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DISTRIBUTION AND ORIGIN OF PHOSPHATE IN THE LAND-PEBBLE PHOSPHATE DISTRICT OF FLORIDA

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This preliminary report is released without editorial and technical review for conformity with official standards and nomenclature, to make the information available to interested organizations and to stimulate the search for uranium deposits.

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GEOLOGY AND MINERALOGY

DISTRIBUTION AND ORIGIN OF PHOSPHATE IN THE LAND-PEBBLE PHOSPHATE DISTRICT OF FLORIDA*

By James B. Cathcart and D. F. Davidson

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ABSTRACT

The land-pebble phosphate district of Florida is a part of the Gulf Coastal Plain. The geologic formations cropping out in the district are the Miocene Hawthorn, Pliocene Bone Valley, and Pleistocene terrace sands.

The Bone Valley formation consists of a lower strongly phosphatic unit and an upper less phosphatic unit. This paper is concerned principally with the lower unit, which contains the bulk of the minable phosphate deposits of the district.

The land-pebble district is divided into two parts: a northern part in which the P_2O_5 content of the pebble phosphate rock is high and a southern part in which it is generally lower. The material in the phosphate deposits in these areas appears to reflect the character of the underlying Hawthorn formation. The northern part of the district is underlain by limestone of the Hawthorn formation, and the phosphate deposits contain abundant phosphatized limestone fragments. The southern part is underlain by sandy and silty Hawthorn, and the phosphate deposits contain little if any phosphatized limestone.

The northern part of the district may be divided in two areas: the phosphate deposits of the central area contain large phosphatic particles with low P_2O_5 content and the deposits of the outlying area contain smaller phosphatic particles with a higher P_2O_5 content.

Recent studies have lead to the conclusion that the pebble phosphate of the central area of the northern part of the district is depositional and that the phosphate in the outlying belts may be, at least partly, residual in origin.

*This report concerns work done on behalf of the Division of Raw Materials of the U. S. Atomic Energy Commission.

INTRODUCTION

Several geologists of the U. S. Geological Survey have studied the land-pebble phosphate deposits of Florida from time to time since mining began in 1888. Reports of these studies have been written by Eldridge (1893), Matson and Clapp (1909), Matson (1915), Cooke (1929), (1945), Roundy (1941), and Mansfield (1942).

Since 1947 the Geological Survey has maintained a field party in the district in order to study the geology in detail -- to study the distribution, composition, and origin of the phosphate deposits of the district, to determine the relation of the deposits to the geologic formations of the district, and to bring up to date the estimates of tonnage and grade of phosphate published by Mansfield (1942). This paper will show what progress has been made in the study of the distribution and origin of the deposits.

Such a project in an active mining district can not succeed without the whole-hearted cooperation of the mine owners and operators of the district. The writers are happy to acknowledge such cooperation by the active mining companies in the land-pebble district: American Agricultural Chemical Company, International Minerals and Chemical Corporation, Swift and Company, American Cyanamid Company, Coronet Phosphate Company, and the Davison Chemical Corporation. U. S. Phosphoric Products Company and the Royster Guano Company who are principally processors of phosphate rock, have furnished information, as has Mr. Wayne Thomas, an independent consultant on Florida phosphate land.

In the years since 1947, 21 geologists have helped in the investigations of the Florida phosphate deposits and each of these men has contributed to the present knowledge of the deposits. Most of the ideas expressed in this paper have been expressed in frequent discussions among the party members; thus the writers can be credited only with presenting them here. This work was done on behalf of the Division of Raw Materials of the Atomic Energy Commission.

GENERAL GEOLOGY

The land-pebble phosphate district (fig. 1) is a part of the East Gulf Coastal Plain, which in turn is a part of the Eastern Coastal Plain. King (1951) points out, however, that the geology of peninsular Florida differs considerably from that of the remainder of the Eastern Coastal Plain. Peninsular Florida was stable duri... a large part of Mesozoic and Cenozoic time and because of its distance from the main part of the North American continent, it received relatively small amounts of land-derived sediments. In addition, the Ocala uplift in northwest central Florida alters the usual gentle seaward dip of coastal plain formations.

Concerning regional structure, suffice it to say that unconsolidated formations with nearly indeterminate contacts are exposed at the surface over nearly all of the land-pebble district, and in the few places where normally harder materials such as limestone are exposed, weathering has destroyed nearly all evidence of bedding.

On the basis of published data (Jordan, 1950), (Vernon, 1951), the harder rocks are thought to dip southward on the order of a few feet per mile.

Most writers describe four geologic formations in the land-pebble phosphate district. They are the Hawthorn formation, which underlies most of the district, the Bone Valley formation, terrace sands, and Recent deposits (Cooke, 1945, MacNeil, 1951). Recent work suggests that at the northern boundary of the district the Bone Valley formation may be underlain by Miocene Tampa limestone or the Oligocene Suwanee limestone.

STRATIGRAPHY

Hawthorn formation

The Hawthorn formation is middle Miocene in age (MacNeil, 1947). Recent work by the Geological Survey field party suggests that in the land-pebble district the Hawthorn may be roughly divided into three lithologic units: lowermost, phosphatic marls and hard limestones; next a series of clastic beds comprising sands, clays, and sandy clays; and uppermost, dolomites and dolomitic limestones.

Phosphate particles as much as 10 centimeters in diameter occur throughout the formation. No stratigraphic control of the size or amount of phosphate in the Hawthorn is recognized at the present time, except that conglomeratic beds of phosphatized limestone have been seen in the lower part of the formation in the northern part of the district.

The thickness of the Hawthorn formation in the district ranges from a feather edge to about 600 feet (Cathcart, 1950). A more comprehensive discussion of the Hawthorn formation in Florida may be found in Cooke (1945).

Bone Valley formation

The Bone Valley formation has been correlated with the Pliocene Caloosahatchee formation (Cathcart, 1950), which crops out south of the land-pebble phosphate district, on the basis of similar vertebrate fossils. Thus the Bone Valley is thought to be Pliocene in age.

In Polk and Hillsborough Counties--the northern part of the land-pebble district--the Bone Valley formation consists of two parts: the lower part is composed of sands, sands or silty clays, and gravels. Almost all of the gravel and a large part of the sand and clay-sized material in this zone are phosphate. The remainder of the sand is quartz, with minor amounts of feldspar, and trace amounts of "heavy" minerals (ilmenite, zircon, tourmaline, staurolite, and others); the remainder of the clay-sized material is chiefly montmorillonite, although minor amounts of kaolin are present (Altschuler and Boudreau, 1949). The upper part of the Bone Valley formation is deeply weathered and leached and is composed chiefly of a residue of quartz sand cemented by the aluminum phosphate mineral, wavellite (Altschuler and Boudreau, 1949).

The lower part ranges in thickness from less than 1 foot to more than 50 feet and is commonly about 20 feet in thickness; and the upper leached part ranges from a feather edge to 40 feet, and is commonly about 6 feet in thickness. The two parts tend to complement one another in thickness in most areas.

In Hardee and Manatee Counties--the southern part of the district--the Bone Valley cannot be divided into an upper and lower zone on the basis of present information. The entire formation is homogeneous, consisting of fairly well sorted quartz and phosphate sand, or sandy clay.

Other information on the formation may be found in Cooke (1945).

Terrace sands

Loose quartz sands, in terraces said to be of Pleistocene age by most writers who have described them in the district, overlie the Bone Valley formation in most of the district. Although Cooke (1945) has described seven terraces in peninsular Florida, MacNeil (1951) recognizes only three in the land-pebble district, one at an altitude of 30 feet, one at 100 feet, and one at 150 feet above sea level.

Recent deposits

Soil, carbonaceous sands, silt, and muck at the surface are considered Recent.

DISTRIBUTION AND CHARACTER OF PHOSPHORITE IN THE LOWER ZONE OF THE BONE VALLEY FORMATION

The land-pebble phosphate district can be divided in two parts: a northern part in which the P_2O_5 content of the phosphate of the Bone Valley formation is high (32 to 36 percent P_2O_5) and a southern part in which it is generally lower (28 to 32 percent P_2O_5). The division between the northern and southern parts of the district lies approximately at the line marking the northern boundary of Hardee and Manatee Counties. The character of the phosphate of the northern and southern parts of the district seems to be related to the character of the underlying Hawthorn formation. In the north where the phosphatic argillaceous limestone and relatively hard limestones of the lower part of the Hawthorn formation underlie the Bone Valley, the phosphate deposits contain abundant fragments of phosphatized limestone. In the south, the phosphate deposits are underlain by the middle, clastic unit of the Hawthorn and the phosphate deposits contain few, if any phosphatized limestone particles. Because little more than this is known about the southern part of the district, the remainder of this discussion is restricted to the northern part of the district.

The northern part of the land-pebble district may be divided into two areas; a central one containing coarser phosphate particles, bounded on the north, east and west by an area containing finer phosphate particles (fig. 2). It should be pointed out here that the ratios of coarse (+1.19 mm) to fine (-1.19 +0.105 mm) material used in preparing figure 2 are for coarse and fine particles of phosphate only, because the data available at the time of preparation of this paper were for phosphate and not for the entire deposit. However, it is the writers' belief that if data for the whole deposit were available, the picture presented in figure 2 would not be appreciably changed. This belief has been strengthened by an examination of nine bar graphs (fig. 3) showing the size distribution of material in samples of minable phosphate rock of the district.

The bar graphs from the mines in the central area (Nos. 3, 4, and 5, fig. 3) show a very pronounced double peak. One of the peaks is of coarse phosphate, one of finer quartz, with only minor phosphate.

This double peak may be due to two sources of material, or removal of finer material by an agency unable to transport the coarser, heavier, phosphatic material. However, whether or not this "winnowing" occurred, it does not account for the fact that the graphs show the presence of a large amount of fine quartz sand which should logically have been removed along with the fine phosphate.

The P_2O_5 content of the phosphate, as well as phosphate particle size, varies from east to west across the district. The phosphate of the outer area where finer phosphate particles predominate has a higher P_2O_5 content than the inner one, where coarser particles predominate. The variation in P_2O_5 content may be due to incomplete removal of calcium carbonate in the coarser particles plus addition of P_2O_5 to the particles, a process which would be more effective in the smaller sizes. Several studies of the relation of P_2O_5 to particle size have been made in small areas, and the general relation that decreasing size coincides with an increase in P_2O_5 content has been established in every place; therefore, the writers think that the relationship holds generally throughout the area.

Work done in the past few months has pointed out a relationship between phosphate-particle size and the "topography" of the present surface of the Hawthorn formation in the northern part of the district. In a general way it has been found that relatively coarse phosphatic material is likely to be found on top and on the shoulders of high parts of the surface of the Hawthorn formation and that finer phosphatic material is usually found low on the slope and in the Hawthorn "valleys" (fig. 4).

ORIGIN

The origin of the phosphate deposits of the land-pebble phosphate district has been speculated upon by all of the people who have worked in the district, and hypotheses concerning the origin of the deposits can be found in most Geological Survey reports of work in the district.

It might be well to point out here that study of the origin of the deposits is more difficult than one might assume, as weathering has obscured the relationships between the various formations of the district. Secondly, only exposures of minable phosphate are seen, for the mining companies only dig their pits in areas where phosphate particles are abundant, high in P_2O_5, and of an easily recoverable nature.

Most of the early workers in the land-pebble district thought that the phosphate of the district was deposited in either a marine, estuarine, or fluviatile environment. Matson (1915) and Cooke and Mossom (1929), however, suggest that part of the phosphate deposits may be residual in origin; that is, some of the phosphate deposits of today are Hawthorn limestone from which calcium carbonate has been removed by ground water. These two hypotheses, here are called the "depositional" and the "residual" theory of origin for the sake of brevity.

A detailed discussion of the evidence for and against each of these ideas is beyond the scope of this paper, but a few of the more important facts and ideas are presented.

Many fossil vertebrates and invertebrates of middle Miocene age and vertebrates of late Miocene and early Pliocene age have been found in the Bone Valley formation. Workers in the district agree that the fossils of middle Miocene age are probably reworked from the Hawthorn formation, but that the later vertebrate fossils are to be considered diagnostic in a study of the age of the Bone Valley.

Vertebrate fossils have been identified by Mr. C. L. Gazin and Miss Jean Hough of the U. S National Museum. The following is a list of species and their locations (fig. 2).

	Age	Mine
Teleoceras proterus	Pliocene	#2
Nannippus ingenuus	Lower Pliocene	#3
Nannippus minor	" "	#4, #5, & T. 32 S., R. 24 E.
Neohipparion phosphorum	" "	#4, #5, & T. 32 S., R. 24 E.
Tayassuid of Desmathyus Matthew	Lower to Middle Pliocene? possibly Miocene	T. 28 S., R. 24 E.
? Aphelops	Middle Miocene	#7 and #6
Merychippus westoni	" "	#6
Bison	Quaternary	Sec. 15, T. 29 S., R. 23 E
Antilocaprid, Generically undet.	Upper Tertiary	T. 31 S., R. 25 E.

It should be noted that the fossils from the central area, where the deposits are coarse, have been identified as Pliocene, and that fossils from the outlying area, where the deposits are fine, have been idendified as Miocene. However, the determinations from the central area are from numerous teeth, while only a single tooth has been found in the outlying areas.

The Bison tooth was discovered very recently in the top of the matrix, was identified as Quaternary in age, and may indicate that part of the matrix may have been reworked in that era.

Several of the earlier papers describe unconformities at the top and bottom of the Bone Valley formation, and members of the present field party have seen and described the unconformity at the base of the Bone Valley formation in the central area, but not in the outlying areas. The unconformity at the top of the Bone Valley formation is difficult to see because of superimposed weathering, but old channels that have cut into the formation have been seen at several mines. The channels are filled with loose sand, presumably Pleistocene in age.

Articulated skeletons of manatees and of a whale have also been found in the central area of the northern part of the district. Although they are not diagnostic so far as age is concerned, it is felt that they do suggest a depositional origin for that part of the phosphate deposits in which they are found.

Graded bedding and crossbedding have been seen by the writers and others, in both the coarse and fine areas of the northern part of the field. In the writers' experience, however, examples of good cross-bedding are relatively common in the central area and rare in the area that borders it.

In view of the foregoing data it is the writers' opinion that the central area of the northern part of the district is depositional. Good bedding of types not seen in the Hawthorn formation, the presence of articulated skeletons of marine mammals, and for that matter, the presence of fossils of the hard parts of other Pliocene animals, rounded pebbles of phosphatized Hawthorn limestone--all of these things seem to be good evidence for a depositional origin of the phosphate deposits of the central area.

In the outlying area of the northern part of the district, however, data that are at present available do not particularly substantiate either the residual or depositional hypotheses of origin of the phosphate deposits. The unconformities at the top and bottom of the Bone Valley formation have not been seen; as stated earlier, only one diagnostic fossil has been found, and bedding has been found only in a few places. Rounded phosphatized limestone particles are present, but they are smaller and different in appearance from those of the central area of the district.

The age and origin of the phosphate deposits are not proved; however, it is the writers' opinion that much of the phosphate was derived from the underlying Hawthorn formation; that in the central area of the northern part of the district the residuum was reworked, probably in a near-shore, marine or estuarine environment, and probably is Pliocene in age, although part of the reworking may have extended into the Pleistocene; and that in the outlying areas the matrix may be a true residuum, or reworked, or a combination of the two. Only through further work can the origin of that part of the deposit be determined.

SUMMARY

Phosphate found in the Bone Valley formation reflects the character of the underlying Hawthorn formation; where the Hawthorn is hard limestone, the Bone Valley contains much phosphatized limestone; where the Hawthorn is made up of clastic material other than limestone, little if any phosphatized limestone if found in the Bone Valley.

In the northern part of the district, the P_2O_5 content of the phosphate rock in the Bone Valley and the size and character of the phosphate are related. Phosphatized limestone particles are usually large, and low in P_2O_5 and other phosphate particles are smaller, and higher in P_2O_5. In the southern part of the district, phosphatized limestone is not common, and there, the phosphate particles are low in P_2O_5 and neither coarse nor fine, but rather uniform in size.

In the northern part of the district, the size of the phosphate particles and "topography" of the top of the Hawthorn formation appear to be related; coarser phosphate is found on Hawthorn highs and finer phosphate in lows.

The age and mode of origin of the phosphate deposits are not proved; however, it is the writers' opinion that the central area of the northern part of the district is made up of material that has been reworked, and is probably Pliocene in age, and that the outlying area may be least partly residual in origin.

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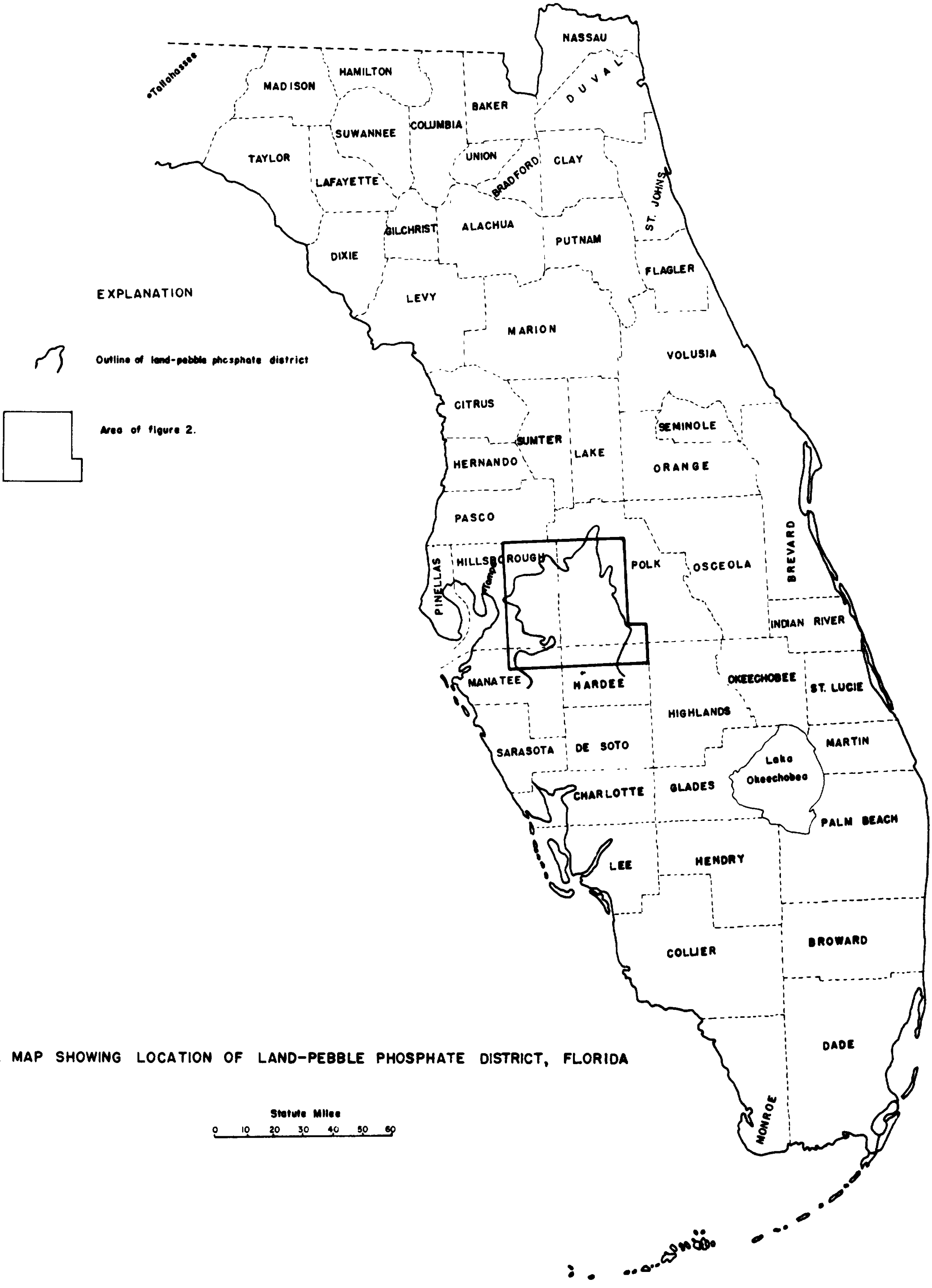

FIGURE 1. INDEX MAP SHOWING LOCATION OF LAND-PEBBLE PHOSPHATE DISTRICT, FLORIDA