# Chapter 17

## THE GEOLOGY OF THE CENTRAL FLORIDA PHOSPHATE DISTRICT A COMPARISON OF THE BONE VALLEY DEPOSITS VS. THE SOUTHERN EXTENSION DEPOSITS

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Abstract. The Central Florida Phosphate District, one of the most productive phosphate districts in the world, has been mined principally within Polk and Hillsborough Counties, Florida. Recent development is extending the district southward into Hardee, Manatee, and DeSoto Counties. This area is known as the Southern Extension. The combined area of these two phosphate-bearing areas encompasses about 2,000 square miles.

Structurally, the district and its Southern Extension lie at the southern end of the Ocala Arch and are flanked by the Hillsborough High to the northwest. South of this area is the South Florida Embayment. The Osceola Low lies to the east. The phosphorite within the Central Florida Phosphate District generally dips very gently (<0.1°) to the south. The boundaries of the Central Florida Phosphate District are generally defined by thinning of the phosphorite due the adjacent structurally high areas to the north, west, and east, and by increased clay, CaO, and MgO content reflecting lithologic differences to the east and south.

The Bone Valley Member of the Peace River Formation and reworked sediments of more recent age were the primary ore-bearing horizon in the Polk-Hillsborough County area. As those reserves are depleted, the less desirable phosphorites of the Peace River Formation are being exploited in the Southern Extension.

## INTRODUCTION

The Central Florida Phosphate District is located in southwestern Polk, southeastern Hillsborough, eastern Manatee, western Hardee, and northwestern DeSoto counties. The major portion of this district, which is currently active and which has been one of the primary sources of phosphate for many years, is the Polk and Hillsborough Counties area, commonly known as the "Bone Valley". The area known as the Southern Extension encompasses the described portion of the other three counties. These phosphate deposits are geologically located along the southern flank and south of a major structural uplift known as the Ocala Arch. The deposits found here are geologically and economically unique in the United States. However, deposits of similar origin and/or similar characteristics can be found in the States of Georgia, South Carolina, and North Carolina.

The land surface in Florida is remarkably flat and over the most part is covered by a blanket of sands and clayey sands with some areas of limestone outcroppings such as is seen in Central Florida around Ocala. The state, when viewed in cross-section, appears as a series of stair steps from both the Atlantic and Gulf sides with a central major ridge running lengthwise of the state and passing through Lake Wales. Bok Tower is located on the most prominent high point of this series of discontinuous ridges which run the length of the state. Phosphate occurs in the Central Florida District in Polk and Hillsborough Counties underlying what is a relatively flat lowland plain which does not exhibit much topographic relief locally. Here the area may be divided into three principal types of terrain. Poorly drained and virtually

undissected sand plains and hammocks, long narrow ridges rising 15 m (50 ft) to 60 m (200 ft) above the surrounding plains and trending approximately north-northwest, and the slightly rolling areas associated with the shallow valleys of the Peace, Alafia, and Hillsborough Rivers which transect the phosphate mining district.

As these rivers are approached, the topography becomes more rolling and there has been dissection of the landscape by secondary streams which feed into them. It was along the Peace River that some of the first mining in this district was carried out. Here the phosphate deposits had been exposed by recent erosion, winnowed by stream action, and redeposited relatively free of foreign material along the banks of the river. As the mining district grew, and exploration was undertaken, it was found that the deposits were quite extensive and that they underlie several hundred square miles in the subject counties. In recent years the rapid rate of depletion of the reserves in Polk and Hillsborough Counties and the desire of most of the active mining companies, as well as newcomers into the fertilizer industry field, to extend the economic life of their reserves, additional exploration was undertaken in that portion of the district now known as the Southern Extension.

## GENERAL GEOLOGY OF THE POLK AND HILLSBOROUGH COUNTIES PORTION OF THE CENTRAL FLORIDA PHOSPHATE DISTRICT THE BONE VALLEY

### General

As previously stated, the Central Florida Phosphate District, or "Bone Valley", is located in southwestern Polk and southeastern Hillsborough Counties. These deposits occur as a thin blanket of sediments on the southern flank of the southward plunging Ocala Arch, and range in age from Middle Miocene through Pleistocene. Abundant vertebrate and invertebrate fossils occur in the section.

The most popular theory of the origin of these phosphate deposits was previously summarized (Altschuler, et. al., 1964) and cited (Riggs and Freas, 1965) as follows: "The Bone Valley Formation is a shallow-water marine and estuarine phosphorite of Pliocene age...(It)...is an excellent example of marine transgression during which the phosphate was derived, by reworking, from the underlying, weathered, Hawthorn Formation."

### Geologic History

The State of Florida has been submerged and has emerged many times in the geologic past. During the Middle Miocene, a period in which the state was submerged beneath the seas, there was an upwelling of phosphorus-rich waters from the ocean deeps and consequent warming and the precipitation of the phosphorus on the the shallow continental shelf areas (Kazakov, 1937). The continental shelf at this time was undergoing a period of carbonate deposition and abounded in many forms of marine life. The theories on the origins of these deposits vary somewhat, but it is the authors' belief that there was some lithification of the phosphate-rich sediments deposited during this period, and their subsequent destruction and redeposition in the form of phosphate grains. A second mode of origin for which there is much evidence is that during the period of lithification much of the phosphate was deposited in the form of fecal pellets in the carbonate and other sediments on the continental shelf.

After deposition, the complete Miocene through Pleistocene sequences have been subjected to intensive chemical weathering. The chemical weathering process or leaching has resulted in some of the phosphate minerals being broken down chemically and some of their constituents translated downward by downward percolating ground waters. The resulting section is characterized by a leached zone near the top where phosphate has been totally removed from the overlying sands. Gradationally downward, a transition may be seen from highly weathered phosphate materials which are white to light cream in color into tan, brown and black phosphate grains near the bottom of the section. The resulting grade of the phosphate grains is affected by the degree of weathering to which each individual deposit has been subjected. Generally, the higher the degree of

weathering, the higher grade the remaining phosphate particles will be. Uranium is concentrated near the base of the leached zone by secondary enrichment (Altschuler, et. al., 1958). This material is discarded in the overburden stripping process as the matrix zone is mined.

Stratigraphy and Lithology

The phosphate-bearing ore horizon in the Polk and Hillsborough Counties portion of the Central Florida Phosphate District is typically characterized by a mixture of sands, clays, and phosphate grains, approximately equally distributed throughout the ore zone. The ore zone or matrix section, as it is termed by the miners, ranges from approximately 3.05 m (10 ft) to as much as 15.2 m (50 ft) and is generally overlain by from 1.5 m (5 ft) to approximately 12.2 m (40 ft) of unconsolidated sands or overburden.

Stratigraphic nomenclature for the State of Florida and in particular for the Central Florida Phosphate District has evolved over the past 50 or so years and gives some confusion to the interpretation of prior authors' discussions of the geology of the district. The nomenclature set forth in this discussion was presented by (Scott, 1986) and is accepted by most geologists working in the district today. In the "Bone Valley" area of Polk and Hillsborough Counties, the phosphorite being mined today occurs predominantly in the Bone Valley Member of the Peace River Formation of the Hawthorn Group. This unit is defined as the coarse clastic horizon containing abundant pebble-size phosphate particles interspersed with coarse-to-medium-grained quartz, phosphatic sand and clay. Post Miocene reworking of this unit has resulted in the Pliocene to recent fluvial and terrestrial deposits which discontinuously overlie the Bone Valley Member. Stratigraphically below the Bone Valley Member is a finer grained clastic unit termed the Undifferentiated Peace River. The Peace River Formation throughout most of the district overlies the Arcadia Formation, also included in the Hawthorn Group. The Arcadia Formation is phosphatic but is not considered matrix in the major portion of this area. Lithologically, the upper portion of the Arcadia Formation consists of interbedded, hard dolomites, silty dolomitic clays or dolosilts, clays, carbonates, and occasional phosphatic quartz sand lenses. All of these lithologies are phosphatic to some degree.

The lower portion of the Arcadia Formation consists of the Tampa (Limestone) Member and the basal clastic Nocatee Member.

A brief sketch of the geologic history would start, as previously noted, in the Middle or Upper Miocene with peninsular Florida submerged beneath the sea. Its subsequent emergence and sub-aerial erosion which developed the coarse clastic sediments which were later incorporated in the younger Miocene, Pliocene and Pleistocene sequences. There is a distinct depositional break and erosional period also found between the Pliocene and Pleistocene age materials. In a few instances it has been noted that the Pleistocene sediments have been reworked at the top of the matrix section in some mines.

The matrix or ore zone ranges in age from Middle Miocene to Pleistocene or a span of some fifteen million years. Upon the first emergence of the phosphate-rich Miocene sediments and their subsequent destruction and redeposition in the form of Pliocene and Pleistocene materials, now observed in the mine walls, Florida underwent an excellent example of marine regression from a marine offshore environment through a near shore to an estuarine and terrestrial environment. This is exhibited in the fossil suites which may be collected here. In the Pliocene section sharks' teeth and skate grinding plates are the most prevalent forms of marine life noted. Interbedded with this sequence, Gavial (alligator), Sirenian (seacow), horse, rhinoceros, camel and other animal remains are found. The Pleistocene sediments are characterized by a greater abundance of larger land vertebrate remains such as Mastodon and Wooly Mammoth. From the Miocene age rocks upwards the history of the evolution of the horse in North America may be readily traced from remains found in the phosphate deposits. The frequent occurrence of both marine and terrestrial fossil remains in the same bed is due to the intensive degree of reworking which most of the matrix has undergone throughout geologic time.

## GENERAL GEOLOGY OF THE SOUTHERN EXTENSION OF THE CENTRAL FLORIDA PHOSPHATE DISTRICT

### General

The phosphate deposits of the Central Florida Phosphate District extend south into Hardee, Manatee, and DeSoto Counties, known as the Southern Extension, with some lateral changes in lithologic character which affect the economics and grade of these deposits so that the reserves in this area are being developed as the resources of the Polk and Hillsborough Counties portion of the Central Florida Phosphate District are depleted. The boundaries of the Southern Extension are generally delineated by a decrease in phosphate content and grade associated with increased clay, MgO, and CaO content to the east, west, and south.

### Geologic History

The general geologic setting and history for the Southern Extension is basically the same as for the Polk and Hillsborough Counties area to the north with the prime differences being that the sediments in the Southern Extension were deposited in a more predominantly marine environment which has undergone less extensive post-depositional weathering.

### Stratigraphy and Lithology

The overburden thickness of the Southern Extension generally ranges from as little as 4.6 m (15 ft) to as much as 30.5 m (100 ft), and averages 13.7 m (45 ft). The matrix thickness ranges from 0 to 24.4 m (80 ft), with the district generally exhibiting a matrix thickness of 7.6 m (25 ft) to 9.2 m (30 ft). Matrix less than 1.5 m (5 ft) thick is generally not considered minable.

The section encompassed by the Hawthorn Group thickens from the Polk and Hillsborough Counties, "Bone Valley", portion of the Central Florida Phosphate District into the Southern Extension and displays a lithologic character suggesting lower energy marine conditions of sedimentation, presumably farther from the shoreline.

A stratigraphically lower and thicker major phosphate-bearing, phosphorite horizon, the Undifferentiated Peace River, occurs within the upper part of the Hawthorn Group in the Southern Extension. Less phosphate pebbles, increased calcium and magnesium content of all phosphate particles, and a greater clay and carbonate content in the phosphorite cause the grade to be lower in the Southern Extension than to the north in Polk and Hillsborough Counties. The increased carbonate content is probably due in part to the decreased extent of post-depositional weathering and reworking of these strata compared to the phosphorites in the area to the north. The decreased amount of pebble-size phosphate is probably due to the lower energy conditions in the deeper water offshore environment (Cathcart, 1966, 1968).

## CONCLUSION

Throughout the Polk and Hillsborough Counties, "Bone Valley", portion of the Central Florida Phosphate District, the phosphate resources occur primarily in the coarse clastics of Pliocene to recent age, the Bone Valley Member of the Peace River Formation, and the upper portion of the Undifferentiated Unit of the Peace River Formation of the Miocene age Hawthorn Group. The upper portion of the Arcadia Formation, consisting of phosphatic, dolomitic clays, silts, sands and dolomites, represents the remainder of the phosphate-bearing portions of the Hawthorn Group. Phosphate grains also occur erratically in the Pleistocene and Recent overburden throughout the district. Locally, the mining industry refers to the phosphate-rich beds as matrix, which does not necessarily parallel stratigraphic horizons.

The Hawthorn Group consists of fluvial and estuarine deposits and marine limestone and dolomite which contain phosphate, quartz sand and silt, and

clay. The minable phosphate zone of the Hawthorn Group includes both clastic depositional horizons, as well as residuum derived from weathering of the carbonate rocks, containing varying proportions of sand and clay in addition to phosphate grains. The Hawthorn Group thickens southward and in the Southern Extension the Undifferentiated portion of the Peace River Formation is the major phosphate-bearing horizon of current commercial interest.

The Peace River Formation lies unconformably above the Arcadia Formation and is generally comprised of two units. The lower unit is a zone consisting of fine-to-coarse, poorly sorted phosphatic, clayey sand and sandy clay. The upper unit, the Bone Valley Member, is usually comprised of phosphatic, clayey sand. Both zones contain varying percentages of phosphate grains which range in size from coarse particles, greater than one millimeter in size, termed pebble by the industry, to sand-size and smaller grains. The sand-size phosphate particles, when separated during beneficiation, are termed concentrate. Where intense lateritic weathering has occurred at the top of the Bone Valley Member of the Peace River Formation, or the younger Pliocene to Recent deposits, an aluminum phosphate (leached) zone is developed. This zone is generally disposed of with the overburden during the mining process because its phosphate content is not economically recoverable. The minable matrix is generally comprised of Pliocene to recent sediments as well as both units of the Peace River Formation and sometimes part of the upper Arcadia Formation. This relationship varies from mine to mine and between the "Bone Valley" and Southern Extension areas. The non-phosphatic, unconsolidated sands and clays of upper Pliocene and younger strata constitute the typical overburden (Fountain and Hayes, 1979).

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# Beneficiation of Phosphate: Theory and Practice

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