DEPARTMENT OF THE INTERIOR
UNITED STATES GEOLOGICAL SURVEY

MISCELLANEOUS FIELD STUDIES
MAP MF-1879
PAMPHLET

GEOLOGY AND MINERAL RESOURCE POTENTIAL OF THE BILLIES BAY, ALEXANDER SPRINGS, LITTLE LAKE GEORGE, AND JUNIPER PRAIRIE WILDERNESSES, AND THE BAPTIST LAKE ROADLESS AREA, LAKE, MARION, AND PUTNAM COUNTIES, FLORIDA

By

Cornelia C. Cameron, James B. Cathcart, and Paul G. Schruben

1987

Studies Related To Wilderness

Under the provisions of the Wilderness Act (Public Law 88-577, September 3, 1964) and related acts, the U.S. Geological Survey has been conducting mineral surveys of wilderness and primitive areas. Areas officially designated as "wilderness," "wild," or "canoe" when the act was passed were incorporated into the National Wilderness Preservation System and have been 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. The act directs that the results of such surveys are to be made available to the public and are to be submitted to the President and the Congress. This report discusses the results of mineral surveys of the following areas in Florida: Little Lake George (Forest Service number 08-109), Juniper Prairie (L8-309), Billies Bay (08-011), and Alexander Springs (08-011) Wildernesses; and the Baptist Lake Roadless Area (08-307). Little Lake George Wilderness is in Putnam County, the Juniper Prairie Wilderness and the Baptist Lake Roadless Area are in Marion County, and the Billies Bay and Alexander Springs Wildernesses are in Lake County. The Baptist Lake Roadless Area was classified as a nonwilderness and the other areas recommended for wilderness during the Second Roadless Area Review and Evaluation (RARE II) by the U.S. Forest Service, January, 1979. Little Lake George, Juniper Prairie, Billies Bay, and Alexander Springs were established as Wildernesses by Public Law 98-430, September 28, 1984.

SUMMARY

This report is concerned with the geology and mineral resource potential of the Little Lake George, Juniper Prairie, Billies Bay, and Alexander Springs Wildernesses, and the Baptist Lake Roadless Area in the Ocala National Forest, Florida. The five areas are underlain by sedimentary rocks having low potential for metallic minerals. Peat is the most important identified resource in these areas. The Billies Bay Wilderness contains an estimated 2 million tons of air-dried peat, the Little Lake George Wilderness contains an estimated 750,000 tons, and the Juniper Prairie Wilderness contains an estimated 700,000 tons. The other areas do not contain peat resources. Phosphate-bearing rocks are present in all the areas, but the deposits of phosphate are subeconomic at the present time. In general, the phosphate deposits are below the present economic standard for grade (28 percent phosphorus pentoxide (P_2O_5)) and tonnage, and are slightly high in deleterious elements, such as magnesium, calcium, iron, and aluminum. The ratio of thickness of overburden to thickness of phosphate rock, however, is slightly above economic standards. The general area has a low potential for oil and gas, indicated by numerous holes drilled in the vicinity that were abandoned as dry and by the absence of the formations that produce hydrocarbons in south Florida and in the western panhandle of Florida. Nearly pure limestone underlies the study areas, but it is deeply buried. Kaolinitic and smectitic clays are present in the area, but these have little value. The kaolinite in the Citronelle(?) Formation is only about 15 percent by weight of the total rock, which is far too impure to be of value. Lenticular beds of smectitic clay in the Hawthorn Formation are too deeply buried to be minable. No commercial heavy-mineral deposits are known to be present in the areas, and none are likely to be found. Heavy-mineral concentrations in the surficial sand average only about one-tenth as much as in minable deposits.

The only mining in the region was of surficial clayey sand that was used as road metal. These deposits, however, are not considered useful because virtually unlimited quantities of clayey sand are present at the surface outside of the five areas.

INTRODUCTION

These five areas are scattered through the eastern one-half of the Ocala National Forest in northcentral peninsular Florida (Index map and fig. 1). Little Lake George (fig. 2) is in Putnam County, Billies Bay (fig. 3) and Alexander Springs (fig. 4) are in Lake County, and Juniper Prairie (fig. 5) and Baptist Lake (fig. 6) are in Marion County.

Little Lake George Wilderness

The Little Lake George Wilderness is located at the confluence of the Oklawaha and St. Johns Rivers. The area can be reached by Florida highway 19 and Forest Service road 77. It is 40 miles southeast of Gainsville and 30 mi northeast of Ocala. The Little Lake George Wilderness contains 2,500 acres (Public Law 98-430, September 28, 1984). Most of the area is swamp and marsh land along the rivers, where altitudes are less than 5 feet. The highest places in the area are along the western boundary, where altitudes are a little more than 20 ft. The swamp and marsh vegetation is composed primarily of cypress, ash, cabbage palm, red maple, and smilax. Dry and intermittently dry areas are forested by pond, slash, and loblolly pines.

Juniper Prairie Wilderness

The Juniper Prairie Wilderness is northwest of the junction of Florida Highways 40 and 19, approximately 25 mi east of Ocala. The area, which contains 13,260 acres (Public Law 98-430, September 28, 1984), is in the Central Highlands physiographic province. Altitudes range from 10 to 100 ft. Lush aquatic vegetation grows around springs, streams, and prairie lakes. Dry and intermittently dry areas support several species of pine.

The three private tracts present within the Juniper Prairie Wilderness (fig. 5) consist of a 3.64-acre triangular area in the north central part and, along the northern edge, the 2.7-acre Long family cemetery and a 1.25-acre school lot owned by the State Internal Improvement Fund (U.S. Forest Service, Tallahassee, Fla., memorandum, September 16, 1983).

Alexander Springs and Billies Bay Wildernesses

The Alexander Springs and Billies Bay Wildernesses were formed from parts of the larger Alexander Springs Creek Roadless Area. They are 8 to 15 mi west of Deland in the Atlantic Coastal Plain physiographic province. Alexander Springs contains 7,700 acres, and Billies Bay, 3,120 acres (Public Law 98-430, September 28, 1984). Primary access is by Florida Highway 445 and then from several Forest Service Roads (figs. 3 and 4). Altitudes range from less than 5 to 75 ft. Vegetation consists of cypress, ash, cabbage palm, red maple, bay, smilax, and poison ivy. Scattered dry and intermittently dry areas support bay leaf and sand pine.

Baptist Lake Roadless Area

The Baptist Lake Roadless Area is in the southcentral part of the Ocala National Forest. The Area is approximately 40 mi southeast of Ocala and can be reached by Florida Highway 19 and Forest Service road 73. The Baptist Lake Roadless Area contains 7,641 acres (U.S. Forest Service, Tallahassee, Fla., memorandum September 16, 1983) in the Central Highlands physiographic province, where elevations range from 55 to 170 ft. Sand pine dominates the area, but a variety of scrub vegetation provides a dense understory.

PREVIOUS INVESTIGATIONS

The general geology of central Florida was discussed by Cooke (1945), Espenshade and Spencer (1963), and Puri and Vernon (1964). The geologic maps and descriptions by these writers have been used in the discussion of the geology in this report.

Subsurface geology of northern peninsular Florida is discussed in reports by Applin (1951), Applin and Applin (1944, 1965, and 1967), and Rainwater (1971).

The geology and mineral resource potential of the nearby Farles Prairie and Buck Lake Roadless Areas were discussed by Cathcart and Patterson (1985), Cathcart and others (1983), and Crandall (1981).

Although no detailed surveys of the mineral resources of the Ocala Forest have been made, general information is included in the following references: limestone (Schmidt and others, 1979), phosphate (Cathcart, 1968; Espenshade and Spencer, 1963; Mansfield, 1942; Sever and others, 1967), clay (Calver, 1949), peat, (Davis, 1946), and heavy minerals (Garner, 1972, 1981).

PRESENT INVESTIGATION

J.B. Cathcart reviewed published informaton on the geology of the Ocala National Forest region and reconnoitered the area in February 1980. A drilling program was carried out jointly with the U.S. Bureau of Mines (USBM) in September and October 1980. During the program, one hole (No. 1, fig. 7) was drilled just to the south of the Alexander Springs area, one (No. 2, fig. 7) was drilled just to the east of Billies Bay; three (Nos. 3, 3A, 4, fig. 7) at the Farles Prairie-Buck Lake Roadless Areas, one (No. 5, fig. 7) at the west edge of Juniper Prairie, and one (No. 6, fig. 7) at the north edge of Little Lake George. All holes were drilled through the overburden with a fishtail bit. Drilling was stopped at 10-foot intervals, and mud was circulated so that reasonable samples of the cuttings could be collected. With the first appearance of phosphate or dark-olive-green clay typical of the Hawthorn Formation, a core barrel was installed, and the hole was cored to the very hard dolomite of the Hawthorn. At this point, a tricone bit was installed, and the hole was drilled to the top of the Ocala Limestone. Core and cuttings were logged at the site, and samples were collected for later investigation in the laboratory. The results were discussed in Crandall (1981) and Cathcart and others (1983).

C.C. Cameron and P.G. Schruben investigated the peat resources in the Little Lake George, Juniper Prairie, and Alexander Springs Wildernesses in December 1980. In December 1983, they investigated the peat resources in the Billies Bay Wilderness and reconnoitered the Baptist Lake Roadless Area.

ACKNOWLEDGMENTS

The authors are grateful for the cooperation of the Florida Bureau of Geology and the U.S. Forest Service. Thomas M. Scott, geologist with the Florida Bureau, worked with Cathcart and Thomas Crandall (USBM) during the drilling program and helped in logging and sampling core and cuttings. Rich Deuerling of the Florida Bureau logged two of the drill holes with a gamma-ray logging unit and assisted in

sampling. Discussions with these geologists were of great value in making stratigraphic interpretations from lithology. David Curry and F.A. Pointigo, Jr., also of the Florida Bureau, aided in gathering information on oil and gas. George Hemingway, District Ranger, Seminole Area, and Bobby Brady, District Ranger, Lake George Area of the Ocala National Forest, provided maps and storage facilities for drilling equipment. William R. Waite, soil scientist, U.S. Forest Service, Tallahassee, Fla., provided maps and background information on the region.

GEOLOGY

The five areas are covered by a thin veneer of unconsolidated surficial sediment of probable Holocene age. The sediment consists of white sand or slightly clayey sand with only minor amounts of organic matter and roots. In most places, the surficial sediments are no more than 5 ft thick, but a few company drill holes penetrated as much as 100 ft of unconsolidated sediment described as "sand and humus" or "slightly clayey sand with organic matter." Thicknesses exceeding 100 feet of unconsolidated sediments are sink-hole fillings. Organic muck and humus accumulations are present in many of the swampy areas, and the Billies Bay, Juniper Prairie, and Little Lake George Wildernesses contain significant deposits of peat.

The surficial blanket of sand is underlain by mottled white, red, and orange sand and clayey sand that contain minor amounts of heavy minerals and trace amounts of phosphate particles. Although the age of these sediments is uncertain because they contain no fossils, they are probably of Pliocene and Pleistocene age because these strata are lithologically identical with the Pliocene Citronelle Formation, which is shown as cropping out in the area on the geologic map of Espenshade and Spencer (1963); this formational name will be used tentatively in this report. The Citronelle(?) is, in a sense, bedrock throughout the Ocala National Forest. This unit is 40 to 60 ft thick where penetrated by holes drilled during this investigation (fig. 7), but is known to be as much as 100 ft thick elsewhere in the Ocala National Forest. The Citronelle(?) rests unconformably on an unnamed formation considered to be upper Miocene in age (fig. 7). This unnamed formation overlies fossiliferous sediments of the Hawthorn Formation. The Hawthorn, as well as the unnamed formation, underlies the five study areas and extends to the east but has been eroded from the westernmost part of the Ocala National Forest where rocks of the Citronelle(?) rest directly on the Ocala Limestone. The Ocala Limestone underlies all of the Ocala National Forest. More than 3,000 ft of sedimentary rocks ranging in age from Cretaceous to Eocene (fig. 1) underlie the Ocala Limestone, and Cretaceous rocks rest unconformably on an older basement of crystalline and sedimentary Paleozoic rocks.

SUBSURFACE STRATIGRAPHY

Paleozoic or Possibly Older Crystalline Rocks

Studies of cuttings and drill cores from dry holes (Applin, 1951; Puri and Vernon, 1964; Bridge and Berdan, 1952; Milton, 1972) have revealed the presence of crystalline Paleozoic rocks at depth in the region of the five areas. Crystalline rocks were penetrated in six dry holes (fig. 1; table 1); the rock type and depth intervals are as follows: tuff or welded tuff—holes 6 (3,879-3,881 ft), 8 (4,601-4,633 ft), and 17 (4,615-4,637 ft); basalt—hole 13 (4,344-4,377 ft); rhyolitic volcanic rock—hole 19 (5,424 ft); and dioritic rock—hole 21 (5,952-5,956 ft). The basalt in hole 13 overlies Lower Ordovician black shale, and hole 17, which passed through tuff, bottomed in Lower Ordovician quartzite. Lower Ordovician quartzite, sandstone, or shale was penetrated in holes 1, 3, 4, 12, 14, 15, and 17.

MESOZOIC ERA

Cretaceous Period

According to Applin and Applin (1965), Cretaceous strata rest unconformably on Paleozoic rocks in the region of the five areas. The Lower Cretaceous beds at depth (table 2) are probably similar to the three major stratigraphic units penetrated by hole 19 (fig. 1; table 1) located east of the areas (Applin and Applin, 1965, pl. 6). The lowest unit, which is of Trinity age, is composed of sandstone and shale overlain by dolomite; the middle unit of Fredericksburg age is chiefly dolomite; and the uppermost of the three units, which is of Washita age, is limestone and shaly sandstone. The total thickness of the three units is about 630 ft. The Upper Cretaceous beds in test well 17 (fig. 1), located west of Buck Lake, are divided into four major units having a total thickness of nearly 1,600 ft (Applin and Applin, 1967, pl. 7). The Atkinson Formation is the lowest unit and consists of basal beds of conglomerate, sandstone, and chalk that are overlain by chalk and sandy chalk. The second unit, consisting of beds of Austin age, is mainly chalk containing anhydrate and gypsum inclusions. The third unit, which is of Taylor age, consists of basal beds of dolomite, a middle part of chalk, and an upper part of dolomite. The Lawson Limestone, uppermost of the four units, is composed of limestone and dolomite containing anhydrate and gypsum inclusions.

CENOZOIC ERA

Paleocene Epoch

The Paleocene beds in the region of the five areas are assigned to the Cedar Keys Limestone (Applin and Applin, 1944, p. 1703-1708; Puri and Vernon, 1964, p. 42). Dry hole 14, located 35 mi west-northwest of Farles Prairie (fig. 1), passed through the Cedar Keys Limestone, which was 505 ft thick (1,730-2,235 ft depths). In most of peninsular Florida, the Cedar Keys consists of cream- to tan-colored hard limestone containing distinctive foraminifers.

Eocene Epoch

Applin and Applin (1944, fig. 23) recognized five Eocene formations in the region of the five areas. The lowermost is the Oldsmar Limestone, which is 445 ft thick (1,285-1,730 ft depths) where penetrated by dry hole 14 (fig 1). The Oldsmar is lithologically similar to the overlying Lake City Limestone, from which it is separated primarily by a distinctive microfauna.

The Lake City Limestone consists of alternating layers of dark-brown and chalky limestone; it is 370 ft thick (915-1,285 ft depths) where penetrated by dry hole 14. The beds above the Lake City Limestone form an unnamed nonfossiliferous formation that is 555 ft thick (360-915 ft depths). This unnamed formation consists of cream-colored to white, hard, dense, saccharoidal, and porous varieties of limestone.

The fourth is the Avon Park Formation, which according to Puri and Vernon (1964, p. 52), consists of three general lithologic units. The lowest unit is thin-bedded and laminated, finely crystalline dolomite containing layers of lignite and carbonaceous plant remains. The middle unit consists of cream-colored to brown, pasty, and fragmental marine dolomite that contains flecks and seams of peat. Abundant bryozoa, foraminifers, and ostracods are concentrated in hard layers interbedded with the peat and pasty limestone. The upper lithologic unit is cream-colored to brown, fragmental to pasty, marine limestone that contains abundant foraminifers, mollusks, and corals. The Avon Park is 130 ft thick (230-360 ft depths) in dry hole 14 (Applin and Applin, 1944, fig. 22).

The Ocala Limestone is the uppermost of the five Eocene formations. In many places in peninsular Florida, the Ocala can be divided into two members. The lower member is light-cream-colored limestone containing abundant molds and casts of small foraminifers. The upper member is soft, white, chalky, porous coquina made up mainly of large foraminifers. The Ocala is approximately 100 ft thick in the region of the five areas. The Ocala Limestone is overlain unconformably by the Miocene Hawthorn Formation because no Oligocene beds have been identified near the study areas.

Miocene Epoch

Rocks of Miocene age in the five areas include the Hawthorn Formation and an unnamed formation of probable late Miocene age. The Hawthorn Formation of early and middle Miocene age is present under the northern and eastern parts of the Ocala National Forest. The formation has, however, been eroded from the higher parts of the Peninsular Arch to the west and is present only as irregular erosional remnants in the southwestern part of the forest (fig. 7). The line on the map that represents the western limit of the area where the Hawthorn is unbroken is based on drilling data and matches closely the line on the geologic map of Espenshade and Spencer (1963) that indicates the contact between the Ocala Limestone on the west and the younger Hawthorn and Citronelle(?) Formations on the east. The Hawthorn is present throughout the area east of the line, but west of the line it is present only as erosional remnants that become less abundant toward the crest of the Peninsular Arch.

Hawthorn Formation.—Based on the drilling done for this project, the Hawthorn can be divided into an upper, dominantly clastic unit and a lower, dominantly carbonate unit. This division also can be inferred from the lithologic logs of company drill holes in the Ocala National Forest. The two units vary in thickness, but where best developed in the eastern part of the Ocala Forest, they are more or less equal. Toward the west, the lower carbonate unit is thicker because of erosion of the upper clastic unit.

The carbonate rock of the lower unit of the Hawthorn is almost entirely dolomite, although some calcite is present as fossil shell material and as yellow-brown elongated "rice-grain" crystals. The dolomite is hard and dense to finely crystalline and contains abundant rounded grains of phosphate. These phosphate grains range in size from fine to granular, are highly polished and well rounded, and are predominantly dark colored (shades of brown, black, and gray), although some are light-gray to almost white. Some grains may be internal molds of fossils, and others are phosphatized rock fragments, but most are structureless. The rock fragments have the same texture as the dolomite and probably represent a replacement, by phosphate, of the original dolomite groundmass. The carbonate unit in the eastern part of the forest ranges in thickness from a feather edge to about 90 ft, and although no trends in thickness could be seen in this area, there is a general regional thickening to the east and south, away from the crest of the Peninsular Arch.

The clastic rocks of the upper unit of the Hawthorn consist of clay, sand, variable amounts of fine-grained dolomite rhombs, and abundant rounded and highly polished black, brown, gray, and white phosphate pellets. The phosphate pellets tend to be very fine to medium grained in size, but some coarse sand to granule-sized pellets are present. The rocks are gray-green to olive green when wet but are light gray to almost white when dry. Clay minerals include attapulgite (palygorskite), smectite (montmorillonite), and some sepiolite.

Most of the clayey beds in the Hawthorn in this area are very sandy, and all are lenticular. Some relatively pure clay beds are present, however. A bed from 86 to 90 ft below surface in drill hole no. 4 (fig. 7) was olive-green clay that contains only 5 percent, by weight, of material greater than 0.1 millimeter in diameter. Material less than 0.1 mm in diameter consists mainly of iron-rich smectite, minor attapulgite, and trace amounts of quartz, dolomite, and apatite.

The upper unit ranges in thickness from 0 to about 40 ft and thickens from west to east. This unit does contain some thin, lenticular dolomite beds but is generally unconsolidated and contains recoverable phosphate.

Unnamed Upper Miocene Formation.—An unnamed upper Miocene formation of distinctive lithology that ranges in thickness from 0 to almost 70 ft is present in cores from the six holes drilled during the prospecting program in the Ocala National Forest (fig. 7). The formation consists of dark-gray to dark-olive-gray and green (almost black) sandy clay to clayey sand containing abundant shell fragments and black phosphate grains. Where best developed, the basal part of the unit, just above the contact with the underlying Hawthorn Formation, contains abundant "pea"-sized quartz and black phosphate grains. This may represent a basal conglomerate and a break in deposition.

The shell material in the upper Miocene formation consists of calcite and aragonite, whereas fragmental shell material in the Hawthorn Formation is entirely calcite. The clay mineral in this post-Hawthorn is predominantly smectite, although some attapulgite is present in those samples that are just above the contact with the Hawthorn. Dolomite is present in only a few samples; calcite and aragonite are the dominant carbonate minerals. The shell material was too fragmental to be useful in identification, although fragments of a large pecten appeared to be different from the characteristic Hawthorn species. This formation is separated from the overlying Citronelle(?) Formation by a distinct difference in lithology and probably by a break in sedimentation. This upper contact may also be unconformable or disconformable.

All the formentioned data indicate that this unnamed formation is not a part of the Hawthorn but is separated from it by an unconformity. The unit is clearly younger than the Hawthorn and late Miocene in age, about equivalent to the Bone Valley Formation of the land-pebble phosphate district to the south.

Post-Miocene Beds

Beds of problematic age overlie the Miocene rocks. They consist of unconsolidated orange, red, and white mottled, poorly sorted, subrounded, fine to medium, and in some cases, coarse sand and clayey sand, typical of the lithology of the Pliocene Citronelle Formation (Cooke, 1945). The contact with the underlying "black" sandy clay of the upper Miocene is a profound break in lithology and may represent an unconformity. The Citronelle(?) is overlain by white loose surficial sand in the higher elevations and by sand and some swamp muck in the lower elevations, particularly along the shores of Little Lake George (fig. 2). The Citronelle(?) penetrated by holes drilled during the field investigation ranged from 40 to 60 ft in thickness; elsewhere in the Ocala National Forest, the unit is as much as 100 ft thick, as indicated by lithologic logs of company drill holes.

The Citronelle(?) was derived from erosion of older rocks in the immediate vicinity and contains a mixture of materials; for example, some samples contained dolomite and apatite fragments mixed with the aluminum phosphate mineral crandallite and, in one sample, the aluminum hydroxide mineral gibbsite. Samples of the clay fraction from these core holes contained mixtures of attapulgite, smectite, and koalinite.

The Citronelle(?) contains sediments that are characteristic of unweathered Hawthorn Formation (upper clastic and lower carbonate), the slightly weathered upper Miocene, and thoroughly weathered material. Possible sources for these materials are found in Hawthorn outcrops on the high parts of the Ocala Uplift and in the shallow subsurface close to the area of deposition. White surficial sand in the higher elevations is probably windblown sand of Holocene age. Swamp deposits and sand at lower elevations are probably the same age. These materials are present as thin surficial veneers no more than 5 ft thick at most places, but some company drill hole logs showed as much as 100 ft of "sand and humus," which are probably sink-hole fillings of Holocene age.

STRUCTURE

The Mesozoic and Cenozoic sedimentary rocks that underlie the Ocala National Forest dip gently to the east and thicken in that direction (fig. 1). The area is on the east flank but close to the crest of the Peninsular Arch, a broad anticline that extends in a northwest-southeast direction from Hamilton County on the north to Palm Beach County on the south, a distance of about 300 mi (Applin and Applin, 1967). In the Ocala National Forest, Cenozoic rocks are about 2,600 ft thick, and Cretaceous rocks are about 1,600 ft thick (fig. 1). To the east, at dry hole no. 19, Cenozoic rocks are about 3,100 ft thick, and Cretaceous rocks are 2,300 ft thick (fig. 1).

The surface of the Ocala Limestone is 50 ft above sea level at the western edge of the Ocala Forest and is 100 ft below sea level at the eastern edge (fig. 7), confirming the general shallow dip to the east. However, the surface is not uniform. A ridge, or high, on the surface trends southeast in about the center of the map, with distinct lows north and south of the high. These features may be due, in part, to erosion, but they probably also reflect local structure.

No faults have been recognized in the area, but the southeast-trending high on the Ocala surface (fig. 7) may have been caused by the slumping of blocks on either side of the high into solution cavities. The Hawthorn Formation is thin or absent on the high and thickens markedly in the lows to the north and to the south. The crustal movement that formed the Peninsular Arch probably continued into the Miocene during the deposition of the Hawthorne. Uplifting at this time would account for the westward thinning of the Hawthorn (fig. 7), inasmuch as deposition would have been restricted and erosion more active in the higher areas.

ASSESSMENT OF MINERAL RESOURCE POTENTIAL

Limestone, clay, sand, and peat are produced in the region in which the five areas are located (fig. 1). Peat is the most important identified resource. Hard-rock phosphate was produced many years ago from small mines located along and near the crest of the Peninsular Arch, about 40 mi to the west, and phosphate is being produced from mines in Hamilton County, about 100 mi to the north, and from Polk and Hillsborough Counties, about 90 mi to the south. Inferred subeconomic phosphate deposits underlie much of the five areas, but total tonnage and grade cannot be estimated with existing prospect data. Extensive deposits of limestone underlie the areas but are deeply buried. No heavy-mineral concentration rich enough for mining is known in the area. Although beds of clay are known to be present, they are probably lenticular and are buried too deeply to be minable. Clayey sand has been dug in the area for use in construction of Forest Service roads, but none is being mined at the present. The area has a low resource potential for oil and gas.

PEAT

Peat is a naturally occurring accumulation of plant remains in swamps and marshes. The term "peat" as defined by the American Society for Testing and Materials (1969) as organic material that, when burned, has an ash content not exceeding 25 percent on a dry weight basis. This ash results from clay or other inorganic material in the peat. To have resource potential for horticultural use, peat must have a thickness of 5 ft or more over an area exceeding 80 acres, or 4 ft or more over an area of several hundred acres. Peat for use as fuel must be at least 5 ft thick and extend over large areas. Some samples of organic material taken with a Davis sampler in the five areas were evaluated by an empirical hand-squeeze-ball method that permits determination of whether or not the ash content will exceed 25 percent. When a handful of peat is squeezed tightly, the resulting ball will easily fall apart if the ash content is less than 25 percent. Peat having an ash content greater than 25 percent will retain the ball shape. A Macaulay peat auger was used for coring and selection of samples for laboratory analyses. The Billies Bay, Juniper Priairie, and Little Lake George Wildernesses are the only areas in the Ocala National Forest that contain peat resources.

The Billies Bay Wilderness contains a large central swamp. Eight core holes (fig. 3) and numerous probe sites indicate an area of 1,455 acres containing commercial quality peat having an average thickness of 7 ft. Assuming an average density that will allow 1 acre-foot of peat to yield 200 tons of air-dried peat, we estimate peat resources of the Billies Bay Wilderness to be 2 million tons.

The cores show the stratigraphic relation of the peat with other organic materials and with marl and sand (fig. 8). Samples for laboratory analyses selected from cores number 1 through 8 of the Billies Bay Wilderness (figs. 3 and 8), contain humus and reed-sedge peat. Plant fibers readily distinguished in reed-sedge peat are so disintegrated in humus peat as to be indistinguishable. Quality differences between the reed-sedge and humus peat, however, are slight. Both generally contain less than 10 percent ash. British thermal units per pound range from 8,442 to 10,084, but decrease markedly for peaty material with ash content higher than 25 percent. The pH of the cores range from 2 to 3 near the surface to 6 to 7 at depth, especially near marl. Table 3 shows the proximate and ultimate analyses, British thermal units per pound, and forms of sulfur for samples from cores 6, 2, 8, 3 and 1. This data shows that British thermal units per pound is inversely proportional to, and sulfur is directly proportional to, ash content.

Trace element content is shown in table 4. Concentration of elements in the commercial quality peat appears to be greater in the samples with ash content of 10 to 25 percent. However, no significant anomalies occur.

The Juniper Prairie Wilderness (fig. 5) contains a cypress, cabbage palm, and hardwood swamp comparable to the Billies Bay swamp. It has an average thickness of 7 ft of commercial-quality peat throughout its 515 acres. Resources are estimated to be 700,000 tons of air-dried peat. A core taken near the center of the swamp shows 9 ft of humus peat resting on sand. Analyses of a sample taken at the 5-foot depth reveals an ash content of 21.4 percent and a pH of 6.8.

The Little Lake George Wilderness contains an area of 750 acres underlain by an average thickness of 7.5 ft of generally commercial-quality peat (fig. 2). However, the upper 2.5 ft contains thin layers of silt deposited when the river flooded during peat accumulation. Peat resources after the upper layer is removed is estimated to be 750,000 tons of good quality air-dried peat.

The Alexander Springs Wilderness (fig. 4) was probed for peat. Although the thickness of peaty material exceeds 5 ft at some places, the ash content below a depth of 4 ft exceeds the maximum for commercial-quality peat. A core taken near the center of the area revealed 8 ft of black peaty material resting on sand. A sample selected at the 5-foot depth in this core has an ash content of 64.5 percent and pH of 6.6.

The Baptist Lake Roadless Area (fig. 6) contains no peat resources as determined by probing and empirical testing.

PHOSPHATE

The phosphate deposits of central peninsular Florida are in the southernmost part of the north Florida-south Georgia district. Phosphate is present in the Hawthorn Formation and in younger rocks in which most of the phosphate has been reworked from the Hawthorn (Cathcart, 1968).

In the late 1960's, several phosphate companies drilled about 200 holes in the Ocala National Forest (fig. 7). Most drill cores contained so little phosphate that samples were not analyzed, and no commercial deposits were found.

The Hawthorn has been removed by erosion on the higher parts of the Peninsular Arch and is present only as erosional remnants in the westernmost part of the Ocala National Forest (fig. 7). The formation is present throughout the eastern part of the forest where drill hole data show that it ranges from 20 to about 90 ft in thickness. Moderate concentrations of phosphate are present in the upper part of the Hawthorn and in rocks of probable late Miocene age that overlie the Hawthorn.

Characteristics of Minable Phosphate Deposits

The economic limits for phosphate deposits are listed below. The maxima and minima listed are estimates of industry standards, based on current company practices. None of the criteria are absolute but are interdependent; for example, a deposit with very high P_2O_5 content probably could be mined even if the tonnage numbers were below the minimum listed here.

1. The phosphorus content is expressed as percent P_2O_5 or percent bone phosphate of lime (BPL). Chemically, BPL is equal to tricalcium phosphate $Ca_3(PO_4)_2$ and is equal to percent P_2O_5 x 2.185. The minimum in minable deposits is 60 percent BPL or about 28 percent P_2O_5.
2. Excess amounts of iron, aluminum, calcium, and magnesium are deleterious in phosphate deposits. Maximum iron and aluminium (expressed as the oxides Fe_2O_3 + Al_2O_3) allowable in commercial deposits is 5 percent, and the maximum magnesium (MgO) is 1.0 percent. Calcium is present in the minerals apatite, calcite, and dolomite. The ratio of CaO (in percent) to P_2O_5 (in percent) in apatite ranges from about 1.40 to about 1.55; the maximum ratio allowable is about 1.60.
3. The minimum minable tonnage, expressed as recoverable phosphate tons per acre per foot of thickness (tons per acre-foot), is 400, which is equal to about 20 percent, by weight, of recoverable phosphate particles (pebble plus concentrate).
4. Minimum minable thickness of a phosphate bed is about 3 ft, which is the least thickness that can be mined with large draglines.
5. Thickness of overburden that can be removed in profitable mining is expressed as the ratio of

this thickness to the thickness of the phosphate bed. The maximum is about 5 to 1.

6. The present maximum thickness of overburden plus phosphate that can be mined profitably in Florida is about 200 ft; however, this maximum applies only to high-grade deposits where the phosphate bed is more than 25 ft thick. Maximum limits of depth of phosphate strip mining in northern peninsular Florida are presently no more than 150 ft.

The phosphorite in the five areas is a subeconomic resource by today's standards. Some samples of the concentrate fraction contain more than 28 percent P_2O_5 (table 5), but the pebble fraction averages only about 13 percent. The concentrate fraction at drill hole 2 (fig. 4) could be economic, except that it is too deep. Although iron and alumina contents are below the maximum, tonnages of acceptable material are too low, and contents of MgO and CaO are slightly high. The phosphorite in the area is a subeconomic resource that will increase in value as the reserves presently being mined elsewhere are exhausted. Data from the scattered drilling indicate that the best phosphate is in the eastern parts of the study areas.

Uranium is present in all marine phosphorites in amounts that typically range from 1 to 300 parts per million (Cathcart, 1978). The uranium is syngenetic in origin and substitutes for calcium in the apatite structure. Analyses of uranium contents of samples from the core drilling of this study (table 6) show that the pebble fraction contains more uranium than the concentrate fractures. Samples of phosphorite from the unnamed upper Miocene formation are slightly higher in uranium than samples from the Hawthorn. Slime (-150 mesh) samples contain much less uranium than either the pebble or the concentrate samples and contain very nearly the same amount of phosphate as the head (total rock) samples.

Uranium has been recovered as a byproduct of the manufacture of phosphoric acid at several plants in the Florida land pebble phosphate district.

CLAY

Clay is mined from several localities to the north and to the west of the Ocala National Forest. Kaolinite is mined in the area near Edgar in T. 10 S., R. 23 E., about 40 mi to the north; the kaolinite is from sandy clay of the Citronelle(?) Formation. Fuller's earth is mined from the Hawthorn Formation near Emathla in T. 13 S., R. 20 E., 38 mi to the west.

Although kaolinite is present in samples taken from holes drilled in the Citronelle(?), the amount of the slime (-200 mesh) fraction is low, ranging from 4 to about 30 percent and averaging about 15 percent. The slime fraction contains abundant quartz as well as montmorillonite and some dolomite and attapulgite. The material, therefore, is such a mixture of minerals that it is very doubtful whether any deposits of kaolinite could be even remotely considered a potential resource.

Smectite is a common clay mineral in the Hawthorn, but examination of the core during the drilling showed that almost all samples were very sandy. Only one sample of clay was taken for tests by the USBM. According to Crandall (1981), the sample showed excellent ceramic properties and bloating characteristics. The sample, taken from the interval 86 to 90 ft below the surface at drill hole 4 (fig. 7), was chiefly a high-iron smectite, but also contained some attapulgite, quartz, dolomite, and a trace amount of apatite. The clays in the five areas have no value because they are too impure or too deeply buried

HEAVY MINERALS

Heavy minerals have been mined for many years from deposits about 60 air miles to the north of the five areas. Ilmenite, the ore of titanium oxide, is the principal mineral produced, but staurolite, monazite, zircon, garnet, and kyanite also are recovered (Garner, 1972, 1981). The heavy mineral deposits in the Trail Ridge mineral district are thought to have been concentrated by the winnowing action of ocean waves and currents (Pirkle and Yoho, 1970; Garner, 1972, 1981). The deposits are reported to contain about 3 percent heavy minerals (Pirkle and others, 1977).

No commercial heavy-mineral deposits are known to be present in the study areas, and none are likely to be found. Surficial sand and the sands of the Citronelle(?) Formation are low in heavy minerals—nine samples of cuttings from the drill holes contained from 0.2 to 0.8 percent and averaged only about 0.4 percent of heavy minerals, which is only about one-tenth of the concentration of commercial deposits. Mineral species found include ilmenite, garnet, zircon, staurolite, rutile, sillimanite, tourmaline, and kyanite, but no monazite has been identified.

LIMESTONE

The Ocala Limestone is quarried at several localities about 30 mi west of the Juniper Prairie Wilderness north and south of the town of Ocala (fig. 1). The limestone that underlies the Ocala National Forest is very pure (Schmidt and others, 1979) and contains from 96 to 98 percent $CaCO_3$ (Mossom, 1925). The amount of limestone present must be enormous; however, the top of the Ocala Limestone in the five areas is about 100 ft below surface. Abundant resources of limestone at or close to the surface are available in the area around the town of Ocala.

Sandy, phosphatic dolomite of the lower unit of the Hawthorn Formation is present under all of the area but is impure and deeply buried.

OIL AND GAS

Oil and natural gas are produced from the Lower Cretaceous Sunniland Limestone in southern Florida and from the Jurassic Smackover Formation in western panhandle Florida. Jurassic beds are not present in the area of the Ocala National Forest, and beds of Early Cretaceous age, present to the east and west, also are missing. Beds of Late Cretaceous age overlie Paleozoic rocks (Applin and Applin, 1944; U.S. Geological Survey, 1974).

Several exploratory holes for oil and gas have been drilled in and around the Ocala National Forest (fig. 1; table 1); all holes were dry and abandoned. Two holes were drilled by Amoco Production Co. in the Ocala National Forest (Nos. 18, 20, table 1). According to Crandall (1981), Amoco personnel stated that the primary production target was the Upper Cretaceous Atkinson Formation (fig. 1). The Atkinson is correlated with the Tuscaloosa Formation, from which oil is produced in Alabama and Mississippi (Applin and Applin, 1965).

In summary, the potential for oil and gas resources in the five areas is low. The reasons for this are the number of dry holes in the surrounding areas and the lack of rocks containing oil and gas that are present elsewhere in Florida.

REFERENCES CITED

American Society for Testing and Materials, 1969, D2607-69, Standard classification of peats, mosses, humus, and related products: Philadelphia, Pennsylvania, 1 p.

Applin, P.L., 1951, Preliminary report on buried pre-Mesozoic rocks in Florida: U.S. Geological Survey Circular 91, 28 p.

Applin, P.L., and Applin, E.R., 1944, Regional subsurface stratigraphy and structure of Florida and southern Georgia: American Association of Petroleum Geologists Bulletin, v. 28, no. 12.

_____1965, The Comanche Series and associated rocks in the subsurface in central and south Florida: U.S. Geological Survey Professional Paper 447, 86 p.

_____1967, The Gulf Series in the subsurface in northern Florida and southern Georgia: U.S. Geological Survey Professional Paper 524-G, 34 p.

Bridge, Josiah, and Berdan, J.M., 1952, Preliminary correlations of the Paleozoic rocks from test wells in Florida and adjacent parts of Georgia and Alabama, *in* Florida Bureau of Geology Guidebook, Association of American State Geologists 44th Annual Meeting Field Trip, 1952: p. 29-38.

Calver, J.L., 1949, Florida kaolin and clays: Florida Geological Survey Information Circular 2, 59 p.

Cathcart, J.B., 1968, Phosphate in the Atlantic and Gulf Coastal Plains, *in* Forum on Geology of Industrial Minerals, 4th, Austin, Texas, Proceedings: Texas University Bureau of Economic Geology, p. 23-34.

_____1978, Uranium in phosphate rock: U.S. Geological Survey Professional Paper 988-A, 6 p.

Cathcart, J.B., and Patterson, S.H., 1985, Geology of the Farles Prairie and Buck Lake Roadless Areas, Marion County, Florida: U.S. Geological Survey Miscellaneous Field Studies Map MF-1591-A, scale 1:24,000.

Cathcart, J.B., Patterson, S.H., and Crandall, T.M., 1983, Mineral resource potential of the Farles Prairie and Buck Lake Roadless Areas, Marion County, Florida: U.S. Geological Survey Miscellaneous Field Studies Map MF-1591-B, scale 1:24,000.

Cooke, C.W., 1945, Geology of Florida: Florida Geological Survey Bulletin 29, 339 p.

Crandall, T.M., 1981, Mineral resources of the Farles Prairie and Buck Lake RARE II Further Planning Areas, Marion County, Florida: U.S. Bureau of Mines Mineral Land Asssessment Report MLA 46-82.

Davis, J.H., Jr., 1946, The peat deposits of Florida,their occurrence, development and uses: Florida Geological Survey Bulletin 30, 247 p.

Espenshade, G.H., and Spencer, C.W., 1963, Geology of phosphate deposits of northern Peninsular Florida: U.S. Geological Survey Bulletin 1118, 115 p.

Garner, T.E., Jr., 1972, Economic geology of Florida heavy mineral deposits, *in* Puri, H.S., eds., Proceedings of Seventh Forum on Geology of Industrial Minerals: Florida Bureau of Geology Special Publication 17, p. 17-19.

_____1981, Heavy mineral industry of North America, *in* Coope, B.M., ed., Proceedings of the 4th Industrial Minerals International Congress: Atlanta, Georgia, 1980, p. 29-42.

Gulbrandsen, R.A., 1966, Chemical composition of phosphorites of the Phosphoria Formation: Geochimica et Cosmochimica Acta, v. 30, p. 769-778.

Mansfield, G.R., 1942, Phosphate resources of Florida: U.S. Geological Survey Bulletin 934, 82 p.

Milton, Charles, 1972, Igneous and metamorphic basement rocks of Florida: Florida Bureau of Geology Bulletin No. 55, 125 p.

Mossom, Stuart, 1925, A preliminary report on the limestones and marls of Florida: Florida Geological Survey, 16th Annual Report, p. 27-203.

Pirkle, E.C., and Yoho, W.H., 1970, The heavy mineral ore body of Trail Ridge, Florida: Economic Geology, v. 65, no. 1.

Pirkle, E.C., Pirkle, W.A., and Yoho, W.H., 1977, The Highland heavy-mineral sand deposit on Trail Ridge in northern peninsular Florida: Florida Bureau of Geology Report of Investigation No. 84, 50 p.

Puri, H.S., and Vernon, R.O., 1964, Summary of the geology of Florida and a guidebook to the classic exposures: Florida Bureau of Geology Special Publicaton No. 5 (revised), 312 p.

Rainwater, E.H., 1971, Possible future petroleum potential of peninsular Florida and adjacent continental shelves, *in* Cram, I.H., ed., Future petroleum provinces of the United States—their geology and potential: American Association of Petroleum Geologists Memoir 15, v. 2, p. 1311-1341.

Schmidt, Walter, Hoenstine, R.W., Knapp, M.S., Lane, Ed, Ogden, C.M., Jr., and Scott, T.M., 1979, The limestone, dolomite, and coquina resources of Florida: Florida Bureau of Geology Report of Investigations No. 88, 51 p.

Sever, C.W., Cathcart, J.B., and Patterson, S.H., 1967, Phosphate deposits of south central Georgia and north central Peninsular Florida: Georgia Department of Mines, Mining, and Geology, Project Report No. 7, South Georgia Minerals Program, 62 p.

U.S. Geological Survey, 1974, Final environmental statement—Proposed oil and gas operations in the Ocala National Forest, Florida: p. 2-19.