UNITED STATES DEPARTMENT OF THE INTERIOR
Harold L. Ickes, Secretary

U.S. GEOLOGICAL SURVEY
W. C. Mendenhall, Director

Bulletin 934

PHOSPHATE RESOURCES OF FLORIDA

BY

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UNITED STATES
GOVERNMENT PRINTING OFFICE
WASHINGTON : 1942

For sale by the Superintendent of Documents, Washington, D. C. - - - - - - - - - - Price $1.00

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PHOSPHATE RESOURCES OF FLORIDA

By G. R. Mansfield

ABSTRACT

At the hearings before the Congressional Joint Committee to Investigate the Adequacy and Use of Phosphate Resources of the United States, held at Lakeland, Fla., November 28, 1938, much information not hitherto available regarding the phosphate resources of Florida was presented. Wayne Thomas, as spokesman for the phosphate industry, read a brief that forms the background of the investigation here reported.

Through the courtesy of company officials and Mr. Thomas the writer has had access to much prospecting and other information, some of it confidential, and has been able to check parts of Mr. Thomas' statement and to frame more or less independent estimates of the phosphate reserves of Florida. Methods of prospecting and their bearing upon the estimation of reserves and selection of minable areas are briefly discussed. The introduction of finer-sized screens and of flotation and other means of concentration have increased available tonnage in some areas from 1½ to 10 times and have improved the grade of material to be recovered. Examples of older and newer methods of prospecting are discussed and illustrated. Reserves in the different fields are classified, so far as practicable, according to grade and as known, probable, and possible. Maps especially prepared for this report by Mr. Thomas and by W. L. Akin through D. B. Kibler, Jr., manager for J. Buttgenbach & Co., show revised outlines of known prospected areas in the hard-rock field, new boundaries for the land-pebble areas, and principal ownership of phosphate lands in the pebble field. Estimates are made separately, according to the categories mentioned, for river pebble, land pebble (several different areas), and hard rock; and for the Steinhatchee district, which contains both hard rock and pebble. These estimates total 1,377,000 acres and 5,081,839,000 long tons, all grades considered. Of the total tonnage, 2,058,583,000 tons are classified as known, 1,227,146,000 tons as probable, and 1,796,110,000 tons as possible. The Hawthorn formation and Caloosahatchee marl mentioned in the Thomas brief as possible sources of immense tonnages of phosphate are not included in these figures, as information about their phosphate content is at present too meager.

The report also contains an account of the 66,796 acres of withdrawn public lands in the Florida phosphate fields, including a list of individual areas arranged by counties and by township, range, and section. The results of prospecting activities by the Government on some of these lands (in 1927 by J. T. Pardee and, as Public Works projects, in 1934 and 1935 by P. V. Roundy) are summarized. Although comparatively little high-grade phosphate has been found in these lands, large tonnages of lower grades are indicated. The relatively large tonnages in the fines, formerly discarded, tend greatly to increase the estimates.

INTRODUCTION

In the light of previous ideas regarding the character and extent of phosphate reserves in Florida, the information contained in the brief presented by Wayne Thomas, real-estate and investment broker of Plant City, Fla., at the hearing before the Congressional Joint Committee to Investigate the Adequacy and Use of Phosphate Resources of the United States, held at Lakeland, Fla., on November 28, 1938, is new and even startling. The brief is restrained in tone, however, and the statements in it are cautiously made with every appearance of fairness and honesty. As a Government agency entrusted with the study of the Nation's mineral resources, the Geological Survey must recognize this new information relating to Florida phosphate, inquire into the background and soundness of the views expressed, and formulate conclusions concerning the phosphate reserves after taking the new information into account. The plan adopted by the writer of this report is to outline the events leading to the presentation of the brief, to quote the brief itself, to explain the methods by which the phosphate companies and others concerned with Florida phosphates estimate the phosphate content of their holdings, and finally to express such independent opinions as the results of the studies seem to justify. In pursuit of this purpose the writer stayed in Florida nearly 3 weeks after the hearings at Lakeland to interview producers and others regarding phosphate resources. Also after the draft of his report was written he revisited Florida in July 1939 and spent about 10 days interviewing the State geologist, company managers, Mr. Thomas, and others to check his findings.

As the Government is a landowner in different parts of the hard-rock and pebble phosphate fields it seems pertinent to include some account of the Government's holdings and of its activities in relation to these holdings.

ACKNOWLEDGMENTS

The producers of Florida phosphate and others interested in the industry have been most cordial and cooperative and have reiterated their desire to assist the writer in every possible way. He has leaned most heavily on Wayne Thomas for information on the pebble-phosphate areas and on D. B. Kibler, Jr., manager for J. Buttgenbach & Co., Lakeland, for data on the hard-rock field. Mr. Thomas, as spokesman for the industry at the hearings, had been entrusted with special information by the producers and, in his own experience as a prospector of and dealer in phosphate lands, had acquired independent knowledge of a wide range of data including the location, character, and ownership of phosphate lands in many parts of the State but especially in the pebble field. His office was a mine of information, including blue prints, maps, prospecting reports, and other data. The writer spent several days in discussions with Mr. Thomas, who

was kind enough to display and explain his material and to give or loan representative samples of it for use in preparation of this report. To Mr. Thomas the writer is also indebted for two important maps especially prepared for his use (see pls. 5 and 7), and for many personal courtesies. Mr. Kibler has been similarly kind and helpful with respect to data on the hard-rock field. In addition to numerous conferences and other courtesies he contributed the services of W. L. Akin, a veteran hard-rock prospector, for the preparation of the map used as plate 8 in this report and for guidance to several field localities. He also made available the mine map used as plate 4 and conducted the writer on a trip to active mines in the vicinity of Dunnellon. R. B. Fuller, manager of the International Agricultural Corporation (I. A. C.),[1] Mulberry, supplied information on the holdings and reserves of his company and the prospecting map used as plate 6, together with many prospecting data. To him and his associates the writer is indebted for an opportunity to see the operations of his company and for many personal courtesies. C. E. Heinrichs, of the same company, contributed valuable suggestions. C. A. Fulton, president of the Southern Phosphate Co., Ridgewood, E. A. Pierce, vice preisdent and manager, and their associates also freely gave data on prospecting results and reserves. Plate 3 of this report is taken from one of their maps. Mr. Fulton afforded the writer an opportunity to view the operations of the company and extended personal courtesies. H. F. Greene, manager of the Coronet Phosphate Co., Plant City, kindly supplied data. Burdett Loomis, Jr., manager of the American Agricultural Chemical Co. (A. A. C.), Pierce, devoted much time to discussion of phosphate problems and tendered numerous personal courtesies. Maj. H. L. Mead, manager of the American Cyanamid Co., Brewster, permitted the writer to inspect data of the company and also tendered personal courtesies. Herman Gunter, State geologist, was very helpful in promoting acquaintance with phosphate producers and in discussing phosphate problems. M. H. Grace, president of the Phosphate Export Association, New York, encouraged the writer greatly in his search for information on phosphate resources. Many other citizens of Florida did much to make the writer's stay in that State pleasant and to promote his project, and their assistance is deeply appreciated.

INTEREST IN PHOSPHATE IN 1938

The activities of the Tennessee Valley Authority in the production of phosphatic fertilizers for experimental purposes and the results of experiments conducted by agricultural experiment stations, farmers' associations, and individuals in association with the Tennessee Valley Authority have been made public from time to time. Stress has been laid on the proper use and conservation of phosphate and on the need

[1] The International Agricultural Corporation has now become the International Minerals & Chemical Corporation.

for wider use of phosphates by farmers, not only to improve the yield of specific crops but also to restore the depleted fertility of soils and to prevent soil erosion. The need for reducing the cost of fertilizers to the farmer has been emphasized.

The various estimates of phosphate reserves in Florida and Tennessee published by the Geological Survey and other agencies seemed to show that future supplies of phosphate in these two States were meager in comparison with those in the States of Idaho, Utah, Montana, and Wyoming. Persons interested in the development of the western phosphates were desirous of setting up in that field some agency that would do for the farmers of the Western States what the Tennessee Valley Authority was doing for those in the Southeastern States.

The President, having had the matter brought to his attention, sent to Congress a special message, dated May 20, 1938, in which he declared that the Nation should adopt a national policy for the production and conservation of phosphates and recommended that a joint committee be named to study the subject of phosphate resources and to make a report to the next Congress. Pursuant to this message the Seventy-fifth Congress passed Public Resolution No. 112, approved June 16, 1938, and in accordance with section 2 of this resolution appointed the Congressional Joint Committee to Investigate the Adequacy and Use of the Phosphate Resources of the United States. This Committee at once proceeded to hold hearings in Washington, D. C. Later hearings were held in Pocatello, Idaho (July 20–23). Wilson Dam, Ala. (November 21–22), Knoxville, Tenn. (November 23–25), and Lakeland, Fla. (November 28–30). The writer, as a representative of the United States Department of the Interior, was delegated to attend all these hearings.

The evidence presented in the earlier hearings stressed the inadequacy of the available supplies in Tennessee and Florida and the desirability of their conservation, including even the proposal that export of phosphate from these States be prohibited by law. Producers in these States took alarm at this proposal. Hitherto they had not worried greatly about future supplies, as each company had prospected and blocked out deposits of phosphate sufficient to provide for many years of operation. With the threat of possible loss of their export trade, which constituted about a third of their annual business, they put aside for the time being considerations induced by the highly competitive nature of the business and made available for presentation to the Committee information that hitherto had been closely guarded.

The results of this action in expanding the knowledge of the phosphate resources of Florida and Tennessee were probably little less amazing to the producers themselves than to the members of the Committee and the interested public who attended the hearings. Each producing group in these States committed its information to a spokesman, who prepared a brief for presentation before the Committee. The spokesman from Tennessee was H. Alison Webster, of Columbia, Tenn., whose material [1a] has been considered in a publication of the Division of Geology, Tennessee Department of Conservation. The spokesman from Florida was Wayne Thomas.

THE THOMAS BRIEF

As Mr. Thomas' brief and the ensuing discussion based upon it form the principal substance of this report it seems well to present the brief in full.

CONGRESSIONAL PHOSPHATE HEARING,
Lakeland, Fla., November 28, 1938.

My name is Wayne Thomas. I live in Hillsborough County. I have been a resident of Florida since 1904. My business is the discovery, development, and sale of phosphate properties; and land utilization with particular reference to pasture lands, timber, and reforestation. As a boy in Bartow, Fla., more than 30 years ago, I studied phosphate plants then operating—the old Foote-Commercial on Peace River; the Pharr phosphate plant south of Bartow; Greenhead, Dominion, Phosphoria, Tiger Bay, and other mines in Polk County. During the last 12 years I have prospected phosphate lands extensively in Polk, Hillsborough, Manatee, Hardee, Lake, Pasco, Hernando, and other counties. I have examined phosphate properties in many parts of the State and have records bearing on all types of phosphate lands. In recent years I have developed and sold several properties located well beyond the boundaries of the hitherto recognized phosphate district. I know more than 30 prospectors who, as field foremen, have operated from 1 to 8 prospecting crews in the pebble field, some of them for 25 or 30 years. I have maps, field notes, and reports of many of these men showing their findings throughout the State. Several are residents of Lakeland, and most of them live in some part of Polk County. It is upon the work of these men that the figures and estimates which I am about to give you are largely based.

The outstanding survey of Florida phosphate was that by George H. Eldridge in 1890, published in 1892 as a part of the Eleventh Census, Department of the Interior, report on mineral industries.[2] Mr. Eldridge visited Florida for several months in 1890, again in 1891; subsequently he prepared the map here shown. [See pl. 1.] Mr. Eldridge's investigations were made under the United States Geological Survey. Evidently because his map was made by the Census Bureau, it became lost to our Florida operators and has only recently come to our attention. Mr. Eldridge classified Florida phosphate in three divisions:

(1) A hard-rock belt extending from Tallahassee to a point south of Dade City in Pasco County—a belt 200 miles long, averaging 20 miles in width.

(2) Land-pebble areas, centering around Jasper in Hamilton County, around Waldo in Alachua County, north of Green Cove Springs in Clay County, north of Leesburg in Sumter and Marion Counties, south of what is now Lakeland (then not even a spot on the map), west of Peace River including portions of Polk, Hillsborough, Manatee, and De Soto Counties.

[1a] See Smith, R. W., and Whitlatch, G. I., The phosphate resources of Tennessee: Tennessee Div. Geology Bull. 48, pp. 378-387, 1940.

[2] Eldridge, G. H., Phosphate rock, Florida, in 11th Census, 1890, Report on mineral industries in United States, pp. 687-689, map, 1892. See also Eldridge, G. H., A preliminary sketch of the phosphates of Florida: Am. Inst. Min. Eng. Trans., vol. 21, pp. 196-231, 1893.

(3) Two large areas of so-called river pebble, embracing a large part of Hillsborough County, nearly all of Manatee County, including what is now Sarasota County, the northern part of De Soto and Charlotte Counties, and a large part of Lee County. Subsequently these then-called river-pebble deposits have been reclassified as Manatee marl and Caloosahatchee marl. These marls cover an extensive area. They lie in many cases under an overburden only 3 to 6 feet in thickness, and they contain 25 to 40 percent bone phosphate of lime (B. P. L.). By the application of oil flotation, it is a simple matter to improve this feed to grades ranging from 66 to 74 percent B. P. L. When other and better Florida phosphates are exhausted, these large areas of low grade could produce millions of tons, perhaps as much as a billion tons of commercial phosphate at a cost comparatively low.

PEBBLE PHOSPHATES

Hamilton County.—The pebble phosphates of this county occur under overburden averaging 16 feet, and with an indicated average of 3,800 tons per acre, containing in some holes more than 10,000 tons per acre. These deposits extend over a wide area between the Withlacoochee and the Alapaha Rivers. The Alapaha shows extensive shoals of pebble phosphate supposedly eroded from land-pebble deposits north and west, extending across the Georgia line. The pebble-bearing area of Hamilton County embraces 62,000 acres, of which the area of greatest concentration is estimated at 14,000 acres containing a probable reserve of 50 million tons which averages in grade from 58 to 70 percent B. P. L., with iron and alumina (I and A) content less than 4 percent. It has been determined that at the cost of grinding and applying flotation, grades of Hamilton County phosphate can be raised to 77 percent B. P. L.

Clay County.—The pebble-phosphate area of this county is an extensive tract of which Black Creek is the approximate center. This area, about 15 miles long and 10 miles wide, shows pebble phosphate under light overburden, averaging 3,500 tons per acre. In 100,000 acres of this district, one-fourth, or about 25,000 acres, is calculated to yield pebble phosphate between 55 and 68 percent B. P. L. to a total of 90 million tons. As in Hamilton County, the principal impurity in the deposit is coarse silica, easily removed by grinding and flotation.

Bradford County.—In this county, north of the Santa Fe River between Sampson, Brooker, and Hampton, is a pebble area ranging up to 70 percent B. P. L and embracing an estimated total of 16,000 acres containing a probable 55 million tons. Like the Hamilton County deposits, these Bradford deposits are adaptable to the process of grinding and flotation, which will materially improve the grades. A secondary pebble-phosphate deposit occurs along both sides of Olustee Creek, in Columbia and Union Counties. This little-known area may prove extensive, as geological conditions are favorable and the overburden is light.

Lake and Orange Counties.—A pebble deposit of large extent, under light overburden, extends south of Lake Norris, along Blackwater Creek and in the vicinity of Lake Tracy. Prospectors report phosphate pebble in the vicinity of Cassia and in Orange County north and east of Rock Springs Run. In the sparsely inhabited portions of eastern Lake County and extending into northern Orange County it seems possible to develop 100 millions tons of pebble phosphate analyzing in B. P. L. 55 percent or better—some of it very high grade.

Polk and Hillsborough Counties.—The extensive pebble-phosphate field of these counties reaches a long distance into Manatee, Hardee, and Highlands Counties. This area includes southeastern Hillsborough, the western half of Polk from the Withlacoochee River south, the northern half of Hardee County and Northeastern Manatee County to the Sarasota County line. The southeastern corner of the pebble field is indefinite, but it is known to include a considerable part of Highlands County. At one point in Highlands County is a proven bed of 5 million tons on 1,000 acres, under 16 feet overburden and averaging 70 percent B. P. L. This largest of pebble areas, called Bone Valley, is estimated at 1,400,000 acres. [See pl. 5.] Pebble-phosphate deposits of a concentration of above 1,000 tons per acre are found under half of this area, or on about 700,000 acres. Many parts of Bone Valley have a pebble concentration ranging from 10,000 to 36,000 tons per acre. In one instance 24,000 tons per acre has been mined—all that could be removed economically at the time—and still a stratum of several feet remains for mining at some future time. The entire phosphate-bearing area under 700,000 acres appears to contain an average of 4,000 tons per acre. A total of 2 billion 800 million (2,800,000,000) tons of 55 percent B. P. L. or better in this area is classified as follows:

800,000,000 tons averaging 66 percent B. P. L. or better, under an overburden ranging from 6 to 36 feet and averaging under 20 feet, with I and A impurities of less than 4 percent.

1,000,000,000 tons ranging from 60 percent to 66 percent B. P. L., with an I and A content of less than 4 percent, overburden averaging less than 25 feet and ranging from outcroppings to 60 feet.

1,000,000,000 tons averaging from 55 percent to 60 percent B. P. L., with I and A content of less than 4 percent and overburden less than 30 feet average.

The bed upon which these Bone Valley deposits rest is a subdivision of Hawthorn, resting upon Vicksburg limestone. The bedrock, under the pebble-phosphate deposits worked at present, varies in thickness from a few feet to 800 feet. This formation is highly phosphatic, containing a heavy concentration of phosphate pebbles, fossils, and coarse phosphate rock ranging up to 80 percent in B. P. L., and often averaging in the mass 40 percent B. P. L. or higher. The tonnage of these bedrock deposits is so great and the totals so enormous that I hesitate to suggest any figures. If ever needed, these deposits can be mined and concentrated to high grades at moderate cost.

The bedrock underlying now minable pebble areas in Hamilton, Clay, Columbia, Bradford, and other counties previously mentioned, contains an aggregate of billions of tons of phosphatic material, possibly as high in grade as the bedrock of the pebble deposits in the Polk-Hillsborough field. Logs of wells from Nassau County down to Fort Myers, in Lee County, show existence of successive phosphate strata down to a maximum of more than 800 feet. We have here a map showing the location of some of these wells. We have analyses recently made of the phosphatic content of some of them. [Exhibit.]

The seven companies now operating in the Bone Valley pebble field have nominally set up their reserves as 477,311,735 tons. Keep in mind that in these figures the pebble-producing companies, with two exceptions, have not included:

(1) Their recovery (flotation) values.
(2) Any estimate for unprospected lands.
(3) Any grades averaging less than 66 percent B. P. L.
(4) Any deposits with overburden averaging more than 36 feet.
(5) Any rock with I and A content averaging more than 4 percent.
(6) As minable, any deposit with grade under 70 percent B. P. L. where the deposit averages less than 3,000 tons per acre.

In other words, the active companies have considered only the cream of their proven deposits—rock of high commercial grade which can be produced under keenly competitive conditions at the lowest possible cost. These seven active companies now operating in the pebble field are:

	Acreage owned
American Agricultural Chemical Co	52, 085
International Agricultural Corporation	44, 070
American Cyanamid Co	20, 140
Phosphate Mining Co	16, 480
Coronet Phosphate Co	13, 116
Southern Phosphate Corporation	11, 360
Swift & Co	6, 630
	163, 881

The total acreage owned by these companies is 163,881. The reserves they have prospected and included in the above estimates cover less than 80,000 acres.

In addition to the reporting companies, there are these inactive companies which by the same standards have a total of 250,000,000 tons of pebble rock:

	Acreage owned
Armour Fertilizer Works	2, 560
Baugh Chemical Co	2, 760
Bradley Estates, Inc	10, 190
Davison Chemical Co	2, 125
Dominion Phosphate Co	653
Florida Phosphate Mining Co. (Royster)	1, 670
Pembroke Chemical Co	1, 230
Polk Phosphate Co	5, 315
Tennessee Corporation	2, 760
Tilghman (Independent Chemical Co.)	4, 820
Virginia-Carolina Chemical Co	18, 545
	52, 628

In addition to these inactive companies, there are 42 local corporations and individuals owning phosphate property, none of which has been included in the above totals; the estimated tonnage so owned is in excess of 300 million tons.[3]

RIVER PEBBLE

Extensive river deposits on the Caloosahatchee, Alafia, Peace, Withlacoochee South, Withlacoochee North, Alapaha, Santa Fe, Olustee, and other rivers and streams were once actively worked, particularly along Peace River, which was the locale of 30 mines. These mines were definitely abandoned in 1908, not because of exhaustion of these deposits but because of the competition of high grades from the land-pebble field. It seems reasonable to assume that there is a total of more than 50 million tons of river-pebble rock in the many Florida streams.

TOTAL PEBBLE PRODUCED

Succeeding the production of river pebble, the mining of land-pebble phosphate began in a small way in 1889. Since that time a total of 70 million tons has been produced in the pebble field. This includes both river pebble and land pebble—river pebble prior to 1908 and all pebble through 1937. The land-pebble production has been taken from about 14,000 acres. In other words, only 2 percent of this Bone Valley pebble area has been mined in the 49 years since land-pebble mining began. Many of these original deposits have been reworked, with the

[3] The properties held by the active and inactive companies are shown in plate 7.

reclaiming, included in the totals, of more phosphate the second time than was taken out when first mined. Many of these old workings can be mined again with the recovery of greater values and in many cases higher grades than were secured from the original operations. This conservation has been achieved by scientific improvements, engineering, and flotation.

HARD ROCK

The Florida hard-rock industry has been established 50 years, or since 1888 In this 50 years a total of 12 million tons of phosphate has been mined. The total mined-out acreage producing the 12 million tons is slightly less than 2,000 acres, or about 4 percent of the total estimated area of Florida reserves of hard rock. A few pits opened 40 years ago have been worked and reworked continuously—each time to deeper levels—thus reclaiming more material. In the beginning the average tons mined per acre was much less than it is today. Under present improved mining methods, up to 25,000 tons per acre has been mined on some deposits. For example, note these mines in Marion, Citrus, and Hernando Counties:

	Tons
(1) Globe:	
Original mining	25, 000
Recent mining	180, 000
(2) Section 22 No. 1:	
Original mining	15, 000
Recent mining (1928)	175, 000
(3) Section 22, No. 2:	
Original mining	15, 000
Recent mining	185, 000
(4) Section 35:	
Original mining [4]	105, 000
Recent mining and prospecting	175, 000
(5) Felicia:	
Original mining	40, 000
Recent mining (1919–28)	275, 000
(6) Blue Run:	
Original mining [4]	25, 000
Recent mining (1919–26)	225, 000
(7) Griggs:	
Original mining [4]	50, 000
Recent mining (1928)	150, 000
(8) Anderson & Eureka:	
Original mining	100, 000
Shown by 1937 and 1938 prospecting	250, 000

Mines in the past have operated in more than 500 locations in the hard-rock field of Florida, some of these in far western counties such as Gadsden. In 1907 there were 45 operating companies producing hard-rock phosphate. In 1909 there were only 20 companies operating in 74 locations. One of the 74 was in Suwanee County, 3 in Columbia County, 22 in Alachua County, 12 in Marion County, 34 in Citrus County, and 2 in Hernando County. The outbreak of the World War closed the hard-rock field except for a limited output by 1 company. Immediately after the war 9 companies resumed mining and operated until 1922. Competition from north Africa and falling prices reduced these until at the

[4] See Mr. Akin's figures on p. 45.

present time only 3 companies are operating. Thirty-five percent more phosphate is now saved by the 3 companies operating than was the case 5 years ago (1933) before recovery processes were developed and applied. These 3 companies remain in business only because they are able to export almost all of their output. All rock exported to foreign countries is sold at a much higher price f. o. b. Florida ports than domestic users pay f. o. b. Florida ports. The land now owned by these 3 companies contains a reserve, according to their own prospecting figures, of 46,506,000 tons.

One prospector, W. L. Akin, of Dunnellon and Ocala, has devoted himself for the past 30 years to locating hard-rock deposits. His activities have been confined entirely to the eastern edge of the hard-rock belt—along this edge because he sought to locate deposits convenient to existing railroads and under moderate overburden, where production costs could be kept low. In this 30 years Mr. Akin from preliminary prospecting has located 11,390 acres of high-grade phosphate land and 19,100 acres of lower-grade phosphate land. [See pl. 8.] On the 11,390 acres of high-grade phosphate land, 5 million tons (located on slightly more than 500 acres) has been mined behind Mr. Akin's prospecting. Forty-six million tons of other hard-rock phosphate found by Mr. Akin remains to be mined. These figures are mentioned to illustrate the life work of one man devoted continously to the location of minable phosphate convenient to a railroad. In this work Mr. Akin has covered the hard-rock area, as it is now outlined, from end to end, but only along the eastern edge of the field, it being necessary to remain close to existing rail lines so that low production cost can be maintained.

Hard-rock deposits are found in 15 Florida counties. The heaviest known concentration is an axis through Suwannee, Columbia, Gilchrist, Alachua, Levy, Marion, Citrus, Sumter, and Hernando Counties, ending in Pasco County northeast of Dade City. This area is 100 miles long, 30 miles wide in the center, and contains 1,500 square miles. Workable high-grade deposits have been found to occur on about 5 percent of this highly phosphatized area. In this hard-rock district the total workable areas, carrying 5,000 to 20,000 tons per acre, cover an estimated 480,000 acres, which at the low figure of 5,000 tons per acre account for two billion four hundred million tons (2,400,000,000). Approximately one-third of the total hard-rock phosphate reserves of heavy concentration is phosphatic clay or soft phosphate. This phosphatic clay runs 55 percent B. P. L. and without treatment shows 3 to 7 percent immediately soluble P_2O_5 available to crops. This product is now used only for composting, direct application to soils, or as a filler in fertilizers.

Steinhatchee District.—The hard-rock phosphate of the Steinhatchee district lies in an area 3 to 10 miles wide and 25 miles long, covering about 150,000 acres and embracing parts of three counties—Taylor, Lafayette, and Dixie; principally Lafayette. Hard-rock boulder is the predominating, immediately considered value, for the reason that the hard-rock boulder in the formation analyzes from 76 to 85 percent B. P. L. One report recently issued by Alabama engineers, after an extensive survey and much prospecting, accounts for the existence of 19 million tons of rock on 2,000 acres. Much of the tonnage in the Steinhatchee district is in phosphatic gravels and soft phosphates. The Steinhatchee district apparently will account for a total of 600 million tons, of which 100 million tons is hard-rock boulder of large size and high grade, 250 million tons is phosphatic gravel containing from 55 to 60 percent B. P. L., and 250 million tons of phosphatic clay containing an average of 55 percent B. P. L. While much of the Steinhatchee boulder rock is low in I and A content, the bulk of it appears to run from 4 to 5 percent, making it undesirable for the manufacture of superphosphate by the wet process but desirable for furnace use for recovery of elemental phosphorus and phosphoric acid. The Monsanto Chemical Co. has recently acquired holdings in the Steinhatchee district to be held as a reserve.

SUMMARY

Summarizing the known Florida phosphates of immediate interest, we find these reserves:

	Million tons
River pebble	50
Hamilton County pebble	50
Bradford County pebble	55
Lake County pebble (including Orange County)	100
Clay County pebble	90
Bone Valley pebble	2, 800
Total land pebble and river pebble	3, 145
Total hard-rock tonnage, combining boulder rock, gravel, and phosphatic clay	3, 000

In addition to the above more than 6 billion tons, we have several probable areas on which sufficient data to make adequate estimates is lacking at this time. Florida has two large areas of so-called phosphatic marls in Manatee, Charlotte, and Lee Counties, and extending into other counties, which by beneficiation may be raised to adequate commercial grades.

Florida's vast group of phosphates lying deep in the Hawthorn formation is too enormous to be estimated. In this connection note that the Hawthorn formation occupies 20 million acres; it extends down to 800 feet; its average depth is certainly more than 100 feet. Investigations so far made indicate that in 33 wells from 20 counties there are strata of 50 feet to 100 feet of phosphatic material, on which beneficiation may be applied if needed, raising the rock to grades of 66 to 80 percent B. P. L. Some of these wells show a tonnage of 50,000 tons per acre. The average may be 5,000 tons per acre, or it may be 10,000 tons per acre. In any case the totals run to astonishing figures. This estimate is best left to some future report of the United States Geological Survey. Apparently a few feet of the top crust of the shallow phases of the concentrated high-grade Hawthorn will yield 20 billion tons. * * * The use of all these enormous phosphate deposits is simply a matter of economics. The rock is here, whenever the market will pay something more for it than it does today.

EARLIER OFFICIAL ESTIMATES OF PHOSPHATE RESERVES IN FLORIDA

The first official estimates of phosphate reserves in Florida were published in 1916 by Phalen,[5] who estimated 227,000,000 long tons of phosphate for the whole of Florida but who did not say how this figure was obtained. In a subsequent publication, however,[6] he explained his method as follows:

HARD ROCK

Several maps of the Florida phosphate fields have been published, but they are of a general nature and attempt to show only the approximate location of bound-

[5] Phalen, W. C., Phosphate rock in 1915, with simple tests for phosphate, by W. B. Hicks: Mineral Resources U. S., 1915, pt. 2, p. 238, 1916.

[6] Phalen, W. C., The conservation of phosphate rock in the United States: Am. Inst. Min. Eng. Trans., vol. 57, pp. 122–123, 1918. See also Tennessee Geol. Survey, Resources of Tennessee, vol. 6, pp. 193–216, 1916; 2d Pan-Amer. Sci. Cong. Proc., vol. 8, pp. 772–806, 1917. Mr. Phalen credits Dr. E. H. Sellards, former State geologists, with valuable suggestions in preparing this note on the Florida phosphate rock reserves.

aries. Even this is difficult to do with any degree of accuracy without careful prospecting. In estimating the available hard rock, some idea of the total area in the State within which such deposits may occur is essential. The estimates made agree fairly closely and indicate that the workable beds of hard phosphate rock in Florida occur throughout an area of several hundred square miles. The area actually underlain by workable deposits of hard rock is, however, but a small fraction of that within which the deposits have been mapped. There are, moreover, no existing data from which one may calculate the area underlain by workable deposits with a degree of accuracy that would have any practical value whatever.

Sections of square miles could be taken within which the deposits have been most completely mined out and tonnage estimates made from them, but figures thus obtained could not be used in other areas as a standard, since over many square miles there are no deposits at all. The deposits in the sections which have been most completely mined out, moreover, are usually the most accessible. With due allowances, it is conservatively estimated that there is as much hard rock available in Florida as has already been removed, that is, approximately 10,000,000 tons, and with an annual output of 500,000 tons the hard-rock phosphate deposits may be expected to last at least 20 years longer.

LAND PEBBLE

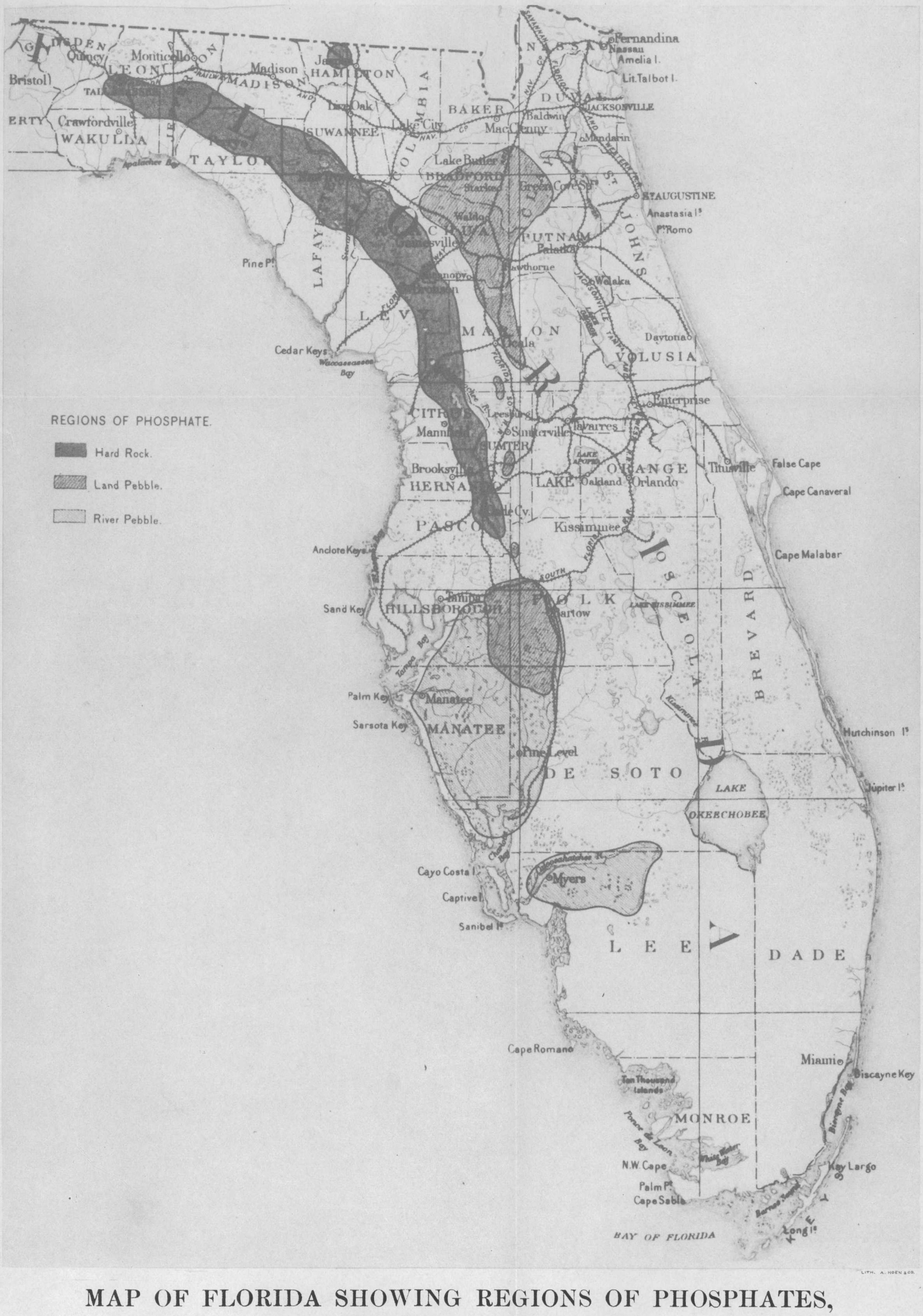
The land-pebble beds are more regular in their occurrence than the hard-rock deposits, but close estimates cannot be made except by actual prospecting; and this will be done only gradually by those who are interested in or are engaged in mining. The land-pebble phosphate belt is approximately 30 miles long by 5 to 10 miles wide. On the basis of a conservative estimate of acreage and of tonnage per acre, the writer has calculated a total of 190,000,000 tons of land pebble.

The output of land pebble per year in Florida is, in round numbers, 2,000,000 tons. The estimate of available land pebble, which is considered extremely conservative, leads to the conclusion that this type of phosphate rock in Florida will last several generations, and for present purposes it may be considered practically inexhaustible. The refinements in methods of mining land pebble are gradually reducing the quantity of small pebbles that go to the waste dump, and this factor will tend to prolong the life of these deposits beyond that calculated from the figures given above.

In making up the estimates for Florida, river pebble has not been included, owing to the difficulties connected with estimating its quantity. This factor also adds to the conservatism of the figures given for this State.

WASTE MATERIAL

The phosphoric acid in the Florida deposits in the form of soft phosphate, so-called together with large quantities of aluminum and iron phosphate, go to the dumps in the preparation of the hard and pebble rock for market. The loss calculated in terms of phosphate of lime is considerable and it may possibly equal the actual quantity saved and marketed. It has been calculated by W. H. Waggaman [U. S. Bur. Soils Bull. 76, p. 14, 1911] that the marketed material is probably not more than 15 percent of the total material mined, and that in the discarded material is an average of at least 10 percent phosphoric acid. The total quantity of Florida phosphate rock marketed up to and including 1914 is approximately 27,500,000 long tons. On these bases, the low-grade material in the waste heaps is approximately equivalent to 27,000,000 to 30,000,000 tons of high-grade material.



MAP OF FLORIDA SHOWING REGIONS OF PHOSPHATES, 11TH CENSUS, 1890

In 1922 the writer,[7] by allowing 15,000,000 tons for the rock mined in the period 1916–22, revised Mr. Phalen's estimate downward to 212,000,000 long tons.

In 1923 G. W. Holland [8] of the Geological Survey collected data on reserves while investigating public phosphate lands in Florida. From one of the most experienced operators in the pebble field he received estimates relating to phosphate rock remaining in the ground in the recognized pebble area. It was stated that these estimates were based on developments or prospecting and that for some tracts the estimates had been used in financial transactions by some of the companies. Their total indicated that the pebble field alone contained a minimum of more than 288,000,000 tons of minable phosphate, a figure that exceeded by 36 percent the previous estimate for the entire State.

In 1924 the writer [9] revised the figure of the previous year by deducting the quantity of rock mined at the end of 1924 and obtained the figure of approximately 294,000,000 tons. In these and the preceding figures only rock of commercial grade treated by the ordinary washing process was considered.

In 1936 Jacob,[10] basing his figures on those of the Geological Survey just cited and taking into account both the quantity of rock mined or used to December 31, 1936, and the quantity economically recoverable by flotation methods (estimated at 100 percent), obtained the figure 544,566,000 long tons as of that date. As no estimate was available for the extent to which hard rock could be improved by flotation and as estimates of the reserves of river-pebble and soft phosphates in Florida were also not available, he considered the figure given as very conservative.

DIFFICULTY OF OBTAINING ACCURATE FIGURES

The Florida phosphate deposits, though differing in kind and origin, are mostly concealed by overburden ranging in thickness from about 10 feet to 100 feet or more. Outcrops are so rare as to be almost nonexistent. Although little can be told by surface indications about the phosphate beneath, Mr. Thomas, who has made an intensive study of the available soil maps published by the Bureau of Chemistry and Soils, thinks that in some places he has been helped by them in following certain leads. Prospecting by boring or digging is essential

[7] Mansfield, G. R., Phosphate rock in 1922: Mineral Resources U. S., 1922, pt. 2, p. 116, 1925 (previously published as an advance chapter in 1923).

[8] See Mansfield, G. R., Phosphate rock in 1923: Mineral Resources U. S., 1923, pt. 2, pp. 250–251, 1926 (previously published as an advance chapter in 1924).

[9] Mansfield, G. R., Phosphate rock in 1924: Mineral Resources U. S., 1924, pt. 2, p. 88, 1927 (Previously published as an advance chapter in 1925).

[10] Jacob, K. D., The phosphate rock reserves of the United States: Commercial Fertilizer Year Book, p. 10, 1938.

to gain any knowledge of the character and quantity of the phosphate in any given area, and all mining operations or business transactions involving phosphate are based on prospecting by such methods. Boring is the usual method employed.

As the phosphate-mining business is highly competitive and as phosphate is a bulk commodity of low unit value, close watch is kept on grades and costs. Data obtained by prospecting, at least for the higher grades, are kept confidential. For some companies that have been in business for many years the handling of the great accumulation of prospecting and other records has become a problem, especially if it has been necessary to change headquarters. For these and other reasons the records of companies that have gone out of business have been destroyed, so that information once possibly available is lost, perhaps irretrievably.

CHANGES IN METHODS OF MINING AND PROSPECTING

During the half century or more of mining operations in the phosphate fields in Florida, methods and standards of mining and prospecting have changed notably with technological advances. In the early days of mining by pick and shovel or by horse and scraper the depth was limited by water level. With the advent of dipper dredges mining could proceed below water level but was limited by the capacity of the bucket and the length of its handle. The introduction of hydraulic mining and later of the electric drag line excavator has progressively increased the depth of mining and the amount of material that can be handled economically; thus the unit costs of production have been reduced.

Prospecting in the early days was limited to depths that could be reached by the mining methods of the time. Hence, where the overburden was deep enough to inhibit such mining, the prospecting holes were shown blank on the prospecting maps, and the land was declared valueless. Again, where shallow depth controlled, only the upper part of a given deposit might be within reach and considered minable. If the tonnage of that part was small, for example less than 1,200 tons, this land also might be declared valueless. In many such places later prospecting at greater depths has disclosed quantities of minable rock as great as or even far greater than that first discovered. The introduction of finer-sized screens and of laboratory-flotation procedure in prospecting has further changed the picture of what may be considered minable rock. For example, in some areas where the results of early prospecting showed a thick matrix but only small quantities of pebble, later prospecting by means of modern methods has disclosed large quantities of finer material suitable for flotation. As a result of such methods small and scattered tonnages shown on prospecting plats have been changed by reprospecting to large tonnages. In some holes, too, the finer-sized material serves to improve the grade of the recoverable rock. In one tract for which prospecting data of both earlier and later work have been available to the writer, the later work showed from 1½ to 6 times the tonnage shown by the earlier work. In this same tract an area of 380 acres prospected by modern methods yielded the following results:

Phosphate yield as estimated by recent prospecting methods

	Washer rock		Flotation concentrate		Total washer rock and flotation concentrate	
	Tons	Percent	Tons	Percent	Tons	Percent
Phosphate in 380 acres	1, 141, 520		1, 443, 240		2, 584, 760	
Phosphate per acre	3, 004		3, 798		6, 802	
Average grade B. P. L.		73. 91		75. 59		74. 9
I and A (average)		2. 23		1. 93		2. 06

In the earlier method of prospecting, only the washer rock was reported; as a result of reprospecting by modern methods the product was more than doubled and the average grade of the B. P. L. was raised.

A random example of a site that was prospected by both earlier and later methods shows the following results: The old hole is 10 feet deep but has no phosphate; the later hole has 32 feet of overburden and 13 feet of phosphate. The phosphate bed in the latter hole was divided for sampling into an upper 8½-foot unit and a lower 4½-foot unit. The sample from the 8½-foot unit on a 3/64-inch screen yielded 2,635 tons of phosphate per acre of 72.74 percent B. P. L. and 2.36 percent I and A; the sample from the 4½-foot unit was apparently too fine to collect on this screen. The 8½-foot sample on a 1/32-inch screen yielded an additional 744 tons of phosphate of 69.16 percent B. P. L. and 2.21 percent I and A; the 4½-foot sample yielded 1,552 tons of phosphate per acre of 70.77 percent B. P. L. and 2.43 percent I and A. Thus where no phosphate was shown by early methods modern prospecting disclosed 4,931 tons per acre with a weighted average grade of 71.58 percent B. P. L. and 2.36 percent I and A.

MARKET REQUIREMENTS

The table following, published by the United States Bureau of Mines, [11] illustrates market conditions and requirements:

[11] U. S. Bur. Mines Minerals Yearbook, 1940, p. 1272, 1941.

Phosphate rock sold or used by producers in the United States, 1939-40, by grades, uses, and classes of consumers

	1939			1940		
	Quantity		Value	Quantity		Value
	Long tons	Percent of total		Long tons	Percent of total	
Grades—B. P. L.[1] content (percent):						
Below 60	395,709	11	(2)	347,696	9	(2)
60 to 66	18,818	1	(2)	55,359	1	(2)
68 basis, 66 minimum	356,512	9	(2)	357,983	9	(2)
70 minimum	383,483	10	(2)	339,744	9	(2)
72 minimum	1,227,806	33	(2)	1,390,284	35	(2)
75 basis, 74 minimum; 75 minimum	769,360	20	(2)	936,309	23	(2)
77 basis, 76 minimum; 77 minimum	328,784	9	(2)	328,628	8	(2)
Above 85 (apatite)	(3)	(3)	(2)	(3)	(3)	(2)
Undistributed[4]	276,595	7	(2)	246,697	6	(2)
	3,757,067	100	$12,294,042	4,002,700	100	$12,334,662
Uses:						
Domestic:						
Superphosphates	2,192,779	58	(2)	2,564,844	64	(2)
Phosphates, phosphoric acid, ferrophosphorus	479,020	13	(2)	532,980	13	(2)
Direct application to soil	95,667	3	(2)	106,292	3	(2)
Fertilizer filler	30,994	1	(2)	32,804	1	(2)
Stock and poultry feed	1,794	(5)	(2)	1,311	(5)	(2)
Undistributed[6]	10,423	(5)	(2)	6,747	(5)	(2)
Exports[7]	946,390	25	3,747,608	757,722	19	2,995,591
	3,757,067	100	12,294,042	4,002,700	100	12,334,662
Classes of consumers:						
Affiliated companies	948,640	25	3,035,268	1,089,045	27	2,961,334
Other domestic consumers	1,862,037	50	5,511,166	2,155,933	54	6,377,737
Export[7]	946,390	25	3,747,608	757,722	19	2,995,591
	3,757,067	100	12,294,042	4,002,700	100	12,334,662

[1] Bone phosphate of lime.
[2] Figures not available
[3] Included under "Undistributed"; Bureau of Mines not at liberty to publish figures.
[4] Includes grades of B. P. L. content between 68 and 70; 69/66; 71; 73; 73.8; 74.8; 76; 76.55; 78/76; 78; and above 85 percent; also ground phosphate rock and dust, B. P. L. content not known.
[5] Less than 0.5 percent.
[6] Includes some calcined phosphate and phosphatic material used in pig-iron blast furnaces, in concrete aggregates and in the manufacture of concentrated fertilizers.
[7] As reported to the Bureau of Mines by producers (exclusive of exports by dealers, etc.).

This table shows how the grade of phosphate rock that is produced affects its marketing. Some producers, who are also manufacturers of fertilizer products or who have some special customers, are able to use phosphate of grades as low as 60 percent. Grades lower than that can be used in the electric-furnace process but not in acidulation processes. The bulk of the trade requires 68 percent or more of B. P. L. Mr. Grace[12] in his testimony before the Congressional Committee reported that the average grade of pebble phosphate exported is about 72 percent, which is about 1 percent lower than the average grade used in the domestic market. According to Mr. Kibler the average grade of hard-rock phosphate for export is about 73 percent. Many of the contracts for export phosphate are on a basis of 75 per-

[12] Hearings before the Joint Committee to Investigate the Adequacy and Use of Phosphate Resources of the United States, 75th Cong., 3d sess., pursuant to Public Res. 112, p. 975, 1939.

cent, with 74 percent minimum. In general, the trade tries to get rock of the highest possible grade, a practice that affects the prospecting and sale of phosphate land. Most producers have already blocked out areas of phosphate land sufficient to meet their needs for many years, and each producer is mining the highest grade he has—a common mining practice. As there is little incentive to buy anything except land that will yield rock of the highest grades, the dealer who wishes to sell phosphate land must resort to more and more selective and discriminating methods of prospecting. He passes over large areas that are more or less well known to contain intermediate or lower grades and devotes his attention to those areas in which he sees a possibility of working out minable bodies of rock of the higher or highest grades. In estimating reserves of phosphate rock, therefore the tendency is to emphasize the highest grades and not to bother about intermediate or lower grades even if the difference between these and the highest grades amounts only to a few percent.

PROSPECTING METHODS AND INTERPRETATION OF RESULTS

PEBBLE FIELD

OLDER PROSPECTING DATA

Thorough prospecting in the pebble-phosphate field involves boring 16 holes to a 40-acre tract. The holes are regularly spaced with respect to a grid that is marked by letters from west to east and by numbers from south to north. A separate grid is prepared for each section of land. For a full section the letters run from *A* to *P* and the numbers from 1 to 16. As the system is in wide use throughout the pebble field it is easy to identify any hole and to compare it with any other hole. The accompanying map of the Hooker tract, in Polk County (see pl. 2), which was kindly supplied by Mr. Thomas, is a good example of the detailed prospecting data obtained during the period before the more refined methods of prospecting were introduced. J. H. Pratt, who prepared it, was for many years the recognized authority on phosphate prospecting in the pebble field. The data for each hole, which in this spacing apply to 2½ acres, are compactly arranged in appropriate places. At the left the thicknesses of overburden and phosphate are given in the form of a fraction, with overburden above and phosphate below. At the right, in descending order, are stated the percentages of B. P. L. and I and A in the sample and the tonnage per acre. For some holes details of the overburden are added at the top and left. For example, hole *A*–11 in sec. 20 has hard sand rock between the depths of 3 and 4½ feet; the overburden is 9½ feet thick and the phosphate bed 12½ feet; the B. P. L. content is fairly good (70.58 percent) but the I and A is high (5.87 percent); the tonnage is satisfactory (6,056 tons per acre).

The circles indicate that the holes so marked are disregarded in computing acreage and tonnage. In this tract the phosphate would probably average about 70 percent B. P. L., although some areas have a low tonnage and a B. P. L. content of less than 70 percent. The tonnage in general is fairly large. If this tract were reprospected by modern methods it seems likely that the grade might be improved and the tonnage greatly increased.

NEWER PROSPECTING DATA

In preliminary prospecting, so-called 8-hole or even 4-hole work is frequently employed, and 8-hole work may give sufficient information for use in purchasing phosphate land. A good example of both kinds of work is presented in plate 3, which was kindly supplied by the Southern Phosphate Corporation. The township, range, and section are not given. The same grid system for locating holes is used for this type of work as for that with 16 holes, but in 8-hole work only the alternate spaces in the grid are used. In this tract modern methods of prospecting were employed, including the splitting of certain samples and the use of two sizes of screen, $\frac{3}{64}$-inch and $\frac{1}{32}$-inch. Plate 3 represents a section of land divided into 40-acre tracts. It shows the grid location of each hole, with the figures for overburden above and those for phosphate below. At the left are figures for the coarser fraction (washer rock) and at the right those for the flotation concentrate. Where the phosphate sample has been divided into two or more parts, as in hole *O*–10, the data for the lower samples are placed below those for the upper. At *O*–10 the overburden is 19 feet thick, and the phosphate bed is 22 feet, divided into two samples, each 11 feet thick. The upper sample yields 700 tons per acre of washer rock and 6,000 tons of concentrate with a weighted average content of 76.82 percent B. P. L., 1.83 percent I and A, and 6.44 percent insoluble, probably chiefly silica. The lower sample yields 2,800 tons per acre of washer rock and 3,000 tons of concentrate with a weighted average content of 75.43 percent B. P. L., 1.79 percent I and A, and 7.00 percent insoluble. Altogether the 22-foot phosphate-bed yields 12,500 tons per acre with a weighted average content of 76.8 percent B. P. L., 1.81 percent I and A, and 6.70 percent insoluble. This is a very good hole. It would represent 5 acres in any computation of acreage and tonnage in this section. Numerous other holes in the section are equally good or better. For example, the neighboring hole to the southeast (*P*–9) yields a total of 18,012 tons per acre of phosphate averaging more than 75 percent B. P. L. and only about 2.00 percent I and A. The tonnage in this section is heavy, for some holes have more than 20,000 tons, and the grade usually runs high—probably 75 percent or more B. P. L. It is interesting to note that in general the flotation concentrate greatly exceeds the washer rock in tonnage—in some holes as much as 6 or 7 times. Yet under the earlier methods of operation this vast tonnage of concentrates would not have been included in estimates of reserves and would have been washed out into waste pits or perhaps entirely lost.

SELECTION OF MINABLE AREAS

In selecting minable areas from prospecting plats such as those just discussed the prospector or operator takes care to exclude those holes that show too low a tonnage per acre, too high a percentage of I and A, too high a flotation ratio, or too high a ratio between overburden and available rock. Thus even some holes that show fairly high grades of B. P. L. (70 percent or more) may be excluded. Accordingly, the number of acres considered minable in a given prospected tract is usually somewhat smaller, and in some tracts much smaller, than the number prospected.

According to Captain Tillotson of the I. A. C., 10 yards of overburden to 1 yard of recoverable rock is the lower limit of depth of overburden. Rock containing more than 4 percent I and A and less than 66 percent B. P. L. is also considered unminable under present conditions. The tonnage considered minable varies with the grade of the available rock. Mr. Thomas states that grades below 70 percent were not considered formerly unless the tonnage exceeded 3,000 tons per acre. At present no mines are being operated on grades below 70 percent unless they average 10,000 tons per acre. Even stock piles of rock of grades less than 70 percent do not move well. However, when the rock is of export grade—72 percent or better (see p. 16)—it can be mined profitably if the tonnage per acre is as low as 500 and if the overburden does not exceed 5 feet. The flotation ratio mentioned above is defined by Mr. Thomas as the ratio between the total tons of rock recovered and the number of tons of material treated by the flotation plant. This ratio may vary from about 1.4 to 6.5.

The limitations discussed above afford considerable leeway in selective prospecting. Mr. Thomas states that much of the earlier work includes as overburden only the material down to the top of the matrix. This allows maximum tonnage for the matrix, but as the upper part of the matrix may be unduly high in I and A any excess may unfavorably affect the I and A content of the whole mass. If some of the poorer matrix is included with the overburden, the remaining tonnage, though smaller, may be improved in grade and have a lower content of I and A. The principle originated about 30 years ago with E. C. Stuart of Bartow and has been followed by Mr. Thomas, who not long ago applied it to some property that is now owned and operated by one of the companies. This principle is important in making properties formerly unsalable now salable and minable at commercial grades. As a result of it, some companies now separate the matrix into fractions on the basis of B. P. L. and I and A content and mine the fractions separately—sometimes leaving a lower fraction in the ground for possible later recovery.

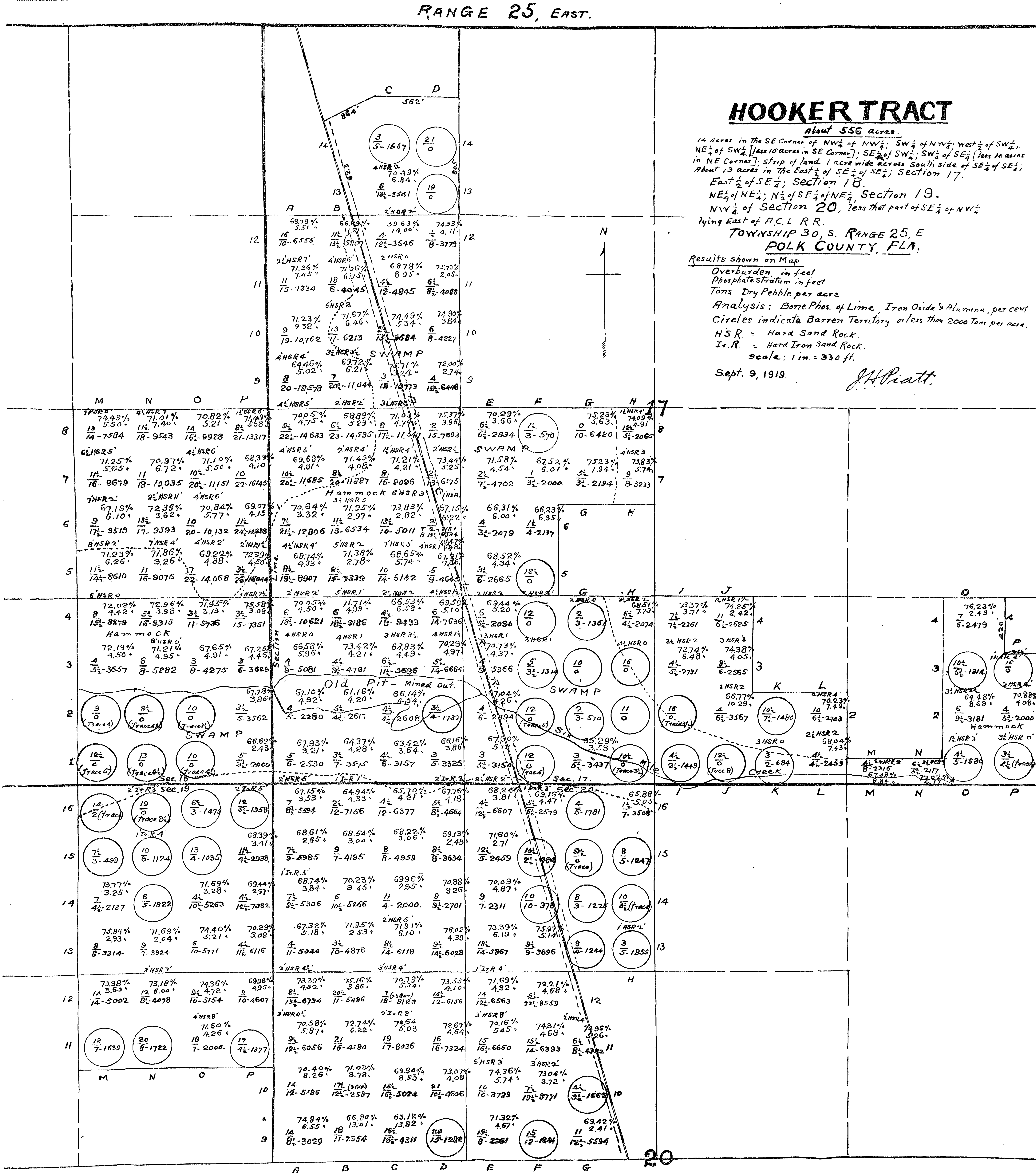
To develop a mine in a new location under existing conditions of power and railroad facilities, a minimum of 2,000,000 tons of high-grade rock, including flotation, is required; but if a given tract lies within the mining radius, about a mile from an existing plant, much smaller quantities may be considered minable. With few exceptions the pebble deposits of the area are susceptible to flotation treatment.

HARD-ROCK FIELD

In the hard-rock field thorough prospecting involves the boring of 16 holes to an acre, whereas in the pebble field 16 holes ordinarily suffice for 40 acres. Prospecting costs in the hard-rock field are correspondingly higher, though direct comparison cannot be made on the basis of cost, as prospecting methods in the hard-rock field differ from those in the pebble field.[13] In the hard-rock field, 16-hole work requires the spacing of 50 feet between holes. In preliminary prospecting, 100-foot intervals may suffice; but for guidance in mining, 25-foot intervals are at times desirable and rarely even 12½-foot intervals. The closer spacing in the hard-rock field as compared with the pebble field is required by the highly irregular surface of the bedrock on which the matrix rests, whereas in the pebble field the bedrock surface is generally fairly even.

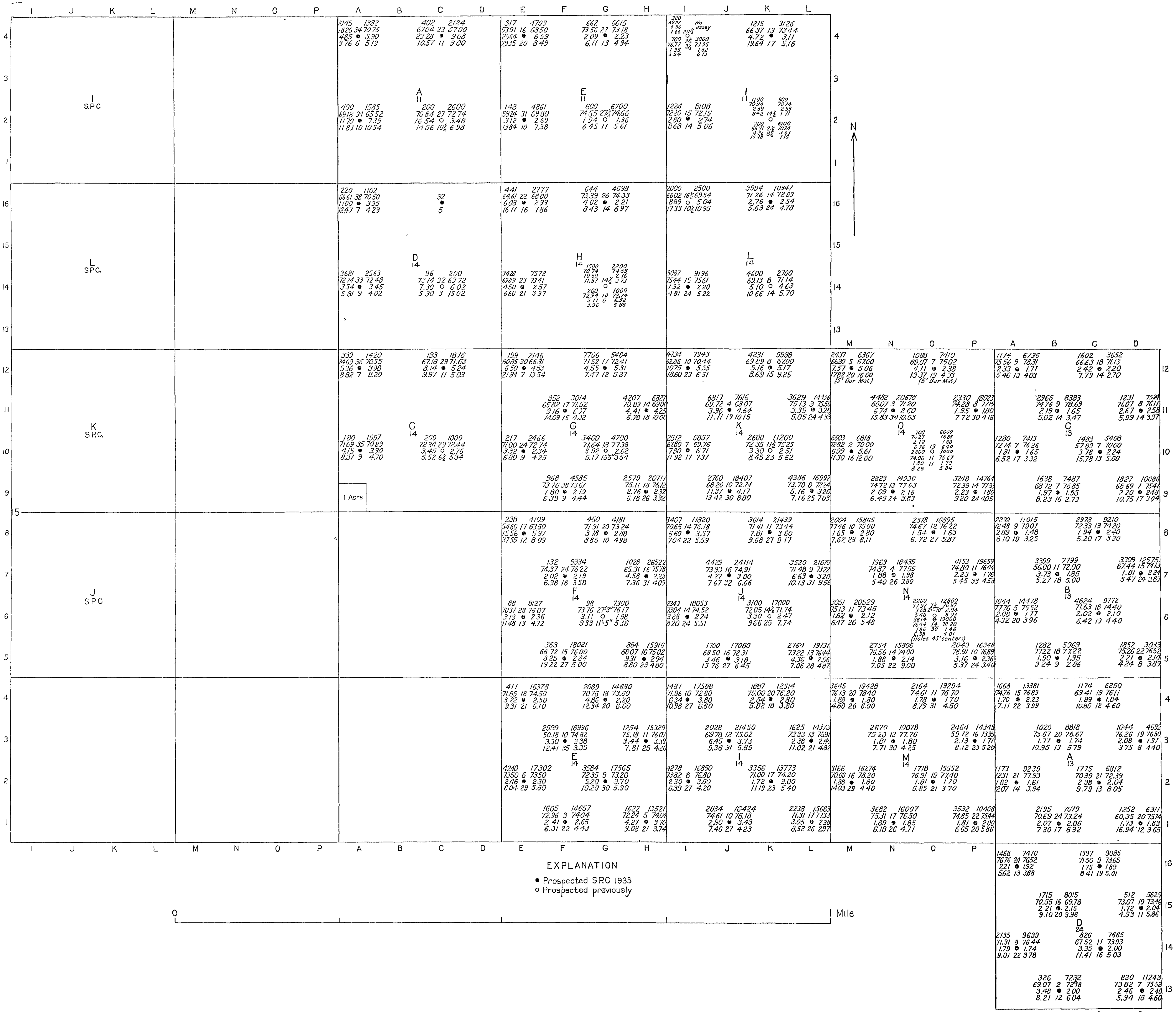
Plate 4, which was kindly furnished by D. B. Kibler, Jr., is a prospecting map of an area in Citrus County that was being mined by J. Buttgenbach & Co. at the time of the writer's visit. It illustrates both 50-foot and 25-foot work. It also illustrates the results that may be obtained by reprospecting an old abandoned pit. Such a pit is shown with new prospecting in the eastern part of the area mapped. Adjacent land on the west is also shown with prospecting results in greater detail. The locations of the holes are determined by a grid in which the numbers run from east to west and the letters from north to south. Whole numbers are assigned to 50-foot intervals and half numbers to 25-foot intervals. Complete data for each hole are given in its appropriate space—the depth of water level for each hole, the depth of working required both above and below water level, the nature and thickness of the overburden and of the phosphate, and the grade of the rock. In hole *H*–26½, for example, 33 feet of sand and 10 feet of clay lie above water level, which is at a depth of 43 feet. Below water level the overburden continues with 11 feet of clay, 4 feet of thin phosphate matrix, 8 feet of matrix that is considered fair, and finally 18 feet of rich phosphate matrix, where the hole stops at a depth of 84 feet. The grade is 80.25 percent B. P. L.

[13] For a description of field methods used in prospecting both pebble and hard rock, see Roundy, P. V., Phosphate investigation in Florida, 1934 and 1935: U. S. Geol. Survey Bull. 906–F, pp. 281–286, 1941.



PROSPECTING MAP OF HOOKER TRACT, T. 30 S., R. 25 E., POLK COUNTY, SEPTEMBER 9, 1919

Courtesy of Wayne Thomas



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SAMPLE PROSPECTING PLAT SHOWING DATA OBTAINED BY MODERN METHODS OF PROSPECTING

Courtesy of E. A. Pierce, Southern Phosphate Corporation

Hole H–20½, which is 41 feet deep, is in an old pit that has recently been partly mined for the second time. In it, 12 feet of sand and clay and 8 feet of phosphate matrix were drilled before water level was reached at 20 feet. Below water level the hole continues through 6 feet of phosphate matrix, 6 feet of sand, and finally 9 feet more of phosphate matrix that rests on a bedrock of Ocala limestone. The grade of the phosphate is 80.28 percent B. P. L. The rest of the old pit available for a second mining contains substantial thicknesses of phosphate matrix, the grade of which will average between 75 and 80 percent B. P. L.

W. L. Akin, who prepared the information for plate 8, is a prospector of long experience in the hard-rock field. In mining the tract represented in this plate the company follows the prospecting record much as a dog will follow a scent on the ground: The better holes are mined and those of lower grade rejected. Mr. Kibler reports that this company has always found that Mr. Akin's estimates are conservative and that the actual quantities of phosphate mined are substantially greater than those figured by Mr. Akin.

Flotation in the hard-rock field is not practiced. In the C. and J. Camp Bros.' Felicia mine, however, which the writer observed, the matrix is deslimed by special machines, and the slime, containing soft phosphate and clay, is washed into an abandoned pit, where it is conserved for future use. The so-called colloidal phosphate sold by several concerns for direct application to the soil or for use as a filler in fertilizers is largely taken from such waste pits. Meanwhile the finer sizes are tabled to separate the phosphate from sand. Thus practically all of the available phosphate mined is or ultimately will be used.

PROSPECTING WORK AND COMPANY RESERVES

The producing companies work out from prospecting data the tonnage of rock in each of several grades for each of their mines or other phosphate holdings. An annual statement furnished by the Southern Phosphate Corporation shows five commercial grades: 80.00–76.00, 75.99–74.00, 73.99–72.00, 71.99–70.00, and 69.99–66.00. As the rock from any tract is mined under careful chemical control, stock piles representing the different grades can be built and maintained. From these, by mixture, shipments can be made up to meet any requirements within the outside limits stated. Each company prepares an annual inventory and thus keeps track of its reserves of different grades. Although the figures of the annual inventories are confidential, E. A. Pierce and C. N. Becker of the Southern Phosphate Corporation were kind enough to show the writer their company's statement for December 31, 1937, and to explain in detail how the figures were obtained. As previously stated, practically all the producing companies have sufficient reserves in their present holdings for many years of operation, and some of them have large holdings of medium- or low-grade rock that they have not yet prospected in detail and that in annual statements such as the one just cited would be grouped as noncommercial.

RESERVES

GENERAL CONSIDERATIONS

The term "reserves" as used by the producing phosphate companies refers generally to the tonnage of rock of specified grades, as determined by prospecting, that are owned or controlled by any given company. It is ordinarily applied only to so-called commercial grades, which can be mined and sold under present technological and market conditions. Such conditions change, however, with advancing technical knowledge, discovery of new supplies, development of new transportation facilities, and because of other reasons. Hence in considering reserves in a broad policy of conservation of the Nation's phosphate resources the Government must obviously make allowance for all sorts of conditions that are difficult or impossible to forecast now. The very fact that the electric furnace can utilize profitably grades of phosphate rock containing as little as 50 percent B. P. L., whereas most of the producing companies who supply rock for acidulation find it impracticable to mine rock of lower than 66 percent grade, is an illustration of a possibly impending change, which may greatly affect the whole phosphate industry. In considering the problem of conservation, the Government must take these lower grades into account, for it is concerned in this problem because of the generations yet unborn; therefore, as this report is written from the Government's viewpoint, the writer desires to consider grades, where suitable information is available, and to distinguish as far as possible between reserves already more or less well known and those that may be considered as probable or possible.

HIGH-GRADE PHOSPHATE

In the pebble field the phosphate deposit or matrix, as it occurs in the ground, contains generally 15 to 40 percent B. P. L. Mr. Thomas says that material containing 35 percent B. P. L. is about the most favorable for yielding the products of greater value. When the matrix contains 40 percent or more B. P. L. so much of the material will go into slime that much of the higher-grade portion may be lost. High-grade phosphate therefore does not occur as such in the ground. It is obtained first by selective prospecting and mining and then by careful processing by washing and flotation. Whether a given deposit is of high-grade or perhaps of noncommercial grade may depend on whether the entire thickness of the deposit is considered or whether parts high in I and A or insoluble material are excluded. Though the amount available in a given area may be forecast by selective prospecting, the actual segregation of high-grade rock for stock piles or immediate shipment comes at the end of a long and chemically controlled beneficiation process. In practice, high-grade rock must contain 74 percent or more of B. P. L., though rock of lower grade is exported under some contracts (see p. 16). Rock of 74-percent quality, though more deisrable for use in acidulation because it requires less sulphuric acid and less handling than lower-grade material, is less desirable for use in the electric furnace because silica and other substances removed in its production must be added again for fluxing. Thus it would probably be cheaper and more satisfactory to select for furnacing a deposit whose matrix contains about the right proportions of silica and lime for fluxing and to improve its phosphate content by adding higher-grade material to the mix.

MEDIUM AND LOW GRADES

Some phosphate producers apparently consider anything below 74 percent B. P. L. as of low grade. For the purposes of this report medium grades may be considered to range between 70 and 74 percent and low grades to be anything below 70 percent. Commercially low grades would range from 70 down to 66 percent, below which the rock would be considered noncommercial. From the viewpoint of one interested in long-range conservation, however, it is clear that grades much lower than 66 percent should be included. Although any limit that is set must be arbitrary, it could perhaps be safely extended downward to 50 percent or perhaps even as low as 40 percent. The electric furnace even now is able to use 50-percent material. H. F. Greene states that the railroads have an intrastate classification for "phosphatic sand," which requires that the material shall not contain more than 55 percent B. P. L. Several companies are shipping this sort of rock ground for use as a filler in fertilizer or for direct application to the soil.

KNOWN RESERVES VERSUS PROBABLE AND POSSIBLE RESERVES

Strictly speaking, known reserves are limited to those disclosed by actual prospecting. Individual companies, prospectors, or owners have their information classified to a greater or less extent according to grades. As much potential phosphate land in Florida has not been prospected, known reserves are limited to a small part of it. Probable reserves are those based on available prospecting data, extrapolated to wider areas to such degree as seems reasonable on the basis of actual or assumed limiting factors. Possible reserves are those that, on the basis of scattered but suggestive data, imply the presence of deposits, which later prospecting may prove to have potential or actual commercial value.

Plate 7, which shows the ownership of much of the company-owned phosphate land in the pebble field, probably gives a good idea of the distribution of the known reserves in that field, though it does not differentiate according to grade. Similarly, plate 8 shows the distribution of much of the prospected and formerly mined areas in the hard-rock field, as well as the distribution of the known reserves in that field. Plate 5, which attempts to show the probable reserves in the pebble field, also distinguishes between deposits of high, medium, and low grade as defined above. It further shows certain areas that at present must be classified as possible reserves, though such evidence as is available suggests that they may ultimately disclose large tonnages of rock of commercial grades.

RIVER PEBBLE

GENERAL OCCURRENCE

In an article on pebble phosphates, Sellards [14] writes that the river-pebble phosphates are found wherever streams have cut their channels into the phosphatic marls of the Alum Bluff or †Jacksonville formation [15] or across the phosphate conglomerate of the Bone Valley gravel. The deposits then called Jacksonville are now included in the Hawthorn formation, a member of the Alum Bluff group. The pebbles may be found either in recent bars of present streams or in channels or valleys of earlier streams. The age of the deposits on any one stream may therefore range from Pleistocene or earlier to Recent. The immediate origin of these local river deposits is obviously the formation across which the stream flows. The grade of washed river-pebble deposits seldom exceeds 66 percent B. P. L. The phosphate beds in the Peace River, in Polk and De Soto Counties, have historic interest, as it was in them that phosphate mining in Florida began in 1888. Although most of the river-pebble production in Florida, which ceased in 1908, was from this river, river-pebble deposits also occur in the Alafia River in Polk and Hillsborough Counties, where they have been worked to some extent; in the Manatee River and North Creek in Manatee County; in the Caloosahatchee and Orange Rivers in Lee County; in Black Creek in Clay County; in Olustee Creek and its tributaries in Bradford and Columbia Counties; in the Alapaha River in Hamilton County; and in the Sopchoppy River and some other streams in Wakulla County.

Published references to the occurrence of river-pebble phosphate

[14] Sellards, E. H., The pebble phosphates of Florida: Fla. Geol. Survey 7th Ann. Rept., pp. 29-84, 1915.

[15] A dagger (†) preceding a geologic name indicates that the name has been abandoned or rejected for use in classification in publications of the Geological Survey.

give little more than the names of streams in which they have been found. Sellards, in his account just cited, says that the Peace River flows across both the phosphatic marl of the Alum Bluff and the land-pebble phosphates. As the conditions for the accumulation of pebble phosphates in the valley of this stream have therefore been particularly favorable, "it is on this stream that the most extensive river-pebble phosphates in Florida have been found." Of Black Creek he writes: "It may be of interest to note that the Black Creek phosphatic marls, together with secondary pebble deposits derived from them, were at one time worked to a limited extent by the late Gov. N. B. Broward. The development of the deposits, however, was found not commercially practicable." He says that phosphates similar to those in the Peace River are found in the Alafia River and that they have been worked to some extent. He writes likewise that a "limited amount of pebble phosphate is found along Manatee River and its tributaries." He notes "interesting occurrences" of river-pebble phosphate in North Creek, Manatee County, but gives no suggestion as to the amount. Of the other occurrences that he mentions (previously cited) he says that "a limited amount" of pebble phosphate is found on the Alapaha River near Jennings, in Hamilton County, and that pebble phosphate has been found "to some extent" in the valley of the Sopchoppy River and in some other streams in Wakulla County.

Matson [16] notes that river-pebble phosphate was formerly mined along the Peace River from Mulberry southward. Although Arcadia was at one time the principal center for river-pebble mining, considerable river pebble was mined later near Fort Ogden and Hull. He mentions production in the Alafia River and on Black Creek, a tributary of the St. Johns River, and says that pebble phosphate has been reported on the Manatee, Miakka, Kissimmee, and Caloosahatchee Rivers and at the mouth of Fisheating Creek, but that "none of these streams is known to afford workable deposits." He [17] states that recent accumulations of river-pebble phosphate are insignificant when compared with those of former periods. He [18] says that the matrix of the river-pebble phosphate consists of sand and sandy clay of various colors. The sand predominates and is in places difficult to separate from the phosphate. In some localities, as on the Miakka and Caloosahatchee Rivers, so many shells of marine organisms are mixed with the phosphate pebble that mining is impracticable. He [19] says further that the proportion of phosphoric acid in river pebble falls below

[16] Matson, G. C., The phosphate deposits of Florida: U. S. Geol. Survey Bull. 604, p. 10, 1915.
[17] Idem, p. 23.
[18] Idem, p. 45.
[19] Idem, pp. 83–84.

30 percent in most deposits, which is equivalent to about 65.5 percent tricalcium phosphate. Generally speaking, rock of this type ranged in composition from 55 to 65 percent tricalcium phosphate, though in some places it averaged less than 55 percent and in a few places higher than 65 percent.

Eldridge [20] writes that river-pebble phosphate is found not only in the rivers of today but also in the broad deposits filling their ancient channels, in coastal sands, and in certain hammock lands, as on the upper Caloosahatchee River. Along the Peace River, where it has been most studied, it occurs in bars in both present and ancient river channels, into which it has been washed from the bordering beds of clay and marl on each side and from the land-pebble deposits that underlie the watershed. These types of deposits occur in the Peace, Caloosahatchee, Alafia, and other rivers entering the Gulf south of Tampa and Hillsborough Bays. The rivers to the north—the Withlacoochee and Aucilla—and those of central-western Florida carry a mixture of pebbles, hard-rock fragments, and bones, according to the strata through which they flow. He says:

> The bars of Peace River are more extensive than those of other streams, owing to the greater area drained, and the consequent greater supply of material. They vary as in all rivers in the quantity of material, and shift from point to point with the change of currents from whatever cause. The position of the bars is usually in the slack water below the convexities of the stream-channel, although, in the case of heavier deposits, they may accumulate over the entire width of the river bed.

Mr. Thomas notes that some of the areas mapped by Eldridge (see pl. 1) as river pebble have since been reclassified as Caloosahatchee and †Manatee River marl. More recently [21] the †Manatee River marl and the †Jacksonville, to which earlier reference has been made, have been classed as Hawthorn. As the Hawthorn is the formation that supplied the materials that constitute much of the land-pebble as well as the river-pebble phosphates, it is difficult locally to distinguish the pebble deposits from their parent rock and from each other.

PRODUCTION

Figures of production covering the entire period of river-pebble mining have been published by the Federal Geological Survey and the Florida Geological Survey.[22] These figures are given in the following table:

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[20] Eldridge, G. H., A preliminary sketch of the phosphates of Florida: Am. Inst. Min. Eng. Trans., vol. 21, pp. 208–213, 1893.

[21] See Cooke, C. W., and Mossom, Stuart, Geology of Florida: Florida Geol. Survey 20th Ann. Rept., p. 115, 1929.

[22] See U. S. Geol. Survey, volumes on Mineral Resources U. S., 1888–93, and Annual Reports, 1894–1908; Florida Geol. Survey 16th Ann. Rept., p. 23, 1925.

Production of Florida river-pebble phosphate 1888–1908

Year	Long tons	Year	Long tons	Year	Long tons
1888	3,000	1896	100,052	1904	81,030
1889	8,100	1897	97,763	1905	87,847
1890	46,501	1898	79,000	1906	41,463
1891	54,500	1899	88,953	1907	36,185
1892	[1] 102,820	1900	59,863	1908 [2]	11,160
1893	122,820	1901	46,974		
1894	102,307	1902	5,055	Total	1,305,007
1895	73,036	1903	56,578		

[1] Includes 12,120 tons carried over from preceding year.
[2] Some rock sold during 1911–14, but figures not reported separately; probably hold-over material, as it is stated elsewhere that none was produced after 1908.

Most of the production was from mines in the Peace River but the Alafia River and some other streams furnished small amounts.

ESTIMATE OF RESERVES

Pratt's unpublished prospecting report, dated April 26, 1899, on the Marvinia property on the Alafia River and Turkey Creek, describes 950 acres that would yield 869 tons per acre, or a total of about 825,000 tons of material of grade 66.32 percent B. P. L. and 3.05 percent I and A, not counting the removal of the deposit in the most accessible river bars and about 25 acres on land previously mined. The deposit prospected is river drift similar to that found in the lower Peace River and contains pebble in a sandy matrix. The main body lies, as usual, in and along the swamps and lowlands immediately adjoining both banks of the Alafia River and Turkey Creek. The shape of the land area so underlain is a long, narrow, irregular strip that extends about 4½ miles in a northeasterly direction and is from half to three-fourths of a mile wide—in one place a mile wide.

Roundy [23] prospected an 80-acre tract of Government land in sec. 27, T. 32 S., R. 25 E., in and along the banks of the Peace River. Four wells were drilled, and phosphate was found in three of them at an average depth of 5½ feet. Allowing 10 acres for the bed of the river, he estimated that the total B. P. L. content of the rest of the unit was about 91,000 long tons. The average per acre was 900 tons of pebble and 400 tons of fines, or a total of 1,300 tons per acre. The grade was 47.46 percent B. P. L. and 0.24 percent I and A. He states that here and there in the Peace River small banks or bars contain phosphate pebbles, together with quartz pebbles, lime, and much sand. The amount of phosphate in the river bed is small. The river bed is lower than the top of the Hawthorn formation except in one well, where the hard bedrock is about level with the exposure of the Hawthorn in the river, west of the well.

[23] Roundy, P. V., Phosphate investigation in Florida, 1934 and 1935: U. S. Geol. Survey Bull. 906-F, pp. 307-310, 1941.

In response to a request for further data on river-pebble phosphate, Mr. Thomas [24] wrote as follows:

It will be difficult for me to give you any more data on river-pebble deposits other than that already supplied. Naturally there has been little or no interest in river pebble in more than 30 years. However, I have personally seen many river-pebble deposits on streams not even mapped—one of these since you came down here. One of the company's lands—many miles of river pebble—have recently been withdrawn from the market, the company believing that it may have a value again at some time. If so, there are important river-pebble deposits in Hillsborough County, which we have never previously taken into account. These lie along Fish Hawk Creek and Bell Creek, tributaries of the Alafia River; and along Whidden and Paines Creeks in Polk County, tributaries of Peace River. Both show large quantities of river pebble.

The prospecting reports cited for the Alafia and Peace River areas, covering a total of about 1,000 acres and selected more or less by chance, show roughly 1,000,000 tons that can be classed as known reserves. To these might be added another 4,000,000 tons to include the area owned by the company mentioned in the letter from Mr. Thomas and the areas personally seen by him. These would make the known reserves of river-pebble phosphate 5,000,000 tons.

The production table given above shows for a period of 21 years substantial but fluctuating production that amounted in all to about 1;300,000 tons and that reached a maximum of 122,820 tons in 1893, in the first third of the period. This activity was maintained in the face of increasing production of the more desirable hard-rock and land-pebble types during the same period. River pebble mining did not stop because of the exhaustion of the deposits but because it was crowded out in severe competition with the other types mentioned.

The Peace River rises in the west-central part of Polk County and has a course of about 80 miles southward before reaching the vicinity of Punta Gorda. Mr. Thomas in his brief states that the Peace River was the "locale of 30 mines." These mines were presumably located at the more favorable places as then known. But a river that is 80 miles long must have had many unmined places that were equally or nearly as good as those mined. Part of the recorded production undoubtedly came from the Alafia River, Black Creek, and possibly other streams, though the bulk of it came from the Peace River. How far it is wise to extrapolate the production figures it is impossible to say, but to the writer it seems safe to consider 10 times the reported production as a conservative figure for the probable reserves, or roughly about 15,000,000 tons. These reserves would presumably lie mostly in the Peace River Valley, as the references cited seem to show that amounts available in other streams are relatively less important. Considering additional tonnage that might be obtained from the Peace River and including the other streams with their smaller de-

[24] Thomas Wayne, personal letter dated April 1, 1939.

posits, it might be safe to add as a possible reserve the other 30,000,000 tons required to bring the total to the 50,000,000 mentioned in the Thomas brief. Such action would seem to be justified in view of Mr. Thomas' long experience in and intimate knowledge of the Florida phosphate fields.

In summary, the total reserves of river-pebble phosphate are classified as follows: Known, 5,000,000 tons; probable, 15,000,000 tons; possible, 30,000,000 tons. Although the grade would be less than 66 percent B. P. L., much of it might range near that figure; however, a probably greater proportion of it would range from about 55 percent downward.

LAND PEBBLE

GENERAL OCCURRENCE

The general occurrence of the phosphate deposits of Florida, except the river-pebble type, which cannot well be illustrated on the scale used, is shown in figure 1, which is a modification of a diagram by Sellards.[25] The Bone Valley gravel, which contains the land-pebble phosphates, lies unconformably on the Hawthorn formation, the phosphatic-marl formation that supplied the phosphate to the overlying formations. The Hawthorn in turn rests unconformably on the Ocala limestone. In the hard-rock field the phosphate is assigned to the Alachua formation, believed to be equivalent in age to the Bone Valley gravel and, like that formation, derived from the phosphatic marls of the Hawthorn. In the hard-rock field, however, the Hawthorn has been eroded away and the Alachua, containing the phosphates, rests directly on the Ocala limestone.

The land-pebble phosphates are the most important commercial source of phosphate in Florida today. Their general distribution is shown in plate 5. As formerly known they underlie approximately the west half of Polk County, the east half of Hillsborough County, and adjacent parts of Manatee and Hardee Counties. The extension of their boundaries northward, eastward, and southward is due to later knowledge gained from prospecting and drilling records. Outlying areas classed as pebble are known in Hamilton, Bradford, and Lake Counties and some adjoining counties, though in some places river pebble and phosphatic marl undoubtedly of the Hawthorn formation may be included with the land pebble. As the general character of the pebble phosphates has been well described in the literature already cited and elsewhere, it is not necessary here to discuss it further. Production statistics need not be cited here because abundant prospecting data are available for the main areas from which the commercial phosphates are being produced. For the outlying areas, however, information available to the writer is meager.

[25] Sellards, E. H., op. cit., fig. 4.

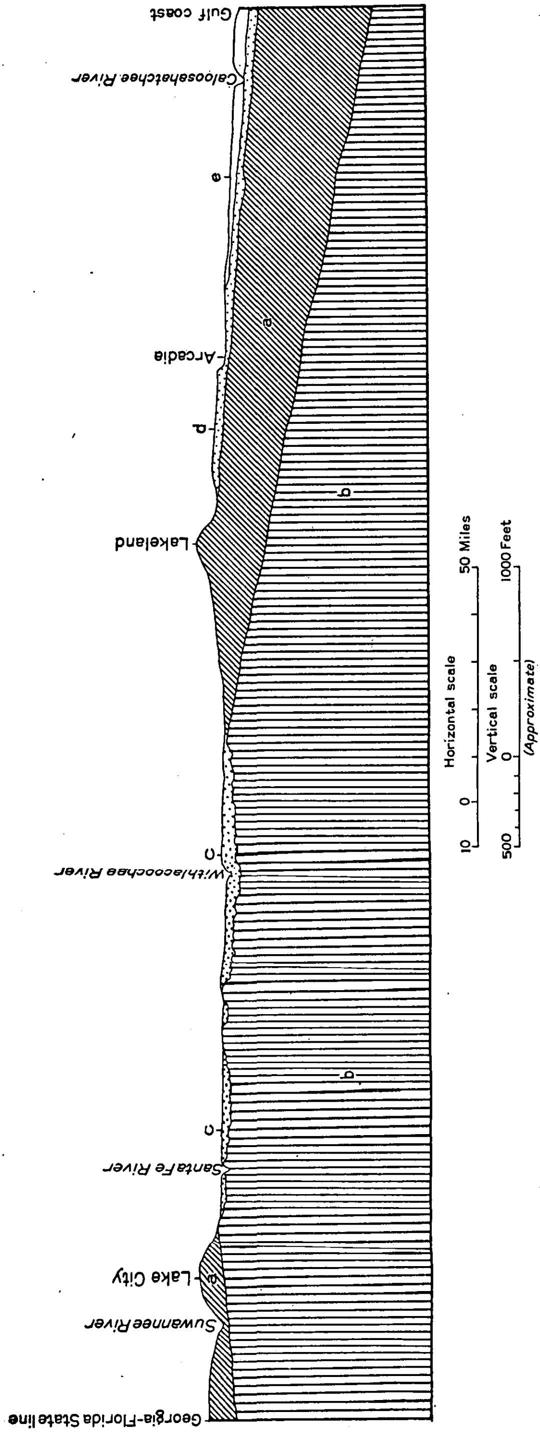

FIGURE 1.—Diagram showing structural relations of phosphate deposits of Florida. a, Upper Oligocene phosphatic marls; b, Ocala limestone (Eocene); c, hard-rock phosphate deposits; d, Bone Valley gravel; e, Pliocene and Pleistocene deposits. (Florida State Geological Survey, 7th Ann. Rept.)

HAMILTON COUNTY

Eldridge in the two papers cited shows an area, which he apparently classifies as hard rock, and a mine in Hamilton County, though he gives no description of the deposits there. Sellards, as previously noted, mentions the occurrence of pebble phosphate near Jennings, in Hamilton County, but does not describe the deposits other than to say "this pebble is derived without doubt from the Alum Bluff formation." In an earlier publication Sellards [26] writes that "phosphate in a gray coarse sandstone matrix occurs in Hamilton County, having been mined to a limited extent near the Allapaha River, west of Jasper. River pebble occurs in this county north of Jennings near the Georgia-Florida line." Mossom,[27] in his report on limestones and marls, throws a side light on the phosphate in Hamilton County. He writes: "The whole county is covered by reddish-yellow sands and sandy clays of the Alum Bluff (Miocene) and some light-colored Pleistocene sediments, the latter chiefly along the rivers and in the southwestern part of the county, which is in the hammock belt. The rivers have cut down through these unconsolidated beds. * * *" Though Mossom does not mention phosphate in his discussion, the Alum Bluff group normally includes the Hawthorn, the parent rock of the pebble phosphates, and the Pleistocene includes some river-pebble deposits. His statement therefore lends support to the idea that bedrock and pebble phosphate may be widespread in the county. Cooke and Mossom,[28] in the latest geologic map of the State, show that most of the county, except along the larger rivers, is underlain by the Hawthorn, mantled by Pleistocene or Recent sands. These authors mention the occurrence of possibly phosphatic pebbles embedded in brittle gray rock on the Suwannee River 2½ miles north of Belmont and show phosphatic material in geologic sections measured at White Springs.

One prospecting map, furnished by the International Agricultural Corporation, has been available to the writer. It covers parts of four sections in T. 2 N., R. 11 E., in the northwestern part of Hamilton County. Of 60 holes drilled, 25, or about 42 percent, were considered worth sampling, and from most of them products were obtained representing both washer rock and concentrates. The B. P. L. content of the washer-rock samples ranged from about 26 to 71 percent and that of the concentrates from about 64 to 72 percent. The insoluble constituents ranged from about 8 to 66 percent in the washer rock and from about 9 to 21 percent in the concentrates. Partial analyses of three samples from Hamilton County were also furnished by the

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[26] Sellards, E. H., Mineral industries: Florida Geol. Survey 2d Ann. Rept., p. 239, 1909.

[27] Mossom, Stuart, A preliminary report on the limestones and marls of Florida: Florida Geol. Survey 16th Ann. Rept., p. 137, 1925.

[28] Cooke, C. W., and Mossom, Stuart, op. cit., pp. 125-127 and geologic map, 1929.

I. A. C. It is not known whether the corresponding samples are from the prospected area just mentioned or from some other area. They show a B. P. L. content ranging from 59.37 to 65.5 percent. Each sheet specifically notes the quartz content of the sample but gives no figure for it.

Mr. Thomas in his testimony before the congressional committee spoke of the quartz content of the phosphate in Hamilton County and gave the impression both orally and by showing samples that the insoluble portion of the washed samples was chiefly quartz in large grains. R. B. Fuller,[29] manager of the International Agricultural Corporation in Florida, says that the quartz particles are very large—of the size of rice grains or "English peas." He says that when the raw material, including both quartz and phosphate, is broken down to a minus 35 mesh, the phosphate-rock particles can easily be separated from the silica by flotation. Mr. Thomas in his brief states that if this material is separated the grades of phosphate in Hamilton County can be raised to 77 percent B. P. L.

The prospecting data mentioned above were studied with the idea in mind of separating the quartz from the phosphate. The writer rejected the insoluble portions of the samples and recalculated the percentage and tonnage of B. P. L. for each sample. On the basis of this recalculation the 25 samples show a recovery of 4,199 tons per acre of material of 77.7 percent grade. As the prospecting work was of a reconnaissance nature only four holes were drilled in a 40-acre tract, and some of the spaces in the tract were left undrilled; but for the purposes of this report the prospecting may be considered four-hole work, with each hole representing 10 acres. The prospected area in such work would comprise 250 acres, and the total phosphate content would be about 1,049,700 tons.

Hamilton County, which contains 528 square miles, or 337,920 acres, has widely distributed deposits of the phosphate-bearing Hawthorn formation. As streams have been active in the county both river-pebble and land-pebble phosphate deposits have been found. Although the writer has no independent knowledge of the extent of these pebble deposits, Mr. Thomas' estimate of 14,000 acres, underlain by deposits of suitable concentration for mining does not seem unreasonable, as it represents only about 4 percent of the total acreage in the county. The results of the study of the prospecting map, if extrapolated to cover 14,000 acres, would yield 58,783,200 tons, as compared with the 50,000,000 tons estimated by Mr. Thomas.

If Mr. Thomas' estimate is accepted as a general figure, at least 1,000,000 tons of it could be classed as known reserves, and fully half of it could be classed as probable reserves. The rest, as a margin of safety, would then be considered as possible reserves.

[29] Fuller, R. B., personal letter dated April 1, 1939.

In summary, the phosphate reserves of Hamilton County could be classified as follows: Known, 1,000,000 tons; probable, 24,000,000 tons; possible, 25,000,000 tons.

CLAY COUNTY

The writer understands that some lands in Clay County are owned or controlled by one of the phosphate companies and that more or less prospecting in the county has been done. However, he has had no access to information concerning the results of this prospecting and has no basis for independent judgment as to the statements made by Mr. Thomas in the brief quoted.

The phosphate on Black Creek was mentioned by Eldridge[30] in his general description of Florida phosphates. Eldridge noted that the "Black Creek phosphate differs from those of the west side of the peninsula in its diminished quantity of phosphorus anhydride and consequently of tricalcic phosphate; the sample taken (No. 1), containing 21.06 P_2O_5 (45.97 $Ca_3P_2O_8$), affords about the average percentage."

Sellards[31] in his report on the pebble phosphates mentions the Black Creek area but seems to attach greater importance to the phosphatic marls than to the pebble phosphates. Cooke and Mossom[32] describe the rocks at points on Black Creek but do not mention phosphate. On their State geologic map the area is shown as Hawthorn mantled by Pleistocene and Recent sands.

Mr. Thomas calls attention to the high silica content of the phosphate deposits, comparable to the conditions in Hamilton County, and states that grinding and flotation would remove the silica and raise the grade of B. L. P. to 55–68 percent. Judging from his study of the prospecting data on Hamilton County, the writer would concede that such a beneficiation might easily be possible. The available data are so scanty, however, that he is hesitant to consider the 90,000,000 tons mentioned by Mr. Thomas as known or probable reserves, and he prefers to classify them as possible reserves until more specific information is at hand.

BRADFORD COUNTY

The available references to phosphates in Bradford County are rather indefinite and seem to apply to the Hawthorn formation (bedrock) rather than to land pebble. Thus Sellards[33] writes:

> In a deep sink about 3 miles southeast of Brooker, in Bradford County, 39 feet of matrix containing varying amounts of pebble phosphate lies beneath 37 feet

[30] Eldridge, G. H., A preliminary sketch of the phosphates of Florida: Am. Inst. Min. Eng. Trans., vol. 21, p. 225, 1893.

[31] Sellards, E. H., The pebble phosphates of Florida: Florida Geol. Survey 7th Ann. Rept., p. 39, 1915.

[32] Cooke, C. W., and Mossom, Stuart, op. cit., pp. 128, 129, and geologic map.

[33] Sellards, E. H., Mineral industries: Florida Geol. Survey 2d Ann. Rept., pp. 239, 240, 1909.

of shell marl and covered slopes. [Here he gives a detailed section.] From its considerable thickness the phosphate-pebble-bearing formation of this section may be expected to be found underlying a considerable area in this part of the State. The pebble phosphate in this exposure is of a brownish color differing from the land-pebble phosphate of south Florida and resembling in this respect the river pebble. This formation is without doubt the matrix from which have been washed the phosphates of Black Creek and other tributaries entering the St. Johns River.

In his account of the pebble phosphates[34] he writes:

In Columbia County typical gray phosphatic and calcareous sands of the Alum Bluff formation are seen well exposed at Langston sink, about 4 miles northwest of Lake City. A similar rock containing an abundance of light- and dark-colored phosphate pebble is found in Columbia and Bradford Counties on Olustee Creek near Lulu. Here also in the small streams tributary to Olustee Creek are found considerable secondary deposits of phosphate pebble derived from this rock.

The writer has seen analyses of four samples from this area. Three range in B. P. L. content from 63.69 to 74.53 percent. No estimates of tonnage are available.

As no prospecting data on Bradford County are available to the writer, he is inclined to classify as possible reserves the 55,000,000 tons of phosphate ranging up to a grade of 70 percent reported from this county by Mr. Thomas.

LAKE AND ORANGE COUNTIES

The writer has found no reference in published accounts to phosphate in Lake and Orange Counties and has seen no prospecting data from them. Cooke and Mossom's geologic map of Florida shows both counties to be underlain by the Hawthorn formation and to be covered over large areas by the Citronelle formation and by undifferentiated Pleistocene and Recent deposits. The fact that prospecting data for T. 25 S., R. 25 E., just south of Lake County, show extensive deposits of pebble phosphate, averaging 4,344 tons per acre and grading up to 72 percent B. P. L., makes it easy to believe that similar deposits may extend into Lake and Orange Counties. In these counties, as in Clay and Bradford Counties, the writer thinks it best to consider as possible reserves the 100,000,000 tons of pebble of 55 percent or better grade mentioned by Mr. Thomas.

MAIN PEBBLE FIELD

EXTENT OF DEPOSITS

The main pebble field, as shown on plate 5, is now regarded as extending from the southern part of T. 24 S., R. 25 E., just north of

[34] Sellards, E. H., The pebble phosphates of Florida: Florida Geol. Survey 7th Ann. Rept., pp. 38, 39, 1915.

the Lake County line, through Polk, Hillsborough, Manatee, and Hardee Counties as far as the south line of T. 38 S., Rs. 22 and 23 E., about on the line between Sarasota and De Soto Counties. Thus it is approximately 85 miles long from north to south and has a maximum width of about 66 miles along the south line of T. 33 S., Rs. 19–29 E., inclusive.

The mapping on plate 5 extends the boundaries of the pebble field in all directions beyond those shown in the latest geologic map of the Bone Valley gravel.[35] On that map the phosphate-bearing formation occupies an oval area flattened at the north and extending southward from the southern part of T. 28 S., Rs. 21–26 E., to the northern part of T. 34 S., Rs. 23 and 24 E. The extension of the area as indicated on plate 5 is due to information not previously made public. The extensions to the north are justified by detailed prospecting data in Tps. 25–27 S., Rs. 24 and 25 E., which show large tonnages of fair- to high-grade rock. As Mr. Thomas reports a proved bed of 5,000,000 tons of 70 percent rock on 1,000 acres in Highlands County, the boundary is accordingly extended on the east. The southern and western limits are less well defined. So far as the writer is aware detailed prospecting results are not available on the west much beyond the west line of the twenty-first range of townships or south of the thirty-fourth tier; however, well data and occasional samples analyzed from localities in these areas suggest that the land-pebble phosphate may extend as far as the indicated boundary.

Mr. Thomas in his brief states that the Bone Valley gravel area in Polk and Hillsborough Counties, with certain extensions south and east, comprises about 1,400,000 acres. On the basis of later information obtained from operating companies and from individuals, he has enlarged his estimate of the area to the limits just discussed. The writer, by counting townships and partial townships in the area as now mapped, estimates the newer figure to be about 2,800 square miles, or about 1,792,000 acres.

PROSPECTING DATA

International Agricultural Corporation.—The International Agricultural Corporation (I. A. C.), in preparation for the hearings on phosphate, assembled data for 38 townships in Polk, Hillsborough, Manatee, and Hardee Counties, which are given in the accompanying table.

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[35] Cooke, C. W., and Mossom, Stuart, op. cit., geologic map.

Estimate of unmined acres and unmined tons of pebble phosphate and flotation concentrates in the south Florida field, Sept. 24, 1938

Polk County

Township south	Range east	Townships with I. A. C. and other ownerships						Phosphate-bearing areas in which I. A. C. has no ownership			Total unmined acres in township [1]	Total unmined tons in township
		I. A. C. lands			Lands not owned by I. A. C.							
		Unmined acres	Average tons per acre	Unmined tons of phosphate	Unmined acres	Average tons per acre	Unmined tons of phosphate	Unmined acres	Average tons per acre	Unmined tons of phosphate		
28	23	3, 280	3, 500	11, 480, 000	8, 520	3, 500	29, 820, 000				11, 800	41, 300, 000
29	23	7, 083	2, 324	16, 458, 000	6, 567	2, 300	15, 104, 000				13, 650	31, 562, 000
30	23	7, 512	4, 967	37, 315, 000	5, 954	5, 000	29, 770, 000				13, 466	67, 085, 000
31	23	6, 697	6, 686	44, 774, 000	8, 969	6, 680	59, 913, 000				15, 666	104, 687, 000
29	24	1, 073	6, 128	6, 575, 000	5, 558	6, 100	33, 904, 000				6, 631	40, 479, 000
30	24	3, 868	6, 371	24, 642, 000	10, 710	6, 370	68, 223, 000				14, 578	92, 865, 000
31	24	2, 047	8, 801	18, 015, 000	11, 920	8, 800	104, 896, 000				13, 967	122, 911, 000
30	25	1, 100	9, 423	10, 365, 000	8, 140	9, 400	76, 516, 000				9, 240	86, 881, 000
31	25	1, 300	6, 139	7, 981, 000	8, 980	6, 100	54, 778, 000				10, 280	62, 759, 000
32	25	430	6, 000	2, 580, 000	16, 350	6, 000	98, 100, 000				16, 780	100, 680, 000
27	24							11, 520	6, 000	69, 120, 000	11, 520	69, 120, 000
25	25							17, 280	4, 000	69, 120, 000	17, 280	69, 120, 000
26	25							14, 400	2, 500	36, 000, 000	14, 400	36, 000, 000
26	24							8, 625	2, 500	21, 562, 000	8, 625	21, 562, 000
32	26							11, 520	5, 000	57, 600, 000	11, 520	57, 600, 000
29	25							9, 825	5, 000	49, 125, 000	9, 825	49, 125, 000
28	24							5, 760	6, 000	34, 560, 000	5, 760	34, 560, 000
28	25							6, 900	6, 000	41, 400, 000	6, 900	41, 400, 000

Hillsborough County

Township south	Range east	Unmined acres	Average tons per acre	Unmined tons of phosphate	Unmined acres	Average tons per acre	Unmined tons of phosphate	Unmined acres	Average tons per acre	Unmined tons of phosphate	Total unmined acres in township [1]	Total unmined tons in township
31	22	5, 440	4, 778	25, 993, 000	11, 840	4, 700	55, 648, 000				17, 280	81, 641, 000
30	22	120	2, 883	346, 000	17, 160	2, 880	49, 420, 000				17, 280	49, 766, 000
32	22							17, 280	4, 200	72, 576, 000	17, 280	72, 576, 000
29	22							15, 080	5, 000	75, 400, 000	15, 080	75, 400, 000
29	21							17, 080	3, 500	59, 780, 000	17, 080	59, 780, 000
30	21							16, 180	3, 000	48, 540, 000	16, 180	48, 540, 000
30	20							8, 170	2, 500	20, 425, 000	8, 170	20, 425, 000
31	21							17, 280	2, 000	34, 560, 000	17, 280	34, 560, 000
32	21							17, 280	2, 000	34, 560, 000	17, 280	34, 560, 000

Manatee County												
34	19	----------	----------	----------	----------	----------	----------	8, 640	2, 000	17, 280, 000	8, 640	17, 280, 000
34	20	----------	----------	----------	----------	----------	----------	17, 280	2, 000	34, 560, 000	17, 280	34, 560, 000
34	21	----------	----------	----------	----------	----------	----------	17, 280	2, 000	34, 560, 000	17, 280	34, 560, 000
35	19	----------	----------	----------	----------	----------	----------	8, 640	2, 000	17, 280, 000	8, 640	17, 280, 000
35	20	----------	----------	----------	----------	----------	----------	8, 640	2, 000	17, 280, 000	8, 640	17, 280, 000
35	21	----------	----------	----------	----------	----------	----------	8, 640	2, 000	17, 280, 000	8, 640	17, 280, 000
Hardee County												
33	23	----------	----------	----------	----------	----------	----------	17, 280	2, 250	38, 880, 000	17, 280	38, 880, 000
33	24	----------	----------	----------	----------	----------	----------	17, 280	2, 250	38, 880, 000	17, 280	38, 880, 000
34	23	----------	----------	----------	----------	----------	----------	17, 280	2, 250	38, 880, 000	17, 280	38, 880, 000
34	24	----------	----------	----------	----------	----------	----------	17, 280	2, 250	38, 880, 000	17, 280	38, 880, 000
35	24	----------	----------	----------	----------	----------	----------	17, 280	2, 250	38, 880, 000	17, 280	38, 880, 000
Total		39, 950	5, 667	206, 524, 000	120, 668	5, 652	676, 092, 000	349, 700	3, 171	1, 056, 568, 000	510, 318	1, 939, 184, 000

[1] Acres shown in the columns "Unmined acres" are estimated by first making a blanket reduction of 25 percent from the phosphate-bearing area in a township. It is assumed that this deduction will cover all highway and railroad rights-of-way, watercourses and lakes, small unmapped communities, and other lands not suitable or obtainable for mining purposes. Where appropriate, the minable acreage in a township was further reduced to cover mined-out lands, areas covered by cities and towns, and land planted to citrus groves.

This table, which is evidently based on prospecting data and which makes allowance for flotation procedure, applies to a total of 510,318 acres, estimated to contain 1,939,184,000 tons or about 3,800 tons per acre. Some inconsistencies are manifest in the table, for the final estimate of tonnage as shown in smaller than the figure obtained by computation from the other totals given. The figure thus obtained is 2,017,310,886 tons, which corresponds to 3,953 tons per acre. The discrepancy may be due to the deductions mentioned in the footnote or to the use of rounded figures here and there.

In reprospecting some of their lands, the I. A. C. obtained an average of 4,572 tons per acre, including recovery of fines, as compared with an average of 1,779 tons per acre for certain other lands not reprospected. In other words, assuming that the two sets of lands had about the same average content of phosphate the rock recovered by older methods of prospecting was only 39 percent of what was later obtained by reprospecting. Although the figure 4,572 tons per acre represents a yield nearly 3 times greater than that obtained by older methods, some of the detailed prospecting plats of the I. A. C. show yields of concentrates more than 10 times that of washer rock, which would have been the only rock recovered by older methods. Plate 6, which was kindly supplied by the I. A. C., is such a plat. Mr. Heinrichs [36] of that organization explains this illustration as follows:

> The prospect holes as shown were put down in the center of a 2½-acre square. The values given alongside each prospect hole represent tonnage per acre, and when multiplied by 2.5 give the same tonnages shown under the headings "Washer" and "Concentrates" in each one of the 2½-acre squares.
>
> For example, in L–1, there is shown 500 tons per acre of washer rock and 5,700 tons per acre of concentrates. When multiplied by 2.5, these values yield, respectively, 1,250 tons of washer rock and 14,250 tons of concentrates for the 2½-acre area. * * * K–2 shows only 750 tons of washer product from the 2½ acres, whereas the indicated yield of concentrates is 15,500 tons. Again, in K–1 the indicated yield of washer rock is only 1,750 tons for the 2½-acres with an average grade of 71.17 B. P. L. On the other hand, the indicated yield of concentrates for the same area is 28,500 having a grade of 74.33 B. P. L. Without flotation these areas would properly be considered barren, or at least unminable, but with flotation they represent really minable areas.
>
> We would like to call your attention to the data at the bottom of the sheet [pl. 6] for the cubic yards of overburden and matrix per ton of product. You will note that on the basis of washer rock above there are 33.98 cubic yards of combined overburden and matrix per ton of washer rock recoverable. However, when the concentrates are taken into account this yardage is reduced to only 5.86 cubic yards per ton of product recovered. We think that figures such as these illustrate more vividly than words the tremendous effect which the flotation process has had on the minable reserves of phosphate rock of the United States.

Plates 3 and 6 both show that high tonnages per acre are not unusual in the pebble field, where both washer rock and concentrates are considered.

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[36] Heinrichs, C. E., personal letter dated October 17, 1939.

Roundy's work.—Roundy,[37] prospecting some 3,280 acres of Government land distributed in parcels ranging from 40 to a few hundred acres each and distributed in 10 townships, estimated an average of about 3,800 tons per acre and a total of 13,506,000 tons, including both washer rock and fines.

The Thomas statement.—Mr. Thomas, before revising the map used in the preparation of plate 5, estimated the main land-pebble area to contain 1,400,000 acres, of which he considered half, or 700,000 acres, to be underlain by phosphate with a concentration of 4,000 tons per acre. The restricted area on plate 5, estimated to contain phosphate averaging 70 percent or more B. P. L., contains about 1,055 square miles, or about 675,200 acres, according to the writer's measurements. The lands tabulated by the I. A. C. comprise about 76 percent of this area and contain about 2,000,000,000 tons of phosphate. If the remaining 24 percent is considered phosphate-bearing in the same way, the total phosphate content of the 675,200 acres would be about 2,631,580,000 tons, which is not far from Mr. Thomas' estimate of 2,800,000,000 tons based on a somewhat larger acreage and a slightly larger figure for tons per acre.

ESTIMATE OF RESERVES

The writer has studied independently 34 sets of prospecting data, representing 90,722 acres that are distributed fairly well through the pebble field. Some of these areas had been reprospected, and in a few of them reprospecting data were available for certain locations that had been prospected by earlier methods. Reprospecting at these locations showed increases ranging from 1½ to 10 times. The average yield for the 90,722 acres under the conditions stated was 3,166 tons per acre.

The ownership map (pl. 7) was measured to find the total acreage of the properties shown by patterns on the map. This was done by counting the acres in each section of each township that contains such lands. The total was 221,060 acres. At the estimated rate of 3,166 tons per acre, the total tonnage would be 677,769,960, which may be considered a minimum figure as it largely disregards recovery of the fines; at the rate of 3,953 tons per acre, obtained from the I. A. C. table, the tonnage would be 873,850,180. This corresponds very well to the 889,240,000 tons that would be obtained if Mr. Thomas' average of 4,000 tons per acre were applied.

In considering the distinction between known and probable reserves containing 70 percent B. P. L. the writer believes it would be better to use the more specific figure of 2,631,580,000 tons, obtained by use of the I. A. C. table and measurements of the "70-percent area" on plate 5, than the more general figure of 2,800,000,000 tons given by Mr.

[37] Roundy, P. V., op. cit., p. 344.

Thomas. The I. A. C. figures of 510,318 acres and 2,000,000,000 tons seem to the writer sufficiently specific to justify their classification as known reserves. As information about the other 24 percent of the area containing the 70-percent grade, comprising 164,882 acres and 631,580,000 tons, is less specific, these lands would better be classed as probable and possible reserves, perhaps including half in each category. This would give 82,441 acres and 315,790,000 tons as probable reserves and the same figures for possible reserves.

The "70-percent area," as shown on plate 5, includes some lands that contain material of 74-percent grade or better. Though the writer has seen prospecting data relating to these high-grade areas he has no basis for an independent estimate of reserves of material of this grade and therefore cites the figures given orally by Mr. Thomas, who states that about 55,000,000 tons of such material are owned by phosphate companies and an additional 75,000,000 tons by others. The known high-grade rock is therefore estimated altogether at 130,000,000 tons, which is included in the figure of known reserves just given. It is probable that by selective prospecting, additional minable areas of 74-percent rock can be blocked out, but it is not believed that the total tonnage mentioned can be greatly increased in this way.

The area indicated on plate 5 as containing phosphate ranging from 55 to 70 percent B. P. L. comprises, according to the writer's measurements, about 1,766 square miles, or about 1,130,240 acres. Prospecting data are scarce, especially in the southern and western parts. If we assume rock of about 70-percent grade and 3,500–4,000 tons per acre at the boundary where this area is in contact with the higher-grade area just discussed, the deposits presumably diminish irregularly in quality and thickness toward the outer border, which is very indefinite. Prior to 1916, prospecting data in T. 33 S., R. 23 E., and T. 34 S., Rs. 23 and 24 E., had developed more than 8,000,000 tons on about 2,500 acres, or 3,200 tons per acre, without the advantage of flotation. The grades ranged from about 60 to 66 percent B. P. L. These localities furnish the southernmost prospecting data that have come to the writer's attention. Roundy's prospecting [38] developed considerable tonnages on the east side near the margins of the area containing the 70-percent grade. For example, in T. 29 S., R. 26 E., he developed 562,000 tons on 280 acres, or 1,650 tons per acre; in T. 30 S., R. 26 E., 1,956,400 tons on 692 acres, or 2,827 tons per acre; in T. 31 S., R. 26 E., 1,470,800 tons on 348 acres, or 4,263 tons per acre; and in T. 32 S., R. 26 E., 5,242,000 tons on 1,240 acres, or 4,227 tons per acre.

When Mr. Thomas made his estimate for the pebble field he had not differentiated the areas of different grades now shown on plate 5.

[38] Roundy, P. V., op. cit., pp. 310–334.

Presumably his estimate applied chiefly to the area of 70-percent grade but may have taken into account also the areas in Tps. 33 and 34 S. just mentioned. It would seem that some recognition should be given to the area containing 55- to 70-percent grades in the reserves. If half of it may be assumed as capable of yielding 1,000 tons per acre, the area would contain 565,620 acres and about 565,000,000 tons. This area is of course not proved and in fact is not very well known. The figure for tonnage might therefore be divided again, with one-quarter of it, or 141,250,000 tons, being shown as probable reserves and the remaining three-quarters as possible reserves.

The writer, in summarizing, would list the phosphate reserves of the main pebble field, or Bone Valley gravel area, as follows:

Estimated reserves of phosphate in Bone Valley gravel area

Reserves	Acres		Long tons		
	70 percent B. P. L.	55–70 percent B. P. L.	74+percent B. P. L.	70–74 percent B. P. L.	55–70 percent B. P. L.
Known	510, 318		130, 000, 000	1, 870, 000, 000	
Probable	82, 441	141, 250		315, 790, 000	141, 250, 000
Possible	82, 441	423, 750		315. 790, 000	423, 750, 000
Total	675, 200	565, 000	130, 000, 000	2, 501, 580. 000	565, 000, 000
Combined total	1, 240, 000		3, 196, 580, 000		

HARD-ROCK PHOSPHATE

GENERAL OCCURRENCE

The area containing the hard-rock phosphate as mapped by Mr. Akin (see pls. 5 and 8) extends in a slightly southeasterly direction from the southern part of Suwannee and Columbia Counties to the northern part of Pasco County, a distance of about 110 miles. In the northern and southern parts its width ranges from less than 5 to about 12 miles, but in the central part, between Williston and Hernando, it reaches a maximum of about 30 miles. Here it includes the best parts of the "plate rock" area mapped and described by Matson,[39] together with some intervening territory. Matson's map includes in the main hard-rock field what is described in the Thomas brief as the "Steinhatchee area," which is separately considered in this report. The belt thus lies in the northern peninsula of Florida halfway between the central line and the west coast. It is usually covered by an overburden of sand and clay or other materials and can be explored only by prospecting.

CHARACTER

Though in places it contains pebbles, sand, clay, and soft phosphate that apparently have been deposited from water, it is characteristically and chiefly a jumble of pebbles and boulders that range in size from

[39] Matson, G. C., op. cit., pp. 9-10.

less than an inch to masses weighing several tons and that are mixed with clay and with sand resting on a limestone, the surface of which has been made deeply irregular by solution. Many of the boulders contain fragments of earlier masses or boulders of phosphate cemented by later-deposited phosphate. The phosphate rock itself is generally light colored, hard, and dense and breaks with a conchoidal fracture. It is apparently the end product of a long process of residual concentration by repeated solution and redeposition of phosphates and other less-soluble material, which was formerly contained in limestone beds but which has been removed by solution and erosion. These limestone beds are still present in areas bordering the phosphate field and cover large areas in other parts of the State. They are grouped in the Hawthorn formation, which contains not only limestone but in some places beds of bentonitic clays and fuller's earth, some of which are in active production. The nature and origin of the hard-rock phosphate have been fully discussed in earlier State and Federal reports and need not be further considered here.

STRATIGRAPHIC RELATIONS

The hard-rock phosphate deposits and accompanying materials are part of the Alachua formation,[40] of Pliocene age, and are thus comparable in age to the pebble deposits of the Bone Valley gravel, derived from the same source. The distribution of the Alachua formation as recognized by Cooke and Mossom is shown in plate 5. As mapped, it occupies less space than the area prospected by W. L. Akin shown in plates 5 and 8. This area agrees very well with the geologic mapping in much of its length but extends farther north and south and has the eastward extension just mentioned.

The Alachua lies unconformably on the Ocala limestone of Eocene age. The ground prospected by Mr. Akin lies mostly in the areas mapped as Alachua formation and Ocala limestone, though it overlaps the Hawthorn here and there. Its extensions beyond the previously known Alachua strongly suggest that other areas or patches of Alachua may be found in the Ocala limestone area by further prospecting, if the overburden is not too deep. This suggestion is strengthened by the presence of older workings here and there outside the prospected area.

STRUCTURAL RELATIONS

As shown in figure 1 the phosphate accumulations, whether hard-rock or pebble, are closely related to a broad anticlinal or domelike arch, a structural feature whose top is now covered in part by the Alachua formation as mapped. The dome has been unroofed as far down as the Ocala limestone, and during the process the phosphate accumulated. Though gentle, the arch has affected the whole penin-

[40] Cooke, C. W., and Mossom, Stuart, op. cit., pp. 173-179.

sula of Florida, and the successive formations above the Ocala have been eroded back on all sides but curve around where they cross the axis of the fold. Thus the Hawthorn crosses the axis at the northwest in Wakulla and Leon Counties.

Regarding the structure, Cooke and Mossom [41] write:

The movement that raised the Ocala limestone into a dome in central Florida took place a little at a time, between periods of quiescence. Central Florida appears to have been above water in early and late Oligocene time and possibly also in middle Oligocene time, for the Glendon limestone of middle Oligocene age is the only known representative of that time in the region and has been found only along its northern margin. During part of early Miocene time central Florida was dry land, for the lower Miocene Tampa limestone is very thin and at most places is lacking; but during later Miocene stages it was submerged while the sandy limestone of the Hawthorn formation was being deposited. Since Miocene time uplift has continued, and much of the once continuous cover of Hawthorn has been eroded away.

The general features of this anticline or dome have been described and mapped with structure contours by Mossom.[42]

EXTENT OF DEPOSITS

Eldridge [43] writes as follows about the distribution of the hard-rock phosphate:

The distribution of the rock phosphates of the Eocene area is irregular. In some localities heavy deposits exist, while in others there may be none at all. The extent of those portions of the belt thus far yielding to the prospector no evidence of phosphates, it is impossible to conjecture. While a general examination has been made of the entire area, the lines of productive and unproductive areas have been established in but few instances. The southern limit of the Eocene belt is in the vicinity of Richland, in Pasco County. From this point it follows the course of the Withlacoochee River, lying generally to the west of the stream, until, at Dunnellon, where the river turns sharply to the west, the deposits cross it and hold their course with slight deviation to the vicinity of Fort White and Ichetucknee, whence the belt turns westward, and appears finally productive in the vicinity of Luraville on the Suwanee River.

The deposit shown in sec. 17, T. 4 S., R. 12 E. (see pls. 5 and 8), is a mile or 2 north of Luraville (not shown on either map) and is the one mentioned by Eldridge as near that village. Mr. Akin apparently did not extend his prospecting work as far south as Richland. On the map that accompanies his article, Eldridge shows two workings in Gadsden County and one in Leon County, all northwest of Tallahassee. These workings may be in the Hawthorn or in land- or river-pebble deposits derived from it. He also shows in areas designated as hard rock four workings in Jefferson County, as nearly as may be determined from his map, one in Taylor County, and one in Suwannee

[41] Cooke, C. W., and Mossom, Stuart, op. cit., p. 41.

[42] Mossom, Stuart, A review of the structure and stratigraphy of Florida: Florida Geol. Survey 17th Ann. Rept., pp. 254-256, 1926.

[43] Eldridge, G. H., A preliminary sketch of the phosphates of Florida: Am. Inst. Min. Eng. Trans., vol. 21, p. 211, 1893.

County. The last is perhaps the one near Luraville. In addition, he shows one in Hamilton County. On his larger-scale map (pl. 1) he shows an area of hard rock in that county. (See also pl. 5.) It is not known whether the working referred to lies in this hard-rock area or in the pebble field shown in plate 5 and discussed under the heading "Hamilton County." Other workings are shown apparently in Gilchrist, Columbia, and Alachua Counties, which may or may not be included in the area shown in plate 8. The workings shown by Eldridge seem to be along both sides of the hard-rock belt, whereas those shown by Mr. Akin are mostly distributed along the east side.

Sellards [44] has mapped the locations of phosphate mines operating in the hard-rock field during 1908, but as he uses a different scale it is difficult to tell whether these mines all lie in the area mapped by Mr. Akin. A few of them may be outside. On the whole, the evidence seems to show that hard rock may occur here and there throughout a considerable territory not covered by Mr. Akin's map.

AKIN'S PROSPECTING

Mr. Akin [45] submitted with his map (see pl. 8) supplementary data on the areas prospected, together with estimates of tonnage. He writes:

I beg to submit herewith a map * * * showing the hard-rock belt which has been prospected, inspected, and/or surveyed by me over a period of the past 29 years.

I beg to call your attention to the fact that this map does not show the entire hard-rock territory as outlined by Mr. Herman Gunter [46] and Mr. George H. Eldridge, who was formerly with the United States Geological Survey. This map covers only the work that I have done in the period of time outlined above, to which I have added lands around old plant sites where mining operations were conducted in past years. From my personal knowledge and the information that I have, there have been 174 plant locations in the hard-rock territory, and many of these plants operated on from 1 to 10 pits. Some of the pits were located as far as 1 mile from the plant site. Up until the year 1913 a total of 9,313,071 tons of hard-rock phosphate was mined from 174 plants. This gives an average of 52,523 tons to each plant, but it is estimated that the 174 plants mined from approximately 500 different pits. Using the 500 different pits where mining was conducted, we find that the average tonnage mined from each pit was approximately 18,626 tons.

From my experience during the past 15 years I have rediscovered from 3 to 10 times as much phosphate when prospecting on old locations as was originally mined. In Mr. Wayne Thomas' brief he submitted eight old locations that were mined many years ago and gave the tonnage that was originally mined, together with the tonnage that has been recently mined or that is to be mined on these locations in the near future. [Here he repeats the list given by Mr. Thomas (see

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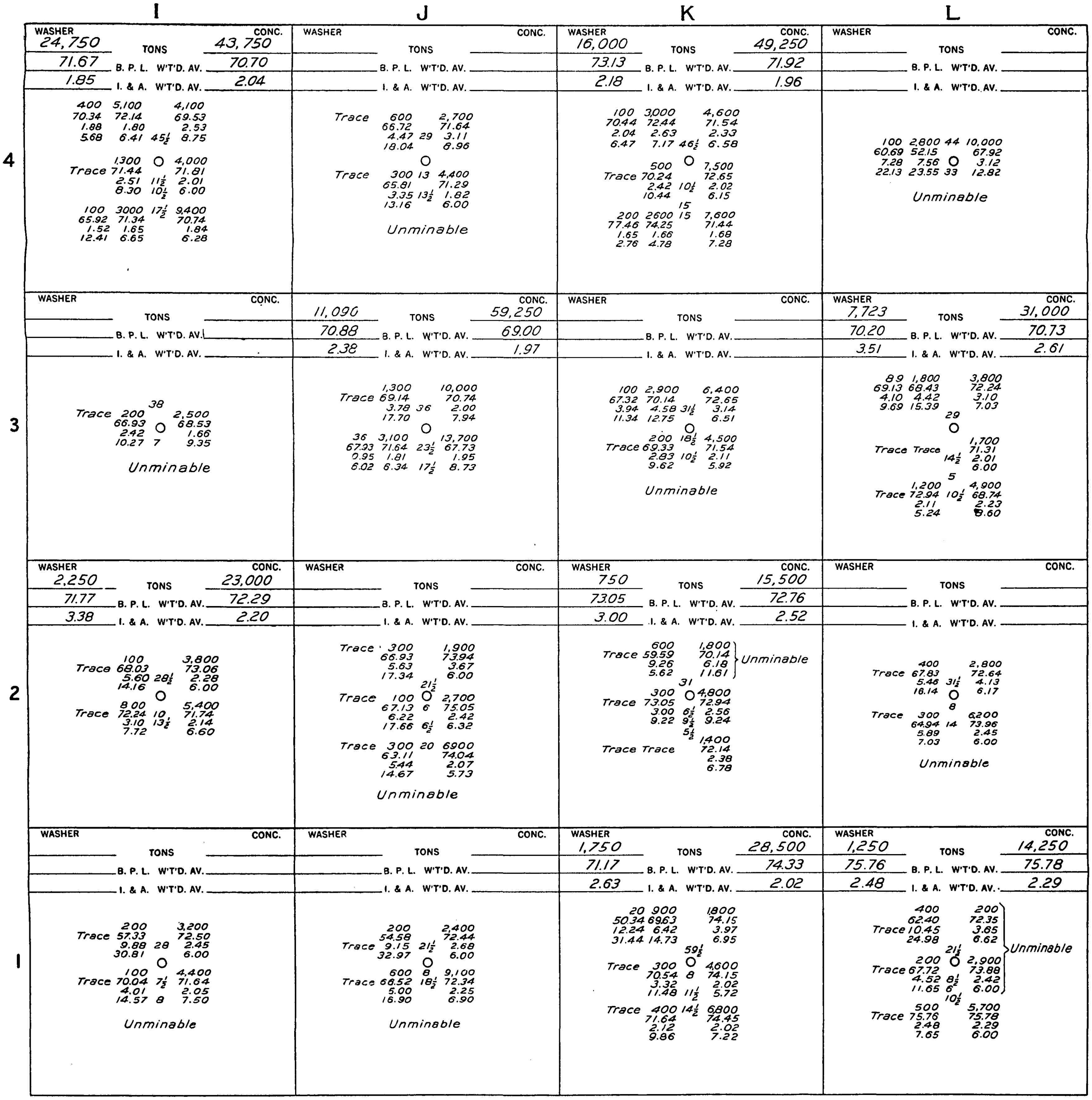
[44] Sellards, E. H., *Mineral industries: Florida Geol. Survey, 2d Ann. Rept.*, p. 236, 1909.

[45] Akin, W. L., personal letter dated January 16, 1939.

[46] See Cooke, C. W., and Mossom, Stuart, op. cit., geologic map.

ACRES	TONS WASHER	TONS CONC.	GRADE	I. & A.	INS.
			66-68%		
		59,250	68-70%	1.97	8.34
12.5	47,563	174,000	70-72%	2.55	8.57
5.	16,750	38,500	72-74%	2.48	6.95
2.5	1,250	42,750	74-76%	2.26	6.65
			+76%		
MINABLE 20.	65,563	314,500			
TOTAL 40.	TOTAL 380,063		W'T'D. AV. I. & A. 2.42		

W'T'D. AV. G'R'D.
71.59 WASHER
71.41 CONC.
71.44 W. & C.



EXPLANATION

WASHER SAMPLES ON LEFT OF HOLE
COARSE ROCK SAMPLE ON EXTREME LEFT
CONC. SAMPLE ON RIGHT OF HOLE
CONC. TONS CORRECTED FOR ADDITIONAL SLIME LOSS AND LABORATORY TAILINGS

CONC., CONCENTRATES
I. A. C., INTERNATIONAL AGRICULTURAL CORPORATION
B. P. L., BONE PHOSPHATE OF LIME
I. & A., IRON AND ALUMINA
W. & C., WASHER AND CONCENTRATES

AVERAGE DEPTH OVERBURDEN	40.81	AVERAGE DEPTH MATRIX	28.25
CU. YDS. O.B. ON MINABLE AREA	1,316,531	CU. YDS. MATRIX ON MINABLE AREA	911,345
CU. YDS. O.B. PER TON OF WASHER ROCK	20.08	CU. YDS. MATRIX PER TON OF WASHER ROCK	13.90
CU. YDS. O.B. PER TON OF WASHER AND CONC.	3.46	CU. YDS. MATRIX PER TON OF WASHER AND CONC.	2.40

CU. YDS. O.B. & MATRIX PER TON OF WASHER ROCK 33.98
CU. YDS. O.B. & MATRIX PER TON OF WASHER & CONC. 5.86

DATE PROSPECTED *Sept. and Oct. 1935*

PLAT SHOWING RESULTS OF REPROSPECTING BY MODERN METHODS

Courtesy of R. B. Fuller, International Agricultural Corporation

p. 9) but makes the following changes in his figures: No. 4, Section 35, original mining 50,000 tons instead of 105,000; No. 6, Blue Run, original mining 30,000 tons instead of 25,000; No. 7, Griggs, recent mining 60,000 tons instead of 150,000 tons.]

In the past 29 years I have prospected, inspected, and/or surveyed a total of 49,320 acres, and in accordance with actual experience on closely prospected properties I have found that on an average 10 percent of the lands contain phosphate deposits; therefore it is my opinion that 10 percent of the 49,320 acres will contain phosphate deposits, which will give 4,932 acres of these lands as being phosphate deposits.

When mining operations first began practically all of the mining was done by pick and shovel, and in the early days it was not possible to mine more than 6 to 10 feet in depth. As improvements in mining operations came about the phosphate companies have been able to mine during recent years as much as 40 feet of phosphate matrix below water level, and in some instances where there is a very deep water level have mined as much as 85 feet of phosphate matrix, and in the deeper and more recent mining the average has been from 9,000 to 25,000 tons per acre. If we add the increased tonnage mined per acre to the comparatively small tonnage mined in the beginning we arrive at a figure of approximately 6,200 tons of phosphate mined per acre over a period of the past 50 years. This averge mining does not include any recovery or soft phosphate.

Since 1935 the companies operating in the hard-rock territory have been using recovery plants from which they have averaged recovering 35 percent additional phosphate rock from the matrix down to 48 mesh in size. My prospections further indicate that there is a minimum of 35 percent of soft phosphate and sizes finer than 48 mesh which is being stored in debris dumps. The grade of all material that has been and is being mined, plus 48-mesh material, is from 65 percent B. P. L. and up. The fine particles of rock, minus 48 mesh, together with the soft phosphate which is being stored in the debris dumps, ranges in grade from 40 to 65 percent B. P. L. By adding 35 percent that is being recovered from the matrix in recovery plants to the average of 6,200 tons per acre, we arrive at a figure of 8,370 tons per acre of phosphate in the deposits. Thirty-five percent of the material of minus 48 mesh and soft phosphate will show approximately 2,170 tons of this material per acre.

While I have prospected, inspected, and/or surveyed a total of only 49,320 acres in a period of 29 years, nevertheless my work has been from the northern to the southern part and from the eastern to the western part on the area indicated by the map. In applying the ratio of 10 percent to this acreage as containing phosphate deposits, I find that 4,932 acres will contain phosphate deposits at an average of 8,370 tons of rock per acre, grading 65 percent and better, which gives a total of 41,280,840 tons of rock in the territory indicated by my map of plus 48-mesh material. I am adding to this figure 2,170 tons per acre × 4,932 acres, which gives an equivalent of 10,702,440 tons of rock finer than 48 mesh and soft phosphate, ranging in grade from 40 to 65 percent B. P. L. Taking into consideration all of the tonnage grading above 40 percent, we arrived at a grand total of 51,983,280 tons on the indicated area.

The area outlined * * * on the map submitted herewith contains 742,400 acres. All of this land is in the hard-rock phosphate belt. By applying the ratio that has been illustrated previously, we find that 74,240 acres of this territory may be considered as probable phosphate reserves. Seventy-four thousand two hundred and forty acres × an average of 8,370 tons per acre is equivalent to 621,388,800 tons of phosphate plus 48 mesh in size and grading 65 percent B. P. L. and above. Seventy-four thousand two hundred and forty acres × 2,170 tons per acre is equivalent to 161,100,800 tons of soft phosphate and material finer than 48 mesh which ranges in grade from 40 to 65 percent B. P. L. I arrive at a total of 782,489,600 tons of all grades of phosphate from 40 percent B. P. L. and above.

I beg to reiterate that the probable phosphate reserves estimated by me do not take into consideration the vast territory in the hard-rock belt that is outlined in the geological maps of Mr. Gunter and Mr. Eldridge. Mr. Wayne Thomas is submitting a supplementary report giving estimates of the additional tonnage in the hard-rock belt that has not been prospected, inspected, and/or surveyed by me.

In checking over Mr. Akin's map, the writer found that the colored areas reached a total of 53,940 acres, as compared with the figure 49,320 given by Mr. Akin. As some of the tracts indicated were indefinite in outline and not readily shown on the scale of the map, there was doubtless exaggeration here and there in mapping as well as error on the writer's part in estimating uncertain acreage. On the whole, the writer's figure may be taken as supporting Mr. Akin's. On Mr. Akin's map the writer counted 172 mines and earlier workings (represented by special symbols), which are the "plants" mentioned by Mr. Akin.

Mr. Akin shows by a boundary on the map the general area within which he has found hard-rock phosphate. He states that this area contains 742,400 acres. The writer, by estimating to the nearest square mile for each township, found the area to contain about 1,258 square miles, or about 805,000 acres. Here again the writer's estimate is probably rougher than Mr. Akin's but serves to support his figure.

Mr. Kibler[47] supports Mr. Akin's estimate in a letter as follows:

In the letter submitted to you as of January 16th, on page 2 we stated that we had averaged mining over a period of 50 years 6,200 tons of phosphate per acre, not including any recovery [product] or soft phosphate. Our records for the last few years show that we have increased our tonnage per acre by recovery methods approximately 35 percent. Thirty-five percent of the 6,200 tons per acre gives a total of 2,170 tons of material which is minus 16, plus 48 mesh. Prospections have further shown that we have accumulated in our debris dumps soft phosphate—minus 48, plus 200 mesh—that will average 35 percent of 6,200 tons. This accounts for an additional 2,170 tons of phosphate material. In taking all grades from 40 percent B. P. L. and up, the average per acre will amount to 10,540 tons.

I wish to state that the above figures are extremely conservative because in recent years we have actually averaged around 14,000 tons per acre, not including the soft phosphate stored in the debris dumps.

ESTIMATES OF RESERVES

Known.—On the basis of the facts just recited, which have been supplemented by personal conversations and visits to field operations, the writer is prepared to accept Mr. Akin's figures as conservative and would classify as known reserves the 4,932 acres underlain by

[47] Kibler, D. B., Jr., personal letter dated February 16, 1939.

41,280,840 tons of phosphate above 48 mesh and containing 65 percent or more B. P. L., together with the 10,702,440 tons of finer rock and soft phosphate contained in the same area.

Probable.—Mr. Akin estimates that the lands containing probable phosphate in the hard-rock area, as outlined on his map, amount to 74,240 acres, and that the total quantity of phosphate above 48 mesh containing 65 percent or more B. P. L. amounts to 621,388,800 tons. Similarly, he estimates that the finer sized and soft phosphate ranging from 40 to 65 percent B. P. L. amounts to 161,100,800 tons. As the figures for the larger area undoubtedly include those of the smaller, it will be necessary to subtract these latter to obtain results for the land reasonably estimated to contain phosphate and hence classed as probable reserves but not actually prospected. The subtraction gives 69,308 acres estimated to contain 580,107,960 tons of rock coarser than 48 mesh and with a B. P. L. content of 65 percent or higher, together with 150,398,360 tons of finer textured and soft phosphate ranging in B. P. L. content from 40 to 65 percent.

Possible.—Mr. Kibler in the letter quoted above writes that his company's mining over a period of years has resulted in an average of about 14,000 tons per acre instead of the 8,370 used by Mr. Akin. If Mr. Kibler's figure were substituted for Mr. Akin's the total phosphate in the 74,240 acres used by Mr. Akin as a basis for computing probable reserves would be 1,039,360,000 instead of 621,388,800, the figure actually used. It would seem legitimate to consider the difference, or 417,971,200 tons, as a possible reserve in the area studied by Mr. Akin and outlined on plate 5. This takes no account of the minus 48-mesh material and soft phosphate, which, if the same percentage of increase were assumed, would yield an additional 107,400,500 tons.

It has been shown on the basis of Mr. Eldridge's work that the area containing the older phosphate workings extends northwestward at least as far as the west side of Jefferson County and as far south as Richland, in Pasco County. If the outlines of the Eldridge mapping are followed (see pls. 1 and 5) about 40 townships, or 1,440 square miles, of potential phosphate land are not included in the area studied by Mr. Akin. Though no mining is in progress in this area and though the prospecting was done by older methods, the returns now obtained from reprospecting and remining old workings justify the hope that these now unproductive areas may ultimately produce. Forty townships include 921,600 acres. If we accept Mr. Thomas' ratio of 5 percent we may consider about 46,000 acres of this area as prospective phosphate land. At 5,000 tons an acre, 46,000 acres would yield 230,000,000 tons, all of which for the sake of being conservative would better be considered as of lower grade.

Summary.—The estimates given above are summarized as follows:

Estimated reserves of phosphate in main hard-rock field

Reserves	Acres	Long tons	
		65 percent B. P. L.	40–65 percent B. P. L.
Known	4,932	41,280,840	10,702,440
Probable	69,308	580,107,960	150,398,360
Total known and probable	74,240	621,388,800	161,100,800
Possible:			
Area examined by Akin		417,971,200	107,400,500
Additional area examined by Eldridge	46,000		230,000,000
Combined total	120,240	1,039,360,000	498,501,300

STEINHATCHEE DISTRICT

The Steinhatchee district as outlined by Mr. Thomas (see pl. 5) covers about 7 townships, or 250 square miles, and comprises about 160,000 acres. This compares with his figure 150,000. The writer has been unable to verify the statement attributed to Alabama engineers, who reported 19 million tons of rock on 2,000 acres. Mr. Akin, however, shows on his map (see pls. 5 and 8) an area of prospected land in T. 6 S., Rs. 10 and 11 E., comprising around 3,000 acres, about which he had no detailed information and for which he presented no estimates

The writer talked with two prospectors who had worked in the area, E. B. Polk and G. D. Mendenhall, both of Lakeland, Fla. Each had done his work some years ago and neither had in his possession when interviewed copies of his prospecting data. Efforts to locate the data have thus far been unavailing. As far as the writer was able to learn, they had been destroyed in the course of passing through the hands of several owners, at least one of whom had since died.

Mr. Polk stated that he had worked in Lafayette County but had found only small scattered deposits and nothing of commercial interest.

Mr. Mendenhall said that he had worked throughout Lafayette and Taylor Counties. The land that he had examined comprised many thousand acres, mostly swamp and cypress timberlands, which included small phosphate deposits, some containing a few hundred or thousand tons of high-grade rock but too scattered to be of commercial interest in themselves or to be combined with other commercial deposits. He said, however, that he had prospected an area on Owl Creek in what is known as Cook's Hammock, about 15–18 miles south of Mayo, which contained much good phosphate but which had 6 to 8 percent of I and A. He thought that an estimate of 600,000 tons for this area would not be too high. From his description it seems likely that this is the area mapped by Mr. Akin and already referred to. Mr. Mendenhall stated that in this area the better rock is mingled with much soft phosphate, and some of it is so soft as to be almost soapy. Soft or soapy rock would escape recovery by usual prospecting methods and could not well be recovered by any washing process, except perhaps as a slime in some waste pit; but it could be utilized along with coarser material in an electric furnace and be largely saved in that way.

In considering phosphate reserves in the Steinhatchee district, the writer believes that on the basis of such independent evidence as he has been able to obtain it is unwise to accept so large a figure as that suggested by Mr. Thomas, but he considers the figure 600,000 tons mentioned by Mr. Mendenhall safe and conservative and is inclined to classify this tonnage as known reserves. To this he would add as probable reserves at least an equal tonnage to include soft and other fine-textured phosphate that would normally be obtained as concentrates by some flotation or tabling process. These figures together amount to 1,200,000 tons. According to the testimony of both Mr. Polk and Mr. Mendenhall, small deposits of no current commercial interest are widely scattered throughout the district. In any long-range view of reserves for coming generations it would seem that these deposits should be given some consideration. Accordingly, it is thought safe to assume that these deposits, which may be classed as possible reserves, would aggregate in quantity at least as much as the sum of those classified as known and probable reserves—that is, 1,200,000 tons. Although their total quantity is probably much greater, present data are insufficient to justify anything but a guess.

In summary, the phosphate reserves of the Steinhatchee district are estimated to total not less than 2,400,000 tons, of which 600,000 tons are classified as known, an additional 600,000 tons as probable, and 1,200,000 tons as possible. It is thought that these figures are conservative because, as already shown, the experience of prospectors and producers in both hard-rock and pebble fields demonstrates that the finer-textured parts of the deposits, formerly lost but now largely recovered by methods previously discussed, may range in quantity from 1½ to perhaps 10 times that of the coarser fractions.

OTHER SOURCES OF PHOSPHATE

Two other sources of phosphate are mentioned by Mr. Thomas—the phosphatic marls in Manatee, Charlotte, Lee, and adjoining counties, and the Hawthorn formation or phosphatic limestone that underlies the phosphate-pebble deposits. The Hawthorn formation is the source of both pebble and hard-rock deposits and is widely distributed through much of the State.

PHOSPHATIC MARLS

The "Manatee River marl" of some of the earlier reports is mapped as Hawthorn by Cooke and Mossom,[48] who thought that it was impracticable to map it separately, although its fauna seems to be younger than that of the typical Hawthorn. A sample taken by R. B. Fuller or one of his associates from a bed 6 feet below the surface near Terra Ceia Island, north of Palmetto, and said to represent a large area, was examined by the writer. It is white and friable and consists of phosphatic grains and pebbles that range from about one-sixteenth of an inch up to about half an inch in length or diameter, together with quartz grains and some other constituents, in a soft matrix that contains calcium carbonate. An analysis of this sample, made in the Federal Geological Survey Laboratory, shows 32.11 percent of B. P. L., 9.90 percent of I and A, and 44.36 percent of insoluble material at 105° C. An analysis of "Manatee marl" furnished by the I. A. C. shows 26.97 percent of B. P. L., 10.39 percent of I and A, and 59.96 percent of sand and insoluble silicates. It is not certain that this analysis represents the sample described, but whatever the material analyzed, the removal of the sand and insoluble constitutents by flotation or tabling would raise its B. P. L. content to about 61 percent.

The name Caloosahatchee marl has been extended by Cooke and Mossom [49] to include all the known marine Pliocene deposits. It is probably unconformable on the Hawthorn, although its contact with underlying formations has not been seen. It is widely distributed in southern Florida and is also mapped in Volusia County. Most of the published references to it make little or no mention of its phosphate content, though Matson [50] writes that neither the Caloosahatchee nor the †Nashua marl (now included with the Caloosahatchee) "includes any commercially important deposits of phosphate, though pebbles of phosphate have been reported from the Caloosahatchee marl on Caloosahatchee River. It is not probable * * * that these pebbles are sufficiently numerous to have any commercial value." Sellards,[51] writing of the pebble phosphate along the Caloosahatchee River, states that the "Caloosahatchee marl * * * contains occasional phosphate pebble and phosphatized casts of shells, but probably not in sufficient abundance to account for the accumulation of the phosphate in the bed of the river, particularly in the lower course of the stream."

The writer has seen no analyses of true Caloosahatchee marl. The analysis given above in connection with the marl from Manatee County cannot be considered representative, as the material is probably referable to the Hawthorn instead of the Caloosahatchee.

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[48] Cooke, C. W., and Mossom, Stuart, op. cit., p. 115 and geologic map.
[49] Cooke, C. W., and Mossom, Stuart, op. cit., p. 152.
[50] Matson, G. C., op. cit., p. 19.
[51] Sellards, E. H., The pebble phosphates of Florida: Florida Geol. Survey 7th Ann. Rept., p. 82, 1915.

Matson[52] describes as follows the phosphatic marl that in some places rests upon the Bone Valley gravel: "The contact of the marl with the gravel is as a rule slightly irregular, and the marl itself is generally intermingled with more or less sand similar to that which forms the overburden. This marl has been mined in the vicinity of Fort Meade and, after burning, is reported to contain a high percentage of tricalcium phosphate." Whether this marl is part of the Bone Valley sequence or of the Caloosahatchee is not known.

The Caloosahatchee marl is with little doubt phosphatic, but in the absence of carefully selected samples and analyses too little is known about its possibilities to justify any consideration of it now as a possible phosphate resource. The evidence supplied by the "Manatee marl," described above, probably does not apply.

HAWTHORN FORMATION

The "Alum Bluff formation," now raised to the rank of a group which includes the Hawthorn, is discussed by Matson,[53] who gives some lithologic details, discusses the scource of the phosphoric acid, and furnishes analyses, which are utilized in the table on page 59.

The Hawthorn formation is also described at some length by Cooke and Mossom,[54] who give many details of its occurrence in different parts of the State. According to these authors.

> The most persistent component of the Hawthorn formation is white or cream-colored sandy limestone containing brown grains of phosphorite. Rock of this kind is widely distributed in the peninsula and the northern part of the State but is rarely seen in natural exposures, for it readily disintegrates into sand. * * * Green or gray siliceous clay or fuller's earth forms an important part of the Hawthorn in Gadsden County and is present in less abundance in the peninsula.

The general distribution of the Hawthorn as mapped by Cooke and Mossom is shown in plate 5. A rough count of the townships mapped as Hawthorn gives 315, which is equivalent to 11,340 square miles, or 7,257,600 acres. Undoubtedly the formation underlies far greater territory but is concealed by heavy overburden of overlying formations. The greatest thickness reported by the authors cited is approximately 500 feet in a well in Jacksonville. Because of the generally low relief of Florida, only part—and usually a small part—of the thickness is revealed in any exposed section. In many of the exposures the phosphate has apparently been leached away and only sand remains. Phosphate beds beyond the range of leaching are present however, at least locally, at considerable depth, as shown by well logs.

Four of these logs have been published by Sellards:[55] Well No. 3, Palmetto Phosphate Co., Tiger Bay, Fla.; well No. 3, Palmetto

[52] Matson, G. C., op. cit., p. 44.
[53] Matson, G. C., op. cit., pp. 58-64, 76-79.
[54] Cooke, C. W., and Mossom, Stuart, op. cit., pp. 115-137.
[55] Sellards, E. H., The pebble phosphates of Florida: Florida Geol. Survey 7th Ann. Rept., pp. 45-53, 1915.

Phosphate Co., near pit No. 1, about 2¾ miles northwest of Tiger Bay; well of the Phosphate Mining Co., Christina, Fla.; and City well, Fort Myers, Fla. When Sellards published these logs the name Hawthorn was not in use, but it is applicable now to the beds to which he applies the following description:

Beneath the land-pebble phosphate beginning with the "bed rock," as the term is used in mining operations, is found a succession of phosphatic marls extending at Tiger Bay to a depth of about 360 feet. At Christina, about 16 miles north of Tiger Bay, the formation is not more than 100 feet thick, while at Fort Meyers, about 70 miles south of Tiger Bay, it is at least 600 feet thick. The material throughout this whole thickness, while by no means uniform, apparently represents a single geologic formation, which is locally variable; the phosphate pebbles which occur throughout the whole thickness are black, brown, or white in color and are rounded, smooth, and shiny. The pebble is imbedded in a marl which is light buff or grayish. The marl is throughout more or less sandy, so much that in some samples it becomes almost a calcareous sandstone. Locally the material of this marl has become compact and close grained, probably in the form of small boulders which are broken up in drilling. Boulders of this type may be either calcareous or flinty. * * * The marl is with little doubt the present formation from which by reworking and concentration the pebble phosphate conglomerate of the Bone Valley formation was formed.

Excerpts from five other well logs, kindly loaned by Mr. Thomas, are given on the following pages:

Log of city of Bradenton's well No. 1

[Owner, city of Bradenton. Location, Bradenton, Manatee County. Started, Dec. 16, 1926; completed, Feb. 15, 1927. Altitude, 14 feet. Total depth, 922 feet. Driller, Virginia Machinery & Well Co.]

	Thickness (feet)	*Depth (feet)*
Upper 20 feet not recorded	20	20
Dark-colored sandy muck	20	40
Soft white slightly sandy marl; small specks of phosphate (?)	4	44
Soft white phosphatic marl, slightly sandy	5	49
White to gray fairly soft phosphatic marl with considerable flint	9	58
Soft grayish phosphatic marl	7	65
Grayish slightly sandy phosphatic marl	5	70
Gray very clayey phosphatic marl	50	120
Grayish quite clayey phosphatic marl	10	130
White phosphatic marl	10	140
[Missing]	10	150
Light-colored, greenish clay; some phosphate pebbles	15	165
Grayish phosphatic marl	15	180
Gray clayey phosphatic marl	20	200
Mainly phosphate pebbles and sand with some marl	14	214
Phosphatic marl, some white calcareous and some gray and clayey; one large specimen of flint	16	230
Gray very sandy phosphatic marl	35	265
White slightly sandy marl; very little phosphate apparent; some shell fragments	5	270

Log of city of Bradenton's well No. 1—Continued

	Thickness (feet)	Depth (feet)
White quite hard limestone; quite a few phosphatic pebbles	5	275
Greenish clayey phosphatic marl	10	285
Light-yellowish sandy phosphatic marl (perhaps hard rock in streaks)	25	310
Mainly phosphatic marl with pieces of cream-colored limestone; some casts of mollusks in limestone, also *Orbitulites floridanus* Dall. From drillers log it would appear that the top of the Tampa limestone was encountered at 335 feet	32	342
Cream-colored limestone; Tampa limestone	18	360

Log of Coronet Phosphate Co.'s well

[Owner, Coronet Phosphate Co. Location, about 2 miles east of Mulberry, Polk County. Started, March 1929. Altitude, about 90 feet. Total depth, 778 feet. Driller, Virginia Machinery & Well Co.]

	Thickness (feet)	Depth (feet)
Gray-white sandy slightly phosphatic marl	145	145
Fairly hard gray marl	5	150
Dark-gray clay, white sandy marl, some phosphate and some chert	5	155
Greenish-gray very clayey marl	5	160
Same	5	165
Same	5	170
Greenish-gray very sandy phosphatic marl	5	175
Light-gray and white sandy phosphatic marl. Mollusca casts in white marl. Shark teeth	5	180

Summary (in part): Surface to 180 feet, no samples preserved. In this interval we know from sections made in the pebble-phosphate pits that there is but a few feet of Pleistocene sand, resting unconformably on the beds of the Pliocene (Bone Valley gravel). Toward the bottom of the Bone Valley gravel at a depth of from 10 to 25 feet occur the workable beds of land-pebble phosphate. These workable beds, 18 to 20 feet thick, lie immediately but unconformably on the Hawthorn formation; and the formation continues to 180 feet.

Log of Waverly well

[Owner, Waverly Growers and town of Waverly. Location, ⅛ of a mile north of post office, Waverly, Polk County. Started, May 1, 1937; completed June 1937. Altitude, about 130 feet (5 feet below depot). Total depth, 545 feet. Driller, A. W. Marquardt. Static water level reported 15 feet below surface]

	Thickness (feet)	Depth (feet)
Fine brown sand	8	8
Fine gray sand	6	14
Fine cream-white sand	6	20
Fine light-gray sand	10	30
Fine dark-gray sand	10	40
Dark argillaceous sand	10	50
Dark calcareous sandy clay	10	60
Hard, grayish-white limestone with phosphate pebbles	10	70
Hard, grayish-white limestone and considerable pebble phosphate	10	80

Log of Waverly well—Continued

	Thickness (feet)	Depth (feet)
Grayish-white limestone with phosphate pebbles	10	90
Same	10	100
Cream-colored limestone with some fragments of casts of fossils; phosphatic	10	110
[Missing]	20	130
Fairly hard gray sandy phosphatic marl or limestone. Quite phosphatic	10	140
Fairly hard white sandy phosphatic limestone with fragments of fossils	10	150

Summary: From the surface to 40 feet are sands probably of Pleistocene age. At 40 feet a decided change in color and texture of the sands probably represents a formational change (Pliocene?). At 60–70 feet another change takes place, a phosphatic light-colored limestone being encountered. This is the Hawthorn formation, of Miocene age. Material of this character continues to 140 feet. The sample taken from 140–150 feet is a fairly hard white sandy phosphatic limestone and this may indicate another formation, possibly the Tampa limestone of lower Miocene age. At 150–160 feet a soft, white limestone full of fossils characteristic of the Ocala limestone was penetrated. The top of the Eocene is placed at this level, and the samples indicate that this formation continues to the completed depth of the well.

Log of Carmichael No. 8 well

Owner, American Agricultural Chemical Co. Location, Northeast corner of SE¼NE¼ sec. 18, T. 30 S., R. 22 E., at Carmichael, Hillsborough County. Started, Sept. 30, 1929; completed Nov. 15, 1929. Altitude, 89 feet. Total depth, 776 feet. Driller, Virginia Machinery & Well Co. Flows 660 gallons a minute; discharge on pump 3,900 gallons a minute]

	Thickness (feet)	Depth (feet)
BONE VALLEY—PLIOCENE		
[Missing]	10	10
Mainly brown sandy phosphatic marl with some gray phosphatic marl	10	20
White slightly sandy phosphatic marl	10	30
Gray clay	10	40
Gray sandy clayey phosphatic marl	10	50
HAWTHORN—MIOCENE		
Hard gray cherty sandy marl	10	60
Same with a few casts of mollusks—*Pecten* sp., cf. *P. acanikos* Gardner	10	70
Fairly soft light-colored sandy phosphatic marl	10	80
Same	10	90
Gray-green very sandy phosphatic marl	10	100
Same	10	110
Same	10	120
Soft white sandy slightly phosphatic marl, quite limy	10	130
Same	10	140
Same	10	150
Same, less sand and more lime	10	160
Same	10	170

Log of Carmichael No. 9 well

[Owner, American Agricultural Chemical Co. Location, 300 feet west and 600 feet north of the center of sec. 6, T. 30 S., R. 22 E., in Hillsborough County. Started, June 28, 1933; completed, Mar. 24, 1934. Altitude, 100 feet. Total depth, 805 feet. Driller, Layne-Southeastern Co. On March 26 the well was tested and showed a volume of 4,425 gallons a minute.]

	Thickness (feet)	Depth (feet)
PLEISTOCENE		
Purplish-colored clayey sand	5	5
Purplish-colored clayey sand with a few white clay balls	5	10
BONE VALLEY—PLIOCENE		
Gray phosphatic sand with some darker clayey sand	5	15
Gray sandy phosphatic marl	1	16
Brown-green sandy phosphatic clay	4	20
Gray sandy phosphatic marl	10	30
[HAWTHORN]—MIOCENE		
Yellow sandy and clayey phosphatic marl	5	35
Yellow sandy and clayey phosphatic marl	11	46
Sandy yellow phosphatic marl	3	49
Yellow phosphatic marl and brown pebble phosphate	3	52
Yellow phosphatic marl with some brown pebble phosphate	3	55
Yellow phosphatic marl; some sand and small phosphate pebbles	3	58
Yellow phosphatic marl; some sand and small phosphate pebbles	2	60
Light-colored phosphatic marl	1	61
Light-colored phosphatic marl	4	65
Light-colored phosphatic marl	5	70
Mostly sand with fine phosphate pebbles and some pieces of light-colored phosphatic marl	1	71
Gray limestone with light- and dark-colored pebble phosphate	4	75
Gray sand with fragments of rather hard dark limestone and dark-colored pebble phosphate	2	77
Gray sand with fragments of rather hard dark limestone and dark-colored pebble phosphate	2	79
Light-colored limestone with some fragments of rather hard dark limestone and light and dark phosphate pebbles	1	80
Same	5	85
Light-colored limestone with some fragments of rather hard dark limestone and sand; light and dark pebble phosphate	5	90
Light-colored limestone with some fragments of darker limestone, considerable sand, and few phosphate pebbles	3	93
Mostly light-colored fine sand with some minute pebble phosphate	4	97
Same	1	98
Soft light-colored limestone and sand	2	100

Log of Carmichael No. 9 well—Continued

[HAWTHORN]—MIOCENE—continued	*Thickness (feet)*	*Depth (feet)*
Soft light-colored limestone and some sand	3	103
Soft light-colored limestone and some sand and phosphate pebbles	2	105
Finely powdered soft light-colored limestone, sand, and some phosphate pebbles	1	106
Light-colored limestone and light and dark phosphate pebbles	5	111
Same	5½	116½
Soft light-colored limestone and a fragment of hard light-colored limestone	½	117
Soft light-colored limestone, sand, and some phosphate pebbles	2½	119½
Light-colored limestone; some sand	4½	124
Light-colored limestone; some sand and phosphate pebble and hard limestone	6	130
Light-colored limestone and fragments of chert	4	134
Soft light-colored limestone with an abundance of dark chert fragments	8	142
Same with less chert	3	145
Principally dark chert with some light-colored limestone	7	152
Soft light-colored limestone and finely broken dark chert	4	156
Same	9	165
Same with considerable percentage of sand	3	168
Light-colored limestone	3	171
Light-colored brownish limestone and sand	9	180
Light-brown limestone and sand	5	185
Very light brown limestone	5	190
Very light brown limestone	5	195
Light-colored limestone and sand	5	200
Light-colored limestone and sand	5	205
Light-colored limestone and sand	5	210
Fairly hard light-brown limestone with some light almost white limestone	5	215
Light-colored limestone	3	218

The first well, No. 1, city of Bradenton, lies outside the pebble-phosphate area and presumably penetrates no pebble phosphate. The first 44 feet may be considered overburden, and the remaining part of the section down to about 335 feet is probably Hawthorn, making a total of about 291 feet of phosphatic beds to be ascribed to this formation.

The second well, Coronet Phosphate Co., is in the pebble-phosphate area and reveals 35 feet of beds ascribed to Hawthorn, to which should probably be added 120 feet, for which no details are available, making a total of 155 feet for the Hawthorn formation at this locality.

The third well, Waverly, about 5 miles north of Lake Wales, is outside the pebble area as mapped. The overburden is about 60 feet thick, and the Hawthorn is presumably 80 to 90 feet thick.

The fourth well, No. 8, Carmichael, is in the pebble field. The Hawthorn is about 120 feet thick and reveals about 80 feet of phosphatic material.

The fifth well, No. 9, Carmichael, is also in the pebble field. It discloses Hawthorn from depths of 30 to about 210 feet; hence the Hawthorn is here about 180 feet thick.

None of the well logs just given is accompanied by analyses showing the richness of the phosphate beds in the Hawthorn, as this was a matter of little general interest at the time the wells were drilled. However, analyses were made in November 1938 of nine samples from the Waverly well. These analyses, which show something of the range in phosphate content of this formation, are given in the following table, together with such other analyses of samples from the Hawthorn formation as are available.

As might be expected, the analyses show wide variation in B. P. L. content as they were not systematically collected. Those samples that came from the bottom of phosphate mines and from the well at Waverly appear most promising, possibly because they all came presumably from below water level. The rocks from which they came escaped leaching and may have benefitted by secondary enrichment.

Mr. Thomas [56] comments on the samples from the well at Waverly as follows:

> I * * * attach a certificate of analysis showing the material taken from the town well at Waverly, in Polk County. Please note that Waverly is far east of the limits of the Bone Valley field as we have previously conceived them. Kindly note the very high grade found in the well borings from 50 feet to 80 feet. Flotation tests under Mr. Fuller's direction show that all of the material covered by analyses 369,770 to 369,774 are very excellent flotation feed. These analyses are higher on an average than much of our standard pebble matrix. Much good phosphate is being mined at present where the matrix analyzes only 30 percent B. P. L. From this material Mr. Fuller has had no trouble in recovering grades up to 74 percent or better. It is an excellent flotation feed.

The well at Waverly is perhaps not a clear case because the better grades of phosphate lie within depth ranges not uncommonly occupied by pebble deposits, the well log shows them to be associated with phosphate pebble, and the well itself is only 10 or 12 miles east of the boundary of the pebble field as now drawn. Extending the boundary eastward to include this area would involve less violence to former ideas than the change already made in stretching the boundary into northwestern Highlands County.

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[56] Thomas, Wayne, personal letter dated November 17, 1938.

Analyses of phosphate samples from the Hawthorn formation at different localities in Florida

Locality	Description	Number		Depth (feet)	B. P. L. (percent)	I and A (percent)	Insoluble (percent)	Source
		Sample	Analysis					
165 feet east and 495 feet south of NW. corner NE¼ sec. 31, T. 29 S., R. 24 E.	2 feet below bottom of phosphate matrix		368,273	39½	67.88	2.80	13.79	I. A. C.
Do	do		368,274	39½	75.46	3.33		Do.
Worthington Springs	State road project 888-B	1	370,754		14.11			Do.
Wekiva River	State road project F. A. S. 3-B	3	370,739		8.76			Do.
Do	do	4	370,740		10.21			Do.
Do	do	5	370,741		9.92			Do.
Do	do	6	370,742		4.58			Do.
Do	do	7	370,743		8.65			Do.
Do	do	8	370,744		3.67			Do.
Suction well, San Gully, cut 96, east end	4½ feet top part		75,601		15.88	9.60	63.64	Southern Phosphate Corporation.
Do	2 feet bottom part		75,602		8.45	2.24	23.10	Do.
Do	5 feet middle part		75,603		9.44	3.88	53.88	Do.
Suction well, San Gully, cut 97, west end about 2,000 feet from cut 96.	7 feet hard clay		75,950		36.75	8.77	43.50	Do.
Do	3 feet soft clay		75,951		42.85	7.00	31.73	Do.
Do	3 feet hard clay		75,952		16.80	5.26	30.14	Do.
Do	do		75,953		13.01	4.22	30.26	Do.
Rock pit No. 9, Carmichael	Bed clay or rock sample:							
	0-14 inches clay	1	96,833		37.51	5.49	39.75	A. A. C.
Do	14-30 inches clay	2	96,834		29.64	3.50	55.00	Do.
Do	30-38 inches clay	3	96,835		23.03	3.10	63.65	Do.
Do	38-50 inches clay	4	96,836		31.01	2.53	54.70	Do.
Do	50-62 inches clay	5	96,837		28.84	2.77	55.50	Do.
Do	62-70 inches clay	6	96,838		20.98	2.63	61.60	Do.
Do	70-84 inches clay	7	96,839		15.85	2.12	66.10	Do.
Do	84-89 inches clay	8	96,840		15.96	12.10	56.65	Do.
Do	89-96 bedrock	9	96,841		9.80	1.64	29.25	Do.
Rock pit No. 38, South Pierce	Bed clay or rock sample:							
	0-9 inches clay	1	96,802		18.58	7.02	65.91	Do.
Do	9-22 inches clay	2	96,803		18.01	6.61	66.85	Do.
Do	22-34 inches clay	3	96,804		27.47	4.45	56.31	Do.
Do	34-44 inches clay	4	96,805		19.03	6.56	62.94	Do.
Do	44-54 inches clay	5	96,806		14.59	2.55	51.00	Do.
Town of Waverly	Well (W-345)		369,769	30-40	.11			I. A. C.
Do	do		369,770	50-60	34.96			Do.
Do	do		369,771	60-70	35.06			Do.
Do	do		369,772	70-80	40.68			Do.
Do	do		369,773	80-90	24.05			Do.
Do	do		369,774	90-100	15.34			Do.
Do	do		369,775	100-110	9.70			Do.
Do	do		369,776	130-140	9.66			Do.
Do	do		369,777	150-160	3.52			Do.

Near Hawthorn	Limestone formerly quarried	31			35.11	21.28	46.76	U. S. G. S. Bull. 604 p. 77.
Do	do	32			28.50	14.68	50.73	Do.
Prairie Phosphate Co. mine near Mulberry.	Matrix	33A			3.74	1.32	14.62	U. S. G. S. Bull. 604, p. 78.
	Nodules	33B			60.17	3.79	3.51	Do.
Central part of region	Limestone	34			19.77	6.33	13.21	Do.
Christina	Phosphatic limestone	35			66.81	8.08	14.45	Do.
1 mile north of Bartow	Bedrock				5.00	.5		U. S. G. S. Bull. 604, p. 81.

On the other hand, the better values beneath the phosphate mines, so far as shown by the samples analyzed, reside in the so-called "bed clay" immediately below the phosphate matrix rather than in the bedrock. This fact suggests that before abandoning mined-out areas operators would do well to consider whether they might not increase their recovery by applying flotation methods to the bed clay where analyses seem favorable.

Of the last seven samples listed, five apparently represent actual bedrock (the samples of nodules and matrix are excluded). Three of the five samples have a sufficient B. P. L. content to suggest that with the application of flotation methods high-grade phosphate products might be obtained.

The analyses given apply to only 14 different localities in a group of deposits that underlie more than 11,000 square miles. Hence they afford little basis for any judgment of the phosphate content of the formation as a whole. The analyses vary considerably and are not all definitely referable to the Hawthorn. Moreover, none of them, unless possibly those from the well at Waverly, show anything of the phosphate content of beds deep within the formation. The samples from the well at Waverly may actually be from an outlying bed of Bone Valley gravel and hence not applicable to the problem of the Hawthorn formation. Though some of the analyses serve to draw attention to the Hawthorn as a possible source of vast reserves of phosphate, any estimate of such reserves is not now feasible. Systematic prospecting by drilling will be necessary before any worthwhile figures can be formulated. The companies now operating in the pebble field are the ones who could drill most readily and cheaply. As pits are mined out, one or more test holes drilled in each 40 acres, or any other selected unit area, would gradually build up the required reliable information. The writer therefore refrains from offering any estimate as to the quantity and quality of the admittedly great store of phosphate contained in the Hawthorn formation.

SUMMARY OF PHOSPHATE RESERVES IN FLORIDA

The results of the preceding discussion of phosphate reserves of different types in different fields are summarized in the following table:

Summary of phosphate reserves in Florida

Type or field	Acres	Grade (percent of B. P. L.)	Reserves (long tons)			Remarks
			Known	Probable	Possible	
River pebble		55+	5,000,000	15,000,000	30,000,000	Rounded figures throughout.
Land pebble:						
Hamilton County	14,000		1,000,000	24,000,000	25,000,000	77 percent grade possible by crushing and flotation.
Clay County					90,000,000	Similar to deposits of Hamilton County.
Bradford County					55,000,000	May be Hawthorn. Grade probably under 70 percent.
Lake and Orange Counties					100,000,000	Grade 55 percent or better.
Main field, Bone Valley gravel	675,000	74+	130,000,000			
		70–74	1,870,000,000	315,790,000	315,790,000	
	565,000	55–70		141,250,000	423,750,000	
Hard rock:						
Main field	120,000	65+	41,281,000	580,108,000	417,970,000	
		40–65	10,702,000	150,398,000	337,400,000	
Steinhatchee district	3,000		600,000	600,000	1,200,000	
Total	1,377,000		2,058,583,000	1,227,146,000	1,796,110,000	

Total known, probable, and possible tons in areas considered, all grades, 5,081,839,000 long tons.

PUBLIC PHOSPHATE LANDS IN FLORIDA

On May 24, 1924, the Geological Survey published a statement (Press notice No. 17320) prepared by G. W. Holland relative to the public phosphate lands in Florida, together with a list of those lands. As this statement has long been out of print it is here reprinted with such modifications as are now necessary. The lands are listed by counties, as well as by township, range, and section.

Public Lands in Phosphate Fields

Under authority of the act of Congress approved June 25, 1910 (36 Stat. 847), tracts of land in Florida amounting to about 66,796 acres are now withdrawn from unrestricted disposal under the nonmineral land laws because of their prospective value for deposits of phosphate. To these should be added 120 acres that have been prospected and classified as phosphate land. These tracts were withdrawn in pursuance of the general policy of administering the public lands in accordance with their principal value. Under this policy lands that are believed to contain phosphate must be disposed of with due regard to their mineral character instead of as agricultural land or by application of scrip, as formerly. The peak of activity in the disposal of public land in Florida was reached many years before phosphate was discovered, in 1888, and the withdrawals under the act of June 25, 1910, have resulted in the reservation of only small isolated tracts distributed in a broad belt that extends from Apalachicola River southeastward and then southward to the mouth of Caloosahatchee River, near Fort Myers.

Although most of the lands withdrawn are in areas where phosphate-bearing rocks may occur, only a few tracts have been prospected, and the quality and extent of the phosphate deposits are practically unknown in the remainder of the lands. Until prospecting has definitely shown whether or not the latter lands contain valuable deposits of phosphate a classification as to their mineral or nonmineral character cannot definitely be made. However, applications for nonmineral entries for such lands may be filed and allowed under General Land Office Circular No. 1303, in accordance with the act of March 4, 1933 (47 Stat. 1570), if, in the opinion of the Secretary of the Interior, the granting of surface rights with a reservation of the phosphate deposits to the Federal Government will not interfere with or seriously embarrass operations under the mineral leasing acts.

Leasing of Government-owned Phosphate Deposits

The deposits of government-owned phosphate, whether title to the surface of the land in which they occur has been disposed of or remains in the United States, are subject to disposition under authority of the act of Congress approved February 25, 1920 (41 Stat. 437), generally known as the mineral leasing law. Circular No. 696 of the General Land Office, which may be obtained from the Commissioner of the General Land Office, Washington, D. C., contains the sections of this law that relate to phosphate and the regulations thereunder issued by the Secretary of the Interior, as well as a form of lease in current use, which may be modified in some particulars according to circumstances that may affect individual applications. Leases for areas of 2,560 acres or less are issued to citizens of the United States, to associations of citizens, and to corporations organized under the laws of the United States or of any State or Territory. The leases are drawn for indeterminate periods and are subject to readjustment of terms and conditions at 20-year intervals. A minimum bona fide expenditure for mine operations, development, or improvement is required, and bond must be given to insure compliance with the terms of the lease. Royalties are paid according to production, at rates specified in the lease, the lowest rate being fixed by the law at 2 percent of the gross value of the output of phosphate at the mine. A ground rental of not less than 25 cents per acre is charged for the first year of the lease, 50 cents per acre for the second, third, fourth, and fifth years, respectively, and $1 an acre for each year thereafter, the rental for each year being credited against the royalties as they accrue for that year. All applications for lease of Florida phosphate lands should be filed in the United States Land Office at Gainesville and should incorporate the information called for in General Land Office Circular No. 696.

In the absence of objection in the local land office the applicant is required to publish at his own expense for a period of 30 days in a newspaper of general circulation in the county in which the deposits are situated a notice of the application, and upon proof of publication the application is transmitted to the General Land Office with a report. If the application is considered favorably by the General Land Office the terms of the lease to be given by the Government are agreed upon between the applicant and the Department of the Interior. The filing of an application segregates the land, and if the terms finally fixed are acceptable to the applicant the lease is awarded without competition.

LIST OF PUBLIC PHOSPHATE LANDS

Federal lands in Florida withdrawn for phosphate classification or classified as phosphate land as of January 1, 1939

[Tallahassee meridian. *indicates uncertain title; (R) indicates sections prospected by P. V. Roundy; (P) indicates sections prospected by J. T. Pardee]

ALACHUA COUNTY

T. 6 S., R. 17 E., sec. 36, NW¼SE¼.
T. 7 S., R. 17 E., sec. 12, lots 1, 2, and 4.
T. 8 S., R. 17 E., sec. 6, SE¼NW¼.
T. 11 S., R. 17 E., sec. 4, SW¼NW¼, W½SW¼, SE¼SW¼.
sec. 8, E½NE¼.
sec. 10, N½NW¼, SW¼NW¼, W½SW¼, N½SE¼, SE¼SE¼.
T. 7 S., R. 18 E., *sec. 13, W½NE¼.
sec. 21, lot 5.
T. 12 S., R. 23 E., sec. 6, lots 18, 19, 23, and 24.

CHARLOTTE COUNTY

T. 41 S., R. 19 E., sec. 13, lot 1.
T. 41 S., R. 20 E., sec. 19, lots 1, 4, and 5.
sec. 29, lot 1.
sec. 33, lots 4, 6, 8, 9, 10, 11, 12, 14, and 15.
T. 42 S., R. 23 E., sec. 32, NE¼SE¼.
T. 40 S., R. 26 E., sec. 1, SW¼NW¼, W½SW¼, SE¼SW¼, SW¼SE¼.
sec. 2, SE¼NE¼, SW¼NW¼.
sec. 3, S½NW¼.
sec. 4, SE¼NW¼.
sec. 5, W½NE¼, SE¼NE¼, SW¼NW¼, SE¼.
sec. 8, NE¼NE¼, S½NE¼.
sec. 12, lots 3, 4, W½SW¼, SE¼SW¼.
sec. 13, lots 1 and 2.
sec. 14, NW¼NW¼.
sec. 21, SE¼.
sec. 25, NW¼SE¼.
sec. 29, NE¼SE¼.
sec. 36, lots 1, 2, 3, 6, 7, NW¼NE¼.

CITRUS COUNTY

T. 17 S., R. 17 E.,	sec. 7,	SF¼SW¼.
	sec. 25,	N½NE¼.
	sec. 36,	NE¼SE¼.
T. 19 S., R. 17 E.,	sec. 4,	W½NE¼.
T. 17 S., R. 18 E.,	sec. 35,	S½SW¼.
T. 18 S., R. 18 E.,	sec. 6,	N½NE¼.
	sec. 19,	NE¼NE¼, NW¼NW¼.
	sec. 21,	NW¼NW¼.
T. 19 S., R. 18 E.,	sec. 7,	W½NE¼, S½NW¼.
	sec. 29,	NE¼NW¼.
	sec. 30,	SW¼NE¼, S½NW¼.
T. 17 S., R. 19 E.,	sec. 22,	NE¼NW¼.
T. 19 S., R. 19 E.,	sec. 14,	NE¼ (R).
T. 20 S., R. 19 E.,	sec. 20,	SW¼NW¼ (R).
T. 17 S., R. 20 E.,	sec. 30,	SF¼NW¼.
T. 18 S., R. 20 E.,	sec. 18,	SW¼NE¼, E½SW¼, NW¼SE¼.
	sec. 20,	N½NW¼.
	sec. 28,	SE¼SW¼.
T. 19 S., R. 20 E.,	sec. 9,	SW¼NE¼.
T. 20 S., R. 20 E.,	sec. 6,	NW¼SW¼.
T. 19 S., R. 21 E.,	sec. 8,	NE¼SW¼.

COLUMBIA COUNTY

T. 2 S., R. 15 E.,	sec. 13,	NW¼SW¼, S½S½.
T. 2 S., R. 16 E.,	*sec. 32,	SW¼SW¼.
T. 3 S., R. 16 E.,	sec. 1,	SW¼NE¼.
	sec. 22,	NE¼SE¼.
T. 4 S., R. 16 E.,	sec. 21,	W½NW¼, N½SW¼.
T. 6 S., R. 16 E.,	sec. 29,	NW¼NW¼.
T. 7 S., R. 16 E.,	sec. 35,	lot 5.
T. 5 S., R. 17 E.,	sec. 34,	SE¼SW¼.
T. 6 S., R. 17 E.,	sec. 2,	NE¼SE¼.
	sec. 6,	NW¼SW¼, SE¼SW¼.
	sec. 7,	NE¼NW¼.
	*sec. 27,	E½SW¼, S½SE¼.
T. 6 S., R. 18 E.,	sec. 18,	NE¼SW¼, SW¼NW¼, S½SW¼.

DE SOTO COUNTY

T. 38 S., R. 23 E.,	sec. 6,	SE¼NE¼.
	sec. 25,	SW¼SE¼.
T. 39 S., R. 23 E.,	sec. 1,	lot 3.
	sec. 12,	N½NW¼ (frac.), SW¼NW¼.
T. 38 S., R. 24 E.,	sec. 3,	N½NW¼.
	sec. 6,	N½NE¼, S½SE¼.
	sec. 7,	NW¼NE¼.
T. 37 S., R. 25 E.,	sec. 20,	E½NE¼.

DIXIE COUNTY

T. 9 S., R. 12 E., sec. 32, NW¼SE¼.
sec. 34, SW¼NE¼, W½NW¼, SE¼NW¼.
sec. 36, S½NE¼, N½SW¼, NE¼SE¼.
T. 8 S., R. 13 F., sec. 14, N½SE¼.
sec. 26, NE¼SW¼.
T. 9 S., R. 13 E., sec. 3, NW¼NW¼.
sec. 9, SE¼.
sec. 10, S½NE¼, SE¼NW¼, S½.
sec. 13, lots 3, 4, and 7.
sec. 15, all.
sec. 17, NE¼, E½NW¼, SE¼SW¼, SW¼SE¼.
sec. 18, SE¼NE¼.
sec. 19, N½NE¼.
sec. 21, NW¼NE¼, NE¼NW¼.
sec. 22, NE¼.
sec. 23, S½NE¼.
sec. 24, lots 3, 4, 5, 6, 7, and 8.
sec. 31, SE¼NW¼, SE¼SE¼.
T. 10 S., R. 13 E., sec. 18, NW¼NE¼.
sec. 28, E½NW¼, NE¼SW¼.
sec. 29, NW¼SW¼, NE¼SE¼.
sec. 31, SE¼SW¼, SW¼SE¼.
sec. 32, F½SE¼.
sec. 33, E½NE¼, SE¼.
sec. 35, E½NW¼.
sec. 36, S½, lot 10.
T. 11 S., R. 13 E., sec. 1, N½ lot 4.
sec. 3, NW¼NE¼, SE¼NE¼, NE¼SF¼.
sec. 4, N½NE¼, SW¼NE¼, SW¼NW¼, N½SW¼.
sec. 6, lot 6.
sec. 7, N½ lot 1.
sec. 8, S½NE¼, SE¼NW¼, SE¼SE¼.
sec. 9, NW¼SE¼.
sec. 15, NE¼SE¼.
sec. 17, NE¼SF¼.
sec. 22, NW¼NW¼, SE¼SW¼, SW¼SE¼.
T. 8 S., R. 14 E., sec. 19, NE¼SW¼.
sec. 29, lot 2.
T. 9 S., R. 14 E., sec. 19, lot 3.

GADSDEN COUNTY

T. 3 N., R. 1 W., *sec. 29, NE¼NE¼.
T. 1 N., R. 2 W., sec. 20, NW¼NE¼.
T. 3 N., R. 2 W., sec. 15, SW¼NE¼.
T. 2 N., R. 5 W., sec. 28, NW¼NE¼, NE¼SW¼.
T. 4 N., R. 5 W., sec. 34, NW¼SW¼.
T. 2 N., R. 6 W., sec. 18, SW¼SE¼.
sec. 20, E½NE¼, SE¼.
sec. 22, SW¼NW¼, S½SW¼.
sec. 30, NE¼.
T. 3 N., R. 6 W., sec. 32, SE¼SW¼.

GILCHRIST COUNTY

T. 7 S., R. 14 E., sec. 24, SE¼.
sec. 25, NE¼NE¼, SW¼NE¼.
T. 8 S., R. 14 E., sec. 9, NE¼SE¼.
sec. 12, NE¼NE¼.
sec. 13, E½NE¼, NE¼SE¼.
T. 9 S., R. 14 E., sec. 20, N½SW¼.
T. 10 S., R. 14 E., sec. 7, N½ lot 3.
T. 6 S., R. 15 E., sec. 34, NW¼NE¼, SW¼SE¼.
T. 7 S., R. 15 E., sec. 2, NE¼SW¼, W½SE¼.
sec. 3, W½SE¼.
sec. 4, SE¼NW¼, N½SW¼.
sec. 10, W½NE¼, S½SW¼, NE¼SE¼.
sec. 11, NE¼NE¼, NE¼SW¼, SW¼SE¼.
sec. 14, E½NW¼.
sec. 15, NE¼NE¼, W½W½.
sec. 17, SW¼SE¼.
sec. 19, SE¼SE¼.
sec. 22, E½NW¼, NW¼SW¼.
sec. 28, SW¼SW¼.
sec. 29, SE¼SW¼, E½SE¼.
sec. 30, NW¼NE¼, NW¼NW¼, SW¼SW¼.
sec. 31, NW¼SE¼.
sec. 32, N½NE¼, SW¼NE¼.
sec. 33, SW¼NE¼, NW¼SE¼.
T. 8 S., R. 15 E., sec. 4, SW¼NE¼.
sec. 5, NE¼NW¼.
sec. 6, SW¼NW¼.
sec. 7, SW¼SW¼.
sec. 8, W½NE¼, NE¼NW¼.
sec. 20, NW¼SE¼.
sec. 29, NE¼NE¼.
T. 9 S., R. 15 E., sec. 8, SW¼NW¼.
sec. 28, NE¼NW¼.
T. 7 S., R. 16 E., sec. 19, N½ lot 3.
T. 8 S., R. 16 E., sec. 5, SE¼NW¼.
sec. 6, NE¼NE¼.
sec. 8, S½SE¼NW¼, S½SE¼.
sec. 10, W½NE¼.
sec. 24, N½NW¼, SW¼NW¼.
sec. 26, S½NE¼, SE¼NW¼, E½SW¼.
T. 9 S., R. 16 E., sec. 4, N½NE¼.
sec. 6, NE¼NE¼.
sec. 34, W½NW¼.
T. 10 S., R. 16 E., sec. 8, NE¼NW¼.

GLADES COUNTY

T. 40 S., R. 28 E.,	sec. 1,	NW¼, N½SW¼.
	sec. 2,	NW¼.
	sec. 3,	N½NE¼, SE¼NW¼, S½SW¼.
	sec. 4,	SE¼SW¼.
	sec. 5,	S½SW¼, W½SE¼.
	sec. 6,	S½NW¼, SW¼SW¼, S½SE¼.
	sec. 7,	N½NE¼, W½NW¼.
	sec. 12,	SW¼NE¼.
	sec. 13,	NW¼NE¼, S½NW¼, N½SW¼, SE¼SW¼.
	sec. 14,	NE¼NE¼, S½NE¼, N½SE¼.
	sec. 15,	NE¼NE¼, W½NW¼, SE¼NW¼.
	sec. 18,	E½SW¼.
	sec. 19,	E½NE¼, N½SW¼, SE¼SW¼, W½SE¼.
	sec. 21,	S½SW¼.
	sec. 22,	E½SE¼.
	sec. 23,	SW¼NE¼.
	sec. 27,	NW¼SE¼.
	sec. 28,	N½NW¼, E½SW¼
	sec. 29,	E½SW¼, W½SE¼.
	sec. 30,	SE¼SE¼.
	sec. 32,	NW¼, N½SE¼.
	sec. 33,	W½NE¼, N½SW¼
	sec. 34,	N½NE¼.
T. 42 S., R. 28 E.,	sec. 4,	NE¼SW¼.
	sec. 9,	NW¼NE¼, NW¼.
	sec. 27,	SE¼NW¼, NE¼SW¼, S½SW¼, NE¼SE¼.
	sec. 28,	SW¼SE¼.
	sec. 29,	SW¼, S½SE¼.
	sec. 30,	W½NE¼.
	sec. 31,	W½, W½SE¼.
	sec. 33,	NW¼.
	sec. 34,	W½SE¼.
	sec. 35,	W½NW¼.
T. 40 S., R. 29 E.,	sec. 2,	NW¼NW¼, SW¼SE¼.
	sec. 3,	NE¼, W½SW¼, SW¼SE¼.
	sec. 4,	SE¼NE¼, E½SE¼.
	sec. 6,	E½SW¼.
	sec. 7,	NW¼NW¼.
	sec. 9,	S½NW¼.
	sec. 18,	NE¼SW¼, S½SW¼, W½SE¼.
	sec. 19,	S½NE¼, W½, SE¼.
	sec. 29,	W½NW½, NW¼SW¼.
	sec. 30,	NE¼.

HAMILTON COUNTY

T. 3 N., R. 12 E.,	sec. 31,	lot 2.
T. 1 N., R. 13 E.,	*sec. 10,	NE¼NE¼.
	sec. 15,	SW¼NE¼.
T. 2 N., R. 13 E.,	sec. 5,	lots 1 and 2.
	sec. 17,	NW¼NE¼.
T. 1 N., R. 14 E.,	sec. 28,	N½NW¼.
	sec. 29,	NE¼NE¼.
T. 2 N., R. 14 E.,	sec. 3,	lot 1.
	sec. 12,	NW¼NW¼.
	sec. 21,	NW¼NE¼.
T. 1 S., R. 14 E.,	sec. 18,	lot 1.
T. 1 S., R. 15 E.,	sec. 12,	NW¼SE¼.
T. 2 S., R. 15 E.,	sec. 2,	SW¼NW¼.
T. 2 S., R. 16 E.,	sec. 8,	lots 7 and 8.

HARDEE COUNTY

T. 33 S., R. 25 E.,	sec. 7,	SE¼SE¼.
	sec. 12,	S½SW¼.
	sec. 23,	NE¼NE¼, S½NE¼, NE¼SW¼, SW¼SW¼, N½SE¼.
	sec. 26,	SW¼SW¼.
T. 34 S., R. 25 E.,	sec. 2,	NE¼.
	sec. 7,	SW¼SW¼.
	sec. 18,	S½SE¼.
	sec. 19,	N½NE¼.
T. 36 S., R. 25 E.,	sec. 4,	NE¼NW¼.
	sec. 12,	NE¼NE¼.
T. 33 S., R. 26 E.,	sec. 1,	NW¼NW¼, E½SW¼, SE¼.
	sec. 2,	N½N½, SE¼NW¼, W½SE¼.
	sec. 3,	NW¼NE¼, N½NW¼, SW¼NW¼.
	sec. 4,	N½N½, SW¼NW¼.
	sec. 6,	N½NE¼, NE¼NW¼, S½SW¼.
	sec. 12,	NE¼, N½SE¼.
T. 35 S., R. 26 E.,	sec. 4,	W½NE¼, E½NW¼, SE¼.
	sec. 11,	S½SE¼.
	sec. 14,	W½NE¼.
	sec. 21,	NW¼NE¼.
	sec. 22,	NW¼NW¼.
	sec. 24,	E½NE¼, W½NW¼, W½SE¼.
	sec. 25,	N½NE¼.
	sec. 31,	SE¼NW¼, W½SW¼.
	sec. 32,	E½SW¼, SE¼.
	sec. 33,	SE¼NE¼, SE¼SE¼.
	sec. 34,	SE¼NE¼, SE¼NW¼.

HENDRY COUNTY

T. 43 S., R. 28 E.,	sec. 2,	S½SE¼.
	sec. 4,	SE¼NW¼.
	sec. 5,	NE¼NE¼, N½NW¼.
	sec. 6,	W½NW¼, SW¼SE¼.
	sec. 8,	SE¼NW¼, E½SW¼.
	sec. 17,	W½NE¼, N½NW¼, SE¼NW¼.
	sec. 18,	NE¼.

HERNANDO COUNTY

T. 21 S., R. 18 E., sec. 19, W½NW¼, NW¼SW¼.
sec. 30, SE¼NE¼.
T. 21 S., R. 19 E., sec. 25, SW¼NW¼.
T. 23 S., R. 19 E., sec. 36, NE¼NE¼.
T. 22 S., R. 20 E., sec. 5, NE¼SW¼.
T. 23 S., R. 20 E., sec. 9, E½NW¼.
sec. 29, NW¼NW¼, NE¼SE¼.
sec. 30, SW¼NW¼.

HIGHLANDS COUNTY

T. 34 S., R. 28 E., sec. 4, SE¼SW¼, W½SE¼.
sec. 9, W½NE¼, NE¼NW¼.
sec. 22, S½NE¼, NE¼SW¼, S½SW¼, N½SE¼.
sec. 23, SW¼NW¼, NW¼SW¼.
sec. 26, NW¼, N½SW¼.
sec. 27, N½, N½SE¼.
T. 35 S., R. 28 E., sec. 1, S½SE¼.
sec. 11, SW¼SW¼.
sec. 12, N½NE¼.
sec. 14, NW¼, NE¼SW¼, S½SW¼.
sec. 15, NE¼NE¼.
T. 33 S., R. 31 E., sec. 17, W½.
sec. 18, E½NW¼, N½SE¼, SE¼SE¼.
sec. 19, NE¼.
sec. 20, NW¼, W½SW¼.
sec. 29, W½W½.
sec. 30, E½E½.
sec. 31, E½E½.
sec. 32, W½NW¼.
T. 34 S., R. 31 E., sec. 27, lot 2.
T. 35 S., R. 31 E., sec. 12, S½NW¼, N½SW¼.

HILLSBOROUGH COUNTY

T. 30 S., R. 20 E., sec. 24, SW¼SW¼.
T. 28 S., R. 21 E., sec. 32, SW¼NE¼.
sec. 35, SE¼.
T. 30 S., R. 21 E., sec. 11, SW¼NE¼, SE¼NW¼, NE¼SW¼, NW¼SE¼.

JEFFERSON COUNTY

T. 2 N., R. 4 E., ***sec. 29, lot 1.**

LAFAYETTE COUNTY

T. 5 S., R. 10 E., sec. 1, SW¼SE¼.
sec. 3, SE¼NW¼.
sec. 12, SE¼NE¼.
T. 7 S., R. 10 E., sec. 10, SE¼SW¼.
T. 5 S., R. 11 E., sec. 5, NE¼NE¼.
sec. 7, SW¼NW¼, NW¼SW¼, NE¼SE¼.
sec. 21, NW¼NE¼.
sec. 22, NE¼SW¼.
sec. 23, SE¼NW¼, NE¼SW¼.

T. 6 S., R. 11 E., sec. 7, NE¼NW¼.
sec. 15, NW¼SW¼.
sec. 28, NE¼SE¼.
T. 5 S., R. 13 E., sec. 28, NE¼SE¼.
T. 7 S., R. 13 E., sec. 25, lot 7, N½ lot 8, N½ lot 9, N½ lot 10.
sec. 35, N½NE¼.
T. 6 S., R. 14 E., sec. 20, S½SE¼.
sec. 31, NW¼NW¼.
T. 7 S., R. 14 E., sec. 10, W½NE¼, SW¼SE¼.
sec. 11, lot 2.
sec. 15, SE¼NW¼.
sec. 23, NE¼NW¼.
sec. 33, N½SW¼.
sec. 34, lot 5.

LEE COUNTY

T. 43 S., R. 23 E., sec. 8, SW¼NW¼.
T. 44 S., R. 23 E., sec. 9, NW¼NE¼, N½NW¼.
sec. 10, NE¼, N½SE¼, SW¼SE¼
sec. 21, E½, E½W½.
sec. 27, NW¼.
sec. 28, N½, N½SW¼.
sec. 33, E½NE¼, N½SW¼.
sec. 34, N½S½.
T. 45 S., R. 23 E., sec. 3, N½, SW¼.
sec. 4, NE¼NE¼, S½NE¼.
sec. 10, N½.
sec. 12, SE¼SW¼.
sec. 27, lot 1.
T. 43 S., R. 25 E., sec. 25, lot 4.
T. 43 S., R. 26 E., sec. 23, lot 2.
T. 43 S., R. 27 E., sec. 13, SE¼SE¼.
sec. 31, W½SW¼.
sec. 36, W½SW¼.

LEON COUNTY

T. 2 N., R. 1 E., *sec. 6, E½SW¼.
T. 3 N., R. 1 E., sec. 19, Island No. 17.
sec. 28, Island No. 12.
T. 1 N., R. 1 W., sec. 3, lot 4.
T. 2 N., R. 1 W., sec. 10, W½SW¼.
sec. 34, lot 1.
T. 1 N., R. 2 W., sec. 28, lot 2, E½NE¼.
sec. 36, SW¼SE¼.
T. 1 S., R. 1 W., sec. 24, NW¼NE¼.
T. 1 S., R. 2 W., sec. 14, lot 1.
T. 2 S., R. 1 E., sec. 23, fraction of section outside Forbes claim.
T. 1 S., R. 2 E., sec. 26, E½SW¼, W½SE¼.
T. 2 S., R. 2 E., sec. 22, E½SW¼.
sec. 30, fraction of section outside Forbes claim.

LEVY COUNTY

T. 11 S., R. 13 E.,	sec. 36, NE¼NE¼.
T. 12 S., R. 13 E.,	sec. 2, NE¼, N½SE¼, SW¼SE¼.
	sec. 10, SE¼SW¼.
	sec. 12, NE¼, E½NW¼, SW¼, N½SE¼, SW¼SE¼.
	sec. 14, E½NW¼, E½SE¼.
	sec. 24, all.
	sec. 26, E½E½.
	sec. 36, NE¼NE¼.
T. 11 S., R. 14 E.,	sec. 10, S½NW¼.
	sec. 32, E½SW¼.
T. 12 S., R. 14 E.,	sec. 18, W½NW¼, N½SW¼.
T. 13 S., R. 14 E.,	sec. 6, W½, W½SE¼.
	sec. 8, SW¼SW¼.
	sec. 14, W½SW¼.
	sec. 22, NE¼.
T. 12 S., R. 15 E.,	sec. 22, NE¼SW¼.
T. 12 S., R. 16 E.,	sec. 12, NE¼NW¼.
	sec. 20, E½SW¼.
T. 13 S., R. 16 E.,	sec. 32, SW¼SE¼.
T. 14 S., R. 16 E.,	sec. 2, SE¼NE¼, SW¼SE¼.
	sec. 6, NE¼NE¼.
T. 15 S., R. 16 E.,	sec. 28, W½SE¼.
T. 11 S., R. 17 E.,	sec. 14, S½.
	sec. 26, N½NE¼, S½SW¼.
	sec. 28, NE¼, N½NW¼, SE¼SW¼, SE¼.
	sec. 32, SW¼NW¼.
	sec. 36, W½SE¼.
T. 12 S., R. 17 E.,	sec. 10, NE¼NW¼, S½NW¼SW¼, W½SW¼SW¼, E½SE¼SW¼, E½SE¼.
	sec. 12, E½, N½NW¼, S½SW¼.
	sec. 26, NW¼.
T. 13 S., R. 17 E.,	sec. 2, SW¼SE¼.
	sec. 8, SE¼SE¼.
	sec. 24, W½NW¼, SE¼SE¼.
	sec. 26, NE¼SW¼.
	sec. 32, E½SE¼.
	sec. 34, E½NE¼.
T. 14 S., R. 17 E.,	sec. 18, SE¼SW¼.
	sec. 28, NE¼NE¼.
T. 16 S., R. 17 E.,	sec. 7, N½NE¼, SW¼NE¼.
T. 12 S., R. 18 E.,	*sec. 21, NW¼SE¼.
T. 13 S., R. 18 E.,	sec. 28, W½SW¼.
T. 14 S., R. 18 E.,	sec. 4, E½NE¼, NE¼SE¼.
	sec. 20, NE¼SW¼, NE¼SE¼, S½S½.
	sec. 30, NE¼SE¼.

LIBERTY COUNTY

T. 1 N., R. 6 W.,	sec. 2, SW¼NE¼.
	sec. 6, lot 1, N½ lot 2, W½NW¼, NW¼SW¼.
T. 2 N., R. 6 W.,	sec. 30, S½.
	sec. 32, lots 1 and 4.
	sec. 34, NE¼NE¼, SW¼NE¼.

T. 1 N., R. 7 W., sec. 12, lots 2, 3, 4, NW¼.
T. 2 N., R. 7 W., sec. 26, E½SE¼.
sec. 33, NW¼NE¼.

MADISON COUNTY

T. 1 N., R. 6 E., sec. 36, SE¼.
T. 3 N., R. 7 E., sec. 26, NE¼SW¼.
T. 3 N., R. 8 E., sec. 28, lots 1 and 2.
sec. 32, NW¼SW¼.
T. 1 N., R. 9 E., sec. 8, NW¼NE¼.
T. 3 N., R. 9 E., *sec. 26, lot 1.
sec. 36, SE¼NE¼, SE¼SW¼.
T. 1 N., R. 10 E., *sec. 10, SW¼.
*sec. 28, N½NE¼, E½NW¼, NE¼SW¼.
T. 1 S., R. 6 E., sec. 11, SW¼SW¼.
T. 1 S., R. 8 E., sec. 25, NE¼NE¼.
sec. 36, SW¼NE¼, SE¼NW¼, E½SW¼, W½SE¼.
T. 2 S., R. 8 E., sec. 8, SE¼SW¼, S½SE¼.
T. 2 S., R. 9 E., sec. 8, SE¼SW¼.
T. 1 S., R. 10 E., *sec. 18, SE¼NE¼, NE¼NW¼, NE¼SE¼.
sec. 22, SE¼SW¼.
T. 2 S., R. 10 E., sec. 4, SE¼NE¼.

MANATEE COUNTY

T. 34 S., R. 16 E., sec. 27, lot. 1.
T. 34 S., R. 17 E., sec. 21, lot. 1.
T. 34 S., R. 18 E., sec. 10, NW¼NE¼.
sec. 12, N½NW¼, SE¼NW¼.
T. 35 S., R. 18 E., sec. 1, SW¼NW¼.
T. 34 S., R. 19 E., sec. 13, E½SW¼.
sec. 21, NE¼NW¼, NE¼SE¼.
sec. 23, E½SE¼.
sec. 25, SW¼NW¼, NW¼SW¼.
sec. 26, SE¼NE¼, NE¼SE¼.
sec. 32, NE¼NE¼, SW¼NE¼.
T. 35 S., R. 19 E., sec. 3, SW¼SW¼.
sec. 22, S½NW¼.
T. 33 S., R. 20 E., sec. 3, S½SE¼.
sec. 12, SW¼SE¼.
sec. 13, SE¼SW¼, W½SE¼, SE¼SE¼.
sec. 24, NE¼NE¼, S½NE¼.
T. 34 S., R. 20 E., sec. 30, SE¼NE¼.
sec. 31, NE¼SW¼, SW¼SW¼.
sec. 32, NE¼NW¼.
T. 35 S., R. 20 E., sec. 3, NE¼SW¼.
sec. 5, N½SE¼.
sec. 35, SE¼NE¼.
T. 33 S., R. 21 E., sec. 1, E½NE¼.
sec. 5, SE¼SE¼.
sec. 8, NE¼NE¼.
sec. 12, W½NW¼, SW¼SW¼.
sec. 20, E½SE¼.
sec. 21, SW¼SW¼.
sec. 22, SW¼SW¼.
sec. 32, SE¼NE¼, SW¼NW¼, SE¼SE¼.

T. 34 S., R. 21 E.,	sec. 6, NW¼NW¼.
	sec. 14, S½NE¼, SE¼.
	sec. 23, W½NE¼, E½NW¼, NW¼SE¼.
	sec. 36, SE¼SE¼.
T. 35 S., R. 21 E.,	sec. 3, SW¼NW¼.
	sec. 4, NE¼SE¼, SW¼SE¼.
	sec. 5, lots 1 and 2.
	sec. 9, NW¼NE¼, NE¼NW¼, SW¼NW¼, SW¼SW¼.
	sec. 17, N½NW¼, SW¼NW¼.
	sec. 19, N½NE¼, SW¼NE¼.
	sec. 23, SE¼SE¼.
	sec. 24, SW¼SW¼.
	sec. 26, SW¼SE¼.
T. 36 S., R. 21 E.,	sec. 7, NE¼SW¼, S½SW¼, SE¼.
	sec. 8, SW¼NW¼, SW¼, W½SE¼, SE¼SE¼.
	sec. 15, S½SE¼.
	sec. 18, NW¼NW¼.
	sec. 19, SW¼SW¼.
	sec. 22, NE¼NE¼.
	sec. 30, E½NW¼.
T. 33 S., R. 22 E.,	sec. 18, NE¼NW¼.
T. 35 S., R. 22 E.,	sec. 10, NW¼NE¼, NE¼NW¼.
T. 36 S., R. 22 E.,	sec. 1, NW¼SW¼.

MARION COUNTY

T. 16 S., R. 18 E.,	sec. 19, SW¼NW¼.
	sec. 31, NW¼NW¼ (R).
	sec. 32, SW¼NE¼
T. 14 S., R. 19 E.,	sec. 31, SE¼NE¼.
	sec. 34, SE¼SW¼.
T. 15 S., R. 19 E.,	sec. 12, S½NE¼, NE¼SE¼.
T. 15 S., R. 20 E.,	sec. 9, SE¼SW¼.
T. 16 S., R. 20 E.,	*sec. 22, N½NE¼ (R).
	sec. 36, NE¼.
T. 17 S., R. 20 E.,	sec. 33, NE¼SE¼.
T. 13 S., R. 21 E.,	sec. 1, S½NE¼.
T. 15 S., R. 21 E.,	sec. 21, NE¼NE¼, S½NE¼, SE¼NW¼.
T. 16 S., R. 21 E.,	sec. 18, NW¼NW¼.
	sec. 25, NE¼NE¼.
	sec. 26, SE¼SW¼, N½SE¼, SW¼SE¼.
T. 17 S., R. 21 E.,	sec. 18, E½SE¼.
	sec. 36, E½E½.
T. 12 S., R. 22 E.,	sec. 31, SW¼NE¼.
T. 13 S., R. 22 E.,	sec. 35, E½NE¼.
	sec. 36, W½NW¼, S½SE¼.
T. 14 S., R. 22 E.,	sec. 26, E½, W½SW¼.
T. 16 S., R. 22 E.,	sec. 13, NE¼SW¼.
	sec. 28, NW¼SE¼.
	sec. 29, SW¼NE¼.
T. 12 S., R. 23 E.,	sec. 1, N½SE¼, SE¼SE¼.
T. 13 S., R. 23 E.,	sec. 1, NE¼, N½SE¼.
	sec. 11, NE¼NE¼.
	sec. 19, lot 7.

T. 14 S., R. 23 E., sec. 8, SW¼SW¼.
T. 15 S., R. 23 E., sec. 7, S½SE¼.
sec. 8, NW¼ NW¼.
sec. 19, SE¼SW¼, SW¼SE¼.
sec. 20, W½SW¼.
sec. 23, NE¼SW¼.
sec. 30, NW¼, E½SW¼.
T. 16 S., R. 23 E., sec. 8, SE¼NW¼.
sec. 15, E½SW¼.
T. 17 S., R. 23 E., sec. 29, W½NW¼, NW¼SW¼.
sec. 30, NE¼SE¼.

PASCO COUNTY

T. 26 S., R. 19 E., sec. 19, S½SE¼.
T. 26 S., R. 21 E., sec. 6, SE¼NW¼.
sec. 33, NE¼NE¼.
T. 23 S., R. 22 E., sec. 26, N½NE¼.
T. 24 S., R. 22 E., sec. 19, SW¼SW¼.
sec. 30, NW¼NW¼.

POLK COUNTY

T. 29 S., R. 23 E., sec. 11, W½NW¼.
T. 31 S., R. 23 E., sec. 2, NE¼ SE¼.
T. 28 S., R. 24 E., sec. 4, NW¼NE¼.
sec. 36, W½NE¼, NW¼SE¼ (R).
T. 29 S., R. 24 E., sec. 25, SE¼NE¼ (R).
sec. 28, NW¼SE¼ (R).
sec. 32, N½,NW¼ (R).
T. 30 S., R. 24 E., sec. 2, SW¼NW¼ (R).
sec. 4, NE¼SE¼ (P), SW¼SE¼ (R).
sec. 22, NW¼SW¼ (R).
sec. 24, NW¼NE¼ (R).
T. 28 S., R. 25 E., sec. 21, SE¼SE¼ (R).
sec. 23, N½SW¼ (R).
sec. 26, SE¼NW¼ (R).
T. 30 S., R. 25 E., sec. 2, SE¼NE¼, N½NW¼ (R).
T. 32 S., R. 25 E., sec. 27, E½NW¼ (R).
T. 29 S., R. 26 E., sec. 1, S½SE¼.
sec. 27, NW¼NE¼, NW¼ (R).
sec. 29, SW¼NW¼ (R).
sec. 30, SE¼NE¼ (R).
T. 30 S., R. 26 E., sec. 6, S½NW¼, NE¼SW¼ (R).
sec. 7, NE¼SE¼ (R).
sec. 8, E½ NE¼.
sec. 19, NE¼SW¼ (R).
sec. 25, SW¼NE¼, SE¼NW¼ (R).
sec. 26, SW¼NE¼.
sec. 27, SE¼SW¼.
sec. 29, N½SW¼ (R).
sec. 36, N½NE¼, E½NW¼, SW¼ (R).
T. 31 S., R. 26 E., sec. 1, N½N½ (R).
sec. 10, W½NW¼ (R).
sec. 13, SW¼NW¼ (R).
sec. 14, SW¼NW¼ (R).
sec. 23, NE¼SE¼ (R).

T. 32 S., R. 26 E., sec. 1, S½NE¼, S½SW¼, SE¼ (R).
sec. 2, SE¼SE¼.
sec. 8, NE¼SE¼ (R).
sec. 9, W½NW¼, SE¼SW¼, S½SE¼ (R).
sec. 10, SE¼NW¼, SW¼, S½SE¼ (R).
sec. 11, E½NE¼, NE¼SE¼ (R).
sec. 12, N½NE¼, SE¼NE¼, W½SW¼, NE¼¼SE¼ (R).
sec. 13, NE¼NE¼ (R).
sec. 19, NW¼NE¼, SW¼SW¼, E½SW, NW¼SE¼.
sec. 20, SE¼NW¼, E½SW¼.
sec. 30, SW¼NW¼, N½SW¼, SE¼SW¼, SW¼SE¼, N½NW¼.
T. 30 S., R. 27 E., sec. 6, SW¼SE¼.
sec. 24, lot 11.
sec. 29, lot 3 (R).
sec. 33, NW¼SW¼.
T. 31 S., R. 27 E., sec. 18, lot 7.
sec. 22, N½SW¼.
sec. 30, NW¼NE¼, S½SE¼.
sec. 31, NW¼NW¼.
sec. 36, NE¼SE¼.
T. 32 S., R. 27 E., sec. 1, E½SW¼, NW¼SE¼.
sec. 6, E½NW¼.
sec. 11, SE¼NW¼, SE¼SW¼.
sec. 12, S½SW¼, SW¼SE¼.
sec. 19, W½NW¼.
sec. 20, SW¼SE¼.
sec. 25, E½SW¼.
sec. 36, SW¼NE¼, E½NW¼.
T. 30 S., R. 28 E., sec. 3, SE¼SW¼.
T. 32 S., R. 28 E., sec. 12, SW¼NE¼.
sec. 35, SE¼SE¼.
T. 30 S., R. 29 E., sec. 12, SW¼SW¼.
sec. 14, NW¼SE¼.
sec. 18, NE¼NE¼.
T. 31 S., R. 29 E., sec. 5, NW¼NW¼.
T. 32 S., R. 29 E., sec. 17, E½W½.
sec. 19, E½SE¼.
T. 31 S., R. 30 E., sec. 3, SW¼SW¼.
sec. 10, N½NW¼, SW¼NW¼, NW¼SE¼.
sec. 21, SE¼.
sec. 22, S½S½.
sec. 28, S½NE¼.
sec. 34, N½NE¼.
sec. 35, W½.
T. 32 S., R. 30 E., sec. 9, NE¼NE¼.
sec. 17, E½NE¼, SE¼NW¼.

PUTNAM COUNTY

T. 11 S., R. 23 E., sec. 23, SW¼NW¼.

SARASOTA COUNTY

T. 36 S., R. 17 E., sec. 36, lot 3.
T. 37 S., R. 18 E., sec. 18, lot 4.
T. 36 S., R. 19 E., sec. 13, S½SW¼.
sec. 24, N½NW¼.
T. 38 S., R. 19 E., sec. 15, SW¼SW¼.
T. 36 S., R. 20 E., sec. 19, SW¼NE¼, NE¼SE¼, S½SE¼.
sec. 25, NE¼NE¼.
sec. 30, NE¼NE¼.
T. 38 S., R. 20 E., sec. 6, W½SW¼.
T. 40 S., R. 20 E., sec. 2, lot 5.
T. 39 S., R. 21 E., sec. 15, SE¼SW¼.
sec. 17, NE¼NE¼.

SUMTER COUNTY

T. 18 S., R. 21 E., sec. 14, W½SW¼.
T. 19 S., R. 21 E., sec. 4, NE¼.
T. 21 S., R. 21 E., *sec. 4, W½NW¼.
T. 18 S., R. 22 E., sec. 25, NW¼NE¼, NE¼NW¼, SE¼SE¼.
T. 19 S., R. 22 E., sec. 9, SE¼SE¼.
T. 21 S., R. 22 E., sec. 17, SW¼SE¼.
T. 22 S., R. 22 E., sec. 18, NE¼NW¼.
T. 18 S., R. 23 E., sec. 4, N½NW¼.
sec. 19, NW¼SW¼.
sec. 29, NW¼NW¼.
T. 19 S., R. 23 E., sec. 18, NW¼NW¼.
sec. 24, E½NW¼.
T. 22 S., R. 23 E., sec. 4, NE¼NW¼.

SUWANNEE COUNTY

T. 1 N., R. 12 E., sec. 35, lot 7.
T. 4 S., R. 11 E., sec. 25, NE¼NW¼.
sec. 35, lot 1.
sec. 36, lot 3.
T. 4 S., R. 12 E., sec. 4, NW¼NW¼.
*sec. 28, SW¼NE¼, NE¼NW¼, S½NW¼.
T. 1 S., R. 13 E., sec. 34, NW¼NW¼.
T. 4 S., R. 13 E., sec. 6, SE¼SE¼.
T. 1 S., R. 14 E., sec. 26, lot 8.
T. 3 S., R. 14 E., sec. 4, NW¼NE¼.
T. 5 S., R. 14 E., sec. 4, NE¼NE¼.
T. 6 S., R. 14 E., sec. 17, NW¼NW¼.
sec. 20, S½SE¼ (or Lafayette County?).
*sec. 22, NW¼SW¼.
T. 7 S., R. 14 E., sec. 1, E½SW¼, NW¼SE¼.
sec. 11, lots 5, 6, and 7.
T. 3 S., R. 15 E., sec. 22, NW¼NE¼.
sec. 24, SW¼NE¼.
*sec. 26. NE¼NW¼.

TAYLOR COUNTY

T. 2 S., R. 7 E., sec. 24, W½SW¼.
sec. 34, SW¼SE¼.
T. 3 S., R. 7 E., sec. 2, N½NE¼.
T. 5 S., R. 7 E., sec. 32, SW¼SW¼.
sec. 34, NW¼NW¼.
T. 2 S., R. 8 E., sec. 29, NE¼NW¼.
sec. 32, N½NE¼, SW¼NE¼, NE¼SW¼, S½SW¼.
T. 3 S., R. 8 E., sec. 5, W½SE¼.
sec. 6, N½NE¼, N½SE¼, SW¼SE¼.
sec. 7, NE¼SE¼.
sec. 8, W½NE¼, SW¼, NW¼SE¼.
sec. 17, NE¼, S½NW¼, SW¼.
sec. 20, SW¼NE¼.
sec. 28, NE¼, E½NW¼.
sec. 33, NE¼NE¼, S½NE¼, NW¼SE¼.
T. 4 S., R. 8 E., sec. 4, NE¼SE¼.
T. 5 S., R. 8 E., sec. 18, N½NW¼.
T. 6 S., R. 8 E., sec. 8, NE¼NE¼.
sec. 17, NE¼SE¼.
sec. 20, S½NE¼.
sec. 21, SW¼NW¼.
sec. 31, NE¼SW¼.
T. 4 S., R. 9 E., sec. 28, S½NE¼.
sec. 30, NW¼NE¼.
T. 5 S., R. 9 E., sec. 14, N½SE¼.
sec. 22, NW¼NE¼, NW¼SE¼.
sec. 32, E½SW¼.
T. 7 S., R. 9 E., sec. 11, NW¼SW¼.

UNION COUNTY

T. 6 S., R. 18 E., sec. 14, SW¼SE¼.
sec. 18, NW¼NW¼.
sec. 28, lots 1 and 2.
sec. 29, E½NE¼.

RESULTS OF PROSPECTING ON PUBLIC LANDS

In 1924, J. T. Pardee of the Geological Survey undertook the examination and classification of ten 40-acre tracts of public phosphate land in Florida. The results of this work have been published[57] and are summarized in the table that follows. On the 140 acres examined Pardee found phosphate deposits aggregating about 910,000 tons and ranging in grade from 30 to 69+ percent B. P. L.

[57] Mansfield, G. R., Phosphate rock in 1924: U. S. Bur. Mines, Mineral Resources U. S., 1924, pt. 2, p. 89–91, 1927.

Results of prospecting by J. T. Pardee on Florida public lands, 1924

Location of area	Description	Results
T. 3 N., R. 2 E., NW¼-NW¼ sec. 28.	Except for narrow strip along the east the tract is covered by Forshala Lake.	Negative.
T. 2 N., R. 6 E., NE¼-NE¼ and S½NE¼ sec. 28.	Part of Aucilla swamp, and at time of examination all under water except about 1 acre.	North part of southwest "40" (SW¼NE¼) contains deposit 4 to 11 feet thick beneath overburden 24 to 34 feet thick and covering 20 acres or more. Mostly soft phosphate (some pebble of fairly good grade) averaging about 30 percent B. P. L. and 20,000 tons per acre. Deposit becomes thicker, richer, and shallower toward northwest.
T. 14 S., R. 23 E., NE¼-SE¼ sec. 31.	About 1 mile north of Silver Springs, 6 miles east-northeast of Ocala. Low, sandy, with standing water here and there.	Unfavorable.
T. 28 S., R. 22 E., SW¼-NE¼ sec. 3.	About 4 miles north of Plant City. About ⅓ covered by swamps and ponds. Remainder partly cleared and cultivated and partly utilized for turpentine.	Do.
T. 29 S., R. 23 E., W½-SW¼ sec. 11.	About 4 miles south of Lakeland. North half and part of southwest corner swampy.	1,100–1,300 tons per acre, 88,000 tons for entire tract. Grade not stated.
T. 29 S., R. 23 E., NW¼-SW¼ sec. 21.	About 3 miles northwest of Mulberry.	Lowland comprising about 25 acres contains between 500 and 900 tons of pebble per acre or 12,500–22,500 tons. The remaining 15 acres (upland) contains 200–300 tons per acre, or a total of 3,000–4,000 tons.
T. 30 S., R. 24 E., NE¼-SE¼ sec. 4.	4 miles west of Bartow on road to Plant City.	Overburden about 35 feet thick. Phosphate matrix 18+ feet thick. Total phosphate pebble, about 400,000 tons; grade 61.88 to 69.65 B. P. L. In addition, about equal amount of phosphatic clay and sand.

In 1934 and 1935, under 2 successive grants from the Public Works Administration, the Geological Survey examined 83 tracts of public phosphate lands in Polk County, comprising about 3,300 acres, and 6 tracts in Citrus and Marion Counties, comprising 240 acres. The lands in Polk County were in the pebble field; those in the other 2 counties were in the hard-rock field. The Survey party was in charge of Mr. Roundy,[58] whose report should be consulted for details

The object of the investigation was to obtain data on which to base a decision as to whether the phosphate rock in any given tract is sufficient in quantity or is of suitable quality to justify the Government in retaining the mineral rights in that tract Although standard methods of prospecting were used, they were not carried so far as is both customary and necessary in commercial practice because no problem of early utilization of the land was involved and because under existing law the burden of proving up a commercial deposit is laid on the prospective lessee.

In all, 107 wells were drilled, averaging 61 feet in depth, the deepest being 109½ feet. As methods of recovery by operators now include flotation and other means of saving fine materials formerly wasted, the Survey party saved also the finer parts of the deposits and made

[58] Roundy, P. V., Phosphate investigations in Florida, 1934 and 1935: U. S. Geol. Survey Bull. 906-F, p. 267-345, 1941.

estimates of its phosphate content along with those for the phosphate pebble or hard phosphate rock. Although these estimates are less detailed than those prepared for commercial purposes, the summary given in the following table brings out some significant facts.

In phosphate mining in the Florida field attention at the present time is concentrated on material that contains more than 70 percent B. P. L. and less than 3 percent of I and A. Rock of this kind has been much in demand for the manufacture of superphosphates by the acidulation process. Operations of the Tennessee Valley Authority and others have shown, however, that by the use of the electric furnace, material of much lower grade can be successfully utilized; and it is thought that by this and other possible methods material even as low as 40 percent in B. P. L. content may eventually be used.

In the following table, therefore, the results are grouped according to the grade of the phosphate pebble recovered. The results listed are all for the pebble field in Polk County. None of the wells drilled in the hard-rock field yielded material of grade as high as 40 percent B. P. L., but as the distribution of phosphate in the hard-rock field is known to be very irregular the results obtained would probably justify in most of the tested areas retention of mineral rights by the Government.

The most significant of the results shown in the table is probably the remarkable increase in total B. P. L. per acre in the different acreage groups when the phosphate contained in the matrix is taken into account. Next in significance is the fact that 99 percent of the area tested in Polk County contains phosphate of at least 40 percent B. P. L. content, 85 percent of the area contains material of 50 percent grade or better, and 52 percent contains material that has 60 percent or more of B. P. L.

The tracts tested were not selected in accordance with any particular arrangement, but they were nevertheless fairly well scattered through the pebble-phosphate field and may be considered representative of the field as a whole.

The acreage tested therefore affords an example of how greatly an estimate based only on rock of 70 percent grade or better may be expanded if lower grades are taken into account. The bearing of this example on the life of the Florida pebble-phosphate field is obvious.

Results of prospecting on public phosphate lands in Florida in 1924 and 1934–35

Grade of pebble, B. P. L. (percent)	Acres examined			Depth of over-burden (feet)	Average B. P. L. (long tons per acre)			Total B. P. L. in acreage shown (long tons)	
	Number	Part of total (percent)	Part with I and A more than 3 percent		Pebble	Matrix	Total	Pebble only	Pebble and matrix
70	120	4	0	14–50	1,300	2,500	3,800	156,000	456,000
60–70	1,588	48	6.5	11–86	2,517	3,483	6,000	3,997,000	9,528,000
50–60	1,092	33	10.8	9–88	775	1,295	2,070	846,000	2,260,000
40–50	480	14	0	5–59	940	1,690	2,630	451,000	1,262,000
0–40	40	1							
Roundy	3,320	100						5,450,000	13,506,000
Pardee	140							910,000	910,000
Total	3,460							6,360,000	14,416,000

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