GEOLOGIC FEATURES OF AREAS OF ABNORMAL RADIOACTIVITY SOUTH OF OCALA, MARION COUNTY, FLORIDA

By Gilbert H. Espenshade

Trace Elements Memorandum Report 941

UNITED STATES DEPARTMENT OF THE INTERIOR

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Geology and Mineralogy

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Gilbert H. Espenshade

March 1956

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GEOLOGIC FEATURES OF AREAS OF ABNORMAL RADIOACTIVITY SOUTH OF OCALA, MARION COUNTY, FLORIDA

By Gilpert H. Espenshade

ABSTRACT

Areas of abnormal radioactivity south of Ocala, Marion County, Fla., discovered in 1953 by aerial survey, were investigated by surface examination and by 10 power auger drill holes. Interbedded clay, clayey sand, and uraniferous phosphorite occur in the areas of anomalous radioactivity. Miocene fossils occur at three localities in these beds which are evidently outliers of Miocene sediments on the Ocala limestone of Eocene age. The preserved outliers are southwest of the main belt of Miocene sediments.

The principal uraniferous rocks are clayey, sandy, pellet phosphorite that occurs in beds a few feet thick, and very porous, phosphatic sand rock which makes abundant float at many places. Apatite forms the phosphate pellets in the unweathered phosphorite. The very porous, phosphatic sand rock is the highly leached residuum of the pellet phosphorite and is composed mainly of quartz, kaolinite, wavellite, and crandallite (pseudowavellite). It closely resembles the aluminum phosphate rock of the "leached zone" of the Bone Valley formation in the land-pebble phosphate district.

INTRODUCTION

The geology of some areas of abnormal radioactivity south of Ocala, Marion County, Fla., was investigated as part of the Geological Survey's program of study of uraniferous phosphate deposits on behalf of the Division of Raw Materials of the U. S. Atomic Energy Commission. These anomalies had been discovered by the Geological Survey in 1953 in the course of aerial reconnaissance for uraniferous phosphate deposits (Moxham, 1954). One of the anomalous areas was examined at that time, and several other anomalies were later explored by means of a jeep-mounted power auger (Cathcart, 1954). The writer and L. A. Brubaker examined most of the anomalous areas in March 1955, and put down 10 drill holes at 3 localities with a power auger. Samples were taken for chemical analysis and mineralogic study, and the drill holes were logged with a portable scintillation gamma-ray logger.

The writer is grateful for the contributions made to this study by L. A. Brubaker during the field work and by other colleagues of the Geological Survey.

RADIOACTIVITY ANOMALIES

The occurrence of phosphate in this area had previously been reported by Matson (1915, pl. 3), and Cooke (1945, p. 158-159, pl. 1), who recognized outliers of phosphatic Hawthorn formation resting upon Ocala limestone, and by various prospectors (Cathcart, J. B., personal communication, 1955). For this reason the area was one of ten in Florida selected by J. B. Cathcart for airborne radioactivity survey. The aerial survey was made with scintillation-detection equipment by flying parallel traverse lines, a quarter of a mile apart, at about 500 feet above the ground (Moxham, 1954). Irregular areas of abnormal radioactivity were found between Ocala and Summerfield, about 13 miles to the southeast (fig. 1). The average background radioactivity here, presumably over Ocala limestone, was about 1 μr per hour (microroentgens per hour) at 500 feet above the ground; the highest anomalies recorded reached a maximum of 11 μr per hour. _/ Moxham (1954) points out that the anomalies seem to conform more or less to outliers of Hawthorn formation, shown on the state geologic map by Cooke (1945). Several small areas of high radioactivity found during the geologic investigation are shown on figure 1; these evidently lie between the flight lines of the aerial survey. The area was not completely covered by ground examination, and it is possible that other small anomalies exist which were not detected.

_/ These values have been corrected from the values originally reported by Moxham (1954), namely 0.25 μr per hour for average background radioactivity and 2.75 μr per hour for maximum radioactivity, which were found by later calibration tests to be too low (Moxham, personal communication, 1955).

GEOLOGY

Stratigraphy

Ocala limestone

The Ocala limestone of late Eocene age is the oldest formation exposed in the region. Exposures of the Ocala limestone are scarce. Beds a few feet thick crop out in some sink holes, but the formation is best exposed in abandoned quarries in the area covered by figure 1, and in active quarries a few miles to the north. Ocala limestone presumably lies beneath a thin mantle of soil and sand, in nearly all of the area shown in figure 1 except the areas of anomalous radioactivity.

The Ocala limestone is a very fossiliferous, soft, porous, white to cream-colored limestone; weathered surfaces are bluish-gray. This limestone is characteristically almost pure and contains very little insoluble material. Light gray chert with silicified fossils occurs in lenticular masses a few inches to several feet thick that extend along the bedding.

Miocene sediments

Within the areas of abnormal radioactivity, the Ocala limestone is overlain by beds of clay, sandy clay and sand. Phosphate pellets are abundant in some layers. These layers are exposed in only a very few places, but float of phosphate pellets, sandy phosphorite, and leached porous phosphorite is found at various places in the areas of abnormal radioactivity. Information about the detailed stratigraphy and lithology of these beds is derived mainly from the logs of the auger drill holes (figs. 2, 3, and 4). Beds composed largely of clay alternate with sandy beds that contain moderate amounts of clay; phosphate pellets are larger and more abundant in some sandy beds than in clay. The thickest sequence of beds presumed to be of Miocene age, nearly 65 feet, was cut in drill hole 28 (fig. 3); a thickness of 58 1/2 feet of beds assigned to the Miocene was cut in hole 30 (fig. 4).

Fossils of Miocene age were found on the surface at three localities within areas of radioactivity anomalies. Hard, white sandy limestone with small phosphate pellets is exposed in slumped beds about 5 feet thick in a small pit about 200 feet northeast of drill hole 21 (fig. 2, fossil locality 63). Similar fossiliferous limestone occurs as float and low edges along the road bed at fossil locality 108, about 9 miles to the northwest (fig. 1); silicified oysters, shark teeth, manatee ribs, and abundant phosphate pellets are scattered over the surface here. The fossils at these two localities are considered by Druid Wilson of the U. S. Geological Survey to be of early or middle Miocene age; his report on these fossil collections is quoted below.

"Locality 63 - NW1/4 SW1/4 sec. 2, T. 17 S., R. 22 E., Marion County, Fla.
Fossiliferous sandy phosphatic limestone 5 ft. below surface in small pit about 15 ft. deep.

Foraminifera:

"Sorites" sp.

Pelecypoda:

Modiolus cf. curtulus Dall
Cyrena? sp.
Macrocallista cf. floridana (Conrad)
Chione (Lirophora) sp.
Venus cf. halidona Dall
Venus cf. marionana Dall
Dosinia cf. chipolana Dall

Gastropoda:

Pleurodonte cf. kendrickensis Mansfield
Bulimulus sp.
Uzita cf. paraprista Gardner
Calyptraea trochiformis Lamarck

Locality 108 - Along dirt road, about 0.6 mi. NE from junction (in NE 1/4 sec. 35, T. 15 S., R. 21E.) with Shady Lane road, Marion County, Fla.

Foraminifera:

"Sorites" sp.

Pelecypoda:

Chama cf. draconis Dall
Chione cf. trimeris Gardner
Dosinia sp.

Gastropoda:

Pleurodonte sp.
Bulimulus sp.
Calyptraea trochiformis Lamarck

Other marine genera of mollusks which cannot be identified specifically might be listed from both localities 63 and 108.

Age (Localities 63 and 108): Early or middle Miocene.

The collections from localities 63 and 108 apparently represent the same fauna from Marion County referred by Mansfield (1937, Fla. Geol. Survey Bull. 15, p. 23) to the Tampa limestone. It should be pointed out that none of the distinctive Tampa genera was listed by Mansfield nor do they occur in the present collection. The land snails Pleurodonte and Bulimulus are common in the two collections but this cannot be regarded as proof that the fauna is of early Miocene (Tampa) age, although land snails have not been reported in Florida either in the Oligocene or later than Tampa Miocene. Some species, as indicated by Mansfield (p. 24) and some in the present collection suggest an age younger than Tampa. The group of Chiones to which Chione cf. trimeris belongs has not been reported earlier than the Chipola Miocene."

In a limestone quarry at locality 78, about 1 1/2 miles south-southwest of Belleview (fig. 1), solution pipes 5 to 10 feet deep in Ocala limestone are filled with dark brown to green, stiff clay containing phosphate pellets, manatee ribs, and large silicified oysters. Wilson has identified these oysters as Ostrea normalis Dall of Miocene (Hawthorn) age.

The Miocene foraminifera, "Sorites" sp., was identified by Druid Wilson in sample X280 from a depth of 30 to 37 feet in drill hole 27 (fig. 3). The late Eocene foraminifera, Heterostegina ocalana Cushman, and orbitoid sp. and camerinid sp. were found associated with "Sorites" sp. in sample X281 from a depth of 37 to 41.5 feet in drill hole 27.

The fossils cited above support the view that the beds of phosphorite, sands, and clays within the areas of anomalous radioactivity are Miocene in age. Cooke (1945, p. 158 - 159) reached the same conclusion on the basis of the abundant float of very porous sandy phosphorite that occurs in these areas. He recognized this rock as the completely weathered remnant of phosphatic beds which he regarded as outliers of the Hawthorn formation. The outliers of Hawthorn formation which he shows on the geologic map of Florida south of Ocala (Cooke, 1945, pl. 1) correspond closely to the areas of anomalous radioactivity here. Larger outliers of the Hawthorn formation also occur northwest of Ocala; the main outcrop belt of the formation is farther east and north.

At various places in the canal cuts west of the radioactive anomalies (fig. 1), tough clayey sand that is mottled red and orange by weathering rests upon Ocala limestone and is covered with loose, light yellow sand. This massive clayey sand is probably Miocene in age; it closely resembles clayey sand about 30 miles to the south in Hernando and Pasco Counties that Cooke (1945, p. 153, 159) believes to be derived from the Hawthorn formation.

The Miocene sediments rest unconformably upon the Ocala limestone in the Ocala area. The Suwannee limestone of Oligocene age, which is widespread in Hernando and Pasco Counties, is not known to be present here.

Pleistocene sediments

Some geologists working in the southeastern Coastal Plain have recognized ancient shore lines and terraces at various altitudes, and have concluded that the sea stood at higher levels during interglacial stages of the Pleistocene. The highest shore line is regarded as the oldest, and each lower shore line as being successively younger. Cooke (1945, p. 245 - 311) has recognized seven, and possibly eight, shore lines, with the highest at an altitude of 270 feet. MacNeil (1950) has recognized four Pleistocene shore lines in Florida, the highest being at 150 feet; he believes that Cooke's higher shore lines may be fluvial in origin rather than marine.

No ancient shore lines can be recognized with certainity in the Ocala area from study of the topographic maps or aerial photographs; but, as Cooke (1945, p. 285) has pointed out, ground-water solution of the Ocala limestone has modified the surface topography and may have obliterated such shore lines here. However, pebble deposits and sands that may be beach deposits and are probably of Pleistocene age, are found at several places. Several hundred feet west of sample locality 94 (fig. 1), a gravel sheet composed of pebbles and cobbles of sandstone and leached sandy phosphorite is exposed in the roadbank between 115 and 135 feet altitude. Near the small radioactivity anomaly about 0.7 mile to the southeast, similar gravels are exposed at two places along the road; the altitude at one locality is about 150 feet, and at the other locality about 125 feet. Bedded, light yellow sand with thin clayey layers several inches apart and containing charcoal fragments is exposed at an altitude ranging from 70 to 80 feet in the canal cut 2 to 3 miles west of the area shown in figure 1. The bedded sand is as much as 8 feet thick, and overlies the mottled red and orange tough clayey sand of probable Miocene age, and lies beneath several feet of loose, white and light yellow sand that also contains charcoal fragments. This unbedded surficial sand may be wind blown in origin; it is well exposed at altitudes ranging from 80 to 100 feet in the canal cuts shown in figure 1.

Structure

This area is about 20 miles east of the axis of the Ocala uplift, an extensive northwest-trending anticline that is the major structural feature in the Eocene and younger formations in northern peninsular Florida. Northwest-trending faults and irregular flexures occur on the anticline, according to Vernon (1951, pl. 2). His structural map suggests that the Miocene outliers south of Ocala may be preserved in a locally downwarped area.

None of these regional structural features was detected in the small area studied. Bedding in the Ocala limestone where exposed in quarries seems to be horizontal. A nearly vertical fault plane, trending more westerly than those shown by Vernon (1951), is exposed in the northwestern corner of a small abandoned quarry in the SW 1/4 sec. 25, T. 15 S., R. 21 E. (fig. 1). The fault strikes between N. 80° and 85° W.; grooves and slickensides on the fault plane plunge 15° to 20° W., indicating the major component of movement to have been horizontal. The nature of the slickensides suggests eastward movement of the northern block, but the evidence is inconclusive.

Effects of weathering

Ground-water leaching of the soluble constituents of the Ocala limestone and the Miocene sediments has been very thorough and has been a dominant factor in the development of the soils and topography in the area. The Ocala limestone is very permeable and contains little insoluble material; solution sinkholes have been widely developed in the limestone.

The Miocene sediments, however, contain much insoluble material in the form of clay and sand, and they are less susceptible to leaching. The apatite pellets in the Miocene phosphorite commonly have been rather resistant to weathering and are found scattered over the ground at many places. However, apatite pellets have been completely dissolved in some phosphorite to leave a very porous, pumicelike sandstone with cavities relict from the pellets. Soils in the areas of Miocene sediments are characteristically dark brown, and their composition ranges from loamy sand through sandy loam to sandy clay. A soil sample from about 1 1/2 miles east-southeast of Ocala was found to contain 5.35 percent P_2O_5 (Sellards and others, 1915, p. 123). These soils support a distinctive native vegetation, including such deciduous trees as hickory, sweet gum, red oak, white oak, and maple (Sellards and others, 1915).

In all probability, a sheet of Miocene sediments originally covered the Ocala limestone in this area. Stream erosion removed much of the Miocene sediments, but as the Ocala limestone was exposed, the surface drainage gradually changed from a stream system to a sinkhole system. All drainage now is by underground channels.

The areas of anomalous radioactivity for the most part have an altitude of 100 feet above sea level or higher, although considerable land above the 100-foot contour is outside the radioactive areas. It would appear, therefore, that the altitude of the contact between the Ocala limestone and the Miocene sediments is about 100 feet above sea level at many places. However, this contact is extremely irregular probably because of both pre-Miocene erosion and solution of the Ocala limestone, and post-Miocene solution of the Ocala limestone accompanied by slumping of the Miocene sediments.

About 0.6 mile northwest of Monroes Corner (fig. 1), the base of the Miocene beds was found at an altitude of about 54 feet in drill hole 25, but is at least 66 feet lower in drill hole 28 on the edge of a sinkhole, 600 feet to the north. In many exposures of the Ocala limestone, solution pipes filled with residuum of Miocene sediments are evident. Ground-water solution of the Ocala limestone has resulted in random draping of the Miocene sediments and their residuum into hollows and over hummocks in the limestone.

DRILLING AND SAMPLING METHODS

Areas of anomalous radioactivity were explored at three localities by 10 drill holes (total length of 335 feet) drilled by means of a jeep-mounted power auger. The auger drill cut readily through the unconsolidated phosphatic clayey and sandy beds, and also into soft Ocala limestone in several holes but would not penetrate consolidated rock; probably the hard rock that stopped the drill in most holes was hard Ocala limestone or silicified Ocala limestone, but in some holes it may have been hard phosphatic limestone of Miocene age.

Cuttings brought to the surface by continuous drilling with the auger provide poor samples because it is not possible to determine closely the depths from which the cuttings came. In order to reduce this uncertainity, the holes were drilled in 5-foot increments, and the drill rods were pulled out and the cuttings removed after each 5-foot run. Where drilling was above the ground-water table, the cuttings from a 5-foot interval usually filled the screws for a distance of 8 to 10 feet above the bit, and it was a simple matter to estimate depth of contacts. The surface of the mass of cuttings on the screws was usually coated with sand rubbed on from the sides of the hole as the rods were pulled up; before taking the sample off the rod, the sand was sliced off the cuttings over a width of several inches along the full length of one side of the rod, and about an ounce of material was then taken off every screw flange or every other screw throughout an interval of uniform lithology. Several holes were drilled into soft, water-soaked material that would slide off the screw flanges and yield very poor recovery of cuttings. Where recovery was good, it is believed that the lithologic logs made as the cuttings were taken off the rods are fairly reliable, because the highly phosphatic zones indicated by the cuttings generally correspond rather well with the strongly radioactive zones recorded by the scintillation detector (figs. 2, 3, and 4). It was not possible to log each hole with this instrument immediately after drilling, with the result that caving occurred in the lower parts of some holes, and only the uncaved parts of the holes could be logged with the scintillation detector.

URANIFEROUS PHOSPHATIC MATERIALS

The uraniferous phosphatic materials found in drilling consist of fresh, soft, phosphatic sediments (principally pellet phosphorites and phosphatic clays), and the highly weathered, leached residuum of these phosphatic sediments. Each of these classes of materials was also found in surface exposures or float. The general characteristics of these different phosphatic materials are described below.

Pellet phosphorite

Pellet phosphorite beds were cut in the auger drill holes 0.6 mile northwest of Monroes Corner (fig. 3) and in the drill holes about 2 1/4 miles east of this locality (fig. 2). The beds range from several feet to 14 1/2 feet in thickness. The phosphorite is a light gray to tan sandy clay that contains variable amounts of phosphate pellets. These pellets are well-rounded, usually less than half an inch in size, and are light colored with shiny surfaces; they are composed of apatite (carbonate-fluorapatite variety according to George Ashby, U. S. Geological Survey, oral communication) and contain inclusions of quartz grains.

The content of U, P_2O_5, and quartz in samples of pellet phosphorite are given in table 1. Total P_2O_5 ranges from 3.1 to 20.8 percent, and total U ranges from 0.004 to 0.022 percent. No consistent relation exists between the total amount of U and the total amount of P_2O_5 in these samples. In several samples (X260, X296, and X297) high P_2O_5 and high U are associated, but in other samples high P_2O_5 is accompanied by low U (samples X280 and X281) and low P_2O_5 is accompanied by high U (samples X266 and X277).

Within the different size fractions of these samples, however, a rather consistent relation exists between the content of U and P_2O_5. Both P_2O_5 and U are most abundant in the plus 20 mesh fractions and the minus 150 mesh fractions. Between 80 and 90 percent of the total P_2O_5 and U in all but one sample (X270) is contained in these two size fractions together. The material between minus 20 mesh and plus 150 mesh in size consists largely of quartz sand. The plus 20 mesh fractions have a high content of apatite pellets; the percent of this size fraction in the different samples ranges from 3.3 to 40.8 percent. In the minus 150 mesh fractions, phosphate is presumably present as fine apatite, and is accompanied by clay and fine quartz. In samples with large plus 20 mesh fractions, most of the P_2O_5 and U are present in this coarse fraction, but in samples with small plus 20 mesh fractions, P_2O_5 and U are mainly in the minus 150 mesh fractions.

Table 1. U, P_2O_5, and quartz content (in percent) of different size fractions of samples of pellet phosphorite from drill holes in area south of Ocala, Marion County, Florida.

Sample	U	P_2O_5	quartz 1/	total sample weight	total U in sample	total P_2O_5 in sample	total quartz in sample
X260 (DH25, 1.0'-3.0'):							
+20 mesh	0.019	25.8	---	38.1	48.7	57.2	---
-20 +48 mesh	0.009	12.4	---	7.7	4.7	5.5	---
-48 + 150 mesh	0.005	7.4	---	7.4	2.5	3.2	---
-150 mesh	0.014	12.5	---	46.8	44.1	34.1	---
Total	0.015	17.1	---	100.0	100.0	100.0	---
X266 (DH25, 17.0'-21.0'):							
+20 mesh	0.031	20.4	29.3	14.5	22.7	34.9	11.9
-20 + 48 mesh	0.008	5.4	79.6	9.5	3.9	6.0	21.1
-48 + 150 mesh	0.002	1.6	92.4	24.0	2.4	4.5	61.9
- 150 mesh	0.027	8.9	3.5	52.0	71.0	54.6	5.1
Total	0.020	8.4	37.8	100.0	100.0	100.0	100.0
X270 (DH26, 4.5'-7.5'):							
+20 mesh	0.010	18.2	---	3.3	7.7	7.5	---
-20 + 48 mesh	0.004	7.8	---	11.8	10.9	11.5	---
-48 + 150 mesh	0.002	5.0	---	25.0	11.7	15.7	---
- 150 mesh	0.005	8.7	---	59.9	69.7	65.3	---
Total	0.004	8.0	---	100.0	100.0	100.0	---

1/ Quartz in + 20 mesh fractions consists mostly of grains included in phosphate pellets.

Analysts: G. Daniels, G. Edgington, T. Murphy, R. Smith, A. Sweeney, J. Waring, U. S. Geological Survey.

Table 1. U, P_2O_5, and quartz content (in percent) of different size fractions of samples of pellet phosphorite from drill holes in area south of Ocala, Marion County, Florida.--Continued.

Sample	U	P_2O_5	quartz 1/	total sample weight	total U in sample	total P_2O_5 in sample	total quartz in sample
X272 (DH26, 12.0'-16.0'):							
+20 mesh	0.018	28.2	18.2	18.5	63.2	50.2	14.1
- 20 + 48 mesh	0.007	13.2	54.1	3.9	5.2	5.0	8.9
- 48 + 150 mesh	0.003	6.6	77.5	11.3	6.4	7.1	36.5
- 150 mesh	0.002	5.9	14.6	66.3	25.2	37.7	40.5
Total	0.005	10.3	23.9	100.0	100.0	100.0	100.0
X276 (DH27, 9.0'-17.5'):							
+ 20 mesh	0.015	11.7	---	5.4	9.2	20.3	---
- 20 + 48 mesh	0.007	2.3	---	10.6	8.3	7.8	---
- 48 + 150 mesh	0.001	0.6	---	43.1	4.8	8.2	---
- 150 mesh	0.017	4.9	---	40.9	77.7	63.7	---
Total	0.009	3.1	---	100.0	100.0	100.0	---
X277 (DH27, 17.5'-21.0'):							
+ 20 mesh	0.020	14.0	35.8	8.2	7.4	20.4	6.9
- 20 + 48 mesh	0.012	3.9	75.1	10.8	5.7	7.4	18.9
- 48 + 150 mesh	0.001	1.4	93.2	31.8	1.4	7.9	69.3
- 150 mesh	0.039	7.4	4.3	49.2	85.5	64.3	4.9
Total	0.022	5.6	42.8	100.0	100.0	100.0	100.0

Table 1. U, P_2O_5, and quartz content (in percent) of different size fractions of samples of pellet phosphorite from drill holes in area south of Ocala, Marion County, Florida. --Continued.

Sample	U	P_2O_5	quartz 1/	total sample weight	total U in sample	total P_2O_5 in sample	total quartz in sample
X280 (DH27, 30.0'-37.0'):							
+ 20 mesh	0.005	30.2	---	37.7	37.3	54.5	---
- 20 + 48 mesh	0.005	17.8	44.9	11.0	10.9	9.4	---
- 48 + 150 mesh	0.003	9.1	71.8	15.3	9.1	6.7	---
- 150 mesh	0.006	17.1	12.1	36.0	42.7	29.4	---
Total	0.005	20.8	---	100.0	100.0	100.0	---
X281 (DH27, 37.0'-41.5'):							
+ 20 mesh	0.006	27.9	---	40.8	52.3	55.4	---
- 20 + 48 mesh	0.005	21.1	---	11.0	11.8	11.3	---
- 48 + 150 mesh	0.002	11.0	---	12.2	5.2	6.6	---
-150 mesh	0.004	15.2	---	36.0	30.7	26.7	---
Total	0.005	20.5	---	100.0	100.0	100.0	---
X290 (DH28, 40.0'-43.5'):							
+ 20 mesh	0.014	23.5	15.5	29.9	79.4	76.9	9.4
-20+48 mesh	0.005	10.7	44.8	4.7	4.5	5.5	4.3
-48+150 mesh	0.001	2.0	90.6	45.6	8.6	10.0	84.2
- 150 mesh	0.002	3.5	5.2	19.8	7.5	7.6	2.1
Total	0.005	9.1	49.1	100.0	100.0	100.0	100.0

Table 1. U, P_2O_5, and quartz content (in percent) of different size fractions of samples of pellet phosphorite from drill holes in area south of Ocala, Marion County, Florida.--Continued.

Sample	U	P_2O_5	quartz 1/	total sample weight	total U in sample	total P_2O_5 in sample	total quartz in sample
X296 (DH29, 4.5'-7.5'):							
+ 20 mesh	0.021	26.9	12.7	34.5	50.8	60.6	13.0
-20 + 48 mesh	0.010	11.6	55.2	9.0	6.3	6.9	14.8
- 48 + 150 mesh	0.003	4.8	82.8	27.1	5.7	8.5	66.6
- 150 mesh	0.018	12.5	6.5	29.4	37.2	24.0	5.6
Total	0.014	15.2	33.7	100.0	100.0	100.0	100.0
X297 (DH29, 7.5'-9.0'):							
+20 mesh	0.023	27.3	14.5	20.3	30.8	38.1	17.8
-20 +48 mesh	0.011	15.6	50.4	3.1	2.2	3.3	9.4
- 48 + 150 mesh	0.004	4.8	82.4	12.1	3.2	4.0	60.5
- 150 mesh	0.015	12.3	3.2	64.5	63.8	54.6	12.3
Total	0.015	14.5	16.5	100.0	100.0	100.0	100.0

The U, P_2O_5, and quartz content of samples of what appears to be the same phosphorite bed in 4 different drill holes are compared in table 2. This bed ranges from 3 1/2 to 4 1/2 feet in thickness, and is underlain by a bed of clay (fig. 3). In drill hole 28 a phosphorite bed 14 1/2 feet thick may be the same bed that has been thickened by flowage or slumping into a sink hole. The variation in composition of this bed within short distances is very marked. Percent P_2O_5 ranges from 5.6 to 15.0, percent U from 0.005 to 0.022, and percent quartz from 23.9 to 42.8; percent of plus 20 mesh fraction ranges from 8.3 to 29.7, and percent of minus 150 mesh fraction from 41.1 to 66.4.

Clay

Beds of stiff, greenish clay, 2 to 9 feet in thickness, were cut in most of the drill holes (figs. 2, 3, and 4). Small white phosphate particles are commonly present in the clay. The percent P_2O_5 ranges from 3.5 to 9.8, and percent U from 0.001 to 0.006 (table 3). The mode of occurrence of uranium was not determined; it is not known whether uranium is associated only with apatite, or whether some uranium may be associated with the clay minerals. Considerable fine-grained quartz occurs in the clay; some of the samples that are reported to have more than 20 percent quartz may have been contaminated by adhering loose sand that was not completely removed when the sample was taken.

Leached phosphorite

White to gray, very porous sandy rock with numerous ovoid cavities forms abundant float at many places in the areas of abnormal radioactivity. This float was originally more widely distributed than it is now; much of it has been gathered into piles of field stone, or used to build walls, chimneys, or foundations. The material makes a good building stone, because it commonly occurs as massive blocks several feet in size, and can be readily sawed or cut.

Table 2. U, P_2O_5, and quartz content (in percent) of samples of same (?) bed of pellet phosphorite from 4 different drill holes in area, south of Ocala, Marion County, Florida.

	X296 and X297 (DH29, 4.5'-9.0')	X272 (DH26, 12.0'-16.0')	X266 (DH25, 17.0'-21.0')	X277 (DH27, 17.5'-21.0')
Entire sample:				
U	0.014	0.005	0.020	0.022
P_2O_5	15.0	10.3	8.4	5.6
quartz	28.0	23.9	35.8	42.8
+ 20 mesh fraction				
U	0.022	0.018	0.031	0.020
P_2O_5	27.0	28.2	20.4	14.0
quartz (nearly all included in phosphate pellets)	13.3	18.2	29.3	35.8
total sample	29.7	18.5	14.5	8.3
total U in sample	44.1	63.2	22.7	7.4
total P_2O_5 in sample	53.1	50.2	34.9	20.4
total quartz	14.6	14.1	11.9	6.9
- 150 mesh fraction:				
U	0.017	0.002	0.027	0.039
P_2O_5	12.4	5.9	8.9	7.4
quartz	5.4	14.6	3.5	4.3
total sample	41.1	66.4	52.0	49.2
total U in sample	46.0	25.2	71.0	85.5
total P_2O_5 in sample	34.2	37.7	54.6	64.3
total quartz in sample	7.9	40.5	5.1	4.9
+ 20 mesh and - 150 mesh fractions combined				
total sample	70.8	84.9	66.5	57.4
total U in sample	90.1	88.4	93.7	92.9
total P_2O_5 in sample	87.3	87.9	89.5	84.7

Analysts: G. Edgington, R. Smith, A. Sweeney, J. Waring, U. S. Geological Survey

Table 3. U, P_2O_5, and quartz content (in percent) of samples of clay from drill holes in area south of Ocala, Marion County, Florida.

Sample	U	P_2O_5	quartz
X245 (DH21, 6.2'-10.0')	.002	5.6	25.8
X246 (DH21, 10.0'-11.0')	.001	4.3	16.2
X250 (DH22, 10.5'-13.5')	.002	7.0	26.7
X251 (DH22, 13.5'-17.5') 1/	.001	7.2	---
X258 (DH24, 5.0'-11.5')	.002	5.1	30.0
X261 (DH25, 3.0'-4.8')	.001	5.8	16.9
X263 (DH25, 6.0'-9.0')	.002	4.3	28.7
X265 (DH25, 12.0'-17.0')	.006	7.3	10.1
X267 (DH25, 21.0'-23.0')	.003	7.1	11.4
X271 (DH26, 7.5'-12.0')	.002	6.1	12.4
X273 (DH26, 16.0'-17.5')	.004	8.3	20.9
X278 (DH27, 21.0'-27.0')	.002	9.8	20.1
X279 (DH27, 27.0' -30.0')	.001	4.1	---
X293 (DH28, 54.5'-60.5')	.001	4.1	9.2
X298 (DH29, 9.0'-13.5')	.001	5.9	21.8
X309 (DH30, 34.5'-43.5')	.001	3.5	23.6

1/ X251 also has 10.4 percent CaO, 9.5 percent, total Al_2O_3, 7.8 percent soluble Al_2O_3.
X-ray powder diffraction analysis of minus 250 mesh fraction of X251 showed quartz, a montmorillonite mineral, attapulgite, and apatite.

Analysts: G. Daniels, M. Delevaux, T. Murphy, D. Riska, R. Smith, A. Sweeney, W. Tucker, and J. Waring, U. S. Geological Survey .

The rock is composed mainly of quartz grains held together by a white cement in a cavernous or honey-combed structure. Ovoid cavities containing a little sand or claylike material are obviously relict from dissolved apatite pellets; partly decomposed pellets are still present in some cavities. The rock is the end product of weathering of clayey, sandy, pellet phosphorite, such as the beds that were cut in drill holes 25 to 29 (fig. 3). Minor amounts of compact phosphatic sand with low porosity are found with the vesicular rock; this compact rock was derived probably from sandy-clayey phosphorite that did not contain large apatite pellets.

Partial chemical analyses of surface samples of leached phosphorite are given in table 4. Samples of very porous, leached phosphorite are rather uniform in composition, with P_2O_5 ranging from 12.7 to 16.8 percent, U from 0.019 to 0.023, Al_2O_3 from 14.7 to 20.0, and quartz from 40.1 to 54.1; specific gravity of the rock is about 1. The compact, leached sandy phosphorite is more variable in composition; a sample containing apatite pellets (82) has less Al_2O_3 and much more CaO than samples of the highly leached material.

The samples of leached phosphorite from 3 drill holes differ somewhat in composition from the surface samples; P_2O_5 is lower in all the drill samples, and U is lower in the 3 samples from one drill hole (table 5). Minerals present in the minus 250 mesh fractions of 2 drill samples were determined by X-ray powder diffraction methods to be wavellite, crandallite (pseudowavellite), kaolinite, and quartz. The mineralogy, as well as the physical appearance, of the leached porous phosphorite of this area resembles that of the aluminum phosphate rock of the "leached zone" of the Bone Valley formation of the land-pebble phosphate field, about 85 miles to the south (Altschuler, Jaffee, and Cuttitta, 1955).

CONCLUSIONS

The areas of abnormal radioactivity south of Ocala are related to thin beds of uraniferous phosphorite in outliers of Miocene sediments. Much of the radioactivity is probably derived from outcrops and float of leached porous phosphorite that is similar in appearance and composition to the aluminum phosphate rock of the "leached zone" of the Bone Valley formation. Abnormal radioactivity at some places in the Ocala area is caused by unleached, uraniferous pellet phosphorite.

Table 4. U, P_2O_5, Al_2O_3, CaO, and quartz content (in percent) of samples of leached phosphorite from surface outcrops and float in area south of Ocala, Marion County, Florida.

Sample	Specific gravity	U	P_2O_5	Al_2O_3 (total)	Al_2O_3 (soluble)	CaO	quartz
Very porous, leached phosphorite:							
83	0.9 - 1.0	0.023	16.8	20.0	18.3	1.24	40.1
84	<1.0	0.021	15.5	17.2	16.3	0.73	47.6
87	1.2	0.022	15.4	16.1	15.5	0.90	50.8
94	0.9	0.020	12.7	16.0	14.2	2.82	47.1
97	1.0	0.020	13.7	14.7	13.5	0.34	54.1
C	---	0.019	14.6	---	---	---	---
Compact, leached sandy phosphorite:							
82	1.3 - 1.4	0.016	15.9	7.9	7.2	18.8	42.3
85	1.8	0.006	6.6	13.8	9.7	0.17	58.4
89	1.5	0.017	15.0	17.2	15.7	2.59	42.8

Analysts: R. Moore, R. Smith, A. Sweeney, and W. Tucker, U. S. Geological Survey

Description and location of samples:

82 - Composite sample from boulders of white phosphatic sandstone containing phosphate pellets. From NW 1/4 NE 1/4 sec. 10, T. 17 S., R. 22 E., Marion County, Fla.

83 - Composite sample of porous, leached phosphorite containing a few relict phosphate pellets. From SW 1/4 NE 1/4 sec. 3, T. 17 S., R. 22 E., Marion County, Fla.

84 - Composite sample of very porous, leached phosphorite. From NW 1/4 SE 1/4 sec. 4, T. 17 S., R. 22 E., Marion County, Fla.

85 - Composite sample of compact, sandy-clayey phosphorite. From NW 1/4 SE 1/4 sec. 4, T. 17 S., R. 22 E., Marion County, Fla.

87 - Composite sample of very porous, leached phosphorite. From NW 1/4 sec. 4, T. 17 S., R. 22 E., Marion County, Fla.

89 - Composite sample of sandy phosphorite with soft white phosphate pellets. From SE 1/4 SE 1/4 sec. 5, T. 17 S., R. 22 E., Marion County, Fla.

94 - Composite sample of very porous, leached phosphorite. From center of south edge of sec. 1, T. 16 S., R. 21 E., Marion County, Fla.

97 - Composite sample of very porous, leached phosphorite. From SE 1/4 NW 1/4 sec. 1, T. 16 S., R. 21 E., Marion County, Fla.

C - Sample taken by J. B. Cathcart (see Cathcart, 1954) of "outcrop of aluminum phosphate zone" in sec. 11, T. 16 S., R. 21 E., Marion County, Fla.

Table 5. U, P_2O_5, Al_2O_3, CaO, and quartz content (in percent) of samples of leached phosphorite from drill holes in area south of Ocala, Marion County, Florida.

Sample	U	P_2O_5	Al_2O_3 (Total)	Al_2O_3 (Soluble)	CaO	quartz
X242 (DH21, 1.0'-2.5')	0.008	6.3	---	---	---	64.8
X243 (DH21, 2.5'-8.5') 1/	0.004	6.6	8.8	7.5	1.80	---
X244 (DH21, 3.5'-5.7')	0.006	5.4	---	---	---	68.1
X249 (DH22, 1.0'-10.5') 1/	0.026	8.7	13.8	10.6	0.11	---
X307 (DH30, 23.5'-30.5') 2/	0.017	3.3	---	---	---	---

1/ Analyses of minus 250 mesh fractions of X243 and X249 by X-ray powder diffraction methods showed wavellite, crandallite (pseudowavellite), kaolinite, and quartz.

2/ U and P_2O_5 content of different size fractions of Sample X307 are as follows:

Size fraction	U	P_2O_5	total sample weight	total U in sample	total P_2O_5 in sample
+ 20 mesh	0.018	12.5	8.3	9.0	31.3
-20 +48 mesh	0.005	2.3	8.8	2.7	6.1
-48 +150 mesh	0.002	0.5	58.9	7.1	8.9
-150 mesh	0.056	7.4	24.0	81.2	53.7
Total	0.017	3.3	100.0	100.0	100.0

Analysts: G. Daniels, M. Delevaux, G. Edgington, T. Murphy, D. Riska, R. Smith, A. Sweeney, W. Tucker and J. Waring, U. S. Geological Survey.

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