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Petrology of Some Holocene Peat Sediments from the Okefenokee Swamp-Marsh Complex of Southern Georgia

ABSTRACT

Ten or more samples of surface peat were obtained from each of six peat-forming environments in the Okefenokee swamp-marsh complex of southern Georgia. These peat-forming environments were chosen for study because they were found from core studies to have been the most important peat producers throughout much of the history of peat formation in the swamp.

The peat samples were dehydrated in alcohol, embedded in paraffin (using the methods of Cohen and Spackman, 1972), and sectioned (to 15 μ) with a sliding microtome. The microscopic features found to be most useful in characterizing the peats and relating them to their original depositional and vegetational environments were (1) their color (at 30×); (2) the ratio of framework to matrix; (3) the ratio of nonsedimentary to sedimentary constituents; (4) the proportions of remnants of plants assignable to particular plant species; and (5) the percentages of various accessory ingredients, such as fungal remains, fecal pellets, diatoms, insect parts, sponge spicules, quartz, and charcoal.

The peat-forming environments investigated were (1) the *Nymphaea* environment (open-water marshes dominated by floating aquatic plants); (2) the *Carex*, *Panicum*, and *Woodwardia* environments (glades or island fringes dominated by emergent aquatic plants); and (3) *Cyrilla* and *Taxodium* environments (tree islands and swamps). The peat sediments deposited in each of these regions were found to have distinctively different micropetrographic characteristics.

Aside from the qualitative and quantitative data collected for the purpose of defining the peat types, data were also collected in a form which could be used to determine the most likely eventual coal compositions of the peats. The herbaceous peats were found to have low percentages of pre-resinites (cell fillings and secretions), pre-sclerotinites (fungal remains), and fusinite (charcoal), and high percentages of pre-micrinites (fine granular debris). On the other hand, peats derived from tree vegetation had higher percentages of pre-resinites, pre-sclerotinites, and fusinites, and had relatively smaller amounts of pre-micrinitic materials. The former would probably result in a massive (unlaminated) dull coal, and the latter would probably become a somewhat brighter laminated type.

INTRODUCTION

This study was initiated for the purpose of establishing some of the petrographic-paleobotanic characteristics of the more common surface-peat sediments now being formed in the Okefenokee swamp-marsh complex of southern Georgia (Fig. 1). These peat types represent only a few of the many sediment types presently occurring in this region. Observations from core samples suggest that the peat-forming environments herein described have accounted for a significant portion of the peat sediments which have been deposited in the swamp from its inception.

Depending on conditions of water depth, temperature, acidity, and rate of sedimentation, peat sediments may undergo considerable diagenetic change within the top layers of a deposit. The limits of these surface changes must be established before one can hope to reconstruct original vegetational or depositional environments of samples found at depth. The study of surface samples is also important in trying to analyze buried peats with respect to their "level of coalification," that is, the

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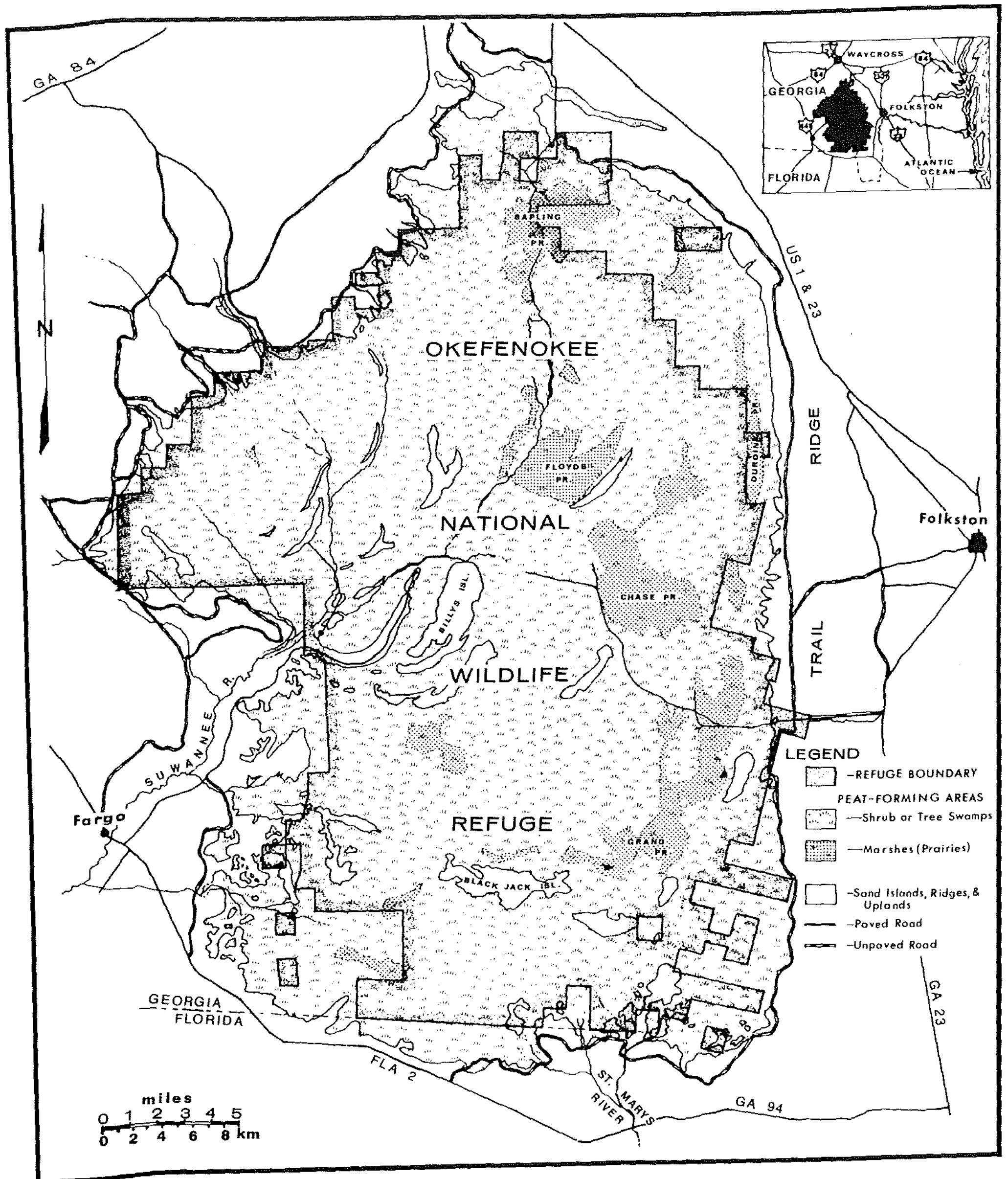

Figure 1. Location and physiographic features of the Okefenokee Swamp.

degree of differential transformation of particular plant tissues from their living state to their greatly altered condition at depth. Therefore, it was felt that detailed microscopic analyses of surface samples would aid in making paleoecological interpretations of core samples and would also help in understanding the early stages of coalification.

METHODS

About 70 surface samples were obtained by hand or trowel to a depth of about 6 in. In order to retard fungal growth, these samples were sealed in plastic boxes containing a few ounces of formaldehyde. About 45 additional samples were obtained from the top 6 in. of 3-

in.-diam peat cores taken with a modified piston-coring device.

In the laboratory, small cubes of peat (about ½ in. on a side) were sliced from these samples with a razor blade, dehydrated in alcohol, and embedded in parafin. Microtome sections (15 μ in thickness) were sliced from these embedded samples with a sliding microtome. (See Cohen and Spackman, 1972, for additional details of these laboratory procedures.)

Point counts and petrographic descriptions were made from microtome sections viewed at 125× or 500×, depending on whether framework or matrix constituents were being described. Counts of 500 to 1,000 points were made on two slides prepared from each of the peat samples. Pore space was disregarded in this study.

Field identifications of modern plant species were made using the methods of Radford and others (1964), Small (1933), and Fassett (1940). Identifications of peatified plant fragments in microtome sections were made by comparison with a reference collection of differentially stained microtome sections of modern plants, prepared according to the methods of Johansen (1940).

PEAT-FORMING ENVIRONMENTS

The peat-forming environments analyzed in this paper can be grouped into three categories: (1) open-marsh environments; (2) glades and island fringes; and (3) tree-island and swamp environments. The open-marsh environments are dominated by floating aquatic plants (such as water lilies) with scattered emergent aquatic plants. The most common type of open marsh in the Okefenokee is one dominated by *Nymphaea odorata* Ait. (white water lily; Fig. 2). These regions are almost always covered with standing or very slow moving water (commonly from 1 to 3 ft in depth) and may support other floating aquatic plants such as *Utricularia* spp. (bladderworts) and *Nymphoides aquatica* (Gml.) Kuntze (floatingheart). *Xyris smalliana* Nash (bullhead), *Orontium aquaticum* L. (neverwet), *Pontederia cordata* L. (pickerel weed), and *Sagittaria* spp. (arrow-heads), which root on the bottom and protrude above the water surface, are widely scattered as individual plants or small clumps of plants throughout the open-marsh environment. *Vallisneria americana* Michx. (eel grass) is the most common bottom-dwelling plant and may, in some cases, form dense, submerged, grasslike stands.

Figure 2. A typical open-marsh environment ("prairie") occupied primarily by floating white water lilies (*Nymphaea odorata* Ait.) with scattered clumps of emergent aquatic plants (such as *Orontium* and *Xyris*). The hydroperiods here are very long with standing water generally varying from 1 to 3 ft in depth.

At various times within these regions, patches of surface peat as much as 1 ft thick and from a few feet to tens of feet in diameter may break away from the rest of the peat deposit and float up to the surface. This phenomenon may be due to the build-up of marsh gases within the upper layers of the peat where biological decay is undoubtedly the most active. The trapped gas bubbles would cause the upper peat layers to be bouyed up to the surface. These "floating batteries" (as they are known locally) become a drier habitat upon which such plants as *Lachnanthes caroliniana* (Lam.) Dandy (paintroot), *Rhynchospora inundata* (Oakes) Fern (beak-rush), *Carex hyalinolepis* Steudel (sedge), *Woodwardia virginica* (L.) Smith (chainfern), *Panicum hemitomon* Schultes (maidencane), and the terrestrial bladderwort (*Utricularia cornuta* Michx.) may grow. These plants may contribute minor amounts of debris to the surrounding open marsh.

Within the shallower "glades" and "tree-island fringe" environments, the most common peat-forming zones are ones dominated by (1) *Panicum hemitomon* (maidencane); (2) *Woodwardia virginica* (chainfern); and (3) *Carex hyalinolepis*.

Panicum usually occurs as a fringe (from a few feet to tens of feet in width) bordering tree islands (Fig. 3), but also may occur as dense

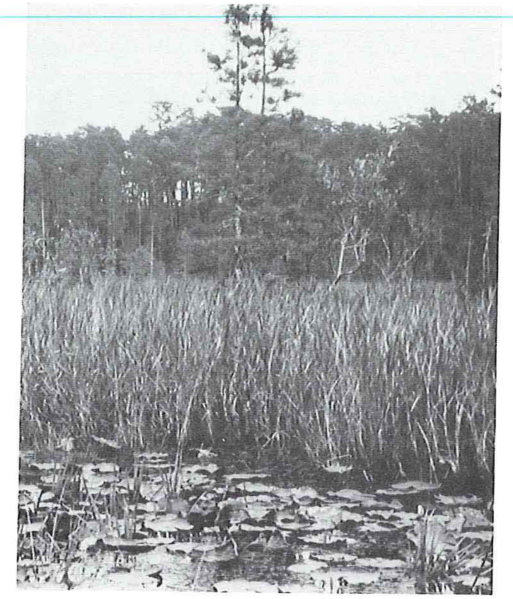

Figure 3. An island-fringe zone consisting primarily of maidencane (*Panicum hemitomon* Schultes) with some saw grass and a few shrubs. In the background is a large cypress head; and in the foreground is an open-water marsh. Surface degradation is relatively high in the *Panicum*-dominated environment.

stands on floating batteries or, in drier parts of the Okefenokee, may form extensive glade marshes. The surface of the relatively shallow *Panicum* marsh usually consists of a dense mat of intertwined roots and rhizomes which may support a surface layer of *Sphagnum* (peat moss). For some as-yet-undetermined reason, very little surface litter was found in this environment. Presumably, it was destroyed by biological decay or ingestion by some organisms at the surface or before it dropped to the surface. Within these *Panicum* stands, such accessory plants as *Carex*, *Woodwardia*, *Sphagnum*, *Sagittaria*, and in wetter areas, yellow pond lilies (*Nuphar advena* Ait.) or white water lilies (*Nymphaea*) may occur.

Carex occupies a similar niche to that of *Panicum*, except that it is less common on floating batteries and in a few places (especially in the northeast portion of the swamp) may form dense stands covering hundreds of acres. In a few cases, sedges were observed to be occupying portions of the prairie that had recently burned. Cypert (1961), in his studies of the effects of the fires of 1954 and 1955 on the Okefenokee Swamp, showed that within 3 yr after a severe burn in the Suwannee Canal region, an unidentified sedge (later identified as *Carex*) made up more than 50 percent of the ground cover. This was also found to be the case for the sedge *Mariscus* (saw grass) in the Everglades of Florida (Cohen, 1968), and may suggest that sedges can more readily colonize such areas than many of the other marsh plants. As in the *Panicum* environments, very little surface litter was found to be accumulating; that which did occur was very soft and slimy. In contrast, the living leaves and stems are very rigid and tough. The accessory plants are similar to those associated with *Panicum* stands.

Woodwardia virginica is most commonly found as a fringe or broad band around topographic islands, *Cyrilla* (or bay tree) islands, or cypress heads (Fig. 4). It generally occurs in slightly more shaded areas than *Panicum* or *Carex*, but may also be intimately mixed with these two genera. It seems to grow best in water less than 1 ft in depth. In contrast to the previous two environments, *Woodwardia* leaf litter was very common. In fact, it was unusual to find any decayed *Woodwardia* leaves at the surface. Upon falling into the swamp waters, the leaves seemed to become very tough and leathery in appearance This resistance of *Woodwardia* leaves to decay. would account for the more common occurrence of recognizable *Woodwardia* peats in the subsurface than the other two glades or island-fringe peats. It is also likely that peat that had formed from mixed *Woodwardia* and other marsh species would become increasingly purer in *Woodwardia* litter as more and more of the litter of other plants is differentially decomposed.

Surface peat dominated by debris from the shrub *Cyrilla racemiflora* L. (Titi) is most commonly being formed in the center of small clumps of trees (tree islands or "houses") which dot the open-marsh areas. Cypert (1972) suggested that these houses could originate as floating batteries. This is a plausible explanation for many of the houses in the Okefenokee and may also be a significant causative agent for some bay "hammocks" in the Everglades of Florida. In general, the densest *Cyrilla* vegetation occurs toward the outside of these islands and may grade into other types of shrub or tree vegetation toward the centers of the islands (for example, *Ilex* spp. [hollies], *Gordonia lasianthus* [L.] Ell. [loblolly-bay], *Magnolia virginica* L. [sweetbay], *Lyonia lucida* [Lam.] K. Koch, or *Taxodium* spp. [cypress]).

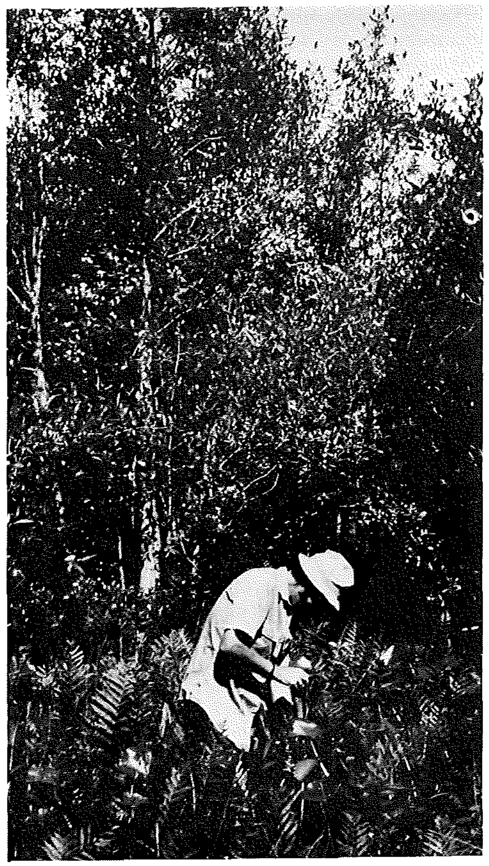

Figure 4. A slightly shaded, shallow-water, island-fringe environment (in the foreground) dominated by virginia chainfern (*Woodwardia virginica* [L.] Smith) with occasional (ephemeral) water lilies. In the background is a small shrubby "tree house" dominated by *Ilex*, *Lyonia*, and *Cyrilla*.

Cyrilla peat may also form in the transitional zones between forested swamp regions and open marshes. The density of the *Cyrilla* growth often precludes the growth of an herbaceous ground cover. Upon breaking through the dense, shrubby, outer vegetation, one will often encounter shallow pools of open, clear water, with no floating or submerged vegetation, surrounded by bare, moist mounds of peat which are raised a few inches above the swamp-water surface. These slightly raised mounds within some houses may be due to the accumulation of debris around and over old stumps and logs or over old alligator nests, or may simply be due to differential accumulation and compaction of debris. The surface within these clumps of trees is usually covered with a thick layer of differentially preserved (light-orange to dark-brown) leafy surface litter which has presumably been subject to periodic drying and surface degradation with only very slight changes in the water table.

Only one of the peats derived from tree-dominated environments has yet been found in any appreciable amount in cores. This was cypress peat. Cypress swamps are dominated by large *Taxodium* trees draped with spanish moss (*Tillandsia usneoides* L.; Fig. 5), standing in a few inches to several feet of water. Other trees and shrubs (such as *Magnolia*, *Persea pubescens* [Pursh] Small, *Gordonia*, *Lyonia*, *Itea*, and *Cyrilla*) may be common in these regions. Where light can penetrate through the trees and where the water is sufficiently deep, some floating aquatic plants (such as *Nuphar*, *Nymphaea*, and *Utricularia*) may be common. *Sphagnum* and other mosses, as well as liverworts, may form a thin but dense floating or attached mat around the swollen bases of the cypress trees or on the surface of the moist peat in the drier, raised areas. Surface litter consists primarily of *Taxodium* twigs and leaflets, *Ilex* and bay leaves, fruits and twigs, and spanish moss.

Of the more than 45 cores obtained from within the Okefenokee, *Nymphaea* and *Taxodium* peats were by far the most abundant types; *Woodwardia* peat was common, but less so than the other two; *Panicum* and *Carex* peats occurred in even smaller amounts; *Cyrilla* peat was the least common and most

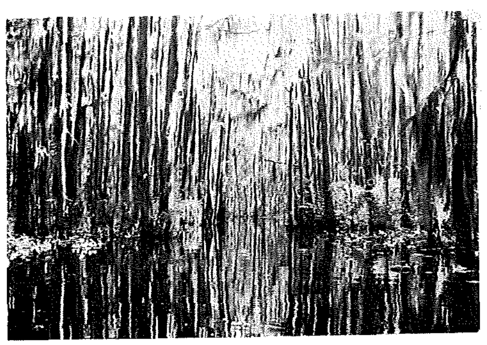

Figure 5. Boat trail through a typical mature cypress swamp dominated by *Taxodium* trees. Spanish moss (*Tillandsia usneoides* L.) drapes the trees and *Nuphar advena* Ait. (the yellow pond lily) extends out into the open water. The relatively high proportion of charcoal and dark surface litter in the cypress surface sediments implies periodic drying and fires.

restricted. Numerous other peat types, not described in this paper, have been encountered in small amounts in restricted areas. Some of these are bay tree, *Ilex*, *Nyssa*, *Vallisneria*, and *Nuphar* peats.

GENERAL CHARACTERISTICS OF OKEFENOKEE PEAT SEDIMENTS

Certain characteristics of peat samples in microtome section have been found to be especially useful in describing the peat and in establishing the original environments of deposition of the sediments (Cohen, 1970). These characteristics are listed across the top of Table 1. Before discussing the individual peat types with respect to these characteristics, some additional explanation is required. Megascopic characteristics of peat (such as color and texture) have proven to be of minor importance in distinguishing peat samples. Many different peat-forming environments may produce megascopically similar peat sediments (Cohen, 1968). The color and texture of peats in microtome section, on the other hand, have been shown to be much more useful. Color is often an index of oxidation of the peat constituents.

The texture of peat in section may be described as a ratio of framework to matrix constituents. Framework constituents are relatively intact organs such as leaves, roots, and large tissue fragments (over 200 μ), and matrix constituents are the fine-grained interstitial materials. A high ratio of framework to matrix (F/M) often means a low rate of surface degradation, but may also be a function of the types of source plants.

Another important characteristic of peat sediments is the ratio of nonsedimentary to sedimentary framework constituents (N/S). Sedimentary constituents are organs and tissues (such as fragments of leaves, twigs, or fruits) that accumulate on the surface of the deposit and that are acted upon by the normal surface processes of oxidation, biological decay, ingestion, and differential settling. Nonsedimentary constituents are such things as roots and rhizomes. These grow into the deposit and are thus not usually subject to surface processes. A high ratio of roots (N) to leaves (S) almost always indicates a high ratio of surface degradation.

One of the most important characteristics of any peat sediment is its content of plant fragments that are assignable to particular plant species. Plant species are very sensitive indicators of the various parameters of the environments in which they are growing. They can aid in predicting the limits of water depth, acidity, strength of current, and temperature.

Charcoal (fusinite) is present in small quantities in many peats, but is consistently higher in those types which represent drier or more fire-prone areas.

Quartz, although included in Table 1, is not especially related to any particular peat type, but was present as one or two very small angular pitted grains in nearly all of the peat samples. These grains may represent either wind-blown sand from nearby sandy islands and upland regions, or greatly corroded (partially dissolved) opaline silica phytoliths derived from marsh plants. The ubiquity of the grains and the lack of still-recognizable partially dissolved phytoliths of this general shape might favor the first hypothesis.

DISTINGUISHING CHARACTERISTICS OF THE PEAT TYPES

Nymphaea peat (Table 1) is easily distinguished from the other types by its content of well-preserved *Nymphaea* roots and occasional (but well-preserved and easily recognizable) *Nymphaea* leaf fragments (Fig. 6). Even when the peat is highly decomposed, the thick-walled, pitted sclereids (idioblasts) of *Nymphaea* leaves and roots are common and easily recognized, as are the vesicular tanniniferous cell fillings of *Nymphaea* rhizomes and the needlelike ones from *Nymphaea* leaves (Cohen, 1968).

Some of the other distinguishing characteristics of this peat type are the relatively small amount of framework and the high proportion of nonsedimentary materials (especially roots). As might have been expected in a region of standing water and floating aquatic plants, fungal remains and charcoal are not especially common.

The peat petrology of samples from the *Carex*-dominated regions in the Okefenokee Swamp suggests that biogeochemical surface conditions in the Okefenokee must differ significantly from those in the Everglades of Florida. Although the surface vegetation is dominantly *Carex* plants, the peat seems to be derived primarily from the debris of minor aquatic plants. In addition, the *Carex* organs present in the sections are highly degraded "ghosts" of their original structure (Fig. 7).

TABLE 1. CHARACTERISTICS OF SOME SURFACE PEAT SEDIMENTS FROM THE OKEFENOKEE SWAMP, GEORGIA

Dominant plant species		Megascopic characteristics		Microscopic characteristics											
		Color	Texture	Color (30x)	Avg ratio (F/M)	Avg ratio (N/S)	Characteristic plant fragments	Fungal remains*	Fecal pellets†	Diatoms*	Insect parts*	Sponge spicules§	Quartz*	Charcoal†	Microscopically identifiable plant species
Open-water marshes	*Nymphaea odorata* (white water lily)	reddish brown	fine fibrous to granular	light yellow	44/56	75/25	*Nymphaea* lf. & rt. sclereids; vesicular red cell fillings of rhizome	absent to common	rare to abundant	rare to common	rare to common	common	rare (fine-grained, angular, pitted)	rare	*Nymphaea* roots, leaves, stems, and seeds; other species (for example *Sagittaria, Orontium*) less common
Shallow "glades" and island fringes	*Carex hyalinolepis* (sedge)	reddish brown to brown	fine fibrous to granular	light yellow to light brown	46/54	60/40	*Nymphaea* lf. & rt. sclereids	rare to common	absent to rare	rare to common	absent to common	rare to common	rare (fine-grained, angular, pitted)	absent to common	*Carex* leaves and roots not esp. common; mostly debris from *Nymphaea, Sphagnum*, and *Vallisneria*
	Panicum hemitomon (maiden-cane)	reddish brown to dark brown	coarse fibrous	light yellow	52/48	75/25	*Panicum* phytoliths	absent to common	absent to common	common	rare to common	common	rare (fine-grained, angular, pitted)	rare to common	*Panicum* leaves and roots common; *Nymphaea* debris also common
	Woodwardia virginica (chain fern)	reddish brown to dark brown	fibrous to granular	red-brown	49/51	60/40	Root hairs and inner cortical cells of *Woodwardia*	absent to common	absent to common	common	rare to common	rare to common	rare (fine-grained, angular, pitted)	absent to common	*Woodwardia* leaves, roots, rhizomes; *Sphagnum, Nymphaea, Carex, Taxodium, Panicum* common
"Tree islands" and swamps	*Cyrilla racemiflora* (titi)	reddish brown to dark brown	coarse granular to woody	light brown	66/34	35/65	red-brown to yellow cell fillings (abundant)	common (esp. in lvs. & wood)	common	common	common	common	absent to rare	rare to abundant	*Cyrilla* leaves, roots, and wood; *Lyonia, Ilex, Persea, Leucothoe, Carex, Sagittaria, Magnolia*, and *Sphagnum* common
	Taxodium distichum (swamp cypress)	dark brown	coarse granular to woody	red-brown	50/50	40/60	orange to yellow "vitreous" spheres	common (esp. in lvs. & wood)	common	common	absent to common	common to abundant	rare (fine-grained, angular, pitted)	common to abundant	*Taxodium* leaves, twigs, roots, wood; occasional hardwood debris, *Tillandsia*, and *Sphagnum*

* *rare <0.5%*
common 0.5-2%
abundant >2%.

† *rare <2%*
common 2-10%
Abundant >10%.

§ *rare <1%*
common 1-3%
abundant >3%.

Explanation: F, framework; M, matrix; N, nonsedimentary debris; S, sedimentary debris.

Figure 6. Photomicrograph of a vertically oriented microtome section of *Nymphaea* surface peat. Note the numerous circular cross sections of *Nymphaea* roots scattered over the slide and the large, horizontal, partially degraded *Nymphaea* leaf near the center (arrow).

Figure 7. Photomicrograph of a vertically oriented microtome section of surface peat deposited in an island-fringe environment dominated by *Carex hyalinolepis* Steudel. Aside from a few very fragile, highly altered fragments of *Carex* tissue (arrow), most of the identifiable sediment is derived from accessory plants, such as, in this case, chainfern.

This was not found to be the case for sedge peats in the Everglades, where sedge debris constituted the bulk of the biomass (Cohen, 1968). This anomaly might be partially explained by the high rate of surface decay previously inferred in the description of the surface environment. It may also be that *Carex* stands may be relatively ephemeral within the Okefenokee, perhaps occurring only briefly after fires or other disturbances.

Panicum peat (Fig. 8) is distinguished primarily by the presence of numerous well-preserved *Panicum* roots and rhizomes, and a few fragments of highly decomposed *Panicum* leaves. The ratios of framework to matrix and nonsedimentary to sedimentary constituents are decidedly different from the previously described herbaceous peat types.

Woodwardia peat has very similar F/M and N/S ratios to that of *Carex* peat, but its other characteristics make it readily distinguishable from the previous types. Microtome sections of this peat reveal abundant, easily identifiable *Woodwardia virginica* roots, leaves, and rhizomes (Fig. 9). Even when highly degraded, this peat contains remains of *Woodwardia* roots and rhizomes. The color of this peat in microtome section is also reddish brown rather than the light yellow and yellowish brown which characterized the former three types.

The peats derived from shrub or tree vegetation (that is, *Cyrilla* and *Taxodium* peats) have certain characteristics in common. Megascopically, the peats are dark in color and coarsely granular to woody. They invariably have a higher porportion of leaf and twig litter (sedimentary debris) than the open-marsh or glades peats. Because of the great number of cell fillings and secretions in the leaves, bark, and wood of the source plants, these ingredients are common in the peats and may be useful in distinguishing between the peat types (see Table 1). Because of the slightly drier or more fire-prone nature of these environments, there is a greater likelihood of fires, fungal activity, reworking, and ingestion of surface layers by various animals (for example, crayfish, insects, and worms). Thus charcoal, fungal remains (hyphae, sclerotia, and spores), fecal pellets, and insect parts are relatively common in most of these surface peats.

Cyrilla peat generally has a higher frame-

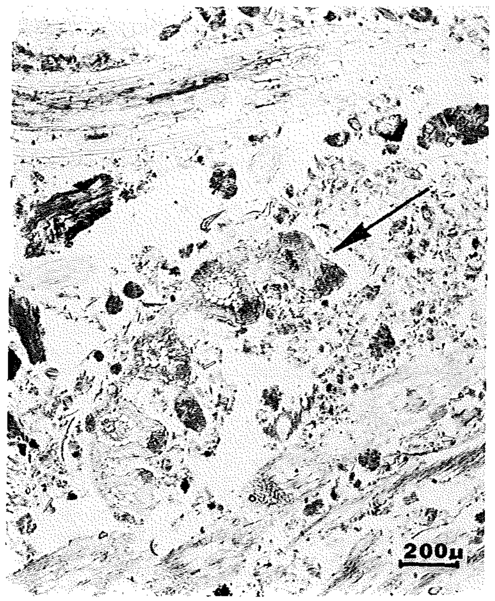

Figure 8. Photomicrograph of a vertically oriented microtome section of *Panicum* surface peat. The elongated object near the top is a *Panicum* root. A relatively well preserved fragment of a *Panicum* leaf occurs near the center (arrow).

Figure 9. Photomicrograph of a vertically oriented microtome section of peat from the surface of a *Woodwardia* island-fringe environment. Note the great numbers of circular cross sections of *Woodwardia* roots (with root hairs) and the relatively well preserved *Woodwardia* leaf with its characteristic saddlelike cross section (arrow). The phytogenic constituents which compose this sediment are generally somewhat darker in color than those of the other herbaceous peats.

work-to-matrix ratio than *Taxodium* peat, and tends to have more of a light brown than a reddish-brown color in microtome sections. In addition, *Cyrilla* and *Taxodium* peat can easily be distinguished by their complements of microscopically identifiable plant species. *Cyrilla* peat generally contains numerous leaves, roots, and wood of *Cyrilla*, and significant quantities of debris from assorted shrubs and trees, such as *Ilex*, *Lyonia*, and *Magnolia* (Fig. 10). *Taxodium* peat is composed predominantly of *Taxodium* leaves, twigs, roots, and wood with occasional fragments of *Tillandsia*, *Sphagnum*, and leaves and twigs of such hardwoods as *Magnolia* and *Persea* (Fig. 11).

COAL PETROLOGIC ANALYSES

Although the types of data contained in Table 1 have been found to be very useful in characterizing the various peat types with respect to their original vegetational and depositional environments, it is sometimes useful to obtain some quantitative data in a form that may prove to be more useful in predicting the eventual petrography of the coal which could result from each peat type. Table 2 gives the average percentages of cell fillings (and/or secretions), structurally intact cell walls (or cell-wall fragments), fine, granular (unstructured) materials including mineral matter, fungal remains, and charcoal. The cell fillings and secretions will probably become the resinite or phlobaphenite (Szádeczky-Kardoss, 1948) macerals of lignites or bituminous coals. Cell-wall materials will probably become the vitrinites. Much of the fine, granular debris will probably become the micrinite macerals, although some small portion may result in very fine grains of vitrinite. The fungal remains will become sclerotinite, and the pieces of charcoal and partially burned materials will constitute the fusinitic and semifusinitic portions of the coal. Of course, this type of analysis should only be taken as a rough approximation of the eventual coal composition because at this early stage of peatification, many of the structured plant tissues have yet to be altered in a way which would be characteristic of these tissues with depth. This is especially true of the roots, which make up a significant portion of

TABLE 2. QUANTITATIVE PETROGRAPHIC DATA APPLICABLE TO THE ORIGIN OF COAL TYPES

	Peat type	Average percent* cell fillings and secretions (pre-resinites and pre-phlobophenites)	Average percent cell wall materials (pre-vitrinites)	Average percent fine granular debris (predominantly pre-micrinites with some pre-vitrinites and mineral matter)	Average percent fungal remains (pre-sclerotinites)	Average percent charcoal (fusinites and semi-fusinites)
Herbaceous types	*Nymphaea*	1	49	49	0.3	1
	Carex	1	65	32	0.3	2
	Panicum	1	62	35	0.3	2
	Woodwardia	2	46	49	0.3	3
Arboreous types	*Cyrilla*	15	56	25	1	4
	Taxodium	10	60	24	1	5

* *Data based on point counts of 5 vertically oriented microtome sections of each peat type (1,000 pts. at 125X; pore space disregarded).*

some of these samples. Roots tend to alter in such a manner as to produce appreciable amounts of pre-micrinitic materials (Cohen, 1968). This would especially affect the predictions concerning the open-marsh and glades peats, since these have a high N/S ratio (Table 1).

The herbaceous peats have very little pre-resinitic, fusinitic, or sclerotinitic material, and considerable amounts of fine granular (pre-micrinitic) materials. It is very likely that these peats will increase in pre-micrinitic and decrease in pre-vitrinitic materials as peatification progresses. The coal which might be predicted from these peats would be fine grained, massive (that is, relatively unlaminated on a megascopic or microscopic scale), and very dull in appearance.

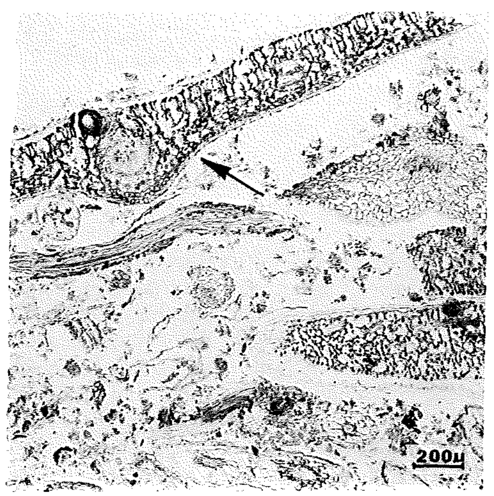

Figure 10. Photomicrograph of a vertically oriented microtome section of surface peat from a *Cyrilla* "tree house." Note the common occurrence of elongated leaf fragments (near the top center and right of the section). A *Cyrilla* leaf (arrow) has been accidentally cut perpendicular to its midvein. The dark circle within this leaf represents fungal attack prior to incorporation into the peat. This section typifies peats with high ratios of sedimentary to nonsedimentary constituents.

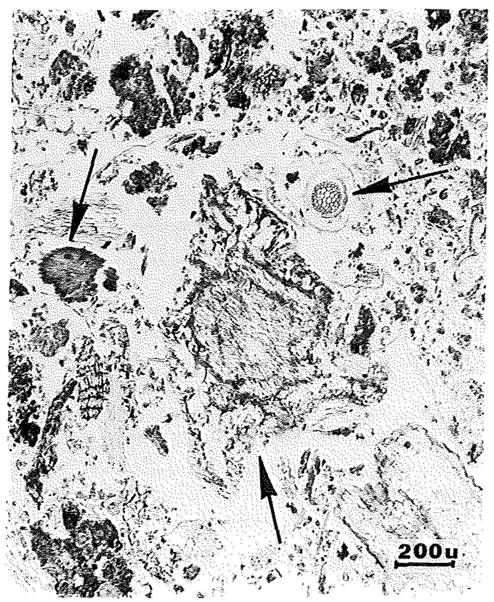

Figure 11. Photomicrograph of a vertically oriented microtome section of *Taxodium* surface peat. Note the darkness of the interstitial matrix. This darkness is presumably due in part to increased oxidation in the cypress-swamp environment. A cross section of a *Taxodium* twiglet is shown in the center of the photograph (lower arrow). The other two arrows point to remains of two common accessory plants in the cypress environment, spanish moss (*Tillandsia usneoides* L., left arrow) and peat moss (*Sphagnum* sp., right arrow).

On the other hand, the peats derived from tree vegetation (that is, *Cyrilla* and *Taxodium*) have significantly greater percentages of pre-resinites (or phlobaphenites), fusinites, and sclerotinites than the herbaceous peats and considerably less pre-micrinitic debris. The resulting coal should therefore be somewhat brighter and more laminated (due to the higher proportion of woody or leafy debris) than the coals from herbaceous sources. In fact, these predicted coals would seem to be somewhat similar in composition to some duroclarainic bituminous coals of Pennsylvanian age.

SUMMARY AND CONCLUSIONS

Microtome sections were used to determine the micropetrographic and botanical characteristics of surface peats derived from several of the most important peat-forming environments in the Okefenokee swamp-marsh complex of Georgia. These environments were (1) open marshes occupied by floating aquatic plants (*Nymphaea* peat); (2) shallow glades and tree-island fringes of emergent aquatic plants (*Carex*, *Panicum*, and *Woodwardia* peats); and (3) tree islands and swamps (*Cyrilla* and *Taxodium* peats). Core studies have shown that by far the most common peats that have formed in this region in the past are *Nymphaea* and *Taxodium* peats; *Woodwardia* peat is the next most common; the other types are much rarer.

Some petrographic constituents of Okefenokee peats were found to exhibit no clear trends with respect to particular vegetational or sedimentary environments. This was true of diatoms and insect parts, which occurred in small percentages in nearly all peat types. Similarly, very fine, angular, pitted quartz grains occurred in minute quantities in almost all peats sampled, irrespective of peat type or proximity of the sampling sites to the sandy uplands. This sand could be of aeolian origin.

In general, however, marsh peats (that is, those derived from herbaceous vegetation) differed from swamp peats (that is, those derived from tree vegetation) in the following ways:

1. The texture of marsh peats in hand sample was usually fibrous (due to the fibrousness of the roots of herbaceous plants), and that of swamp peats tended to be granular or woody (due to a larger quantity of leafy and woody debris).

2. In hand sample, herbaceous peats tended to be somewhat lighter in color than swamp peats, although this could often prove to be misleading. This darker color was probably due to increased oxidation and (or) greater amounts of charcoal.

3. In microtome section, herbaceous peats (with the exception of *Woodwardia* peat) tended to be in the light-yellow to light-brown color range (at 30× magnification and 15 μ thickness); whereas the woody peats tended to be naturally stained reddish brown or brown. This staining might be due in part to oxidation and in part to chemical reactions between the cellular material and the peat fluids.

4. Marsh peats contained a much higher percentage of roots and rhizomes (that is, ingrown, nonsedimentary constituents) than they did sedimentary constituents (for example, leaves, fruits, wood, and so forth). This could result from the fibrousness of the root systems and (or) differential decay or ingestion of surface litter in these regions. The opposite relationship existed for tree-derived peats.

5. Fungal remains were found more consistently in swamp than marsh sediments. This could be partly a function of the greater dryness of the swamp environment and partly a function of the increased contribution of surface litter to the swamp peats. Materials that accumulate on the surface of a deposit would more likely undergo fungal decay than those which grow into the deposit.

6. Fecal pellets were more consistently present in swamp sediments, but occasionally occurred in great numbers in marsh peats.

7. Since sponge spicules occurred in all peats studied, it is presumed that fresh-water sponges actually lived in these environments even though they were very difficult to find. The presence of ocasional abundant quantities (>3 percent) in *Taxodium* peats might suggest that either: (1) *Taxodium* litter provided a better substrate or more ecological niches suitable for the growth of sponges; or (2) the siliceous sponge spicules could be differentially concentrated in the somewhat drier *Taxodium* environments by biological decay, slow oxidation, or fires. The close correlation in cores between zones of high charcoal and high percentages of spicules might favor the latter hypothesis.

8. Charcoal was present (at least in very small amounts) in almost every peat type, but occurred in greater quantities in the swamp peats. This could be due to the slightly drier

conditions within the woody areas or to the fact that trees are more likely to catch fire due to lightning than herbaceous plants. In addition, dead twigs or leaves are often trapped and suspended in the tree branches and undergrowth and thus can very likely burn even when the water level in the swamp is high. Furthermore, marsh plants tend to have very little and greatly dispersed woody tissues, so that burning of their surface litter or subaerial parts would tend to produce only small quantities of very fine, dispersed charcoal. On the other hand, woody surface litter and woody peats found in swamps would more likely produce larger quantities and bigger pieces of charcoal. A certain portion of the fine charcoal found in many of the wet marsh environments could also have been blown in from nearby fires, which would account for the presence of at least small amounts of charcoal in nearly all peat-forming regions.

9. The high percentages of fine granular debris (pre-micrinitic material) and low percentages of sedimentary framework materials found in herbaceous peats would most likely produce fine-grained, massive, durainic coals. On the other hand, peats derived from arboreous vegetation contained relatively greater amounts of sedimentary debris and higher percentages of pre-resinites, fusinites, pre sclerotinites, and lower percentages of pre-micrinitic materials. The resulting coals derived from these peats would be laminated (streaky) and somewhat brighter than the former types.

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