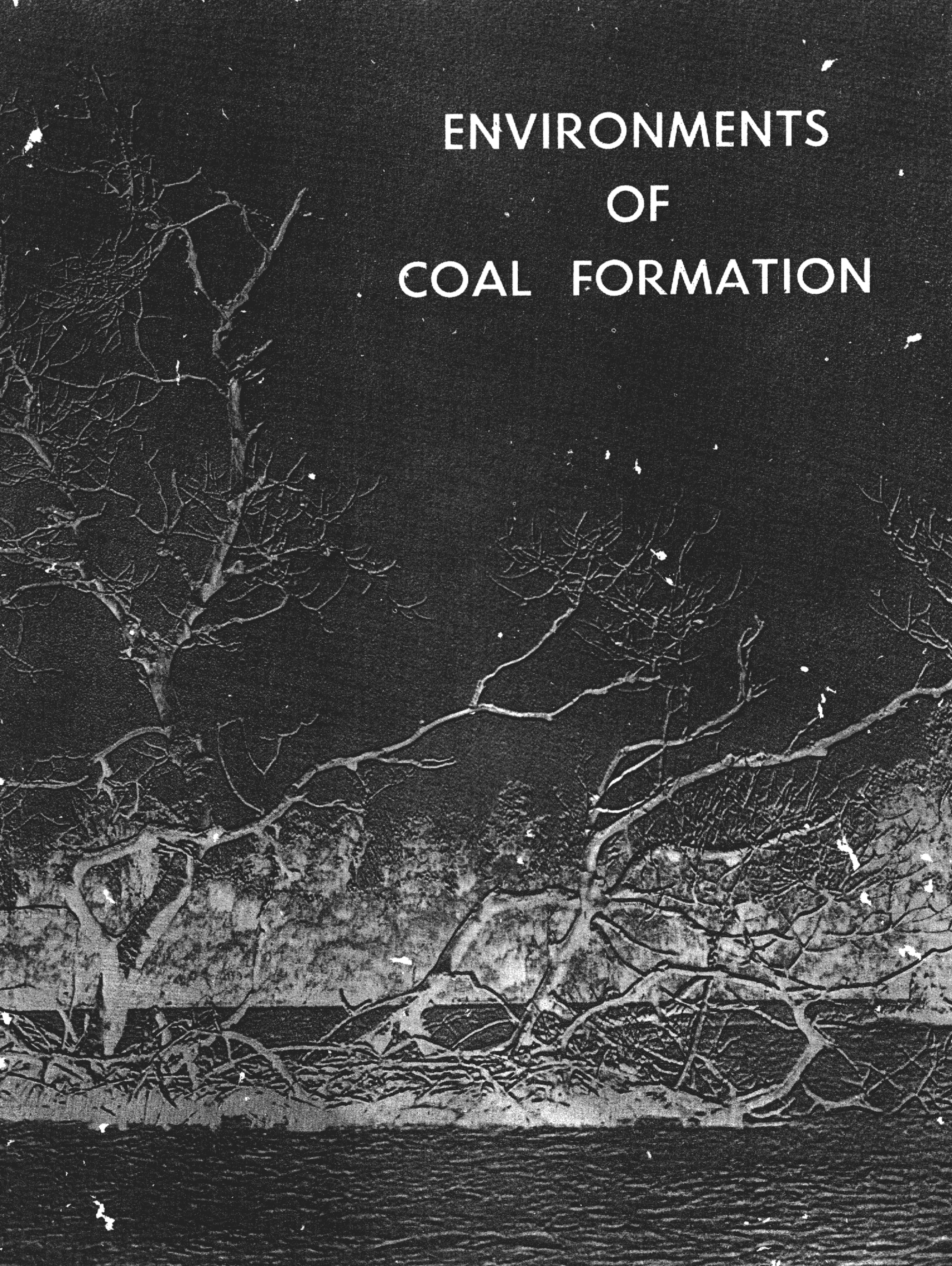
ENVIRONMENTS OF COAL FORMATION



FIELD GUIDEBOOK

to

ENVIRONMENTS OF COAL FORMATION IN SOUTHERN FLORIDA

Trip Leaders

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ENVIRONMENTS OF COAL FORMATION
IN
SOUTHERN FLORIDA

INTRODUCTION*

Accurate interpretation of the ecological significance of geologically ancient sediments has been inhibited in many areas by a lack of detailed information on the relationships between sediment type and depositional environment. Recognition of this fact has led to the recent increased effort devoted to the study of "modern sediments" and has stimulated publication of data on a variety of sediment types. The Proceedings of the First National Coastal and Shallow Water Research Conference provide an insight into the scope of these research efforts (Gorsline, 1962).

In spite of this increased interest in recent sediments, few investigators have focused their studies on the plant derived deposits that represent the progenitors of coal seams. There are exceptions to this including geochemical studies (e.g. Swain, Blumentals and Miller, 1959), geological studies as represented by that of Fisk (1960), palynological studies of investigators motivated by the needs of the oil industry as exemplified by the work of Kuyl, Muller and Waterbolk (1955) and those motivated by interests in post-glacial climatic and vegetational history (e.g. Dansereau and Segados - Vianna, 1952; Potzger, 1953). Even with the data provided by these and similar studies, it remains difficult, if not impossible, to attach an accurate paleoecological description to

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* Portions of this Guidebook are taken from Spackman, W., C.P. Dolsen and W. Riegel, Phytogenic Organic Sediments and Sedimentary Environments in the Everglades-Mangrove Complex, Part I: Effects of the Transgressing Sea on Environments of the Shark River Area of Southwestern Florida. (Accepted by Paleontographica for publication in 1965.)

the individual lithobodies that compose coal seams of Tertiary and older strata. This not only minimizes the amount of ecological information to be derived from the study of the coal seam, but it also confounds attempts to correlate seams. Detailed stratigraphic and paleogeographic reconstructions are also difficult to develop because of a lack of knowledge on the botanical and geological significance of the lithotypes encountered in the coals of coal measure sequences.

The Atlantic and Gulf Coastal Palins of eastern United States contain a variety of swamp and marsh environments in which the progenitors of coal substances are forming. These include the Dismal Swamp region of Virginia and North Carolina, the Okefenokee Swamp of southern Georgia, the inland swamps and related lakes and marshes of central and north-central peninsular Florida, and the river swamps of the Florida panhandle. Each of these areas appears to possess the potential of yielding information useful in interpreting the significance of Tertiary coal sequences. The panhandle river swamps contain a remarkable number of the floristic elements represented in such deposits as the mid-Tertiary Brandon Lignite (see Barghoorn and Spackman, 1950). In certain environments in Okefenokee Swamp the peat appears remarkably similar to many of the European brown coals in color, texture and phyteral content. If a mass of this material were to be dehydrated it would be difficult to differentiate it from a "woody" brown coal. The geologic settings associated with the Okefenokee area and with the deltaic river swamps render these comparable to many of the swamps that contributed to the development of at least some of the Tertiary coal sequences. The numerous and varied environments in central and north-central Florida can provide much information that will prove critical in recognizing certain of the more uncommon coal types. The sapropel deposit and underlying 30 feet of peat in Mud Lake near Ocala, Florida and the woody, fibrous and amorphous peats of the Lake Isotokpoga area are of particular significance in this connection.

However, the vast Everglades, occupying much of peninsular Florida from Lake Okeechobee southward, are also of considerable importance in view of the apparent significance of these environments in such brown coal sequences as those of Germany (Thomson, 1950; Teichmuller, 1958).

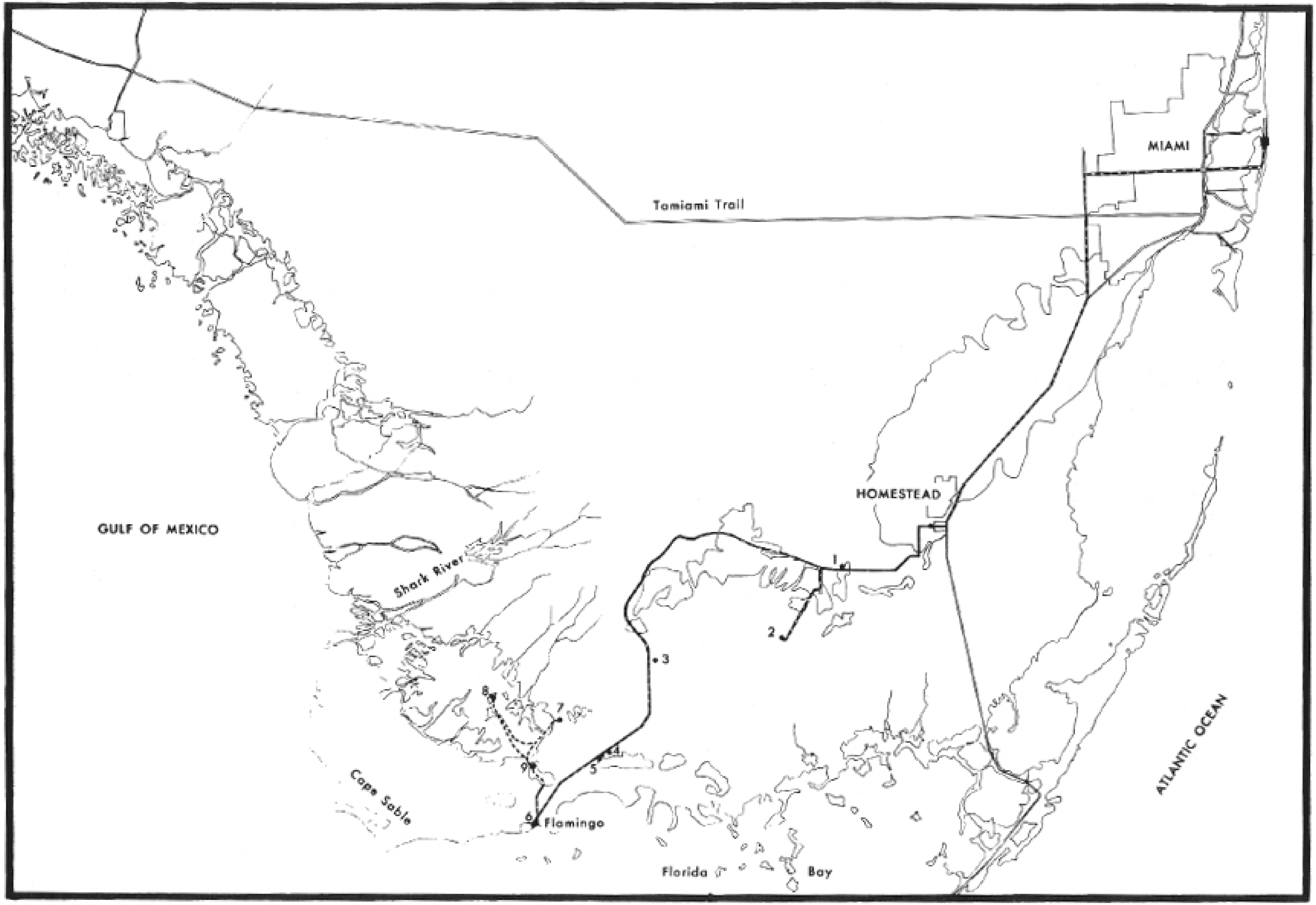
In southernmost Florida this Everglades area is fringed by a mangrove forest that attains its best development on the southwestern coast in the vicinity of the Shark River. Because this southwestern sector of Florida is now a National Park, it has been modified by agricultural practices to a lesser degree than the area between the Tamiami Trail and Lake Okeechobee. Inspection of the National Park area will make evident that (1) the plant communities involved are relatively simple in composition and comparatively few in number, (2) several environments are rather readily recognized and environmental boundaries appear sharp as opposed to gradational, and (3) six to fifteen feet of peat can be found beneath the mangroves, the saw grass of the Everglades and the "hammocks" or "heads" that occur as "tree islands" in the open saw grass sea. It can be argued that the limestone substratum upon which the peat lies and the general geologic setting render these sites unlike those commonly represented in coal measure sequences. This is true to a certain extent, for it is difficult, to say the least, to envision how an underclay could develop beneath these peats. However, it is probable that the influence of the sub-peat strata becomes less and less significant as the swamp plants find themselves rooted in peat alone. Moreover, the conditions present in this region make it possible to compare similar environments and peats as they have developed on substrata composed of different mineralogical composition and to examine the effects of burial beneath a cover of quartz sand on the one hand and marine or fresh-water marl on the other. Nevertheless, until it is shown that the limitations imposed by the dynamic geologic history of peninsular Florida are insignificant, it must be emphasized that the data presented may have meaning only for the particular types of geologic setting involved as opposed to being generally applicable.

ROUTE FOR THE FIRST DAY

(Trip Map No. 1)

Starting Point: Visitor's Center at Entrance to Everglades National Park

Mileage	Description
0.0	STOP 1: ORIENTATION AND REST STOP at Visitor's Center, Everglades National Park. Leave bus and gather in Main Lobby of Visitor's Center. Rest Rooms are at south end of building.
0.0 - 2.2	Leave Stop 1 and proceed westward on road to Flamingo. The presence of pines is an indication that this area is comparatively high ground and that bedrock is near the surface. The open areas provide an opportunity to get an initial impression of the "Everglades". A "slough" area where surface water flows southward "through" Long Pine Key will be represented at the road by a small open water area.
2.2	Leave main Park road to Flamingo, turn left on road to Royal Palm Hammock.
2.2 - 3.0	Proceed south on road to Royal Palm Hammock to intersection with Old Flamingo Road.
3.0	Leave Royal Palm Hammock Road by turning right onto Old Flamingo Road.
3.0 - 8.3	Follow Old Flamingo Road to "Cypress Head". This road will carry you outside the National Park boundary in places, hence, evidences of agricultural practice will be noted. As a weed tree along the roadside one will find poisonwood [*Metopium toxiferum* (L.)] in abundance. The sap , juice from the fruits and leaf fluids are all powerful skin poisons, many times more potent than poison ivy. It is useful to learn to recognize this tree and avoid it. The canal along the road was constructed as a private enterprise for


MIAMI
Tamiami Trail
HOMESTEAD
GULF OF MEXICO
Shark River
1
2
3
4
5
6
7
8
9
Flamingo
Cape Sable
Florida
Bay
ATLANTIC OCEAN

TRIP MAP NO. 1

navigational purposes. The intent was to use it as an avenue through the swamp that would permit transportation of produce from Cape Sable to the Miami area. The dream failed to bear fruit.

8.3 STOP 2: CYPRESS HEAD. This is the first field stop. A discussion of the objectives of visiting this site is presented on pages 14 to 20 , together with factual information relating to the site.

8.3 - 13.6 Return to Royal Palm Hammock Road.

13.6 Leave Old Flamingo Road by turning left onto Royal Palm Hammock Road.

13.6 - 14.4 Proceed north on Royal Palm Hammock Road to new Flamingo Road.

14.4 Leave Royal Palm Hammock road by turning left on the "new road" to Flamingo (the main highway in the Everglades National Park).

14.4 - 23.7 Proceed west and south on the Flamingo Road. Through the first segment of this unit of travel you will be moving in, or adjacent to, pineland areas. These constitute visible evidence of the western extension of the Miami Rock Rim. Forested areas in the open Everglades are sometimes called "Everglades Keys", hence, this pineland, which is elongate in an east-west direction is known as Long Pine Key. The road flanks the northern and western margin of Long Pine Key for reasons that were important to the road builder, but for our purposes it would have been more useful to have the road constructed well away from this area in which the bedrock is essentially at the surface.

Except when passing through a pineland area, the open Everglades will be seen on the right side of the road. The view is not quite typical because you will be travelling in the transition zone between the "highlands" of the Miami Rock Rim and the "lowlands" of the peat-forming Everglades.

23.7 Pass over a "rock reef". These are conspicuous linear features found in this area of the Everglades. They are low, narrow, ridges in which the bedrock is at, or near, the surface. Their elevation above the surrounding area (a few inches) permits the growth of shrubby and arborescent vegetation. Although referred to as "reefs", the authors are unaware of any published evidence justifying the use of this term.

The pitted nature of the bedrock surface in this area is well illustrated by exposures on the northeast side of the rock reef. This can be observed from the roadside.

23.7 - 27.7 Just beyond the reef a large number of stunted cypress trees may be observed in the open saw grass areas. These display the typical Taxodium ascendens Brogn. growth form with their leaves closely appressed to the twigs. Although living under adverse conditions, they have successfully colonized the open Marshland.

27.7 - 35.7 Continue along main Park highway. The spur road entering the main road on the right will be the road leading to Pay-Hay-Okee Lookout. A low observation tower has been constructed at Pay-Hay-Okee for visitor use. A fair view of the saw grass marsh is available from this Lookout.

35.7 The incipient cypress hammock on the right side of the road is one illustrated as Figure 11b.

35.7 - 36.4 Continue along main Park highway.

38.4 Turn left on side road to water pumping station.

STOP 3: BAY HEAD. This is the second field site to be visited. A discussion of the objectives of making this stop is presented on pages 20 to 24.

38.4 - 39.5 Return to main Park Highway and continue south.

39.5 On the right is a small hammock ringed with saw-palmetto. This is the hammock shown as a sectional profile in Figure 11a.

39.5 - 41.0 Continue along main Park Highway.

41.0 The water is now too brackish for the cypress. The red mangrove appears to be colonizing this open marshland as did the cypress in the "Rock Reef" area. This brackish water zone is readily recognized from the roadside, not only by virtue of the loss of the cypress and the occurrence of the small mangroves, but by the presence of a distinctive palm as one of the members of the hammock communities. The Paurotis palm (*Paurotis wrightii*) seems to flourish in this vicinity in a rather narrow belt in the brackish water area. It is easily recognized by its slender stems that hold the clusters of leaves and brownish red fruits above the other trees at the hammock margins.

41.0 - 46.4 Continue south on main Park Highway. Within about a half-mile the mangroves will begin to dominate the scene. They will become less shrubby and begin to form the mangrove forest swamp. Hammocks that have been engulfed by the inland march of the mangroves will be detectable on both sides of the road.

46.4 STOP 4: SAW GRASS SITE. The objectives to be attained at this site are discussed on pages 24 to 27.

46.4 - 47.7 Continue south on main Park Highway. (One has little choice.)

47.7 **STOP 5: WEST LAKE - LUNCH**

Box lunches will be provided. Toilet facilities are available in the small building. For those finishing lunch early, a "mangrove trail" leads off from the parking area. It provides an opportunity to see some of the features of this brackish water mangrove environment. Recent hurricane damage has modified the area, however.

47.7 - 51.5 Proceed south on main Park Highway. Evidence of recent hurricanes will become more conspicuous. Paurotis palms will disappear but occasionally a hammock will be discernible in the now dense mangrove cover.

51.5 Coot Bay Pond - formerly the site of one of the National Park Ranger Stations, now the home of one or two alligators. This is a natural pond and is an example of one type of open water environment in the mangrove swamp.

51.5 - 54.1 Continue south on main Park Highway. The effects of Hurricane Donna (1961) will be particularly evident after about one mile of travel. The canal we will cross is the one to be used in order to have access to the more remote portions of the swamps and marshes.

54.1 **STOP 6: FLAMINGO MARINA.** Leave bus and board waiting boats. Take with you only those things that you must have (guidebook, notebook, camera, etc.). Your tagged baggage will be delivered from this point to your motel room while you are aboard the boat. The bus will return to Miami before we return from the afternoon's trip so be sure all articles left on the bus are tagged or labelled. Board the boats carefully with both hands unencumbered by personal effects. Put the latter on the pier or hand them to someone in the boat before attempting to board. Be alert to the possibility of losing articles (e.g. glasses) from unbuttoned shirt pockets. During the afternoon, toilet facilities, first aid equipment, sunburn lotion, sample cans, etc. will be available on the Pearson Express Cruiser. Notify your pilot if you wish to have him alter his course.

54.1 - 57.3 Proceed north in Buttonwood Canal to Channel Marker No. 2 in Coot Bay. A "marl prairie" covers much of the area around Flamingo. No peat is present at the surface in this area. At the point of entry of the Homestead Canal, note color of water that is moving into Buttonwood Canal.

57.3 - 59.5 Alter course and follow channel markers northwestward to Tarpon Creek.

59.5 - 60.2 Proceed through Tarpon Creek to Channel Marker No. 10 in Whitewater Bay.

60.2 At Channel Marker No. 10 alter course to a 30° heading for 2.4 miles. This is the southeastern section of a sizeable open water environment known as Whitewater Bay. The forest bordering the open water is composed of red mangrove trees with little else in evidence.

62.6 Alter course to 74°.

62.6 - 63.7 Proceed on a 74° heading for 1.1 miles. Note that the elongate island to the west has been dissected into two segments.

63.7 - 64.5 Employ navigational chart (C. and G.S. 599) or aerial photographs to enter mouth of East River and proceed to entry to first, elongate, N-S trending Mangrove Pond.

64.5 - 64.6 Alter course to 180° and proceed into Mangrove Pond. Raise engines and pole or paddle after entering pond.

64.6	<u>STOP</u> <u>7</u>: MANGROVE POND. Bring boats alongside one another and secure using halter lines. See pages 27 to 30 for a discussion of the significance of this site.
64.6 - 69.2	Return to Channel Marker No. 10 via course just traversed.
69.2	At Channel Marker No. 10 alter course to 345°.
69.2 - 74.0	Proceed on 345° heading to Channel Marker No. 14, then alter course to 315° and follow channel markers to Marker No. 23.
74.0	Alter course to 7°.
74.0 - 74.6	Proceed on 7° heading to newly developed water pass near the north end of North Midway Key.
74.6	<u>STOP</u> <u>8</u>: MIDWAY KEY (Island Mangrove Environment) This water pass represents a recent breaching of North Midway Key, producing two separate islands. Pages 30 - 31 describe some of the facts that pertain to this and related sites.
74.6 - 75.1	Adopt a heading of 187° and proceed to Channel Marker No. 23.
75.1	Alter course to 135°.
75.1 - 80.4	Proceed on headings required by channel markers and return to Channel Marker No. 8 at northwestern end of Coot Bay.
80.4 - 80.5	At Channel Marker No. 8 alter course to 40° and proceed 0.1 mile.
80.5	<u>STOP</u> <u>9</u>: TARPON CREEK SITE. Data obtained from the study of the onshore sediments in this area will be presented if time permits. See discussion on pages 31 to 32.
80.5 - 80.6	Return to Channel Marker No. 8
80.6 - 85.1	At Channel Marker No. 8 alter course and follow channel to Flamingo.

85.1 FLAMINGO MARINA - FIRST DAY'S TERMINATION STOP.

Leave boats and proceed on foot to motel. Obtain key to your room from "Housing Aide". Time of dinner and evening program to be announced.

SITES TO BE VISITED ON FIRST DAY

STOP 1: Visitor's Center, Everglades National Park.

Objectives of Stop:

A. Presentation of geological and botanical setting in which the field trip will take place.

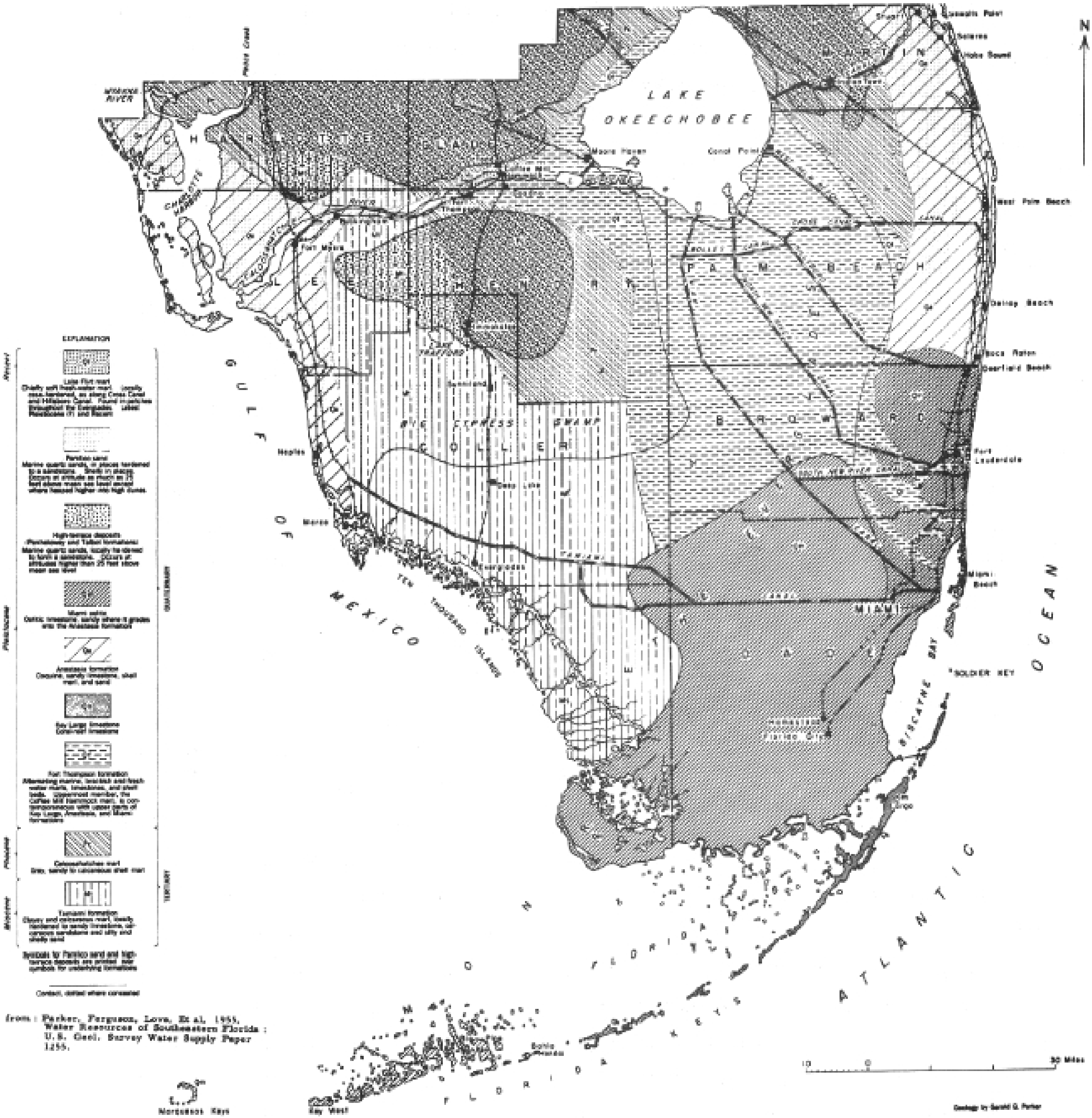
B. Orientation for first day's travel.

C. Rest Stop.

Discussion:

The Florida peninsula has been described as the emergent portion of a much larger extension of continental North America that is known as the Floridian Plateau (Vaughan, 1910; Parker and Cooke, 1944). Along the east coast of Florida, the Plateau extends only a few miles into the Atlantic Ocean. Along the west coast the Plateau extends for many miles under the Gulf of Mexico, hence, it is only a sector of the eastern portion of the Plateau that is above sea level at the present time. Tertiary and Quaternary formations compose the sub-surface strata in southern Florida (see Figure 1). The Eocene Ocala limestone crops out in central Florida and all overlying strata dip gently away from this area to the west, south and east (Parker and Cooke, 1944; Jones, et al., 1948). In the field trip area (see Trip Map No. 1) the northwest section is said to be underlain by the Miocene Tamiami formation and in the remainder of the area this rock unit is unconformably overlain by the Pleistocene Miami oolite (Parker, Ferguson, Love, et al., 1955). The boundary between these two rock units is represented as being more or less coincident with the course of the Shark River.

The Miami oolite is a soft, marine limestone that varies from relatively pure calcium carbonate to a sandy limestone. In some areas it



from: Parker, Ferguson, Love, Et al. 1955, Water Resources of Southeastern Florida: U.S. Geol. Survey Water Supply Paper 1255.

GEOLOGIC MAP OF SOUTHERN FLORIDA

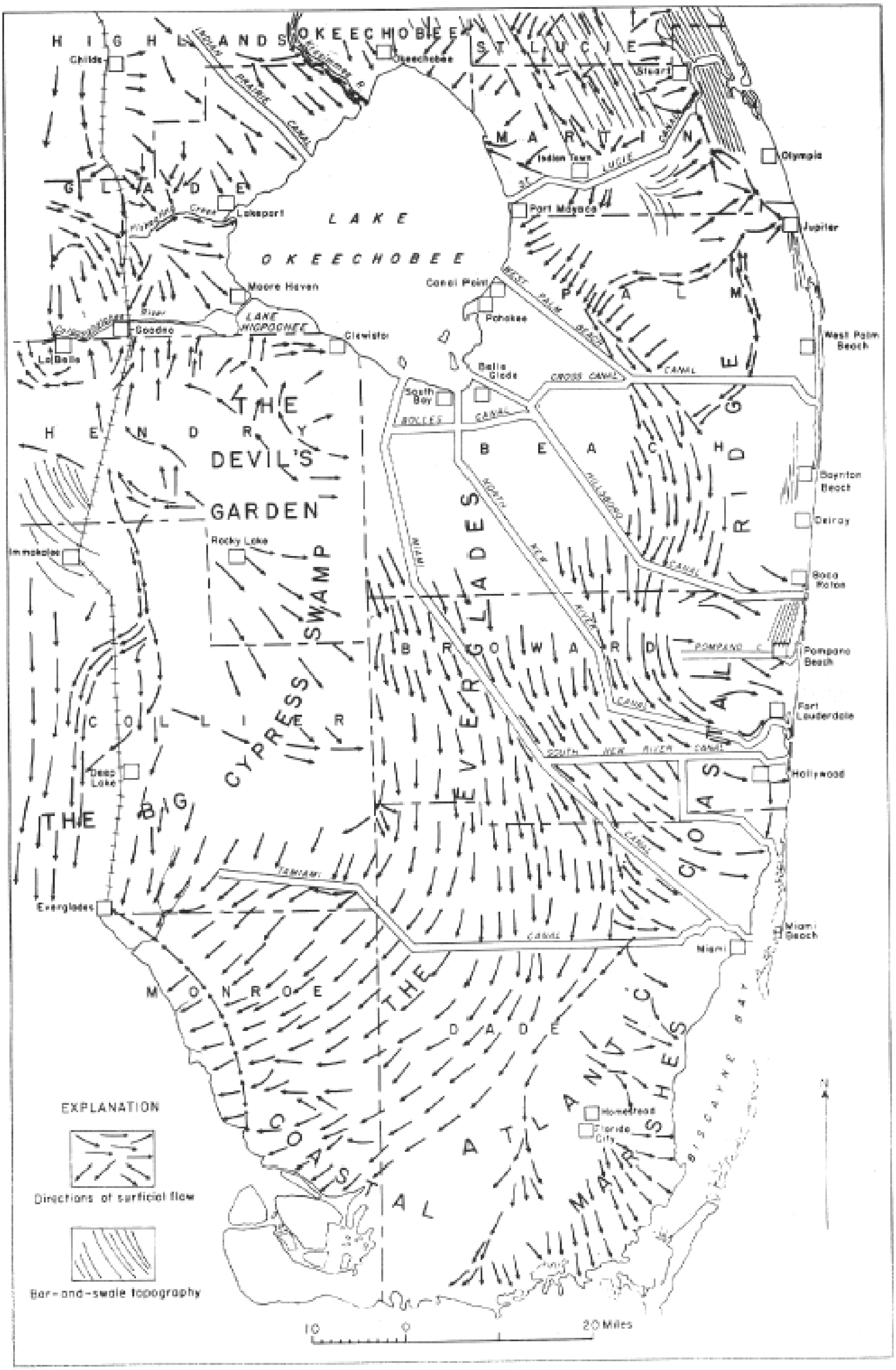
FIGURE 1

contains steeply dipping cross-bedded units that are truncated by shelly layers. In other areas it is massive and oolitic. The Tamiami formation is a calcareous sandstone or sandy limestone containing beds and pockets of quartz and sand (see Parker and Cooke 1944 and Parker, Ferguson, Love et al., 1955).

Topographically, southern Florida exhibits little relief. In the area south of Lake Okeechobee the surface is fifteen to thirty feet above sea level and it slopes gently to the south. The southward flowing drainage tends to be contained on the east by the slightly elevated Atlantic Coastal Ridge and on the west by the high land (10-15 feet) on which the Big Cypress Swamp is developed. In the broad expanse of some 4000 square miles between these two topographic highs, the Everglades attain their best development as a vast "river of grass". Near the southern tip of Florida the Atlantic Coastal Ridge swings inland and diverts the drainage to the southwest. Thus, in the field trip area, the surficial drainage is from the northeast (Figure 2). Topographically the subject area is generally less than one foot above sea level with a maximum height of five feet in Royal Palm Hammock.

In spite of its subdued character, the topography of south Florida plays a major role in determining the nature of the vegetative cover. The effect of topography is modified by the impact of overland flow of water from Lake Okeechobee southward and by the inland flow of tidal water along the coast. These three aspects of the physical environment appear to exert the major control over the distribution of the various plant communities.

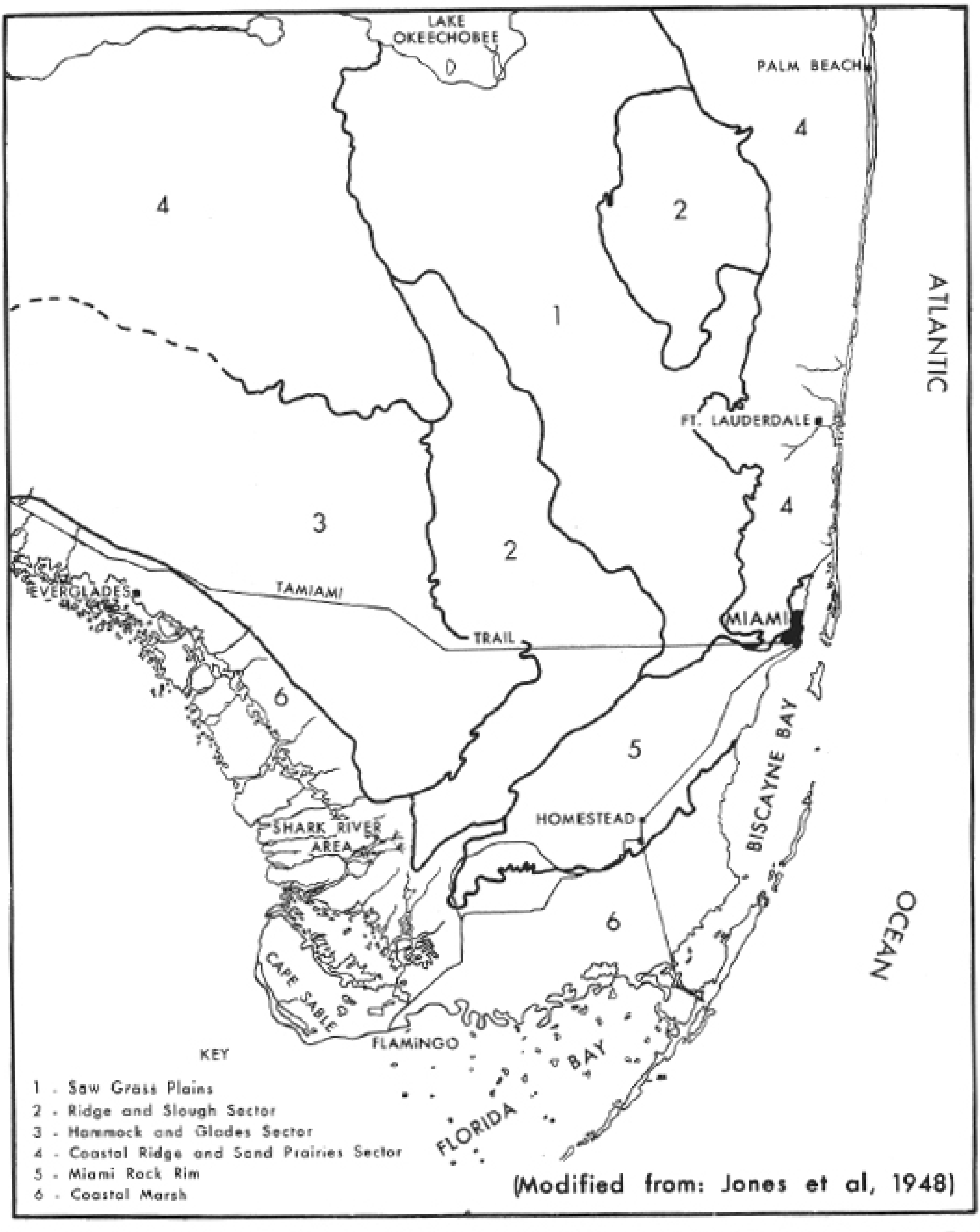
Jones et al. (1948) suggested that the area south of Lake Okeechobee consisted of six physiographic divisions: (1) the saw grass plains, (2) the ridge and slough sector, (3) the hammock and glades sector, (4) the coastal ridge and sand prairies sector, (5) the Miami rock rim, and (6) the coastal marsh. A slightly modified version of his "physiographic map" is presented as Figure 3. The vegetation associated with each of these areas has been described by Jones et al. (op. cit.),by Davis (1940, 1943), and more recently by Loveless (1959). From these descriptions it is clear that the plant communities involved vary from almost pure stands of single species to complex sub-tropical forests. Only four of the aforementioned physiographic units occur in the field trip area. These are the so-called



MAP OF SOUTHEASTERN FLORIDA, SHOWING DIRECTIONS OF SURFICIAL DRAINAGE AND TRENDS OF BAR-AND-SWALE TOPOGRAPHY

(Taken from U.S.G.S. Water Supply Paper 1255)

FIGURE 2



PHYSIOGRAPHIC DIVISIONS OF THE EVERGLADES REGION
Figure 3

Coastal Marsh, the Hammock and Glades, the Ridge and Slough and the Miami Rock Rim. The "Coastal Marsh" is covered in much of the area by a well-developed mangrove forest. The Hammock and Glades and the Ridge and Slough are covered by a sedge marsh that is interrupted by "hammocks", "heads" or "tree islands" as they are variously called. These hammocks are covered either by cypress or by some hardwood complex. The western segments of the Miami Rock Rim are usually known as "Everglades Keys" and are commonly covered with a pine forest or by a hardwood-palm complex. As will be shown later, each of these areas includes several environments, each with its own distinctive vegetation but for present purposes it is sufficient to recognize that the coastal area in the vicinity of the Shark River is occupied by a mangrove forest that forms a continuous coastal fringe. This forest extends inland for eighteen or more miles along the water courses. In back of the mangrove fringe in this area is the remarkably different saw grass plain with its hammocks breaking the otherwise herbaceous cover and with the occasional pineland where the higher ground of the Miami Rock Rim invades the area.

The mangrove forest is well developed all along the southwestern coast of Florida but is particularly luxurious near the vicinity of Ponce de Leon Bay at the mouth of the Shark River. Here the red mangrove (Rhizophora mangle L.) and the black mangrove (Avicennia nitida Jacq.) are almost the sole constituents of the plant communities. They form dense stands of tall trees covering the mainland coast and the numerous coastal islands (Plate Ia). In contrast, the headwaters of the Shark River rise in the saw grass plains in a totally different environment, as shown in Plate Ib.

The headwater channels of the Shark River leave the open Everglades about 17 miles from the Gulf coast. Most of the "saw grass plain" in this area is dominated by Mariscus jamaicensis (Crantz) Britton, but locally this is displaced by concentrations of Eleocharis spp., Juncus spp., or Scirpus spp. "Tree islands" are as numerous and as well developed in the headwaters area as they are in the inland sectors of this vast "sea of grass".

a

VIEW OF THE MATURE MANGROVE FOREST
NEAR THE MOUTH OF THE SHARK RIVER

b

SAW GRASS COVERED EVERGLADES SHOWING
SEVERAL HAMMOCKS OR "TREE ISLANDS"

PLATE I

STOP 2: Cypress Head

Objectives:

A. Inspection of typical cypress hammock, cypress surface litter and cypress hammock peat.

B. Discussion of hammock types, hammock origin and hammock maintenance.

C. Inspection of "algal mat" in the open marsh and discussion of its possible role in the development of sediments.

D. Discussion of element concentration and palynology of cypress hammock peat.

Discussion:

The "Everglades" region of southern Florida occupies an area of at least two and one-half million acres. Prior to institution of extensive drainage programs in the 1930's and 1940's, most of this area was under water for a large part of the year. As the result of the construction of drainage canals, hundreds of thousands of acres south of Lake Okeechobee have been "reclaimed" for agricultural purposes.

The Everglades consist of herb covered marshes and forested swamps with the marsh environments occupying the greater area. Typically they consist of a "saw grass" plain in which a sedge (Mariscus) rather than a true grass dominates the environment. Usually this sedge is so abundant that casual inspection leaves one with the impression that it is the only plant species present in the open marsh. This saw grass plain is interrupted by the presence of relatively small forested areas that are usually either elliptical, round, or tear-drop shape in plan. These are often called "tree islands" because they appear to be island-like masses in the open marsh. They are also referred to as "heads", presumably because of the dome-shaped profile that some of them exhibit. The term "hammock" is also applied to them; this word is of obscure origin but probably is simply a variation of "hummock", the latter being of unknown derivation and meaning a low ridge, mound, or pile of material. Although they may begin in small depressions, the tree islands soon develop into "low mounds" of peat. If the hammock site was initially a bedrock high, the "low mound" may be formed largely of humus. By virtue of their elevation, the hammocks represent environments in which hardwood tree species can successfully compete with the sedges that dominate the slightly lower adjacent areas. In favorable sites the arborescent hammock cover develops into a complex plant community in which the gumbo limbo (Bursera simaruba L.), royal palm [Roystonea regia (H.B.K.) O.F. Cook], mahogany (Swietenia mahogani Jacq.), strangler fig (Ficus aurea, Nutt.) and other "dry" habitat species flourish. Some of the larger and higher hammocks support a particularly complex, sub-tropical vegetation and it has been suggested that the term "hammock" be restricted for use in describing such sites. For present purposes, it will be more useful to regard all small, isolated areas of arborescent or shrubby vegetation that are surrounded by saw grass marsh or its equivalent as "hammocks". These appear to pass through several developmental stages, if undistrubed, and ultimately result in the development of the complex forest that is the successional climax under the present climatic regime.

Plates I and II show the hammock - marsh relationship, the latter plate showing a "young" hammock that has reached the "bay head" stage of development and that has been modified vegetationally as the result of fire. The latter is evident from the abundance of saw palmetto [Serenoa repens (Bartr.)Small] which is said to be a fire-resistant species.

In the area surrounding Stop 1, the hammocks tend to have a tear-drop shape with a truncated leading margin. The environments present are represented in Figure 4. Most of the hammocks in this vicinity are in what might be termed a "late cypress" stage of development. They appear to have developed beyond the stage in which cypress is the only tree species present and now include a number of hardwood species, notably the coco plum (Chrysobalanus icacao L.) and pond apple (Annona glabra L.). Typically the hardwoods take root on the mounds created by old cypress stumps. As more and more organic material accumulates on the hammock floor, the area of open water is gradually diminished and hardwood seedlings begin to develop in areas unassociated with cypress stumps. Gradually the cypress is eliminated from the central areas of the hammock and flourishes only on the perimeter where an open water site is still

PLATE II

HAMMOCKS

MARSH

HAMMOCK SWALE

CYPRESS SLOUGH

MAP OF ENVIRONMENTS IN THE CYPRESS HEAD AREA

Figure 4

available. Thus, the cypress hammock develops into a tree island covered with a mixed hardwood vegetation often dominated by "bay" trees and hence, called a "bay head".

The origin of the hammocks in the Everglades has never been satisfactorily explained. Even more difficult to understand is the mechanism that has served to restrict their size and shape. It has been suggested that fire creates a site suitable for the initial development of a hammock by killing the saw grass but leaving little clumps or hummocks on which the arborescent species can root and grow before the saw grass repopulates the site. Frequent fires have also been suggested as the mechanism for maintaining the hammocks as comparatively small "islands". Presumably this would be accomplished either by the complete destruction of the hammocks prior to their achieving any appreciable size or by restricting their expansion by frequent partial burning.

Some hammocks appear to develop on areas in which the bedrock forms a topographic high, some appear to have been developed in areas in which the bedrock surface was topographically low, and still others seem to bear no particular relationship to the topography of the bedrock. It might be argued that this suggests a "chance" origin, as the result of the successful germination of hardwood seeds on randomly located sites. Some may, in fact, have originated in this manner, but most hammocks thus far inspected show evidence of origin on either a topographically low or high site. Both of these conditions create situations in which the saw grass is no longer the most effective competitor. In the "deep" water sites the cypress can colonize the area and initiate hammock development. In the "dry" sites the hardwoods can immediately occupy the area and initiate hammock formation.

With respect to vegetative cover, several different hammock classes exist. Although certain of these grade compositionally into one another, it is useful to consider each as a hammock "type". The more important types are:

1. The Cypress Hammock
2. The Bay Tree Hammock
3. The Mahogany Hammock

4. The Palm Hammock
5. The Shrub Coppice Hammock

The shape of the hammocks appears to be influenced by the direction and rate of surficial water flow. The circular form is most common in areas characterized by low rates of surface water flow and the elongate forms seem to be restricted to the "slough" areas where surface flow is great. The truncation of the more northerly ends of many of the hammocks in the area of Stop 2 is, at the moment, unexplained.

The hammock at Stop 2 exhibits the dome-shaped profile that some of the cypress heads show when viewed from a particular angle (see Plate III). This is presumably related to the age of the trees and the center of origin of the hammock. The cypress common in this area has been designated pond cypress (Taxodium ascendens Brong.) by some authors. This species is said to differ from the bald cypress (Taxodium distichum) in that the leaves are borne appressed to the stem axis as opposed to being borne in a plane with each leaf projecting out from the axis at a more or less right angle. It is also said to be smaller and to possess a smoother bark. Examination of a few of the trees near the margin of the hammock is likely to reveal the presence of both types of leaf arrangement, suggesting the presence of both species. Further inspection may reveal both types of leaf arrangement on the same plant. This could represent hybridization, however, most of the botanists who have observed this situation have concluded that the cypress present here is Taxodium distichum (L.) L.C. Rich and that the appressed leaf condition and other characteristics are merely features of a growth form related to the fact that these trees are growing on relatively "poor" sites under rigorous edaphic conditions.

The interior of the hammock is more "open" than many other hammock types. In the open water areas, cypress "knees" are well developed (Plate III). Old stumps are common in the interior, although often reduced to a pile of brownish organic debris. Hardwoods have taken root on many of these mounds and in certain areas the hammock is relatively dry with hardwoods dominating the scene. In the cypress areas the peat is granular in texture, very non-coherent by virtue of the quantity of

a

b

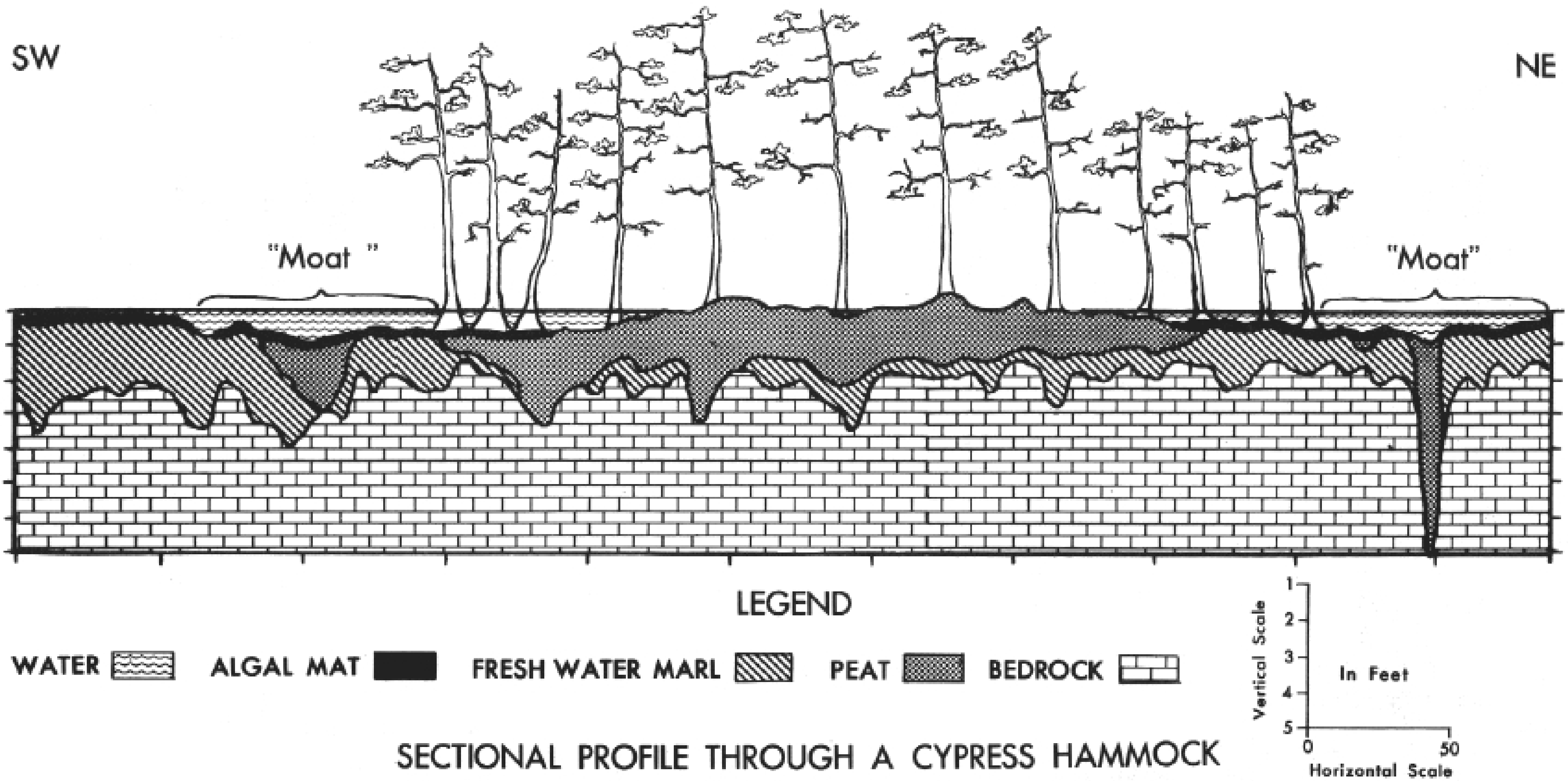
c

PLATE III

water present and it seldom contains large pieces of woody material that one might expect to find in view of the well-known resistance of cypress to decay organisms.

In section, the hammock at Stop 2 is of interest because the marl that blankets the adjacent marshland extends beneath the hammock peat, indicating a period of marl formation prior to onset of hammock development (see Figure 5). In some of the deeper depressions underlying the hammock, the marl is absent, perhaps because of non-deposition or perhaps because of solution of the lime sediments as the result of the new set of geochemical conditions introduced by the initiation and continuation of peat accumulation. Craighead's observations have led him to suggest that marl is being removed by solution in areas of active peat accumulation. Such solution effects may extend into the bedrock, thus providing a mechanism that tends to insure subsidence and continued peat accumulation.

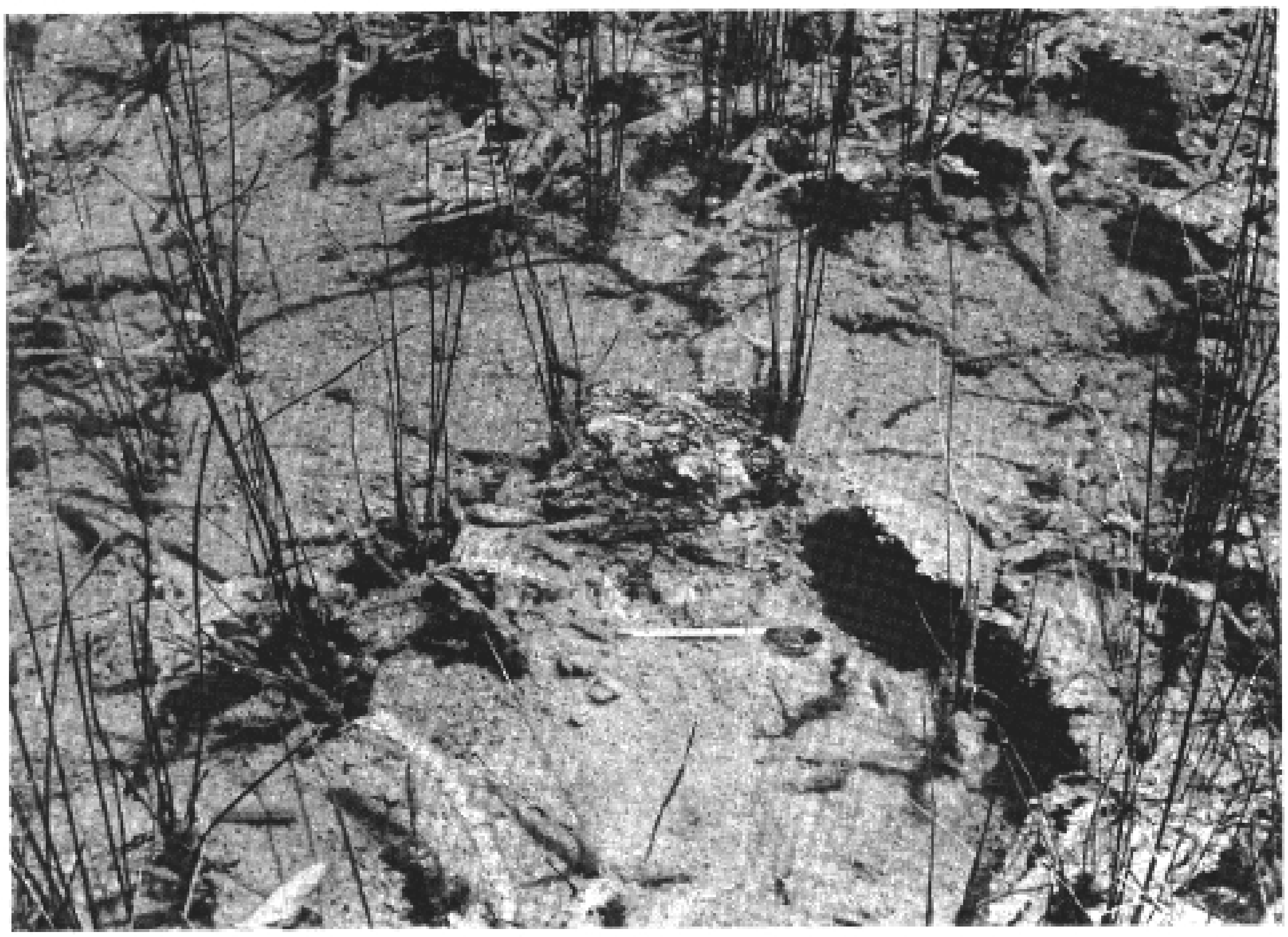
The origin of the sub-peat marl and the surficial marl found in the open marsh appears to be related to the occurrence of what is loosely termed an "algal mat". This mat is found in areas in which the saw grass forms a sparse stand or in marsh areas in which the spike rush , Eleocharis spp., forms the vegetative cover. In general, these sites appear to be areas of somewhat deeper water and the "algal mat" develops on the ground surface between the herbaceous plants and actually clothes the sub-aqueous portions of the sedge or rush leaves (see Plate IV). The mat is composed of a complex mixture of filamentous and colonial algae, diatoms, and bacteria plus entrapped organic and inorganic debris. It is commonly an inch or more in thickness, where it occurs on the sub-aqueous ground surface. Platelets of the mat are commonly observed, partially afloat, with a section of the plate still attached to the main mat that rests on the marl surface. The invariable association of mat and marl suggests the possibility of a genetic relationship. It would seem that the calcium contained in the surficial water could be readily precipitated, either by lime secreting algae or by the combined effect of all plants present on the carbon dioxide content of the flowing surface water.



SECTIONAL PROFILE THROUGH A CYPRESS HAMMOCK

Figure 5

a



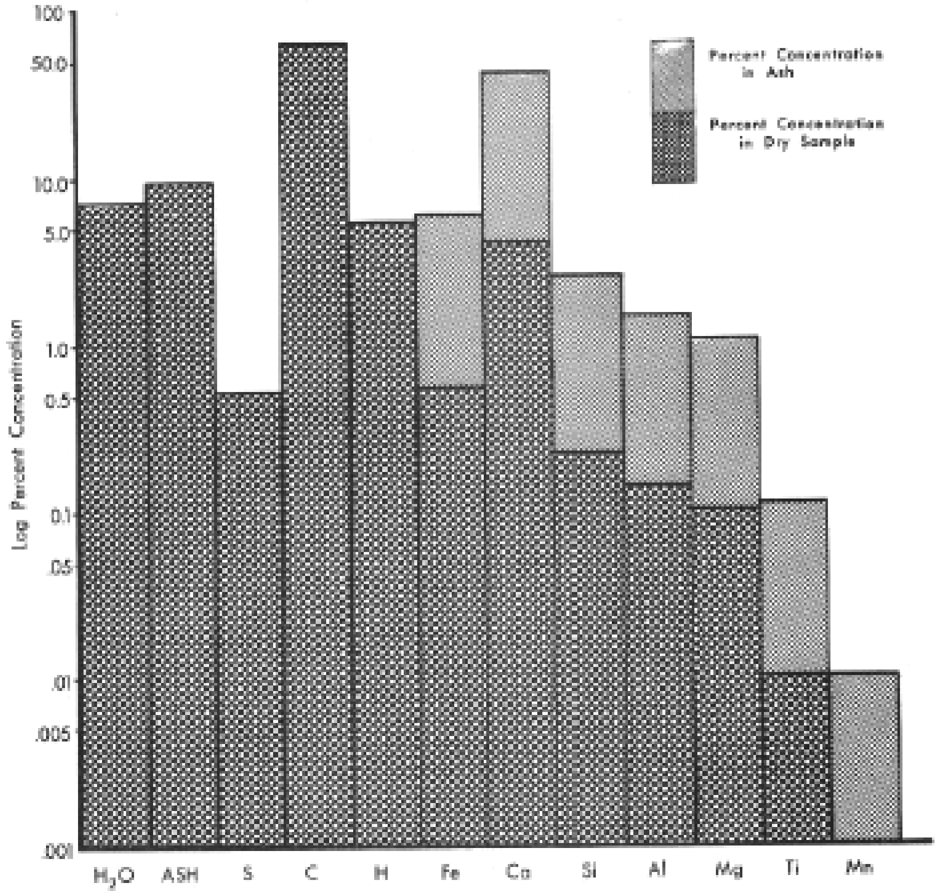
b

PLATE IV

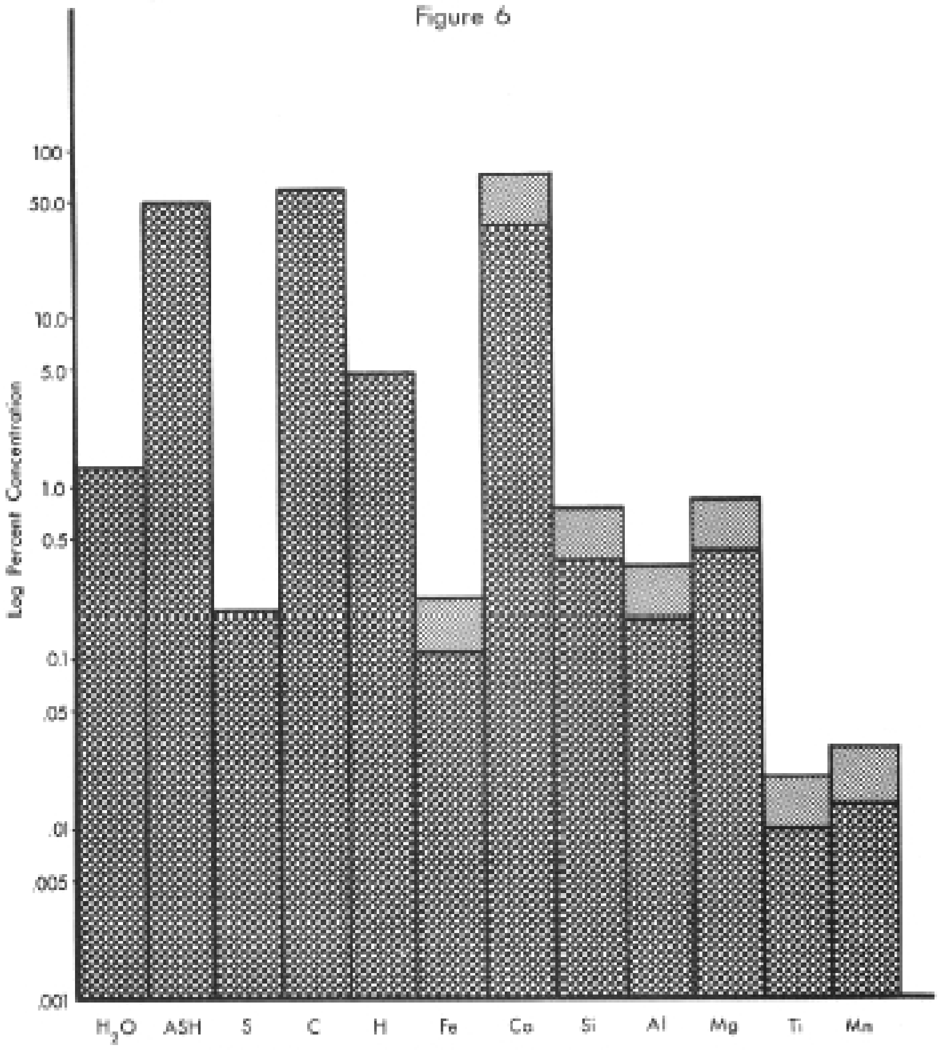
The algal mat may also effect the concentration of manganese, as the data thus far collected suggest a higher concentration in the mat than is present in many of the peat types. Figures 6 and 7 provide an opportunity to compare the concentrations of various elements encountered in the cypress peat with those encountered in the algal mat. The high calcium content and correspondingly high ash yield in the case of the mat suggests that calcium carbonate precipitation may proceed within the mat itself.

The pollens contained in cypress hammock peat are derived from a sizeable number of different plant species. Several of these do not participate in the formation of the vegetative cover of the hammocks. This is, of course, not surprising for the hammocks represent a minor fraction of the area involved in any given square mile. The latter fact might suggest that the pollen content of the cypress peat would reflect the areal dominance of the saw grass marsh to such an extent that it would mask the presence of any distinctive hammock pollen assemblage. In utilizing pollen and spores in stratigraphic work, it is often emphasized that the great value of these fossils is related to the fact that they are wind disseminated and hence transgress local environmental boundaries. In view of this, it is argued that time equivalent assemblages are readily recognized and the confusing effects of environmental changes at any one time horizon are minimized. There is no question of the validity of this argument. However, it is equally useful to emphasize that if the pollen and spore assemblages are examined more critically, both age and environmental setting are often detectable. The extent to which environment can be interpreted will become evident to some degree as the pollen assemblages encountered at the various sites are examined.

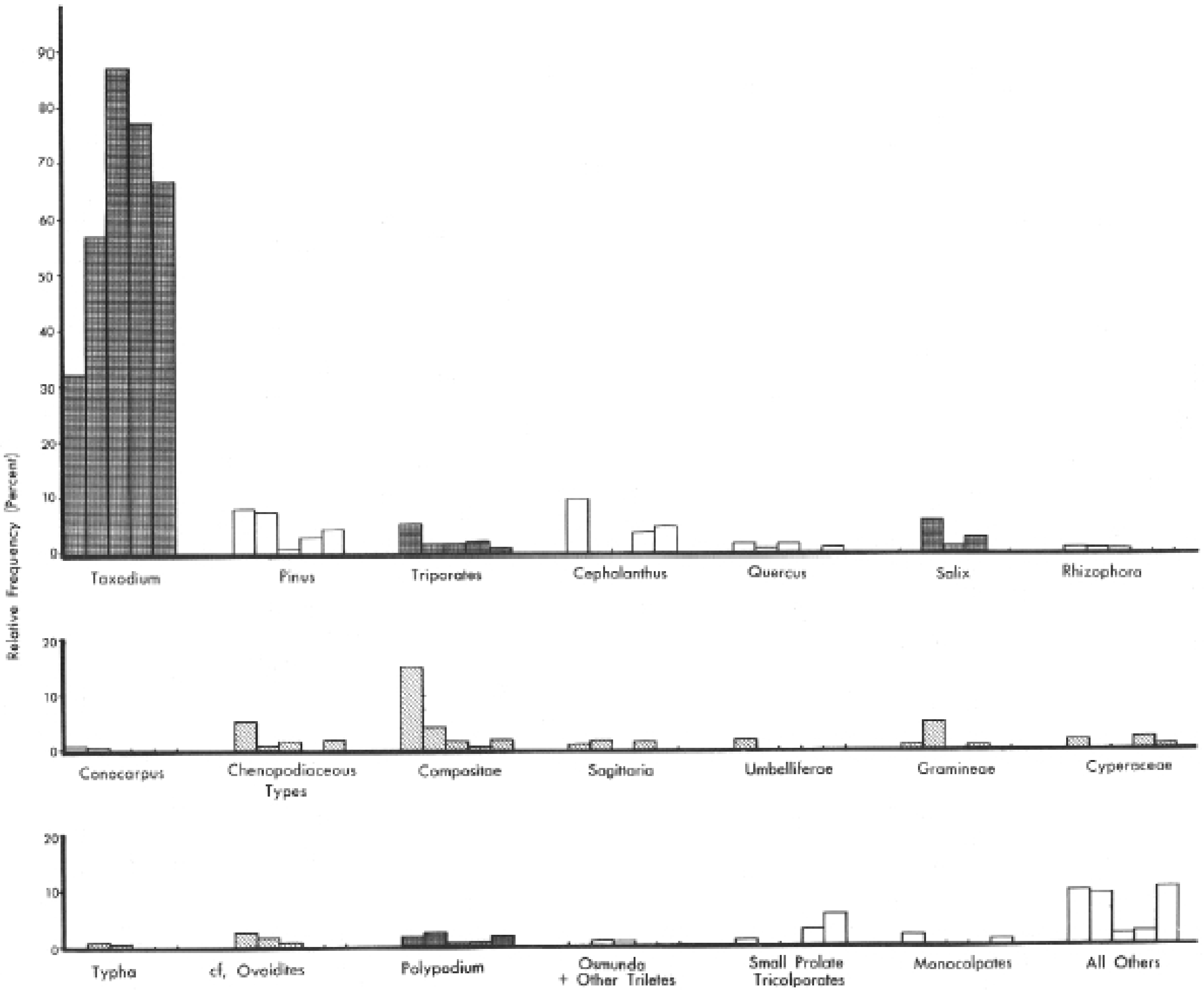
The pollen and spore assemblage contained in the cypress hammock peat (Figure 8) renders this environment recognizable, and readily distinguished from any others in the area. This does not mean that each species in the plant cover is represented in direct proportion to the frequency with which their individual plants occur, but it does mean that this plant community yields a characteristic assemblage of preserved



ELEMENT CONCENTRATIONS IN CYPRESS HEAD PEAT
Figure 6



ELEMENT CONCENTRATION IN "ALGAL MAT"
Figure 7



POLLEN AND SPORE CONTENT OF FIVE CYPRESS HAMMOCKS
Figure 8

pollen and spore materials. Certain species in the plant cover are not represented in the sediment by preserved pollen grains, others are over-represented. Accordingly, the plant community, and hence the environment in question, leaves a unique pollen "signature" in the fossil record. It is in connection with the interpretation of these signatures that the palynologist ceases to be a technician and must become a botanist.

In addition to providing a basis for distinguishing the cypress hammock environment from other environments, the pollen and spores may also provide a clue as to the stage of development reached by the vegetation in the cypress hammock - bay head hammock succession. If this is confirmed by the collection and analysis of additional data, it will demonstrate the extent to which precise reconstructions of past environments can be made once the required information is amassed through the study of modern sediment - environment - vegetational relationships.

STOP 3: Bay Head

Objectives:

A. Inspection of a Bay Tree Hammock.

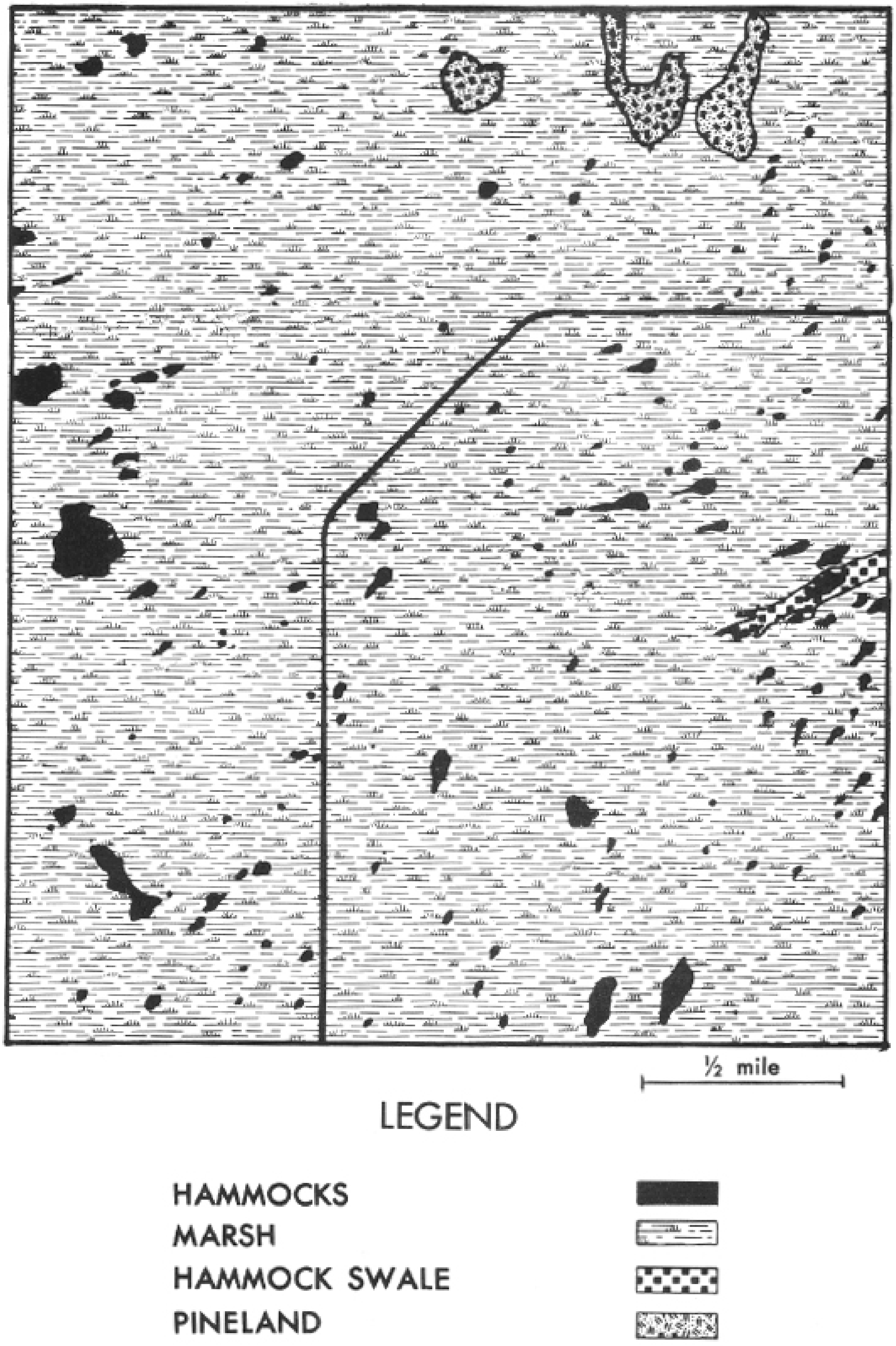
B. Comparison of cypress hammock surface litter and peat with bay head surface litter and peat.

C. Discussion of sectional profiles through hammocks.

D. Discussion of the role of cypress and mangrove in colonizing marshland areas.

Discussion:

Bay tree hammocks in the Shark River Slough area are known to be underlain by as much as 14 feet of peat. Such hammocks are surrounded by a saw grass marsh underlain by three to five feet of saw grass peat. Ideally, they should be inspected but their inaccessibility makes this impractical. The hammock at Stop 3 is reasonably similar and is typical of the bay heads east of the Slough area. It differs from some of the Slough hammocks in that a thick peat layer has not been developed beneath it and it is not surrounded by saw grass peat. Figure 9 shows that the hammock lies in a vast marshland area that is interrupted to the north by small outliers of the Miami Rock Rim (the Pineland environment). No



MAP OF ENVIRONMENTS IN THE BAY HEAD AREA

Figure 9

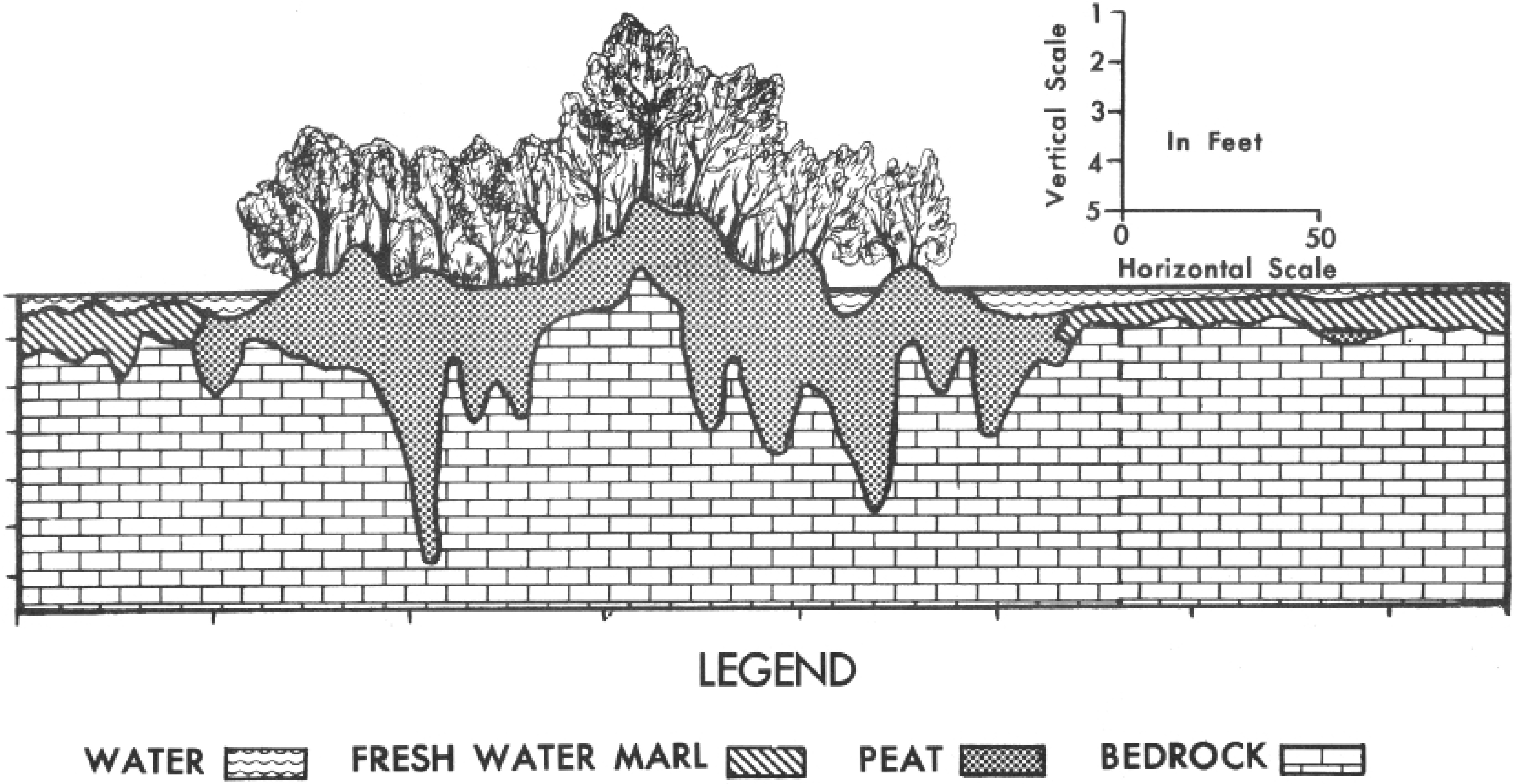
peat is found in these pinelands, although some organic debris accumulates in the small solution holes that pit the bedrock surface. The marshland in the vicinity of Stop 3 is covered largely by saw grass but the plants are less abundant and the individuals smaller and less healthy than those in the better developed portions of the saw grass plain to the west and north. Plate V provides an aerial view of the site and gives some impression of the density of the forest cover. A few small cypress trees can be seen on the "downstream tail" of the hammock and an occasional tree may be seen near to, but not at, the margin of the hammock. It would appear that if this bay head has developed on the site of a cypress hammock, the transition from one vegetative cover to the other is essentially complete.

The hardwood trees, shrubs, epiphytes and vines that compose the vegetation include many species that need not be listed here. The "bay trees" from which this type of hammock takes its name are the sweet bay (Magnolia virginiana L.) and red bay [Persea borbonia (L.) Spreng.]. Other genera that often are conspicuous elements in this type of hammock are Chrysobalanus, Ilex, Ocotea, Myrica, Metopium, Smilax and Serenoa.

As one might expect, the surface litter in the bay tree hammock differs markedly from that encountered in a cypress head. The latter contains appreciable quantities of plant substances and tissues that are poorly represented in the bay head litter, partly because the deciduous habit of the cypress involves shedding both twig and leaf material. The bay head litter is primarily a leaf litter. In the drier areas in this hammock and in similar sites in other hammocks that are located in areas affected by artificial drainage, the sub-litter organic material is quite similar to a forest "humus". A more typical peat is often found beneath this humus, although frequently the "sub-humus layer" is composed of slightly altered and thoroughly wetted humic material.

The sectional profile of the hammock at Stop 3 (Figure 10) shows considerable variation in surface elevation, in peat thickness and in bedrock surface contour. The variations in surface elevation may be unduly amplified by the exaggerated vertical scale. Such differences in level are not uncommon in the hammocks in this vicinity, however.

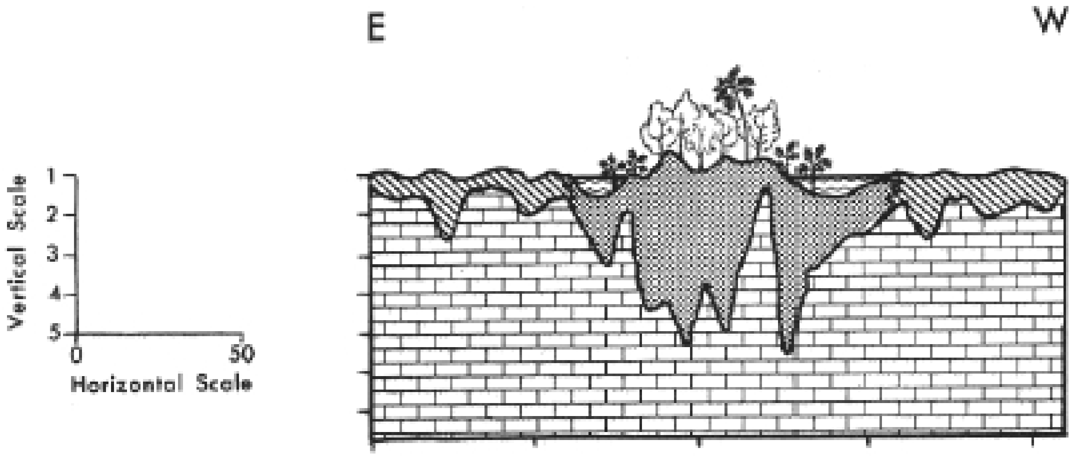
PLATE V



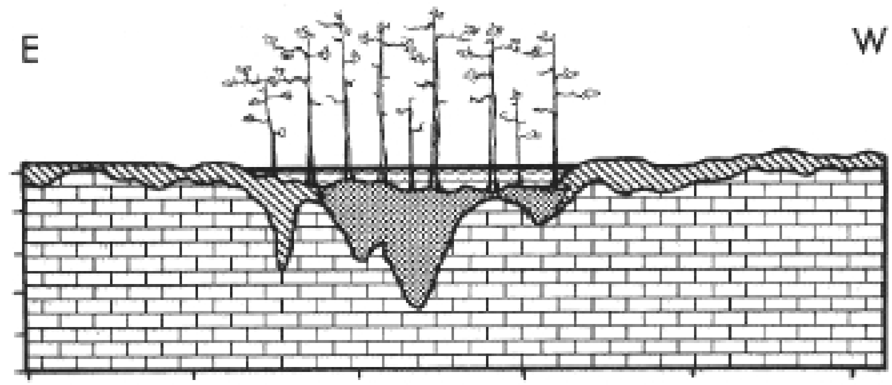
SECTIONAL PROFILE THROUGH A "BAY HEAD"
Figure 10

Depressed surface areas in the hammocks seem, in some instances, to be related to animal activities. In other cases, lower areas appear to have been the product of a differential decomposition of the peat or a differential compaction related, perhaps, to the recent lowering of the water level in this area by the hand of man. Mounds of slightly higher elevation develop around stumps and fallen logs and although these have only an ephemeral existence, there are always some present to contribute to the irregularity of the surface. Some of the hammocks observed in other areas possess surfaces that are relatively uniform in elevation, hence it appears premature to generalize from the few data available. With regard to the irregularity of the bedrock surface a more positive statement can be made. Sizeable differences in the elevation of the bedrock surfacd are easily detected by simple probing in any hammock. It is not uncommon to find a two or three foot difference in elevation in probe holes that may be only inches apart. Indications of pitting of the bedrock surface on a smaller scale is readily found as is evidence of the "rotted" nature of the sub-peat bedrock surface. Typically, the hammocks are located on what is now a very irregular bedrock surface, the irregularities being an expression of the presence of numerous solution pits, holes and cavities of various sizes and shapes. Figure 11 presents sectional profiles of three randomly selected hammocks showing the variations in the bedrock floor encountered in a transect across each hammock with probe holes located six feet apart. In addition to the irregularity of the rock surface, it is of interest that in none of these hammocks was marl encountered beneath the peat.

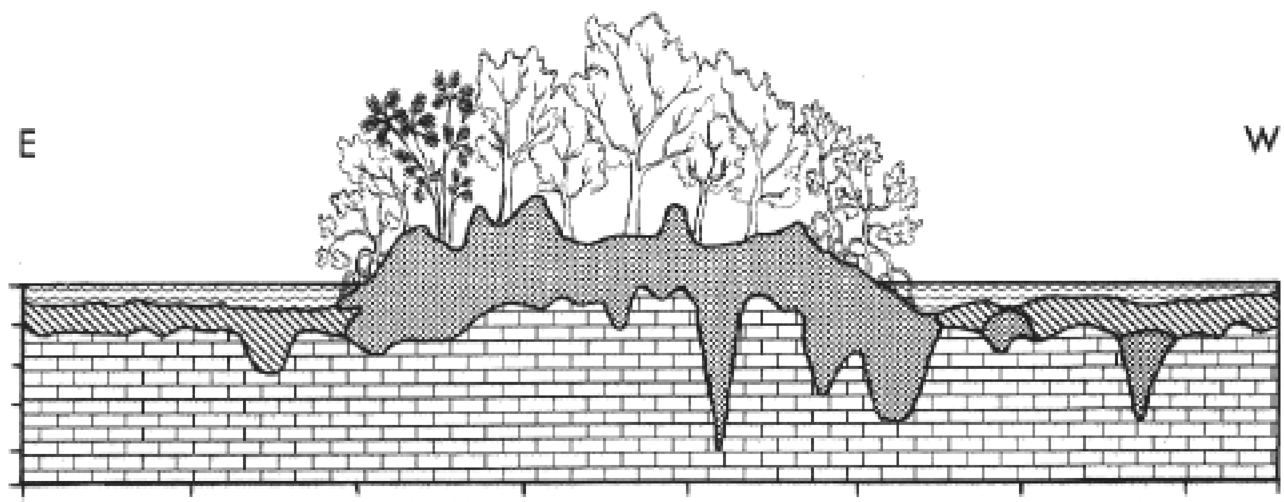
In general the surface peats in the bay tree hammocks contain only small quantities of identifiable pollen. The assemblages are recognizably different from the cypress hammock assemblages and are quite variable in composition. This variability is related in part to the important effects of differential pollen decomposition in this geochemical environment, and in part to the more complex nature of the vegetation. It makes evident that a more extensive sampling is required in this type of environment before data comparable to those described for the cypress peat are obtained.



a. Sectional Profile through Saw Palmetto Head



b. Sectional Profile through Incipient Cypress Head



c. Sectional Profile through Paurotis—Bay Head

LEGEND

WATER PEAT FRESH WATER MARL BEDROCK

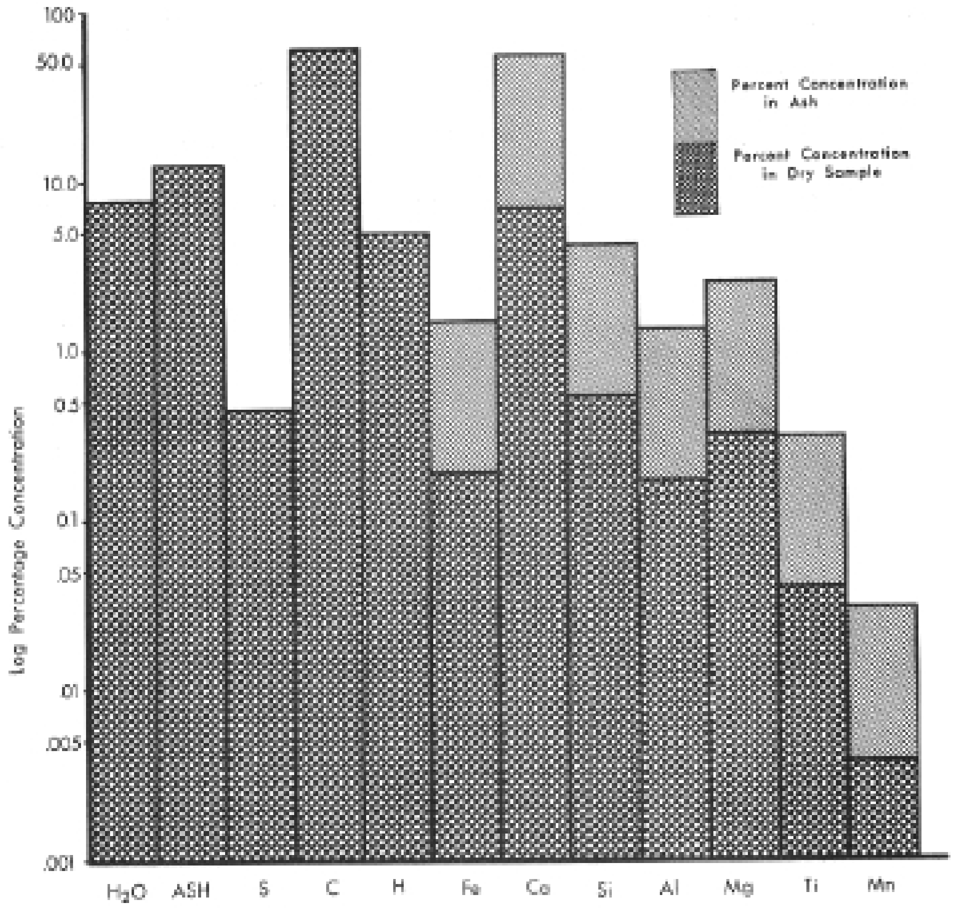
TYPICAL HAMMOCK PROFILES

Figure 11

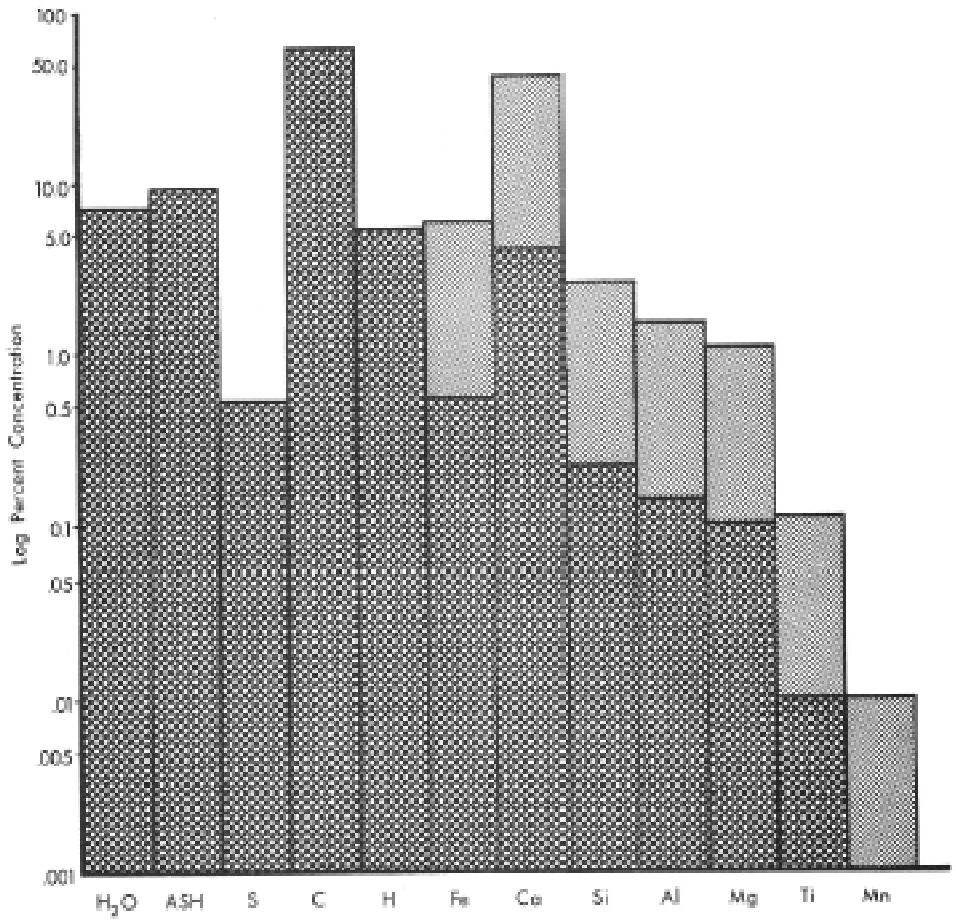
With respect to the concentration of various elements in the peat mass, the bay head type of sediment is remarkably similar to the cypress hammock peat. Figure 12 presents the two sets of data for comparative purposes. The manganese content in cypress head peat appears to be slightly lower than that encountered in bay head peats and the iron content seems to be somewhat higher, but the differences are so small that their significance should be questioned.

The saw grass marsh that occupies most of the area in the vicinity of Stop 3, and, that which dominates the Saw Grass Plain and the Ridge and Slough Sectors of south Florida shown in Figure 3, is clearly a fresh water environment.

As is evident from the isolated trees, the small groups of trees, the small cypress stands and the cypress heads of various sizes, the bald cypress is one of the few trees that can colonize in the open fresh-water marsh in the absence of the occurrence of bedrock at the surface. As one proceeds from Stop 3 toward Florida Bay, evidences of saline conditions begin to appear. Small red mangroves now occur in the open marsh and the cypress is no longer present. Salinity data show that the water is somewhat brackish even at Stop 3. In colonizing the open marsh the mangrove does not form heads or hammocks nor does it occupy only the areas of somewhat deeper water as does the cypress. As soon as the environment is slightly saline, the mangrove is able to invade the area and compete effectively with the saw grass. The saw grass seems able to persist with the mangrove for an appreciable period of time and may even form small pure stands within the mangrove forest. The area to the south of Stop 3 can be viewed either as a stable and typical transition zone between the fresh and salt water environments, or it can be viewed as an area being actively invaded by marine environments. In the former case the small mangroves would be considered as dwarf forms, some of which might be very old but modified in growth form by virtue of the ecology of the marginal site in which they live. The opposite view is that these small mangroves are "young pioneers" that have occupied the site recently and whose progeny are furthering the invasion inland. Plate VI casts some light on determining which



A. ELEMENT CONCENTRATIONS IN BAY HEAD SURFACE "PEAT"



B. ELEMENT CONCENTRATIONS IN CYPRESS HEAD SURFACE PEAT

Figure 12

PLATE VI

interpretation is correct. In this photograph the typical hammock and glàde physiognomy is partially obliterated by the numerous mangrove trees that become more abundant and larger as one progresses toward the south. This suggests that the mangrove forest has been superimposed on the hammock and marsh environmental complex, after the latter was well-developed. It is difficult to conceive of the synchronous development of these three components.

STOP 4: Saw Grass Site

Objectives:

A. Inspection of saw grass environment, saw grass surface litter and saw grass peat.

B. Discussion of marsh environments.

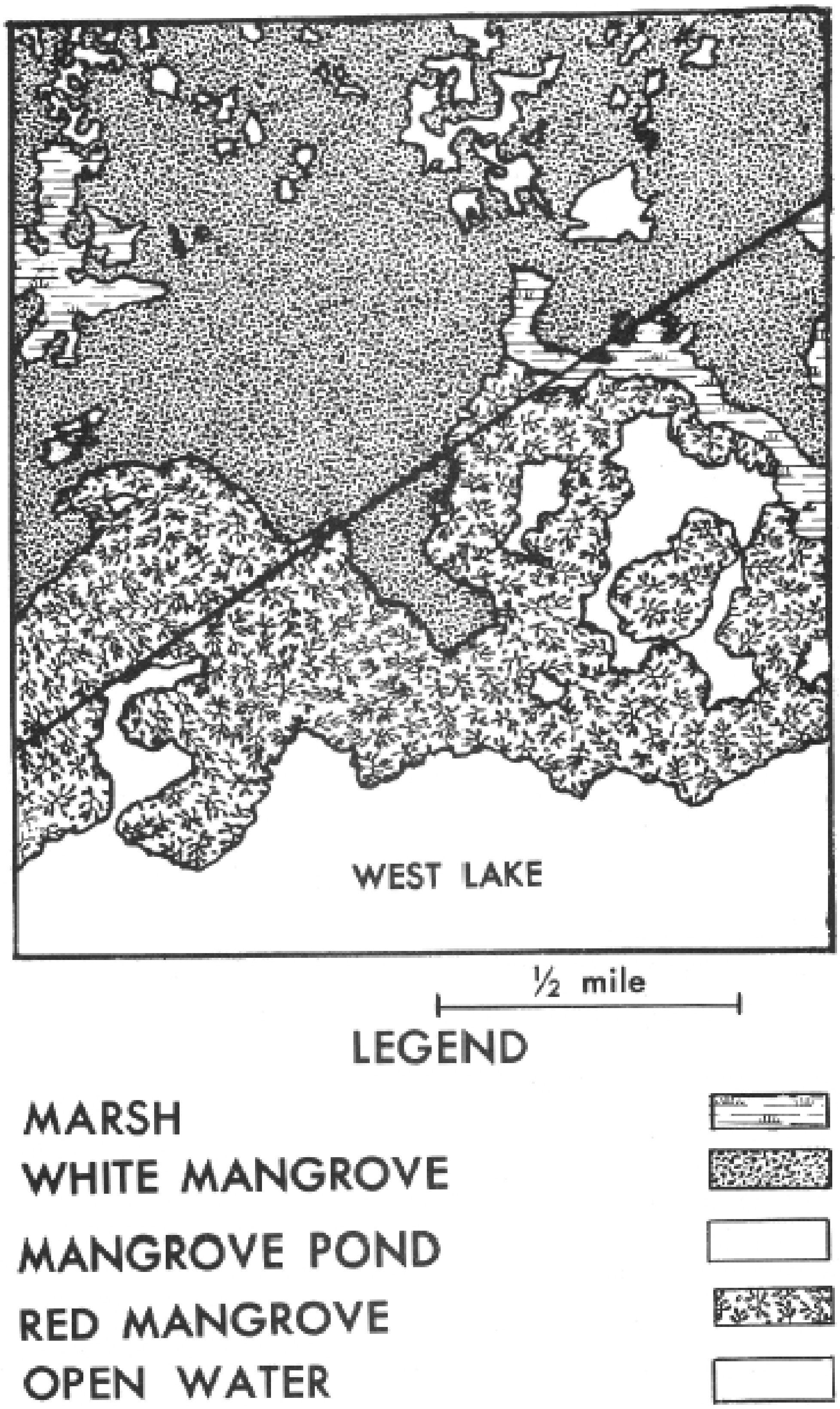
C. Discussion of element concentration and the pollen and spore content in saw grass peat.

Discussion:

Areally the saw grass marsh is the most important environment in south Florida. It is also the most important peat-forming environment accounting for at least 400,000,000 tons of Florida's available peat reserves.

The general setting in which Stop 4 is located is not typical of either the Saw Grass Plains to the north or the Ridge and Slough Sector to the west. The site is located in a small patch of saw grass that is merely a remnant of the saw grass marsh that occupied this general area in the past. It is surrounded by a mangrove forest that has engulfed the hammocks of the area and destroyed the saw grass glades. In spite of these facts, the saw grass at the site itself forms a vigorous growth of closely spaced plants that is quite similar to that encountered in more typical settings. Moreover, the peat at the site appears quite comparable to that examined in sites in the Slough area and in the Plains to the north. In view of this, inspection of the site will provide much of the desired information on this type of marsh environment.

Figure 13 depicts the areal relationships of the major environments in this vicinity. The surrounding area includes a swamp dominated by



MAP OF ENVIRONMENTS IN THE WEST LAKE AREA

Figure 13

the red mangrove (Rhizophora mangle L.) with occasional specimens of white mangrove (Laguncuiaria racemosa Gaertn.), black mangrove (Avicennia nitida Jacq.) and buttonwood (Conocarpus erectus L.). Also included is an area designated "White Mangrove Swamp Environemnt" that is more open in aspect and is dominated by small white mangroves. This is not a major environment when the region is considered in its entirety, for mature white mangroves seldom form pure stands that occupy large areas. They appear able to colonize areas laid bare by hurricanes before other mangroves are able to get started and temporarily they dominate the scene and perhaps influence the nature of the environment. Their influence appears to be local and short-lived but more data are needed before such areas are regarded as unimportant components of the mangrove swamp complex. Another environment that is of interest in this general area is here designated the "Mangrove Pond Environment". One such environment is shown just beyond the road in Plate VII and some indication of their frequency in certain localities may be obtained from inspection of the northwestern quarter of Figure 13. This type of open water environment typically contains one or more clumps of red mangrove in the shallow pond area. Its features will be discussed further on subsequent pages.

Although emphasis has been given to the importance of the saw grass environment, it should be recognized also that the marshland areas include several other spatially significant environments. Among these are:

1. The Spike-Rush Marsh
2. The Bulrush Marsh
3. The Cattail Marsh
4. The Salt Grass Marsh

The spike-rush and bulrush environments are particularly important in the Ridge and Slough Sector northeast of the headwaters of the Shark River and, in fact, in the entire southern section of the Everglades.

The spike-rush or Eleocharis environment is developed in areas in which the water is slightly deeper in the wet season than it is in the saw grass environment. The sparse cover provided by the Eleocharis

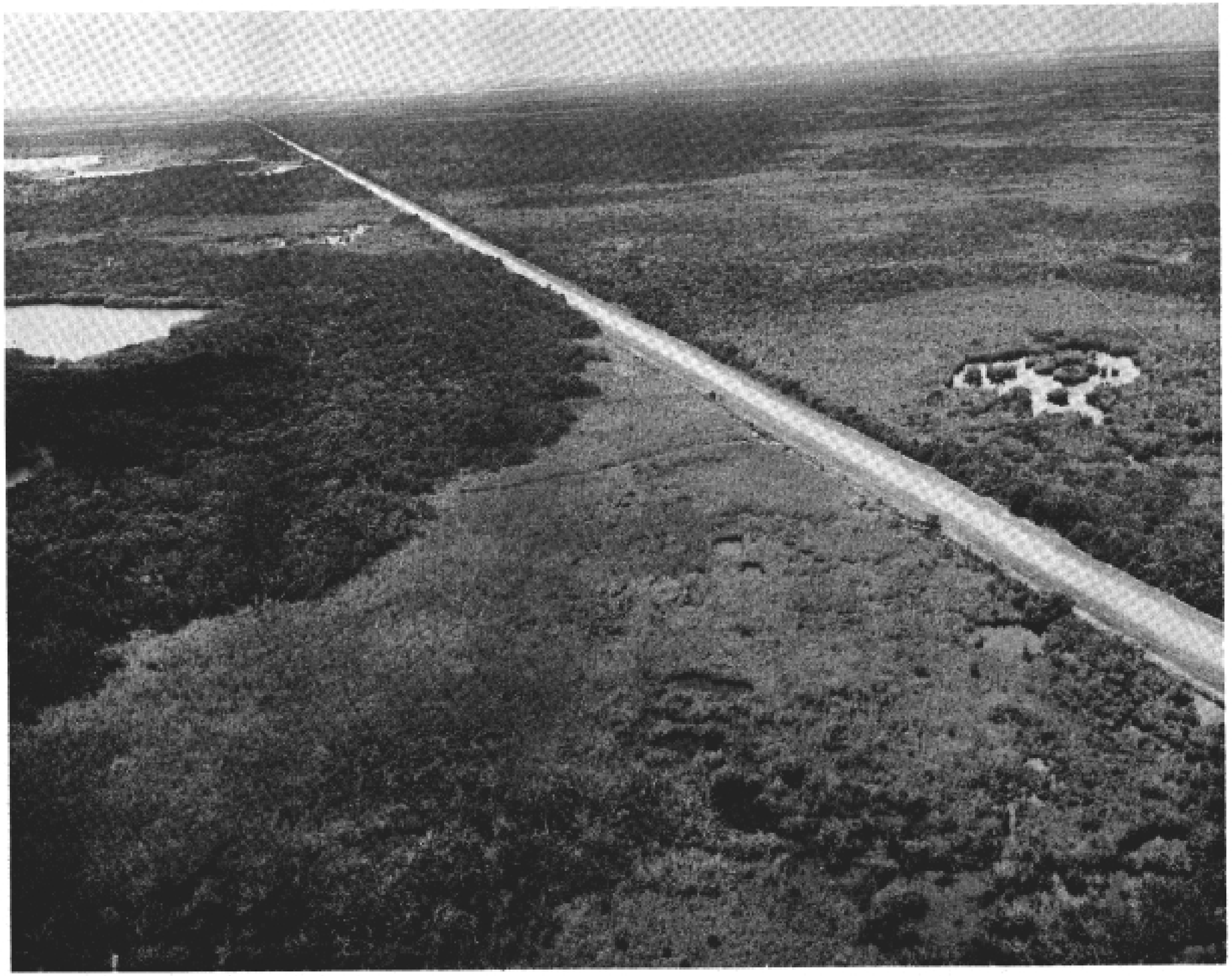


PLATE VII

permits development of the algal mat. As previously mentioned, these areas are sites in which marl is deposited as opposed to peat. As shown in Plate VIII, these areas are extensive and their boundaries are well-defined. In the Ridge and Slough Sector these environments appear to develop on saw grass peat surfaces in a manner that is still unknown. The depression of the area and destruction of the saw grass cover may be related to fire, differential peat compaction, changes in the surficial drainage pattern, differential solution of the underlying bedrock, or some complex combination of these and other factors. A few inches of difference in water depth is all that appears to separate the two environments but the size of the areas involved is often to be measured in terms of acres and sometimes in terms of square miles. It seems probable that a rather delicate balance between the rate of subsidence and the rate of peat acumulation must obtain in order to maintain the saw grass marsh. If the rate of subsidence (or water table rise) is too slow, the site may become drier and drier as the result of peat build-up, until it may permit the entry of hardwoods and the subsequent destruction of the marsh. This does not appear to have happened in any of the areas with which we are concerned. On the other hand, if the rate of subsidence (or water table rise) is too fast, during some prolonged unit ot time the "water depth tolerance" of saw grass might be exceeded over sizeable areas and the Eleocharis environment would develop on the saw grass peat surface. Soon the algal mat would form and a layer of marl would begin to develop. This development might continue until the area had been built up to a level that would permit repopulation by saw grass. After repopulation, saw grass peat might again accumulate burying a lens of marl between two saw grass peat layers, forming a sequence similar to occurrences encountered in coring the Ridge and Slough and adjacent areas.

Apart from such hypothetical considerations as those discussed above, it is clear that marl and not peat is deposited in the <u>Eleocharis</u> environment. In contrast with this, the other marsh environments are often sites of peat accumulation but the peat and the geochemical conditions appear to differ from those characteristic of the saw grass areas.

a

b

PLATE VIII

Saw grass peat is a very black material that is homogeneous in appearance when examined with the naked eye. Because of the nature of the source material, it is devoid of any woody, fibrous, or coarse granular texture and is grossly amorphous. In view of the abundance of silica in the leaf blades (being present in the saw tooth margin and over some of the leaf veins), it is remarkable that the peat does not show a concentration of this element (Figure 14). Instead, the sulfur content is unusually high and the magnesium content appears to be somewhat above that which might be expected. In view of the frequent proximity of environments in which calcium is concentrated in large quantities, it is interesting that saw grass peats usually exhibit low calcium contents.

The pollen and spore content of saw grass peat is as distinctive as that of cypress peat. As is evident from Figure 16, the nature of the assemblage could not be readily inferred from a knowledge of the vegetative cover, but again the environment provides a "signature" assemblage in the preserved pollen record. Detailed studies in saw grass areas have shown that the presence of adjacent plant communities can be detected by the inspection of several samples from a transect and the general location of the adjacent environment can be identified.

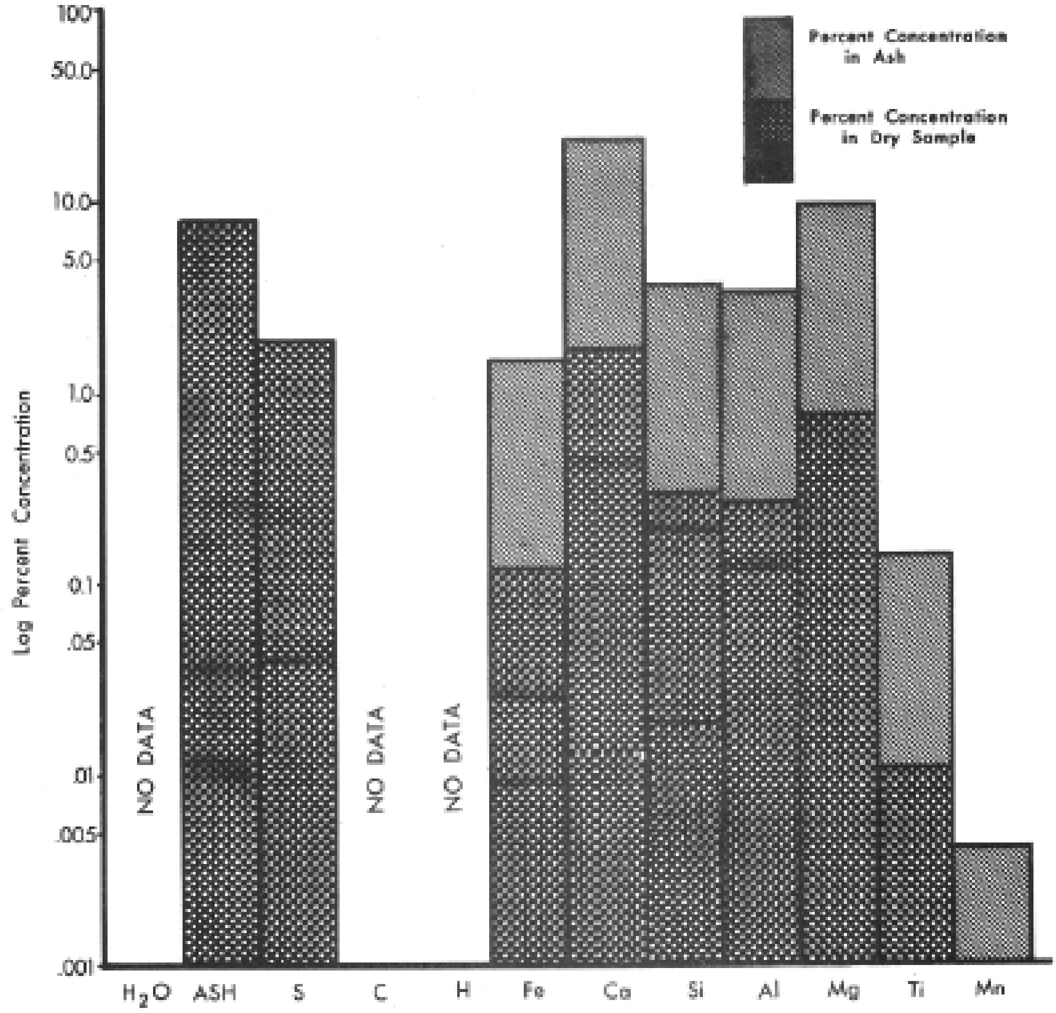
STOP 7: East River Site - Mangrove Pond Environment

Objectives:

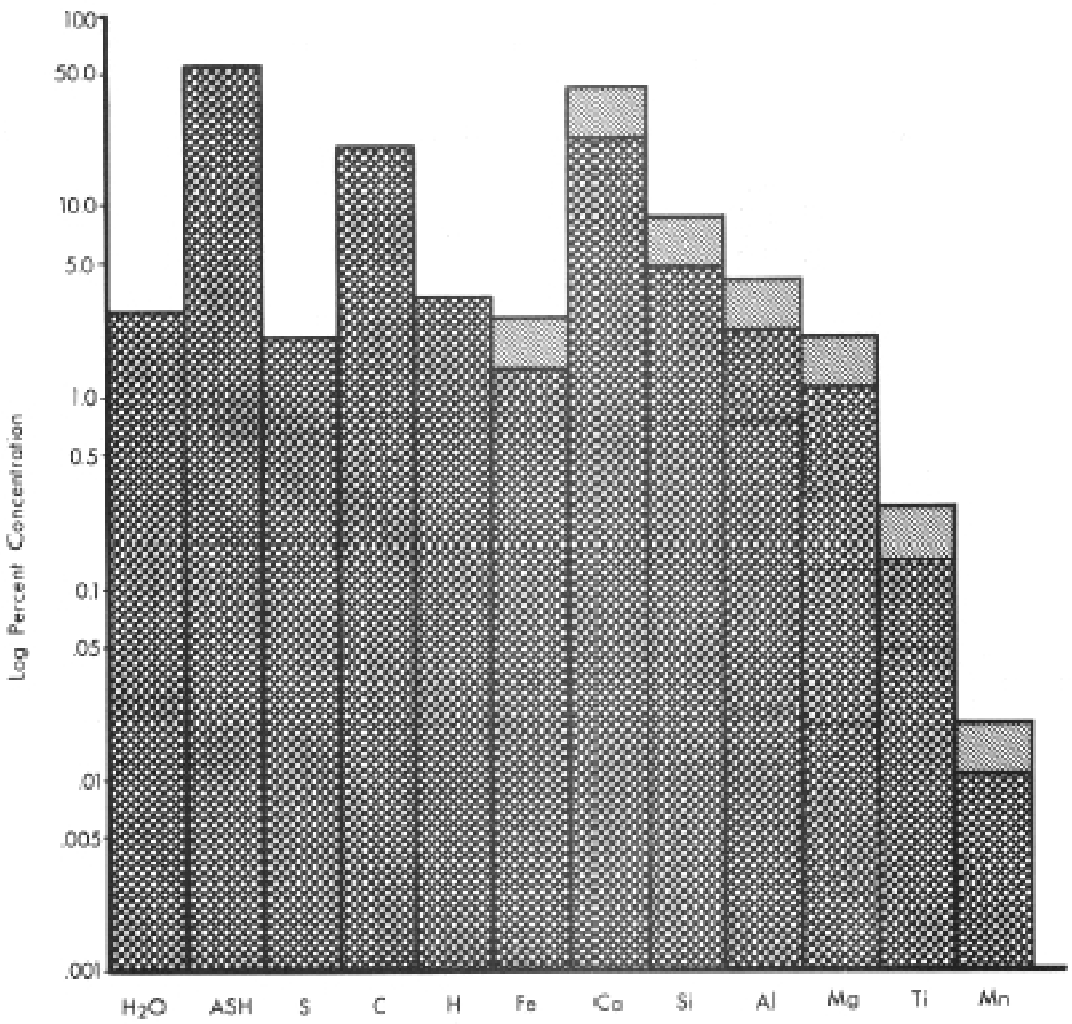
A. Inspection of one type of open water site in the red mangrove environment.
B. Inspection and discussion of "liver mud" in terms of its origin, nature and future fate in an organic sediment.
C. Discussion of the sediment bordering the northeastern margin of Whitewater Bay.

Discussion:

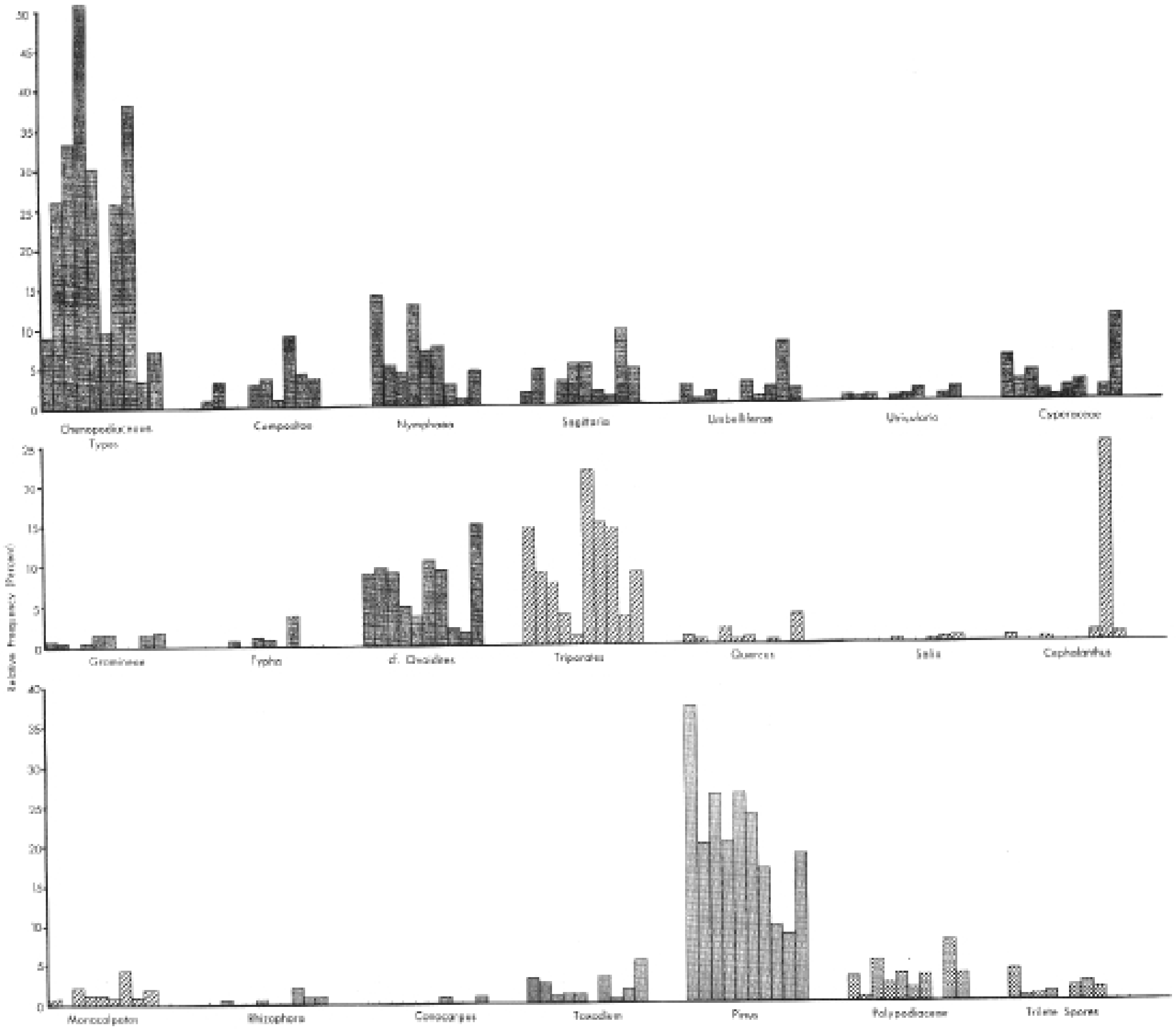
The Mangrove Pond is a common feature of the Mangrove Swamp Environmental Complex. Those that occur northeast of Whitewater Bay are in, or adjacent to, the transition zone that separates the mangrove



ELEMENT CONCENTRATIONS IN SAW GRASS PEAT
Figure 14



ELEMENT CONCENTRATIONS IN "LIVER MUD"
Figure 15



POLLEN AND SPORE CONTENT OF SEDIMENT FROM MARSH ENVIRONMENT

Figure 16

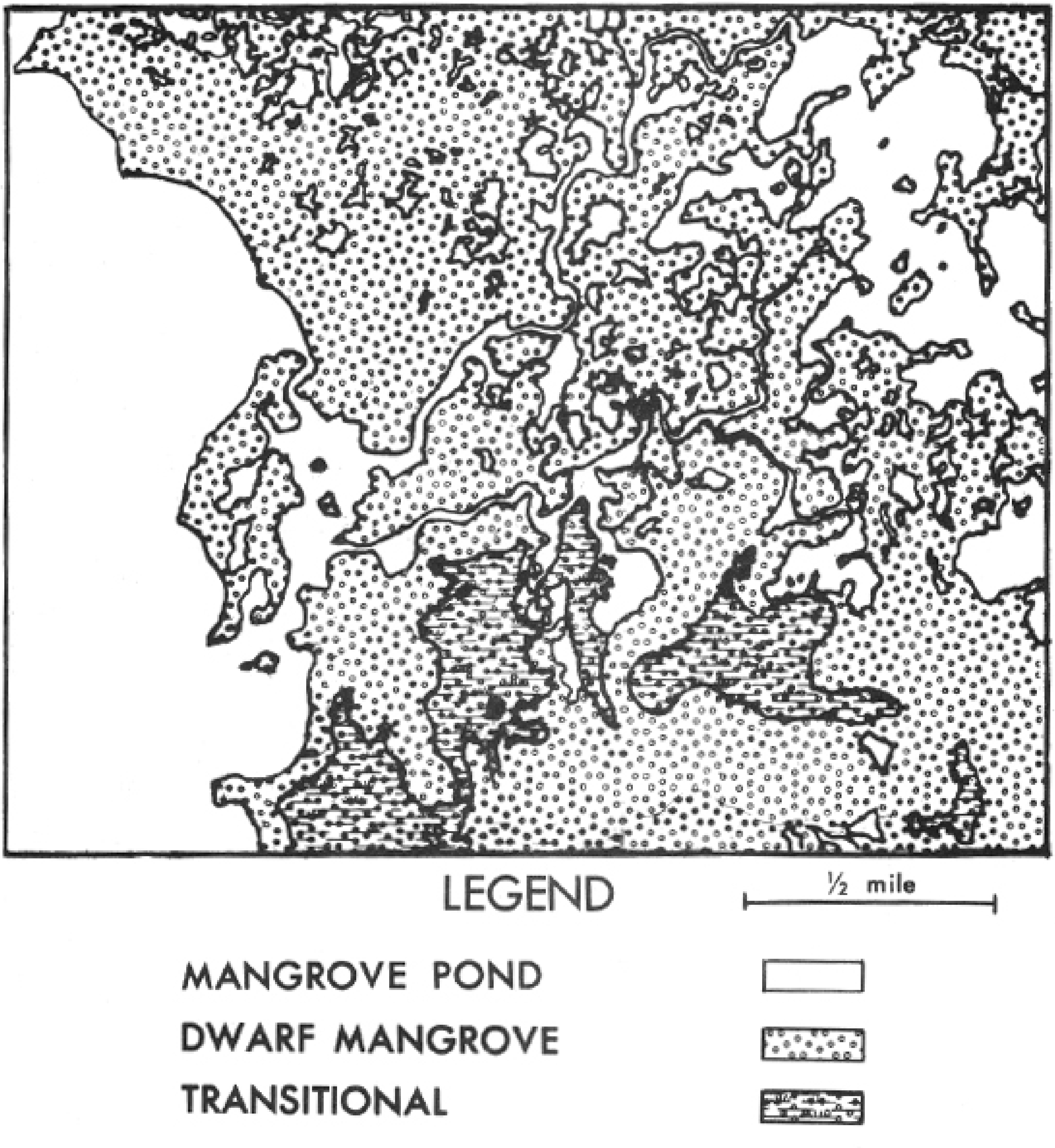
swamp from the open Everglades. Figure 17 shows the distribution of the Ponds in the vicinity of Stop 7. The extent to which the ponds are interconnected is greater than that shown, particularly when the water level is high. The figure also shows the presence of "transitional environments" in which the surface is covered with a mixed red mangrove-saw grass growth. Plate IX shows an aerial view of the actual site and its relationship to East River and Whitewater Bay.

The origin of these open water areas has not been explained and as yet the "on shore" peat has not been studied in detail. Such ponds may be simply the product of the incomplete colonization by red mangrove of an area that has recently undergone rapid inundation with somewhat saline waters. Although seemingly shallow because of the accumulation of non-compacted recent sediment, the pond basins and associated river channels are deeper than one might expect, if the relatively flat saw grass marsh were simply inundated by the inland effects of marine transgression. Figure 18 shows a sectional profile across East River near the location of Stop 7. From this it is evident that the Ponds are bordered on all sides by a relatively thick peat layer. The basins are, in fact, depressions or holes in the peat blanket.

The Ponds usually contain two types of recently deposited sediment. The basal sediment is usually a light colored marl. On this marl rests a peculiar suspension that conforms in many ways to the material termed "liver mud" by Davis (1940). When held on the end of a paddle or shovel it is coherent but responds as would a mass of jelly to any sharp movement of the supporting object.

Vast quantities of this "liver mud" exist in the innumerable Mangrove Ponds in this area. It appears to be a mixture of organic and inorganic material, the latter being mainly calcium carbonate. In addition to the presence of large concentrations of calcium, the elemental analyses show that this material also contains relatively high concentrations of sulfur and manganese (see Figure 15). The composition of this material will be discussed further in connection with description of the Whitewater Bay sediments.

The source of this "liver mud" has not been fully established, but it seems probable that the peat fraction is derived from the chemical



MAP OF ENVIRONMENTS IN THE EAST RIVER AREA

Figure 17

a

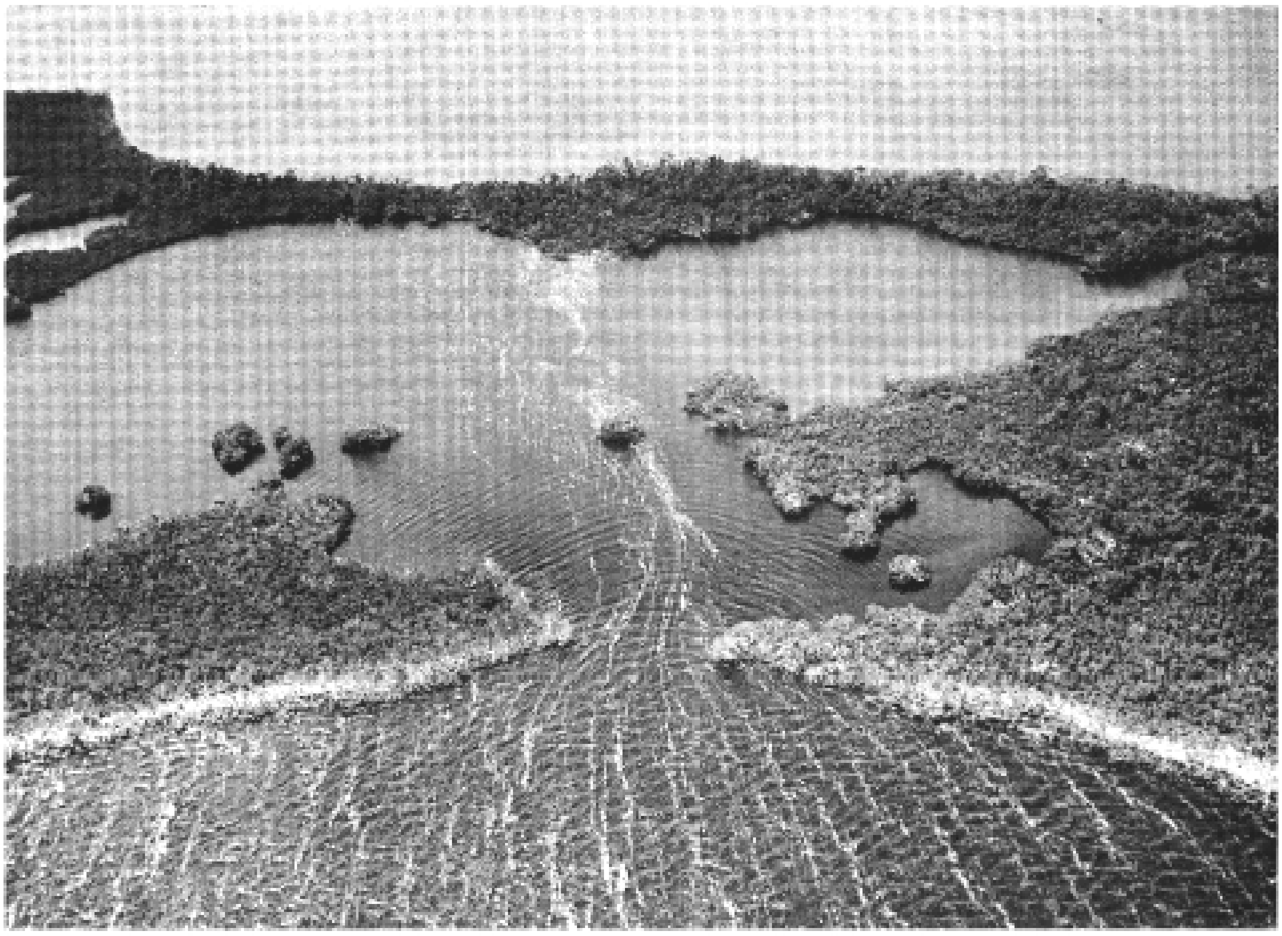


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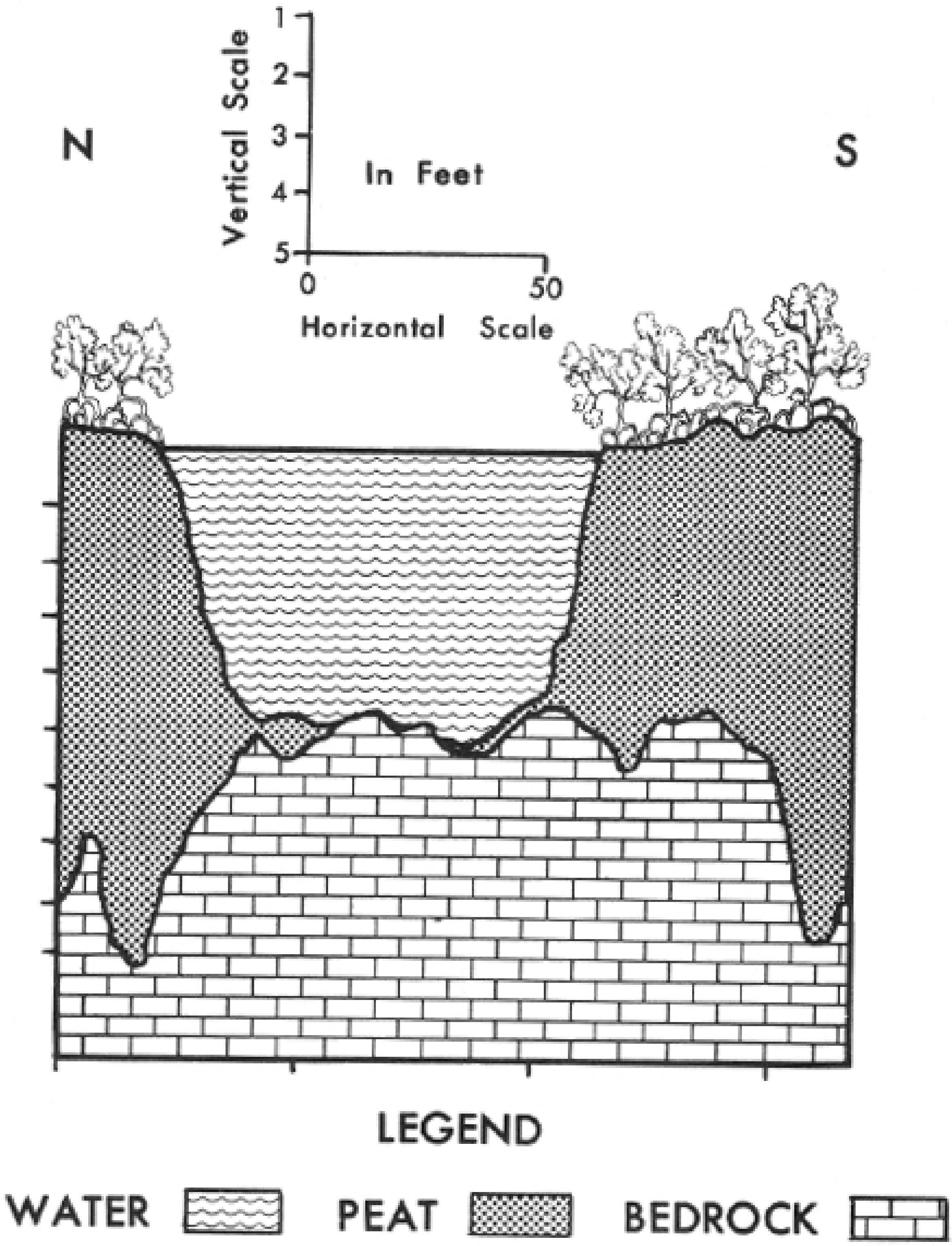
PLATE IX



SECTIONAL PROFILE ACROSS EAST RIVER

Figure 18

and physical degradation of the surface peat in the nearby areas. As one travels through the Hell's Bay area, small, steep-sided, mounds of peat are encountered. Saw grass grows on the surface of these blocks at an elevation that is commonly one foot above the general level on which the dwarf mangrove grows. The sides of the blocks of peat are torn and irregular, indicating they are erosional and not depositional features. It is suggested that the marine transgression implied by the previously observed vegetational relationships is further documented by these remnant peat blocks and the presence of the liver mud. The invading saline water reduces the suitability of the habitat as far as vigorous saw grass growth is concerned and this may result in a reduction in the health and number of individual plants. The rapid advance of the mangrove forest and the coverage of the area with young mangroves is inhibited, however, until tidal water can flow over the surface and carry the seedling plants inland. During the initial period of transgression when tidal flow merely moved the salinity contours landward or when it caused only an inch of water to flow over the surface, the mangroves' advance would still be inhibited but erosion of the loose, fine-grained surface peat could easily be affected. By this means the surface in small areas would be lowered, permitting increased effectiveness as far as further erosion by tidal flow would be concerned. After the surface was lowered sufficiently, the mangrove seedlings could float freely into the area and colonize it completely. Further lowering of the surface would proceed, however, until the mangrove rootlets had bound the upper peat layer to the point of immobility.

If the above approximates the truth, the occurrence of an occasional remnant peat mound would be inevitable until the entire surface was reduced to a level below normal high tide. Moreover, the products of erosion should be found in the immediate area for some time, because of the nature of the process. Further, the degraded peat material should be mixed with any material being brought into the area by fresh water flow. The "liver mud" seems to be a mixture of degraded peat and fresh water marl and it occurs in all quiet, open water areas in the Hell's Bay region. It is postulated that this sediment contains the erosional products of the surface lowering process that has been active in the recent past and may still be operative in this brackish water zone.

The pollen content of a core taken through the liver mud in a Mangrove Pond is presented as Figure 19. Because this material appears to be secondarily deposited and because of the flocculent nature of the sediment, it is questionable as to whether one should attempt to reconstruct the area's history from the superposed pollen assemblages. The abundances of pine, chenopodiaceous pollen, buttonwood and myrtle in the core indicate collectively and individually that the sediment is foreign to the environment in which it is now found. Perhaps coincidentally the upper two inches contains high concentrations of *Conocarpus* and *Myrica* and a small percentage of *Rhizophora*, suggesting a trend in the direction of representing the present vegetation.

STOP 8: Midway Key

Objectives:

A. Demonstration of sample collecting techniques.

B. Inspection of red mangrove peat.

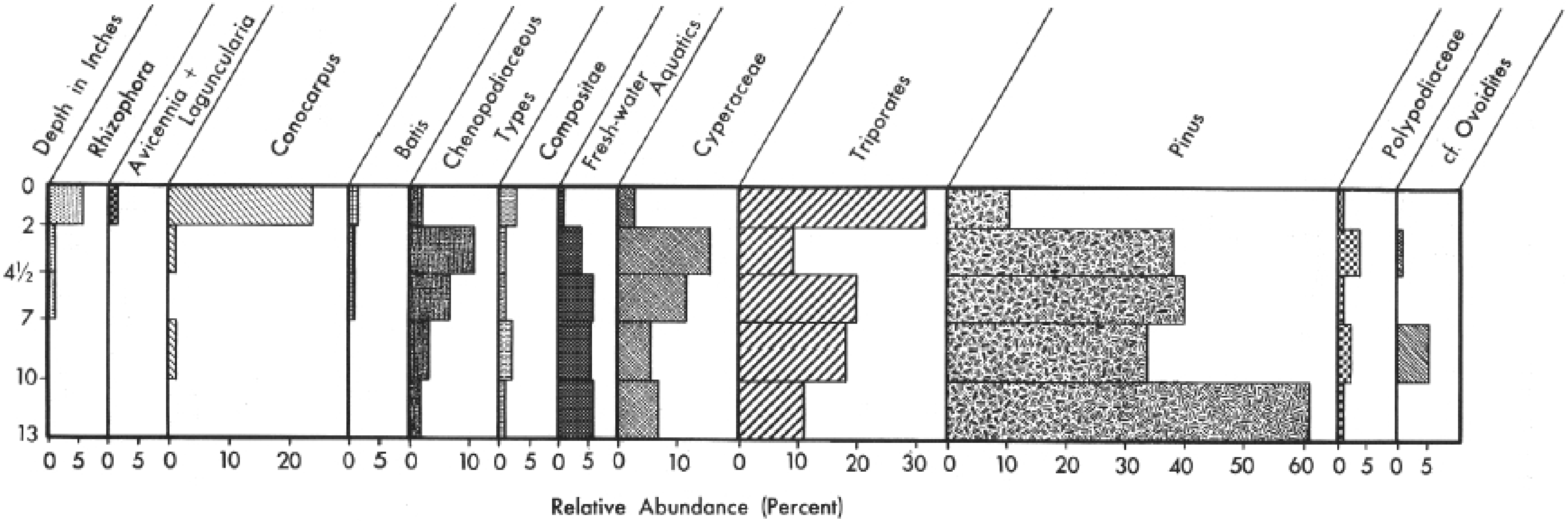
C. Discussion of the form and composition of Whitewater Bay islands.

D. Discussion of island destruction..

Discussion:

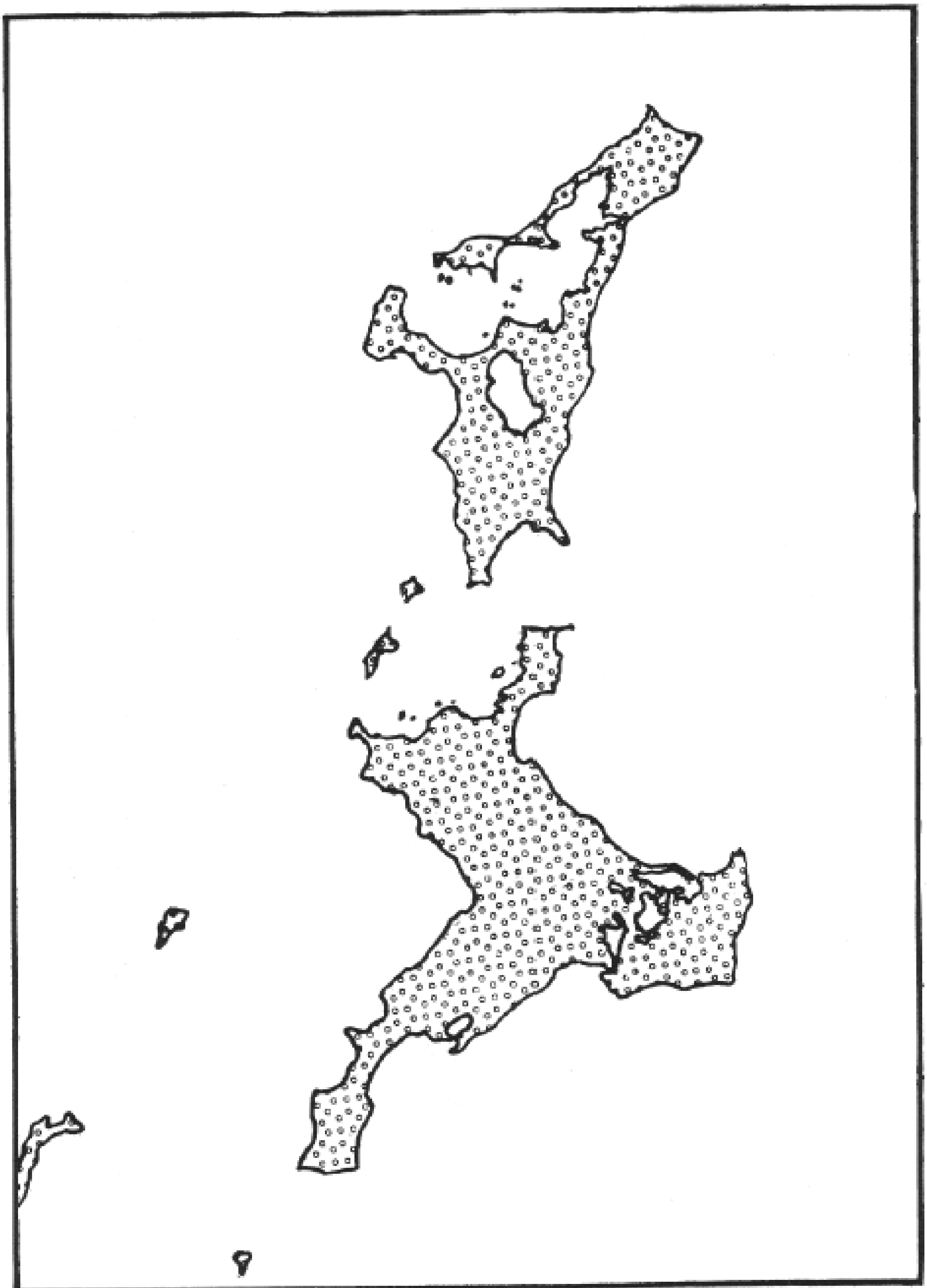
Reference to the trip map (Trip Map No. 1) will show that Stop 8 is located near the center of the shallow open water area known as Whitewater Bay. Comparison of the map (Figure 20) with the photograph of the site (Plate IXb) will show that the small isthmus depicted on the map on the east side of the large north island (the map was taken from a 1953 aerial phtograph) has been destroyed within the last ten years. A similar event can be documented in the case of several other islands. This suggests that island dissection may be another erosional process associated with the aforementioned marine transgression.

Whitewater Bay contains a large number of islands, varying in size from a few square yards to many acres. These islands are blocks of peat standing either on the bedrock floor or on a thin layer of marl. The



POLLEN AND SPORE FREQUENCIES IN THE UPPER SECTION OF A MANGROVE POND CORE

Figure 19



LEGEND ½ mile

DWARF MANGROVE

OPEN WATER

MAP OF ENVIRONMENTS IN THE MIDWAY KEY AREA

Figure 20

peat block is usually six to eight feet in thickness. The blocks tend to be steep sided. In some instances the sides are essentially vertical, as they are in the small Cormorant Pass island shown in Figure 21. Even more extreme cases can be observed in which the block is actually undercut to some degree. As might be expected, the vertical sides and undercut conditions are encountered where the islands are located in areas swept by the higher velocity currents. A more typical island is the one lying just to the east of Midway Pass (Figure 22). The sides of this island are clearly erosional features but they dip more gently into the water and under the recently deposited bay sediments.

No evidence has been found indicating that the area occupied by the islands is increasing. Instead, the opposite appears to be occurring. Not only are islands being dissected as suggested above, but several shown on the 1953 charts and aerial photographs of the area have been reduced in area and a few have been completely destroyed. A cruise through Whitewater Bay will reveal islands in all stages of destruction.

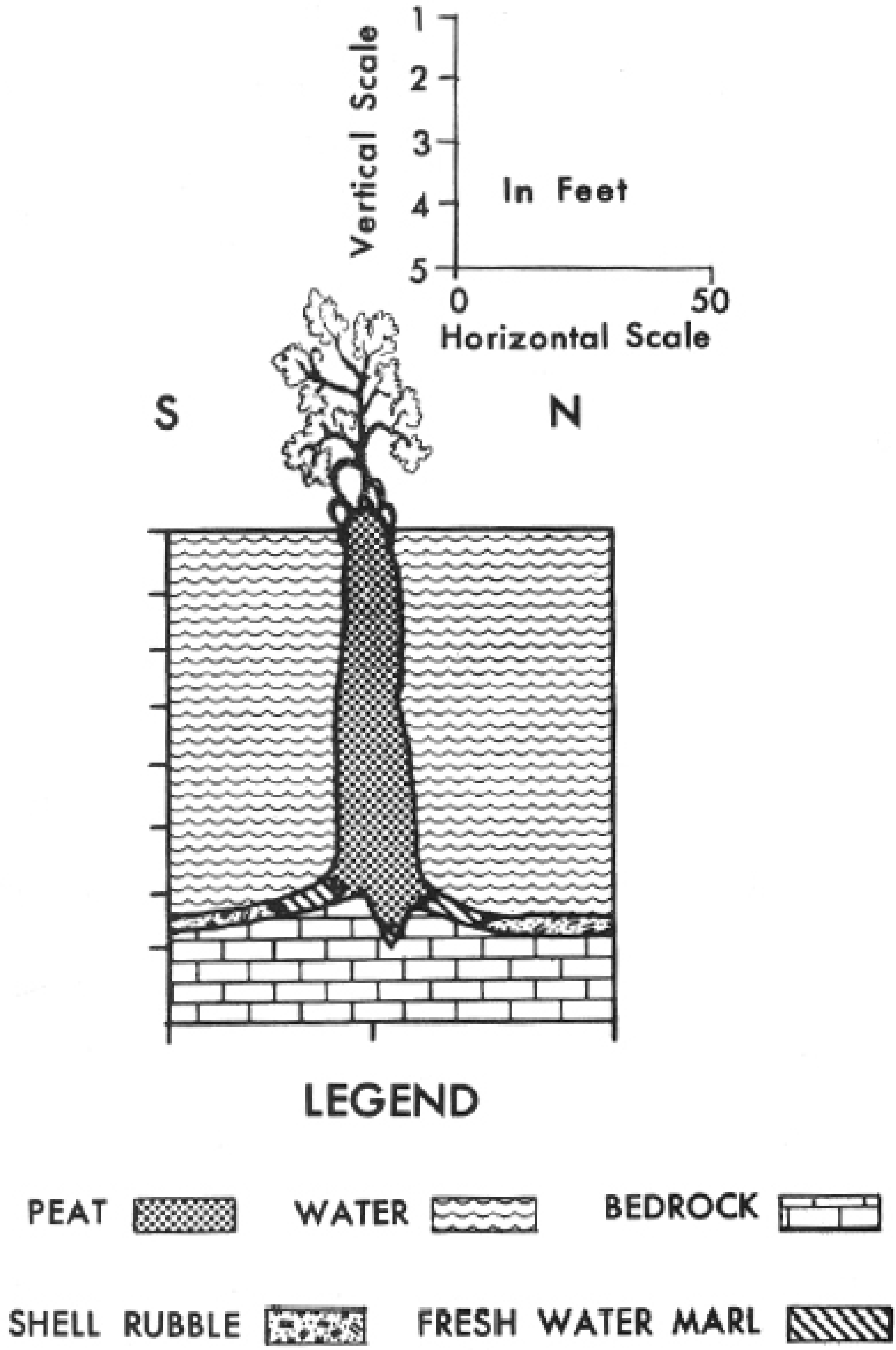
The surface peat at Stop 8 is a good example of red mangrove peat. It is unlikely that peat is accumulating at this site at the present time. Although no radiocarbon dates have been obtained from the surface peat on Midway Key, it is estimated that this material would be found to be 500 to 1000 years old. The roots of the red mangrove appear to make an important contribution to the peat mass. This may be the result of the tidal wash that bathes the surface twice a day removing large quantities of surface litter. If protected from effective tidal wash, a somewhat different type of peat might result.

The peats and other sediments of this area can be sampled in a variety of ways. For pollen studies either the Hiller or Davis Borer has proved satisfactory. If uncompressed core samples are required, an aluminum or plastic tube is forced into the sediment while maintaining an air-tight plunger in the tube at the ground level (Plate X).

STOP 9: Tarpon Creek Site

Objectives:

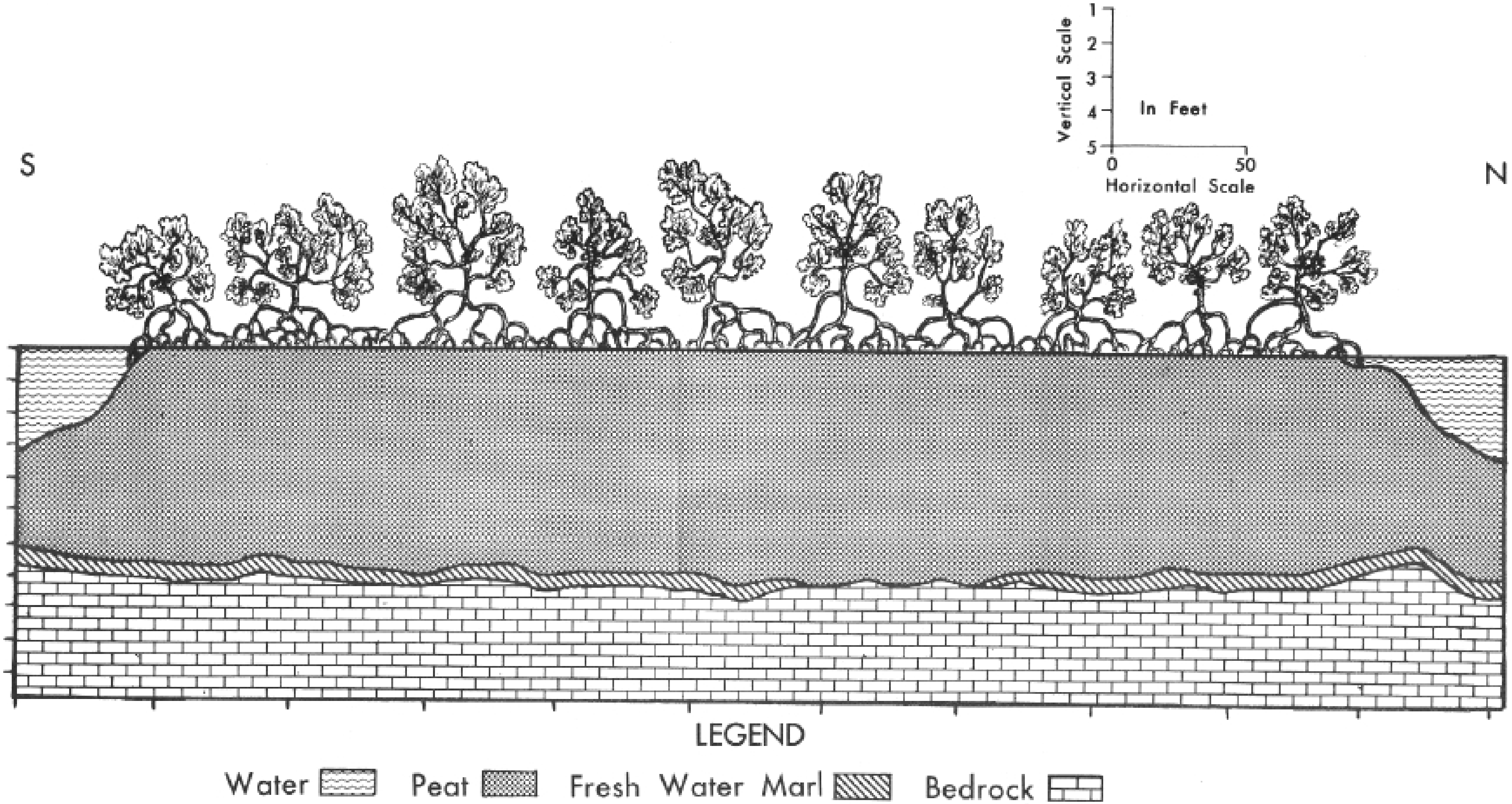
A. Inspection of marine marl, peat, fresh-water marl stratigraphic sequence.



SECTIONAL PROFILE

THROUGH ISLAND IN CORMORANT PASS

Figure 21



SECTIONAL PROFILE THROUGH TYPICAL ISLAND IN WHITEWATER BAY

Figure 22

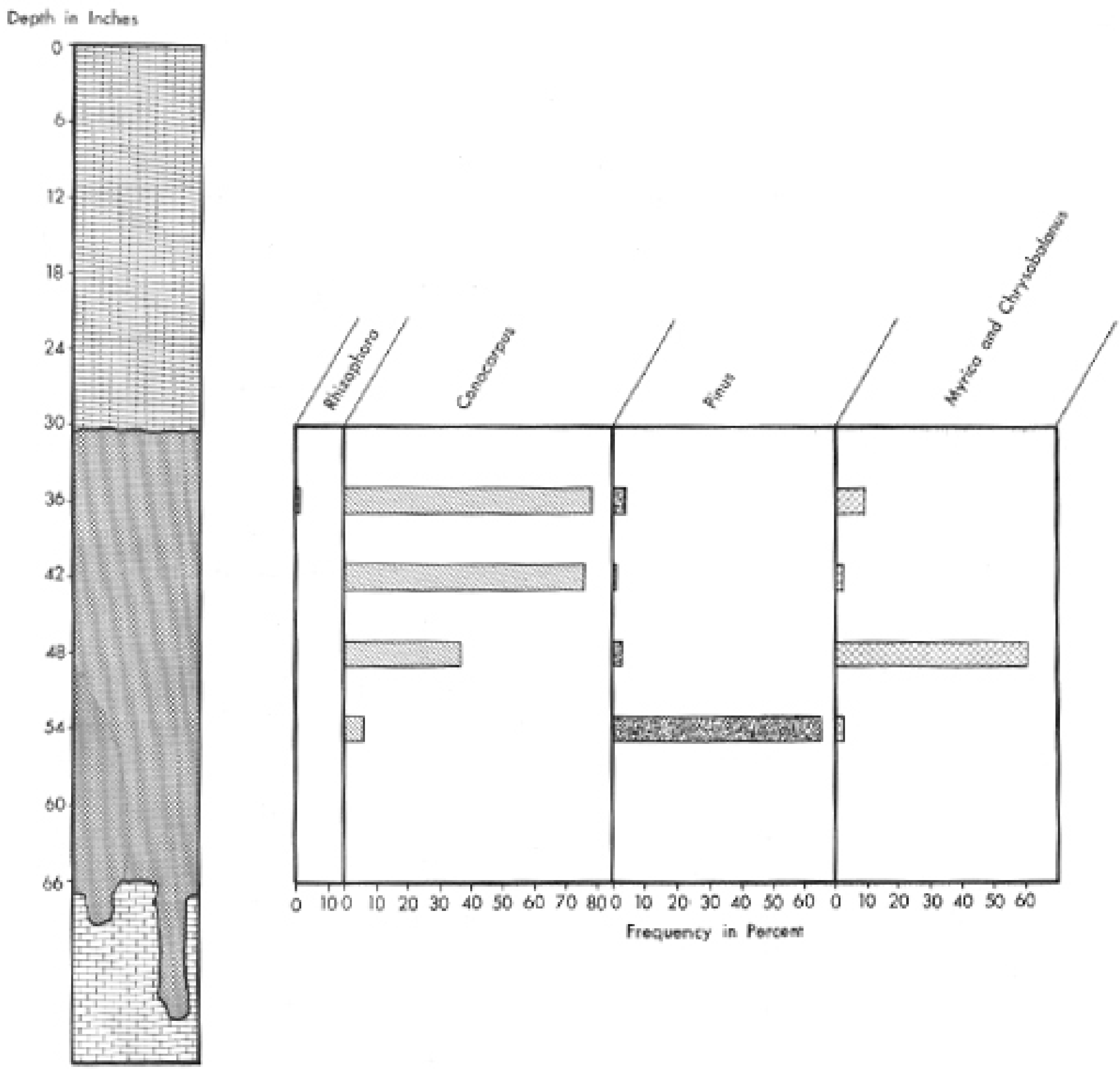
PLATE X

B. Discussion of the southwestern margin of Whitewater Bay.

Discussion:

As one moves southward from the Lane Bay - Hell's Bay area, the peat disappears from the surface and becomes buried under a calcareous sediment that has been interpreted as having a marine origin. The composition and origin of this sediment will be discussed in detail on some of the following pages. If a southwesterly course is taken from the Lane Bay area, one must travel much farther before the marine marl - peat contact is encountered on the ground surface. The entire southwestern shore of Whitewater Bay along the Joe River is formed of a thick peat mass. In the western half of Cape Sable peat remains at the surface for at least three miles southwest of Joe River where it is more than nine feet thick.

At Stop 9 the marine marl mixed with a small amount of plant debris covers the peat to a depth of 31 inches. Below this lies 38 inches of peat resting either directly on the bedrock or on a thin layer of fresh-water marl. As shown in Figure 23, the most frequently encountered pollens in the peat are those of Conocarpus, Chrysobalanus and Pinus. Rhizophora pollen was encountered 7 inches beneath the top of the peat and appeared to increase in abundance as the upper peat layer is approached. The presence of grass, sedge and pine pollen near the base of the peat, in the proportions in which they occur, suggests the presence of a fresh-water open saw grass type of environment. The gradual increase in Conocarpus and the appearance of Rhizophora near the top of the peat is evidence of a gradual transgression of more marine conditions. The peat - marine marl contact is clearly disconformable. This, plus the absence of higher concentrations of Rhizophora in the peat, indicates erosion of a portion of the upper peat mass prior to burial with the marine marl.



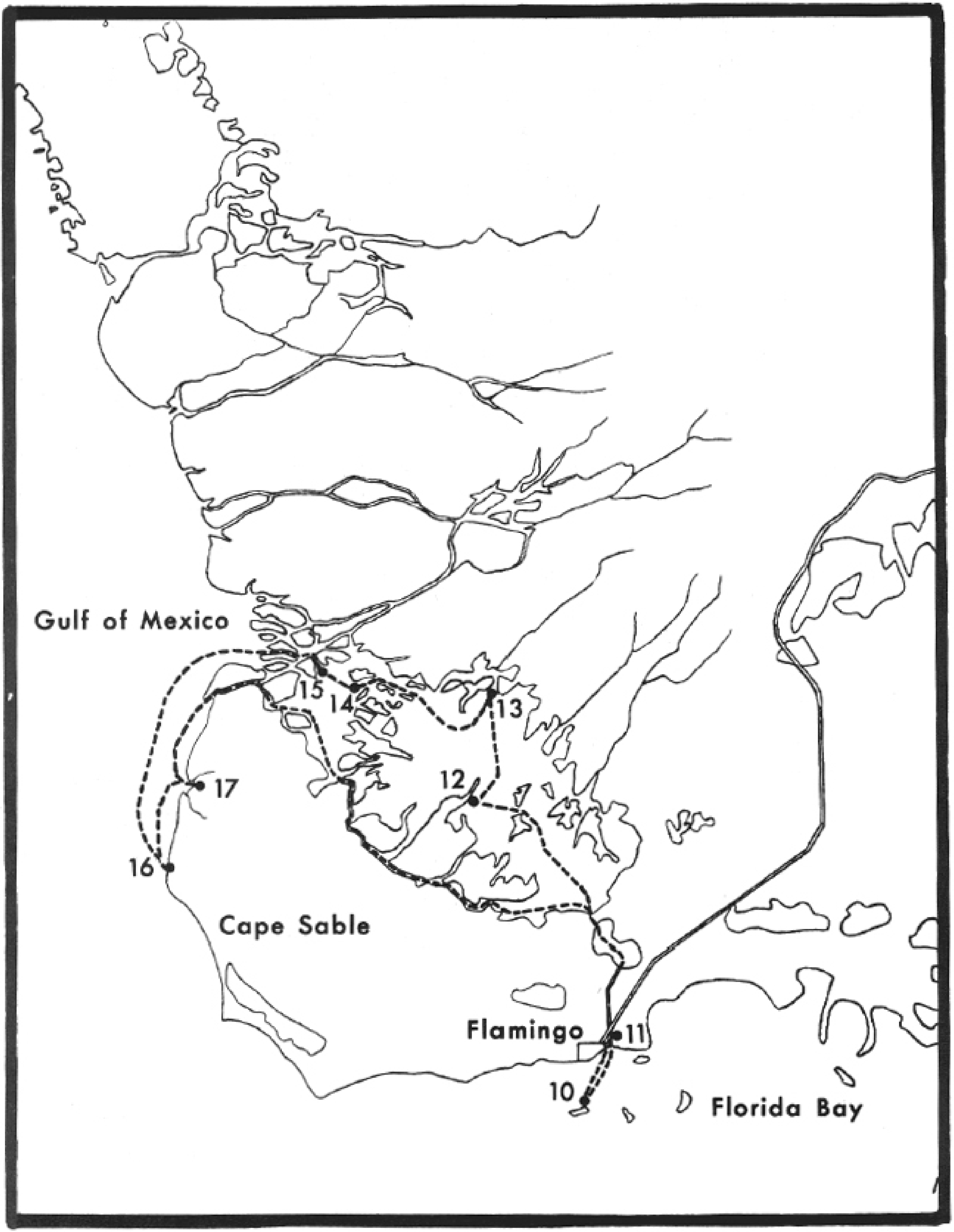
FREQUENCY OF THE COMMON POLLENS IN THE SUB-MARL PEAT NEAR TARPON CREEK
Figure 23

ROUTE FOR THE SECOND DAY

(Trip Map No. 2)

Starting Point: Flamingo Marina. Board large tour boats from piers at south end of Marina.

Nautical Miles	Description
0.0 - 1.7	Enter Florida Bay via Buttonwood Canal. Proceed south following channel to Channel Marker No. 9.
1.7	Alter course and proceed on 227° heading.
1.7 - 2.1	Proceed for 0.4 miles on 227° heading.
2.1	STOP 10: FLORIDA BAY SITE. Drop anchor 0.5 mile off eastern end of Murray Key. See pages 36 to 38 for a discussion of this site.
2.1 - 2.5	Assume heading of 43° and return to Channel Marker No. 9.
2.5 - 4.2	Proceed into channel and return to mouth of Buttonwood Canal.
4.2	Alter course as necessary to enter Buttonwood Canal.
4.2 - 4.7	Proceed north in Buttonwood Canal.
4.7	STOP 11: BUTTONWOOD CANAL SITE. The boats may not actually stop here but your attention will be called to the sediments exposed in the canal's walls.
4.7 - 6.7	Continue north in Buttonwood Canal to Channel Marker No. 2 in Coot Bay.
6.7 - 14.8	Alter course as necessary to follow channel through Coot Bay, Tarpon Creek and Whitewater Bay to Channel Marker No. 28, just west of Midway Pass.
14.8	At Channel Marker No. 28 alter course and assume a heading of 246°.


Gulf of Mexico
15
14
13
12
17
16
Cape Sable
Flamingo
11
10
Florida Bay

TRIP MAP NO. 2

14.8 - 16.0	Proceed on 246° heading for 1.2 miles then drop anchor.
16.0	STOP 12: WHITEWATER BAY - HIGH SALINITY SITE. A discussion of this site is presented on pages 38 to 41.
16.0 - 17.0	Set course at 47° and proceed 1.0 miles to Channel Marker No. 30.
17.0 - 20.2	Change course to due North at Channel Marker No. 30 and proceed 3.2 miles. Drop anchor.
20.2	STOP 13: WHITEWATER BAY - LOW SALINITY SITE. See discussion on pages 38 to 41.
20.2 - 22.3	Proceed due south 2.1 miles.
22.3 - 23.2	Change course to due West and proceed 0.9 miles to Channel Marker No. 34.
23.2 - 28.1	Follow channel proceeding in a northwesterly direction. After passing between the first two island masses, note clarity of water and nature of bottom. The eastern margin of Whitewater Bay is formed by a large number of irregularly shaped islands. The channel moves through an area known as Cormorant Pass. The small elongate island to the right of the channel between Marker No. 42 and Marker No. 44 is shown in the sectional profile presented as Figure 21. Drop anchor midway between Channel Markers 50 and 51.
28.1	STOP 14: OYSTER BAY SITE. See comments on page. 41.
28.1 - 32.3	Proceed to Marker 53 and anchor at south end of adjacent island.
32.3	STOP 15: LUNCH. Note remnant island to the southeast.
32.3 - 38.0	Return to channel and follow it to the mouth of the Little Shark River.

38.0 - 41.2	At 4 second beacon at the mouth of the Little Shark River, alter course to 202° and proceed 3.2 miles to a point off Big Sable Creek.
41.2 - 44.0	Alter course to 180° and proceed 2.8 miles to a point south of Little Sable Creek.
44.0 - 44.3	Alter course and proceed toward land to the shallowest depth permitted by the boat's draft. Anchor. Leave tour boat and enter ferry skiffs and proceed to shore.
44.3	STOP 16: CAPE SABLE BURIED FOREST. A discussion of the objectives of this stop together with pertinent factual information is presented on pages 41 to 44.
44.3 - 44.6	Board ferry skiffs and return to tour boats.
44.6 - 47.4	Proceed due North 2.8 miles to point off mouth of Big Sable Creek.
47.4 - 48.1	Alter course to 74° and proceed .7 miles,anchoring in Big Sable Creek Bay near main stream mouth.
48.1 - 48.5	Leave tour boats and board ferry skiffs. Proceed .4 miles into Big Sable Creek.
48.5	STOP 17: BIG SABLE CREEK SITE. See pages 44 to 46 for discussion.
48.5 - 48.9	Return to tour boat by means of ferry skiffs.
48.9 - 49.7	Set course to 320° and proceed 0.8 miles.
49.7 - 51.9	Alter course to 23° and proceed 2.2 miles to 4 second beacon at the mouth of the Little Shark River.
51.9 - 76.7	Follow Channel Markers to Flamingo Marina (24.8 miles) or use alternate route involving navigation from Big Sable Creek around Cape Sable and to Flamingo via Florida Bay (36.0 miles).
76.7	FLAMINGO MARINA - TERMINATION OF SECOND DAY'S FIELD ACTIVITIES. Time of dinner to be announced.

SITES TO BE VISITED ON SECOND DAY

During the first part of today's trip, two distinctly different sedimentary environments, those of Florida and Whitewater Bays, will be examined. Florida Bay (Figure 24) is a shallow embayment of the broad continental shelf off western Florida. Virtually the only sediment forming in the bay is calcareous mud composed of metastable carbonate minerals. In contrast, Whitewater Bay is a nearly enclosed lagoonal embayment lying a few miles north of Florida Bay. Whitewater Bay is part of the widespread coastal mangrove swamps of southwestern Florida (Davis, 1940). Sediments in the bay vary from peat to fine-grained calcitic mud. Both Florida and Whitewater Bays formed 3000 - 3500 years ago when the postglacial rise in sea level (Holocene transgression) reached southern Florida (Scholl, in press, A and B). Today's field study will demonstrate rapid facies changes.

STOP 10: Florida Bay Site

Objectives:

A. Inspection of sediment found in an environment occurring adjacent to, and related with, the swamp environments.

B. Discussion of the mineralogical, chemical and physical characteristics of the Florida Bay sediments.

C. Procurement of cores of Florida Bay sediments.

Discussion:

Unconsolidated sediments in Florida Bay are calcareous muds. If lithified, these sediments would be classified as shelly or fossiliferous calcilutites or as biomicrites. Some of the important physical, chemical and mineralogical characteristics of the calcareous sediments of Florida Bay are listed in Table 1.

Seaward of Flamingo, Florida, the sediment in the bay is as much as six feet thick (Figure 25). The sediment overlies the Miami oolite, a limestone of Late Pleistocene (probably Sangamon) age. The sediment does not form a blanket deposit over bedrock but is concentrated in sinuous banks. Most of the mangrove-crested islands in the bay rise from these banks (Figure 24). Radiocarbon dates on a thin layer of peat

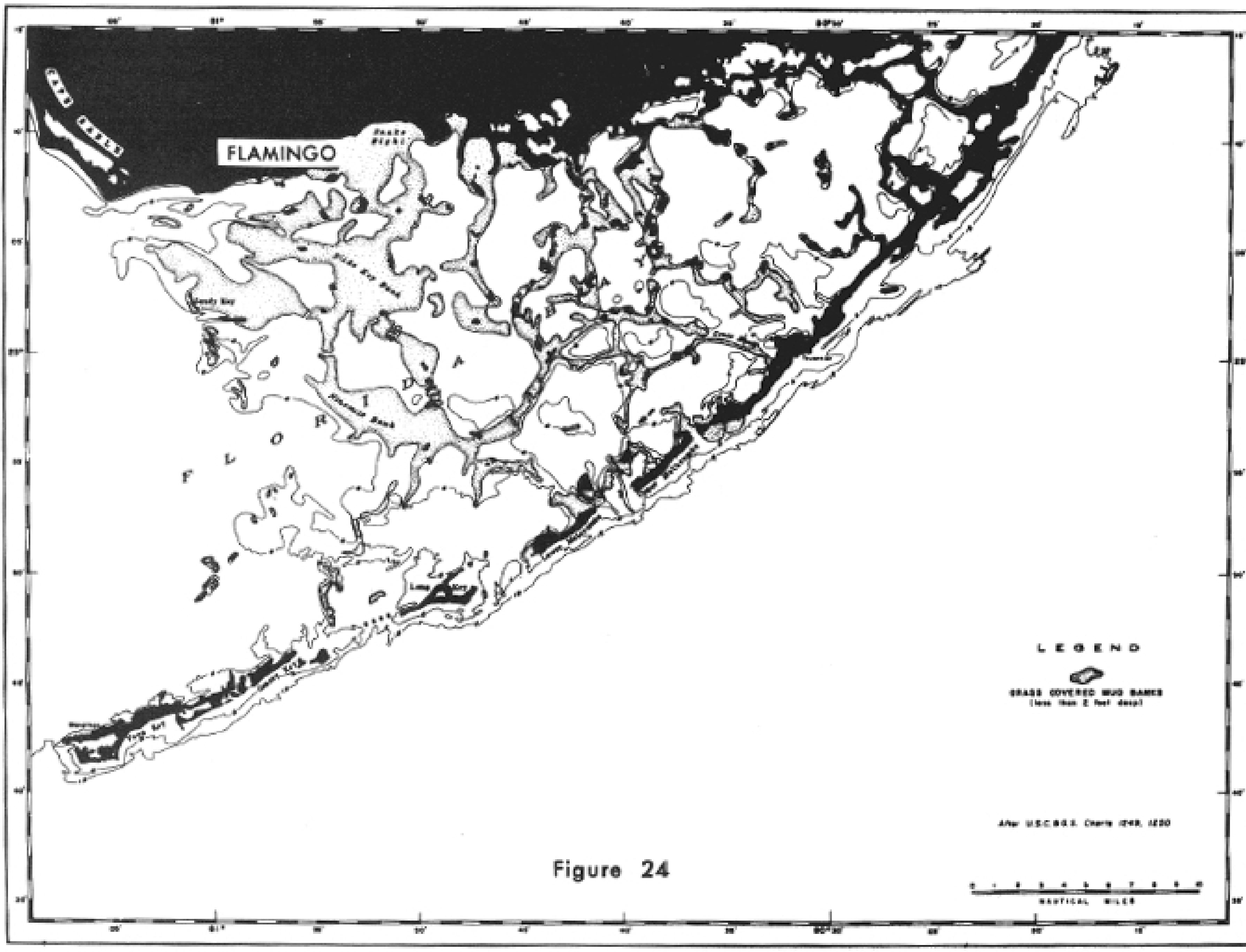


Figure 24

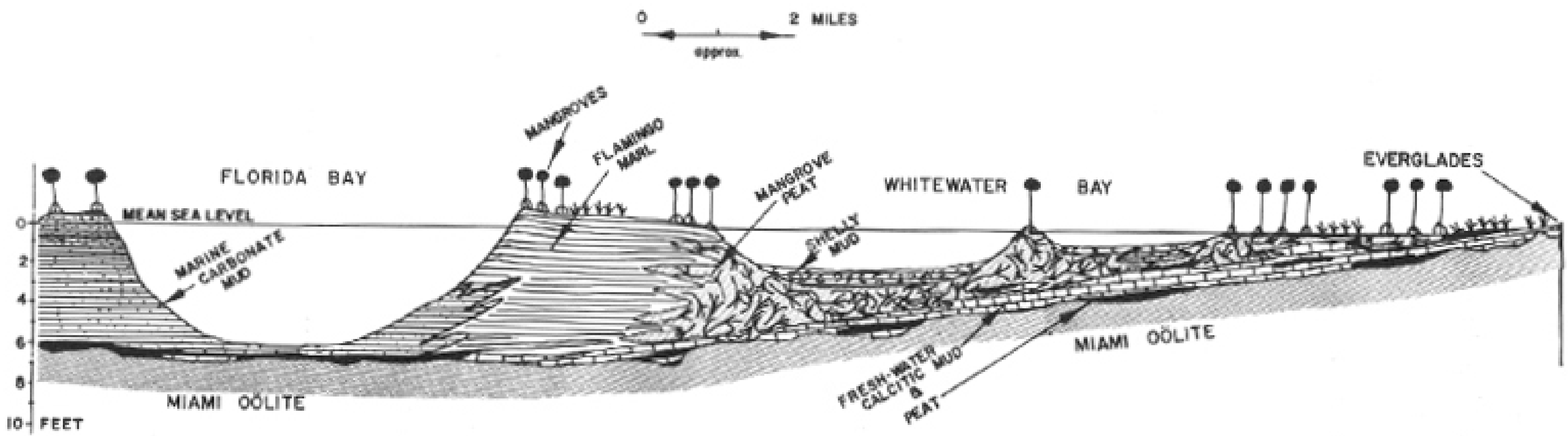
Figure 24. Index map to Florida Bay (from Ginsburg, 1956). Most of the calcareous sediments in the bay are concentrated in the sinuous to irregular-shaped banks. These sediments average about 6 feet thick and overlie the Miami oolite. Near Flamingo, coral in the Miami oolite has a radiocarbon age greater than 30,000 B.P.

Table 1

Properties of Calcareous Sediments in Western Florida Bay[1]

Characteristics	Average Values	Range
Mass properties		
Water content (dry weight)	71.5%	
Porosity	65.9%	
Grain density	2.71 g/cc	
Bulk density	1.58 g/cc	
Grain Size distribution		
Median diameter	0.028 mm	
Trask sorting coefficient	6.81	
Percent >0.062 mm (sand)	30	1-52
Percent 0.062-0.001 mm	48	9-70
Percent < 0.001 mm (subclay)	22	5-50
Carbonate mineralogy		
Percent aragonite	59	35-77
Percent high-Mg calcite	27	3-54
Percent low-Mg calcite	14	1-29
Percent dolomite	present	?
General Chemistry		
Ca/Mg	25	6-41
Sr/Ca X 10^3	8.7	6.3-11.7
Percent calcareous minerals	87	81-90
Percent non-calcareous mineral	9	8-13
Percent organic matter	4	2-6
Percent organic carbon	2.1	1.3-3.7
Percent organic nitrogen	0.15	0.29-0.09
Organic carbon/organic nitrogen	17	13-26

[1]Data are from Taft and Harbaugh (1964) and Scholl (in press, C).



SECTIONAL PROFILE THROUGH FLORIDA BAY AND WHITEWATER BAY

Figure 25

- A schematic generalization of the overall stratigraphic relations of the modern sediments of western Florida Bay, Whitewater Bay, and the Everglades. The line of cross-section runs approximately northward through Flamingo, Florida.

underlying the calcareous sediment and overlying bedrock indicate that the sedimentary fill in Florida Bay began to form about 3500 years ago. A core of this sediment will be taken at Stop 10.

The constituent particles of the calcareous sediment are largely contributed by mollusks and foraminifera. The relatively coarse skeletal parts of these animals are broken down by other animals and plants (e.g. algae) to form the finer fractions of the bay sediment (Ginsburg, 1956; Taft and Harbaugh, 1964).

Mineralogically, sediments in the bay are chiefly composed of the metastable carbonates aragonite and high-magnesian calcite (Figure 26). Low-magnesian calcite and dolomite form only a minor fraction of the sediment (Stehli and Hower, 1961; Taft, 1961; Taft and Harbaugh, 1964). Surprisingly, solution or recrystallization of the metastable carbonate minerals in Florida Bay do not appear to be taking place (Pilkey, 1964; Taft and Harbaugh, 1964).

In the vicinity of Flamingo, Florida and for many miles along the northern shore of Florida Bay, a ridge of bay sediment has been heaped upon the mainland by storm waves (Craighead and Gilbert, 1962). This storm levee of bay mud rises 18-24 inches above sea level and has been termed the Flamingo marl by Davis (1943). The storm levee will be examined at Stop 11.

Landward of this coastal ridge are extensive tracts of brackish-water (Whitewater Bay) and fresh-water swamps (Everglades). The probable relation of the sediments underlying Florida Bay to those in Whitewater Bay and the Everglades is schematically diagrammed on Figure 25.

STOP 12: Whitewater Bay "High Salinity" Site.

STOP 13: Whitewater Bay "Low Salinity" Site.

Objectives:

A. Inspection of the open water sedimentary facies in Whitewater Bay.

B. Discussion of the relationships between the mineralogical plus textural characteristics of the basal calcitic mud and comparable characteristics of the fresh-water marl of the open Everglades.

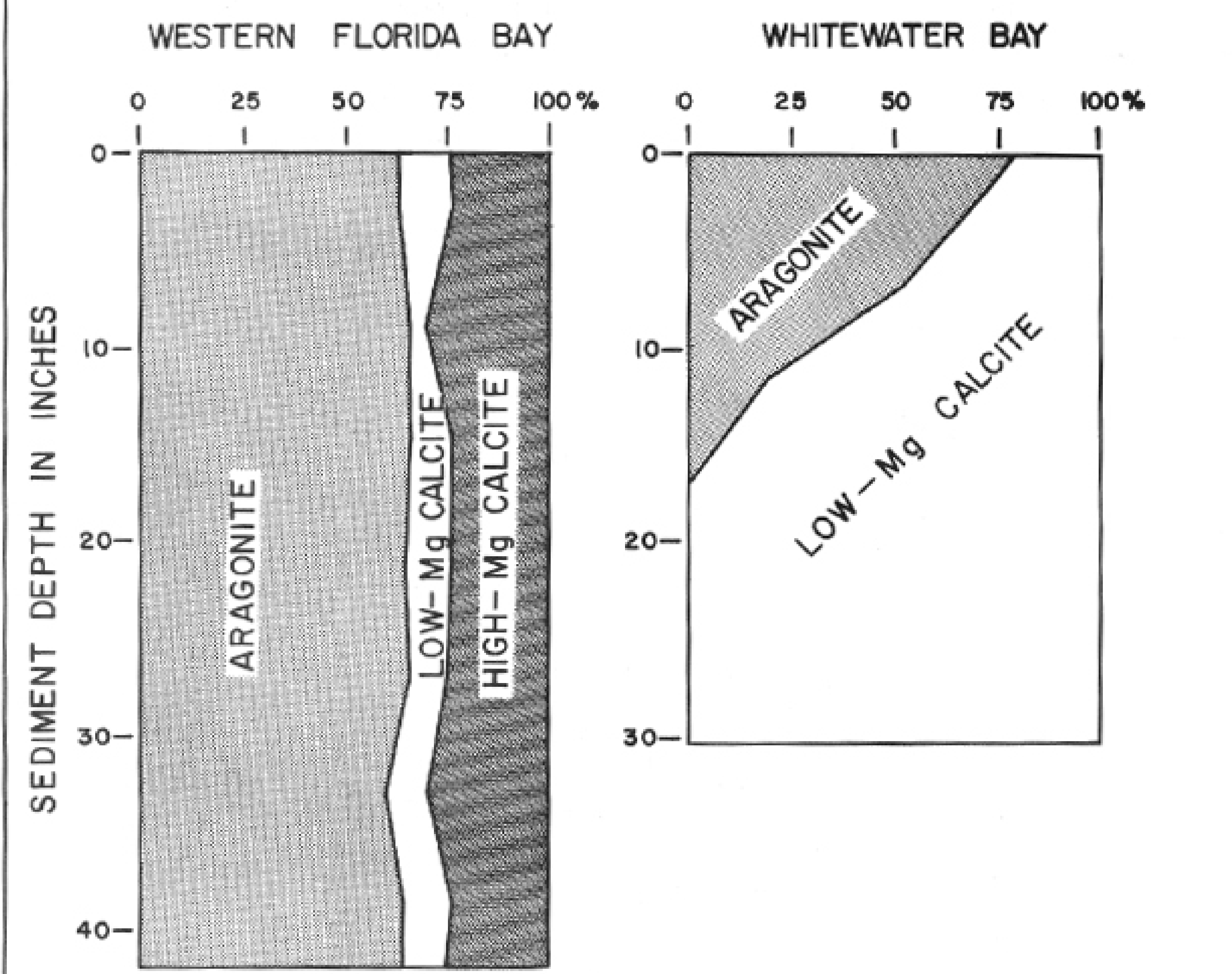


Figure 26 - Relative concentrations of carbonate minerals in sediment cores from western Florida Bay and Whitewater Bay. The lack of aragonite and high-magnesian calcite in the basal portion of the Whitewater Bay core is not due to recrystallization or conversion of these minerals to low-magnesian calcite, but reflects the presence of highly calcitic fresh-water sediments underlying marine and brackish-water deposits.

C. Discussion of the evidences of marine transgression.

Discussion:

Whitewater Bay lies landward of Cape Sable, a broad marshy platform that rises 1 to 2 feet above sea level (Figures 24 and 27). The Cape is in part composed of marsh sediments and the Flamingo marl. A bedrock high may underlie Cape Sable, which possibly initiated the accumulation of the storm and marsh deposits that form the subaerial part of the Cape.

During the dry season, fall to spring months, marine water from the Gulf of Mexico entering the bay through sinuous between-island passes, raises the water salinity in the bay to values similar to those found in Florida Bay (i.e., $35^{o}/oo$). However, high rainfall and mainland runoff during the summer rainy months cause the bay to become very brackish (Scholl, 1963).

In general, a northeast gradient of decreasing salinity can be found in the bay at any time of the year. This is because runoff enters the bay along its northeastern margin.

Unconsolidated sediments in the open water environments of Whitewater Bay are rarely more than four feet thick; they rest on the Miami oolite, the same bedrock platform that underlies Florida Bay to the south. Structural contours on this formation delineate a drainage pattern (Figure 27). Apparently prior to the formation of the bay, streams draining the Everglades crossed this area. Two stops will be made in the bay to collect cores of the sediment fill. One core (to be taken at Stop 12) will be taken along the "high-salinity" (annual range is $26\text{-}35^{o}/oo$) or southwestern side of the bay; the other core (to be taken at Stop 13) will be taken along the "low-salinity" (annual range is $4\text{-}32^{o}/oo$) or northeastern margin of the bay. Stratigraphic diagrams of typical cores collected along these two sides of the bay are shown on Figures 28 and 29.

Cores taken in Whitewater Bay typically have a basal fresh-water section, a middle brackish-water section, and an upper brackish-water to marine (polyhaline) section. The basal section comprises fresh-water peat and calcitic mud overlying bedrock; these fresh-water units were

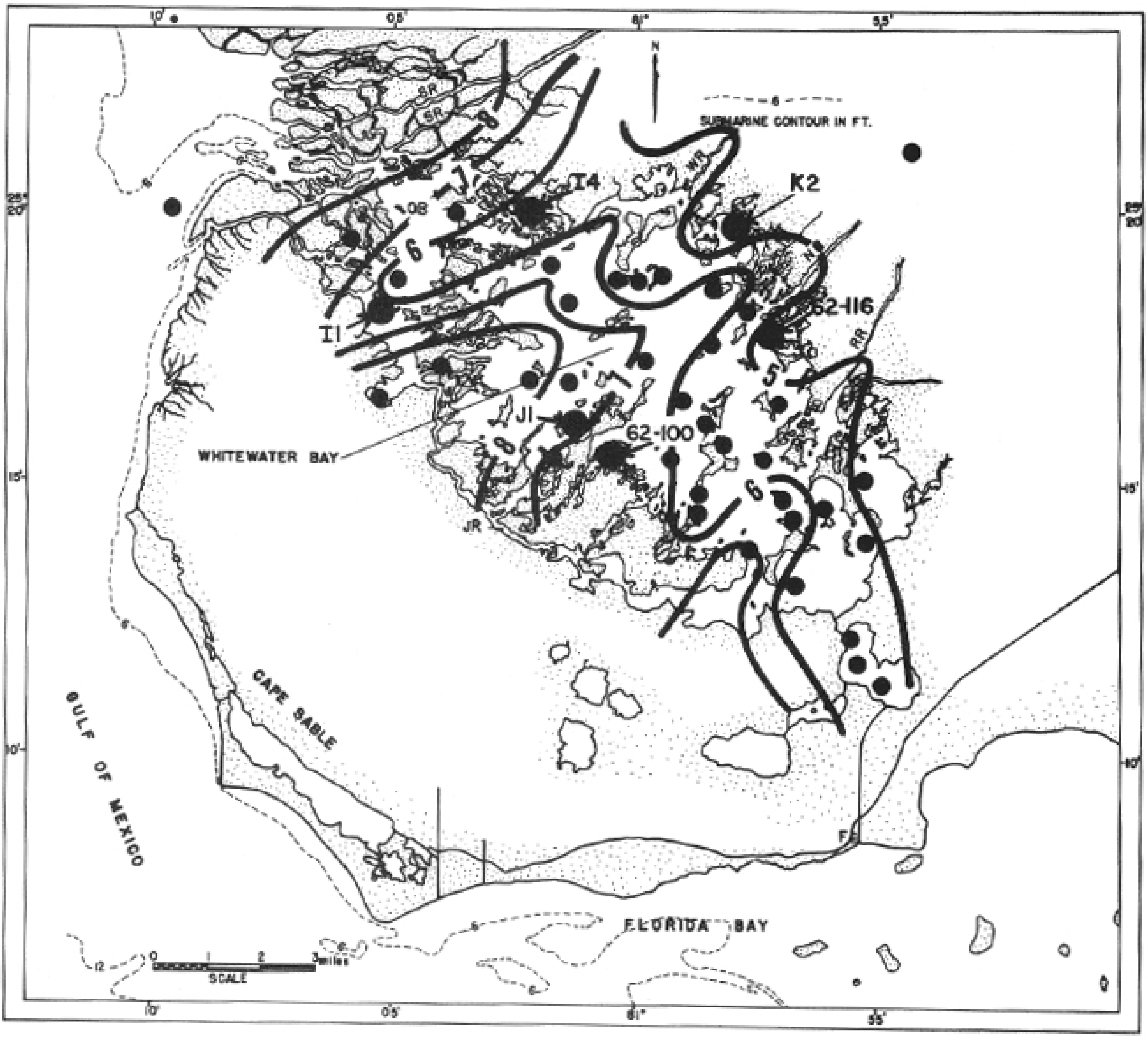
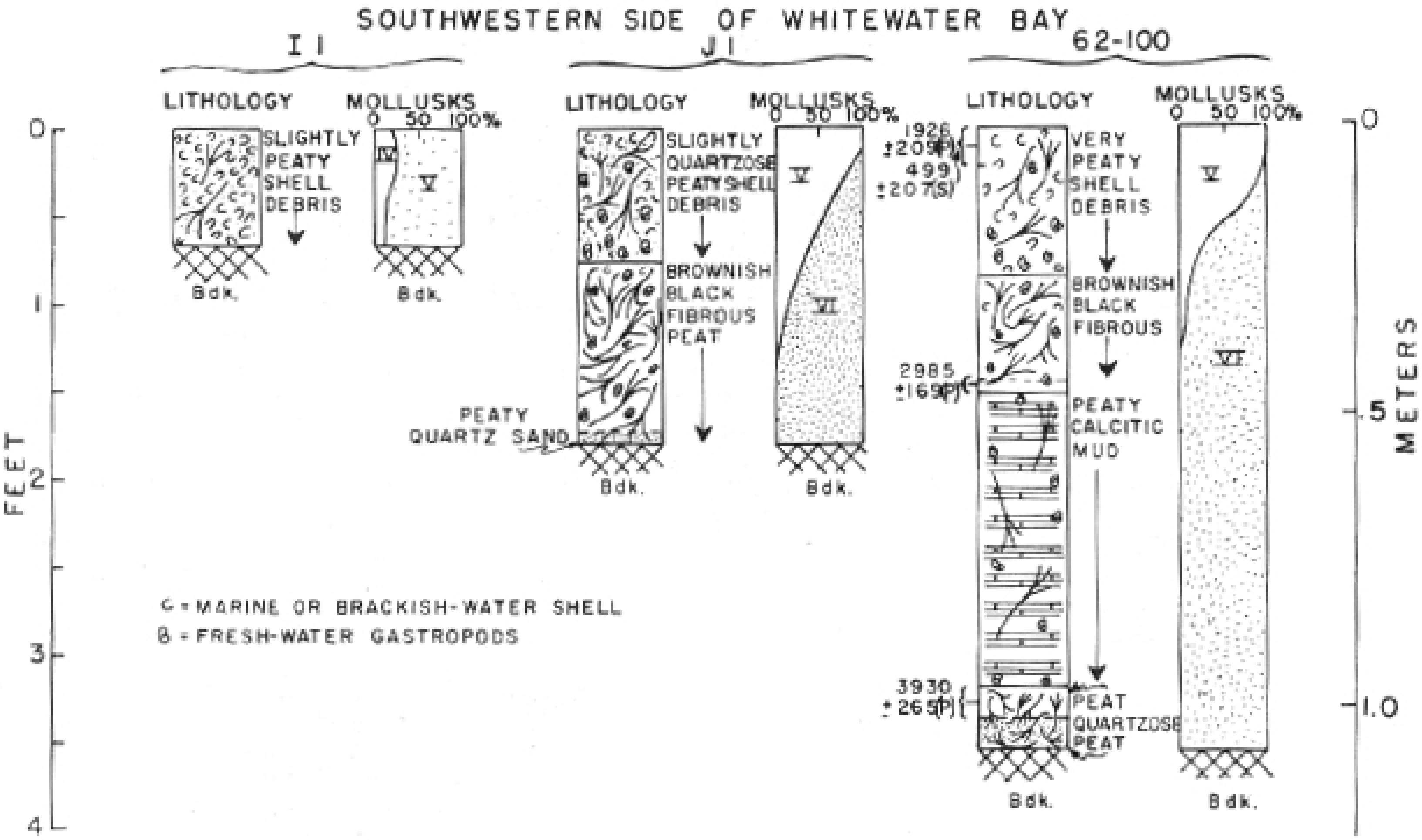


Figure 27 - Structural contours on the Miami oolite, which is the bedrock floor underlying the sediments of Whitewater Bay. The contours read in feet below mean sea level. A pre-Whitewater Bay drainage pattern is apparently delineated by the contours. Evidently the Watson (WR), North (NR) and Roberts (RR) Rivers drained southwestwardly across the area of Whitewater Bay towards Cape Sable prior to about 3500-3000 years ago. A bedrock high also appears to underlie Oyster Bay (OB), which is at the western end of Whitewater Bay.

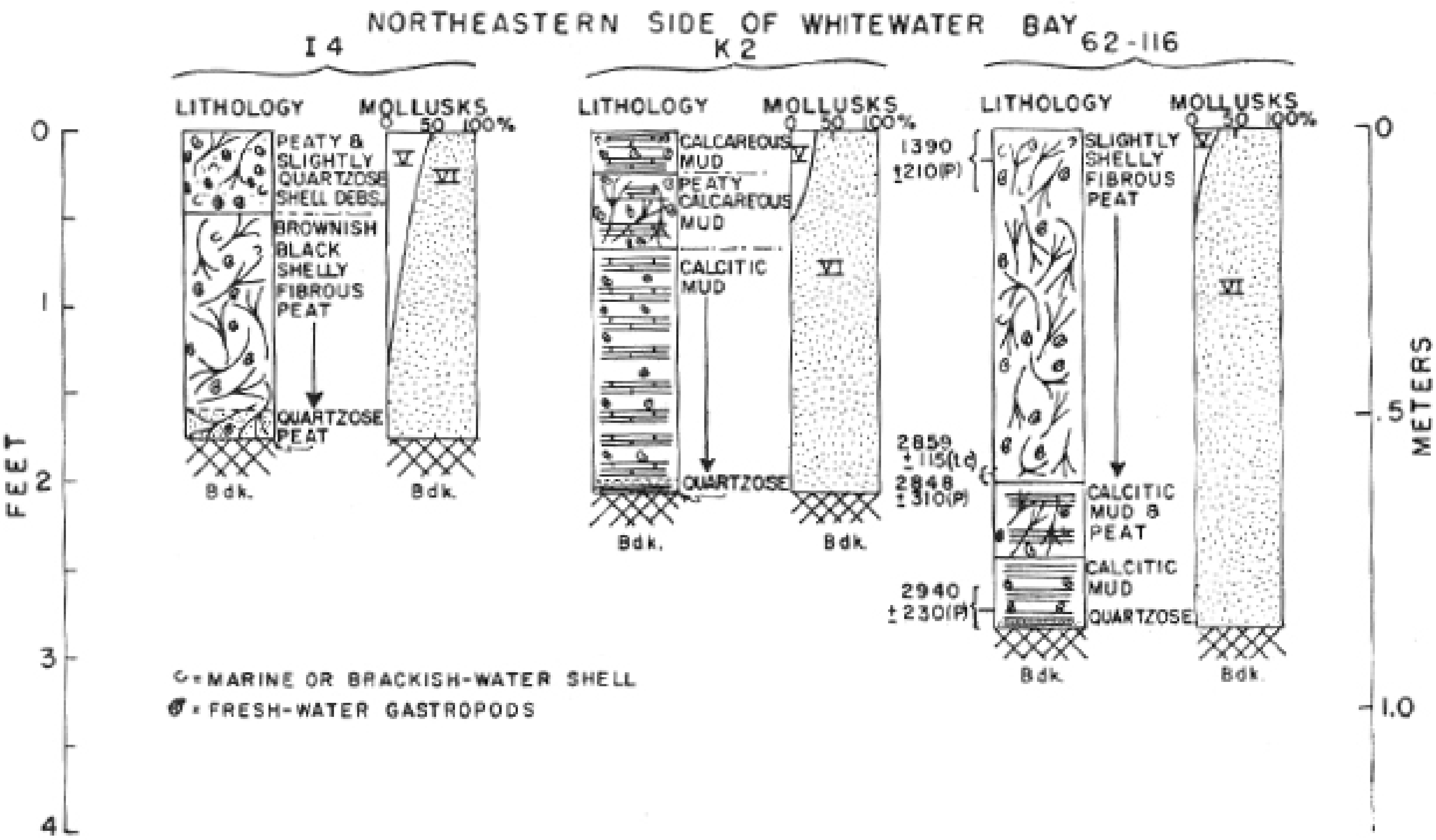


STRATIGRAPHY, AGE AND FAUNA OF SEDIMENTS UNDERLYING SOUTHWESTERN WHITEWATER BAY

Figure 28

Core stratigraphy, radiocarbon dates and molluscan fauna of sediments underlying the southwestern side of Whitewater Bay. Core locations are shown on Figure 26; faunal descriptions are given in Scholl (1963). Molluscan fauna IV is essentially marine, fauna V is a mixture of marine and brackish-water forms (polyhaline) and fauna VI is composed of fresh-water gastropods. Cores I1, J1 and 62-100 were taken at progressively greater distances into (or southeastwardly) Whitewater Bay from a point near its entrance.

Radiocarbon dates are given in years before 1950. Material used for C-14 age dating is designated by (p) for peat or plant remains, (s) for shell debris, and (tc) for total calcareous matter.



STRATIGRAPHY, AGE AND FAUNA OF SEDIMENTS UNDERLYING NORTHEASTERN WHITEWATER BAY

Figure 29

Core stratigraphy, radiocarbon dates, and molluscan fauna of sediments underlying the northeastern side of Whitewater Bay. See explanation for Figure 28.

deposited about 4000 years ago (see radiocarbon dates on Figures 28 and 29). The middle brackish-water section is chiefly composed of in situ (autochthonous) mangrove peat. According to radiocarbon dates, the peat began to form about 3000 years ago. The upper section consists of calcilutaceous and peaty marine and brackish-water shell debris over the southwestern and central regions of the bay, and gray, fine-grained calcitic mud (locally known as "liver mud") along the northeastern margin.

The basal calcitic mud in Whitewater Bay is mineralogically and texturally identical (Table 2) to calcitic mud (locally referred to as "marl") now forming in the fresh-water swamps of the Everglades. The two deposits also have essentially identical fresh-water molluscan

Table 2

Properties of Basal Calcareous Mud in Whitewater Bay and Surficial Calcareous Mud of the Everglades

	Whitewater Bay, basal 1.4 feet of core taken near the southeast end of bay	Surficial 0.5 feet of core taken in Everglades near Homestead, Florida
Median diameter	0.008 mm	0.008 mm
Sorting Coefficient	2.34	1.65
Percent Calcite	98-99	98-99
Percent aragonite*	1-2	1-2
Percent high-Mg calcite	0	0
Sr/Ca X 10^3	2.40	1.75
Ca/Mg	95.7	80.9
Radiocarbon age	ca. 3400 B.P.	726 B.P.

* Due to the presence of fresh-water gastropod shells; chiefly genera of Helisoma, Physa and Planorbis.

faunas (principal genera are Helisoma, Physa and Planorbis). Deposition of the brackish-water mangrove peat on top of the fresh-water calcitic mud and fresh-water peat in the Whitewater Bay area must have been caused by marine flooding and the growth of a mangrove forest over a former region of the Everglades (Scholl, in press, B). Continued submergence apparently destroyed the mangrove forest that deposited this peat and brought about the deposition of the shelly surface sediment that overlies most of the bay. Influx of marine water into the bay is also reflected by a sharp increase in the relative abundance of aragonite over calcite in bay sediments; the aragonite is chiefly derived from mollusk shells (Figure 26 and Taft and Harbaugh, 1964).

STOP 14: Oyster Bay Site

Objectives:

A. Inspection of sediments in the open water area near the entrance to Whitewater Bay.

B. Discussion of the sedimentary facies in Florida Bay, Whitewater Bay and Oyster Bay.

C. Discussion of the relationship between the marine transgression and post-glacial sea level rise.

Discussion:

Broadening of Whitewater Bay to its present size has apparently been under way since about 3000 B.P. Because southern Florida is thought to have remained tectonically stable during this time, the sedimentary section in Whitewater Bay must record the final phases of the world-wide post-glacial rise in sea level (Scholl, in press, A). A curve showing this rise in sea level across southern Florida is given in Figure 30.

The next stop, Stop 14, will be west of Cormorant Pass in Oyster Bay (Figure 27). This area is near the entrance to Whitewater Bay and therefore is swept by tidally generated currents. As a consequence, the floor is covered with only a thin veneer of relatively coarse shelly sediment. The molluscan fauna is also essentially marine in character.

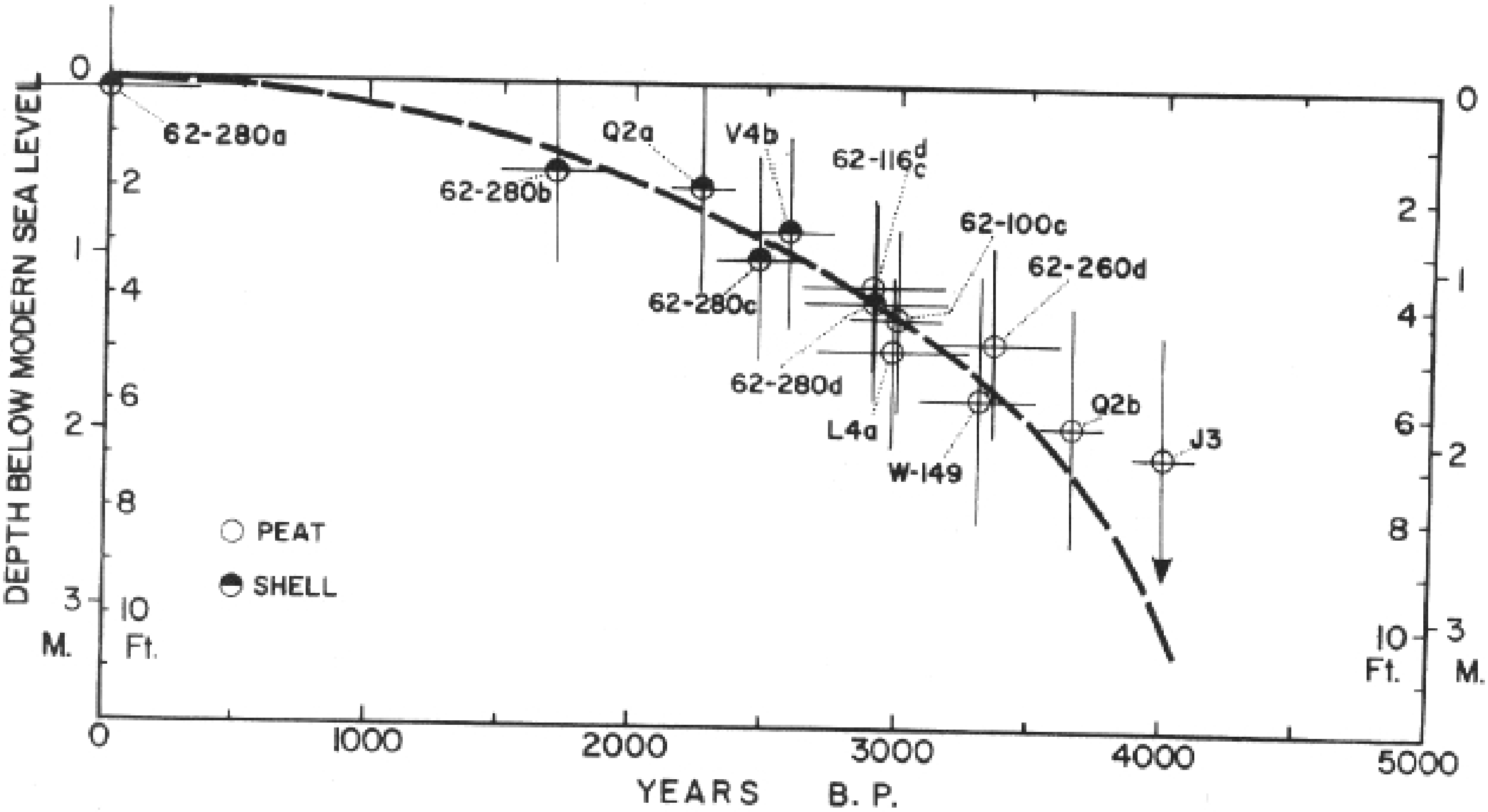
STOP 16: Cape Sable Buried Forest

Objectives:

A. Inspection of the effects of shoreline processes interacting with swamp environment processes - Sector 1: an "exposed" coastline.

B. Inspection of a black mangrove swamp.

C. Discussion of Cape Sable shoreline development.



CURVE SHOWING RATE OF SEA LEVEL RISE DURING LAST 4000 YEARS

Figure 30

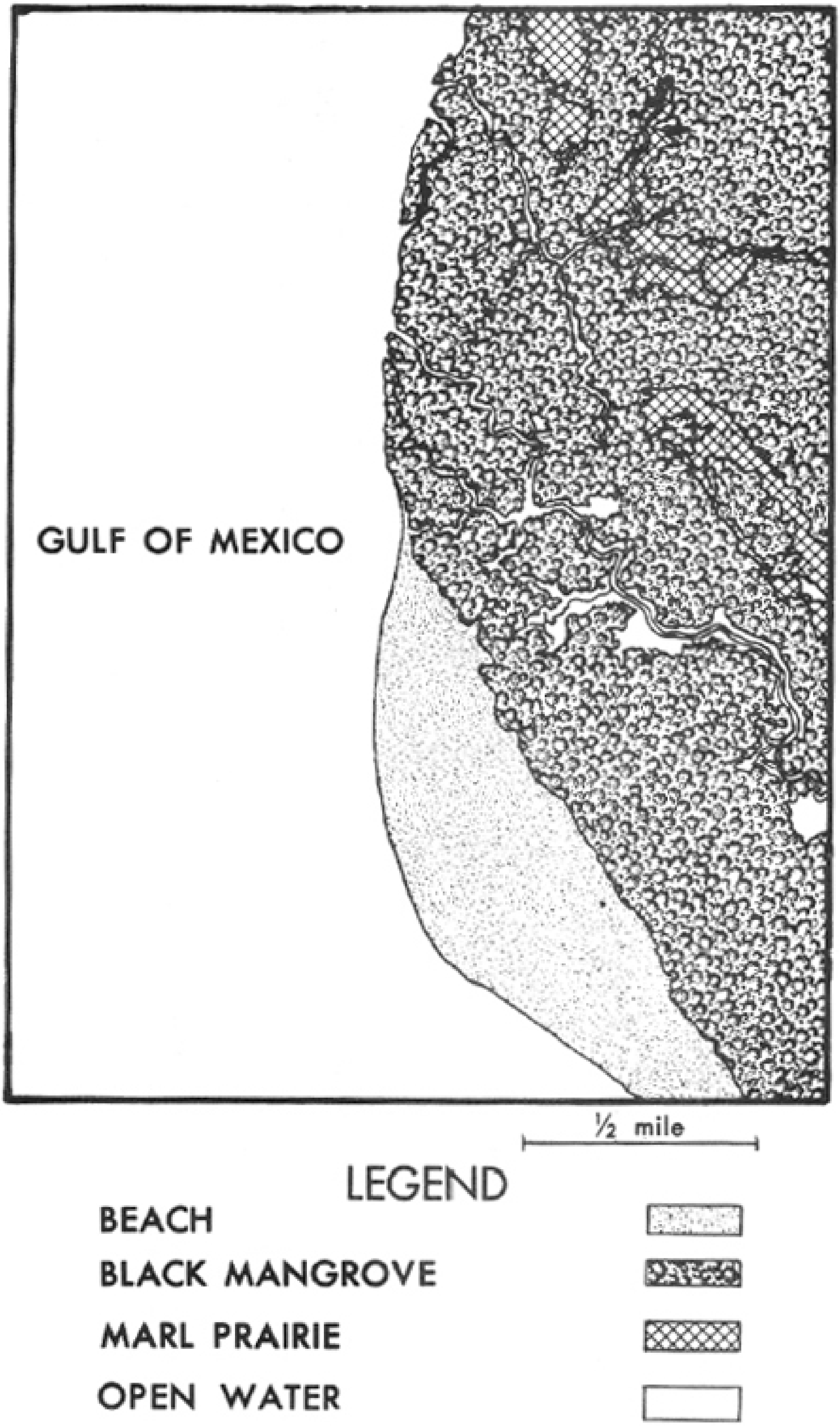
Curve showing rise in sea level across southwestern Florida. Vertical line through data points indicates range of uncertainty in positioning former stands of sea level; horizontal line gives age uncertainty. Arrow at base of vertical line means sea level was probably below plotted data control point.

D. Discussion of forest peat buried beneath storm beach.

Discussion:

The three major environments in the vicinity of "Northwest Cape" are the beach environment, the black mangrove environment and the marl prairie (Figure 31). One of the most interesting features of this site is the buried forest shown in Plate XI. As is evident from the photograph in the Plate, the black mangrove forest recently extended further to the west. It was developed on a layer of peat that is visible at the water's edge with black mangrove stumps still standing on the peat surface. Dead mangrove stumps are also visible projecting up through the beach ridge that was produced after or during the destruction of the living margin of the forest. Behind the beach ridge is the beginning of an extensive forest swamp that occupies many square miles to the north and east.

Before discussing the features of the site in detail, some comments on the shoreline development of Cape Sable may be of interest. Plate XII shows the prominence of land that is called Middle Cape. The successively developed beach ridges are reasonably well-defined in this photograph. Similar photographs could be presented for the other two prominences, namely East Cape and Northwest Cape. The locations of these three capes relative to one another and to Stop 16 are shown in Figure 32 and Plate XIII. Initial inspection of the photo mosaic might suggest that these "capes" are the products of the present coastline developmental processes. This may be the case, however, attention is called to the truncation of the ridges on the west in the case of Northwest and Middle Capes and on the east in the case of East Cape. Moreover, erosion of the coastline north of Northwest Cape is evident not only from the truncated beach ridges but also from the course of the small stream that meanders out into the Gulf of Mexico and then back into the land mass (see Plate XIII and Figure 31). It is difficult to say whether the present net effect along this coastal sector is one of deposition or erosion. In terms of the last 3000 - 4000 years, the situation is much clearer. The net effect over this period of time has been one of aggradation. Several successively older coastlines are evident in the mosaic (Plate XIII). Five of these have been represented and labelled in the map presented

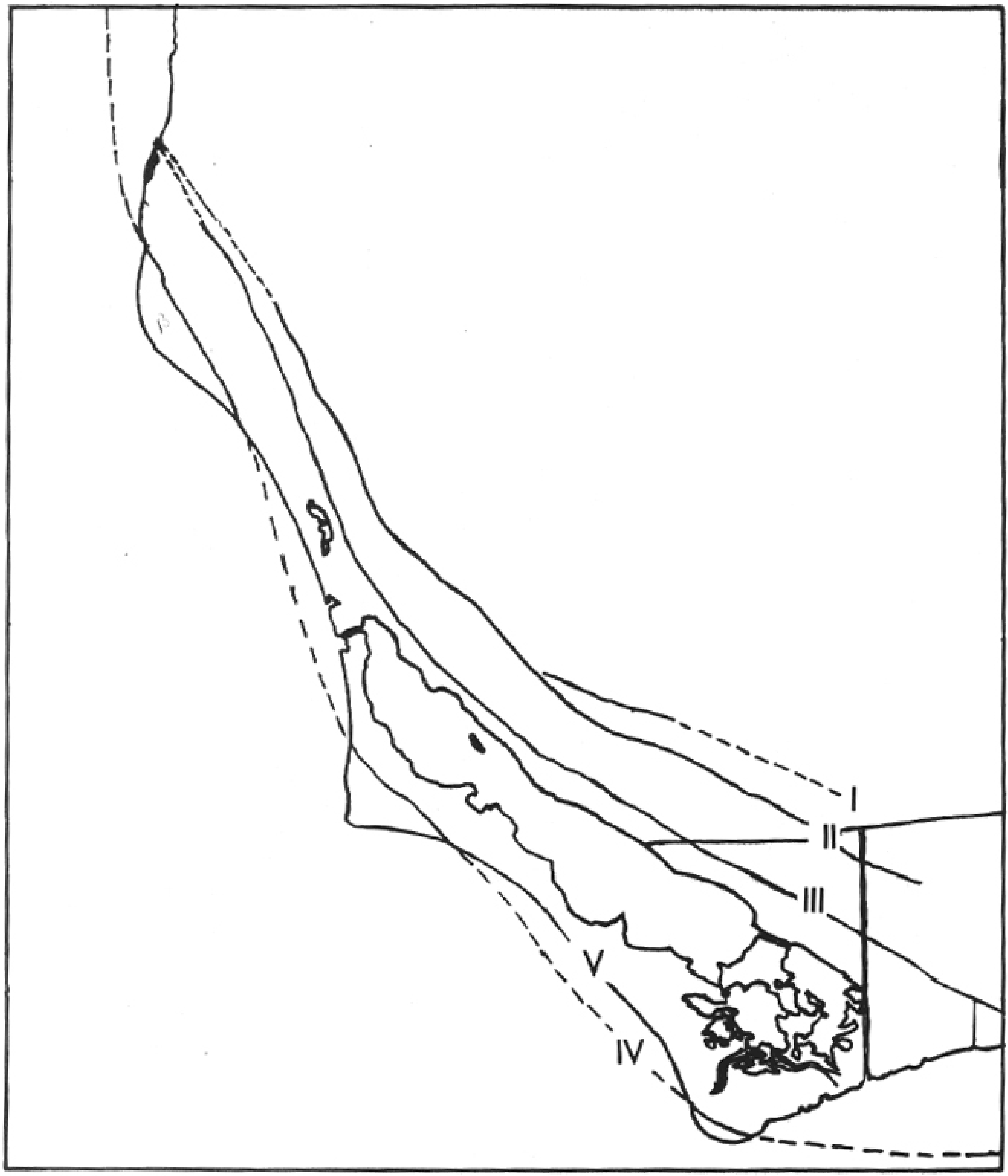


MAP OF ENVIRONMENTS IN THE NORTHWEST CAPE AREA

Figure 31

PLATE XI

PLATE XII



CAPE SABLE SHORELINES

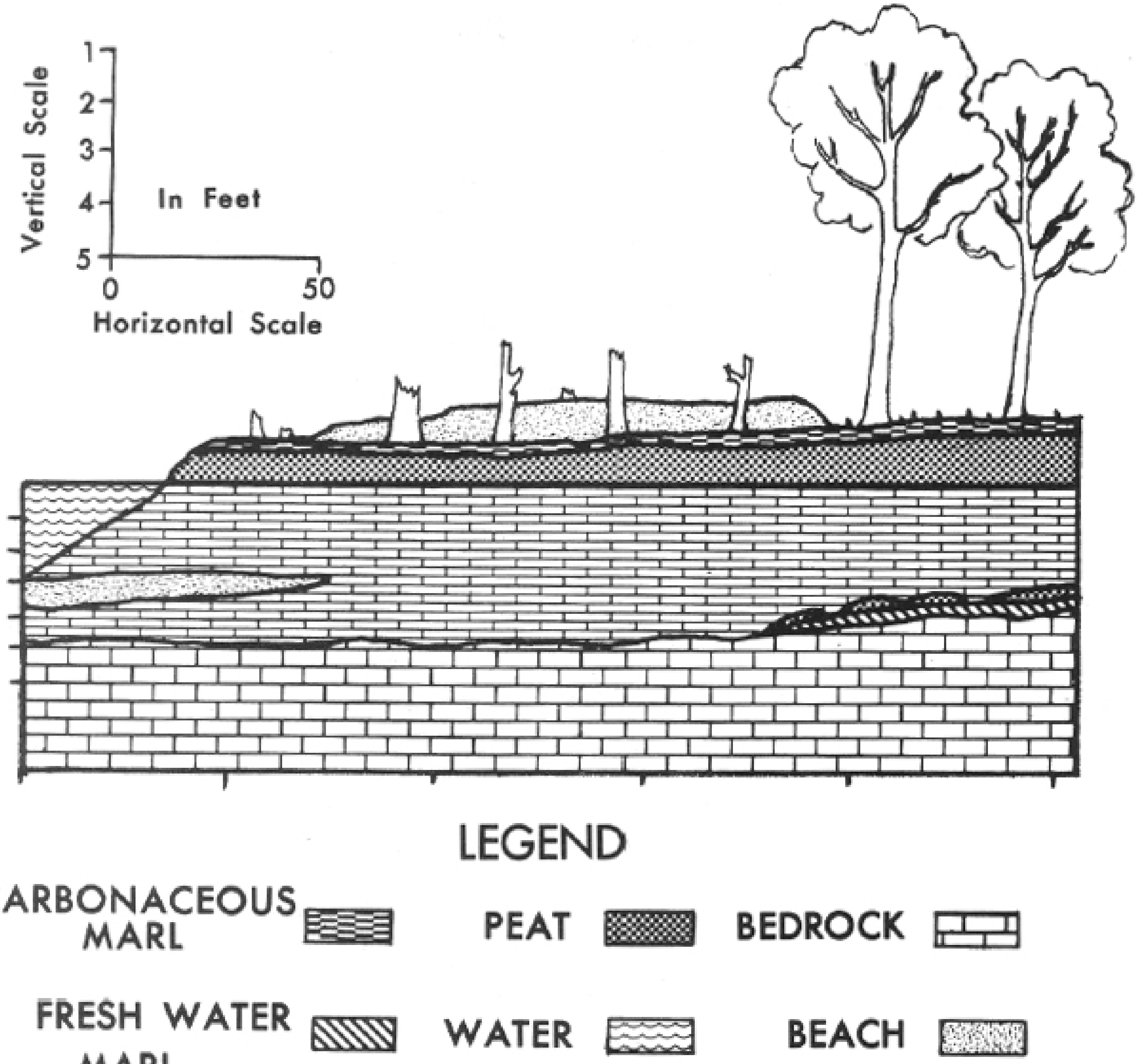
Figure 32

PLATE XIII

as Figure 32. The more accomplished eye will probably detect even more, or suggest modifications of the interpretation presented in this Figure. However, the fact will remain that this coastline has been moving in a southwestward direction as the result of the accumulation of marine marl over the past few thousand years.

At the site of the buried forest the marine marl referred to above will be found immediately beneath the peat stratum that presents its eroded margin at the low-tide shoreline (Figure 33). The composition and origin of this marl has been discussed and need not be reviewed here. The peat will be recognized as red mangrove peat in spite of the fact that the stumps are obviously those of Avicennia and not Rhizophora. This is not surprising in view of the red mangrove's ability to colonize shallow open water areas along the coast. The presence of the peat on the marl documents the existence of a period of time during which swamp-forming processes overcame the tendency for beach-forming processes to dominate in this coastal sector. The swamp forest was built out to well beyond the present peat margin and peat deposited under a red mangrove swamp environment. The black mangrove which dominates at this site cannot colonize in open marine waters (Davis, 1940) and typically inhabits the areas that lie behind the pioneer mangrove stand in which the high tide waters provide a more shallow cover. In normal swamp environments, black mangrove occurs at the coastline only as the result of a rapid transgression of the shoreline that destroys the marginal red mangrove zone, or as the result of the elevation of the soil surface through the rapid accumulation of either peat or inorganic detritus. In the case of the latter event, the coastline accumulation of sediment must essentially cease at the shoreline and the entry of the surface into open water must be steep or a red mangrove zone will be retained.

It will be noted that the upper surface of the peat stratum contains large quantities of calcareous material, foretelling the event that is so dramatically shown by the beach that sits upon the peat layer. Inspection of the beach will show that it is composed almost entirely of shells and shell fragments, as are all of the beaches in this sector of the coastline. Beyond the beach the limey peat may again be observed on the surface



SECTIONAL PROFILE THROUGH BURIED FOREST

Figure 33

with the red mangrove peat beneath it. Now, however, these form the sub-strata for the roots of living trees, as opposed to providing support for remnants of the seaward extension of this swamp forest.

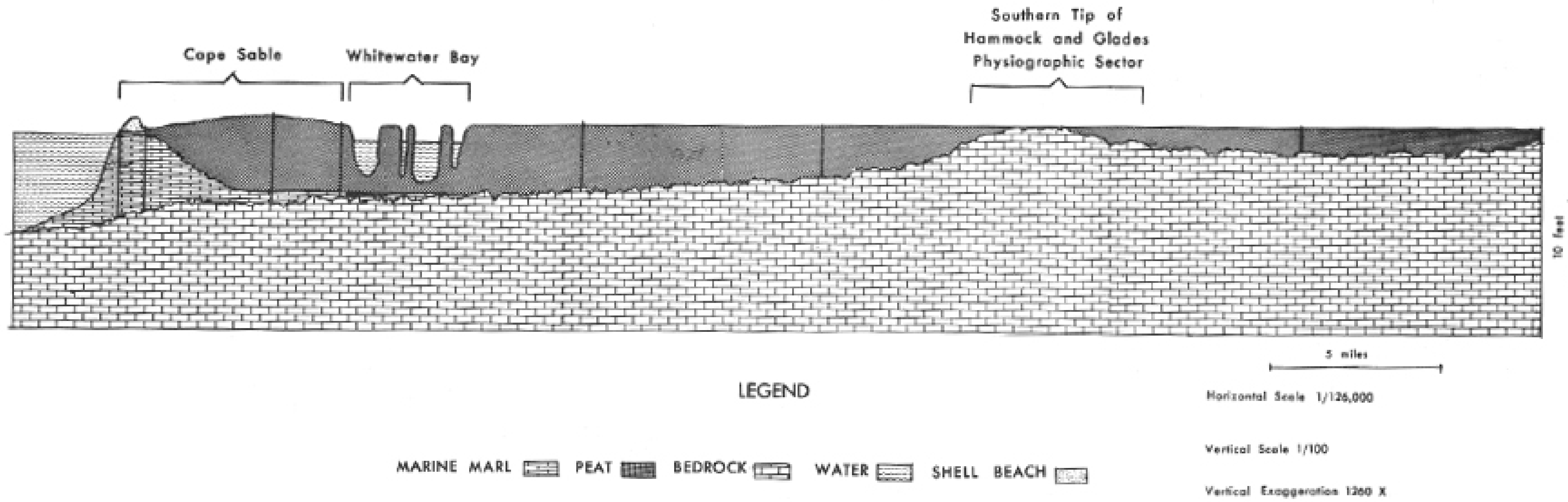
This type of oscillation between peat-forming and beach-forming processes is not restricted to this site. Similar relationships of "inorganic" and organic sediments can be observed at other exposed sites along the southwestern coast of Florida. Shark Point and Highland Beach are two additional examples. In the case of the latter, the storm beaches and normal beach sediments are less calcareous and more siliceous, reflecting an increase in the amount of quartz contained in the bedrock of he source area (i.e. the Tamiami formation vs. the Miami oolite).

From the preceding description of Stop 16 and from the inspection of the Florida Bay - Whitewater Bay areas, it is evident that the deposition of calcareous marl predominates along the southwestern margin of Cape Sable. Also, there is an interfingering and intercalation of peat into these "inorganic" sediments. As one proceeds northeastward, the marl is soon completely replaced by peat, the latter forming a major part of the walls of the Whitewater Bay basin. Beyond Whitewater Bay, as one proceeds northeastward toward the Tamiami Trail, the peat blanket thins gradually. Figure 34 shows a 42 mile NE-SW section that illustrates these relationships. The bedrock rise in the profile represents a place where the transect passed over a prong of the Hammock and Glades Physiographic Sector (see Figure 3). This Sector borders the Slough area on the West and is a region in which the bedrock immediately underlies the thin veneer of surface sediment. The "Big Cypress Swamp" occupies all but the lowermost segment of this physiographic division.

STOP 17: Big Sable Creek Site

Objectives:

A. Inspection of the effects of shoreline processes interacting with swamp environment processes - Sector 2: The Tidal Scour Sector.
B. Inspection of degraded mangrove peat.
C. Discussion of movement of organic material out of the swamp environment.



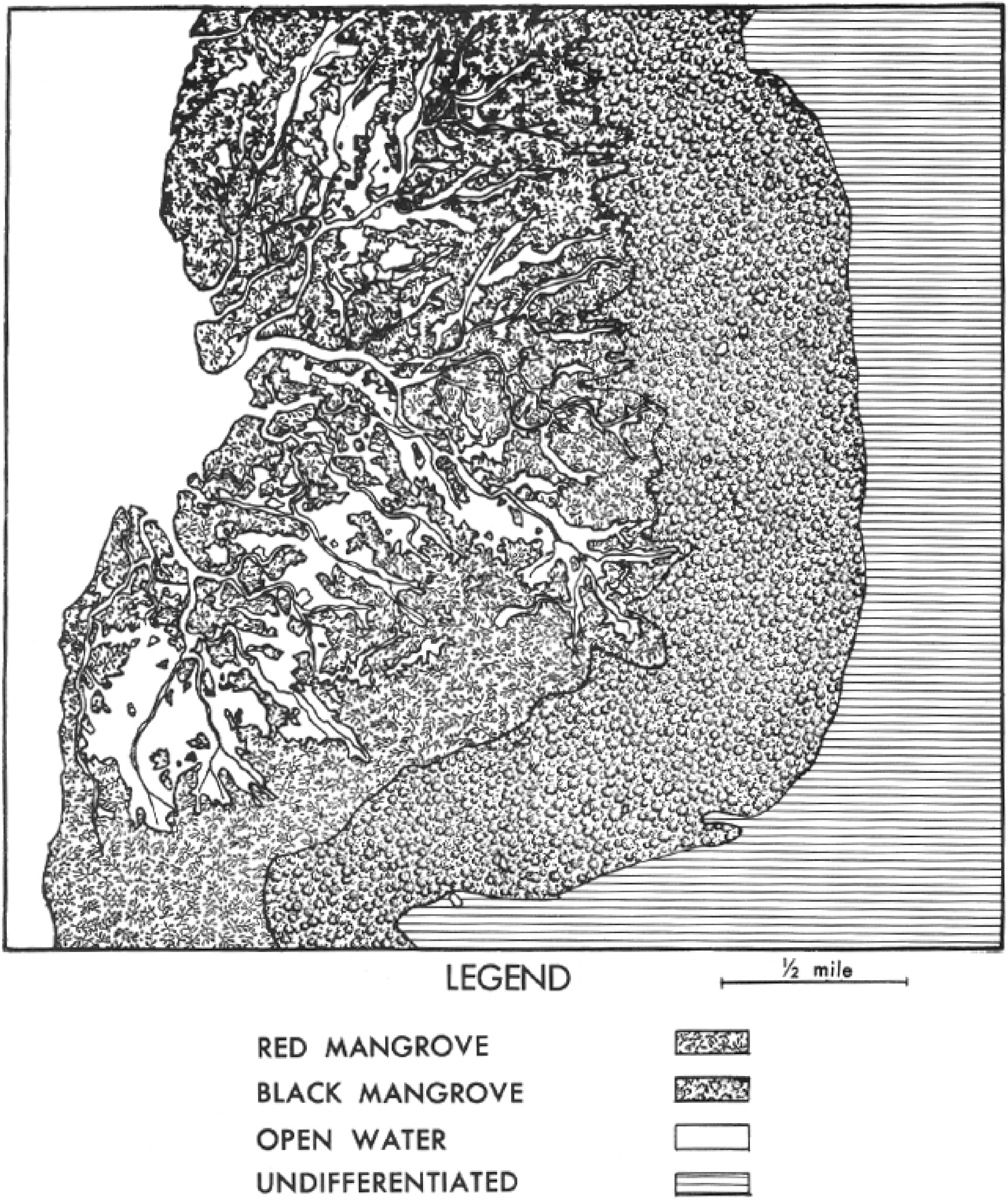
FORTY MILE SW-NE SECTION FROM CAPE SABLE TO VICINITY OF TAMIAMI TRAIL
Figure 34

D. Discussion of shorelines along the mangrove coast of southwestern Florida.

Discussion:

The area surrounding Big Sable Creek provides an excellent opportunity to observe the differences in ecological amplitude exhibited by the red and black mangroves. On the more exposed sites that are flooded twice daily to a depth of a foot or more, the red mangrove forms the major part of the plant cover. Behind the zone that is covered deeply by the tides, a mixture of black and red mangrove form the forest, with black mangrove dominating and red mangrove being most abundant along the slight depressions produced by minor channelization of tidal flow. Figure 35 shows the relationships of the areas occupied by these two swamp environments. The fact that these two environments are fairly well-defined in this particular locality should not be taken to mean that the mangrove boast is formed by a red mangrove belt along the shoreline with a belt of black mangrove behind it. Such is not the case, for the factors affecting the nature of the coastline vegetation are many and varied.

The aerial view of the Big Sable Creek Site (Plate XIV) shows an area in the tidal scour zone that is typical of the locality. The dead tree trunks lying like match-sticks on the bare peat flats have been killed and toppled by having their roots undermined. This undermining process has probably involved a removal of the upper peat layer by both chemical and physical action. The degraded peat seems to be produced by an initial, in situ, alteration (chemical?) that renders the mass more susceptible to disruption and transport. From the altered "peat mud" that covers the peat flats it is evident that the material moves seaward slowly, often making several stops before being destroyed or finding a resting place in open water. Plate XVA shows the organic debris as it flows out of the area. Longshore currents and wave action often cause some of the suspended organic debris to be deposited, at least temporarily, on the beach as shown in the picture of the Cape Sable shoreline south of Northwest Cape (Plate XVB). Much of the material that colors the streams flowing out of the swamps appears to be either in solution or

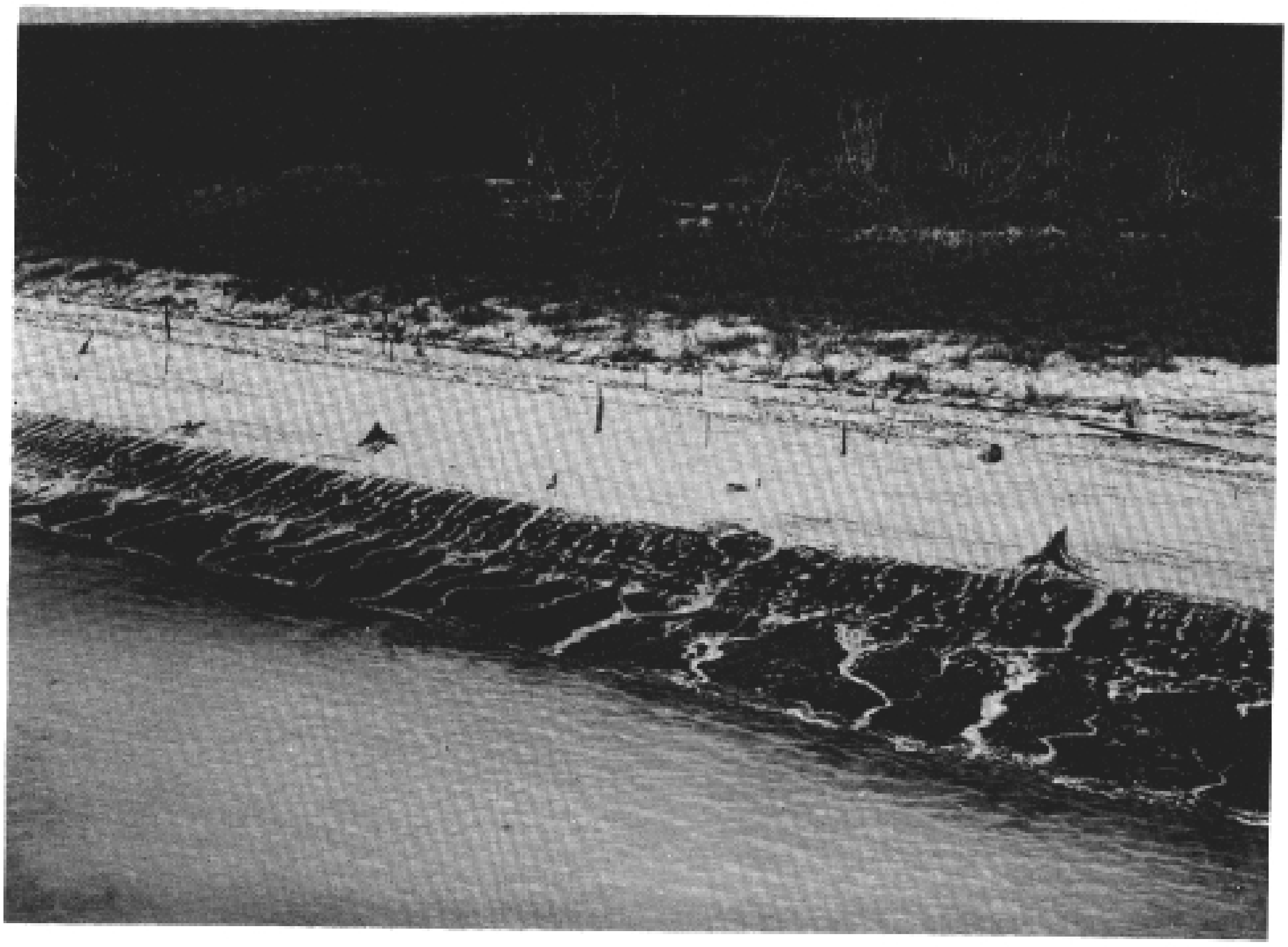


MAP OF ENVIRONMENTS IN THE BIG SABLE CREEK AREA

Figure 35

PLATE XIV

a



b

PLATE XV

in colloidal suspension, for attempts to extract the material by centrifuging have proved futile. The undermining processes together with the subsequent removal of the debris, have the effect of lowering the surface elevation, thus producing the bare peat flats and the areas tolerable only to the red mangrove.

This type of tidal flat characterizes the coastline from Little Sable Creek to the mouth of the Little Shark River. It is effectively illustrated in the copy of the Soil Conservation Service aerial photograph reproduced as Plate XVI. This Sector of the coastline contrasts markedly with the adjacent Sector to the south, where storm beaches are currently being formed and deposition of inorganic marl has dominated the coastline processes. To the north is an equal contrast where the "Slough Entry Sector" is composed of a series of islands with no "coastline" discernible. Further to the north the "River Sector" exhibits a smooth and well-defined coastline in spite of the large number of streams that enter the Gulf in that area. It differs from the Tidal Scour Sector in many ways, for in the Big Sable Creek area there are no streams of any consequence entering the Gulf. Above the River Sector lies the Bay Sector, characterized by the development of arcuate embayments along the coast and extensive lagoonal or bay areas that parallel the coast but lie two or three miles inland. Still farther north lies the spectacular Ten Thousand Island Sector, distinctly different in form and composition from all other Sectors. These segments of the coastline are identified on the map presented as Figure 36.

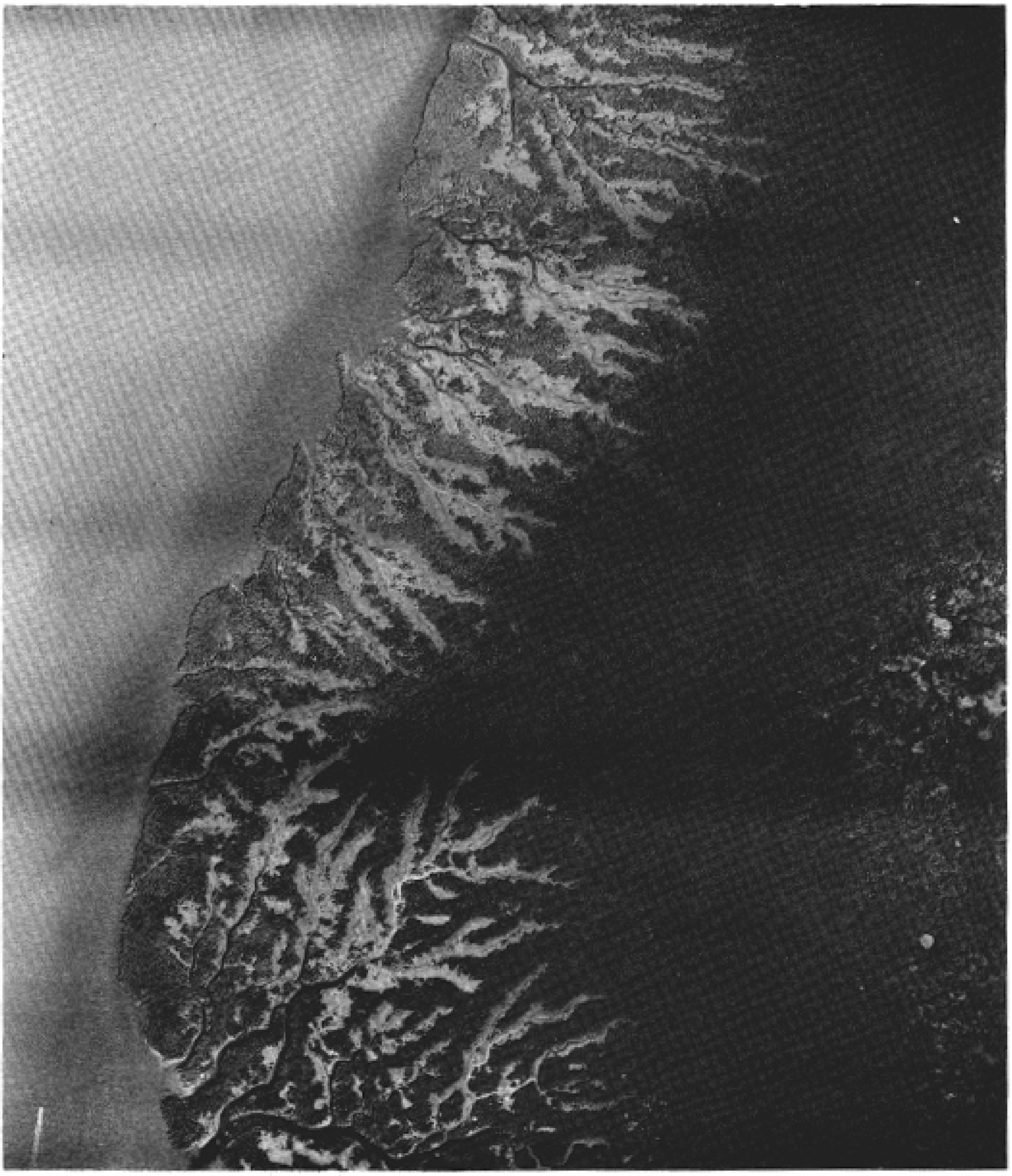
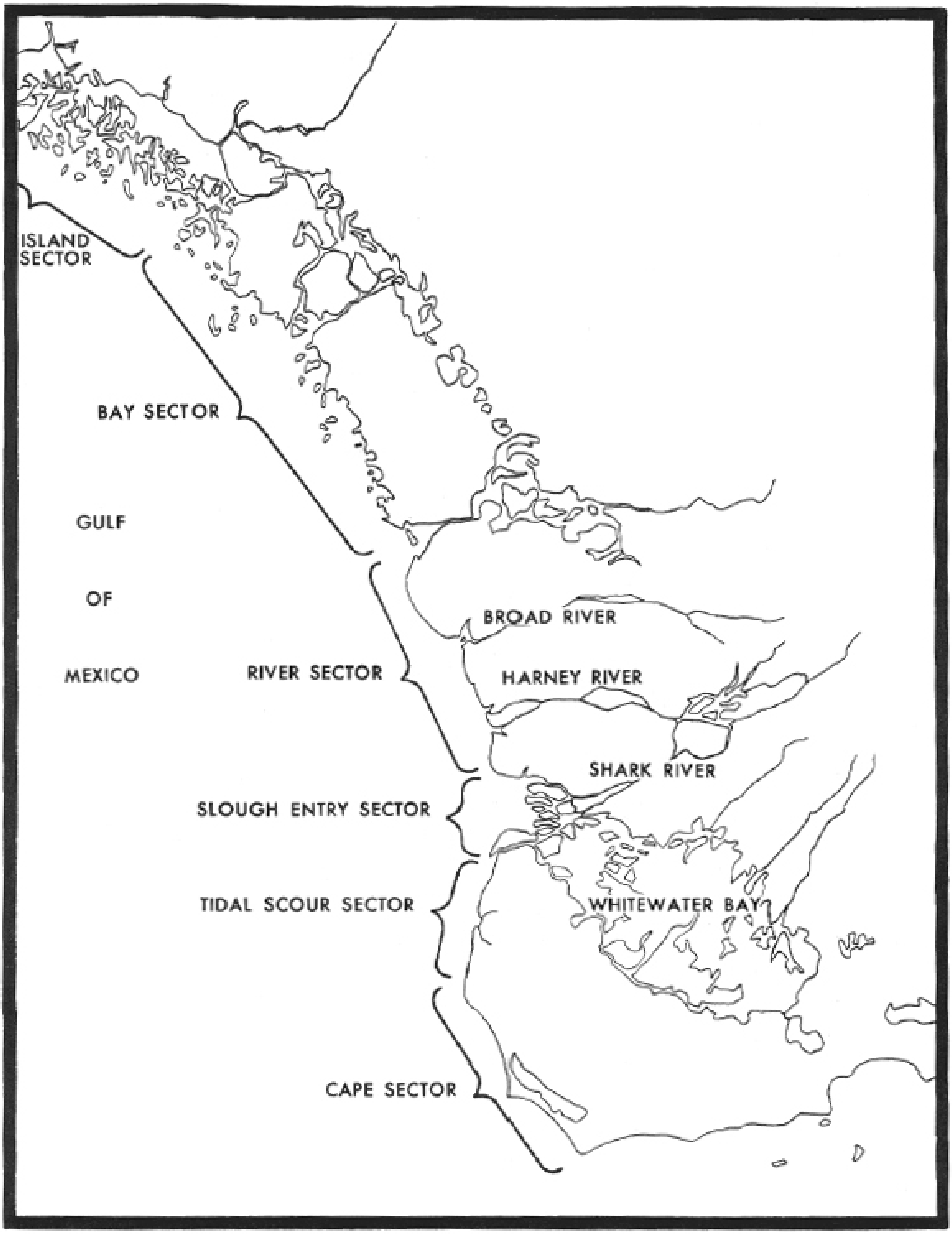


PLATE XVI



MAP OF SHORELINE TYPES COMPOSING THE MANGROVE COAST OF SOUTHWESTERN FLORIDA

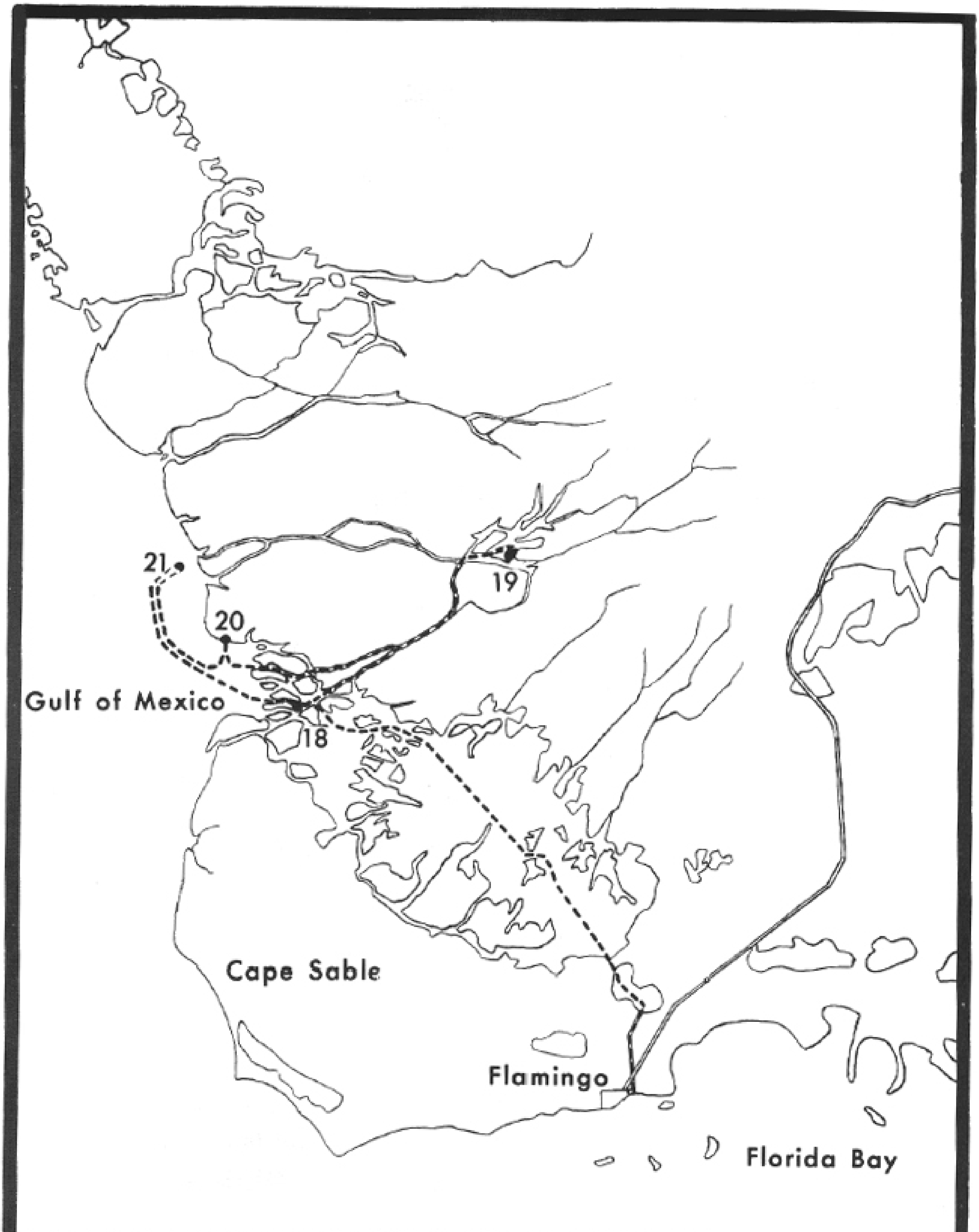
Figure 36

ROUTE FOR THE THIRD DAY

(Trip Map No. 3)

Starting Point: Flamingo Marina. Board large tour boats from piers at south end of Marina.

Nautical Miles	Description
0.0 - 3.2	Follow Buttonwood Canal to Channel Marker No. 1 in Coot Bay.
3.2 - 18.8	Follow channel markers through Coot Bay, Tarpon Creek, Whitewater Bay and Cormorant Pass to Channel Marker No. 51.
18.8	Alter course to 317°.
18.8 - 20.8	Proceed 2.0 miles on 317° heading.
20.8	Alter course to 240°.
20.8 - 21.3	Proceed on 240° course to small pier on southeastern side of Jewfish Key.
21.3	STOP 18: JEWFISH KEY SITE. Leave tour boats and go ashore on Jewfish Key via the aforementioned pier. See pages 49 to 54 for a discussion of this site.
21.3 - 29.7	Proceed upstream following Little Shark River and the Shark River to Tarpon Bay.
29.7	Upon entering Tarpon Bay alter course to 8°.
29.7 - 30.7	Proceed on 8° heading for 1.0 mile to a point off the apex of the large deltoid island.
30.7	Alter course to 62°.
30.7 - 31.5	Proceed 0.8 mile on 62° heading.
31.5	Alter course to 136°.
31.5 - 31.9	Proceed on 136° heading for 0.2 mile to channel between deltoid island and mainland. Proceed in a southerly direction into the channel to the small pier on the



TRIP MAP NO. 3

	eastern side of the deltoid island.
31.9	<u>STOP 19</u> - TARPON BAY BULRUSH SITE. Leave tour boats via temporary pier and proceed through the mangrove fringe into the marsh environment. See pages 54-59 for a discussion of this site.
31.9 - 40.1	Set course at 189° and proceed into Tarpon Bay.
40.1	Alter course to 285°.
40.1 - 41.3	Proceed on 285° heading for 1.2 miles to Shark River.
41.3 - 50.9	Enter Shark River and follow it to its mouth in Ponce de Leon Bay.
50.9	Upon entering Ponce de Leon Bay, set course due west.
50.9 - 52.8	Proceed on 270° course for approximately 1.9 miles until your position is due south of the mouth of Graveyard Creek.
52.8 - 54.8	Alter course to due north and proceed around shallows and into Graveyard Creek.
54.8	<u>STOP 20</u> - GRAVEYARD CREEK - LUNCH. Leave tour boats and go ashore via permanent pier.
54.8 - 55.3	Proceed 0.5 mile into Ponce de Leon Bay via Graveyard Creek channel.
55.3	Alter course to 310°.
55.3 - 58.3	Proceed 3.0 miles on a 310° heading into the open Gulf of Mexico.
58.3	Alter course to due north.
58.3 - 59.9	Proceed due north for 1.6 miles. Drop anchor.
59.9	<u>STOP 21</u>: BURIED PEAT SITE. Remain in tour boats for discussion or enter water if you choose. Do not enter water without shoes and be sure that someone has surveyed the area for sharks.

59.9 - 88.9 Return to Flamingo Marina via Ponce de Leon Bay, Oyster Bay, Whitewater Bay, Coot Bay and the Buttonwood Canal.

88.9 TERMINATION OF FIELD TRIP. Return to motel for clean up. Time of bus departure for Miami Beach to be announced.

SITES TO BE VISITED ON THIRD DAY

STOP 18: Jewfish Key Site

Objectives:

A. Inspection of the effects of shoreline processes interacting with swamp environment processes - Sector 3: The Slough Entry Sector.

B. Inspection of a mature red mangrove forest and red mangrove "peat" from a coastline site.

C. Inspection of a "lime levee".

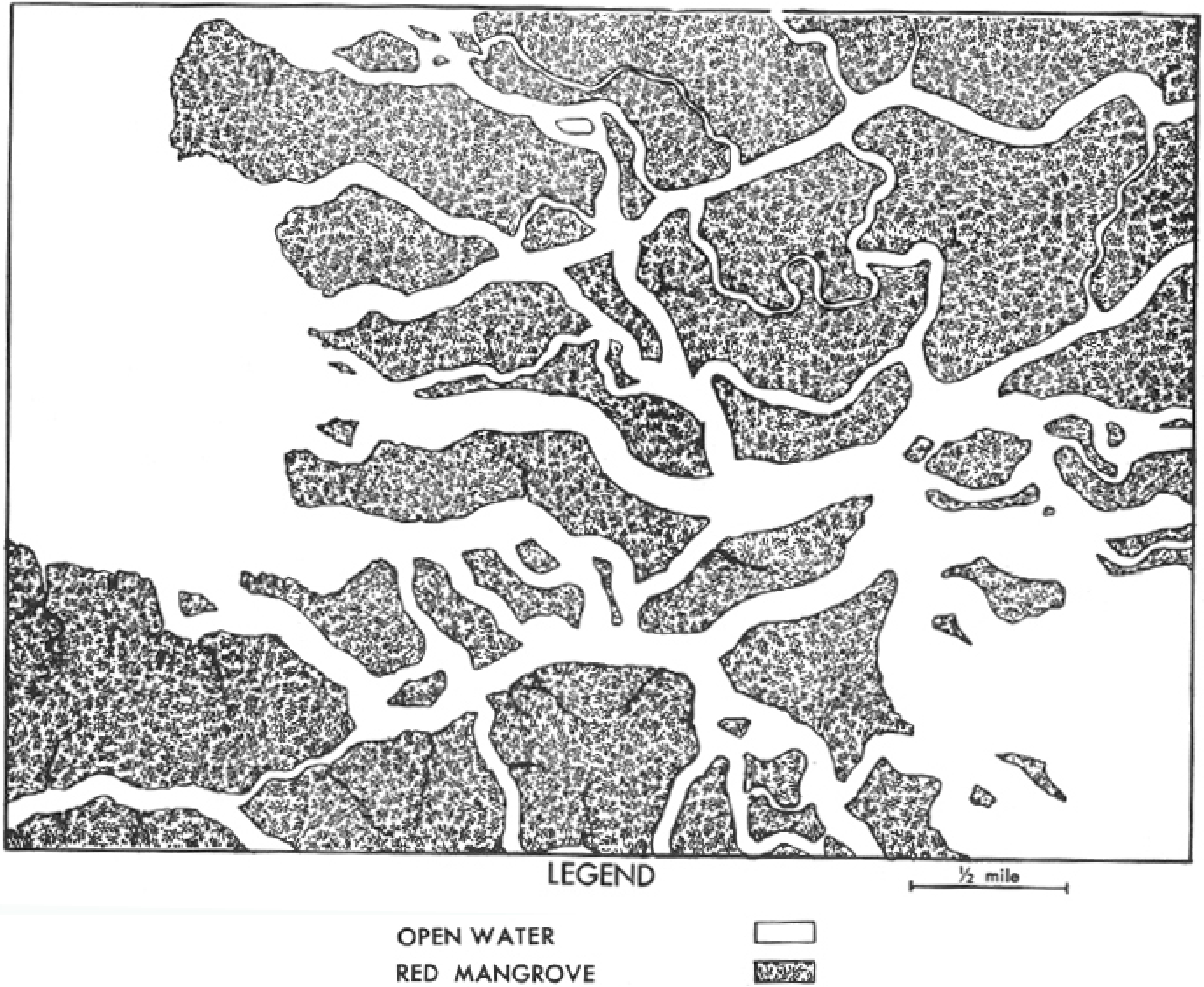
D. Discussion of the mangrove forest swamp and the habits of the red mangrove.

E. Discussion of the chemistry and palynology of the mangrove forest swamp.

Discussion:

This is a unique area. At no other place in the world are red, black, and white mangroves known to achieve the heights that they did in this locality. Unfortunately, but perhaps, normally, the hurricanes of the last few years (particularly Donna in 1961) have smashed into this area taking most of the big trees down. The red mangrove is generally pictured as a shrubby, much-branched tree growing to perhaps 25 feet in height. Here the red mangrove is a straight boled,little-branched tree 50 - 75 feet or more in height.

Figure 37 shows the extensive island system that is coincident with entry of the Shark River Slough into the Gulf of Mexico. This Slough is



MAP OF ENVIRONMENTS IN THE PONCE DE LEON BAY AREA

Figure 37

merely an extension of the Ridge and Slough Sector (see Figure 3) of the Midland Peat Province of southern Florida. These islands, like those in Whitewater Bay, are composed of blocks of "peat" that rest either on the bedrock floor or on a thin layer of marl. In this case, however, the upper half of the block may be composed of carbonaceous mud as opposed to peat. The vegetation in this coastal sector is dominated by red mangrove, as these islands represent relatively exposed sites. An occasional black or white mangrove may be encountered either as relicts of the time when this area was better protected or as chance invaders that managed to survive in an inhospitable habitat. No shrubs, grasses, ferns or other herbaceous plants can survive here. There is no "forest undergrowth". There is no "ground cover". Only where a new environment is developed by ridge development along the island's margin can herbaceous forms survive.

The island on which Stop 18 is located is shown in Plate XVIIA. The hurricane damage is evident from the number of defoliated trees. Some impression of the effects of Donna's 200 mile an hour winds on the mangrove forest can be gained by inspection of photograph B in Plate XVII. The trees in the area of the forest shown were, in general, 50 to 60 feet tall.

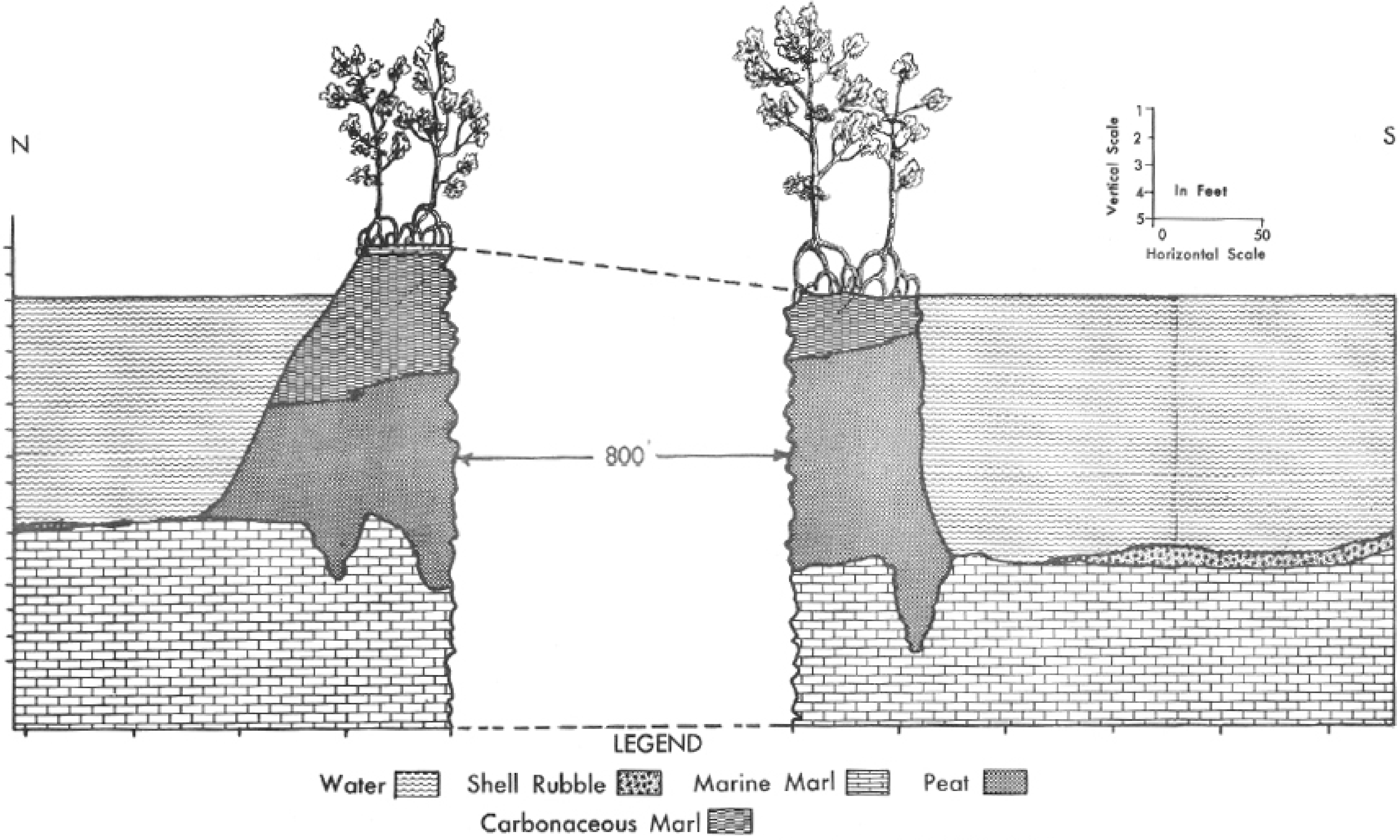
Because there are strong fresh water currents and strong tidal currents flowing past these islands, their sides tend to be steep, often approaching the vertical. The channel floors are generally free of sediment except for occasional shell rubble. The channels often pursue courses that are reminiscent of meandering stream channels and some of the islands appear to be formed as the result of the dissection of a larger island mass whose shape is still discernible. It is difficult to know, however, whether the islands are the product of recent erosional processes or the product of continual upbuilding of ancient island masses in an area characterized by numerous tidal channels.

The islands' surfaces are commonly higher on the sides most exposed to the Gulf or to tidal currents. Figure 38 shows a sectional profile across Jewfish Key, illustrating this fact. This exposed margin will often serve as the site on which a "marl levee" is developed. Figure 39 shows a hypothetical but reasonably accurate representation of one of

a

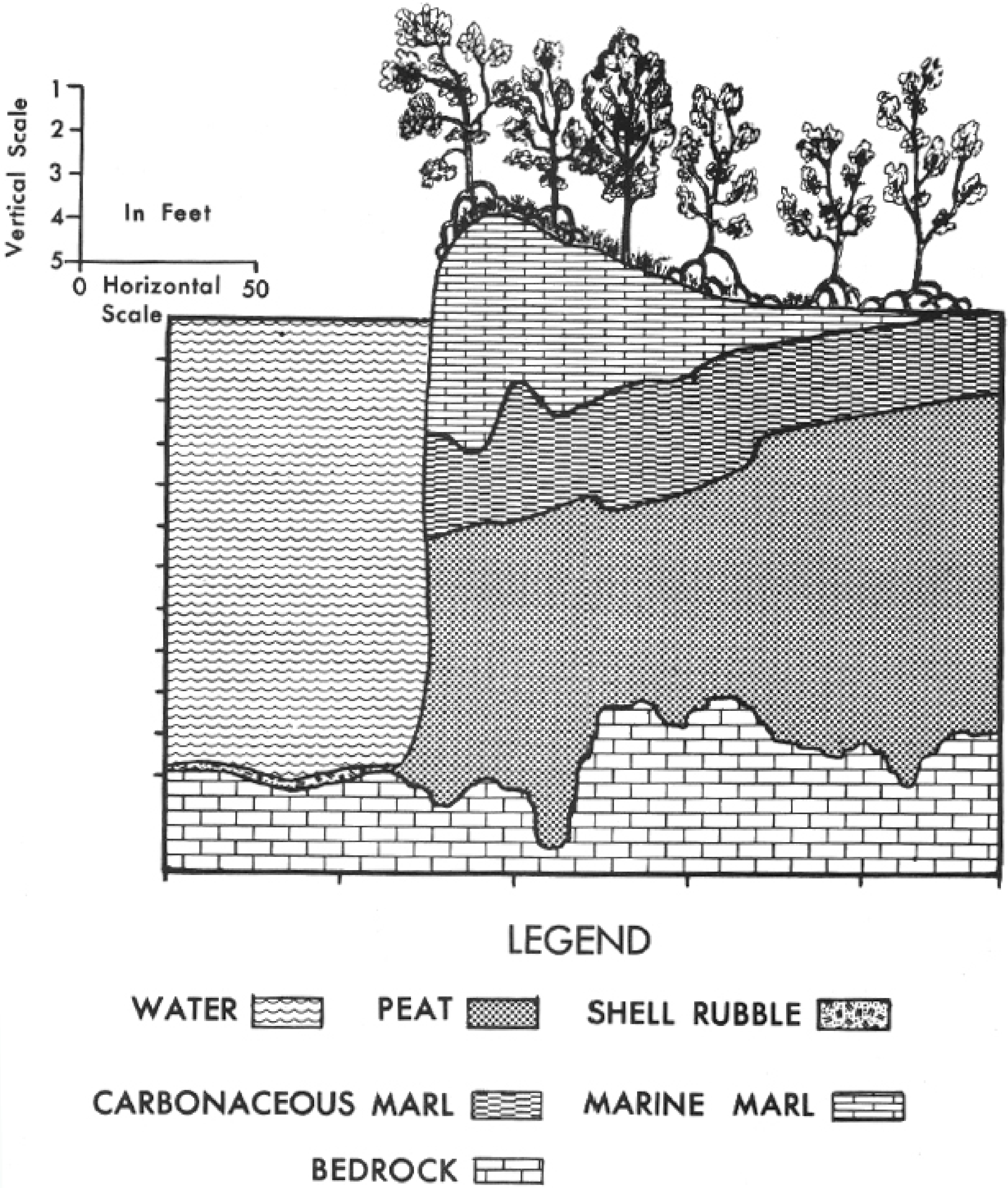
b

PLATE XVII



SECTIONAL PROFILE THROUGH MARGINAL SECTORS OF JEWFISH KEY

Figure 38



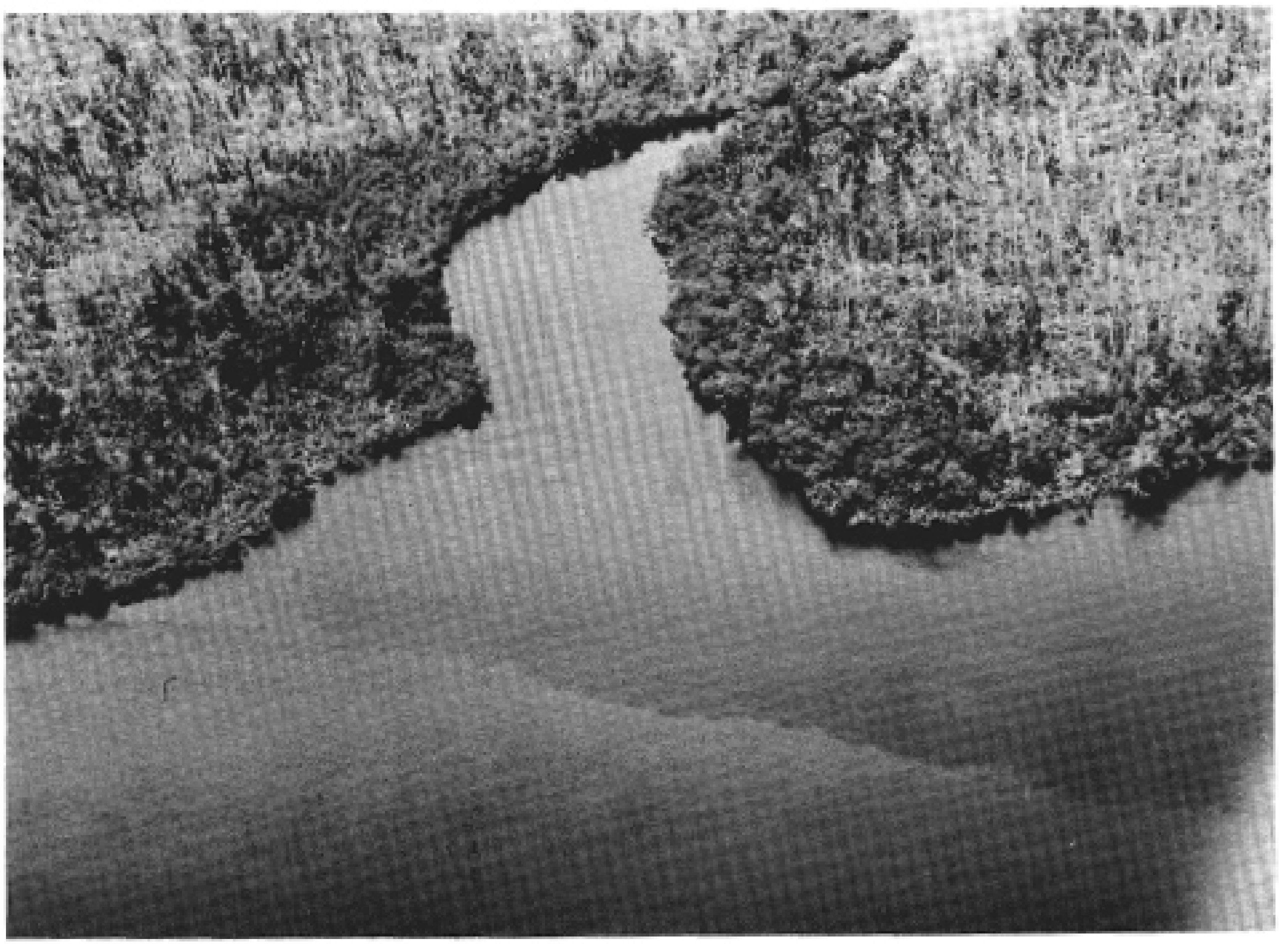
GENERALIZED SECTION THROUGH A 'MARL LEVEE'

Figure 39

these ridges in section. The sediment composing them is derived from the calcareous and siliceous muds of the shallow Gulf water nearby. During storms, the bottom muds are churned up and brought inland on high tides. The material tends to be deposited in ridges along the exposed island margins forming the "levees". Some of the mud is carried over the levee and is mixed with the accumulating organic material to form the carbonaceous mud that forms the upper portion of these "peat" blocks. A certain amount of the mud may be brought onto the island surfaces without the aid of storm tides, hence, there probably is a continual mixing of organic and inorganic material on the surface below levee height. The levees are readily recognized from a distance because they provide an environment in which the succulent salt-wort (Batis maritima) can grow. This provides the immediate area with its only herbaceous vegetation.

Even though inorganic sediment and organic material are accumulating on the surface of these islands, organic material still moves off in perceptible quantities. The photographs in Plate XVIII are comparable with those in Plate XV and show that similar processes are operating in the two areas.

An attempt has been made to understand the micro-environments and the overall nature of the swamp environment here designated the " Coastal Mangrove Complex". A series of sites was selected "near shore" and another series about one mile behind the shoreline. Surface samples were obtained from these sites and analyzed chemically and palynologically. A rather small range of variation characterizes the analytical results. Figure 40 summarizes the chemical data by presenting simple averages of all data associated with a particular element. The low sulfur content, at first, seems surprising in view of the well-known correlation between sulfur and marine strata associated with coal seams. On an ash-free basis, this value would be doubled, bringing the level to about 1.5 percent. Even more interesting than this is the change that occurs in the concentration of sulfur as one analyzes different levels beneath the surface. Figure 41 shows three such sets of data obtained at a site near the shore opposite Stop 21. In this figure the sulfur and carbon



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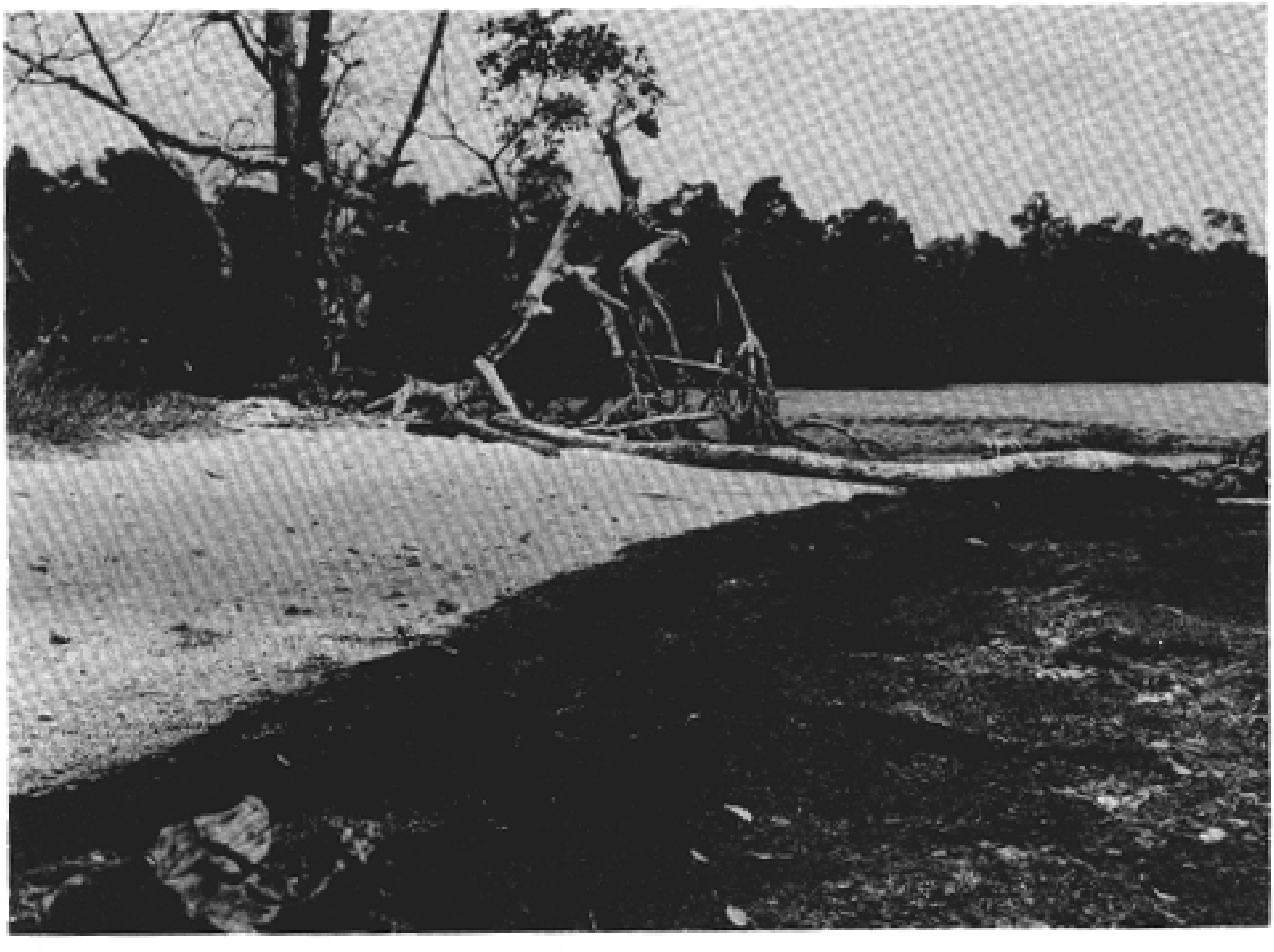

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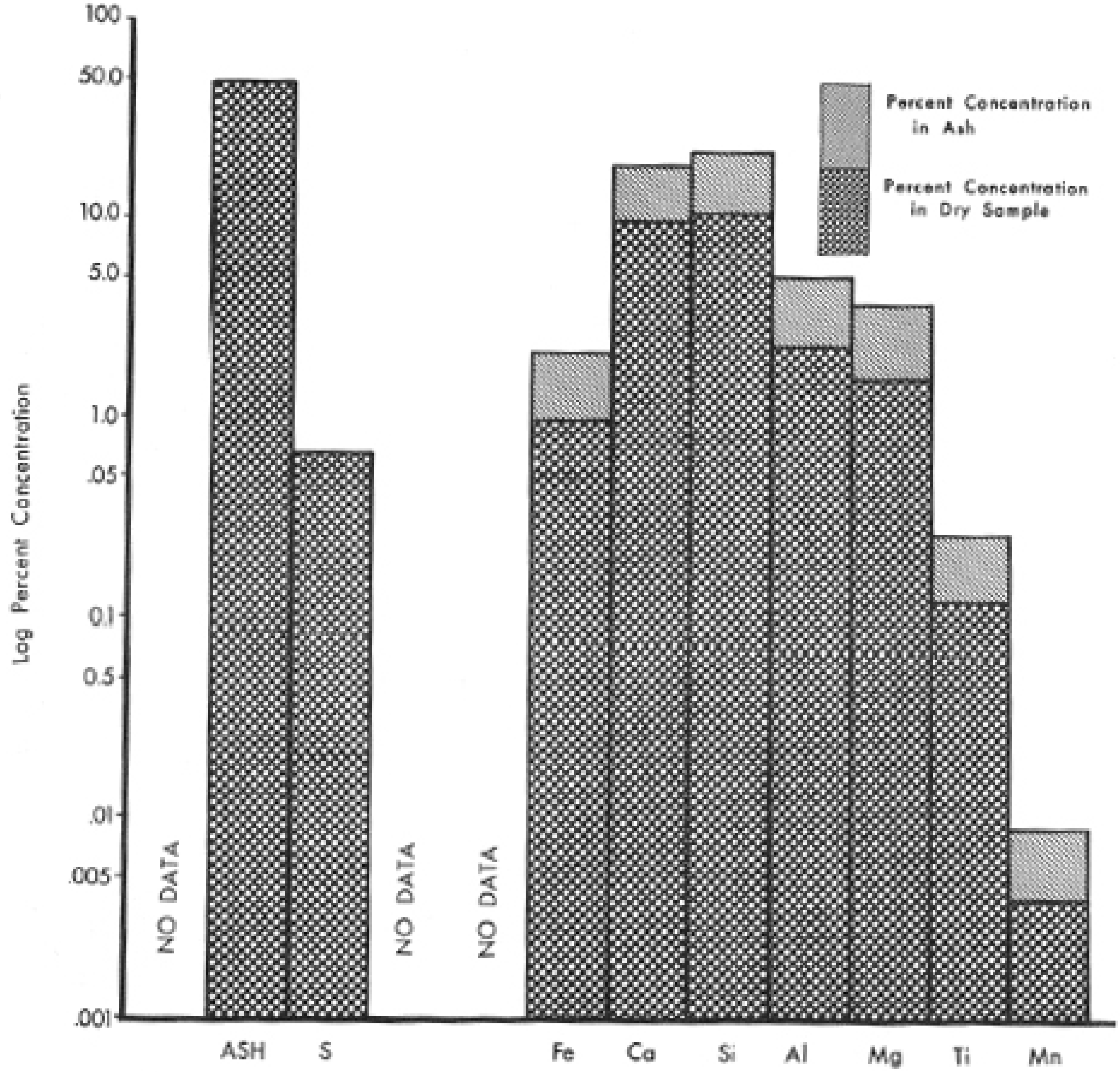
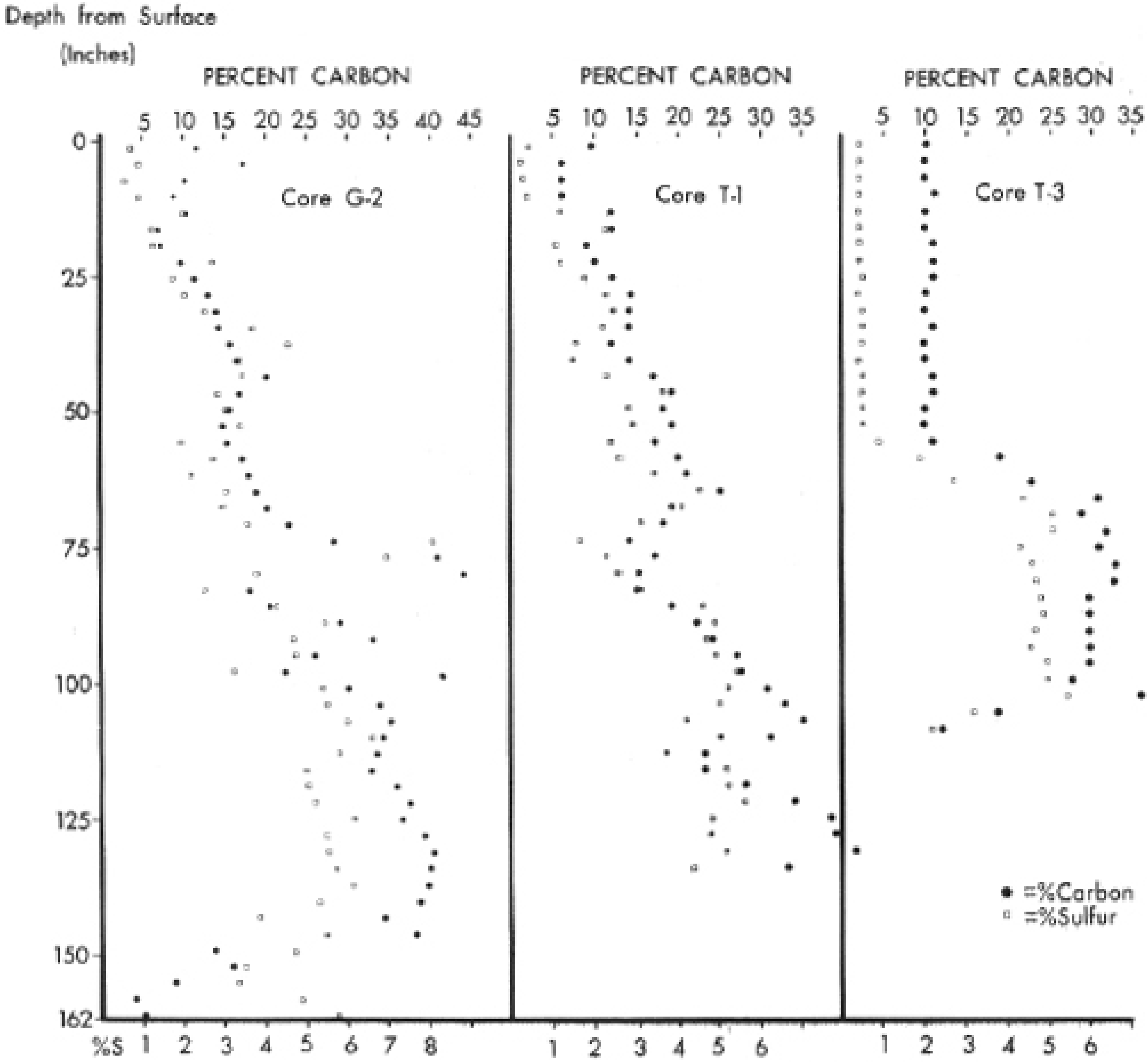
PLATE XVIII



ELEMENT CONCENTRATIONS IN SURFACE SEDIMENTS IN THE COASTAL MANGROVE ENVIRONMENTS

Figure 40

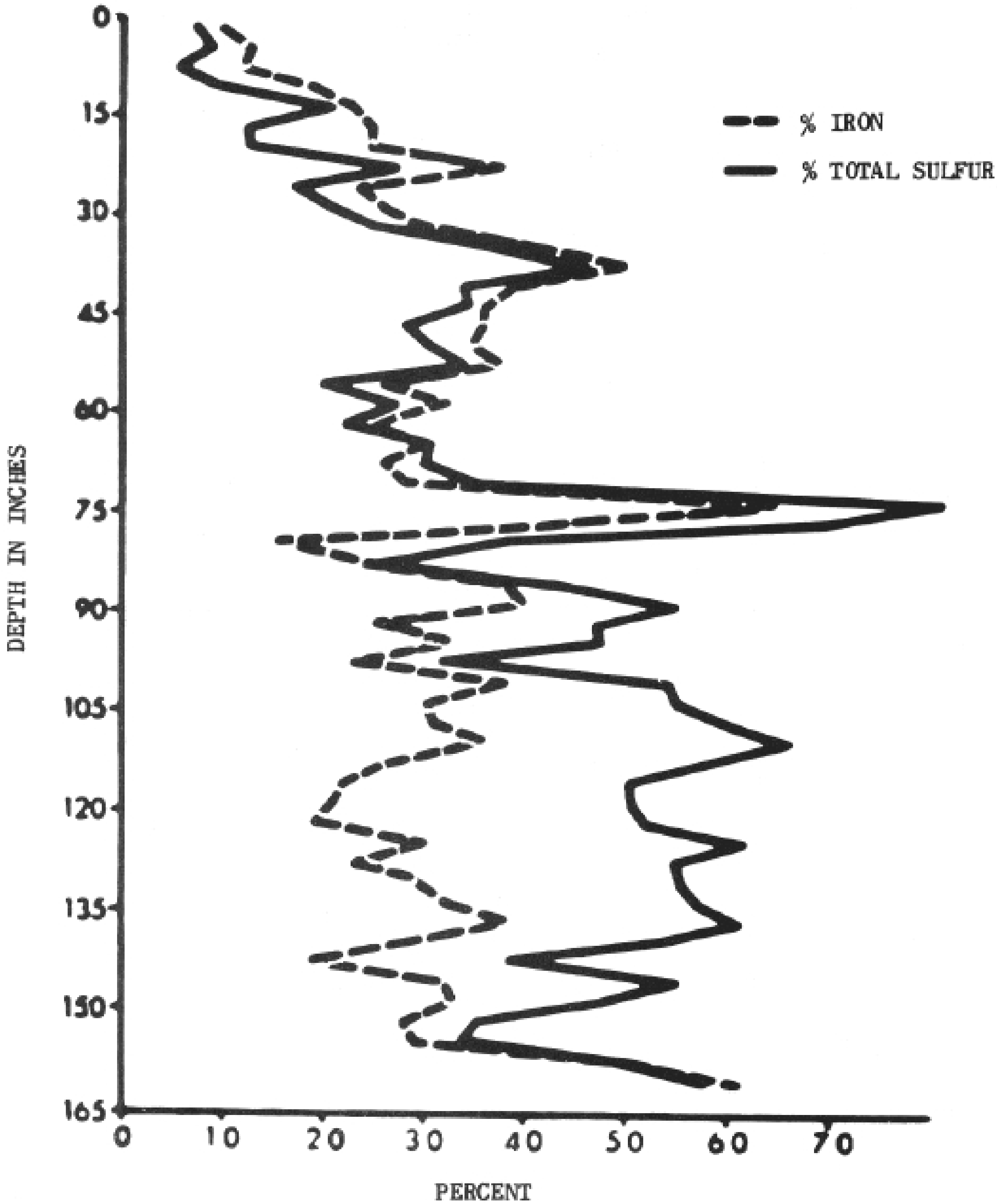


CARBON AND SULFUR CONCENTRATIONS
AT VARIOUS LEVELS IN COASTAL MANGROVE SEDIMENTS
FIGURE 41

are plotted on the same graph. Two facts are noteworthy. First, the high degree of correlation between the two suggest that the living plants may be the primary agents in concentrating the sulfur and contributing it to the environment. It can also be argued that more plant debris permits more bacterial metabolism, hence more sulfur concentration in the sediment. Of additional interest is the fact that when the sediment becomes a true peat (i.e. yields less than 50 percent ash) the sulfur content ranges between 4 and 6 percent. This is much more than that required to account for the sulfur content of most coal seams. Examination of Figure 42 will show that iron tends to be correlated with sulfur in the upper section of the core and not in the lower. This, of course, suggests the development of pyritic minerals in the upper sedimentary layers at this site. A quantitative assessment of the pyrite content of the core has not been made.

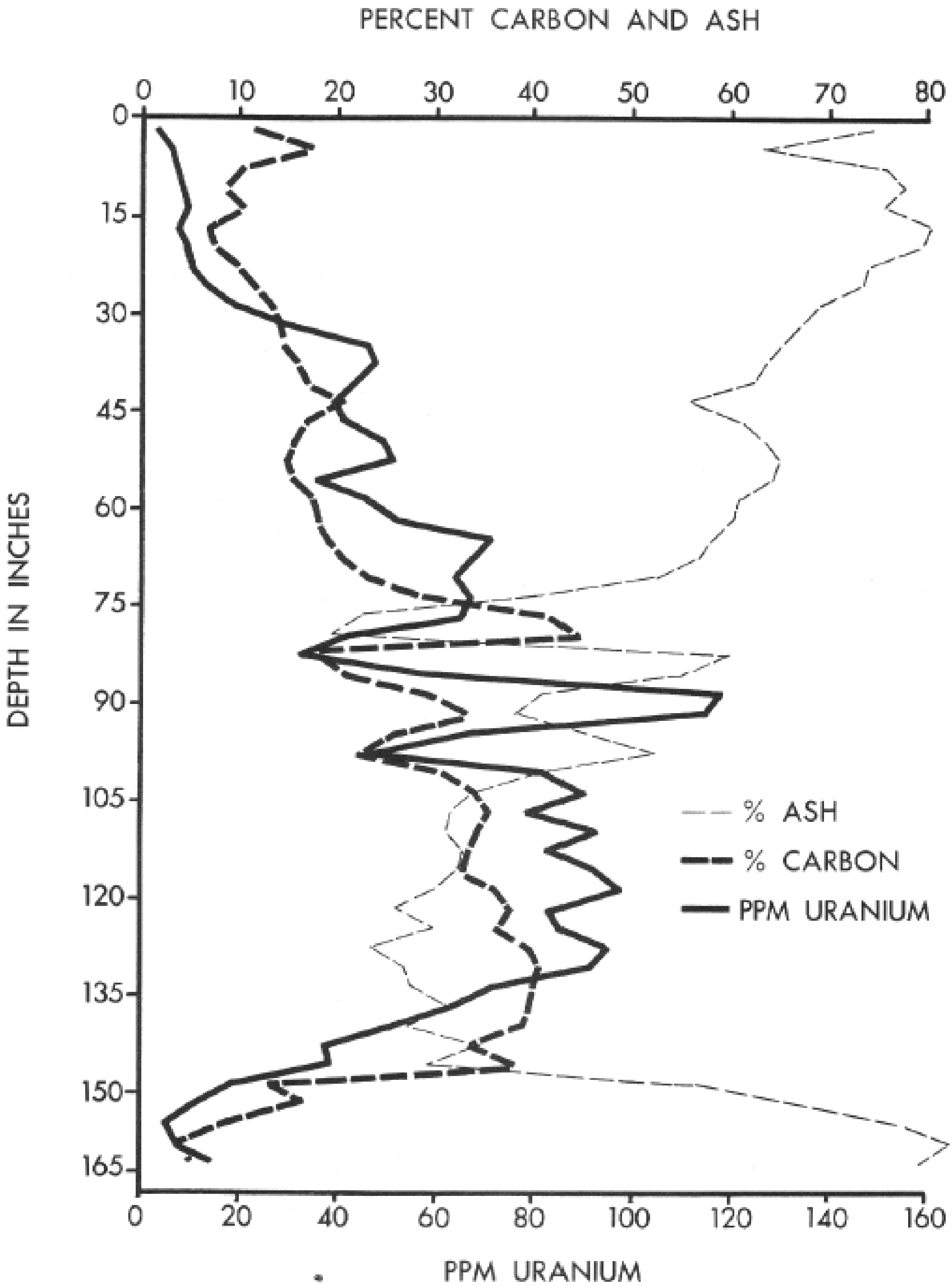
Another element that is present in concentrations that correlate with carbon is uranium. The uranium-ash-carbon relationships are shown in Figure 43.

The pollen and spore content of surface sediment in the Coastal Mangrove Complex appears distinctive of the environment as a whole, and, in addition, it reflects differences from one micro-environment to another. The effects of differences in adjacent vegetation also seem detectable as do north-south and east-west trends in the frequency of various pollen types. Figure 44 presents the frequencies of some of the more significant pollens in the sediment of the mangrove environment. In the same figure similar data are presented for contrasting brackish and fresh-water environments. The ease with which these are recognized is apparent even without a more fundamental differentiation of the pollen and spore types. This, of course, is a case selected for illustrative purposes and full knowledge of the botanical affinities of the pollens and spores should be sought in connection with attempts to make other than gross environmental interpretations. Figure 45 illustrates the trends in the frequency of Rhizophora and Chenopodiaceous pollen as one follows a north-south transect through some 15 miles of the coastal mangrove environments. This serves to illustrate how



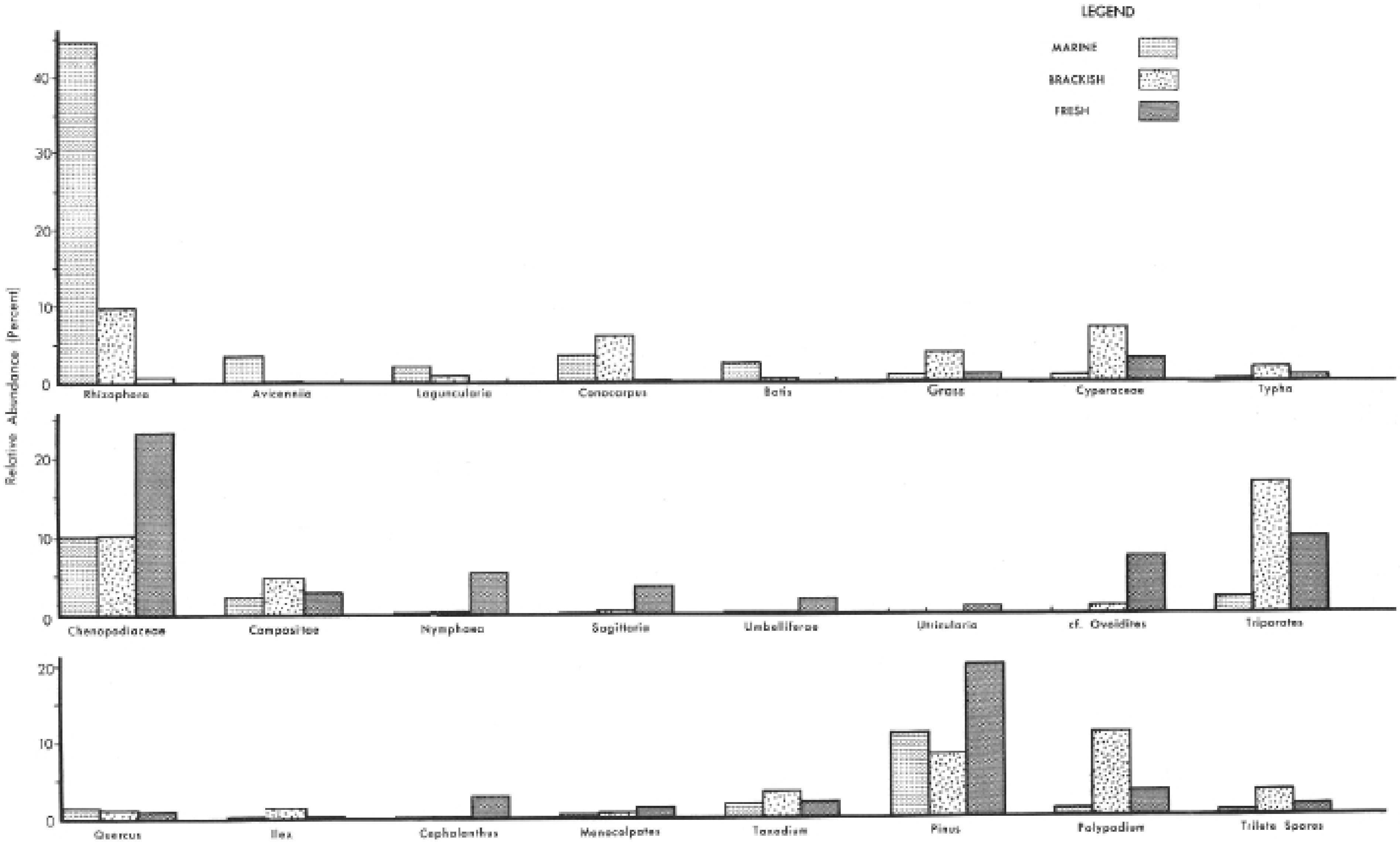
DISTRIBUTION OF IRON AND SULFUR IN CORE 59-G2

Figure 42

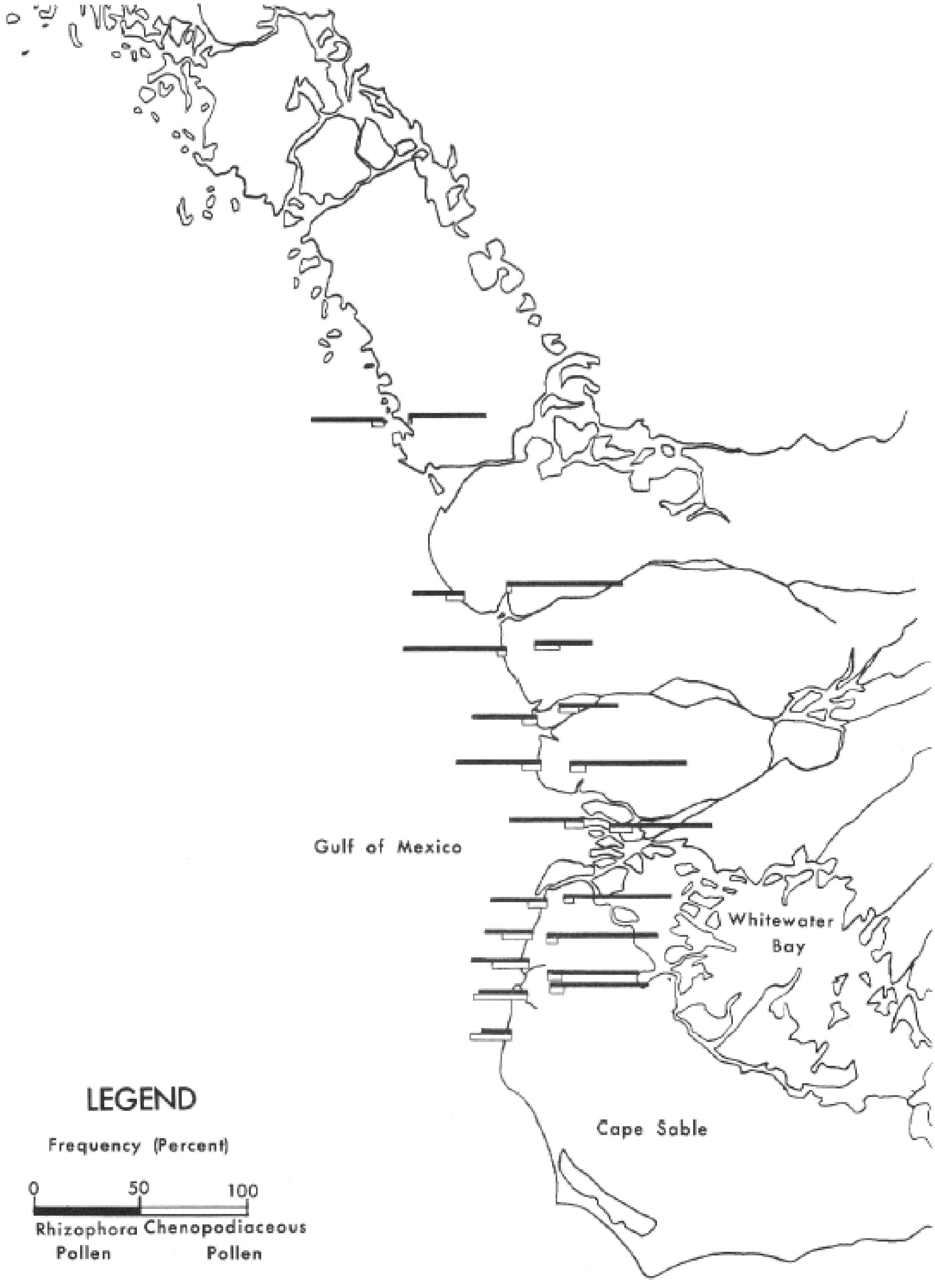


VARIATION IN CARBON AND URANIUM CONTENT AT SITE 59-T1

Figure 43



COMPARISON OF THE RELATIVE ABUNDANCE OF VARIOUS POLLENS AND SPORES
IN CERTAIN MARINE, BRACKISH AND FRESH-WATER ENVIRONMENTS
Figure 44



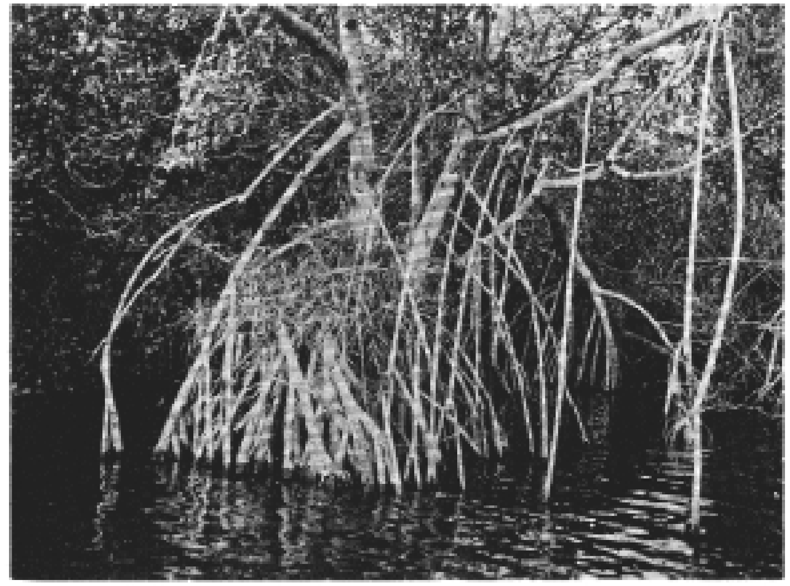
VARIATIONS IN RHIZOPHORA AND CHENOPODIACEOUS POLLEN AT SHORELINE AND "INLAND" SITES IN THE COASTAL MANGROVE COMPLEX

Figure 45

interpretations concerning adjacent vegetation can be made once the pollen signature of a plant community is understood. Salicornia, which makes up a large percentage of the Chenopodiaceous pollen, is clearly not a component of the mangrove forest nor is its pollen characteristic of the mangrove forest signature. The data suggest that it grows in an adjacent community in the Cape Sable Region. This is, in fact, the case.

Stop 18 represents just one of the environments in the Coastal Mangrove Complex. Others include almost pure black mangrove stands, various mixtures of red, black and white mangrove, and still others that include additional hardwood plants. It may be of value to note the changes in the growth habit of the red mangrove and the associated changes in the composition of the mangrove forest as one proceeds upstream from the open Gulf. As shown on Plate XIX and as previously noted, the red mangrove at the mouth of the Shark River is a straight boled tree with a few, sturdy, basal prop roots. It is often unbranched for the first 30 feet and bears a well-formed crown that may extend to 75 feet. Few, if any, adventitious roots arise from the lofty branches. The trunk is conspicuous, light-colored, often tinged with orange and dotted with tree snails and mangrove crabs. As one proceeds upstream, the height of the red mangrove is gradually reduced and the habit is changed. The prop roots become more numerous and less sturdy; the main trunk becomes less erect and less conspicuous; the adventitious roots become more numerous, arising from many branches and dangling toward the water. Further on, the trunk of the tree becomes invisible behind a shrubbing of leaves that now reaches the water's edge. Close inspection may reveal the trunk to be horizontal in attitude without any remaining connection with the place in which it was first rooted. On upstream, the red mangrove becomes even smaller and becomes limited to a narrow fringe along the stream margin. Here other plants participate with the red mangrove in forming the streamside vegetation including buttonwood (Conocarpus erectus), pond apple (Annona glabra), willow (Salix spp.) fig (Ficus spp.)and grape (Vitis spp.). Beyond the headwaters of the Shark the red mangrove exists in the open Everglades in the form of small bush-like trees with many thin prop and aerial roots, and no discernible main stem. In certain areas,"second growth"stands have developed, both near the open Everglades and along the river courses.

a



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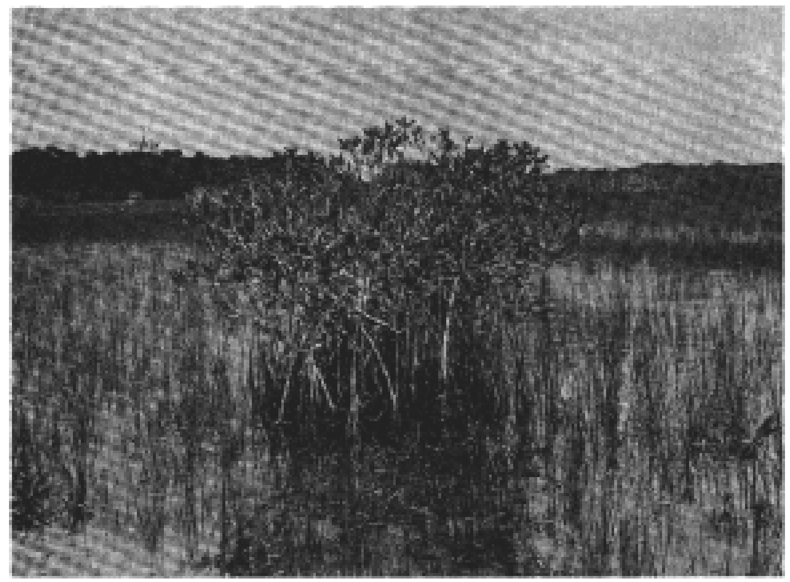


d

PLATE XIX

These "shade grown" trees possess the habit of young counterparts of the Shark River giants and may in fact be such. These unusual growth habits plus the great ecological amplitude of the species, plus the viviparous method of reproduction, make these plants interesting even to the casual observer.

STOP 19: Tarpon Bay Bulrush Site

Objectives:

A. Inspection of a marsh environment dominated by *Scirpus*.

B. Inspection of remnant saw grass peat mounds on marsh levels supporting *Scirpus* spp.

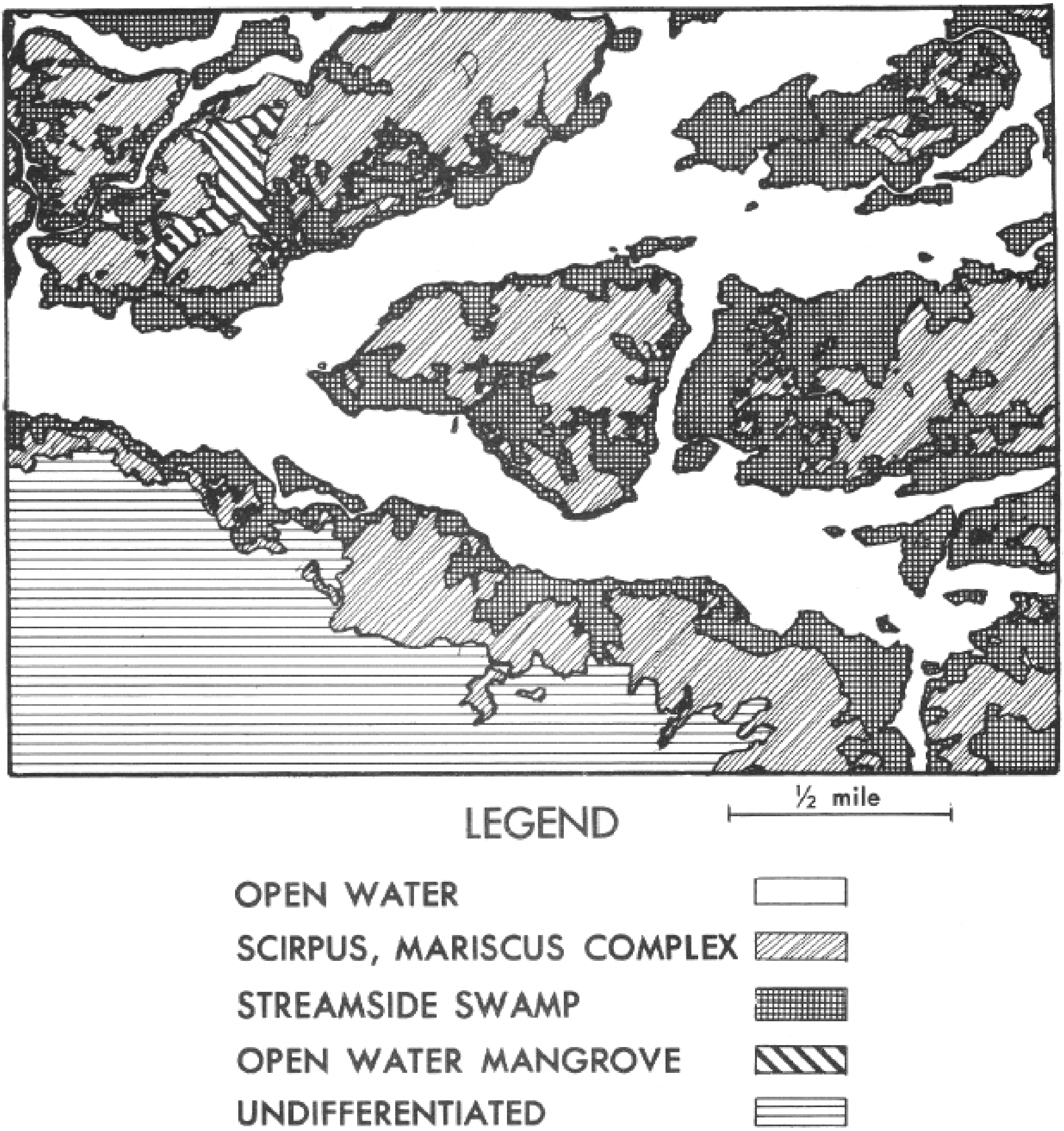
C. Discussion of environmental changes occurring upstream from Tarpon Bay.

D. Discussion of element concentration in *Scirpus* vs *Mariscus* environments.

E. Discussion of changes in element concentration and pollen content in surface sediments in a transect from marine open water to the fresh-water Everglades.

Discussion:

The map of environments in the Tarpon Bay area (Figure 46) shows only three environments of areal importance in this locality: the open water channels, the streamside forest and the *Scirpus* - *Mariscus* marsh. An impression of the height of the mangroves in the streamside forest and the width of this channel-fringing environment in this area can be obtained from the aforementioned figure and Plate XX. The type of marsh shown in the Plate covers large areas in the brackish water zone. Because they are usually concealed to the water traveler by the streamside swamp, they have received little attention in the past. In many places saw grass is much less conspicuous in the environment than it is at Stop 19 and may be completely absent over large areas. As one proceeds inland from this locality, the *Scirpus* marsh soon disappears and the saw grass and spike-rush environments dominate the marshland area. The streamside forest continues to thin and finally disappears as the Shark River headwaters become indistinguishably a part of the surficial water flow in the Slough area (Plate XXI).



MAP OF ENVIRONMENTS IN TARPON BAY AREA

Figure 46

PLATE XX

a

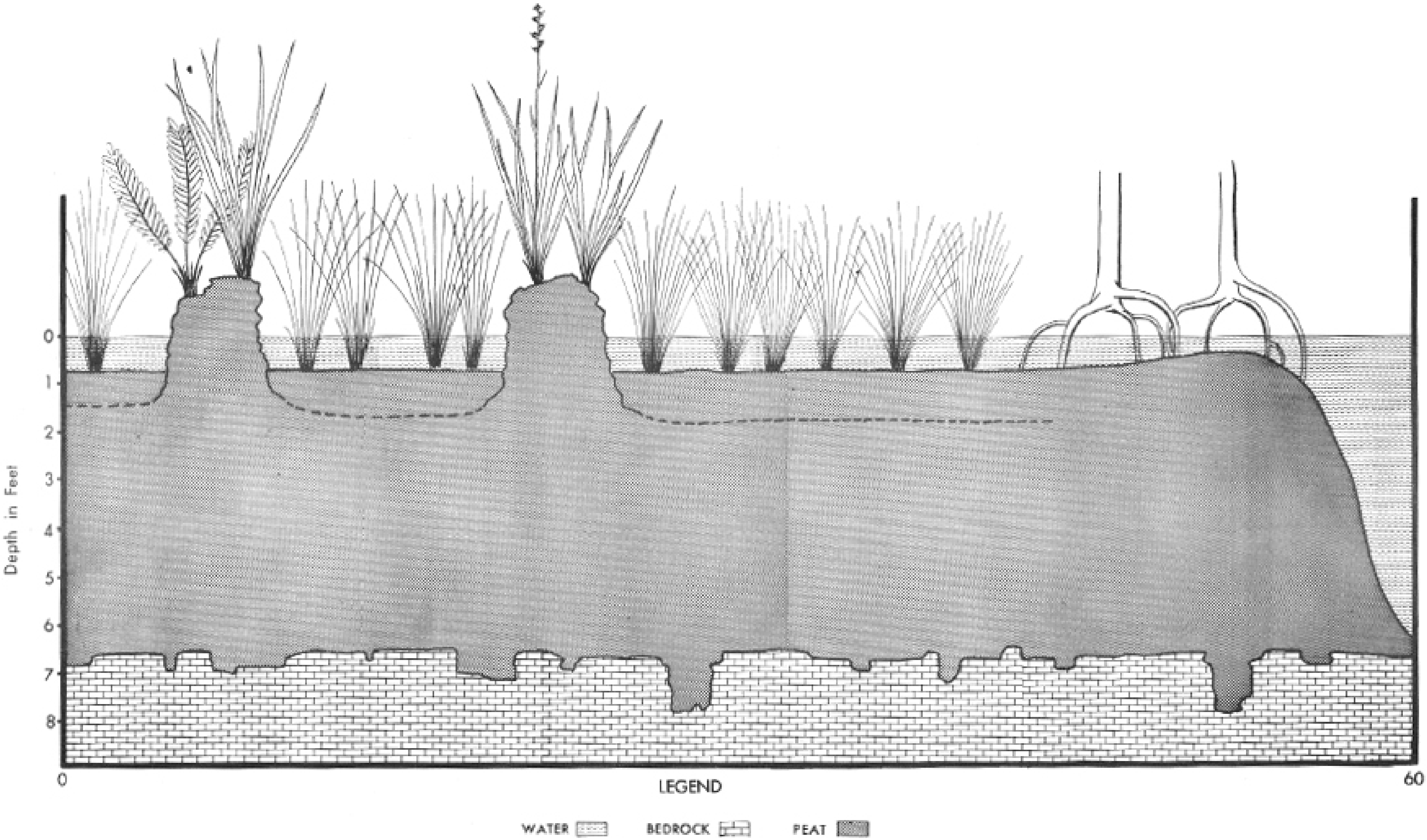
b

PLATE XXI

Of interest at Stop 19 is the occurrence of what may be remnant patches of saw grass marshland growing on mounds of peat at an elevation that is often as much as 2 feet above the level on which the *Scirpus* marsh is developed. The mounds are composed of saw grass peat and the sides are usually ragged and steep. The appearance is that of an erosional remnant. Figure 47 is a generalized sketch of these observed relationships. If these are erosional remnants of a former surface, as they appear to be, they indicate the removal of vast amount of peat and an appreciable lowering of the surface as an event associated with the marine transgression. At present no radiocarbon dates are available on the upper surface of the mounds and on the sub-*Scirpus* peat. Such data should be useful in determining whether or not these are evidence of extensive erosion.

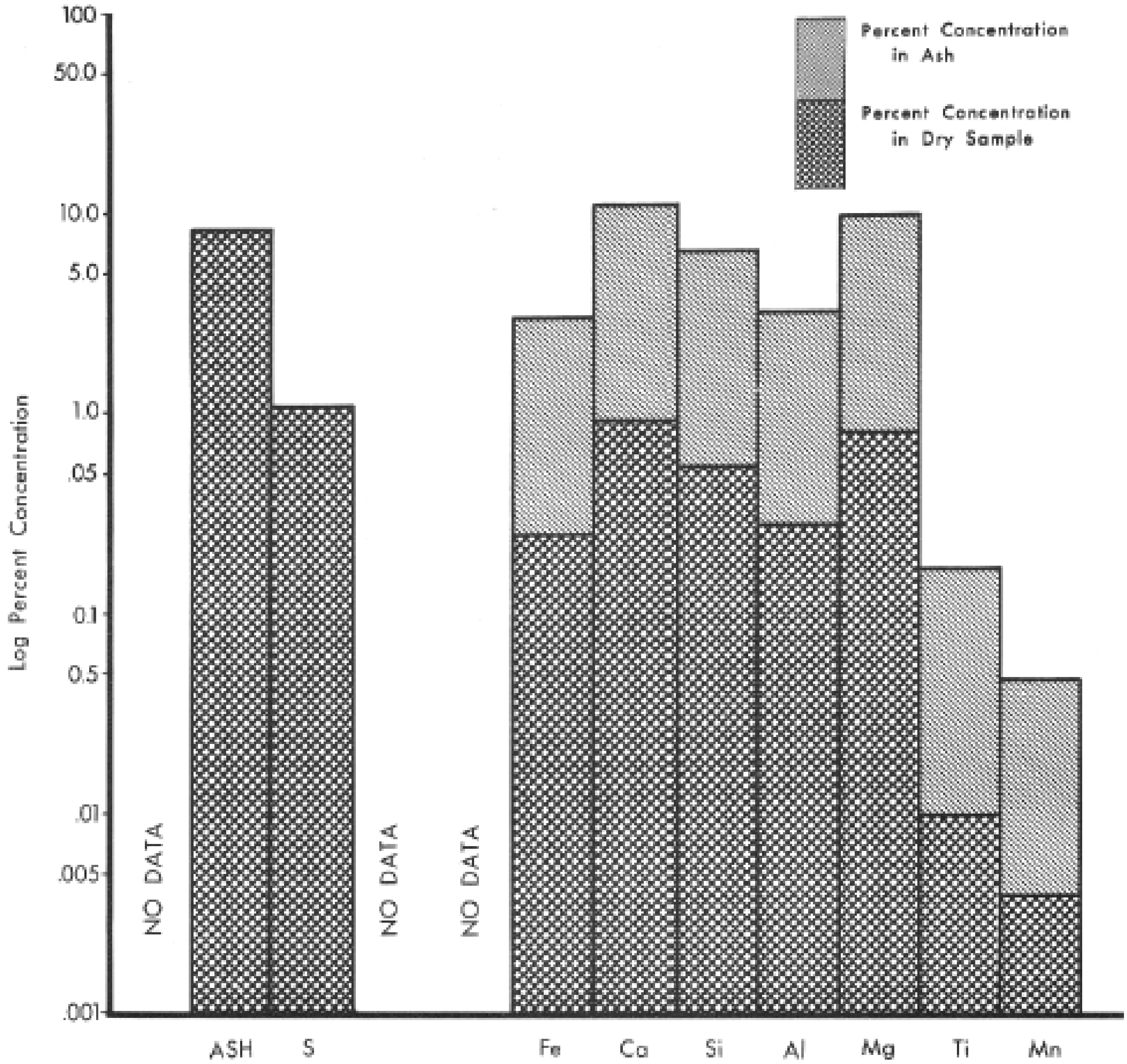
Data on the chemical character and pollen content of the *Scirpus* marsh sediment are meager and the data presented should be thought of as representing this particular site, as opposed to the *Scirpus* environment in general. The element concentrations encountered at this site are graphically presented in Figure 48 and should be compared with those of a brackish saw grass site (Figure 14). The values appear quite similar at the two sites except for the significantly higher concentration of sulfur in the brackish saw grass peat. This difference does not appear to be a function of differences in carbon content, for the ash in the saw grass peat is higher than that in the *Scirpus* sediment. The data amassed to date point rather emphatically to the brackish saw grass marsh and the brackish cat-tail marsh as sites in which high concentrations of sulfur are found in the surface sediments.

In order to determine the extent to which trends in elemental concentrations and pollen content were associated with distance from the open waters of the Gulf, a series of samples was taken in the streamside swamp environment. These were surface samples taken on each side of the Shark and Little Shark Rivers at one mile intervals without regard for the environmental setting involved (i.e. width of the streamside swamp, composition of the streamside swamp at the sampling site, nature of adjacent environments, etc.). The sample locations are plotted on Figure 49, and the chemical data are summarized in Table 3. Several facts that

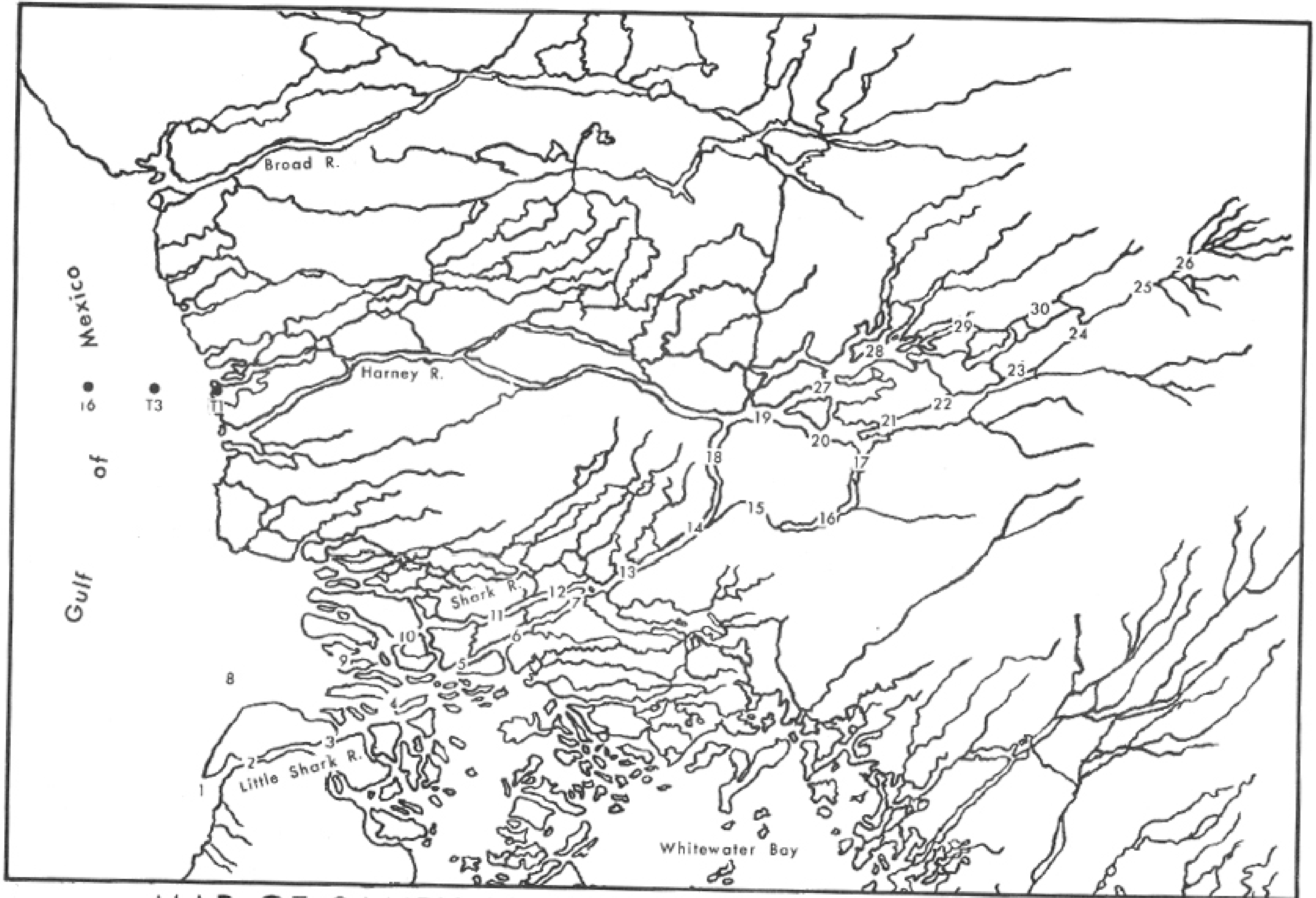


IDEALIZED SECTION THROUGH THE MARGIN OF A TARPON BAY ISLAND SHOWING SAW GRASS PEAT MOUNDS

Figure 47



ELEMENT CONCENTRATIONS IN SURFACE PEAT IN BULRUSH MARSH
Figure 48



MAP OF SAMPLING SITES ALONG THE SHARK RIVER AND THE CORE SITES IN THE BURIED PEAT (59-T1, T3, AND T6)

Figure 49

TABLE 3

Summary of Chemical Data Obtained on

Samples Collected Along the Course of the Shark River

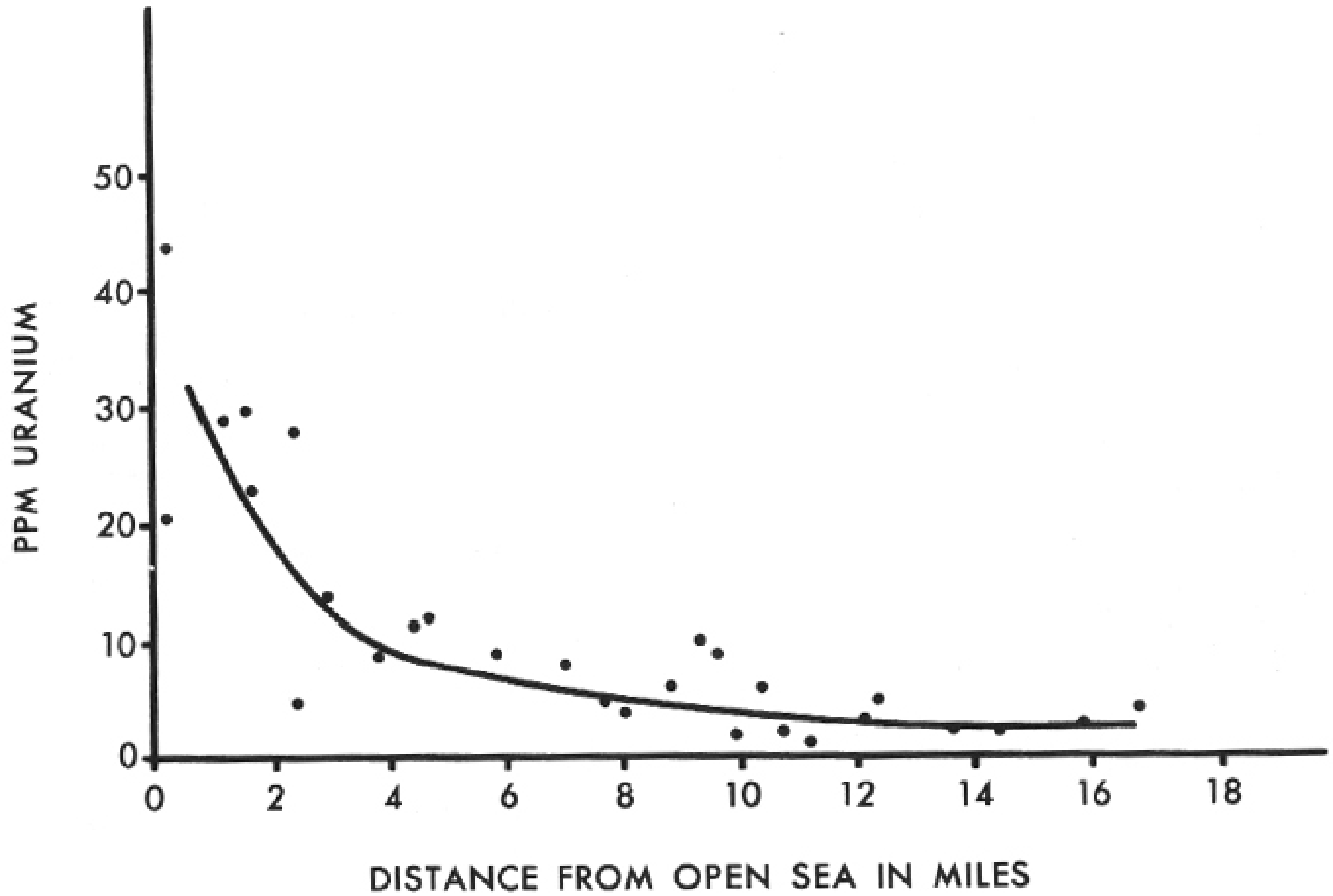
Sample No.	H_2O*	C*	S*	H*	Ash*	Fe*	Ca*	Si*	Al*	Mg*	Ti*	Mn*	U*
1	4.27	12.68	2.57	2.05	68.90	3.6	0.69	16.9	7.8	1.8	0.43	0.0050	0.0021
2	6.73	8.49	1.85	2.13	56.63	1.8	6.1	12.2	2.9	1.4	0.21	0.0028	0.0029
3	6.49	38.03	3.13	3.58	28.17	0.93	1.6	2.4	1.2	1.8	0.06	0.0014	0.0028
4	9.86	34.17	3.17	3.33	34.64	1.4	1.9	5.0	2.0	1.4	0.14	0.0024	0.0030
5	4.06	16.93	0.94	1.04	56.06	0.62	27.0	4.0	0.95	1.3	0.07	0.0026	0.0005
6	12.00	25.40	3.34	2.10	50.91	1.7	6.8	7.7	2.7	1.9	0.18	0.0092	0.0009
7	8.96	36.22	3.05	3.24	32.91	0.86	2.8	6.4	2.3	1.5	0.15	0.0025	0.0012
8	0.52	11.15	0.40	0.33	60.52	0.40	37.3	3.4	0.91	0.28	0.05	0.0014	0.0004
9	8.12	21.00	2.44	1.87	56.51	2.1	3.0	11.8	4.5	1.8	0.26	0.0036	0.0044
10	5.16	30.94	2.93	3.18	40.26	2.1	1.5	5.9	2.4	0.34	0.14	0.0048	0.0023
11	4.98	26.92	2.42	2.85	43.40	1.3	9.4	6.7	0.03	1.4	0.16	0.0037	0.0014
12	4.67	27.84	2.26	2.45	45.85	1.7	6.4	8.6	2.1	1.4	0.16	0.0060	0.0011
13	7.77	38.88	4.29	3.50	29.09	1.1	1.5	4.5	2.4	1.2	0.13	0.0044	0.0009
14	6.02	40.16	3.40	3.79	27.23	1.2	0.92	4.1	1.6	1.2	0.08	0.0033	0.0008
15	5.73	34.61	1.33	3.97	33.05	0.83	3.5	6.3	1.9	1.0	0.09	0.0059	0.0004
16	6.46	44.20	2.39	4.32	13.09	0.42	2.1	2.7	0.90	1.0	0.05	0.0018	0.0010
17	7.68	48.88	2.51	4.76	13.82	0.25	2.4	1.1	0.52	0.94	0.03	0.0050	0.0006
18	4.92	32.86	2.66	5.05	36.03	0.72	4.1	6.8	1.8	1.2	0.12	0.0043	0.0005
19	6.88	45.14	3.23	4.27	17.14	0.41	2.0	1.9	1.1	1.2	0.06	0.0031	0.0006
20	8.62	47.47	1.84	4.26	12.12	0.31	2.4	0.90	0.38	1.4	0.02	0.0037	0.0009
21	6.76	36.06	4.42	3.43	35.82	2.8	8.3	1.5	0.86	1.4	0.06	0.0201	0.0002
22	3.99	23.54	3.08	1.89	54.02	1.8	23.8	2.3	0.24	0.59	0.01	0.0167	0.0003
23	5.35	33.99	4.28	3.00	40.02	3.0	9.9	3.9	0.52	0.80	0.04	0.0204	0.0003
24	5.46	42.56	3.58	4.57	23.14	2.2	6.3	0.65	0.28	0.62	0.01	0.0155	0.0002
25	6.04	48.40	2.50	4.53	17.60	1.8	3.3	0.98	0.30	0.86	0.02	0.0150	0.0003
26	4.43	25.03	4.17	2.26	50.21	2.6	13.0	6.2	3.2	0.75	0.22	0.0171	0.0004
27	6.90	45.33	2.01	4.31	16.24	0.19	3.8	0.39	0.21	1.8	0.01	0.0029	0.0002
28	9.62	49.05	1.99	3.76	20.18	0.44	2.8	0.89	0.20	1.2	0.01	0.0022	0.0001
29	4.47	21.84	2.20	1.74	62.66	1.1	4.5	21.2	0.53	0.69	0.02	0.0075	0.0005
30	7.24	49.94	2.76	4.39	12.64	1.4	2.3	0.87	0.25	0.50	0.02	0.0034	0.0002

* Concentrations in percent.

are of interest will be noted when these data are inspected. For example, the sulfur content exceeds 4.0 percent in nine of the samples and there is no clearly defined trend toward an increase in total sulfur as one approaches more marine conditions. The sulfur measured is exclusive of most of the H_2S originally present in the samples. Essentially all of this would have been lost in the drying, grinding and pulverizing of the samples for analysis. Also of interest is the relationship between the uranium content of the samples and the distance from the open Gulf. This relationship is plotted in Figure 50.

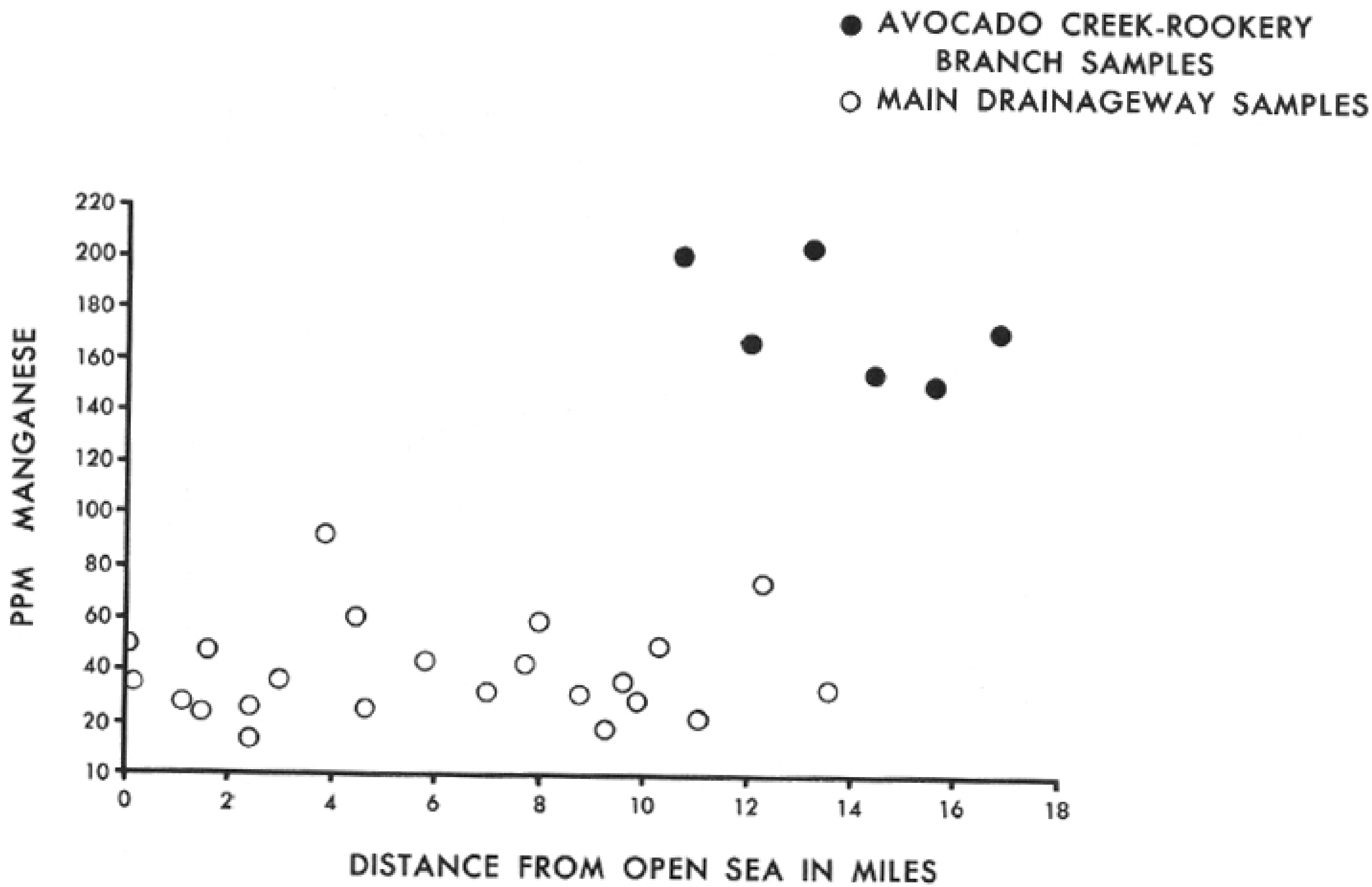
A more thorough discussion of these and other chemical data from this general area will be presented in a series of papers now in preparation. Of significance for present purposes, however, is the concentration of manganese in certain of the inland brackish sites. Figure 51 shows that there are two populations of samples as far as manganese content is concerned. One includes the sites along the main drainageway and the samples in this population usually contain fewer than 50 ppm of manganese. In contrast, the Avocado Creek - Rookery Branch sites all contain greater than 150 ppm of this element. Thus it would appear that some, but not all, inland brackish environments in this area are characterized by a concentration of manganese that is about three times as great as most of the more marine sites.

Some of the palynological data collected on the river bank samples are presented in Table 4. The salient trends shown by these data are diagrammatically represented in Figure 52. As is evident, and as would be expected from a knowledge of the present vegetational distribution patterns, pollen derived from red mangrove is represented in the largest concentrations at the coastline. Proceeding upstream there is a progressive decrease in the amount of <u>Rhizophora</u> pollen until it constitutes only 1-2 percent of the total pollen present in the sediment. (Sampling Site No. 30 apparently represents a localized and atypical concentration of <u>Rhizophora</u>.) Conversely, the pollen of Chenopodiaceous affinities is usually present in only small quantities in most of the marine samples and reaches its peak concentration in the headwaters areas. Thus, these two pollen types, particularly when used in combination, may provide a



DISTRIBUTION OF URANIUM ALONG THE SHARK RIVER

Figure 50



DISTRIBUTION OF MANGANESE ALONG THE SHARK RIVER

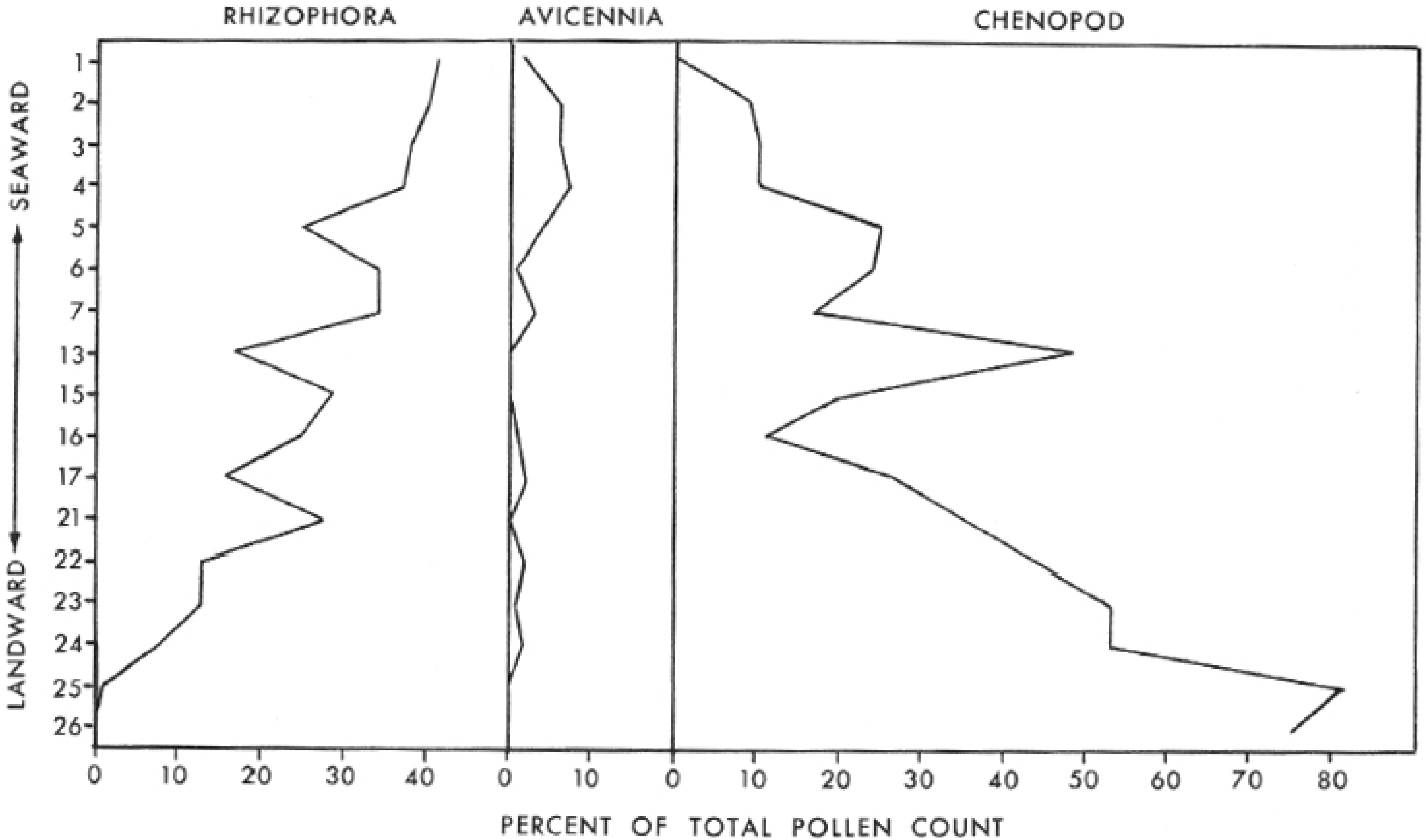
Figure 51

TABLE 4

Summary of Palynological Data Obtained on Samples Collected Along the Course of the Shark River

Locality No.	Pollen Types in Percent			
	Rhizophora	Avicennia	Chenopodiaceae	Other Pollen
1	41	2	0	57
2	40	6	9	45
3	38	6	10	46
4	37	7	10	46
5	25	3	25	47
6	34	1	24	41
7	34	3	17	46
9	48	3	6	43
10*	-	-	-	-
11*	-	-	-	-
12*	-	-	-	-
13	17	0	48	35
14*	-	-	-	-
15	29	0	20	51
16	25	1	11	63
17	16	2	27	55
18	31	0	33	36
19	20	2	25	53
20	22	0	32	46
21	27	-	35	38
22	13	2	44	41
23	13	1	53	33
24	8	2	53	37
25	1	0	81	18
26	0	0	75	25
27*	-	-	-	-
28	2	0	80	18
29	3	0	90	7
30	25	3	14	58

* Pollen too rare to warrant count.



DISTRIBUTION OF MAJOR POLLEN TYPES IN THE SEDIMENTS ALONG THE SHARK RIVER

Figure 52

useful index to the environmental site - shoreline relationships when the conditions are comparable to the area herein described. Also of interest is the concentration of Avicennia pollen in the various samples. The pollen of this plant is most commonly represented in the marine to brackish zone just behind the coast and disappears from the sediment before the headwaters are reached. Therefore, the pollen concentration in the sediment accurately reflects the greater areal distribution of Rhizophra and the comparatively restricted range of Avicennia. All of the sources of the Chenopodiaceous pollen have not as yet been ascertained, hence the relationship of these pollen concentrations to the source plants cannot be stated. It seems apparent, however, that a large concentration of Chenopodiaceous pollen associated with a very small representation of Rhizophora pollen reflects the brackish to fresh-water transition zone in this area (salinity of 200 ppm NaCl). A more or less equal representation of these two pollen types plus a reasonable amount of Avicennia pollen is an index of brackish environment (salinity of ca. 4000 ppm) and a large concentration of Rhizophora pollen, with little or none of the other two represented, is a reflection of the type of marine conditions prevalent along the coastline (salinity of 36,000 ppm).

STOP 21: Buried Peat Site

Objectives:

A. Procurement and inspection of cores of the sediment sequence one-half mile off the western coast of Florida.

B. Discussion of the age of the sediment, elemental concentrations and pollen content in onshore and offshore cores taken in an E-W transect.

C. Discussion of the evidence for marine transgression provided by the core data.

D. Summary of the distribution of phytogenic sediments in southwestern Florida.

Discussion:

Davis (1940) pointed out that the thickness of the peat near the mouth of the Shark River was far greater than the tidal range and he inferred this to be evidence of a relative rise in sea level. The mean tide range at the Shark River mouth is 3.6 feet (U.S.C.G.S. 1962), with spring tides sometimes reaching 4.5 feet. Davis mentioned peat thickness "greater than 10 feet" and the present investigation has shown sediment thicknesses greater than 15 feet in this area. Since there is no evidence to indicate a greater tidal range in the past, and in view of the fact that the present peat surface is awash at high tide, Davis' inference appears valid. Or, perhaps, it is more accurate to say that either a sea level rise or a local subsidence is indicated.

When extensive coastal swamps form the shoreline as they do in southwestern Florida, it is possible for the accumulation of peat to keep pace with either a rising sea level or a local subsidence. It is also possible for the aggradation of organic material to either lag behind or exceed the rate of sea level rise. Thus, one can conceive either a still-stand of the coastline or a regression or transgression of the sea, depending on the differential rates involved. Davis implied that historical accounts of red mangrove inland from their present limits suggested that the mangrove forest was moving seaward (Davis, 1940). The evidence encountered in the course of more recent studies makes it quite evident that the southwestern Florida coast has been under the influence of a transgressing sea for the last 4000 - 5000 years.

The most convincing evidence of the transgressing sea was encountered while coring near the mouth of the Harney River, some two miles north of the mouth of the Shark River (see Figure 53 and Plate XXII). About one-fourth of a mile from shore a layer of peat was encountered beneath three feet of lime mud. The peat layer proved to be 6 to 7 feet thick and additional exploration showed it to be continuous with the 13'6" of peaty sediment present on shore beneath the mangrove forest. Seaward the peat extends out at least a mile and three-quarters in this area, at which point only one foot of peat is present and this is covered by 6'6" - 7' of marly sediment. The basal peat a mile and one-half off-shore has been dated at 4420 ± 200 years and the basal peat (13'3" - 13'5") at the onshore site was dated at 4080 ± 180 years.*

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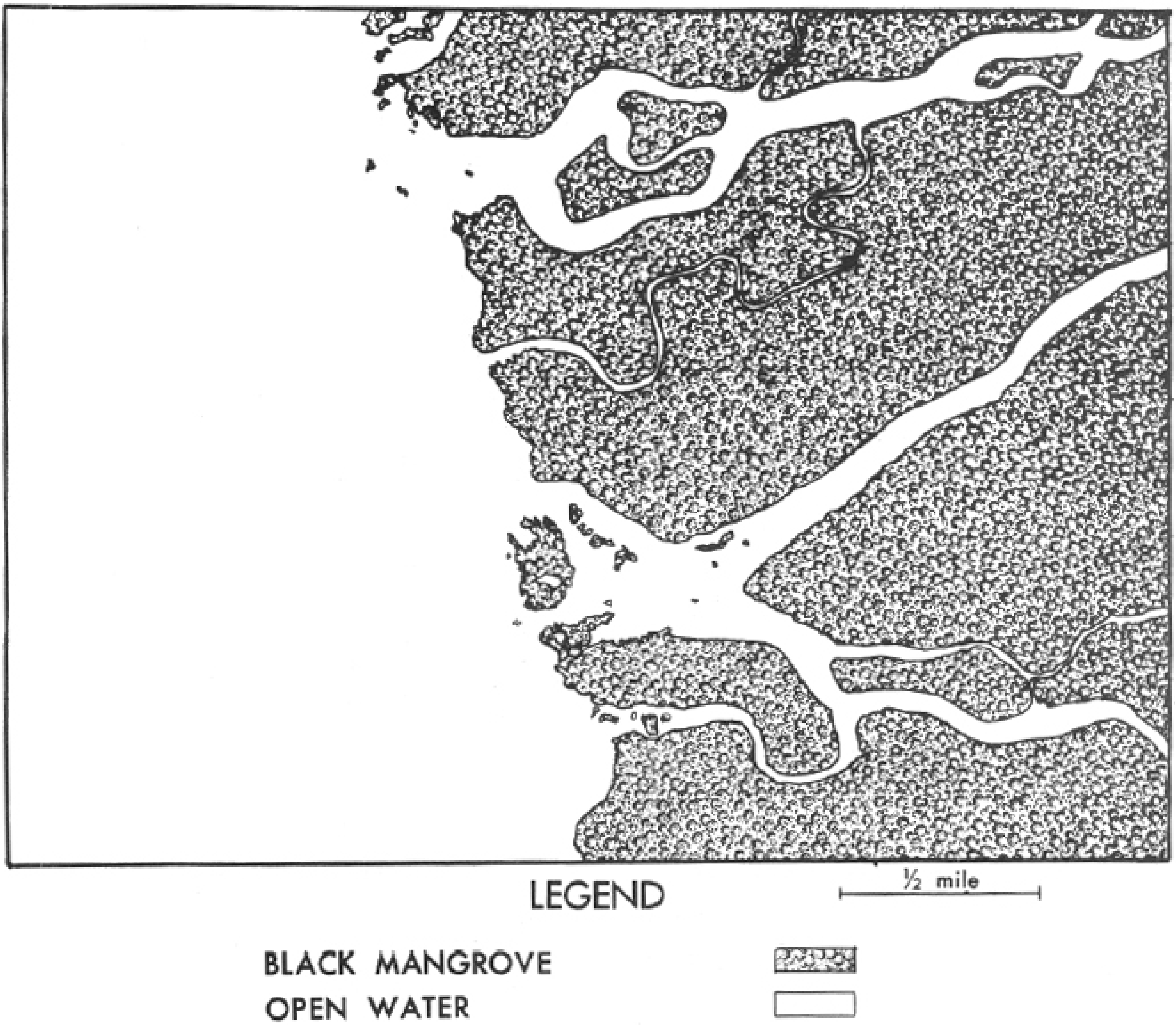
* Radiocarbon dates courtesy of Shell Development Company.



MAP OF ENVIRONMENTS IN THE HARNEY RIVER AREA

Figure 53

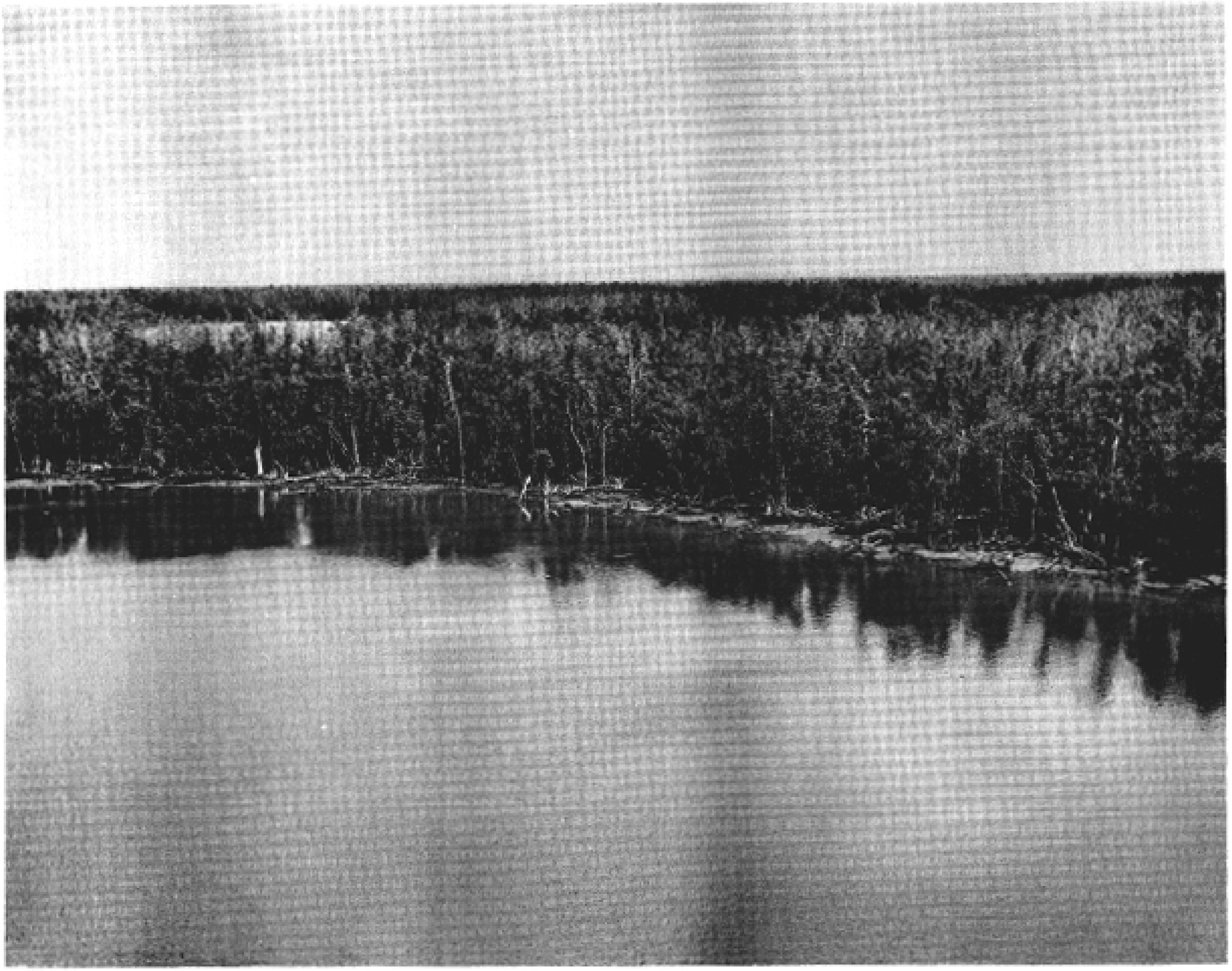


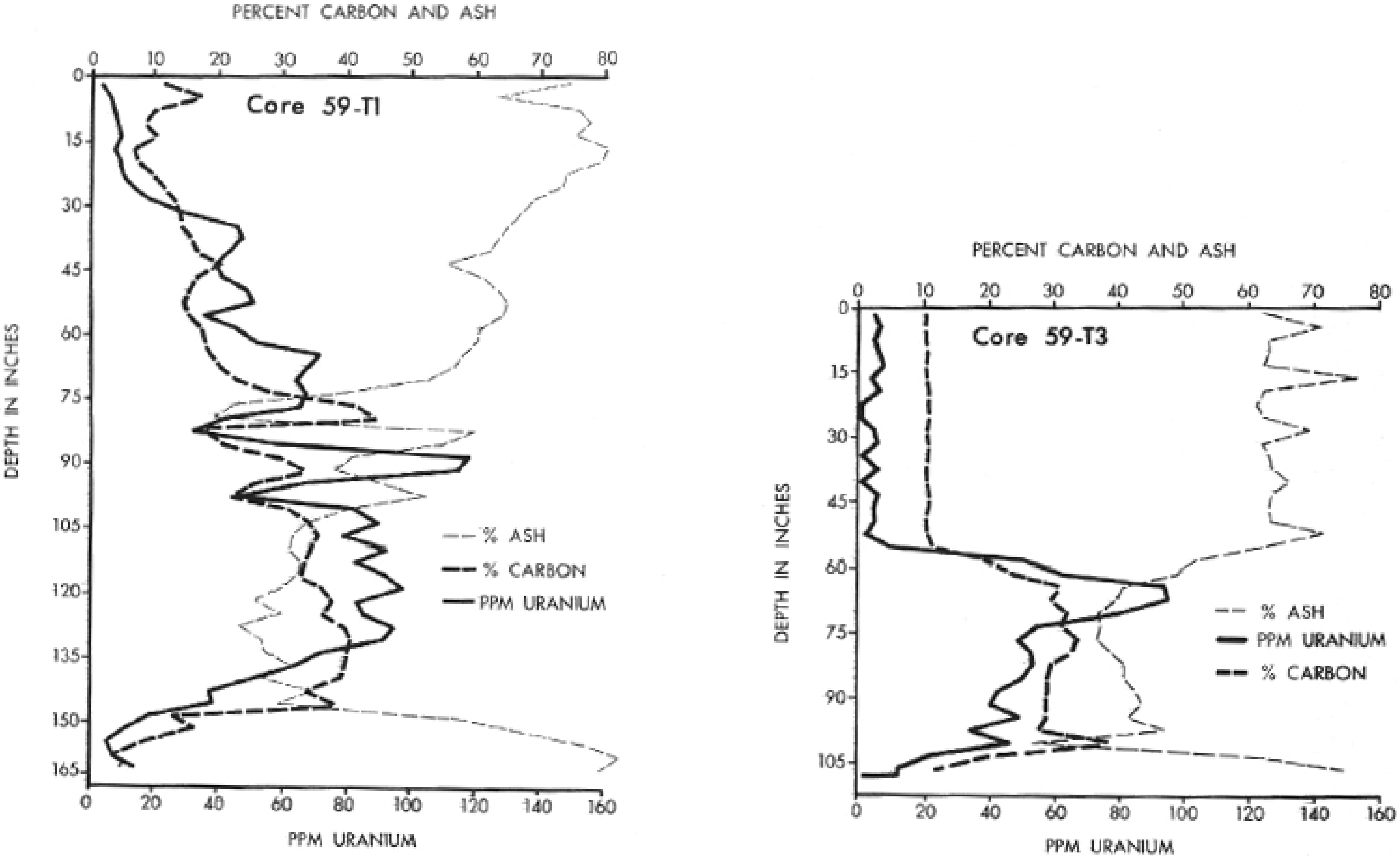
PLATE XXII

A marked change in the character of the core taken at the onshore site (Site T1) occurs several feet above the flat Miami oolite surface on which the peat was deposited. At this level the sediment changes to a limey peat and then to a peaty lime mud. This is well illustrated by the graph presented as Figure 54 which shows the relative concentrations of ash, carbon and uranium in the sediment. In the upper zone foraminifera were common in the sediment but they were not noted below the 7 foot level. The same general relationships hold three-quarters of a mile offshore as shown by Figure 54. Note the positive correlation of the concentration of uranium with the concentration of carbon and the negative correlation with ash.

On the basis of these data, the reconstruction presented as Figure 55 appears justified. There seems little doubt that the sea has been transgressing over the land in this area, as evidenced by the autochthonous peat layer that extends out more than a mile and a half as a continuation of the sediment mass now found under the coastal mangrove forest.

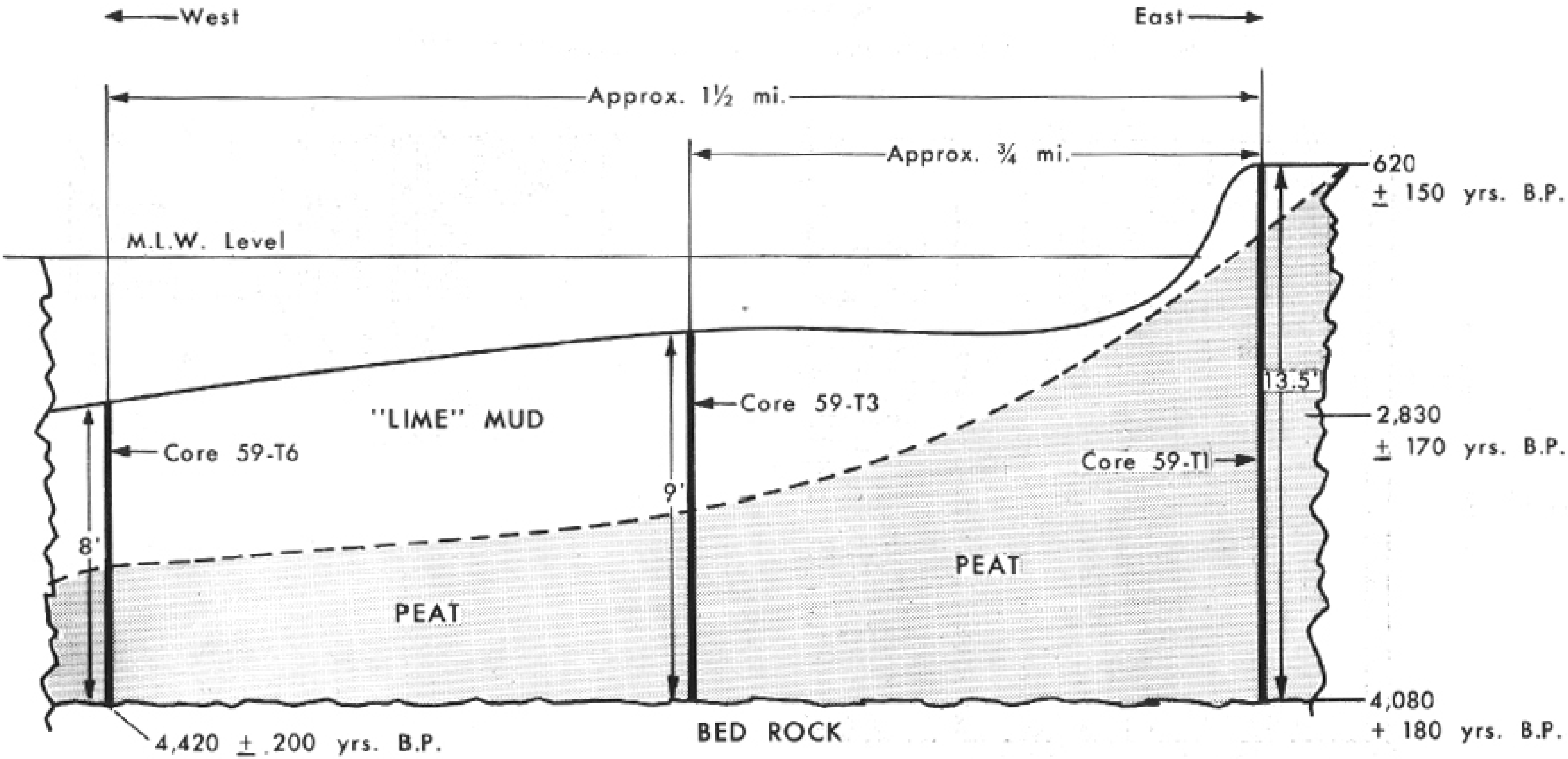
A second convincing evidence of transgression is to be found in the character of the peat in the onshore core (Site T1). Inspection of the data presented in the pollen profiles (Figure 56) will show the manner in which the concentrations of certain pollens in the sediment have changed during the past 4000 years. The basal two feet of sediment in the deeper core are quite different in pollen content from the overlying sediments. They contain only very small quantities of Rhizophora pollen, even less Avicennia pollen, and sizeable quantities of pollen from fresh-water species, particularly from sedges, fresh-water aquatics and pine. Such a pollen assemblage was encountered some 14 to 15 miles inland where the salinity is less than 200 ppm. Hence, this basal peat layer appears to be a fresh-water or mildly brackish sediment whose geographic position is now coincident with the shoreline and hence overlain by a marine environment. Such a condition could come about only with a transgression of the Gulf over the southwestern Florida coast.

If the above is true and if the transgression has been more or less continuous, one would expect to find a series of progressively more marine strata lying on the basal peat. Further inspection of the pollen profile



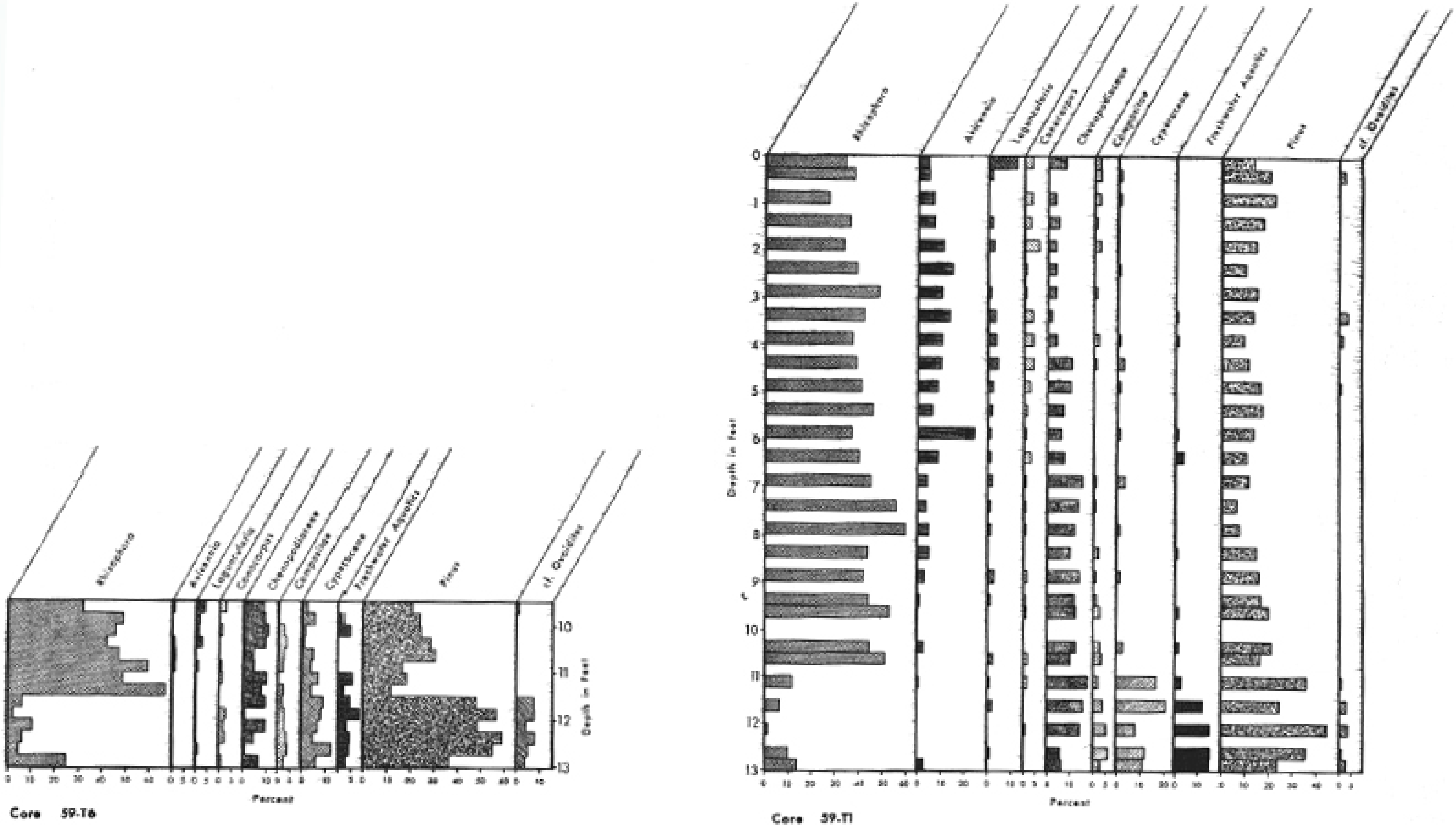
VARIATION IN CARBON AND URANIUM CONTENT AT SITE 59-T1 AND SITE 59-T3

Figure 54



GENERALIZED CROSS SECTION SHOWING SEAWARD EXTENSION OF PEAT

Figure 55

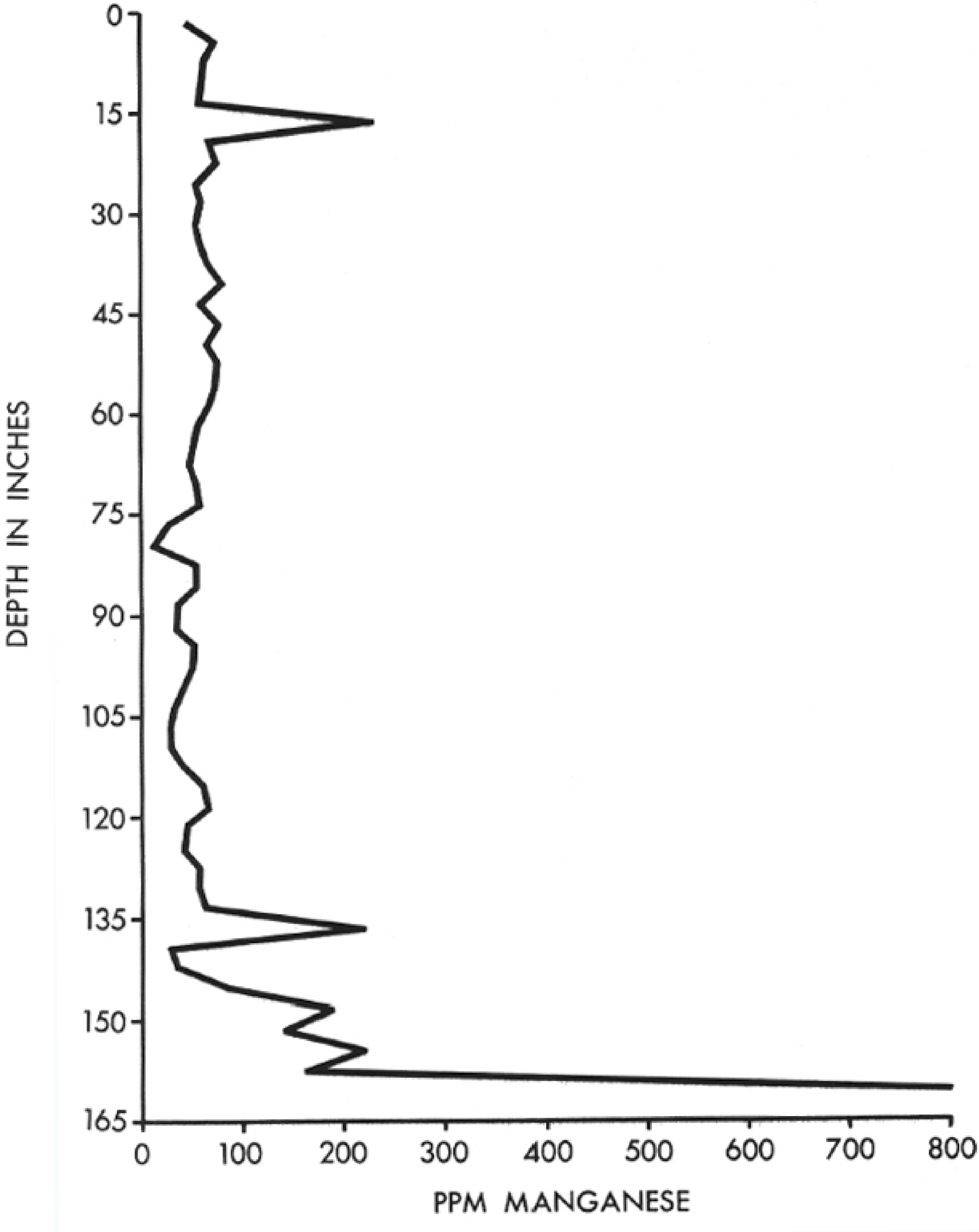


POLLEN AND SPORE CONCENTRATIONS AT VARIOUS LEVELS IN CORES FROM SITES T-6 AND T-1

Figure 56

will reveal that there is an abrupt increase in the concentrations of Rhizophora pollen near the 11 foot zone, suggesting a rapid change in conditions or a disconformity at that level in the peat. Avicennia reaches its maximum concentration in a zone that lies between one and six feet below the present surface. In the upper one foot of the sediment, Avicennia is reduced in concentration and the Chenopodiaceous pollen reaches its maximum abundance in the center section of the core. These facts suggest that this core contains, in its 13 feet, representatives of three major environmental zones: the fresh-water zone, the brackish zone and the coastal marine zone. Thus, the equivalent of some 15 miles of swamp is recorded in the vertical sequence. Whether the coast was ever 15 miles offshore during the last 5000 years is another question, as it is obviously not necessary that 15 miles be involved in the marine to fresh-water transition. In the case in question, however, considerable evidence could be brought to bear to show that the broad expanse of the Shark River channel system has been a main drainage way for water flowing southward from Lake Okeechobee for a considerable period of time. This, plus the essentially horizontal attitude of the Floridian Plateau surface in the offshore area, suggests that the salt to fresh-water transition has not been very abrupt in the recent past along what is now the course of the Shark River. It seems likely that at least several miles of shoreline regression have occurred during the last 5000 years.

Confirming the conclusions derived from the pollen data are data derived through the studies of trace elements in the sediments. The best example of this is to be found in the distribution of manganese in the onshore core (Site T1). Figure 57 is a graphic profile showing the relative concentration of manganese at various levels in the thirteen and one-half feet of sediment. As is evident from the figure, the basal two feet contain quantities of this element that tend to set this section of the core apart from the overlying strata. Reference to Figure 51 will show that concentrations of manganese comparable to those in this basal layer were characteristic of certain brackish to fresh-water sites that lie between 10 and 18 miles from the present shoreline. Hence, two quite different analytical techniques provide data that point to the



MANGANESE CONCENTRATION IN CORE FROM SITE T

Figure 57

same conclusion.

It appears probable that the transgression has proceeded at different rates at various points in time. For example, during the interval represented by the basal six feet of peat, the rise in sea level must have only slightly exceeded the rate of accumulation of organic material, thus yielding a peat with comparatively small amounts of mineral matter, while permitting a gradual transgression of the saline environment over the fresh water site represented by the basal one or two feet. About 3000 years ago the rate of accumulation of organic material fell below the rate at which mineral matter was brought into the area of tidal overflow. This may imply a more rapid rate of transgression and relative sea level rise. Were this not true, the accumulating peat would minimize the impact of tidal overflow and hold the concentration of mineral matter at a low level. In the very recent past another increase in the rate of sea level rise must have occurred, for the surface sediment at the onshore site was dated as being 500-600 years old. This, of course, suggests that accumulation of sediment may have ceased and that the surface is undergoing erosion at the present time. Abundant evidence of a recent reduction of the general level of much of the tidal area has been shown at inland sites where clumps of saw grass and other vegetation stand on steep sided pillars of peat with the surface 12-18 inches above the present high water level (see Figure 47).

A series of other features of the area attributable in some measure to the influence of the transgressing sea have been observed. Some that have been described might be attributed to normal storm action along the coast and it would be difficult to prove that this was not the case. The reason for reiterating these features at this point, is that one should expect them as commonplace effects where a low plain coast is subjected to marine transgression. Were they to fail to occur here, it might cast some doubt on the validity of the conclusions thus far drawn.

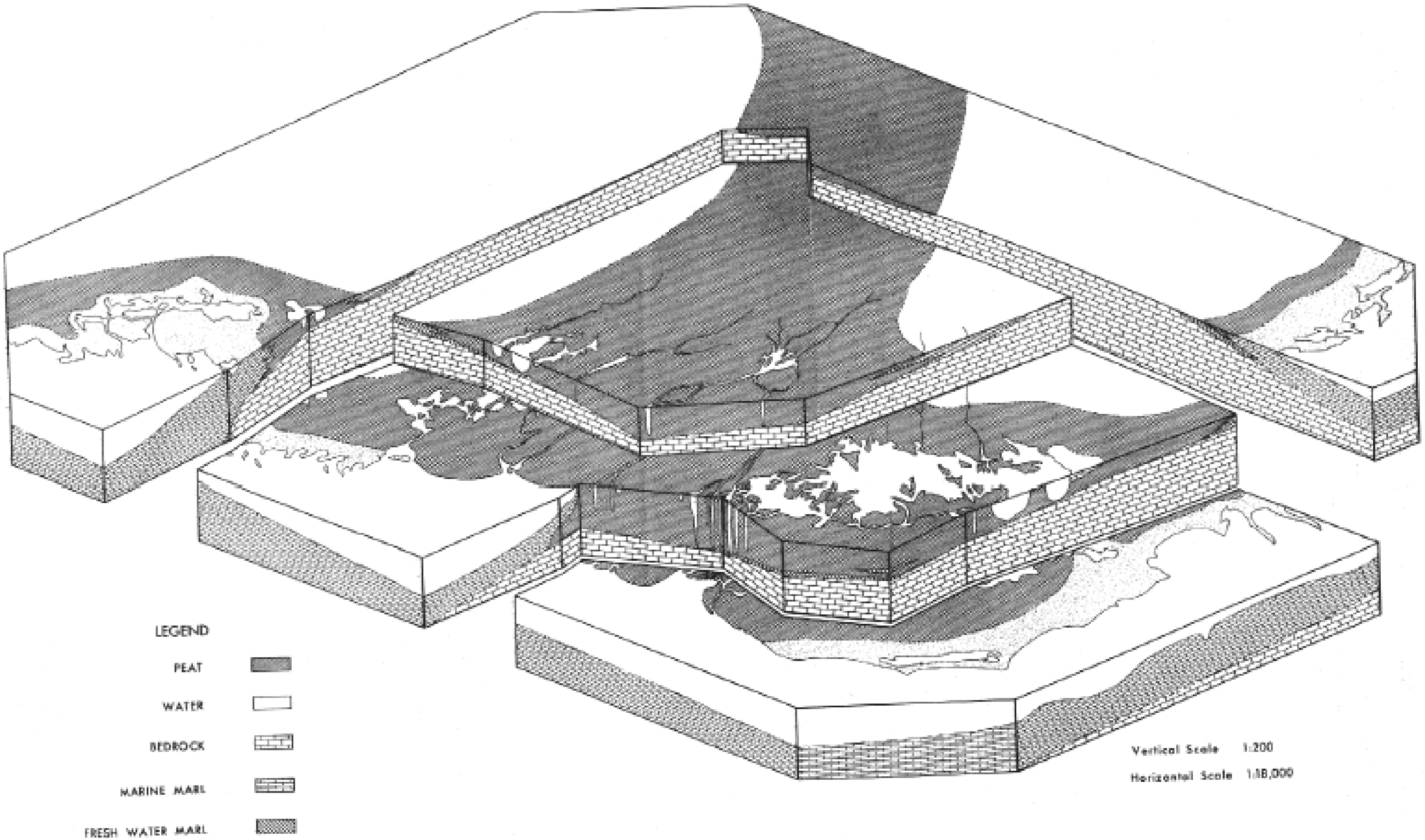
One of the most obvious evidences of the sea's transgression is to be seen at the coast. Although the red mangrove trees have often been referred to as a pioneer species which build up new land by catching and retaining debris in their maze of prop roots, the great number of fallen and dead trees along this coast make it evident that the mangroves are here losing ground to the sea (Plate XXII). The coastal chart of the area shows islands and points which exist presently only as shallows or mud banks, often covered by the sea even at low tide. An anchor dropped in the middle of Ponce de Leon Bay will take hold in solid peat.

In some places drowned forests extend out beyond the shoreline in the form of stumps that are still rooted in their original site. In areas receiving the full impact of prevailing winds and currents, extensive storm beaches have partially buried and killed the marginal forest. To some extent this is to be expected along any exposed coast of this type but the effect appears to be intensified in this area.

The coastline in certain sectors is being dissected into an array of isolated but clearly related islands and the islands themselves are undergoing dissection through intense tidal scour. Every stage in the dissection of an island can be observed in the area. The steepness of the inter-island channel walls in the Ponce de Leon Bay area is evidence that the peat forming the islands and standing like a pillar beneath the forest, is in an environment quite dissimilar from the one in which the sediment accumulated. The channels are carved down to the Miami oolite surface and are 12-15 feet deep, often with almost vertical walls.

After some study of the area, one develops the impression that the intensive tidal scour initially produces extensive tidal flats where the mangrove forest once stood. These are well developed in the area south of Little Shark River where the outflow of fresh-water does not buffer the effects of the tidal overflow. After tidal flat development, channel deepening and island formation begins as the area undergoes its dissection. In some sectors, such as those in the vicinity of the Lostman's and Rodgers Rivers, inland bays begin to form, ultimately converting a former land surface into a vast inland lagoon as the result of removing the peat that formed the land to begin with. Hence, it seems likely that a gradual rise in sea level was initially responsible for the creation of much of the land surface in this area and the continued rise at an accelerated rate is now causing the destruction of the coastal area.

A block diagram of southwestern Florida showing the extent of the blanket of phytogenic sediments is presented as Figure 58. From the preceding discussion it is evident that these sediments are the products of a number of different swamp and marsh environments. The boundaries between these environments is often well-defined and the vegetation occupying the sites is often relatively simple in composition. This renders the area suitable for initial studies of the complex processes involved with peat formation. Study of the area is also informative in connection with gaining some insight into the impact of a transgressing sea on peat-forming environments.



BLOCK DIAGRAM OF SOUTHWESTERN FLORIDA
Figure 58

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