GEOLOGICAL SURVEY OF GEORGIA

W. S. YEATES, State Geologist

BULLETIN NO. 5—A

A PRELIMINARY REPORT

ON A PART OF THE

Phosphates and Marls

OF

GEORGIA

BY

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Assistant Geologist

1896

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GEOLOGICAL SURVEY OF GEORGIA,
ATLANTA, October 12th, 1896.

To His Excellency W. Y. Atkinson, Governor, and President of the Advisory Board of the Geological Survey of Georgia: —

Sir: — I have the honor, to transmit, herewith, the report of Mr. S. W. McCallie, Assistant Geologist, on a part of the Phosphates and Marls of Georgia, to be issued as one of a series of bulletins on this subject.

In his work on the Phosphates, as at first begun, Mr. McCallie found, that the Marls were so closely identified with the Phosphate deposits, that it would be best to incorporate the two subjects under one report. This bulletin will, therefore be of interest to the farmer, as well to the manufacturer of fertilizers; and in this connection, I desire to call special attention to the writer's conclusions, as to the great value of the Marl deposits of Georgia, when properly applied as a fertilizer.

Very respectfully yours,
W. S. YEATES,
State Geologist.

PHOSPHATES AND MARLS OF GEORGIA

CHAPTER I

GENERAL DISTRIBUTION OF PHOSPHATE DEPOSITS

Phosphorus, the element which enters so largely into the composition of commercial fertilizers, is of almost universal occurrence, in both organic and inorganic bodies. It exists, in more or less abundance, in all sedimentary and crystalline rocks; it enters largely into the composition of the bones of animals; and it is found in the tissues of plants, being especially abundant in the fruits and grains. It never occurs in nature in a free state; but it is always combined with other elements, forming a number of compounds, known as phosphates. The most important of these, is calcium phosphate, or bone-ash, which is one of the essential constituents of a productive soil, and which is the first of the plant-foods, to become exhausted by the growing crops. To restore this essential ingredient to the soil, at the least possible cost, has, for many years, been one of the most important practical questions, that has been presented to the agricultural scientist, for solution. The Romans and the Peruvians, at a very early date, are said to have used the excrements of birds, to restore their cultivated fields to their original fertility. About the middle of the last Cen-

tury, we find the English farmers, in the vicinity of Sheffield, using the chippings of bones from the knife-factories for a similar purpose; but they, like the Romans and the Peruvians, appear to have been ignorant of the fact, that the fertilizing properties of bones, as well as the excrements of birds, are mainly due to the calcium phosphate, they contain. It was not until 1843, that the Duke of Richmond, an eminent English scientist, demonstrated by a series of elaborate experiments, that the fertilizing properties of these organic manures were caused by their high percentage of phosphoric acid. This discovery was soon followed by the use of the mineral phosphates, which were already known to occur, both in Europe and America, for the purpose of manufacturing commercial fertilizers. Three years previous to this, the first twenty barrels of guano were imported to England from Peru. Humboldt described these deposits, and called the attention of Europe to them, as early as 1804; and six years afterwards, Sir Humphry Davy suggested, that they would likely prove to be a valuable manure. It seems quite likely, from the reports of the early explorers of the Peruvian coast, who found, at various places, ancient mines in the guano beds, containing crude wooden quarrying implements, that the value of the deposits was known, and more or less extensively used, by the ancient inhabitants, before the discovery of America. History shows, that these deposits were held in great value by the Incas, who imposed the penalty of death on any subject for killing a sea-bird, or even visiting the islands, during the breeding season.

Guano[1] of the best quality is made up mainly of the excrements, skeletons and the fragments of eggs of fish-eating sea-birds, which, in great numbers, have found the rainless rocky islands near the coast, a suitable roosting-place, for many centuries. The Peruvian deposits,

[1] A corruption of *huanu*, the Peruvian word for dung.

the most valuable so far discovered, formerly existed in large quantities, covering a considerable portion of a number of small islands, where, in places, it attained the depth of more than a hundred feet; but, owing to the extensive shipments to North America and the European countries, it is now practically exhausted. The largest shipment from these islands was made about the year 1870, when Great Britain's importation alone, was valued at more than $12,000,000, and the royalty, exacted by the Peruvians from these exportations, far exceeded all the other revenues, accruing to their general government. Since then, the shipments gradually decreased, from year to year, until 1883, when further exportations were finally prohibited by an act of the Peruvian government.

Venezuela, Guiana and the coast of Africa, in the last decade, have furnished the European markets with considerable quantities of guano; but, as a result of the more humid condition of the atmosphere, under which it has been accumulated, it is usually inferior to the Peruvian deposits in ammonia, and, consequently, less valued as a fertilizer.

Previous to the introduction of guano into Europe, the chief commercial fertilizers used, were animal charcoal and crushed bone, the only form of phosphates then known. On account of the insolubility of these manures, it was frequently necessary to use from one to two thousand pounds per acre, in order to obtain satisfactory results. During the year 1841, Dr. Liebig, the German chemist, discovered a process of treating bones with sulphuric acid, which rendered the calcium phosphate soluble. Bones, thus treated, were found, by experiment, to have increased their fertilizing property more than fourfold. This important discovery was almost immediately followed by the erection of the first acid phosphate factory, in London, by J. B. Lawes, for the purpose of making artificial fertilizers from bones

treated with sulphuric acid. Soon after this, Prof. Henslow, who had previously made a study of the Cambridge phosphatic nodules, suggested their use as a valuable substitute for bone, in the manufacture of commercial fertilizers. This suggestion was soon carried out, with encouraging results; and, as a consequence, the phosphate deposits of England and France, formerly considered of only local importance, were now, for the first time, seen to be of great value in the manufacture of manures.

THE PHOSPHATES OF ENGLAND

The Greensands of England have been used as a soil stimulant, by the farmers in the locality where they occur, for more than a century. These deposits, belonging to the Cretaceous period, outcrop at various places in the eastern part of England, where they form a belt, more or less continuous, many miles in length. They consist principally of a greenish sand, in which are embedded numerous nodules of phosphate, weighing from a fraction of an ounce to five pounds. These nodules, formerly discarded by the English farmers as worthless, are usually of a gray or dark color, and form, with the associated phosphatic shell-casts, bones and teeth, a stratum, varying from a few inches to two feet in thickness. In the counties of Cambridge, Bedford and Suffolk, where these nodules have been worked for the last fifty years, they are found to carry from forty to sixty per cent. of calcium phosphate. The Tertiary formation of Norfolk, Suffolk and Essex have also produced considerable phosphate, in the form of nodules and bones; however, it is said to be generally inferior, both in quality and quantity, to the Cretaceous deposit. The production of

phosphate in England appears to have reached its greatest development in 1876, when the entire output aggregated 250,000 tons. Since then, on account of the best deposits becoming partially exhausted, and on account of the extensive importations of the high-grade phosphates from the United States, the amount mined has become gradually less, from year to year, until it has ceased to be of importance in the phosphate markets of the world.

THE PHOSPHATES OF WALES

In 1863, phosphate was discovered in the Lower Silurian formation near Llanfyllin, Wales. It occurs there, as a bed of nodules, cemented together with a dark-colored matrix, containing fossil remains. The average thickness of the bed is not over ten inches. A number of mines were opened, and worked to a limited extent, in the vicinity of Berwyn; but they were finally abandoned as unprofitable.

THE PHOSPHATES OF BELGIUM

Workable phosphate occurs in the southern portion of Belgium, near the French border. It has been discovered here, in two very dissimilar beds, both of which belong to the Cretaceous formation. The upper bed, known as the Conglomerate, consists of brownish-colored phosphatic nodules of various sizes, with fossils cemented to-

gether by calcium carbonate. The deposit is said to attain a thickness, in places, of three feet; but it is usually much thinner. It has been worked to a limited extent. However, it has generally proved to be unprofitable, on account of its low grade, and the difficulty, with which it is separated from the calcareous matrix. The lower bed, which furnishes the greater part of the Belgium phosphate, used in making commercial fertilizer, is made up of a very fragile, porous limestone or chalk, in which occur numerous small phosphatic concretions, no larger than a mustard seed. The concretions frequently form ten per cent. of the entire mass. They are separated from the calcareous matrix, by washing, after having been ground or allowed to become disintegrated, by exposure to the atmosphere. In 1890, the mines in the vicinity of Mons and Liege produced over 300,000 tons of phosphate. The greater part of this output was exported to France, England and the United States, where it was used as a drier, and to mix with the high grades of phosphates, deficient in calcium carbonate.

THE PHOSPHATES OF FRANCE

Phosphate was discovered in the old province of Guyenne, now the department of Gironde, in southwest France, in 1865; but no mining operations of any importance were attempted, until 1870, when a number of mines were opened, which produced annually, for five years, 20,000 tons of high-grade phosphates, for exportation. At the expiration of this time, the most valuable deposits were either exhausted, or were found to be unprofitable; and no mining, except to supply a limited, local demand, has since been carried on. The phos-

phatic material is found in a grayish, compact Jurassic limestone, where it occurs in two different sets of fissures or cavities, running at almost right-angles with one another. These fissures sometimes attain a thickness, at the surface, of 25 feet, though they do not usually extend to any great depth, and are always limited to a few hundred feet, or even much less, in length. The phosphate appears in a number of forms. It may be nodular, radiate, mammillary, compact, amorphous, or even fibrous in structure. The best variety, which is compact, and has a hardness of apatite, is of a yellowish-brown color; but red, blue and white also occur. Phosphate is also found in the Cretaceous formation in the departments of Ardennes and Meuse, in the northeastern part of France. It was discovered here in the Greensands in 1852, and has since been extensively worked. Its mode of occurrence and general appearance is quite similar to the English and Belgian deposits, of which it may be considered a continuation.

The most noted phosphate deposits of France, and probably the richest in the world, were discovered at Beauval, in the department of Somme in 1886. Phosphate in the form of nodules was known to occur at various places in Somme, as early as 1863; but it was not until nearly a quarter of a century later, that Monsieur Merle, a French geologist, announced that the so-called sand, which was then being used at Beauval, for making brick and mortar, was a high-grade phosphate. This announcement was followed by extensive prospecting, which revealed a number of deposits, in the neighborhood of Beauval, of marvelous richness. An instance is cited, where three acres, which changed hands for the sum of $120,000, produced 80,000 tons of phosphate. The area, over which these deposits extend, is said to be limited to less than 500 acres; and it has been estimated to contain 1,500,000 tons of 70 per cent. phosphate. The deposits are found in the Cretaceous chalk, where they occur, as a phosphate sand, in large cyl-

inder or cone-shaped pockets, from ten to twenty feet in diameter, and, sometimes, a hundred feet in depth. The Somme deposits produced, in 1890, 170,000 tons of phosphate, much of which was exported. The Cretaceous deposits of central France also produce a limited quantity of phosphate; but it is usually of a low grade; and the entire output goes to supply the local demand.

THE PHOSPHATES OF SPAIN

The phosphates of Spain, a variety of the mineral, apatite, called phosphorite, occur in the province of Estremadura, near the towns of Logrosan and Caceres. The Logrosan deposit was known as early as 1782, while those of Caceres appear not to have been discovered, until 1860. Mining operations, on a small scale, were begun at the former place in 1855, and at the latter, five years afterwards. The Logrosan deposit occurs in veins, varying from two to thirty feet in thickness, and from a few yards to three miles in length. They penetrate or lie at the point of junction of the slates and gneisses, which are supposed to belong to the Silurian formation. The phosphate has a fibrous, mammillary, massive, or semi-crystalline structure, with the hardness of apatite, which renders it very difficult to pulverize. The color, however, is somewhat variable. The high grades, running from 80 to 85 per cent. of bone phosphate, are usually of a yellowish-white. On account of the expense of transportation, together with the difficulty of grinding, the output of these mines has been limited to only a few hundred tons per annum. The Caceres phosphates occur in pockets in limestone and quartz veins. They have been quite extensively worked, and have furnished nearly all the phos-

phate for exportation. In structure and color, they differ but little from the Logrosán phosphates. Spain has also valuable deposits of apatite at Malpartida de Caceres, Ceclavin and other places, which have produced, from time to time, several thousand tons per annum; but the output from these mines, for various reasons, has ceased to be of importance.

THE PHOSPHATES OF RUSSIA

The phosphate beds of Russia are found mainly in the Cretaceous formation, between the Dnieper and Volga rivers, where they underlie an area of several thousand square miles. The territory, over which these deposits outcrop, is probably the most extensive known; but the quality of the phosphate is of a low grade; and it is usually overlaid by such a heavy overburden, that it is too expensive to work. It occurs in the Greensands, in the form of nodules and shell-casts, either as a loose mass, or cemented together into a conglomerate, by sand or calcareous material. The deposit was discovered, in the early part of the present century; but its value was not made known, until 1845. Sir R. I. Murchison, in his geological survey of Russia, speaks of it as "shelly conglomerate, and concretionary iron-stone." On account of the heavy overburden and the low grade of the phosphate, the mines, which have been opened in the last few years, have not always proved to be financial successes. The exports to England of small shipments were unsatisfactory, in the manufacture of superphosphate. The entire output, at present, is used to supply the local demand. High-grade phosphates are also reported to be found in the Silurian and other geological formations of Russia. However, they have not as yet become of any commercial importance.

THE PHOSPHATES OF GERMANY

The phosphate deposits of Germany, discovered in 1864, are located in the Hessian province. The most extensive mining operations are carried on, in the valley of the Lahn river, where two large acid-phosphate factories now consume almost the entire output of the mines, amounting, at present, to about 30,000 tons per annum. Formerly, much of the material was shipped to England, where it brought a fair price; this trade, however, was finally discontinued, owing to the abundance and cheapness of the higher grade phosphates, that flood the English market. In structure and general appearance, this phosphate resembles, very closely, the phosphorites of Spain. It occurs in the Devonian limestone, filling large irregular cavities, and varying from a few inches to four feet, in thickness. It carries from forty to sixty per cent. of calcium phosphate, and runs quite high in both iron and aluminum.

THE PHOSPHATES OF NORWAY

The phosphates of Norway are apatites, found on the southwest coast. They occur in the old crystalline formation, as veins penetrating the gneisses, granites, schists etc. The veins are from a few inches to several feet in width, and of unknown depth. They dip at a high angle; and, where they attain their greatest thickness, they usually carry mica and hornblende, forming alternate bands with the apatite. The first mining was done near Kragerö in 1854; it was fol-

lowed, a few years afterwards, by the opening of the more productive mines, at Oedegarden and Bamle. The entire output of these mines, for a number of years, did not exceed 4,000 tons per annum. The largest shipment, so far, reported for any one year, was made in 1890, when about 12,000 tons were exported. The mineral appears, both in a massive and a crystalline form and is commonly of a greenish or reddish gray color. Picked specimens yield 92 per cent. of calcium phosphate, the richest of all known phosphates.

THE PHOSPHATES OF TUNIS AND ALGIERS

In 1886, the French explorers reported the finding of extensive deposits of phosphate in Tunis. This was followed, in 1893, by the announcement, that similar deposits had been discovered in the eastern part of Algiers, in the region of Tebessa. The former deposits, either on account of their unfavorable location or otherwise, seem, so far, not to have attracted very wide attention, while the latter have been pretty thoroughly investigated. Both English and French capitalists have made large investments, and are now constructing railroads and making surveys of the deposits, with a view of beginning work at an early date, on a large scale. Two English and one Scotch company, which were early in the field, have already become producers. The output of these companies, for 1894, was estimated at about 30,000 tons. The phosphate is said to be composed mainly of bones and sharks' teeth, which form beds, in places ten feet thick. It averages from 60 to 70 per cent. calcium phosphate, while choice specimens have been known to run as high as 83 per cent.

THE PHOSPHATES OF CANADA

The first description of the Canadian phosphates or apatites was given, in the Canadian geological report, by Dr. T. Sterry Hunt, in 1848. At that time, they appeared to attract but little attention; and it was not until 1863, that mining began in Lanark county, Ontario. For a number of years, the work was carried on, in a very unscientific way. The entire output was extracted by the farmers, who owned the lodes, devoting a portion of their leisure time, during the winter, to mining. The greater part of the apatite, thus mined, was collected by buyers or agents, and was used in the manufacture of commercial fertilizers. The result of this peculiar, haphazard mode of mining is said to be still quite noticeable, in the great number of now partially filled pits, scattered along the line of the outcroppings of the phosphate veins in Lanark and Leeds counties. The first regular mining operations of any importance were commenced, by the Buckingham Mining Company, on the Lievre river in the Ottawa district, in 1871. These works were successfully operated, until 1875, when a reduction in the price of phosphate caused the mines to shut down, after which, work was continued, on a small scale, by individual parties, until 1880, when English and American capital became interested in the deposit, and large investments were made. This was soon followed by the organization of several companies, the purchasing of machinery and the beginning of very active mining operations. In 1891, thirteen companies, with capital varying from $30,000 to $700,000 were engaged in the Canadian phosphate industry. The total output for that year, most of which was exported to England, was 25,000 tons, valued at $400,000. On account of not being able

to compete with the low prices of the phosphates from the United States, which have recently glutted the European markets, all these companies have, since, either suspended operations, or greatly reduced their working-force; and, as a consequence, the output has become of minor importance.

The Canadian, like the Norwegian apatites, are found in the Archæan, the oldest of the geological formations, which is made up of granite, gneiss, hornblende, and other crystalline rocks, supposed to be of igneous origin. Apatite, in workable quantity, appears in both Quebec and Ontario. In the former province, they occur in a belt, from 15 to 20 miles wide, and 60 miles long; while, in the latter, the belt is from 50 to 60 miles wide, and more than 100 miles in length. Within these belts, are to be found a great number of veins, or irregular fissures, from a few inches, to many feet in width, consisting of apatite, pyroxene and other associated minerals. The veins can sometimes be traced, for many miles; but the workable part usually consists of enlargements or pockets in the main vein, which extends down to very great depth. The apatite nearly always contains foreign minerals, so intimately associated with it, that they can only be gotten rid of, by hand-picking. This extra labor adds considerable to the original cost of mining. However, it appears to be the only practicable way of producing from the mines the high-grade phosphates, in large quantities for exportation. In 1890, the various grades of Canadian phosphate, costing on board of vessels at Montreal $14 per ton were selling in the European markets at the following prices: —

For phosphates, guaranteed to contain					85	per cent	--------	$25.00	per	ton
"	"	"	"	"	80	"	--------	22.50	"	"
"	"	"	"	"	75	"	--------	18.00	"	"
"	"	"	"	"	70	"	--------	14.50	"	"
"	"	"	"	"	65	"	--------	11.25	"	"

The physical condition of the apatite is quite variable. It occurs in a massive granular or crystalline form; also as crystals, some of which have been found, weighing several hundred pounds. The color of the best varieties is usually some shade of green; but yellow and red, white and black are also common.

THE PHOSPHATES OF SOUTH CAROLINA

In 1837, Prof. F. S. Holmes, then a young, enthusiastic student in geology, became interested in the geological formations in the vicinity of Charleston. By diligent work, and frequent excursions into the surrounding country, he was able, in a very short time, to make quite a collection of fossils and rock specimens, from a number of localities. It appears to have been on one of these excursions, that his attention was first directed to the numerous water-worn nodules scattered over an old rice field, on the west bank of Ashley river, in St. Andrew's parish, near Charleston. The nodules, supposed to be composed mainly of lime carbonate, were found to contain many shell-casts and fossil remains. These curiosities, for the time being, seemed to have absorbed the entire attention of the collector; and no attempt was made to ascertain their true chemical composition. Mr. Ruffin, who was appointed to make an agricultural and geological survey of South Carolina, at the suggestion of Prof. Holmes, visited, in 1844, the old rice-fields, with a view of locating marl deposits. His report on the outcropping of marl, on the river-bank, near by, was quite favorable; but the nodules were thought not to have sufficient lime, to be of any value as a fertilizer. About the same time, while a prospecting-pit was being put down, for marl, on an adjoining rice-field,

a stratum of nodules, twelve inches in thickness, was struck, only a short distance from the surface. This material was compared with that, scattered over the surface of the field, and was found to be almost identical, which was supposed to be sufficient evidence, to condemn it, as worthless for agricultural purposes.

Prof. Tuomey, Mr. Ruffin's successor, published his complete geological report of South Carolina, in 1846; but it contains nothing of importance, concerning the Ashley river nodules. It is said that Prof. Tuomey, during the survey, had some analyses made of nodules, collected in the vicinity of Charleston, which ran as high as 16 per cent. of calcium phosphate. These analyses, however, for some reason, seem never to have been published in the official report. In 1867, Dr. N. A. Pratt, who has since become so well identified with the phosphate industry of the United States, was handed a specimen of a nodule by Dr. St. Julien Ravenel, from Goose creek, with a request, that an analysis of it be made. It was found to contain nearly 35 per cent. of calcium phosphate. This result was unexpected; but, nevertheless, it was of unusual interest to Dr. Pratt, as he had already contemplated the erection of a plant at Charleston, for the manufacture of commercial fertilizer; and, if this material could be found in large quantities, he saw, at once, that it would greatly aid him in carrying out his plans. A short time afterwards, Dr. Pratt called on Prof. Holmes, who was well acquainted with the geological formations of the State, especially in the vicinity of Charleston, and showed him a fragment of the nodule, which he had secured from Dr. Ravenel. Prof. Holmes examined the specimen, and stated, that he was quite familiar with the material, and had known of an extensive deposit of it on the Ashley river, for a number of years. Specimens from this locality were secured from Prof. Holmes's private collection, and being analyzed,

they showed about 60 per cent. of calcium phosphate. Two days afterwards, Dr. Pratt visited the deposit, and was greatly delighted, to find it more extensive, than he had anticipated. He at once realized the value of the discovery, and immediately went to work, assisted by Prof. Holmes, to organize a company for the purpose of mining and manufacturing the material into artificial fertilizer. But little encouragement was given to this new enterprise, by the people of Charleston; and it was generally looked upon, as a visionary scheme.

Fortunately, at this time, Dr. Ansted's book on practical geology fell into the hands of the projectors of the so called visionary phosphate scheme. The description of the Cambridgeshire phosphate deposits of England, herein given, were found to correspond almost exactly with the description of the Ashley river deposits. This was a strong argument, in favor of the importance of the discovery; and it had its influence on James T. Welsman of Charleston, who furnished Dr. Pratt and Prof. Holmes with the necessary means to make a trip to Philadelphia, for the purpose of organizing a company. Their trip was quite successful, and resulted in the organization of the Charleston, South Carolina, Mining and Manufacturing Company. The company, in a short time, began mining operations on the Ashley river; and in 1868, the first shipment of phosphate was made, to Philadelphia.

Other companies were soon organized; and, in a comparatively short time, the deposits of phosphate in the vicinity of Charleston were pretty thoroughly explored; and the phosphate industry quickly became one of the most important industries in the State.

The workable phosphate deposits of South Carolina occur, in three separate localities, which may be designated as the Charleston, Jacksonboro and Beaufort deposits. The Charleston deposit is located a few miles northwest of the city, where it has been found to underlie

an area of about 200 square miles of lowland, drained by the Cooper and Ashley rivers. It contains the most valuable land deposits, and has been extensively worked. The Jacksonboro deposit occupies both sides of Edisto river immediately west of Jacksonboro. It is supposed to cover an area of nearly 100 square miles; but, owing to the thinning out of the beds in some places, and the thickness of the overburden in others, only a small portion of the total area will probably pay for working. The Beaufort deposit occurs in the beds of the streams, and underlying the islands and swamps, in the neighborhood of Beaufort. It covers an area of about 75 square miles, and is noted for its valuable river deposits.

The phosphate is found on the land, beneath a thin overburden of clays and sands, where it forms a well-defined layer or stratum, from a few inches to two feet in thickness. It also occurs in streams, forming beds of variable thickness. The former, called land phosphates, is composed of innumerable, irregular nodules, usually of a dark- or light-brown color, and varying in size, from a mustard seed to pieces weighing several pounds. Associated with these nodules, there also occur sharks' teeth and fragments of bones of both living and extinct animals. The latter deposit, called river phosphate, has been derived from the land by washing, and differs from the land phosphate only in being usually of a darker color and more water-worn. Both varieties run from 50 to 70 per cent. of calcium phosphate, and cost, on board of vessels, dried, and ready for shipment, from $2.00 to $4.00 a ton. The market value varies greatly. The first cargo sold in Philadelphia at $14.50 per ton; but, since then, it has been known to sell, as low as $3.00 a ton.

The following table shows the total production of South Carolina phosphate, from 1867 to 1893 inclusive: —

Years Ending	Land Companies (Long tons)	River Companies (Long tons)	Total (Long tons)
May, 1867	6	. . . . .	6
1868	12,262	. . . . .	12,262
1869	31,958	. . . . .	31,958
1870	63,252	1,989	65,241
1871	56,533	17,655	74,188
1872	36,258	22,502	58,760
1873	33,426	45,777	79,203
1874	51,624	57,716	109,340
1875	54,821	67,969	122,790
1876	50,566	81,912	132,478
1877	36,431	126,569	163,000
1878	112,622	97,700	210,322
1879	100,779	98,586	199,365
1880	125,601	65,162	190,763
1881	142,193	124,541	266,734
1882	191,305	140,772	332,077
1883	219,202	159,178	378,380
1884	250,297	181,482	431,779
1885	225,913	169,490	395,403
Dec. 31, 1885[1]	149,400	128,389	277,789
1886[2]	253,484	177,065	430,549
1887[2]	261,658	218,900	480,558
1888[2]	290,689	157,878	448,567
1889[2]	329,543	212,102	541,645
1890[2]	353,757	110,241	463,998
1891[2]	344,978	130,528	475,506
1892[2]	243,652	150,575	394,228
1893[2]	308,425	194,125	502,564

[1] From June 1st to Dec. 31st.

[2] Calendar year.

The total output for 1893, 502,564 tons, was valued at $4,136,-070, giving an average value of nearly $8.25 per ton. At present, a large per cent. of the entire production is exported and sold, mainly in the English and German markets.

The future of the phosphate industry of South Carolina, although not now so encouraging, as it was, before the discovery of other extensive deposits in the United States, nevertheless, has been established on a solid scientific and financial basis, and will evidently continue, for many years, to be one of the most important industries in the State.

THE PHOSPHATES OF FLORIDA

Capt. J. F. LeBaron of the United States Army, while employed, in 1881, by the Government, in making a preliminary survey for a canal, uniting the headwaters of the St. John's river and Charlotte harbor, was attracted by the numerous water-worn pebbles and fragments of bone, in the bed of Peace river. It is said, that a number of barrels of the material were collected by him, and sent to the Smithsonian Institution, where it was examined, under the direction of Prof. Baird, who became much interested in the collection, and at once made efforts to have a complete geological survey made of the river and the adjacent country. His plans, however, for some reason, were never carried out. The importance of the discovery seemed to have been fully realized by Capt. Le Baron; but, having been called away on other duties, he was unable to make further investigation.

Returning in 1886, after an absence of five years, he made a more extensive examination of the river-bed, and reported the result of his

investigations to a party of northern capitalists, whom he wished to interest in the deposits. His plans for purchasing a large tract on the Peace river, for the purpose of mining phosphate, did not meet the approval of the capitalists, and his project was finally abandoned.

About this time, Col. G. W. Scott, of Atlanta, who was interested in the manufacture of commercial fertilizers, hearing of these phosphate beds, at once had the deposits investigated; and, as a result, he purchased a large area of land along the Peace river. Shortly after this, Mr. T. S. Morehead, of Pennsylvania, made a similar purchase on the river, in the vicinity of Arcadia, and began mining-operations, during the following spring. In May, 1888, the first shipment of Florida phosphate was made from these works, consigned to the G. W. Scott Manufacturing Company, of Atlanta, Ga. Other shipments soon followed; new companies were quickly organized; mining machinery was purchased; and, in a comparatively short time, Peace river became the seat of very active mining operations.

About the first of May, 1888, Mr. Albertus Voght, while having a well put down at Dunnellon, in Marion county, discovered a peculiar rock, which he submitted to Dr. R. R. Snowden, of Ocala, for examination. A chemical analysis of the specimen showed, that it contained over 76 per cent. calcium phosphate. This led to further examination of the rocks, in the vicinity of Dunnellon, resulting in the discovery of an extensive deposit of phosphate. Prospecting now became general, and almost the entire western coast of Florida, from Tallahassee to Charlotte harbor, was soon found to have rich beds of phosphate.

The Florida phosphates occur in the form of pebbles and water-worn grains, or as hard or soft rock. The former are found in the beds of streams; also on land, where they form beds, from a few inches to a number of feet in thickness. They are of a light-gray or very dark color, and vary in size, up to three inches in diameter. As-

sociated with them, are numerous bones of the elephant, the mastodon, the shark, the alligator etc., all united by a sandy or clay matrix into a more or less compact stratum. The land pebbles have nearly always an overburden of sand or clay, of various thicknesses, the removal of which, frequently adds greatly to the cost of mining, and is one of the most important points, to take into consideration, in estimating the value of a deposit. The pebble-phosphates are confined principally to Polk, De Soto, Hillsborough and Manatee counties, where they are known to underlie a large tract of country; but only a small part of the total area can probably be worked with profit, on account of the thickness of the bed, and the great depth of the overburden. The percentage of calcium phosphate is always high, usually running from 60 to 80 per cent.

The hard and soft rock-phosphates, which differ from each other, principally in their physical conditions, are frequently found associated together, in the same deposit, and have evidently had a common origin. They appear to reach their greatest development in the neighborhood of Dunnellon, although valuable deposits, which are now being extensively worked, occur in the counties, both north and south of this point. The physical structure of the hard rock-phosphate is variable. It may be either laminated, concretionary, or compact; and it frequently resembles, very closely, limestone, or some of the varieties of flint, which are associated with it. The prevailing color is white or light-gray; but a close approximation to black, and other colors, besides white and light-gray, are to be seen. It occurs in pockets or beds, of limited extent, either as small nodules or large bowlders, embedded in a clay or sandy matrix. These deposits sometimes extend to the depth of 50 to 60 feet, where they come in contact with the eroded surface of the Eocene limestone, which underlies much, if not all, of the phosphate region.

The age, to which the phosphates themselves belong, has not yet been fully decided. However, it probably belongs to the early Miocene, or late Eocene.

The hard and soft rock-phosphates run from 60 to 80 per cent. of calcium phosphate, and cost on board of cars, ready for shipment, from $2.00 to $4.00 per ton. The total area, covered by these deposits, is known to aggregate, at present, several hundred square miles, which is gradually being increased, from year to year, by new discoveries.

The following table shows the amount and value of the production of Florida phosphates, for 1893 and 1894: —

	1893		1894	
	Quantity (Long tons)	Value	Quantity (Long tons)	Value
Hard rock	215,685	$1,117,732	326,461	$ 979,383
Soft rock	13,675	64,626	. . . . .	. . . . .
Land pebble	86,624	359,127	98,885	296,655
River pebble	122,820	437,571	102,307	390,775
Total	438,804	$1,979,056	527,653	$1,666,813

THE PHOSPHATES OF TENNESSEE [1]

The Tennessee phosphate is a comparatively recent discovery. However, sufficient is already known about it, to demonstrate, that

[1] Since this report was written, Dr. C. W. Hayes, of the U. S. Geological Survey, has published a valuable paper on the Tennessee Phosphates. See Sixteenth Annual Report of the Director of the U. S. Geological Survey, Part IV., p. 610.

it is one of the most important deposits known. It reaches its greatest development in Hickman and Lewis counties, where it forms two well-defined beds, one above, and the other below, the Devonian Black Shale. The upper layer is formed of a layer of kidney-shaped concretions of phosphate, usually too thin to be worked with profit, while the lower consists of a compact dark-colored oölitic and fossiliferous layer of high-grade phosphate, from 1 to 4 feet in thickness. In places, the intervening Black Shale is said to thin out, so that the two beds can be worked together. Dr. J. M. Safford, State Geologist of Tennessee, who has examined the deposit with considerable care, and who is thoroughly conversant with the Geology of the State, estimates the amount of workable phosphate in Hickman and Lewis counties, at 123,000,000 tons. Several companies are, at present, in active operation, with a daily output of about 300 tons, which runs from 50 to 70 per cent. of calcium phosphate.

The phosphate industry of Tennessee seems, at present, to have a very bright future; and it is thought to be only a question of time, when these phosphates will control the entire interior trade.

CHAPTER II

ORIGIN OF PHOSPHATES

Deposits of calcium phosphate are found in all the geological formations, from the earliest to the most recent. They exist in the form of the mineral, apatite, filling veins and fissures, in the old crystalline rocks, which are, probably, much altered portions of the original molten crust of the earth; they are, also, found in the salt marshes along our seacoast, where they are, at present, being deposited. Deposits, which have thus been accumulating, for long ages, must have been brought about, at various times, by the action of different agencies; and, as a consequence, no one theory, alone, can satisfactorily explain the origin of all these deposits. In the earliest geological times, while the earth's crust was still in a highly heated condition, and the elements were arranging themselves into various chemical combinations, calcium phosphate, mainly in the form of apatite, seems to have crystallized out of the molten magma, or to have condensed from the cooling phosphatic vapors. This is, at least, a probable explanation of the origin of the mineral apatite, found in crystalline form, sparingly scattered through the primitive granites, mica-schists, gneisses, hornblende rocks etc. From these crystalline forms, which have, since, undergone many modifications, brought about by chemical, physical and organic agencies, have originated the extensive beds and deposits of phosphate, that are now known to occur, in the various geological formations.

The Canadian phosphates are considered, by the late Dr. T. Sterry Hunt, to be segregations, which have been collected from the sur-

rounding rocks by means of hot water, and deposited in fissures, in the same manner as quartz and other vein-forming minerals. This theory is supported by the occurrence of apatite crystals, with rounded angles, drusy cavities in the veins, and masses of calcite within apatite crystals. Sir William Dawson supposed, that they were of animal origin; and he points out the great abundance of graphite, iron ore and the remains of the Eozoon Canadense, found in the associated rocks, as an argument in favor of his belief.

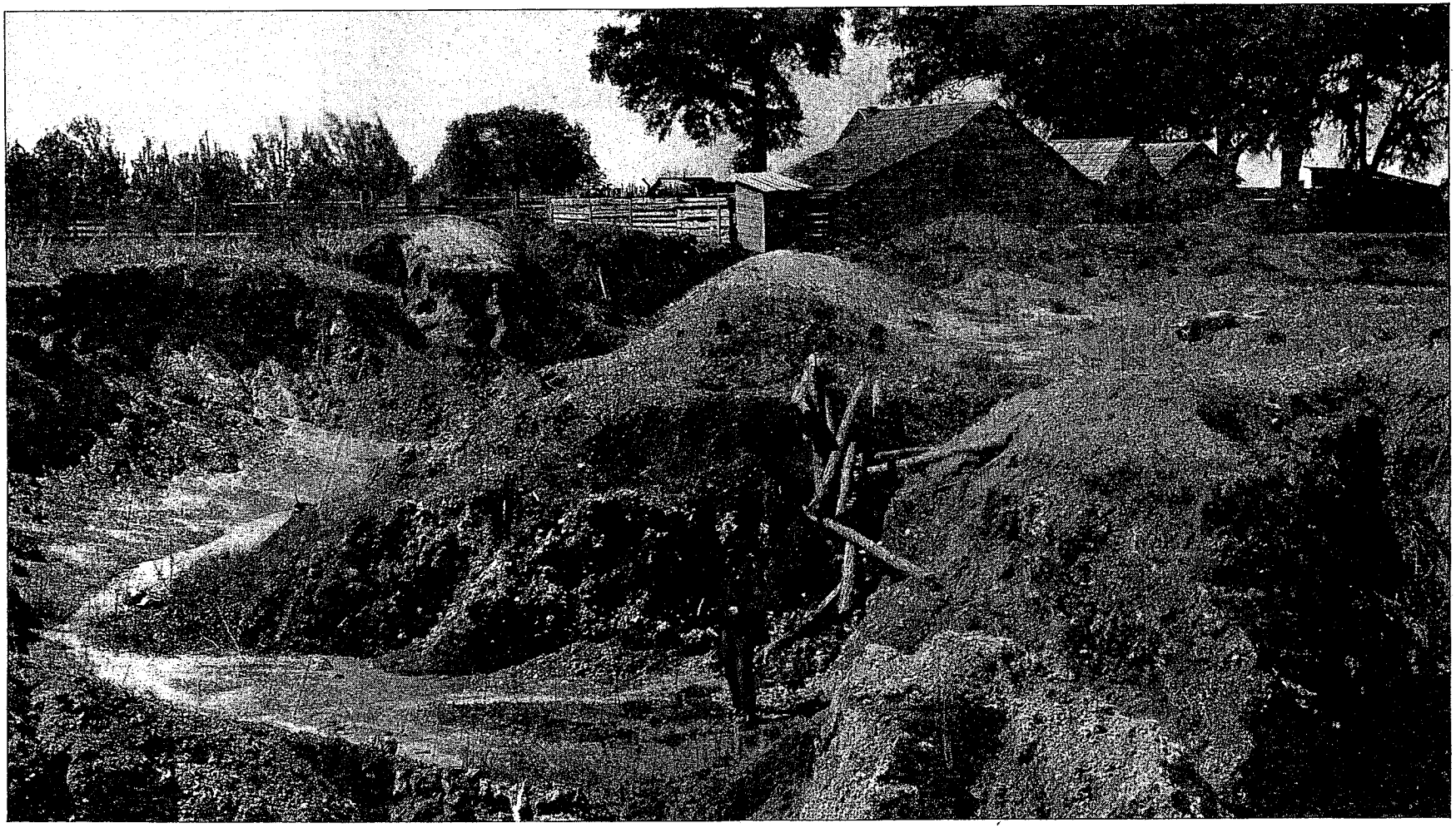
Still others are of the opinion, that apatite is of igneous orign, and has been brought to the surface, by volcanic action. Prof. A. R. C. Selwyn, formerly Director of the Geological Survey of Canada, holds this view, and thinks, that they had a similar origin to that of the Norwegian apatite, which has been investigated by Brögger and Reusch. These latter deposits have a banded structure, the outside material of the veins being fine-grained, while the inside is coarse-grained. This peculiar structure of the vein is accounted for, by supposing, that the material was injected into open fissures in a molten condition, where the difference in the rate of cooling, of the outer and inner portions of the mass, produced the above effect. It has, furthermore, been suggested by some, that heated phosphatic gases, escaping from the earth's interior, have been condensed, in open fissures, where they gave rise to apatite veins. The deposits of phosphorite, in the Triassic limestone of Southwestern France, are thus accounted for, by Combes. These different theories are all based, on well established, scientific fact; and they appear to explain the origin of many, if not of all, of the deposits of mineral phosphate, or apatite, found in the older geological formations.

The more recent phosphate deposits, however, seem to have a somewhat different origin. They have evidently been derived from the older deposits of phosphatic material, in the ancient crystalline rocks,

by a long continued process. The conditions and the manner, under which these changes are supposed to have been brought about, have given rise to a number of interesting theories, as to their origin.

One of the first attempts, to speculate on the origin of rock-phosphate, was made, before they became of commercial value, and when but little was known of their true nature. The theory thus advanced, which asserted that all phosphatic nodules are coprolites or the fossilized excrements of animals, seems to have been based on an imperfect examination of the nodules of the Greensands of England. It was supposed, by the advocates of this theory, that, during the deposition of the English Greensand, the sea was teeming with innumerable fishes and reptiles, the excrements of which gave rise to extensive beds of phosphatic material. The theory, first applied, as an explanation of the origin of the so-called Cambridge Coprolite deposits, was afterwards thought to account, also, for similar deposits, in both Europe and America. Recent investigation, however, into the structure and composition of the nodules, has revealed the fact, that comparatively few of them can be referred to coprolitic origin.

Prof. F. S. Holmes, who has made a study of the South Carolina phosphates, came to the conclusion, that these deposits are all, either directly or indirectly, of animal origin. He thinks, that the phosphatic nodules were formerly fragments of limestone from the Eocene marl-beds, rounded by the action of the waves. These limestone nodules, with the remains of sharks and other animals, were then supposed, by him, to be swept, by the action of currents and waves, into depressions along the margin of the shallow sea, where they were finally covered by a thin layer of mud or sand. The elevation of the coast then followed, and the hollows, in which the nodules were laid down, became lakes or lagoons of salt water. In process of time, the water was gradually evaporated, leaving deposits of salt, which at-



BOSTON PHOSPHATE WORKS, NEAR BOSTON, THOMAS COUNTY, GEORGIA.

tracted, from the surrounding country, great numbers of animals, whose fecal deposits and decaying carcasses added quantities of phosphatic material to the sands and clays, overlying the bed of limestone nodules. The phosphate of these organic remains was now leached out, by the action of rain-water, and carried below, where it replaced the lime carbonate of the nodules. Such, in brief, is a condensed statement of a rather ingenious theory, the weak point of which lies in an insufficient proof of the existence of the great numbers of land animals, that it supposed inhabited the marsh swamps, in the vicinity of Charleston, during the Post-Pliocene age.

Dr. N. A. Pratt, formerly chemist of the Geological Survey of Georgia, holds a somewhat similar view. He is, however, of the opinion, that the material was originally deposited far inland, and that it was afterwards, brought to its present position, by action of the rivers, flowing from the more elevated region, lying to the west. He contends, that both the chemical composition and the physical appearance, as shown by the microscope, reveal the original organic structure of the nodules. The writer's observation of the structure of the nodules also confirms the above opinion, as to their organic structure; yet, it does not necessarily follow, that they have always retained the same mineralogical composition. On the contrary, the evidences seem to be almost conclusive, that a greater part of the material was formerly deposited, as lime carbonate, which, afterwards, was replaced by lime phosphate, without obliterating the original structure.

The late Prof. W. C. Kerr, formerly State Geologist of North Carolina, ascribes the origin of the South Carolina phosphates to a small bivalve shell, belonging to the genus *lingula*. These shells are found, more or less plentiful, at a number of points along the eastern coast of the United States. They contain

from 40 to 50 per cent. of lime phosphate, which corresponds very closely to the composition of bone. It appears quite plausible, that these shells should have existed in such great quantities, at one time, in the sea near Charleston, as to give rise to the phosphatic material, which, upon being dissolved by rain-water, replaced the carbonate of lime in the marl-beds, which were, in turn, broken into fragments and rounded, either by the action of waves or by running water, and finally deposited, as we now find them.

It was suggested, by Prof. C. U. Shepard, in 1869, that the phosphatic material originated from the droppings of birds. He compares its formation to the guano deposits, now taking place on the Mosquito coast of the Caribbean Sea.

A number of similar theories have also been advanced, to account for the phosphate deposits of Florida. Mr. N. H. Darton, of the U. S. Geological Survey, thinks, that they originated from deposits of guano. According to this theory, during, probably, the early Miocene, the whole eastern coast of Florida, from Tallahassee to Charlotte Harbor, was, for a long period of time, a favorite resting place for innumerable sea-birds, that frequented the coast. The excrements of these birds, having accumulated along the shore, in great quantities, were finally leached out, by carbonated rain-water, and carried below, where they phosphatized the underlying limestone.

Dr. N. A. Pratt has suggested, that the phosphatic material originated from the remains of foraminifera, which had the power of secreting phosphate of lime from the sea-water, in the same manner as lime carbonate is now being formed, by the coral polyps, off the southern coast of the State. It has been urged against this opinion, however, that there is, at present, no foraminifer known, which secretes a skeleton of phosphate of lime, nor has there, yet, been discovered any fossil remains of these animals, having such a chemical composition.

It is the opinion of Dr. Francis Wyatt, author of the book, entitled Phosphates of America, that the Florida phosphates originated, mainly, from the Vicksburg limestone. The formation is known to contain, throughout its different layers, more or less phosphatic material, originally from organic remains; is usually of a porous nature; and is supposed to have been permeated by acidulated waters, which dissolved the lime carbonate, and carried it away in solution, while the less soluble phosphates were left behind. This residual phosphatic material was finally drifted, by the waves and currents into depressions, crevices and irregular weathered cavities in the limestone, where it now forms more or less extensive deposits.

The observations of the writer, on the Eocene and the Miocene formations of Florida and Georgia, appear to confirm Dr. Wyatt's theory, as to the origin of the phosphates. He frequently found, embedded in the limestones and marls, belonging to these periods, numerous remains of vertebrates. These fossils are quite conspicuous in the limestone near Faceville, Decatur county, Ga., where they make up a considerable portion of the rock-mass.

Both the rock and the pebble phosphates are thus referred to a common origin, while the peculiar form of the latter is accounted for, by the action of the waves, or by running water. Associated with these pebbles, are numerous remains of mammals and other animals. These fossils frequently occur in great abundance; and they have been considered, by some, to be the original source of much of the phosphatic material, found within the limits of the State.

The presence of these remains is explained, on the theory, which, however, seems unsupported by any well-established facts, that during the Glacial period, great numbers of land and other animals were driven south, by the extreme cold, to perish on the Florida peninsula.

Perhaps the latest theory, concerning the deposition of the Florida

phosphates, and one, that deserves the most attention, by reason of the author's extensive knowledge of the deposits, has recently been advanced by Mr. Geo. H. Eldridge of the U. S. Geological Survey. He refers the formation of the soft and the hard-rock phosphates to three different periods. The first period, in which the primitive rock was formed, he describes as follows: — "This stage began, probably, not later than the close of the Older Miocene and within the Eocene area — it may have begun much earlier. Whether the primary phosphate resulted from a superficial and heavy deposit of soluble guano, covering the limestones, or from the concentration of phosphate of lime, already widely and uniformly distributed throughout the mass of the original rock, or from both, is a difficult question. In any event, the evidence indicates the effect of the percolation of surface waters, highly charged with carbonic and earth-acids, and thus enabled to carry down, into the mass of the limestone dissolved, phosphate of lime, to be redeposited under conditions favorable to its separation. Such conditions might have been brought about, by the simple interchange of bases, between the phosphate and carbonate of lime, thus brought together, or by the lowering of the solvent power of the waters through loss of carbonic acid. The latter would happen, whenever the acid was required for the solution of additional carbonate of lime, or when, through aeration, it should escape from the water. The zone of phosphate deposition was evidently one of double concentration, resulting from the removal of the soluble carbonate, thus raising the percentage of the less soluble phosphate, and from the acquirement of additional phosphate of lime, from the overlying portions of the deposits. The thickness of the zone of phosphatization in the Eocene area is unknown; but it is doubtful, if it was ever twenty feet. In the Miocene area, the depth has been proved, from the phosphates in sight, to have been between 6 and 12 feet.

"The second period includes the secondary depositions, brought about, mainly, through sedimentation, in cavities of the primitive rock. The deposits of phosphate, formed, during this period, which was long continued, and finally closed, by some physical change, were quite free from iron and aluminum.

"The third period includes the time, during which the deposits, previously formed, were broken up; and their fragments were redeposited in the form, in which they are now found. These changes are supposed to have taken place, about the time of the last elevation of the peninsular above the sea-level."

Mr. Eldridge thinks, that the phosphate was originally derived from the remains of birds, mammals, marine animals and, possibly, also, from chemical precipitation. It is supposed, that the sea-water, at some remote period, contained much more phosphate of lime than at present; and there appears to be no satisfactory reason, he suggests, for its not having been deposited, under certain conditions, in the same manner, as calcium carbonate and other minerals. The porous Eocene and Pliocene limestones are pointed out, as presenting favorable conditions, for rapid solution, by the acidulated waters, and the concentration of their phosphatic material.

Dr. Safford, has advanced the following theories, to account for the origin of the Tennessee phosphates: —

"The phosphate bed of Swain creek, and of other creeks as well, not unfrequently contains fish remains, especially of jaw-bones. Fragments of bones, as wide as one's hand and ten inches long, have been collected. Smaller fragments are quite common. The rocks of middle Tennessee, be it remembered, are made up of matter, once deposited from the waters of ancient seas. The sea, which was a chief factor, in giving us the members of the Black Shale group, was of great extent, reaching from Arkansas and Missouri to the eastern border of Penn-

sylvania and New York. From this sea, in the course of long ages, were deposited the clays, sands and limy material, but chiefly clays, that made up the series of strata, with which we are now especially concerned. There were, also, during much of the same time, conditions existing, which, as will be seen, led to the depositions of phosphatic material and débris. All were dropped and accumulated on the bottom of the sea — the clays, sands, limy materials and, in a smaller measure, the phosphates. The sea, during this time, was the home of a prolific fish life. Fishes abounded throughout its great extent. Some of them, clothed with heavy armor, after the fashion of a heavy iron-clad, and of great size and fearful strength, were monsters, and easily rulers, of the sea. They have been named *placoderms*, a word meaning plated or cuirassed hide. In addition, sharks were plentiful, and fought with the cuirassed placoderms for supremacy. Then, there were multitudes of small fry, together with a quota of phosphate-bearing mollusca.

"Here we recall the fact, that the main phosphate lies immediately under the Black Shale, appearing to have close associations with it, an association, or the thought of it, strengthened by the further observation, that, now and then, a layer of phosphate occurs interstratified with the layers of shale. There is, thus, reason, for believing, that they have, in some measure, a common history, and that both are of the Devonian age. The fishes lived, multiplied and held their own, for a time, then died and passed into decay, scattering all, that was lasting of them, over the sea-bottom. Fish eat fish; hence their excrements contained largely comminuted bone and like matter, and are themselves a fair phosphate.

"In Ohio, all the refuse bone and excrements, from these ancient races, are diffused through hundreds of feet of strata. In Tennessee, during the same long ages, there was, on the one hand, only a mini-

mum of clay and sand deposited; but, on the other, just as much fish refuse. There, it is disseminated through a great vertical thickness of shales; here, it is concentrated in a thin bed, with little or no shale; concentration of this kind, we are inclined to believe, has been a factor in giving to Tennessee its remarkable beds of phosphate.

"Thus it would appear, that for a long time, during the first of the fish era, as we may call it, when the shales in Ohio were accumulating, there was no clayey deposition in Tennessee; and therefore, no shale was found. During this time, phosphate débris, gathered in Tennessee, was washed and transported by oceanic currents, and widely and thinly distributed over the sea bottom; but locally, perhaps, in eddies, heaped up in thick deposit, now, the veritable bonanzas of rock phosphate. This done, a time followed, when the waters of the sea, bearing light changes of clayey and organic matters, invaded our southern latitudes; and, unloading their burden, covered the phosphate scantily with the sediment, which is now the Black Shale."

"Another view, as to the source of phosphate of calcium in the phosphate bed, is as follows: — It has been maintained, that the mineral has been derived, primarily and chiefly from the minute shells, so often spoken of. These occur, in parts of the phosphate, in great numbers. Pieces of the rock have been seen, that were wholly made up of the casts of their interiors. With them, too, are the worn teeth. While mostly calcareous, some of the shells are known to have had more or less phosphate in their composition. This is certainly true of a flat, comparatively large, tongue-shaped shell, often associated with the others, and named *lingula*.

"For this view, it is argued, that, while the fish remains and débris occur, they are not abundant enough, to account for the accumulation of such a store of phosphate, as we find in the rock. At Comer's mines, for example, in Totty's Bend, the bed rarely shows a fish-bone,

while the shells abound. Again, by this theory, we can account for the phosphate in the lowest, or the limestone bed. Plenty of shells are seen in it; but, so far, no fish remains. Furthermore, the bed has been shown to be Trenton; and no large fish bones are known, as yet, in the Trenton, at least in Tennessee."

In speaking of the phosphate deposits of Cambridge, England, Prof. T. G. Bonney has the following to say, concerning their origin: —

"With regard to the mode of formation of these phosphatic casts, nodules etc., we have to consider, not only the probable source of the phosphate, but also the mode, in which it has been concentrated into these "coprolites." Phosphate of lime, in the form of apatite is present in granite, gneiss, slate, talc and chlorite schists, and several kinds of lava. . . . . It is, also, present, in the waters of numerous mineral springs. . . . . It has been detected in the waters of several rivers, and is probably present in all, as well as in the sea, though of course in small quantities. Again, phosphates (chiefly lime) are present in marine and other plants. In short, the various investigations, that have been made, show, that it is almost universally present in organic, and, not unfrequently, in inorganic bodies. . . . . .

"Next, it has been shown, by numerous experiments, that phosphate of lime is soluble in carbonated water, and further, that phosphate of lime, present in an organism (plant or animal), is much more soluble, than that in a mineral. . . . . Again, phosphate of lime, dissolved in carbonated water, is precipitated by ammonia, which is a result of decomposition of organic bodies. It appears then, to me, that the best explanation of these phosphatic nodules is to consider them formed, by what, for want of a better name, we may call concretionary action. The excreta, softer tissues, and smaller bones of the Vertebrata, the bodies of numerous Invertebrata, many of which

have left no other trace behind, the various marine plants, which probably flourish abundantly in a shallow sea, to say nothing of any apatite, which might be present in the detritus, wherein they were entombed, would furnish a considerable supply of phosphates; in fact, *coeteris paribus*, a shallow sea appears to me more likely to be rich in phosphates, than a deep one. The phosphates of the more perishable parts of the above named organisms would be dissolved, in the water permeating the mud of the sea bottom, which would, also, be supplied with carbonic acid from decomposition, and so the mud be saturated with a weak solution of phosphate of lime. Now, if at a certain point in the mud, there were an excess of phosphate of lime, and, especially, if ammonia were being evolved at that point, the phosphate in the neighboring solution might be precipitated; and, probably (for it seems to have often happened with other minerals), all the phosphates of the surrounding mass would be precipitated about the nucleus. I regard, then, these nodules, as the result of a process, which took place, during a part of the Gault period, and was continued, during the Greensand epoch, which began, shortly after the death of the organisms, and lasted for a long time; and I explain their abundance, as I have already said, by considering the seam of the riddlings of a considerable deposit. It is noteworthy, how often a bed of phosphate nodules comes just above a more or less marked stratigraphical break. It appears to me, therefore, that the progress of formation of these nodules is . . . . . very analogous to that of flint — both, in many cases, proceeded from the mineralization of sponges.

"It may not unfairly be asked, why, seeing, that weak solutions of phosphate of lime must be almost always present in sea-water, are not phosphate nodules generally present in rocks? The answer to this

is, that the phosphate nodules are far from rare, and that the difficulty is exactly of the same kind, as exists in the formation of flint.

"It may be, that local circumstances, as indicated above, have been favorable, to slightly concentrating the phosphatic element in the sea-water; but, without availing ourselves of this possibility, we may fairly answer, that the process of deposition from weak solutions, one, of which we are very ignorant, is probably a complex process, which requires several independent conditions to be fulfilled; so that it is but rarely, that all are satisfied."

CHAPTER III

DISTRIBUTION OF PHOSPHATES IN GEORGIA

Ever since the discovery of phosphate in Florida, it has been the prevailing opinion of many persons, that these deposits extend north, and would likely, at some time, be found in paying quantities, along the various streams and in the numerous swamps, of the border counties of South Georgia. This belief, in many instances, has caused the planters of the region to become generally interested; and frequent reports have been current, from time to time, of extensive and valuable discoveries, in several localities. During the spring of 1894, the writer visited South Georgia, to investigate these various reports, and, at the same time, to make an examination for deposits of marl. It was my good fortune, to have with me, for the first few days, Mr. Geo. H. Eldridge of the U. S. Geological Survey. Mr. Eldridge, who had spent three seasons in Florida, studying the phosphate deposits of that State, gave me much valuable information, concerning the nature of the deposits, and advised me, how to proceed with the work, in order to obtain the best practical results. Only about six weeks were spent in the field in South Georgia, the first season. During the following spring, the work was again taken up, and continued, until all the counties, bordering on the Georgia-Florida state-line, together with some of the counties of the Atlantic coast, were examined. The plan, adopted in the work, consisted of a pretty thorough examination of almost all the natural and artificial exposures of rocks and

marl-beds, reported in these counties. Chemical tests were made in the field, on all rocks, which were supposed to contain phosphoric acid; and, where its presence was found, in considerable quantities, the deposit was further studied, with reference to its economic importance, and samples were taken, for a complete analysis. Typical fossils were collected, wherever found, in order to establish the geological horizon, and, if possible, to correlate the different formations with the Florida deposits.

As it is almost impossible, for persons, not familiar with phosphate, to distinguish some of its forms from the different varieties of limestone, or chert, it was deemed best, to visit, as far as practicable, all the rock exposures. Much time was thus consumed, in examining outcrops which proved to have but little or no commercial value. This, however, seemed to be the only feasible way, of obtaining the necessary data, for a reliable report. The swollen condition of the rivers, in a few instances, seriously interfered with our making a satisfactory examination of their beds and banks. With these exceptions, the work was sufficiently complete, to give a general idea of the deposits, in the several counties traversed, and at the same time to establish, with a considerable degree of certainty, the truthfulness or falsity of the various current reports, concerning the discovery of valuable beds of phosphate in that region.

The topography of the region under consideration, has the general appearance of a plain. At only a few points, does it attain an elevation, of more than 300 feet above tide-water. Much of the area is practically level; and it is occasionally traversed, by cypress swamps, or series of lime-sinks, which frequently form chains of beautiful lakes, that add variety to the otherwise monotonous landscape. In places, notably the greater part of Brooks, Thomas and Decatur counties, the surface becomes quite rolling, and resembles, in a somewhat

general way, the rolling portions of North Georgia. The streams are all sluggish, with no well defined valleys. In the more elevated areas, they have cut deep channels, exposing, in places, bluffs, from 30 to 60 feet in height. The bluffs commonly lie adjacent to long stretches of low palmetto lands, which become flooded, during the rainy season. Large springs, that appear to be the outlet of small subterranean rivers, are frequently met with. They commonly occur, in the vicinity of lime-sinks, with which they seem to be intimately connected.

The soils of South Georgia, along the Florida state-line, may be divided, for convenience, into two classes, the sandy and the clayey soils. The former is much more abundant, than the latter, and, also, less productive. The natural growth of the sandy soil consists mainly of long-leaf pine, dwarf palmetto and wire-grass. When first cleared, these soils produce good crops of cotton, sugar-cane, potatoes etc.; but, owing to their porous nature, the plant-foods are soon leached out, and almost continuous fertilizing is afterwards necessary, in order to keep up their original fertility. While this may be stated, as a general rule, applying to all the sandy soils, there are, however, some very interesting exceptions. These exceptions consist of certain fields, which have been under almost constant cultivation, for many years, and which still retain, to a remarkable degree, their former productiveness. An examination of some of these fields showed, that there are scattered through the soil numerous small sandstone boulders or pebbles, whose cementing material consists mainly of phosphates of lime. Thus, the continuous fertility of these fields is undoubtedly due, in a general measure, to the slow disintegration of these boulders, and a gradual liberation of the phosphate, which has become a perpetual source of plant-food.

The clayey soils are found, in the more elevated areas; and they are

both fertile and durable. They are locally known, as hummock lands; and they were originally heavily wooded with oak, hickory and other species of hard woods. These lands yield, without the aid of fertilizers, good crops of corn, cotton, oats etc., besides pears and various other fruits.

The geological formations, occurring in the various counties visited, consist of the Columbia and Lafayette, together with certain portions of the Miocene and Eocene. Both the Columbia and the Lafayette are superficial deposits of sands and clays, extending over the entire area, and forming the above named soils. The Miocene and the Eocene formations, which consist principally of limestone, chert and marl-beds, are rarely exposed, except along the larger streams, and in the numerous lime-sinks. The boundary line, separating the outcropping of these two latter formations, has never been accurately determined. Dr. Spencer, formerly State Geologist of Georgia, in his report for 1890, covering the western part of this area, maps the northern half of Decatur county, and also the northwestern corner of Thomas county, as Eocene, the boundary line passing a short distance south of Bainbridge and near Forest Falls. My own observation shows, that the white limestone, the upper beds of the Eocene formation, extends much further to the east, underlying the Lafayette, in the greater part of Thomas and Brooks counties, the eastern boundary extending, in places, as far as the Withlacoochee river, or even beyond.

DECATUR COUNTY

The greater part of Decatur county, lying between the Chattahoochee and Flint rivers is practically level; and only a few opportunities

are offered, throughout this wide stretch of piney woods, to study the formation, underlying the superficial layer of sand. Spring creek, a stream of considerable size, traversing the center of the area, has, at different points along its course, outcroppings of rock, that were examined. These exposures usually occur on the gradually sloping hillside, close to the stream, or in the lime-sinks, near by. No high banks or bluffs were seen, where a geological section could be made out.

W. D. LANE'S PROPERTY

One of the most extensive rock exposures, observed on the creek, appears on W. D. Lane's property, *lot 234, 27th district*, four miles north of Brinson. The exposure, here, extends over a number of acres in the piney woods, near the creek, and consists of numerous flint boulders, many weighing several tons, and all well filled with fossil oysters, pectens, sea-urchins and small gastropods.

THE PROPERTIES OF C. R. ASH AND OTHERS

Similar outcroppings were also observed, on C. R. Ash's property, one mile west of Brinson, and at a number of other points along Spring creek, as far south as its junction with the Flint river. Specimens of these rocks occasionally show traces of phosphate; but the amount is too small to be of any economic value, as a fertilizer. Besides this siliceous material, there also occurs, at a few places, lime-

stone, that has frequently been mistaken for phosphate. One of the best exposures of the limestone appears in the woods, on the right bank of Spring creek, just below the Savannah, Florida & Western R. R. bridge, a few hundred yards west of Brinson. It is seen, here, outcropping near the roadside, where it forms thin, compact layers, which weather, with a comparatively smooth surface. Only a few fragments of fossils were observed here; but a number of wells, sunk in the neighborhood, show, that the upper beds of this limestone are composed largely of comminuted shells.

J. L. GRAYHAM'S PROPERTY

Still further down the creek, near its mouth, while a well was being dug, a short time ago, on property owned by J. L. Grayham, a soft, light-colored, marly rock resembling certain varieties of phosphate, was struck. Considerable local interest was manifested, at the time, over the discovery; and the report became current, that a valuable deposit of phosphate had been located. An examination of the material proved it to consist, almost entirely of carbonate of lime, with a slight trace of phosphoric acid.

In the immediate vicinity of Grayham's property, on the bank of Spring creek, is to be seen one of the most magnificent springs, probably the largest, in South Georgia. It compares favorably, in size and the transparency of its waters, with the Silver Springs of Florida; and it will well repay a visit, to any one, passing through this part of the country. In some of its deepest parts, are exposures, of what appear to be outcroppings of limestone; but they lie at such a great

depth below the surface of the water, that it was found impossible to secure specimens for examination.

EAST OF THE FLINT RIVER

That portion of Decatur county, lying east of the Flint river, has a more varied topography, than its western part. In the vicinity of Whigham, the surface becomes quite rolling and broken, many of the hills reaching an elevation of nearly 300 feet above the sea-level. The small streams in this locality are often rapid, and flow in deep channels, cut in the clays and underlying limestone. The more level areas, known as the piney woods, have their numerous lime-sinks and slues, the abandoned beds of former streams, all exposing, to a greater or less extent, the formations beneath the superficial clays and sands.

THE RED BLUFF EXPOSURES

The Flint river, which traverses, in a southwestern direction, the central portion of the county, exposes, at numerous points along its course, high banks, where the different formations may be studied. One of the most interesting of these exposures occurs on the right bank of the river, about seven miles above Bainbridge, at what is known as Red Bluff. Just below this point, running parallel with the river, and extending back from it, for some distance, is a terrace, fifteen or twenty feet high. This natural embankment gradually approaches the river, where it finally terminates, forming the upper part of the

bluff. At the base of the bluff, which is, here, more than forty feet high, and almost perpendicular, is to be seen, near the surface of the water, a light brownish-colored limestone, whose weathered surfaces exhibit many irregular cavities and angular projections, of fantastic shape.

The limestone contains a considerable quantity of siliceous material, frequently in the form of shell-casts. Fossil oysters, sea-urchins, orbitolites etc., are common; but they are usually imperfectly preserved, and difficult to remove from the calcareous matrix. Overlying the limestone, are beds of reddish and grayish sands and clays. Some of the lower beds are made up, mainly of coarse sand and water-worn pebbles; but none of them contain either phosphate or marl.

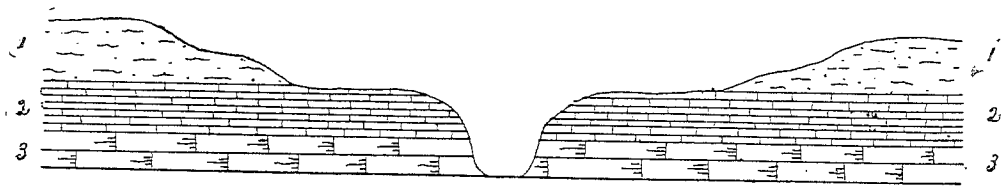
SOUTH OF BAINBRIDGE

Further down the river, especially south of Bainbridge, are numerous other bluffs, ranging in height from 10 to 30 feet. Many of these have, outcropping at their base, huge masses of chert, made up largely of the casts of fossils. Beneath the chert, and just above the water's edge, was noticed, at a few points, a light-colored, compact, partially crystalline limestone, that appears to be well suited for building purposes.

Between Bainbridge and the state-line, several small streams, entering the river, from the more elevated region to the east, have eroded deep channels, that expose the different formations, to the depth of many feet. The most interesting of these natural sections is the one, formed by a stream, which takes its rise near Faceville, the most elevated point in the county. In its course to the river, which does not

exceed three miles in total length, it has a fall of nearly one hundred and fifty feet. Within this distance, are to be seen, at places, a number of rapids, where the stream has cut a deep channel, only a few feet wide, into the underlying limestone. At other points, the

Fig. 1



Section through the Gorge along Faceville Branch. 1. Sandy Clays. 2. Partially Decomposed Limestone. 3. Compact, Quick-bedded Limestone.

stream flows underground, giving rise to lime-sinks, by carrying away, in solution, the overlying calcareous rocks. Near the source of the stream, which is in the head of a deep hollow, within a few rods of the Savannah, Florida & Western R. R., are numerous exposures of limestone, both in the bed of the stream and along the adjacent hillside. The limestone is compact and of a light color, with many small cavities, filled with calcite. It contains numerous fossil shells, besides fragments of bones in great abundance. The bones are usually small, only a few being more than an inch and a half in diameter. Analyses of specimens of the rock show an average of nearly 4 per cent. of calcium phosphate. In the bed of the stream, near by, were found some small pieces of a rock phosphate, which resembles very closely, in general appearance, the laminated variety of phosphate, found in Florida. The original source of the rock phosphate, occurring here, could not be definitely located. However, it seems quite likely, that it appears in the limestone, where it has been deposited, in thin layers. Half a mile or more down the stream, the limestone becomes semi-crystalline; and it has been quarried to a limited extent, for building

purposes. It contains, here, but few fossils. Still further down the stream, near where it enters the river, is a section, where a calcareous clay or marl, containing oyster shells, overlies the semi-crystalline limestone.[1]

About six miles southwest of Faceville, the same argillaceous, rotten limestone, or marl, again appears in a lime-sink, located close to the railroad, a few hudred yards west of Recovery station. It, here, carries a small percentage of phosphoric acid; and it might be used, with profit, as a fertilizer on sandy soils. Overlying these calcareous deposits, are reddish- and orange-colored clays and sands, which frequently show cross-bedding. Only a few fragments of fossils were noticed here; and these were confined entirely to the calcareous beds.

BETWEEN FACEVILLE AND RECOVERY

At several places, along the small stream between Faceville and Recovery, were observed exposures of limestone and flint. In some of the more highly cultivated fields, near the river, boulders of these rocks are so abundant, that they interfere with the cultivation of the soil, and have to be heaped together in piles. Large pieces of silicified coral, weighing 50 pounds or more, are often seen in these heaps, besides fossil oysters, sea-urchins etc. A chemical test, made on specimens, taken from several of these exposures, showed only a trace of phosphoric acid. Nevertheless, many of the siliceous nodules resemble very closely, in appearance, certain types of hard-rock phosphate.

[1] See Fig 1.

THE FREEMAN PROPERTY

In going east from Recovery, no exposure of any importance was seen, until the Freeman plantation, which is on Big Attapulgus creek, was reached. This stream, which, in places, has considerable fall, has carved out of the overlying sandy and clayey formations a wide valley, that is now frequently covered with water, forming a swamp, through which the stream meanders. On either side of these swamps, the surface is often quite rolling; but it soon becomes comparatively level, and forms the typical "piney woods." In making an excavation for a mill-site, a few years ago, on the above plantation, a layer of marl, containing fossil bones and casts of shells, was struck, near the surface, and penetrated, to the depth of about eight feet. The discovery, at the time, attracted some local interest, merely as a curiosity, but it was soon forgotten. At the time of our visit, the stream was swollen by the recent rains; and only a very imperfect examination was made of the deposit. However, a sufficient amount of it was exposed to give a general idea of its character. It consists of a sandy calcareous clay, or marl, of light color, containing fragments of bones and many shell-casts. These bones, which were examined, were all small, appearing to be the vertebræ of fishes. Besides these, there is said to occur here, also, large bones of mammals, probably remains of the mastodon. Analysis of a specimen of the marl, taken from the excavation, showed 6.80 per cent. of calcium phosphate. There appears to be no reason, why the farmers in the immediate vicinity, might not use it with profit, on their growing crops, as a natural manure. Such a test could be easily made, with but little expense; and it will evidently prove of great value to the adjacent country. At any

rate, the deposit seems to be of sufficient promise to warrant a thorough, practical test of its fertilizing properties.

J. R. McCALL'S PROPERTY

About seven miles southwest of Attapulgus post-office, near the state-line, a similar deposit occurs on J. R. McCall's property. It is exposed, here, along a small stream, at a number of places, where it has frequently been mistaken for phosphate. Analysis shows, that it contains a considerable amount of phosphoric acid, but not in sufficient quantity, to be of value, in the manufacture of commercial fertilizers. Certain layers of the deposits are compact, and form an impure limestone; while others are comparatively soft, and can be easily excavated, with the shovel or pick. Fossil shells are found in all the different layers, being especially abundant in some of the softer beds. In digging a mill-race on the property, a few years ago, there is said to have been discovered, near the surface, the remains of a large animal, whose vertebræ measured several inches in diameter. The exact geological position, occupied by these remains, could not be definitely determined. However, it is more than likely, that they were embedded in the clays, overlying the marl-beds. There can be little doubt, but that these calcareous deposits or marl-beds, which, probably, belong to the Miocene formation, underly the greater part of the southern portion of the county; and they are likely to be found, outcropping along the numerous streams, that have removed, by erosion, the overlying formations. Should the deposit prove to be of economic value as a fertilizer, the supply, which is practically inexhaustible, may become of very great importance to that part of the county, in restoring the now exhausted lands to their original fertility.

THE TERRITORY AROUND WHIGHAM

In the southern portion of the county, in the vicinity of Whigham, several days were spent, in examining the various localities, where phosphate was reported to occur. Under the guidance of Hon. R. A. Connell, who has done much, toward advertising the natural resources of this part of the county, I visited many exposures and outcroppings of the various formations, for several miles around. While my investigation, here, did not reveal what the more sanguine had expected; nevertheless, it showed, that some of the reports, at least, of the occurrence of phosphate in that region, were founded on fact.

One of the most interesting natural exposures, in this part of the county, is to be seen, at what is locally known as Forest Falls, seven miles north of Whigham. There occurs, here a magnificent waterfall, eighty feet in height, formed by a small stream flowing into a lime-sink. A view of the falls,[1] from the side of the sink, forms a picture of remarkable beauty. Especially is this true, at noonday, when the falling column of water is lighted up, by the sun's rays, from top to bottom, and the rainbow, with its many colors, is to be seen on the rising mist. The attractiveness of the picture is strengthened, by a background, formed by a primitive forest of pines, that has given to the falls their appropriate name.

There is exposed, here, an excellent geological section, more than ninety feet in thickness. The upper part of the section consists of sand and motley-red clays, twenty feet thick, belonging to the Lafayette formation. Beneath this, occur beds of limestone, which extend to the bottom of the sink. The upper portion of the calcareous formation consists of a bed of soft argillaceous limestone, of a grayish or green-

[1] See Plate III.

ish color. It contains fossil shells, and, also, a few fragments of bones, some of which appear to be portions of ribs, which frequently measure more than an inch in diameter. These osseous remains always run high in phosphoric acid; but the calcareous deposit itself usually runs quite low. The remaining beds differ somewhat in their general appearance and structure. Some are compact, weather slowly, and form projecting shelves. Others are soft, of a porous nature, and weather more rapidly. Nearly all the different beds contain a few fossils, the most abundant being barnacles, spines of sea-urchins, and casts of pectens. Almost the entire formation has a peculiar, concretionary structure, due, apparently, to the natural tendency of the calcareous material to collect about a center, during the time of its deposition. It is questionable, whether any of these different beds contain anything more, than a mere trace of phosphoric acid. Nevertheless, the soft, upper layers might be used to an advantage, as a fertilizer, on sandy soils, deficient in lime. The report of the occurrence, here, of high-grade phosphate seems, to have originated, from the chemical analysis of fragments, consisting largely of bone.

About four miles northwest of Forest Falls, *in the 16th district*, is located, what is known, as the "Water Falls." It is formed, by a small, evanescent stream falling, about thirty-five feet, into a circular lime-sink, twenty feet in diameter. There extends back from the falls, for more than a hundred yards, a narrow sinuous gorge, twenty-five feet deep, through which the stream flows. Both sides of the gorge are nearly vertical; and they give a good exposure of the superficial clays and sands, as well as a few feet of the upper bed of the underlying calcareous formation. The sands and the clays have the usual characteristics of the Lafayette formation, as seen elsewhere in the county, while the calcareous beds differ slightly, from any hitherto described. The upper portion of the calcareous formation con-

sists of very soft, clayey limestone, in which occurs a layer of very compact semi-crystalline limestone, well suited for building material. The soft layers contain a small amount of phosphoric acid, and could probably be used, with profit, as a fertilizer. Some of the beds are fossiliferous. The most common fossils are pectens, sea-urchins, orbitolites and gastropods. The last mentioned are frequently quite large, measuring, sometimes, four or five inches in diameter. There was, also, found in the gorge, projecting from the upper layers of the rotten limestone, a piece of a rib of some animal, fifteen inches long and one and a half inches in diameter. Analysis of the bone gave the following results: —

Sand and insoluble matter	0.50
Loss on ignition	10.00
Al_2O_3, Fe_2O_3	0.26
CaO	52.12
P_2O_5	33.24
Undetermined	3.88
	100.00

33.24, P_2O_5 corresponds to 72.46, $Ca_2(PO_4)_2$.

It seems quite probable, that much of the phosphoric acid, found in these calcareous deposits, has been derived from the osseous material, which they contain.

F. A. BURROWS' PROPERTY

About three quarters of a mile from the "Water Falls," on an adjoining farm, owned by Mr. F. A. Burrows, is another lime-sink,

known as the Blowing Cave. It is so named, on account of an alternate current of air, passing in and out of an opening, in the bottom of the sink. There are other lime-sinks on the property, all showing practically the same formations, as those, which occur at the "Water Falls." Natural exposure of limestone are, also, to be seen on the property. These outcroppings usually occur on hillsides, and consist of a compact, more or less fossiliferous limestone, which has been used, to a limited extent, for building purposes. In the cultivated fields, and along the roadsides, in the vicinity of the Blowing Cave, were noticed many fragments of silicified corals, some of which weighed several pounds.

SINK OF THE LEVELS AND OTHER PROPERTIES

Some eight or ten miles northwest of Whigham, in the *16th district,* are a number of interesting ponds, lakes and lime-sinks. The most noted of these are the Rock and Camp ponds, Open View and Black lakes, and the Sink of the Levels. All are surrounded, by outcroppings of rocks, that have been mistaken for phosphate, from time to time. These rocks were found to consist of chert or flint and limestone. The former usually occurs as immense boulders; and in places they are made up, largely, of the casts of shells, the most common being pectens and oysters. The chert has evidently originated from the silicification of highly fossiliferous limestone. It appears to form no continuous bed; but, on the contrary, it is made up, of large, irregular masses, distributed promiscuously throughout the superficial sands and clays. Many of the boulders, when freshly broken, resem-

ble, very closely, certain varieties of rock phosphate. Chemical tests, however, show them to contain only a trace of phosphoric acid. The limestone is usually quite fossiliferous, and frequently phosphoric. The following section, made from a well, recently dug on Mr. A. McChester's property, near Open Vine lake, gives a good idea of the geological formations, in a descending order, occurring in this part of the county: —

Light-colored, Sandy Clays	10 feet
Motley-red Clays	12 "
Dark-blue Clays	10 "
Shelly Limestone, or Marl	3 "
Soft Limestone, with Sea-urchins	10 "
Hard, Compact Limestone	8 "

Both the shelly and the soft limestone contain phosphoric acid; and they could doubtless be used, with profit, as a fertilizer.

A small hand specimen of hard-rock phosphate, secured from Mr. J. H. Brown's property, *lot 74, 16th (?) district*, gave, upon chemical analysis, the following results: —

Sand and insoluble matter	8.16
Loss on ignition	3.31
Al_2O_3, Fe_2O_3	1.98
CaO	48.79
P_2O_3	35.19
Undetermined	2.57
Total	100.00

35.19, P_2O_5 corresponds to 76.71, $Ca_3(PO_4)_2$.

The occurrence of hard-rock phosphate on this property is quite limited, and is not considered to be of any commercial importance.

G. W. RAGAN'S PROPERTY

About eight miles south of Cairo, in the *19th district*, on property, belonging to Mr. G. W. Ragan, occurs a peculiar sandstone formation, observed at no other place in the county. It appears, here, as large boulders and disconnected masses, covering an acre or more, in the open piney woods. An attempt was made, a few years ago, to use it in the manufacture of mill-stones; but it proved unsatisfactory, on account of its softness. It has since been used, to a limited extent, in the neighborhood, in making foundations for houses, constructing chimneys etc. Chemical analysis of hand specimens, chipped from the boulders, shows a fraction over 2 per cent. of calcium phosphate. The phosphatic material seems to form a part of the white-colored cement, uniting the grains of sand.

In the extreme southwestern corner of the county, along the state-line, are a number of exposures of marl-beds, that resemble, very closely, those, found further west on the Freeman property. One of the best exposures is to be seen on Ponto creek, just across the state-line. The exposure, here, consists of a soft, marly limestone, several feet in thickness. It contains many fossil oysters, pectens and fragments of bones, all well preserved.

THOMAS COUNTY

THE TOY PROPERTY

Much interest was manifested in this county, during 1889 and 1890, over the discovery, in the vicinity of Boston, of what was then supposed, to be a valuable deposit of phosphate. The discovery was

first made by Mr. Dunwoody Jones of Atlanta, on Mr. T. S. Toy's property, 3 miles west of Boston, near the Savannah, Florida & Western R. R. Shortly afterwards, a similar deposit was found on the Eaton property, near by; and later, still, a like discovery was made on L. C. Varnador's farm, 3½ miles east of Thomasville. A company, styled the Georgia Mining Company, was soon organized by Mr. Jones and others, and mining operations were begun on the Toy property. A phosphate plant, consisting of rock-crushers, driers, washers etc., was erected, and the necessary side-track was constructed, for the shipment of phosphate. The work was carried on, irregularly, for about two years, when it was finally shut down. During this time, several large excavations were made on the property; but only one or two car-loads of phosphate were shipped. The main cause, which led to the abandonment of the work, seems to have been the limited quantity of phosphate, together with the great thickness of the overburden, that had to be removed by pick and shovel.

The works, on the Toy property, are situated on both sides of the Thomasville & Boston road, a few hundred yards west of Aucilla creek. The fields, where they occur, slope gradually towards the creek; and, on either side of the road, they have been eroded into deep gullies, exposing numerous irregular masses of flint, of various sizes. The phosphate generally appears, in the form of nodules or concretions, varying, from an inch or less to a foot or more, in diameter. These nodules occur, scattered promiscuously throughout the motley-reddish, sandy clays, which overlie an irregularly eroded surface of limestone. Besides the nodules, or hard-rock phosphate, there also occurs a limited quantity of soft phosphate, which resembles very closely common chalk. The prevailing color of both varieties is white, though they are often tinted, with yellow or green. A chemical anal-

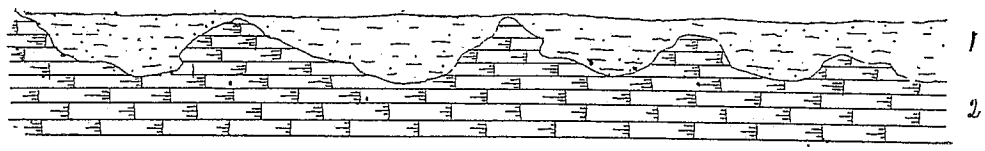
ysis, of what was supposed to be an average specimen of the hard-rock variety, gave the following results: —

Sand and insoluble matter	4.60
Loss on ignition	4.95
Al_2O_3, Fe_2O_3	2.78
CaO	49.60
P_2O_5	35.45
Undetermined	2.62
Total	100.00

35.45, P_2O_5 corresponds to 76.38, $Ca_3(PO_4)_2$.

The limestone, underlying the sandy clays, is of a white or creamy color. It contains much siliceous material, is frequently highly fossiliferous, and weathers irregularly. Dr. Spencer has classed the limestone as middle Miocene. The occurrence of numerous orbitolites, in

Fig. 2



Ideal Section Showing Unconformity at the Boston Phosphate Works. 1. Sandy Clay Containing Nodules of Phosphate. 2. Limestone Showing Irregularly Eroded Surface.

its upper layers, indicates, that it is probably the White Limestone of the Upper Eocene. There is a marked unconformity, existing between the limestone and the overlying sands and clays.[1] Immediately overlying the limestone, is a thin layer of sandy clays, containing many siliceous shells of oysters. In this bed, are sometimes found nod-

[1] See Fig. 2.

ules of phosphate; but they more frequently occur in the sandy clays above, which often attain a depth of twenty feet or more.

J. B. EASON'S PROPERTY

About one mile southwest of the Toy phosphate pits, are other similar excavations on J. B. Eason's property. The excavations are located in a field on the south slope of a hillside, near the Savannah, Florida & Western R. R., thirty or forty feet above the surface of Aucilla creek. There is exposed, here, a highly siliceous, fossiliferous, white-colored limestone overlaid by motley, sandy clays, containing phosphatic nodules. The clays vary, in thickness, from three to twenty feet, and are unconformable with the underlying limestone. The following analysis may be taken, as showing the chemical composition of a fair average sample of the nodules collected: —

Sand and insoluble matter	6.58
Al_2O_3, Fe_2O_3	2.14
CaO	48.20
P_2O_5	33.67
Undetermined	9.41
Total	100.00

33.67, P_2O_5 corresponds to 73.40, $Ca_3(PO_4)_2$.

L. C. VARNADOR'S PROPERTY

The deposit of phosphate on L. C. Varnador's property is located on *lot 131, 13th district,* Thomas county. It outcrops, about three hundred yards north of the mansion-house, along the side of a low ridge, which overlooks a small branch to the west. The outcropping occurs about thirty feet below the top of the hill, and ten feet above the water-level; and it may be traced, east and west, for three hundred yards. The phosphate appears in the form of nodules, distributed through a stratum of about six feet of brownish, sandy clays. Associated with it, are many nodules of flint and sandstone. The cementing material of the latter consists mainly of phosphate. Most of the phosphate nodules are of a white or cream color; but there also occur specimens of a brownish or yellowish color, due to the presence of iron. A small number of prospecting pits, which have been sunk along the line of outcropping of the almost horizontal phosphate-bearing stratum, indicate, that the deposit is not of sufficient abundance, to be of any economic value.

The analysis of two samples, taken from the deposit, showed the following results: —

SAMPLE NO. 1

Sand and insoluble matter	6.71
Loss on ignition	3.72
Al_2O_3, Fe_2O_3	2.66
CaO	48.60
P_2O_5	34.89
Undetermined	3.42
Total	100.00

34.89, P_2O_5 corresponds to 76.06, $Ca_3(PO_4)_2$.

SAMPLE NO. 2

Al_2O_3, Fe_2O_3	1.14
CaO	51.17
P_2O_5	35.96
Undetermined	11.73
Total	100.00

35.96, P_2O_5 corresponds to 78.39, $Ca_3(PO_4)_2$.

MRS. MITCHELL'S PROPERTY

Several exposures of rocks, which have been supposed to be phosphate, occur near the roadside, between Boston and Thomasville. Some of the most extensive of these exposures are to be seen at the lime-sinks, on Mrs. Mitchell's farm, seven miles east of Thomasville. The exposure, around the pond, south of the road at this point, is made up chiefly of large siliceous brecciated boulders, slightly phosphatic, and weathering, on the surface, into a white, porous mass, resembling chalk. The outcropping, at the lime-sink, on the opposite side of the road, consists mainly of limestone, which has been used, to a limited extent, for making lime. It is a light-colored, soft and somewhat porous limestone, containing a few fossil orbitolites, pectens, sea-urchins etc.; and, when weathered, it presents a very irregular surface. The entire bed carries a small percentage of phosphoric acid; but the quantity is too small, to be of any value.

THE HEARD PROPERTY

A siliceous deposit similar to the one, exposed at the pond, south of the road, on the Mitchell property, occurs in a swamp on the Heard property, six miles east of Thomasville, near the Thomasville and Quitman road. The exposure consists of numerous boulders, imbedded in the wet, marshy soil. Some of these weigh many tons; but they are usually much smaller. Their outer surface is generally white and chalky in appearance, while within, they are compact, and frequently have a greenish tint. All are phosphatic; but the percentage of phosphoric acid is always low.

DR. MALLETT'S PROPERTY

There occurs, four miles south of Boston, on Dr. Mallett's property, *lot 14, 14th district*, an interesting deposit of phosphatic material. It is exposed on a hillside, in deep gullies, along both sides of the road, leading from Boston to Monticello. The thickness of the exposed part of the deposit is about ten feet; and is made up of a tough, tenacious, light-colored clay, in which are embedded numerous phosphatic nodules, which vary, from one inch to a foot or more, in diameter. The nodules are quite soft; and, when exposed a short time to the atmosphere, they crumble into a white, friable powder. A chemical analysis, of what was supposed to be an average sample, gave the following results: —

Loss on ignition	12.27
CaO	12.06
Phosphate of Al and Fe	30.45
SiO_2	45.34
Total	100.12

The phosphoric anhydride present is equal to 20.42 per cent., which corresponds to 44.51 per cent. of $Ca_3 (P O_4)_2$; but the lime present is sufficient to combine with only 10.25 per cent. of $P_2 O_5$. This gives 22.34 per cent. of $Ca_2 (P O_4)_2$, the actual per cent. of the commercial bone phosphate present.

Associated with the phosphatic nodules are many silicified coral masses, some of which are more than 18 inches, in diameter. No other fossils were noticed, at this point; but, along the roadside, near by, were seen numerous fragments of oyster shells, in the yellowish, sandy clays, overlying the phosphate bed. No prospecting has been done on the property, and consequently little is known of the extent of the phosphatic deposit. The overburden is a yellowish, sandy clay, about three feet in thickness.

THE McINTYRE, CLAYPOLE AND MITCHELL PROPERTIES

The McIntyre, Claypole and Mitchell properties, located from 8 to 12 miles south of Thomasville, all have rock exposures; but an examination proved, that they contain little or no phosphoric acid. The outcropping consists chiefly of limestone, with an occasional thin layer or nodule of sandstone or flint. The best exposure of these deposits is to be seen on the McIntyre property, where quite an outcropping oc-

curs, on a gradual sloping hillside, in an old field, near the roadside. The limestone is usually thick-bedded; and some of the layers, which are semi-crystalline, have been used, to a limited extent, locally, for building purposes, and for tombstones. It is not adapted to the latter use, by reason of its softness; but, for the former, it seems to be better suited, especially for retaining-walls etc. Many of the less compact layers contain fossils, the most common being pectens, orbitolites, fragments of sea-urchins etc. Strewn about the field, were noticed numerous pieces of silicified coral, some of which weighed several pounds. The overlying, reddish, sandy clays are frequently unconformable, and often contain oyster shells in the lower layers. These clays are well exposed, in the deep gullies, on either side of the public road, passing through the plantation, where they may be studied.

J. L. CUTLER'S PROPERTY

Further east, on Mr. J. L. Cutler's property, which is situated nine miles south of Boston, are other rock exposures on a small tributary of Aucilla creek. The outcropping occurs, here, in the bed of the stream, at a small grist-mill; also along the adjacent hillsides. The upper part of the exposure consists of siliceous, brecciated boulders, embedded in the red clays. The outer, weathered surface of the boulders is quite soft, and of a light color; while, within, they are of a greenish tint and compact, breaking with a conchoidal fracture. They contain a small amount of phosphoric acid; but the percentage is too low, to be of any economic value. Underlying these flint boulders, is a light-colored, compact limestone, also slightly phosphatic. As far

as our observation extended, there appear to be no organic remains, in either the siliceous boulders or the limestone.

OTHER PROPERTIES

South of this point, are numerous other rock exposures, in the vicinity of lake Imonia, near the state-line. They consist of limestone, flint and sandstone. The latter generally appears, in disconnected masses, on the hillsides of cultivated fields, and along the shores of ponds or small lakes. The cementing material is of a whitish color; and is made up chiefly of carbonate of lime and phosphate.

BROOKS COUNTY

The topographic features of Brooks county differ but little, from that of Decatur and Thomas counties. The surface is often rolling; and, in places it is traversed, by chains of lime-sinks, forming beautiful ponds and small lakes. The streams are numerous; and, in places they have cut deep channels, in the clays and overlying sands. Much of the county still retains excellent virgin forests of pine and the various hardwoods. The soil is generally fertile, and produces good crops of cotton, corn, oats, potatoes etc. Many of the farmers have excellent homes, and are in independent circumstances, a natural result of the varied crops, together with the fertility of the soil. There occurs along the many streams, and about the lime-sinks, in the county,

numerous rock exposures, which were visited and tested for phosphoric acid.

GRIFFIN HALLAWAY'S PROPERTY

One of the most interesting of these exposures is to be seen in the extreme northwestern part of the county, on Mr. Griffin Hallaway's property, *lot 447, 13th district*, four miles east of McDonald. There appears, here, in the open piney woods, a large irregular lime-sink, known as the Devil's Hopper, which exposes the different formations to the depth of nearly forty feet. The two wet-weather streams, entering the sink from opposite sides, have cut deep channels, that extend back, for several rods, and give good sections of the superficial clays and overlying sands. At the bottom of the sink, is exposed about twenty feet of cream-colored arenaceous limestone, which seems to be entirely destitute of organic remains. The different layers vary in hardness; but all weather into a sandy, calcareous mass, containing a small percentage of calcium phosphate. Much of this calcareous material is soft and friable; and it could doubtless be used, with profit, as a fertilizer on the surrounding cultivated fields. Overlying the limestone is a grayish, sandy clay, that appears to have originated from the weathering of the limestone. This, also, contains phosphoric acid; but the percentage is so low, that it could hardly be used, with profit, as a fertilizer.

THE BRICE AND CHAPMAN PROPERTIES

On the Brice and Chapman properties, a few miles east of the Devil's Hopper, occur numerous loose boulders, scattered about the cultivated field, which have been supposed, by some, to be phosphate. These rocks usually appear on the hillsides, that have been washed into gullies, and are frequently so abundant, as to interfere with the cultivation of the soil. They consist of sandstone and concretions of impure iron ore, with slight traces of phosphoric acid. With the above exception, there seems to be no other rock exposure, of any importance, in the northern part of the county. This appears to be mainly due to the sluggish condition of the streams, which have not, yet, succeeded, in cutting their channels through the overlying sands and clays. In several wells, in this part of the county, it is reported that rock has been struck at depths, varying from 20 to 40 feet, below the surface.

From the description, given, of the rocks thus exposed, it appears, that they consist principally of limestone, with, however, a few exceptions.

DUKE'S WELL

One of the most interesting of these exceptions, which came under our observation, occurs in Duke's well, in the *12th district*, a short distance from Morven. There were discovered here, at a depth of 15 or 20 feet from the surface, in a layer of sandy clay, some very peculiar, siliceous concretions, which resemble very closely some varieties of

hard-rock phosphate. The concretions vary, from an ounce to several pounds in weight, and are of all conceivable shapes. They are of a beautiful snow-white color, and very similar, both in weight and physical appearance, to casts made of plaster-of-paris.

OTHER EXPOSURES ALONG THE WITHLACOOCHEE RIVER

Besides the above exposures, there are many others, along the Withlacoochee river, that were examined. This stream, which forms the greater part of the eastern boundary of the county, carries a considerable volume of water, during the rainy season; and it has, at a few points, cut a deep channel into the superficial deposits. The bluffs, thus exposed, vary from 20 to 40 feet in height, and are formed principally of stratified clays and sands. At the base of the bluffs, near the water's edge, are frequently seen outcroppings of limestone; but these are mostly confined to the bed of the stream; and they can be satisfactorily examined, only when the river is quite low. They occur, at various points, in the channel, as far up the river, as the Savannah, Florida & Western R. R. bridge, and even beyond. Just below this bridge, within a few rods of the river, an exposure of calcareous rock may be seen, in a large spring, located in what is now known as Wade's Park. The spring furnishes a large volume of transparent water, which comes up, with considerable force, through an irregular opening in the rock below. Owing to the depth of the exposure from the surface, it was found to be impractical, to make any satisfactory examination. However, judging from the small fragments, broken from the rock, it consists mainly of soft, siliceous limestone, containing a trace of phosphoric acid.

T. J. APAIN'S PROPERTY

About three miles south of Wade's Park, the same calcareous formation again appears in the bed of the river. There also occurs, here, on T. J. Apain's property, *lot 253, 12th district,* a short distance below the mouth of Piscola creek, a deposit of marl, forming a bed, about two feet in thickness. It outcrops, near the base of a steep hill or bluff, which, at this point, has an elevation of about 60 feet above the surface of the river. The marl-bed is a soft, light-colored, highly siliceous deposit, containing many fossil pectens, barnacles, etc., and carrying from 3 to 4 per cent. of calcium phosphate. It is overlaid, by a thin stratum of sandstone, above which are massive, reddish, sandy clays, extending to the top of the hill. Beneath the marl, is a stratum of stratified yellowish or grayish sand, that probably extends to the limestone, below. Previous to our visit, little was known of the nature of the deposit, and no attempt had been made, to use it as a fertilizer. It contains ample phosphoric acid, to make a valuable manure; and it will no doubt produce satisfactory results, when applied to the growing crops.

THE ROBERTS PROPERTY

A number of other bluffs, exposing similar formations, occur at different points, further down the river; but none of these were examined, except one on the Roberts property, *lot 77, 15th district.* The bluff, here, is about thirty feet high. Its upper part is formed of sandy, red clays, beneath which, is an exposure of about twenty feet of impure limestone, extending down to the water's edge. The limestone is of a light color, usually quite soft, and contains many fossil gastropods, orbitolites and pectens. It weathers into a sandy, grayish, marly material, that is slightly phosphatic. In a cultivated field, near by, on the same lot, are to be seen many siliceous nodules, which also carry a small percentage of phosphoric acid. It is said that the soil, where these nodules occur, is generally more productive, than elsewhere. This increased fertility is doubtless due to the presence of phosphate, derived from the gradual breaking down of the nodules.

WILLIAM HADDOCK'S PROPERTY

An examination of a number of lime-sinks and wells, in the southwestern part of the county, reveals deposits similar to those, exposed along the river. There is quite an outcropping of limestone, on *lot 96, 15th district;* also, on the adjoining lots, owned by William Haddock. A well, recently dug, to the depth of 65 feet, on the Haddock property gives, in the descending order, the following section: —

Reddish, sandy clays	25 feet
Coarse sand	15 "
Bluish clay	12 "
Flint	3 "
Soft limestone	6 "

Hard limestone, with numerous orbitolites, underlying.

THE BLALOCK PLANTATION

A few miles southeast of the above locality, on the Blalock plantation, near the state-line, occur numerous siliceous boulders, which are slightly phosphatic. These appear, in great abundance, in a sandy hammock on an adjoining lot, owned by the Hintons, and situated just across the state-line. The boulders, at the latter place, vary in size, from a few ounces to many pounds; and all seem to be more or less water-worn. They are of a light-gray color, and consist of rather coarse sand, cemented with phosphate, which frequently makes up a high percentage of the entire mass. The field, where the boulders occur in such abundance, is said to have been under cultivation, for many years; and still it produces excellent crops, without the aid of fertilizers.

LOWNDES COUNTY

Much of the southern and eastern portion of Lowndes county is rolling, has a clay soil, and yields good crops; while the northwestern portion is more level, generally sandy, and often traversed by bays or cypress swamps. Along the state-line are many small lakes and ponds, occupying lime-sinks, which are depressions produced by subterranean streams carrying away, in solution, the underlying calcareous formations. The water, in some of these lakes, has been known to rise and fall, or to entirely disappear, in a few hours. This phenomenon seems to be due to the sudden stoppage, or to the opening, of subterranean passages, through which flow the underground streams, supplying the lakes. Lime-sinks of considerable size, now filled with water, and forming beautiful, transparent ponds or small lakes, are said to have had no existence, a few years ago. Instances are given, where these depressions have actually been seen to take place, and to have been gradually filled, by the inflowing of water, from below. The largest of these lakes is Ocean Pond, located in the southeastern part of the county, near Lake Park. It is a beautiful, irregular sheet of water, covering an area of several hundred acres; and it is well stocked, with many choice varieties of fish, which makes it a favorite resort for the sportsman.

The numerous streams of Lowndes county are usually sluggish; and, only at a few places, have they succeeded, in cutting through the superficial sands and clays. For this reason, our work in the county was generally unsatisfactory; and but little knowledge was gained, concerning the underlying geological formations. The Withlacoochee river, which forms the western boundary of the county, was examined at several different points between the state-line and Old

Troupville. With but few exceptions, the banks of the stream are low and sandy, and offer only a few opportunities, for the study of the different formations. Just below the bridge, at Old Troupville, may be seen, outcropping along the river bank, a stratum of argillaceous limestone, slightly phosphatic.

G. R. McREE'S PROPERTY

This same formation again appears, a few miles further down the river, on G. R. McRee's property, near the mouth of a small stream, where it overlies a fossiliferous limestone. Above the argillaceous limestone, at this point, occurs a greenish, siliceous, sandy marl deposit; and its associated clays are well exposed, in the narrow gorge, cut by the small stream, that has its source near the McRee residence. Siliceous oyster shells, and what appear to be fragments of roots, were noticed, in the marl-bed, at one point in the region, near the river. With this exception, no other organic remains were found in the formations, overlying the limestone. A short distance from the river, and only a few yards from the McRee branch, near an old mill-site, a bore-hole, put down a short time previous to our visit, to the depth of twenty feet, passed through marl and sands, containing water-worn phosphate pebbles. The pebbles are of a dark- or light-gray color, varying in size, from a fraction of an inch to an inch in diameter; and they usually run high, in phosphoric acid. An attempt, to determine the extent and character of the bed, containing the phosphatic pebbles, by boring, was unsuccessful. It was demonstrated, by this means, however, that the bed lies considerably below the surface; and, consequently, it can be of little economic value, by reason of its thick overburden.

A chemical analysis of samples of marl, taken from different points on the property, ran from 3 to 4 per cent. of calcium phosphate. This indicates, that the deposit is a valuable fertilizer; and it would, no doubt, produce satisfactory results, if applied to the soil, in sufficient quantities.

JUMPING GULLEY CREEK AND OTHER LOCALITIES

A short distance south of the McRee property, and just across the river from Wade's Park, occurs quite an exposure of siliceous breccia. It outcrops, on a slope, near a small stream, and also along the roadside, where it appears, in the form of large, irregular boulders, in the sandy clays. It is of a light-greenish color, and contains fragments of oyster shells. A similar exposure occurs near the Clyattville road, three quarters of a mile south of Rocky Ford bridge, and also near the mouth of Jumping Gulley creek, in the extreme southwestern part of the county. At the latter place, it is quite abundant; and it has attracted some attention, on account of its resemblance to hard-rock phosphate. Analyses made from samples, taken from the different places, show from 1 to 6 per cent. of calcium phosphate. Near the mouth of Jumping Gulley creek, and at other points, further up the Withlacoochee river, are several low bluffs, that expose, at their base, impure fossiliferous limestone, overlaid by grayish and greenish sandy clays. There were found, at one or two places, along these bluffs, small phosphatic nodules, that appear to have been washed out of the overlying clays. The nodules are water-worn, compact, and of a cream color, and are probably of animal origin. They are of rare occurrence, and are not considered to be of economic importance.

Besides the above siliceous and calcareous deposits, exposed along the streams, there occur, at several places in the county, in cultivated fields, sandstone boulders, that run high in phosphate of aluminum and iron. These are frequently seen, in the fields and along the roadsides, in the lake region, near the state-line; they are, also, abundant on I. H. Freeman's property, a short distance north of Old Troupville. The boulders vary from an inch to a foot or more in diameter, and are generally of a brown or gray color; they rarely appear in beds. Where they are found in large numbers, they are said to have a marked effect on the productiveness and durability of the soil.

ECHOLS COUNTY

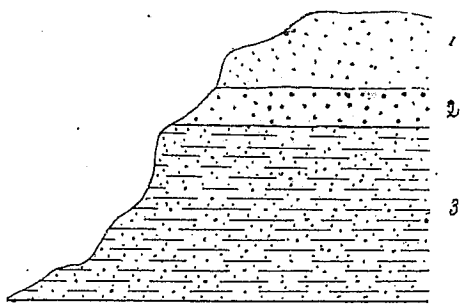
Echols county is comparatively level, has a sandy soil, and still retains, in its eastern part, extensive forests of long-leaf pine. The inhabitants, who are few in number, are chiefly engaged in the lumber and turpentine business. These industries were formerly quite profitable; but, at present, they have become less remunerative, by the reason of the exhaustion of the timber, and the reduction, in price, of the lumber and turpentine. Farming is confined mainly to the western part of the county, where the greater part of the timber is now exhausted, and the soils are best adapted to agricultural purposes.

THE PROPERTIES OF W. T. GREEN AND OTHERS

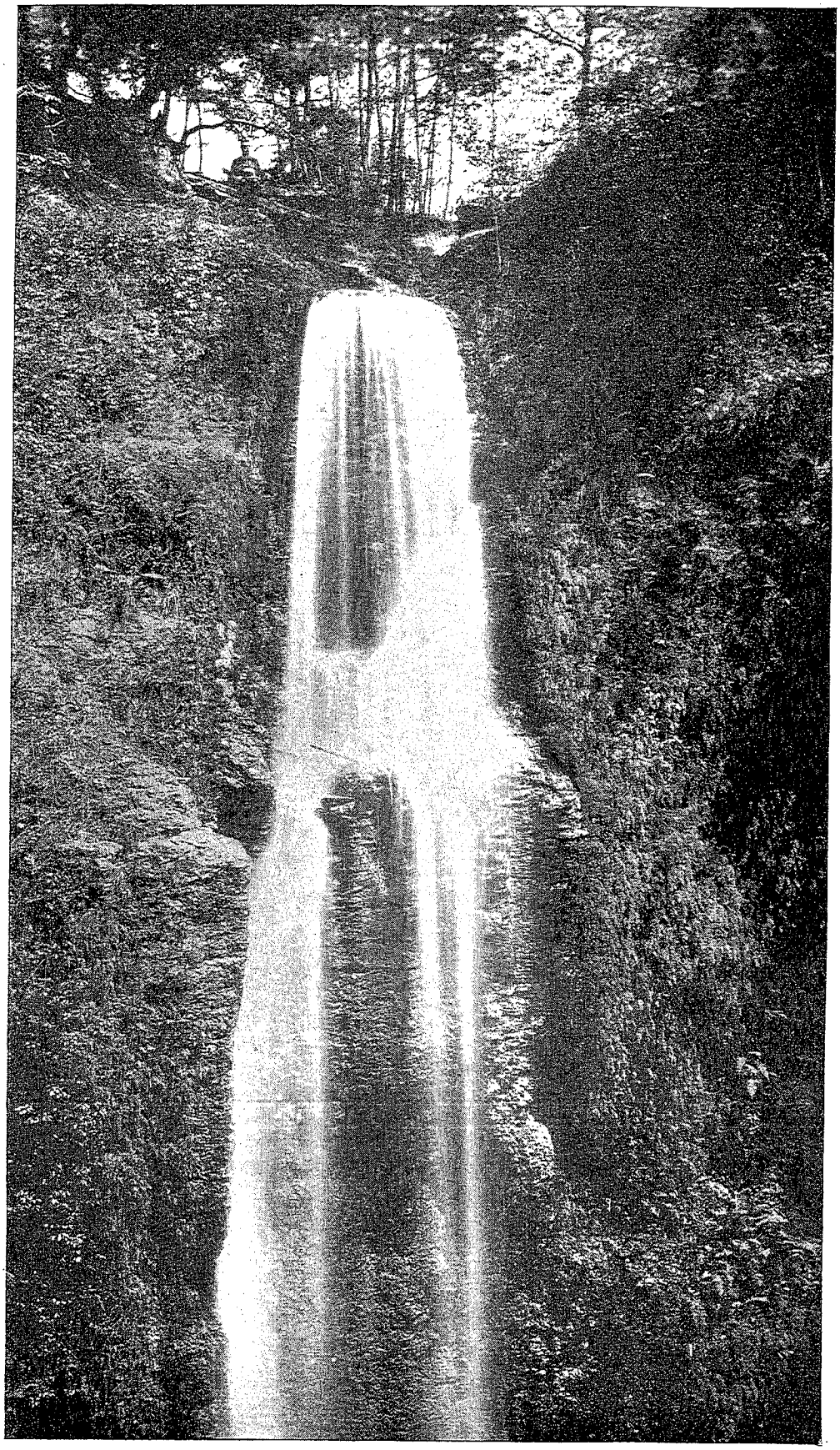
The streams are few; and, having but little current, they have rarely succeeded in cutting through the superficial sand and clays. The exceptions to this general rule occur along the Allapacoochee creek and the Allapaha river, near the state-line. Along the latter stream, south of Statenville, are a number of bluffs, varying in height from 20 to 30 feet. They are mostly confined to the east bank, and usually lie opposite low, flat palmetto lands. One of the highest of the bluffs is located about half a mile south of Statenville, on the right bank of the river. It has a height of about thirty feet, and presents the following geological section: —

The phosphate pebbles vary in size from a mustard seed to half an inch or more in diameter. They are of a dark-gray or jet-black color; and usually they have a smooth enameled surface, which readily distinguishes them from other pebbles. They appear to be pretty evenly distributed throughout the entire stratum of sand; but they make up only a small percentage of the entire mass. A similar exposure occurs on the east bank of the river, in a deep gully, a few rods below the bridge at Statenville. There is to be seen, here, underlying the phosphatic sand and calcareous deposit, a bed of limestone, the upper lay-

Fig. 3



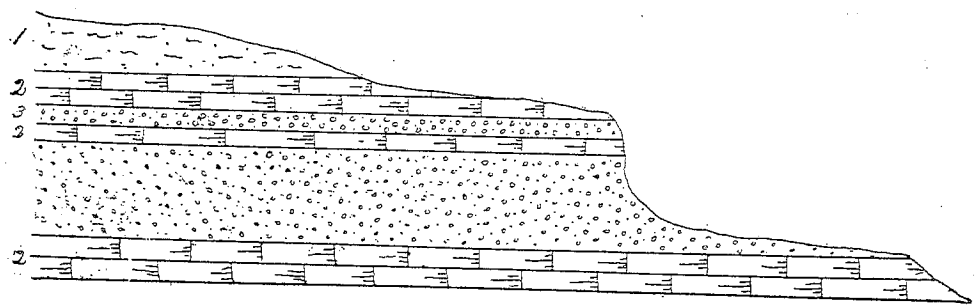
Section through Rocks along the West Bank of the Allapaha River, Half a Mile below Statenville. 1. Massive Sands. 2. Reddish, Coarse Sand. 3. Yellowish Sand Interstratified with Thin Layers of Clay.



FOREST FALLS, DECATUR COUNTY, GEORGIA.

ers of which consist of a soft, calcareous material, or marl, about three feet in thickness. It contains many fragments of sea-urchins, with other fossils, and with numerous phosphate pebbles. Below the marl-bed, is a stratum of argillaceous limestone, two feet thick, made up of a number of thin, compact layers, between which occur phosphatic pebbles. This stratum is followed, in turn, by a compact, heavy bedded, siliceous limestone, forming the bed of the river. There appears, here, a slight unconformity, existing between the superficial sands and the deposits below.[1] These calcareous deposits, containing phosphate pebbles, outcrop at several points along the river between Statenville and the state-line. They are well exposed on W. T. Green's property, *lot 189, 16th district*, and, also, on the Prescott property, further up the river. The section, indicated in the figure below, occurs at the mouth of a small stream, on the Green property, a few hundred yards from the state-line.

Fig. 4



Section through the Rocks on W. T. Green's Property. 1. Sandy Clays. 2. Limestone. 3. Phosphate Pebbles in Calcareous Matrix.

The total thickness of the layers of phosphate, at this point, as seen in the above section, is only about 22 inches. They consist of phosphate pebbles, cemented into a hard, compact mass, by a cream-col-

[1] See Fig. 4.

ored, calcareous matrix, which also frequently runs high in phosphoric acid.

A chemical analysis of the pebbles, which constitute, probably, 30 per cent. of the phosphatic mass, gives the following results: —

Sand and insoluble matter	6.38
Loss on ignition	12.64
Al_2O_3, Fe_2O_3	3.39
CaO	44.67
P_2O_5	26.78
Undetermined	6.14
Total	100.00

26.78, P_2O_5 corresponds to 58.38, $Ca_3(PO_4)_2$.

The limestone, underlying the phosphate at this point, is compact, more or less sandy, and weathers into irregular cavities. It is slightly phosphatic; and it frequently contains nodules of flint; but rarely does it contain organic remains.

A few miles west of the Allapaha river, the same deposits again outcrop, along the banks of Allapacoochee creek. The best exposures, on this stream, are to be seen at the Swilley and the Kersey bridges, where the deposits are exposed, in bluffs, from 15 to 20 feet high. At the latter place, there occurs, overlying the phosphatic sands and conglomerate, a tough, greenish, laminated clay, with thin layers of sand, containing phosphatic pebbles. A remnant of this clay was noticed at one or two points on the Green property; and it shows up well, at the bluff at the mouth of the small creek, which enters the river, just above Statenville. The exposure, at the Swilley bridge, consists mainly of sands with pebbles of phosphate. Associated with the phosphate, are numerous fragments of bone, sharks' teeth and fossil shells, the latter

being especially abundant, in the lower beds, which are usually highly calcareous.

Specimens of the pebbles, collected at the Swilley bridge, show the following chemical composition: —

Sand and insoluble matter	16.35
Al_2O_3, Fe_2O_3	3.65
CaO	39.37
P_2O_5	26.22
Undetermined	14.41
Total	100.00

26.22, P_2O_5 corresponds to 57.23, $Ca_3(PO_4)_2$.

The extent of the area, underlaid by the deposit of phosphate, could not be definitely determined. However, it seems quite likely, that it underlies much, if not all, of the area between the Allapaha river and the Allapacoochee creek, from the state-line, as far north as Statenville. This conclusion is based upon the similarity of the deposits, on the two streams, together with the fact, that some of the small branches, between the above streams, expose, at different places along their course, outcroppings of the upper beds of the deposit. The banks of both the Suwannee river and Toms creek were examined, at different points, with the view to locating the deposit further east; but, at no place, was there noticed any indication, whatever, of its presence. Along the former stream, occur at several places near the state-line, exposures of limestone, which is fossiliferous, and often slightly phosphatic. The banks are usually low and sandy, and rarely present opportunity, for studying the underlying formations.

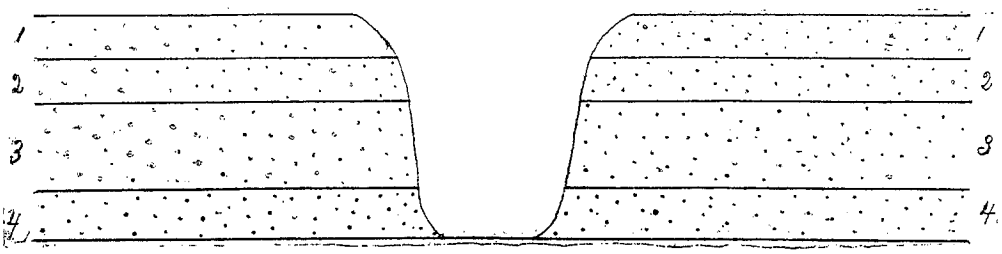
CHARLTON COUNTY

Much of the western part of Charlton county, and a considerable portion of the southern part of Ware and Clinch counties, are covered by the Okefenokee Swamp. This is an extensive cypress swamp, lying partly in Florida and partly in Georgia. It has a length of about 40 miles, and varies, in width, from five to twenty miles. The total area is 500 square miles. The greater part of this area, which has an elevation of about 90 feet above sea-level, is covered, during the most of the year, by water, from a few inches to several feet in depth. The surplus water, supplied to the swamp from all sides, by an almost indefinite number of small streams, ultimately finds an outlet through the Suwannee and St. Mary's rivers, one flowing, south, to the Gulf of Mexico, and the other, east, into the Atlantic Ocean. The surface of the swamp, with the exception of the places, where the water is several feet deep, is covered by a luxuriant growth of aquatic plants, whose decaying bodies and leaves form, on the bottom, a layer of vegetable material or peat, from one to ten feet in thickness. Besides the herbaceous aquatic plants, there are, also, in places, extensive forests of cypress, which is now being utilized, by the Suwannee Canal Company in the manufacture of lumber. The above Company, which purchased the greater part of the swamp from the State of Georgia, in 1891, at a cost of $65,000, has recently constructed a canal, connecting the swamp with the St. Mary's river, at a point a few miles south of Trader's Hill. The total length of the canal, including the part extending into the swamp, is several miles. It is from 10 to 40 feet deep, and about 30 feet wide. The company had two objects in view in constructing the canal; first, the conveyance of the cypress timber to the mills, located at the head of the canal; second, the drainage of

the swamp, and the reclaiming of an extensive area of land, for agricultural purposes.

The following geological section, taken from the canal near the mill, gives an idea of the formations, which probably underlie much of the swamp area.

Fig. 5



Cross-section of the Suwannee Canal, near the Okefenokee Swamp. 1. Soil. 2. Light-Colored Sands. 3. Dark Sands. 4. Yellow Sands.

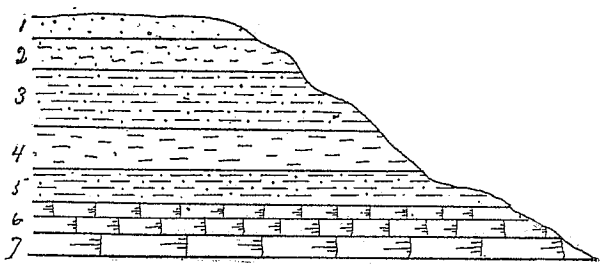
The surface of Charlton county is unusually low and level, and presents rarely, but slight variations, in its topographical features. The St. Mary's and the Satilla rivers, forming the eastern boundary, are both tidal rivers, and, only at a few places, have they succeeded, in cutting through the superficial deposits, and exposing the underlying formations. The bluffs, which are few in number, are generally low, and are formed mainly of sand, interstratified with thin layers of clay. There occur, however, at some points along St. Mary's river, both above and below Trader's Hill, bluffs several feet in height, where the underlying formations may be examined.

CAMP PERRY

The most interesting of these bluffs is to be seen at Camp Perry, on the St. Mary's river, at the south end of the Savannah, Florida &

Western R. R., about two miles below Trader's Hill. The entire thickness of the deposit, occurring here, including the exposure on the river-bank and in the railroad-cut above is about 40 feet, consisting of sands, clays, limestone and marl.[1] The marl-bed, which outcrops just above the water's edge, has an exposure of about five feet, and consists of a mass of small, loose, compact shells, with a greenish clay matrix. With the exception of the unconsolidated condition, the deposit resembles very closely the Coquina beds, near St. Augustine. The limestone appears in layers, from three to eight inches thick, and is quite compact, showing but little indication of organic remains. Similar deposits are reported to occur, at a number of points along the river above Trader's Hill; but, owing to the swollen condition of the river, at the time of our visit, it was found impossible to examine these exposures

Fig. 6



Cross-section at Camp Perry. 1. Massive Sands. 2. Motley, Jointed Clays. 3. Yellowish, Laminated Clays. 4. Reddish Clays, Containing Cavities Filled with Sand. 5. Greenish, Stratified Sands. 6. Shell Marl. 7. Limestone.

CAMDEN COUNTY

Camden county, which lies in the extreme southeastern corner of the State, has extensive salt marshes, along the eastern border; and, only far inland, along the Big and Little Satilla rivers, are there op-

[1] See Fig. 6.

portunities offered, for the study of the different geological formations, in natural exposures. These rivers frequently traverse wide and fertile bottoms, that produce extensive crops of rice; and, only occasionally, do the bluffs attain a sufficient height, to give a geological section of more, than a few feet in thickness. In the vicinity of Owen's Ferry and Burnt Fort, are to be seen, at various points along the Satilla river, bluffs, or steep banks, from 20 to 30 feet in height. The Bluffs are made up of sands and stratified clays, with an occasional layer of either mud-stone or clayey limestone. The latter generally outcrops, just above the surface of the water, and consists of a number of layers, from 3 to 8 inches in thickness, separated by thin beds of bluish or white-colored clay. As far as our observations extended, the calcareous layers appear to be entirely free from organic remains; but they carry a small amount of phosphoric acid.

JAMES P. KING'S PROPERTY

Several miles further up the river, on Mr. Jas. P. King's estate, occurs an extensive marl-bed. The property, on which the deposit is located, is situated six miles south of Atkinson; and, of late years, it has become quite a popular resort, for fishing parties, whose attention is usually attracted, by the peculiar appearance of the deposit. The principal exposure occurs, at the base of a bluff, on the left bank of the river, a few hundred yards north of the mansion-house. The bluff, which is about 30 feet in height, shows the following geological section: —

Soil	1½ feet
Bluish clays	2 "
Motley, sandy clays	10 "
Light-colored, sandy clays	5 "
Yellowish, sandy clays	4 "
Laminated blue clays	2 "
White sand	1 "
Blue clay	2½ "
Marl	2 "

At the time of our visit, only about two feet of the marl-bed was exposed above the surface of the water; however, detached fragments of the bank, below this level, show, that the bed attains a thickness, at this point, of four feet or more. The deposit consists almost entirely of small bivalve shells, with a sandy clay matrix. Associated with the shells, are fragments of bones, and what appear to be the remains of the carapaces of turtles and crabs. The marl has been used, to a limited extent, by Mr. King, as a fertilizer, on various crops; and it is said to have given very satisfactory results. It is evidently of much value, locally, as a fertilizer; however, it could not probably be transported to any distance, with profit. Another outcropping of the deposits occurs about a mile further up the river; but it here seems to be diminished in thickness, and also contains more sand and clay.

ALONG WHITE OAK CREEK

In the eastern part of the county, along White Oak creek, are other marl deposits. These can be best examined, during low tide, at the trestle, crossing the creek, near White Oak station. The banks of the

creek, at this point, are almost eight feet high, and are formed of greenish and light-colored sandy clays, that overlie the marl, forming the bottom of the stream. The marl deposit, which contains numerous fossil shells and fragments of bone, is of unknown thickness and of a grayish color; and it contains a high percentage of calcium carbonate. Phosphoric acid is present through the entire mass; but it is especially abundant in the bones and in the small, dark-colored particles, which seem to be of animal origin. The bed of the stream, in places, is frequently strewn with fragments of bones, that have been washed out of the marl-beds. This has led to the belief, that there occurs, somewhere along the creek large deposits of bones, which are available for phosphate. A diligent search, however, has, so far, failed to reveal any such deposit.

A chemical analysis of samples of bones, collected, gives the following results: —

Sand and insoluble matter	1.37
Al_2O_3, Fe_2O_3	1.67
CaO	51.15
P_2O_5	32.57
Undetermined	13.34
Total	100.00

32.57, P_2O_5 corresponds to 71.00, $Ca_3(PO_4)_2$.

GLYNN COUNTY

Glynn county differs but little, topographically, from Camden. It has, along its coast, extensive salt marshes, made classic by the poems

of Sidney Lanier. Further inland, are large tracts of low, swampy lands, which, when properly drained, bring crops of cotton and corn, without the aid of fertilizers. The western portion of the county is frequently undulating; has a sandy soil; and is generally well timbered, with long-leaf pine. The streams, especially the Altamaha, forming the northern boundary, often have wide, fertile bottoms, that yield large crops of rice.

COLLEGE CREEK AND TURTLE RIVER DEPOSITS

At the time of our visit to the county, numerous reports were current, concerning the recent discovery of phosphate, at different places, along College creek and Turtle river, two small tidal streams, a few miles west of Brunswick. Both these streams were visited, at several points, and the reports were investigated. College creek, so called, on account of the land, in its immediate vicinity, having been originally granted to Rev. Geo. Whitfield, by the Countess of Nottingham, for endowing a college, is, more properly speaking, a slough, or narrow ravine, containing but little water, during low tide. Its banks are frequently precipitous; and, on the Livingstone property, they attain a height of about ten feet. There is exposed here, along the bank, just above the surface of the water, at low-tide, a bed of argillaceous limestone, which has frequently been taken for phosphate. The bed is exposed along the stream, for a quarter of a mile, or more. It is made up of many thin layers, that break up, when exposed to the atmosphere for a short while, into small, regular blocks, the surface of which, when freshly broken, is of a dark-blue color; but,

often, exposure gradually changes this to a pale yellow. Chemical analysis shows, that it contains only a trace of phosphoric acid, and can be of no commercial importance, as a fertilizer. Immediately overlying the limestone, is a bed of sandy marl, about six feet in thickness. Its upper layers are made up largely of greenish sands, containing numerous fossil shells, fragments of bones, and sharks' teeth; while the lower layers are of a light color, consist chiefly of calcium carbonate, and are even more fossiliferous. In the lower part of the bed, were found, associated with the fragments of bones, a few phosphatic pebbles, which showed, by chemical analysis, the following composition: —

Sand and insoluble matter	3.17
Loss on ignition	10.61
Al_2O_3, Fe_2O_3	1.71
CaO	49.55
P_2O_5	32.34
Undetermined	2.62
Total	100.00

32.34, P_2O_5 corresponds to 70.50, $Ca_3(PO_4)_2$.

The whole marl deposit contains phosphoric acid; but it is usually low, varying from a half to two per cent. It, however, seems to be sufficiently abundant, throughout the entire bed, to make the deposit of value, locally, as a commercial fertilizer. With the exception of the occurrence of limestone, the deposit along Turtle river was found to be similar to that, exposed along College creek. A like deposit is also said to be found along the Satilla river. This statement could not be verified, on account of the swollen condition of the river, during the time of our visit.

Besides these calcareous deposits, there are also others, to be seen, at various points, in the cuts and drain-ditches, along the Florida Central & Peninsular R. R. in the southwestern part of the county. These consist largely of oyster shells, which form beds, from a few inches to three feet in thickness. They are frequently encountered in wells and other excavations, only a few feet beneath the surface.

McINTOSH COUNTY

McIntosh county, like the counties lying further south, has a very irregular coast-line, indented by numerous sounds and inlets, separating the main land from numerous low, marshy islands. Inland, the surface is generally low and level, with a sandy soil. The Altamaha river, which forms its southern boundary, is the only stream of any importance in the county. It usually flows through wide bottoms or swamps, and offers but little opportunity, to study the different geological formations, along its low, sloping banks.

MOUTH OF SAPELO RIVER

The only natural exposures of any consequence, that were examined in the county, occur along the headlands, near the mouth of Sapelo river, a few miles north of Darien. There are to be seen, here, at several points, long stretches of bluffs, from 20 to 30 feet high. The

most noted of these bluffs are known as Belleview, Crescent and Southerland. They are formed almost entirely of sand, some of the layers of which have become indurated, and have resisted, to a great extent, the action of the waves, and are now seen, to form step-like shelves, projecting from the face of the bluffs. While examining these bluffs, our attention was called to a deposit of bog iron ore, in an old rice field, belonging to Mr. James Walker, on the Sapelo river, near Crescent bluff. The deposit forms a more or less continuous bed, about 8 inches thick, extending over an area of less than an acre in extent. Beneath the bog ore, is a layer of dark-colored marsh mud, containing small, irregular masses of vivianite, a hydrous iron phosphate. When first dug up, it is very soft, and of a light color; but, after exposure to the atmosphere, for a short time, its color changes to a deep blue. This deposit of vivianite is local, and including its matrix, is only a few feet in thickness. It is of no economic importance.

CHAPTER IV

GENERAL CONCLUSIONS

The result of our investigations, in the various counties, lying along the Georgia-Florida state-line, demonstrates, to a considerable degree of certainty, two very important economic facts. First, that there do not likely exist, anywhere along the state-line, with the exception, probably, of Thomas county, deposits of phosphate, of sufficient extent and purity, to be mined with profit, for the manufacture of commercial fertilizer, at its present market value. Second, that all these counties contain more or less extensive beds of marl, or low-grade phosphate, a valuable natural fertilizer, that might be used to a great extent, in replacing the more costly artificial manures. It seems difficult to understand, why the planters of these counties, who are always desirous of raising good crops, without the use of expensive artificial fertilizers, have not, before now, tested the merits of these deposits. The explanation appears to be due, to a great extent, to the want of knowledge, concerning the mode of occurrence, physical appearance and the nature of marl, and the manner of applying it to the soils. It has been further suggested, that the cheapness of land and the abundance of virgin soil, which needs no artificial stimulant, for a few years, have, also, caused the farmers to be slow, about seeking out natural fertilizers. In many instances, it has been found cheaper, to purchase and clear up new lands, rather than to attempt to build up the old to its former fertility, by the use of costly artificial manures. Fortunately for the future welfare of that part of the State, this con-

dition of things, on account of the gradual increase in the price of lands, and the growing scarcity of virgin soils, seems to be drawing rapidly to a close; and the time will soon arrive, when the planters will, of necessity, be driven to the use of natural manures, or the final abandonment of large areas of land, which are now becoming rapidly exhausted, under the present mode of cultivation. There can be little doubt, but that there exists in many, if not all, of the above counties, deposits of marl, more or less extensive, and equal, in many respects, to the Greensand beds of New Jersey. In only a few instances, have they been tried on growing crops; but, in all cases, they are reported to have produced beneficial results. Our work, both in the field and in the laboratory, was necessarily preliminary in its character, and gave only general results. The true economic value of these deposits can be definitely determined, only by making a number of practical field-tests. If some of the leading farmers, in this section, can be induced to give these marls a thorough trial, there is little doubt but that the results, in many cases, will prove to be satisfactory, and will finally lead to their general use, as a fertilizer. The importance, to the farmer, of the discovery of valuable marl deposits in South Georgia, can hardly be overrated. It would enable him, not only to restore thousands of acres of land, exhausted by long cultivation, to their original fertility; but also to greatly increase the productiveness of all other lands, with much less expense, than is now being done, by the use of artificial manures. The result of the extensive use of marls, as natural fertilizers, is well illustrated, in the case of the State of New Jersey. The late Prof. Geo. H. Cook, formerly State Geologist of New Jersey, in speaking of these deposits in his report for 1868, says: — "The marl, which has been described in the preceding pages, has been of incalculable value to the country, in which it is found. It has raised it, from the lowest stage of agricultural exhaustion to a high state of improvement. Lands, which, in the old

style of cultivation, had to lie fallow, by the use of marl produce heavy crops of clover, and grow rich, while resting. Thousands of acres of land, which had been worn out and left in commons, are now, by reason of this fertilizer, yielding crops of the finest quality. Instances are pointed out, everywhere in the marl district, of farms, which, in former times, would not support a family; but which are now making their owners rich from their productiveness. Bare sands, by the application of marl, are made to grow clover, and then crops of corn, potatoes and wheat."

The marls in South Georgia are found, in many instances, to equal, in plant-food, those of New Jersey; and, if abundantly and judiciously used, there appears to be no reason, why they might not produce a similar effect, on the fertility of the soil. The great advantage, in the use of marl, over the commercial fertilizers, is its lasting effect. Prof. Cook, in speaking of this, says: — "While all other fertilizers are exhausted and the soil becomes poor, I have never seen a field, which was once well marled, that is now poor. Its effect is said to be visible, for thirty years."

The first cost of marling lands is usually great. Especially is this true, where the marl has to be transported some distance. Yet, in the long run, it is found to be cheaper, than to use commercial fertilizer, on account of its durable effects. The amount of marl, which should be used per acre, differs greatly. It depends largely on the character of the soil and the nature of the marl. In some cases, where it is scattered broadcast over the fields, it has been found to take as much as six or eight tons per acre; while, on the contrary, similar effect is often produced, with less than one fourth of that quantity. The question of the amount to be used per acre must be determined, mainly, by practical field-tests.

The plant-foods, which are found to occur in marls, are numerous;

but the more important are limited to a few chemical compounds, viz., calcium carbonate, phosphoric acid and potash. Prof. H. W. Wiley, Chemist of the U. S. Department of Agriculture, in speaking of marls, in the year-book for 1895, says: — "The chief agricultural constituent of marls is always lime carbonate, although some samples of marl, which are placed on the market, may have only a small per cent. of this material. In so far as the fertilizing properties are concerned in a general way, however, they must be ascribed principally to carbonate of lime. It is for this reason, that marls act in such a beneficial way, when applied to stiff, clay soils and others deficient in lime. Many of the Virginia marls, however, are found to contain, in addition to the lime, considerable quantities of potash and phosphoric acid, while marls, from other localities, contain, also, potash and phosphoric acid, the potash being usually in the form of silicate.

"The per cent. of phosphoric acid, in phosphate-bearing marls, varies from a mere trace to as much as 4 or 5 per cent. Usually, however, the marls contain from 1 to 3 per cent. of phosphate. When marls contain over 5 per cent. of phosphate, they can hardly be considered under the name of marls; but should then be transferred to the place of natural phosphate. . . . . On account of the small proportion of plant-food in marls, they will not bear transportation to any great distance. There are very few marls, that are worth, when placed on the field, more than 4 or 5 per cent.; and, in a great majority of cases, the value is not even so great."

While this statement as to the value of marls is much more conservative, than the statements of many previous writers on the subject, it, nevertheless, shows, that they are still considered to be of importance, as a fertilizer. On the supposition, that marls are worth only $2 per ton, which is certainly a low estimate for many of the deposits found in South Georgia, even then there exists a considerable margin

for profit. The marls, where found on the farm, and favorably located, can be placed on the field, in many cases, at a cost of not over 50 cents per ton, thus giving a return of 400 per cent. on the outlay. Dr. George F. Payne, Chemist for the Agricultural Department of the State of Georgia, fully realizes the importance of these deposits. In a bulletin, published in 1892, Dr. Payne, in speaking of the natural fertilizers of the State, says: — "In Southwest Georgia exist enormous deposits of carbonate of lime, in a number of different forms, and marls peculiarly rich in carbonate of lime, many of them containing from 40 to 50 per cent. of actual lime. It is strange, that goods mined in different States should be bought by our farmers, when a better article lies unusued in boundless profusion, in the lower part of our State."

The statement in reference to the value of the marl deposits of South Georgia may seem to many overdrawn. However, it is the writer's opinion, that, when the marls, clays, etc., of this section are fully developed, they will equal, or even surpass, in value, the more varied mineral resources of the northern part of the State.

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