate the 70 foot elevation which seems to be maximal in the northern part of the Eastern Valley.

The solution that lowered the beach ridges of the upper St. Johns River (Eastern) Valley to an essentially reliefless plain may have been done in Pamlico time. The elevation of this plain is very close to the level of the Pamlico sea, and the Pamlico relict shore line scarp truncates the Eastern Valley on the east.

It seems instructive to compare the effects of solution in the upper St. Johns River Valley with its lesser effects in two other places where solution doesn’t seem to have been so complete. Apparently three progressive stages in the maturity of topographic reduction by solution can be seen in the Miami Ridge, the DeLand Ridge, and the southern part of the Eastern Valley.

The Miami Ridge is shown to be younger than the other two places by its location on the seaward side of the Pamlico shoreline scarp which separates them from it. It seems to have been an oolite shoal in the Pamlico sea. Apparently because of its greater youth the Miami Ridge has suffered less dissection or reduction by solution. In gross aspect its surface is the one it acquired from the sedimentation which built it. Thus it still has the form of an oolite shoal surmounted by relict mangrove islands and cut by the Transverse Glades which seem to be relicts of tidal channels that were coeval with the accretion of the oolite. The effects of solution are seen mostly in narrow, vertical, cylindrical sinks or “pipes” which perforate the surface to depths that range down to some 15 feet or so (Fig. 38). Although these pipes may be closely spaced in some places, the original depositional surface of the oolite between them is preserved essentially intact.

The effects of solution as seen in the walls of the pit that holds the town dump of DeLeon Springs in the DeLand Ridge differs from that seen in the Miami Ridge. Solution has perforated the limestone here also, but the perforations are broader and their shape is more of an inverse cone than a cylinder. The “divides” between them are “mature”, they are either rounded or sharp. The original surface of the
limestone has been wholly destroyed and its present surface is wholly made of the walls of small conical sinks. In figure 39 the upper surface of the undissolved limestone has been outlined with a dashed line to demark it from the overburden of insoluble residue. Dissection and reduction by solution seem to have gone farther here than in the Miami Ridge. However, the two situations are not wholly similar. The Miami Ridge is made of oolite and the rock at the DeLeon Springs site is a sandy shell bed but, aside from the possible influence of differences in the amount and nature of insoluble residue, the difference in karstic form seems to be one of difference in maturity.

In the southern part of the St. Johns River Valley, as seen in the section at South Canal described above, this same process seems to have
matured to a stage in which the sinks have enlarged to the maximal possible extent by completely consuming the septa between them. Solution seems to have been arrested at a maximally lowered water table that could not fall lower than the contemporaneous Pamlico level of sea. No evidence of perforation survives and the only evidence of solution is insoluble residue arranged in horizontal layers that resemble pedogenic horizons (see figure 35).

These three instances of dissection and lowering of the surface mark three different stages in the maturing of denudation by solution

Figure 39  Irregular contact between limestone and insoluble residue overlying it in wall of pit used by De Leon Springs as a town dump
which was effected by water percolating downward rather than seeping or flowing in an essentially horizontal direction. The solution took place wholly above the water table in the zone of aeration. The solution process seems to have been completely stopped where the surface of the limestone had been lowered to the water table. This is a strong argument in favor of the development of caverns wholly within the vadose zone as espoused by Swinnerton (1932) and others. Complementarily it casts doubt on the validity of the lately more popular two-cycle theory of cave development (Davis 1930), and even the idea (Davies 1960 and others) which suggests that caverns are formed by solution in the upper part of the phreatic zone just below the water table.

THE ST. JOHNS RIVER LAKE CHAIN

The St. Johns River is the longest river of the Florida Peninsula. It heads at Florida Highway 60 about 20 miles due west of Vero Beach with the heads of the streams which flow into Blue Cypress Lake, and extends to Mayport about 200 miles to the north. For some 60 miles at the north it is estuarine and throughout its remaining headward part it occupies a broad swampy valley which has very little fall and includes a dozen-odd large lakes.

These lakes differ from most of those found farther inland in that every one is elongate in the direction the river flows through it. This is true regardless of the orientation of the lake. No matter what turns the river takes if it passes through a lake it threads the lake from end to end along its longest axis. Moreover, some of the lakes through which the river passes are “L” shaped and in those cases the river enters the lake at the distal end of one leg of the “L” and leaves it via an outlet at the distal end of the other leg.

All this suggests that the lakes threaded by the river are remnants of a once continuous body of standing water which has been filled in by sediment and vegetal accumulation in the reaches between lakes. This former estuary has been differentially filled with sediment in its upper reaches to make the present flat, swampy flood plain, while the unfilled places remain as the chain of lakes in the more headward reaches of the river and as the presently remaining estuary farther down stream to the north.

At the southern end of the St. Johns River Lake Chain, Blue Cypress Lake has two parallel streams flowing into its southern end and is elongate in a north-south direction. Although it is not directly
connected with the St. Johns River by any natural open channel and has no natural outlet stream, the drift of swamp water seems to have been toward the head of the St. Johns River about 12 miles to the north, for the topography falls off gradually in that direction. Immediately down stream from the head of the St. Johns River is Lake Helen Blazes elongate in a north-south direction and located midway of a north-south reach of the St. Johns River that is 9 miles long. This north-south reach of the river ends at the head of Sawgrass Lake. There the river turns eastward and threads the length of this similarly east-west oriented lake. Turning again northward the river shortly enters the north-south elongate Lake Washington, the north end of which it leaves in a westerly direction, but the lake also makes such a westerly turn from the end of which the river leaves it. Farther down stream the river turns northeastward and enters the northeast-southwest elongate Lake Winder, whence it continues to flow northeastward until it reaches the northeast-southwest oriented Lake Poinsett which it enters at the southeast end and leaves at the northwest end, where it immediately turns northward. Thence the river flows generally in a direction a little west of north for some 16 miles until it reaches the similarly elongate Lake Harney. It leaves Lake Harney on the same trend. At the northern edge of the City of Sanford the river enters Lake Monroe on a course which is in line with the south side of the lake. It threads the lake along its longest axis. The flow of the river splits near DeLand above Lakes Woodruff and Dexter but one component of it threads the length of both of these lakes. The western end of Lake Dexter is "L" shaped turning a right angle from west to north in a down stream direction, and the river leaves the lake at the distal (north) end of this "L". Continuing northward for about six miles the river enters the large Lake George which, although broad, is slightly elongate in a north-south direction. It leaves Lake George still flowing in the same northerly direction, a trend which it holds until it turns eastward to round the northern end of the DeLand Ridge and leave the great reentrant of the Eastern Valley to pass the City of Palatka in frankly estuarine condition. From there to its mouth at Mayport some 15 miles east of Jacksonville, the river is a broad winding estuary whose width is never much in excess of the normal width of the lakes farther upstream which have just been described.

In support of the suggestion that these lakes along the St. Johns River are relics of a former estuary rather than depressions made by solution of limestone after the Flood Plain was formed, it may be noted that the large lakes farther inland, whose form seems more directly associated with solution of limestone, are different in shape, grouping, and orientation in relation to drainage. Such inland karst lakes tend to
appear in groups or clusters on the map rather than in lineal chains like those along the St. Johns River. Thus in the Osceola Plain some twenty large lakes occur in a group covering a large fraction of an area 40 to 30 miles square. This group includes such lakes as Arbuckle, Weohyakapka, Rosalie, Kissimmee, Marian, Jackson, Hatchineha, Cypress, Russell, Tohopekaliga, East Tohopekaliga, Alligator, Gentry, Hart, etc. A similar roughly equidimensional group of large solution-basin lakes occurs in the southern part of the Central Valley. It includes such lakes as Apopka, Harris, Griffin, Dora, Eustis, Yale and Weir.

Again it will be noted that these solution-basin lakes have outlets, and occasionally inlets, which are randomly oriented in respect to their length. Thus the elongate Lake Panasoffkee has inlets at each end and an outlet in the center of one side. Lake Harris drains from a cove on its side into an adjacent end of Lake Eustis which in turn has an outlet in the middle of its northwestern side that debouches into the middle of the eastern side of Lake Griffin (Fig. 40). These drainage patterns are so different from the “straight-through” plan of the St. Johns River Lake Chain that they suggest a different origin in which the pattern of drainage has been determined by the lakes rather than the lakes being remnants of a formerly continuous estuary.

Still further support for the idea that the lakes along the St. Johns River are remnants of a former estuary may be had from the aerial photographs of Brevard County. Figure 41 shows aerial photographs of the reach of the St. Johns River that includes Lake Helen Blazes, Sawgrass Lake, Lake Washington, Lake Winder and Lake Poinsett. Encompassing all these lakes can be seen a fluvial plain, the boundaries of which maintain a general parallelism with both the direction of elongation of the lakes and the included reaches of the river. The fluvial plain makes pronounced bends, but both the direction of flow of the river and the direction of elongation of the lakes make similar bends, maintaining essential parallelism with the reach of the fluvial plain that includes them.

ST. JOHNS RIVER OFFSET

Between Lake Harney and Lake Monroe in the latitude of Sanford the St. Johns River jogs westward and its valley changes character. Between Sanford and Palatka it occupies a narrower valley which has been shown on the map as the “Saint Johns River Offset” because, although coast parallel like the other parts of the river’s valley it is offset to the west from the part of the valley south of Lake Harney and
Figure 40 Drainage of Lakes Griffin, Eustis, Harris, Dora and Apopka
Figure 41  Air Photos of part of the St. Johns River Lake Chain in Brevard County, Florida
north of Palatka. The offset part of the St. Johns River Valley seem to have a different history than its other parts.

Referring to the similar bends near Sanford in the several lines of lakes which are discussed in the section of this report entitled “Central Highlands”, under the heading “Genetic Relation between Lakes, Karst and Relict shoreline features in Deland and Crescent City Ridges, Geneva Hill, and the Osceola Plain”, it is notable that the St. Johns River jogs to the westward a few miles north of these bends. This westward jog has a counterpart immediately above Palatka where the river jogs back the same distance to the east to follow the trend of the more easterly line of lakes for some eight miles before making another eastward jog to another coast-parallel course that takes it northward to Jacksonville where it makes a third jog eastward to its mouth at Mayport.

Obviously some complexity of geomorphic history is necessary thus to carry the St. Johns River out of a headwater consequent course upstream from Lake Harney on a low beach ridge plain of some presently 25 feet elevation into a downstream reach from Sanford to Palatka which had been located by shore features of a much earlier and higher stand of the sea. Probably this offset part of the St. Johns River Valley was first cut during some low stand of sea level in late Tertiary or early Pleistocene time. Apparently this reduction was accomplished mostly by solution that began under the topographic control of water movement by coast-parallel Atlantic shoreline features such as relict lagoons or swales between beach ridges. However it has been suggested by Pirkle (1969) that solution was helped by structural attributes of the underlying rocks that presented Eocene limestone near to the surface in a coast-parallel zone. Since linear Atlantic shoreline features seem to have dominated virtually all the surface of this part of Florida as it emerged from the sea, it is quite possible that these two different controlling influences worked in sequence toward the same result.

Pirkle (1969) thought that this offset part of the St. Johns River Valley was older than the headwater reaches upstream from Sanford. He notes that Brooks (1966, 1968) regards the Caloosahatchee (Nashua) deposits here as old estuarine fill in an ancestral river valley. Since the present stream valleys are incised in these deposits, it follows that this part of the St. Johns River Valley has a long and repetitive history. At any rate it is suggested that, during some low stand of sea-level, the offset part of the St. Johns River Valley captured the present headwaters east of Sanford. When sea-level again rose this valley was inundated to become an estuary. Upon retreat of the inundating sea, the St. Johns River became an integrated stream
flowing along the relict beach ridge plain to Lake Harney and then jogging westward, deflected by solution-capture, to enter the Sanford-Palatka offset and follow it thru the area of greater solution along the course of the former estuary. At Palatka, it apparently followed the old valley eastward, out of the reentrant, back again into the same, lower, beach-ridge plain, following it northward until it was deflected seaward by the delta of the sediment-bearing St. Mary’s River at Jacksonville. The older, offset part of this valley, incised in the higher land, probably was cut by an entrenched tributary of the Oklawaha River, for the Oklawaha River flowed out of still higher land to the west and therefore should antedate the St. Johns River.

Other places which were peculiarly vulnerable to solution seem also to have been cut down during periods of low sea level, dissection, and karst development. Perhaps the Wekiva plain north of the Orlando Ridge was cut down to sub-Pamlico elevation at that time; also the lower valley of the Oklawaha and low areas tributary to the present St. Johns River that lie east of the offset such as those that hold Crescent Lake and Lake Disston.

When sea-level rose all these lowered surfaces were inundated to become estuaries or sounds. Sediments deposited in them then probably became part of the present St. Johns River flood plain, Wekiva plain, lower Oklawaha flood plain, etc., after regression of the sea caused them to emerge. However, the history of eustatic changes is obscure. And quite plausibly most of the present lakes of the St. Johns River chain are remnants of an estuarine condition caused by sea level rise to Silver Bluff or present height. The sediments which separate these lakes may have been deposited during several different times of high sea-level when the St. Johns River recurrently became estuarine.

**HISTORY OF THE ECONLOCKHATCHEE RIVER**

The Econlockhatchee River rises in the northern part of the Osceola Plain and flows northward in a coast-parallel course to a point some two miles east of Oviedo where it makes an abrupt right-angled turn to the east, separating Geneva Hill to the north from the Osceola Plain to the south. It continues this easterly lower course to confluence with the St. Johns River by flowing into the western side of Lake Harney.

There would be little of note about this eastward turn of the Econlockhatchee River were it not for the fact that it leaves a broad, low, straight, flat-floored valley to turn into a narrower steeper walled
one which traverses much higher ground. The gentle northward slope of the valley floor of the upper, north-flowing part of the Econlockhatchee River Valley continues on the same northward slope to the shore of Lake Jessup, but the Econlockhatchee River turns abruptly out of it to traverse the narrow valley which separates Geneva Hill from the northern end of the Osceola Plain.

In attempting to explain this erratic and circuitous course of the lower Econlockhatchee River the process just described suggests itself. Possibly in Pamlico time, the Econlockhatchee debouched into a sound or estuary which flooded the St. Johns River Valley including the vicinity of the present Lake Jessup. The elevation of Pamlico sea-level is the same (30 feet) as the divide between the Econlockhatchee River and Lake Jessup at the point of tangency of the river’s eastward bend. Thus it would seem probable that the mouth of the river was there in Pamlico time. During the Pamlico stand of the sea, insoluble sediments may have been deposited at the mouth of the river and after sea-level dropped below the Pamlico level, subterranean leakage on the east flank of the river opened a lower route to the east via the present lower Econlockhatchee Valley.

In support of the idea of a late origin for the lower east-flowing part of the Econlockhatchee River it seems significant that this is the only river which passes through the Caloosahatchee formation in a narrow cleft. All the other streams pass between remnants of the Caloosahatchee formation in valleys which form broad interruptions of the continuity of the Caloosahatchee outcrop zone. This suggests that the other valleys essentially acquired their present form before Pamlico inundation and sedimentation while the lower Econlockhatchee Valley was cut at a later time after withdrawal of the Pamlico sea.

SOUTHERN END OF THE EASTERN VALLEY

Toward the headwaters of the St. Johns River Valley the zone east of the western bounding scarp begins to lose the valley-like character it has farther north. The manner in which the head of the St. Johns River becomes a broad marsh of indeterminate drainage has been described above. Beyond its recognizable headwaters a broad area is significantly termed “St. Johns River Marsh”.

It is notable that Ten Mile Ridge also loses stature (and ultimately identity as well) in a southerly direction and its degeneration is closely parallel with that of the St. Johns River Valley which it here bounds on the east. Actually the last derelict remnant of Ten Mile Ridge at its
southern end lies immediately east of the southern part of the St. Johns River Marsh.

From the head of the St. Johns River southward the land surface has little slope. There is little more than five feet of local relief throughout the area bounded by the headwaters of the St. Johns River at the north, the scarp on the west, the St. Lucie Canal on the south and Ten Mile and Green Ridges on the east. The flatness of this part of Florida is second only to the Everglades and makes a transition zone between the country of more relief to the north and the almost reliefless plains of the southern end of the peninsula exemplified by the Everglades into which it leads. The surface of the entire area has elevations close to 25 or 30 feet.

A very poorly drained area known as Allapatah Flats lies to the west of Green Ridge in much the same way that the St. Johns River Marsh lies west of Ten Mile Ridge. Possibly the presence of these ridges on such flat and low terrain has helped to impound water behind them to landward.

The pattern of subparallel, slough-like, shallow lakes and marshes of Allapatah Flats suggests a group of progradational beach ridges, but the relief is so little here that they must have lost nearly all topographic expression — probably by solution of sands which were dominantly shell.

Ten Mile Creek, the headwaters of the North Fork of the St. Lucie River, drains the northern part of Allapatah Flats around the northern end of Green Ridge, and the southern end of Green Ridge seems to have influenced the location of the bend in the course of the St. Lucie Canal.

Between the Atlantic Coastal Ridge on the east, and Ten Mile and Green Ridges on the west is a shallow valley drained by Sebastian, Turkey, Grove and Elbow Creeks in its northern part, and by the St. Lucie River in its southern part.

THE ST. MARYS MEANDER PLAIN

At Jacksonville the St. Johns River turns eastward to the sea and immediately north of this terminal coast-perpendicular reach the character of the terrain changes. To the south, as discussed above, the dominant geomorphic factors have been marine but to the north of this rather sharp natural boundary, the dominant factor seems to have been the meandering of a plexus of muddy sediment laden streams. Within the confines of the Florida State Boundary Line these are the Nassau and St. Marys Rivers and their network of tortuous abandoned chan-
nels, tributaries and distributaries. In a broader more regional way the St. Marys Meander plain is the southern end of a large section of the coast known as the Sea Islands which extends from north bank of the St. Johns River to the Santee River of South Carolina. The name “Sea Islands” derives from a barrier chain which is separated from the mainland by a plexus of meandering tidal creeks which seem to result from a mixture of fluvial and tidal sedimentation in derelict lagoons or coast-parallel marshes between beach ridges. These characteristic traits of the Sea Islands persist true to form through the more seaward parts of the St. Marys Plain in Florida. Thus Amelia Island and Big and Little Talbot Islands are typical sea islands and the plexus of meandering tidal creeks which connect the St. Marys, Nassau and St. Johns Rivers in a zone immediately landward of these islands is typical of the degenerate sediment-dominated lagoons of the entire Sea Island coastal section to the north.

Farther inland there is some 25 feet of local relief which seems to have resulted from incision of the more active streams. This incision attended sea level drop from higher levels. However, despite this entrenchment of the broad flood plains of the present meandering streams it would appear that a similar fluvial environment prevailed in Pamlico time, for there are many older meandering channels at the Pamlico level. It would seem plausible that these large rivers coming from the mainland might be able to behave repetitively in the same senile fashion at the crest of any marine inundation, as they seem to be doing now after the crest of the Flandrian transgression.

The terminal, coast-perpendicular reach of the St. Johns River shows some of the characteristics of the streams of the Sea Island region and it may well be that it was this strong fluvial environment which ended the 200 mile long north-flowing St. Johns River and finally turned it seaward caught in an agrading plexus of meandering sediment laden streams.

THE CENTRAL HIGHLANDS

The Central Highlands comprise a number of rather localized areas of higher ground such as the Lake Wales, Brooksville, Winterhaven and Orlando ridges which rise above much broader general uplands of considerably less elevation and usually much less local relief such as the Polk, Lake, Sumter and Marion uplands. The general area also encloses large lowlands — the Central and Western Valleys and the valley occupied by the St. Johns River offset described above. For the most part the higher areas are elongate and ridge-like, especially the
Lake Wales Ridge which is only a few miles wide but more than 100 miles long. Many of the others, are more or less equidimensional in general but the arrangement of higher places within their boundaries shows strong lineation parallel with the Atlantic Coast. The lineation of these "Supra-ridge" higher places is best seen on the topographic map or in some instances on aerial photographs. The great valleys also share the same general elongation parallel with the length at the peninsula.

The larger areas of higher ground are the Lake Wales, Brooksville, Lakeland, Winter Haven, Lake Hendry, Mount Dora and DeLand Ridges, the Fairfield Hills and the Ocala Hills. The intervening areas of lower ground, the several broad uplands and great valleys enumerated in the paragraph above, seem for the most part to have been reduced from a once ubiquitous highland. Apparently parts of this still remain to form the present ridges. These ridges seem to have been preserved by some attribute obtained from linear coastal features which must have been formed during times when the several parts of the highland were undissected surfaces at sea level.

A glance at the physiographic map of Florida (or preferably a topographic map on which the different contours have been set off by different colors) reveals the fact that all the major ridges of the central zone of the peninsula owe their general trend to relict coastal features for they are all subparallel with the present Atlantic coast.

This is a surprising discovery in a region of several hundred feet of local relief that is underlain by a variety of different rocks. One would be more inclined to expect that the higher areas would be upheld by underlying rocks that offered greater resistance to denudation than did more vulnerable rocks that underlay the lowlands. In a broad way, this is true, for the insoluble Miocene beds generally cap the larger ridges, such as the Brooksville and Lake Wales Ridges, while the soluble Eocene rocks have been dissolved down to make the lowlands. But these underlying Tertiary formations are gently-dipping strata of broad regional expanse. And the ridges that are made of their higher remnants are all long, narrow, and elongate in the common orientation of the relict beach ridges built along the eastern shore of the peninsula during the many migrations of shoreline that accompanied changes of sea level. Furthermore on aerial photographs these elongate ridges show the characteristic parallel stripes of relict beach ridges.

That the present ridges have been thus protected by such relict coastal features from the reduction which lowered the intervening valley floors is aptly shown by the fact that they are all subparallel and that smaller remnants of the original highland surface fall neatly into line with the longer ones to suggest the subparallel trends of relict
Atlantic coastal beach ridges, barrier chains or lagoons. All are oriented similarly to present Atlantic shores on the east coast of the peninsula.

That the present ridges (and for the most part the lower lands between them) have never been beneath the sea since these lowlands were reduced from the former universal highland is also well demonstrated. The evidence being the many long, straight, subparallel relict Atlantic beach ridges that extend continuously from locations on unreduced remnants of the highland through drops of elevation of the best part of 100 feet down to the lowland floors between remnants (White, 1958, p. 35 et. seg.).

This great range of elevation along the length of the same beach ridges supports the conclusion that the sea has not been over this area since the beach ridges were formed on the original integrate highland surface before its dissection, for had there been such a later marine transgression, the lower sections of these relict beach ridges would have been destroyed or masked by later coastal features which would have had much different orientations since they would have been made by shorelines that curved around the contour of islands formed by inundation of the lower slopes of the present remnants of the former widespread highland. In a few exceptionally low places this may have happened, McNeill (1949, p. 101 and plate 24) writes of seeing such relict shorelines on aerial photographs.

The preservation of the same relict beach ridges through such a wide range of elevation further shows that the highland surface has been differentially reduced by solution-subsidence for had surface erosion reduced the surface, the surficial beach ridges would have been destroyed in the process.

Again since many of these beach ridges extend from elevations commensurate with the highest marine terrace at 150 feet above present sea level (Okefenokee) down to elevations lower than the Wicomico sea level at 100 feet elevation, it becomes apparent that much of the solution which dissected the once integrate highland and caused the beach ridges to sag differentially along their length must have taken place since Wicomico time else Wicomico inundation would have destroyed the relict beach ridges which had sagged to levels lower than Wicomico sea level at 100 feet above present sea level. Thus it would seem probable that Wicomico terrace features should not be found through much of the Central Highland regions even though the range of present elevations includes figures both higher and lower than Wicomico sea level.
ORIGIN OF LINES OF LAKES IN RIDGES OF THE CENTRAL HIGHLANDS

The rectilinear grouping of lakes parallel with subsiding beach ridges throws light on the origin of these lakes and at the same time supports the above argument that Wicomico and younger marine shoreline features should not be found in much of the central highland.

The basins occupied by these lakes must have been located by the relict beach ridges, because they are arranged in lines along the length of the ridges. Therefore, the lakes of these lines:

1) postdate the sea transgression which produced the relict beach ridges.

2) would seem to be first generation sinks rather than second or multiple generation Karst reactivated after marine submergence and reemergence, for second generation sinks would not plausibly be related in pattern to beach ridges which postdate their original development.

3) would not depend for their location on bed rock conditions (structural, lithologic, stratigraphic, etc.) except to the extent that such conditions were necessary to present soluble rocks at a suitable depth beneath the beach ridges.

Actually, the Wicomico shoreline seems to be the most important dividing line between different types of terrain in the Florida Peninsula. It will be noted (see sections of this report entitled "The DeSoto Plain" and "The Polk Upland") that the scarp which separates the Polk Upland from the lower DeSoto Plain for some 60 miles has a toe of 75 to 85 feet elevation and a crest which is usually slightly over 100 feet, a plausible relation between elevations on and off shore along a relatively low-energy, relict, oceanic shoreline whose sea level stood at about 100 feet elevation. This scarp separates the very flat terrain of the lower DeSoto Plain from the much more irregular landscape of the higher Polk Upland. This contrasting topography above and below the Wicomico shoreline is seen very clearly in the vicinity of the southern end of the Lake Wales Ridge. The ridge itself rises with abrupt local relief to heights differentially greater than the 100 foot elevation of the Wicomico sea level. Around it in dramatic contrast stretches the flat, reliefless terrain of the DeSoto Plain, the Okeechobee Plain, the Osceola Plain and the Caloosahatchee Incline.

Again the great zone of beach ridges of the Osceola Plain, Geneva Hill and DeLand Ridge begins at its western edge with maximum elevations close to 100 feet, suggesting an origin as a Wicomico shore.
Also the Brooksville Ridge is largely surrounded by flat lands with elevations between 75 to 100 feet at the foot of the Ridge.

It is notable that in all these instances the land above the Wicomico shore is significantly rougher and more dissected, frequently very much rougher, as in the Lake Wales and Brooksville Ridges and much of the Northern Highlands. Much land surface of the central peninsula stands at elevations of 60 to 70 feet. It is probable that much of this represents former sea bottom offshore from the Wicomico shoreline. In general, present offshore depths in the Atlantic ocean and the Gulf of Mexico are commensurate with the difference in elevation between these relict submarine surfaces and the present 100 foot contour which approximates the Wicomico sea level.

Surfaces older than Wicomico, i.e. — surfaces that were not inundated by the Wicomico sea can be recognized by their dissected nature or rather by the maturity of their Karst. While surfaces which emerged at elevations lower than Wicomico sea level, i.e. surfaces which once were submerged beneath the Wicomico sea can usually be recognized by their smoother topography and less mature Karst.

The ridges of the southern part of the Central Highlands consist for the most part of a paradoxical fretwork of divides between lakes that occupy the bottoms of rather deep, steep walled basins. Possibly they are explicable by the apparent genetic relation between lakes and sand-coated ridges as discussed by White (1958, p. 73 and 75). There seem to be all gradations of maturity of the process. Beginning with a newly uplifted, beach-ridge-coated plain, apparently solution begins to take place beneath the sands of the beach ridges or more plausibly in the swales between them and as a result lakes and swampy depressions begin to develop. An example of an area which seems to be in this stage of development may be seen in the strongly oriented lakes and swampy swales which mark the trend of swales between relict beach ridges southeast of Orlando on the Osceola Plain. They can be seen on the following 7½ minute topographic maps Narcoossee N.W., Narcoossee, Narcoossee S.E., Ashton, Holopaw and Holopaw S.E. A prominent pattern of beach-ridge-controlled topography and drainage is expressed on these maps but the local relief is rather small amounting to little more than ten feet at the most. Elevations are generally close to 75 feet. Despite this small vertical range of topographic elevation, solution seems to have produced a number of lakes whose shape, location and orientation show a strong control by the beach ridge pattern. They include lakes Mary Jane, Preston, Myrtle, Joel, Conlin and Cat which seem to be controlled by two prominent swales between relict beach ridges which extend for thirty miles across the several topographic maps enumerated above.
It would seem possible that this low-relief landscape of the Osceola Plain is a fair counterpart of the southern ridges of the Central Highlands during an earlier stage of their development. Because the ridges of the Central Highlands are higher and have been subaerially exposed for a longer time there would have been greater solution of the underlying limestones. This would have deepened the lake basins and left the interlake divides standing up in the intersecting fretwork of ridges which comprise much of the Lake Wales, Winterhaven and Lakeland Ridges. The parallel lines of lakes on the DeLand and related ridges may be similar in origin.

Swales between relict beach ridges seem to have prolonged influence on the development of Karst. This may be because they locate the original consequent drainage. Thus, when sea level drops and water tables fall, these swales become places where greater volumes of surface water are available for downward movement into the ground. Such arterial downward movement of water would initiate sinks and once formed the sinks would constantly be enlarged by the water that passed through them and thus become increasingly dominant in controlling the passage of surface water to the subsurface aquifer.

Possible such a waxing process accounts for certain enigmatic peculiarities of the Lake Wales Ridge and similar ridges to the west of it. These ridges and the valleys between them tend to be long, straight and parallel. Their parallelism is identical with that of relict Atlantic shoreline features—beach ridges, lagoons, and barriers. They are generally surfaced with a veneer of old beach sand which overlies the coarse fluvial sediments of the Citronelle formation which in turn is usually underlain by limestone.

On the aerial photographs these ridges generally show a pattern of relict beach ridges in parallel stripes. This striped pattern seems to control the location of the lines of lakes that follow the axes of the ridges. Usually these lakes occupy basins that pock the ridges along their axes and reduce them to a skeletal fretwork of narrow divides between broad basins. In many instances these divides are remnants of the Citronelle formation.

It seems at least within the realm of possibility that the lakes which now occupy these aligned basis were originally similar to the small shallow swale-engendered lakes of the Osceola Plain southeast of Orlando. And the pattern of water movement from surface to subsurface which they then engendered has persisted to mature into the present lines of lake basins that pock the Lake Wales Ridge and the other ridges of the Central Highlands to the west of Lake Wales Ridge.
As an alternative to such a hypothesis there seems also a good possibility that topographic inversion is involved in the origin of the ridges and valleys of the Central Highlands. These ridges have anomalous characteristics that are difficult to explain by the usual geomorphic processes of simple deposition, erosion or solution. Thus the Lake Wales Ridge and certain parallel associated ridges to the west are largely made of the coarse, clay-bound sands and gravels of the Citronelle formation or Hawthorn Delta. They are remanents of a blanket of fluvial sediment that formerly covered a much larger area (Vernon 1951, Bishop 1956). The large fraction of quartz cobbles and binding kaolinite assure that these deposits were made by streams that flowed out of a continental old land to the northwest; probably the Piedmont of Georgia. However, the pattern of distribution of the present remnants of this blanket of fluvial sediment suggests that they were preserved through some influence of relict Atlantic coastal features. The Citronelle gravels are preserved mostly as the essential insoluble stuff of which the larger ridges of the Central Highlands are made. But these ridges, such as the Lake Wales Ridge, the Lakeland Ridge and the Brooksville Ridge have the orientation of relict Atlantic Coastal beach ridges, barriers and lagoons. They are parallel with present and relict Atlantic Coastal beaches. And, like more easily recognized relics of Atlantic beaches, barriers and lagoons, these larger ridges of the Central Highlands are long, narrow, straight and parallel.

In trying to find a plausible way to explain this anomalous pattern of distribution of these present remnants of the Citronelle fluvial gravels, a hypothesis that involves topographic inversion by differential solution present itself. The pre-Citronelle landscape may have been much like the present one. Pirkle, Yoho and Allen (1965) found extensive relief in the limestone surface buried beneath the Citronelle fluvial blanket. They state that it contained sinks and valleys. In emerging from the sea those limestones may well have acquired overlying littoral features with coast-parallel trends which would have engendered a coast-parallel drainage similar to the present one. The present Withlacoochee, Oklawaha, St. Johns, Econlockhatchee, Kissimmee and Peace Rivers have such coast-parallel valleys. Plausibly a pre-Citronelle drainage developed in the same way along similar coast parallel lines during emergence of the lower Miocene sediments. And over such coast-parallel valleys the Citronelle fluvial gravel was laid down. It was graded into a smooth surface of fluvial aggradation on top but it had great differences in thickness; thin over the buried uplands and much thicker where it filled the valleys.

With uplift, or lowering of sea level, this landscape began to feel the effects of solution in the limestones that lay buried beneath the
blanket of Citronelle gravel. These effects of solution were greatest over the buried uplands where the upper surface of the limestone was covered by only a small thickness of Citronelle Gravel. Here the new generation of broad valleys was made by dissolving out the limestone of the old buried, uplands. But there was less solution and less subsidence where thicker masses of Citronelle, clay-bound gravel and sand filled the old valleys. Hence the Citronelle fill of these old valleys became the present residual ridges. And these ridges preserve many of the gross morphologic features of the original pre-Citronelle, Atlantic coastal features such as straightness, narrowness, and parallelism with the present Atlantic coast.

In some instances insoluble components of the Alachua and Bone Valley formations may have substituted for the Citronelle formation in preserving ridges against reduction by solution. One of the two more popular theories that seek to explain the peculiarities of the Alachua and Bone Valley formations considers them to be insoluble residue of leached Miocene sediments. (Late proponents of this theory are Ketner and McGreevy, 1959; and Carr and Alverson, 1959.) Thus the position of these two enigmatic formations as major parts of the masses that form the more westerly of these great parallel ridges of the Central Highlands lends some credence to the thought that all these ridges owe their present topographic stature above intervening lowlands to the solution of more abundant carbonates beneath the present lowlands and the survival of more abundant insoluble matter in the intervening ridges.

Such features as the long lines of lakes that are coextensive with the length of the present ridges are less easily explained, but they may occupy places where the original limestone floors of the Citronelle-filled valleys were somewhat higher and the fill of Citronelle sediment was correspondingly thinner. Solution of these buried paleo-topographic highs would allow the thinner overburden of Citronelle sediment to sag to lower present surface elevations than it did where the Citronelle sedimentary fill was thicker over the deeper parts of the old, pre-Citronelle valleys.

As noted above in the part of this report entitled “Influence of Structural Lineaments on Solution in the Distal Zone of the Peninsula,” there are two prominent sets of structural lineaments in the Florida peninsula, one of which is essentially parallel with the relict Atlantic beach ridges. This coincidence of orientation between two different kinds of geomorphic features lends the possibility that these long lines of lakes, and possibly the great peninsular ridges in which they occur, are the result of solution controlled by ground water
movement through the fractures that produce the coast-parallel set of lineaments.

There is little doubt that these lineaments have influenced solution in the limestones since they are manifest wholly through the topographic sagging that has resulted from it. But there seems little probability that they were involved in locating either the long lines of lakes or the great peninsular ridges in which these lines of lakes occur. Where the structural lineaments show themselves, both are seen more or less equally, manifesting themselves through their rectilinear control of stream courses, elongate swamps and included lines of shallow lakes. If buried relict features of this sort had been influential in determining the trends of the great peninsular ridges, I would think that both sets of lineaments would have been involved there also. But since the great ridges all have the same coast-parallel trend, I assume that it was derived from relict shoreline features rather than from coast-parallel structural lineaments. Cross-peninsular ridges are notably absent.

THE LAKE WALES RIDGE

The most easterly of the great ridges of the Central Highlands is the Lake Wales Ridge. This long narrow ridge is the most prominent topographic feature of the Florida peninsula and is the severed distal remnant of a much longer ridge which seems once to have included the present Trail Ridge farther north in northeastern Florida and southeastern Georgia. (White 1958, p. 39. See also earlier discussion by MacNeil 1950, p. 102).

THE INTRARIDGE VALLEY

Along its length from Lake Placid near its southern end to the north shore of Lake Livingston near the city of Frostproof the Lake Wales Ridge is split by an axial valley which is here referred to as the "Intraridge Valley". It is a rather steep-walled lowland which usually maintains a width of some two miles with occasional stricutures and one short interruption of its continuity (immediately east of the city of Avon Park). It contains the more southerly part of the line of lakes described below. The valley floor between these lakes is largely covered with peat and peaty muck according to the Polk County soils map. This Intraridge Valley seems to result from the more complete reduction of a beach-ridge-controlled zone by solution of the underlying soluble limestone. Such interlake divides as those which form the fretwork of the Winter Haven Ridge having been almost completely removed in the
case of the Intraridge Valley, the exception being the above mentioned strictures and the break in continuity east of Avon Park.

Still further maturation of this process of beach-ridge-controlled Karst seems manifest in the fact that the line of lakes which begins at the south with these occupying the Intraridge Valley continues northward through the mid-peninsula region of eastern Lake County and Marion County where the ridge has largely been reduced to the level of the surrounding country and the counterpart of the Intraridge Valley has broadened out to carry the principal stream of the central peninsula, the Oklawaha River.

Beginning at the southern end of the Intraridge Valley, this line of lakes comprises (in sequence northward) Lakes Placid, June-in-Winter, Frances, Hill, Josephine, Ruth, Charlotte, Huckleberry, Little Red Water, Letta, Lotela, Pythias, Livingston, Clinch, Crooked, Easy, Wales, Mountain, Starr, Mabel, Annie, Hamilton, Lowery, Louisa, Minehaha, Mineola, Harris, Griffin and others along the west side of the highland dune area known as the Ocala National Forest and others still farther north along the western flank of Trail Ridge. Together they comprise the longest smooth line of genetically associated lakes in the United States. They extend over a distance of more than 200 miles in the Intraridge Valley and its more maturely dissolved counterparts along the western flank of the higher eastern part of the Lake Wales Ridge and Trail Ridge; two features which together form the topographic axis of the peninsula for two-thirds of its length. Farther west similar but shorter lines of lakes parallel this most prominent one in a number of places, especially in Lake and Polk counties where the lakes occupy basins dissolved out of the Winter Haven Ridge. In all instances the lakes seem to be of common character. They probably have a common origin in differential solution controlled either by the influence of beach ridges on ground water movement or by variable thicknesses of impermeable clay-rich fill overlying soluble limestone.

THE HIGHER PARTS OF THE LAKE WALES RIDGE

The Lake Wales Ridge seems to have a fundamental existence as a residual highland of coarse siliclastics and limestone which was dissected subaerially by streams and Karst (compare Saddle Creek, Rudy Creek, head waters of Peace River), and straightened on its flanks by coastal erosion to produce its present western bounding scarp (which curves around into close parallelism with other relict marine scarps east of Tampa Bay) and a probable buried former eastern bounding scarp. The toe of this eastern scarp has been buried by dunes along most of its
length, and these dunes in turn seem to have been truncated on their eastern boundary by erosion along the shores of lower stands of the sea. What appear to be remnants of the upper parts (crest) of the older shoreline scarp are shown by the long, smoothly curved line which joins the eastern flanks of the higher hills that extend in an intermittent chain along the eastern edge of the older ridge. This line is west of, and higher than, the dune zone. This higher of the two eastern scarps is shown on the physiographic map (Pl. 1) as a line composed of pairs of dots separated by dashes west of the solid line which marks the eastern edge of the greater ridge including the dune zone. It does not mark the base of a continuous scarp nor a uniform elevation, although in general it traverses terrain whose elevation approximates 100 feet. It merely marks the eastern limit of a chain of hills. However, the solid line farther east is a nearly continuous scarp toe where the dune zone abuts the younger, lower marine shore line. Nevertheless the upper more broken scarp seems to mark the more regionally significant geomorphic boundary for it is straighter, has much greater stature, and is smoothly in line with the eastern edge of Trail Ridge in northern Florida and Georgia.

The discontinuity of the line of higher hills is plausibly explained by the fact that erosional shoreline scarps are characteristically uniform in elevation at their bases but may be irregular in elevation at their crests because of subaerial dissection before the shoreline erosion which cut the scarp. The toe of this scarp is differentially buried by dunes hence its straightness and elevation are matters of conjecture.

In further support of the idea that the higher hills mark the crest of a former scarp of shore-line erosion, it seems significant that they are mostly composed of pre-Pleistocene rocks except at the southern or distal end of the chain where they seem to be made of younger sand which has been shaped into dunes. Also the distal (southern) end of the chain of higher hills curves westward in the characteristic manner of spit termini of the Atlantic coast, a characteristic shared by the lower solid line which marks both the eastern edge of the lower dune zone and a later marine shoreline.

A number of highland areas which generally attain elevations comparable with those of the northern highlands and the higher parts of the Lake Wales Ridge occur along a very straight line between Polk City and Gainesville. The most prominent of these are the higher parts of the Ocala Ridge. Together they suggest a formerly continuous ridge which would have been nearly parallel with the Lake Wales-Trail Ridge to the east, but diverging slightly from it toward the north. Like the Lake Wales-Trail Ridge this more western ridge also suggests an origin
as an Atlantic shoreline feature. However, there is no assurance that these aligned remnants of a former ridge were ever continuous in their present stature of local relief. Most plausibly any former continuity they may have possessed would have been as beach ridges rising only a few tens of feet at the most above a general emergent coastal plain of low relief which may well have resembled that of the Osceola Ridges southeast of Orlando, but at a considerably higher elevation. The present ridges, Lakeland, Winter Haven, Lake Wales, Ocala, etc., are probably intricately dissected remnants of this former broad plain which have resisted reduction. And the same factors which helped one of them to resist seem also to have helped the others. As described above, these factors seem largely to have been controlled by certain relict beach ridges or other Atlantic littoral features. Hence the present ridges of the Central Highland all have similar orientation and are essentially parallel with each other and with the Atlantic coast. The more discontinuous scarp at the eastern edge of the higher components of the Lake Wales Ridge described above seems to represent a marine scarp of some considerable antiquity which formed the edge of this formerly extensive coastal plain. South of Avon Park it seems to have been a spit for it extends as a narrow highland some forty miles farther south than does the rest of the Central Highlands. The topographic stature and mature dissection of this scarp, as well as its position as the eastern boundary of the coarse siliclastic surficial sediments (Citronelle formation) and the fact that its plan on the map simulates an Atlantic oceanic shoreline with great sweeping coastal arcs all suggest that it is correlative with the Citronelle Scarp of Doering (1960) and the Orangeburg Scarp of Colquhoun (1962). The presence of the upper Miocene Tamiami formation lying against its toe in the Kissimmee River Valley (Bishop 1956) also helps to support its correlation with the Orangeburg Scarp which has lately been regarded as a relict upper Miocene sea cliff by several workers (Colquhoun, 1962; Alt and Brooks, 1965). In fact Bishop's (1959) perspicacious interpretation as shown in the geologic cross sections B-B' and C-C' of his figure 4 are presagent of the buried scarps discussed later by Colquhoun (1962) from his findings in South Carolina. Bishop's cross-sections show surficial deposits overlying the Tamiami formation east of the Lake Wales Ridge with both pinching out abruptly at the toe of the eastern bounding scarp of the ridge.

The preservation of the higher parts of the Lake Wales Ridge as a highland today seems in some way associated with the presence of the coarse, claybound, gravelly sand that has been variously called Citronelle, Hawthorne Delta and "Coarse Clastics" by different Florida geologists. This suggests that the straight scarp at the eastern edge of the Lake Wales Ridge was produced by erosion; for the coarse clastics
are not present to the east of the scarp and they bear little resemblance to a beach deposit. However, the scarp's straightness and its parallelism with other relict Atlantic coastal features make it rather difficult to regard it as a product of erosion of older rocks else it would truncate or cut into some of the other relict shoreline features which follow its crest. For the hundred-odd miles of its length it fails to make such inroad but maintains smooth parallelism with them instead.

This problem is further complicated by the tendency of the Lake Wales Ridge as well as the Lakeland Ridge to have a preferred orientation of minor drainage lines in a southeasterly direction. This is at odds with the orientation one would expect the relict beach ridges to have impressed upon the streams. One is tempted to suggest that the drainage escaped from the control of the beach ridges through subsurface solution dominated by one of the major directions of structural lineaments. However, this seems a rather ill founded speculation. Other possibilities for the origin of the southeasterly oriented drainage as relicts of Citronelle stream valleys, I have discussed earlier (White, 1958, pp. 44 and 45). Since these fluvial relicts occur on the highest ridges they may never have been submerged beneath the sea that made the highest beach ridges.

GENETIC RELATION BETWEEN LAKES, KARST AND RELICT SHORELINE FEATURES IN DELAND AND CRESENT CITY RIDGES GENEVA HILL AND THE OSCEOLA PLAIN

The regional importance of control of Karst (and therefore also of drainage) by relict Atlantic shoreline features is further expressed by the parallel valleys and lines of lakes which make it difficult to separate the Central Highlands from the Eastern Valley between Palatka and Sanford. These lines of lakes share the straightness and parallelism of those farther west. The most easterly of them begins at the north with the widening of the St. Johns River at Palatka then successively southward it includes the valley of Dunn's Creek, the large Crescent Lake, Lake Disston and some thirty odd small lakes between Lake Disston and the town of Osteen 33 miles south from Lake Disston. Some of these are at the eastern edge of DeLand. South of Osteen the line of lakes is crossed by the St. Johns River where it makes its coast-perpendicular jog between Lakes Harney and Monroe. The line of lakes is expressed in the river by a local irregular widening between Osteen and Mullet Lake, and south of the river it continues thru nine
small lakes beginning with Mullet Lake and ending in a small swampy lake about a mile east of the community of Snow Hill. From this small lake a tributary of the Econlockhatchee River follows the same trend southward and is opposed by a north-flowing paired tributary, Melba Creek, both of these follow the same closely controlled trend as the line of lakes.

In total, this remarkably straight line of lakes is 76 miles long and if the two tributaries of the Econlockhatchee River are included it is 82 miles long. Through the last 22 miles of its length at the south the line of lakes is double; the more westerly component ending in Lake Pickett just south of the Seminole-Orange County boundary line. Throughout its length the elevation of the terrain traversed by this line of lakes varies irregularly from sea level at the north to elevations greater than 75 feet at Osteen a few miles north of the coast-perpendicular reach of the St. Johns River. Near Geneva a few miles south of the river it reaches an elevation of 85 feet. Such wide variation in elevations of relict shoreline features further attests the extent to which solution has affected the topography of the older parts of the landscape in the peninsula.

Coast-parallel streams following the rectilinear trend of this line of lakes also appear north of the Palatka coast-parallel reach of the St. Johns River. These streams; the south-flowing headwater reaches of Simms Creek and the opposed north-flowing headwater reaches of Peters Creek traverse terrain which exceeds 100 feet in elevation.

Another line of lakes parallels this one closely on the west. The interval between their axes remains very close to 4 miles throughout their length. This more westerly line of lakes begins at the north with Lake Broward just west of the north end of Crescent Lake at Pomona Park. It follows a line marked by the communities of Huntington, Seville, Connersville, Barberville, Orange City, Enterprise and the eastern edges of Lakes Monroe and Jessup at Sanford.

Still farther to the west is the Sanford-Palatka offset of the valley of the St. Johns River. It probably came into existence under the initial control of a relict Atlantic shoreline feature similar to and parallel with those which produced these two lines of lakes, but solution and erosion have so modified it that it has lost much of its original straightness. However, its general trend is nicely parallel with the lines of lakes just described suggesting that it has a common origin with them. Apparently they all had their beginnings in the beach ridges or barriers of a coastal plain surface of some 100 feet of elevation. But favorable structural and lithologic conditions beneath the St. Johns River offset allowed solution to be greater there.
Both these lines of lakes have been picked out on the map by dotted lines drawn along their axes, and it will be noted that they all make similar westward bends as they pass south of a line connecting the southern ends of lakes Jessup and Harney. This is in general the place where the relict shoreline features change from being expressed by lines of lakes to the north, to being expressed by coast-parallel streams to the south.

Farther south many other streams on the Osceola Ridge continue the coast-parallel trend which suggests that the same relict shoreline features persisted into this area of apparently less easy solution. Here the essential nature of the shoreline features is more lucidly expressed on the 7½ minute contour maps, where closely parallel, straight, alternate, dry swells and swampy swales show the location of relict beach ridges.

POSSIBILITY OF A RELICT CAPE AT ORLANDO

It seems significant that the trends of all these relict coastal features change orientation with similar bends at the place where extensive solution to the north gives way to less effective and more superficial solution to the south, for it is on the same general cross-peninsula axis on which the major drainage divide is located; the Peace and Kissimmee Rivers flowing southward from it and the Oklawaha and Withlacoochee flowing northward from it. Also it lies approximately between the major prominence of the present Atlantic coastline, False Cape and Cape Canaveral to the east, and the major eastward salient of the Central Highlands; the Orlando Ridge to the west. A line of alternate dots and dashes on the map Plate 1 joining the eastern edges of areas on the Mount Dora and Orlando Ridges is so smoothly curved that it suggests the remnants of a former coast line on the north side of a coastal salient similar to the present False Cape and Cape Canaveral. Actually this curve is remarkably similar to the present western shoreline of Mosquito Lagoon which was obviously the oceanic shore of a barrier island before the present barrier was built.

These two curves are compared in figure 42. They are practically identical – a fact which may be coincidence but nonetheless adds to other evidence to suggest that there was a prominent cape at Orlando during some time when sea level was somewhat less than 125 feet. It may well have been Wicomico and the curved, ragged, deeply dissected scarp may be the counterpart of the Surry Scarp; one of the few which have been mapped for great distances along the Atlantic Coastal Plain.
Figure 42 Restoration of relict cape at Orlando showing similarity to present Cape Kennedy
It will also be noted that the areas of ground higher than 125 feet elevation fall away rapidly to the southwestward immediately south of Orlando, forming the southern ends of the Orlando and Mount Dora Ridges. These higher areas, though sparse and small, nonetheless determine a smooth curve as shown on figure 42 which suggests the sort of reverse curve in the beach down-drift from a cape, such as the curves of the beach south of Cape Canaveral, or any of the Carolina capes farther north.

Again it may be noted that there usually is a shoal off the distal end of a cape such as that southeast of the present tip of Cape Canaveral. The offshore profile there is more gentle than it is immediately to the southwest along the curve of the oceanic shoreline. A very similar situation exists in the seaward slope of the Orlando Ridge. The part which suggests the distal extremity of a relict cape has a very gentle southeastward slope and does not show a prominent scarp or topographic break at the edge of the ridge. Father to the southwest however around the reverse curve on what would have been the leeward, down-drift side of the relict cape, the scarp reappears in the same way that deep water reappears immediately offshore a few miles southwest (down-drift) from Cape Canaveral.

Also it seems significant that the closely spaced clusters of lakes at the southern ends of the Orlando and Mount Dora Ridges end abruptly with the southern ends of the ridges. The clusters of lakes for reasons discussed above suggest the influence of relict beach ridges. This southwestward turn of the edge of the higher ground and the abrupt termination of the relict beach ridge country resembles the similar southwestward turn in the present oceanic coastline southwest of Cape Canaveral where multiple beach ridges to the north give way to open sea to the south.

Again the straight, higher scarp of the Lake Wales Ridge persists northward to the west of the Orlando relict Cape as expressed by the Orlando and Mount Dora Ridges. This situation mimics the present coast where the straight mainland shore of Indian River passes landward of the present barrier as seen in Merritts Island, False Cape and Cape Canaveral. It might even be ginerly suggested that the Mount Dora Ridge lying between the straight, higher scarp of Lake Wales Ridge and the relict Cape of Orlando Ridge is the counterpart of the present Merritts Island lying similarly between Cape Canaveral and the straight mainland shore of Indian River, both apparently being products of progressive progradation.

Another feature which suggests the existence of such a relict cape is the scarp which bounds this dissected highland east and southwest of
Orlando. For appreciable distances the toe of this scarp approximates 90 to 100 feet elevation. This is the characteristic elevation of the toe of the Surry Scarp where it is unequivocably preserved farther north in southern Virginia, the Carolinas and Georgia (Flint, 1940). The scarp here like the Surry Scarp farther north separates a much dissected upland to landward from a flatter terrain to seaward.

THE MARION UPLAND AND THE MOUNT DORA RIDGE

In eastern Marion and Lake counties is a large shelf-like part of the Central Highland which lies between the eastern foot of the Mount Dora Ridge and the Western valley wall of the St. Johns River offset. There are no detailed topographic maps of this area and little can be said about its topography. Upland elevations generally range between 50 and 75 feet and the stream such as Alexander Springs Creek and Salt Springs Creek have flood plains at about 25 feet elevation.

The western part of the Marion Upland rises gradually to the Mount Dora Ridge with which it shares the outcrop area of Miocene rocks which are largely insoluble clastics. Perhaps their resistance to solution explains the greater elevations.

The northern part of the Mount Dora Ridge is largely surfaced with clean sand whose topographic patterns on air photographs suggest an aeolian origin. Much of this land is included in the Ocala National Forest. It seems to be a northern extension of the dune zone at the eastern foot of the Lake Wales Ridge farther south. It has comparable elevations and falls along the same north-south line.

As I have suggested previously (White 1958, p. 39) these dunes may support the idea that a former connecting ridge between Lake Wales Ridge to the south and Trail Ridge to the north has been reduced by solution in the area occupied by the present Oklawaha Valley to the west of the northern part of the Mount Dora Ridge.

THE BROOKSVILLE RIDGE

The Brooksville Ridge is the most massive of the ridges which rise above the general level of the Central Upland. Equal in length to the Lake Wales Ridge, (some 110 miles in all) it is much wider and less geometric or lineal in plan. It is divided into two subequal parts by the valley of the Withlacoochee River at Dunnellon. The larger part to the south is some 60 miles long and varies between 10 and 15 miles in
width. The smaller, northern part is about 50 miles long and has widths ranging between 4 and 6 miles. Also the larger southern part of the ridge attains extreme elevations some 75 feet higher than those of the smaller northern part.

The Brooksville Ridge has the most irregular surface to be found in any area of comparable size in peninsular Florida. Elevations vary in short distances through a range from about 70 to some 200 feet. There are few persistent valleys and there is little surface drainage. Most of the surface is coated with sand a few feet thick which is unerlaim by the red clastic sediments of the Bone Valley and Alachua formations. Near the western side of the ridge there are thicker deposits of white sand which seem to be old stabilized dunes.

The Brooksville Ridge is coextensive with the areas of outcrop of the Alachua and Bone Valley formations and there seems little doubt that it has been held up against the reducing efforts of solution by the insoluble clastic components of these formations while the more soluble limestones surrounding it were lowered by a mature karst cycle to produce the Gulf Coastal Lowlands to the west and the Western Valley to the east. Nonetheless it should be noted that the Brooksville Ridge throughout its 110 miles of length parallels the other Ridges to the east as well as their associated lines of lakes, relict beach ridges, etc. Described elsewhere in this report these suggest that relict Atlantic shoreline features have something to do with the form of these ridges. In this connection it might be mentioned that Vernon (1951, p. 18) called this the Okefenokee — Coharie Sand Ridge, and it is notable that there is a sharp line of demarkation between the red claybound sands of the substratum and the clear white sands of the surface.

However, it should be noted that the higher elevations of the Brooksville Ridge (those reaching 175 to 200 feet) are concentrated in a zone which runs generally along the western side of the southern half of the southern component (south of Dunnellon) of the Brooksville Ridge. The western edge of this zone of higher hills is rather straight and is oriented in a northwest-southeast direction making an angle of some 15 or 20 degrees with the trend of the Brooksville Ridge as a whole and the trend of the other ridges and lines of highlands and lakes farther east. Possibly this suggests control by some Gulf Coastal feature rather than an Atlantic one.

The scarp which forms the western edge of the Brooksville Ridge is discussed elsewhere in this report under the heading “Terraces of the west side of the Peninsula” in the section entitled “Gulf Coastal Lowlands”. 
THE FAIRFIELD HILLS AND THE OCALA HILLS

The Fairfield Hills and the smaller Ocala Hills a few miles to the south are two areas of high ground named for two communities within their respective bounds.

The Fairfield Hills are irregular in plan having an extreme dimension of some 20 miles in a north-south direction and 15 miles in an east-west direction. A small outlier two miles south of the Fairfield Hills has been named Martel Hill for a small community on its northern flank on Florida Highway 328.

The Ocala Hills extend nine miles southwestward from the city of Ocala. Their maximum width is five miles. The Fairfield Hills sprawl out in amoeboid fashion but an axial ridge slightly east of the Center attains elevation appreciably higher than the rest of the area. This axial ridge is smoothly in line with a ridge of commensurate elevations in the Northern Highlands which extends northward from the City of Gainesville. It is also in line with a similar high spot of commensurate elevation in the southwestern half of the Ocala Hills. All three of these higher elements determine the same straight line which includes the Winter Haven Ridge 63 miles down the peninsula southward from the southern end of the Ocala Hills. Another small highland a few miles southeast of the southwestern corner of Lake County (called Rock Ridge Hills for a small community nearby to the west) also reaches elevations of 150 feet and is located on this same general trend between the Winter Haven Ridge and the Ocala Hills. The line determined by these highlands parallels Trail Ridge, Lake Wales Ridge and the present Atlantic coast. All of these larger highlands reach elevations of some 150 to 200 feet. Elevations which are exceptional in peninsular Florida and are attained only in the higher ridges which have been described above as remnants of a former ubiquitous upland surface preserved from reduction by solution through protection apparently provided by relict coastal features. The Ocala, Fairfield and Gainesville Ridges are thought to have the same origin and to be part of the same system of relict Atlantic coastal features.

THE COTTON PLANT RIDGE

The Cotton Plant Ridge is anomalous among the ridges of the Central Highlands. Its elevation is less and its orientation is different. Its elevation is rarely above 100 feet and it is elongate in a northwest-southeast direction. Its length is 16 miles and extreme width about five miles.
This ridge is named for the small community of Cotton Plant located where the northeastern edge of the ridge crosses Florida State Highway number 328 five miles east of Romeo.

The surface of Cotton Plant Ridge is coated with deep white sand and has a fine textured relief of some fifty feet. It has little if any surface drainage and appears to be an assemblage of dunes. The aeolian origin of the surface is suggested by the pattern of the hills on the map which show the characteristic aeolian tendency toward intersecting longitudinal and transverse wind ridges and an occasional suggestion of the related U-shaped dune. The trends of these ridges have the same orientations as those in other dune areas of Florida and it is notable also that the elongation of the whole dunefield is parallel with the length of the transverse wind ridges; that is perpendicular to the direction of the dune-building southwest wind. It should be noted however, that the southeastern end of Cotton Plant Ridge is traversed by cuts of the unfinished and abandoned cross-peninsular ship canal. In this deep cut other materials are exposed and suggest that the Ridge is not wholly composed of dunes.

THE LAKE AND SUMTER UPLANDS

Between the Polk Upland at the south and the clustered Ocala, Fairfield, and Cotton Plant Ridges at the north lie the Lake Upland at the south named for Lake County and the Sumer Upland at the north named for Sumter County. Each is roughly 35 miles long and some 15 miles wide. They are separated by the Lake Harris cross valley, and lie in general between the western and Central Valleys but are partly bounded by highlands which rise above them such as the Lake Wales Ridge on the eastern side of the Lake Upland and the Ocala, Fairfield and Cotton Plant Ridges at the northern end of the Sumter Upland. In elevation they are roughly equal to the Polk Upland to the south and the dividing line between the Polk Upland and the Lake Upland was drawn arbitrarily without any secure topographic distinction on which to base it. The Lake Upland is dominated by relict beach ridges which have been differentially reduced by subsidence resulting from solution of the underlying limestones. As mentioned in the discussion of the Lake Wales, Winter Haven and Lakeland Ridges elsewhere in this report and also White (1958, pp. 35-38). The mean elevation of these relict beach ridges lessens gradually with distance northward and it is largely because of this declining elevation that the Lake Upland was separated from the Polk Upland to the south. As the beach ridges and their intervening swales decline with increasing distance northward a large,
closely-spaced group of many small lakes appears. It is this which gives Lake County its name and the presence of this same group of lakes as a dominant feature of the northern half of the Lake Upland makes the name equally applicable to this physiographic division.

In general this northward decline in elevation continues through the length of the Sumter Upland north of the Lake Harris Cross Valley. From a general elevation of 125 to 150 feet at the southern end of the Lake Upland the mean elevation drops gradually northward to some 75 to 100 feet at the northern end of the Sumter Upland. Like most of the Polk Upland, the Sumter Upland has relatively few lakes. The large Lake Weir is a notable exception.

As in other physiographic divisions in this part of Florida the absence of good topographic maps makes an adequate description of the topography of the Lake and Sumter Uplands difficult.

THE POLK UPLAND

The Polk Upland, named for Polk County which occupies much of its eastern half, is a roughly square area surrounded by lower ground on three sides; the DeSoto Plain on the south, the Gulf Coastal Lowland on the west, and the valley of the Hillsborough and upper Withlacoochee Rivers on the north. On the east it is bounded by the higher ground of the Lake Wales Ridge, and the Winter Haven and Lakeland Ridges rise from its surface in its northeastern part. Aside from these ridges the ground surface generally has elevations between 100 and 130 feet. An inconspicuous but persistent outfacing scarp separates the Polk Upland from the DeSoto Plain on the south. This scarp turns a right angle northward at the southwestern corner of the Polk Upland and dies out about half way up its western side. The toe of this scarp is some 75 to 85 feet elevation. The crest is somewhat more variable in elevation but generally well above 100 feet.

In the northern part of the western boundary a lower scarp overlaps the higher one and becomes the boundary of the Polk Upland. This also is a definitive scarp but the boundary on the north is not as clear cut. Most clearly marked toward the west as a demonstrable steepening of slope downward toward the valley of the Hillsborough River, it becomes less definitive, to the east as the slope becomes more gradual. Here an arbitrary boundary has been drawn across the northern ends of the Lakeland and Winter Haven Ridges to the western flank of the Lake Wales Ridge.
The southern bounding scarp of the Polk Upland is quite irregular in plan and its origin is not clear. Most probably it is an erosional marine scarp made by a Gulf of Mexico shoreline at Wicomico sea level.

The Bone Valley formation underlies most of the Polk Upland and much of the adjacent DeSoto Plain to the south. Its siliciclastic composition has contributed to the topographic character of these areas for in most of the Polk Upland the effects of solution are not as intense as they are generally throughout peninsular Florida and complimentarily there is much more ramification of surface streams here. The Peace, Manatee, Little Manatee and Alafia all head in the Polk Upland with widely branching tributaries. This attributes of the drainage is shared by much of the adjacent DeSoto Plain. Topographic dissection in the Polk Upland generally amounts to some fifty feet. It is appreciably less in the lower DeSoto Plain to the south.

THE WESTER AND CENTRAL VALLEYS

In the differential reduction which left the above-described ridges, uplands and hill areas as residual remnants of a former regional upland, the unprotected soluble areas were reduced to lower elevations. These lower areas are large in area but rather irregular in plan. In a general way, however, they form two large lowlands that are elongate parallel both with the ridges which separate them and with the length of the peninsula.

THE WESTERN VALLEY

The longer and more westerly of these lowlands is here called the “Western Valley”. The shorter eastern one is called the Central Valley. Two short cors s valleys connect them. The more southerly of the connecting valley, is called the Lake Harris Cross Valley for Lake Harris at its eastern end. The more northerly is called the “Alachua Lake Cross Valley” for the former Alachua Lake or Payne’s Prairie south of Gainesville.

Near its southern end the Western Valley makes an abrupt turn to the southwest near the town of Zephyr Hills, passing south of the southern end of the Brooksville Ridge. In the delineation on the physiographic map (plate 1) it has been terminated rather arbitrarily at a low ridge which extends northward from Tampa. Actually there is no significant topographic break but the terrain west of this line seems to owe its character to relict marine features which extend for great
distances along the Gulf Coast. Therefore it has been included in the Gulf Coastal Lowlands rather than in the Western Valley.

It is difficult to make a categoric statement about the elevations of the floors of these valleys save that they range generally between some fifty and 100 feet.

The Western Valley is the larger of the two. It includes the Tsala Apopka Plain an area, south of Dunnellon, some fifty miles long from north to south and of variable width reaching a maximum of about 14 miles in the center. This area is flatter and lower than most of the other parts of these great valleys. It has been named for Lake Tsala Apopka which occupies much of its northern part. Its probable origin has been discussed elsewhere (White, 1958, pp. 19-22). Briefly stated, I think Lake Tsala Apopka is a relict of a larger former lake which occupied most of the area encompassed within the Tsala Apopka Plain. The Tsala Apopka Plain ranges from about 50 to 75 feet in elevation and much of its local relief results from patches of higher irregular topography which in some ways resemble dunes.

The Western Valley includes the strath or valley of the Withlacoochee River which enters it at its southwestward turn near Zephyr Hills and leaves it at the Dunnellon Gap in the Brooksville Ridge. This strath includes the Tsala Apopka Plain. Southwestward from its turn to the southwest the Western Valley contains the strath or valley of the Hillsborough River. The Withlacoochee and Hillsborough rivers are diffluent at the Zephyr Hills turn of the Western Valley and most probably their diffuence is the reason that the valley is continuous through the areas drained by both streams, for there is no divide between them. Their common headwater is the upper Withlacoochee River. It extends upstream eastward from the point of diffuence across the Western Valley into the Lake Upland along the same general trend which the Hillsborough River follows in the opposite direction downstream from the point of diffuence.

The southern half of the eastern edge of the Western Valley is poorly drawn for no detailed topographic maps of that area were available. The same is true for the boundary between the Western Valley and the Brooksville Ridge adjacent to the northwest.

North of Dunnellon the Western Valley narrows abruptly to a width of only two miles at Romeo where the northwestern end of the Cotton Plant Ridge approaches that close to the eastern flank of the Brooksville Ridge. Aside from this stricture the Western Valley maintains a subequal with throughout its 140 miles of length. Considering the atypical orientation of the Cotton Plant Ridge (elongate in a
northwest-southeast direction, perpendicular to the dune-forming winds of peninsular Florida) and the resemblance of its small scale topographic features to dunes, it seems probable that this stricture is a lately acquired attribute of the Western Valley rather than an original one. This supposition opens the way for speculation on the possibility that the entire length of the Western Valley, including its southwestward turn toward the Gulf Coast at its southern end, may once have held a single long stream, as the central valley presently holds the Oklawaha River and the eastern valley holds the St. Johns River.

THE ZEPHYR HILLS, DUNNELLON AND HIGH SPRINGS GAPS

There are three openings in the western valley wall of the Western Valley by which drainage has egress to the Gulf Coastal lowland. These are located at both ends of the Brooksville Ridge and a little north of its center. The most southerly of these gaps is named the Zephyr Hills Gap for the town of that same name. Through it the Hillsborough River attains egress to the sea. The central gap is named the Dunnellon Gap. It offers egress to the Withlacoochee River. And at the northern end of the Western Valley the Santa Fe River flows through the High Springs Gap to confluence with the Suwannee River. Of these three, the Zephyr Hills Gap seems to be the oldest for it carries the Hillsborough River into the great estuary of Hillsborough and Tampa Bays and the Pamlico terrace turns up this valley some considerable distance suggesting its existence during Pamlico time. This same terrace makes no entry into the Dunnellon gap but cuts straight across the valley of the Withlacoochee River on the west flank of the Brooksville Ridge (White 1958).

THE LAKE HARRIS AND ALACHUA LAKE CROSS VALLEYS

Somewhat similar to these three gaps which offer egress from the Western Valley to the Gulf coastal lowland are two short cross valleys which join the Western Valley to the Central Valley.

The more southerly of these separates the Lake Upland on the south from the Sumter Upland on the north. It is some 8 to 10 miles long, 3 to 5 miles wide and is called the Lake Harris Cross Valley for Lake Harris, the large lake which lies at its juncture with the Central Valley.

Similarly farther to the north the Alachua Lake Cross Valley joins the northern end of the Central Valley with the Western Valley
between the northern end of the Fairfield Hills and the Northern Highlands at Gainesville. It is named for the former Alachua Lake which intermittently occupied the basin otherwise known as Paynes Prairie. This basin is the largest of several which floor this valley. Levy Lake occupies the other large one a short distance south of Paynes Prairie.

THE CENTRAL VALLEY

The Central Valley is much shorter than the Western Valley, but roughly commensurate with it in width. It is occupied throughout most of its length by a single surface drainage system; that of the Oklawaha River and its tributary Orange Creek. It has a more prominent system of lakes on its floor than does the Western Valley. By comparison with the two large lakes Tsala Apopka and Panasoffkee of the Western Valley, the Eastern Valley has at its southern end the large Lake Apopka north of Winter Garden and a short distance to the north is the group of large lakes which includes lakes Harris, Dora, Griffin, Eustis and Yale, all in the general vicinity of the cities of Leesburg and Tavares. At the northern end of the Central Valley are the large Orange, Lochloosa and Newmans Lakes. The last of which occupies a deep reentrant in the edge of the Northern Highlands between the cities of Gainesville and Hawthorne.

The topography of the Central Valley is imperfectly known because there are no detailed topographic maps of the area it covers save for a small part of its northern end. The drainage of the Central Valley finds egress to the St. Johns River via Kenwood Gap named for a small community near its center. Here the Oklawaha River turns sharply eastward to join the St. Johns River in Little Lake George.

The Mount Dora Ridge separates the Central Valley from the Marion Upland to the east. In large measure the Mount Dora Ridge seems to be supported by the coarse claybound siliclastic sediments of the Citronelle formation. However, the northern half of the Ridge, the part incorporated in the Ocala National Forest, seems to be a great stabilized dune field. Between these two major components of the Mount Dora Ridge is a gap but its floor is rather high and it has no stream running through it. The town of Umatilla lies near its center and Florida Highway 42 runs through it. Between here and the Kenwood Gap at the north are three other gaps, none more than a mile wide and none carrying through streams. Because they do not affect the drainage they are not named here, although they are shown on the physiographic map as interruptions in the continuity of the Mount Dora Ridge.
In concluding the discussion of these great internal western and central valleys, one is tempted to note a correlation between the zone they occupy and the absence of less soluble younger rocks overlying the great limestones exposed by the Ocala Arch. It may be noted that there are no comparable topographic features south of the trans-peninsular divide between the Oklawaha and Withlacoochee-Hillsborough Rivers to the north and the Peace and Kissimmee Rivers to the south. This divide crosses the peninsula at the southern end of these two broad, deep valleys. South of it the Polk Upland and Osceola Plain have no such interruptions. The Peace River, where it drains the Polk Upland, and to a lesser extent, the Kissimmee River, where it drains the Osceola Plain have cut narrow typically fluvial valleys through these areas wholly unlike the broad regional lowlands of the Western and Central Valleys north of the trans-peninsular divide. The reason for difference between these two sets of valleys (north and south of the transpeninsular divide) seems to be the general surface exposure of soluble rock north of the divide and the presence of some considerable insoluble material at the surface of the ground south of the divide.

THE OSCEOLA PLAIN

Between the eastern foot of the Lake Wales Ridge and the western edge of the Eastern Valley, some 35 or 40 miles to the east, is a broad flat area which is here referred to as the Osceola Plain; named for Osceola County which is almost wholly encompassed within it and includes more than half its area.

The Osceola plain is bounded on the west and northwest by the higher land of the east side of the Lake Wales Ridge and the southern ends of the Mount Dora and Orlando Ridges. On the northeast, east and south it is bounded by an outward-facing scarp which looks out onto lower ground which for the most part is the solution-reduced beach ridge plain at about 25 feet elevation which has been described above as the solution part of the Eastern Valley. Bounded thus on part of its periphery by marine scarps which rise above it and on the remaining part by lower marine scarps which fall away below it. The proper term for its topographic form is “terrace”. But this term has been used so widely throughout the Atlantic coast of the southeast as a correlation term for lands formed at specific sea levels, that one is loath to use it in the name of a specific local topographic feature.

The extreme elevation of the Osceola plain is about 90 to 95 feet. This elevation is reached near its northern edge where it rises gradually but with increasing local relief toward the southern edge of the Orlando
Ridge. It attains an elevation of some 80 feet in a local swell east and northeast of Lake Kissimmee. Elsewhere its local relief is very small, usually encompassed within the ten feet between elevations 60 and 70 feet.

One conspicuous prominence rises from the surface of the Osceola Plain. It lies east of Frostproof and Avon Park. Its northern part is in Polk County; its southern part in Highlands County. It forms the divide between the Kissimmee River to the east and Arbuckle Creek to the west. It is midway between these streams. Twenty-one miles long in a north south direction and 3 to 4 miles across it attains elevations of 125 to 145 feet and for some distance can be seen rising above the horizon as a conspicuous ridge on the otherwise flat terrain. Since the only culture on it is military it has been referred to here as "Bombing Range Ridge". It has all the attributes of a large marine sand bar made by the Atlantic. And like Lake Wales Ridge, it has a westward curve at its southern end and a large spur projecting from its western side which suggests an earlier westward-curving termination before waves and currents extended it southward to its present, similarly curved, southern end.

The Kissimmee River passes through the length of the Osceola Plain slightly west of the center line and roughly parallel with the axis of the peninsula. For the southernmost 25 miles of this route it occupies a valley about a mile and a half wide which is cut rather sharply into the surface of the plain. But from Lake Kissimmee northward (upstream) the valley opens out into a large group of big lakes which take up a large percentage of the area of the northern half and western three quarters of the main part of the Osceola Plain. This group of lakes includes some of the largest in Florida such as Lakes Kissimmee, Weohyakapka, Tohopekaliga, East Tohopekaliga, Hatchineha, Marian, Alligator, Hart, etc. Through much of this sprawling chain of lakes the Kissimmee drainage system maintains a recognizable valley with a flood plain discrete from the upland surface of the Osceola Plain. But in most places the distinction between the drainage ways and the upland surface is obscure.

The part of the Osceola Plain west of Bombing Range Ridge holds the valley of Arbuckle Creek which drains Lake Arbuckle into Lake Istokpoga below the southern bounding scarp of the Osceola Plain.

Although the various parts of the Osceola Plain show little recognizable difference in relief, there is nonetheless a notable distinction in the terrain east and west of a line running approximately parallel with the Axis of the Peninsula, following in general the route of United States Highway 441 between Fort Drum at the south thru Osowaw
Junction, Yeehaw Junction and Kenansville, to Cat Lake and then passing just east of the eastern edge of the Orlando Ridge to become the trend followed by the Sanford-Palatka reach of the St. Johns River valley. This line is almost straight throughout its length and seems to mark a relict Atlantic shore. Where it traverses the Osceola plain the terrain east of it has a drainage pattern and topography which shows it to be composed wholly of relict beach ridges and their intervening swales. But to the west of the dividing line the topography and drainage pattern are more indeterminate and randomly arranged.

Possibly this line marks the position of the first of a series of progradational beach ridges which grew into a broad barrier separating a broad lagoon to the west from the Atlantic ocean to the east. The Kissimmee River may have come into existence as the axial drainage of such a lagoon after sea level dropped slightly to allow the sea to withdraw.

The Osceola plain narrows markedly toward the southeast as its outward-facing southern bounding scarp curves southeastward around the northeastern part of the Okeechobee Plain and approaches the eastern scarp. The two scarps intersect at the southern end of a long attenuate apolyse near the St. Lucie-Martin County boundary where the surface becomes stepped to form two southeasterly facing scarps. The higher of these scarps has its crest at 60 feet elevation and toe at 40 feet. The narrow terrace plain at the 40 foot elevation extends south-eastward to Indiantown where the Osceola Plain ends in what seems to have been a long spit or off-cape shoal, similar to the above-mentioned southern termini of Lake Wales Ridge and Bombing Range Ridge.

Through much of its length the eastern bounding scarp of the Osceola Plain is steep enough to be readily visible in the field. But the southern scarp which leads down from the Osceola Plain to the Okeechobee Plain is not readily perceptible in the field although it is easily demonstrated on the 7½ minute topographic maps and can also be traced on the aerial photographs. These two scarps have about the same elevation at their toes.

THE CALOOSAHATCHEE INCLINE AND THE DESOTO PLAIN

At its southwestern extremity, the Osceola plain narrows to end between Lake Istokpoga and Lake Wales Ridge where the southwestern shore of the lake abuts against the toe of the scarp which forms the eastern flank of the ridge. But south of the lake there is a long, narrow,
sloping surface which seems related to the Osceola Plain. It inclines gently eastward from the eastern toe of the Lake Wales Ridge at 50-60 feet elevation down to 30-35 feet at the edge of the Okeechobee plain below it to the east (see Fig. 43).

This sloping surface curves concentrically around the southwest-curving, distal (southern) end of the Lake Wales Ridge. From the shore of Lake Istokpoga southward for 10 miles it is some 1½ to 2 miles wide. But for the next 30 miles it describes a westward-curving arc 5 or 6 miles wide. It mimics the curvature of the end of the Lake Wales Ridge on a larger plan always maintaining a toe at 30 to 35 feet and a crest at 60 feet as it curves smoothly westward to a point on the north side of the Caloosahatchee River two miles west of La Belle. There it turns abruptly northward, narrows and steepens markedly and then flares out to the westward in a broadening fan of increasing gentleness of southward slope. This abrupt northward turn is also mimicry of the distal end of the Lake Wales Ridge.

This broad gentle incline is here called the "Caloosahatchee Incline" since it forms much of the northern valley wall of the Caloosahatchee River.

West of the end of Lake Wales Ridge the Caloosahatchee Incline forms the southern bounding scarp of a broad plain some 45 to 50 miles in north south dimension and varying in east-west dimension from about 25 miles at the south to some 50 miles at its northern edge where it adjoins the Polk Upland. It has been named the DeSoto Plain for DeSoto County which is wholly encompassed within it.

Perhaps I take some license in using the word scarp in aluding to a gradual incline of 30 feet vertical measure in a horizontal distance of five to six miles. But it has every attribute of a major scarp except abruptness. It marks the steeper transition zone between two of the largest and flattest plains of Florida. It slopes down to the vast lowland to the south which comprises the Okeechobee Plain, the Immokalee Rise, the Big Cypress, and the Everglades, none of which exceed the 30 foot elevation of the toe of this incline. Complimentarily in the opposite direction it rises northward to the southern edge of the DeSoto plain at an elevation of 60 feet.

The DeSoto Plain is also a very flat one. Its northern edge at the foot of the south-facing scarp which terminates the Central Highlands has elevations of 75 to 85 feet. Whereas its southern edge forty odd miles to the south at the crest of the Caloosahatchee Incline is only 15 to 25 feet lower at an elevation of 60 feet.
Figure 43  Topographic sketch showing the DeSoto Plain as a flat relict marine shoal in the lee of the distal end of Lake Wales Ridge, and the Caloosahatchee Incline as the steeper off-shore end of the shoal.
It will be noted that the range of elevations is the same as those involved in the Osceola Plain on the opposite side of the Lake Wales Ridge, and it is probably proper to regard them as coeval. It is the writer’s impression that they both are submarine plains, and that both were made by the same sea level probably Wicomico. The Caloosahatchee Incline at least, seems to be a depositional feature; the steeper incline at the distal or down-current end of a submarine shoal. Probably such features are rarely preserved in subaerial exposure because they suffer wave erosion and wind action when they pass through the shore zone in the process of emergence. However, the Caloosahatchee Incline would seem to have been preserved by virtue of emerging thru the protected waters of a low energy coast.

The submarine origin of both the DeSoto Plain and the Osceola Plain west of the beach ridge zone is suggested by the notable absence of lineal features to suggest relict shore lines. There are no relict beach ridges throughout these areas.

The writer suggests that the Caloosahatchee Incline and the adjacent parts of the DeSoto Plain are one of the best preserved examples of a large emergent relict submarine shoal essentially unmodified by shoreline process. It is probably the emergent counterpart of the shoals which are currently extant down-current from present capes such as Canaveral and the Carolina Capes. Although its morphology probably differs somewhat because it would have been the shoal formed in the lee of a long, spit-like peninsula formed by the southern part of Lake Wales Ridge.

It may be worth noting that the Peace River traverses the DeSoto plain in much the same manner as the Kissimmee traverses the Osceola plain. Both are somewhat entrenched. The Peace River some 30 or 40 feet; the Kissimmee about 25.

There is a line of elongate swamps in the southern part of the DeSoto Plain which mimics the curvature of the Caloosahatchee Incline a few miles back from its crest. Perhaps it represents a lagoon which had a brief existence during the emergence of the DeSoto Plain. It comprises Long Island Marsh shown on the Long Island Marsh S.W. and the Long Island Marsh S.E. quadrangles; Rainsy Slough shown on the Telegraph Swamp N.E. and LaBelle N.W. quadrangles and the valley of Fisheating Creek on the LaBelle N.W. quadrangle. The similarly elongate and concentric Telegraph Swamp at the foot of the Caloosahatchee Incline suggests a similar lagoon made after further fall of sea level when the shore was located at the foot of the Caloosahatchee Incline. Parts of Caloosahatchee Valley may occupy parts of this same lagoon system.
THE OKEECHOBEER PLAIN

At the foot of the generally south-facing scarp which ends the Osceola Plain, there begins an unbroken, extremely gradual descent to the south across one of the most reliefless parts of the United States. The larger, southern part of this is the Everglades; but to the north of the Everglades Lake Okeechobee, nearly 30 miles wide, stretches almost completely across this plain and separates the northern part from the larger southern part. This northern part is here called the Okeechobee plain for Okeechobee County and the adjacent Lake Okeechobee. However, its taxonomic separation from the larger unit is not defensible on any basis of topographic distinction other than a slightly better drainage and a slightly steeper slope. Its soils, however, have a greater mineral content than do those of the Everglades south of Lake Okeechobee.

In southward progression generally the soils of the Osceola Plain have a thick mantle of clastic insoluble mineral matter. Those of the Okeechobee Plain have a thinner mantle of insoluble clastic material overlying carbonate and the Everglades have organic soil overlying carbonate.

From elevations of about 30 to 40 feet at the toe of the northern bounding scarp which separates it from the Osceola plain, the Okeechobee Plain slopes gradually southward to elevations of about 20 feet at the north shore of Lake Okeechobee.

THE GULF COASTAL LOWLANDS

TERRACES OF THE WEST SIDE OF THE PENINSULA

As stated above the Caloosahatchee Incline diminishes its angle of inclination as it turns northwestward away from the Caloosahatchee River, and by the time it reaches the Charlotte-DeSoto County boundary line it has merged with the regional southwestward slope. However, a somewhat similar local steepening of regional slope reappears some 25 miles farther north along the western edge of the DeSoto Plain. It begins near the place where Horse Creek leaves the DeSoto Plain, and extends with differential inclination and width to a point near the Little Manatee River. Genetically this incline along the northwestern side of the DeSoto Plain is probably similar to the Caloosahatchee Incline farther south representing an offshore submarine slope.

From its northwestern corner the DeSoto Plain extends a long narrow apophyse northward parallel with the general trend of relict
shoreline features of that area. It becomes thus a terrace flat between the toe of the higher out-facing scarp of the Polk Upland to the east and the crest of the seaward sloping incline, just described, in the place where the latter reaches its maximum angle of slope and its minimum width of somewhat less than a mile.

This terrace-like apophyse of the DeSoto Plain marks an abrupt change in the nature of the topography left by the regression of the Gulf of Mexico. South of this point in the areas just described the topography is dominated by broad marine plains and gentle depositional slopes. But, to the north the regional slope steepens and narrows as it accomplishes the entire descent from the Polk Upland to the shore of Tampa Bay in a few miles. As this slope narrows and steepens progressively, it becomes more prominently terraced; until, in the area between the Alafia and Little Manatee Rivers, it becomes one of the most conspicuously terraced parts of the Coastal Plain showing four flats and three intervening scarps, counting the present coastal flat and the Polk Upland as the flats at the lower and upper extremities of the terrace flight.

These terraces die out quickly at the south valley wall of the Alafia River. They don’t reappear with clarity north of the Alafia; save for the nearly ubiquitous Pamlico terrace and scarp, which persist up the Gulf Coast of the peninsula to the vicinity of the Waccasassa River, and the Scarp that forms the western edge of the Brooksville Ridge. This last is probably a scarp of Wicomico age made by a +100 foot sea level. However, it has suffered so much differential subsidence from solution of underlying limestone that it is difficult to correlate.

Southward from the focal area of the terrace flight between the Alafia and Little Manatee Rivers the terraces flare out horizontally and the scarps between them become obscure. They tend to die out on the near sides of stream valleys. Thus they turn up the south side of the Alafia River and the north side of the Little Manatee but they are poorly expressed in the topography beyond either stream save for the gentle incline that rises to the DeSoto Plain and the lowermost terrace of the flight which extends southwestward toward Bradenton along the route of the Atlantic Coast Line Railroad. This lowermost terrace with a toe at 10 to 15 feet elevation appears again a short distance back from the mainland coast of Sarasota Bay extending from Palma Sola Bay at the north to the northern environs of the city of Sarasota at the south. This or other terraces may exist still farther south along the Gulf Coastal lowland but the contour interval on the available maps is too great to reveal them if they are present. The only other known to the writer begins a short distance south of Punta Gorda and extends
southward to the vicinity of the Charlotte-Lee County boundary line. Its toe is at about 5 feet elevation and its crest at about 20.

The strong development of terraces on the southeast side of Hillsborough Bay does not seem to be unique but rather the optimal development of a systematically repetitive pattern. The Waccasassa, the Hillsborough, and the Peace Rivers all have greater terrace development on their southern sides than on their northern or up-peninsula sides. Thus there are no terraces for a great distance northwest of the mouth of the Waccasassa River but two of them begin south of it. Similarly the dramatic flight of terraces described above occupies the first few miles southeast of Hillsborough Bay which is the estuary of the Hillsborough River. And again, although terraces are extremely rare south of the Sarasota-Bradenton area, a clearcut example is found extending southward from Punta Gorda at the mouth of the Peace River.

There is no noticeable change in the character or number of terraces on opposite sides of the lower Withlacoochee River, a fact which further suggests that the Withlacoochee below Dunnellon is a new stream which has not long been in existence. Other evidence supporting this idea has been presented by Vernon (1951, p. 31) and by White (1958, pp. 19-27) who has also suggested that the Withlacoochee formerly debouched into Hillsborough Bay via the Hillsborough River. The presence of the exceptional flight of marine terraces southeast of Hillsborough Bay offers some additional support for this suggestion, since it is consistent with this regional pattern of terrace flights made on the south sides of stream valleys during former high stands of sea level.

Certain attributes of the Lower Suwannee River valley suggest that it also is a stream which has not long occupied its present valley. This matter has been discussed by Vernon (1951, pp. 31-36) who presented evidence to suggest that the Suwannee River may formerly have debouched through the valley of the present Waccasassa River. Perhaps some support for such an idea can be had from the observation made above, that the terraces begin immediately south of the small Waccasassa River rather than immediately south of the large Suwannee River which is some 20 miles to the northwest.

Vernon suggested that the Suwannee formerly followed a coast-parallel course through a broad shallow valley which at its northern end intersects the present valley of the Santa Fe River south of Fort White about midway between the Suwannee-Santa Fe confluence and the Town of High Springs, and at its southern end becomes the headwaters of the Waccasassa River. This valley is conspicuous on aerial photo-
graphs. However, no topographic maps were available at the time of Vernon’s work and later Yon and Puri (1962) working in Gilchrist County discovered topographic barriers athwart this valley which made it difficult to think that it had ever been occupied by a through-flowing stream.

The discovery of the above described repetitive pattern of coastal terrace development on the south sides of major peninsular Gulf Coast river valleys led me to think that Vernon might be right about the Suwannee River having debouched through the present lower Waccasassa River. Realizing the difficulties encountered by Yon and Puri, I looked at the topographic maps to see if there was some other route by which the Suwannee River might have reached the valley of the Waccasassa River.

As seen on the Manatee Springs and Chiefland sheets, Long Pond strongly suggests a relict river channel (Fig. 44). It is long, narrow and sinuous, and occupies a valley of very uniform width. It forks in a “Y” shaped manner with the acute angle opening northward, which would be upstream if the Suwannee flowed through it. The eastern branch extends northward toward Chiefland, the western branch extends northwestward. Through the western branch of the valley the lake drains into the Suwannee River at times of high water. This is an apparent reversal of the original drainage. A tributary chain of swampy lakes extends off to the northeast from the stem of the “Y” made by Long Pond strongly suggesting a former tributary stream that flowed into the Suwannee River from the northeast when it flowed through the valley that now holds Long Pond.

Of the countless lakes of the Florida Peninsula few if any others share this sinuous and branching shape which characterizes Long Pond.

From the southern end of Long Pond one can go into the headwaters of Otter Creek, a principal tributary of the Waccasassa River without rising more than five feet above the elevation of either. Otter Creek heads in a long narrow swamp which extends directly toward the southern end of Long Pond. The northern end of this swamp and the southern end of Long Pond are less than 2 miles apart.

The western part of this abandoned valley between the northwest end of Long Pond and the Suwannee River is sufficiently prominent to show on Vernon’s physiographic map of Citrus and Levy counties (Vernon 1951, figure 2) separating his Chiefland limestone plain into two parts. Vernon (1951, p. 46) discussed the peculiarities of Long Pond and the valley which sometimes drains it into the Suwannee. He noted its relation to the Pamlico terrace and the presence of fluvial and
Figure 44  Parts of the Manatee Springs and Chiefland 7½ minute sheets showing the fluvial appearance of Long Pond and its tributary valleys
brackish water sediments in its basin. He also called attention to a scarp on its western side which he ascribed to the upthrown block of his Long Pond fault. To my mind all these observations increase the plausibility of assuming that the Suwannee River once flowed through this area. The brackish water sediments suggest estuarine conditions during Pamlico times. The fault scarp (or fault line scarp) suggests a reason for the river to follow this route. And the fact that the valley which extends from the west end of Long Pond to the Suwannee River drains westward into the Suwannee is easily explained by the erosion and solution that would attend the lowering of the present channel of the Suwannee following sea level drop after Pamlico time.

The western edge of the Brooksville Ridge is probably a marine terrace scarp, but the elevation of its toe is variable. This may be because certain parts of the scarp have been shores at more than one sea level. Thus the Pamlico scarp merges with the western edge of the Brooksville Ridge for about 18 miles from a point about three miles northeast of the town of Crystal River to one about 10 miles northwest of Brooksville. Here the toe of the scarp is lower and more uniform in elevation than it is to the north or south.

Northward from the place near Crystal River where the Pamlico scarp diverges westward from it the base of the Brooksville Ridge has elevations of 55 to 60 feet for a long distance. About eight miles north of the Withlacoochee River a relict barrier of this 55 to 60 foot shore line begins. It apparently extended northward from this point as a spit, and can be traced with diminishing clarity for some 10 miles until it becomes unrecognizable in the vicinity of Chunky Pond (Johnson’s Pond) a few miles south of Bronson. It can be seen on the Tidewater and Bronson S.E. quadrangles. Big Wolf Arbor and Sand Slough seem to be the relics of a lagoon between the barrier and the toe of the Brooksville Ridge. They can be seen north and south of Florida State Highway 335 on these same two quadrangles.

Northward from the point (10 miles northwest of Brooksville) where the Pamlico scarp diverges southward from it the western base of the Brooksville Ridge follows a smooth crescentic line unbroken save at the Dunnellon Gap. Thus it would seem to be a relict erosional oceanic shoreline part of which, at least, was later separated from the open Gulf of Mexico by the above described barrier. North of Crystal River the shoreline would seem to have been occupied only by a sea level which left relict features at 55 to 60 feet but south of Crystal River it was apparently occupied by the lower Pamlico sea level as well.

The Pamlico scarp is somewhat obscure south of its point of divergence from the base of the Brooksville Ridge at the south. Perhaps
the obscurity results from dunes but the general suggested trend continues the smooth crescentic curve described above which thus extended would reach 100 miles from the north end of the Brooksville Ridge to a point six miles east of New Port Richey. This great relict coastal arc would have been very different from the present irregular marshy coastline which parallels it today. Probably its smooth curvature was made possible by the availability of beach building materials in the clastic rock of the brooksville Ridge. It is not understood why the northern half of this curve (beyond Crystal River) should have been abandoned by sea levels lower than 55 feet while the southern half was occupied by the Pamlico shore at 30 feet. Possibly differential subsidence during the interval of time between the making of the two shorelines may be the reason.

The southern part of the western base of the Brooksville Ridge (south of the point where the Pamlico scarp diverges to the southwest) is rather irregular in plan and reaches elevations considerably higher than those of the relict shorelines described above. It would seem to be the result of subaerial denudational process rather than marine shoreline erosion.

**BELL RIDGE**

This outlier of the Brooksville Ridge is intermediate in height between the surrounding Gulf Coastal Lowland and the Brooksville Ridge to the southeast. The delineation was made possible by the work of Yon and Puri (1962) in Gilchrist County. The only topographic map of this area is one made for them by the Florida State Road Department. It shows Bell Ridge as an elongate hill essentially parallel with the western side of the Brooksville Ridge. Its eastern side is some three miles west of the adjacent western side of the Brooksville Ridge but it extends farther northward than does the Brooksville Ridge.

The origin of Bell Ridge is not clear but it may be associated with a relict barrier chain which seems to be present in sporadically preserved remnants off the western foot of the Brooksville Ridge. Differential subsidence from solution of carbonates is probably involved also.

**THE COASTAL SWAMPS**

The coastal swamps are delineated extensively along those parts of the peninsular coast where there is a dearth of sand for building beaches; these are principally the mainland coast of Florida Bay and the contiguous Gulf of Mexico coast as far north as Naples; also the
coast of Suwannee Bight or the Gulf of Mexico coast between Tarpon Springs and the west side of Apalachee Bay. The entire Atlantic coast, and the Gulf of Mexico coast between Naples and Tarpon Springs are sand dominated and apparently have been so for a long time. These sand dominated coasts are in general higher and do not have extensive coastal swamps. A number of sub-parallel relict beach ridges assure a dry, even if low, hinter-coast area along most of the Atlantic shore; and Miocene clastic rocks as well as relict beach ridges provide a dominantly dry-land terrain on the west coast between Naples and Tarpon Springs.

The coastal lagoons include some considerable areas of swamp where they have accumulated sediment and grown up with vegetation. For the most part these swampy decadent lagoons are in the northern part of the Atlantic Coast. However, these have not been included in the category of coastal swamps because there is dry land between them and the oceanic shore.

The landward edge of the Coastal Swamp has been delineated as a line enclosing all continuous areas of swamp adjacent to the coast. That is, areas shown on the quadrangle maps by swamp symbols. All isolated patches of swamp symbol separated from the coast by dry land were excluded. No distinction has been made between salt marsh and fresh water swamp.

The reason for this association of the coastal swamps with the beachless segments of the coast has been discussed in the section of this report entitled “The Lower West Coast of the Peninsula”.

AEOLIAN FEATURES OF THE WEST SIDE OF THE PENINSULA

On the west coast of the peninsula north of Tampa Bay there are many dunes, which seem to be useful indices to the evolution of this part of the coast. They occur isolated and in groups as well as in extensive dune fields. The more isolated of them are usually giant U-shaped dunes which reach widths of as much as two miles and lie for the most part between the Pamlico Scarp and the present coast. Some of them, such as those which form Cedar Keys in Levy County and Horseshoe Beach in Dixie County, are partially drowned, being wholly or partly surrounded by sea water. The more conspicuous of these dunes are outlined in plan on Plate 1.

For the most part these dunes are now inactive and their periods of activity seem to have been those in which there were beaches along this now beachless part of the West Coast. As mentioned elsewhere in
this report there is no local source of sand for beach building here, the rocks all being carbonates, and as a result the coast is a marshy one with no definite shoreline.

However, there seem to have been beaches here at other times for there are sandy areas adjacent to the Pamlico and higher scarps. The higher and more easterly of these, lies at the western foot of the Brooksville Ridge, which is composed largely of clastic materials that might readily have supplied sand to the shore to build a beach. In this connection it is notable that the most extensive dune field of this region lies immediately east of this scarp on the western flank and adjacent top of the Brooksville Ridge. The dunes there seem to have been supplied with sand blown eastward (landward) from a beach built of voluminous, locally derived sands.

From the Withlacoochee River southward as far as northern Hernando County the Pamlico and Wicomico Scarps coalesce and dunes are voluminous east of them but sparse to the west.

North of the Withlacoochee River the Pamlico scarp is located on the soluble limestones some distance west of the Brooksville Ridge and its associated dunes are more sparsely distributed. There is an extensive dune field to the east of it in northern Pasco and southern Hernando counties. (See Port Richey N.E. sheet). The only source for the sand which built the Pamlico beaches would seem to be the clastic sandy rocks to the north or south of this practically sandless section of the coast. This would suggest that the Pamlico shoreline existed for a longer time than the present coast line has thus far existed and during this longer existence was able to carry sand by littoral drift to build the Pamlico beaches and supply the Pamlico dunes from those beaches. The present sandless and beachless coast apparently has not yet been able to bring a supply of sand in from these littoral extremities and hence with its marshy, vegetation-dominated shores can not be the course of sand supply for the sparsely distributed dunes which lie west of the Pamlico shore and extend all the way across the coastal marshes and even into the waters of the Gulf of Mexico as at Cedar Keys and Horseshoe Beach. If these westernmost dunes have been supplied like all the others from the west and have no source of supply from the present shore and even extend into the Gulf of Mexico west of the present shore line, it would seem most probable that they were supplied by a post-Pamlico, pre-modern beach which was built at a sea level lower than the present one and was better supplied with sand than is the present shore. This would suggest that the present shore is a very young one indeed, for this earlier lower one should have been longer in existence in order that it might supply itself with sand by littoral drift.
to explain the nourishment of the dunes such as those that form Cedar Keys which now rise from the nearshore waters of the Gulf of Mexico and the present coastal marsh. However, subsidence may have been a strong factor in this region of soluble limestone and if it has been rapid it would vitiate the above speculations about beaches made at sea levels lower than the present one.

The drowned dunes on the West Coast of the peninsula may imply that there has been a lower-than-present stand of sea since the Silver Bluff shoreline was made. If this were not true these U-shaped dunes would plausibly have been destroyed by marine erosion or covered by marine sediment during Silver Bluff time. However, there is much in this region to suggest extensive solution and it may be that the surface on which these dunes were built has subsided from a former positive subaerial elevation to a present negative submarine one.

Since the dune fields obscure the Pamlico scarp north of Tarpon Springs they would seem to have been made during the time of a shore lower and later than Pamlico. Therefore the sand must have moved landward to cover the Pamlico scarp as climbing dunes and a southwest wind was apparently responsible for them rather than a northeast wind, thus they would seem to be big U-shaped dunes rather than barchans.

Dunes are apparently more voluminous in areas of former Gulf beaches than of former Atlantic beaches. The on-shore winds across west-facing beaches seem to produce the dunes but mainland shores of lagoons seem ineffective to produce many dunes. Only the oceanic shore has enough wave energy to make a beach that is able to supply enough sand to the wind to build dunes. The dunes built on the barriers apparently migrate into the lagoons and are destroyed by the wind which goes into an erosional phase for lack of sand. Possibly this explains the paradox of distribution of dunes on the west side of the peninsula. For they are more common (or perhaps more easily recognized) inland from the now beachless part of the west coast (north of Anclote Key) than farther south where the beaches are presently continuous between Anclote Key and Sanibel Island.

Where sand supply seems to have been scarce, as along the great coastal embayment of Suwannee Bight, north of Anclote Key, dunes tend to be isolated and individual. For this reason they are easily recognized both on the ground and on the topographic map as regularly oriented, curvilinear mounds of sand which contrast with the otherwise flat terrain. Farther inland however, where former beaches seem to have been more voluminously supplied with sand than is the present shore, the origin of sandy terrain is often obscure.
Surface sand is very common in Florida and there are several plausible ways to explain its presence. Choosing between them is often difficult. In the past the sand has usually been mapped as Pleistocene and it has tacitly been inferred that it was marine. However, its origins are probably various. It may be relict beach deposits, lagoon bottoms, dunes, or the result of erosion or of soil-forming process which has concentrated it from underlying Tertiary rocks which contain sand as Altschuler (1960) found. This last local source of sand by subaerial process probably increases in importance with the length of time the particular terrain has been emergent. Thus such sand should become more significant with elevation and should increase notably above the Wicomico shoreline. For pre-Wicomico denudation in extensive suggesting that areas which were not submerged by Wicomico seas have been subaerially exposed for a very much longer time than those which were submerged by Wicomico and younger sea levels.

The terrain resulting from these several processes has a number of attributes in common which tend to obscure origin. Thus, aeolian sands tend to make a terrain of hummocks and depressions without persistent ridges or valleys that have surface drainage, but so also does solution of carbonate rocks, and such rocks concealed beneath sand (and frequently other intervening materials as well) may be differentially affected by solution to produce sand-coated Karst which is difficulty distinguished from dune fields. No doubt I have occasionally confused them.

An unhappy coincidence accentuates this confusion in Florida. The dunes tend to produce ridges elongate in two mutually perpendicular directions. One parallel with the southwest wind, the other at right angles to it. And very similar results are produced in sand-blanketed Karst which seems to be controlled by two sets of bed rock fractures which have the same orientation as the dune ridges and flutings. These two sets of fractures have been discussed by Vernon (1951, p. 48 and fig. 1, and also elsewhere in this report).

Aeolian sand is probably much more common than is usually recognized. Our criteria for its recognition are derived from migrating bodies of sand. We recognize the land forms produced by such migrant accumulations of sand or when their internal structure has been exposed we recognize them by their characteristic cross bedding which results from their migrant behavior. Since such dunes move by erosion of the stoss slope and deposition or the slip face their internal structure usually comprises a series of steeply inclined forest beds which we look for as criteria of aeloian deposition.
However, such dunes and cross bedding can be produced only where aeolian sand is able to overwhelm the vegetation and build up into a migrating topographic mass.

Much wind blown sand in such well vegetated regions as Florida probably is not able to overwhelm the local vegetation and build such migrant dunes. Under natural conditions, before land was cleared, the only source of wind blown sand was the beaches, and immediately adjacent to them there commonly seem to have been well vegetated areas into which the sand could be blown. Although much of this vegetation may have been overwhelmed in building structurally or morphologically recognizable dunes, in other instances the vegetation may have been able to maintain itself while the sand trapped by it built up a non-migrant mass under continuous vegetal cover. Such a mass of sand would show neither the characteristic form of the migrant dune nor its characteristic cross bedding.

Beach ridges and dunes are probably so congenitally associated that it is frequently impossible to disassociate them and doubtless in this study many of each have been included in delineations of the other. They are sometimes confused even where they are not coeval; the dunes apparently having migrated onto relict beach ridges. Such problems of physiographic classification are very common in peninsular Florida for it has been repetitively passed over by the sea and has suffered subaerial denudation during the intervals between marine invasions.

The Pamlico shore (scarp) is dotted on Plate 1 where it traverses dunes on the west coast of the peninsula north of Tampa Bay because it is obscured to a considerable extent by the dunes.

**GULF BARRIER CHAIN AND LAGOONS**

On the west coast of the Florida Peninsula a barrier chain is found only between Anclote Key at the north and Naples at the south although what appears to be a degenerate relict of a barrier chain continues southward in the person of the Ten Thousand Islands and similar features along the north side of Florida Bay which are separated from the mainland by lagoon-like areas of more open water.

These barrier lagoon systems of the peninsular west coast differ from those of the east coast in that much of the sand which builds the barriers seems to have been locally derived by erosion of the headlands. The barriers seem to have developed in the fashion of the spits of winged headlands by erosion of the coastal prominences formed by the
divides between estuaries. They are integrate with the mainland at points midway between estuary mouths and separate farther and farther from the mainland toward their distal ends in such manner that the lagoons consistently widen toward their mouths and narrow toward their heads.

The most northerly barrier of the peninsular west coast is Anclote Keys which lies off the estuary of the Anclote River. There is a six mile gap in the chain between the south end of Anclote Keys and the north end of Caladesi Island, but from there to the mouth of Tampa Bay the chain is broken only by ordinary tidal inlets. St. Joseph Sound, between the barrier and the mainland narrows progressively in a southward direction past Clearwater Beach to its head at Indian Rocks where the barrier is in essential contact with the mainland, midway between Anclote River and the mouth of Tampa Bay (the estuary of the Hillsborough River).

A similar relation of barrier to mainland shore is seen farther south in the stretch of coast between Tampa Bay and Charlotte Harbor. There Sarasota Bay narrows southward through Roberts Bay and Little Sarasota Bay to its head near Venice where the barrier joins the mainland. Similarly a more or less continuous lagoon variously known in its different parts as Lemon Bay, Placida Harbor and Gasparilla Sound heads a short distance south of Venice and opens southward widening generally toward its mouth at Charlotte Harbor.

South of Charlotte Harbor and the Caloosahatchee estuary, Estero Bay narrows southward to its head near Naples where its enclosing barrier joins the mainland.

As discussed previously (White, 1941, pp. 58 and 59) this process of building spit-like barriers from headlands at the drainage divides seems to have been a habit of this part of the Gulf coast for some time. The lower parts of the Myakka and Braden Rivers in Charlotte, Sarasota and Manatee counties seem to follow relict lagoons which headed at the same divide that separates the lagoons described in the preceding paragraph. Similarly Lake Butler (Lake Tarpon) and Old Tampa Bay may occupy relict lagoons which were the counterparts of the present St. Joseph Sound and Boca Ciega Bay. The view from the air shows a nearly continuous line of lakes and swamps along this trend from the head of Old Tampa Bay at the south through Lake Tarpon and emerging on the coast a few miles south of Port Richey.

There are no barrier chains (and hence no lagoons) in the great coastal reentrant between Anclote Key and Bald Point at the west end of Apalachee Bay. Apparently this is because there is no sand supply
available in this part of the coast. South of Anclote Key the miocene
siliclastic rocks outcrop and afford a plentiful local source of sand for
building barriers. But north of Anclote Key soluble limestone outcrops
in the coastal zone and it does not seem to afford enough sand to build
beaches or barriers. Locally sand dunes occur as at Cedar Keys and
Horseshoe Beach. However, as discussed elsewhere in this report these
dunes seem to have been supplied with sand from a beach which existed
at a lower sea level, for some of them are based below present sea level
and appear now as islands. The source of the sand for this lower earlier
beach is obscure but it may have been transported by longshore
processes at a time when sea level had been stationary for a longer
period than it presently has; thus allowing more time for sand to be
transported along shore.

THE PROXIMAL OR NORTHERN ZONE
THE NORTHERN HIGHLANDS EAST OF THE
SUWANNEE RIVER

The Northern Highlands extend across the northern part of the
State of Florida from Trail Ridge on the east to the western boundary
where they extend into Alabama. To the north they extend into
Georgia and Alabama along the entire length of the northern boundary
of Florida west of Trail Ridge. They are limited on the south and east
by an outfacing scarp which extends regionally through the East Gulf
and Atlantic Coastal plains (Doering 1960, Figure 12). This scarp is the
most persistent topographic break in the State. Its continuity is
unbroken save by the valleys of major streams, but its definition is
variable. In many places it can be delineated with unequivical sharp-
ness; in others it is shown only by a gradual reduction of average
elevation and a general flattening of terrain as the lower elevations are
reached.

In general this bounding scarp can be divided into three parts that
are somewhat different in erosional history.

The Atlantic or eastern part of the scarp is the southern end of
what is perhaps the best known relict marine scarp of the Atlantic
Coastal Plain. It is the seaward or eastern side of Trail Ridge which is
described under that caption. The second part begins near Palatka
where the bounding scarp turns west to cross the peninsula. Here there
is little evidence of marine shoreline erosion although in places the
Wicomico sea may have reached the toe of the scarp as the shoreline of
straits and sounds (McNeil 1949, p. 103 and plate 19). This transpenin-
sular part of the scarp is much more irregular in plan than the first or relict Atlantic Coastal part. It seems largely to have been shaped by stream erosion and solution.

Farther west in the Florida panhandle is the third part of the scarp. Here, as in the first part, marine erosion seems to have been an important factor in shaping it. In general it is straighter here and has more definition than in the transpeninsular part. This third part lies outside the geographic scope of this report.

The Northern Highlands are separate from the several ridges of the Central Highlands of the Florida peninsula only because of greater dissection in the peninsula. Both Northern and Central Highlands appear to be remnants of a once integrate highland which has been partitioned by erosion and solution leaving a number of remnants in the peninsula to form the present ridges of the Central Highlands and a still intact mass at the north which is the Northern Highlands. Actually the division between the two is not prominent for the Northern Highlands are separated from the northern end of the Brooksville Ridge only by the High Springs Gap some 12 miles across; from the Fairfield Hills by the Alachua Lake Cross Valley about eight miles across; and from the Mount Dora Ridge by the Kenwood Gap also about eight miles wide. These gaps are in no way different from those farther south which separate the several parts of Ridges of the Central Highlands such as the Gap through which the Withlacoochee River flows at Dunnellon between the two parts of the Brooksville Ridge. All these highlands seem to be dissevered remnants of a once continuous residual highland.

The topographic character of the Northern Highlands east of the Suwannee River is various. In general the terrain is maturely dissected in a gentle rolling manner for some 10 to 15 miles back from the toe of the scarp zone. Maximal elevations are reached at the upper (northern) edge of this rougher peripheral zone as exemplified by the 150 to 200 foot elevations encountered along the route of the Seaboard Airline Railway and U.S. Highway 90 from Ellaville through Live Oak to Lake City. Northward from this crestal line the terrain flattens markedly and drops off very gradually northward toward Okefenokee swamp.

In the flatter undissected parts of the area toward the north, streams in general have little freeboard and flow in shallow channels essentially at the level of the surrounding terrain. In the dissected peripheral zone on the other hand the streams tend to be incised and with surprising frequency go underground into cavernous subteranean avenues as they approach the toe of the scarp.

Mr. W. D. Reves (personal communication) called my attention to such an apparent connection between Rose Creek which disappears
underground at Columbia City and the Itchatuucknee River which rises in springs of large discharge at the head of a five mile reentrant into the scarp. A longer stream which goes underground at Bass three miles north of Columbia City probably is also a subteranean contributor to the Itchatuucknee River.

A well known example of this disappearance of surface streams as they approach the toe of the scarp is the Santa Fe River which goes into a subteranean course at O'Leno State Park and emerges at the surface several miles down valley. This instance is somewhat different from that of the above-mentioned streams which seem to contribute to the Itchatuucknee River for they show no conspicuous abandoned surface channel between the point of disappearance and the point of reemergence. The Santa Fe River not only has a surface channel between the points of disappearance and reemergence but at times of freshet discharges water through it.

This disappearance of the Santa Fe River at O'Leno State Park occurs on an inactive flood plain into which the river is incising itself. A somewhat similar situation prevails on the Suwannee River in the vicinity of the scarp. At Ellaville it has a floodplain which is obviously inactive and must have been made during some earlier phase of the river's history, for the river is entrenched with limestone bedrock showing on both banks of the channel. Moreover, the flood plain is pocked with young sinks which suggest a lowered river level.

These inactive flood plains in the scarp zone assure that the scarp is not the product of the present cycle of stream erosion alone. They may have been made at a time when the streams were adjusted to a base level higher than the present one during a higher stand of sea level, possibly when the Wicomico sea was standing near the foot of the scarp. However, the incision of the streams below the level of these floodplains as well as their habit of going underground may result from a lowered piezometric surface or water table which in turn may have resulted from a retreat of the sea or merely from the enlarging of subteranean passages with the passage of time and the progress of solution. At any rate these observations suggest some considerable antiquity for this scarp just as the topographic complexities of the Lake Wales Ridge suggest it also has had a long history.

The tendency for streams to go underground in the lower part of the scarp zone is a dominant attribute of the drainage all the way from Gainesville to the Suwannee River. With the exception of the Suwannee River itself every stream which enters the scarp zone goes underground and emerges again in the process of crossing the scarp.
East of Gainesville and along the eastern bounding scarp all streams maintain surface discharge as they cross the scarp zone. None goes underground. This difference of drainage habit east and west of Gainesville seems to result from a capping by clays of the Hawthorn formation in the eastern part of the area, and exposure of soluble limestone in the western part. In the east the clays have confined artesian flow sufficiently to maintain a piezometric surface generally higher than the ground surface in the stream valleys and thereby have assured surface drainage in these valleys. West of Gainesville there is no such pressure-holding cap and the piezometric surface is lower than the valley floors in the more steeply sloping scarp zone. This allows the streams to go underground in the cavernous limestone.

The erosional scarp which bounds the Northern Highlands east of the Suwannee River seems to mark the retreating edge of a formerly more extensive high plain which sloped northward toward Okefenokee swamp. Where the divide was originally located, and how much farther south the northward slope extended are moot questions and deeply involved with the history of this higher surface of the coastal plain which is frequently referred to as the Okefenokee terrace. A hint of a former extensive land mass at this level or higher is suggested by certain peculiarities of the southern end of Trail Ridge.

TRAIL RIDGE

Trail Ridge is a relict littoral feature which crowns the eastern edge of the Northern Highlands. Its exact relation to the sea level which produced it is not wholly clear. It is commonly thought of as a relict barrier or spit which had a lagoon or sound to landward and the present Okefenokee swamp is considered to be the remnant of such an intra-coastal waterbody. (Fenneman, 1938, pp. 42, 43) suggested that it grew northward from islands that rose above the sea which covered the Sunderland terrace. He did not think it was anchored to the mainland at its northern end, apparently because it loses elevation and becomes indeterminate toward the north. For this reason apparently he thought it had been built by a northward drift of beach sand, a possibility which would seem small in the light of so much evidence that littoral drift is characteristically southward in this part of the Atlantic Coast. This is shown by the distal ends of capes which all extend southward. This same tendency is also seen in relict spits and capes which show the same tendency, as in the case of the southern ends of Lake Wales Ridge and Bombing Range Ridge described elsewhere in this report.
To me two genetic possibilities seem plausible; Trail Ridge was a barrier which extended more or less persistently between the mainland at the north and an island at the south or else it closed off the mouth of a broad bay the southern shore of which was somewhere in the zone of high ground into which has been cut the transpeninsular part of the southern bounding scarp of the Northern Highlands of Florida.

The fact that Trail Ridge is abruptly interrupted south of the Altamaha River seems unimportant for all features of the Atlantic coast are broadly breached by the major river valleys. This is well displayed on Doering’s (1960, figure 12) map.

The fact that Trail Ridge loses elevation northward is also of little significance when one notes (again beautifully displayed on Doering’s map) that it is part of an ancient relict shoreline scarp which varies widely in elevation throughout its length; both elevation of toe and elevation of crest.

In Florida, Trail Ridge loses its character as a relict barrier toward its southern end. It gains elevation, broadens into a more or less equidimensional highland, and becomes a karstic landscape dominated by multiform solution depressions many of which hold lakes as exemplified by the classic Interlachen sheet which has been widely used as an illustration of Karst in the teaching of map interpretation.

Moreover, the eastern slope of Trail Ridge, which is regarded as a relict offshore seaward slope, is offset to the east twice toward its southern end as it approaches this Karstic highland just described. From each of these offsets emerges a north-flowing coast-parallel stream which suggests that the offsets represent two relict spits which grew northward from the land mass at the south. The more northerly of these two relict spits is separated from Trail Ridge proper by the north-flowing Black Creek, the more southerly spit which is offset still farther to the east is separated from the karstic highland at the south by the north-flowing Ates Creek.

**FLORAHOME VALLEY**

Completely enclosed within the karstic southeastern part of the Northern Highlands along the Clay-Putnam county boundary line is a basin-like valley some 10 miles long and four miles wide. Its floor is much flatter than the surrounding terrain. Its origin is obscure but quite possibly it is a large solution valley. It has been named the Florahome Valley for the town of Florahome which is situated near its center.
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TOPOGRAPHIC MAP
of THE
MIAMI RIDGE
SHOWING
RELIET MANGROVE ISLANDS
AND
THE SILVER BLUFF BEACH RIDGE

PLATE 2
SOUTHEASTERN REGION of FLORIDA

RELI CT SHORELINE ARCS and MANGROVE ISLANDS

(NORTHERN PART)

PLATE 3 - A

EXPLANATION

- RE L I CT SHORELINE ARCS
  - > 25 FEET
  - 20 - 25 FEET
  - 15 - 20 FEET
  - 10 - 15 FEET
  - 5 - 10 FEET
  - 0 - 5 FEET

LETUCC E LAKE

HUGH TAYLOR BIRCH STATE PARK

FORT LAUDERDALE

BOCA RATON

DEERFIELD BEACH

POMPANO BEACH

BOYNT ON BEACH

DEL RAY BEACH

LANTANA

LAKE WORTH

MATCH LINE
SOUTHERN PART of the EASTERN VALLEY

INCREASING DESTRUCTION OF RELICT BEACH RIDGES WITH DISTANCE NORTHWARD.

EXPLANATION

- Elevations between 5-10 Feet
- 10-15 Feet
- 15-20 Feet
- 20-25 Feet
- 25-30 Feet
- 30-35 Feet
- 35-40 Feet
- Above 40 Feet

1 0 1 2 3 4 5 MILES

4-A. SOUTHERN PART OF THE EASTERN VALLEY SHOWING INCREASING DESTRUCTION OF RELICT BEACH RIDGES WITH DISTANCE NORTHWARD (NORTHERN PART)
The area at the southern end of the Eastern Valley is shown in this insert at a larger scale than the rest of the map. It lies in broad flat divide area between the head of the St. Johns River to the north and the Everglades in the south. In this area there has been less reduction of the relict beach ridges and they complicate the pattern of many parallel patches of land whose elevation exceeds the 30-foot contour line establishing a larger scale map. Throughout much of the area covered by this insert map the relict beach ridges are shown by the configuration of many parallel patches of land whose elevation exceeds the 30-foot contour line by less than 5 feet. Elsewhere no contour intersects the surface. In such places the swales between beach-ridges have been shown by the elongate parallel areas of swamp they characteristically hold.

EXPLANATION for INSERT:

- Elevations between 25-30 Feet
- 30-35 Feet
- 35-40 Feet
- Above 40 Feet
  - Swamp Area

For this area see insert

4-B. SOUTHERN PART OF THE EASTERN VALLEY SHOWING INCREASING DESTRUCTION OF RELICT BEACH RIDGES WITH DISTANCE NORTHWARD (SOUTHERN PART)