

**STATE OF FLORIDA
STATE BOARD OF CONSERVATION**

Ernest Mitts, Director

FLORIDA GEOLOGICAL SURVEY

Herman Gunter, Director

GEOLOGICAL BULLETIN NO. 39

MINING AND MINERAL RESOURCES

JAMES L. CALVER

Published for
THE FLORIDA GEOLOGICAL SURVEY
Tallahassee, 1957

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LETTER OF TRANSMITTAL



Florida Geological Survey

Tallahassee

November 1, 1957

MR. ERNEST MITTS, *Director*
FLORIDA STATE BOARD OF CONSERVATION
TALLAHASSEE, FLORIDA

SIR:

This report entitled, "Mining and Mineral Resources," prepared by Dr. James L. Calver, Geologist, with the Survey from 1947 to May 1, 1957, is transmitted with the recommendation that it be published as Florida Geological Survey Bulletin No. 39. The Study is broad in its scope and contains practical discussions of the geologic occurrence, economic development and utilization of Florida's mineral resources. It is written in language understandable to the interested inquirer, and this basic, authoritative information will, I believe, assist materially in further development of our mineral resources in Florida.

Under favorable economic conditions the raw mineral materials of the State could be substantially developed and used by industry. Florida's productive mineral wealth has increased in annual value, as reported by the mineral industry, from nearly \$15 million in 1940 to nearly \$133 million in 1956. This remarkable increase has broadened the tax base of the State. Florida currently ranks third among all the states in the value of nonmetallic mineral production.

The Geological Survey sincerely appreciates your cooperation and continued interest in its work.

Respectfully yours,

HERMAN GUNTER, *Director*

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ACKNOWLEDGMENTS

All statistical data, unless otherwise indicated, were obtained from publications of the U. S. Bureau of Mines. The annual publication *Minerals Yearbook* contains a complete review of all mineral activity in the United States and the data for Florida are collected under a cooperative agreement between the U. S. Bureau of Mines and the Florida Geological Survey. That publication, together with the series *Mineral Resources of the United States* which was formerly published annually by the U. S. Geological Survey, contains the most complete source of information on the growth and development of the mining industry in the United States. The author's indebtedness to these sources of data is here acknowledged.

In writing this report, no attempt was made to give credit to all sources of data because many paragraphs would require ten or more references. The publications of the Florida Geological Survey have been freely drawn upon without specific reference and this use of material is gratefully acknowledged. Special credit is due Dr. Herman Gunter, State Geologist, and to the members of the Florida Geological Survey's staff who have aided in the preparation of this manuscript.

MINING AND MINERAL RESOURCES

JAMES L. CALVER

INTRODUCTION

GENERAL STATEMENT

In area, Florida ranks in size with Georgia, the largest state in the southeastern United States. With 58,666 square miles of land surface within its boundaries, the area of Florida is only 210 square miles less than that of the State of Georgia. Situated wholly within the Coastal Plain Province, Florida is underlain by 4,000 feet or more of sedimentary rocks that overlie a basement of older sedimentary, metamorphic and igneous rocks. By far the greater portion of the State is covered by a surface mantle of soils and sands that may reach 200 feet in thickness. This mantle obscures the underlying sediments and rocks except where they are exposed around its borders and in areas where the cover is thin or absent as a result of erosion. The character of the sediments can best be determined by the study of samples recovered from borings, wells, test holes, and pits. It is, therefore, easy to understand why the mineral resources of Florida have not been fully explored or evaluated.

The development of the mineral industry in Florida, its continued growth and diversification, is dependent upon the utilization of materials ordinarily classified as nonmetallic minerals. The foremost mineral products of the State are phosphate, limestone, sand and gravel, fuller's earth, kaolin, cement, ilmenite, rutile, zircon, petroleum and peat. These rock and mineral industries have experienced a tremendous increase in production in recent years and the value at the mines and quarries for these products increased more than 730 percent from 1940 to 1955. The value for 1940 production as reported to the U. S. Bureau of Mines was \$14,854,000, and for the 1955 production, \$108,917,000. During this 15-year period, Florida's rank in mineral production among the states increased from thirty-fifth in 1940 to twenty-fourth in 1954, the last year for which comparable data are available. According to the 1954 census of mineral industries that was completed by the U. S. Bureau of the Census, Florida ranks third among all the states in the value of nonmetallic mineral mining. Only California and Texas reported higher values for the production of non-

metallic materials. The mining industry continued to expand during 1956 with total mineral production estimated at \$132,955,000 or 22 percent above 1955.

CONSERVATION PRACTICES

Conservation of ores and various mineral and rock materials does not include the concept of hoarding. The only realistic definition of conservation, as applied to the mining industry, is efficient production for prudent and beneficial use. While there is concern about the continual drain and dwindling of mineral resources, and wonder about what succeeding generations will do, such concern and wonder is largely misplaced. Future needs will be met through more efficient utilization, replacement by alternates, and continuous discovery of new deposits. The conservation of soil by the control of erosion and the conservation of forests by the prevention of fires are entirely different concepts. The purpose is to prevent waste, useless dissipation, and needless loss. Keeping ore either in the ground or hoarding it above ground achieves none of these objectives as long as the products of the mines are used to good purpose by individual consumers.

There is a vital difference between the proved reserves and the potential resources of any area, state, or nation. Without implying that all of the outcropping mineral deposits have been found, attention must be turned to the deposits that do not show on the surface. It is the existence of such hidden deposits about which some people are skeptical. Although hidden deposits can be proved conclusively only by penetration of drills, a strong case for the fact that these deposits do exist can be based on geologic science, experience, and the history of mining districts. To doubt the existence of concealed deposits of great size and value is contrary to the laws of probability and in areas in which geologic conditions are distinctly favorable, it is unrealistic to doubt the existence of deposits of tremendous importance.

Progress in the methods, techniques, and processes of mining and of treating minerals and rock materials for recovery of usable constituents make possible the working of progressively lower grade and lower quality deposits. Accompanying the development and use of more efficient methods, there is an expansion, in an economic sense, of the total reserves, but even the most proficient methods are of no avail unless deposits of usable materials have been found. The hidden deposits do nothing to replenish supplies unless they can be found and it is a challenge to the resourcefulness of geologists, geophysicists, geochemists, and mining

VALUE OF FLORIDA MINERAL INDUSTRY

ANNUAL TREND AND AVERAGE RATE OF INCREASE

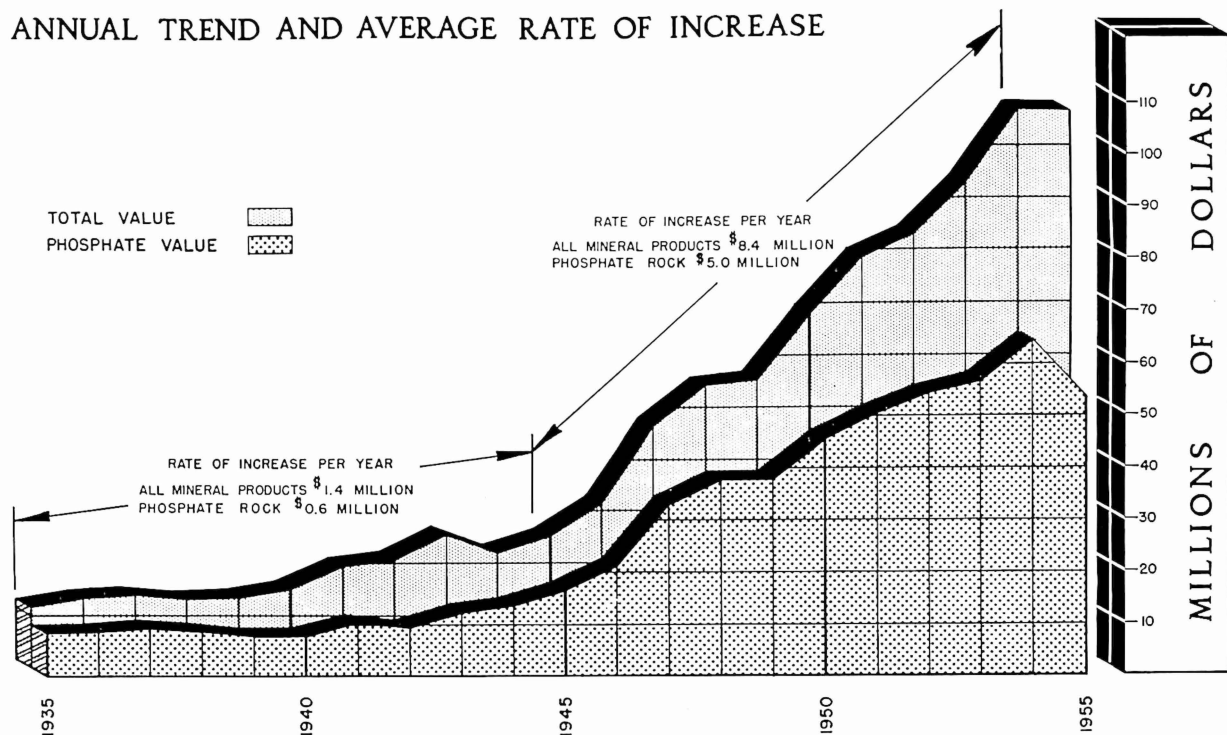


Figure 2

Graph illustrating the growth of Florida's mineral industry. Preliminary data for 1956 indicate a total value for that year of nearly \$133 million and that the value of phosphate production increased to nearly \$66 million.

engineers to find them. New techniques and methods, new mechanical devices and electrical instruments all contribute to the search for hidden deposits. The application of airborne radioactivity surveys to make rapid low-cost reconnaissance of large areas in the search of uranium and thorium ores is a relatively recent addition to technique and methods that are at the disposal of geologists. The development and use of geophysical methods to translate rock structures thousands of feet underground has given the petroleum industry a tool which has led to the discovery of tremendous quantities of new oil. Unfortunately, the known techniques are not universally effective and in some areas, including the State of Florida, the interpretations of the data developed by known methods of geophysical investigation are inconclusive. Progressively new methods and new electrical and mechanical instruments of intricate design and extreme sensitivity will displace older ones. Notwithstanding the fact that many problems encountered in the search for mineral deposits are far different and more complex than those associated with the search for promising oil structures, the progress and success that has been achieved in the fields of geochemistry, geophysics, and the varied branches of electronics gives justification to the belief that problems involving the detection, measurement, and determination of composition of hidden ore deposits are capable of solution. To doubt that this need will be met is to underestimate the resourcefulness of scientists, technologists, and engineers.

The mining industry has come to the realization that proper after-treatment and restoration of worked-out areas will be demanded by the general public. Proper land utilization requires that the resources extracted from the earth be incorporated into the economy as efficiently as possible. Urban encroachment on usable deposits may result in the permanent withdrawal of those materials from the economy of the community. In order to avoid such waste, it is necessary that planning boards and other groups that exercise supervision of industrial development give favorable classification of such land for mining purposes. In the Miami area of Dade County, for example, the limestone producers, working in cooperation with the zoning and planning boards, are developing quarries according to definite plans and the site will be left in condition suitable for residential development. In fact, real estate values are enhanced and higher values will exist after completion of the quarry operations than existed prior to mining.

An outstanding example of land use in an abandoned mining area is found in the northern part of St. Johns County at Ponte

Vedra. Following the termination of mining activities in 1929, the area that had produced rutile, ilmenite, and other heavy minerals since 1916, was developed into residential property. Not only are several hundred homes situated in the original mining area but the Ponte Vedra Country Club and golf course are located on the "mined-out" portion of the property.

All of the operating companies in the land-pebble phosphate field are very conscious of the value of progressive land conservation and have programs for utilizing unmined land, as well as realizing return from mined-out lands. Landownership by the major companies totals more than 300,000 acres in Polk and Hillsborough counties. Portions of both the prospected areas and the mined-out areas are being operated as tree farms and pastures. One company has over 40,000 acres under an intensive forestry program and selective cuttings have been made on the slash pines that were planted in 1939. New plantings by that company are being made at the rate of one-half million trees per year, and a total of more than 4 million trees have been planted. Other land-use practices by the phosphate companies include the establishment of recreational areas and the conversion of mined-out pits into lakes that may be stocked with fish.

In 1956, one of the phosphate producing companies entered into a large-scale land reclamation program that will extend over a five-year period. During the project, a tract consisting of 700 acres located on the south side of Lakeland will be reclaimed for residential use. As in the example of land reclamation completed in 1942 at Ponte Vedra, and that under way in the Miami area, the development of enhanced surface values of real estate is being accomplished with the cooperation of planning groups and the mining companies.

THE HEAVY MINERAL INDUSTRY

REVIEW OF DEVELOPMENT

The first heavy mineral mining development in Florida was located at Ponte Vedra, then known as Mineral City, St. Johns County, where production began in 1916 to supply ilmenite for titanium tetrachloride manufacture. This fuming liquid was used during the first World War in smoke screens, tracer bullets, and spotting shells. The original company, Buckman and Pritchard, Incorporated, operated under the name of the discoverers and developers of the deposit, Henry H. Buckman and George A. Pritchard. After 1922, the company became a subsidiary of the National Lead Company. At first only ilmenite was recovered from

the heavy mineral concentrate but later when uses for zircon and rutile became known, these minerals were also recovered. The first commercial production of zircon was reported in 1922 and that of rutile in 1925. Production from this mining venture reached a peak in 1927 but was discontinued entirely in 1929. Depletion of the best ore and availability of cheaper ores from India and Australia led to the termination of the mining activities. The subsidiary, renamed the Ponte Vedra Company, developed the property residentially and sold it in 1942. Ponte Vedra Beach, with several hundred homes, is situated on the original mining area and the country club and golf course are located on the "mined-out" portion of the Buckman and Pritchard property.

There were no companies producing heavy minerals in Florida from 1929 to 1939 but in 1940 a small quantity of ilmenite, rutile, and zircon was produced by the Riz Mineral Company, from natural concentrates found in the beach sands near Melbourne, Brevard County. This company separated ilmenite, rutile, zircon, and monazite from ores selectively mined on the ocean beaches in the vicinity of Melbourne, and later from a dune area situated near Vero Beach, Indian River County. The mineral separation plant, located at Palm Bay, was several miles from all of these deposits and the concentrate was trucked to the plant for processing. Production was more or less continuous until the fall of 1946 and intermittent until 1948 when the company was sold and reorganized as the Florida Ore Processing Company, Incorporated. That company made improvements in the Palm Bay mineral separation plant and five products were sold: ilmenite, rutile, zircon, garnet, and monazite.

By arrangement with Hobart Brothers, Incorporated, Troy, Ohio, manufacturers of welding rods, a mining company was organized under the name Florida Minerals Company to dredge and concentrate the heavy minerals from dune deposits situated immediately south of Vero Beach, Indian River County. All of the concentrate produced by this company's operations was trucked to the Palm Bay plant in Brevard County. Florida Minerals Company later developed a deposit in a dune area situated west of Winter Beach, Indian River County, and used a suction dredge to mine and a concentration plant to remove the quartz sands from the heavy mineral grains. This concentration depends upon the specific gravity differences between the heavy mineral grains and the quartz grains and is accomplished by the use of a restricted trough through which a slurry of mineral sands and water is directed. As

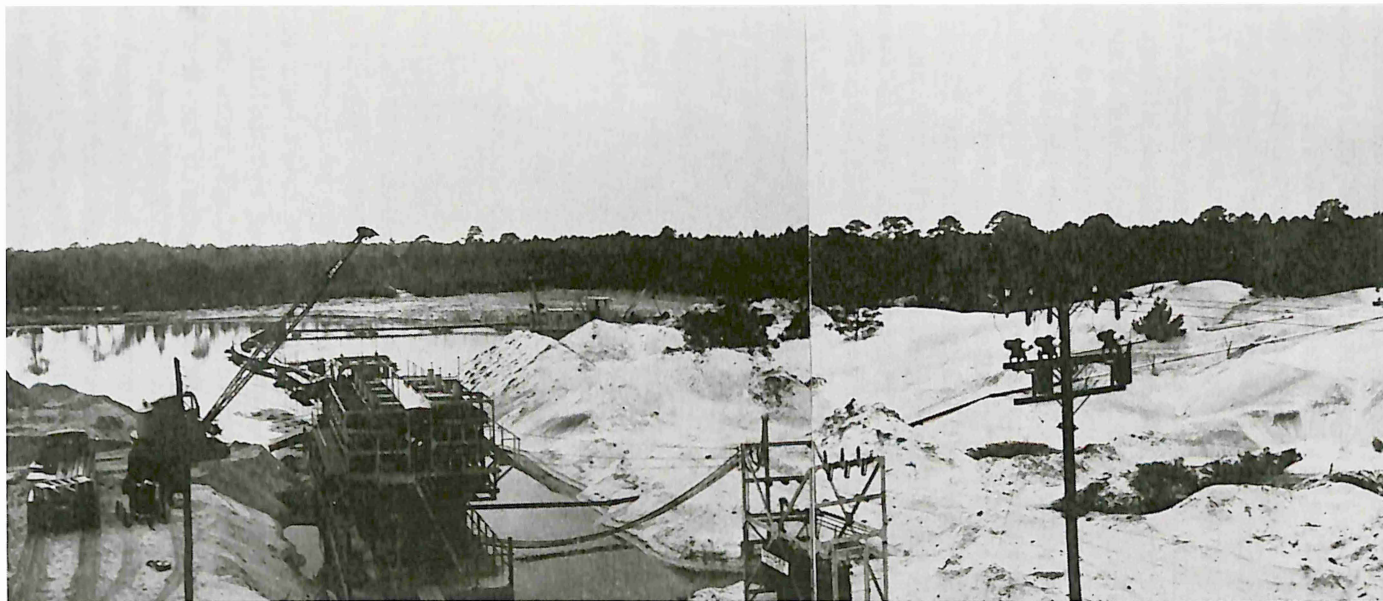


Figure 3
Dredge and heavy mineral concentration barge, Florida Minerals Company, Winter Beach, Indian River County.

the trough narrows and deepens, the minerals heavier than quartz tend to settle and the discharge from the lower end of the trough is split to recover the heavy concentrate. Because the troughs are arranged in a circle and the pipes that feed the slurry to the troughs have the appearance of ribs, this concentrator is named an inverted umbrella concentrator. In March 1955, the Florida Ore Processing Company discontinued its mining activity and processed the heavy mineral concentrate supplied by Florida Minerals Company. On October 17, 1955, the Palm Bay mineral separation plant was destroyed by fire. A new processing plant, built by Hobart Brothers, Incorporated, was constructed near the Winter Beach mine and full scale operation began in February 1956. The products recovered are ilmenite, rutile, zircon, garnet, and monazite.

In August 1943, the Rutile Mining Company of Florida, a subsidiary of the National Lead Company, started to mine and recover ilmenite and rutile from sand dunes on a 500-acre tract situated in Duval County midway between Jacksonville and the Atlantic Coast. Operating under a lease from the Rutile Mining Company of Florida, the Humphreys Gold Corporation moved its entire plant and equipment from Coos County, Oregon to Florida and began operations in Florida on April 1, 1944. The concentration plant was designed to treat 8,000 tons of sand per 20-hour day and the quality of the ore averages between four and five percent heavy mineral. The heavy mineral concentrate has the following assemblage of minerals:

Titanium minerals:	
Ilmenite	40 %
Leucoxene (altered ilmenite)	4 %
Rutile	7 %
Zircon	11 %
Monazite	0.5 %
Kyanite, Sillimanite, Staurolite and others	37.5 %
100.0 %	

From that quantity of ore, approximately 2,000 tons of ilmenite and 300 tons of rutile were separated per month. In 1946, production of zircon was begun and the tailings from the ilmenite-rutile dry separation plant, which were stored for that purpose, were reworked. Zircon production, about 1,000 tons per month, required installation of additional spirals and a second dry separation plant using electromagnetic and high-tension separators. In 1949, the production of monazite, about 20 tons per month, was added to the plant's output. The profitable production of these minerals over a period of 12 years was made possible principally

by use of the Humphreys spiral concentrator which replaced flotation cells and shaking tables in the beneficiation of the ores. The current development is under the joint ownership of the National Lead Company, Titanium Division, and the Rutile Mining Company of Florida. The output from this mine and plant, supplemented by imports from Australia, provided an adequate supply of rutile during the war years for coating the welding rods which were essential to the tremendous shipbuilding and armament program of the United States during World War II. Production from the Jacksonville plant has been continuous since it began operation.

The U. S. Bureau of Mines, working in cooperation with the Florida Geological Survey, conducted a drilling program in Florida during 1947 to establish reserves of titanium minerals. This study outlined an ore body of considerable size situated in the western portions of Clay and Duval counties. This deposit, located in Trail Ridge, occupies only a small portion of the entire ridge and the ridge constitutes a relatively minor portion of the Central Highlands area of the Florida Peninsula. Where mined, the sand averages about four percent heavy mineral grains, the remainder being quartz. The mineral composition of the heavy portion of the sand varies from place to place but includes the following assemblage with which a typical analysis is listed.

Titanium minerals	45%
Zircon	15%
Staurolite	20%
Sillimanite	5%
Tourmaline	5%
Kyanite	4%
Andalusite, pyroxene, spinel, and corundum	6%

The ore zone ranges in thickness from 35 to 60 feet, and no overburden is removed as the ore lies at the surface. The deposit rests on a five-foot layer of trees and other organic material below which is coarse sand that is barren of heavy minerals. The ore zone includes a "hardpan" that occurs at varying depths and thicknesses below the surface. It consists of masses of sand cemented with a tar-like substance, a product of decomposition of vegetable growth. The hardpan approaches the hardness of ordinary sandstone.

In December 1947, E. I. du Pont de Nemours & Company, Incorporated, entered into a long-term agreement with the State Armory Board to mine the titanium-bearing property situated on Trail Ridge within the boundary of Camp Blanding, Clay County. The Humphreys Gold Corporation, under contract with Du Pont,

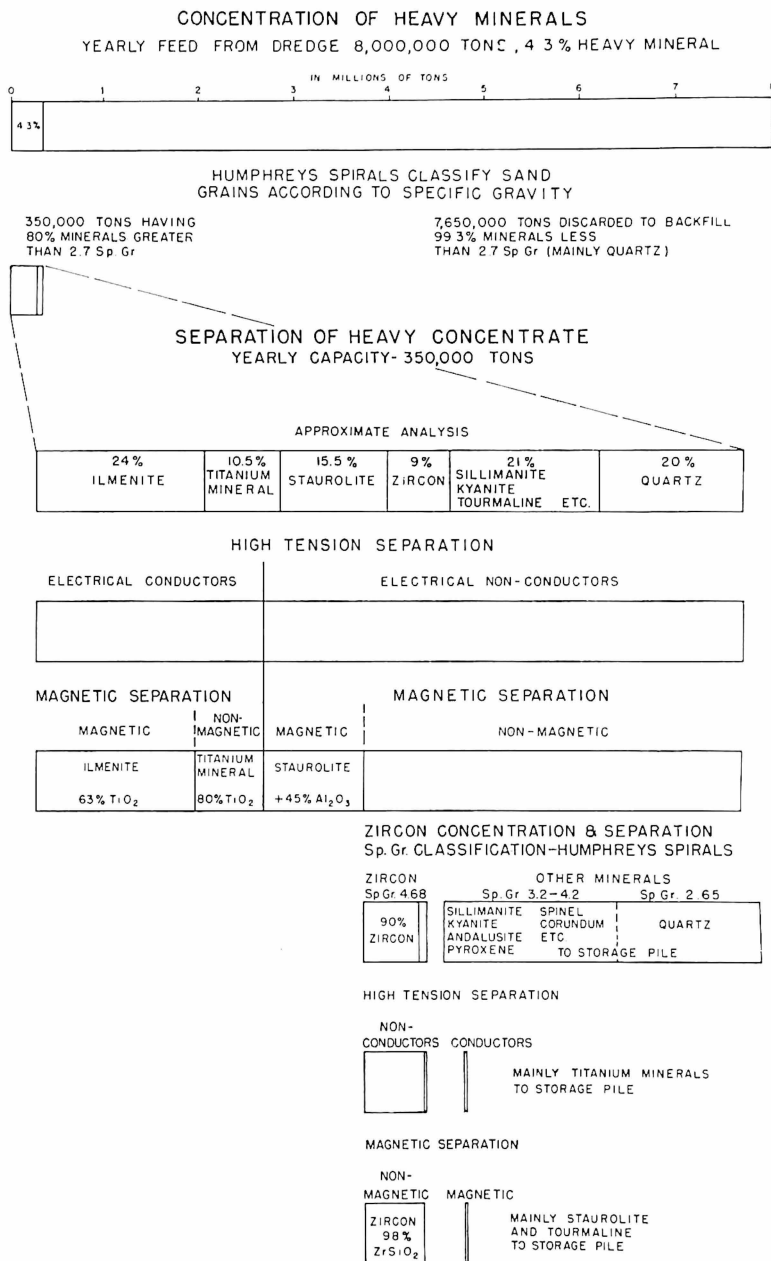


Figure 4

Schematic flow-sheet of the Trail Ridge heavy mineral mine and mineral separation plant.

built the Trail Ridge mineral concentration and separation plant which has a capacity to treat 20,000 tons of sand per day. The mining and processing is contracted by the Humphreys Gold Corporation and production from the plant began in April 1949. The titanium mineral produced consists of a weathered ilmenite that analyzes about 63 percent TiO_2 and a residue of altered titanium-bearing minerals, largely leucoxene, that contains about 80 percent TiO_2 .

The recovery of staurolite from the tailings of the titanium mineral dry plant was begun in the summer of 1952. This by-product analyzes more than 45 percent Al_2O_3 and is used by the Lehigh Portland Cement Company as a source of alumina in the manufacture of portland cement at its Bunnell plant. A small quantity of the product is also used in sandblasting. In addition to staurolite, this product contains a small percentage of tourmaline, zircon, ilmenite, quartz, and other minerals. Zircon is recovered from the tailings that remain after the staurolite has been removed. Concentrations of this mineral are made by taking advantage of the specific gravity difference between zircon (sp. gr. 4.68) and the associated minerals, sillimanite, kyanite, andalusite, pyroxene, spinel, and others having specific gravities ranging from 3.2 to 4.2. The plant operated by the Humphreys Gold Corporation at the Trail Ridge mine has a capacity of 2,500 short tons per month. The mineral zircon is used for foundry sand, refractory uses, ceramic uses, sandblasting, and as the ore from which zirconium and hafnium are recovered. The tailings of the mineral separation plant are stockpiled for future recovery of sillimanite, kyanite, and possibly other minerals when methods are developed for their separation.

The second heavy mineral mine and plant to be located on Trail Ridge was developed by the Du Pont Company and placed in operation in April 1955. The Highland plant is almost a duplicate of the Trail Ridge plant and is likewise operated by Humphreys Gold Corporation. Each plant has a designed yearly capacity of 100,000 tons of titanium minerals consisting of ilmenite and titanium mineral residue (mainly leucoxene, altered ilmenite, and rutile). At the Highland plant, the heavy mineral tails from the titanium mineral separation plant are stockpiled for possible future recovery of zircon, staurolite, sillimanite, kyanite, and possibly other minerals. Here, as at the Trail Ridge mine, monazite occurs in insufficient quantities to warrant separation.

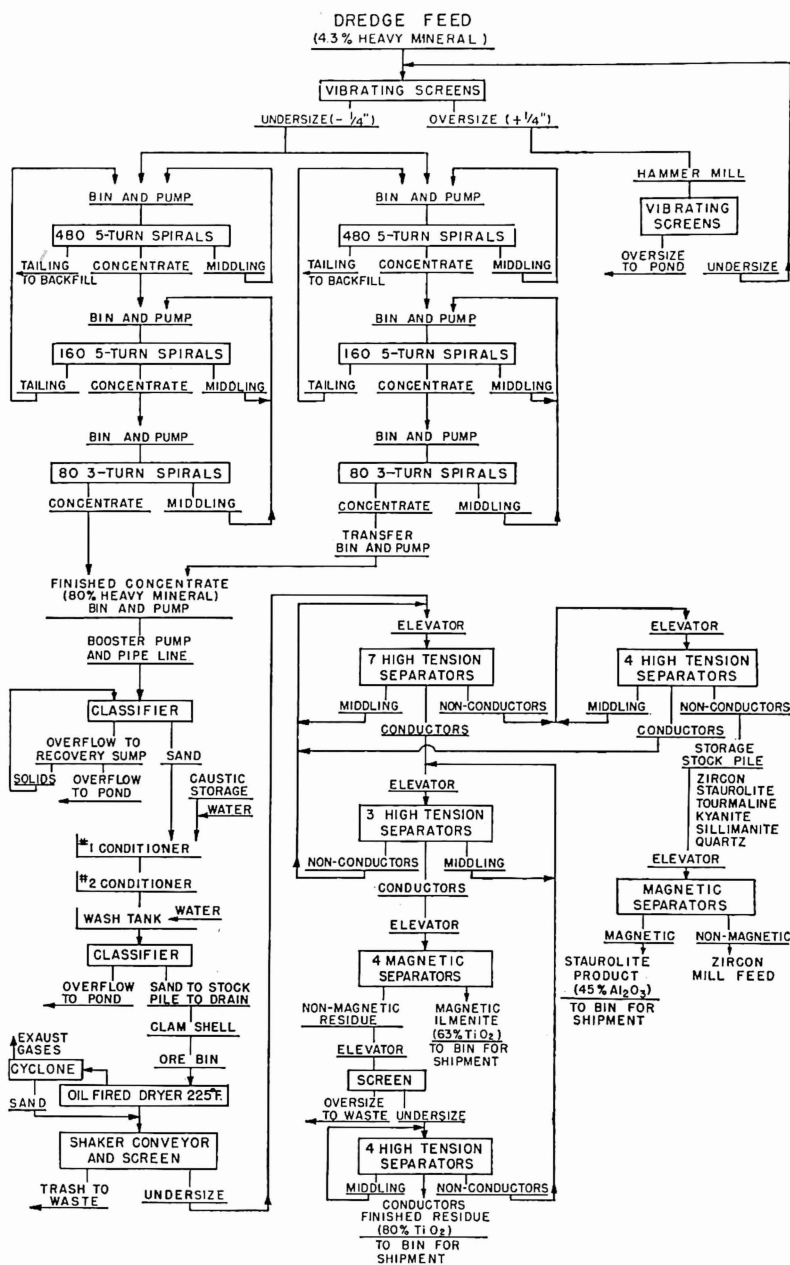


Figure 5
Generalized flow-sheet of Trail Ridge mine and plant.

MONAZITE

Monazite is one of the by-product minerals that is recovered in the processing concentrates of heavy mineral sands that contain ilmenite, rutile, zircon, and other valuable minerals. Monazite $[(\text{Ce}, \text{Y}, \text{La}, \text{Th}) \text{PO}_4]$ is a phosphate of rare-earth elements that contains up to 12 percent thorium oxide and one percent uranium oxide. Both the thorium and uranium content of this mineral may be recovered as a by-product in the extraction of the rare-earth elements from the monazite. The rare-earth family of elements is composed of 15 metals that have closely related properties. These elements are neither rare nor earths but only within the past few years has technology advanced sufficiently to produce these elements in quantities sufficient for research. The group of elements were called "earths" because their oxides resemble the oxides of the family of alkaline-earth metals (barium, calcium, and strontium) and "rare" because they were thought to be scarce. In the heavy mineral sands of Florida, monazite occurs as small, round, glassy grains that have a yellowish-brown color; the mineral has a hardness of 5 to 5.5 and a specific gravity of 4.6 to 5.3. It is the chief ore mineral from which thorium is recovered and

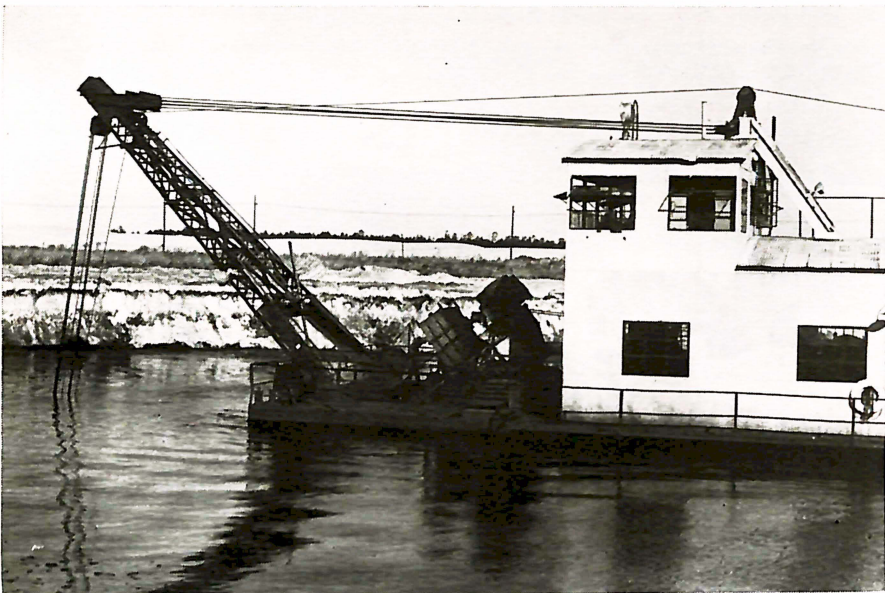


Figure 6

Suction dredge at Trail Ridge mine, Clay County. The ore zone is about 60 feet thick and, as shown in the photograph, about 15 feet of the deposit extends above water level. F. S. N. B. photograph.

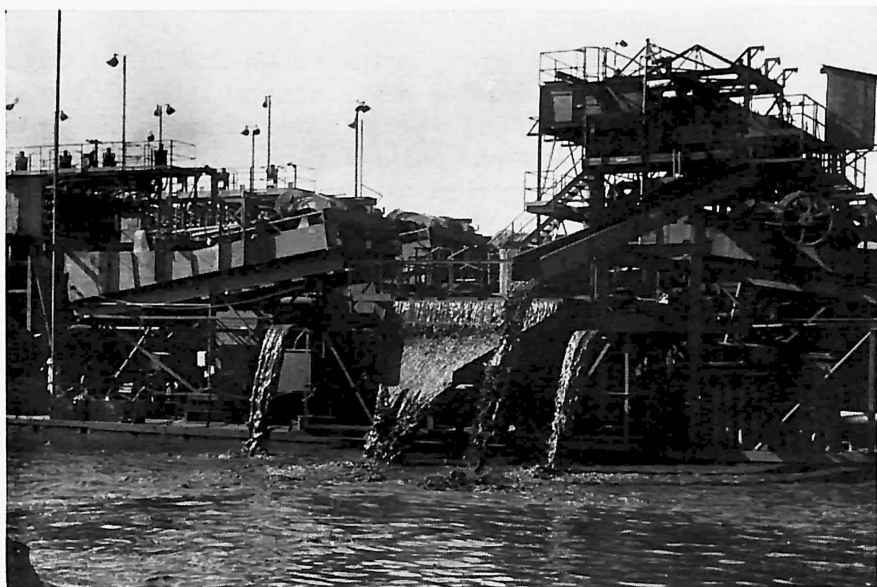


Figure 7

Floating concentration plant at the Trail Ridge mine in which the ore containing approximately four percent heavy mineral is beneficiated to eighty percent heavy mineral by use of Humphreys spiral concentrators.

F. S. N. B. photograph.



Figure 8

Back-fill or mined-out area at Trail Ridge heavy mineral mine, Clay County.

F. S. N. B. photograph.

this element is distributed in the crust of the earth in quantities only a little less than lead and about three times as abundant as uranium.

Cerium is the most important rare-earth element produced from monazite and the principal commercial product made from it is misch metal. This metal contains about 40 to 55 percent cerium; 22 to 30 percent lanthanum; 15 to 17 percent neodymium; 8 to 10 percent praseodymium, yttrium, samarium, and other rare-earth elements. When alloyed with iron, the product is used as sparking flints for cigarette lighters, miners' lamps, and acetylene welding torches. Approximately one-quarter of the rare-earth metals is consumed in misch metal and ferrocerium; one-half of the production is used in carbon arc electrode cores, and the remaining one-quarter in miscellaneous uses including glass and metal polishing compounds, waterproofing, mildew-proofing, and glass manufacture. Cerium oxide is an excellent abrasive material and is used in polishing both metal and glass surfaces.

Although thorium is found in at least 100 minerals, almost all of the thorium of commerce is obtained from monazite. The chief uses of thorium and its compounds are in the manufacture of gas mantles, refractories, and polishing compounds, and in the preparation of various chemical and medical supplies. Of potential importance in the field of atomic energy, is the fact that thorium—232, when subjected to bombardment by neutrons, is converted into uranium—233, in an amount exceeding the quantity of uranium—233, uranium—235, or plutonium—239, that is consumed in providing the necessary neutrons for the conversion. It is this creation of an excess of nuclear fuel that is known as "breeding." It is reasonable to assume that when the utilization of thorium as a fissionable material develops, demand for the metal will be equal to that for uranium.

The thoria content of monazite varies considerably with locality. The material recovered from the heavy mineral sands of Florida contains about five percent thoria. The average of five analyses of monazite, samples of which were recovered from the heavy mineral sands located on Amelia Island, St. George Inlet, Mayport, Ponte Vedra, and Anastasia Island, gives a ThO_2 content of 4.96 percent and a U_3O_8 content of 0.55 percent.

ZIRCON

The mineral zircon is a silicate of zirconium and is composed, theoretically of 67.2 percent zirconia and 32.8 percent silica. This composition is expressed in the formula ZrSiO_4 . Contrary to the

common belief that zircon is a rare mineral is the fact that it is widely distributed in all types of rocks and sediments and zirconium is more plentiful in the crust of the earth than nickel, copper, zinc, or lead. Zircon is a constituent of practically all stream and beach sands; however, it occurs in rather small quantities in most deposits. In many instances it can be detected only through careful chemical and microscopic examination. The specific gravity of zircon (4.68) is much higher than that of quartz (2.65), and the mineral commonly occurs with the heavy mineral sands found associated with beach deposits. In Florida, zircon is a constituent of the heavy mineral sands and it is recovered in the mineral separation plants after the titanium minerals, ilmenite and rutile, have been removed from the concentrate of heavy minerals.

Almost the entire zircon production for the United States for every year from 1944 through 1949 may be accounted for by the output from the South Jacksonville plant of the Rutile Mining Company of Florida, which is operated by the Humphreys Gold Corporation. During these years, a small portion of the total zircon production was reported by the Florida Ore Processing Company located near Melbourne. Early in 1949, the titanium mineral plant of the E. I. du Pont de Nemours & Company, located near Starke, began operations and in 1950 large quantities of zircon were being produced by this plant. The total quantity of zircon produced annually from these mining operations has placed the United States in a position of self-sufficiency with respect to zircon.

The production of zircon in 1953 amounted to 21,234 short tons, dropping to 17,959 short tons in 1954 and in 1955 rose to 28,913 short tons. This favorable situation came about only incidentally through the exploitation of the heavy mineral sand deposits of Florida for their titanium mineral content.

According to data published by the U. S. Bureau of Mines Minerals Yearbook 1950, from 20,000 to 30,000 tons of zircon are consumed annually in the United States. Zircon and the prepared oxide of zirconium, zirconia, are extensively employed in the ceramic industry in the manufacture of porcelains and glazes. The use of zirconia as an opacifier in enamels, once an important use, has been largely discontinued and replaced by titanium dioxide. Ground zircon finds use in the form of bricks, cements, and molded shapes, as a refractory material capable of withstanding very high operating temperatures. Zircon refractories are used in foundries and in furnaces for melting glass and aluminum. Zircon sand is replacing quartz sand in foundry practice for gray iron, steel,

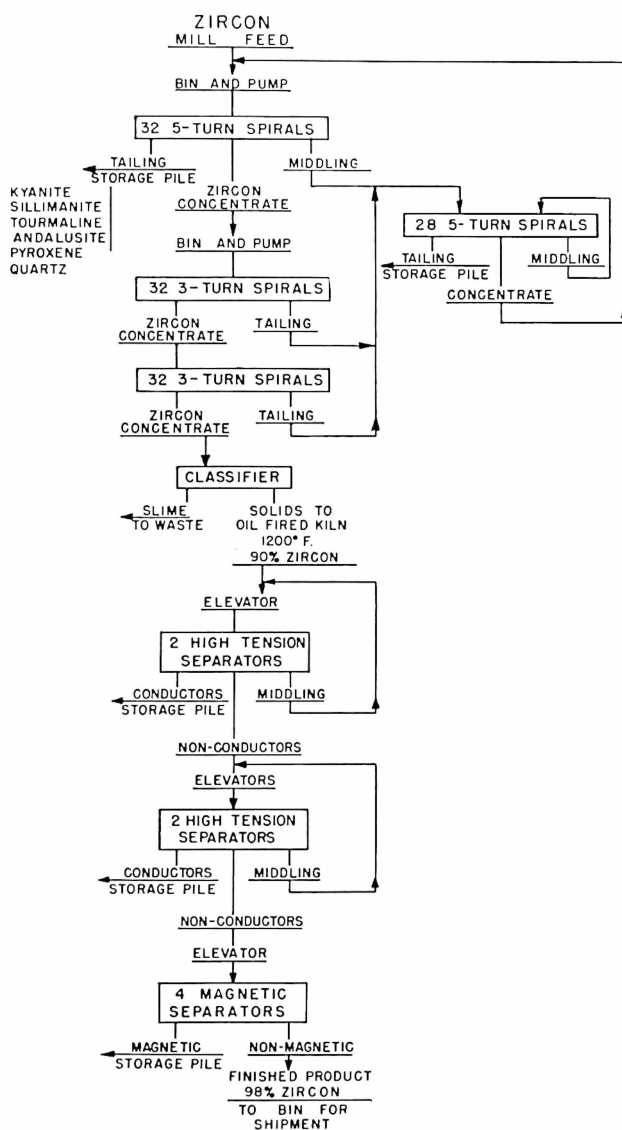


Figure 9
Generalized flow-sheet of the Humphreys Gold Corporation's zircon recovery plant at the Trail Ridge mine, Clay County.

bronze and light metal castings. The thermal conductivity of zircon is much higher than that of quartz and the more rapid chilling results in superior castings that require a minimum of buffing and grinding. The molten metal does not wet the zircon, and foundry sand and molding sands made from zircon do not adhere to the outer surface of the castings. Zircon is the highest temperature refractory in common use that can be produced in bulk. It is preferred over other super-duty refractories because there is no penetration of the brick by metal, it has a low coefficient of expansion, and high resistance to corrosion and to mechanical abuse occurring in the course of charging and cleaning the furnace. Certain compounds of zirconium possess such high refractory characteristics as to allow their use in the stationary parts of combustion chambers of gas-turbine and jet engines. Commercial applications of zirconium compounds include chemical catalysts, textile water repellents, and tanning agents.

The metal zirconium has found use in powder form for flash-light powders, flares, fireworks, and detonators. The metal is also used in various radio and electronic tubes to absorb gases within the tube. Zirconium is essential in making certain special steels and in alloys of magnesium for airplane construction. One of the most interesting properties of the metal zirconium is its great affinity for various gases, such as oxygen, nitrogen, carbon monoxide, carbon dioxide, hydrogen and water vapor. Considerable quantities of these gases can be absorbed by zirconium at high temperatures and retained permanently in the metal. This property of acting as a "gas sponge" makes zirconium particularly valuable as a "getter" in the manufacture of high vacuum radio and electronic tubes. The excellent strength of the metal, coupled with its corrosion resistance and extremely low neutron absorption characteristics indicate that increasing quantities of zirconium will be utilized as a structural material in atomic power reactors. Inasmuch as uranium atoms are split by neutrons, any absorption of the neutrons by the structural material of the reactor, or atomic engine, would lower the efficiency of the reactor.

Hafnium: Almost all zircon contains one to three percent hafnium, an element that has such similar chemical properties to the element zirconium that their separation is difficult. In order to produce pure zirconium and hafnium metal, zircon must undergo a complicated and expensive chemical process. The metal hafnium has properties opposite to zirconium with respect to neutron absorption and is used to make control rods for nuclear reactors.

Hafnium, discovered in 1923, is a metallic element that is

ductile, is highly resistant to corrosion, and has a very high absorption cross section for neutrons. The hafnium content of the earth's crust has been estimated to be greater than mercury and silver, and just as plentiful as beryllium and uranium.

TITANIUM MINERALS (ILMENITE AND RUTILE)

Titanium is a metallic element and is the ninth most common element in the earth's crust. It is more abundant than all of the lead, zinc, tin, antimony, nickel, copper, gold, and silver combined and occurs as a minor constituent or impurity in many ores and minerals. Only in ilmenite, rutile, and related materials does titanium occur in sufficient abundance to be commercially useful. Ilmenite (FeTiO_3) is a black, tabular mineral with a metallic luster. Ideally, it contains 36.8 percent iron, 31.6 percent titanium, and 31.6 percent oxygen, although the iron-titanium ratio may vary considerably. The mineral is magnetic and becomes more strongly magnetic after heating. Rutile (TiO_2) is a reddish-brown to black prismatic mineral with an adamantine luster and a pale brown streak. It is composed of 60 percent titanium and 40 percent oxygen but some iron is usually present. Both of these titanium minerals, together with altered ilmenite and leucoxene, are recovered as sand grains from the heavy mineral portion of the sands of Florida.

By far the largest use for ilmenite is in the manufacture of titanium dioxide pigment. Its whiteness, spreading quality, chemical stability, and cheapness, make it the most popular white pigment. It has a high index of refraction and remarkable opacity or hiding power that is made use of in pigments for paints, paper, rubber, enamels, coated fabrics, floor coverings and many other products. Rutile and rutile-ilmenite mixtures are used for coating electric welding rods. This is the largest use for rutile, and its function is to shield the arc from oxidation during welding and to produce a slag which protects the cooling weld.

The production of titanium metal from rutile and from altered ilmenite has received a great deal of publicity during recent years naming titanium the "miracle metal," the "wonder metal," and the "Cinderella metal." Production of titanium sponge metal in the United States has increased from 10 tons in 1948 to about 7,400 tons in 1955, and the titanium metal expansion program calls for an annual output of 21,600 short tons in 1957. The shortage of titanium metal is the result of metallurgical obstacles and not to scarcity of titanium minerals. Titanium minerals are reduced to metal with great difficulty because of the characteristic of titanium

to hold to or combine with oxygen. Titanium base alloys are as strong as structural steel alloys but weigh only one-half as much as steel; they retain their strength at elevated temperatures where other structural metals lose strength, and they also possess great resistance to corrosion.

GARNET

The name "garnet" is given to a group of seven minerals, all of which are silicates of aluminum, calcium, and iron. The most common garnets are almandite and andradite which are dark red to reddish-brown in color. Some of the material that is recovered from the heavy mineral sands of Brevard and Indian River counties, Florida, is pink in color and is the variety called rhodolite. All of the Florida production is utilized in the abrasive industry for sandblasting in monument works and in cleaning the carbon from spark plugs. The production of garnet in Florida is strictly a by-product of the heavy mineral industry.

STAUROLITE

Staurolite is an iron aluminum silicate that contains ideally 15.8 percent FeO, 55.9 percent Al_2O_3 , 26.3 percent SiO_2 and 2 percent H_2O . The mineral was first recovered at the Trail Ridge heavy mineral separation plant in sufficient quantities to be an industrial mineral. Although staurolite was first used for a sandblasting material, the first important industrial use is in the manufacture of portland cement where it substitutes for clay in supplying the necessary alumina and also contributes to the iron content as required by the cement formula. Current production from the Trail Ridge plant where the heavy mineral fraction contains 14 percent staurolite, is estimated at 20,000 short tons annually.

KYANITE AND SILLIMANITE

Modern technology in many industrial processes demand ever increasing high temperatures and superior refractory materials are continually in demand. Requirements for refractory materials are most exacting when high temperatures are required, or sudden changes in temperature are encountered, or when contact with molten metals and slags are necessary. The refractories used for these high temperature applications are identified commercially as mullite, kyanite, or sillimanite. Prior to World War II, most of the kyanite-mullite refractories were made from kyanite imported from India. Since that time, synthetic mullite, made from bauxite and various alumina-silica mixtures, have been used commercially.

Kyanite and sillimanite are aluminum silicates ($\text{Al}_2\text{O}_3 \cdot \text{SiO}_2$) which when heated are transformed to mullite ($3\text{Al}_2\text{O}_3 \cdot 2\text{SiO}_2$). Kyanite exhibits considerable expansion when heated between $2,200^\circ\text{F}$ and $2,400^\circ\text{F}$ and is converted to mullite and glass at $2,450^\circ\text{F}$. Because of its expansion characteristic, kyanite ore is calcined prior to its use. Sillimanite conversion to mullite is accomplished without volume change, but the mineral does not occur in quantities large enough to be mined. Kyanite and mullite produced from kyanite are on the United States list of strategic minerals.

Both kyanite and sillimanite occur in sand-size grains in the tailings from the heavy mineral separation plants. Recent studies conducted by the U. S. Bureau of Mines show that both of these minerals can be separated and recovered. Also, tests have shown that the kyanite-sillimanite mixture has a pyrometric cone equivalent of cone 38 (about $1,835^\circ\text{C}$) whereas the pyrometric cone equivalent of commercial kyanite ranges from cone 36 to cone 37 (about $1,815^\circ\text{C}$). The fine-grained material is suitable for making special shapes, porcelains, and clay-mullite mixtures. Refractory bricks require coarser material but with nodulation it may be possible to produce a satisfactory product.

PEAT

Peat production in Florida established a new record in 1955 totaling 61,098 tons valued at \$231,829. Within the past ten years, production and value of this commodity has increased nearly four times. During the same period, the production of peat in the United States increased about two and one-half times. The substantial increase in demand for peat is attributed to the expanding markets in the agricultural and horticultural fields. Peat is extremely varied in nature and composition and varies widely in chemical and physical characteristics. In commercial usage three types are recognized in accordance with established marketing terminology: moss peat, which consists of poorly decomposed remains of sphagnum and other mosses; reed or sedge peat, which is formed from poorly or moderately decomposed plants of the sedge family, reeds, cattails, and other swamp plants; and humus, a term used to designate peats which are decomposed to the extent that their biological identity is lost. Muck is referred to a "miscellaneous" classification of peat if it is composed of 75 percent peat on a dry basis—usually muck does not meet this requirement for classification as a peat. Most of the peat produced in Florida

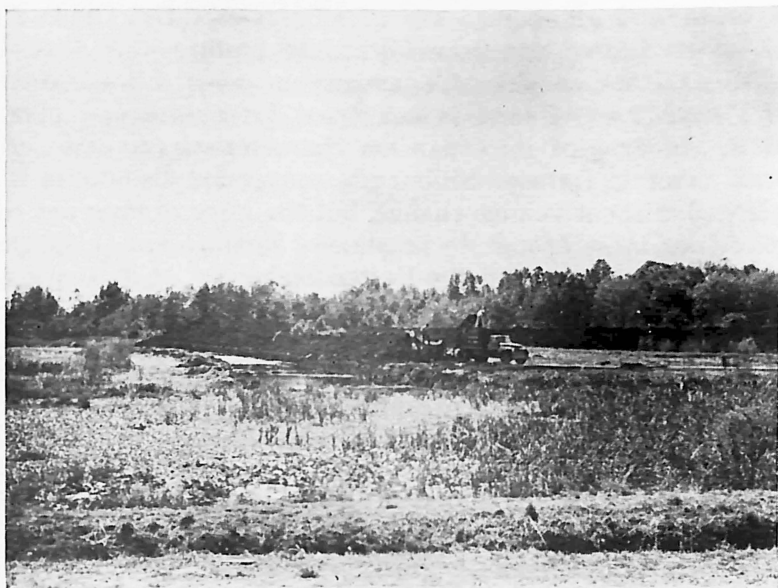


Figure 10

Mining and loading peat at deposit located near Florahome, Putnam County.

is classified by the producing companies as humus. No general agreement exists on the classification of peats according to their biological characteristics and no standards have been developed for classifying peat into fuel grades. For specific details of individual deposits, reference should be made to *The Peat Deposits of Florida*, Florida Geological Survey Bulletin No. 30.

The principal use for peat is as a soil conditioner and large amounts are used for lawns, golf courses, in nurseries and in greenhouses. Although peat has a relatively high nitrogen content, it is not readily available as plant food like the "soluble nitrogen" of artificial fertilizer. The benefits derived from the use of peat result largely from improved physical conditions in the soil medium. Another factor in its use as a soil conditioner is its ability to retain moisture. Nearly all of the peat produced in the State is marketed or used in soil improvement. Minor quantities of peat are used as a filler in mixed fertilizers, packing material for plants and vegetables, and as poultry litter. In its use as a filler in mixed fertilizers, peat acts as a carrier for primary plant nutrients—nitrogen, phosphorus, and potash—and not as an agent for supplying plant food.

The known original reserves of peat in Florida are recorded on an air-dried basis as 2 billion short tons, see U. S. Geological Survey Circular 293, 1953. This quantity represents 14 percent of the entire peat reserves for the United States. For many years Florida has ranked among the foremost peat producing states and in 1955 reported the highest production with 22 percent of the total for the entire United States. During that year, Washington ranked second and Michigan third in the quantity produced.

Table 1
Production and Value of Peat in Florida

<i>Year</i>	<i>Short Tons</i>	<i>Value</i>
1942	2,400	\$ 12,600
1943	7,316	16,950
1944	3,100	30,000
1945	15,194	66,747
1946	19,979	81,832
1947	42,300	126,000
1948	24,750	56,171
1949	11,800	69,000
1950	23,022	151,000
1951	25,748	161,000
1952	23,729	154,164
1953	27,678	185,524
1954	37,449	168,004
1955	61,098	231,829
1956 Est.	65,000	260,000

Data—U. S. Bureau of Mines

PETROLEUM

The discovery well of the Sunniland Oil Field, Collier County, was brought in September 26, 1943, and produced 20,550 barrels of 20.8° API gravity oil before it was converted into a salt water disposal well on May 10, 1946. The discovery well was drilled by the Humble Oil and Refining Company, and that company further explored the region in the vicinity of Sunniland and developed a small field that consists of 12 field wells. Figure 11 illustrates the production record of the field. In January 1950 at the completion of the last field well, there were 12 producing wells, seven of which were flowing. By the end of that year, however, there was only one flowing well. The field produced nearly 50,000 barrels a month during 1951, and production has decreased slowly to an average of 40,000 barrels per month during 1956. Figure 12 is a photograph of a rework derrick and oil well pump at the Sunniland field. Total cumulative production of the field through 1956 is recorded at 4,797,721 barrels.

The discovery well of the Forty-Mile Bend field, Dade County, was completed February 6, 1954, and a field well, about three miles east of the discovery well, was completed April 5, 1954. These wells had initial daily production of 76 barrels and 112 barrels respectively. The production record from these wells was disappointing and the field was abandoned in September 1955. A total of 32,888 barrels of oil is recorded as the entire production.

Both in the Sunniland and the Forty-Mile Bend fields, the producing zone is a porous limestone, named the Sunniland, that occurs in the section of Lower Cretaceous rocks. This zone was found at a depth of about 11,500 feet at Sunniland and about 11,300 feet at Forty-Mile Bend.

During the 17-year period from January 1, 1940 through December 1956, 270 wells were drilled for oil and gas in Florida and only 15 of these were completed as producers. When it is remembered that there are 58,666 square miles of land surface within the boundaries of Florida, a density of one well per 217 square miles can only indicate the truly exploratory nature of the drilling to date. The entire State remains a potential area for future discovery and no portion of the State has been eliminated from the classification of a potential producing area.

PHOSPHATE ROCK

GENERAL STATEMENT AND RESERVES

For nearly half a century, the Florida deposits of phosphate rock have supplied much more phosphate than all of the other domestic deposits combined. Phosphate rock is constant neither in composition nor occurrence and consists of a variable mixture of calcium phosphates and other minerals. X-ray studies have shown that the dominant phosphatic mineral in the Florida deposits is fluor-apatite and this mineral is found in the extensive bedded deposits of marine origin, in the residual or detrital deposits, and in the replacements of limestone. Recent studies by the U. S. Geological Survey show that the uranium-bearing phosphorites of the Bone Valley formation and of the Hawthorn formation are of marine origin. The hard-rock phosphate deposits, on the other hand, were formed by weathering of surface rocks, and deposition of the phosphate as replacements of limestone. Such deposits are not of marine origin and do not contain appreciable uranium.

The most recent reserve estimate by the U. S. Geological Survey of the phosphate deposits of Florida is contained in an open file report by V. E. McKelvey and others, 1953. This estimate was

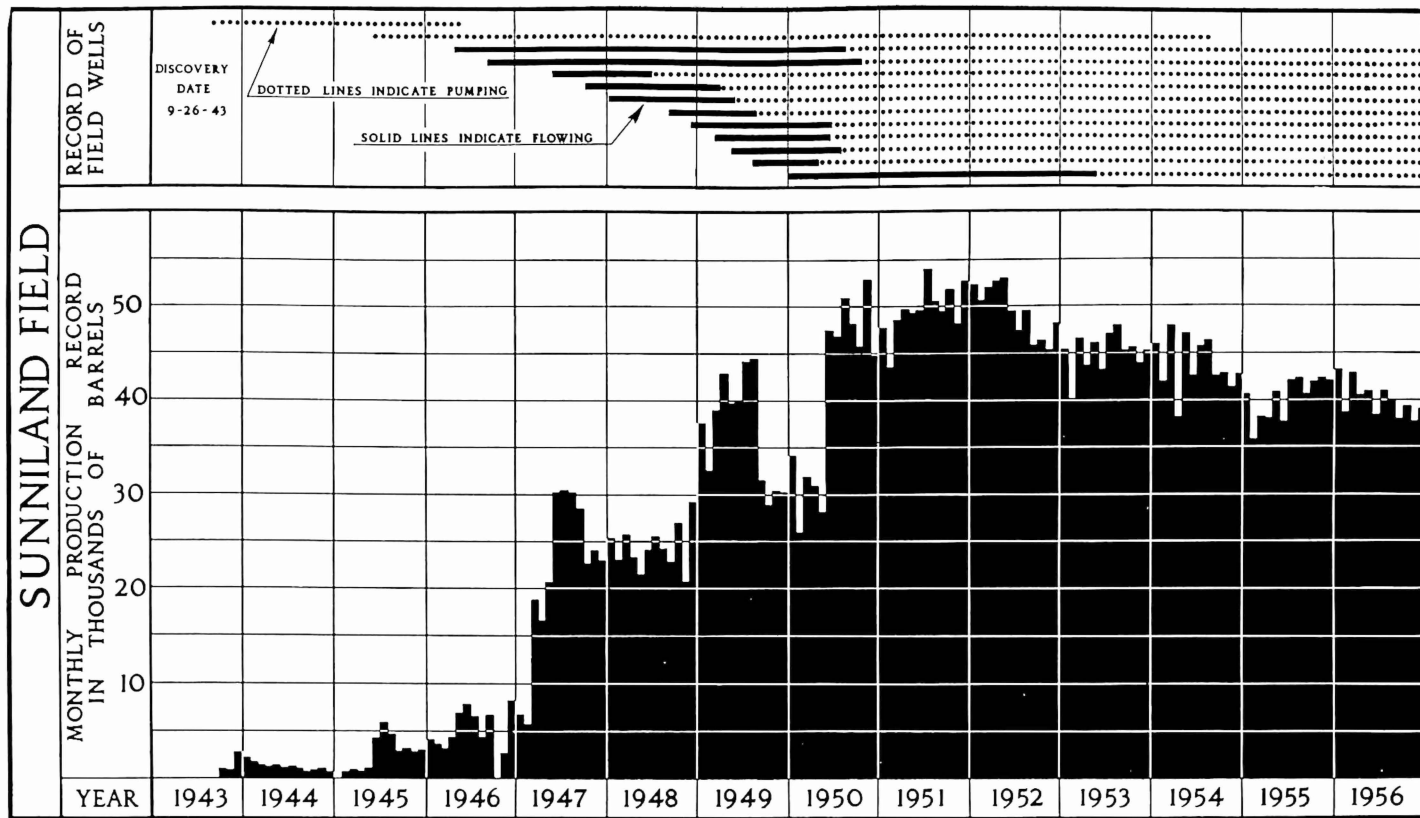


Figure 11
Production record of the Sunniland Field, Collier County.

published in U. S. Bureau of Mines Minerals Yearbook 1953, vol. 1, and table 2 summarized the data for Florida.

Table 2
Production and Reserves of Phosphate Rock in Florida
in Millions of Long Tons

	<i>Production</i>		<i>Inferred Reserves</i>			
	<i>From beginning of Mining through 1949</i>		<i>Minable under present conditions</i>		<i>Minable under changed conditions</i>	
	<i>Marketed Product</i>	<i>P₂O₅</i>	<i>Marketable Product</i>	<i>P₂O₅</i>	<i>Product</i>	<i>P₂O₅</i>
Florida:						
Land-pebble:						
Matrix	124.7	41.7	1,000	330	2,000	600
Leached zone	-----	-----	-----	-----	800	180
River pebble	1.3	.3	-----	-----	50	12
Hard-rock	14.0	4.8	1,040	330	500	140
Soft-rock	1.1	.2				
Hawthorn formation	-----	-----	-----	-----	20,000	4,000
Total	141.1	47.0	2,040	660	23,350	4,932
U. S. Total	195.0	62.0	5,100	1,500	49,000	12,000

Source: McKelvey, V. E., and others, Domestic Phosphate Deposits, U. S. Geological Survey Open File Report, 1953.

At the current rate of production, the inferred reserves minable under present conditions will be sufficient for over 200 years and the reserves minable under changed conditions would extend this, perhaps, well over 1,000 years.

RIVER-PEBBLE AND LAND-PEBBLE

In 1881, Captain J. Francis Le Baron, U. S. Army, Corps of Engineers, accidentally discovered the presence of rich phosphate deposits in the "bed of Peace River." Mining of river-pebble phosphate by means of a floating steam dredge began in 1887. At the heights of the river dredging era, some 12 companies were engaged in the operations which were located on tributary streams as well as on the Peace River itself. This precipitated a "boom" period which affected Charlotte, Hardee, and DeSoto counties as

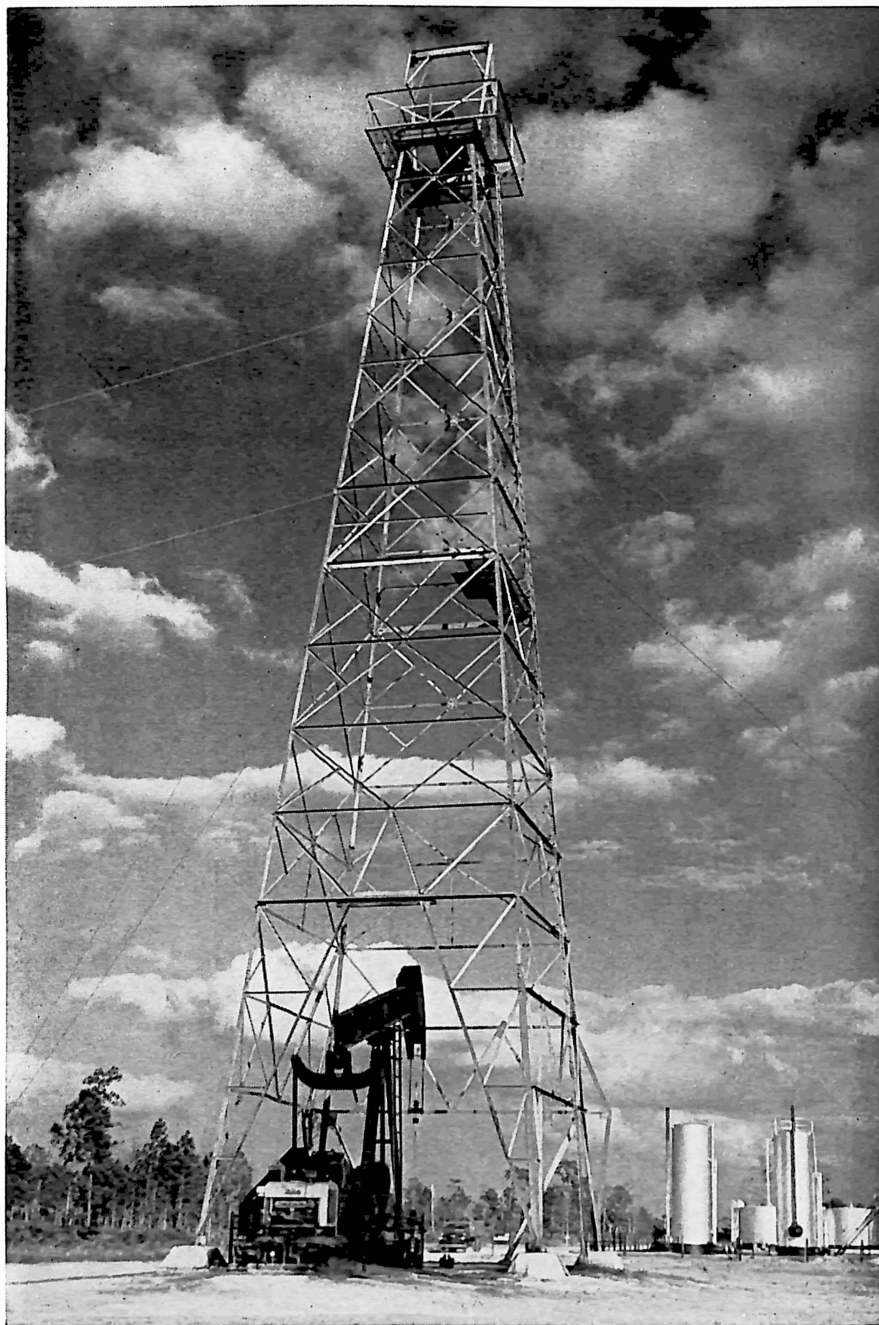


Figure 12

Sunniland Oil Field, Collier County, rework derrick in foreground and storage tanks in background. F. S. N. B. photograph.
Published as Figure 4, 10th Biennial Report

well as Polk County. These river operations consisted of pumping the mixture of rock and matrix through flexible suction hoses connected to 8-inch or 10-inch centrifugal pumps. The material was put through a revolving screen in which the larger pebbles were separated from the rest of the material, which was dumped back into the river. The separated phosphate pebbles were discharged to a nearby barge for transportation to Charlotte Harbor. Mining operations continued in the river until 1908 when increased mining costs and a slump in the market caused the cessation of operations.

The discovery of high grade land-pebble phosphate deposits and the development of economical means for strip mining these deposits led to the growth of phosphate operations in ever increasing magnitude from 1891, the year the first shipments were made, until 1917 when the first World War caused the loss of a lucrative export business and another depression period for the industry. Following World War I, the course of production was upward and the industry continued to flourish until the second World War again curtailed operations. In the intervening years, however, new uses and techniques for using phosphates had developed and these, together with the tremendous needs for rebuilding agriculture in Europe and feeding devastated countries until such rebuilding could be accomplished, led to the industry's rapid expansion during the post-war years.

The main portion of the land-pebble field covers approximately 2,600 square miles in Polk, Hillsborough, Manatee, and Hardee counties. Known boundaries of the field extend into Highlands, DeSoto, and Sarasota counties, and other deposits of land-pebble phosphate are known in Hamilton, Clay, Lake, and Orange counties. Since 1905, the mines in Polk and Hillsborough counties have been the most important source of phosphate for American industry. The land-pebble district produces about 70 percent of the phosphate rock mined in the United States and more than one-third of the estimated production of phosphate for the entire world.

In the portion of the land-pebble field under development, the tonnage of recoverable phosphate ranges from 500 to 35,000 tons per acre and is typically 5,000 tons per acre.

Mining and Processing: In former years, most of the rock was mined from the bottom and edges of streams with floating hydraulic dredges that discharged the spoil back into the river. This method of recovery produced "river-pebble phosphate" and the broad stream beds that exist in the headwaters of the Alafia, Peace, and other rivers were formed during these dredging operations. Modern mining methods utilize huge draglines and complicated

washers, crushers, screens, hydraulic separators and flotation plants in which practically all particles of phosphate rock that are larger than 200 mesh are recovered. The industry has developed earth moving equipment and techniques that are in themselves modern industrial miracles. Draglines that consume 29 cubic yards at a scoop, water systems to supply 150 million gallons a day from wells with capacities up to 26,000 gallons a minute, flotation plants to produce a million tons of high grade phosphate a year are a portion of the land-pebble industry.

The huge quantities of water and the suspended slimes and clays removed from the matrix are pumped to large settling lagoons for clarification and, if possible, for reuse of the water. The larger solids may be discharged to separate "tailing" ponds or may be deposited near the point of influent to the slime pond. The semi-colloidal slimes are distributed more or less evenly throughout the lagoon. These slimes occupy more volume than the removed material, consequently, even if the mined-out areas are utilized, storage must be provided above the ground surface. These storage lagoons cover areas upward to 1800 acres and are frequently subdivided into several lagoons for better control. The clear water that accumulates above the slime layer may be re-used by the plant or may discharge into streams. The accidental discharge of slimes into streams through dam failure brought about by faulty structures, excessive rainfall, or other reasons, continue to be a matter of concern to the industry, property owners and others that utilize the rivers.

The land-pebble phosphate field produces and ships about 10 million tons of phosphate rock annually, all of which is a concentrate obtained by scrubbing, screening and flotation processes. To obtain that quantity of commercial-grade rock, it is necessary to treat approximately 30 million tons of ore (matrix) and to remove another 30 million tons of overburden. The character of the rock, the climate, and the abundance of both surface and subsurface water all contributed to the development of hydraulic mining and hydraulic transportation of the ore throughout the district. Mining and processing in the land-pebble phosphate district is characterized by the use of huge draglines, the use and reclamation of large volumes of water, and the disposition of great volumes of slimes. The outstanding feature of mining practice established in the district is the use of large draglines by each of the eight producing companies. Within the district, there are 12 large draglines that have bucket capacities of 14 to 29 cubic yards, and 14 smaller draglines with bucket capacities of 6 to 10 cubic yards. The



Figure 13
Noralyn mine and plant of the International Minerals and Chemical Corporation,
Bartow, Polk County. F. S. N. B. photograph.
Published as Figure 7, 10th Biennial Report

large draglines are of the Monighan walking type, have boom lengths from 175 to 235 feet, and digging capacities from 1,000 to 2,000 cubic yards per hour. The most common dragline is the Bucyrus-Erie 650B, equipped with a 175-foot boom and a 17-cubic yard bucket, that can dig an average of 1,100 cubic yards per hour. The largest machine, named the "Super-Scooper," is a Bucyrus-Erie 1250B walking dragline, which swings a 29-cubic yard bucket on a 235-foot boom.

After the overburden is stripped and placed in either single or double windrows, the ore or matrix is excavated, lifted to ground level, and dumped into a "well" or depression dug about six feet below ground level by a bulldozer where hydraulic monitors play water upon the matrix which disintegrates and is sluiced through a grizzly into a sump. The slurry is pumped from the well by large electrically driven centrifugal pumps and is transported in 16-inch pipelines to the washing plant. Standard in the field is a 14-inch pump with a 34 to 40-inch in diameter impeller that can handle a maximum rock size of six inches in diameter. These pumps are coupled directly to 500 to 800-horsepower electric motors and usually handle 5,000 gallons of water per minute in which from 10 to 15 cubic yards of solids are suspended. They normally deliver 7,000 to 8,000 gallons per minute of slurry that contains from 25 to 45 percent solids or 500 to 600 cubic yards of matrix per hour. Depending upon the condition of the matrix, the ratio of coarse to middle to fine sizes, the stratification in the lines and other factors, the pumps occasionally may deliver from 800 to 1,000 cubic yards per hour. As the distance between the sump and the washer increases, booster pumps are added to the line. One pump carries about $1\frac{1}{2}$ miles of pipeline and lines that are four or five miles long are common in the field. One company operates a six-mile long line. The pipeline delivers the mined material to the washing plant and the solids have been in the line an average of 8 to 10 minutes for each mile traveled.

Beneficiation of the land-pebble phosphate is illustrated in the flow sheet of the washer and flotation plants (fig. 15).

At the washer, the incoming matrix is separated into three portions—the fines (minus 14 mesh) go to the flotation plant; the coarse (larger than $7/8$ inch) are crushed, reduced in size, and re-circulated; and the middlings (plus 14 mesh, minus $7/8$ inch) are called "pebble phosphate rock" or "washer rock." Generally two sizes are separated, the finer fraction (minus 5 mesh, plus 14 mesh) being somewhat higher grade than the coarser fraction (plus 5 mesh, minus $7/8$ inch). After the pebble has been removed



Figure 14

Preparing matrix for pipeline transportation. As the matrix or ore bed in the land-
pebble phosphate field is mined by dragline and dumped into a well, hydraulic guns
transform it into a slurry which is pumped to the washery. F. S. N. B. photograph.
Published as Figure 8, 10th Biennial Report

in the washer, the remaining portion of the slurry goes to a flotation plant where additional sizing and concentration is carried out. The largest fragments (plus 14 mesh) that were not removed by the washer are recovered as "pebble phosphate rock," the middle fractions (minus 14 mesh, plus 35 mesh and minus 35 mesh plus 150 mesh) receive further treatment and the finest fraction constitutes the slimes. The coarser portion of the middle fraction receives various treatments, depending on the individual plant; nevertheless, the material is treated with reagents and the phosphate grains are separated from the quartz grains by use of vibrating tables, Humphrey spirals, conveyor belts, or coarse-feed cells. The coarse concentrate is one product of the flotation plant.

BENEFICIATION OF LAND-PEBBLE PHOSPHATE ORE

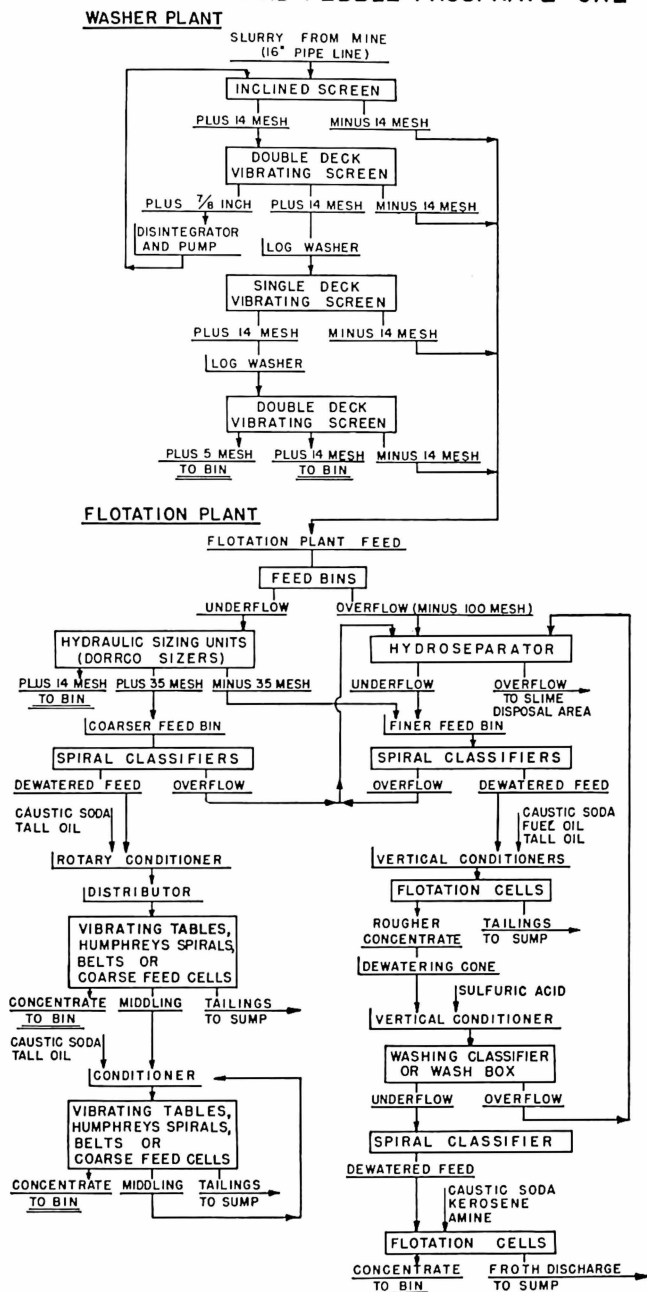


Figure 15

Generalized flow-sheet of a land-pebble phosphate washer and flotation plant.

The finer fraction of the flotation plant feed is dewatered, treated with reagents, and fed into flotation cells, rectangular tanks containing paddles which agitate the pulp and introduce air into the mixture. The phosphate particles being coated with reagent are attached to the air bubbles and are removed in the froth. The concentrate is then treated with sulfuric acid to remove the reagent and after washing is again treated in flotation cells. This step, however, is the reverse of the first treatment inasmuch as the quartz sand is floated out in the froth and the phosphate rock is left behind. This nonfloat portion is the final concentrate of the flotation plant and analyzes 32 to 35 percent P_2O_5 . The "washer rock" products and the flotation concentrates are stored in separate bins from which they are transferred to wet storage prior to drying and further treatment. The tailings, primarily of quartz

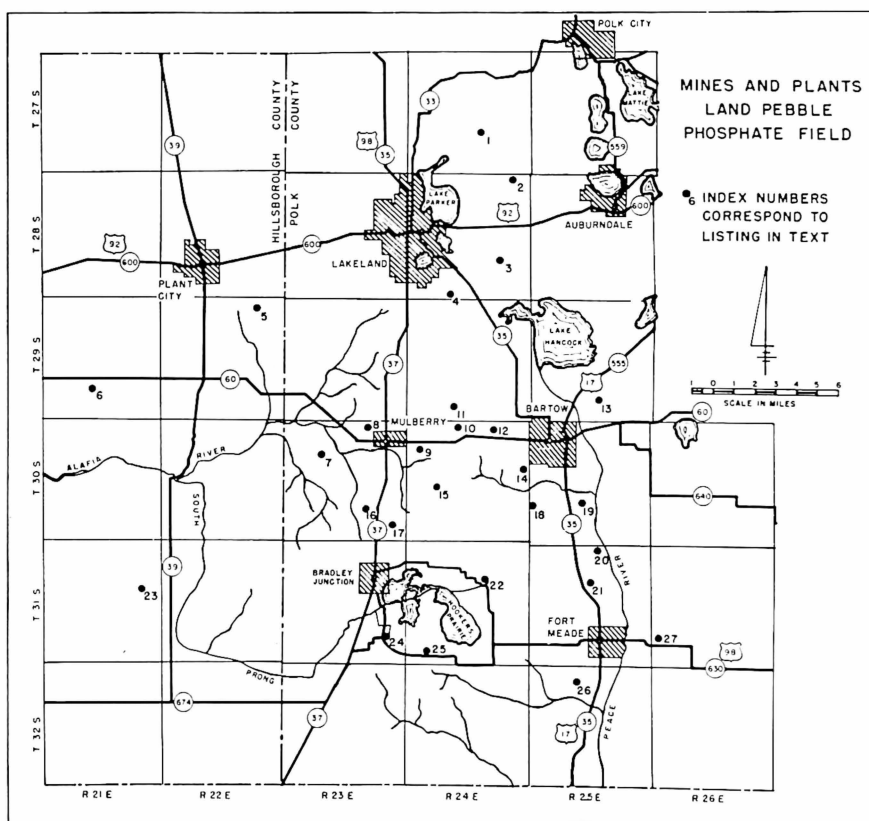


Figure 16

Index map to mines and plants in the land-pebble phosphate rock district.

sand, analyze 2 to 5 percent P_2O_5 , and are pumped to waste ponds.

The principal mines and plants in the land-pebble phosphate field are located by index number on the map of the district (fig. 16), and are identified in the accompanying listing.

LIST OF COMPANIES, MINES AND PLANTS IN THE
LAND-PEBBLE PHOSPHATE DISTRICT

(Refer to numbered localities on figure 16)

<i>Index No.</i>	<i>Company and Florida Address</i>	<i>Installation</i>
1	American Cyanamid Company Brewster	Orange Park mine Washer and flotation plant
2	Coronet Division, Smith-Douglas Co., Inc. Plant City	Teneroc mine Washer and flotation plant Wet storage Drying and shipping installations
3	American Cyanamid Company Brewster	Saddle Creek mine Washer and flotation plant (to be abandoned 1957)
4	Davison Chemical Company Bartow	Pauway No. 4 mine Washer and flotation plant
5	Coronet Division, Smith-Douglas Co., Inc. Plant City	Main office Drying and shipping installations Defluorination plant
6	American Cyanamid Company Brewster	Sydney mine Washer and flotation plant
7	Virginia-Carolina Chemical Corp. Nichols	Main office Drying and shipping installations Electric furnace-elemental phosphorus Superphosphate plant Triple superphosphate plant Synthetic cryolite plant Uranium recovery plant
8	International Minerals and Chemical Corp. Bartow	Mulberry research laboratory Drying and shipping installations
9	F. S. Royster Guano Company Mulberry	Triple superphosphate plant
10	Davison Chemical Company Bartow	Main office Ridgewood washer and table concentration plant Drying and shipping installations Triple superphosphate plant
11	Davison Chemical Company Bartow	Bonny Lake mine

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12	Armour Fertilizer Works, Inc. Bartow	Main office Bartow mine Washer and flotation plant Triple superphosphate plant
13	Virginia-Carolina Chemical Corp. Nichols	Phosmico flotation plant Drying and shipping installations
14	International Minerals and Chemical Corp. Bartow	Main office
15	International Minerals and Chemical Corp. Bartow	Bonnie triple superphosphate plant Uranium recovery plant
16	International Minerals and Chemical Corp. Bartow	Achan mine Washer and spiral plant
17	American Agricultural Chemical Co. Pierce	Main office Drying and shipping installations Electric furnace-elemental phosphorus Superphosphate plant
18	International Minerals and Chemical Corp. Bartow	Noralyn mine Washer and flotation plant Drying and shipping installations
19	Virginia-Carolina Chemical Corp. Nichols	Clear Springs mine Washer plant (flotation feed is pumped to Phosmico plant—No. 13 above)
20	Virginia-Carolina Chemical Corp. Nichols	Homeland mine Washer and flotation plant
21	International Minerals and Chemical Corp. Bartow	Peace Valley mine Washer and flotation plant
22	Swift and Company R.F.D. Bartow	Main office Agricola drying and shipping installations Triple superphosphate plant
23	American Agricultural Chemical Co. Pierce	Boyette mine Washer and flotation plant
24	American Cyanamid Company Brewster	Main office Drying and shipping installations Triple superphosphate plant
25	American Agricultural Chemical Co. Pierce	South Pierce tract, No. 12 mine
26	Swift and Company R.F.D. Bartow	Watson mine Washer and flotation plant
27	Swift and Company R.F.D. Bartow	Varn mine Washer and flotation plant

The phosphate mined in the 14-year period 1943-1956 inclusive, equals the quantity produced in the 55-year period 1888-1942 inclusive. The value at the mines as reported by producers during the past nine years, 1948-1956 inclusive, is equal to the cumulative value of the previous 60 years, 1888-1947 inclusive.

Table 3

Production and Value of Phosphate Rock Mined in Florida from the Beginning of Mining in 1888 through 1956 (Includes Land-Pebble, Hard-Rock, Soft-Rock, and River-Pebble Phosphate)

<i>Year</i>	<i>Quantity in Long Tons</i>	<i>Value</i>	<i>Year</i>	<i>Quantity in Long Tons</i>	<i>Value</i>
1888	3,000	\$ 21,000	1923	2,547,653	\$9,059,427
1889	4,100	28,000	1924	2,432,581	8,017,476
1890	46,501	338,190	1925	2,929,964	8,789,070
1891	112,482	703,013	1926	2,708,207	8,683,508
1892	287,343	1,418,418	1927	2,637,420	8,646,162
1893	438,804	1,979,056	1928	2,883,446	9,424,022
1894	527,653	1,666,813	1929	3,088,298	9,901,074
1895	568,061	2,112,902	1930	3,248,071	10,790,305
1896	495,199	1,547,353	1931	2,061,466	7,202,086
1897	552,342	1,493,515	1932	1,469,976	4,779,612
1898	600,894	1,847,796	1933	2,136,123	6,417,110
1899	726,420	2,804,061	1934	2,369,334	8,076,317
1900	706,243	2,983,312	1935	2,422,804	8,361,558
1901	751,996	3,159,473	1936	2,624,900	8,528,523
1902	785,430	2,564,197	1937	2,996,820	9,142,985
1903	860,336	2,986,824	1938	2,707,335	8,773,680
1904	1,072,951	3,974,304	1939	2,678,784	7,893,457
1905	1,194,106	4,251,845	1940	2,845,012	7,741,177
1906	1,304,505	5,585,578	1941	3,365,572	10,234,031
1907	1,357,365	6,577,757	1942	3,012,240	9,378,577
1908	1,692,102	8,484,539	1943	3,588,493	12,089,477
1909	1,779,702	8,541,301	1944	3,752,795	13,534,947
1910	2,067,507	8,647,774	1945	4,238,228	16,298,474
1911	2,436,248	9,473,638	1946	5,005,511	21,017,174
1912	2,406,899	9,461,297	1947	6,482,027	32,920,252
1913	2,545,276	9,563,084	1948	6,539,258	37,732,894
1914	2,138,891	7,354,744	1949	6,815,989	37,857,983
1915	1,358,611	3,762,239	1950	8,085,870	45,377,842
1916	1,515,845	4,170,165	1951	8,496,831	50,262,562
1917	2,022,599	5,464,493	1952	8,781,125	51,541,799
1918	2,067,230	6,090,106	1953	9,166,855	55,612,272
1919	1,660,200	7,797,929	1954	10,437,197	65,499,877
1920	3,369,384	19,464,362	1955	8,747,282	53,640,301
1921	1,780,028	10,431,642	1956	10,500,000	65,920,000
1922	2,058,593	8,347,522	TOTAL	197,101,313	\$904,244,253

HARD-ROCK AND SOFT-ROCK

In recent years, only one company has produced hard-rock phosphate but several small companies have been active in producing soft-rock phosphate from the waste ponds of former hard-rock operations. The combined production from these operations constitutes only a minor portion of the quantity of phosphate rock produced in Florida. In 1942, the production record (table 4), shows the combined tonnage of hard-rock and soft-rock phosphate was about four percent of the total produced in the State. More recently, every year since 1948, the combined tonnage of hard-rock and soft-rock phosphate has been less than two percent of the total quantity produced. Neither the production of hard-rock nor of soft-rock phosphate contributes a significant amount to the phosphate industry. Under changed economic conditions, the hard-rock reserves of the State again may be mined.

USES

The principal use of phosphate rock is in the production of superphosphate for use as a fertilizer. Under natural conditions, the phosphorus taken up by plant growth is returned to the soil upon the death and decay of the plant, and the efficiency of the soil is maintained. Under cultivation of soil, the phosphorus is removed with each crop that is harvested and, if the productivity of the soil is to be maintained, the phosphorus must be replaced in the form of superphosphate or some other soluble phosphate. Finely divided phosphate rock, phosphatic clay, or colloidal phosphate, however, is used successfully as a fertilizer in regions of heavy rainfall. In fertilizers such as superphosphate, which is made by treating phosphate rock with sulphuric acid, the phosphorus is available to plants in a much more soluble form than in the untreated phosphate rock. This available phosphorus is determined in the form of phosphorus pentoxide, P_2O_5 , and ordinary superphosphates contain 17 to 22 percent available P_2O_5 . "Triple" or "double" superphosphate may be prepared by treating phosphate rock with concentrated phosphoric acid and the product contains 40 to 50 percent available P_2O_5 . A product containing calcium metaphosphate that analyzes 60 percent available P_2O_5 is obtained by the action of phosphoric anhydride on phosphate rock. The chief advantage of these higher-grade fertilizers over the ordinary superphosphate is that they are more concentrated, and smaller expenditures for handling and transportation are possible.

Table 4
Mineral Industry in Florida 1942-1955

Mineral Product(1)	1942		1943		1944		1945		1946		1947		1948	
	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value
Clays (including kaolin and fuller's earth)	53,458	\$ 717,749	58,533	\$ 835,649	64,329	\$ 917,526	64,436	\$ 964,442	93,438	\$ 1,206,412	110,214	\$ 1,448,468	111,337	\$ 1,636,912
Clay sold or used in cement manufacture	(2)	(2)	(2)	(2)	35,089	17,544	41,266	20,633	35,000	17,500	42,000	21,000	49,000	37,000
Diatomite	(2)	(3)	(2)	(3)	(2)	(3)	(2)	(3)	-----	-----	-----	-----	-----	-----
Lime	21,510	212,291	20,507	202,276	17,959	185,565	18,431	211,077	(2)	(3)	(2)	(3)	(2)	(3)
Natural gas, 1,000 cu. ft.	-----	-----	-----	-----	-----	-----	6,000	180	6,000	193	8,000	258	27,000	1,000
Oyster shell	(2)	(2)	(2)	(2)	(2)	(2)	15,231	119,303	(2)	(2)	-----	-----	-----	-----
Peat	2,400	12,600	7,316	16,950	3,100	30,000	15,194	66,747	19,979	81,832	42,300	126,000	24,750	56,171
Petroleum, 42 gal. bbls.	-----	-----	4,032	(3)	11,838	(3)	27,510	(3)	56,884	(3)	259,345	(3)	291,221	(3)
Phosphate rock (4)-long tons	3,012,240	9,378,577	3,588,493	12,089,477	3,752,795	13,534,947	4,238,228	16,298,474	5,005,511	21,017,174	6,482,000	32,920,000	6,539,000	37,733,000
Land-pebble - long tons	2,893,756	8,826,705	3,483,194	11,633,241	3,607,208	13,136,472	4,103,022	15,578,980	4,807,563	19,867,339	6,314,077	31,975,858	6,421,725	37,070,381
Hard-rock - long tons	70,014	396,527	34,128	201,241	22,500	138,952	63,491	426,061	100,881	762,127	79,330	618,330	48,198	368,586
Soft-rock - long tons	48,470	155,345	71,171	254,995	60,087	259,523	71,715	293,433	97,067	387,708	88,620	326,064	69,335	293,927
Sand and gravel	1,834,863	1,339,361	1,833,453	1,527,985	1,335,569	1,180,299	1,314,011	1,074,055	1,534,667	1,320,819	2,067,000	1,881,000	2,312,000	2,433,000
Stone (except limestone for cement and lime)	6,632,680	5,733,697	8,741,200	7,446,388	2,730,020	2,600,462	2,617,180	3,024,465	2,863,070	3,212,135	3,534,000	4,512,000	4,155,000	5,116,000
Ilmenite	(2)	(3)	(2)	(3)	21,386	422,440	(2)	(3)	(2)	(3)	(2)	(3)	(2)	(3)
Rutile	(2)	(3)	(2)	(3)	3,730	588,120	(2)	(3)	(2)	(3)	(2)	(3)	(2)	(3)
Zircon	(2)	(3)	(2)	(3)	(2)	(3)	(2)	(3)	(2)	(3)	(2)	(3)	(2)	(3)
Undistributed	-----	3,470,022	-----	3,649,493	-----	3,339,699	-----	3,941,233	-----	5,005,456	-----	5,901,000	-----	8,315,000
Total		\$20,303,948		\$25,070,000		\$21,852,000		\$24,928,000		\$31,093,000		\$45,847,000		\$53,654,000

Mineral Product(1)	1949		1950		1951		1952		1953		1954		1955	
	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value
Clays (including kaolin and fuller's earth)	96,000	\$ 1,447,000	127,000	\$ 1,955,000	133,000	\$ 2,289,000	112,113	\$ 1,985,587	148,000	\$ 2,842,448	371,948	\$ 3,337,130	412,766	\$ 4,815,855
Clay sold or used in cement manufacture	80,000	40,000	84,000	63,000	70,000	70,000	86,000	86,000	109,911	109,911	(2)	(3)	(2)	(3)
Diatomite	(2)	(3)	(2)	(3)	(2)	(3)	(2)	(3)	(2)	(3)	(2)	(3)	(2)	(3)
Lime	39,000	2,000	8,000	(3)	10,000	1,000	15,000	1,000	34,000	2,000	35,000	2,900	35,000	4,000
Natural gas, 1,000 cu. ft.	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
Oyster shell	11,800	69,000	23,022	151,000	25,748	161,000	23,729	154,164	27,678	185,524	37,449	168,004	724,342	1,653,669
Peat	441,720	(3)	486,021	(3)	596,043	(3)	591,855	(3)	541,284	(3)	548,000	(3)	61,098	231,829
Petroleum, 42 gal. bbls.	6,816,000	37,858,000	8,086,000	45,378,000	8,497,000	50,263,000	9,205,138	54,085,524	9,330,952	56,587,790	10,437,197	64,499,877	8,747,282	53,640,301
Phosphate rock (4)-long tons	6,715,097	37,339,985	7,933,009	44,430,646	8,329,033	49,185,072	9,036,237	52,931,460	9,185,971	55,575,120	10,288,332	63,301,900	8,586,294	52,545,200
Land-pebble - long tons	23,804	173,211	71,319	538,601	75,615	582,247	85,900	662,289	68,200	537,400	78,990	622,440	91,200	733,800
Hard-rock - long tons	77,088	344,787	81,542	408,595	92,183	495,243	83,001	491,775	76,781	475,270	93,956	575,537	69,788	452,301
Soft-rock - long tons	2,244,000	1,880,000	2,794,000	2,807,000	4,419,000	4,301,000	4,154,613	3,848,077	3,731,432	3,199,368	3,468,842	2,661,152	5,065,503	4,349,148
Sand and gravel	4,215,000	4,748,000	5,313,000	6,885,000	8,033,000	9,420,000	7,836,634	9,577,541	9,428,959	11,309,421	14,225,356	16,832,066	16,303,625	21,312,339
Stone (except limestone for cement and lime)	(2)	(3)	(2)	(3)	(2)	(3)	(2)	(3)	151,109	2,322,451	157,157	2,411,823	(3)	(3)
Ilmenite	(2)	(3)	(2)	(3)	(2)	(3)	(2)	(3)	6,475	702,791	7,305	869,677	(3)	(3)
Rutile	(2)	(3)	(2)	(3)	(2)	(3)	(2)	(3)	21,234	793,685	17,959	820,041	28,913	1,425,641
Zircon	-----	9,014,000	-----	10,541,000	-----	12,113,000	-----	13,226,587	-----	14,453,548	-----	14,913,943	-----	23,868,651
Undistributed														
Total		\$55,018,000		\$67,717,000		\$78,548,000		\$82,878,000		\$92,336,000		\$106,517,000		\$108,917,000

- (1) Reported in short tons unless indicated otherwise.
(2) Data not available.
(3) Value included under "undistributed."
(4) 1942-1951 inclusive phosphate reported on sold or used basis.
1952-1955 inclusive reported on marketable production basis.

There is a trend in the phosphate district toward increased numbers of phosphate processing plants and this industrial growth has been stimulated by the increased use of triple superphosphate and the recovery of uranium as a by-product. Triple superphosphate is manufactured by treating phosphate rock with an excess of sulfuric acid to form phosphoric acid, and then treating more phosphate rock with the phosphoric acid to form the so-called triple superphosphate, a product that contains about three times as much available phosphate (expressed as P_2O_5) as would be obtained by treating phosphate rock with a limited amount of sulfuric acid in a single operation. The by-product uranium is recovered from the phosphoric acid that is produced in the first step of the process. Gypsum ($CaSO_4$) and soluble fluorine compounds

Table 5

Consumption of Phosphate Rock Produced in Florida
in 1954 by Uses

	1954 Long Tons
Land-pebble	
Ordinary superphosphate	4,912,435
Triple superphosphate	1,036,406
Nitra phosphate	12,851
Direct application to soil } Stock and poultry feed }	577,231
Fertilizer filler	-----
Elemental phosphorus, ferro-phosphorus, and phosphoric acid	622,563
Phosphoric acid (wet process)	439,056
Exports	1,061,619
Total	9,565,529
Hard-rock	
Elemental phosphorus, ferro-phosphorus, and phosphoric acid	74,303
Soft-rock	
Direct application to soil } Stock and poultry feed }	90,519
Total	9,730,351

are likewise produced. The gypsum collects in settling ponds but the soluble compounds may be present in the waters that discharge from the ponds. Fluorine compounds are likewise formed in the second step of the process for triple superphosphate manufacture and, together with other stack gases (sulfur dioxide and carbon

dioxide) are captured by scrubbing with water. The whole new industry of synthetic detergents is a development of industrial chemical research in the discovery of new phosphate chemicals and their utilization. The expanded use of household detergents and water softeners has created an increased demand for elemental phosphorus.

ORIGIN

The traditional explanation of phosphate origin has been seriously challenged in recent years by a theory which proposes precipitation of calcium phosphate from sea water. While it is recognized that significant amounts of phosphate are derived from the decay of organic matter, major quantities are formed by chemical precipitation. The depth of water at which phosphate precipitation occurs is an important factor in establishing the environment for precipitation from sea water. The theory as originally presented suggests that the zone of deposition would lie between depths of 150 and 600 feet. The depth of this zone, however, has not been established and many deposits, including those of the land-pebble district, suggest that the deposition occurred in shallow water. The question of water depth is still an open issue and the mechanics of moving the upwelling water across wide shelf areas has been given as an objection to this theory. Such an objection may not be valid in the case of the Florida deposits because upwellings that bring phosphatic waters from depth to the surface are known to occur in the Gulf of Mexico, and strong surface currents that act much like the jet streams in the atmosphere have been recorded. Such currents are believed to be the source of the phosphate concentration associated with the so-called red-tide condition that sometimes occurs in the Gulf waters west of the peninsula of Florida. Such currents offer a plausible explanation not only for the establishment of a phosphate cycle but also for phosphorite precipitation from sea water and its deposition in shallow water.

ALUMINUM

The discovery of a continuous reduction process in 1886 marked the beginning of aluminum as a commercial metal. Its widespread use in both metallic and nonmetallic applications has occurred during the past 50 years. Aluminum is the most abundant metallic element in the earth's crust and among all metals it is second only to iron in volume of production. Bauxite, the principal ore of

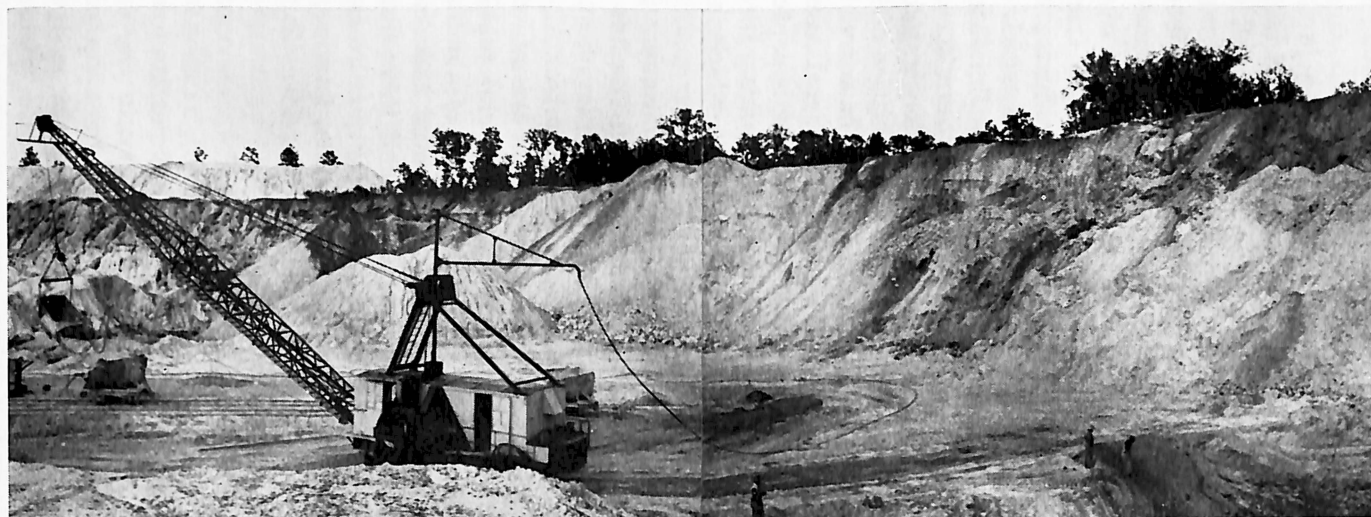


Figure 17
Kibler-Camp Phosphate Enterprise, Sec. 18 Mine, Citrus County. The only company
and mine producing hard-rock phosphate in Florida.

aluminum, is used in the production of metal, synthetic abrasives, chemicals and refractories.

In the United States, bauxite production began in Georgia in 1889 but for every year since 1905 over one-half of the domestic production has come from Arkansas. Relatively small quantities of bauxite have been mined in Tennessee, Virginia, and Mississippi but in recent years, Arkansas, Alabama, and Georgia have been the only producing states. The North American continent has limited reserves of bauxite, and about 60 percent of the quantity used in the United States has been imported from British Guiana. Expansion of the aluminum industry during and after World War II brought about increased demands which are being met by shipments from the huge deposits in Jamaica. During 1942, enemy submarine activity in the Caribbean seriously curtailed shipments from South America and demonstrated the need for economical processes to utilize the vast quantities of low grade alumina materials which would substitute for bauxite. Extensive research programs have been conducted by federal agencies and by industry to find and develop competitive methods for the recovery of alumina from clay and other materials. In the land-peggle phosphate district, both the raw matrix, which is the commercial source of phosphate rock, and that portion of the overburden which consists of the altered zone of aluminum phosphate offer potential sources for alumina production. The fine or minus 150-mesh fraction of the matrix and the aluminum phosphate zone of the overburden contain from 15 to 30 percent of Al_2O_3 and of P_2O_5 . More than 25,000,000 tons of raw matrix are mined annually to produce 10,000,000 tons of phosphate rock and peggle concentrate, and it is estimated that 14,000,000 tons of aluminum phosphate which occur in the overburden are moved and discarded as waste. The utilization of these materials and their potential exploitation to produce not only phosphate for fertilizers, but also co-product and by-product recovery of alumina, fluorine, uranium, and possibly other materials of value, is under investigation.

PORTLAND CEMENT

In the United States, the manufacture of portland cement has grown to become the largest single industry in the entire field of nonmetallic industrial minerals. In 1954, the value of portland cement constituted nearly 30 percent of the value assigned to the nonmetallic minerals (fuels excluded) that were produced in the country. Cement is so low priced, easy to use, and durable that it

has become the foundation stone of the construction industry. The first manufacture of portland cement in the United States was made in 1871 in the Lehigh Valley of Pennsylvania and production in the United States has increased steadily to reach the enormous production in 1955 of 292,600,000 barrels, valued at \$791,000,000. Although data on the quantity of cement manufactured in Florida are unavailable, nearly 9,000,000 barrels were used in the State during 1955. During that year, the per capita use of cement in Florida was 2.67 barrels, and in the United States 1.80 barrels. Florida ranks third among the States in per capita use of portland cement and ninth in total quantity used.

Portland cement is produced by heating or calcining a finely ground artificial mixture of lime, silica, alumina, and iron oxide in a rotary kiln to form a silicate clinker which is then pulverized. Definite proportions of these ingredients are necessary to produce a satisfactory product. Natural cement is produced by calcining at relatively low temperatures an impure limestone that contains the necessary proportions of silica, alumina and iron oxide. Masonry (natural) cement is a special type of natural cement that is suitable as a mortar for bricks or other masonry work. Pozzolan cement is produced by mixing powdered slaked lime with either volcanic ash or pulverized blast-furnace slag. This material differs from a slag portland cement in that the mixture is not calcined. All of these varieties of cement are classified as "hydraulic" inasmuch as they will set or harden under water. Portland cement, however, is most widely known and used because manufacturers are able to control the properties of the product by proportioning the ingredients of the mixture from which it is made.

Many different raw materials theoretically may be used in portland cement manufacture but only a few are actually used. Some argillaceous limestone, or natural cement rocks, have the approximate proportions of lime, silica, iron and alumina necessary for portland cement, while others require additions of minor quantities of one or more of these materials to produce the proper chemical mixture. More often, however, the necessary lime is supplied by one material (limestone, shells, or marl), the silica by sand or sandstone (or as a portion of the clay or shale that is used), the alumina by clays and shales, and the iron oxide by iron ore, or by high iron clays or shales.

The huge kilns in which portland cement is manufactured rank in size with the largest pieces of moving equipment that are used by any industry. At the Lehigh Portland Cement Company's Bunell plant, rotary kilns that are 10½ feet in diameter and 380 feet

long are in use, while those at the Tampa plant of the General Portland Cement Company, Florida Portland Cement Division, are 426 feet long. The capacity of the Tampa plant has been increased from 1,500,000 barrels at the end of World War II to 4,000,000 barrels annually as of January 1955. The Bunnell plant was completed in December 1952, at a designed capacity of 1,400,000 barrels. A plant expansion program, completed in 1956, increased the annual capacity to 2,500,000 barrels. Although the actual production data from these plants are not available, the demand for cement in Florida is much greater than the combined capacity of the plants. The quantity of portland cement sold and used in the State increased from two million barrels in 1945 to nearly nine million barrels in 1955. It is also reported that 2,500,000 barrels of cement were shipped to Florida from Puerto Rico, and 900,000 barrels from Europe during 1955.

The great strength of concrete masonry structures is illustrated by their remarkable resistance to windstorms. One of the most severe storms ever experienced in this country is believed to have been the 1926 Florida hurricane. Wind velocities soared as high as 125 m.p.h. and in some areas rainfall amounted to 15 inches during the 16 hours of the storm. The City of Coral Gables, then the only city in the United States restricted by law to concrete construction, was in the direct path of the hurricane. Some 2,500 residences, apartments, and other buildings, all of concrete masonry construction, survived with only slight damage. There was not a single instance of total destruction. The inherent strength of concrete masonry construction is desirable in any structure and that type of building predominates throughout Florida. A property owner may prefer to build principally with wood or brick rather than with concrete block or poured concrete, but almost without exception, every structure uses a certain quantity of cement in foundation, basement, mortars, floor or roof. The choice of principal structural material is governed by many factors including cost, personal preference, and building code specifications.

Significant trends in the use of portland cement include the prestressing of concrete to impart sufficient strength in order that concrete beams and girders may be substituted for structural steel; the use of lightweight concretes to save structural steel, and the development of tilt-up construction of houses and small-sized commercial buildings. Information concerning these and other uses may be obtained from the Portland Cement Association, 33 West Grant Avenue, Chicago 10, Illinois, or their district office in Orlando, Florida.

The raw materials that are used by the General Portland Cement Company, Florida Division, Tampa, and produced by that company in the State are limestone and clay. Huge quarries for limestone are situated in Hernando County, near Gay, and in Citrus County, a few miles southwest of Floral City. Clay is obtained from a pit located in the southern portion of Citrus County. The raw materials produced in Florida that are used in the manufacture of portland cement at the Bunnell plant of the Lehigh Portland Cement Company are coquina and staurolite. The coquina is dredged from a quarry located adjacent to the plant and it consists of shell and sand of the Anastasia formation. The shell is separated from the sand and a portion of the latter is recombined with the shell in order to produce the correct proportion of calcium and silica. The mineral staurolite, a by-product of the Trail Ridge heavy mineral separation plant, is used to supply the alumina and a portion of the iron that is required by the cement formula. The elevation of the staurolite to the rank of an industrial mineral was accomplished by its utilization in portland cement manufacture at the Bunnell plant of the Lehigh Portland Cement Company.

Portland cement is usually packed in 94-pound paper bags, which is equivalent to one cubic foot. The unit of measure in reporting cement production is the 376-pound barrel which is equivalent to four 94-pound bags. The average value of portland cement in the United States rose from \$1.46 per barrel in 1940 to \$2.35 per barrel in 1950, to \$2.86 per barrel in 1955. The average value of the Florida product is somewhat higher than that of the national average.

The cost of construction of portland cement plants ranges between \$7 and \$10 per annual barrel of capacity, with a minimum economic capacity of about 600,000 barrels per year. The high initial cost of a new plant has discouraged investment of capital by sources not already concerned with cement production. During 1956, both of the producing companies in Florida announced plans to construct new portland cement plants to be located a few miles west of Miami. The General Portland Cement Company will have a capacity of 2,500,000 barrels annually and is scheduled to begin operations late in 1957 or early in 1958. The Lehigh plant will have a capacity of 2 million barrels.

CLAY

GENERAL STATEMENT AND CLASSIFICATION

Clays are hydrous aluminum silicates mixed with varying proportions of impurities. These silicates occur in many mineral forms, each of which has distinctive properties that give rise to the suitability of the different clays to particular industrial uses. The principal industrial clays are kaolin or china clay, ball clay, fire clay, bentonite, fuller's earth, and miscellaneous or "common" clays. About three-quarters of all the clay that is produced enters into the manufacture of ceramic products. Kaolin is used for whitewares, cement, fillers, and other applications. Ball clays and fire clays are used by the ceramic industry. Bentonite and fuller's earth are used for clarifying and cracking petroleum products, foundry facings, drilling muds, insecticide carriers and other non-ceramic purposes. Miscellaneous clays include those materials generally referred to as common clays and are used for manufacturing heavy clay products such as brick and tile and portland cement.

The different types of clay have distinctive properties; nevertheless, these properties show considerable variation within the same type. Significant properties of clays that are used for ceramic purposes include plasticity, dry and fired color, dry and fired strength, dry and fired shrinkage (or expansion), fired apparent porosity, density, softening point on firing, vitrification range, bloating, adsorption, and particle size and shape. Significant properties for nonceramic uses vary with use and include texture, freedom from grit, color, relative decolorizing ability and oil retention. No two clays are exactly alike and it is seldom possible to substitute one clay for another without extensive experimentation. Most ceramic bodies contain several clays and any change in composition results in uncertain firing behavior. For this reason, ceramic raw materials are usually produced for long periods of time and ample reserves are required before development and production can begin.

Each clay possesses a number of characteristics that are more or less common to other clays, even though their physical and chemical compositions may have wide variations. For most purposes, the chemical composition is of little importance and chemical analyses serve only to indicate further investigation for a specific purpose or composition. The cost of such analyses may exceed that of a simple ceramic test which might be more meaningful to a competent clay technologist. In spite of the great advances that

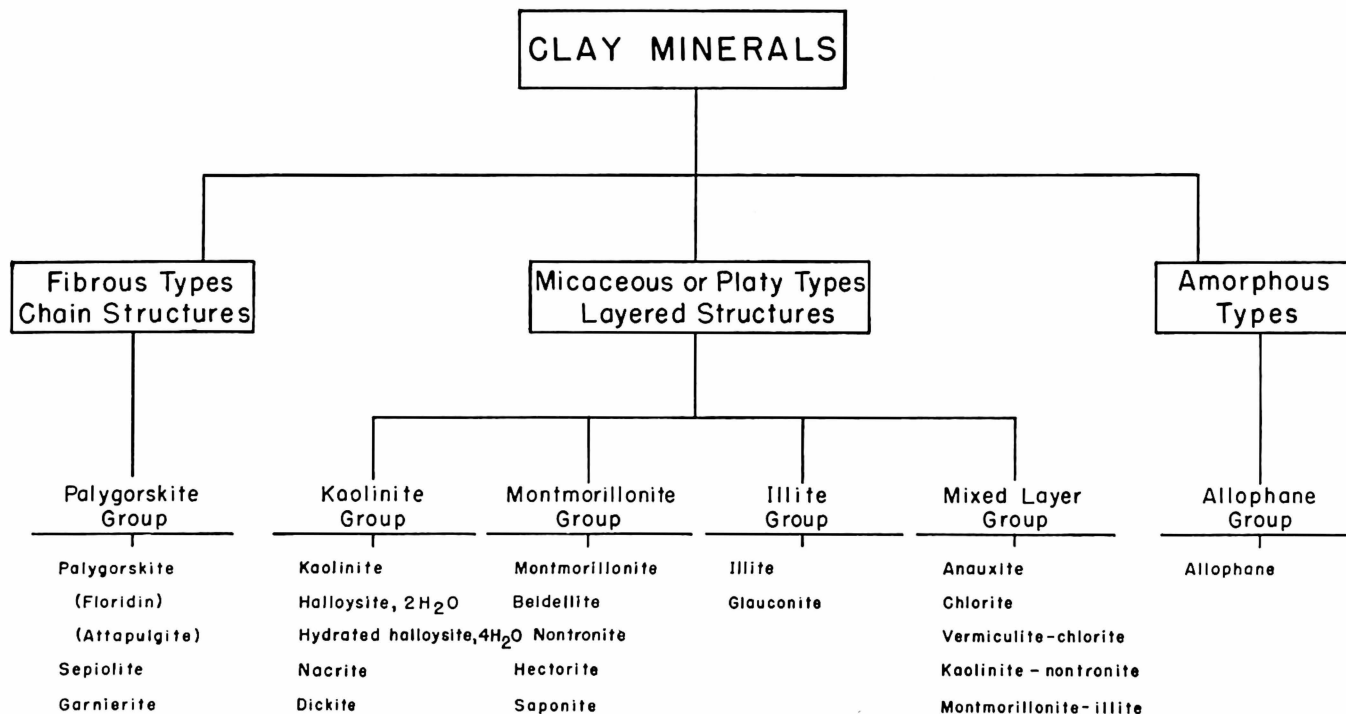
have been made during recent years in the field of ceramics and clay technology, many of the significant properties of clay are still evaluated by rule-of-thumb methods.

The crystallographic structure and chemical composition of clay minerals have undergone extensive investigations during the past 15 years and new mineralogic classifications have been made. Clay minerals fall into three main structural categories. Most of the clay minerals fall into the layer-silicate types composed of micaceous or platy structures. This type is further subdivided into groups according to the characteristics of the layered structure. With reference to figure 18, it may be seen that the clay minerals having layered structures fall into the kaolinite group, the montmorillonite group, the illite group and the mixed layer group. The clay minerals of the chain-silicate type have fibrous structures and are classified in the palygorskite group. Clay minerals that have an amorphous silicate structure are classified in the allophane group.

KAOLIN

Kaolin, or china clay, is a mixture of clays that has the mineral kaolinite as an important part of its composition. Kaolins are not uniform in physical properties but their chemical composition ranges within narrow limits and good grades contain 37 to 40 percent alumina, 45 to 55 percent silica, 8 to 15 percent ignition loss, and minor amounts of ferric oxide, titania, alkaline earth oxides and alkali oxides. Whiteness, both in the dry and fired condition, is an important property in kaolins used in paper fillers and whiteware and this property requires a low content of iron compounds. Most kaolins have low plasticity, low dry and fired strength, low drying and firing shrinkage and high fired porosity. The notable exception to these characteristic properties is the well-known plastic kaolin of Florida that is produced in Putnam County by the Edgar Plastic Kaolin Company and the United Clay Mines Corporation. This material has physical properties that are intermediate between the ball clays and the more typical kaolins.

The commercial deposits of kaolin in Putnam County consist of a mixture of sand and clay with the clay content averaging about 18 percent of the material that is mined. This kaolin mixture is beneficiated by removal of impurities, principally quartz grains and minor amounts of mica, feldspar, and heavy minerals, through a series of disintegrating, washing, screening, classification, thickening, filtering and drying operations. Disintegration by hammer mills and air classification to produce dry pulverized material of specified particle size complete the milling process.



After Grim, 1953
Mielenz and King, 1955

Figure 18
Classification of clay minerals.

The uses for kaolin may be divided into four general classifications: fillers, whiteware, refractories, and cement. For paper filler, the physical properties of grit, color, particle size, and retention determine its suitability. For rubber, where kaolin competes with carbon black and zinc oxide, desirable properties include uniformity, purity, fineness of particle size, absorption and dispersion characteristics. For oil cloth and linoleum filler, kaolins should be white, free of grit, and should slake readily to a smooth cream or slip and have low oil absorption. For paint where kaolin is used as a pigment as well as an extender, fineness of grain size and freedom from grit are essential but the only reliable evaluation test for its use in paint is the endurance of the paint that extends over a period of years. Kaolins find use as fillers in a number of other products, textiles and window shades, calcimine, crayons, toilet and tooth powders, soaps, polishing compounds and matches. Tests and specifications for these uses have not been established.

Whiteware is a clay product manufactured from a combination of white burning kaolin and ball clay, feldspar, ground silica or flint, and other ingredients. The kaolin content of various whiteware bodies ranges from 10 to 50 percent of the dry weight of the ingredients and averages about 25 percent. The ball clay content ranges from 10 to 30 percent; feldspar from 5 to 40 percent; and flint up to 40 percent. To replace the feldspar, both nepheline syenite and talc are used as substitutes. The chief types of whiteware include pottery, tableware, electrical porcelain, floor and wall tile, and sanitary ware.

The quantity of kaolin used in the manufacture of refractories has increased during recent years and this trend probably will continue because new supplies of high grade fire clays are not being found. The refractories made from the kaolins of the Coastal Plain of Georgia, South Carolina and Florida have not been fully evaluated but for some uses they are comparable with the refractory brick made in Missouri and Pennsylvania. Because the specifications for kaolin used for refractory raw materials are not as exacting as those for some ceramic uses and because there is an increasing demand for firebrick, the utilization of the kaolins of Florida for this purpose may be considered for the establishment of a new industry in the State.

Stoneware clays of Jackson, Washington, and other counties in West Florida are suitable for use as fire clays and are capable of withstanding temperatures above 2,900°F. The clays found in the Chipley area that fire to a light buff or cream color were



Figure 19

Dredge of the Edgar Plastic Kaolin Company pit, Edgar, Putnam County. The overburden is removed by pan scrapers and the clay-sand strata are recovered by suction dredge.

formerly produced and utilized without beneficiation to make brick. This product was used for common brick although the p.c.e. (pyrometric cone equivalent) was 33. Besides having a high p.c.e., refractory brick must withstand rigid thermal spalling and high-temperature load tests. Super-duty brick has a p.c.e. of 34 or higher; high-heat duty refractories 32-33, while intermediate-duty refractories have a p.c.e. of 31-32. In the cooler portions of industrial furnaces low-duty refractories that have a p.c.e. of 29 give excellent service.

BENTONITE

The original material that was named bentonite is a greenish-yellow plastic clay found in the Black Hills area of Wyoming and South Dakota. The name implies neither an exact mineralogical composition nor definite physical or chemical properties. Clays found in other localities that had some of the characteristics of the original bentonite were called bentonite and in this way the group of clays that consist chiefly of montmorillonite or beidellite or mixtures of these materials (see fig. 18) became known as bentonite. Two main types are distinguished by physical properties: (1) the swelling variety absorbs large quantities of water, up to

5 times its weight or 15 times its volume and remains in suspension when dispersed in water; (2) the nonswelling variety that absorbs only a moderate amount of water, and settles rapidly from water dispersions. The swelling bentonites characteristically have sodium as an exchangeable base, while the nonswelling varieties have calcium. The sodium bentonites are preferred for drilling muds and the calcium bentonites are used in oil refining. Both varieties find use as the bond in manufactured molding sands.

The suitability of bentonites for commercial uses depends upon physical characteristics and chemical analyses are of little value. The calcium bentonites that are produced chiefly in Mississippi are highly adsorbent when activated with acids and compete with fuller's earth in the oil refining industry. Several bentonite localities are known in West Florida, particularly in Jackson County, but deposits of sufficient tonnage to warrant commercial development have not been found and are not indicated.

FULLER'S EARTH

General properties: Fuller's earth is an inexact term applied to certain clays that have a marked ability to adsorb coloring materials from oils of animal, vegetable and mineral origin. Many clays have this adsorbing power to a slight or very limited degree and certain other clays, chiefly bentonites, as well as other minerals, such as bauxite, can be made highly adsorbent by activation with acids or alkalies, but the term fuller's earth is generally reserved for clays that are naturally highly adsorptive. In most fuller's earths and practically all activable clays, montmorillonite is a dominant mineral. No definite clay mineral or group is implied in the name fuller's earth and the distinction between fuller's earth and other clays that have more or less bleaching power is not sharply drawn. The name as generally used has no generic or mineralogical significance. The fuller's earth that is produced in the Florida-Georgia district contains the clay mineral palygorskite ("floridin" or "attapulgitite"). The name "attapulgitite" was first used (Grim 1942) in 1935 by DeLapparent to apply to a hydrous aluminum magnesium silicate found in the fuller's earth from Attapulgius, Georgia, and Quincy, Florida, even though this material had been called "floridin" since 1910. An essential component of its structure, determined by Bradley in 1940, is that the silica chains of the molecule are arranged similar to those of the amphibole minerals. The fibrous nature of the lath-like crystals of "attapulgitite" is apparent under magnifications reached by the electron microscope. The ideal formula, $[(OH_2)_4(OH)_2Mg_3Si_5O_{20} \cdot 4H_2O]$,

contains no aluminum but there is considerable replacement of the magnesium by aluminum. Buehrer (1955) has shown by X-ray diffraction analysis that the main clay mineral in the deposits of "attapulgitite" in the Florida-Georgia fuller's earth district is palygorskite, a valid mineral name of long standing. Palygorskite has a very similar, if not identical chemical composition and X-ray diffraction pattern to attapulgitite, consequently the name "palygorskite" has precedence over "attapulgitite."

In most fuller's earths and bentonites, the clay mineral montmorillonite is the dominant constituent. The fuller's earth produced in the Florida-Georgia district contains as an essential constituent palygorskite ("floridin" or "attapulgitite"), the physical and chemical properties of which produce a fuller's earth that has many superior properties.

The use of fuller's earth for its adsorbent properties dates from ancient times and the clay-like earthy substance obtained its name because the clay was used by fullers to full, or remove, grease and fat from woolen cloth. The first discovery in the United States of clay suitable for fuller's earth was made at Quincy, Florida, in 1893, where the earth has been produced commercially since 1895. Extensive deposits of the clay occur in Gadsden County, Florida, and in Decatur County, Georgia, where mining began in 1907. Since 1896, the details of mining and production have appeared annually in publications of the U. S. Geological Survey and the U. S. Bureau of Mines. From these reports, it may be seen that for many years the United States has been the world's leading producer and consumer of fuller's earth. Domestic production increased steadily to a peak of over 335,000 tons in 1930, almost parallel to the increase in petroleum production. During the next decade, the industry experienced a sharp decline in production to a low of about 146,000 tons in 1940. This decline is attributed to changes in petroleum refining methods, increased use of colored gasolines and the substitution of activated bentonites, activated bauxite, and synthetic magnesium silicate in the mineral oil bleaching industry.

With reference to table 6, which shows the annual production of fuller's earth in the Florida-Georgia district and in the United States for the years 1940 to 1955 inclusive, it may be seen that the combined output from Florida and Georgia constituted in 1940, about 54 percent of the quantity and 62 percent of the value of the total United States production; in 1955 these states produced 67 percent of the quantity and 78 percent of the value of the fuller's earth production.

Table 6

Production and Value of Fuller's Earth 1940-1955

Year	Florida-Georgia		U. S. Total	
	Short Tons	Value	Short Tons	Value
1940	79,898	\$ 917,365	146,568	\$1,471,083
1941	91,925	1,075,318	207,446	2,111,674
1942	83,007	1,091,062	204,244	2,139,670
1943	105,647	1,444,936	271,667	2,664,027
1944	128,654	1,833,682	294,737	3,297,064
1945	134,401	1,939,035	296,368	3,463,913
1946	144,214	2,100,652	298,752	3,702,993
1947	168,557	2,699,660	329,068	4,660,614
1948	188,014	3,224,169	342,081	5,273,851
1949	181,933	3,194,551	320,906	5,199,642
1950	247,390	4,273,890	396,025	6,504,733
1951	299,071	5,258,330	483,623	8,131,761
1952	270,261	4,829,552	422,853	6,875,483
1953	271,187	5,093,501	435,837	7,614,759
1954	263,571	5,244,591	376,321	6,861,603
1955	Est. 250,000	Est. 5,980,000	369,719	7,620,319

Data—U.S. Bureau of Mines

In recent years, all of the Florida production has come from mines located in Gadsden County, but fuller's earth was formerly mined in Marion and Manatee counties. The abandoned pits in sec. 34, T. 13 S., R. 20 E., Marion County, and sec. 10, T. 34 S., R. 18 E., Manatee County, mark the sites of these operations. The clay mineral found at the Marion County locality is montmorillonite while the clay minerals found at the Manatee County locality consist of a mixture of montmorillonite and palygorskite ("floridin" or "attapulgitite"). Recent studies of the clay mineral composition of the sediments in the land-pebble phosphate district have reported palygorskite ("attapulgitite") as a component of the overburden and of the matrix. The Florida-Georgia fuller's earth district includes portions of Gadsden County, Florida, and Decatur and Grady counties, Georgia, and the locations of active mines and plants are shown on the sketch map, figure 20.

Florida-Georgia District: Exposed at the surface throughout the district, the Hawthorn formation is nearly horizontal and attains a thickness in excess of 200 feet. The City of Quincy water well penetrated 210 feet of sediment assigned to this formation. There are both continental and marine fossils above and below the fuller's earth beds, indicating that the sediments were laid down during a transitional period, probably in shallow fresh water along a sea coast. Throughout the district, the Hawthorn formation contains lenses of fuller's earth and of dolomitic limestone but, for the most

part, consists of poorly sorted, coarse to fine-grained argillaceous sands. In a typical section as exposed in the mines, there are two beds of fuller's earth, each two to eight feet thick, separated by a bed of gray, clayey sand, which is usually less than five feet in thickness. The sandy stratum between the fuller's earth beds yields manatee and other vertebrate fossils, as well as Pectens, oysters and fossil wood.

The overlying sandy clays that make up the remaining portion of the section generally contain lumps and pebbles of fuller's earth in the base and grade upward into a brown quartz soil zone at the top. In some areas, the upper clay bed is too thin to be mined or lenses of sand may be present in it. Under such conditions, the clay is removed with the overburden.

Mining practice consists of removal of overburden by dragline, bulldozer, or pan scrapers, depending on the depth of the overburden and the distance that it must be moved. The clay bed is carefully cleaned and the dragline loads the clay on trucks for removal to the processing plants. Very little blasting is necessary in the removal of the overburden but the clayey sand layer between the beds of fuller's earth may require blasting to loosen it sufficiently for removal by the dragline.

Preparation: In the preparation of fuller's earth for market, three processing treatments are utilized to control the properties of fuller's earth; these are extrusion, drying, and milling. The crude fuller's earth is crushed, kneaded with water in a pug mill, and then fed through an auger-type extruder in which the plastic earth is forced through openings of about three-quarters of an inch in diameter to form rods of fuller's earth. In this extrusion process, laminations in the earth are disrupted, the apparent density of the material is lowered, and both the porosity and the decolorizing capacity of the product are increased considerably. The drying temperatures have a marked effect on the characteristics of plasticity, dehydrating capacity, and decolorizing capacity. For the colloidal product used as drilling mud, it is necessary to dry the clay at relatively low temperatures (below 250° F) in order that the earth will disperse readily in water; in order to develop the maximum absorptive capacity, a higher drying temperature is required. Absorbent grades of fuller's earth for use on floors are dried at temperatures above 700° F to prevent the product from "mudding up" in water. The milling process consists of a series of crushing, grinding and sifting operations to produce granules and powders. The grades produced range from granules of 16 to 30 mesh to powders 90 to 95 percent finer than 325 mesh.

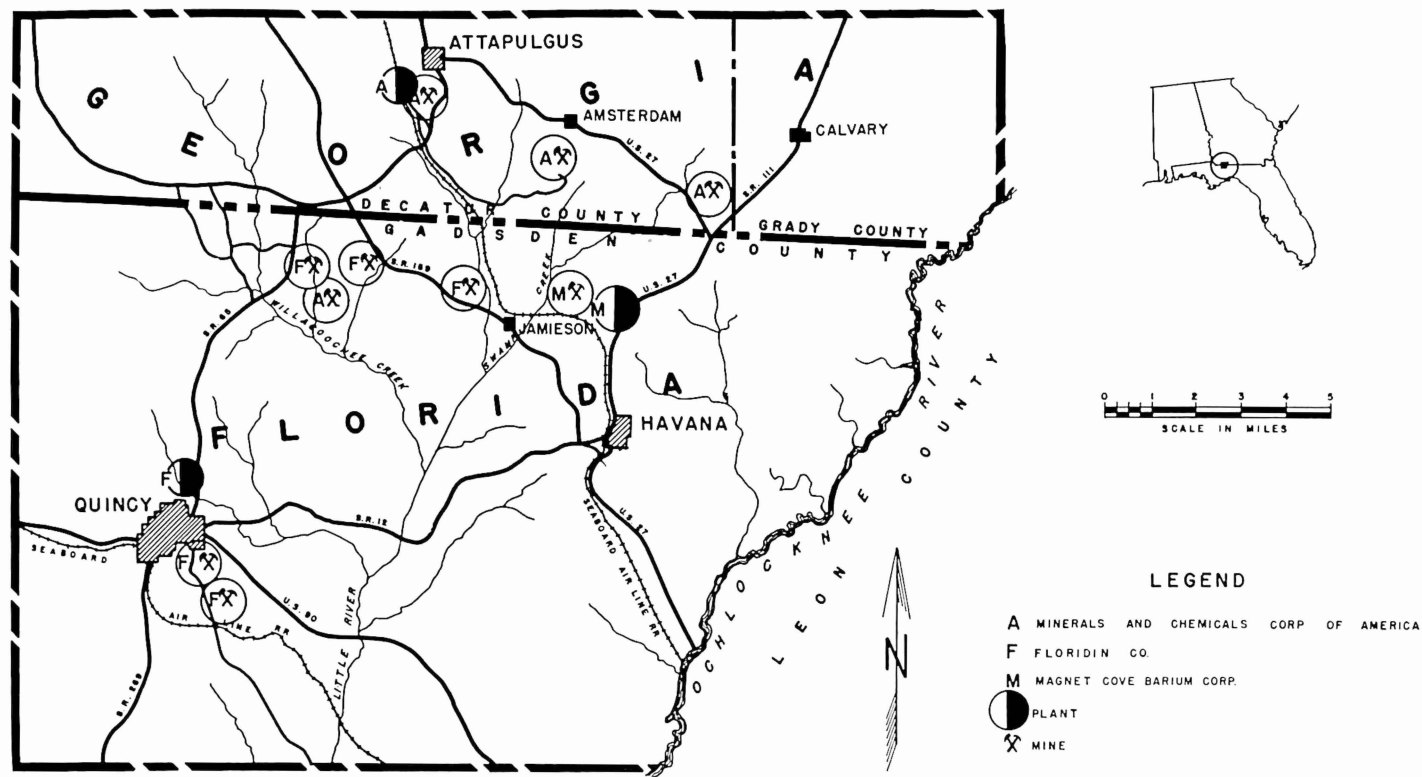


Figure 20

Location of the principal mines and plants in the Florida-Georgia fuller's earth district.



Figure 21

The Floridin Company's Frank Smith No. 2 mine showing the dragline with a $1\frac{1}{2}$ -yard bucket used to remove overburden from the clay bed. The area to the right has been leveled by pan scrapers.

Uses: Decolorizing and refining mineral oil and vegetable oil were formerly the main uses for fuller's earth, and as late as 1943 more than 87 percent of the production was consumed in these uses. For many years, fuller's earth has been on the market for use in rotary drilling muds, but advances made in well drilling techniques in 1943 and 1944 resulted in increased tonnages to be used by the petroleum exploration industry. In 1955, 13 percent of the production was sold for drilling mud. Beginning in 1943, granular grades of fuller's earth were first marketed for absorbent use and this product was an immediate success. This cleaning agent finds use in service stations, factories, machine shops, bakeries, and other establishments where oil and grease spills are likely to occur. Measured in terms of tonnage consumed annually, these absorbent uses have become the most important market for fuller's earth and in 1955, 37 percent of the production was consumed in these uses. In 1946, the large adsorption capacity of pulverized fuller's earth was utilized in processing the newer organic insecticides and it has become an important carrier of insecticides and fungicides. In 1955, these uses ranked second in terms of tonnage and accounted for 25 percent of the production. The quantity of fuller's



Figure 22

Chesebrough mine of the Floridin Company, located south of Quincy, Florida, showing dragline with 3-yard bucket and 90-foot boom used to remove 40 feet of overburden and to load trucks. In the portion of the mine under development, the clay bed reaches a thickness of 16 feet.

earth that was utilized in filtering and decolorizing mineral oils and vegetable oils decreased to 16 percent of the 1955 production.

MISCELLANEOUS CLAYS

Miscellaneous clays include those that are frequently designated as surface clays or common clays and the clay products companies that utilize them usually mine and process them. Products that are made from common clays include building bricks, sewer pipe and roofing tile, as well as lightweight aggregate and portland cement. Throughout the country, production of common brick, hollow tile and roofing tile has not kept pace with industrial growth. Utilization of Florida clays for these materials has decreased and no modern clay brick plants are located in the State. Locality and firing test data on a number of clay deposits are included in Florida Geological Survey Information Circular No. 2, and in Florida Geological Survey Fifteenth Annual Report.

The only clay that is utilized as an ingredient of portland cement is mined in Citrus County by the General Portland Cement Company, Florida Portland Cement Division. For this purpose,

no special requirements are necessary but the clay must provide the alumina and silica for the cement formula.

Clays that are suitable for lightweight aggregate production must be naturally bloating clays or must have ingredients added to them before processing to produce bloating. At the present time, no lightweight aggregate manufacturing plant that utilizes Florida clay is located in the State. A plant near Ellenton, Manatee County, formerly produced aggregate from a clay which had previously been used to manufacture fuller's earth. This plant, abandoned and dismantled soon after World War II, produced the aggregate called "nodulite" which was used in the manufacture of concrete ships and barges at Tampa. During recent years, the U. S. Bureau of Mines, working in cooperation with the Florida Geological Survey and others, have conducted a search to find suitable material in Florida for making lightweight aggregate. Tests have been conducted on the washery slimes produced in the processing of land-pebble phosphate. While an acceptable aggregate was made, the cost of drying the slimes was so great that commercial utilization was prohibitive. Tests thus far conducted on clays from localities throughout the northern portion of the State have failed to indicate a natural bloating clay that is suitable for aggregate manufacture.

DIATOMITE

Diatomite or diatomaceous earth is a valuable earthy material that is composed of minute particles of opaline silica, the fossil remains of microscopic aquatic plants related to algae. This material is essentially hydrous amorphous silica and pure varieties are chalk-like in appearance, light in weight, porous and friable. When pure and dry, its apparent density is less than one so that it will float on water until saturation overcomes its bouyancy. More than 10,000 varieties of diatoms have been classified and these occur in every conceivable shape.

The acceptance of diatomite by consumers depends on the physical structure, size, shape, and purity of the material. The 1954 output was utilized in the following ways: 51 percent in filtration of sugar, beverages, water, pharmaceuticals, oils and other liquids; 29 percent as a filler in rubber, paper, asphalt, plastics, explosives, insecticides, paints and other products; 8 percent in the manufacture of insulation, and 3 percent in abrasives. Miscellaneous uses such as absorbents, catalyst carriers, as pozzolanic material in concrete, and in ceramics. In recent years,

diatomite produced in the United States exceeded 300,000 short tons per year, valued at the mines at nearly \$10,000,000.

Uniformity in grade and high quality standards are maintained in the industry, except when the diatomite is supplied from local sources or for such purposes as concrete admixture. In 1954, California led all states in production, followed by New Mexico, Nevada, Oregon, Washington and Arizona. Diatomite occurs in three types of deposits: (1) ancient marine beds, such as the California deposits that cover several square miles and are 700 feet thick in places; (2) deposits adjacent to rivers and lakes that contain fresh-water diatoms; and (3) deposits in lakes and swamps where deposition and accumulation is still going on. Deposits of the second and third types are found in Florida and these contain more or less organic matter in the form of muck and peat. From such wet, bog-type deposits, recovery by dredges, pumps or dragline would be required and preparation would include dewatering by draining or pressing, drying on racks or in kilns, calcining, grinding and air classification. For nearly all uses freedom from impurity is important and in filtration uses the type, size, shape of the diatoms as well as the absence of broken and very small specimens are important factors that influence the rate of flow and clarity of the filtrate. Careful grading of the diatoms to produce a uniform product that consists of the most advantageous shapes and sizes is necessary to obtain a superior filter aid.

Diatomite has many industrial applications and products that are filtered with the aid of diatomite include acids and chemicals, polluted waters, petroleum compounds, varnishes, shellacs, waxes, resins, gum solutions, sugar solutions, vegetable oils, animal fats, gelatins and many others. As a mineral filler, diatomite adds bulk strength, absorptiveness and other desirable physical properties to asphalt products, rubber, and paper products, plastics, insecticides, explosives and other chemicals. As an insulating material, diatomite is used in industrial furnaces and kilns for heat and in building construction for both heat and sound insulation. Diatomite is used as an abrasive, as a support and carrier for catalysts in chemical processes, as a source of silica in ceramic bodies and glazes and in the manufacture of "water glass," or sodium silicate. Its characteristic to absorb up to 200 percent of its weight of water is made use of in desiccants and absorbents.

The problem of utilizing the relatively small deposits that exist in Florida, and in other eastern states, continues to attract the attention of possible producers because the largest markets are

located in the eastern states, the huge reserves of easily mined and processed diatomite that exist in the Pacific Coast states, and Nevada, are more than ample to supply the anticipated expanding needs for diatomite. It is possible, however, that some of the deposits of Florida, particularly those in Polk County, could be produced commercially as a by-product. In part of the land-pebble phosphate district, diatomaceous muck and peat occur in the overburden above the phosphate ore bed. The economics of producing diatomite from this material that would otherwise be removed and discarded as overburden is under study by at least one of the major phosphate producers.

A review of the diatomaceous earth localities in Florida is included in Florida Geological Survey Bulletin No. 30, *The Peat Deposits of Florida*.

LIME

Lime is a calcium oxide (CaO), or the combined oxides of calcium and magnesium (Ca-MgO) and does not occur in nature. It is a product manufactured from limestone (CaCO_3) or dolomite [$\text{CaMg}(\text{CO}_3)_2$] by the process of calcination, in which carbon dioxide (CO_2) is driven off at moderately high temperatures. For most uses, high calcium and dolomitic limes are interchangeable. Lime has numerous uses and the principal groups of uses include: (1) industrial and chemical applications, such as metallurgy, alkalis (ammonium, potassium, and sodium compounds), paper mills, calcium carbide and cyanamide, water purification and glass; (2) building materials such as finishing lime and mason's lime and mortar; (3) agricultural lime for soil improvement, and (4) refractory lime, or dead-burned dolomite, is calcined at high temperatures to produce a product that has a high melting point and is suitable for furnace linings. Within the lime industry in the United States, there is a long and continued trend toward fewer and larger plants. The number of lime plants has decreased from 1,073 in 1910, to 336 in 1930, to 154 in 1954, when more than 60 percent of the total output was produced by 26 plants. Approximately six percent of the annual production of limestone and dolomite is consumed by the lime manufacturing industry.

The only commercial lime producer in Florida is the Dixie Lime Products Company, located at Reddick, Marion County. That company has nine shaft kilns and one hydrator and produces high calcium quicklime and hydrated lime. Both wood and fuel oil are utilized to burn the limestone and the capacity of the plant is

approximately 12,000 tons of quicklime annually. The only other lime producer in Florida is the by-product production from the Hialeah water softening plant that is operated by the City of Miami. In this water treatment plant, the calcium carbonate that is removed from the water is recalcined in an oil fired rotary kiln to produce quicklime. Between 10 and 15 percent more quicklime is produced than is utilized in the water treatment process and this excess is sold to other municipal water treatment plants in Florida. The rotary kiln in use has an annual capacity of about 26,000 tons of quicklime.

The apparent consumption of lime in Florida as reported by the U. S. Bureau of Mines indicates that the State is deficient in lime production and that considerable quantities are purchased from other states. During recent years, data on the production of lime within the State have not been made available for publication, nevertheless, the capacity of the existing plants is about one-third the tonnage of lime that is consumed within the State, see table 7. Because there are considerable variations in the physical and chemical properties of limes, specifications for a particular use or industry may require shipments from distant points. Not only do the physical and chemical characteristics of the limestone but also the rate of heating, the temperature, and other kiln factors influence the properties of the finished product.

Table 7
Apparent Consumption of Lime (Both Quicklime and Hydrated Lime) Sold or Used in Florida

Year	Quantity Short Tons
1945	67,586
1946	77,103
1947	80,070
1948	103,853
1949	100,427
1950	99,559
1951	107,005
1952	117,180
1953	139,720

Because fragmentation of the limestone in the quarrying process produces small sizes of rock that are not suitable for kiln feed, most lime companies also produce agricultural limestone and crushed stone for concrete aggregate. By use of modern shaft kilns, not more than three-quarters of the rock that is quarried is suitable for loading into the kilns. In order to manufacture 100 tons of lime per day, it would be necessary to quarry about 250

tons of rock and the disposal of the finer sizes of rock becomes an important factor in the success of the operation. The rotary kiln makes possible the utilization of finer materials but the cost of such equipment is considerably more. The design of calciners of the vertical type has undergone changes in recent years to allow use of smaller sizes of rock. The recovery and utilization of the carbon dioxide gas that is driven off in the calcining process is a serious problem in the industry because nearly one-half the weight of the kiln feed is lost as this gas is dissipated into the air.

By far the largest quantity of lime enters chemical and industrial processes and new lime plants may be expected in Florida with the establishment of new lime-consuming industries. The leading volume consuming uses of lime include metallurgical applications as a flux in steel manufacture, in nonferrous smelting, and in ore concentration; in the manufacture of alkalies (ammonium, potassium, and sodium compounds); in paper mills; water purification; in calcium carbide and cyanamide manufacture; in glassworks, and in sewage and industrial waste treatment.

FLUORINE

The element fluorine occurs in minute quantities in a large number of rocks and minerals but large quantities of the element are found in only two commercial minerals, fluorite and cryolite, both of which are distinctly uncommon. A small area located along the Ohio River in southern Illinois and western Kentucky processes about 80 percent of the fluorite while several smaller deposits in Colorado, New Mexico, and other western states contribute to the quantity mined. In the United States, fluorite, or fluorspar, is the only fluorine mineral of commercial importance; and the only other fluorine mineral of commerce, cryolite, is obtained from only one locality situated in Greenland. In recent years, the domestic production of fluorite amounted to about two-thirds of the quantity used in this country but current trends indicate imports will increase to supply over one-half the quantity used by United States industry by 1965. Fluorine compounds are used in the production of aluminum, high-octane gasoline, Freon refrigerants, and in the manufacture of steel, glass, and enamels.

The reserves of fluorine contained in the fluorapatite, the mineral that constitutes the bulk of the collophane or phosphate rock produced in the land-pebble field of Polk and Hillsborough counties, are very large. Phosphate rock contains 1 to 3 percent fluorine which may be recovered as a by-product in the manufacture of

superphosphate fertilizer. This by-product is not limited to plants located in Florida, and is produced wherever superphosphate plants are located. The Bureau of Mines reports show that in 1955, there were 19 plants reporting production of fluorine by-products. Only two of these were located in Florida. In the acidulation process for fertilizer manufacture, phosphate rock is treated with sulfuric acid and about one-half of the fluorine is evolved as a toxic gaseous mixture which may be captured in water absorption towers or in a bed of lump limestone. A large potential source of fluorine chemicals exists in the phosphate industry, although recovery of this material is practiced only to a small extent at the present time. The development of competitive methods for the recovery of fluorine compounds from phosphate rock not only will relieve a possible shortage of fluorite but also will provide a market for a toxic gas that has caused much concern to the phosphate industry. New techniques to improve the present methods for defluorination of phosphate rock and to produce fluorine by-products that have industrial value are actively being sought by the research programs conducted by the industry.

GYPSUM

Measured by production and sale of gypsum products, the gypsum industry is one of the most important in the nonmetallic field. Although the United States has huge reserves of gypsum, considerable tonnages of crude ore are imported for use in consuming areas that are situated in the Atlantic coastal states. Much of the raw gypsum that is consumed in Florida by the gypsum products plant at Jacksonville and by the portland cement plants, is imported from Nova Scotia.

Gypsum (hydrous calcium sulfate) is a common mineral and the large or most important deposits of the material are believed to have been formed by the evaporation of sea water. Many gypsum beds were originally deposited as anhydrite (anhydrous calcium sulfate) which was changed to gypsum in alteration processes associated with weathering. The minor occurrences of gypsum in Florida, particularly the clear or slightly stained crystals, are associated with the sulfur waters which have encountered shell or limestone fragments. Several gypsum localities are known in Florida but none has enough indicated tonnage to be worked. The earliest report of gypsum in the State was published in 1899 in the U. S. Geological Survey's Twentieth Annual Report (U.S.G.S. 20th Ann. Rept., part 6, cont. p. 662-663, 1899) and records a

gypsite deposit in the E $\frac{1}{2}$, sec. 23, T. 20 S., R. 21 E., Sumter County. This material was described as a clay-like substance that hardens upon exposure to air; and that the surface deposits occurred as hummocks from three to six feet high. Gypsum crystals are found in the alluvium of the St. Johns River valley, and at the locality three miles east of Christmas, Orange County, where scattered gypsum crystals up to three-quarters of an inch in length are present at a depth of four feet. Scattered crystals of gypsum have also been obtained from the St. Johns River valley at Sanford, Seminole County.

In addition to natural gypsum, a calcium sulfate waste product is obtained in the preparation of superphosphate fertilizer. This "gypsum" could be recovered, however, from a commercial point of view; the quantity of such material is rather small. The possibility of a by-product use for this "gypsum" presents an interesting problem in industrial chemistry for its conversion into ammonium sulfate fertilizer, or some other industrial chemical.

RADIOACTIVITY SURVEYS

Airborne radioactivity surveys have been made in Florida by the U. S. Geological Survey during their investigations of the uranium and thorium content of the surface formations of the State. These investigations were carried out at the request of the Division of Raw Materials, Atomic Energy Commission. The areas of the State that were covered by these surveys are shown on figure 23, and the index numbers shown on the map correspond to the following government publications:

REPORTS CONTAINING RADIOACTIVITY DATA FOR AREAS IN FLORIDA

(Refer to numbered localities on figure 23)

Index
No.

1. Moxham, R. M., and Johnson, R. W., *Airborne Radioactivity Survey of Parts of the Atlantic Ocean Beach, Virginia to Florida*, U. S. G. S., Trace Elements Memorandum Report 644, June 1953.
2. Meuschke, J. L., Moxham, R. M., and Bortner, T. E., *Airborne Radioactivity Survey of the Gulf of Mexico Beach between Sanibel Island and Caladesi Island, Florida*, U. S. G. S., Trace Elements Memorandum Report 678, November 1953.
3. Moxham, R. M., *Airborne Radioactivity Surveys for Phosphate in Florida*, U. S. G. S., Trace Elements Investigations Report 387, August 1953.
Moxham, R. M., *Airborne Radioactivity Surveys for Phosphate in Florida*, U. S. G. S., Geological Circular 230, 1954.

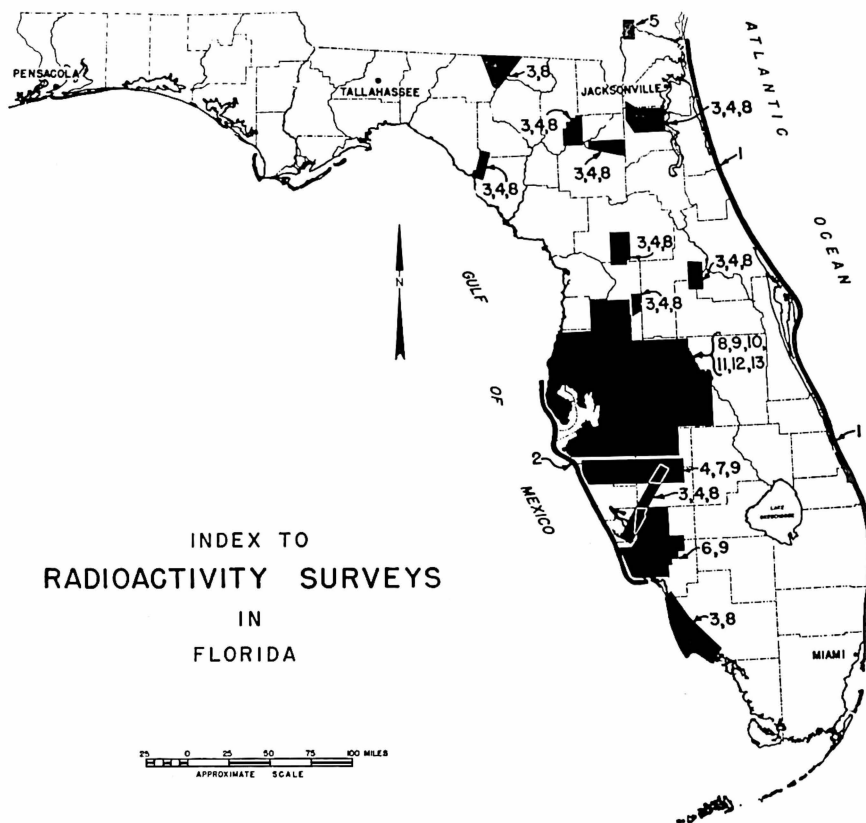


Figure 23

Index to reports on radioactivity surveys in Florida.

4. Cathcart, J. B., *Drilling of Airborne Radioactivity Anomalies in Florida, Georgia, and South Carolina—1954*, U. S. G. S., Open file report released September 30, 1954.
5. Moxham, R. M., *Airborne Radioactivity Survey in the Folkston Area, Charlton County, Georgia, and Nassau County, Florida*, U. S. G. S., Geophysical Investigations Map GP 119, 1954.
6. Meuschke, J. L., *Airborne Radioactivity Survey of the Fort Myers Area, Charlotte and Lee Counties, Florida*, U. S. G. S., Geophysical Investigations Map GP 121, 1954.
7. Meuschke, J. L., *Airborne Radioactivity Survey of the Gardner Area, DeSoto, Hardee, Manatee, and Sarasota Counties, Florida*, U. S. G. S., Geophysical Investigations Map GP 122, 1955.
8. *Search for and Geology of Radioactive Deposits*, Semiannual Progress Report, December 1, 1952 to May 31, 1953, U. S. G. S., Trace Elements Investigations Report 330, June 1953.
9. *Geologic Investigations of Radioactive Deposits*, Semiannual Progress Report, June 1 to November 30, 1953, U. S. G. S., Trace Elements Investigations Report 390, December 1953.
10. *Geologic Investigations of Radioactive Deposits*, Semiannual Progress Report, December 1, 1954 to May 31, 1955, U. S. G. S., Trace Elements Investigations Report 540, June 1955.

11. *Geologic Investigations of Radioactive Deposits*, Semiannual Progress Report, December 1, 1953 to May 31, 1954, U. S. G. S., Trace Elements Investigations Report 440, June 1954.
12. (a) Cathcart, J. B., and others, *The Geology of the Florida Land-Pebble Phosphate Deposits*, U. S. G. S., Open file report released March 1953.
 (b) McKelvey, V. E., and others, *Domestic Phosphate Deposits*, U. S. G. S., Open file report released March 1953.
13. *Contributions to the Geology of Uranium and Thorium*, U. S. G. S. Professional Paper 300, 1956, 739 pp.

The following chapters deal with Florida geology:

- (a) *Natural occurrence of uranium in the United States—a summary*, by Hobart E. Stocking and Lincoln R. Page, pp. 5-12.
- (b) *Distribution and occurrence of uranium in the calcium phosphate zone of the land-pebble phosphate district of Florida*, by James B. Cathcart, pp. 489-494.
- (c) *The aluminum phosphate zone of the Bone Valley formation, Florida, and its uranium deposits*, by Zalman S. Altschuler and others, pp. 495-504.
- (d) *Geology of thorium deposits in the United States*, by William S. Twenhofel and Katherine L. Buck, pp. 559-566.
- (e) *Mineralogy of thorium*, by Clifford Frondel, pp. 567-580.
- (f) *Monazite in southeastern United States*, by William C. Overstreet and others, pp. 597-604.

LIGHTWEIGHT AGGREGATES

GENERAL STATEMENT

Lightweight mineral aggregates, when used with portland cement, produce concrete that has a unit weight of less than 120 pounds per cubic foot. There are three principal types of lightweight aggregates that are employed according to the kind or use of the concrete. In structural concrete, for use in monolithic concrete for buildings, floors, roofs, partitions, bridge decks, etc., the main purpose is to reduce weight to economize on the design. For such purposes, the workability and strength characteristics of the lightweight concrete should be similar to ordinary concrete but the unit weight may range from 90 to 120 pounds per cubic foot. In masonry uses, the concrete is usually precast or fabricated into machine-made units for walls and partitions that may be either load-bearing or nonload-bearing. For these uses, good insulating and sound-deadening characteristics are desirable in addition to lightweight and moderate strength. The range in unit weight for such concrete varies from 75 to 95 pounds per cubic foot. In insulation and fill uses, as in monolithic lightweight concrete for partitions, walls, and floors, and roof fills, precast units are employed that have little strength but lightness and insulation values are desired. For such uses, the unit weight of the concrete varies from 35 to 75 pounds per cubic foot.

The classification of lightweight aggregates is based on source of the material as either *natural* or *artificial*. Artificial aggregates may be by-products or specially manufactured. The most common natural lightweight aggregates are pumice, other volcanic rocks like scoria and volcanic cinders. By-product aggregates include cinders and coke while special manufactured aggregates are produced from clay, shale, slate, furnace slag, perlite, vermiculite and other materials. These materials when processed develop a porous, vesicular, or exfoliated structure that results in a lightweight product. The most important properties to users of lightweight concrete are unit weight, strength, durability, thermal conductivity, fire resistance, sound absorption, water absorption, shrinkage, and nailability. These characteristics vary with the type of aggregate, and the shape, size, and surface texture of the individual particles. No one aggregate can meet all of the various requirements and each has characteristics that suit the material for particular uses. Because lightweight aggregates are usually more expensive than ordinary aggregates, justification for their use involves consideration of the advantages offered with regard to weight reduction, thermal insulation, fireproofing, nailability, as well as savings in structural design.

PERLITE AND VERMICULITE

Expanded perlite has found wide acceptance in the construction industry where it substitutes for sand in plaster and concrete. Perlite is a rock of volcanic origin containing silica and combined water and other gases which when heated to its softening temperatures will expand 4 to 20 or more times in volume. The resulting lightweight, glassy, white particles are used to make lightweight plasters and concretes as well as for loose-fill insulation. The quantity of perlite sold is limited by the furnace capacity available and an increase in number of plants may be expected in Florida. Most of the crude perlite is mined in Nevada, New Mexico, and Colorado where it is shipped throughout the United States. In 1955, there were 91 perlite processing plants located in the United States and three of these were situated in Florida, one each at Jacksonville, Vero Beach, and Hialeah.

Approximately three-quarters of the production of expanded perlite is used as an aggregate in gypsum plaster where it replaces sand and the resulting plaster is lightweight, and has good thermal, acoustical, and fireproofing properties. Perlite is also used in concrete to make poured roof decks and floors, and in prefabricated units of various kinds. Many minor uses have extended the

applications of this material as a filler for rubber, soap, paints, plastics, and resins, as well as a substitute for diatomaceous earth in filtration beds. Perlite is such a new material that all of its potential markets are not yet developed.

Vermiculite is a micaceous material that is associated with igneous and metamorphic rocks. No deposits of this material are found in Florida but two companies operate plants in Jacksonville, Tampa, and Boca Raton to process crude vermiculite into a lightweight, exfoliated material that is used for insulation, lightweight aggregate in plaster, and for a soil conditioner. The raw material that is used by the Florida plants is obtained from deposits located in Montana, South Carolina, and South Africa.

SLAG AND PUMICE

Slag production in the State is a by-product of the electric furnace production of phosphorus. In this process, the molten slag from the furnace is chilled with water. If the molten material is immersed in water, a granular, glassy product is formed; if a water spray is used, the molten material expands into a cellular lump product that is crushed and screened. Slag is produced at Tarpon Springs by the Victor Chemical Works; at Pierce by the American Agricultural Chemical Company; and at Nichols by the Virginia-Carolina Chemical Corporation. The granular, glassy product finds use in road building whereas the expanded material is used as aggregate in making lightweight concrete products.

The slag-producing industries of Florida do not furnish sufficient volume to satisfy the demand for lightweight aggregates by the concrete products companies of the State. Slags and expanded shale aggregates are shipped into the State from Alabama, Georgia and Tennessee. The cement products industries in the West Palm Beach and Miami areas utilize pumice, volcanic cinder and scoria imported from Greece.

EXPANDED CLAY

In order to develop a source of lightweight aggregate within the State, the Florida Geological Survey working in cooperation with the U. S. Bureau of Mines, has collected clay samples from a number of localities for testing and determination of the bloating or expansion characteristics. These tests have shown that most of the clays are too refractory for commercial utilization in the production of lightweight aggregate. Based on the data listed in table 8, the most promising clay deposits are situated in Clay, Citrus, and Volusia counties.

Lightweight aggregate can be produced from clay by two methods—the rotary kiln and sintering processes. The rotary kiln is similar to that used by the cement industry and the maximum temperature utilized is usually within the range 1,900° to 2,100°F. Most clays probably require pelletizing before firing and this can be done by means of a horizontal drum pelletizer, an extrusion machine, or any apparatus where the clay can be mixed with a small quantity of water and be formed into small pellets. If the clay pellets agglomerate in the kiln, the discharge must be crushed to give the desired aggregate size. In the sintering process, the clay is mixed with from 5 to 10 percent coal, coke, or other fuel and pelletized. The mixture is fed into either a traveling grate, or a rotating hearth sintering machine where the charge is ignited and

Table 8

Lightweight Aggregate Test Data from Selected Localities in Florida.
Test Determinations by the U. S. Bureau of Mines

County & Locality	Sample No. and Thickness	Range of Bloat °F	Sticking Temp. °F	Bloating Quality	Needs Ex- trusion
Alachua Road cut on State Hwy. 26, sec. 4, T. 10 S., R. 19 E.	0-273 0-274 6½ ft. be- low 5 ft. of overburden	2100-2200 2100-2200	2200 2200	Good Good	No No
Clay Auger sample near old brick plant, sec. 6, T. 5 S., R. 24 E.	0-241 2 ft.	2100-2300	2300	Good	No
Citrus Channel sample from General Portland Cement Co.'s pit, sec. 3, T. 21 S., R. 19 E.	0-229 15 to 20 ft.	2000-2300	2300	Excellent	No
Marion Clay exposed in abandoned fuller's earth pit, sec. 34, T. 13 S., R. 20 E.	0-266 30 ft. of green plas- tic clay be- low 6 ft. impure limestone	2000-2200	2000	Good	No
Volusia Auger sample from sec. 26, T. 19 S., R. 31 E.	Auger sam- ple 12 ft. clay	2000-2300	2300	Excellent	No

an induced draft draws the burning zone through the charge. The quantity of fuel in the clay mixture must be sufficient to heat the material to the bloating temperature. The product is a sintered cake that is crushed to the desired aggregate size.

The first lightweight aggregate to be made from Florida materials was produced at Ellenton, Manatee County, during World War II. In order to be assured a source of aggregate, the firm of McCloskey and Company that held a contract with the Maritime Commission to build 24 self-propelled concrete cargo carriers at Tampa, purchased land at an abandoned fuller's earth mine and established a lightweight aggregate plant. This property, situated in sec. 10, T. 34 S., R. 18 E., was acquired in September 1942 and aggregate made from fuller's earth was being produced at the rate of 300 cubic yards per day in June of the following year. The first concrete barge was launched in July 1943. The aggregate plant operated for only a relatively short time and after it was sold in 1947 by the War Assets Administration, the plant was dismantled. The manufactured aggregate was called *Nodulite* and consisted of spheres of clay that had a coating of sand or cement. These spheres were fired in rotary kilns, and the resulting *Nodulite* aggregate ranged in diameter from one-eighth inch to one inch approximately. Concrete made with the aggregate weighed approximately 112 pounds per cubic foot and developed a crushing strength at 28 days of 7,000 pounds per square inch.

In 1948, the U. S. Bureau of Mines published a series of tests that were made on some Florida clays and phosphate washery slimes to determine bloating characteristics and their possible use in lightweight aggregate manufacture. These data are listed in the U. S. Bureau of Mines Report of Investigations 4401, "Production of Lightweight Concrete Aggregates from Clays, Shales, Slates and other Materials." While an excellent aggregate was made from the phosphate washery slimes, the principal objection for use of this material is its high water content which reaches 40 percent by weight.

LIMESTONE

DIMENSIONAL STONE

The term "dimensional stone" is applied to slabs or blocks of a natural stone that are cut or broken into shapes that are suitable for utilization in buildings or construction. The product may have rather rough surfaces or may be polished, depending upon its use. The quarrying of dimensional stone is done with great care in

order to produce blocks that are suitable for sawing, splitting, carving and polishing. In general, stone is difficult to work and is not adapted to mass production methods. The use of stone for construction began, in the United States, with the earliest settlements and the coquina found on Anastasia Island has the distinction of being the first dimensional stone used. The oldest buildings in St. Augustine were constructed, at least in part, of blocks cut from the shell limestone known as coquina that makes up a portion of the Anastasia formation. With the development of the building industry, stone was replaced by steel as the load-bearing material and later reinforced concrete replaced stone in structures. Modern stone buildings have only a thin veneer of stone. Stone is generally more expensive than concrete, brick and other substitutes; consequently, it is used primarily in high class construction where its attributes of permanence, dignity and architectural adaptability may be displayed. Many factors enter into the suitability of a particular rock formation for use as a dimensional stone and pleasing texture and color stability are important considerations.

Research by the industry has developed improved machines and techniques for fabricating stone and among the improvements are the diamond saws, the cutting and splitting machines. The Bradenton Stone Company, Manatee County, produces a variety of stone products including split-face ashlar, smooth-face ashlar, flagstone, sills, and coping in a modern plant located at Oneco, Florida. This company quarries dolomite from a location south-east of Bradenton, see figure 24, and trucks the large blocks to the plant at Oneco, figures 25 and 26. The rock formation has been quarried for many years not only for building stone, which is sold under the commercial name "travertine," but also for agricultural stone. It is considered to be a portion of the Hawthorn formation of Miocene age.

The coralline limestone of the Key Largo formation of Pleistocene age has likewise been quarried for many years for dimensional stone. Figures 27 and 28, the quarry on Windleys Key, Monroe County, produces large blocks that are trucked to Miami for cutting into dimensional stone by the Keystone Art Company. The porous or open texture of the coralline limestone gives a very pleasing appearance but it makes the rock more suitable for interior work than exterior surfaces. This building stone has been used in many buildings in South Florida, particularly in the Miami area on exteriors as well as interiors.



Figure 24
Quarry of the Bradenton Stone Company, Manatee County.

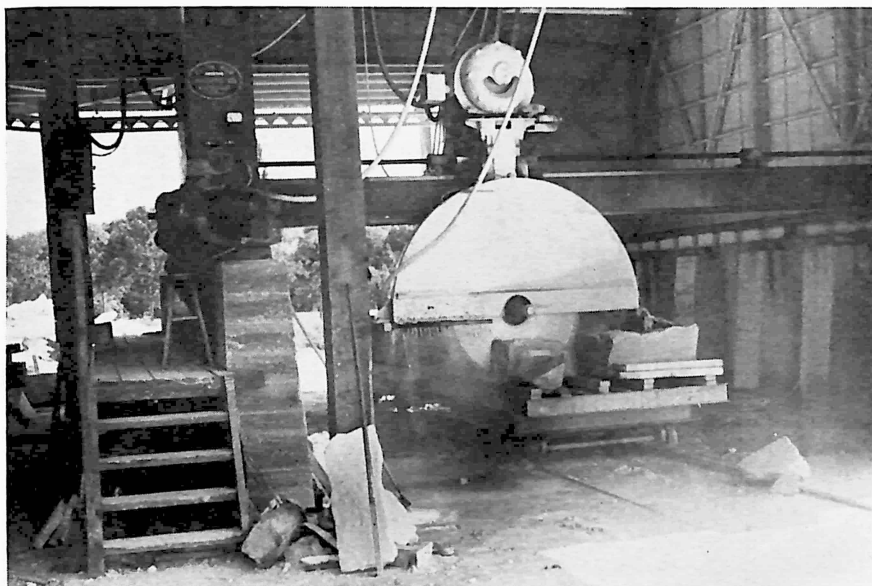


Figure 25
Cutting "Travertine" at the Bradenton Stone Company, Manatee County.

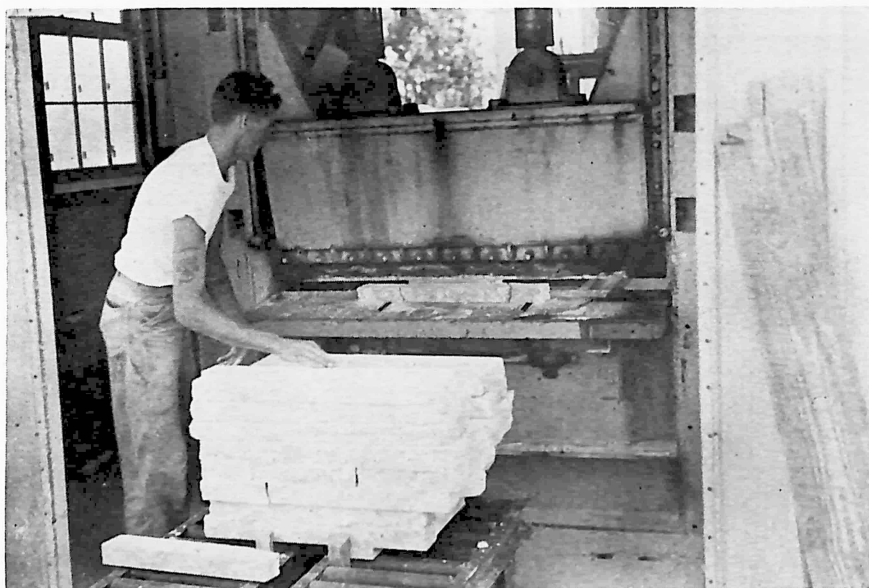


Figure 26
Splitting "Travertine" at the Bradenton Stone Company, Manatee County.

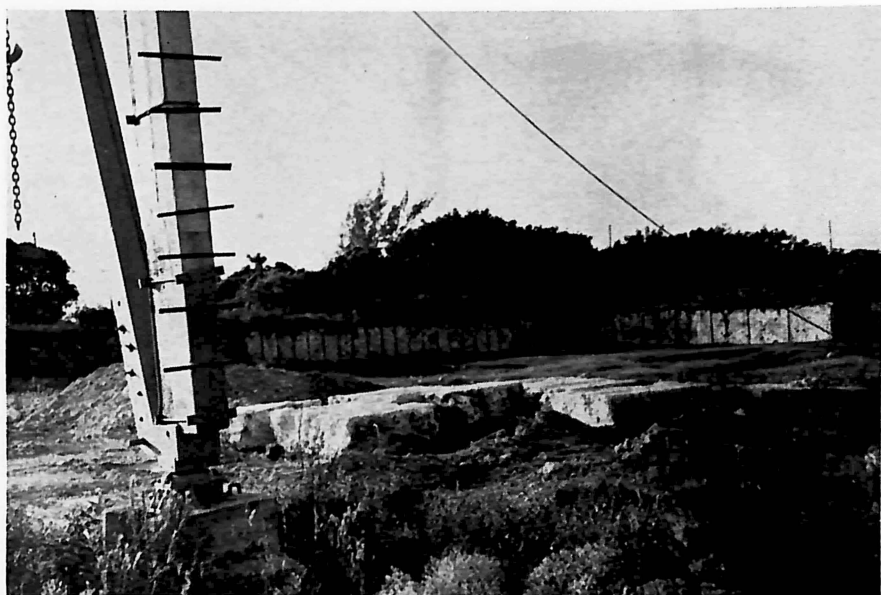


Figure 27

Dimensional stone quarry in the Key Largo limestone, Windleys Key, Monroe County.



Figure 28

Detailed view of Key Largo limestone at Keystone Art Company's quarry on Windleys Key, Monroe County.

The Marianna limestone of Oligocene age which is found in Jackson County, was formerly quarried by several companies. In recent years, however, the only production has been by individuals on special order and an organized company no longer exists in that area to produce dimensional stone. The Marianna limestone was used chiefly to produce building stones. These were the approximate size of concrete blocks and were used in load-bearing walls. As noted above, the changes that have come to pass in the construction industry have all but eliminated dimensional stone for that purpose.

In general, the dimensional stone industries do not enjoy prospects for future expansion. Newer construction materials, architectural concrete, glass, aluminum, and others, compete with stone, nevertheless, these substitute materials cannot replace the dignity that is associated with stone.

CRUSHED OR BROKEN STONE

Limestone, in its broader sense, includes dolomite and together these carbonate rocks are the most widely used of all rock. Almost the entire production of rock or stone in Florida is some variety of limestone. In 1955, the data collected by the U. S. Bureau of Mines and the Florida Geological Survey shows that commercial limestone was produced from 73 quarries located in 18 counties, see accompanying list, table 12, page 102. With reference to the resource map (in pocket), it may be seen that there is a concentration of quarries in Dade and Broward counties and in the northwestern portion of peninsular Florida, including Suwannee, Lafayette, Dixie, Alachua, Levy, Marion, Citrus, Sumter, and Hernando counties. Dolomite is produced from locations in Levy, Citrus, and Manatee counties. The quantity and value of crushed limestone produced in recent years is recorded in table 9. It is interesting to note that the value assigned to the crushed limestone produced in 1956 is nearly equal to the value of the entire mineral industry of Florida for the year 1945.

The greatest tonnage of crushed limestone is consumed in uses classified as concrete, road metal, and screenings. In 1955, the year for which the most recent data are available, over 82 percent of the tonnage was consumed in these uses. The tonnage of agricultural limestone (including dolomite) amounted to nearly 2½ percent of the entire production of crushed limestone. Riprap, railroad ballast, portland cement, lime, fuel oil additive and other miscellaneous uses accounted for the remainder of the production. The exact totals for these uses are not available for publication at the

Table 9

Crushed Limestone Sold or Used by Producers
1945 through 1956

Year	Short Tons	Value
1945-1949 average	3,470,608	\$ 4,097,991
1950	5,313,400	6,885,394
1951	8,032,966	9,419,682
1952	7,836,124	9,572,575
1953	9,428,959	11,309,421
1954 *	14,225,356	16,832,066
1955 *	16,303,625	21,312,339
1956 *	17,303,000	24,123,000

Data—U. S. Bureau of Mines

*Includes stone used in cement and lime manufacture.

request of the producing companies and of the policy adapted by the U. S. Bureau of Mines to avoid disclosure of production data from individual operations. All of the limestone quarries in the State are of the "open pit" variety; in fact, there are no mines or quarries of either the drift or shaft types to be found in Florida.

The dolomite or dolomitic limestone that is quarried at Lebanon, Levy County, is a dolomitic facies of the Ocala group, upper Eocene and Avon Park limestone of middle Eocene age. This rock is produced for agricultural stone. At Red Level, Citrus County, a poorly consolidated dolomitic facies of the lower limestone formation of the Ocala group, upper Eocene age, is quarried. This rock is pulverized and is used as a fuel oil additive to produce a fluffy boiler scale that is easily removed from boilers. Dolomites and dolomitic limestone facies of the formations in the Ocala group occur in western Taylor and Dixie counties. The dolomite that is quarried in Manatee County is early or possible middle Miocene and is a facies of the Hawthorn formation. This rock is quarried not only for agricultural limestone, see figure 29, but also for dimensional stone, see figures 25 and 26.

In general, the limestones of the Ocala group that are quarried in Alachua, Levy, Marion, Citrus, Sumter, and Jackson counties have a uniform texture that allows ready crushing and pulverizing. They are free from grit and the rock approaches the purity of 100 percent calcium carbonate. Rock used in highway construction for base course material that is produced from the Ocala group of formations must meet the State Road Department's specifications of a purity not less than 95 percent calcium and



Figure 29

Dolomite quarry of the Southern Dolomite Company, Palmetto, Manatee County.

magnesium carbonate. In spite of their purity, these limestones enter into many common uses which include road base material and concrete aggregate. Part of these formations contain cherty concretions and boulders and these are eliminated during the quarrying. In former years, chert boulders were collected from the surface in Alachua, Marion and Sumter counties for crushing and for shaping into blocks for furnace linings. This industry, however, ceased a number of years ago and is mentioned only for historical record.

The Marianna limestone of Oligocene age has been mentioned in the discussion of dimensional stone. The Suwannee limestone of Oligocene age is quarried in Suwannee County at the Ralph quarry of the Suwannee Limerock Company and the Live Oak quarry of the Live Oak Stone Company, see figure 30. This formation varies in character from a hard, resonant limestone to a soft, granular limestone that contains clay and sand. In the Brooksville area of Hernando County, limestones of Oligocene age (Suwannee limestone) and Miocene age (Tampa formation) are quarried extensively and are designated commercially as "Brooksville Stone." In Hernando County, these formations are hard and massive but they contain impurities of chert and clay. Figure 31, a



Figure 30

Live Oak Stone Company quarry, Live Oak, Suwannee County. Approximately 35 feet of Suwannee limestone is exposed in this quarry. The overburden consists of 12 feet of clay and three feet of weathered limestone.



Figure 31
Lansing quarry, Florida Rock Products Corporation, Hernando County.

picture of the Lansing quarry, Florida Rock Products Company, Hernando County, shows a 60-foot face of Suwannee limestone. The "Brooksville Stone" is used for cement manufacture, railroad ballast, concrete aggregate, and agricultural stone.

The limestone formations of the Pleistocene epoch that occur along the east coast of Florida from the vicinity of St. Augustine, St. Johns County, southward to Key Largo, and then westward to Key West, Monroe County, contain some of the largest quarry operations in the State. The Anastasia formation produced the first building rock that was used by the settlers at St. Augustine. A conspicuous part of this formation is the coquina, a rock composed of whole or broken shells that are more or less firmly cemented, and the harder portions of the coquina make the attractive and durable building stone. Other portions of the formation consist of sand, calcareous sandstone, sandy limestone and shell marl; south of the Palm Beach-Broward County line, the Anastasia formation merges into the Miami oolite. Figure 32, a photograph of a small quarry on Anastasia Island, shows layers of unconsolidated shell and sand alternating with firm or consolidated layers. The slabs of the harder portions are fashioned into building stone



Figure 32

Coquina quarry in Anastasia formation, Anastasia Island, St. Johns County.

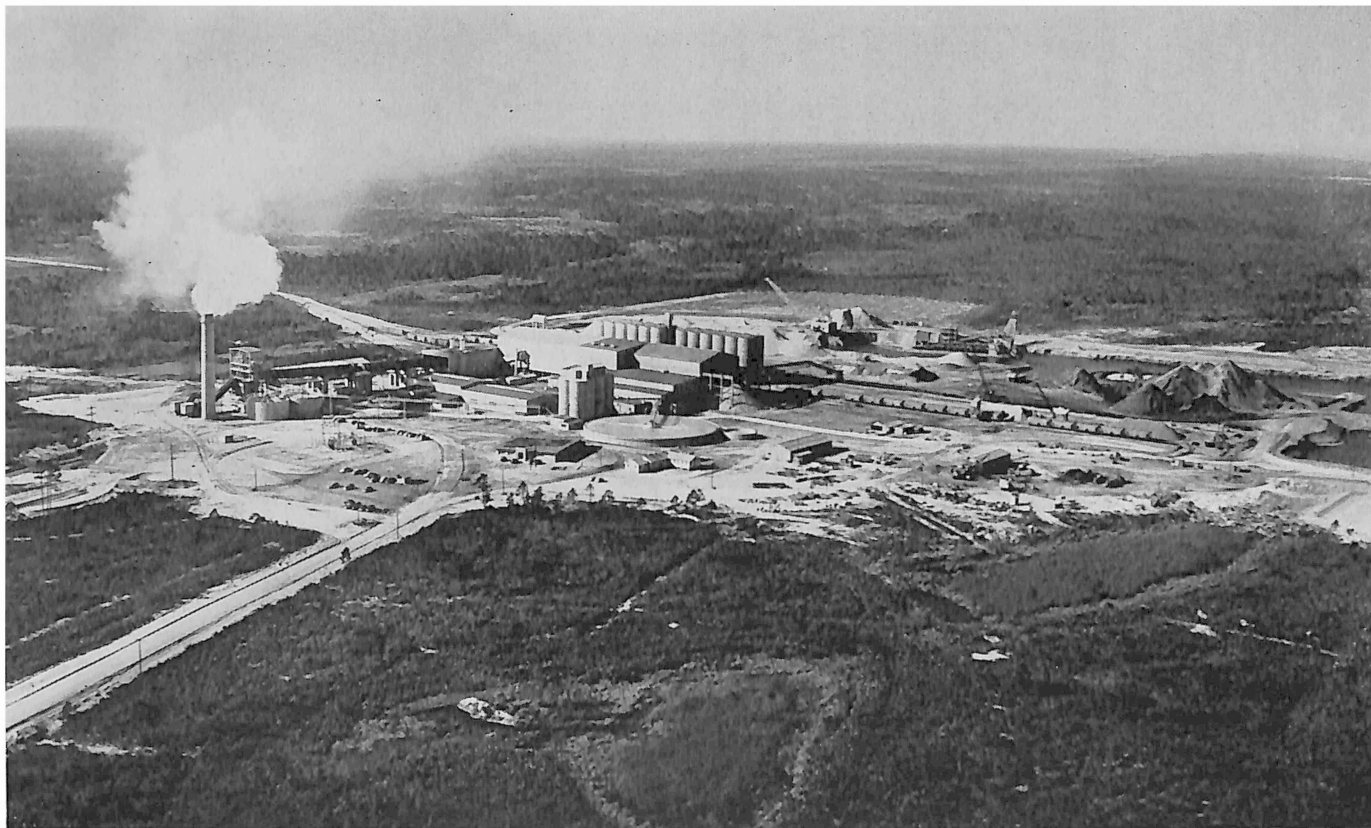


Figure 33

The Lehigh Portland Cement Company's Bunnell plant. Coquina is dredged from the pit adjacent to the plant. Photograph courtesy of the company.

while the sand and shell is used for aggregate. One of the largest quarries on the east coast of Florida is located adjacent to the Bunnell plant of the Lehigh Portland Cement Company, see figure 33. The quarry or pit adjacent to the mill produces shell and sand from the Anastasia formation. This mixture is screened and a portion of the sand is recombined with the shell for cement manufacture. This plant began operation in December 1952, and this is the first extensive use of coquina.

From a commercial quarrying point of view, the Miami oolite is the most important limestone in Broward, Dade, and Monroe counties. It underlies the Atlantic coastal ridge that extends along the eastern portion of Broward and Dade counties and in Monroe County it is below sea level in Florida Bay but it forms the lower Florida Keys from Big Pine Key to Key West. Generally, this formation is a comparatively soft, white limestone composed of small spherical grains, or oolites, sand and shell fragments. The limestone often contains solution holes and channels and in some places these have been filled with crystals of secondary calcite. In 1953, the last year for which production data have been released for the limestone produced in each of the counties, the combined production from Broward and Dade counties totaled 5,932,000 short

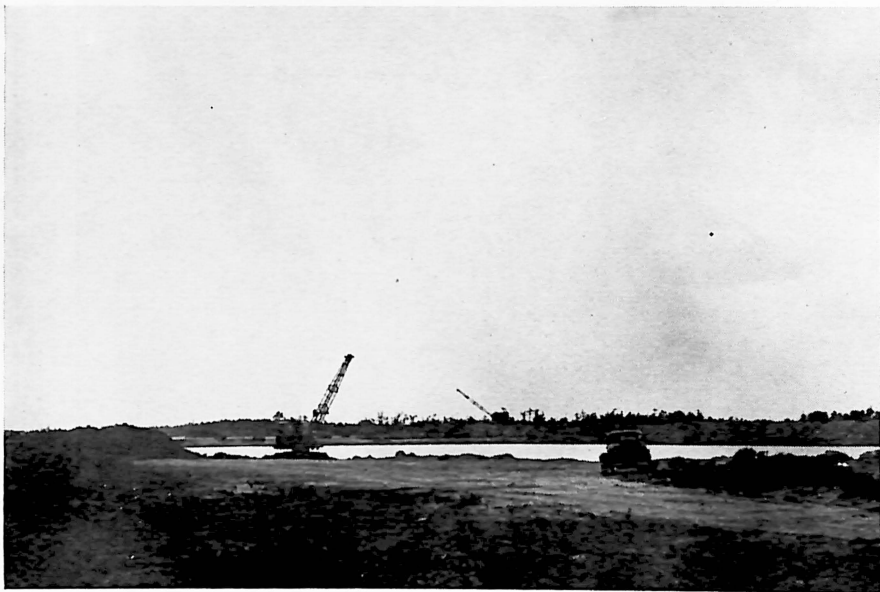


Figure 34

Smith Brothers' quarry, Brevard County. Draglines pile Miami oolite in windrows to drain before loading onto trucks.

tons valued at \$5,830,000. This tonnage represents 63 percent of the limestone quarried in the entire State and 51 percent of the value assigned to the limestone production for 1953. The quarries are large rectangular pits that may cover an area as much as one-fourth mile wide and one-half mile long. These pits are dug to a depth of 20 to 40 feet, depending upon the thickness of the formation. The quarrying operation is illustrated in figure 34, a picture of Smith Brother's quarry, Brevard County. The leading limestone-producing companies have been progressive in planning land-use programs for the quarry sites rather than abandoning them. With the cooperation of planning and zoning groups, the companies are engaged in developing the quarries in such a manner as to create attractive and safe sites for residential use. Almost all of the production of stone from quarries in Dade, Broward, and Monroe counties finds use in either the building industry or in road construction.

SAND AND GRAVEL

Commercial sand production comprised 91 percent of the sand and gravel industry in 1954; while this percentage was about the same for both 1955 and 1956, the quantity and value of gravel production for these years have not been disclosed by the U. S. Bureau of Mines. Listed in order of tonnage, sand and gravel produced in Florida enters into the following uses: structural sand, paving sand, structural gravel, paving gravel, railroad ballast sand, engine sand, blast sand and molding sand. Although glass sand is not recorded in these uses, a small tonnage is produced as a by-product of the kaolin industry in Putnam County. Table 10 records the growth of sand and gravel industry of Florida and the 1955 production is at an all time high in both tonnage and value. By way of contrast, the industry reported the quantity and value of the 1932 production as 276,068 short tons and \$178,654.

Definitions of sand and gravel vary with use and among authorities but, in general, sand is unconsolidated granular material that is coarser than 200 mesh and finer than one-fourth inch. Gravel is coarser than one-fourth inch and finer than $3\frac{1}{2}$ inches. Both sand and gravel may be composed of a mixture of many minerals; nevertheless, a single mineral, usually quartz predominates. All of the quartz sands of Florida have had a complicated history and have been transported into the State and are found in fluvial, deltaic, marine or aeolian deposits. The gravel deposits

Table 10

Quantity and Value of Sand and Gravel Produced in Florida
1945 through 1955

Year	Short Tons	Value
1945-1949 (average)	1,894,422	\$1,717,609
1950	2,793,865	2,806,431
1951	4,418,573	4,300,682
1952	4,154,613	3,848,077
1953	3,731,432	3,199,368
1954	3,468,842	2,661,152
1955	5,065,503	4,349,148

Data—U.S. Bureau of Mines

that have been worked commercially are fluvial materials. With the exception of the shell and carbonate content of the coastal sands, the dominant mineral in the sand deposits is quartz. Even in the kaolin-bearing sand deposits that are mined and processed for kaolin, quartz sand that meets specifications for glass manufacture is produced as a by-product. In fact, most of the commercial sands fall into the classification of high silica (95 percent or more silica) sand and the largest producing companies are located in Polk, Orange, Lake, and Putnam counties on the ridge area of the Peninsula. Figure 35 illustrates a typical method of mining sand by suction dredge. The hydraulic gun is used to undermine the bank to allow the sand to slump into the pit.

Sand and gravel are low value materials and cannot tolerate high cost transportation over long distances. Markets must be found within economic shipping distance. It is interesting to note the type transportation used in sand and gravel shipments in Florida and in the United States, see table 11. The marked increase in truck transportation is attributed to the relatively short haul to market and to the improvement of roads and highways. Truck transportation is cheaper than rail haul for short distances and freight costs have increased more rapidly than trucking costs.

The production of sand and of limestone are essential to construction industries and all types of construction buildings, houses, plants, bridges, highways, etc., are essential to progress. The value of these commodities is directly proportional to the total value of construction, and as cost of their production increases so must the cost of construction.

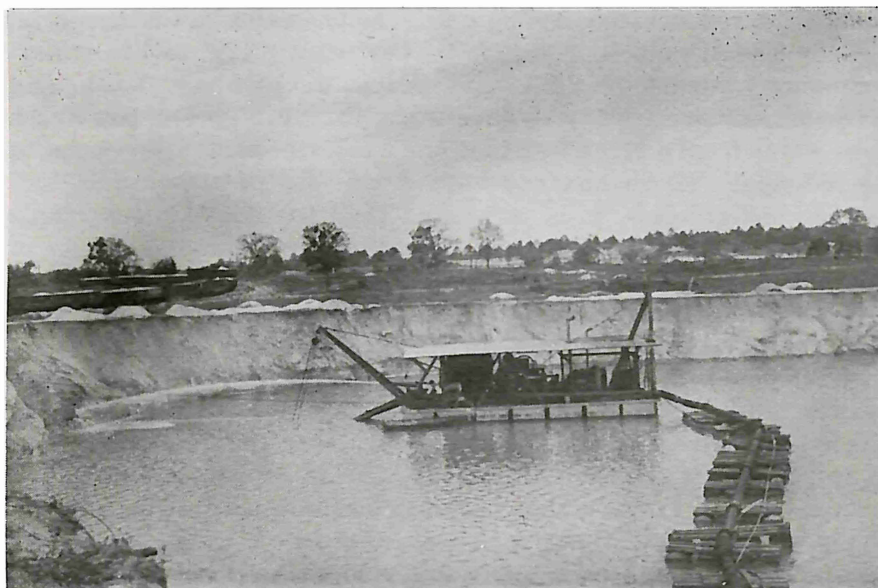


Figure 35

Dredge of the All-Florida Sand Company, Unincorporated, Interlachen, Putnam County.

Table 11

Movement of Sand and Gravel to Market by
Method of Haulage

Type of Transportation	U. S. Average		Florida	
	1942	1955	1942	1955
Railway	42%	14%	60%	28%
Truck	48%	77%	15%	69%
Water and unspecified	10%	9%	25%	3%

Data—U. S. Bureau of Mines

SEA WATER AND BRINE

In water-softening systems that utilize zeolite in the water treatment, it is necessary to regenerate the zeolite by treating it with brine or sea water. During the past few years, including 1956, there have been four major water-softening plants in Florida that use sea water for this purpose and one plant that uses brine pumped from a well. The Rayonier Corporation, Fernandina, has the largest zeolite water-softening system in the State

and it is regenerated by pumping salty water from the tidal Amelia River that is adjacent to the plant. The zeolite water-softening systems of Hollywood Beach, Jacksonville Beach, and Sarasota, all utilize sea water while the City of New Smyrna Beach uses water from a brine well that has a chloride content in excess of 16,000 ppm. There has not been a canvass of this use of salt water; nevertheless, it is estimated that the above listed plants utilize the equivalent of 10,000 tons of salt annually. This use of sea water and of brine is a significant practice in resource utilization. The utilization of other dissolved solids and their extraction from sea water as a by-product of desalting sea water is a distinct possibility. Efforts to develop processes for extraction of potable water from sea water have been known for centuries and the ancient Greeks knew that pure water could be obtained by evaporating sea water. Efforts to develop economically feasible processes have lowered the cost of producing such water. Where the need is sufficiently great, such as aboard ocean ships, cost considerations may justify treating sea water to obtain fresh water. Water for industrial and agricultural uses, however, cannot be supplied from the sea until lower cost methods are developed.

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Table 12
Rock and Mineral Producers 1954 and 1955

Product	Company, Name and Location of Pit, Quarry, or Plant	Production Reported		Address
1954	1955			
Cement	General Portland Cement Company Florida Portland Cement Division Hillsborough County Tampa Mill	X	X	Box 1528 Tampa 1, Fla.
	Lehigh Portland Cement Company Flagler County Bunnell Mill	X	X	Bunnell, Fla.
Clay Common	General Portland Cement Company Florida Portland Cement Division Citrus County Section 2, T21S, R19E	X	X	Box 1528 Tampa 1, Fla.
	Osceola Clay & Topsoil Company Escambia County Alden Pit—Sec. 15, T2S, R30W	X	X	P. O. Box 649 Pensacola, Fla.
	Jackson Pit—Sec. 15, T2S, R30W	X	X	
	Taylor Brick and Tile Company Escambia County Molino Plant	X	X	I and Manresa St. Pensacola, Fla.
	Walton Brick and Tile Company Walton County Glendale Rd. Plant	X		DeFuniak Springs, Fla.
	Apalachee Correctional Institution Gadsden County River Junction Brick Plant—Sec. 4, T3N, R6W	X	X	Box 548 Chattahoochee, Fla.
Non-Commercial				

Rock and Mineral Producers 1954 and 1955 (continued)

Product	Company, Name and Location of Pit, Quarry, or Plant	Production Reported		Address
		1954	1955	
Fuller's Earth	Floridin Company, Inc.			P. O. Box 989 Tallahassee, Fla.
	Gadsden County			
	Quincy Plant	X	X	
	Jamieson Plant	X	X	
	Pits: Sec. 18, T2N, R3W			
	Sec. 7, T2N, R3W			
	Sec. 9, T3N, R3W			
	Sec. 8, T3N, R2W			
	Sec. 11, T3N, R3W			
	Magnet Cove Barium Corporation			P. O. Box 677 Havana, Fla.
	Gadsden County			
	Havana Mine and Plant—Sec. 15, T3N, R2W	Developing		
	Minerals and Chemicals Corp. of America			Attapulcus, Ga.
	Attapulcus Division			
	Gadsden County			
	Pit—Sec. 15, T3N, R3W	X	X	
Kaolin	Edgar Plastic Kaolin Company			Edgar, Fla.
	Putnam County			
	Edgar Mine—Sec. 25, T10S, R23E	X	X	
	United Clay Mines Corporation			P. O. Box 27 Hawthorne, Fla.
	Putnam County			
	No. 4 Mine—Secs. 27 & 28, T10S, R23E	X	X	
Dolomite Crushed	Dixie Lime Products Company			P. O. Box 578 Ocala, Fla.
	Levy County			
	Lebanon Quarry—Sec. 12, T16S, R16E	X	X	

Rock and Mineral Producers 1954 and 1955 (continued)

Product	Company, Name and Location of Pit, Quarry, or Plant	Production Reported		Address
		1954	1955	
Dolomite Crushed (cont'd)	Florida Dolomite Company Sarasota County Sarasota Quarry—Sec. 1, T36S, R17E	X	X	Pembroke, Fla.
	Golden Dolomite Company Citrus County Red Level Quarry—Sec. 25, T17S, R16E	X	X	P. O. Box 1193 Orlando, Fla.
	Manatee Dolomite Company Manatee County Minton Quarry—Sec. 5, T35S, R18E	X	X	P. O. Box 37 Samoset, Fla.
	Southern Dolomite Company Manatee County Palmetto Quarry—Sec. 19, T34S, R18E	X	X	P. O. Box 23 Bradenton, Fla.
	Bradenton Stone Company Manatee County Bradenton Quarry—Sec. 32, T34S, R18E (Quarry and Mill at Oneco under development)			P. O. Box 256 Bradenton, Fla.
	Florida Travertine Company Manatee County Clark's Quarry—Sec. 7, T35S, R18E (Under development—Formerly Alclaries Travertine Company)			Oneco, Fla.
Dimensional (Also, see limestone, dimensional)				
Garnet	Florida Ore Processing Company, Inc. Brevard County Palm Bay Plant (Destroyed by fire 1955)	X	X	Box 417 Melbourne, Fla.

Rock and Mineral Producers 1954 and 1955 (continued)

Product	Company, Name and Location of Pit, Quarry, or Plant	Production Reported		Address
		1954	1955	
Ilmenite	E. I. du Pont de Nemours and Company, Inc. Clay County Highland Plant—Sec. 18, T4S, R22E Trail Ridge Plant—Secs. 5 & 6, T6S, R23E (Contractor: Humphreys Gold Corp. P. O. Box 5492, Jacksonville 7)	X X	X X	P. O. Box 631 Starke, Fla.
	Florida Ore Processing Company Brevard County Palm Bay Plant (Destroyed by fire 1955)	X	X	P. O. Box 417 Melbourne, Fla.
	The Hobart Brothers Company Indian River County Winter Beach Plant—Sec. 4, T32S, R39E		X	Box 1482 Vero Beach, Fla.
	Humphreys Gold Corporation Clay County Trail Ridge Plant—Sec. 13, T2S, R27E	X	X	Box 753 Starke, Fla.
	Rutile Mining Company of Florida, and Titanium Alloy Manufacturing Division of the National Lead Company Duval County Jacksonville Plant—Sec. 13, T2S, R27E (Contractor: Humphreys Gold Corp. P. O. Box 5492, Jacksonville)	X	X	P. O. Box 5492 Jacksonville, Fla.
Lime	Dixie Lime Products Company Marion County Reddick Plant	X	X	P. O. Box 578 Ocala, Fla.

Rock and Mineral Producers 1954 and 1955 (continued)

Product	Company, Name and Location of Pit, Quarry, or Plant	Production Reported		Address
		1954	1955	
Lime (cont'd)	City of Miami Department of Water and Sewers Dade County Hialeah Plant	X	X	P. O. Box 316 Coconut Grove Sta. Miami 33, Fla.
Limestone Crushed	Alachua Corporation Alachua County S. M. Wall Quarry—Sec. 36, T9S, R18E (Sold to Williston Shell Rock Company)	X		1650 NE 23rd Blvd. Gainesville, Fla.
	Belle Glade Rock Company Palm Beach County South Bay Quarry—Sec. 23, T44S, R36E	X	X	P. O. Box 37 Northwest Branch Miami, Fla.
	Brooksville Rock Company, Inc. Hernando County Annutteliga Quarry—Sec. 23 & 26, T21S, R18E	X	X	Box 158 Brooksville, Fla.
	Burnup and Sims, Inc. Palm Beach County Peanut Island Mine—Sec. 34, T42S, R43E	X	X	505 Park Street West Palm Beach, Fla.
	Camp Concrete Rock Company Hernando County Gay Plant—Secs. 6 & 7, T22S, R19E	X	X	Box 608 Ocala, Fla. and Rt. 2, Brooksville, Fla.
	Central Quarries, Inc. Sumter County Sumterville Quarry	X	X	P. O. Box 822 Leesburg, Fla.
	Claussen-Laurence Construction Co. St. Johns County Anastasia Quarry	X		Augusta, Ga.

Rock and Mineral Producers 1954 and 1955 (continued)

Product	Company, Name and Location of Pit, Quarry, or Plant	Production Reported		Address
		1954	1955	
Limestone Crushed (cont'd)	W. L. Cobb Construction Company			1102 N. 22nd St.
	Marion County			Tampa, Fla.
	York Quarry—Sec. 26, T15S, R20E	X	X	and
	Sumter County			Box 2, Hernando, Fla.
	Sumter Quarry	X	X	
	E. E. Collins Construction Company			2175 S. W. 32nd Ave.
	Dade County			Miami 34, Fla.
	Collins Quarry	X	X	
	Connell and Shultz			Box 97
	Levy County			Inverness, Fla.
	Williston Quarry—Sec. 31, T12S, R19E	X	X	
	Cummer Lime & Manufacturing Company			P. O. Box 4640
	Marion County			Jacksonville, Fla.
	Kendrick Quarry—Sec. 24, T14S, R21E	X	X	
	Martin Quarry—Secs. 10 & 11, T14S, R21E	X	X	
	Deerfield Rock Corporation			P. O. Box 781
	Broward County			Ft. Lauderdale, Fla.
	Deerfield Quarry—Secs. 4 & 9, T48S, R42E	X	X	
	Dixie Lime Products Company			P. O. Box 578
	Marion County			Ocala, Fla.
	Plant No. 1 Reddick	X	X	
	Plant No. 3 Kendrick	X	X	
	Driskell and Mayo			Jupiter, Fla.
	Palm Beach County			
	DuBois Quarry—Sec. 31, T40S, R42E	X		

Rock and Mineral Products 1954 and 1955 (continued)

Product	Company, Name and Location of Pit, Quarry, or Plant	Production Reported		Address
		1954	1955	
Limestone Crushed (cont'd)	Florida Rock Products Corporation Hernando County Lansing Quarry—Sec. 22, T21S, R19E	X	X	P. O. Box 4667 Jacksonville, Fla. and P. O. Box 332, Brooksville, Fla.
	General Portland Cement Company Florida Portland Cement Division Citrus County Storey Quarry—Sec. 35, T20S, R19E	X	X	Box 1528 Tampa 1, Fla.
	Hallandale Rock Corporation Broward County Hallandale Quarry—Sec. 28, T51S, R42E	X	X	Box 781 Ft. Lauderdale, Fla.
	Handley Construction Company Palm Beach County Palm Beach County Quarry	X	X	Airport Road Pahokee, Fla.
	Leo Haskins Monroe County Haskins Rock Pit		X	726 Caroline St. Key West, Fla.
	Hialeah Crushed Stone Company Dade County Dade County Mine—Sec. 35, T52S, R41E (Purchased by Three Bays Improvement Co., June 1956)	X	X	2601 NW 75th St. Miami 47, Fla.
	Hollywood Quarries, Inc. Broward County Broward County Quarry	X	X	W. Taft Street and SAL Railway Hollywood, Florida.

Rock and Mineral Products 1954 and 1955 (continued)

Product	Company, Name and Location of Pit, Quarry, or Plant	Production Reported		Address
		1954	1955	
Limestone Crushed (cont'd)	Ideal Crushed Rock Company, Inc. Dade County Dade County Pit—Sec. 4, T56S, R40E	X	X	5500 NW 37th Ave. Hialeah, Fla.
	T. J. James Construction Co., Inc. Dade County James Quarry	X	X	1700 NW 119th St. Miami 47, Fla.
	Levy County Lime Rock Corporation Levy County Quarry No. 1—Sec. 19, T12S, R19E		X	Box 194 Williston, Fla.
	Quarry No. 2—Sec. 25, T12S, R19E		X	
	Quarry No. 3—Sec. 29, T12S, R19E		X	
	Live Oak Stone Company Suwannee County Live Oak Quarry (Developing—1955)			P. O. Box 327 Live Oak, Fla.
	Marjax Company Jackson County Marjax Quarry—Sec. 30, T5N, R10W	X	X	Marianna, Fla.
	Maule Industries, Inc. Broward County Prospect Quarry—Sec. 18, T49S, R42E	X	X	5220 Biscayne Blvd. Miami, Fla.
	Dade County South Dade Ojus—Sec. 5, T52S, R42E	X	X	
	Red Road—Lots 1 & 2, T53S, R40E	X	X	
	Tropical—Sec. 22, T54S, R40E	X	X	

Rock and Mineral Products 1954 and 1955 (continued)

Product	Company, Name and Location of Pit, Quarry, or Plant	Production Reported		Address
		1954	1955	
Limestone Crushed (cont'd)	W. P. McDonald Corporation of Florida Hernando County Conroc Quarry—Sec. 19, T22S, R20E	X	X	Box 1256 Lakeland, Fla. and Box 157, Brooksville, Fla.
	Phillip McLeod St. Johns County McLeod Quarry—Sec. 28, T7S, R30E	X	X	Box 673 St. Augustine, Fla.
	E. B. Meade and Sons St. Johns County Anastasia Quarry—Sec. 28, T7S, R30E	X	X	Box 677 St. Augustine, Fla.
	Meekins, Inc. Broward County Meekins Quarry—Sec. 20, T51S, R42E	X	X	Box 36 Hollywood, Fla.
	E. L. Montgomery, Inc. Broward County Montgomery Quarry	X		815 NW 7th Terr. Ft. Lauderdale, Fla.
	Murphy and Mills Corporation Dade County Quarry—Sec. 2, T53S, R41E	X	X	2601 NW 75th St. Miami 47, Fla.
	Quarry—Sec. 22, T54S, R40E (Sold to Maule, Inc., June 1955)	X	X	
	Quarry—Sec. 32, T51S, R42E (Abandoned May 1955)	X	X	
	Naranja Rock Company Dade County Naranja Quarry—Secs. 33 & 34, T56S, R39E	X	X	P. O. Box 98 Naranja, Fla.

Rock and Mineral Products 1954 and 1955 (continued)

Product	Company, Name and Location of Pit, Quarry, or Plant	Production Reported		Address
		1954	1955	
Limestone Crushed (cont'd)				
	Newberry Corporation Alachua County Haile—Sec. 13, T9S, R17E	X	X	P. O. Box 1588 Jacksonville, Fla.
	Ocala Lime Rock Corporation Marion County Kendrick Quarry	X	X	P. O. Box 842 Ocala, Fla.
	Oolite Rock Company Dade County Oolite Rock Quarry—Sec. 23, T54S, R40E	X	X	P. O. Drawer 868 South Miami 43, Fla.
	Charles E. Peacock Levy County Peacock Quarry		X	Williston, Fla.
	Peffer Construction Company Dade County Hialeah Gardens Quarry	X	X	Box 185 Shenandoah Sta. Miami 45, Fla.
	Charles E. Phillips Pinellas County Alverton Road Quarry	X	X	1307 2nd Ave. SW Largo, Fla.
	E. A. Pynchon Dade County North Miami Quarry—Sec. 29, T52S, R42E	X		P. O. Box 1921 North Miami, Fla.
	Road Rock, Inc. Broward County Road Rock Quarry—Sec. 20, T50S, R42E	X	X	2700 W. State Rd. 84 Ft. Lauderdale, Fla.

Rock and Mineral Products 1954 and 1955 (continued)

Product	Company, Name and Location of Pit, Quarry, or Plant	Production Reported		Address
		1954	1955	
Limestone Crushed (cont'd)				
	Rozzo Mining Company			1900 SW Road 84
	Broward County			Ft. Lauderdale, Fla.
	Quarry—Sec. 4, T48S, R42E	X	X	
	Quarry—Sec. 32, T50S, R42E	X	X	
	Quarry—Sec. 17, T49S, R42E	X	X	
	(Worked out in 1955)			
	Quarry—Sec. 24, T50S, R43E	X	X	
	(Worked out in 1955)			
	Seminole Rock Products Company			P. O. Box 335,
	Dade County			Tamiami Station
	Red Road Quarry—Sec. 31, T53S, R41E		X	Miami, Fla.
	Medley Quarry—Secs. 9 & 10, T53S, R40E		X	
	Finley P. Smith			Rt. 1, Box 733
	Davie			Ft. Lauderdale, Fla.
	Broward County			
	Quarry—Sec. 4, T48S, R42E	X	X	
	Snyder Paving Company, Inc.			P. O. Box 1199
	Broward County			Ft. Lauderdale, Fla.
	Dania Quarry—Sec. 4, T51S, R42E	X	X	
	Ft. Lauderdale Quarry—Sec. 17, T49S, R42E	X	X	
	Sumter Lime Products			P. O. Box 6,
	Sumter County			Sumterville, Fla.
	Sumter Quarry—Sec. 18, T20S, R23E	X		
	Sunniland Limerock Company			Box 1547
	Collier County			Fort Myers, Fla.
	Sunniland Quarry—Sec. 29, T48S, R30E	X	X	
	Suwannee Limerock Company			Branford, Fla.
	Suwannee County			
	Ralph Quarry—Sec. 32, T5S, R14E	X	X	

Rock and Mineral Products 1954 and 1955 (continued)

Product	Company, Name and Location of Pit, Quarry, or Plant	Production Reported		Address
		1954	1955	
Limestone				
Crushed (cont'd)	Charlie Toppino & Sons, Inc. Monroe County Stock Island Quarry	X	X	Box 787 Key West, Fla.
	Troup Quarries, Inc. Dade County Kendall Quarry—Sec. 15, T55S, R40E Perrine Quarry—Sec. 29, T55S, R40E	X X	X X	P. O. Box 168 Miami 33, Fla.
	United Limerock Company Levy County Williston Quarry	X	X	P. O. Box 4667 Jacksonville, Fla.
	W. & M. Construction, Inc. Levy County Raleigh Quarry—Sec. 24, T12S, R18E	X	X	Williston, Fla.
	West Florida Lime Company Jackson County Cottdale Quarry (Developing)			Cottdale, Fla.
	Williston Shell Rock Company Alachua County Buda Quarry—Sec. 32, T8S, R17E Haile Quarry Lafayette County Dell Quarry—Sec. 32, T4S, R11E	X X X	X X X	Box 600 Ocala, Fla.
	R. H. Wright & Son, Inc. Broward County Wright Quarry	X	X	Box 781 Ft. Lauderdale, Fla.
	Zinke-Smith, Inc. Broward County Quarry—Sec. 31, T48S, R42E	X	X	Box 2004 Pompano Beach, Fla.

Rock and Mineral Products 1954 and 1955 (continued)

Product	Company, Name and Location of Pit, Quarry, or Plant	Production Reported		Address
		1954	1955	
Non-Commercial	Palm Beach County Highway Department Palm Beach County County Quarries	X	X	Box 2429 West Palm Beach, Fla.
Dimensional	Bradenton Stone Company, Inc. (Dolomite) Manatee County Bradenton Quarry—Sec. 32, T34S, R18E (Mill at Oneco under development 1956)			P. O. Box 256 Bradenton, Fla.
	Florida Travertine Company (Dolomite) Manatee County Clark's Quarry—Sec. 7, T35S, R18E (Under development—Formerly Alclaries Travertine Company)			Oneco, Fla.
	Keystone Art Company Monroe County Windleys Key Quarry	X	X	684 NW 7th Street Miami, Fla.
	Native Stone, Incorporated Dade County Ball Quarry	X	X	Box 252 Miami 43, Fla.
	Bay Dredging & Construction Company Hillsborough County Dredge—Lease No. 639		X	P. O. Box 1484 Tampa 1, Fla.
	Duval Engineering & Contracting Company Duval County Dredge		X	Box 1588 Jacksonville, Fla.
Oyster Shell	White Shell Corporation Duval County Dredge		X	1746 E. Adams St. Jacksonville, Fla.

Rock and Mineral Products 1954 and 1955 (continued)

Product	Company, Name and Location of Pit, Quarry, or Plant	Production Reported		Address
		1954	1955	
Monazite	Florida Ore Processing Company Brevard County Palm Bay Plant (Destroyed by fire 1955)	X	X	Box 417 Melbourne, Fla.
	Humphreys Gold Corporation Duval County Jacksonville Plant—Sec. 13, T2S, R27E Owned by: Rutile Mining Company of Florida and National Lead Company	X	X	Box 5492 Jacksonville 7, Fla.
Natural Gas	Humble Oil and Refining Company Collier County Sunniland Field—Sec. 13, T48S, R29E and Secs. 18, 19, 20, T48S, R30E	X	X	Box C Everglades, Fla.
Peat	Agricultural Organics Corporation Hillsborough County Seffner Pit—Sec. 2, T29S, R20E	X	X	Rt. 1, Box 25 Seffner, Fla.
	Arnold Soil Company Broward County Ft. Lauderdale Pit		X	P. O. Box 558 Ft. Lauderdale, Fla.
	Daetwyler Peat Mine Orange County Pine Castle Pit	X	X	Rt. 7, Box 535 Orlando, Fla.
	Fernwood Humus Company Orange County Zellwood Pit	X	X	P. O. Box 183 Zellwood, Fla.

Rock and Mineral Products 1954 and 1955 (continued)

Product	Company, Name and Location of Pit, Quarry, or Plant	Production Reported		Address
		1954	1955	
Peat (cont'd)	Glen St. Mary Nurseries Company Putnam County Florahome Pit—Sec. 11, T9S, R24E	X	X	Glen St. Mary, Fla.
	Jack O. Holmes, Inc. Hillsborough County Tampa Pit	X	X	P. O. Box 417 Tampa 1, Fla.
	Norman R. and G. M. Latham Palm Beach County West Palm Beach Pit	X	X	P. O. Box 165 West Palm Beach, Fla.
	Mulford-Hickerson Peat Humus Corp. Orange County Apopka Pit	X	X	P. O. Box 156 Apopka, Fla.
	Palatka Peat Humus Company Putnam County Florahome Pit—Sec. 11, T7S, R24E		X	P. O. Box 404 Palatka, Fla.
	Southern States Nurseries, Inc. Putnam County Florahome Pit—Secs. 2 & 11, T9S, R24E	X	X	Macclenny, Fla.
	Tropical Peat Moss Company Hamilton County Jasper Pit		X	P. O. Box 428 Jasper, Fla.
Petroleum	Humble Oil and Refining Company Collier County Sunniland Field—Sec. 13, T48S, R29E and Secs. 18, 19, 20, T48S, R30E	X	X	Box C Everglades, Fla.

Rock and Mineral Products 1954 and 1955 (continued)

Product	Company, Name and Location of Pit, Quarry, or Plant	Production Reported		Address
		1954	1955	
Petroleum (cont'd)	Gulf Oil Company Dade County Forty-Mile Bend Field—Sec. 16, T54S, R35E, and Sec. 18, T54S, R36E (abandoned 1955)	X	X	P. O. Drawer 2100 Houston, Texas
Phosphate Rock Hard Rock	Kibler-Camp Phosphate Enterprise Citrus County Sec. 17 mine, T17S, R19E	X	X	Box 608 Ocala, Fla.
Soft Rock or Colloidal Clay	The Camp Phosphate Company (The Delta Phosphate Company) Citrus County Hernando Mine		X	Ocala, Fla.
	The Howard Phosphate Company Citrus County Inverness Mine	X	X	Box 3028 Orlando, Fla.
	The Kellogg Company Citrus County Hernando Mine—Sec. 23, T17S, R19E	X	X	P. O. Box 665 Ocala, Fla.
	The Loncala Phosphate Company Columbia County Fort White Mine	X	X	Box 338 High Springs, Fla.
	Gilchrist County Mona Mine—Sec. 25, T10S, R16E	X	X	
	Pedrick and Bernard Marion County Morrison Mine—Sec. 25, T14S, R19E	X	X	Dunnellon, Fla.

Rock and Mineral Products 1954 and 1955 (continued)

Product	Company, Name and Location of Pit, Quarry, or Plant	Production Reported		Address
		1954	1955	
Phosphate Rock Soft Rock or Colloidal Clay (cont'd)	Soil Builders, Inc. Citrus County Mincoll Mine—Sec. 23, T18S, R19E	X	X	Box 368 Dunnellon, Fla.
	The Sun Phosphate Company Citrus County Sec. 34 Mine—T17S, R19E (Previously reporting as: Knight & Bevis Seaboard Phosphate Company Globe Phosphate Company)	X X X	X	Dunnellon, Fla.
	The Superior Phosphate Company Citrus County Bar Mine—Sec. 20, T17S, R19E	X	X	Box 476 Dunnellon, Fla.
	The American Agricultural Chemical Co. Hillsborough County Boyette Mine—Sec. 14, T31S, R21E	X	X	Pierce, Fla.
	Polk County South Pierce tract, No. 12 Mine, Sec. 31, T31S, R24E	X	X	
	American Cyanamid Company Hillsborough County Sydney Mine—Sec. 28, T29S, R21E	X	X	Brewster, Fla.
	Polk County Saddle Creek Mine—Sec. 36, T28S, R24E (To be abandoned)	X	X	
	Orange Park Mine—Sec. 22, T27S, R24E (Under development)			
Land Pebble				

Rock and Mineral Products 1954 and 1955 (continued)

Product	Company, Name and Location of Pit, Quarry, or Plant	Production Reported		Address
		1954	1955	
Phosphate Rock Land Pebble (cont'd)	Armour Fertilizer Works, Inc.			Bartow, Fla.
	Polk County			
	Bartow Mine—Secs. 11 & 12, T30S, R24E		X	
	Coronet Phosphate Company, a Division of Smith-Douglas Company, Inc.			P. O. Box 790 Plant City, Fla.
	Polk County			
	Tenoroc Mine—Secs. 26, 35, 36, T27S, R24E	X	X	
	Davison Chemical Company, a Division of W. R. Grace & Company			P. O. Box 471 Bartow, Fla.
	Polk County			
	Bonny Lake Mine—Sec. 33, T29S, R24E	X	X	
	Pauway Mine No. 4—Sec. 33, T28S, R24E	X	X	
	International Minerals & Chemical Corp.			P. O. Box 867 Bartow, Fla.
	Polk County			
	Achan Mine—Sec. 23, T30S, R23E	X	X	
	Noralyn Mine—Sec. 25, T30S, R23E	X	X	
	Peace Valley Mine—Sec. 10, T31S, R25E	X	X	
	Swift and Company			P. O. Box 200 Bartow, Fla.
	Polk County			
	Varn Mine—Sec. 31, T31S, R26E	X	X	
	Watson Mine—Secs. 5, 8, 9, T32S, R25E	X	X	
	Virginia-Carolina Chemical Corporation			Nichols, Fla.
	Polk County			
	Clear Spring Mine—Sec. 27, T39S, R25E	X	X	
	Homine Mine—Sec. 3, T31S, R25E	X	X	

Rock and Mineral Products 1954 and 1955 (continued)

Product	Company, Name and Location of Pit, Quarry, or Plant	Production Reported		Address
		1954	1955	
Rutile	Florida Ore Processing Company Brevard County Palm Bay Plant (Destroyed by fire 1955)	X	X	P. O. Box 417 Melbourne, Fla.
	The Hobart Brothers Company Indian River County Winter Beach Plant—Sec. 4, T32S, R39E		X	Box 1482 Vero Beach, Fla.
	Rutile Mining Company of Florida and Titanium Alloy Manufacturing Division of the National Lead Company Duval County Jacksonville Plant—Sec. 13, T2S, R27E (Contractor: Humphreys Gold Corp. P. O. Box 5492, Jacksonville, Fla.)	X	X	P. O. Box 5492 Jacksonville, Fla.
	ABCO Concrete Company Brevard County Melbourne Pit (Ceased operation in Aug. 1955)	X	X	Box 846, Airport Melbourne, Fla.
	All-Florida Sand Company, Unincorporated Putnam County Interlachen Pit—Sec. 21, T10S, R24E	X	X	P. O. Box 4667 Jacksonville, Fla.
Sand and Gravel	Asa Maige Sand Company Leon County Norfleet Pit—Sec. 36, T1N, R1W	X	X	409 W. Gaines St. Tallahassee, Fla.
	E. E. Boone Construction Company Escambia County Bell's Head Dredge	X		Route 7, Box 378 Pensacola, Fla.

Rock and Mineral Products 1954 and 1955 (continued)

Product	Company, Name and Location of Pit, Quarry, or Plant	Production Reported		Address
		1954	1955	
Sand and Gravel (cont'd)	Brewton Engineering Company Bay County Mill Bayou Pit	X	X	P. O. Box 1039 Panama City, Fla.
	Campbell Sand & Gravel Company Escambia County Flomaton Mine—Sec. 22, T5N, R30W	X	X	Rt. 1, Box 89 Flomaton, Ala.
	C. & P. Dredging Company Brevard County Micco Dredge (Ceased operations 1954)	X		Box 101 Palm Bay, Fla.
	Cato Sand Company Bay County Mill Bayou Pit	X	X	Box 21, Springfield Station, Panama City, Fla.
	Central Sand Company Lake County Tavares Pit	X	X	P. O. Box 1175 Tavares, Fla.
	K. C. Chapman Volusia County Holly Hill Quarry—Sec. 37, T15S, R32E	X		547 N. Ridgewood Ave. Daytona Beach, Fla.
	Clark Sand Company Escambia County Pensacola Pit—Sec. 37, T2S, R30W	X	X	901 Dominquez Pensacola, Fla.
	Davenport Sand Company Polk County Davenport Pit—Sec. 24, T26S, R27E		X	P. O. Box 350 Lake Wales, Fla.
	Des Rochers Sand Company, Inc. Dade County Cape Florida Pit	X	X	3660 NW North River Drive, Miami 42, Fla.

Rock and Mineral Products 1954 and 1955 (continued)

Product	Company, Name and Location of Pit, Quarry, or Plant	Production Reported		Address
		1954	1955	
Sand and Gravel (cont'd)	Diamond Interlachen Sand Company Putnam County Interlachen Pit—Sec. 21, T10S, R24E	X	X	P. O. Box 4667 Jacksonville, Fla.
	F. A. Edwards Sand Company Manatee County Manatee River Dredge	X		Ellenton Road Palmetto, Fla.
	Florida East Coast Railway St. Lucie County St. Lucie Pit		X	St. Augustine, Fla.
	Florida Gravel Company Gadsden County Dredged from Apalachicola River	X	X	P. O. Box 156 Chattahoochee, Fla.
	Hauser Concrete Company Volusia County Volusia County Pit	X	X	336½ W. Michigan DeLand, Fla.
	A. E. Hoffman Osceola County Hoffman Pit		X	Skees Road West Palm Beach, Fla.
	Hoyt Sand and Muck Palm Beach County Pit—Sec. 20, T41S, R43E	X	X	Box 50 Lake Park, Fla.
	Ideal Crushed Stone Company, Inc. Dade County Dade County Pit—Sec. 4, T53S, R40E	X	X	5500 NW 37th Ave. Hialeah, Fla.
	Johnson Sand Company Leon County Norfleet Pit	X	X	1002 S. Adams St. Tallahassee, Fla.

Rock and Mineral Producers 1954 and 1955 (continued)

Product	Company, Name and Location of Pit, Quarry, or Plant	Production Reported		Address
		1954	1955	
Sand and Gravel (cont'd)	Keuka Sand Company Putnam County Keuka Pit—Sec. 29, T10S, R24E	X	X	Box H Edgar, Fla.
	Keystone Sand Company Putnam County Grandin Pit—Sec. 8, T9S, R24E	X	X	47 W. Forsyth St. Jacksonville, Fla.
	Lake Wales Concrete Sand Company Polk County Lake Wales Pit—Sec. 10, T30S, R28E	X	X	P. O. Box 707 Lake Wales, Fla.
	Lake Wales Independent Sand Company Polk County Independent Pit—Sec. 4, T30S, R28E	X	X	415 N. Scenic Hwy. Lake Wales, Fla.
	Largo Washed Sand Company, Inc. Pinellas County Largo Pit—Sec. 25, T29S, R15E	X	X	P. O. Box 677 Largo, Fla.
	MacCalla Brothers, Inc. Polk County Auburndale Pit	X	X	Box 791 Winter Haven, Fla.
	Mammoth Sand Company Polk County Lake Wales Pit	X	X	Pembroke, Fla.
	Middle Florida Sand Company, Inc. Leon County Tallahassee Pit—Sec. 5, T13N, R1W	X	X	P. O. Box 922 Tallahassee, Fla.
	Oak Ridge Sand Company, Inc. Polk County Achan Pit	X	X	P. O. Box 2565 Mulberry, Fla.

Rock and Mineral Producers 1954 and 1955 (continued)

Product	Company, Name and Location of Pit, Quarry, or Plant	Production Reported		Address
		1954	1955	
Sand and Gravel (cont'd)	Perry's Sand Company Okaloosa County Ft. Walton Pit	X		Box 525 Ft. Walton Beach, Fla.
	Sand Lake Development Company Dade County Tarbert Pit	X	X	260 NW 27th St. Miami 37, Fla.
	Jose N. Suarez Hillsborough County Suarez Pit	X		1708 Jetton Ave. Tampa, Fla.
	The Suwannee River Sand Company Lafayette County Dell Pit—Sec. 8, T4S, R11E	X	X	Drawer C Foley, Fla.
	Standard Sand and Silica Company Polk County Standard Pit—Sec. 27, T26S, R27E	X	X	P. O. Box 35 Davenport, Fla.
	E. C. Thompson Volusia County Barbour Pit—Sec. 37, T15S, R32E		X	109 S. Hollywood Ave. Daytona Beach, Fla.
	United Clay Mines Corporation Putnam County Crossley Mine—Sec. 27, T10S, R23E	X	X	P. O. Box 27 Hawthorne, Fla.
	B. M. Walker Indian River County Vero Beach Pit	X	X	1945 18th Ave. Vero Beach, Fla.
	Ward Gravel Company Escambia County Century Pit—Sec. 22, T5N, R30W	X	X	Route 1 Flomaton, Ala.

Rock and Mineral Producers 1954 and 1955 (continued)

Product	Company, Name and Location of Pit, Quarry, or Plant	Production Reported		Address
		1954	1955	
Sand and Gravel (cont'd)	White Sands & Materials Volusia County White Pit	X	X	Box 1168 New Smyrna Beach, Fla.
Staurolite	E. I. du Pont de Nemours and Company, Inc. Clay County Highland Plant—Sec. 18, T4S, R22E Trail Ridge Plant—Secs. 5 & 6, T6S, R23E (Contractor: Humphreys Gold Corp. P. O. Box 5492, Jacksonville 7, Fla.)	X X	X X	P. O. Box 631 Starke, Fla.
Zircon	Florida Ore Processing Company Brevard County Palm Bay Plant (Destroyed by fire 1955)	X	X	P. O. Box 417 Melbourne, Fla.
	The Hobart Brothers Company Indian River County Winter Beach Plant—Sec. 4, T32S, R39E		X	Box 1482 Vero Beach, Fla.
	Humphreys Gold Corporation Clay County Trail Ridge Plant—Sec. 13, T2S, R27E	X	X	Box 753 Starke, Fla.
	Rutile Mining Company of Florida and Titanium Alloy Manufacturing Division of the National Lead Company Duval County Jacksonville Plant—Sec. 13, T2S, R27E (Contractor: Humphreys Gold Corp. P. O. Box 5492, Jacksonville, Fla.)			P. O. Box 5492 Jacksonville, Fla.



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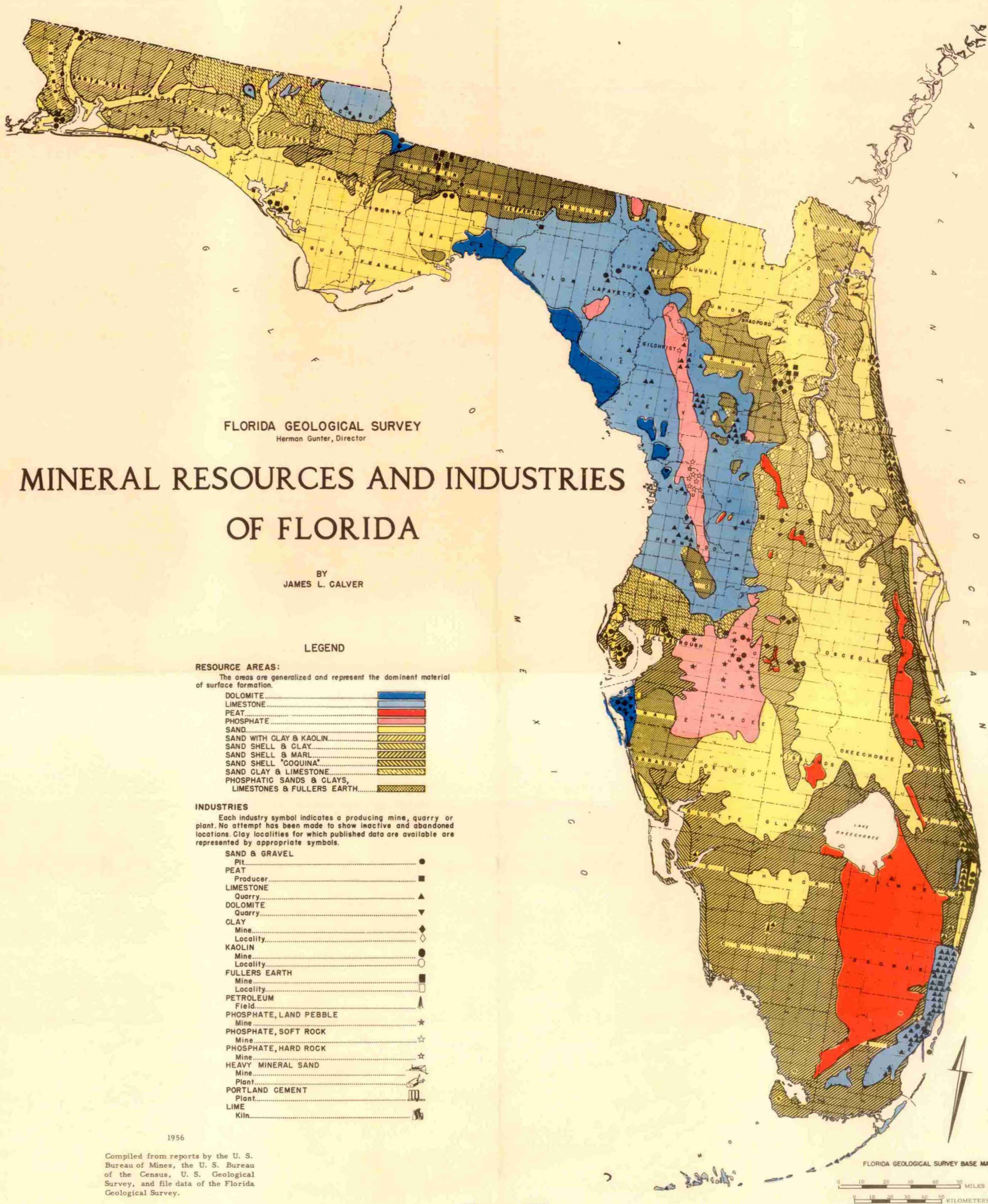
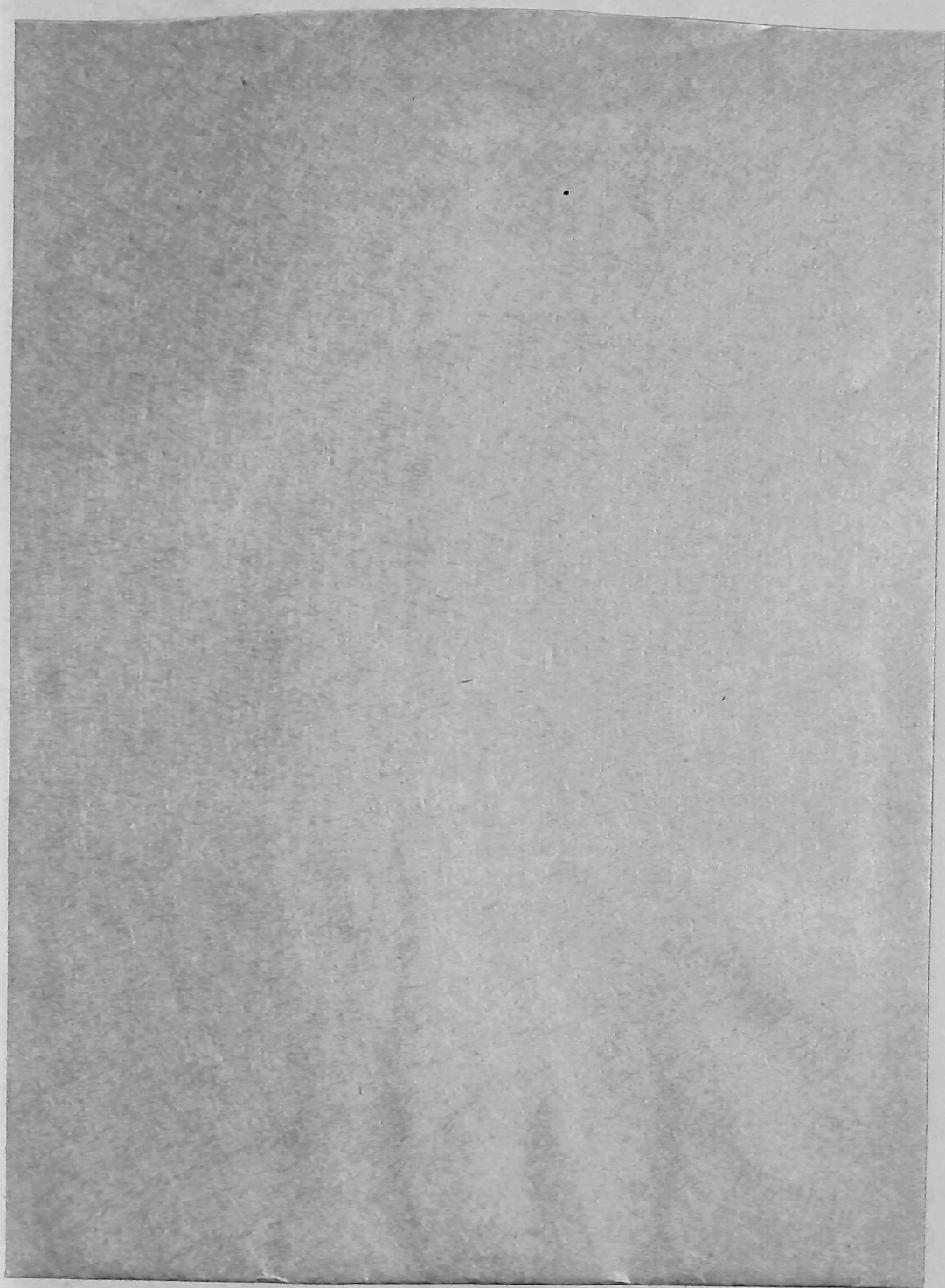


Figure 1



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