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GEOLOGICAL SURVEY

Mineral resources of the Wambaw Swamp Wilderness Study Area, Charleston County, South Carolina

by

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STUDIES RELATED TO WILDERNESS
WILDERNESS AREAS
AND
WILDERNESS STUDY AREAS

In accordance with the provisions of the Wilderness Act (Public Law 88-577, September 3, 1964) and the Joint Conference Report on Senate Bill 4, 88th Congress, and as specifically designated by Public Law 93-622, January 3, 1975, the U.S. Geological Survey and U.S. Bureau of Mines have been conducting mineral surveys of wilderness and primitive areas. Studies and reports of all primitive areas have been completed. Areas officially designated as "wilderness", or "wild", or "canoe" when the Act was passed were incorporated into the National Wilderness Preservation System, and some of them are presently being studied. The Act provided that areas under consideration for wilderness designation should be studied for suitability for incorporation into the Wilderness System. The mineral surveys constitute one aspect of the suitability studies. This report discusses the results of a mineral survey of some national forest land in the Wambaw Swamp Study Area, South Carolina, that is being considered for wilderness designation (Public Law 93-622, January 3, 1975). The area studied is in Francis Marion National Forest in Charleston County.

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Mineral resources of the Wambaw Swamp Wilderness Study Area, Charleston County, South Carolina

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SUMMARY

The Wambaw Swamp Wilderness Study Area comprises about 600 hectares in the Francis Marion National Forest about 40 km northeast of Charleston, South Carolina. It is a swamp-covered valley floor with very low relief. Deposits directly underlying the area consist of sand, clay, muck, and peat of Pleistocene to Holocene age overlying marl and limestone of Eocene and Oligocene age. These lie in turn on a thick sequence of Paleocene and Cretaceous sedimentary rocks and (probably) igneous rocks of Triassic- Jurassic age. Pleistocene and Holocene deposits upward from the base are river, estuary, bay, marsh, and swamp deposits; higher areas adjacent to Wambaw Swamp are Pleistocene sand spit and barrier deposits.

No significant mineral resources were found in the area; phosphate, uranium, peat, well sorted sand, heavy minerals, and clay occur only in very limited amounts. Phosphate occurs in the northern half of the study area as grains and scattered nodules overlying and within the weathered surface of the Cooper Formation of Tertiary age. There is an estimated 500,000 metric tons of P_2O_5. However, it lies under 12 to 15 m of overburden and the grade is considerably lower than that presently being mined elsewhere in the United States. Uranium, associated with the phosphate, is also below the grade currently considered economically feasible to mine; the total amount is only about 300 metric tons U_3O_8. Peat is too thin and too high in ash content to be a potential resource. Well-sorted Pleistocene beach sands locally useful for road construction do not extend far into the study area; heavy minerals in these sands have little economic value. The only clay body which might be suited for lightweight aggregate or vitreous clay products occurs at depths of 10-18 m. The underlying limestone is too deep to warrant an evaluation of quality. Oil and gas potential is believed to be slight.

INTRODUCTION

Wambaw Swamp Wilderness Study Area is about 40 km northeast of Charleston and 1-2 km north of the towns of Awendaw and Buck Hall, Charleston County, South Carolina (fig. 1). The area,

Figure 1 near here.

comprising 600 hectares, lies within the Francis Marion National Forest, between the Cooper and Santee Rivers, and contains the Little Wambaw Swamp Scenic Area, 410 hectares in extent. Wambaw Swamp serves as a collecting basin for the surrounding sandy uplands and is the headwater area for Steed Creek. Water flows southward except during periods of unusually heavy rainfall when movement direction is temporarily reversed.

The swamp contains a fairly uniform mixture of swamp and water tupelo along with stands of bald cypress (fig. 2). A few

Figure 2 near here.

red maples are present in the main canopy, but generally are more prominent in the understory. Sweet bay, southern bayberry, and leucothoe are fairly common in the understory. Herbaceous vegetation is neither rank nor rich in species due to the flooding and heavy shade. Pine and oak forest surround the swamp. Relief is so slight that at first glance the study area appears to be a mass of vegetation extending monotonously in all directions. However, a second look reveals patterns of contrasting trees and shrubs that reflect environmental factors such as changes in microrelief, drainage, soil porosity, and acidity. These vegetation patterns are valuable in the study and mapping of the surficial geology and peat deposits.

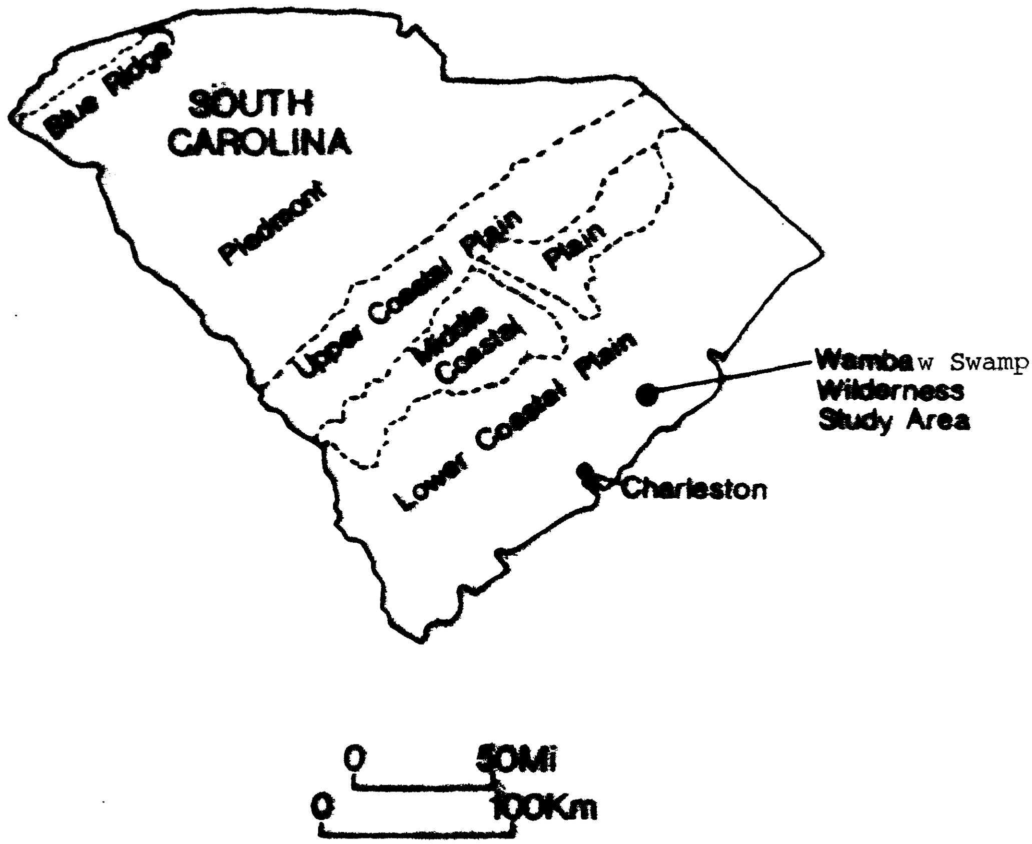

Figure 1.--Index map showing location of Wambaw Swamp Wilderness Area in relation to the physiographic provinces of South Carolina.

Figure 2.--Cypress in Wambaw Swamp in winter.

Previous studies

The stratigraphic framework of the South Carolina Coastal Plain is summarized by Cooke (1936) and Cooke and MacNeil (1952). Cooke's geologic map is outdated but no small-scale map and few large-scale geologic maps are available to replace it. Malde (1959) published a 1:24,000 geologic map of Ladson quadrangle in northwest Charleston.

D.J. Colquhoun (1965, 1969, 1974) has done extensive work on the geomorphology of the area and has presented valuable information on the stratigraphy of surficial units. DuBar and others (1972) have studied the area across the Santee River from the study area.

Phosphate resources of the Charleston phosphate district have been discussed by Sloan (1908), Rogers (1914; see plate 1), Altschuler and others (1958), Malde (1959), and Force and others (1978). A nearby clay deposit is described by Heron, Robinson, and Johnson (1965).

Present investigation

To assist in evaluating the mineral potential of this area, U.S. Bureau of Mines personnel consulted with members of the South Carolina Division of Geology and the U.S. Forest Service, and also with representatives of private industry. During the field investigation in the spring of 1976, three auger samples were taken (pl. 2). The clay portions of these samples were tested for firing characteristics at the U.S. Bureau of Mines Tuscaloosa Metallurgy Research Center, Tuscaloosa, Alabama.

In January, 1977, Cameron, E. Force, Lucy Force, and Dennis Duty of the U.S. Geological Survey drilled with a power auger at sites 1-4 (pl. 2). Cuttings from these holes were submitted to the laboratories of the U.S. Geological Survey at Reston, Virginia and Denver, Colorado for heavy mineral, clay mineral, phosphate, and uranium analyses. Geologic mapping by Cameron and E. Force is based on hand augering, vegetation patterns from air photographs, and soils maps (Miller, 1971).

Acknowledgments

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Acknowledgment for their helpful assistance to the U.S. Geological Survey is extended to U.S. Forest Service members including Don Mudge and Frances Witz of the Wambaw Ranger District, McClellanville; W.R. Harmes, SE Forest Experiment Station, Charleston; and D.D. Devet and J.J. Connell, Columbia, South Carolina. Special thanks are given to D.J. Colquhoun, Geology Department, University of South Carolina, for copies of field logs of auger holes 5-10.

Geomorphology

Wambaw Swamp lies in the outer Atlantic Coastal Plain, near the south central border of the Frances Marion National Forest (Fig. 1). The land surface within the Forest slopes southeastward from an elevation of about 21 m to sea level. Gentle topographic discontinuities called "scarps" are among the strongest geomorphic features present; they are former shore faces formed during higher stands of sea level during Quaternary time. Colquhoun (1965) has named many of the scarps, some of which occur within the National Forest; his Cainhoy, Awendaw, and Mt. Pleasant scarps are present in or near the study area (pl. 1).

Colquhoun (1974) and Colquhoun and others (1972), based on subsurface study of Quaternary sediments as well as geomorphic history, showed that a characteristic set of shore-related deposits formed during each sea level stand. Cross section x - x′ - x" (pl. 1) illustrates Colquhoun′s view of the geomorphic features of the region.

The "scarps" are discontinuous across the area of the geologic map (pl. 2), the gaps together forming the subtle depression which controls the swamp. The geomorphology suggests that the study area was a bay at several stands of sea level. Bulls Bay (pl. 1) is the correlative modern feature.

GEOLOGY

Unconsolidated deposits of Quaternary age conceal the somewhat more indurated rocks of the Santee Limestone and Cooper Formation of Tertiary age in and near the Wambaw Swamp study area (see pl. 2). These Tertiary sedimentary rocks probably rest on 700-800 meters of Upper Cretaceous and Paleocene sedimentary rocks. No deep drilling has been done near the study area but reasonable projections can be made from test holes several tens of kilometers from the study area as shown on Plate 1 (Bureau of Land Management, 1978; Siple, 1958). The geologic section is probably similar to that described by Gohn and others (1977) in the Clubhouse Crossroads core hole 1, 40 km NW of Charleston (see plate 1, site 4 for location of the core and figure 3 for its description). Only the units encountered in our shallow auger holes are described in the text.

Tertiary formations

Santee Limestone

The oldest formation recognized in drill holes near the study area is the Santee Limestone which consists of an upper part formed of sand-sized broken shell fragments, and a lower bryozoan limestone with some strongly cemented beds. Both parts are relatively pure calcium carbonate and are white to cream in color. Hazel (1975) assigns an Upper Eocene age to the Santee. Based on fragments of Santee Limestone encountered in borings made by D.J. Colquhoun at sites 7,8,9, and 10 (Pl. 2 and Table 1), the Santee probably lies closest to the surface in a strip along the northern edge of the study area. The inset map (pl. 2) shows possible distribution of the Santee in the study area directly under the Pleistocene and younger sediments.

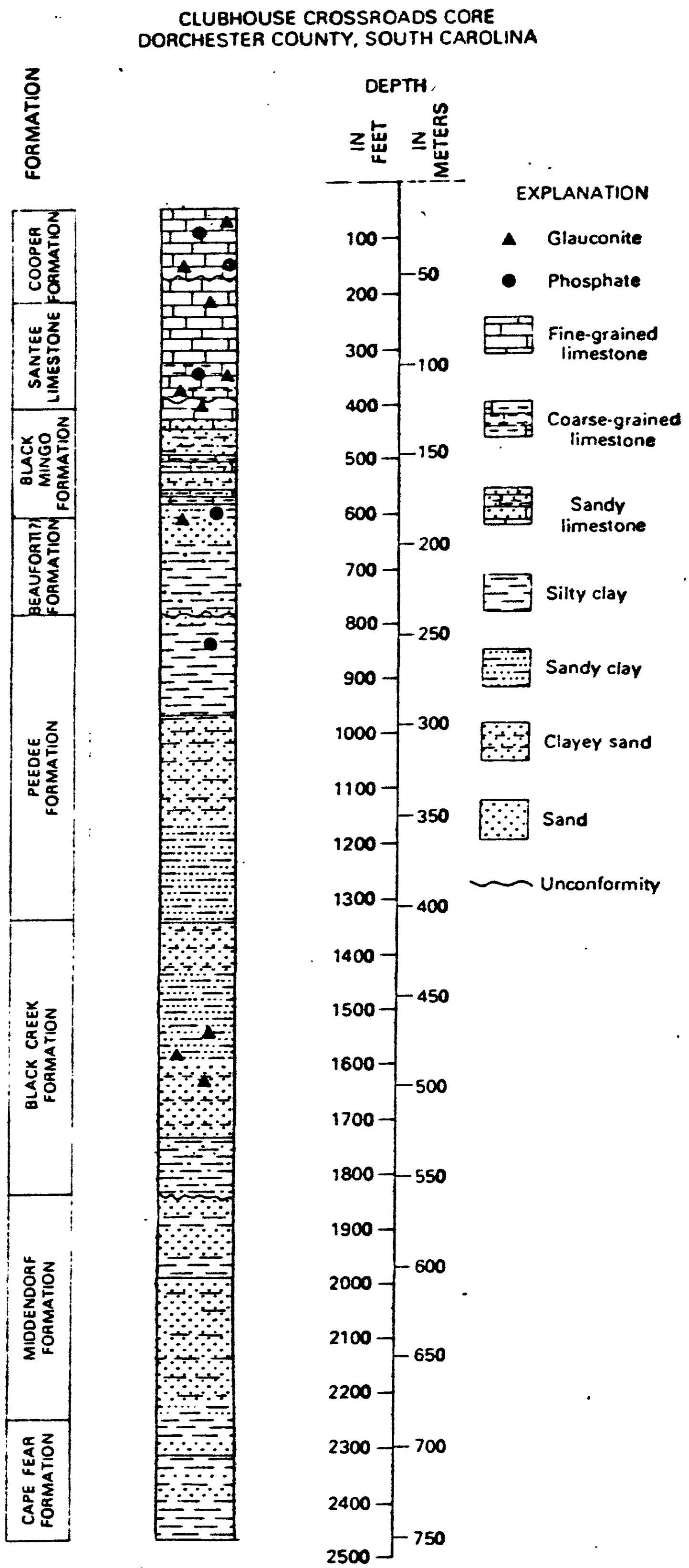

Figure 3.--Stratigraphy of the Charleston region, after Gohn and others, 1977.

Cooper Formation

The Cooper Formation was found at the bottom of auger holes 3,4,5, and 6 (pl. 2 and Table 1) in the study area where it forms erosional remnants resting on Santee Limestone. The Cooper Formation is an impure foraminiferal marl, characteristically homogeneous and plastic, and is distinguished from the Santee Limestone by its color (olive when wet and pale gray when dry), lack of induration, greater phosphate content, and its abundant foraminifera tests.

Malde (1959, p. 7-26) describes the Cooper Formation in the nearby Charleston area as consisting "dominantly of carbonate (25-75 percent), sand (10-45 percent), clay (2-5 percent), and phosphate (5-20 percent)." The carbonates are mostly calcite with some dolomite especially in the upper part. Most of the carbonate is in the form of foraminifera shells. The sand is very fine and consists of quartz and some feldspar in subangular to angular grains. The clay size material consists of mineral clay and siliceous mud. The phosphate consists of well-rounded, brown grains 0.1-0.5 mm in diameter and fragments of teeth and bone.

The Cooper "marl" was assigned to the Oligocene by Cooke and MacNeil (1952), but recent work by members of the U.S. Geological Survey shows that the Cooper Formation is late Eocene and Oligocene, with paraconformities at the base and within the section (Hazel, 1975). The Cooper is entirely marine and may have accumulated in relatively deep, cold water (J.A. Cushman in Stephenson, 1914, p. 81; E.B. Leopold in Malde, 1959, p. 25).

Quaternary deposits

Deposits of clay, silt, sand, and gravel rest unconformably on Santee Limestone and Cooper Formation in and near the study area to a depth greater than 23 m at the southern border (see drill logs, table 1 and cross-sections, Pl. 2). For convenience of discussion, these unconsolidated sediments have been grouped into map units, Qcs to Hfp, described in order of decreasing age.

Map unit Qcs consists of granular or shelly, coarse to medium-grained feldspathic sand, locally grading upward into silty clay containing large wood fragments having a radiocarbon age of greater than 40 thousand years BP (Meyer Rubin, written communication No. W3848, 1977). Microfaunal assemblages in the clay indicate brackish water. Feldspar contents (about 1-5 percent) of the sand suggest deposition by a Piedmont-draining river such as the Santee River. Thus, a fluvial (at the base) to upper estuary environment (at the top) is indicated for unit Qcs.

Blue-gray calcareous sandy muds and muddy fine sands of unit Qm overlie unit Qcs. They locally contain abundant mollusks and foraminifera typical of nearshore shelf, lagoon, and inlet environments (see table 1). Thus they form a continuation of the transgressive sequence.

Unit Qs consists of well sorted sands and occupies the gentle rises around the study area. These are former barrier island and sand spit deposits. The sands interfinger with and overlie the bay deposits of unit Qm. The oldest sands, at the highest elevations toward the north are probably correlative with the Canepatch Formation of Du Bar and others (1972), whereas the youngest sands to the south probably belong to the Socastee Formation.

Fine sand, silt, and organic clay of unit Qfs fills channels associated with the regressing sea, cut into the sediments of units Qs and Qm. The unit locally contains Spartina, a grass indicative of tidal marsh conditions.

Unit Hfp represents the final stage of sedimentation in the fresh water swamps that formed over the sediments of unit Qfs in the old tidal channels and in low places around the sand bars and spits. Organic silt (muck) and peat characterize this unit. The peat is generally less than 30 cm thick in the areas mapped as Hfp_2 and 60 cm to 1.5 m in areas mapped Hfp_1.

Quaternary history

The Quaternary history of the area can be visualized as follows: On an eroding surface of Santee Limestone and Cooper Formation, a Piedmont- draining river deposited in its valley coarse feldspathic sand and reworked fragments of Tertiary formations (lower Qcs). When sea level rose, this river valley was transformed into a brackish water estuary or swamp where non-calcareous clays containing log fragments were deposited (upper Qcs). Continuing sea level rise turned the study area into a bay, somewhat analogous to the modern Bulls Bay, with locally developed barriers and spits not extensive enough to enclose a lagoon (Qm). The well-sorted sands and calcareous sandy shelly clays formed on beaches and spits (Qs).

The study area then began to emerge from the sea and colonization of the bay floor by Spartina grasses took place (Qfs). This sea level drop is recorded by beach sands which are progressively younger and lower in the direction of the sea. Tidal deltas occupied inlet areas during this retreat of the sea (Qfs). When the influence of salt water became negligible, the present fresh-water swamps (Hfp) spread over the study area and remain today.

Table 1.--Logs of auger holes 1-10 (Logs 1-4 by U.S.G.S. and Logs 5-10 from D.J. Colquhoun, written commun., 1977). Macrofossil identification by Blake Blackwelder, U.S.G.S. Microfossil identification by Tom Gibson, U.S.G.S. Locations are shown on plate 2.

Log Hole 1

SW 1/4 Awendaw quadrangle, at south edge of Wambaw Swamp, northwest of Bulls Bay Site at end of small road about 1 km north of road's intersection with Route 17; junction about 2 km miles from west edge of Awendaw quadrangle.

Elevation 5 m above mean sea level

Depth in meters (feet)	Description
0-.6 (0-2)	Road fill.
.6-1.4 (2-4.5)	Quartz sand, medium, angular, dark brown, iron stained.
1.4-1.7 (4.5-5.5)	Clay and silt, blue green.
1.7-2.1 (5.5-7)	Quartz sand, medium, angular, tan; feldspar grains.
2.1-2.5 (7-8)	Quartz sand, black, organic, clayey; iron stained. Some feldspar grains in sand.
2.5-7.0 (8-23)	Quartz sand, medium, angular, light gray. Some feldspar grains in sand.
7.0-8.5 (23-28)	Clay, sandy, blue green; shells at 7.0 m *Mulinia lateralis* (Say, 1822) abundant, all juveniles *Bellucina amiantus* (Dall, 1901) juvenile.
8.5-10.0 (28-32)	As above with coarse sand & shells at 8.5 m *Acteocina canaliculata* (Say, 1822) *Mercenaria* sp. frag. *Mulinia lateralis* (Say, 1822) *Bellucina amiantus* (Dall, 1901) *Chione cancellata*? (Linne, 1767) *Anadara* sp. cf. *A. transversa* (Say, 1822) juvenile *Strigilla mirabilis* (Philippi, 1841) *Pleuromeris tridentata* (Say, 1826)
10.0-10.3 (32-34)	Brown organic clay and gray clay and silt. Quartz sand and mica; abundant shells at 10.0-10.1 m *Mulinia lateralis* (Say, 1822)

Log Hole 1 cont'd

Depth in meters (feet)	Description
10.3-18.3 (34-60)	Clay and silt, homogeneous, sticky, blue gray; chunks of detrital wood at 18.1-19.2m. Restricted brackish water fauna of foraminifera at 12 and 17 m; one reworked early Tertiary form at 17 m.
18.3-19.9 (60-65)	Sand, medium to coarse. Some pebbles and feldspar granules. Detrital wood.
19.9-22.9 (65-75)	Quartz sand, angular with some blue green clay, very compact. Some feldspar grains in sand.

Log Hole 2

Center of arm of Wambaw Swamp along road about 1 km mile from west border of Awendaw quadrangle.

Elevation 5 1/2 m above mean sea level

Depth in meters (feet)	Description
0-1.8 (0-6)	Brown peat
1.8-4.0 (6-13)	Clayey peat
4.0-4.6 (13-15)	Gray green clay
4.6-5.8 (15-19)	Gray green clay; <u>Spartina</u>; abundant shells at 5.2-5.3 m <u>Ilyanassa obsoletus</u> (Say, 1822) <u>Mulinia lateralis</u> (Say, 1822) <u>Anadara ovalis</u> (Bruguiere, 1789) <u>Polinices</u> sp. frag. <u>Crassostrea</u>? sp. frag. <u>Abra aequalis</u> (Say, 1822) <u>Gemma gemma</u> (Totten, 1834) <u>Noetia ponderosa</u> (Say, 1822)
5.8-6.4 (19-21)	Quartz sand, gray green; detrital wood.
6.4-7.0 (21-23)	Quartz sand, abundant shells, blue green to gray; clayey at 6.7-7.0 m <u>Ilyanassa obsoletus</u> (Say, 1822) common. <u>Mulinia lateralis</u> (Say, 1822) abundant <u>Acteocina canaliculata</u> (Say, 1822) common. <u>Anadara</u> sp. cf. <u>A</u>. <u>transversa</u> rare frag. juv. <u>Donax</u> sp. frag. <u>Cyrtopleura</u>? sp. frag.
7.0-8.2 (23-27)	Quartz sand, blue gray to gray clayey
8.2-9.1 (27-30)	Quartz sand, coarse, gray green; some silt
9.1-10.7 (30-35)	Quartz sand, coarse, angular

Log Hole 2 cont'd

Depth in meters (feet)	Description
10.7-16.8 (35-55)	Quartz sand, clean and coarse; quartz pebbles
16.8-19.0 (55-62)	As above with abundant oyster(?) shell fragments. Cream colored pebble 1 1/2 cm in diameter at 18.7 m. Bryozoan branch fragment
19.0-19.3 (62-63)	Quartz sand and pebbles, fragment of <u>Noetia</u>? sp. Abundant limestone fragments

Log Hole 3

End of road on low peninsula projecting eastward into Wambaw Swamp at northwest edge of Wambaw Swamp Wilderness Study Area.

Elevation 7 m above mean sea level

Depth in meters (feet)	Description
0-2.4 (0-8)	Quartz sand, fine, yellow
2.4-5.5 (8-18)	Quartz sand, fine, tan to white, visible amphibole, shells abundant, at 4.9-5.5 m. *Mulinia lateralis* (Say, 1822) abundant *Bellucina amiantus* (Dall, 1901) *Nucula proxima* (Say, 1822) *Acteocina canaliculata* (Say, 1822) *Nassarius acutus* (Say, 1822) *Lunatia*? sp. frag. *Anadara ovalis* juv. Borings of carnivorous gastropods in some shells.
5.5-7.0 (18-23)	Blue gray clay and silt with shells at 7.0 m *Mulinia lateralis* (Say, 1822) *Anadara transversa* (Say, 1822) *Bellucina amiantus* (Dall, 1901) *Acteocina canaliculata* (Say, 1822) *Terebra*? sp. frag. *Diastoma varium* (Pfeiffer, 1840) Barnacle plates
7.0-8.5 (23-28)	Gray clay and silt
8.5-10.1 (28-33)	Purple clay and silt with shells. Large foraminiferal assemblage, showing normal salinity and shallow depth at 9.4 m.
10.1-11.0 (33-36)	Green clay and silt with purple streaks; shells
11.0-13.1 (36-43)	Gray clayey sand and sandy clay
13.1-15.2 (43-50)	Quartz sand with pebbles, clay and silt lenses
15.2-16.8 (50-55)	Cooper Formation; olive green foraminiferal marl; phosphate grains and nodules

Log Hole 4

East edge of Wambaw Swamp Wilderness Study Area at bend in small road; road connects with larger north-south road following an old railroad grade in part.

Elevation 4 m above mean sea level

Depth in meters (feet)	Description	
0-1.8 (0-6)	Sand, black silty	
1.8-2.7 (6-9)	Clay, black, organic clay, greasy; *Spartina*.	
2.7-4.0 (9-13)	Clay, green; silt; detrital wood	
4.0-6.4 (13-21)	Clay, green; mica; many shells at 5.2-6.4 m	
	Bellucina amiantus (Dall, 1901)	rare
	Mercenaria sp. frag.	rare
	Noetia ponderosa (Say, 1822)	rare
	Crassostrea sp. frags.	abundant
	Cyrtopleura sp. frag.	rare
	Anachis avara (Say, 1822)	common
	Nucula proxima (Say, 1822)	rare
	Ilyanassa obsoletus (Say, 1822)	rare
	Diodora sp. fragment	rare
	Mulinia lateralis (Say, 1822)	abundant
	Donax variablis (Say, 1822)	rare
	Parvilucina multilineata(Tuomey and Holmes, 1857)	rare
	Abra aequalis (Say, 1822)	rare
	Terebra dislocata (Say, 1822)	rare
	Anadara ovalis (Bruguiere, 1789) juvenile,	rare
	Anachis obesa (C.B. Adams,1845)	rare
	Nassarius acutus (Say, 1822)	rare
	Brachiodontes? sp. frag.	rare
	Acteocina canaliculata(Say,1822)	rare
	Busycon sp. frag.	rare
	Urosalpinx? sp. frag.	rare
	Barnacle plate	rare
	Echinoid spine (regular)	rare
	Encrusting bryozoans	rare
6.4-8.5 (21-28)	Clay and silt, green, few shells	

Log Hole 4 cont'd

Depth in meters (feet)	Description
8.5-10.7 (28-35)	Clay and silt, green. Large foraminiferal assemblage, showing normal salinity and shallow depth at 9.7 m
10.7-12.2 (35-40)	Clay and silt, green; quartz sand, coarse shells at 10.7 m *Cyrtopleura costata* (Linne, 1758) *Crassostrea virginica* (Gmelin, 1791) *Mulinia lateralis* (Say, 1822) abundant *Nassarius acutus* (Say, 1822) *Anadara ovalis* (Bruguiere, 1789) juv. *Anachis* sp. *Abra aequalis* (Say, 1822) *Seila adamsii* (H.C. Lea, 1845) *Noetia* sp. juvenile *Crepidula fornicata* (Linne, 1758) *Bellucina amiantus* (Dall, 1901) *Diodora* sp. frag. *Ensis* sp. frag. *Tellina agilis* (Stimpson, 1857) *Cumingia tellindoides* (Conrad, 1831) *Nucula proxima* (Say, 1822) *Kurtziella* cf. *K. atrostyla* (Tryon, 1884)
12.2-12.5 (40-41)	Cooper Formation; weathered marl with phosphate.

Log Hole 5

NW 1/4 Awendaw Quadrangle off of State Route 701 on Whilden Road

Elevation 9 m above mean sea level

Depth in meters (feet)	Description
0-3.3 (0-11)	Quartz sand, fine, well-sorted, mica, brown to tan at 1.8 m
3.3-4.6 (11-15)	Quartz sand and clay, mica, dark gray
4.6-7.3 (15-24)	Clay, blue-gray; mica; shells abundant at 4.9 m
7.3-8.2 (24-27)	Clay, blue-gray, plastic; shells
8.2-9.1 (27-30)	Clay, blue-gray, plastic; fine sand, shells, phosphate
9.1-10.1 (30-33)	Stiff clay, green gray; compacted shell hash; mica; phosphate
10.1-10.7 (33-35)	Clay, blue gray; mica; shell hash
10.7-11.6 (35-38)	Quartz sand, fine; phosphate, feldspar
11.6-18.6 (38-61)	Quartz sand, medium, gray, micaceous, feldspathic; blue clay; phosphate
18.6-19.2 (61-63)	Cooper Formation

Log Hole 6

NW 1/4 Awendaw Quadrangle on Whilden Road about 3 km NNW of Awendaw

Elevation 6 1/2 m above mean sea level

Depth in meters (feet)	Description
0-.6 (0-2)	Quartz sand, dark brown
.6-3.4 (2-11)	Clay, plastic, dark gray, mica
3.4-5.2 (11-17)	Quartz sand, very fine, dark gray, scattered mica flakes
5.2-6.1 (17-20)	Quartz sand, dark gray, shells, mica; at 5.8 m is a shell hash *Mulina lateralis*
6.1-7.0 (20-23)	Clay and fine quartz sand, dark gray; shells at 6.2 m; wood
7.0-9.8 (23-32)	Plastic clay, blue-gray; shells to 7.9 m
9.8-11.4 (32-37.4)	Plastic clay, blue-gray, slightly calcareous
11.4-12.1 (37.4-40)	Peat and clay
12.1-13.1 (40-43)	Clay, brown, few shells
13.1-16.5 (43-54)	Quartz sand, medium and coarse; some gray weathered phosphate sand grains
16.5-17.7 (54-58)	Cooper Marl containing phosphate pebbles

Log Hole 7

NW 1/4 Awendaw Quadrangle on Whilden Road at Little Wambaw Bridge

Elevation 4 1/2 m above mean sea level

Depth in meters (feet)	Description
0-3.0 (0-10)	Quartz sand, fine, well-sorted, scattered mica flakes; light brown wood particles
3.0-4.6 (10-15)	Quartz sand, gray-green to gray at 3.4 m; shell hash, mica flakes
4.6-8.5 (15-28)	Plastic clay, blue-gray; few shells, mica flakes, gray-green clay, 7.0-7.9 m
8.5-9.1 (28-30)	Sand, fine and clay, dark gray, shell hash, mica flakes
9.1-10.1 (30-33)	Sand, fine, dark gray, shells, mica flakes, phosphate sand grains
10.1-16.8 (33-55)	Quartz sand, medium to coarse, dark gray; mica flakes; few fossils; wood
16.8-19.2 (55-63)	Santee Limestone

Log Hole 8

NW 1/4 Awendaw Quadrangle on Whilden Road about 1 km north of Little Wambaw Bridge.

Elevation 7 1/2 m above mean sea level

Depth in meters (feet)	Description
0-3.0 (0-10)	Quartz sand, fine, well-sorted, dark to light brown, mica flakes, few shell fragments
3.0-3.4 (10-11)	Clay, gray, mica flakes
3.4-4.6 (11-15)	Quartz sand, fine, mica flakes, light brown grading to dark gray at 4.3 m
4.6-4.9 (15-16)	Clay and fine sand, blue gray, mica flakes
4.9-6.1 (16-20)	Fine sand and clay, shells and shell hash
6.1-7.5 (20-25)	Plastic clay, blue gray, few fossils
7.5-9.1 (25-30)	Stiff fine sand and clay, blue gray with gray green bed at 8.2-8.5 m; few shells.
9.1-9.8 (30-32)	Medium sand, gray, mica flakes; shells abundant
9.8-13.4 (32-44)	Medium and coarse sand, gray; mica flakes, blue quartz and feldspar sand grains
13.4-15.9 (44-52)	Quartz sand, fine to medium; clay, shells, mica flakes
15.9-16.2 (52-53)	Santee Limestone

Log Hole 9

NW 1/4 Awendaw Quadrangle on Whilden Road about 1 km northeast of site of Hole 8.

Elevation 8 m above mean sea level

Depth in meters (feet)	Description
0-2.7 (0-9)	Quartz sand, fine, well sorted, mica, brown grading to tan at 2.4 m.
2.7-3.3 (9-11)	Quartz sand, gray, mica flakes.
3.3-3.7 (11-12)	Quartz sand, clay, blue gray; mica flakes.
3.7-4.9 (12-16)	Clay, blue gray.
4.9-7.6 (16-25)	Quartz sand, fine; clay, blue gray; shells, *Mulinia lateralis*, very fossiliferous 6.1-7.6 m.
7.6-9.1 (25-30)	Stiff clay; quartz sand, fine, green gray, few shells.
9.1-10.1 (30-33)	Plastic clay, brown gray, mica flakes.
10.1-10.7 (33-35)	Clay; quartz sand, fine; green gray, few fossils.
10.7-11.0 (35-36)	Clay, gray, few fossils, mica flakes.
11.0-13.7 (36-45)	Quartz sand, fine, gray; mica flakes, fossils.
13.7-21.0 (45-69)	Quartz sand with feldspar and blue quartz, medium to coarse.
21.0- (69-)	Santee Limestone.

Log Hole 10

NW 1/4 Awendaw Quadrangle about 2 km northeast of Little Awendaw Bridge.

Elevation 8.2 m above mean sea level

Depth in meters (feet)	Description
0-.7 (0-2)	Quartz sand, fine, tan, well sorted.
.7-2.7 (2-9)	Quartz sand, fine, dark brown, mica flakes; few shell fragments.
2.7-4.0 (9-13)	Clay, blue gray.
4.0-4.6 (13-15)	Clay, fine sand, blue gray; mica; few fossils
4.6-6.4 (15-21)	Fine sand, blue gray, little mica; shell hash.
6.4-7.6 (21-25)	Plastic clay, blue gray, shells abundant.
7.6-9.5 (25-31)	Fine sand and clay, blue gray; shells abundant.
9.5-11.0 (31-36)	Medium sand, gray, phosphate grains, shells.
11.0-11.6 (36-38)	Fine sand, dark green, phosphate grains, shell fragments iron stains.
11.6- (38-)	Santee Limestone

RESOURCE POTENTIAL

The potential mineral resources present in the Wambaw Swamp Wilderness Study Area are phosphate and contained uranium, peat, sand and contained heavy minerals, clay, limestone, and petroleum. We conclude that the resources of all of these commodities in the study area are minor and that, for some of these commodities, alternative nearby sources are available.

The U.S. Forest Service holds title to all surface and mineral rights within the study area. According to Bureau of Land Management records, no prospecting permits or leases for development have ever been granted in the Francis Marion National Forest.

Phosphate

More than 13 million tons of phosphate rock were mined in the Charleston area of South Carolina from 1867 until 1938 when richer deposits in Florida and Tennessee were developed (Malde, 1959). The phosphate occurs as nodules and sand-sized grains and is concentrated in the weathered portion of the Eocene-Oligocene Cooper Formation and in the lowermost part of the overlying Pleistocene deposits. Secondary phosphatization of Cooper Formation occurred mostly by subaerial leaching of calcium carbonate and precipitation of phosphate as a cement (Altschuler and others, 1958). Subsequent erosion of phosphatized Cooper Formation resulted in the incorporation of grains and nodules into the overlying Pleistocene beds. Continued reworking brought about local concentrations of phosphate nodules in river and estuary deposits of Holocene age. The distribution of phosphate resources mapped by Rogers (1914) includes phosphatized Cooper Formation remaining in place and redeposited phosphate in overlying Pleistocene and Holocene beds. Grade of P_2O_5 in the phosphatic nodules which were separated from less phosphatic matrix in the mining operations was about 20-30 percent (Malde, 1959). The grade of P_2O_5 in unbeneficiated material was much lower.

Phosphate in the area of this report was found in drill holes 3 and 4 in Pleistocene material lying on Cooper Formation and in the weathered top of the Cooper Formation itself. Phosphate is also reported by D.J. Colquhoun from holes 5 and 6 in and on Cooper Formation. Based on our holes and samples (table 2), we believe the phosphate zone averages 1 m in thickness and 8 percent in P_2O_5 content; this is consistent with regional figures given in Force and others (1978). We estimate that 3 km^2 of the study area is underlain by Cooper Formation (see inset plate 2), though this area could reasonably be as low as 1 km^2 or as high as 5 km^2. Using 3 km^2 and a density of phosphatic material of 2 grams per cubic centimeter, resources of 500,000 metric tons of P_2O_5 are implied. The grade is considerably lower than that presently mined in the U.S. (more than 20% P_2O_5), and the thinness of the phosphate zone and thickness of the overburden (12-18 m) further limit the economic value of these deposits.

Table 2.--Phosphate and uranium contents of sediments from weathered surface of Cooper Formation. P_2O_5 analyses by Floyd Brown and others, U.S.G.S., Reston, Va.; U analyses by neutron techniques by H.T. Millard and others, U.S.G.S., Denver, Colo.

Drill hole	Depth (m)	P_2O_5 (%)	U(ppm)
3	15.2	8.5	47
3	15.9	6.9	41
3	16.8	7.1	40
4	12.2	4.8	33
4	12.5	13.9	123

Uranium

Phosphate of the Cooper Formation contains uranium throughout the Charleston area (Altschuler, 1958; Force and others, 1978). Grab samples of about 1 kg taken from auger stems at holes 3 and 4 (pl. 2) average about 50 ppm uranium (table 2). The lowest grade of uranium currently mined in the U.S. is about 200 ppm in easily leached material. The figures for area thickness and density used above for calculating phosphate resources imply about 300 tons of uranium in the study area. This small amount together with its thick overburden are the reasons for not considering uranium an important resource in Wambaw Swamp.

Peat

Peat, which is partly decomposed vegetable matter that accumulated under water or in a water-saturated environment, has a wide range of physical and chemical properties. For statistical purposes, the U.S. Bureau of Mines classifies peat in three general types: material from decomposed moss is moss peat; that from reed, sedge, shrub, and tree groups is classified as reed-sedge peat; and material so decomposed that its botanical identity is obscured and further oxidation of the material has been impeded is classified as peat humus. The Federal Trade Commission in 1950 defined the requirements for labeling a product "peat". These regulations define peat as any partially decayed plant matter that has accumulated under water or in a water saturated environment. It is unlawful to label a product peat unless 75 percent of the material, by dry weight, is composed of peat as defined, and the remainder is composed of normally associated materials (Michelson, 1975). According to the American Society for Testing and Materials (1969) only peat that has an ash content of not more than 25 percent is of commercial quality.

Fibrous brown peat formed from fresh water swamp vegetation occurs to a depth of 0.6 to 1.2 m adjacent to the northern boundary of the study area (see Pl. 1). This peat contains an ash content generally less than 25 percent by dry weight. But within the study area the peat and muck are generally less than a half meter thick, and ash content is generally greater than 25 percent. This material occurs under the swamp forest but not on the tidal bars, map unit Qfs, marked by the presence of loblolly pines.

The nearest peat mine is located southwest of Charleston in fresh water Snuggedy Swamp along the Ashepoo River (fig. 3). In that swamp, humus peat of commercial value is as much as 3.6 m thick. It is used as a soil conditioner for agricultural and horticultural purposes.

Wambaw Swamp peat has a very low resource potential because it is too thin to be mined economically, and it does not meet Federal Trade Commission standards for peat.

Sand

Large bodies of well-sorted Pleistocene beach sand are found around the Wambaw Swamp study area. They range in thickness from zero to 5.5 m. Medium sand is predominant. These bodies apparently do not extend far into or under the study area.

Buried sands probably of fluvial origin were found in drill holes 1, 2 and 3 and probably extend under the swamp. These range from medium sand to granular coarse sand.

Potassium feldspar contents of both types of sand range from about 1 to 5 percent, with the higher values occurring in the fluvial sands and the younger (seaward) beach sands. In the coarse granular fluvial sands, potassium feldspar typically forms 10-50 percent of the granules. These buried deposits should not be considered resources because large quantities are available at the surface near the study area.

Heavy minerals

Heavy mineral deposits in sands of the southeastern U.S. are important sources of titanium minerals, zircon, and other industrial minerals. Several significant concentrations occur in barrier islands of later Pleistocene and Holocene age as at Hilton Head Island (McCauley, 1960) and Isle of Palms (Neiheisel, 1958a, b), both southwest of the study area. Bull Island, off the coast about 12 km south of Wambaw Swamp (Plate 1) has heavy mineral concentrations in beach and dune sands (Neiheisel, 1958a). Further information on heavy minerals in South Carolina is given in a report by Williams (1967).

Auger samples of clean sands near the study area were analyzed for heavy minerals (table 3). The samples are old beach sands of unit Qs and fluvial sands of unit Qcs; only the latter extend under the study area. None of the samples has a heavy mineral content of as much as 3 percent and, of the heavy minerals, a large proportion are economically worthless, such as hornblende and epidote.

Table 3.--Heavy minerals in Pleistocene sands of Wambaw Swamp

Mineral separations by Andrew Grosz, U.S.G.S.

Drill site	Depth (m)	Heavy minerals (p>2.85) in weight percent	APPROXIMATE WEIGHT PERCENT OF HEAVY MINERALS (P<.5%)										
			"Ilmenite"*	Magnetite	Amphibole +Pyroxene	Epidote	Garnet	Staurolite	Sulfides	Phosphate	Zircon	Sillimanite	Rutile
1	1.7-3.0	2.7	10	P	30	15	2	4	-	P	P	5	1
1	8.4-8.6	1.7	12	P	25	20	2	7	1	1	2	2	2
1	18.3-19.8	1.1	9	P	30	25	5	7	3	3	P	P	P
1	21.3-22.9	2.0	5	P	30	25	2	5	2	4	2	2	2
2	8.2-9.1	0.7	8	1	20	30	3	8	4	P	-	3	P
2	12.5-13.1	0.9	6	1	20	30	5	9	7	P	P	4	2
3	0-5.5	0.8	5	1	20	30	P	12	-	1	2	4	2

* "Ilmenite" is defined by magnetism, density, color, and opacity, but consists mostly of alteration products.

Limestone

Limestone is being quarried for agricultural lime and road metal 25 km north of Wambaw Swamp near Jamestown and for cement, 65 km west near Harleyville (plate 1). The quarries are all in the Santee Limestone except for the Carolina Giant Cement Company at Harleyville which uses a mixture of the more pure Santee with the Cooper Formation which are both quarried from the same site. The Cooper Formation provides the clay content necessary for cement manufacture and eliminates the expense of hauling clay to the plant. Because of some variability of the composition of the Cooper, this suitability for cement could not be expected throughout its extent.

In addition to its usefulness for cement, parts of the Cooper Formation have a magnesian content sufficiently high to make it valuable for agricultural purposes. In general, the $MgCO_3$ content of the Cooper Formation is less than 2 percent but Sloan (1908, p. 383) gives an analysis which shows 27 percent and Malde (1959, p. 9) mentions that samples obtained by drilling showed sporadic replacement of calcite by dolomite throughout the formation.

The quality of the limestone bedrock in the study area was not evaluated because of our lack of data and because of thick overburden which varies from 12.2 to more than 23 meters thick over the Santee Limestone and Cooper Formation.

Clay

The nearest deposit of clay being mined for ceramic use is 2 km NNE of St. Stephens (pl. 2). This clay is heavily leached and unlike any in the study area.

The one possible source of clay in the study area was penetrated in hole number 1 (pl. 2) at depths 10.4 to 18.3 m. It is a non-calcareous clay containing large wood fragments and a few brackish water foraminifera, and therefore probably formed in an estuary. Sand (<250 mesh) contents of two samples tested are 5.6 and 6.4%. Using x-ray diffraction methods, Patricia J. Loferski of the USGS estimated that the clay mineral composition of this clay in parts of ten are as follows: kaolinite, 7, mixed layer illite-smectite, 2, illite, 1, and chlorite, trace.

Bluish muds (most commonly color 5GY 4/1 in the Munsell-Geological Society of America system) are a common lithology below the surface in the Wambaw Swamp area. Most of them are interbedded with shelly marine sands, and themselves contain coarse shells and calcareous micro-organisms. Such unweathered marine clays generally do not fire well, due in part to their calcium content.

Three samples from near the surface of Wambaw Swamp (see locations on Plate 2) were submitted to the U.S. Bureau of mines Tuscaloosa Metallurgy Research Center, Tuscaloosa, Alabama, for an appraisal of their ceramic characteristics. These noncalcareous clays are from beds less than 30 cm thick and are interbedded with sand or sandy clays. Testing showed no favorable ceramic properties and the samples would neither bloat nor bond. They are thus unsuitable for vitreous clay products or for lightweight aggregate.

Oil and gas

By

Edward C. Rhodehamel

The probability of commercial quantities of oil and gas beneath the Wambaw Swamp study area appears small. This conclusion is based on the following observations: (1) Eighteen deep tests in South Carolina show no indication of oil and gas, (2) Little or no surface indication of oil or gas has been reported, (3) Sedimentary rock in this area is less than 1000 m thick, (4) The depositional environment was unfavorable for hydrocarbon generation and preservation, (5) Suitable reservoir rock and adequate hydrocarbon source beds are lacking, (6) The rocks lack the thermal maturity necessary for generating hydrocarbons, (7) Extensive freshwater flushing of the entire Coastal Plain rock sequence has occurred, (8) Suitable structural traps are unknown.

Because there are no test drillings in Wambaw Swamp, sediment character and age are inferred largely from 18 deep (greater than 300 m) holes drilled in South Carolina. The stratigraphy is based chiefly on reports by Richards (1945, 1967), Siple (1958, 1965), Maher (1971), Marine and Siple (1974), Dillon and others (1975), Olson and Glowacz (1977), Bureau of Land Management (1978), and Gohn and others (1977, 1978).

Additional data, concerned with the basement structure and configuration, is presented from geophysical studies of McCarthy (1936), Straley and Richards (1948), Richards and Straley (1953), Pooley (1960), Hersey and others (1959), Bonini and Woollard (1960), Long and others (1975), Krivoy and Eppert (1977), and Bureau of Land Management (1978).

Plate one shows the four closest drilling sites to Wambaw Swamp. Their location, depth, and age and (or) type of rock encountered are: (1) at Georgetown, 45 km northeast, a 750 m deep test bottomed in Upper Cretaceous rock; (2) at Charleston, 45 km southwest along the coast, a 614 m deep test bottomed in Upper Cretaceous rock; (3) at Summerville, 53 km west, a 753 m deep test bottomed in diabase; and (4) at Clubhouse Crossroads, 19 km southwest of Summerville and about 70 km southwest of Wambaw Swamp, three closely spaced U.S. Geological Survey drill holes with depths ranging from 750 m to 1152 m. Two holes bottomed in Upper Triassic or Lower Jurassic basalt, the other bottomed in red, well-indurated, and unfossiliferous feldspathic mudstone, sandstone, and conglomerate of probable Triassic age (Gohn and others, 1978). None of these tests encountered any hydrocarbons. However, a poorly documented occurrence of oil and gas seepages is reported about 120 km northeast of Wambaw Swamp at Allsbrook, Horry County, where Coastal Plain sediments are less than 300 m thick (Richards, 1945). Two oil and gas exploration wells at Allsbrook were unsuccessful.

Wambaw Swamp is in the Atlantic Coastal Plain province on the south flank of the Cape Fear Arch, a positive structural element of the underlying basement forming the northern margin of the Southeast Georgia Embayment. Near the study area the northeastward-trending basement contours bend eastward along the south side of the plunging nose of the arch (Bureau of Land

Management, 1978; Popenoe and Zietz, 1977, p. 124). The basement rocks along the south flank of the arch are of unknown composition and age. Geophysical evidence suggests a pre-Cretaceous basement of Mesozoic continental sediments, interbedded with mafic volcanic and intrusive rocks. These Mesozoic rocks are in downfaulted blocks in a more widespread dense rock having a magnetic pattern unlike the rocks of the Piedmont. Such a basement is considered to have small petroleum resource potential.

Upper Jurassic and Lower Cretaceous rocks are the most promising oil and gas prospects in the emerged Atlantic Coastal Plain and Upper Cretaceous rocks are considered to have only fair hydrocarbon potential where they are more than 1 km thick and overlain by at least 1 km of Tertiary rocks (Maher, 1971). Drilling in the South Carolina Coastal Plain has not encountered Jurassic sediments, and Lower Cretaceous rocks are generally absent in the subsurface.

Geophysical evidence indicates that the sedimentary section in the Wambaw Swamp area is about 0.8 to 1.0 km thick (Popenoe and Zietz, 1977, p. 124) and Bureau of Land Management, 1978).

The lower half of this thin sedimentary section under Wambaw Swamp is probably of Upper Cretaceous age, and the remainder is chiefly of Tertiary age. The entire wedge of sediment under the 6 km^2 study area is therefore less than 6 km^3.

The stratigraphic section overlying the basement under Wambaw Swamp is composed of unconsolidated Upper Cretaceous and Tertiary materials. The Upper Cretaceous rocks are continental, transitional, and nearshore-marine to outer neritic deposits of conglomerate, sand, silt, and a minor amount of carbonaceous black clay and limestone. The Tertiary rocks deposited by marine transgression, overlap the permeable Upper Cretaceous beds. Tertiary rocks, which dip gently 4 m/km southward, are shallow-water marine (inner to outer neritic) sequences with poor to moderate consolidation, and poor to good permeability. They are composed of limestone, glauconite, clay, silt, and sand. The volume of potential source rock, such as black clays and shales high in carbonaceous material, are considered inadequate to form commercial quantities of oil and gas under Wambaw Swamp. Apparently strong oxidizing conditions prevailed within these nearshore and marine depositional environments, and much organic matter was destroyed prior to sediment burial.

Thin to moderately thick coarse clastic beds are present that could form small petroleum reservoirs. However, because the surrounding beds are insufficiently compacted, nonindurated, and have no other known permeability barriers, these clastic beds are unsuited for petroleum entrapment.

Furthermore, the above-sea-level marginal position of Wambaw Swamp and the lack of suitable reservoir conditions as noted above has facilitated fresh groundwater flushing of the sedimentary section thereby hindering any possible hydrocarbon entrapment.

Commonly a minimum rock-burial depth of one kilometer is required to attain the lower threshold of geothermal heating (about 40°C) needed to start petroleum generation (McCulloh, 1978). The Upper Cretaceous and Tertiary rocks beneath Wambaw Swamp have not been buried deeper than one km nor have they been heated to a higher temperature than possessed now. Based on a present geothermal gradient of about 0.9 °C per 30.5 m depth (AAPG, 1976), the 25° to 30°C temperature at the base of Upper Cretaceous sediments is below the required threshold temperature, and therefore, oil generation is not expected.

Geophysical investigations and test drilling have identified several local structural features in the area surrounding Wambaw Swamp. One such feature, the Yamacraw Uplift, is a pre-Cretaceous basement ridge 64 km wide, and about 177 km long having more than 300 m of relief. It trends northeastward between Sea Island, Georgia and Parris Island, S. Carolina, about 130 km southwest of Wambaw Swamp. Upper Cretaceous and lower Tertiary beds do not thin over the uplift suggesting that the Yamacraw Uplift has not been active since at least Lower Cretaceous time. Although a number of much shallower upper-Tertiary structures, having displacements of about 30 m, exist in the general vicinity of the Yamacraw Uplift, no local rock structures seemingly exist under Wambaw Swamp.

In the offshore area adjacent to Wambaw Swamp, Dillon and others (1974) report syndepositional faults and Krivoy and Eppert (1977) report basement-controlled gravity features. The faults lie 16 to 63 km offshore and trend parallel to the coast. They are shallow, of small displacement and are associated with reverse regional dips in Tertiary rocks. These structures, like the shallow onshore structures are not basement controlled and do not continue downward into the underlying Upper Cretaceous rocks. The three large north-south trending positive-gravity anomalies are tentatively interpreted by Krivoy and Eppert (1977) as a series of three volcanic mounts with associated depositional basins. Crests of these volcanic features are less than one km below the sea floor. Apparently they formed prior to the deposition of the overlying sediments, which show no structural disturbance. This suggests the time of basement activity occurred prior to Upper Cretaceous deposition. None of the syndepositional faults or gravity anomalies discussed above seemingly extend onto the land (Long and others, 1975 and Popenoe and Zietz, 1977) and the gravity field under Wambaw Swamp is rather featureless.

The timing of tectonic (structural) events failed to provide suitable hydrocarbon trapping structures. Structures formed either long before (in pre-Cretaceous) or long after (in late Tertiary) Upper Cretaceous rocks were deposited. For example, any migrating hydrocarbons in the thin Upper Cretaceous rocks, deposited long after basement structural activity had ceased, would not encounter closing (trapping) structures such as faults and anticlines and would continue to move along the negative pressure gradient and eventually escape to the surface. Furthermore, the geophysical studies previously mentioned show no basement structural irregularities under Wambaw Swamp, hence development of commercial-size traps related to possible drape structures in the overlying Upper Cretaceous and Tertiary rocks is unlikely. On the other hand the relatively shallow late Tertiary syndepositional structures found offshore most likely have developed subsequent to an escape of all oil and gas possibly generated from the Upper Cretaceous beds. Because the Tertiary and overlying Quaternary deposits have little oil and gas potential owing to a general lack of almost all the favorable criteria necessary for oil accumulation, any development of faults and anticlinal folds within this part of the stratigraphic column would almost certainly contain no commercial quantities of oil and gas.

From the above discussion of the factors essential for the occurrence of hydrocarbons it is concluded that the chances for discovery of commercial quantities of oil and (or) gas beneath Wambaw Swamp are small.

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