ECONOMIC GEOLOGY

INTRODUCTION

Hard-rock phosphate, limestone for road base courses, dolomite for soil conditioning and clay for cement production are the principal materials mined in Citrus and Levy counties. Minor quantities of sand for plaster and mortar, chert and hard limestone for cement aggregate and surfacing driveways are also produced for local consumption, but the quantity used is so small that no definite schedules are maintained.

A deposit of "limonite" in northeast Levy County could be developed as a source of ocher and additional information on the clays of the counties indicate that some of these could be used in the manufacture of structural clay products and fire brick. A resource map of Citrus and Levy counties is presented as figure 37.

Seven wells have been drilled sufficiently deep to test the possibilities of oil and gas in Levy County, but none has been drilled in Citrus County. All of these wells were dry and abandoned.

LIMESTONE

Introduction: Limestone is a sedimentary rock composed essentially of the mineral calcite ($CaCO_3$), sometimes in combination with varying amounts of the mineral dolomite [$Ca(Mg,Fe)(CO_3)_2$] and containing minor impurities, the more common of which are iron oxides, clay, silica, alumina, and vegetable matter. In Citrus and Levy counties limestone occurs in formations of Eocene and Oligocene ages. The Ocala limestone and the Williston member of the Moodys Branch formation are extensively mined near Williston and temporary pits were opened along improved roads during construction. The rock is a soft, porous, massive, detrital limestone composed of fossil shells, grains and nodules of calcite in a pasty matrix and is used for road base courses, upon which the road surface is placed.

The Inglis member of the Moodys Branch formation is similar to the limestone of the Ocala limestone, but is harder and case-hardens upon weathering. Local and irregular deposits can be used for concrete aggregate, but the limestone is used as a road base course only where

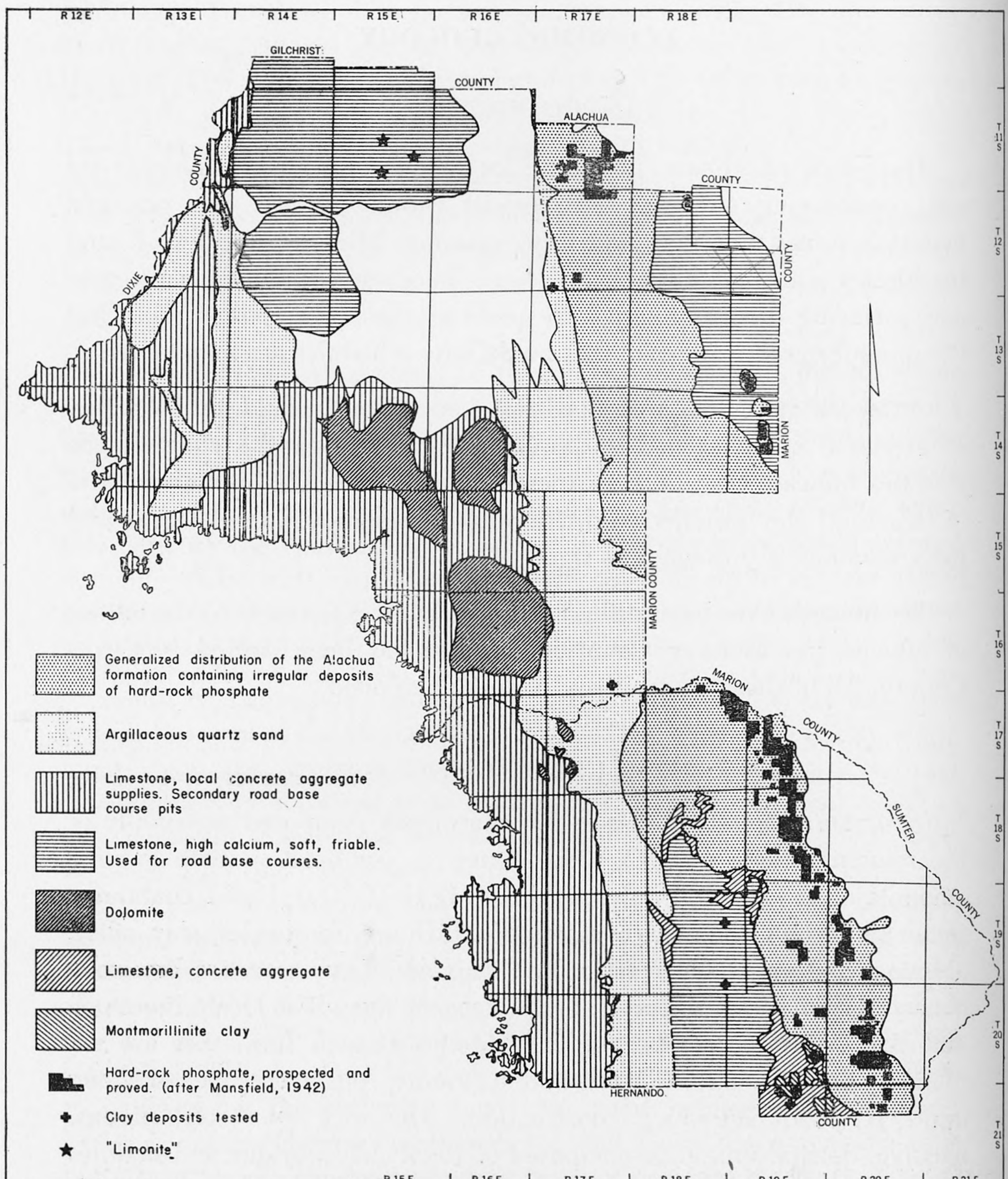

Figure 37. Distribution of the economic deposits of Citrus and Levy Counties.

it is the most available material. The Suwannee limestone is a thin-bedded, fairly hard, slightly sandy, detrital limestone. Interbedded, hard and soft layers and irregular masses make mining rather expensive since the hard layers make poor road base courses, and the soft layers can not be used for aggregate. No use is now made of the limestone except for

road base course material obtained from temporary pits opened along roads under construction in Citrus County. At least two pits were opened in Citrus County and concrete aggregate was produced, but the pits have been abandoned.

Citrus and Levy counties are abundantly supplied with limestone that occurs beneath a shallow overburden. The distribution of the rock is shown on figure 37. Mining of limestone is the second largest mineral industry in Levy County, in spite of a low sales price.

Mining Methods: Six companies have mined road base course limestone in Citrus and Levy counties during the past five years, and in 1949, three of these reported production. These companies all follow similar mining practices. The quarry is generally opened by clearing brush and trees and scraping off the sand and clay overburden. Clay filled solution pipes and irregular depressions are cleared manually, a slow and expensive job. The rock is dug by dragline and occasionally by scrape to a depth corresponding to ground-water levels. Truck road ways and more rarely pit car tracks are then extended on a level, fanning out to quarry faces, so that a high quarry face is maintained. The rock is drilled for shot holes and the quarry face is shattered by dynamite. The limestone is loaded by shovel to cable tram cars which are pulled up an incline and dumped directly into bins feeding a rock crusher. As the quarry face retreats from the crusher, the rock is loaded to trucks which dump into the tram cars, see figure 38.

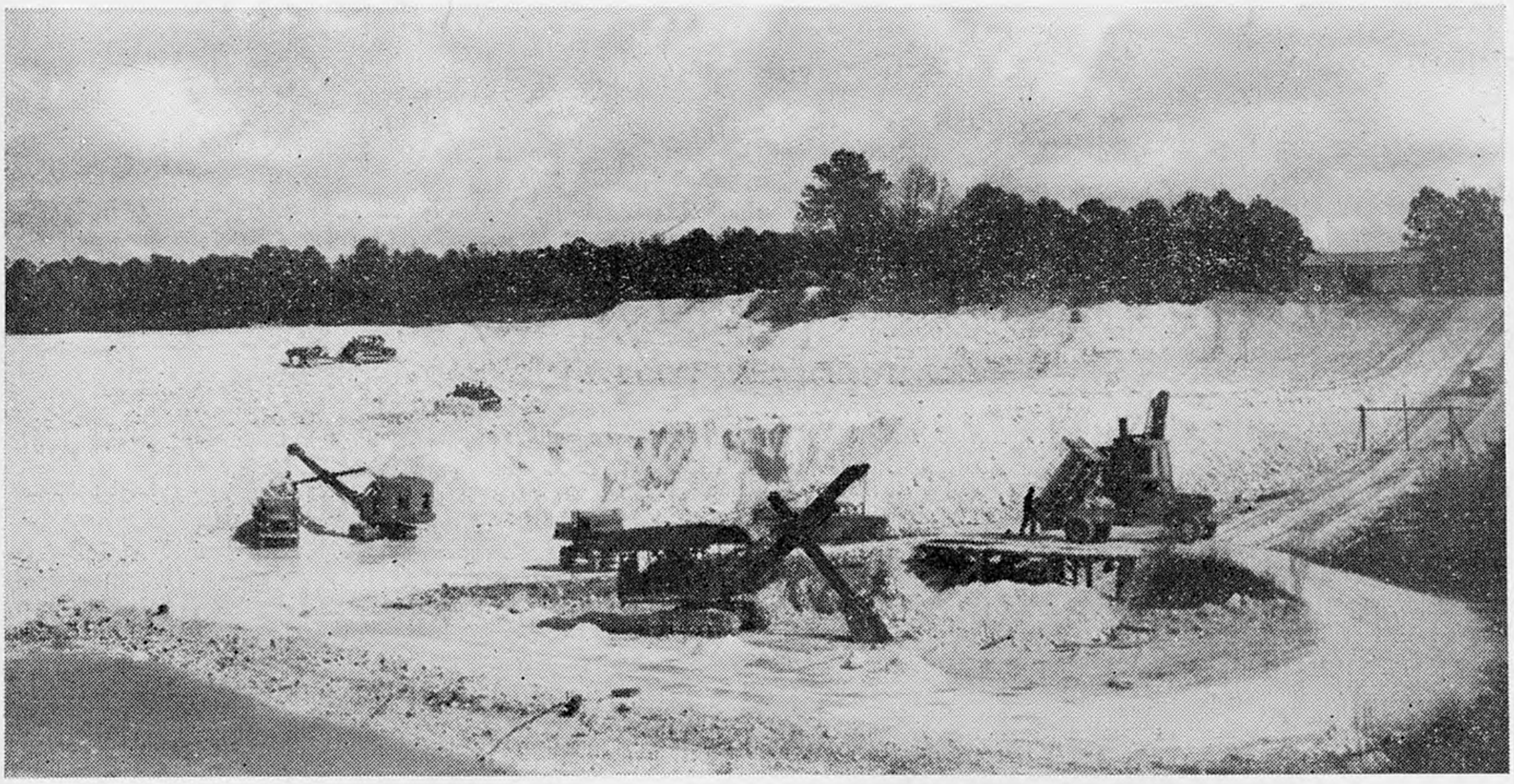

Figure 38. Pit of the Connell and Shultz Company in the NW ¼ SE ¼ Sec. 31, T. 12 S., R. 19 E., locality L-47, exposing 45 feet of Ocala limestone (restricted).

The companies commonly blast large masses of rock by drilling shot holes spaced about 10 feet back of the face and 10 feet apart. These are drilled to approximately the level of the bottom of the quarry and several shots are detonated simultaneously. The blast is usually controlled so that the rock is shattered sufficiently to be loaded directly from the quarry floor.

Uses and Market: The limestone mined in Citrus and Levy counties is used almost exclusively as a road base course material that is packed into the road grade and serves as the foundation for the concrete or macadam-gravel road surface. The prosperity of the industry is directly dependent upon the construction of highways in the State, almost all of the production being sold to road-building contractors. Minor quantities are sold for airport runway base courses, and some of the fine screenings are sold for soil application. The limestone sells for one dollar per ton but sold for only 90 cents per ton up until 1939. Approximately 95 per cent of the production is shipped by rail and the remainder by truck.

The limestone of the Eocene in these counties analyzes 98 to 99 per cent calcium carbonate, with the impurities being principally clay. Only the raw limestone, without refinement, is used and no product is manufactured from it. Lime is produced in only two plants in the State, and the limestone of these counties would make excellent lime if the soft, friable, pure rock could be burned in rotary kilns to overcome the tendency of the limestone to pack in vertical kilns. The low content of magnesium in the limestone would make the rock suitable for use in cement as well as in high calcium lime.

Keller and Quirk (1939) listed limestone as being used 63 times in 150 industrial chemical processes, used as keys for a study of manufacturing. The great utility of limestone favors the development of the large deposits, under little to no cover, located near railroads connecting large population centers; with emphasis on producing refined and manufactured lime products. The limestone is of such purity that it can be used in almost any chemical process where high calcium is a requirement, and combined with the clays of Citrus County, cement and rock wool manufacture are excellent possibilities of expanding the production of limestone.

Economic Expansion: In addition to the limestone in the vicinity of Williston, figure 37, an extensive area around Chiefland offers excellent mining possibilities. The cover is thin to absent and water levels lie 30 to 40 feet below the land surface. The Atlantic Coast Line Railroad

passes through Chiefland and land prices are reasonable, the area being sparsely settled. Although the entire area is underlain by limestone, no stone that can be quarried and used as a building stone is present. The excessive friability and lack of cementing matrix prevents the soft Eocene and Oligocene limestones from being used for this purpose. No other stone is readily available for building although locally, boulders of chert and flint, residuum from the solution of limestone, are abundant and in Williston, Levy County, several structures have been constructed from these rocks.

The Suwannee limestone can be used for a concrete aggregate if a high sales price prevails. Two small pits located in the northwest quarter of Section 1, Township 21 South, Range 19 East, were operated to produce concrete aggregate but were closed soon after opening. The Seaboard Air Line Railway traverses the outcrop of the Suwannee limestone in southern Citrus County and several good possibilities for concrete aggregate production exist along the railroad. Fairly uniform, thin bedded, hard limestone was present in the two quarries mentioned above, and in a quarry in the southeast quarter of Section 24, Township 18 South, Range 18 East, in a new quarry not spotted on Plate 1 in the northeast quarter of Section 21, Township 20 South, Range 19 East, and on a high hill located in the northwest quarter of northeast quarter of Section 10, Township 21 South, Range 19 East.

DOLOMITE ROCK

Dolomite rock is composed of the mineral dolomite, a double carbonate of magnesium and calcium, combined according to the molecular weights of the two carbonates. Dolomite rock commonly contains some calcite, and in fact there are all gradations from pure calcitic limestone through dolomitic limestone, calcitic dolomite rock and dolomite rock. The rock in Citrus and Levy counties will consistently analyze 36 per cent magnesium carbonate and is therefore within the limits of a true dolomite rock. The dolomite produced at Lebanon, Levy County, by the Dixie Lime Products Company analyzes:

Analysis	Per cent
SiO_2	1.01
Al_2O_3	.56
Fe_2O_3	.22
CaO	33.03
MgO	17.49

Dolomite rock in Citrus and Levy counties is tan to brown, very porous, soft and friable, being composed of small euhedral rhombs of

dolomite loosely cemented and having the texture and grain size of siltstone. Thin beds are common in the quarries and locally the rock is thinly laminated by inclusions of carbonized plant remains and peat seams. Hardened ledges and rounded concretions of crystalline dolomite occur irregularly and are eliminated in the production of agricultural dolomite rock. The rock is confined to no particular horizon, being found in the Avon Park limestone of middle Eocene age, the Moodys Branch formation of upper Eocene age and formations of the Pleistocene. The beds being mined by the Dixie Lime Products Company at a pit located near Lebanon, Levy County, in the southwest quarter northeast quarter, Section 12, Township 16 South, Range 16 East, is upper and middle Eocene. That mined by the Golden Dolomite Company in a pit at Red Level, Citrus County, in the northwest quarter southeast quarter of Section 25, Township 17 South, Range 16 East is upper Eocene.

Mining Methods: The pit is cleared of shallow sandy soil overburden by bulldozers, and clay filled fissures are cleaned by dragline and hand labor. The soft rock is shattered by blasting and piled by a scraper-dumper or by dragline excavators into long rows where it is air dried. Small mechanical shovels load the rock on trucks that transport it to drying sheds, where the moisture is reduced to a minimum and pulverized, sacked and loaded into boxcars. The Dixie Lime Products Company must haul the rock five miles from the pit to the plant located at Lebanon Station. The Golden Dolomite Company's plant is located at the pit but the sacked dolomite must be trucked to Crystal River or Dunnellon for transhipment by rail.

The rock extends below water levels and must be mined under water by a dragline excavator or by suction dredge. The depth of mining at the Lebanon pit is governed by a limestone floor, the pit seldom going below 17 feet. Prospect holes have been drilled at Red Level to a depth of 55 feet in dolomite. The depth of the pit is governed by water levels and the limitations of the equipment, and is probably about 30 feet below the ground surface.

Uses: The entire production of dolomite rock mined in Florida is used as a soil conditioner or fertilizer filler and only the softer portion is used, the harder elements being eliminated as waste. Shipment of the bagged dolomite is largely by rail but local sales are delivered by truck. The very finely crystalline, friable dolomite is easily pulverized in a roll crusher and allows a low sales price for soil conditioners. The rock is not refined and no manufactured products are made from it. A study of the economy of the deposit would indicate that since there is no production

of magnesium lime and only two producers of calcium lime in the State, there is a good possibility that lime could be manufactured from the rock. The product would have little competition within the State and would have the advantage of freight differentials in competing with Alabama and Georgia lime. The soft friable nature of the deposit would require that the rock be burned in a rotary kiln. Fuel oil is available by barge at Inglis and Crystal River and it would have to be trucked to the kilns at the pits or the kilns would have to be constructed at Inglis and Crystal River and the rock trucked there.

The harder elements of the dolomite rock, eliminated now in mining, if crushed, could be sold as concrete aggregate. If uncrushed, they offer some use as rip-rap and rubble. The softer dolomite, easily pulverized, could be used for fillers in putty, paint, and rubber and as a substitute for chalk whiting. Pure limestone, however, is generally preferred for these uses.

The Florida Geological Survey and the Florida Engineering and Testing Station at Gainesville are currently engaged in a study of the possibilities of production of rock wool from limestones and dolomite. Deposits of carbonates located near large population centers favor their development at the expense of these deposits in Citrus and Levy counties, but dolomite rock can be used in the manufacture of rock wool.

Reserves: Figure 37 shows the distribution of dolomite in Citrus and Levy counties and a number of areas appear to offer excellent mining possibilities. East of the town of Gulf Hammock the area is relatively high, the rock has little overburden and crops out almost continuously. The Atlantic Coast Line Railroad passes through the town. The hammock extending over much of Township 14 South, Range 15 East in Levy County is paved by dolomite and an area in Section 10 was prospected to depths of 30 feet. Water levels are generally high and the rock would have to be trucked approximately six miles to a railroad. A similar deposit is present throughout the hammock in the north half of Township 16 South, Range 16 East.

Three small deposits of dolomite are present in the east half of Township 17 South, Range 17 East, the most southerly of which is located on Rubington Turner's farm. Prospect holes penetrated at least 20 feet of dolomite. The area is relatively high, and covered by a thin sand overburden which favor its development, but the finished product must be trucked at least six miles to a railway.

The dolomite rock near the town of Gulf Hammock appears to have

the best chance of successful development. This large deposit and the additional reserves in the county warrants the expansion of the industry and the investigation of the possibilities of manufacturing a refined product from these dolomites.

PHOSPHATE ROCK

INTRODUCTION

Phosphate rock is a general term that applies to any rock containing a distinctive amount of phosphorus. The mineral is a form of fluorapatite to which the general terms collophane and phosphorite have been applied. Frondel (1943, p. 215) found that most insular phosphate is a member of the apatite series, usually a carbonate-hydroxyl-fluorine-apatite, and that collophane was a submicro-crystalline variety of apatite. Physically and chemically the Florida phosphate is within the limits of the mineral apatite. It occurs as nodules and pebbles in the Hawthorn formation, of Miocene age, and as detrital particles ranging in size from colloidal clay to boulders in sediments ranging in age from Miocene to Recent.

Three types of phosphate rock are being mined in Florida: land-pebble in Polk and Hillsborough counties; hard-rock in Citrus County; and soft-rock or phosphate-clay in Alachua, Marion, Citrus and Polk counties. In former years two additional types were mined; plate-rock (a type of hard-rock), and river-pebble. The only deposits mined in Citrus and Levy counties are hard-rock and soft-rock phosphate. The last mentioned is the waste from hard-rock plants. Only one schedule mining hard-rock phosphate and seven preparing phosphate-clay are maintained. In former years the hard-rock phosphate fields led in production, but the more abundant and more easily mined land-pebble phosphate has been first since 1906 and now 97 to 98 per cent of the phosphate mined in Florida is from the land-pebble field.

HARD ROCK PHOSPHATE

The hard-rock phosphate occurs in the base of the Alachua formation, Miocene(?) in age, which is well-exposed in many abandoned pits. The only pit now operating is the Section 12 Mine, Kibler-Camp Phosphate Enterprise, the mine and plant being located in the northeast quarter of Section 12, Township 17 South, Range 18 East.

Occurrence of Ore: The base of the Alachua formation is composed of the coarsest kind of conglomerate or rubble in a matrix of fuller's earth-

and phosphate-clays and quartz sand, the conglomerate being composed of boulders, rubble, pebbles and smaller detrital grains of phosphate, chert and silicified limestone. The ore fills depressions in Eocene limestones and encrusts the pinnacles of the very irregular Karrenfeld surface. The deposits are erratic, meanderform, fan-shaped in part and covered by a fine quartz sand set in a matrix of phosphate-clay. This clay fills the barren areas between deposits and the ore frequently ends abruptly against these clays. The phosphate boulders and pebbles are generally grouped and are sometimes surrounded by laminated phosphate and clay. In some pits the ore is associated with a delta-like fan of sandstone and flint pebbles, rounded and flattened, but more frequently large and angular. The phosphate pellets and boulders may be pure apatite but more frequently they contain quartz sand grains and many nodules are agglutinated pellets of varying colors. Many bone and tooth fragments are included.

The hard-rock phosphate occurs in elongate, meandrous, interrupted deposits, the generalized distribution of which is shown in figure 39, trending northwest-southeast and occupying the crest of the Ocala uplift. Its location suggests that the center of the arch, where faulting and jointing has been prominent, may have localized the phosphatization of Eocene limestones. Structurally low areas may also have acted as depositional basins in which conglomerates and stream deposits may have accumulated.

In mining, the operators have found that each deposit differed in location with respect to topography, in thickness of overburden, percentage of ore, and grain size distribution. The characteristics of each deposit are obtained only after careful and expensive prospect drilling. The tonnage of overburden and low grade ore that it is necessary to handle to obtain a ton of ore varies within a workable deposit and from one pit to another, but under improved methods of separation the recovery of phosphate has steadily increased. It is not possible to work continuously on one face because the ore will have pinched out, the grade being too low or excessive cover having precluded remunerative operations. Each pit is mined according to the prospect data, the operator following the rich deposits and avoiding or eliminating the low grade ore.

Prospect Methods: A combination of drilling methods is used in prospecting. The upper 20 to 30 feet is constructed by a jeep-mounted, hydraulically operated soil-auger or by hand labor using a method known as "cupping", in which a modified pipe resembling a post-hole digger is dropped into the hole and a small sample is recovered. Small lengths

of pipe are screwed into the cup to extend the handle. Upon completion of "cupping" a cable-tool drilling rig is moved on the hole, casing is driven to the bottom and the hole is jetted to the top of the matrix, by means of a 1-1/4 inch pipe in the casing. Large boulders often prevent jet drilling and the hole is completed by the cable-tool rig, using churn-drill methods. An accurate driller's log is kept on each hole, and the richness of the ore is determined by inspection of the samples, bailed from the hole. Core samples are occasionally obtained by driving the casing into the ore and pulling the casing by hydraulic jacks to recover the sample.

A composite sample of the ore from each hole is analyzed for bone phosphate of lime (B.P.L.) the unit of sale, iron and aluminum (I and A) and insolubles, and the data from each hole are compiled and placed on prospect maps that show the volume of overburden and matrix and the tonnage of phosphate rock. The estimates of phosphate are prepared from a prospect grid, drilled one hole to 50 feet although occasionally shorter spacing is required, and the average tonnage and grade of rock recovered commonly runs higher than the estimate.

Mining Methods: The overburden in the hard-rock phosphate field may exceed 70 feet and the quantity removed depends upon an economical ratio with the tonnage of phosphate removed. Kibler (1941) reported that up to 15 cubic yards of overburden and matrix may be removed economically for each ton of phosphate and a ratio of 12 to 1 is considered to be good. The overburden is washed by high velocity hydraulic guns into a sump, in which sand pumps force the material over the rim of the pit into an abandoned pit or a waste disposal sump. Water to operate the hydraulic gun is available from the pit or from a well drilled into the underlying limestone bedrock.

The ore is mined by a large electric walking dragline that can reach to a depth of 50 feet below its foundation, and the ore is loaded into cable skip cars of 7 cubic yards capacity. Boulders of phosphate too large to go into the car are broken by dynamite. Large boulders of chert, limestone, silicified limestone and low grade matrix are piled into the mined portions of the pit by the dragline, or these are avoided in mining and left standing. The cable car is pulled up a steep incline and dumps automatically on a dumping skid.

The phosphate rock is cleansed, sorted, and marketable grades of phosphate are prepared. The treatment is illustrated in figure 39, a flow sheet for the Secton 12 Mine, Kibler-Camp Phosphate Enterprise, the only hard-rock company operating in the State at present.

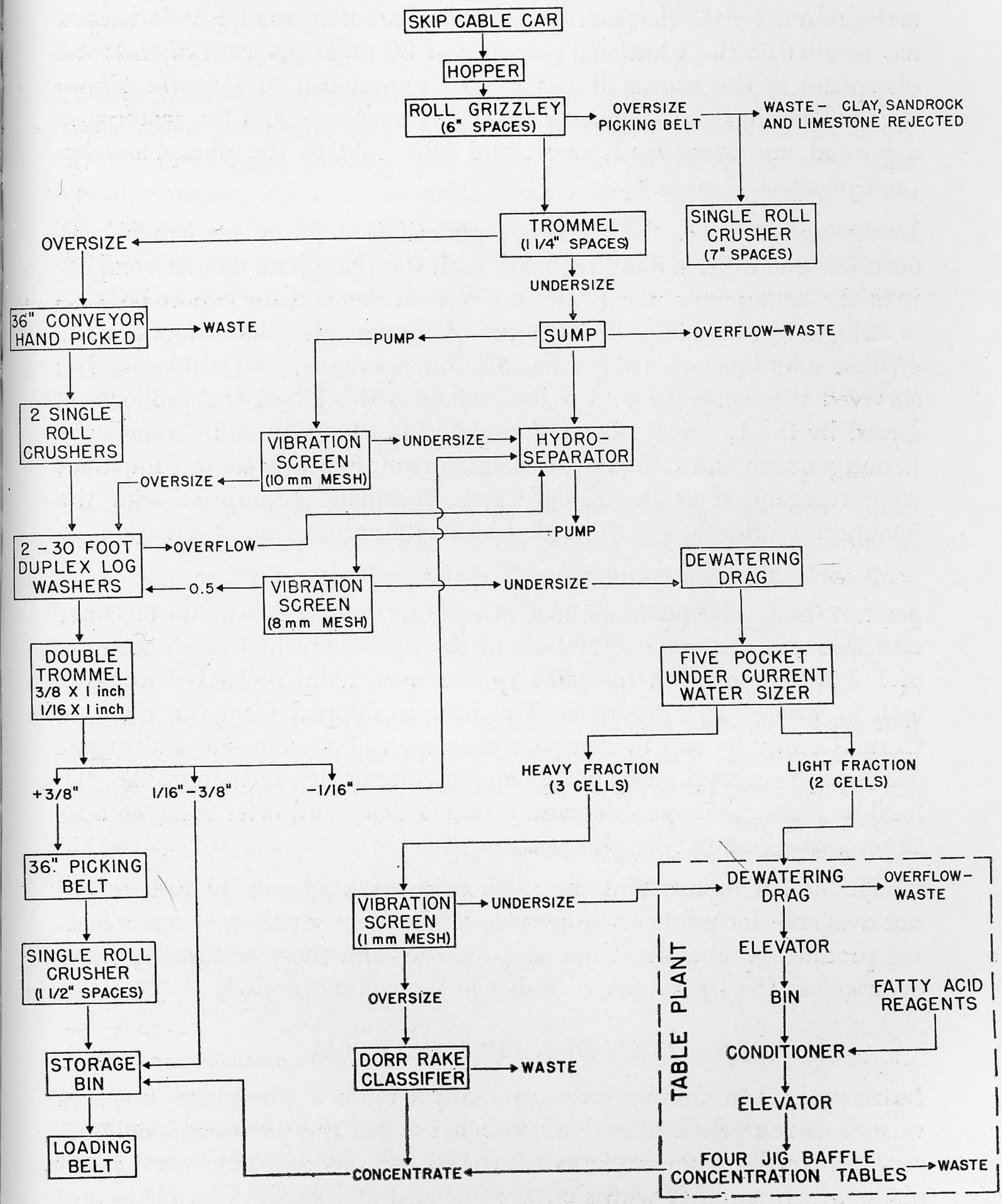

Figure 39. Flow sheet for the Section 12 Mine, Kibler-Camp Phosphate Enterprise.

The installation of fine screens, flotation chambers, and jig-baffle tables to recover the fine particles of phosphate that was formerly wasted has resulted in the additional recovery of 30 to 40 per cent of the total phosphate in the matrix. It has proved impractical to save the slimes because the iron and aluminum content is too large, and the material is deposited into large land sumps and later sold to the phosphate-clay (soft-phosphate) industry.

Marketing: Because the hard-rock phosphate deposits are irregular in occurrence and the mining costs are high the phosphate cannot compete with the land-pebble phosphate, but it is in demand for export because of a higher grade. The development of foreign phosphate deposits has created additional hardships for Florida operators, and only one has survived the competition. Up until about 1949, all of the production, mined by the C. and J. Camp Company, was sold abroad through the J. Buttgenbach and Company, a Belgian firm. Recently these companies were reorganized as the Kibler-Camp Phosphate Enterprise with the intention of offering a high grade phosphate on the domestic market.

Hard-rock phosphate is usually sold on a basis of 75/74 and 77/76 per cent bone phosphate of lime ($Ca_3P_2O_8$) with a maximum of 3 per cent iron and aluminum. The bulk of the rock is crushed to a maximum of 1/2-inch lumps, but for some special uses, lump rocks 1/2 to 2-1/2 inch in size, is also produced. The rock is shipped from the plant in Citrus County by rail to domestic consumers. For domestic and export use requiring a high grade phosphate, low impurities and large sizes, the hard-rock phosphate can demand a higher price and offer some competition to the land-pebble phosphate.

Production figures and the sales price of hard-rock phosphate are not available for publication because of the Survey policy of not releasing production tabulations unless combined with those of three or more companies. The figures are included in the county totals.

COLLOIDAL PHOSPHATE-CLAY

Introducton: In former years probably as much phosphate ore was wasted as recovered. Flotation was not used in the plants and only recently have the modern plants recovered the silt- and sand-sized phosphate which together with slimes, composed of colloidal phosphate and clay, were washed into an abandoned pit or into a series of constructed reservoirs from which the water was recovered after the sediment had deposited. These slimes are sufficiently rich that a guarantee of a minimum of 15 per cent calcium and 8 per cent phosphorous can be made.

The abandoned sump areas are being mined and the phosphate is used as a soil conditioner, in feed where a high fluorine content is not harmful, and in fertilizers as a filler.

Mining Methods: Abandoned sump areas are leased or bought and drained where water levels require it. The cover of vegetation is removed, the surface harrowed and the material turned into loosely piled windrows where the sun and wind reduce the moisture content to the point that it can be stored in drying sheds where the moisture is reduced further and the material is kept out of the weather. Experience has proved that it is impractical, because of low sales price and the volume of material, to completely dry the clay under cover. The air dried phosphate is loaded at the pit by a shovel or ditch digger onto trucks that transport the clay to the storage sheds. When completely dry the clay is pulverized, air separated from sand and other impurities, sacked and shipped by truck or rail.

Operators: Colloidal clay-phosphate, soft phosphate, soft-rock phosphate and phosphatic clay are all names for the soft phosphate, which is mined by the Colloidal Phosphate Sales Company, Soil Builders, Inc., Superior Phosphate Company with offices in Dunnellon, Florida, and the Kellogg Company, with its office in Ocala, Florida. The Seaboard Phosphate Company is a sales company for Soil Builders, Inc.

Deposits are relatively shallow usually and the mining is governed by high water levels, and availability of the deposits. Operations move periodically but at the present, deposits are being mined as follows:

1) Center of Sec. 10, T. 18 S., R. 19 E.
2) NW ¼ of Sec. 23, T. 18 S., R. 19 E.
3) SW ¼, SE ¼ of Sec. 34, T. 17 S., R. 19 E.
4) NE ¼, SE ¼ of Sec. 34, T. 17 S., R. 19 E.
5) SW ¼, NE ¼ of Sec. 19, T. 17 S., R. 19 E.
6) SW ¼, SE ¼ of Sec. 18, T. 17 S., R. 19 E.
7) SE ¼ of Sec. 12 T. 17 S., R. 18 E.

Numerous other pits in the counties are under lease to the operating companies and production is assured for a number of years. In addition to the abandoned phosphate slime pits the clay-phosphate that occurs in the upper part of the Alachua formation as matrix for fine quartz sand is close to the phosphate ore in chemical analysis. A titrated clay sample from this bed was analyzed[31] as follows:

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[31]Dr. J. J. Taylor, State Chemist, letter dated August 18, 1948.

Analysis	Per cent
Total phosphoric acid	31.70
Insoluble phosphoric acid	27.85
Available phosphoric acid	3.85
Silica as SiO_2 (sand grains)	5.07
Aluminum as Al_2O_3	10.70
Iron as Fe_2O_3	1.14
CO_2	2.32

This analysis indicates that it might be possible to mine the clay economically where there is no overburden to remove. The deposit could be pulverized and the sand separated by air and a product equal to, if not better than, that produced from the slime pits could be marketed.

Marketing: Specifications for clay-phosphate vary, but the State requires that the portion sold as soil conditioner or fertilizer show a guaranteed per cent of both total and available phosphoric acid, and the total is generally advertised as 28 per cent total B.P.L. One analysis shows the calcium content to range between 15.0 and 20.0 per cent, a minimum phosphorous content of 8.0 per cent and maximum fluoride of 2.0 per cent. The total production is sold to farmers, stock breeders, fertilizer producers, directly to the consumer and through farm supply houses. The product is bagged and shipped by truck and rail. Production figures are included in the county totals.

CLAY DEPOSITS

Introduction: The Hawthorn formation, cropping out in Citrus County, is a montmorillinite clay that contains lumps and seams of opal, see pages 188 to 189, and can be classified as a type of fuller's earth. A type of clay-phosphate occurs as the matrix of a fine sand in the upper part of the Alachua formation, and some clay deposits occur in the Marine terrace deposits of the Pamlico and Wicomico formations of Pleistocene age. The clay deposits are all irregular masses contained in and interbedded with other sediments. They range in thickness from a thin layer to as much as 40 feet, at the deepest clay mine. All of the clay has been deposited over a very irregular limestone eroded surface and the deposits differ greatly in thickness and content over short distances.

Tests: Samples of these clays were collected and submitted to the Engineering and Industrial Experiment Station, University of Florida, Gainesville, for determination of the physical and firing characteristics and for recommendation for uses. Table 17 and the discussion of the ceramics of the clays are compiled from reports of tests and studies made by R. S. Hagerman and A. F. Greaves-Walker of the Experiment Station.

Sample 1: Pit on the property of G. M. Cannon located on the center of section line, section 33 and 34, T. 16 S., R. 17 E., where 6 feet of gray to brown, argillaceous sand of the Wicomico formation is exposed.

Sample 2: Pit in the center of the SW ¼ Sec. 32, T. 12 S., R. 17 E., exposing 4.1 feet of blue clay of the Wicomico formation.

Sample 3: Abandoned phosphate pit in the SW ¼ NE ¼ Sec. 16, T. 20 S., R. 20 E., exposing the Alachua formation on the north side consisting of a 4-foot montmorillinite greenish-gray clay lying below 20 feet of sandy clay-phosphate. Sample 3 is the montmorillinite, sample 3a is a mixture of equal parts of montmorillinite and clay-phosphate, and sample 3b is a mixture of 70 per cent montmorillinite and 30 per cent clay-phosphate.

Sample 4: Abandoned Florida Portland Cement pit in the center of the NW ¼ Sec. 25, T. 20 S., R. 19 E., exposing 30.8 feet of montmorillinite clay of the Hawthorn formation. Sample 4 is a channel sample, 4a is composed of equal parts of the clay and sandy overburden.

Sample 5: Representative material from the present pit of the Florida Portland Cement Company located in the SW ¼ NW ¼ Sec. 2, T. 21 S., R. 19 E., exposing 25.0 feet of greenish-gray, montmorillinite clay of the Hawthorn formation.

Sample 6: Representative sample from gullies in the NE ¼ Sec. 10, T. 21 S., R. 19 E., on Mrs. Eugenia Whitehurst property, exposing 2 to 4 feet of mottled gray to tan, blocky clay containing lumps of weathered Suwannee limestone.

The specimens were extruded on a hand auger machine and fired in a Globar electric kiln to a maximum of cone 12 (2360°F). Trials were drawn at intervals from cone 07 to 12. Under the fast firing schedule used in the laboratory, higher temperatures are required than in commercial practice in order to obtain the same degree of vitrification. Comparable results in commercial kilns could be obtained approximately 200° below those used in the tests.

The clay of samples 1 and 2 fired to cone 12 have very little strength and are easily abraded and are therefore of little value for structural clay products. A mixture of the two clays might be used in a pottery body, with the addition of feldspar and other fluxes, that will fire buff-colored. Pyrometric equivalent tests indicate a mixture of 60 per cent sample 1 and 40 per cent sample 2 will make a fire brick that will meet specifications of the large percentage of the fire brick requirements in Florida. Sample 3 with some combinations of sandy clay, samples 3b and 3c, can be used as a structural clay, but the deposit is deeply buried and thin.

The very plastic clay of the Hawthorn formation, samples 4 and 5, and possibly weathered clays developed from the Suwannee limestone,

TABLE 17—TESTS OF CLAYS—Tests conducted according to standard specifications of the American Ceramic Society and the American Society for Testing Materials. [1]

SAMPLE DESIGNATION	1	2	3	3a	3b	4	4a	5	6
Physical Properties									
Plasticity	Fair	Good	Good	Poor	Excellent	Good	Excellent	Excellent	Excellent
Water of Plasticity, %	26.0	26.0	37.2	21.0	30.3	47.2	31.7	.....	.....
Linear Shrinkage (% dry length)	2.85	6.00	12.5	5.1	9.8	18.0	11.5	.....	.....
Rapidity of Drying	.....	.....	Medium	Medium	Medium	Very slow	Medium	.....	.....
Firing Behavior	.....	.....	Excellent F&B Cone 4 [4]	Excellent	Excellent	Poor,cracking	Excellent	.....	Good
Linear Firing Shrinkage (% dry length)									
Cone 07, 1787°F	+2.32 [2]	6.62	+2.0 [2]	0.5	0.5	9.6	2.8	.....	.....
Cone 05, 1886°F	.....	.....	+1.3 [2]	2.6	0.1	9.6	3.1	.....	.....
Cone 03, 1976°F	.....	.....	+1.8 [2]	1.6	0.8	9.7	4.6	.....	.....
Cone 1, 2057°F	.....	.....	8.5	2.3	3.3	10.5	5.7	.....	.....
Cone 4, 2129°F	.....	.....	.....	4.2	5.6	7.8	5.1	High	High
Cone 6, 2174°F	.....	.....	.....	4.6	7.2	4.6	5.4	.....	.....
Cone 8, 2237°F	.....	.....	.....	.....	.....	3.2	5.5	.....	.....
Cone 10, 2300°F	3.10	8.68	.....	.....	.....	.....	+6.3 [2]	.....	.....
Cone 12, 2390°F	3.26	8.68	.....	.....	.....	.....	.....	.....	.....
Absorption %									
Cone 07, 1787°F	21.4	23.6	23.2	11.5	15.9	5.2	17.1	.....	.....
Cone 05, 1886°F	.....	.....	23.2	12.1	16.9	5.4	15.9	.....	.....
Cone 03, 1976°F	.....	.....	20.0	12.6	14.8	5.0	15.9	.....	.....
Cone 1, 2057°F	.....	.....	4.0	12.4	10.8	4.9	16.5	.....	.....
Cone 4, 2129°F	.....	.....	.....	9.6	6.9	5.4	16.1	11.6	6.9
Cone 6, 2174°F	.....	.....	.....	7.3	3.6	8.0	15.1	.....	.....
Cone 8, 2237°F	.....	.....	.....	.....	.....	7.5	11.4	.....	.....
Cone 10, 2300°F	20.7	19.2	.....	.....	.....	.....	.....	.....	.....
Cone 12, 2390°F	20.4	19.8	.....	.....	.....	.....	.....	.....	.....
Color—Crude Dry	Cream	Blue-gray	Red-gray	Deep-buff	Orange-buff	Light-red	Buff	.....	.....
Cone 07, 1787°F	Light-salmon	Light-salmon	Orange	Orange-red	Orange	Light-red	Orange	.....	.....
Cone 05, 1886°F	.....	.....	Light-orange	Light-orange	Light-red	Light-red	Orange-brown	.....	.....
Cone 03, 1976°F	.....	.....	Red	Red	Red	Red-brown	Brown-orange	.....	.....
Cone 1, 2057°F	.....	.....	Brick-red	Red-brown	Red	Gray	Light-bloated-gray	.....	.....
Cone 4, 2129°F	.....	.....	Brick-red	Gray	Purple	Gray	Light-purple-red	Dirty-buff	Red
Cone 6, 2174°F	.....	.....	.....	Green	Black-gray	Light-green	Red-green	.....	.....
Cone 8, 2237°F	.....	.....	.....	Gray-green	Bloated-gray	.....	Green-gray	.....	.....
Cone 10, 2300°F	.....	.....	.....	Bloated-gray	.....	.....	Drab-red	.....	.....
Cone 12, 2390°F	Light-gray	Light-gray	.....	.....	.....	.....	.....	.....	.....
Best Firing Range	.....	.....	Cone 02 – 1	Cone 1 – 6	Cone 03 – 6	Cone 07 – 03	Cone 1 – 6	.....	.....
Class of Ware	Pottery & RB [3]	Pottery & RB	B, HT, DT, RT [3]	B,HT,DT,RT	B,HT DT,RT	B,HT,DT,RT	B, HT, DT, RT	Sandy clay bond	Sandy clay bond
Hardness	Less than steel	Less than steel	Steel	Steel	Steel	Steel	Steel	.....	.....

[1] Compiled from reports of tests made by R. S. Hagerman, Assistant Engineer, and A. F. Greaves–Walker, Research Engineer, Clay Laboratory, Engineering and Industrial Experiment Station, University of Florida, Gainesville, Florida.

[2] Expanded on heating.

[3] B = Brick; HT = Hollow Tile; DT = Drain Tile; RT = Roofing Tile. RB = Refractory Brick.

[4] Fused and bloated.

sample 6, will make excellent brick and tile if combined with sandy or silty clays and offer the best chance of developing a brick plant in these counties. The deposits are thick, under little cover, near a railroad and with widely spaced holes the deposits can be prospected over a large area.

Uses: The clays of the Hawthorn formation, sample 5, are mined in Citrus County by the Florida Portland Cement Company and freighted to Tampa, Florida, where it is calcined with limestone, mined in Hernando County, to make cement. A thin, weathered, sandy, black soil zone is removed as overburden. The clay is approximately 25 feet thick and is loaded by a rail mounted dragline directly into gondola railroad cars. An estimated reserve of 150,000 cubic yards is available at the present pit and prospecting should discover additional deposits nearby.

A number of very sandy clays are present in the counties. In order to determine the firing characteristics of these sediments, two samples from the Alachua formation and one from an exposure of weathered Hawthorn formation were tested. The samples were located as follows:

1) Five feet of red and tan mottled sandy clay of the Alachua formation, in pit west of the graded road in the NE ¼ SE ¼ Sec. 35, T. 19 S., R. 18 E.
2) A maximum of 12 feet of mottled red to yellow sandy clay of the Alachua formation extending along the top of a hill on a clay road in the SE ¼ SE ¼ Sec. 11, T. 19 S., R. 18 E.
3) Seventeen feet of weathered Hawthorn(?), blocky, variegated, sandy clay in Hernando County, a sink in the NW ¼ NW ¼ Sec. 5, T. 21 S., R. 19 E.

R. S. Hagerman[32] reported that these clays:

. . . "were all of a sandy nature with very little plasticity. The samples were difficult to extrude, feathered badly and broke easily. They could not be cut due to crumbling.

"Each clay may be good as an additive to a plastic clay but that seems the only possible use for them."

In view of this report and the relative isolation of the known sandy clays, they are considered to be of no economic value.

CEMENT

The area is adequately supplied with the materials necessary for cement manufacture. Soft, high quality limestone is available from not only the Williston area but relatively untouched supplies are present over most of northern and western Levy County and southern Citrus County. An opaline-rich, green clay occurs in southern Citrus County,

[32]Letter dated September 13, 1948.

and is now mined and shipped by the Portland Cement Company to Tampa, and combined with limestone mined in Hernando County.

If economics are considered, it is probably cheaper to locate the cement kiln in large population centers and ship the raw product to the kiln and out of the area. However, a plant site at Inglis or Crystal River where fuel oil can be barged in probably should be considered if the cement industry in Florida is expanded. Crystal River is the better site since both limestone and clay are available nearby and the finished product could be shipped by truck, rail, or water.

CHERT

Throughout most of the area in northeast Levy County, particularly in the vicinity of Runnels, Montbrook and Morriston there are thin deposits of chert lying upon Eocene limestone. This chert is the residuum of silicified portions of limestone, the more soluble parts of which have been removed by solution. The chert is tan to brown, dense to porous, angular blocks, nodules and pebbles and is embedded in the soils of the area.

Farmers pile this chert along their fences, eliminating them from plowed fields. The boulders are purchased periodically by local crushers that produce concrete aggregate. Mr. Ralph Swiney of the Florida Hard Rock Company, Raleigh, produced a small amount of this aggregate in 1946 and 1947.

Crushed flint has sharp edges, that increase the need for sand, when used as concrete aggregate. The absorption and the dry-rodded weight are usually low and the aggregate does not meet the specifications of the State Road Department for use in road surfaces. The crushed rock is sold locally for foundations of small structures and other limited concrete construction.

SAND

Sand occurs as thin deposits veneering Tertiary limestones throughout the low elevations of the counties, as thicker deposits bordering the Wicomico and Pamlico coast lines and along the Coharie-Okefenokee Sand Ridge. The distribution of the thicker deposits is shown on figure 37.

The sand of the Wicomico and Pamlico formations is argillaceous, fine to medium quartz grains; that of the Coharie-Okefenokee formations is only slightly coarser. Large deposits are present along the ridge and

water levels are low, but the sand of the Wicomico and Pamlico formation is usually saturated. These sands are used locally as aggregate and fill but are not mined commercially.

LIMONITE

Limonite is present over a large part of the southeastern portion of Township 11 South, Range 15 East, and concentrations are present in the southeast quarter of Section 16, northeast quarter of Section 21, south half of Section 23, north half of Section 26, southeast quarter of Section 28, and the northeast quarter of Section 33. The mineral is localized over the margins of the nose of a small structure over which the Inglis member of the Moodys Branch formation crops out, and the location of the limonite is obviously associated with the structure. The limonite is very irregular in occurrence and concentrations generally occupy solution depressions but the mineral is also scattered along limestone uplands as pebbles and boulders. Usually the strike of the limonite concentrations parallel the crest of the small fold. In many of the freshly plowed fields the soils are a brownish-red from the limonite nodules, the mapping of which led to the discovery of their relationship to structure.

The limonite is reddish-brown to black and is intimately mixed with fine quartz sand that is imbedded in the matrix. The surfaces of the nodules and boulders are paved with a smooth vitreous varnish-like coating, probably developed by the capillary movement of water from the interior of the nodule to the surface where a film of limonite was deposited. The interior is a yellow to reddish-brown, earthy, porous limonite, sometimes ocherous. The mineral occurs as subspherical masses that range in size from small nodules to boulders that are three feet in diameter and that are composed of smaller nodules of limonite and quartz sand grains cemented together. The iron content of the limonite varies depending to a large degree upon the percentage of sand contained in the nodules. One sample, believed to be representative of the deposit, was analyzed by the State Chemist[33], and found to contain 27.62 per cent SiO_2, 70.93 per cent Fe_2O_3, and a trace of P_2O_5.

No prospecting has been done during this study but a pit dug in the southeast quarter of Section 28, Township 11 South, Range 15 East, penetrated more than 20 feet of limonite nodules and loose quartz sand. The thickness and occurrence of the deposits, as well as the distribution, are highly variable. It is estimated, without an attempt to prospect the

[33]Letter from Dr. J. J. Taylor, State Chemist, dated September 9, 1947.

area, that approximately 50,000 tons of limonite is available. The deposit possibly could be utilized as a pigment. It is suggested that the limonite could be mined by shovel and beneficiated by modern methods. The concentrate could be pulverized and separated from sand by water suspension over a series of settling troughs or vats. The absence of overburden will assist in mining but the irregular occurrence and variable concentrations will increase the costs of recovery.

Only traces of iron-bearing minerals are present in the limestone of the upper Eocene and Oligocene and the deposit could not have been left as residuum from the erosion of these beds. Pyrite, glauconite and dolomite are common in the formations underlying the deposits, however, and the limonite rests upon a sharp but small fold along which fracturing has occurred. The occurrence of the limonite associated along the crest of the small fold in the Eocene limestones, where upward circulation of underground water would be easiest, suggests a possible source and origin of the limonite. The limonite is closely associated with limestone solution features, many of which were obvious water channels. Sink holes, natural wells, and karst topography are well-developed about the limonite and it occupies many of these depressions. The shape of the nodules likewise indicates precipitates from solution.

The beginning of limonite formation possibly started with the concentration of iron in solution in ground waters, by dissolving iron-bearing minerals in deeply buried limestones. Ground water rises to the surface in Citrus and Levy counties, this region being an area of artesian groundwater discharge, and such movements of water are active along water channels created by fracture over structurally high areas. Ground waters dissolve iron from pyrite and dolomite of the lower Eocene limestones and as they pass into the shattered limestone and emerge at the surface in swamps, the solutions are oxidized and the iron precipitated as limonite. Chemical reactions of iron and oxygen in solution and bacteria may also have contributed to the precipitation. In some cases the limonite was precipitated by reaction with the limestone, the limonite replacing the calcite, as evidenced by the excellent preservation of fossils in some of the limonite. There is no evidence that limonite was precipitated by descending waters having dissolved iron from rocks overlying the present bedrock, although doubtlessly the limonite has been concentrated downward by the solution and removal of the limestone after the limonite was originally precipitated.

The limonite is not used, but local residents report that the Confederacy mined the rock during the War Between the States and built

a small smelter in the southeast quarter of Section 28, Township 11 South, Range 15 East.

POSSIBILITIES OF OIL AND GAS PRODUCTION

No oil and gas have been produced in Citrus and Levy counties, and no wells have penetrated any shows. The commercial production of petroleum in these counties appears very unlikely but there are some structures in the counties that are favorable for testing, should factors of porosity, cover, and source beds prove adequate. Faulting, folding, unconformable overlaps, dense and porous interbedded carbonates are all present beneath the counties and the rather remote possibilities of oil and gas production must not be ignored.

The only oil and gas discovered and produced in the State is located approximately 165 air miles south-southeast, near Sunniland, Collier County. A black low gravity oil is produced from beds tentatively assigned to the Glen Rose formation of the Lower Cretaceous in this small field. The producing formation in Collier County is overlapped by younger Cretaceous beds in the vicinity of Hillsborough County and is not present beneath Citrus and Levy counties.

Possible Oil-Bearing Horizons: The sedimentary rocks penetrated by wells beneath Citrus and Levy counties range in age from Lower Ordovician through Recent. The aggregate thickness is greater than 6,100 feet, of which about 4,500 feet are Upper Cretaceous and Tertiary in age. The Tertiary and the large part of the Upper Cretaceous sediments in the area are carbonates. These are fractured and porous with few if any confining beds in them. The upper few hundred feet of beds are filled with fresh artesian water and both counties are a discharge area for this water. However, so little informaion on the subsurface geology is available throughout these counties that oil and gas possibilities in the Upper Cretaceous and Tertiary beds should not be entirely discounted. Reef porosity and possible sand lenses contained under dense and impervious carbonates could be present in the section, although none have been penetrated by the few wells drilled as tests in Levy County.

The most likely reservoir appears to be the sand composing the basal member of the Atkinson formation, basal Upper Cretaceous. This formation is covered by argillaceous, chalky limestones and an occasional clay bed. The Upper Cretaceous has also overlapped a series of red to green shales and sands of possible Lower Cretaceous age. These sediments range from 31 to more than 1,400 feet in thickness and are a mantle or

outwash that covers a near-peneplaned surface developed on Paleozoic sediments and possible Triassic volcanics. Under favorable structure some of the sand lenses could serve as reservoirs. Shows of oil and gas are unknown throughout the northern Peninsula and nothing similar to a source bed, other than black shales of Paleozoic age, has been penetrated in this area.

Favorable Structural Features: The large unconformity developed at the base of the Lower Cretaceous and the overlap of Cretaceous sediments upon this unconformity and of younger upon older Cretaceous beds could have developed stratigraphic traps and could contain porosity pinch outs and limestone reefs. Tertiary beds could contain similar stratigraphic traps, but the presence of fresh water throughout these beds makes the possibility of oil occurrence highly unlikely. The methods of geophysical and geologic exploration used in the State have been ineffective in outlining favorable structures.

The Tertiary section, inclusive of the middle Eocene through the Miocene, is exposed at the ground surface in Citrus and Levy counties. These beds are fractured and have been gently arched into an elongated anticline called the Ocala uplift. The fold is too broadly developed to serve as an oil trap, but certain smaller structures shown on Plate 1 are of interest. The faults and structures shown in detail upon this map appear to be shallow and may not effect beds older than the Tertiary. However, the dome mapped as an inlier of the Inglis member of the Moodys Branch formation in the basal central sections of Township 13 South, Range 13 East; the larger inliers of Avon Park limestone in southern Levy County; the extension of a sharp fold along the west side of Citrus County; and the fault block of the Inglis member along all of the northeastern edge of Citrus County appear to be the most favorable areas for further geophysical and geological investigation.

Paul Applin (1951, p. 407) has classified Florida as a possible future oil province for these reasons:

> "(1) The fact that oil is being produced in one field in Florida; (2) the relatively few test wells in proportion to the area of the state; (3) the thick section of Cenozoic, Mesozoic, and Paleozoic strata underlying the state, and (4) the possible presence of closed structural and stratigraphic traps and limestone reefs."

Mr. Applin also took note of some of the problems of exploration for oil and gas in the State, listing the difficulty of mapping surface geology through a thick cover of Recent deposits, the limited information available on the subsurface geology from widely scattered wells permitting

TABLE 18.—Oil and Gas Tests in Citrus and Levy counties, Florida

Operator	*Farm Name*	*Location*	*Depth*	*Deepest Horizon*
Suwannee Petroleum Co.	Sholtz No. 1	SE ¼ NW ¼ Sec. 16, T 15 S., R 13 E.	4,010	Lower Cretaceous
Florida Oil Development Co	Sholtz No. 2	NE ¼ NW ¼ Sec. 16, T 15 S., R 13 E	5,266	Lower Cretaceous
Sun Oil Co	J. T. Goethe No. 1	NE ¼ SW ¼ Sec. 31, T 14 S, R 17 E	3,997	Lower Ordovician
Coastal Petroleum Co	James B. and Julian P Ragland No. 1	E ½ W ½ SW ¼ Sec. 16, T 15 S, R 13 E	5,850	Upper Silurian or Lower Devonian
Carl M. Brukenfeld Syndicate	Levy–Lennon Syndicate, Inc., No. 1	NE ¼ NW ¼ Sec. 5, T 14 S, R 16 E	2,173	Upper Cretaceous
Humble Oil and Refining Co	C. E. Robinson et ux No. 1.	C NE ¼ NE ¼ Sec. 19, T 16 S, R 17 E	4,609	Lower Ordovician
J. A. Abbott	Prudential Lumber Co. No. 1	150 ft. SE of C Sec. 34, T 13 S, R 16 E	2,013	Upper Cretaceous

only regional generalizations, and the results of geophysical exploration can not be interpreted because of the undetermined factors that adversely affect the determinations.

Previous Oil Tests: Only seven wells have been drilled in Levy County as genuine tests for oil and gas. None have been drilled in Citrus County. No confirmed shows or other indications of the presence of petroleum in any of these wells have been encountered. The oil tests are listed in Table 18 by operator, farm name, location, depth and deepest geologic horizon penetrated:

SURFACE WATER

Insofar as stock is concerned most of the better grazing land located along coastal lowlands and hammocks is adequately supplied with drinking water. Springs are plentiful and surface streams fed by springs are often so numerous as to constitute a nuisance and hardship. Almost no human utilization of surface or spring waters as a source of drinking water is made, but most of the springs are recreational centers.

In the high sand hills of the western part of both counties wells are necessary to sustain stock and to irrigate for some crops. The numerous lakes that occupy sink-hole basins throughout much of the high coastal plains and the limestone flatlands about Chiefland, Williston, Morriston, Inverness, Lake Tsala Apopka, Floral City, retain considerable water and maintain ground-water levels at rather uniform heights. This area is excellent farming land and requires little irrigation. Water for stock is abundant, but domestic consumption is largely from ground waters.

GROUND WATER

All fresh water in Citrus and Levy counties is derived directly from atmospheric precipitation, largely rainfall and dew, which has fallen on these and the adjacent counties. Since this is the entire source, conservation requires that the water consumed in Florida does not exceed that which is readily available from streams, lakes and wells and that this usage be small enough to maintain the normal storage of waters on the surface and in the ground, thus preventing the lowering of lake levels, and the decreasing of spring, well and stream flows. Following precipitation, rain is evaporated and transpired, part runs off on the surface as streams or collects in basins as lakes and part enters the voids in rocks of the land, where it moves by gravity slowly through these rocks to the sea, the rapidity of its movement through the rock depending directly on the number, shape and continuity of the voids.

The water contained in the voids in the rocks is subsurface water and that which completely saturates the rock is ground water. The top of the water in these voids is the ground-water surface. If the ground-water surface is free to fluctuate upwards and downwards the water is under water-table conditions and the ground-water surface grades laterally into swamps, lakes and streams.

If the ground-water surface is overlain by a formation that contains few voids or if these voids are poorly connected or small enough to restrict the flow of water, the water is confined and is under artesian conditions. Where the water pressures throughout an artesian system are plotted on a map and contoured, an imaginary surface called the piezometric surface is determined, see figure 40. This surface also connects with streams, lakes and swamps but only where the confining formation is thin or absent, usually in areas where water is being added to or is flowing out of the water-bearing beds.

The artesian aquifier of peninsular Florida is composed of limestones ranging in age from possibly the Cretaceous through beds of Miocene age and definitely include the Lake City limestone, the Avon Park limestone, the Moodys Branch formation, the Ocala limestone, all of Eocene age; the Suwannee limestone of Oligocene age and in part limestones of the Tampa and Hawthorn formations. The covering bed is the Hawthorn formation and the more or less impervious masses of dense limestone which are contained in the aquifer itself.

In Citrus and Levy counties the unconfined ground-water surface rises in hills and is exposed in valleys as streams and swamps and in basins as lakes and ponds. The configuration of this surface is determined largely from the rain that falls on these and closely adjacent counties and from leakage from the artesian water. This surface is extremely important to crops and stock, being the important source of water in much of the area.

The artesian water system is more complicated in its distribution. The water contained in the aquifer is derived from rain falling on counties as far away as Baker and Polk. In order to understand the source of artesian water and its movements, figure 40, representing diagrammatically an imaginary surface of the artesian-water system, is presented. It has been constructed by measuring water levels in wells that penetrate the principal artesian aquifer, referring these levels to sea level, and locating the wells on a map of Florida. Smooth lines connecting points on the map where these measurements are the same give a representation of the height of the artesian surface throughout the State. Where this surface

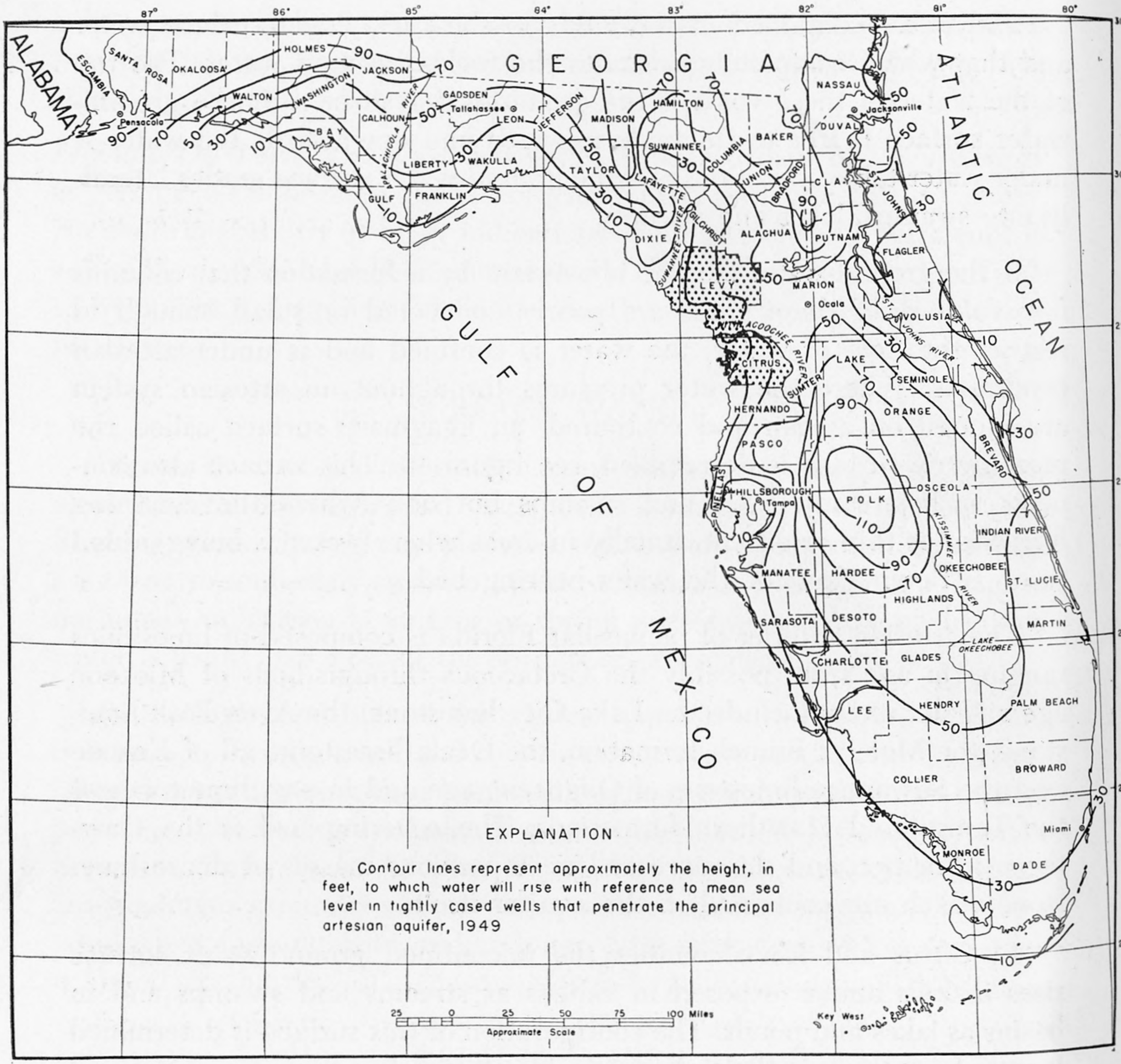

Figure 40. Piezometric surface of Florida.

lies high above sea level, water must be entering the artesian aquifer periodically and moving down toward the sea, from areas where the piezometric surface is high to areas where it is low. The areas of the State where water is being added to the formations are referred to as recharge areas. Where the contours lie at relatively low elevations, water must be emerging from the aquifer by leakage, springs or wells, and these are discharge areas.

The piezometric surface rises more than 120 feet above sea level in an area centered about Polk County. The surface is also high in the area extending northwest from the southernmost tips of Clay and Bradford counties, and in western Pasco County. In these areas large quanti-

ties of water are flooding into the artesian aquifer, and correspondingly must move out from these areas in all directions as it moves toward the sea. The motion of the water will be in a direction perpendicular to the contours, the water moving down gradient. Additional recharge, too small to be defined recharge areas, is obtained throughout the State where the ground-water surface lies higher than the artesian-water surface, if the covering bed is breached by a water passage way. If recharge areas occur in Citrus and Levy counties they are of this latter type.

The deep saddle crossing the State east and west over Marion County, see figure 40, indicates a large area of discharge. The larger number of Florida's springs are located within this saddle. Likewise the deep valley in the piezometric surface that corresponds with the Suwannee River course indicates that heavy discharge is occurring along the river. Divers working along the channel have reported that the bottom of the river valley is a maze of caverns out of which large flows of water are common.

The distribution of recharge and discharge areas indicates that the artesian-ground water in Citrus County is derived from recharge areas in Lake and Sumter counties and the flow of water across the county is almost directly westerly. The supply of artesian water in Levy is obtained from the recharge area centering in the southernmost tips of Clay and Bradford counties and the movement of water in the northern portion of the county is westerly toward the heavy discharge in the Suwannee River Valley and in the southern portion southwesterly toward a smaller discharge along the Withlacoochee River Valley. The heavy discharge in springs of the Gulf Hammock area is reflected by a saddle in the piezometric surface.

Citrus and Levy counties are classified as a discharge area, and artesian pressures range from slightly above 50 feet in northeast Levy County to near sea level along the coast. The occurrence of the 10-foot contour well inland parallel to the coast indicates that, although the limestones of the aquifer are exposed beneath the sea throughout a wide area west of the counties, little if any discharge of fresh water is occurring in the submarine area. This would also indicate that this portion of the aquifer must be filled with salt water, and that some salt-water intrusion has occurred in flat areas lying along the river mouths.

Date of Artesian System: Geologic studies indicate that most of Florida was covered by marine water during the Miocene and that Citrus, Levy and some of the adjacent counties were land in part, becoming dimish-

ingly smaller from the beginning to the end of middle Miocene time. This would indicate that Citrus and Levy counties, while a land mass during the Miocene was open and receiving water. If this land mass had any relief, water pressures could have been sufficient to create some artesian pressures under the Miocene deposits forming and lapping up onto the land masses. Subsequently with changes in sea level throughout the Pleistocene epoch, the formation of structures, and the creation of erosional relief the distribution of artesian pressures were rearranged and the present system created. The artesian system of today dates back to at least the late Pleistocene.

MINERAL PRODUCTION (1944-1949)

Limestone, dolomite and some chert are produced in Levy County; limestone, dolomite, clay, colloidal-phosphate-clay and hard-rock phosphate in Citrus County. In Levy County the road base course production near Williston, although selling for 90 cents to one dollar per ton, competes in total sales with the dolomite production near Lebanon. During good marketing years hard-rock phosphate is the most valuable product produced in Citrus County, but in 1949 the colloidal-phosphate-clay sales were higher. Only minor production of clay, limestone (road base

TABLE 19

Product	*Company*	*Pit Location*
Hard–Rock Phosphate	C. and J. Camp, Inc.	Sec. 12 Mine, Citrus County
	J. Buttgenbach & Co.	Sec. 12 Mine, Citrus County
	Kibler–Camp Phosphate Enterprise	Sec. 12 Mine, Citrus County
	Dunnellon Phosphate Mining Co	Felicia, Citrus County
Colloidal-Phosphate-Clay	Colloidal Phosphate Co.	Citrus and Marion counties
	Kellogg Co	Citrus and Marion counties
	Sea Board Phosphate Co.	Citrus and Marion counties
	Soil Builders, Inc.	Citrus and Marion counties
	Superior Phosphate Co.	Citrus and Marion counties
Clay	Florida Portland Cement Co	Floral City, Citrus County
Limestone	Crystal River Rock Co.	Crystal River, Citrus County
	Connell and Schultz	Williston, Levy County
	Levy County Lime Rock Corp	Williston, Levy County
	L. B. McLeod Construction Co	Williston, Levy County
	Thompson-Williston Mine	Williston, Levy County
	United Limerock Corp.	Williston, Levy County
Dolomite	Dixie Lime Products Co.	Lebanon, Levy County
	Golden Dolomite Co.	Red Level, Levy County
Chert	Florida Hard Rock Co.	Raleigh, Levy County

courses) and dolomite are present in Citrus County, one schedule being operated for each.

The companies listed in Table 19 produced in Citrus and Levy counties during 1944-1949.

The production of dolomite and colloidal phosphate-clay is rather uniform and fluctuates with the farm and cattle market, being used largely for agricultural purposes. The production of hard-rock phosphate was expanded following World War II in the rush to replenish stocks abroad, but this market declined in 1948 and the exports of 1946 were reduced by one-half in 1948 and by one-quarter in 1949. The production of road base course materials expands with road construction in Florida, and the release of men and materials after the war and the period of active road building that followed in 1946 and 1947 caused an expanded production during those years. The production in Citrus and Levy counties is recorded in Table 20.