FLORIDA GEOLOGICAL SURVEY

FIFTH ANNUAL REPORT

FLORIDA STATE GEOLOGICAL SURVEY

E. H. SELLARDS, Ph. D., State Geologist

FIFTH ANNUAL REPORT

Published For
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LETTER OF TRANSMITTAL.

To His Excellency, Hon. Park Trammell,

Governor of Florida.

Sir:—In accordance with the Survey law I submit herewith my Fifth Annual Report as State Geologist of Florida. This report contains the statement of expenditures by the Survey for the fiscal year ending June 30, 1912, to which I have added a list of the expenditures of the Survey for the succeeding half year ending December 31, 1912. The progress of the Survey investigations during the year are shown by the scientific papers that will form a part of this report. These include a paper on the origin of the hard rock phosphates of Florida; a report on the artesian water supply of southern Florida, and a list of elevations in the State together with a second edition of the general topographic map of the State previously published.

I venture to add here a resume of the principal investigations of the Survey since its organization and to make certain recommendations which I believe to be for the good of the future usefulness of the Survey. Permit me to express in this connection my appreciation of the interest you have shown in the work of the State Geological Survey.

Very respectfully,

E. H. SELLARDS,

State Geologist.

ADMINISTRATIVE REPORT.

E. H. SELLARDS, STATE GEOLOGIST.

PRINCIPAL RESULTS OF THE STATE GEOLOGICAL SURVEY INVESTIGATIONS.

Aside from miscellaneous and routine work, the principal investigations that have been carried out by the State Geological Survey since its organization may be grouped under six heads as follows:

1. Assemblage of the literature on the geology of Florida and a review of the important publications issued previous to the organization of the State Survey. This review of the literature together with the bibliography of publications relating to the geology of Florida was included in the First Annual Report. The publications obtained in this connection form a part of the Survey library.

II. A Report on the Geology and Stratigraphy of Florida. This report included in the Second Annual Report was prepared in cooperation with the United States Geological Survey. It serves as a preliminary account of the geology of the State, and brings together all the information relating to the geology that was then available.

III. A General Topographic and Geologic Map of Florida. With the general report on the geology of Florida referred to above there was included a topographic and geologic map of Florida. The topography was shown on this map with as much detail as the information available regarding elevations would permit, the contour lines being placed at 50 foot intervals of elevation. A second edition of this map is included in the report now being issued.

IV. A very important natural resource of Florida is the underground or artesian water supply. This subject was one of the first taken up by the Survey, and with the publication of the present report the preliminary investigation of the water supply is completed. The papers published on this subject are as follows:

The Underground Water Supply of Central Florida, Bulletin No. 1; The Artesian Water Supply of Eastern Florida, Third Annual Report; The Underground Water Supply of West-Central and West Florida, Fourth Annual Report; The Artesian Water Supply of Southern Florida, Fifth Annual Report.

V. The Soils. A general report on the soils of the State formed a part of the Fourth Annual Report. This paper included an account of the origin and character of the soils of Florida, and was intended as a basis for subsequent detailed soil surveys.

VI. The Mineral Resources. Information bearing on the mineral resources of the State has formed a part of each annual report issued. An account of the fuller's earth deposits as complete as the information then at hand would permit was included in the Second Annual Report. Papers on the phosphate deposits formed a part of the Third and the present (Fifth) Annual Reports. The peat deposits of the State, which are extensive, were described in the Third Annual Report. The clay resources have received general treatment in the First and Second Annual Reports.

RECOMMENDATIONS.

MORE OFFICE SPACE NECESSARY.

The State Survey is at present housed in two small rooms. Of these one is used as store room, photo room and exhibition room; the other serves as library, office and work room. These small rooms including about 1,000 square feet of floor space are totally inadequate to the requirements of effective work. Fully 10,000 square feet of floor space is necessary to meet the immediate requirements of the Survey. The library shelves are full, and it is now and for some time has been quite impossible to care for the publications that are being received. Many of these new publications represent the results of investigations by the neighboring State Surveys or by the National Survey, and are very necessary for comparative purposes to the Florida Survey. Other publications being received from various sources are for reference purposes and are necessary to the determination of fossils or mineral specimens, or of geological formations, or other matters in connection with the Survey work.

The Survey at present is practically without a work room. There is no table or desk room available to store or to handle the maps, charts, and drawings that are constantly being used in the Survey work. It is impossible from lack of space to properly open up and study the collection of mineral and fossil specimens that have been obtained by the Survey. The store room space is too small to accommodate even the current issues of the Survey's own publications which must be cared for temporarily awaiting their distribution.

In connection with the work of the Survey there is a constant accumulation of notes, records, photographs, manuscripts, plates and cuts, as well as the general correspondence of the office which must be cared for. The present limited office space affords no room for storing, filing or properly caring for these records.

I urgently recommend, if it meets with your approval, that the Legislature be asked to provide adequate rooms for the future work of the State Geological Survey.

A STATE MUSEUM.

The desirability of an adequate museum in which to properly exhibit the resources of the State is apparent. The State Survey law makes it the duty of the State Geologist to collect, determine and label specimens illustrating the geological and mineral features of the State and large collections have been made since the Survey was organized. The small room used for exhibition purposes has long since been filled and a large amount of material suitable for exhibition remains unopened in boxes as collected. It is important that the State provide for the proper preservation and exhibition of the Survey collections in a State Museum.

DEMAND FOR CLAY TESTING LABORATORY.

There is a very urgent demand on the part of the citizens of the State for a laboratory in which the various clays may be properly tested for brick making and other purposes. It is a well known fact that the utility of clays is determined not so much by their chemical as by their physical properties. To properly test a clay it is therefore necessary to install the testing machinery. Effective clay testing machinery will require for installation more space than is now available in the Survey rooms.

THE PREPARATION OF A DETAILED TOPOGRAPHIC MAP OF FLORIDA.

While a general topographic map of Florida with contour lines at 50 foot intervals of elevation has been issued, as already stated, there is a constant demand for detailed topographic maps on a scale of about one inch to the mile and with contour lines at 10 foot intervals of elevation. Topographic maps are usually made in atlas sheets covering unit areas bounded by parallels and meridians. The unit adopted by the United States Geological Survey in topographic mapping designated as the quadrangle, includes when made on the scale of about one inch to the mile an area of 15′ of latitude by 15′ of longitude. A separate atlas sheet is issued for each unit area and when completed the maps so issued make up a complete map for the State as a whole. The maps thus made show the land area in relief by means of contour lines. In this way all hills, valleys, stream channels, sinks, depressions and all changes in elevation are indicated. The actual elevation above sea, based on exact levels, are also shown by means of figures printed on the contour lines. Each contour passes through points which have the same altitude. One who follows the contour on the ground will go neither up hill nor down hill but on a level. By the use of contours the shapes of the plains, hills and valleys as well as their elevations are shown. The line of the sea coast itself is a contour line, the datum or zero of elevation being mean sea level. The contour line at, say, 20 feet above sea level is a line that would be the sea coast if the sea were to rise or the land to sink 20 feet. Such a line runs back up the valleys and forward around the points of hills and spurs. On a gentle slope this contour line is far from the present coast line, while on a steep slope it is near it. Thus a succession of these contour lines far apart on the map indicates a gentle slope; if close together a steep slope; and if the contours run together in one line, as if each were vertically under the one above it, they indicate a cliff. The heights of many definite points, such as road corners, railroad crossings, railroad stations, summits, water surfaces, triangulation stations and bench marks are also given on the map. The figures in each case are placed close to the point to which they apply, and express the elevation to the nearest foot.

In addition to indicating relief and actual elevation above sea these maps show all other natural features such as lakes, ponds, rivers, streams, canals, swamps and all cultural features including public roads, railroads, towns, cities, county and State boundaries.

The topographic maps thus prepared find many uses. They are above all essential to the proper planning of drainage operations throughout all of the interior of the State. It is a well-known fact that we have in Florida, particularly in the flatwoods section, large areas of land that although not actually flooded yet would be much improved by the more rapid removal of the heavy summer rains. Other large and valuable tracts of land, but little used at present, by a proper system of drainage, can ultimately be made valuable and productive land. The topographic maps such as are here contemplated are essential to the proper planning of drainage operations.

The topographic maps are of very great assistance in the preparation of detailed soil maps. They afford first of all an exact base map of the area to be surveyed, thereby reducing the cost of the soil map about one-half. They also facilitate the study of the soils which bear well known relations to drainage and moisture conditions. In detailed geologic mapping and in the study of the mineral resources topographic maps are practically necessary for the detailed final reports.

Topographic maps find many additional uses. They are of very great assistance in the laying out and developing a system of public roads, showing as they do the relief of the land including hills, depressions and valleys. In planning the location of railroads, canals, waterways or other public improvements they are of great assistance. Finally they afford to the land owners as well as to the citizens in general the manifold conveniences of a well-made and accurate map on a large scale.

COOPERATION WITH THE UNITED STATES GEOLOGICAL SURVEY IN THE PREPARATION OF TOPOGRAPHIC MAPS.

Many of the States cooperate with the National Geological Survey through their respective State Survey organizations in the preparation of topographic maps. The usual basis of such cooperation is an equal contribution of funds on the part of the State and National Survey. The plan of mapping followed is that already developed and established by the National Survey. The men employed in the mapping are the expert topographic mappers already in the employ of the National Survey. The following States are either now cooperating or have in the past cooperated with the National Geological Survey in this work: Alabama, California, Connecticut, Illinois, Iowa, Kentucky, Louisiana, Maine, Maryland, Massachusetts, Michigan, Mississippi, Missouri, New Jersey, New York, North Carolina, Ohio, Oklahoma, Oregon, Pennsylvania, Rhode Island, Tennessee, Texas, Virginia and West Virginia.

It is probable that such cooperation can be secured in the preparation of the topographic maps of Florida, thus practically doubling for the State any appropriation made by the Legislature for this purpose. The Director of the United States Geological Survey has repeatedly expressed his willingness to cooperate with the State Geological Survey in the preparation of topographic maps, meeting any appropriation made by the State with an equal amount so far as funds permit. An appropriation made for the preparation of topographic maps may be so framed as to admit of cooperation with the United States Geological Survey; or may be made if desired contingent upon such cooperation to be carried on in accordance with plans approved by the Governor.

SOIL MAPS.

Another very important line of investigation is the preparation of detailed soil maps. While a general report on the soils of the State has been issued by the Survey, there is a very great demand for specific information regarding local soils such as can be supplied only by detailed soil maps of the several counties. A limited amount of soil mapping has already been done by the United States Bureau of Soils. As in the case of topographic maps many of the States are cooperating with the National Bureaus in the preparation of soil maps, and it is probable that an appropriation made for this purpose would be doubled by the United States Bureau of Soils. I would urgently recommend an appropriation of $5,000 per annum for the preparation of topographic and soil maps. Such an appropriation may be made contingent upon cooperation with the national bureaus and would thus result in the expenditure of $10.000 per annum in the State for this purpose.

EXPOSITIONS.

National Conservation Exposition at Knoxville.—A National Conservation Exposition will be held at Knoxville, Tennessee, during September and October of the present year. This exposition is intended especially to exhibit the natural resources of the Southern States and to encourage their development. The opportunity is favorable for making more widely known both the mineral and agricultural resources of Florida and it is to be hoped that provision will be made by which the State may make a good showing at this exposition.

Panama Exposition at San Francisco.—A world exposition will be held at San Francisco in 1915 to commemorate the opening of the Panama Canal. Florida by reason of its extensive coast line and its nearness to the canal zone is specially interested in this exposition, and can not afford to lose the opportunity of making its favorable location with regard to the canal more widely known. It is none too soon to begin the compilation of data on the harbors of Florida, and the preparation of maps, charts and drawings showing their relation to the canal and to the population and business centers of the United States, as well as to the lines of transportation within the United States. The exhibitions of the mineral and agricultural resources made for the exposition at Knoxville may be used subsequently for the Panama exposition.

MEMBERS OF THE STATE SURVEY.

The members of the State Survey during the past year have been, in addition to the State Geologist, Mr. Herman Gunter, and during a part of the year Mr. Emil Gunter. Stenographic and clerical services were rendered at various times by Ada Moore and T. C. Alford. The chemical analyses necessary to the work of the State Survey are made by the State Chemist.

PUBLICATIONS ISSUED DURING 1912.

The Fourth Annual Report of the Geological Survey was issued during the year. This report contains in addition to statistics on phosphate rock and fuller's earth, papers on the Soils and Other Surface Residual Materials of Florida, and on the Water Supply of West-Central and West Florida.

DISTRIBUTION OF REPORTS.

The reports issued by the State Geological Survey are distributed upon request, and may be obtained without cost by addressing the State Geologist, Tallahassee, Florida.

THE PURPOSE AND DUTIES OF THE STATE GEOLOGICAL SURVEY.

Among the specific objects for which the Survey exists, as stated in the enactment, is that of making known information regarding the minerals, water supply and other natural resources of the State, including the occurrence and location of minerals and other deposits of value, surface and subterranean water supply and power and mineral waters and the best and most economic methods of development, together with analysis of soils, minerals and mineral waters, with maps, charts, and drawings of the same.

A distinctly educational function of the Survey is indicated by Section 4 of the law, which makes it the duty of the State Geologist to make collections of specimens, illustrating the geological and mineral features of the State, duplicate sets of which shall be deposited with each of the State colleges. The publication of annual reports is provided for as a means of disseminating the information obtained in the progress of the Survey. The Survey is thus intended to serve on the one hand an economic, and on the other an educational purpose. In its economic relations a State Survey touches on very varied interests of the State's development. In its results it may be expected to contribute to an intelligent development of the State's natural resources. Its educational value is of no less immediate concern to the State, both to the citizens within the State and to prospective citizens without.

A knowledge of the soil and of the available water supply is very necessary to successful agriculture, and the Survey's investigations along these lines are of value to all land owners. A knowledge of the mineral deposits which may lie beneath the surface, is likewise necessary to a correct valuation of land.

RELATION OF THE STATE SURVEY TO THE OWNERSHIP OF MINERAL LANDS.

The relation of the State Geological Survey to the ownership of mineral lands is specifically defined. The Survey law provides that it shall be the duty of the State Geologist and his assistants, when they discover any mineral deposits or substances of value, to notify the owners of the land upon which such deposits occur before disclosing their location to any other person or persons. Failure to do so is punishable by fine and imprisonment. It is not intended by the law, however, that the State Geologist's time shall be devoted to examinations and reports upon the value of private mineral lands. Reports of this character are properly the province of commercial geologists, who may be employed by the owners of land for that purpose. To accomplish the best results, the work of the Survey must be in accordance with definite plans by which the State's resources are investigated in an orderly manner. Only such examinations of private lands can be made as are incidental to the regularly planned investigations of the Survey.

SAMPLES SENT TO THE SURVEY FOR EXAMINATION.

Samples of rocks, minerals and fossils will be at all times gladly received, and reported upon. Attention to inquiries and general correspondence are a part of the duties of the office, and afford a means through which the Survey may in many ways be useful to the citizens of the State.

THE COLLECTION OF STATISTICAL INFORMATION.

For many purposes the collection and publication of statistical information is helpful, both to the industries concerned and to the general public. Such statistical information is desired from all the mineral industries of the State. Such information will be recognized as strictly confidential, in so far as it relates to the private business of any individual or company, and will be used only in making up State and county totals. The cooperation of the various industries of the State is invited in order that the best possible showing of the State's products may be made annually.

EXHIBITION OF GEOLOGICAL MATERIAL.

The space available for the exhibition of geological material is unfortunately as yet very limited. A part of one room is being used for this purpose. Three cases have been built, designed to serve the double purpose of storage and exhibition. The lower parts of the case contain drawers and are used for storage. In making the collections a definite plan has been followed to secure a representation of the rocks, minerals and fossils of each formation in the State. The collection will be added to as rapidly as space is provided for taking care of the material.

THE SURVEY LIBRARY.

A well equipped reference library is essential to the investigations of the Survey, and an effort has been and is being made to bring together those publications which are necessary to the immediate and future work of the department. The Survey library now contains more than 1,500 volumes. These include the reports of the several State Geological Surveys; the reports of the National Geological Survey; the reports of the Canadian and a few other foreign Geological Surveys; and many miscellaneous volumes and papers on geology and related subjects.

PUBLICATIONS ISSUED BY THE STATE GEOLOGICAL SURVEY.

First Annual Report, 1908, 114 pp., 6 pls.

This report contains: (1) a sketch of the geology of Florida; (2) a chapter on mineral industries, including phosphate, kaolin or ball clay, brick-making clays, fullers earth, peat, lime and cement and road-making materials; (3) a bibliography of publications on Florida geology, with a review of the more important papers published previous to the organization of the present Geologocial Survey.

Second Annual Report, 1909, 299 pp., 19 pls., 5 text figures, and one map.

This report contains: (1) a preliminary report on the geology of Florida, with special reference to stratigraphy, including a topographic and geologic map of Florida, prepared in cooperation with the United States Geological Survey; (2) mineral industries; (3) the fuller's earth deposits of Gadsden County, with notes on similar deposits found elsewhere in the State.

Third Annual Report, 1910, 397 pp., 28 pls., 30 text figures.

This report contains: (1) a preliminary paper on the Florida phosphate deposits; (2) some Florida lakes and lake basins; (3) the artesian water supply of eastern Florida; (4) a preliminary report on the Florida peat deposits.

Fourth Annual Report, 1912, 175 pp., 16 pls., 15 text figures, one map.

This report contains: (1) The soils and other surface residual materials of Florida, their origin, character and the formation from which derived; (2) the water supply of west-central and west Florida; (3) the production of phosphate rock in Florida during 1910 and 1911.

Bulletin No. 1. The Underground Water Supply of Central Florida, 1908, 103 pp., 6 pls., 6 text figures.

This report contains: (1) Underground water; general discussion; (2) the underground water of central Florida, deep and shallow wells, spring and artesian prospects; (3) effects of underground solution, cavities, sinkholes, disappearing streams and solution basins; (4) drainage of lakes, ponds and swamp lands and disposal of sewage by bored wells; (5) water analyses and tables giving general water resources, public water supplies, spring and well records.

Bulletin No. 2. Roads and Road Materials of Florida, 1911, 31 pps., 4 pls.

This bulletin contains: (1) An account of the road building materials of Florida; (2) a statistical table showing the amount of improved roads built by the counties of the State to the close of 1910.

Fifth Annual Report, 1913.

EXPENDITURES OF THE GEOLOGICAL SURVEY FOR THE YEAR ENDING JUNE 30, 1912, AND FOR THE HALF YEAR ENDING DECEMBER 31, 1912.

The total appropriation for the State Geological Survey is $7,500.00 per annum. No part of this fund is handled direct by the State Geologist, as all Survey accounts are paid upon warrants issued by the Comptroller of the State as per itemized statements approved by the Governor. The original of all bills and the itemized statements of all expense accounts are on file in the office of the Comptroller. Duplicate copies of the same are on file in the office of the State Geologist.

LIST OF WARRANTS ISSUED DURING THE YEAR ENDING JUNE 30, 1912.

July, 1911.	
E. H. Sellards, State Geologist, expenses, July, 1911.........$	30.00
Herman Gunter, Assistant, expenses, July, 1911..............	31.05
Ada Moore, stenographic services.........................	25.30
The Record Company, printing............................	7.50
John McDougall, postage	62.75
Southern Express Company	3.02
August, 1911.	
E. H. Sellards, State Geologist, expenses, August, 1911......	48.70
Herman Gunter, Assistant, expenses, August, 1911..........	18.50
American Peat Society, subscription.......................	5.00
John McDougall, postage	20.00
Carried forward ....$	251.82

Brought forward	$ 251.82
September, 1911.	
E. H. Sellards, State Geologist, salary for quarter ending September 30, 1911	625.00
Herman Gunter, Assistant, salary for quarter ending September 30, 1911	300.00
Southern Express Company, express for July and August	5.00
October, 1911.	
E. H. Sellards, State Geologist, expenses, October, 1911	23.70
H. & W. B. Drew Company, supplies	4.62
P. Blankiston's Son & Company, publications	2.00
Verlag für Fachliteratur, subscription	5.76
John McDougall, postage	20.00
November, 1911.	
E. H. Sellards, State Geologist, expenses, November, 1911	38.00
Herman Gunter, Assistant, expenses, November, 1911	12.60
Southern Express Company	3.76
December, 1911.	
E. H. Sellards, State Geologist, salary for quarter ending December 31, 1911	625.00
E. H. Sellards, State Geologist, expenses, December, 1911	41.10
Herman Gunter, Assistant, salary for quarter ending December 31, 1911	300.00
Herman Gunter, Assistant, expenses, December, 1911	68.70
Emil Gunter, Assistant, salary ($62.50), expenses ($48.05), December, 1911	110.55
T. C. Alford, stenographic services	6.00
H. & W. B. Drew Company, supplies	2.34
F. H. King, publications	2.50
American Journal of Science, subscription	6.00
Engineering and Mining Journal, subscription	5.00
January, 1912.	
E. H. Sellards, State Geologist, expenses, January, 1912	27.20
Herman Gunter, Assistant, expenses, January, 1912	103.82
Emil Gunter, Assistant, salary ($75.00), expenses ($91.92), January, 1912	166.92
T. C. Alford, stenographic services	15.00
Francis J. Bulask, subscription	5.00
Carried forward	$ 2,777.39

Brought forward	$ 2,777.39
John McDougall, postage	20.00
Southern Express Company	2.72
February, 1912.	
E. H. Sellards, State Geologist, expenses, February, 1912	37.65
Herman Gunter, Assistant, expenses, February, 1912	108.20
Emil Gunter, Assistant, salary ($75.00), expenses ($81.25), February, 1912	156.25
T. C. Alford, stenographic services	12.20
Wrigley Engraving Company, engravings	39.78
H. & W. B. Drew Company, supplies	4.70
Southern Express Company	8.35
March, 1912.	
E. H. Sellards, State Geologist, salary for quarter ending March 31, 1912	625.00
Herman Gunter, Assistant, salary for quarter ending March 31, 1912	300.00
Herman Gunter, Assistant, expenses, March, 1912	48.95
Emil Gunter, Assistant, salary ($17.30), expenses ($31.10), March, 1912	48.40
T. C. Alford, stenographic and clerical services	36.00
Economic Geology Publishing Company, subscription	3.00
April, 1912.	
E. H. Sellards, State Geologist, expenses, March and April, 1912	29.75
T. J. Appleyard, printing	732.20
The Record Company, printing	18.75
H. & W. B. Drew Company, supplies	2.21
John McDougall, postage	125.00
Southern Express Company	15.70
May, 1912.	
E. H. Sellards, State Geologist, expenses, May, 1912	70.55
Herman Gunter, Assitant, expenses, May, 1912	78.60
Emil Gunter, services, April and May	9.00
Alex. McDougall, postage	25.00
June, 1912.	
E. H. Sellards, State Geologist, salary for quarter ending June 30, 1812	625.00
E. H. Sellards, State Geologist, expenses, June, 1912	60.85
Carried forward	$ 6,021.20

Brought forward	$ 6,021.20
Herman Gunter, Assistant, salary for quarter ending June 30, 1912	300.00
Herman Gunter, Assistant, expenses, June, 1912	23.05
D. R. Cox Furniture Company, supplies	30.00
David S. Woodrow, Agent, subscription	6.00
University of Chicago Press, subscription	4.00
H. & W. B. Drew Company, supplies	2.78
Total expenditures	$6,387.03
Overdrawn from preceding year	.10
	$6,387.13
Balance available	1,112.87
	$7,500.00

LIST OF WARRANTS ISSUED DURING THE HALF YEAR ENDING DECEMBER 31, 1912.

July, 1912.	
T. J. Appleyard, State Printer	$ 100.00
Southern Express Company	13.76
D. R. Cox Furniture Company, supplies	4.13
August, 1912.	
Alex. McDougall, postage	25.00
Southern Express Company	3.03
September, 1912.	
E. H. Sellards, State Geologist, salary for quarter ending September 30, 1912	625.00
Herman Gunter, Assistant, salary for quarter ending September 30, 1912	300.00
Southern Express Company	1.60
October, 1912.	
E. H. Sellards, State Geologist, expenses, October, 1912	62.80
Herman Gunter, Assistant, expenses, October, 1912	42.71
Arthur H. Thomas Company, supplies	19.55
November, 1912.	
E. H. Sellards, State Geologist, expenses, November, 1912	66.47
Herman Gunter, Assistant, expenses, November, 1912	29.10
Carried forward	$ 1,293.15

Brought forward	$ 1,293.15
H. R. Kaufman, repairing typewriter	5.00
Alex. McDougall, postage	25.00
Southern Express Company	3.13
December, 1912.	
E. H. Sellards, State Geologist, salary for quarter ending December 31, 1912	625.00
E. H. Sellards, State Geologist, expenses, December, 1912	72.85
Herman Gunter, Assistant, salary for quarter ending December 31, 1912	300.00
H. & W. B. Drew Company, supplies	1.79
W. & L. E. Curley, supplies	3.70
Keuffel & Esser Company, supplies	39.90
Engineering and Mining Journal, subscription	5.00
Southern Express Company	8.02
Total	$2,382.54

ORIGIN OF THE HARD ROCK PHOSPHATE DEPOSITS OF FLORIDA.

BY E. H. SELLARDS.

CONTENTS.

PLATES.

MAPS.

ORIGIN OF THE HARD ROCK PHOSPHATES OF FLORIDA.

E. H. SELLARDS.

Two kinds of phosphate rock are now being mined in Florida, the land pebble and the hard rock. The deposits which carry the hard rock phosphate are found over a considerable extent of country in the western part of central peninsular Florida. The area includes the southern part of Columbia and Suwannee Counties, the western part of Alachua and Marion Counties, the eastern part of Levy, Citrus and Hernando Counties, and the northern part of Pasco County. From north to south the hard rock area extends through a distance of about 100 miles. Its width from east to west is variable. The greatest width is found in Marion County, almost the whole of the western half of this county being included in this belt. West of the Suwannee River a limited amount of hard rock phosphate has been found in Lafayette, Taylor and Jefferson Counties. The accompanying map shows approximately the extent of the phosphate-bearing deposits. The workable deposits are less extensive than the area here outlined, the mines now operated being confined to a comparatively narrow belt reaching from Alachua to Hernando Counties.

Mining has been carried on continuously in this section for more than two decades. Seventy-four plants, under the ownership of twenty mining companies, operated here in 1909, while forty plants, under the ownership of fourteen mining companies, were operating at the close of 1912. Each phosphate plant opens up in the process of mining one to several pits offering exceptionally good exposures of the phosphate-bearing formation. The following paper is based on observations made in the many pits that have been opened up in this section during the past several years. The results that are presented in this paper have been gradually obtained, and have been published in part in the reports of the Florida Geological Survey during the past few years.

The land pebble phosphates are found in southern Florida in Polk and Hillsboro Counties. This paper relates to the hard rock deposits only, the pebble deposits not being included in the discussion, although their approximate location is indicated on the map. No attempt is made on this map to show the location of the low grade phosphates, which occur extensively in central Florida.

The matrix in which the hard rock phosphate is imbedded is extremely variable. The formation includes a mixture of materials from various sources and of the most diverse character, further complicated by pronounced chemical activity within the formation itself. The prevailing phase of the formation is feebly coherent, more or less phosphatic, light gray sands. Aside from these sands the principal materials of the formation are clays, phosphate rock, flint boulders, limestone inclusions, pebble conglomerate, erratic and occasional water-worn flint pebbles, vertebrate and invertebrate fossils, and occasional pieces of silicified tree trunks.

The gray sands may be observed in every pit that has been excavated in this section. Moreover, from drill and prospect holes it is known that these sands occur very generally over the intervening or barren area. The sands are of medium coarse texture, the grains being roughly angular. The amount of phosphate associated with these sands is variable. Upon prolonged exposure, as seen in numerous abandoned pits, these sands oxidize at the surface, assuming a pink or purple color. When affected by slow decay and by water, carrying more or less iron in solution, they become reddish or ochre yellow in color. Lithologically these sands resemble closely the gray phosphatic sands of the Alum Bluff formation as seen at the type locality at Alum Bluff, on the Apalachicola River.

The clays in this formation occur locally as clay lenses imbedded in the sand, or separating the sand from the phosphate rock, or overlying the phosphate rock. The clays are often of a light buff or blue color. When lying near the surface, however, they often oxidize to varying shades of red. The relative amount of clay in the phosphate-bearing formation increases in a general way in passing to the south. The exposures in the southern part of the area show as a rule more clay than do similar exposures in the northern part of the area. The phosphate boulders seem to have a tendency to group around and to be associated with local clay lenses. Frequently the productive pit gives place laterally to barren gray sands.

Flint boulders occur locally in this formation in some abundance, and occasionally phosphate pits that are otherwise workable are abandoned on account of the number of flint boulders encountered. The flint boulders are usually oval or somewhat flattened in shape and are of varying size, some weighing several tons. The exterior is usually of a light color. Some of the boulders are hollow and occasionally the cavity is filled with water; other boulders are solid, compact and of a bluish color throughout. Limestone inclusions are frequent in this formation.

The pebble conglomerate feature is not of frequent occurrence but may occasionally be observed in the northern part of the hard rock section. An exposure of flint pebbles may be seen in one of the pits of plant number 5 of the Cummer Lumber Company, about one mile southwest of Newberry, in Alachua County. The matrix at this exposure consists of more or less water-worn fragments of varying size together with round or oval water-worn, dark colored flint pebbles. This phase of the formation may be seen through a distance of ten or fifteen feet along the side of the pit. Water-worn pebbles weighing one or more pounds occur occasionally in the northern part of the field.

The invertebrate fossils are found in the limestone inclusions. The vertebrate remains are mixed in with the other materials of the matrix. The fossil wood is of rare occurrence, but is occasionally found in this formation.

Phosphate rock, although the constituent of special economic interest, nevertheless makes up a relatively small part of the formation. The phosphate in these deposits occurs as fragmentary rock, boulder rock, plate rock or pebble. The boulders are often of large size, in some instances weighing several tons, and not infrequently needing to be broken up by blasting before being removed from the pit. It is also necessary to operate a rock crusher in connection with all hard rock phosphate mines to reduce the larger pieces of rock to a size suitable for shipping. A certain portion of soft phosphate unavoidably lost in mining is also present. The relative amount of material that it is necessary to handle to obtain a definite amount of phosphate is always variable with each pit and with the different parts of any one pit. The workable deposits of phosphate lying within this formation occur very irregularly. While at one locality the phosphate may lie at the surface, elsewhere it may be so deep as not to be economically worked; while a deposit once located may cover more or less continuously a tract of land some acres in extent, elsewhere a deposit appearing equally promising on the surface, may in reality be found to be of very limited extent. As to location, depth from surface, extent into the ground, lateral extent, quantity and quality, the hard rock phosphate deposits conform to no rule. The desired information is to be obtained only by extensive and expensive prospecting and sampling.

The phosphate rock may lie beneath the gray sands, or above the gray sands or may be entirely surrounded by them. In some instances the phosphate is interbedded with the sands. Such interbedding of sand and phosphate was observed by the writer in the Central Phosphate Company pit number 25, about three miles west of Clark. This phase of the relation of sand and phosphate occurs not infrequently and is confined to no particular part of the phosphate field. It is frequently stated by the phosphate miners that there is a relation between the local clay lenses and the occurrence of phosphate. It is evident, however, that there are many exceptions to this general statement.

THICKNESS.

The thickness of the phosphate bearing formation is as variable as its other characteristics. It rests upon the Vicksburg Limestone, the top surface of which owing to solution by underground water, has become extremely irregular. The limestone projects as peaks into the phosphate formation. In Citrus County the phosphate bearing formation is known to reach a thickness of from 75 to 100 feet. When of this thickness it is worked to the permanent ground water level by the dry pit method of mining, and is then mined from 40 to 50 feet below this level by the floating dredge. In the northern part of the area the formation is as a rule much thinner, and is worked almost entirely by dry pit mining.

AMOUNT OF HARD ROCK PHOSPHATE.

It is scarcely possible to give an estimate of the amount of hard rock phosphate in Florida that yet remains to be mined. This is due to the fact that the deposits are extremely local and irregular. While the whole extent of the phosphate bearing formation can be mapped with a fair degree of accuracy, the deposits of phosphate within the formation can be located and an estimate of the amount that is mineable made only after very exact prospecting. The cost of such prospecting is such that it is seldom undertaken on a large scale except by the companies actually interested in producing the rock. It is true that some estimates as to the total tonnage available have been made, but these amount to little more than guess work. The amount actually mined during the twenty-two years since mining operations began in this field is approximately 9,313,071 tons. The output at present amounts to about one-half million tons per annum.

FORMATION NAME.

The term Dunnellon formation has been applied by the writer to the phosphate bearing formation.* These deposits are well developed in the vicinity of Dunnellon, in Marion County, and have been extensively mined in that section. It was here also that the deposits were first discovered and mined. The term Dunnellon is, therefore, appropriate. The formation is probably of Pliocene age as indicated by the fauna.

*Florida State Geological Survey, Third Annual Report, p. 32, 1910.

LOCAL DETAILS.

SUWANNEE COUNTY.

The southern and southeastern part of Suwannee County has produced some phosphate, although no mines are operating in this county at present. A variable thickness of pale yellow sand occurs in the pits of this section. At the pits of plant No. 10 of Dutton Phosphate Company, two miles north of Hildreth, from two to twelve feet of this incoherent sand rests directly upon the phosphate bearing matrix. In one of the pits of this plant the phosphate matrix grades at the bottom into a yellow phosphatic clay overlying the limestone to a depth of 4 or 5 feet. In one of the pits at this plant are observed, as frequently seen elsewhere in the hard rock section, many large round elongate siliceous boulders interbedded in the phosphate matrix. The underlying formation here is the Vicksburg Limestone, which occurs as peaks and as "hog backs" of lime projecting into or even through the phosphate matrix.

COLUMBIA COUNTY.

The southern part of Columbia County, adjacent to Suwannee County, has produced considerable phosphate, although only one mine in this county was in operation at the close of 1912.

At plant No. 2 of the Dutton Phosphate Company, now abandoned, about one-half mile west of Ichatucknee Springs, the following section was obtained:

Pale incoherent sand	10 to 20 feet
Phosphate-bearing matrix	20 to 25 feet
Buff yellow phosphatic clays	5 to 6 feet
Dark sandy phosphatic clays (exposed)	4 feet

The incoherent sands in this pit, as at Dutton No. 10, rest directly upon the phosphate stratum, the top of which is exceedingly irregular. Clay lenses 6 to 12 inches thick are of frequent occurrence, especially near the top. The underlying limestone is reached in places. The buff yellow phosphatic clay observed in Dutton No. 10 is seen here also and is underlaid by 4 feet of dark, sandy phosphatic clay.

The following section was made in one of the pits of the Schilman & Bene phosphate plant, about two miles northwest of Ft. White:

Pale yellow incoherent sand	3 to 5 feet
Red clayey sands	5 to 10 feet
Phosphate matrix	15 to 25 feet
Limestone at the bottom of the pit.	

This section differs from the preceding chiefly in the presence of the red clayey sands, which are sufficiently coherent to form a vertical wall in the pit. This clayey sand stratum when present is referred to by the miners as "hardpan."

In the pit of the Fort White Hard Rock Company, one-mile southeast of Ft. White, the foundation rock, as is usual in this section, is the Vicksburg Limestone. The top of this limestone is exceedingly irregular, projecting as rounded peaks. Shells, sea urchins, and other fossils are partly eroded away, the limestone having a comparatively smooth surface. The phosphate rock consists chiefly of angular fragmental pieces, plates, pebbles and boulders imbedded in a sandy clayey matrix. This matrix fills up the irregularities in the underlying limestone. In several instances the phosphate matrix was seen to fill up cavities and solution channels in the limestone. Slickensides occur, due to the settling of the phosphate matrix as the underlying limestone dissolved away. Limestone inclusions and siliceous boulders occur in the phosphate stratum. The following section is seen in an abandoned pit of this plant:

Pale yellow incoherent sand.........................	1 to 15 feet
Phosphate matrix	1 to 20 feet

Limestone top surface exceedingly irregular.

The phosphate producing area of southern Columbia and Suwannee Counties lies adjacent to and in the angle between the Suwannee and Santa Fe Rivers, including the low lying and intensively eroded parts of each county. The limestone lies near the surface in this section and as a rule the phosphate is mined out by dry mining, the limestone being exposed in the abandoned pits. Dredging, which is applicable in the southern part of the phosphate area, is not used in this section.

ALACHUA COUNTY.

The west central part of Alachua County is actively producing phosphate; fourteen plants were operated in this county at the close of 1912.

Pit No. 25 of the Central Phosphate Company, west of Clark, gave the following section:

Pale yellow incoherent sands.......................	5 to 10 feet
Red clayey sands...................................	5 to 10 feet
Phosphate-bearing formation	10 to 25 feet

Limestone at bottom of pit.

The phosphate matrix consists of gray sands, yellow, buff and blue clays, and phosphate rock. At one place in this pit a stratum of gray sand ½ to 2 feet thick is seen interbedded with the phosphate rock.

The incline leading to a pit belonging to T. A. Thompson, near Neals, gave the following section:

Pale yellow incoherent sands	5 to 10 feet
Red clayey sands	7 to 10 feet
Gray phosphate sands (exposed)	15 feet

The gray sands give place laterally to phosphate rock.

Pit No. 2 of the Cummer Lumber Company is, perhaps, the largest single pit in operation in the hard rock phosphate section. This pit is reported to include at the present time about thirteen acres. Pit No. 5 of this company, one mile west of Newberry, gives an exposure of the sandstone and flint pebble conglomerate already referred to as occurring occasionally in the hard rock deposits. The pebbles are round and more or less flattened. They vary in size from very small pebbles to pebbles weighing five to seven pounds.

In the pit of the Union Phosphate Company, at Tioga, a considerable number of rounded elongate siliceous boulders occur. These vary in size, the largest approximating a ton in weight. They are embedded in the phosphate-bearing matrix.

The many other pits which are now being worked, or which have recently been abandoned, although varying much even within a single pit in details, are in general much the same as those described.

The limestone in this county, as a rule, lies relatively near the surface. In most instances the limestone is encountered before or very soon after reaching the water level. The phosphate is thus largely worked out by dry mining and dredges are rarely used. The limestone is encountered at varying depths. One pit may show a great deal of limestone projecting as peaks, while another pit of equal depth near by may scarcely reach the limestone. Some of the limestone peaks project 15 to 25 feet above the general level of the bottom of the pit. The phosphate-bearing matrix here, as elsewhere, fills up the irregularities in the limestone. The top surface of the limestone is, as elsewhere, entirely irregular. The red clayey sand called "hardpan" by the miners may be present or lacking in the pits of this section. The loose, pale yellow sand is practically always present, varying in thickness from 1 to 25 feet.

MARION COUNTY.

The plate rock deposit found in the vicinity of Anthony and Sparr, in the north central part of Marion County, represents an eastward extension of the phosphate-bearing formation. The relation of the phosphate matrix to the underlying limestone is the same as previously described. The limestone projects into the phosphate matrix as rounded peaks. Circular depressions, similar in appearance to pot holes or to "natural wells," are frequent in this section. These are filled with the phosphate matrix. One of these depressions observed by the writer had been cut into, in the process of mining. This depression was about three and one-half feet in diameter at the top, fifteen feet deep and narrowed gradually to the bottom. Other depressions variable in diameter and in depth occur. The limestone lying near the line of the underground water level has usually a rough and jagged surface owing to solution by water in contact with the limestone. Above the water level the limestone has a smooth rounded surface, the shells and other fossils having been eroded off plane with the general rock surface. The plate rock beds show evidence of having been originally faintly stratified. Much of the stratification that originally existed, however, has been destroyed through repeated local subsidence as the underlying limestone was moved by solution. The stratification lines in the plate rock are frequently much curved and distorted owing to this irregular subsidence.

The chief difference noted between the plate rock and the typical hard rock region is in the relatively large amount of fragmentary phosphate rock and the small amount of boulder rock. Flint and limestone boulders chemically formed are likewise absent or rare.

The deposits at Standard and at Juliette, in the western part of Marion County, are similar in general character to the hard rock deposits as previously described. The mines in this section are dry mines and usually reach to the bottom of the phosphate formation in places encountering the limestone.

In the southwestern part of Marion County and in Citrus County the hard rock phosphate-bearing formation reaches its maximum thickness. The underlying limestone is ordinarily encountered at a considerable depth from the surface. Many of the phosphate pits in this section are worked as dry mines to the underground water level and afterwards as dredge mines to such depth as the dipper will reach. Some of the pits on higher lands are mined as dry mines only.

The pit at the Dunnellon Phosphate Company plant No. 10 was one of the first pits regularly worked in the phosphate section and has been continuously in operation for the past twenty years. This mine is operated by a dredge. The bottom of the phosphate is not reached in this pit and the full thickness of the formation at this place has not been reported.

CITRUS COUNTY.

The conditions in Citrus County are in a general way similar to the conditions in the vicinity of Dunnellon, in Marion County. The underlying limestone is occasionally seen in the pits in this section and is frequently reached by the dredge. The surface of the limestone wherever seen projects as rounded peaks. There is on an average more clay to be seen in the phosphate formation in this section than in the northern part of the field. In a few instances, notably that of the pit in the Istachatta Phosphate Company, the water level is within a few feet of the surface and the phosphate formation is entirely submerged. Only the sands of the overburden are here visible.

HERNANDO COUNTY.

Phosphate is being produced in Hernando County in the vicinity of Croom. The mine in operation here is a dredge mine. The relation of the phosphate formation to the underlying limestone, as seen in an abandoned pit several miles west of Croom, is the same as that in other parts of the phosphate section, the limestone projecting as rounded peaks. The material above the phosphate stratum consists largely of incoherent sands. The usual gray phosphatic sands, weathering purple on exposure, are seen surrounding the phosphate rock. In the mines near Croom a considerable amount of clay is associated with the phosphate.

The preceding description of the phosphate-bearing formation is taken with but slight revision from a paper by the writer entitled "A Preliminary Report on the Florida Phosphate Deposits," published in the Third Annual Report of the Florida Geological Survey, 1910. The present paper, like the earlier one, is to be regarded as a report of progress in the investigation of the phosphate deposits and is not in any sense final.

PROBLEMS TO BE ACCOUNTED FOR.

Among the problems that must be accounted for in connection with the hard rock phosphate deposits of Florida are the following: (1.) The source of the miscellaneous materials that make up the formation, including sands, clays, flint pebbles, vertebrate and invertebrate fossils, silicified wood, flint boulders, limestone inclusions and phosphate rock in its varying forms. (2.) The intimate admixture in the formation of these diverse materials. (3.) The processes by which phosphate and flint boulders have formed. (4.) The limitation of the hard rock phosphate formation to a characteristic well marked physiographic type of country. (5.) The localization within the formation of phosphate rock to such an extent as to form workable deposits. (6.) The formation of the plate rock deposits.

SUMMARY OF THE EXPLANATION OFFERED.

The explanation offered, briefly summarized, is as follows: It is believed that the Upper Oligocene and probably some later formations, now found on the surrounding uplands, formerly extended directly across the section that is now the hard rock phosphate fields. The disintegration of these formations supplied the miscellaneous materials of which the deposits are made up. The mixing of the materials was brought about in part by stream action, which has resulted in a reworking and reaccumulation of the residual material from these formations, and in part by the local irregular subsidence such as is constantly going on in a limestone country. In some parts of the phosphate fields the lowering and mixing of the materials by solution of the underlying limestone has been the predominating factor, while elsewhere the reworking of the materials by stream action has predominated. It is probable that local bodies of water existed also in which the materials reaccumulated. The immediate source of the phosphoric acid is the phosphate, which was widely disseminated through the overlying formations. The fossils now found in the formation include those that were residual from the formations that have disintegrated, and those that were incorporated in connection with the reworking and reaccumulation of the materials. The phosphate and flint boulders are formed chemically through the agency of ground water. The formation containing the hard rock phosphate is limited in its distribution to that section of the State in which formations carrying more or less phosphate have disintegrated, overlying a limestone substratum, thus affording conditions favorable for the downward passage of rain water carrying phosphoric acid in solution. The phosphate thus removed from the surface formations is reaccumulated under these conditions in a concentrated form at a lower level. The phosphate deposits are localized within the formation because the formation itself is lacking in uniformity. Local variations, particularly the presence of clay lenses and other conditions which interfere with the free circulation of ground waters, favor the formation of phosphate boulders and thus result in a local deposit of phosphate rock of sufficient amount and purity to be of commercial value. The plate rock represents chiefly fragments of disintegrated boulders.

ACKNOWLEDGMENTS.

In presenting this view of the origin of the hard rock phosphates the writer takes pleasure in acknowledging his indebtedness to the many investigators who have contributed to a knowledge of these deposits. This indebtedness is not alone to those who have written on the origin of the phosphates, but equally to those who have contributed to an understanding of the geology of the State as a whole, and particularly of that part of the State in which these deposits are found. Only a few of these general publications can be mentioned at this time, although a full list is included in the bibliography which forms a part of the First Annual Report, of the State Geological Survey, 1908.

The monograph on the Tertiary Fauna of Florida by Dr. W. H. Dall published in the Transactions of the Wagner Free Institute of Science, 1890 to 1903, includes by far the most extensive study of the invertebrate fauna of the Florida formations that has yet been made, and to these investigations we are indebted for many fundamental facts regarding the succession of forma-

tions in Florida. In the present discussion the writer is particularly indebted to Dall's observations, recorded in Bulletin 84 of the United States Geological Survey, pages 109, 110 and 111, of remnants of the Upper Oligocene formations (then classed as old Miocene) at Levyville, in Levy County, at Fort White, in Columbia County, and near Archer, in Alachua County. These localities lie west, north and east of the northward extension of the phosphate fields, and Dall, in the map which accompanies this report, represents the old Miocene as extending directly across the northern end of the hard rock phosphate area, with local exposures of the Vicksburg formation. These observations by Dall are accepted by the writer and form a part of his argument that the Upper Oligocene (old Miocene) formerly extended across the phosphate fields as a whole.

Messrs. George C. Matson and F. G. Clapp, in connection with cooperative work carried on by the United States Geological Survey and the Florida State Geological Survey, have added important observations regarding the former areal extent of the Upper Oligocene formations in Central Florida, remnants of these formations having been noted by them at many of the phosphate mines of Central Florida. Dr. T. W. Vaughan, of the United States Geological Survey, under whose supervision these co-operative investigations were carried on, has given material assistance in determining the stratigraphic succession in Florida both by directing the field work and by the identification of fossils and of formations.

Of the many other publications on the phosphates of Florida all of those of which a record has been obtained are listed in the bibliography, which follows this paper. In addition, those relating directly to the origin of the hard rock phosphates are reviewed in connection with a discussion of the theories previously advanced; reference to a number of the papers on the Florida phosphates is included in the notes in regard to the discovery, investigation and development of the phosphate deposits. In outlining, on the accompanying map, the probable extent of the land pebble phosphates of Southern Florida the writer has utilized, among other sources of information, maps of these deposits by Geo. H. Eldridge and by C. G. Memminger.

DISCOVERY OF THE FLORIDA PHOSPHATE DEPOSITS.

The knowledge of, or belief in the existence of phosphatic material in Florida seems to have been prevalent from an early date. Thus, in a paper by Pratt (1868) we find a reference to and an attempted explanation of the coprolite or guano-like deposits of Florida. The original of Pratt's paper not having been available to me I have been unable to determine from the reviews of the paper whether Pratt's reference is to phosphatic material known to occur in Florida or assumed to occur.

From Professor J. M. Pickel (1890) we have a statement that "Dr. J. C. Neal, formerly of Archer, now of the Florida Agricultural Experiment Station at Lake City, discovered in Levy and Alachua Counties, in 1876, and tested chemically phosphatic rocks, which were in 1885 sent to the Smithsonian and analyzed quantitatively."

In 1880 Dr. Chas. U. Shepard writing of the phosphate deposits of South Carolina stated that they certainly extended into North Carolina on the north and probably as far south as Florida.

Aside from these references the first definite information of deposits of low grade phosphate rock in Florida seems to have been obtained incidentally in connection with the investigation of building stone made for the Tenth United States Census, 1880. The first samples of the phosphate rock were collected from a quarry being operated for building stone near Hawthorne, in Alachua County. This quarry had been opened by Dr. C. A. Simmons, of Hawthorne, in 1879. The samples were sent to Washington probably during the summer of 1880. The paper which gives the analysis of this rock bears the date, June 29, 1881. It is contained in the Proceedings of the United States National Museum for 1882, which were issued in 1883. Whether Dr. Simmons knew or suspected the phosphatic character of this rock before the analysis by the Census Bureau is not known. However, soon after the analyses had been made, and as a result probably of these analyses, Dr. Simmons began operating a mill in which this rock was ground for agricultural purposes. These operations which were carried on during 1883 and 1884 (Mineral Resources for 1885), were undoubtedly the earliest attempts at mining and utilizing the phosphate rock of Florida.

In 1881 Captain J. Francis LeBaron, while engaged by the government in making a preliminary survey for a proposed ship canal from the head waters of the St. Johns River to Charlotte Harbor, became interested in the water-worn pebbles and fragments of bones in the bed of Peace River. Samples of this material were sent to the Smithsonian Institution. Captain LeBaron obtained leave of absence from the Engineering Department in 1882 and 1883, with a view to interesting capital in the development of the phosphate. Finding many difficulties in developing this new industry, he subsequently accepted employment in connection with the proposed Nicaragua Ship Canal. (Letter of May 23, 1911.) Returning in 1886, Captain LeBaron made further efforts to interest capital in the development of the phosphate but without success.

During the early eighties, due probably to these and to other discoveries, interest became very active in the Florida phosphate, and new localities for the phosphate rock were reported in rapid succession. The volume on mineral industry by the United States Geological Survey for 1882, published in 1883, contains, page 523, reference to phosphatic marls occurring in Florida, in Clay, Alachua, Wakulla, Duval and Gadsden Counties. The volume for 1883 and 1884, page 793, reports that phosphate rock has been found in Florida, in Clay, Alachua, Duval, Gadsden and Wakulla Counties. In 1884 and during the early part of 1885 L. C. Johnson made for the United States Geological Survey a somewhat careful examination of the phosphate deposits in Suwannee, Columbia, Alachua and Marion Counties. That the existence of phosphate rock in Florida was generally known at that time is evident from the fact that Johnson, from his own investigation and from samples sent to him, and from popular report as to the occurrence of phosphate, concluded that the phosphate deposits of Florida extended entirely across the State from the Georgia line through Hamilton, Suwannee, Alachua, Marion, Sumter, Polk and Manatee counties to Charlotte Harbor. (Mineral Resources for 1885, pp. 450-453, 1886.)

During 1886 and 1887, owing doubtless to the efforts of Captain LeBaron and to the general interest in phosphates, careful investigations were made of the Peace Creek section by private interests. These investigations resulted in the purchase of lands and the initiation of mining operations in the river pebble district, the first shipment of Peace River phosphate having been made in 1888.

The deposits that we now know as the Florida hard rock phosphate were discovered in 1888 by Mr. Albertus Vogt. In May of this year Mr. Vogt, while deepening the well at his place, near Dunnellon, dug into a rich matrix of gravel, soft phosphate and sharks' teeth. In June, 1888, a sample of this material was taken to Ocala and was there analyzed by R. R. Snowden and was found to be a high grade phosphate.

The time of the discovery of the hard rock phosphate in Florida has been variously given as spring of 1888, fall of 1888, and spring and fall of 1889. The dates given above are from a letter from Mr. Vogt of August 26, 1909. The discrepancies in the various publications as to the date of discovery probably came about from the fact that the discovery was not made known to the public at once.

As soon as the existence of high grade phosphate rock was made generally known, prospecting became very active and the hard rock phosphate belt substantially as we now know it was quickly outlined.

THE BEGINNING OF THE FLORIDA PHOSPHATE MINING INDUSTRY.

As has been already mentioned the first attempt at mining and utilizing the phosphates of Florida was made by Dr. C. A. Simmons, of Hawthorne, in 1883. This plant, however, was not successful and was closed down in 1884.

The production of phosphate rock on a commercial scale in Florida began with the mining of the Peace Creek pebble deposits, probably in 1887, the first shipments having been made in 1888. The first company to operate on Peace River was the Arcadia Phosphate Company, organized by Mr. T. S. Morehead, of Philadelphia. The first shipments were to the G. W. Scott Manufacturing Company of Atlanta. (Millar, 1892, page 24.)

Hard rock phosphate mining began one or two years later than river pebble mining, but developed much more rapidly. According to Millar, the first of the hard rock mining companies to actually take the field was the Marion Phosphate Company, which broke ground near Dunnellon in December, 1889, and made a first shipment to Liverpool in April, 1890. The Dunnellon Phosphate Company, which was probably the first company organized, began mining in February, 1890, and made their first shipment to London and Hamburg in May, 1890. Following the discovery of the hard rock phosphate deposits mining companies were organized in rapid succession. It is said that fully one hundred hard rock phosphate companies were organized in the United States, and that forty-one of these actually began operations. By the close of 1891 only eighteen companies were operating. At the present time, 1913, fourteen companies are mining hard rock phosphate.

INVESTIGATIONS OF THE FLORIDA PHOSPHATE DEPOSITS.

The chief official investigations that have been made of the Florida phosphates are those of the United States Geological Survey, the United States Census Bureau, the United States Commissioner of Labor, the United States Department of Agriculture, and the Florida State Geological Survey. In addition, the reports of the State Chemist of Florida and of the State Experiment Station contain many analyses of Florida phosphate rock. Dr. J. Kost, during his brief term of office as State Geologist in 1886, also contributed towards the discovery of phosphate and the development of the industry.

The principal investigations made by the United States Geological Survey are those by Johnson (1885, 1893),* Penrose (1888), Darton (1891), Dall (1892), Eldridge (1893), Matson (1909), Clapp (1909), Vaughan (1909). In addition a number of other members of the National Survey have made notes on the Florida deposits in connection with the annual statements of the production of phosphate contained in the volumes on Mineral Industry.

The Census Bureau investigations are those made by the Tenth Census in connection with the study of building stone, by which the low grade phosphates were discovered, and the report on mineral industries by the Eleventh Census. This latter report contains a chapter on the Phosphates of Florida by Edward Willis. The Sixth special report of the Commissioner of Labor, 1893, is devoted to the phosphate industry of the United States. A brief review of the Florida phosphate fields was given in 1911 by William H. Waggaman, of the Bureau of Soils of the United States Department of Agriculture. The investigations of the phosphate deposits by the Florida State Geological Survey, on which this paper is based, have been made at occasional intervals as opportunity was afforded since the organization of the Survey in 1907.

The discovery of the hard rock phosphate in 1888 resulted in many private investigations of these deposits. Of these private investigators a number have made public reports while others unfortunately have made no permanent record of their investigations. Among the earliest of these private investigators was Dr. C. U. Shepard, of Charleston, who examined the phosphates of the Withlacoochee River section in connection with the organization of the Dunnellon Phosphate Company in 1889 and 1890. Among others who examined the hard rock deposits during the first few years of mining operations and who have published their observations are Albert R. Ledoux (1890), Francis Wyatt (1890,

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*The numbers in parenthesis refer to the date of publication as listed in the bibliography, not necessarily to the year in which the investigations were made.

1891), E. T. Cox (1890, 1891, 1892, 1896), Walter B. M. Davidson (1891, 1893), N. A. Pratt (1892), C. C. Hoyer Millar (1891, 1892), G. M. Wells (1896), E. W. Coddington (1896), L. P. Jumeau (1905, 1906).

THEORIES PREVIOUSLY PROPOSED.

The hard rock phosphates of Florida have interested all who have examined them, and many theories have been advanced to account for these remarkable deposits. In the following review these various theories are given as nearly as practicable in the order in which they are proposed. A strictly chronological order is, however, often impossible since when several papers appear during the same year it is difficult to determine which was first issued. Moreover some of the papers were evidently written some years before being printed.

The paper by Dr. Albert R. Ledoux read before the meeting of the New York Academy of Science, January 27, 1890, and published in the transactions for 1890 is apparently the first account of the hard rock phosphate deposits that has been preserved. In this paper Dr. Ledoux offers no specific theory for the Florida deposits. Speaking of phosphates in general, however, he notes the fact that within the rain belt, when guano deposits rest upon limestone the phosphoric acid is leached out and alters the carbonate of lime to phosphate. An instance is cited in this connection in which limestone in one of the South Pacific islands was believed to have been changed to phosphate to a depth of several feet within the period of twenty years. The phosphoric acid in this instance was leached by rainwater from recently deposited guano. The suggestion of the replacement of the carbonate of limestones under certain favorable conditions by phosphate is not offered by Ledoux as a new hypothesis, as this method of formation of certain of the phosphates had been discussed by various previous writers.

In a paper published in the New York Mining and Engineering Journal for August 23, 1890, Francis Wyatt proposed the theory that the hard rock phosphates are due to the evaporation of the Miocene waters which are assumed to have covered this section of the State. While submerged there was deposited upon the limestone, according to Wyatt, more especially in the cracks and fissures, a soft, finely disintegrated calcareous sediment or mud. As the seas dried up estuaries were formed in which were found great numbers of fish, mollusks, reptiles and marine plants. The formation of the phosphate is attributed to the reactions between the calcareous sediments and the decaying animal and plant life.

Professor E. T. Cox, in a paper read before the Indianapolis meeting of the American Association for the Advancement of Science, August, 1890, expresses the view that the hard rock phosphates of Florida are derived from the mineralization of an ancient guano. His argument is that as the peninsula of Florida was elevated above the ocean the land bordering the sea on the west coast became the resting place for numerous aquatic birds and other animals. The humid character of the climate caused the soluble alkalies to be removed, leaving the less soluble phosphate of lime. This accumulation of guano subsequently became mineralized, thus resulting in the hard rock phosphates. This theory is restated in papers subsequently published by Cox in 1892 and 1896.

Professor Cox mentions two other views current at that time. These are stated as follows: "It is a well known fact that phosphorous is an element and, like the element of iron, is almost universally distributed over the globe, and is found in all the living things thereon. Therefore, it is reasoned that it may, like iron, be accumulated in large beds by a natural law which governs the concentration of mineral masses. Again, it is suggested that phosphoric acid, derived from mollusca, deposits from birds, fish and saurians, has filtered down and replaced the carbonic acid in the underlying limestone, converting it into phosphate of lime." To the first of these suggestions Cox offers no objection. Of the second, however, he says, "Against the latter theory the phosphate of lime very rarely contains any trace of organic remains, while the limestone on which it rests is rich in the casts of mollusca that are referred to the Eocene age. Then, again, in proximity to the hard rock phosphate is a soft phosphate of lime that has the consistency of soft, plastic clay. This soft phosphate often underlies the hard and is several feet in thickness."

Mr. N. H. Darton, writing in the American Journal of Science for February, 1891, considers guano as the most probable original source of the phosphate. The early Miocene is regarded as the probable time of deposition of the guano which by leaching supplied the phosphoric acid. Two processes in the formation of the rock are recognized. The first is the replacement of the carbonate of lime by phosphate of lime; the second is a general stalactitic coating on the massive phosphates and in the cavities. Whether or not the restricted distribution of the phosphate was connected with the genesis of the rock Darton regards as undetermined at that time.

Mr. Walter B. M. Davidson contributed a brief paper on the origin and deposition of the Florida Phosphate, which was published in the Engineering and Mining Journal, Vol. 51, pp. 628-629, 1891. This paper has not been available to the writer, but from a reference in a later paper it appears that Davidson at that time believed that the hard rock phosphate boulders were deposited in underground caverns and river beds in the Vicksburg Limestone.

Among important early publications on the Florida phosphates is a paper by Dr. W. H. Dall, published in 1892. Dall's account of the phosphate was given in connection with and was incidental to a general summary of the geology of Florida included in a monograph on the Neocene of North America by Dall and Harris (Bull. 84, U. S. Geol. Survey). In this report Dall expresses the belief that the phosphoric acid of the phosphate deposits was derived directly from bird guano. The local character of the bird rookeries determine the local occurrence of phosphate rock. The influence of local clay beds on the accumulation of workable deposits is also recognized (p. 135).

Davidson, in a paper read before the American Institute of Mining Engineers at the Baltimore meeting in February, 1892, published in the Transactions, 1893, appears to derive the hard rock phosphates as residual material from the Vicksburg Limestone. He says, page 12, "The phosphates of Florida, in all shapes, I derive from the leaching of the Vicksburg limestone, and in the same way I would account for the phosphates of the West India Islands. The phosphatic limestone of these islands has been subject to the leaching action of rains and atmosphere reactions, and the carbonate of lime has been carried away, leaving on the surface the more insoluble phosphate, and the iron and alumina. As in all limestones, the water eats away the rock unevenly, making pits and holes, and caves, and the phosphate of lime fills them up—either in an earthy form, or in the massive variety, which is described as coating the stalagmites and stalactities in the cave in Navassa." Davidson believed that after the phosphate had accumulated in the pits and holes in the limestone, Florida was again submerged, allowing the sea sand to accumulate over and around the boulders.

Pratt (1892) while conceding that the theory of a pure bird deposit, in localities favorable to the roosting of water fowl, more nearly covers the conditions of the problem as presented in all localities than any other so far advanced, considers that in the case of the Withlacoochee River deposits the evidence is all opposed to this theory. In this paper the theory is advanced by Pratt that the phosphate boulder is a true fossil, the boulder being the phosphatic skeleton of a gigantic foraminifera, while the soft phosphate is supposed to be the germ spores or bud of the animals or the comminuted debris of the animals themselves.*

Millar (1892) reviews the theories current at that time (pp. 115-117) and favors the view that guano is the most probable source of the phosphate.

Whether the hard rock phosphates of Florida resulted from a superficial and heavy deposit of soluble guano, or from the concentration of phosphate of lime already widely and uniformly distributed throughout the mass of the original rock, or from both

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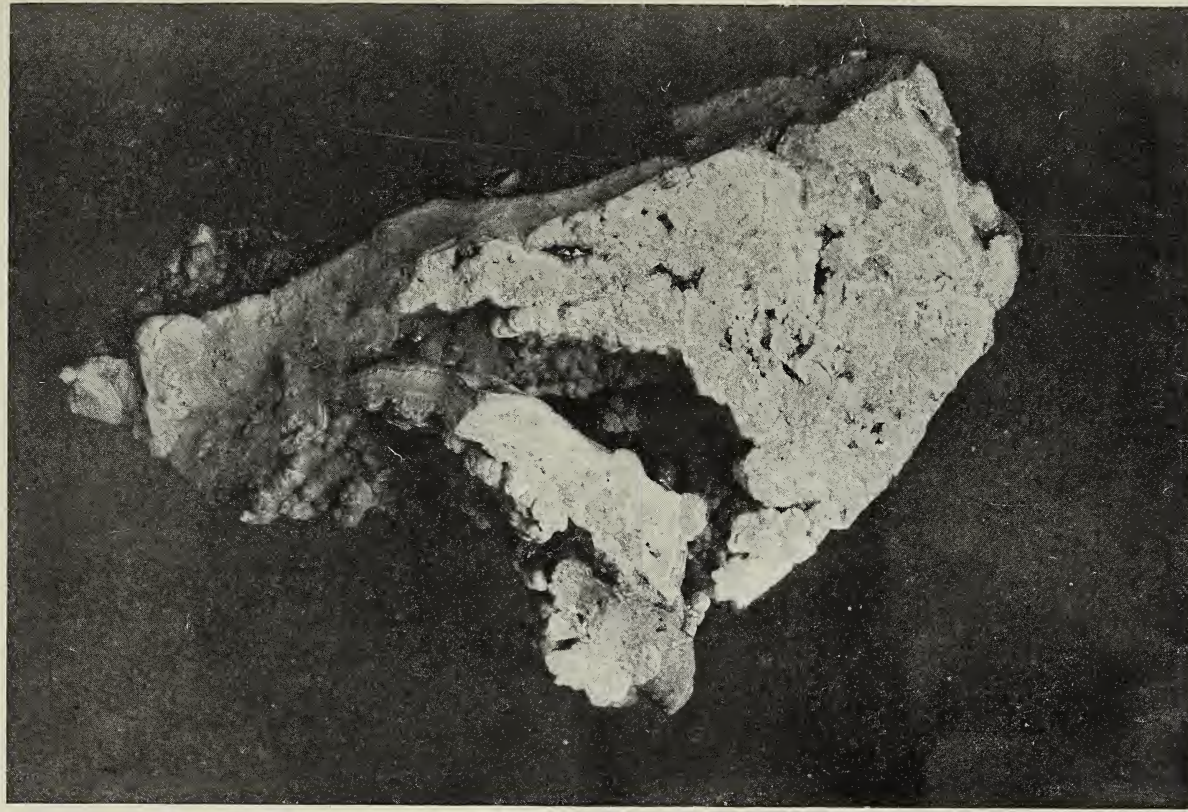
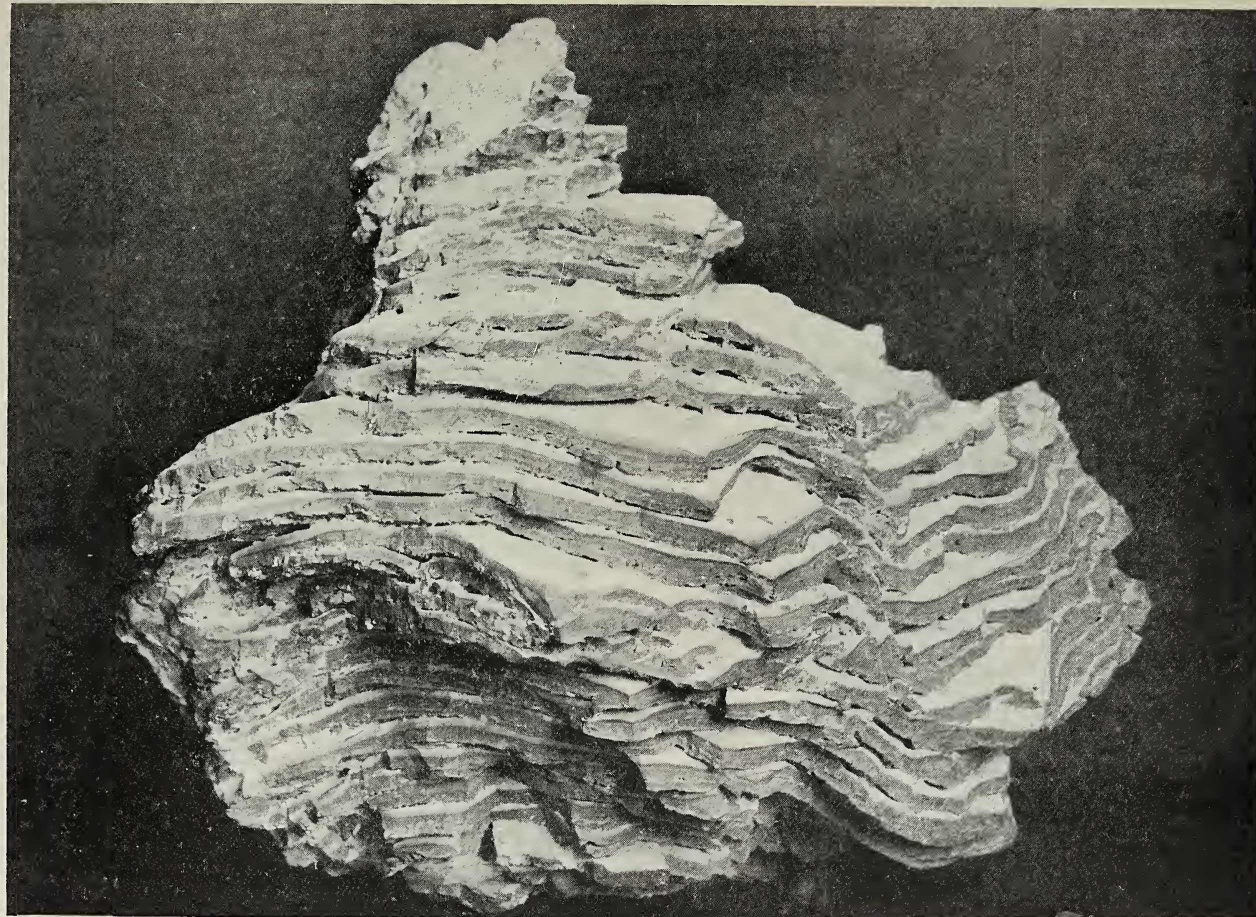
*The original of Dr. Pratt's paper not being accessible to the writer this review is based on the quotation from the paper included in the Phosphate Industry of the United States by Carroll D. Wright, 1893, pp. 24-31, and in the Florida, South Carolina, and Canadian Phosphates by Millar, 1892, pp. 73-77 and 117.



Piece of phosphate rock taken from large boulder and showing secondary deposition of phosphate in the form of layers on the bottom of the cavities and as stalactitic projections from the roof of the cavities. Natural size.



Piece of phosphate rock from laminated boulder. From the collection of H. Bystra.

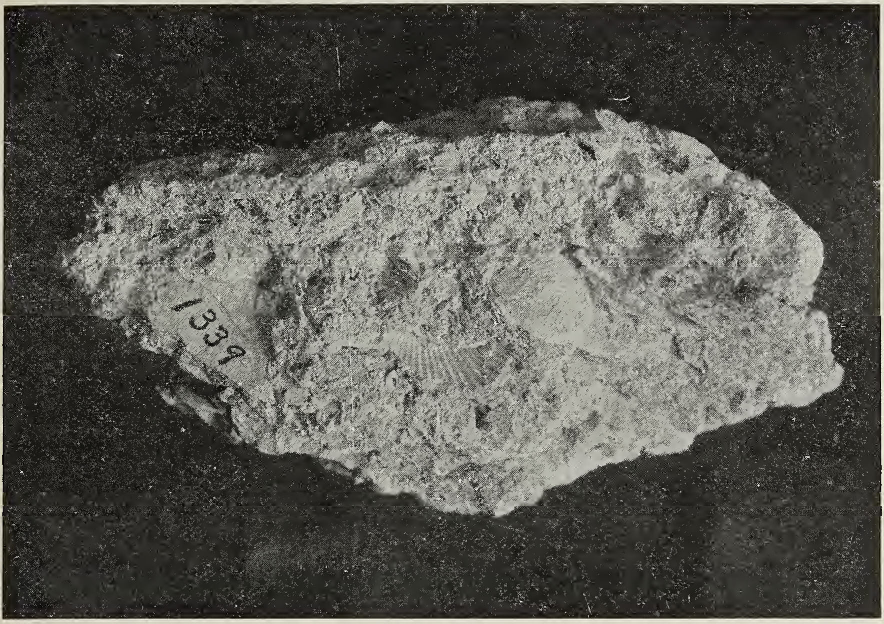


Fig. 1.—Sample of phosphate illustrating the formation of phosphate by the replacement process. The rock was clearly originally limestone of the Vicksburg formation, the form of the shells being well preserved. The carbonate has been replaced by phosphate, and the rock as shown by analysis is now a high grade phosphate. Natural size.

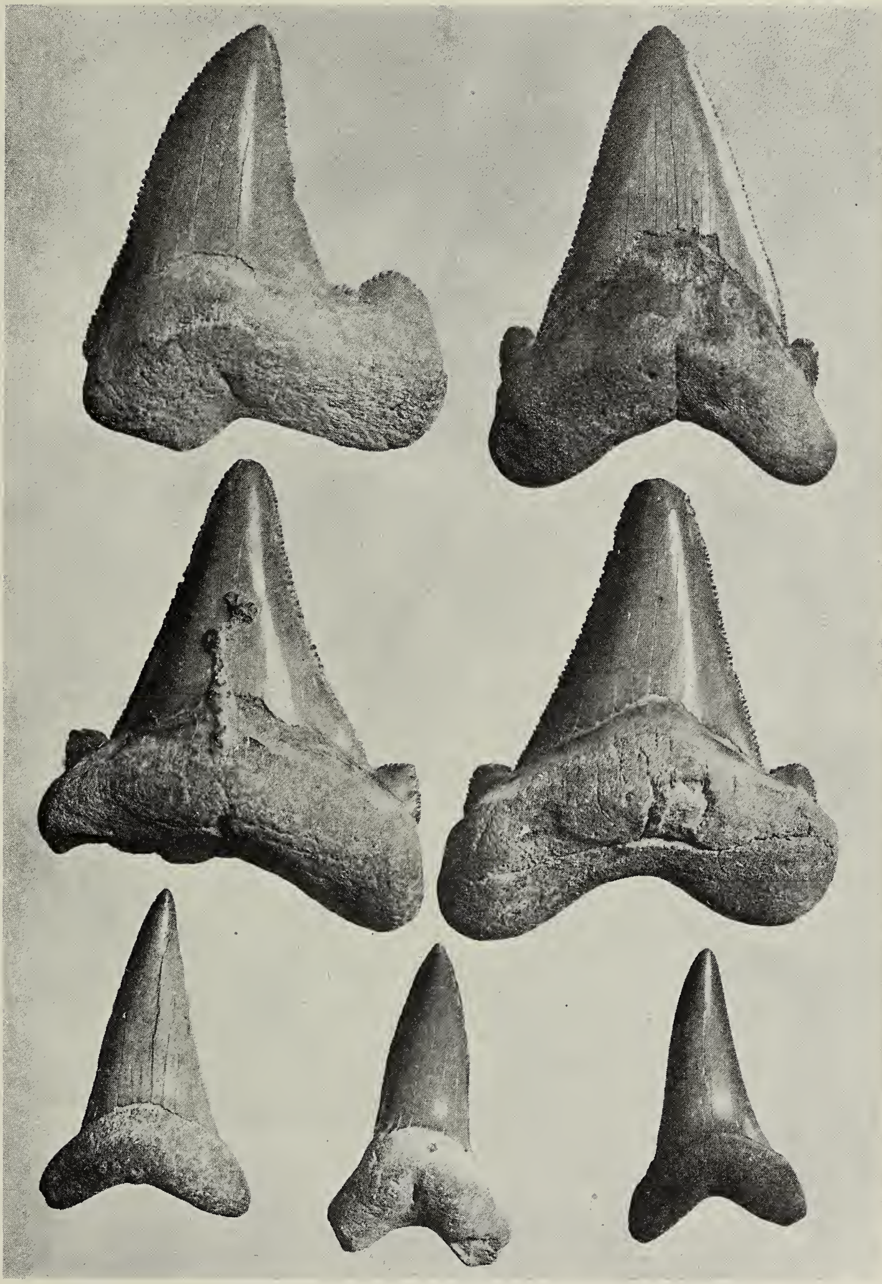
Fig. 2.—Piece of phosphate rock showing secondary deposition in cavities and recementation of broken fragments. Collection of H. Bystra. Natural size.

Fig. 1.—Mastodon tooth from T. A. Thompson's mine at Neals, Fla. This tooth has the gray phosphatic sands of the phosphate formation firmly adhering to it indicating that it came from the phosphate formation. Natural size.

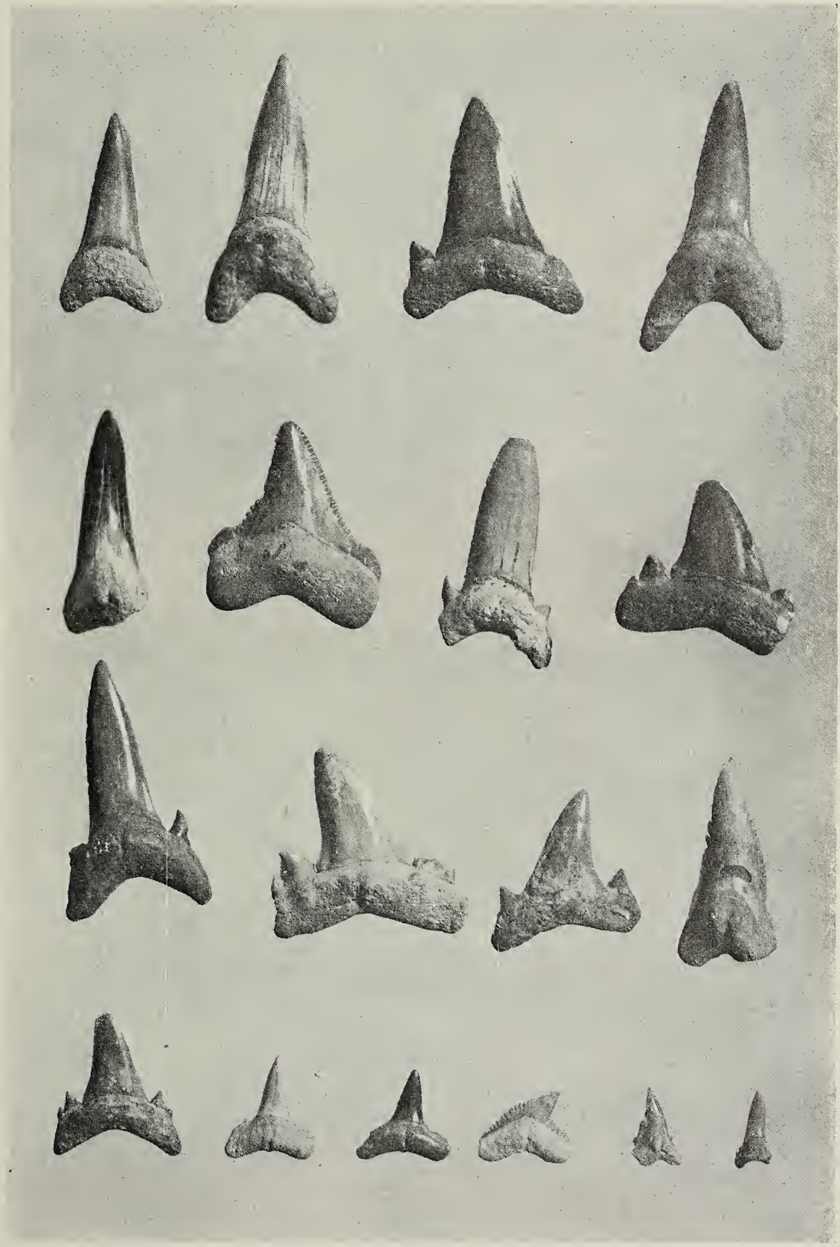
Fig. 2.—Mastodon tooth from T. A. Thompson's mine, Neals, Fla. The gray phosphatic sands clinging to the tooth are evident in the photograph. This tooth shows very little wear. Natural size.

Fig. 1.—A fragment of mastodon jaw with two teeth in place from Neals, Fla. About one-half natural size.

Fig. 2.—Teeth and foot bone of horse. The light colored tooth on the upper side at the left is from the Dunnellon Phosphate Company plant No. 5 at Hernando, in Citrus County. It has the phosphatic sands of the phosphate formation adhering to it. The lower tooth on the left is from the Franklin Phosphate Company mine, Newberry, Fla. (No. 1233). The upper tooth in the center is from the Camp Phosphate Company, Blue Run mine, near Dunnellon (No. 1366). The lower tooth in the center is from Cullens River Mine, Dunnellon (No. 1444). The foot bone is from the Dunnellon Phosphate Company plant No. 6, near Dunnellon (No. 1302). All natural size.



Sharks' teeth from the hard rock phosphate deposits.



Sharks' teeth from the hard rock phosphate deposits.

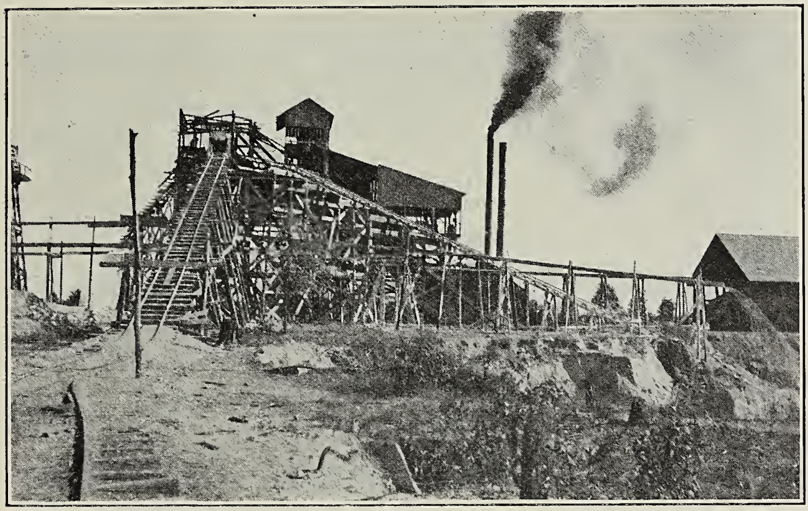


Fig. 1.—Phosphate washer for hard rock phosphate, Cummer Phosphate Company, Alachua County.

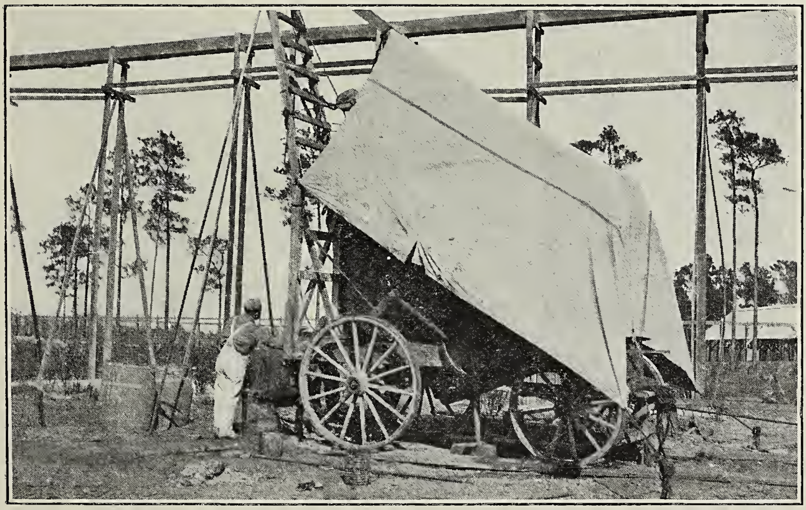


Fig. 2.—Drill for prospecting for hard rock phosphate, in use by the Southern Phosphate Development Company. The prospect holes are drilled through the phosphate formation to the underlying formation, the Vicksburg Limestone, which is reached at this locality at a depth of 75 to 100 feet.

View in the Plate Rock Phosphate Mine at Anthony, showing the very irregular top surface of the limestone after removal of the phosphate.

of these sources is regarded by Eldridge (1893) as a difficult question. Alteration of the limestone and precipitation of phosphate from solution are both regarded as having been active in the formation of the primary phosphates. Phosphate boulders, Eldridge suggests, may have been formed by chemical precipitation of layer upon layer of phosphate, either on a surface exposed to the air or within a cavity in the limestone. By continued growth in the latter case the cavity would become filled with laminated or massive rock which upon the solution of the surrounding materials or the complete breaking down of the formation, as in later times, would result in a rounded body of phosphate of lime resembling a sea rolled boulder.

Referring to phosphate of lime in sedimentary rocks Eldridge says (p. 18), "Its presence in sea-water; its broad distribution in both plant and animal life; its occurrence in rocks of all ages, even to the extent of economic value; and its special presence in limestones, more particularly in Cretaceous and Tertiary limestones, are facts long recognized. Its occurrence in recent time in the form of leached and soluble guanos on many of the oceanic islands, and the phosphatization of the underlying strata, have also been noted by many authorities; the last is by actual observation a tangible source, but the features first detailed point to some other and more general origin of phosphate of lime than localized bird-deposits, or the but little more widely distributed accumulations of animal remains. Its presence in sea-water, after the manner of carbonate of lime, though in far smaller amount, is well established; both materials are of general occurrence, and each play a prominent part in sea-life. The transfer of a considerable percentage of phosphate of lime to localities having conditions favorable for its deposition, either in sediments, then settling, or on surfaces of rocks already laid down, has doubtless been accomplished in many cases through the instrumentality of animals secreting it. Oceanic currents may have assisted this accumulation. Again, southern waters, swamps, and lands give evidence of the presence in them of abundant life, secreting phosphate of lime and afterwards returning it to the beds on which this life rests."

With regard to the plate rock phosphates of Marion County, Johnson (1893) assumes an original deposition of immense beds of guano. These beds after the leaching out of their carbonates and other soluble materials are believed to have become very compact, yet not entirely impervious to water. Small cavities in close contiguity became finally separated by mere plates and in this connection are called laminated rock. By disintegration the laminated rock is broken up into fragments, thus giving rise to the so-called plate rock. Still further disintegration, in the opinion of Johnson, results in the formation of soft phosphate. Johnson's theory as to the origin of the phosphate as expressed in this paper is essentially the same as that advanced by Cox in 1890 to account for the phosphates as a whole. Johnson's view that the plate rock results from the disintegration of laminated boulders had not previously been definitely advanced, although Willis includes a statement to this effect in his paper published in 1892.

Lucius P. Brown (1904) regards it as possible that guano may have contributed in a minor degree to the enrichment in phosphoric acid of the Florida limestones. The workable deposits of phosphate of lime, however, he regards as having been gathered up from miscellaneous sources in sedimentary rocks and concentrated through the agency of underground water with more or less further concentration by mechanical means.

Mr. P. Jumeau (1905) reviews the theories proposed to account for the origin of the phosphate rock, pp. 68-82. That the phosphate rock has accumulated chiefly from the leaching of guano is regarded by him as the most probable theory.

DISCUSSION OF THEORIES.

The theories offered by Wyatt, 1890, and by Pratt, 1892, are highly speculative and are based on assumptions for which no proof is offered. Of this class also are some other theories that have appeared from time to time in newspaper and magazine articles.

Davidson assumes that the phosphate rock existed originally in the Vicksburg Limestone and in its present form is merely residual from the decay of that formation. In answer to this hypothesis it may be noted that while the Vicksburg Limestone is known by surface exposures throughout a large extent of the territory in the Gulf States, and by well borings to a considerable depth in Florida and elsewhere, it is strikingly free from inclusions of phosphate rock, such as would remain upon the disintegration of the limestone to form these phosphate deposits.

Cox, in successive papers, argues that the phosphate rock is itself mineralized guano. This, likewise, was the view of Johnson (1893), as applied at least to the plate rock phosphates of Marion County. The fact that not a few of the phosphate boulders and pieces of rock have retained more or less well preserved evidence of their derivation from limestone sufficiently controverts this hypothesis, which is otherwise improbable.

Darton (1891) and Dall (1892) each assume that guano is the immediate source of the phosphoric acid. Darton's paper on this subject is brief and includes merely a statement of the probable origin of the rock. Dall, however, gives a clear statement of the guano hypothesis in its relation to the hard rock phosphates of Florida. It is even thought probable by Dall that each local deposit of hard rock phosphate may represent the location of an ancient bird rookery. The hypothesis of the origin of the phosphate from guano fails entirely to account for the jumble of materials with which the phosphate is associated. This, in the writer's opinion, is the insurmountable objection to the bird guano theory, as developed by Dall.

Of those who have written on the origin of the hard rock phosphate deposits of Florida, no one, with the exception of Eldridge, has taken sufficient account of the complexity of this formation, or has seemed to appreciate that it is as necessary to account for the associated materials as for the phosphate itself. With the hypotheses proposed by Eldridge, however, the writer is unable to agree.

Whatever the original source of the phosphoric acid, whether from guano or from phosphate of lime, originally disseminated throughout the Vicksburg Limestone, the subsequent process, according to Eldridge, was the formation of a highly phosphatized zone within and presumably at or near the surface of the Vicksburg Limestone. This process Eldridge designates as the first period during which the primary phosphate was formed. To account for the condition in which the rock is now found and for the mixture of materials in the matrix Eldridge assumes that at a late period, probably at the close of the Pliocene, the peninsula of Florida was resubmerged and that during this resubmergence this phosphate stratum was broken up, the pieces being removed more or less from their original location. To account for the associated sands, clays and other materials mixed with the phosphate rock he assumes that strong currents were running which washed in these complex materials. The phosphate that is now present in a finely divided condition and acts as a cementing substance for the gray sands was, he assumes, the ground up sediment from the hard rock which mixed with the sands as they were drifted into their present location.

The writer's hypothesis is based on observations by himself and others which lead to the conclusion that formations later than the Vickburg, formerly extended across the phosphate fields, and that these have now largely disintegrated. It is shown also that these formations, where now found intact, or as remnants on the surrounding uplands, are distinctly phosphatic. From these observations it is concluded that the matrix of the hard rock phosphate deposits is the residue of the formations that have disintegrated *in situ,* and that the phosphate itself is derived from the phosphate originally widely disseminated through these formations, circulating waters being the agency by which the phosphate has been carried to its present location. The gray sands held together by the finely divided phosphate, referred to by Eldridge, are a part of the residue from these earlier formations in which the sands occur under similar conditions.

In the present paper it is not intended to discuss the source of the phosphate, which is found widely disseminated in the Upper Oligocene and some later formations, from which by solution and redeposition it has accumulated to form the workable hard rock deposits. The writer does not believe, however, that the bird guano theory will account for these widely disseminated phosphates, any better than for the intensely localized hard rock phosphates. Upper Oligocene formations, which are throughout more or less phosphatic, attain in Florida a thickness of several hundred feet. Moreover these formations, except where disconnected by erosion, are continuous from the Apalachicola River, in West Florida, to an undetermined distance beyond the point at which they disappear beneath later formations in Central Florida. It is inconceivable to the writer that bird guano deposits could have been so uniformly scattered over so wide an area and through so great a thickness of sedimentary rocks.

As regards the chemical changes involved in the formation of the hard rock phosphate there is much less disagreement among the different writers. Ledoux, Darton, Dall, Eldridge, Brown, Jumeau and others have recognized that phosphoric acid in solution in water may and under favorable conditions does replace the carbonate of limestones thus forming calcium phosphate. Darton recognized the two processes, the first being the replacement of the carbonate by phosphate, and the second the subsequent coating over the surface and in cavities by phosphate thrown out of solution. Eldridge recognized the formation of boulders by replacement of carbonate by phosphate, and by precipitation from solution. The evidence of the formation of phosphate by the replacement of carbonate by phosphate is entirely incontrovertible, since, as has been previously stated, many of the boulders retain the original calcareous shells now phosphatized. The evidence of subsequent secondary deposition in the cavities is likewise obtained from the structure of the rock itself. The formation of boulders by precipitation seems probable from the structure of many of the boulders. Doubtless, as elsewhere stated, the replacement and precipitation have combined in the formation of many boulders. The chemical processes involved are more fully discussed elsewhere.

Turning again to the explanation of the hard rock phosphate deposits offered by the writer, the key to the solution of the hard rock phosphate problems is found, in the writer's opinion, in a study of the geological history of the State. The foundation rock in Central Florida is the Vicksburg Limestone of Lower Oligocene age. In the hard rock phosphate section there is at present no formation, other than the phosphate itself, overlying the Vicksburg. However, there are good reasons, as already stated, for believing that the Upper Oligocene and some later formations, now found on the uplands bordering the phosphate belt, formerly extended across this area. Upper Oligocene deposits are found at the present time bordering the phosphate belt on the north, east and south, while on the west outliers of these formations may still be found in Levy and in Hernando Counties.* Remnants, apparently, of these formations have recently been observed by the writer on the hills near Morganville, west of the phosphate area in Marion County.

Further support of the view that the Upper Oligocene deposits formerly extended across the phosphate belt is found in the topography of the area. The phosphate country has been reduced in elevation more or less by underground solution. The phosphate deposits of Alachua County are found at an elevation of from 75 to 100 feet above sea, while passing to the east the plateau or uneroded section of this county rises to an elevation of 200 feet above sea. In Marion County the phosphates are found at an elevation of from 40 to 100 feet above sea, while both west and east of the phosphate belt, hills, the remnants of the former plateau, rise to an elevation of from 140 to 160 feet above sea. In Citrus County the hill country west of the phosphate area still retains a height of from 150 to 220 feet. The Upper Oligocene formations are found very generally on the east side of the phosphate belt, while remnants, as already stated, are found on at least some of the hills on the west side of the area.

Whether or not marine Miocene formerly extended across the present phosphate fields is undetermined. The character of the residue at some localities suggests Miocene material, although no actual proof of a former extent of the Miocene across this part of the State has yet been obtained. The marine Pliocene probably did not reach across this part of the State. Fresh water deposits of Pliocene and Pleistocene, however, are to be expected since

*Florida Geological Survey, Second Annual Report, Map, 1909.

fresh water Pliocene deposits, the Alachua clays, containing remains of land vertebrates are found locally around the border of the phosphate area. These deposits were formed in small lakes and sinks, and similar deposits, doubtless, formed in the phosphate area. The red sandy clays which form the surface deposits over practically all of the Northern and Central Florida probably extended across the phosphate area.

Assuming the former areal extent of these later formations across what is now the phosphate belt of Florida, the solution of other problems connected with the hard rock deposits is much facilitated. As a result of the action of the weathering agencies these formations have disintegrated, their residue forming the phosphate matrix. The process of erosion and disintegration has been long continued, during which time the general surface level has been gradually lowered by the solution and removal of the underlying limestone. The lowering of the limestone here as elsewhere in limestone countries progresses not uniformly but irregularly, due to the formation of caves, sinks and underground channels. This irregular subsidence has resulted in the mixing of materials originally distinct. Sinks form in the limestone section of Florida by which material at the surface is lowered by the sudden caving of the earth. When these sinks are first formed the walls are vertical or nearly so. As a result of the caving at the sides together with the wash of surface material they fill up. By this process long continued the materials of different formations become intimately mixed.

The mixing of materials by underground solution and subsidence has been supplemented by stream action. While this area is at present practically without streams, yet local streams existed during the earlier stages of physiographic development. These local streams begin their development as soon as sinks are formed and when the stratigraphic conditions are favorable a stream enters each sink; working back from the sink the stream established in time a normal drainage system. These streams are known as disappearing streams since they enter sinks. As has been explained in a previous paper,* the limestone country of Central Florida is gradually encroaching on the non-limestone country. These temporary streams make up one of the characteristic features of the physiography in the transition stage and numerous examples of such streams are found in the partially eroded uplands bordering the phosphate fields. After being formed a sink is frequently filled up by the materials carried by the stream which enters it.

In addition to local streams it is probable that considerable bodies of water existed from time to time in this section into which streams entered. The Pliocene was probably the time of the most active reaccumulation of the material which makes up the matrix of the phosphate deposits. Whether or not this area was partially submerged during the time of the reworking of the materials of this formation can possibly be determined by a careful study of the fossils.

THE FOSSILS OF THE HARD ROCK PHOSPHATE DEPOSITS.

Two distinct groups or lots of fossils are found in this formation. The first of these includes those fossils, chiefly sharks' teeth, that are residual from the formations that have disintegrated. The second group, of which there is a considerable fauna, chiefly land animals, includes those fossils that were incorporated in connection with the reworking of the materials. The invertebrate fossils of this formation are contained for the most part in loose fragments of rock which represent inclusions from the underlying Vicksburg Limestone or remnants from later formations that have disintegrated.

It should be borne in mind in this connection that the residual fossils do not necessarily all come from formations later than the Vicksburg. A part, possibly a majority, are residual from the Vicksburg itself. As already explained, the limestone is being constantly removed by solution and the fossils that it contained, if sufficiently resistant, remain as a part of the residue and hence

*Fourth Annual Report Florida Geological Survey, page 33, 1912.

become incorporated in the phosphate deposits. Among the residual fossils are sharks' teeth, which are obtained in numbers from every pit that is operated. It is frequently stated by the miners that the sharks' teeth become more abundant as the underlying limestone is approached near the base of the deposits. This statement is consistent with the view that many of the teeth are residual from the underlying limestone. The less resistant parts of the skeleton can not be expected to have persisted from these early formations in such abundance and such perfect state of preservation as have the teeth.

The residual fossils are of value to the geologist since from them it may be possible to determine from what particular formations the materials of the matrix have been derived. The fossils included with the phosphate, not residual, indicate the age or time during which the reworking of the materials occurred.

The fossils that were incorporated with the materials while they were being reworked and redeposited are, as would be expected, of much later date than the residual fossils. Of these later animals comparatively fragile bones are frequently preserved. Whole skeletons, however, are rarely found in place. This may be due to the conditions under which they were entombed, or possibly to the fact that the parts of the skeleton have been subsequently more or less dissociated by the subsidence of the materials due to the solution of the underlying limestone.

From the fact that the formation of caves and sink holes in the limestone has continued to the present time it is evident that some comparatively recent fossils are likely to become included with the phosphate. Moreover local fresh water Pleistocene or recent surface deposits are likely to occur as a part of the overburden from which fossils may become mixed with the phosphate. Along the Withlacoochee River, which cuts through these deposits, also there has doubtless been more or less shifting of the stream by which Pleistocene and recent remains are included with the phosphate. These are conditions that must be borne in mind in making and in studying the collections.

Of the fossils that are accepted as contemporaneous with the phosphate formation the best authenticated is a species of mastodon, probably *M. floridanus.* This mastodon has been obtained in the hard rock phosphate section from the following mines: T. A. Thompson, Neals, Alachua County; Dutton Phosphate Company, plant No. 22, Juliette, Marion County; Cullen River Mine, Dunnellon, and Dunnellon Phosphate Company, plant No. 5, Hernando, Citrus County. That the mastodon is actually imbedded in the phosphate bearing formation is not only vouched for by the miners who have personally taken specimens from the pits, but is evident from the specimens themselves, some of which have the gray phosphatic sands of the phosphate formation adhering to them. Associated with the mastodon is found the small three-toed horse, *Hipparion.* The remains of the horse have been obtained only from the picker belt, but notwithstanding the fact that they have gone through the washer, some of the teeth still have bits of the phosphate matrix clinging to them. The horse remains have been obtained from the following mines: Franklin Phosphate Company, mine No. 2, Newberry, and T. A. Thompson, Neals, both in Alachua County; Dunnellon Phosphate Company, plant No. 6, Dunnellon, Marion County, and Dunnellon Phosphate Company, No. 5, Hernando, Citrus County. A number of other fossils have been obtained, which remain to be determined. Among these are teeth of an early camel from Dunnellon Phosphate Company, plant No. 5, Hernando, Citrus County, and Cullen River Mine, Dunnellon.

From the plants working along and near the bed of the Withlacoochee River have been obtained a considerable number of fossils. Among these, in addition to the mastodon, camel and early horse, is the elephant, rhinoceros and a more recent horse, as well as a number of other forms, some of which appear to be comparatively recent. It is evident that a mixing of fossils has occurred along the river due, possibly, to the shifting of the channel.

SOURCE OF THE PHOSPHORIC ACID.

The source of the phosphoric acid is believed to be from the various formations that have disintegrated *in situ.* The Upper Oligocene deposits are very generally phosphatic throughout their entire extent from the Apalachicola River, in West Florida, through Northern and Central Florida. The red sandy clays forming the surface deposits over much of Northern Florida and which probably extended across the phosphate section overlying the Oligocene deposits, contained fragments from the granitic rocks and have doubtless contributed in the process of decay more or less phosphoric acid.

AGENCY.

The agency by means of which the phosphates were accumulated in their present form was ground water. The rainfall, which in Florida amounts to about 54 inches per annum, in passing through the surface materials dissolves a limited amount of the phosphate, which is carried to a lower level and is finally thrown out of solution in a concentrated form. This process long continued results in the accumulation of workable phosphate deposits.

RELATION TO THE UNDERGROUND WATER LEVEL.

It is probable that the ground water level has had an important bearing on the formation of the phosphate deposits. There is, as is well known, a definite relation between the ground water level and chemical reactions within the earth. The conditions above and below this level are radically different. Above the ground water level the movement of water following rains is free and solution is active; below this level the water stands or has a scarcely appreciable movement. Above the water level solution is active, while below this level deposition frequently occurs.

It is important to observe in this connection that the underground water level, in Central Florida, which has such a direct bearing on chemical deposition has not always remained the same. In former times when the surface stood at a higher level the water table was higher above sea than at present. In other words, a lowering of the general surface level by erosion was accompanied by a lowering of the water table. It thus happens that a locality which in one stage of physiographic development is favorable to the formation of phosphate rock, may in a subsequent stage, when conditions have changed, be favorable to the disintegration of these deposits. Moreover, any change in levels, either elevation or depression, affects the water level and hence modifies conditions. Such changes in elevation have undoubtedly occurred. For instance a rise in elevation of 15 to 25 feet along the east side of Florida and a similar depression along the west coast as late as Pleistocene times is fairly well established. This, together with any further changes that occurred in the elevation of the peninsular, must be taken into account in its bearing on the change of water level and the corresponding change in deposition, and disintegration. It is not held that the accumulation of the rock in no case occurs above water level. In fact the secondary stalactitic deposits seen in many boulders evidently form as in caves above water level. The earth is a complex chemical laboratory in which chemical reactions take place in accordance with constantly changing conditions.

THE FORMATION OF BOULDERS.

The phosphate boulders have evidently been formed chemically through the agency of ground water. The boulders of silica are formed by a similar process by which silica taken into solution near the surface is redeposited at a greater depth.

SILICA BOULDERS.

Most of the flint or silica boulders were originally masses of limestone and still retain, in recognizable form, the shells and other fossils of which the limestone was originally composed. In these boulders the calcium carbonate has been replaced by silica. This process is common in nature. Petrification, another term for a similar process, is the slow removal in solution of the substance of which an object is composed and its replacement by some other substance. In the case of petrified wood the wood has been removed and replaced by silica, calcium carbonate, iron carbonate or whatever the petrifying agent may be. Silicified wood, silicified shells, silicified bone all refer to petrification in which silica was the petrifying agent.

The boulders of silica are, therefore, masses of silicified limestone, the fossils originally present in the limestone having for the most part retained their form.

PHOSPHATE BOULDERS.

The phosphate boulders are formed either by replacement of the limestone or by precipitation from solution.

PHOSPHATE BOULDERS FORMED BY THE REPLACEMENT PROCESS.

Some of the phosphate boulders and pieces of rock are evidently formed by the replacement of the carbonate of the original limestone by phosphate. That this is true is proven by the fact that the shells and other fossils that made up the original limestone are sometimes well preserved, and from these shells it is possible to identify the particular formation from which the original limestone comes. Among the illustrations which accompany this paper will be found a photograph of a rock, which was originally pure limestone of the Vicksburg formation but is now changed, as shown by analysis, to a high grade phosphate. The shells and other fossils making up the limestone, which were originally calcareous, were subsequently phosphatized. Otherwise expressed, they have been petrified, phosphate being the petrifying agent. The collection of Dr. H. Bystra at Holder contains a piece of phosphate boulder, in which much larger shells are equally well preserved. While occasional phosphate boulders with fossils in a perfect condition of preservation are found as a rule the preservation of the fossils in the boulders is imperfect. It is probable, also, that in many boulders formed by replacement the fossils are entirely obliterated.

PHOSPHATE BOULDERS FORMED BY PRECIPITATION.

Many of the phosphate boulders are formed in part or entirely by precipitation of calcium phosphate from solution in water. This is probably the method of formation of the laminated boulders.

It is probable that replacement and deposition from solution are both involved in the formation of many boulders.

SECONDARY DEPOSITION OF PHOSPHATE FROM SOLUTION.

In many boulders a secondary deposition from solution may be recognized. Practically all the laminated boulders show a rough mamilated or stalactitic undersurface of each lamina, while the top surface of the lamina next beneath show successive layers, separated by minute parting planes, indicating successive deposition of phosphate from solution. This process is similar to that which takes place in caves where calcium carbonate is deposited to form stalactites and stalagmites, and is probably confined to boulders lying above the permanent ground water level. Many small pieces of rock were doubtless phosphatized without having assumed the boulder form.

ORIGIN OF THE PLATE ROCK.

The plate rock deposits represent a peculiar phase of the hard rock formation. It seems probable that the plate rock represents, in part at least, fragments of boulders that have disintegrated, as was suggested by Johnson in 1893. It has also been suggested that these plates may have been formed by finely divided phosphate mud settling as a sediment.

As previously stated many of the boulders have a laminated structure. When such boulders disintegrate the laminae break up, giving rise to the flattened pieces to which the term plate rock is applied. In this connection it is interesting to observe that the plate rock occurs in those sections of the field in which the phosphate deposits now lie above the water level, and have been subjected to disintegrating influences. The plate rock deposits, as at Anthony and Sparr, form a comparatively thin covering over the Vicksburg Limestone and represent, in the writer's interpretation, the disintegrated remnant of an ordinary hard rock phosphate deposit.

The gravel found mixed with the hard rock very possibly represents in part small bits of rock that have become phosphatized and in part fragments of larger rocks. The soft phosphate associated with the hard rock has very generally been regarded as resulting from the disintegration of the hard rock, although a part of the soft phosphate may be merely phosphatic clays.

LOCALIZATION OF THE HARD ROCK DEPOSITS.

The localized nature of the hard rock deposits within the formation is with little doubt explained by the variable character of the materials in which it occurs. As has been previously stated, the deposits of phosphate boulders are to some extent associated with local clay lenses. Such an association is *a priori* natural since clay interferes with the free circulation of the percolating water. On the other hand, when the matrix is chiefly sands with uniform and open texture, through which the water moves readily, the conditions are not favorable for the chemical deposition of phosphate. However, occurrence of the rock can not be expected to follow too closely the structural conditions as now observed since, as has already been explained, the whole phosphate producing section has been subjected to erosion by solution, which permitted irregular and intermittent local subsidence, thus thoroughly mixing the materials and moving them more or less from their original location.

LIMITATION OF THE HARD ROCK PHOSPHATES.

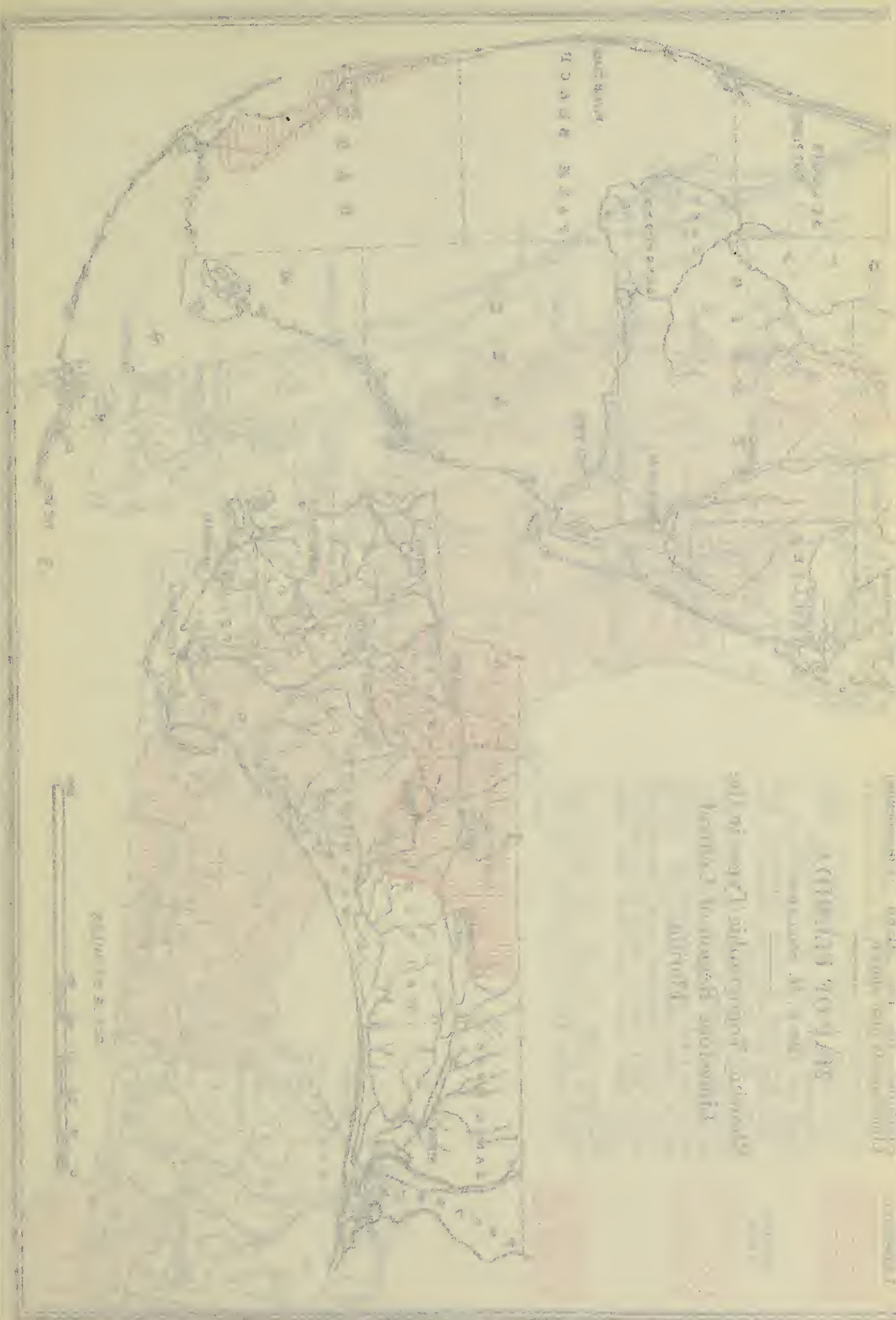
There yet remains the problem of the limitation of the hard rock phosphate to a particular and well recognized physiographic type of country. That the phosphate beds are so confined has long been apparent to those actively engaged in prospecting for and mining phosphate as well as to those who have investigated the deposits from a scientific standpoint. The accompanying map from the Fourth Annual Report of the Florida Geological Survey outlines in a general way the several physiographic types of the limestone section of Central Florida. In the light of what has previously been written, together with the legend, the map is largely self-explanatory. Four well defined physiographic types are recognized as follows: The Gulf Hammock Belt, The Hard

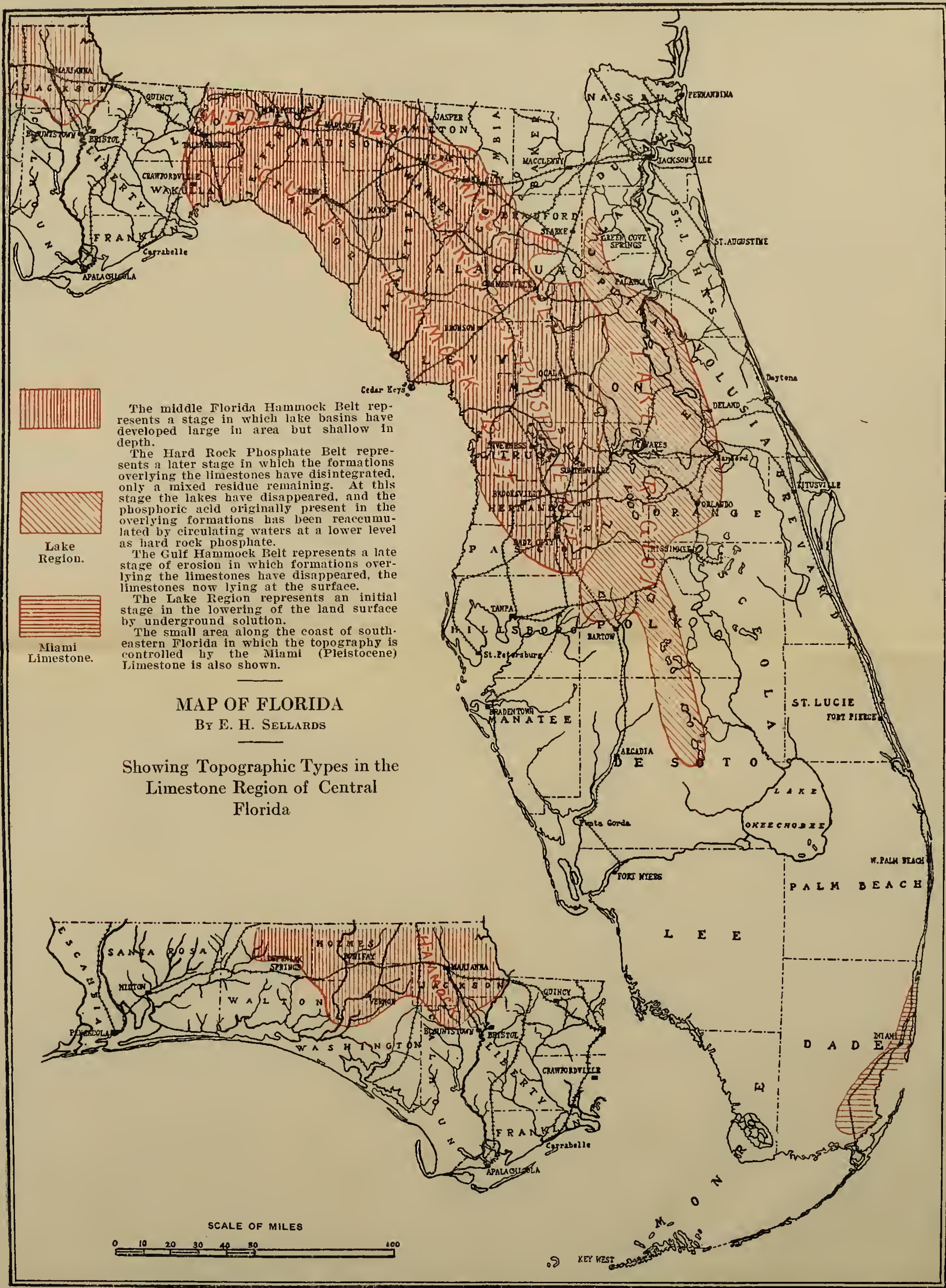
Rock Phosphate Belt, The Middle Florida Hammock Belt, and The Lake Region.

Immediately adjacent to the Gulf coast, in northern Peninsular Florida and for a few miles inland, the limestone lies at or very close to the surface. The underground water level is near the surface, and numerous large springs of limestone water emerge from the rock and flow to the ocean. This coastal strip contains numerous extensive calcareous hammocks and is known as the Gulf Hammock section of Florida. If formations later than the Oligocene limestones were formerly present over the Gulf Hammock area they have, with the exception of a slight residue of sand, disappeared. The Gulf Hammock section, west of Suwannee River, is underlaid by the Upper Oligocene limestones, while east of the Suwannee River the underlying formation is chiefly the Lower Oligocene limestone.

Inland from the Gulf Hammock area, in Peninsular Florida, is found a strip of country over which formations of later age than the Lower Oligocene were clearly present in former times, although there now remains of these scarcely more than the mixed and complex residue. The strip of country of this type extends in well marked development from the southern part of Suwannee and Columbia Counties, roughly paralleling the Gulf coast to Hernando and Pasco Counties. This area includes the hard rock phosphate deposits, these deposits having accumulated by the processes elsewhere explained during the period of erosion through which this section has passed. Few lakes or streams are found in the hard rock phosphate belt, as the rainfall enters through the loose surface material and passes directly into the underlying limestone. The underground water level lies, as a rule, at a greater depth beneath the surface than in the Gulf Hammock country. Numerous sinks form, giving evidence of the continued active erosion by underground solution. The surface contour is rolling, there being no regularity of hills or valleys.

Inland from the hard rock phosphate belt is found areas less affected by erosion, in which more or less of the formations that originally overlaid the Vicksburg Limestone may be identified in position. This type of country is known as the Middle Florida





The middle Florida Hammock Belt represents a stage in which lake basins have developed large in area but shallow in depth.

The Hard Rock Phosphate Belt represents a later stage in which the formations overlying the limestones have disintegrated, only a mixed residue remaining. At this stage the lakes have disappeared, and the phosphoric acid originally present in the overlying formations has been reaccumulated by circulating waters at a lower level as hard rock phosphate.

The Gulf Hammock Belt represents a late stage of erosion in which formations overlying the limestones have disappeared, the limestones now lying at the surface.

The Lake Region represents an initial stage in the lowering of the land surface by underground solution.

The small area along the coast of southeastern Florida in which the topography is controlled by the Miami (Pleistocene) Limestone is also shown.

MAP OF FLORIDA

By E. H. Sellards

Showing Topographic Types in the Limestone Region of Central Florida

Hammock Belt. In this type of country the surface is rolling, or somewhat hilly and occasionally flat bottomed lakes are found, which occupy solution basins. The soils on the slopes are prevailingly red with red clay sub-soil. Surface streams occur, although most of these terminate either in lakes or in sink holes through which they gain entrance to the underlying limestones, forming the disappearing streams characteristic of this type of country. In peninsular Florida two areas of Middle Florida Hammock lands may be designated. One of these includes a narrow belt extending in a northwest to southeast direction, through Columbia and Alachua Counties, into Marion County, A small part of Suwannee County, east of Houston, along the Seaboard Air Line Railway, is also included. This belt occupies the border land between the limestone and non-limestone country of this part of the State. The second well marked area is that which extends north and south through Citrus, Hernando and Pasco Counties, and is surrounded on all sides by more intensely eroded limestone country. A third large area of this type of country lies west of the Suwannee River, including the northern part of Leon, Jefferson and Madison Counties. Temporary lakes, rolling topography, good drainage, and red clay soils are characteristic features of this stage of topographic development.

The Lake Region of Florida, as a physiographic type, has long been known and often referred to in the literature of Florida. This type of topography includes a large area, extending from Clay County, on the north, to near the middle of DeSoto County, on the south, its greatest width being found in Lake and Orange Counties. It is cut into by the St. Johns, Oklawaha and Withlacoochee Rivers. Aside from these rivers surface streams are few, the rainfall passing into the soil. Lakes, as implied by the name, are extremely numerous in this section of the country. They are of a characteristic type, being usually deep, circular in outline and bordered by abrupt sloping banks. They are entirely distinct from the temporary, flat bottomed, shallow lakes of the Middle Florida Hammock Belt.

The lake region represents, in the writer's interpretation, an early stage in the degradation of the surface level by underground solution. The many basins now occupied by lakes have been formed by subsidence due to solution. Following the formation of the basins the surrounding uplands are gradually lowered, the tendency being to fill up the basins and to reduce the land surface once more to a common, although lower level. An examination of the accompanying map, on which the lake region is separately indicated, bears out the view that this region represents the further southeastward migration of the limestone country of the peninsula.

It is not necessary to assume that the hard rock phosphate belt has passed through a stage of development identical with that of either the lake region or the Middle Florida Hammock Belt. Differences in the thickness and character of the formations, or of the drainage, or other conditions may have modified the results in this region. Certain it is, however, that the limestone region of Central Florida is encroaching on the non-limestone areas to the east. Whether or not what is now the hard rock phosphate belt passed through the typical lake region topography, it is at least a reasonable inference that lakes more or less extensive existed in the earlier stages of the development of this area.

ECONOMIC RELATION.

The economic bearing of the observation that the hard rock phosphate is confined to a particular physiographic type is important. Although within the area careful and expensive prospecting is necessary to locate the individual deposits, yet to prospect for hard rock phosphate outside of the particular physiographic type of country with which the hard rock phosphates are associated is recognized as useless. No hard rock phosphate is to be expected, for instance, in the lake region nor elsewhere in the non-limestone areas of Florida, nor in the Middle Florida Hammock Belt, except possibly in such local areas as have by more rapid erosion passed into the stage in which hard rock phosphate accumulates.

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ELEVATIONS IN FLORIDA.

E. H. SELLARDS.

No detailed topographic map of Florida having been made, the elevations given in the following list are necessarily taken from various sources, some of which are based on precise levels, while others represent approximate levels. The principal sources from which the data has been obtained include levels made by the United States Geological Survey, the United States Coast and Geodetic Survey, the United States Army Engineers, the Engineers of the Florida State Drainage Commission, and surveys made in connection with the location of the various railroads in the State.

The elevations from the railroad surveys are either taken direct from the profiles, or are listed as given in the Dictionary of Altitudes, Bulletin 274, United States Geological Survey. The precise levels which have been made by the United States Geological Survey and the United States Coast and Geodetic Survey in Florida are obtained from Bulletin 516 of the United States Geological Survey. The levels made by the United States Army Engineers in Florida are obtained from Preliminary Survey for a Ship Canal from the St. Marys River to the Gulf of Mexico, made in 1879; Survey of the St. Johns River to Charlotte Harbor, by way of Lake Tohopekaliga, for purpose of steamboat communication, Appendix J, Annual Report of Chief of Engineers, 1882; Survey of the Kissimmee River, Florida, and connecting lakes and canals flowing into Lake Okeechobee. thence down the Caloosahatchee River to the Gulf of Mexico, 1899; and Survey of the St. Johns River, above Lake Monroe, 1903. The levels by the State Drainage Commission are from a map of the Everglades drainage district issued in 1913.

In each instance the authority for the elevation is given following the name of the locality. For this purpose abbrevations are used as follows: U. S. G. S. (United States Geological Survey); U. S. C. & G. S. (United States Coast and Geodetic Survey); U. S. Army Engrs. (United States Army Engineers);

Fla. State Engrs. (Engineers of the Florida State Drainage Commission); A. N. R. R. (Apalachicola Northern Railroad); A. C. L. R. R. (Atlantic Coast Line Railroad); C. H. & N. Ry. (Charlotte Harbor and Northern Railway); F. E. C. Ry. (Florida East Coast Railway); G. F. & A. Ry. (Georgia, Florida and Alabama Railway); G. S. & F. Ry. (Georgia Southern and Florida Railway); L. & N. R. R. (Louisville and Nashville Railroad; S. A. L. Ry. (Seaboard Air Line Railway); F. Ry. (Florida Railway); Fellsmere R. R. (Fellsmere Railroad). The elevation given for the towns, unless otherwise stated, is that of the depot of the railroad cited as authority.

TOPOGRAPHIC MAP.

In addition to the list of elevations, there is included in this report a topographic map of the State. The topography on this map is taken from a map previously issued by the Survey in cooperation with the United States Geological Survey and included in the Second Annual Report of the State Survey, 1909. The original map, which showed both geology and topography, was made by Geo. C. Matson, F. G. Clapp, and Samuel Sanford, under the direction of T. Wayland Vaughan, and formed a part of a report on the geology of Florida prepared by the United States Geological Survey, in co-operation with the Florida State Geological Survey. The base map, however, has been redrawn and revised by the addition of new railroads and new counties. The scale has been reduced one-half linear and much of the detail of the base map omitted. To this base there has been added the outline of the hard rock and land pebble phosphate formations, and the areas of artesian flow in the State.

EXPLANATION OF THE TOPOGRAPHIC MAP.

The topography is shown by means of contours. These are lines so placed as to pass through points all of which have the same altitude. On this map the contour lines are printed in brown and are placed at 50 foot intervals of elevation. Each contour represents a definite level above sea and is so marked. The coast line itself may be regarded as the zero contour. In passing from the coast to the interior of the State there is crossed successively the 50, 100, 150, 200 and 250 foot contours, and finally in such limited localities as reach that elevation, the 300 foot contour. As a rule the rise in elevation in Florida is so gradual that the 50 foot contour lies some miles from the coast. On the other hand, where the rise in elevation is rapid, as near Pensacola, in West Forida, the 50 foot contour approaches and may almost touch the coast line.

THE TOPOGRAPHY OF FLORIDA.

Referring to the topography of the State as a whole, it will be noted that a belt of country lying below the 50 foot contour line borders the Atlantic and the Gulf coasts. This belt varies in width and bends inland following the river valleys. In Southern Florida this belt of country lying below the 50 foot contour widens out to include Brevard, St. Lucie, Palm Beach, Dade, Monroe and Lee Counties, and the southern part of DeSoto and Manatee Counties. In peninsular Florida elevations of from 150 to 250 feet are found in Suwannee, Columbia, Baker, Bradford, Clay, Alachua, Marion, Citrus, Hernando, Lake, Polk and De-Soto Counties. In West Florida the elevation rises rather rapidly from the coast to from 200 to 250 feet above sea. The contours, therefore, fall close together, indicating a rolling or hilly country. At Mount Pleasant and at Hardaway, in Gadsden County, the elevation exceeds 300 feet, this being the highest recorded elevation in the State.

The fact that much of the data available in regard to elevations is approximate should be borne in mind in using the topographic map. Moreover, on a general map, such as this, it is often impossible to show minor elevations and depressions. It is to be hoped that subsequently a detailed topographic survey may be made of the State, and topographic maps issued based on precise levels. These detailed maps should be made on a scale of one inch to the mile, with contours placed at ten foot intervals of elevation. This general map, with contours at 50 foot intervals of elevation will, however, serve many useful purposes until more detailed maps are made.

LIST OF ELEVATIONS IN FLORIDA.

LOCALITY.	AUTHORITY.	Elevation Above Sea (feet).
Abbott	S. A. L. Ry.	110
Agnew	U. S. G. S.	70
Alachua, S. A. L. depot	U. S. G. S.	60
Albion, S. A. L. depot	U. S. G. S.	81
Albion, square cut on foundation of chimney of frame building, north of station	U. S. C. & G. S.	89
Alligator Lake, Osceola County	U. S. Army Engrs., 1882	71
Altamonte Springs	A. C. L. R. R.	101
Ankona	F. E. C. Ry.	33
Anthony	S. A. L. Ry.	77
Apalachicola	A. N. R. R.	5
Apopka	S. A. L. Ry.	150
Arcadia	A. C. L. R. R.	56
Archer, S. A. L. depot	U. S. G. S.	80
Archer, copper bolt in chimney of C. W. Banknight's house	U. S. C. & G. S.	85
Argyle	L. & N. R. R.	254
Armour	A. C. L. R. R.	70
Arran	G. F. & A. Ry.	122
Arredondo, S, A, L. depot	U. S. G. S.	89
Arredondo, square cut in stone post in D. G. Harvard's orchard	U. S. C. & G. S.	89
Ashmore	G. F. & A. Ry.	124
Astor	A. C. L. R. R.	15
Atlantic	S. A. L. Ry.	125
Atlantic Beach	F. E. C. Ry.	14
Auburndale	A. C. L. R. R.	167
Aucilla	S. A. L. Ry.	86
Aurantia	F. E. C. Ry.	28
Avoca	G. S. & F Ry.	120
Bakers Mill	A. C. L. R. R.	137
Baldwin	A. C. L. R. R.	83
Baldwin	S. A. L. Ry.	86
Barberville	A. C. L. R. R.	44
Barnett	A. C. L. R. R.	135
Bartow	A. C. L. R. R.	115
Baxter	G. S. & F. Ry.	118
Baywood	G. S. & F. Ry.	148
Bellair	A. C. L. R. R.	49
Belleview	S. A. L. Ry.	87

LOCALITY.	AUTHORITY.	Elevation Above Sea (feet).
Beverly	A. N. R. R.	10
Black Creek	A. C. L. R. R.	18
Black Point	F. E. C. Ry.	11
Black Sink Prairie	U. S. G. S.	60
Blanton	A. C. L. R. R.	105
Bluff Springs	L. & N. R. R.	90
Boardman, A. C. L. depot	U. S. G. S.	73
Bocaraton	F. E. C. Ry.	15
Boden's	U. S. Army Engrs., 1903	14
Bohemia	L. & N. R. R.	16
Bonifay	L. & N. R. R.	120
Bostwick, 150 feet west of depot	U. S. G. S.	34
Boulogne	A. C. L. R. R.	70
Bowes	L. & N. R. R.	128
Bowling Green	A. C. L. R. R.	116
Brandon	S. A. L. Ry.	74
Branford	A. C. L. R. R.	43
Braswell	S. A. L. Ry.	192
Bronson, S. A. L. depot	U. S. G. S.	68
Bronson, copper bolt in chimney of Mrs. L. E. Taylor's house	U. S. C. & G. S.	72
Brooklyn	G. S. & F. Ry.	157
Brooksville	A. C. L. R. R.	126
Buena Vista, stone post near F. E. C. Ry. station	U. S. C. & G. S.	15
Buffalo Bluff, railroad crossing	U. S. G. S.	16
Burnett's Lake	S. A. L. Ry.	69
Bushnell	S. A. L. Ry.	75
Cadillac	A. C. L. R. R.	89
Caledonia	L. &. N. R. R.	192
Callahan	A. C. L. R. R.	20
Calvenia	A. C. L. R. R.	45
Cambon	A. C. L. R. R.	63
Campbell	A. C. L. R. R.	75
Campton	L. & N. R. R.	172
Candler	A. C. L. R. R.	108
Cantonment	L. & N. R. R.	180
Caryville	L. & N. R. R.	72
Carraway	G. S. & F. Ry.	110
Causey	A. N. R. R.	113

LOCALITY.	AUTHORITY.	Elevation Above Sea (feet).
Cedar Keys, bench mark at southeast corner of new concrete store, built in 1877 by Thomas Barnes	U. S. C. & G. S.	12
Center Hill	A. C. L. R. R.	91
Center Park	F. E. C. Ry.	40
Chaffin	L. & N. R. R.	102
Chaires	S. A. L. Ry.	60
Champaign	S. A. L. Ry.	124
Chatmar	A. C. L. R. R.	49
Chubb	A. C. L. R. R.	165
Chipco	A. C. L. R. R.	104
Chipley	L. & N. R. R.	113
Citra	A. C. L. R. R.	61
Citronelle, A. C. L. depot	U. S. G. S.	26
City Point	F. E. C. Ry.	38
Clarcona	A. C. L. R. R.	93
Clayno, northwest corner of house, 100 southwest of railroad crossing	U. S. G. S.	153
Clearwater	A. C. L. R. R.	29
Clermont	A. C. L. R. R.	105
Cleveland	A. C. L. R. R.	3
Cocoa	F. E. C. Ry.	25
Cocoanut Grove	F. E. C. Ry.	12
Cook's Ferry	U. S. Army Engrs., 1903	14
Colegrove	A. C. L. Ry.	125
Coline	A. N. R. R.	26
Collins	A. N. R. R.	158
Conant	A. C. L. R. R.	93
Cone	A. C. L. R. R.	125
Coquina	F. E. C. Ry.	17
Cottondale	L. & N. R. R.	142
Cowan	L. & N. R. R.	173
Cow Creek, Volusia County	F. E. C. Ry.	21
Cow Creek, Levy County	A. C. L. R. R.	30
Crawford	G. S. & F. Ry.	85
Crestview	L. & N. R. R.	175
Criglar	A. N. R. R.	54
Crooked Lake, Polk County	U. S. Army Engrs., 1882	132
Croom	A. C. L. R. R.	58
Cross Bayou	A. C. L. R. R.	10

LOCALITY.	AUTHORITY.	Elevation Above Sea (feet).
Crown Point	A. C. L. R. R.	109
Crystal River, A. C. L. depot	U. S. G. S.	4
Cummer	A. C. L. R. R.	136
Cypress	L. & N. R. R.	146
Cyril, 150 feet north of station at railroad crossing	U. S. G. S.	158
Dade City	A. C. L. R. R.	89
Dade City	S. A. L. Ry.	106
Dania	F. E. C. Ry.	11
Deerhunt	A. N. R. R.	82
Deerland	L. & N. R. R.	239
DeFuniak Springs	L. & N. R. R.	256
DeLand Junction	A. C. L. R. R.	27
Delray	F. E. C. Ry.	16
Dinsmore	A. C. L. R. R.	26
Drake	S. A. L. Ry.	139
Drifton	S. A. L. Ry.	133
Duke	A. C. L. R. R.	154
Dunedin	A. C. L. R. R.	13
Dunnellon, A. C. L. depot	U. S. G. S.	49
Dutton	A. C. L. R. R.	71
Dyal	A. C. L. R. R.	46
Eagle Island	U. S. Army Engrs., 1903	63
Early Bird	S. A. L. Ry.	85
East Aurantia	F. E. C. Ry.	6
East Palatka, square cut on marble post in J. E. Gould's grounds	U. S. C. & G. S.	17
Eau Gallie	F. E. C. Ry.	18
Eddy	G. S. & F. Ry.	128
Eddy, Gadsden County	A. N. R. R.	200
Eden	F. E. C. Ry.	26
Ehren	A. C. L. R. R.	90
Ellaville	S. A. L. Ry.	64
Ellaville	U. S. Army Engrs., 1879	69
Ellerslie	A. C. L. R. R.	118
Ellzey, S. A. L. depot	U. S. G. S.	26
Ellzey, square cut on stone post in yard of house occupied by J. A. Williams	U. S. C. & G. S.	25
Enterprise	F. E. C. Ry.	26

LOCALITY.	AUTHORITY.	Elevation Above Sea (feet).
Enterprise	U. S. Army Engrs., 1903	17
Enterprise Junction	A. C. L. R. R.	26
Escambia	L. & N. R. R.	14
Eustis	A. C. L. R. R.	61
Everglades, near border of Lake Okeechobee	Fla. State Engrs.	21
Evinston, A. C. L. depot	U. S. G. S.	67
Fairbanks, 450 feet north of station	U. S. G. S.	163
Fair Grounds	L. & N. R. R.	129
Falco	L. & N. R. R.	235
Falmouth	S. A. L. Ry.	90
Fellsmere	Fellsmere R. R.	27
Fellowship	U. S. G. S.	180
Fernandina	S. A. L. Ry.	10
Flatford	A. C. L. R. R.	78
Florahome, 0.2 mile east of, at railroad crossing	U. S. G. S.	113
Floral City	A. C. L. R. R.	57
Forest City	A. C. L. R. R.	92
Fort Drum Ridge	U. S. Army Engrs., 1903	67
Fort Gadsden	A. N. R. R.	20
Fort Lauderdale	F. E. C. Ry.	7
Fort Mason	A. C. L. R. R.	66
Fort Meade	A. C. L. R. R.	130
Fort Ogden	A. C. L. R. R.	37
Fort Pierce	F. E. C. Ry.	16
Fort Vinton Island	U. S. Army Engrs.	26
Fort White	A. C. L. R. R.	63
Francis	A. C. L. R. R.	73
Francis, square cut on stone post in yard of R. D. Howell's house	U. S. C. & G. S.	69
Franklin	A. N. R. R.	8
Fruitland Park	A. C. L. R. R.	113
Fulford	F. E. C. Ry.	13
Gabriella	S. A. L. Ry.	80
Gainesville	S. A. L. Ry.	147
Gainesville	A. C. L. R. R.	185
Gainesville, crossing, S. A. L.	A. C. L. R. R.	144
Gainesville, square cut on marble post in court-house grounds	U. S. C. & G. S.	177
Gainesville, square cut on step at west entrance to court house	U. S. C. & G. S.	179

LOCALITY.	AUTHORITY.	Elevation Above Sea (feet).
Gainesville, B. M., on door sill, leading to second story of Barnett block	U. S. C. & G. S.	177
Genoa	G. S. & F. Ry.	146
Getzens	S. A. L. Ry.	125
Gifford	F. E. C. Ry.	17
Glencoe	F. E. C. Ry.	23
Glen Ethel	A. C. L. R. R.	71
Glen St. Mary	S. A. L. Ry.	134
Gonzales	L. & N. R. R.	170
Good Range	L. & N. R. R.	164
Gordon	L. & N. R. R.	227
Graham, southeast corner of station	U. S. G. S.	143
Granada	A. C. L. R. R.	51
Grand Crossing	A. C. L. R. R.	27
Grandin, 200 feet north of railroad station, at northeast corner of store	U. S. G. S.	101
Green Cove Springs	A. C. L. R. R.	28
Greensboro	A. N. R. R.	280
Greens Crossing	L. & N. R. R.	223
Greenville	S. A. L. Ry.	106
Gretna	S. A. L. Ry.	294
Grove Park	A. C. L. R. R.	100
Grove Park, square cut in stone post in lot of M. S. Spray, opposite station	U. S. C. & G. S.	101
Guilford	G. S. & F. Ry.	146
Gulf Hammock	A. C. L. R. R.	33
Gulf Junction	A. C. L. R. R.	67
Hagen	G. S. & F. Ry.	158
Hague	A. C. L. R. R.	174
Haines City	A. C. L. R. R.	157
Hainesworth	A. C. L. R. R.	173
Hainesworth	S. A. L. Ry.	142
Half Moon	A. C. L. R. R.	54
Hallandale	F. E. C. Ry.	10
Hammock Ridge, S. A. L. depot	U. S. G. S.	78
Hampton, 150 feet east of, northeast corner of station	U. S. G. S.	148
Hardaway	A. N. R. R.	303
Haskell	A. C. L. R. R.	116
Hastings, marble post in T. H. Hasting's grounds, near veranda	U. S. G. S.	8

LOCALITY.	AUTHORITY.	Elevation Above Sea (feet).
Hawthorne, copper bolt in chimney of W. T. Broswell's house, east of railroad station	U. S. C. & G. S.	145
Hayes	A. C. L. R. R.	73
Heidtville	U. S. G. S.	61
Hernando	A. C. L. R. R.	50
Highland	S. A. L. Ry.	210
High Springs	A. C. L. R. R.	75
Hilliard	A. C. L. R. R.	66
Hilliardville	G. F. & A. Ry.	142
Hillsboro	A. C. L. R. R.	35
Hillsboro River, crossing S. A. L. Ry	S. A. L. Ry.	45
Hodges	S. A. L. Ry.	71
Hollister, square cut on stone post in yard of T. W. Ralp's house	U. S. C. & G. S.	80
Holt	L. & N. R. R.	212
Homeland	A. C. L. R. R.	139
Homestead	F. E. C. Ry.	9
Homosassa, A. C. L. depot	U. S. G. S.	5
Hosford (old depot)	A. N. R. R.	78
Houston	S. A. L. Ry.	173
Hoyt	G. S. & F. Ry.	12
Huntington	A. C. L. R. R.	56
Interlachen, B. M., on stone post in triangular inclosure near station	U. S. C. & G. S.	105
Inverness	A. C. L. R. R.	38
Island Grove	S. A. L. Ry.	69
Isabel Lake	U. S. Army Engrs., 1882	71
Island Lake	A. C. L. R. R.	54
Istachatta	A. C. L. R. R.	52
Jacksonville	A. C. L. R. R.	8
Jasper	A. C. L. R. R.	152
Jennings	G S. & F. Ry.	150
Jensen	F. E. C. Ry.	19
Johnson	A. C. L. R. R.	100
Johnson Pond	U. S. G. S.	60
Juliette, A. C. L. depot	U. S. G. S.	56
Juniper	A. N. R. R.	254
Kanapaha, S. A. L. depot	U. S. G. S.	87
Kathleen	A. C. L. R. R.	133
Kendrick, A. C. L. depot	U. S. G. S.	82
Kent	G. S. & F. Ry.	70

LOCALITY.	AUTHORITY.	Elevation Above Sea (feet).
Keuka	A. C. L. R. R.	101
Keystone Park	A. C. L. R. R.	32
Killarney	A. C. L. R. R.	119
Kingsford	A. C. L. R. R.	105
Kingsgrove	G. S. & F. Ry.	19
Kingsley Lake, north end of, intersection of Lawtey-Green Cove Springs and Starke-Green Cove Springs roads	U. S. G. S.	211
Kingsley Lake, 2.6 miles northwest of tram and road crossing	U. S. G. S.	238
Kissimmee	A. C. L. R. R.	63
Kissimmee River at Bassenger landing	U. S. Army Engrs., 1902	35
Kissimmee River at Ft. Kissimmee landing	U. S. Army Engrs., 1902	51
Knights	S. A. L. Ry.	117
Komoka	A. C. L. R. R.	86
Lacoochee	A. C. L. R. R.	72
LaCrosse	S. A. L. Ry.	124
Lady Lake	A. C. L. R. R.	77
Lagrange	U. S. Army Engrs., 1903	26
Lake Buffum, Polk County	U. S. Army Engrs., 1882	138
Lake Butler	G. S. & F. Ry.	138
Lake Charm	S. A. L. Ry.	60
Lake City	A. C. L. R. R.	201
Lake City	G. S. & F. Ry.	192
Lake City	S. A. L. Ry.	200
Lake City	U. S. Army Engrs., 1879	203
Lake City Junction	A. C. L. R. R.	51
Lake Clement	U. S. Army Engrs., 1903	9
Lake Geneva, 200 feet south of railroad station, northeast corner of Baldwin & Kennedy's store	U. S. G. S.	130
Lake Harney, Orange County	U. S. Army Engrs., 1903	5
Lake Helen	F. E. C. Ry.	70
Lake Helen Blazes	U. S. Army Engrs., 1903	16

LOCALITY.	AUTHORITY.	Elevation Above Sea (feet).
Lake Istokpoga	U. S. Army Engrs., 1902	49
Lake Jessup, Orange County	U. S. Army Engrs., 1903	4
Lake Kissimmee	U. S. Army Engrs., 1882	59
Lakeland	A. C. L. R. R.	206
Lake Lenore	U. S. Army Engrs., 1882	92
Lake Livingston, Polk County	U. S. Army Engrs., 1882	91
Lake Lochloosa, water level of	S. A. L. Ry.	55
Lake Mary	A. C. L. R. R.	66
Lake Monroe, Volusia County	U. S. Army Engrs., 1903	4
Lake Okeechobee	U. S. Army Engrs., 1902	20
Lake Poinsett, Brevard County	U. S. Army Engrs., 1903	15
Lakeville	A. C. L. R. R.	84
Lake Tohopekaliga, Osceola County	U. S. Army Engrs., 1882	64
Lake Washington, water surface, Brevard County	U. S. Army Engrs., 1903	16
Lake Winder, Brevard Countyy	U. S. Army Engrs., 1882	19
Lake Winder, Brevard Countyy	U. S. Army Engrs., 1903	15
Lane Park	A. C. L. R. R.	61
Lantana	F. E. C. Ry.	7
Largo	A. C. L. R. R.	50
Larkin	F. E. C. Ry.	12
Laurel Hill	L. & N. R. R.	235
LaVilla Junction	A. C. L. R. R.	19
Lawtey	S. A. L. Ry.	140
Ledwith Lake	U. S. G. S.	66
Lees	S. A. L. Ry.	96
Leesburg	A. C. L. R. R.	85
Leesburg, crossing S. A. L. Ry	A. C. L. R. R.	76
Leesburg	S. A. L. Ry.	72
Leitner, A. C. L. depot	U. S. G. S.	73

LOCALITY.	AUTHORITY.	Elevation Above Sea (feet).
Lemon Bluff	U. S. Army Engrs., 1903	15
Lemon City	F. E. C. Ry.	18
Lenard	A. C. L. R. R.	115
Leroy, A. C. L. depot	U. S. G. S.	85
Leroy Lake	U. S. G. S.	63
Lexington	A. C. L. Ry.	69
Liberty	A. N. R. R.	94
Linden	A. C. L. R. R.	90
Little Lake Tohopekaliga	U. S. Army Engs., 1882	71
Little Wekiva River, Levy County	A. C. L. R. R.	28
Live Oak, union station	A. C. L. R. R.	108
Live Oak, crossing S. A. L.	A. C. L. R. R.	107
Live Oak	L. O. P. & G. Ry.	110
Live Oak	U. S. Army Engrs., 1879	110
Lloyd	S. A. L. Ry.	85
Lochapopka Lake	U. S. Army Engrs., 1882	117
Lochloosa, S. A. L. depot	U. S. G. S.	60
Lochloosa, 200 feet southeast of station, between main public road south and railroad	U. S. G. S.	65
Long Bluff	U. S. Army Engrs., 1903	19
Longwood	A. C. L. R. R.	80
Lowell, A. C. L. depot	U. S. G. S.	95
Louisa, iron post 50 feet southwest of station	U. S. G. S.	151
Lyrata	F. E. C. Ry.	6
McAlpin	A. C. L. R. R.	103
Macclenny	S. A. L. Ry.	134
McDavid	L. & N. R. R.	74
McIntosh, A. C. L. depot	U. S. G. S.	73
McMeekin, at railroad crossing	U. S. G. S.	107
McMeekin, stone post in inclosure west of station	U. S. G. S.	120
McPherson	A. C. L. R. R.	184
Madison	S. A. L. Ry.	133
Maitland	A. C. L. R. R.	91
Malabar	F. E. C. Ry.	28
Manning's Mill	L. & N. R. R.	207
Mannville	A. C. L. R. R.	89
Marianna	L. & N. R. R.	89

LOCALITY.	AUTHORITY.	Elevation Above Sea (feet).
Marietta	S. A. L. Ry	63
Marion	A. C. L. R. R	159
Marshall's	U. S. Army Engrs., 1903	15
Martel, A. C. L. depot	U. S. G. S	79
Martin, A. C. L. depot	U. S. G. S	81
Mascotte	A. C. L. R. R	115
Mattox	S. A. L. Ry	87
Maxville	S. A. L. Ry	93
Mayo	F. Ry	69
Mayport	F. E. C. Ry	10
Maytown	F. E. C. Ry	22
Media	F. Ry.	68
Melbourne	F. E. C. Ry	21
Melrose, 0.3 mile east of postoffice, southwest corner of cross roads	U. S. G. S	154
Melrose, southwest corner of town hall, 200 feet north of postoffice	U. S. G. S	162
Mexico	A. C. L. R. R	50
Miami	F. E. C. Ry	15
Micanopy	A. C. L. R. R	100
Micanopy Junction, in front of station	U. S. G. S	72
Micco	F. E. C. Ry	23
Middleton, stone post in P. Weedman's grounds	U. S. C. & G. S	34
Midway	S. A. L. Ry	201
Millard, S. A. L. depot	U. S. G. S	94
Millerton	S. A. L. Ry	89
Millman	A. N. R. R	186
Millwood, A. C. L. depot	U. S. G. S	86
Milton	L. & N. R. R	15
Minneola	A. C. L. R. R	109
Mohawk	A. C. L. R. R	130
Molino	L. & N. R. R	58
Moncrief Spring	A. C. L. R. R	14
Monroe	A. C. L. R. R	20
Montbrook	S. A. L. Ry	82
Monticello	A. C. L. R. R	202
Morriston	A. C. L. R. R	68
Mossy Head	L. & N. R. R	274
Mount Carrie	S. A. L. Ry	197
Mount Pleasant	S. A. L. Ry	301

LOCALITY.	AUTHORITY.	Elevation Above Sea (feet).
Mouth of Bow Legs Creek	U. S. Army Engrs., 1882	73
Mouth of Cow Creek	U. S. Army Engrs., 1882	20
Mule Creek, Levy County	A. C. L. R. R.	29
Mullet Lake	U. S. Army Engrs., 1903	5
Mulberry Mound	U. S. Army Engrs., 1903	26
Narcoossee	A. C. L. R. R.	72
Newberry	A. C. L. R. R.	72
Newburg	G. S. & F. Ry.	155
New River, 200 feet south, southeast corner of railroad station	U. S. G. S.	145
New Smyrna	F. E. C. Ry.	10
Nocatee	A. C. L. R. R.	38
Oakland	A. C. L. R. R.	119
Oak Lawn, A. C. L. depot	U. S. G. S.	79
O'Brien	A. C. L. R. R.	58
Ocala, A. C. L. depot	U. S. G. S.	99
Ocala, S. A. L. depot	U. S. G. S.	68
Ocklawaha	A. C. L. R. R.	66
Ocklocknee	S. A. L. Ry.	133
Odessa	A. C. L. R. R.	57
Ogden	S. A. L. Ry.	114
Okahumpka	A. C. L. R. R.	95
Okeechobee Lake	U. S. Army Engrs., 1882	20
Olustee	S. A. L. Ry.	165
Olustee	U. S. Army Engrs., 1879	169
Orange City	F. E. C. Ry.	43
Orange City, crossing A. C. L	F. E. C. Ry.	38
Orange Heights	S. A. L. Ry.	130
Orange City Junction	A. C. L. R. R.	39
Orange Lake, A. C. L. depot	U. S. G. S.	88
Orange Lake, water level of	S. A. L. Ry.	54
Orange Park	A. C. L. R. R.	23
Orange Springs, 200 feet east of postoffice in inclosure, northwest corner of road crossing, iron post	U. S. G. S.	63

LOCALITY.	AUTHORITY.	Elevation Above Sea (feet).
Orange Springs Ferry, water surface of Oklawaha River, March 13, 1911	U. S. G. S.	13
Orlando	A. C. L. R. R.	111
Osceola	S. A. L. Ry.	50
Osteen	F. E. C. Ry.	48
Otter Creek, S. A. L. depot	U. S. G. S.	29
Otter Creek, copper bolt in chimney of two-story frame house	U. S. C. & G. S.	32
Owensboro	A. C. L. R. R.	76
Ozona	A. C. L. R. R.	5
Pablo Beach	F. E. C. Ry.	13
Padlock	A. C. L. R. R.	124
Palatka, union station, southeast corner of train shed	U. S. G. S.	24
Palatka, square cut on granite door sill on west side of A. C. L. offices	U. S. C. & G. S.	13
Palmer, S. A. L. depot	U. S. G. S.	72
Palmer, square cut on chimney foundation of small house north of track and little west of railroad station, 2 feet above ground	U. S. C. & G. S.	76
Palm Springs	A. C. L. R. R.	61
Panasoffkee	S. A. L. Ry.	58
Panasoffkee Lake	U. S. G. S.	40
Paola	A. C. L. R. R.	79
Paradise	A. C. L. R. R.	192
Park Place, A. C. L. depot	U. S. G. S.	6
Pasco	A. C. L. R. R.	110
Paynes Prairie, water level in sink at low stage	U. S. G. S.	58
Peace Creek, at mouth of Big Charley Apopka	U. S. Army Engrs., 1882	17
Pebble	A. C. L. R. R.	136
Penial, railroad crossing at station	U. S. G. S.	25
Pensacola	L. & N. R. R.	39
Perkins Crossing	L. & N. R. R.	242
Perrine	F. E. C. Ry.	12
Perry	F. Ry.	30
Persimmon Bluff	U. S. Army Engrs., 1903	17
Phosphoria Junction	A. C. L. R. R.	123
Pierson	A. C. L. R. R.	78
Pine Barren	L. & N. R. R.	57
Pine Crest	A. C. L. R. R.	82

LOCALITY.	AUTHORITY.	Elevation Above Sea (feet).
Pine Island	S. A. L. Ry	119
Pine Orchard	L. & N. R. R	165
Pineway	L. & N. R. R	223
Plant City	A. C. L. R. R	137
Plant City	S. A. L. Ry	125
Plummer	G. S. & F. Ry	21
Pomona, 300 feet north of station, in southwest angle of railroad crossing, iron post	U. S. G. S	63
Pompano	F. E. C. Ry	18
Ponce de Leon	L. & N. R. R	73
Port Tampa	A. C. L. R. R	6
Possum Bluff	U. S. Army Engrs., 1903	21
Prospect	A. C. L. R. R	143
Punta Gorda	A. C. L. R. R	3
Putnam Hall, 50 feet north of railroad station, iron post	U. S. G. S	106
Puzzle Lake	U. S. Army Engrs., 1903	6
Quincy	S. A. L. Ry	251
Quintette	L. & N. R. R	120
Raiford	A. C. L. R. R	127
Ramage Place, A. C. L. depot	U. S. G. S	109
Raulerson's	U. S. Army Engrs., 1903	15
Reddick, A. C. L. depot	U. S. G. S	92
Rice Creek, at railroad crossing, opposite station	U. S. G. S	10
Richland	A. C. L. R. R	97
Riley	A. C. L. R. R	73
Riveria	F. E. C. Ry	16
River Junction	L. & N. R. R	84
River Junction	S. A. L. Ry	82
River Junction	A. N. R. R	76
Riverland	A. C. L. R. R	76
Rochelle, A. C. L. depot	U. S. G. S	80
Rochelle, copper bolt in chimney of frame house, owned by S. S. Phifer	U. S. C. & G. S	83
Rock Island	U. S. Army Engrs., 1903	12
Rockledge Junction	F. E. C. Ry	35
Rock Springs, A. C. L. depot	U. S. G. S	75

LOCALITY.	AUTHORITY.	Elevation Above Sea (feet).
Rodman, cross in west concrete foundation for iron gate post, southeast corner of park.....	U. S. G. S........	28
Romeo, A. C. L. depot..........................	U. S. G. S........	42
Roseland	F. E. C. Ry.......	16
Rosewood, S. A. L. depot......................	U. S. G. S........	16
Rosewood, square cut on stone post near post-office	U. S. C. & G. S....	14
Roy, iron post in southeast corner of A. E. Campbell's yard	U. S. G. S........	23
Runnymede	A. C. L. R. R.....	72
Saint Augustine, B. M. on coping of sea wall at entrance to basin, opposite plaza............	U. S. C. & G. S....	7
Saint Augustine, square cut on marble post marking southeast corner of U. S. Reservation...	U. S. C. & G. S....	8
Saint Augustine, square cut on coping near center of sea wall, south of south side of basin, opposite plaza	U. S. C. & G. S....	7
Saint Catherine	A. C. L. R. R.....	66
Saint Cloud	A. C. L. R. R.....	63
Saint Leo	A. C. L. R. R.....	140
Saint Lucie	F. E. C. Ry.......	8
Saint Marks	S. A. L. Ry.......	8
Saint Petersburg	A. C. L. R. R.....	20
Salt Lake	U. S. Army Engrs., 1903	7
Salt Lake Run	U. S. Army Engrs., 1903	7
Sampson City	G. S. & F. Ry.....	146
San Antonio	A. C. L. R. R.....	165
Sanderson	S. A. L. Ry.......	158
Sanderson	U. S. Army Engrs., 1879	162
Sanford	A. C. L. R. R.....	20
Sanford	U. S. Army Engrs., 1903	6
Santa Fe	A. C. L. R. R.....	45
Santos, S. A. L. depot........................	U. S. G. S........	69
Satsuma, iron post 150 feet west of station, in southwest corner of yard	U. S. G. S........	79
Saxton, iron post 400 feet north of railroad crossing, 30 feet west of Seaboard Air Line Railway track	U. S. G. S........	165

LOCALITY.	AUTHORITY.	Elevation Above Sea (feet).
Schells Bluff, 1 mile northwest of, in northwest angle of road forks to southwest, nail in root of pine tree	U. S. G. S.	10
Sebastian	F. E. C. Ry.	19
Sedalia	A. N. R. R.	218
Seffner	A. C. L. R. R.	74
Sellman	A. C. L. R. R.	45
Seville	A. C. L. R. R.	53
Silver Springs, S. A. L. depot	U. S. G. S.	47
Silver Springs Junction, S. A. L. depot	U. S. G. S.	65
Simpson branch	L. & N. R. R.	193
Sims Creek (Putnam County), center of bridge over	U. S. G. S.	33
Sneads	L. & N. R. R.	97
South Jacksonville	F. E. C. Ry.	9
Spencer, A. C. L. depot	U. S. G. S.	94
Spring Garden	A. C. L. R. R.	17
Spring Hill	G. F. & A. Ry.	169
Springside, 150 southwest of railroad crossing, iron post	U. S. G. S.	13
Stanton	A. C. L. R. R.	83
Starke	S. A. L. Ry.	150
Statens	A. C. L. R. R.	111
Stuart	F. E. C. Ry.	12
Sumatra	A. N. R. R.	22
Summerfield	S. A. L. Ry.	85
Sumner, S. A. L. depot	U. S. G. S.	9
Sunset Lake	U. S. Army Engrs., 1903	10
Suwannee	A. C. L. R. R.	152
Suwannee Valley	G. S. & F. Ry.	106
Svea	L. & N. R. R.	241
Tallahassee	G. F. & A. Ry.	69
Tallahassee	S. A. L. Ry.	82
Tampa	A. C. L. R. R.	15
Tarpon Springs	A. C. L. R. R.	14
Tarrytown	A. C. L. R. R.	82
Tavares	A. C. L. R. R.	66
Teasdale, at railroad crossing	U. S. G. S.	65
Telogia	A. N. R. R.	116
Telogia Creek, south crossing of A. N. R. R.	A. N. R. R.	45
Telogia Creek, north crossing of A. N. R. R.	A. N. R. R.	165

LOCALITY.	AUTHORITY.	Elevation Above Sea (feet).
Theressa, iron post at northeast corner of one-story house, 150 south of station:	U. S. G. S.	166
Thomasville	S. A. L. Ry.	84
Thonotosassa	A. C. L. R. R.	49
Tibbals	F. E. C. Ry.	31
Tiger Lake, Polk County	U. S. Army Engrs., 1882	59
Tildenville	A. C. L. R. R.	99
Tillman	F. E. C. Ry.	18
Titusville	F. E. C. Ry.	10
Tocoi Junction, stone post in H. Wood's grounds, near house	U. S. C. & G. S.	35
Toronto	A. C. L. R. R.	117
Trilby	A. C. L. R. R.	69
Tsala Apopka Lake	U. S. G. S.	50
Turkey Creek	S. A. L. Ry.	87
Tuscawilla Lake	U. S. G. S.	80
Varnes	A. C. L. R. R.	143
Valkaria	F. E. C. Ry.	9
Verdie	S. A. L. Ry.	45
Vero	F. E. C. Ry.	17
Waccassassa River	A. C. L. R. R.	27
Wade	A. C. L. R. R.	69
Wainwright	S. A. L. Ry.	129
Waldo	S. A. L. Ry.	150
Waldo, iron post at southeast corner of school building	U. S. G. S.	157
Walk in the Water Lake, Polk County	U. S. Army Engrs., 1882	68
Ward City	S. A. L. Ry.	118
Watertown	S. A. L. Ry.	195
Wauchula	A. C. L. R. R.	107
Webster	A. C. L. R. R.	89
Wekiva River	A. C. L. R. R.	29
Wekiva River, north fork	A. C. L. R. R.	29
Welaka, iron post in southwest angle of two cross streets, corner of Winston Steven's yard	U. S. G. S.	27
Welborn	S. A. L. Ry.	196
Welshton, A. C. L. depot	U. S. G. S.	82
West Farm	S. A. L. Ry.	107
West Jupiter	F. E. C. Ry.	9
West Palm Beach	F. E. C. Ry.	16

LOCALITY.	AUTHORITY.	Elevation Above Sea (feet).
West Tocoi	A. C. L. R. R.	12
Westville	L. & N. R. R.	70
White House	S. A. L. Ry.	84
White Springs	G. S. & F. Ry.	125
Whitesville, A. C. L. depot	U. S. G. S.	122
Wildwood	S. A. L. Ry.	58
Williamson	L. & N. R. R.	226
Wilma	A. N. R. R.	62
Windsor, iron post in northeast corner of cross roads	U. S. G. S.	114
Winfield	G. S. & F. Ry.	65
Winn	G. S. & F. Ry.	130
Winston	A. C. L. R. R.	139
Winter Garden	A. C. L. R. R.	123
Winter Park	A. C. L. R. R.	96
Woodburn, iron post 30 feet south of railroad crossing, at inside corner of wire fence, west side of road	U. S. G. S.	15
Woodstock	S. A. L. Ry.	165
Worthington Springs	A. C. L. R. R.	66
Ybor City	A. C. L. R. R.	20
Yulee	S. A. L. Ry.	25
York, A. C. L. depot	U. S. G. S.	84
Zellwood	S. A. L. Ry.	95
Zolfo Springs	A. C. L. R. R.	61
Zion	A. N. R. R.	75

THE ARTESIAN WATER SUPPLY OF EASTERN AND SOUTHERN FLORIDA.

BY E. H. SELLARDS AND HERMAN GUNTER.

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THE ARTESIAN WATER SUPPLY OF EASTERN AND SOUTHERN FLORIDA

E. H. SELLARDS AND HERMAN GUNTER.

INTRODUCTION.

A study of the water supply of Florida was begun in 1907 as co-operative work between the Florida State Geological Survey and the National Geological Survey. The first paper was issued in 1908 as Bulletin No. 1 of the Florida State Geological Survey, and relates to the underground water of Central Florida. The second paper of the series was published by the State Survey in 1910 and related to the water supply of the counties of Eastern Florida. A third paper included in the Fourth Annual Report, 1912, extended the study of the water supply to the counties of West Central and West Florida. The present paper includes a reprint of the paper on the water supply of Eastern Florida, published in 1910, revised to include a report on the water supply of Southern Florida.

The writers are indebted to the many well drillers and well owners who have contributed data regarding wells. Among the many who have given assistance the following should be especially mentioned: Messrs. Bellough & Melton, J. M. Chambers, C. I. Cragin, Dr. E. S. Crill, Capt. R. N. Ellis, Hughes Specialty Well Drilling Co., W. E. Holmes, John McAllister, Dr. J. N. MacGonigle, McGuire & McDonald, W. J. Nesbitt, Hugh Partridge, H. Walker, Dr. DeWitt Webb, J. W. Wiggins, H. Van Dorn, W. D. Holcomb, G. A. Miller, and Mr. Holmes of the water supply department of the Florida East Coast Railway, J. C. Danielson, T. J. Zimmerman, F. S. Gilbert, W. F. Hamilton, Dibble and Earnest, The Artesian Well Co., D. W. Brown, F. J. White & Co., Sydner Pump and Well Co., E. J. Pettigrew, J. O. Edson, F. B. Bradley, and C. E. Reid.

Extensive well records made in 1907-1908 in cooperation with the U. S. Geological Survey by Messrs. Geo. C. Matson and F. G. Clapp have been utilized in the preparation of this report. Data regarding climate and rainfall have been supplied by Hon. A. J. Mitchell, Director of the Florida section of the U. S. Weather Bureau.

Many of the analyses included have been made in the office of the State Chemist especially for this report. Others have been made at various times by other chemists. Credit is given with each analysis.

THE AREA TREATED.

The area considered in detail in this report includes the following counties: Brevard, Clay, Dade, DeSoto, Duval, Hillsboro, Lee, Manatee, Monroe, Nassau, Orange, Osceola, Palm Beach, Pinellas, Polk, Putnam, St. Johns, St. Lucie, Seminole, Broward, and Volusia. This section borders the Atlantic and Gulf coasts and comprises the principal artesian areas of Peninsular Florida.

GEOLOGY.

A knowledge of the geologic structure is essential to a clear understanding of the underground water conditions. The prevailingly level country of Florida renders geologic observations difficult. Some favorable exposures occur, however, and these together with data obtained from well samples and well records permit a reasonably full understanding of the structure of the State.

The formations found in Florida belong to the: Oligocene, Miocene, Pliocene, and Pleistocene. Of these divisions the Oligocene is the oldest; the Pleistocene the most recent.

OLIGOCENE.

VICKSBURG GROUP.

The oldest or deepest formations reached in well drilling in Peninsular Florida are the Vicksburg limestones. The Vicksburg is an extensive deposit underlying all of Florida and extending into adjacent States. In Central Peninsular Florida, from Columbia to Sumter Counties, these limestones are frequently exposed at the surface. Passing to the east and south from Central Florida they dip beneath the surface, and while nowhere exposed at the surface they are reached by all the deeper wells. It is in fact from these limestones that the principal water supply of Eastern and Southern Florida is obtained. The Vicksburg is very characteristic in appearance and structure, and when once seen is not likely to be mistaken for any other formation in this part of the State. The limestone as seen in well samples has a granular appearance and may contain many small shells. This phase of the limestone is frequently spoken of by the drillers as the "coral" formation. As a matter of fact, however, the formation contains relatively few corals. After passing one or two hundred feet into this formation a more compact limestone is encountered. This part of the formation often has a slightly pinkish cast, the rock being very hard, and the drilling difficult. While these are the general characteristics of the Vicksburg, yet its texture is not uniform. Hard layers usually alternate with soft layers, the water supply as a rule increasing as each hard layer is penetrated. Not infrequently masses of flint are found imbedded in the limestone which in some instances have given much difficulty in drilling.

While, as already stated, the Vicksburg limestones dip on passing to the east and south, yet the dip is not uniform and the depth at which it is encountered varies from place to place.

In the wells at Jacksonville the Vicksburg is reached at a depth of from 500 to 525 feet. At Callahan and at Fernandina, in Nassau County, although no samples have been obtained, the Vicksburg is believed, from well records, to be reached at about the same depth as at Jacksonville.

Along the St. Johns River the Vicksburg maintains a similar depth for some distance. At Ortega, seven miles south of Jacksonville, the limestone was reached at a depth of about 500 feet. At Magnolia Springs, and Green Cove Springs, thirty miles south of Jacksonville, and on Black Creek, while no well samples were obtained, the Vicksburg is believed from well records to occur at a depth of from 325 to 400 feet.

Passing to the south the Vicksburg lies nearer the surface. Samples of drillings from wells at St. Augustine and at Hastings in St. Johns County and at Orange Mills in Putnam County show that the Vicksburg in this section lies at a depth of 130 to 225 feet, the greater depth being at St. Augustine and the minimum depth at Orange Mills. Passing to the south the Vicksburg lies, so far as well records indicate, at a fairly uniform level for a distance of 150 miles. At Sanford, 75 miles south of Orange Mills, the Vicksburg is reached at a depth of from 113 to 125 feet. At Daytona, although samples are lacking, the depth of this formation is believed, judging from well records, not to exceed 150 feet. At Cocoa the Vicksburg is reached at a depth not exceeding 190 feet, while at Melbourne Beach, 150 miles south of St. Augustine, its depth in one well was found to be 221 feet.

Passing to the south from this point the Vicksburg dips rapidly. At Palm Beach, 100 miles farther south, this limestone was reached at a depth of approximately 1,000 feet, *a dip of about 750 feet in 100 miles or 7½ feet per mile. The Vicksburg was not reached in a well 700 feet deep drilled by the Florida East Coast Railway Company at Marathon Key, 175 miles south of Palm Beach.† At Key West, however, the formation is believed to have been reached at a depth of 700 feet.‡

It is thus seen that the Vicksburg forms a broad arch extending from central Florida to the Atlantic Ocean. St. Augustine lies near the north slope of this arch, while Melbourne, as nearly as can be determined, lies near the south slope. On either side of the arch the limestone dips at a moderate rate. On the north side of the arch the maximum depth recorded in Florida is 500 feet. Passing to the south the maximum of approximately 1,000 feet is recorded at Palm Beach.

In view of the importance of the Vicksburg as an artesian water reservoir, the depth at which it is to be expected is a matter

*Darton, N. H.; Amer. Journ. Sci. (3) XLI, pp. 105-6, 1891.

†Florida Geol. Survey. Second Annual Report, p. 206, 1909.

‡Hovey, E. O.; Mus. Comp. Zool. Bull. XXVIII, pp. 65-91, 1896.

of very great importance and it is to be hoped that well drillers will find it possible to keep accurately labeled well samples in order to determine more definitely the distribution of this formation.

APALACHICOLA GROUP.

The Apalachicola group of formations is of a much less uniform character than the Vicksburg and is also of less importance in connection with the water supply. A full description of this group of formations will be found in the Second Annual Report of this Survey, pp. 67-106.

The formations which make up the Apalachicola group include the Chattahoochee and Alum Bluff formations, well exposed along the Apalachicola River; the Hawthorne formation in Central Florida; and the Tampa formation in Southern Florida. The relative position of three of these, the Chattahoochee, the Hawthorne and the Tampa formations, has not been definitely determined, and they may be largely contemporaneous. The Alum Bluff formation lies above the Chattahoochee formation. The limestone of this group consists largely of impure clayey material which upon decay weathers to a sticky blue green clay. The Chattahoochee Limestone is difficult to recognize in well samples. Fossils in this formation are comparatively rare and such as occur are largely destroyed in drilling. In surface exposures it may be recognized by its lithologic character and by the characteristic cubical blocks into which some of the strata break upon exposure.

The Apalachicola group has not been recognized from well drillings in East Florida. Clays taken by Mr. S. L. Hughes from the new city well at Jacksonville at the depth of 320 feet have a very close resemblance to the fuller's earth clays which occur in the Apalachicola group, above the Chattahoochee Limestone. On the other hand, Matson obtained from Jacksonville a Miocene shark's tooth from a well sample supposed to come from the depth of 496 feet. In order to determine more fully the area and extent of the Apalachicola group of formations in Eastern Florida it will be necessary to obtain large and carefully collected well samples. In Southern Florida the Apalachicola group is recognized at Tampa and thence south along the Gulf coast as far as Sarasota Bay.

MIOCENE.

The Miocene deposits are well developed in Eastern Florida. At the city water works at Jacksonville this formation was encountered in excavating for the basin for the city water supply,* and was also reached in the city wells at a depth of from 35 to 36 feet. At Jacksonville this formation has a considerable, although undetermined thickness. It consists of a buff limestone grading to a lighter color, more or less phosphatic, grading below to phosphatic sands and sandy marls. The formation is in places fossiliferous, although the shells are usually preserved as casts.

In Clay County the Jacksonville formation is extensively exposed along Black Creek. The exposure of this formation appears along both the South and North Fork of Black Creek, some miles above Middleburg, and may be observed for five or six miles below Middleburg. The following section was observed at High Bluff, on the South Fork of Black Creek, about five miles above Middleburg:

Covered and sloping	5 feet
Sloping, some sticky clay exposed	5 feet
Yellow sand	8 feet
Buff colored sandy limestone, containing a small proportion of black phosphatic pebbles	12 feet
Same, with greater amount of phosphate	5 feet
Same, with some phosphate	12 feet

This is the thickest exposure of the Jacksonville formation observed at any one place along Black Creek.

The following section was observed in the pit of the Jacksonville Brick Company, two miles southwest of Jacksonville:

Incoherent sand and soil	2.4 feet
Sandy clays, the top 5 or 6 feet oxidizes yellow	16 feet
Bluish fossiliferous marl	4 feet

The marl obtained from test holes in the bottom of the pit is

*Dall, W. H., U. S. Geol. Surv. Bull. 84, 124-125, 1892.

similar in character to the Choctawhatchee marl of West Florida, and the clay used for brick making in Duval, Nassau and Putnam Counties is probably of Miocene age. Beneath this marl, as shown by numerous well drillings, the sandy limestones of the Jacksonville formation occur.

Miocene deposits in Florida were first recognized by Dr. E. A. Smith,* at Rock Springs, in the northwestern part of Orange County. The limestone exposed here is a light, sandy, fossiliferous limestone and is probably of the Jacksonville formation.

PLIOCENE.

Pliocene is known to occur in Eastern Florida, although the extent and distribution of the deposits have been but imperfectly determined. The shell deposits of this period occurring in the St. Johns valley and along the East Coast have been described by Messrs. Matson and Clapp.† Localities mentioned by them are Nashua, on the St. Johns River, in Putnam County, and at DeLand and near Daytona, in Volusia County. Other localities at which these deposits were observed to be exposed are one-half mile above the Atlantic Coast Line bridge over the St. Johns River, in Putnam County; on the east side of the St. Johns River, about five miles north of the Atlantic Coast Line bridge, in Volusia County. Pliocene beds were also recognized from a well near Kissimmee. From the exposures thus recognized it is evident that Pliocene beds underlie a considerable area of Eastern Florida. In Southern Florida the Pliocene is well developed in the valley of the Caloosahatchee River. The land pebble phosphate deposits are also believed to be Pliocene.

PLEISTOCENE.

The marine Pleistocene deposits have been recognized at several localities in Eastern and Southern Florida. Messrs. Matson

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*Smith, E. A., On the Geology of Florida. Amer. Journ. Sic. 3d Ser., Vol. XXI, pp. 302-303.

†Fla. Geol. Surv. Sec. Ann. Rpt., pp. 128-133, 1909.

and Clapp obtained collections from Eau Gallie, Titusville and Mims in Brevard County. It is probable that marine Pleistocene shell deposits are somewhat widely distributed along the coast and perhaps in the St. Johns River valley. Here, again, satisfactory determination can be made only from large and carefully kept samples obtained in well drilling. The coquina rock which occurs extensively at St. Augustine and extends along the coast to the south for 250 miles is also to be placed with the Pleistocene. Some of the older sand dunes of the coast also probably belong to the Pleistocene. In southern Florida Pleistocene limestones are extensively developed in Palm Beach, Dade and Monroe Counties, bordering and underlying the Everglades and on the keys.

The following is an analysis of a sample of the Miami Limestone from near Miami, Florida. Analysis given by John B. Reilly. Name of analyst not recorded.

Silica	6.42
Alumina and iron oxides	0.94
Carbonate of lime	91.23
Carbonate of magnesium	1.08
	99.67

EARTH MOVEMENT DURING PLEISTOCENE.

Changes in the relation of land and water have occurred recently along the East Coast, probably during Pleistocene time. The best evidence of these changes is that offered by the sand dunes and the coquina rock bordering the East Coast. The line of sand dunes along the coast is well developed and largely continuous. From Daytona south these dunes occur, not on the present beach, but back from the beach a variable distance, depending upon the configuration of the country. At Daytona the sand dune lies back from the Halifax River about two miles. From Daytona to Titusville the dunes are to be seen lying mostly to the west of the East Coast Railway at a distance of one or two miles from the coast. At Titusville the dunes lie back from the Indian River two to two and one-half miles. At Rockledge the dunes approach closer to the coast. They recede again, however, to the south and at no place directly face the ocean. The dunes are now quiescent and are covered with a thick growth of trees, indicating that they have been undisturbed for a long time. In the same way the coquina rock, found facing the ocean at Anastasia Island, in St. Johns County, falls back from the coast to the south, extending at places a few miles inland. The presence of this ledge of coquina rock bordering the coast together with the sand dunes lying back clearly indicates that the land level formerly stood lower than at present, the coquina rock and sand dunes having accumulated along what was then the beach.

Conrad as early as 1846 noted the occurrence of marine shells of post-Pliocene age along the bank of the St. Johns River at an elevation of from ten to fifteen feet above the present high tide.

Matson has described* what he believes to be a Pleistocene terrace bordering the St. Mary's River, in Nassau County. A similar abrupt rise in passing onto the upland may be observed in many places bordering the coast and the valley of the St. Johns River. It may be observed that a subsidence of 25 feet would submerge the entire St. Johns valley and would allow the sand dunes once more to face the ocean.

TOPOGRAPHY AND DRAINAGE.

The section of the State to which this report relates borders the Atlantic Ocean and the Gulf of Mexico. From sea level the rise in elevation is as a rule gradual and the country in general level or rolling. It is probable that with the exception of sand dunes all of Monroe, Lee, Dade, Palm Beach, St. Lucie and Brevard Counties as well as the eastern one-half or more of Nassau, Duval, Clay, Putnam, Volusia and Orange Counties and the entire St. Johns River Valley lie below the 50-foot contour line. Elevations exceeding 50 feet occur in the western part of Nassau, Duval, Clay, Putnam and Orange Counties and as a ridge extending from northwest to southeast through Volusia County.

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*Florida Geol. Survey, Second Annual Report, p. 39, 1909.

The maximum elevation for Eastern Florida is found in the northwestern part of Clay County, approaching "Trail Ridge." On this ridge are found, according to levels made in 1911 by the United States Geological Survey, a maximum elevation of 246 feet. In Polk County elevations approximating 250 feet are also reported. (See map.)

RIVERS.

The St. Johns River rises from the lakes of southern Brevard County, within a few miles of the Atlantic coast. From this point it flows north or slightly west of north about 200 miles, entering the Atlantic Ocean within 25 miles of the north line of the State. The elevations along this river at no point exceed 25 feet above sea, the entire valley lying within the artesian flow area of the State. The principal tributaries of the St. Johns are Black Creek and Ocklawaha River. The former heads in the uplands of Clay County, while the latter is fed from numerous lakes of Lake County and receives tributaries from Silver Springs in Marion County and from the lakes of southeastern Alachua County.

The St. Mary's River, forming a part of the northern boundary of the State, rises in or near Okefenokee Swamp, in Georgia. From its origin it flows south until on a parallel with the mouth of the St. Johns river. From this point it bends abruptly and flows north for thirty miles, then, turning again, flows a little south of east to the Atlantic Ocean. Nassau is one of the smaller rivers and with its tributary, Thomas Creek, forms part of the boundary between Nassau and Duval Counties. The Withlacoochee, Hillsboro, Peace and Caloosahatchee rivers flow into the Gulf.

Bordering the streams, both the main rivers and their tributaries, are found in many places, open, flat, imperfectly drained pine lands. These lands are classed in the section treating of soils as open flatwoods. A somewhat different and more extensive type of country is that designated as palmetto flatwoods. An essential difference in these two types of country is the presence or absence of the saw palmetto, the pine forest being common to both. In Nassau and Duval Counties and along the tributaries of the St. Johns River extensive areas of open flatwoods occur.

Along the border of the uplands, back from the river and from the coast, a different type of topography has developed, consisting largely of the sandy or rolling pine type of soil although scrub hammock lands occur. These several types of country are due to a considerable extent to the drainage conditions. On the summit of the plateau, in the interior of Florida, palmetto flatwoods and to some extent open flatwoods are again encountered.

CLIMATE.

The counties of Florida, covered by this report, lie bordering or near the Atlantic Ocean and the Gulf, and are favorably located for a mild and equable climate. The heat of summer, as elsewhere in Florida, is tempered by the proximity to the ocean. By varying the crops, the growing season can be made to extend practically throughout the year.

TEMPERATURE.

As the total length of the section covered by this report extends north and south fully 425 miles, the temperature varies appreciably between northern and southern points. At Jacksonville, in Duval County, within about 25 miles of the north line of the State, the mean annual temperature is 69 degrees Fahrenheit. The means for the four seasons of the year are as follows: Winter, 56; Spring, 69; Summer, 81; Fall, 70. The absolute maximum for summer heat recorded at Jacksonville is 104, although temperatures above 100 are rare. The lowest temperature recorded is 10 above zero. The mean temperatures for the several months of the year at Jacksonville are as follows: January, 55; February, 58; March, 63; April, 68; May, 75; June, 80; July, 82; August, 82; September, 78; October, 71; November, 62; December, 56.*

At New Smyrna, in Volusia County, a station about 100 miles

*United States Weather Bureau Bull. Q, Climatology of the Eastern United States, by Alfred Judson Henry, p. 352, 1906.

south of Jacksonville, as shown by the same report, the annual mean temperature is 70 degrees F. The means for the four seasons are: Winter, 58; Spring, 68; Summer, 79; Fall, 72. The absolute maximum for summer heat recorded at New Smyrna is 100 degrees F. The lowest temperature recorded is 16 above zero. The mean temperatures for the several months of the year (Fahrenheit) are as follows: January, 57; February, 59; March, 65; April, 67; May, 73; June, 78; July, 80; August, 80; September, 78; October, 73; November, 66; December, 58.

At Tampa, in Hillsboro County, the annual mean temperature is 72 degrees F. The means for the four seasons are: Winter, 61; Spring, 71; Summer, 81; Fall, 73. The absolute maximum for summer recorded at Tampa is 96 degrees F. The lowest temperature recorded is 19 above zero. The mean temperatures for the several months of the year (Fahrenheit) are as follows: January, 59; February, 62; March, 67; April, 70; May, 76; June, 80; July, 81; August, 82; September, 80; October, 74; November, 67; December, 61.

At Miami, in Dade County, the annual mean temperature is 75 degrees F. The means for the four seasons are: Winter, 67; Spring, 73; Summer, 82; Fall, 78. The absolute maximum for summer recorded at Miami is 96 degrees F. The lowest temperature recorded is 29 above zero. The mean temperatures for the several months of the year (Fahrenheit) are as follows: January, 65; February, 67; March, 71; April, 74; May, 76; June, 81; July, 82; August, 82; September, 81; October, 78; November, 74; December, 69.

At Key West, in Monroe County, the annual mean temperature is 77 degrees F. The means for the four seasons are: Winter, 70; Spring, 76; Summer, 83; Fall, 79. The absolute maximum for summer recorded at Key West is 100 degrees F. The lowest temperature recorded is 41 above zero. The mean temperatures for the several months of the year (Fahrenheit) are as follows: January, 70; February, 71; March, 73; April, 76; May, 79; June, 82; July, 84; August, 84; September, 85; October, 79; November, 74; December, 70.

At Jacksonville, in the northern part of the State, there is little or no danger of frost before the latter part of October. Light frosts, however, may occur as early as the latter part of October. The earliest killing frost recorded, at this station, is November 2, while the average date of the first killing frost for the past fifty-three years is December 4. The latest date of a killing frost in the spring, at Jacksonville, is April 6, and the average date of the last killing frost is February 14. Light frosts, however, have been known to occur as late as April 28.

At New Smyrna the earliest date of a killing frost in the fall is November 28, while the average date of the first killing frost for the past sixteen years is December 23. The latest date of a killing frost at this place in the spring is March 22. The average date of the last killing frost is February 16.*

At Tampa the earliest date of killing frost recorded is November 28, while the average date of the first killing frost is January 9. The latest date of killing frost in the spring recorded at Tampa is March 19. The average date of the last killing frost is February 8.

At Miami the earliest recorded date of the killing frost in autumn is December 26, and the latest date in the spring is February 19. The killing frost at this locality is so infrequent that no attempt is made to determine the average date.

At Key West, at the extreme southern end of Florida, frosts do not occur.†

PRECIPITATION.

The season of heavy rainfall in Eastern Florida includes the summer and early fall months. As a rule approximately one-half of the rainfall of the year comes during the four months, June, July, August and September.

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*U. S. Dept. Agri. Summary of the Climatological Data for the United States by sections: Section 83.—Northern Florida, A. J. Mitchell, Section Director. Also Climatology of Jacksonville, Fla., and Vicinity, Monthly Weather Review for December, 1907, by T. Frederick Davis.

†United States Weather Bureau, Summary of the Climatological Data for the United States by Sections: Section 84.—Southern Florida, A. J. Mitchell.

The average rainfall at Jacksonville for the 32 years ending with 1903 was 53.4 inches annually. The mean for the four seasons of the year is as follows: Winter, 9.4 inches; Spring, 10.4 inches; Summer, 17.9 inches; Fall, 15.7 inches. The mean for the several months of the year at Jacksonville is as follows: January, 3 inches; February, 3.4 inches; March, 3.5 inches; April, 2.9 inches; May, 4 inches; June, 5.5 inches; July, 6.2 inches; August, 6.2 inches; September, 8.1 inches; October, 5.1 inches; November, 2.5 inches; December, 3 inches.

At New Smyrna the annual rainfall as shown by the same report is 51.1 inches. The mean for the four seasons is as follows: Winter, 8.4 inches; Spring, 6.8 inches; Summer, 17.4 inches; Fall, 18.5 inches. The mean precipitation for the several months of the year at this station is as follows: January, 2.8 inches; February, 3.6 inches; March, 2.6 inches; April, 1.6 inches; May, 2.6 inches; June, 6.2 inches; July, 5.6 inches; August, 5.6 inches; September, 9.2 inches; October, 6.7 inches; November, 2.6 inches; December, 2 inches.*

At Tampa the annual rainfall is 53.1 inches. The mean for the four seasons is as follows: Winter, 8.1 inches; Spring, 7.4 inches; Summer, 24.9 inches; Fall, 12.7 inches. The mean precipitation for the several months of the year at Tampa is as follows: January, 2.8 inches; February, 3.5 inches; March, 2.9 inches; April, 2.1 inches; May, 2.4 inches; June, 8.5 inches; July, 8.0 inches; August, 8.4 inches; September, 8.2 inches; October, 2.8 inches; November, 1.7 inches; December, 1.8 inches.

At Miami the annual rainfall is 58.3 inches. The mean for the four seasons is as follows: Winter, 8.1 inches; Spring, 11.1 inches; Summer, 20.6 inches; Fall, 18.5 inches. The mean precipitation for the several months of the year at Tampa is as follows: January, 4.0 inches; February, 2.5 inches; March, 3.1 inches; April, 3.5 inches; May, 4.5 inches; June, 8.2 inches; July, 7.0 inches; August, 5.4 inches; September, 9.1 inches; October, 7.1 inches; November, 2.3 inches; December, 1.6 inches.

At Key West the annual rainfall is 37.9 inches. The mean

*United States Weather Bureau, Bull. Q.

for the four seasons is as follows: Winter, 5.3 inches; Spring, 5.5 inches; Summer, 12.6 inches; Fall, 14.5 inches. The mean precipitation for the several months of the year at Key West is as follows: January, 2.0 inches; February, 1.6 inches; March, 1.2 inches; April, 1.2 inches; May, 3.1 inches; June, 4.2 inches; July, 3.7 inches; August, 4.7 inches; September, 7.0 inches; October, 5.4 inches; November, 2.1 inches; December, 1.7 inches.

SOILS.

The geologic, topographic, climatic and drainage conditions have much to do with the character of soils. Since the inorganic constituents of soils are derived primarily from the decay of preexistent formations, the character of the soil is determined to a considerable extent by the formation from which it is derived. The thickness and manner of accumulation of the residual material as well as accumulation of the organic constituents is affected by the topographic, climatic and drainage conditions. The following are the more prominent soil types in the part of Florida covered by this report:

Rolling pine lands: This type includes light, sandy, well-drained soils. The native vegetation is pine and wire grass. Oaks and other hard wood trees occasionally occur. The saw palmetto is for the most part absent. This type of soil predominates in the lake region of Florida.

Palmetto flatwoods: The palmetto flatwoods occur over an extensive area in Florida. This type of country is flatter than the sandy pine land and not so well drained. The native vegetation of these lands consists chiefly of pine, saw palmetto and wire grass. The sand is dark at the surface, becoming lighter below. As a rule the so-called "hardpan" underlies the palmetto flatwoods. This "hardpan" consists of sand stained with organic matter and has the appearance of being partly cemented with iron. When dry it is fairly well indurated, but as a rule it may be penetrated with the soil auger. The transition in the bore hole from the light colored sand to "hardpan" is abrupt. The "hardpan" itself is very dark colored at the top and grades into chocolate colored sands below.

The "hardpan" is very objectionable in farming lands as it prevents free movement of water by capillary attraction. The lands underlaid by "hardpan" are not resistant to droughts. However, where an abundance of water can be obtained cheaply, as in the section of flowing artesian water, such lands may be used to advantage by keeping them saturated with water.

Open flatwoods: The open flatwoods are much less extensive than the palmetto flatwoods. The native vegetation of the land of this type is chiefly pine and wire grass with little or no underbrush. The saw palmetto is absent or nearly so and there is little or no "hardpan." The soil to a depth of from one to three feet is dark ashy gray owing to the presence of organic matter mixed with the sand. A clay sub-soil is usually found at the depth of from one to four feet. This type of land when drained and irrigated has been used with great success in growing Irish potatoes, sweet potatoes and other trucking crops and in general farming.

Prairie lands: The word "prairie" is applied to open lands devoid of trees. The native growth is largely grasses.

Muck lands: The term "muck soils" is applied in ordinary usage to lands on which organic matter from decay of vegetation has accumulated to some depth. Vegetable matter accumulates in this way only on such lands as are overflowed during a considerable part or all of the year. The largest tract of muck lands in the State is the Everglades. Many smaller tracts occur, however, throughout the State.

Clay lands: The clay soils are usually of limited extent, occurring at places where the superficial sands have been removed by surface wash. The clay soils are lacking in organic matter and before being farmed must be broken up and organic matter incorporated.

Hammock lands: The term "hammock land" is most frequently applied to lands underlaid by marl or limestone and supporting a thick growth of vegetation, including hardwood trees and cabbage palmetto. These lands when cleared make excellent farming lands. Other hammock lands occur, however, which have no evident relation to marl deposits. These likewise support a heavy growth of hardwood trees. The soil consists of a rich humus due to the accumulation of leaves. Beneath the humus is usually found several feet of orange yellow sand.

Sandy hammock lands: The sandy hammock lands as developed in the sections bordering the coasts are of wind-blown sands or low dunes on which vegetation has gained a foothold. Various hardwood trees grow on this type of land. It has been found in many instances desirable for orange culture. It is used also to some extent in vegetable growing. The open nature of the soil, however, results in a heavy loss of fertilizer from leaching.

Scrub: Scrub is a term applied to very sandy lands which support a dense growth of shrubby plants. The sandy pine lands often pass very abruptly and with no apparent reason into scrub. Few attempts have been made to utilize the scrub lands for farming purposes.

Sand dunes: The sand dunes both of recent and of earlier formation occur frequently in Florida particularly along the coast. The sand dune soil has been found especially adapted to the growing of pineapples, the extensive pineapple farms of St. Lucie County being largely located on quiescent dunes.

River swamp: The river swamp lands support a dense growth of hardwood trees. On the smaller streams where the elevation is sufficient to permit of successful drainage these lands if cleared would furnish desirable trucking and farming land.

Salt marsh: Extensive salt marshes occur along the Atlantic coast and bordering the streams entering the ocean.

UNDERGROUND WATER: GENERAL DISCUSSION.

SOURCE.

Rainfall: The chief source of underground water is the rainfall. Water vaporized through the energy of the sun passes into the atmosphere and is precipitated over the land as rain or condensed as dew or fog. The vapor is supplied to the atmosphere by evaporation, principally from the ocean, which, occupying three-fourths of the earth's surface, is continuously exposed to the sun's rays. To the vapor from the ocean is added that arising from inland waters, from the dry land surface to the earth, and from the leaves of plants.

Small additions to the underground water supply may come through any one of a number of other possible sources, but the total amount thus added is relatively small and may be omitted in a general discussion.*

ANNUAL RAINFALL.

The annual rainfall is the measure of the column of water that would accumulate at any spot in the course of a year, if all that falls should be preserved. The measurement is commonly stated in inches. The average rainfall for the State as a whole for the fifteen years, from 1892 to 1906, inclusive, as deduced from the U. S. Weather Reports, was 53.17 inches, annually. The year 1907 was a year of less than average rainfall, 49.15 inches, and if this year is included the average for the sixteen years, 1892 to 1907, falls below 53 inches, being 52.92 inches. If longer periods be considered the variation from this average is not sufficient to materially change the result. The area covered by this report lies in that part of the State supplied with about the average rainfall, and 53 inches may be safely assumed as a close approximation to the annual rainfall for this section.

DISPOSITION OF RAINFALL.

Of the total rainfall of any area, (1) a part is returned as vapor to the atmosphere without having entered the earth; (2) a part is carried off by streams and rivers to the ocean without penetrating the earth; (3) a part is absorbed into the earth.

(1) WATER EVAPORATED WITHOUT ENTERING THE EARTH.

Immediately following a rain the atmosphere is nearly or quite

*A recent discussion of possible sources of underground water other than rainfall will be found in Bulletin 319, U. S. Geol. Surv., by M. L. Fuller.

saturated. The evaporation at this time is slow, and the part returned to the atmosphere directly from the land is an almost negligible amount. This is especially true of a soil into which the water enters quickly. Some of the water clinging to the leaves of plants is re-evaporated, as well as a part of that which falls into lakes, ponds and temporary pools. While an estimate of the amount evaporated must be regarded as only in the roughest way approximate, yet it is probably safe to assume that not more than two or three per cent. of the total rainfall is returned to the atmosphere by direct evaporation without having entered the earth.

(2) SURFACE RUN-OFF.

The relative proportion between the surface run-off and the surface in-take of water is dependent upon the character of the surface and the deeper formations and upon the topography. The former affects rapidity of in-take of water into the earth; the latter the rapidity of surface run-off.

With regard to topography Peninsular Florida is either flat or rolling. Rarely can a locality within this section be described as hilly. The elevation increases gradually from sea level at the coast to a maximum of scarcely more than 200 feet inland, while large sections are so flat as to present no perceptible slope. Topographically the conditions are, therefore, very unfavorable to surface run-off. On the other hand, the conditions are exceptionally favorable to large surface in-take. The soils are sandy and receive and store the rainfall with great readiness.

(3) RAINFALL ENTERING THE EARTH.

Of the water which enters the earth, a part is ultimately returned to the atmosphere by evaporation. The water retained in soils is slowly given up through evaporation during dry weather. As the evaporation takes place near the surface, the capillary attraction draws a new supply from beneath, thus maintaining to some extent the moisture content of the soil. The amount of water thus brought to the surface and evaporated, while varying with climate and with soils, is, in the course of a year, considerable.

To the evaporation from the surface of the soil must be added that from the leaves of plants. This in turn varies greatly with the different plants and with different climatic conditions. King, in 1892, in one experiment, found that a crop of peas evaporated 477 pounds of water for each pound of dry matter formed, while corn under the same conditions evaporated in one instance 238 pounds of water per pound of dry matter.* Assuming that a citrus tree evaporates approximately as much as the European oak (Quercus cerris), the water evaporated from the leaves of a fifteen-year-old orange tree is estimated, by Hilgard, at 20,000 pounds a year, or about 1,000 tons of water per acre of 100 trees.† This is equivalent to about nine inches annual rainfall over the same area. Water is the chief vehicle for conveying plant food absorbed from the soil by the roots. This enormous evaporation from the leaves is in part for the purpose of disposing of the water thus taken up by the plant. It serves chiefly, however, the purpose of preventing, through the conversion of water into vapor, an injurious rise of temperature during the hot sunshine and dry weather.

It is impossible to estimate within even approximate limits the loss of water by evaporation from the surface of the ground, and from the leaves of plants in the area under consideration. The atmosphere in Florida is relatively humid. On the other hand, the temperature throughout most of the year is high. Much of the country is uncultivated, and practically all of the soil is of medium coarse texture.

It is probable that almost one-half of the rainfall entering the earth is re-evaporated from the surface of the ground and from the leaves of plants, and that not more than one-half of the total rainfall in Florida passes through the soil and surface material to join the underground water supply.

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*20th Ann. Report Wis. Agriculture Experiment Station, p. 320 ,1904.

†Based on weighings made by R. H. Loughridge of the leaves of a citrus tree at Riverside, Calif. Soils, by E. W. Hilgard, p. 263, 1906.

AMOUNT OF WATER AVAILABLE FOR THE UNDERGROUND SUPPLY.

An annual rainfall of 53 inches is found by computation to amount to 921,073,379 gallons per square mile. Of this amount it is estimated that in Central Florida about one-half is added each year to the underground water supply.

UNDERGROUND CIRCULATION OF WATER.

Underground water is found usually to be in motion, threading its way through pores, breaks, crevices, joints and other openings in the rocks. Its movement is ordinarily slow and varies with different rocks and under different conditions.

CAUSE OF MOVEMENT.

The chief cause of movement of underground, as of surface water, is gravity. Capillarity is an additional force which, under special conditions, may become the controlling factor. The water returned to and evaporated from the surface of the ground, as well as that carried to and evaporated from the leaves of plants, is moved by capillarity in opposition to gravity. Gravity, however, is the controlling force in the movement of water through the deep zones of the earth. Pressure, which is an important secondary cause of the movement in the earth, is the expression of gravity. Except in the case of capillarity, the movement of water, apparently in opposition to gravity, is, upon closer observation, found to be in reality movement in response to gravity. The water, which rises in a boring or flows from an artesian well or spring, is forced up by pressure, due principally to the weight of water lying at a higher level. The familiar observation that water seeks its own level has the same explanation.

RATE OF MOVEMENT.

The chief factors affecting the rate of movement of water through a porous medium, as given by Slichter, are as follows:*

*Water Supply Paper, U. S. Geol. Surv., No. 67, p. 17, 18, 1902.

(1.) Porosity of the material.
(2.) Size of the pores in the water-bearing medium.
(3.) Pressure.
(4.) Temperature of the water.

(1.) Rocks contain pores which, in the absence of a liquid, are ordinarily filled with air. The relative proportion of these spaces in the rock to the whole volume is the measure of the porosity. Thus, if a cubic foot of sandstone will hold in its pores one-fourth cubic foot of water, its porosity is 25 per cent. The greater the porosity, the more water absorbed by the rocks.

(2.) The size of the pores in the rock affects the rate of flow. Rocks having large pores receive and conduct water many times more rapidly than those having small pores.

(3.) The greater the pressure, other conditions remaining the same, the more rapid the flow. A pressure of one pound per square inch is required to support each 2.31 feet of a column of distilled water at the temperature of 60 degrees F. The weight of water from the deep zones is increased by solids in solution and in suspension, and is affected by changes in temperature. Something more than a hundred pounds pressure to the square inch is required to cause a flow from the bottom of a well 231 feet deep. Something more than 500 pounds pressure to the square inch is required to cause the rise of water in a boring, a distance of 1,150 feet. Pressure of this magnitude must materially assist in forcing water through the rock.

(4.) The temperature of the water is found to influence the rate of flow. Slichter finds that a change from 50 to 60 degrees F. increases the capacity to transmit water, under identical conditions, by about 16 per cent.†

DEPTH OF UNDERGROUND WATER.

The limit of the downward extent of water has not been reached by borings or tunnels, some of which exceed a mile in

†Water Supply and Irrigation Paper, U. S. Geol. Surv. No. 140, p. 13, 1905.

Fig. 1.—Palmetto flatwoods. View taken on Amelia Island in Nassau County.

Fig. 2.—Palmetto flatwoods. View taken five miles east of Ft. Myers, Lee County.

EXPLANATION OF PLATE 11.

Fig. 1.—Scrub. This type of soil consists of white sand and is not adapted for farming. Photograph by R. M. Harper. View taken on east side of Lake Kingsley, Clay County.

Fig. 2.—Well drained pine lands. This type of soil is well drained, and consists of a sandy loam. The prevailing vegetation is pine, wire grass and oaks. The soil is light, and is suitable for early vegetables, and for orange growing. As a farming soil it requires building up and fertilizing. View taken near DeLeon Springs, in Volusia County.

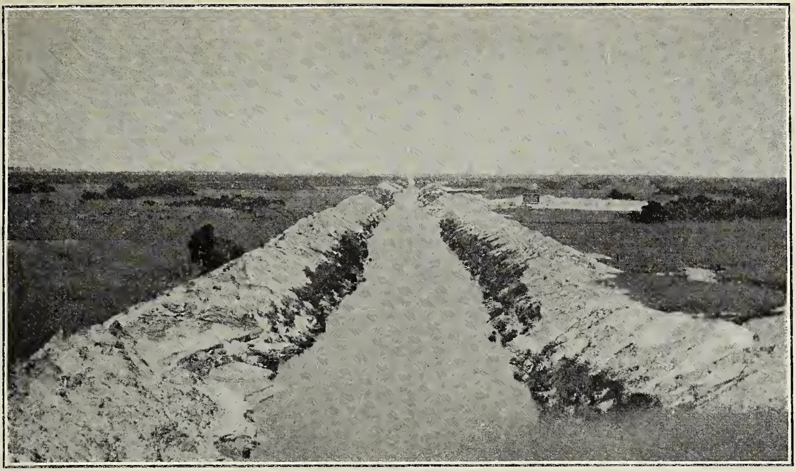
Fig. 3.—Open flatwoods. The soil consists of a dark sandy loam underlaid at the depth of one to five feet by clay subsoil. The prevailing vegetation is pine and wire grass. These flatwoods are naturally poorly drained. When properly drained, however, the soil is good and suitable for trucking and general farming. View taken three miles east of DeLeon Springs.

EXPLANATION OF PLATE 12.

Fig. 1.—Muck soil. The Everglades of Florida along the drainage canal, west of Fort Lauderdale. The soil here consists of muck to a depth of three to five feet, underlaid by sands which, in turn, rest upon oolitic limestone.

Fig. 2.—Prairie soil. One of the typical small prairies. View taken 10 miles west of Sebastian. The soil consists of light colored sands to a depth of several feet, underlaid by clay or hardpan. The small prairie shown in the foreground is surrounded by palmetto flatwoods.

Fig. 3.—Calcareous hammock soil. A view in Turnbull Hammock, one mile west of Daytona. Shell marl here lies at or very near the surface. The native vegetation includes cabbage palmetto and various deciduous hardwood trees. The calcareous soils are desirable, particularly for vegetable growing.



EXPLANATION OF PLATE 13.

Fig. 1.—Sand dune. This view illustrates one of the recent sand dunes near Mayport, at the mouth of the St. Johns River.

Fig. 2.—Ancient sand dune. This view is taken at the crossing of the public road across the dunes, about two miles west of Daytona. The dune here consists of light colored sand to a depth of four or five feet, underlaid by ochre yellow sands.

Fig. 3.—Clay soil. Exposure at Saw Pit Landing on the St. Marys River, in Nassau County. The soil here is a sticky clay soil residual from the decay of the clayey limestone.

Fig. 1.—Exposure of hardpan along Black Bluff on Clarks Creek, eight miles from Fernandina.

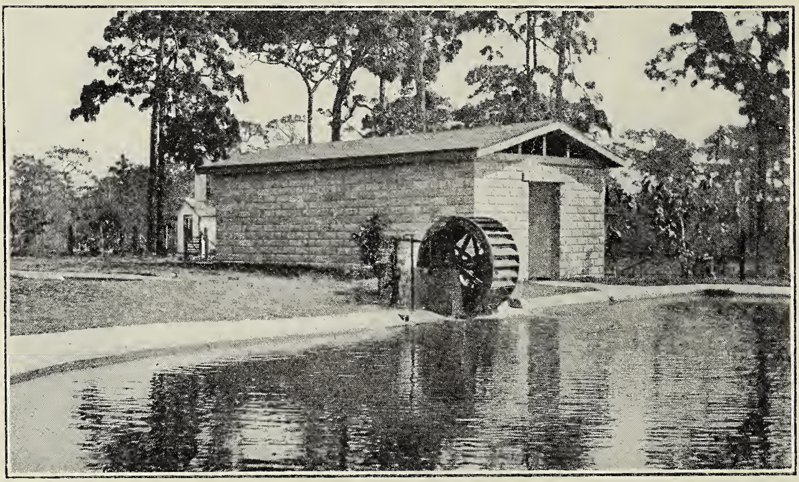


Fig. 2.—Artesian well used for power belonging to H. T. Bowden, Melbourne, Brevard County. The water from the artesian well affords power by which water is pumped from a nearby shallow well.

depth. Water, while thus known to penetrate to a depth greater than a mile, probably does not reach beyond five or six miles at the most. The movement, as has been stated, is through natural openings in the rock. Pressure increases in the earth with depth, and it is estimated that, at a depth of approximately six miles, the pressure is so great that the pores and cavities of even the strongest rocks are completely closed,‡ making it impossible for water to penetrate beyond this depth. Most of the water, however, returns to the surface after a comparatively short underground course, only a small part of it reaching to this great depth.

HYDROGEN SULPHIDE IN UNDERGROUND WATER.

The underground water of Florida is very generally impregnated with hydrogen sulphide (H_2S), also known as sulphuretted hydrogen, and hydro-sulphuric acid. Water containing hydrogen sulphide is commonly known as "sulphur water." Sulphur water is especially characteristic of the areas of artesian flow. In those sections in which open, porous limestone is the surface formation, hydrogen sulphide is usually absent from the first water encountered, although, even here, it is found to exist in the water from the deep wells and in some springs.

Source:—Hydrogen sulphide may originate, in nature, in any one of several ways. The following have been suggested: (1) The decay of organic matter containing sulphur; (2) the reaction of organic matter upon sulphides or sulphates; (3) the reaction of acids upon sulphides; (4) partial oxidization of sulphides; (5) steam passing over sulphur.

The decay of organic matter is an obvious source of hydrogen sulphide in the underground waters of Florida. Chemical analysis shows that sulphur is very generally present in Florida soils,* and apparently invariably present in muck soils. Analyses of samples of peat, which is, like muck, a vegetable accumulation, will be found in the paper on peat deposits published in 1910. The amount of sulphur in the Florida peat, in the dried samples, varies from less than 1 per cent. to over 4 per cent.

‡L. M. Hoskins, 16th Ann. Rept. U. S. Geol. Surv., Part I, p. 859, 1896.

Hydrogen sulphide is formed in connection with the decay of eggs. In this case the albumen of the egg, according to Ostwald, contains the sulphur.† H_2S is also found escaping from sewer drains and cesspools, and is formed, during the decomposition, both of animal and vegetable substances. The H_2S occurring in shallow springs from marsh lands is, doubtless, supplied largely from organic material.

The sulphur in soils is, probably, often present as sulphates. Thorpe states that the decay of organic matter in contact with sulphates results in the formation of H_2S.‡ The reaction in this case, probably, results from reducing properties of decaying organic matter, the sulphates being first reduced to sulphides, according to the following reaction: $Na_2SO_4+C_2$ (carbon of organic matter) $=2CO_2+Na_2S$. The sulphide is then acted upon by the carbonic acid to form H_2S as follows: $Na_2S+H_2CO_3=H_2S+Na_2CO_3$. The reaction of organic matter upon the sulphides is regarded, by Van Hise, as another important source of H_2S in underground water.*

The formation of hydrogen sulphide, as a result of the action of acids upon metallic sulphides, is one of the most familiar of laboratory experiments. This suggests the possibility of the formation of this gas, as the result of the action of acids upon metallic sulphides, contained in the rocks. Sulphides, especially those of iron, are widely scattered in the earth's crust, and occur in sufficient quantity to account for the formation of H_2S gas in water. Hydrogen sulphide is a weak acid, and its salts are decomposed by a stronger acid. Sulphuric and other mineral acids should certainly react upon sulphides liberating H_2S. Carbonic acid, when abundant, reacts upon alkali sulphides to produce hydrogen sulphide. It is true that the alkali sulphides are normally not abundant in the crust of the earth. Stokes has shown, however, that the reaction of sodium carbonate within the

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*Bulletin 43, Florida State Experiment Station, pp. 653, 657, 659, 1897.

†Ostwald, Principles of Inorganic Chemistry, page 274, 1904.

‡Dictionary of Chemistry, Vol. III, p. 697, 1900.

*A Treatise on Metamorphism, Mon. XLVII U. S. Geol. Surv., p. 1112, 1904.

earth, upon pyrite or marcasite, produces sodium sulphide. The reaction given by him is as follows: (L. C. page 1107.)

$8FeS_2+15Na_2CO_3=4Fe_2O_3+14Na_2S+Na_2S_2O_3+15CO_2$.

It is a well-known fact that the carbon dioxide, which unites with water to form carbonic acid, is abundant in the deep waters, especially in the limestone formations; the pressure existing at considerable depth enabling the water to hold great quantities of carbonic acid. The series of reactions given by Stokes accounts for the presence of alkali sulphides in solution in the deep waters. It may be added that all sulphides are soluble, to some extent, in water and, in that condition, may be acted upon by carbonic acid.†

The partial oxidation of sulphides is, according to Van Hise, a possible additional method of formation of hydrogen sulphide, the reaction being as follows: (L. C. p. 1113.)

$3FeS_2+4H_2O+4O=Fe_3O_4+4H_2S+2SO_2$.

The oxidizing processes are the most rapid near the surface, especially above the underground water level, and H_2S derived from this source, probably, supplies relatively shallow rather than deep waters.

The formation of H_2S by steam passing over sulphur, which occurs in connection with volcanoes, may be dismissed in considering the sulphur waters of Florida, since Florida has no volcanoes and no indications of volcanic activity.

SULPHUR WATER NOT EVIDENCE OF BEDS OF SULPHUR.

There is a widespread belief that the presence of sulphur water must necessarily indicate the existence of beds of the mineral sulphur. This conclusion does not follow. The probable sources of the sulphur in sulphur waters, as indicated above, is organic matter, together with metallic sulphates and sulphides scattered through sedimentary rocks.

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†Inorganic Chemistry. International Library of Technology. Sec. 12, p. 11.

SULPHUR DEPOSITS FORMED FROM HYDROGEN SULPHIDE.

As stated in the last paragraph, sulphur waters are not to be regarded as resulting from beds of pure sulphur. On the contrary, it is probably true that these waters may, in some instances, result in the formation of such deposits. Hydrogen sulphide, when acted upon in the water by oxygen, breaks up, forming water and sulphur; the reaction being $H_2S+O=H_2O+S$. It is thus possible that H_2S in the underground water, or escaping from the underground water, may become disassociated, forming deposits of pure sulphur. Such deposits of economic value have not been reported in Florida. It is a noteworthy fact, however, that one large mass of sulphur has been found underneath phosphate beds in Citrus County.* The formation of this mass of sulphur is probably due to hydrogen sulphide. A flocculent white coating of sulphur, or a sulphur compound invariably forms around sulphur springs and flowing sulphur wells.

ABSENCE OF HYDROGEN SULPHIDE FROM CERTAIN WATERS IN FLORIDA.

The absence of hydrogen sulphide from the first water obtained from areas in which the open porous limestone is the surface formation, has already been stated. It is a well-known fact that if sulphur water is allowed to stand in the open air the gas will escape. This method of freeing water from an excess of H_2S gas is a common practice wherever sulphur water is used for domestic purposes. Wherever porous limestone lies at or near the surface the sulphur gas, which the water may have contained, will find a ready means of escape. In other parts of the State, where compact and impervious formations rest upon the limestone, the gas is prevented from escaping and sulphur water is obtained.

*Florida Geological Survey, First Annual Report, p. 44, 1908.

AMOUNT OF HYDROGEN SULPHIDE INFLUENCED BY PRESSURE.

The quantity of H_2S gas, which the water is able to hold in solution under these conditions, is determined by the pressure. The law of the solubility of gases in liquids is as follows: The quantity of the gas which the liquid is able to dissolve is directly proportional to the pressure on the gas. In the open, porous limestone with no confining stratum above, the water at the top of the underground water level is merely under atmospheric pressure. After passing the underground water level, however, the pressure increases rapidly. The increase of pressure is not simply that due to the atmosphere, but that due to the weight of the overlying column of water plus the atmosphere. According to Van Hise:* "The pressure, which really is determinative as to the amount of gas which may be held in solution, is that of a column of water extending to the free surface, plus the atmospheric pressure." From this law it follows that water, at a great depth and under great pressure, is capable of holding a large quantity of hydrogen sulphide in solution. When brought to the surface the pressure is relieved and the gas rapidly escapes. The artesian waters, in the flowing areas of the State, are under considerable pressure, thus enabling them to hold a large quantity of hydrogen sulphide as well as a high proportion of mineral solids in solution.

In order that the deep waters may hold large quantities of H_2S in solution, it is necessary that the gas be available. This implies that the gas in the artesian and other deep waters originates at some considerable depth rather than at or near the surface.

ARTESIAN WATER.

The term "artesian" has been variously used by different writers. Flowing wells first became well known in the province of Artios, France, and hence were called "artesian wells," and

*L. c., page 70.

their water "artesian water." The first meaning of "artesian well" was, therefore, a flowing well; and of "artesian water," water under sufficient pressure to cause it to flow. With the extension into other areas of the use of deep wells as a source of water supply, many instances were found in which the water, although under pressure and rising almost to the surface, would not flow. In some cases the water will flow in areas of low surface elevation, and yet fail to flow in a slightly elevated area nearby. Artesian water thus came to mean water under pressure, causing it to rise in a boring when tapped, regardless of whether or not the pressure was sufficient to cause the water to rise above the surface level, and hence to flow. In the same way, and for similar reasons, the term "artesian well" came to include not only flowing wells, but also wells in which the water rises when the water-bearing stratum is tapped, regardless of whether or not the rise is sufficient to cause a flow. Occasionally, in popular usage, the term "artesian well" has been applied to any deep boring, and "artesian water" to water from such a well. In this report the term *artesian* is applied to water under pressure, and hence rising in a boring when tapped. The water may, or may not, rise to or above the surface. An "artesian well" is any well reaching to and tapping a stratum bearing such water; a "flowing well" is an "artesian well" that gives a surface flow. Artesian pressure is the pressure causing the water to rise in the boring when tapped. This is essentially the usage of these terms as adopted by the Division of Hydrology of the U. S. Geological Survey.*

CONDITIONS NECESSARY TO OBTAIN ARTESIAN WATER.

As essentials for artesian water, it is necessary to have (1) an adequate source of water, and (2) the proper structural conditions to retain the water under hydrostatic or artesian pressure. It will be convenient to discuss first the structural conditions.

*Water Supply and Irrigation Paper, U. S. Geological Survey No. 160.

ARTESIAN BASIN.

A variety of conditions in the arrangement and structure of the underlying deposits may bring about artesian pressure. The simplest, although probably not the most common, is that of a basin-like arrangement of successive relatively pervious and impervious strata. This typical structure, known as an artesian basin, is shown in the accompanying diagram. It consists of a pervious layer (a), out-cropping at the surface on either side and sagging at the middle, above which is an impervious or water-

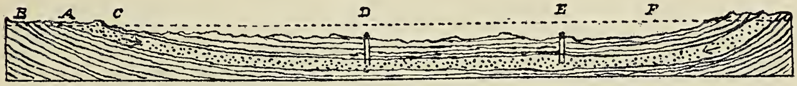

Fig. 1.—Illustrating Structure of an Artesian Basin.

tight confining layer (c), and below which is also an impervious layer (b). Water enters the pervious layer at its surface exposures at the sides. The water collecting in the central part of the basin is under pressure from the weight of the additional water entering from the sides. Therefore, a well put down to the water stratum in any part of the basin will obtain artesian water, or water which will rise in the boring. The rise in the boring is determined by the elevation of the in-take area, and can in no case rise above the elevation of the exposed edges of the stratum. As a matter of observation, it is found in all cases to rise not quite so high as the exposed edge of the stratum, the loss being due to the friction of movement through the rock. This loss of head due to friction necessarily varies with the texture of the stratum through which it passes, the passage being more free through the coarse material, and hence meeting with less friction than through fine. Whether or not wells put down in the basin will obtain flowing or non-flowing artesian water, depends upon the surface elevation of the mouth of the well. The diagram illustrates a basin in which flowing artesian wells may be obtained.

ARTESIAN SLOPE.

The basin arrangement of strata is not the only possible structure resulting in artesian pressure. The same result may, among other ways, be brought about quite effectively by an inclined porous stratum wedging out between two impervious strata. This condition is illustrated by the accompanying simple sketch, in which the pervious stratum (a) is represented as pinching out and disappearing between impervious strata. A pervious stratum grading into an impervious, or less pervious condition resulting

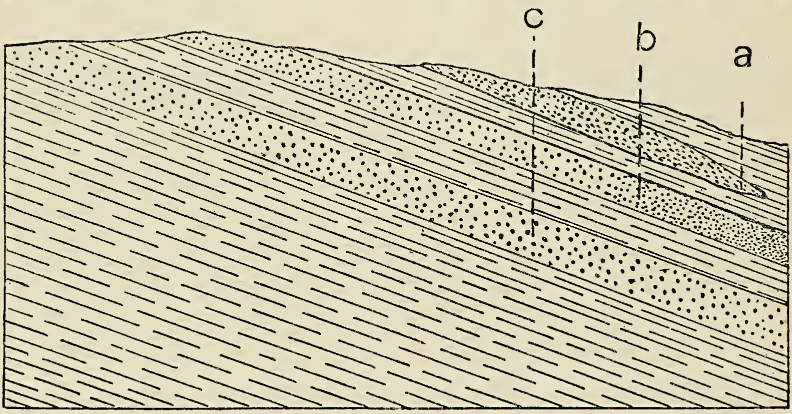

Fig. 2.—Illustrating structures that may prevail in an artesian slope; *a*. a pervious water-bearing stratum which pinches out between impervious strata; *b*. a pervious water-bearing stratum which grades into a less pervious stratum; *c*. a pervious water-bearing stratum in which the artesian pressure is due merely to the friction of water moving through the pores of the rock.

in artesian pressure, is represented by (b) of the same drawing. These conditions are often met with in the strata of the coastal plain. Not infrequently, a sandstone formation grades off shore into a finer sandstone, and ultimately into a shale. This condition comes about naturally through the sorting power of water acting along what was the coastal line at the time of formation of the strata under consideration. The coarser sand particles are dropped near the shore and form the sandstone; the finer sand-grains, together with more or less clay, are carried farther out, and form a finer grained sandstone grading ultimately into a clay. Similarly, a sandstone, or other pervious formation, may pinch out as a result of the thickening of a shale or clay bed. The term "artesian slope" has been applied to such an area to distinguish it from an artesian basin.

The friction of water threading its way long distances through the pores of an inclined pervious formation may result in an appreciable artesian pressure. That this is true, may be demonstrated by the following very simple experiment: Fill a tube of any length with sand, and incline at a convenient angle. The sand of the tube represents the pervious water-bearing stratum; the tube itself, the impervious confining strata. Let smaller tubes placed vertically be welded into the larger tube. These vertical tubes represent bored wells. The water will be found to rise in the vertical tubes, exhibiting an appreciable artesian pressure due to the friction of flow through the sand.

ARTESIAN WATER FROM UNCONFINED HORIZONTAL BEDS.

It is, doubtless, possible to obtain artesian water in some instances from unconfined horizontal beds. This condition is illus-

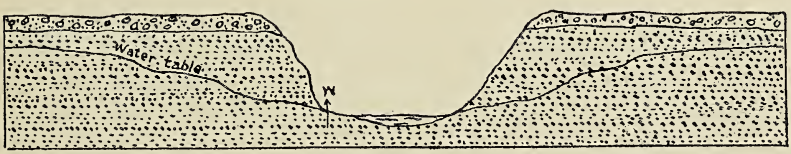

Fig. 3.—Illustrating artesian water from unconfined horizontal beds. The pressure in this case is due to the friction of water moving through the pores of the rock.

trated by the following sketch taken from the report of M. L. Fuller.* It is possible that some of the small local flows obtained in the lake region of interior Florida are due to similar conditions.

ARTESIAN WATER FROM SOLUTION PASSAGES.

Solution passages through limestones undoubtedly facilitate the free movement of water. If limestones should be otherwise relatively water tight, flows might still be obtained, in some instances, from water conducted through the cavities in the limestone. Such possible conditions are illustrated by the accompanying sketch, also taken from Mr. Fuller's paper.* Several other possible structural conditions that may give rise to artesian flows are described and illustrated in the paper referred to. Those illustrated above, however, include the structural conditions which seem likely to prevail in Florida.

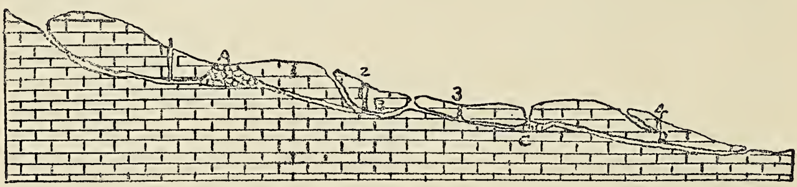

Fig. 4.—Sketch illustrating artesian flow obtained from solution passages in the limestone. After Fuller.

SOURCE OF ARTESIAN WATER OF FLORIDA.

The idea is rather prevalent that the artesian waters of Florida are in no sense local but are derived from the Appalachian Mountains, or some other remote inland point. This is an error, which, if not corrected, may prove detrimental. That the supply is local is evidenced by the fact that the artesian wells of the State are affected by local rains. Many of the well owners have recognized the effect of local rains on their wells; others who have observed less closely recognize no such variation. That the rainfall is sufficient to supply the large quantities obtained has already been demonstrated.

FORMATIONS SUPPLYING THE ARTESIAN WATER OF EASTERN AND SOUTHERN FLORIDA.

As explained in the chapter on Geology, the principal artesian reservoir of the eastern and southern part of Florida is the Vicks-

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*U. S. Geological Survey, Bull. 319, p. 39, 1908. Summary of the Controlling Factors of Artesian Flows.

burg group of limestones. In some localities, however, formations lying above the Vicksburg group supply a flow, although the flow from these more shallow formations is rarely ever so strong as from the deeper or Vicksburg limestones.

DEPTH OF THE ARTESIAN WATER.

The depth at which the artesian water is obtained is variable in different parts of the area. To find the depth for any particular locality, it will be necessary to refer to the subsequent chapters in which the several counties are treated individually.

COST OF WELLS.

It has been only within the past few years that artesian wells have begun to supplant shallow, open dug wells in the rural districts. One cause of the rapid increase of artesian wells in these districts is the necessity of irrigation in order to safeguard trucking and general crops against droughts. Again, from a health standpoint, the water from these deeper wells is less liable to contamination than is the water from the shallower or surface wells.

The cost of an artesian well depends upon the depth to which it is necessary to drill, the size of the well desired, the amount of casing used and the character of the material that will probably be penetrated in drilling. With a knowledge of the nature of the underlying formations in a given area well drillers know approximately the time and labor it will take to complete a certain size well. In such an instance it is frequently the case that a well is completed for a stipulated amount, regardless of the depth. It is more customary, however, to let a contract for a certain size well at a given price per foot. These prices vary in different sections of the State, but on the average two-inch wells are sunk for from $1.00 to $1.25 per foot; three- and four-inch wells from $1.50 to $2.00 per foot. The larger wells range in proportion, a ten-inch well costing about $3.50 per foot. The driller, at these prices, furnishes the casing.

INCREASED FLOW OF ARTESIAN WELLS WITH INCREASED DEPTH.

As a rule, the amount of flow or yield of wells in Eastern Florida increases with depth. To this rule there are, doubtless, exceptions, since the amount of flow, in all cases, depends upon the variable structure of the rock through which the drill passes. As illustrations of increased flow with increased depth, the following may be cited:

In the new city well at Jacksonville, well No. 10 of the city water supply, the first flow obtained was a light flow of 5 gallons per minute at a depth of 270 feet. At a depth of 498 feet the flow increased to 112 gallons per minute. Upon reaching the Vicksburg Limestone, at a depth of 510 feet, the flow increased to 200 gallons per minute. The flow at the depth of 635 feet was found to be 500 gallons per minute. At 900 feet the flow was about 900 gallons per minute. At 980 feet, the full depth of the well, the flow was from 1,500 to 2,000 gallons per minute. For the detailed measurements of flow on this well the Survey is indebted to the drillers, the Hughes Specialty Well Drilling Company of Charleston, South Carolina.

A like increase of flow is shown by the Ponce de Leon well in St. Johns County, the measurements of which were kept, and have been kindly supplied by Messrs. McGuire and McDonald, contractors. The first flow in this well of 50 gallons per minute was obtained at a depth of 170 feet. At 177 feet the flow increased to 350 gallons per minute. At 410 feet the flow was 2,083 gallons. At 520 feet the flow had increased to 4,860 gallons. At 1,110 feet the flow was 6,075 gallons. The well was continued to a total depth of 1,440 feet. The record of the well, however, contains no mention of increased flow below 1,110 feet. While exact measurements, like those given above, are seldom made; the drillers, with few exceptions, report increased flow with increased depth.

INCREASED HEAD WITH INCREASED DEPTH.

Not only does the amount of flow of the water in this section of the State increase with increased depth, but the head or pressure, or height above the ground to which the water will rise likewise increases. The head is, in reality, only a measure of the pressure. The amount of flow is within limits dependent upon the amount of pressure. Other conditions remaining the same, an increased pressure will result in an increased flow. For the records regarding pressure, it is necessary to rely chiefly upon the Jacksonville and St. Augustine wells already referred to.

At 680 feet the pressure of the artesian water in the Jacksonville well was 12 pounds per square inch, or sufficient pressure to cause the water to rise vertically in a pipe 27.72 feet. At 900 feet the pressure, as shown by the gauge, was 15 pounds, or sufficient to cause the water to rise 34.65 feet.

The Ponce de Leon Hotel well, at St. Augustine, affords valuable information as to the possibility of obtaining increased head, in this section of the State, by drilling to greater depths. This well was drilled to a total depth of 1,440 feet. A measure of the head was made at frequent intervals while drilling. The first considerable flow obtained at St. Augustine is under a pressure, causing it to rise about 32 feet above sea. At the depth of 350 feet the head was found to have increased to 38 feet above sea. At the depth of 520 feet the head had increased to 42 feet, a total gain of 10 feet. The head at greater depths than 520 feet is not specifically recorded.

INCREASED TEMPERATURE WITH INCREASED DEPTH.

The temperature of the water at St. Augustine was found to increase with the depth. The temperature of the water in the Ponce de Leon well, at the depth of 35 feet, is reported as 62 degrees F. At approximately 100 feet the temperature was 72 degrees F. At 170 feet the temperature was 74 degrees F. The increased flow obtained at 177 feet showed a temperature of 76 degrees F. At 520 feet the temperature of the water in the pipe was found to be 79 degrees F. At 1,110 feet the temperature was 80 degrees F. Between 1,170 and 1,225 feet the water taken from the sand pump showed a temperature of 85 degrees F. Water taken from the sand pump, between 1,340 and 1,390 feet, showed a temperature of 86 degrees F.

This record of the Ponce de Leon well, at St. Augustine, is supplemented by the record from the new city well at Jacksonville. In the Jacksonville well the following temperatures were recorded: At a depth of 498 feet, the temperature of the water flowing from the pipe was 71 degrees F. At 635 feet the temperature was 74 degrees F. At 900 feet the temperature still registered 74 degrees F. These measurements made, as the water escapes from the pipe, are necessarily approximate measurements. Not only does the water lose in temperature in moving to the mouth of the pipe, but it mingles with the higher and colder waters entering the pipe, which necessarily equalizes the temperature of the whole. They show, however, increase of temperature with increase of depth.

TABLE SHOWING PROGRESSIVE LOSS

RECORD OF JACKSONVILLE

Number of Well	Size of Well, inches	Date When Completed	Flow of Well When Completed. Gallons in 24 Hours.	1886	1888	1889	1891 May 30	1892 Nov. 1	1893 Jan. 1	1894 Jan. 1	1895
1	6	Nov. 1885	864,000	864,000	799,860	568,073	309,096	264,384	243,000	221,616	200,232
4	12	Dec. 1896	1,354,320								
6	10	April 1901	2,095,639								
7	10	Aug. 1904	651,500								
2	6	Mch. 1886	1,296,000	1,296,000	1,167,360	808,485	458,784	412,128	381,024	332,424	309,096
3	10	Feb. 1889	3,360,052			3,360,652	1,995,840	1,829,952	1,752,192	1,440,152	1,347,840
5	8	April 1899	590,676								
Total Flow				2,160,000	1,967,040	4,737,210	2,763,720	2.506,464	2,376,216	1,994,192	1,857,168
Loss in Flow					192,960	590,482	1,973,490	257,256	130,248	382,024	137,024
Gain by New Well						2,770,170					

LOSS OF HEAD AND REDUCTION IN FLOW.

Exact measurements of loss of head and reduction in flow in artesian wells are usually difficult to obtain. In the case of the Jacksonville city water supply, fortunately, measurements of flow have been taken at intervals from the time the first wells were put down in 1885 to the present time. These measurements kept through a period of 24 years afford records of especial interest and value. The following table of flow was supplied by Capt. R. N. Ellis, Superintendent of the Jacksonville city water supply. Two basins are used to receive the flow known as the north basin and the south basin. The wells are grouped in the table according to the basin into which they flow. The wells are

OF FLOW OF ARTESIAN WELLS.

CITY WELLS, 1885-1904.

1896	1897	1898	1899 April	1900	1901	1902 Jan.	1902 Nov. 29	1903	1904 April 1	1904 Oct. 26
188,568	...	...	208,640	207,360	191,805	...	...	...	...	...
1,354,320	1,108,080	881,280	662,640	602,640	419,902	2,287,440	1,710,720	1,710,720	1,684,800	1,684,800
...	...	...	...	...	1,883,093	...	...	...	...	...
...	...	...	...	...	...	...	...	...	...	Aug. 1 601,500
...	...	...	...	...	...	...	...	...	...	...
...	...	...	...	...	...	...	...	...	...	...
285,693	...	...	...	...	...	...	...	...	...	...
1,093,456	1,368,576	1,368,576	1,322,220	1,829,947	1,441,147	1,418,907	1,368,576	1,368,576	1,347,840	1,099,080
...	...	...	590,676	...	...	...	...	...	...	...
...	...	...	...	...	...	...	...	...	...	...
...	...	...	...	...	...	...	...	...	...	...
2,922,037	2,476,656	2,249,876	2,784,176	2,639,947	3,935,947	3,706,347	3,079,296	3,079,296	3,032,640	3,385,380
289,451	445,381	226,800	56,356	144,529	587,093	229,600	627,057	...	46,656	352,740
1,064,869	...	...	534,320	...	1,296,000	...	...	...	...	248,760

numbered chronologically in the order of the date when completed.

This table shows conclusively that, although the rate of flow is variable for different wells and for the same wells at different periods, yet in this group of wells there is a continuous and progressive loss of flow. That the same is true of other wells throughout this area, there can be no reasonable doubt. Those who give no special attention to their wells suppose, as a rule, that the flow remains unaffected indefinitely. Many other well owners, however, have observed this loss in flow with succeeding years. The reduced flow is best observed near the margin of the flowing area in wells located on somewhat elevated ground. Many of the wells from which the water will flow only a few feet above the surface when first drilled may, in time, cease to flow. In these cases the pressure which originally caused the flow having been partly relieved, the water no longer rises above the surface of the ground.

Exhaustion and ultimate failure of an artesian reservoir is not unknown. It is, probably, true that, in nearly all artesian sections, the original pressure gradient in the water-bearing rock is appreciably lowered by the drafts made upon the subterranean supply, with a consequent actual decrease in the capacity of the wells. In this connection, Professor C. S. Slichter states:* "It must be kept well in mind that there is a limit to the amount of water that can be withdrawn from an artesian basin. There is no such thing as an inexhaustible supply in this connection. The amount of water available is limited on the one hand by the amount of rainfall upon the catchment area, and the facility with which the rainfall can obtain entrance to the porous stratum and, on the other hand, by the capacity of the water-bearing rock to transmit the water over long distances and diminution through leakage and seepage. These two limiting conditions are usually of sufficient magnitude to render the overdrawing of the supply a practical and present danger, which should be constantly kept in mind."

With regard to the artesian basin at Denver, Colorado, the

*U. S. Geol. Surv., Water Supply Paper, No. 67, p. 94, 95, 1902.

failure of which was unusually rapid, Slichter says: "This basin was discovered in 1884, and in a few years about 400 wells had been drilled within an area extending a distance of 40 miles, along South Platte River, in a strip about 5 miles wide on both sides of the stream. Most of the wells were within the limits of the city itself. Many of the wells had a good pressure and strong flow when first constructed. In 1886 it was not thought that any general decrease in the flow of the wells could be detected. Between 1888 and 1890, however, a continuous decrease in the flow of the city wells took place, and by the end of the latter year all but six of the city wells had to be pumped, while numerous wells in the basin were permanently abandoned."

CAUSE OF THE LOSS OF FLOW.

The loss of flow may be due to several causes. It is frequently the case that the life of an artesian well is limited. The escape of water through the well relieves the pressure, which results in a reduced flow. In some instances, pressure has so far been relieved that wells have ceased to flow entirely. This may be regarded as a natural and unavoidable loss of flow.

The second cause of reduced flow, which may have affected the Jacksonville and other wells, is interference of wells. Numerous instances are on record where one artesian well has affected surrounding wells.

A third possible cause is clogging of the wells through accumulation of sand or other material in the pipes, or in the formations through which the water comes. In addition to the accumulation of sand, it is not impossible that the porosity of the formation immediately around the well may have been more or less affected by chemical deposition since the well was drilled. It seems probable, however, that the clogging of the pores of the rock is more likely to be caused by material mechanically transported than by chemical deposition.

Improper casing is likewise a frequent cause of failure. It is frequently the case that an insufficient length of casing is used in the well. In such cases the sand gains entrance, or the well caves below the casing, clogging or partly clogging the opening, thereby reducing or entirely stopping the flow.

NECESSITY OF GUARDING AGAINST WASTE OF ARTESIAN WATER.

The records that have been given above indicate clearly that useless waste of water should not be permitted. An artesian well draws not on an inexhaustible supply of water from some remote source, but draws upon a relatively local supply which is appreciably affected by continued use. A well permitted to flow uninterruptedly draws not only on the supply of the land on which it is located, but affects also the supply of the adjacent land. A State, a community, or an individual that permits the useless and reckless waste of artesian water will ultimately find a most valuable asset impaired by extravagance, and possibly no longer adequate.

It is urged by some well owners that to cut off a well, or to stop the flow when not in use is unsafe as sand or other material may get into and clog the well. The flow of the well can be reduced to one-third or one-fourth its normal volume and the danger from the accumulation of sand, when there is such danger, guarded against. Moreover, where wells are cased, as they should be to the Vicksburg Limestone, it is doubtful if there is danger of clogging and reducing or stopping the flow. A law restricting the waste of artesian water is urgently recommended.

SIMPLE METHOD OF DETERMINING FLOW OF ARTESIAN WELLS.

A simple method for measuring approximately the flow from an artesian well has been devised by Professor J. E. Todd, formerly State Geologist of South Dakota. The following is Professor Todd's method in full:

"It is often desirable to know the amount of water delivered by an artesian well. Frequently a contract calls for a certain amount. It is also well to know whether the flow is diminishing and how much.

"When a well is small, its flow may be measured easily with a watch and a gallon measure, or a keg or a barrel of known capacity, but for wells flowing over twenty or thirty gallons a minute, it is not so easy to determine with accuracy.

"If the well is large it may be measured with a weir, but that is constructed only with considerable trouble. If the water runs in a sluice or ditch of uniform width, its cross section may be estimated and its velocity taken. This method, however, is not very accurate. The following are methods which give fairly accurate results with little trouble and in short time. All that is necessary for the purpose is that the water be discharged through a pipe of uniform diameter, a foot rule, still air, and care in taking measurements.

"Two methods are proposed, one for pipes discharging vertically, which is particularly applicable before the well is permanently finished, and one for horizontal discharge, which is the most frequent way of finishing a well. For the measuring a vertical flow we have extended a method which was first used by Mr. P. E. Manchester, C. E., of Chamberlain, who published a table adapted to large wells, in the Chamberlain Register, December, 1895.

"The table below is adapted to wells of moderate size as well as to larger. In case a well is found of other diameter than that given in the table, its discharge may be obtained without much difficulty from the table by remembering that other things being equal the discharge varies as the square of the diameter of the pipe. If, for example, the pipe is one-half inch in diameter its discharge will be one-fourth of that of a pipe one inch in diameter, whose stream reaches the same height, so also a pipe eight inches in diameter may be obtained by multiplying that of the four-inch pipe by four.

"In the first case the inside diameter of the pipe may be measured, then the distance from the end of the pipe to the highest point of the dome of water above, in a strictly vertical direction—*a* to *b* in the diagram. Then these distances may be found in the table and the corresponding figure will give the number of gallons discharged per minute. The blowing of the wind need not interfere in this case as long as the measurements are taken vertically.

"The method for determining the discharge of horizontal pipes requires a little more care. First, measure the diameter of the pipe as before, then the vertical distance from the middle of the opening of the pipe, or some convenient point corresponding to it on the side of the pipe, vertically downward six inches—*a* to

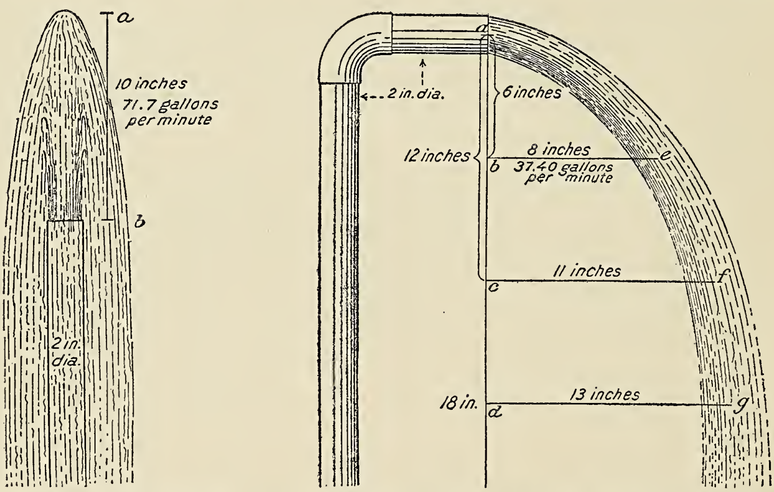

Fig. 5.—Illustrating method of measuring the flow of an artesian well from horizontal and vertical pipes. After Todd.

b, then from this point *strictly horizontally* to the center of the stream— *b* to *e*. With these data, the flow in gallons per minute may be obtained from the table. It will be readily seen that a slight error may make much difference in the discharge. Care must be taken to measure horizontally and also to the middle of the stream.

"Because of this difficulty, it is desirable to check the first determination by a second. For this purpose, columns are given in the tables for corresponding measurements twelve inches below the center of the pipe. Of course, the discharge from the same pipe must be the same in measurements of the same stream. In this case, the occurrence of wind, blowing either with or against the water, may vitiate results to an indefinite amount, therefore measurements should be taken while the air is still.

"The flow of pipes of diameters not given in the Table II, may be easily obtained for corresponding measurements, as follows: For ½ inch, multiply discharge of 1-inch pipe by .25; for ¾-inch, by .56; for 1¼-inch, by 1.56; for 1½-inch, by 2.25. For 3-inch, multiply 2-inch pipe by 2.25; for 4-inch, by 4; for 5-inch, by 6.25; for 6-inch, by 9; for 8-inch, by 16.

TABLES FOR DETERMINING YIELD OF ARTESIAN WELLS.

I. Flow from Vertical Pipes

Height of Jet.	Discharge in Gallons per Minute from Respective Pipes of Diameter given in Inches.				
	1	1¼	1½	2	3
In.					
½	3.96	6.2	8.91	15.8	30.6
1	5.60	8.7	12.6	22.4	51.4
2	7.99	12.5	18.0	32.0	71.9
3	9.81	15.3	22.1	39.2	88.3
4	11.33	17.7	25.5	45.3	102.0
5	12.68	19.8	28.5	50.7	113.8
6	13.88	21.7	31.2	55.5	124.9
7	14.96	23.6	33.7	59.8	134.9
8	16.00	25.1	36.0	64.0	144.1
9	17.01	26.6	38.3	68.0	153.1
10	17.93	28.1	40.3	71.6	161.3
11	18.80	29.5	42.3	75.2	169.3
12	19.65	30.7	44.2	78.6	176.9
13	20.46	31.8	45.9	81.8	184.1
14	21.22	33.0	47.6	84.9	190.9
15	21.95	34.2	49.3	87.8	197.5
16	22.67	35.2	50.9	90.7	203.9
17	23.37	36.3	52.5	93.5	210.3
18	24.06	37.5	54.1	96.2	216.5
19	24.72	38.6	55.6	98.9	222.5
20	25.37	39.6	57.0	101.6	228.5
21	26.02	40.6	58.4	104.2	234.3
22	26.66	41.6	59.9	106.7	240.0
23	27.28	42.6	61.4	109.2	245.6
24	27.90	43.5	62.8	111.6	251.1
25	28.49	44.4	64.1	114.0	256.4
26	29.05	45.3	65.3	116.2	261.4
27	29.59	46.1	66.4	118.2	266.1
28	30.08	46.9	67.5	120.3	270.4
29	30.55	47.5	68.5	121.9	274.1
30	30.94	48.2	69.4	123.4	277.6
36	34.1	53.2	76.7	136.3	306.6
48	39.1	61.0	88.0	156.5	352.1
60	43.8	68.4	98.6	175.2	394.3
72	48.2	75.2	108.0	192.9	434.0
84	51.9	81.0	116.8	207.6	467.0
96	55.6	86.7	125.0	222.2	500.0
108	58.9	92.0	132.6	235.9	530.8
120	62.2	98.0	139.9	248.7	559.5
132	65.1	102.6	146.5	260.4	585.9
144	68.0	106.4	153.1	272.2	612.5

II. Flow from Horizontal Pipes

Horizontal Length of Jet.	Flow in Gallons per Minute for Pipes.			
	1 inch in Diam.		2 inch in Diam.	
	6 in. level.	12 in. level.	6 in. level.	12 in. level.
In.				
6	7.01	4.95	27.71	19.63
7	8.18	5.77	32.33	22.90
8	9.35	6.60	36.94	26.18
9	10.51	7.42	41.56	29.45
10	11.68	8.25	46.18	32.72
11	12.85	9.08	50.80	35.99
12	14.02	9.91	55.42	39.26
13	15.19	10.73	60.03	42.51
14	16.36	11.56	64.65	45.81
15	17.53	12.38	69.27	49.08
16	18.70	13.21	73.89	52.35
17	19.87	14.04	78.51	55.62
18	21.04	14.86	83.12	58.90
19	22.21	15.69	87.74	62.17
20	23.37	16.51	92.36	65.44
21	24.54	17.34	96.98	68.71
22	25.71	18.17	101.60	71.98
23	26.88	18.99	106.21	75.26
24	28.04	19.82	110.83	78.53
25	29.11	20.64	115.45	81.80
26	30.38	21.47	120.07	85.07
27	31.55	22.29	124.69	88.34
28	32.72	23.12	129.30	91.62
29	33.89	23.95	133.92	94.89
30	35.06	24.77	138.54	98.16
31	36.23	25.59	143.16	101.43
32	37.40	26.42	147.78	104.70
33	38.57	27.25	152.39	107.98
34	39.64	28.08	157.01	111.25
35	40.45	28.64	161.63	114.52
36	41.60	59.46	166.25	117.19
	Continue by adding for each inch:			
	1.15	.82	4.62	3.27

"In both these tables it has not been thought necessary to make any allowance for the resistance of the atmosphere. Doubtless, when the velocity of the stream is great, the resistance is considerable; but as the pressure checks the flow, and our object is simply to measure the amount of flow, it need not be taken into consideration. In case pipes are found of diameters not corresponding to the table, the same rule may be applied as in the first case.

"Whenever fractions occur in the height or horizontal distance of the stream, the number of gallons may be obtained by dividing the difference between the readings in the table for the nearest whole numbers, according to the size of the fraction. For example, if the distance from the top of the pipe to the top of the stream, in the first case, is nine and one-third inches, one-third of the difference between the readings in the table for nine and ten inches must be added to the former to give the right result. In case one measures the flow of his well according to both methods, he may think that they should correspond, but such is not the case. In the vertical discharge, as there is less friction, the flow will be larger, so also difference will be found according to the length of horizontal pipe used in the second case. The longer the pipe, the more friction and less the flow.

"As pipes are occasionally at an angle, it is well to know that the second method may be applied to them, if the first measurement is taken strictly *vertically* from the center of the opening, and the second from that point *parallel with the axis* of the pipe to the center of the stream as before. The measurements may then be read from the table as before.

"This method is also applicable to measuring the discharges of different pipes when water is distributed about a farm or in a city.

"Pipes which have been cut in the usual way are frequently diminished in diameter by the incurving of the edge of the pipe. This will diminish the flow, but how much can only be roughly estimated. It will be greater than that of a straight pipe having the exact diameter of the opening as reduced."

THE AREAS OF ARTESIAN FLOW IN FLORIDA.

The accompanying map indicates, in a general way, the flowing and non-flowing areas of the State. In using such general maps it should be borne in mind that artesian water depends primarily upon the structure of the underlying formations, and these are subject to variations of which there may be no surface indications. Moreover, local elevations which affect flow can not be indicated on a small scale map. Thus while the map indicates approximately the limits of flow, the exact limits can be determined in most cases only by drilling.

The shading on the map indicates those parts of the State in which flowing wells have been obtained, or may be expected. There are, as will be seen, three principal areas of flow as follows: the Atlantic Coast area, the Southern Gulf Coast area and the Western Gulf Coast area.

THE ATLANTIC COAST AREA.

The Atlantic Coast area includes much of Nassau and Duval Counties, and, with the exception of local elevated areas, all of St. Johns County; it follows the valley of the St. Johns River almost if not quite to the head waters, while a narrow strip reaches south along the Atlantic Coast for 250 to 300 miles. The artesian water-bearing formation dips in passing to the south, being reached at Palm Beach at the depth of about 1,000 feet. In addition to its increased depth the water at Palm Beach was found to be too salty to be used for household purposes. Between Palm Beach and Key West no wells have been drilled deep enough to reach this formation. The deep well drilled on Key Vaca by the Florida East Coast Railway terminated at 700 feet in quartz sands, with sandstones and clay in streaks, not having reached the Vicksburg Limestone.*

At Key West two wells have been drilled to the Vicksburg, which is reached at that locality at a depth of about 700 feet.

The first of these wells, drilled in 1895, is reported to have

*Florida Geol. Survey, Second Annual Report, p. 205, 1909.

reached a depth of 2,000 feet. The well was non-flowing and the water salty. No adequate record of this well was kept, and it is not known to what depth the well was cased, nor whether or not there was any attempt made to drill beyond and case off the salty water. The second well was drilled, in 1909-10, by S. O. Johnson and reached a total depth of 1010 feet. This well is cased about 150 feet. It is non-flowing and salty. Two samples of water from this well have been received from Mr. Johnson. One is said to have been taken from the water near the top of the well; the other from near the bottom of the well. The first of these samples contains chlorine 2,340 parts per million parts water. The sample said to have come from the bottom of the well contains 1358 parts chlorine per million parts water.

THE SOUTHERN GULF COAST AREA.

Flowing wells have been obtained in areas of low elevation at Tampa, St. Petersburg and elsewhere, along the Gulf Coast for some distance north of St. Petersburg. It is only near the sea level in this northward extent of the area that a flow is to be expected. In Manatee County, along the Manatee River, strong flowing wells have been obtained; some of them having a pressure of eight or more pounds. The wells in this county are used extensively for irrigation. In DeSoto County flowing wells occur at Punta Gorda, and along Peace Creek into Polk County. Some of the wells at Punta Gorda have a head of about fifty feet. In Lee County flowing wells have been obtained at Ft. Myers, along the Caloosahatchee River to Labelle, and in the interior southeast of Ft. Myers. In the well of A. P. Miller, of Ft. Myers, having a depth of 535 feet the water was found to be under a pressure of 17 pounds, giving it a head of 39 feet above the surface. The southward extent of this flowing area has not been determined. Approaching the southern limit the amount of salt in the water increases, certain of the wells toward the southern part of Lee County becoming too salty for use. The Vicksburg Limestone is probably the water bearing formation in Southern as in Eastern Florida.

Whether or not flowing wells can be obtained in the Everglades, east and south of Lake Okeechobee, has not been determined as no wells have been drilled in this part of the State. While definite information is lacking, it is considered probable that flowing wells will be obtained within the Everglades; particularly toward the western side. Subsequent records may show that the Atlantic Coast and Gulf Coast flowing areas are connected by way of the Everglades and around Lake Okeechobee.

While the northern limit of the Southern Gulf Coast area has been given as the Pinellas Peninsula, from recent well records it seems probable that a flow may be obtained north of this limit, and possibly entirely around the Gulf Coast. Two wells have reached this deeper flow, one at Crystal River, in Citrus County, and one at Perry, in Taylor County. The well in Taylor County reached a depth of 1,199 feet. The total dissolved solids in this water, as shown by analysis made by the State Chemist, is 5,650 parts per million parts water. The chlorine alone amounts to 590 parts per million parts water. The water is reported to have medicinal qualities. The well in Citrus County reached a depth of 1,900 feet. The following is an analysis of the water from this well made for the State Survey by the State Chemist in 1907:

Ingredients.	Parts per million.
Calcium oxide (CaO)	1,385.0
Magnesium oxide (MgO)	480.6
Sulphate (SO_4)	2,684.0
Chlorine (Cl)	903.9
Silica (SiO_2)	30.0
Total solids	6,474.0

WESTERN GULF COAST AREA.

The Western Gulf Coast area begins at Carrabelle, in Franklin County, and extends to the western line of the State. The flow along this westward extension of the State is evidently due to the rapid southward dip of the formations exposed along the northern line of the State, and in southern Georgia and Alabama. Both the Oligocene and the Miocene formations exposed along the Ocklocknee, Apalachicola and other rivers crossing Western Florida, from north to south, dip and pass from view in approaching the coast. It is doubtless from these or from later formations that the flowing water of this section is obtained. At Apalachicola the artesian water has a head bringing it only a few feet above the surface. The wells at this locality vary in depth from 350 to 620 feet. A number of deep wells have been drilled along St. Andrews Bay, in Washington County. The artesian water in this section will rise several feet above sea level. One of the city wells at Panama City is reported to flow 13.02 feet above the surface, or about 15 feet above sea level. A second city well, located on higher ground, is non-flowing although drilled to a depth of 630 feet.

Several wells, ranging in depth from 181 to 210 feet, have been drilled along Choctawhatchee Bay, in Walton County. A strong flow is obtained in this section. A well 210 feet deep, 3 miles south of Freeport, owned by the Baker-Wingfield Company, had a pressure when measured September 22, 1910, of 15 pounds, equivalent to a head of 34.65 feet above surface. Another well near by, 189 feet deep, belonging to the Choctawhatchee Lumber Company, had a pressure on the same date of 12½ pounds, equivalent to a head of 28.87 feet above the surface. Both of these wells are located on low ground, near sea level. A well, 181 feet deep, belonging to Messrs. J. C. Blackburn and J. N. McLain, located on higher ground, in the town of Freeport, had a pressure of 6½ pounds, equivalent to a head above the surface of 15 feet.

At Pensacola, and generally along the coast in Escambia County, good flowing wells are obtained. A well at Northrop, 1,030 feet deep, belonging to Stephen Lee, is reported to have a head of 60 feet above the surface. At Muscogee a well, 175 feet deep, belonging to the Southern States Lumber Company, is reported to have a head of 38 feet above the surface. A well on Bayou Grande, near Pensacola, belonging to Messrs. Stephen and W. F. Lee, is reported to be 1,000 feet deep and to have a pressure of 24 pounds, equivalent to a head of 55.44 feet above the surface. The temperature of the water is given as 92 degrees F. and the flow as 225,000 gallons per day.

Among the isolated flowing wells in the State two at Graceville, in Jackson County, are of especial interest. The first well at this locality was drilled some years ago by Mr. F. J. White. When first drilled, Mr. White says, the well flowed slightly above the surface, but soon afterwards ceased to flow. On the day following the great San Francisco earthquake of 1906, however, the well was observed to be flowing, and it has continued flowing from that date. The second well at Graceville was drilled in 1910 for the city by Mr. C. D. Williams. This well is 287 feet deep. The water has a head sufficient to rise about 2 feet above the surface. The well is eight inches in diameter for 161 feet, and six inches to the bottom. The flow is estimated at 20 gallons per minutes. Although no well samples have been obtained it seems probable from the driller's notes that the wells at this locality pass through the Vicksburg Limestone and enter an underlying formation.

A well drilled as a test well for oil about six miles south of Chipley, in Washington County, is said to have flowed at a depth of about 1,250 feet.

During 1912 flowing wells were obtained at and near Ponce de Leon, in Holmes County. These wells vary in depth from 200 to 213 feet. The water rises 5 to 6 feet above the surface. After passing through about 100 to 130 feet of sands, sandstone, and blue marl, limestone is reached from which the artesian water is obtained. The following is a log of one of these wells drilled for the town of Ponce de Leon. This well flows 65 gallons per minute and has a head of six feet above the surface. The record is by the drillers, M. J. Gray & Company.

	Feet.
Coarse yellow sand	0- 10
White sandy clay	10- 39
Yellow sand	39- 43
Sandstone	43- 60
Blue marl	60-130
White limestone	130-203

DISCUSSION BY COUNTIES

NASSAU COUNTY.

LOCATION AND SURFACE FEATURES.

Nassau County lies bordering the Atlantic Ocean in extreme northeastern Florida. The St. Mary's River, taking its source in Okefenokee and other swamps along the Florida-Georgia boundary line, after flowing south and southeast until approximately on a parallel with the mouth of the St. Johns River, turns abruptly and flows directly north for a distance of 30 miles. From this point the river flows slightly south of east to the Atlantic. Nassau County occupies the northern and western part of the peninsula-like extension of Florida formed by the northward bend of this river, the northern and western boundaries of the county being formed by the river.

The surface is in general level or rolling. The highest elevation found within the county is near the western side, where a flat-topped ridge extends north and south, lying only a few miles distant from the St. Marys river. Towns lying on this ridge are as follows: Boulogne, elevation 70 feet; Hilliard, elevation 66 feet; Crawford, elevation 85 feet; Kent, elevation 70 feet. Some places on this ridge may exceed 100 feet in elevation. Aside from this ridge no points are recorded in Nassau County having an elevation reaching 50 feet.

That part of the county east of this ridge, including fully two thirds of the county, is lower in elevation and is prevailingly of the open flatwoods type of soil.

WATER-BEARING FORMATIONS.

Up to the present time the identification of the age and character of the different strata encountered in drilling in Nassau County has been difficult owing to the fact that no complete set of well samples from any well in this county has been obtained.

From an incomplete set of samples from the J. R. Wilson well at Callahan, kindly saved by the driller, Mr. H. C. Russell, it is seen that limestone was encountered at a depth of from 212 to 255 feet. The limestone was very hard and massive and no fossils were observed in the sample. Just above this stratum of rock is reported a twelve foot layer of sand and black pebbles, and in fact these black pebbles were seen imbedded in the underlying limestone. Water is reported to flow from this depth. Below this stratum of rock 100 feet of blue marl with inclusions of several thin strata of shells is reported. In a sample from this stratum the sand was gray in color and the grains were round in outline. The black pebbles, smaller than those in the above stratum, occur also at this depth but may have dropped down from above. At a depth of from 355 to 364 feet a very hard rock is reported, but no further notes were made of this and no samples kept. From 364 to 418 feet indurated gray sand and blue marl are reported and immediately below this is encountered a rock, apparently limestone, in which the water is reported to increase in head and in volume of flow as each hard layer is penetrated. From all information that could be gathered it seems probable that this limestone is the Vicksburg.

Exposures of clayey, impure limestones are found along the St. Marys River, at High Bluff, about six miles and at Saw Pit Bluff, about two miles above the Atlantic Coast Line Railroad bridge; also at Chalk Bluff and at Orange Bluff, near King's Ferry.

The section at Saw Pit Bluff is as follows:

	Feet.
Sticky blue clay with some soil	5
Impure limestone	5

At Chalk Bluff, about two miles above King's Ferry, the following section was observed:

	Feet.
Sticky blue clay with some soil at top	2
Calcareous clay resembling fuller's earth	2
White chalky material	1
Clay resembling fuller's earth	2

Going down the river from Kings Ferry no rock or shell exposures are seen until Reeds Bluff, near Crandall, is reached. This bluff, which lies on the Florida side of the St. Mary's River, is semi-circular in shape and is about three-fourths of a mile long. The following section was made near the middle of this bluff:

	Feet.
Incoherent pale yellow sands	20-40
Oyster shell reef imbedded in fine, sandy clay	10-15
Blue sands and sandy clays oxidizing yellow	10-20

The oyster reef in this section rests irregularly upon the underlying sands, the base of the reef being 10 to 20 feet above low tide. The oyster reef extends about two hundred feet along the face of the bluff.

The unusual thickness of the loose yellow sands at the top of the bluff is due to the fact that the upward moving currents of air carry sand as it is loosened along the face of the bluff to the top, where it accumulates as a sand dune.

Roses Bluff, also on the Florida side of the river, about two miles below Crandall, is semi-circular in shape and is fully two miles long. The following section was made near the middle of this bluff:

	Feet.
Dark colored sand and soil	4
Dark iron-stained sand (hardpan)	7
Ochre yellow sand	8
Sand with some clay	5
Sandy shell bearing marl, blue, oxidizing yellow	4
Sloping to water's edge at low tide	5
	33

AREA OF ARTESIAN FLOW IN NASSAU COUNTY.

That part of Nassau County in which flowing wells can be obtained is indicated on the accompanying map by shading. Flowing wells may be obtained as shown by the map, Fig. 6, in approximately the eastern two-thirds of the county. A relatively small area, including the ridge already mentioned, lying near the western part of the county and extending north and south, parallel with the St. Marys River, stands too high to obtain flowing wells. In this section, however, non-flowing artesian water may be obtained which will stand within a few feet of the surface.

LOCAL DETAILS.

CALLAHAN.

There are several flowing wells at and in the vicinity of Callahan, varying from 410 to 489.7 feet in depth. Three different water-bearing strata are reported in all the deeper wells at Callahan, the first occurring at about 50, the second at from 160 to 200, and the third at 400 to 425 feet. The water from the first stratum does not flow, but rises to within 6 to 10 feet of the surface, and is found in a shell formation. The water from the other two strata rises from 28 to 48 feet above the surface.

The first deep or artesian well at Callahan was drilled in 1904. This well was put down at the instance of several of the residents, by D. C. Stafford. It is a three-inch well and reported to be about 400 feet deep. The main source of domestic water supply at Callahan until the completion of this well had been shallow wells. These wells, which vary in depth from 25 to 60 feet, obtain their water supply chiefly from the underlying sands and clays. The water from these sands and clays, while soft and very desirable for domestic purposes, seemed to be contaminated by surface impurities as was indicated by the many cases of typhoid fever. Several of the citizens suspected that this sickness was due to the drinking of this surface water and their combined efforts resulted in the completion of this first artesian well. Since the completion of this and other deep wells the healthfulness of the locality has greatly improved.

A three-inch well drilled for J. R. Wilson in 1908 by H. C. Russell reached a total depth of 412 feet. It is reported cased 188 feet and has a pressure of 21 pounds, as shown by the pressure gauge February 3, 1910, or a head of 48.51 feet above the surface. The elevation of the depot at Callahan, as given by the Atlantic Coast Line Railroad, is 20 feet above sea. The location of the above well is approximately 2 feet lower than the depot, or about 18 feet above sea, thus making a total head of 66.51 feet above sea.

Another three-inch well was drilled by H. C. Russell for T. R. Wells & Brother. This well reached a total depth of 420 feet and is cased 192 feet. The pressure of this well, as shown by the pressure gauge, February 3, 1910, was 19 pounds or a head of 43.89 feet above the surface. The elevation of the well is approximately 3 feet higher than the depot or 5 feet higher than the Wilson well. The head would thus be 66.89 feet above sea or about the same as that of the Wilson well.

In February, 1910, H. C. Russell completed a second well for J. R. Wilson. This well is located about three-fourths of a mile east of Callahan. It is a three-inch well and reaches a total depth of 489.7 feet. 212 feet of 3-inch casing was used. The first flow in this well was encountered at 200 feet, the second at 275 feet and the third at 425 feet. Although the drilling in this well was continued to a depth of 489.7 feet it is reported that no increase of water was obtained below 460 feet. The following is a log of this well as constructed from the notes kept by the driller and from samples of the drillings saved by him:

	Feet.
Sand	0- 2
Red clay	2- 10
Blue clay and sand	10- 45
Shell deposit, including a thin layer of hard rock at 52 ft. Water above and below this rock comes to within ten feet of surface	45- 60
Blue marl with occasional beds of shells 3 or 4 feet thick and containing black to dark gray water-worn pebbles.	60-200
Medium coarse sand with numerous very small black grains or pebbles. A flow was obtained at this depth	200-212
Limestone (sample)	212-255
Blue marl and fine sands with inclusions of several thin strata of shell. (Sample)	255-355
Very hard rock	355-364
Indurated gray sand and blue marl	364-418
Rock, hard and soft strata with increase of flow upon penetrating each hard stratum. No increase reported below 460 feet. Driller reports the rock to be closer grained from 460 to 489.7 feet, and not containing much water.	418-489.7

CRANDALL.

Two wells are reported at Crandall, both of which are owned by Messrs. L. A. Davis & Brother. These wells are three inches in diameter and both are reported cased to a depth of 80 feet. One was drilled to a depth of 480 feet; the other to a depth of 450 feet. The water is reported to rise 35 feet above the surface. The water from one of the wells is used for the boiler supply at the sawmill and is said to form a hard scale. The other well is used for general drinking purposes.

EVERGREEN.

Flowing wells are obtained at Evergreen postoffice, a village about four miles distant from Evergreen station on the Seaboard Air Line Railway. A well owned by Mr. L. L. Owens and drilled by Mr. D. C. Stafford in 1909 is about 500 feet deep. It is two inches in diameter and is reported cased 270 feet. The water is reported to rise 25 feet above the surface.

FERNANDINA.

Fernandina, the county seat of Nassau County, is located in the northeastern part of the county, on Amelia Island. This island is thirteen miles long and is from one to three miles wide. The greater portion is low and flat, while other parts are gently undulating. The highest elevation on the island is to be found along the line of sand dunes bordering the ocean. The dune on which the lighthouse is placed reaches an elevation of about 55 feet above the sea.

The first flow of water in and near Fernandina is reported to be encountered at a depth of from 400 to 500 feet after drilling through a considerable thickness of sand and blue to greenish clay or marl. The water at this depth, as indicated by notes obtained from well drillers, comes from a sand stratum confined there by the overlying, very compact, blue to greenish clays.

The second water bearing stratum or chief source of supply is obtained at or about the depth of 600 feet. In the log of the new well at the city water works limestone or what was termed by the driller, Mr. H. Walker, "water rock" was encountered at a depth of 556 feet. This was reported to consist of alternating hard and soft strata and the flow of water to increase with depth as each hard stratum was penetrated.

The first well drilled on Amelia Island was put down for the City of Fernandina by Messrs. Wade and Hampton in 1888. This well is located 5 blocks east of the city postoffice and is eight inches in diameter and was drilled to a total depth of 640 feet. It is reported cased 618 feet. At this depth an abundance of flowing water was obtained but as the well subsequently became filled with sand the flow decreased to such an extent that in order to get a sufficient amount of water to supply the city pumping had to be resorted to. Later the well was drilled deeper to a depth of 731 feet. The flow, however, is reported not to be as great as it was originally, although the deepening of the well increased the amount of flow to such an extent that the pumping of the water became unnecessary. This well is reported to have had a pressure of 14 pounds when first drilled in 1888. The following record of measurements of the flow of this well were kindly supplied by Mr. R. V. Nolan, superintendent of the City Waterworks.

Date.	Flow of well. Gallons per day.
1890	1,152,000
1902	641,832
1904	495,408
1905	440,564
1907	425,952
1909	408,000

In 1906 a second well was drilled for the city by Mr. H Walker. This well contains 120 feet of 10-inch casing; 356 feet of 8-inch casing; and 455 feet of six-inch casing and is drilled to a total depth of 733 feet. The head of the water in this well as shown by the pressure gauge January 28, 1910, was 14 pounds to the square inch or 32.3 feet above the surface elevation of the well, which is about 29 feet above sea, thus making a total head of 61.3 feet above sea. The flow of this well in 1909 was 672,-000 gallons per day.

The following is a log of the new well at the City Waterworks as given by Mr. H. Walker, the driller:

	Feet.
Sand	0-110
Medium hard rock	110-126
Sand and clay	126-185
Clay	185-400
Sand	400-450
Green clay	450-512
Rock	512-517
Blue clay	517-556
Limestone, termed "bed rock," with alternating hard and soft strata	556-733

A well three and one-fourth miles south of Fernandina owned by the Nassau Truck & Farm Company was drilled by J. W. Wiggins in 1909. This is a six-inch well, 650 feet deep and cased 442 feet. The first hard rock is reported at a depth of 500 feet. The pressure of this well was taken January 14, 1910, and was found to be 20½ pounds or a pressure sufficient to cause the water to rise 47.3 feet above the surface.

The following is a log of this well as constructed from the notes kept and kindly made available by Mr. Walter Schucht, Superintendent of the company:

	Feet.
Muck	0- 3
Hardpan. A small flow just below this	3- 9
Sand	9-100
Blue clay. A good flow of water reported	100-200
Sand	200-400
Coarse sand and black pebbles	400-500
Hard rock	500-630
Limestone, hard and soft strata. Increase of flow upon breaking through each hard stratum	630-650

The following is an analysis of the water drawn from this well January 14, 1910. Analysis made for the State Survey in the office of the State Chemist, A. M. Henry, analyst:

Constituents.	Parts per million.
Silica, (SiO_2)	24.0
Chlorine, (Cl)	30.0
Sulphates, (SO_4)	133.0
Phosphates, (PO_4)	0.0
Carbonates, (CO_3)	0.0
Bicarbonates, (HCO_3)	195.0
Sodium and Potassium (Na & K)	30.0
Magnesium (Mg)	13.0
Calcium (Ca)	55.0
Iron and Alumina, (Fe & Al)	Trace
Loss on Ignition	130.0
Total dissolved solids	500.0

A well just across Amelia River and about two miles southwest of Fernandina was driven by James Jones for L. G. Hirth. The well is 94 feet deep, two inches in diameter and the water stands 7 feet below the surface.

The following is an analysis of the water from this well made by Dr. E. R. Flint, Chemist, University of Florida, Gainesville, Fla.:

Constituents.	Parts per million.
Free Ammonia	None
Albuminoid Ammonia	Slight Trace
Nitrites	Slight Trace
Nitrates	None
Chlorine	20.40
Total Solids	192.01
Organic and Volatile Solids	30.00
Hardness ($CaCO_3$)	54.86
Permanent Hardness	None

HILLIARD.

Hilliard is located in northwestern Nassau County, on the Atlantic Coast Line Railroad, and about eight miles distant from the St. Marys River. No flowing wells have been reported in this part of the county, the elevation being too great. The elevation of the depot at Hilliard as recorded by the Atlantic Coast Line Railroad is 66 feet. Mr. D. W. Griffing has kindly furnished several points of elevation covering the property of the Cornwall Farm Land Company

The only deep well reported at Hilliard is owned by The Cornwall Farm Land Company and was drilled by J. W. Wiggins in 1909. It is an eight-inch well, 648½ feet in depth and cased about 400 feet. The elevation at the well is somewhat above the depot and the water is reported to rise to within 12 feet of the surface. Hard rock was encountered at 300 feet and the principal supply of water is reported as being obtained from the depth of 400 feet. The following is an analysis of the water from this well. Analysis by the Chemical and Engineering Company, 35 Kinzie Street, Chicago, Ill.:

Constituents.	Parts per million.
Organic Matter	37.0
Silica	36.0
Calcium Carbonate (Lime 91. parts per mil.)	151.0
Calcium Sulphate	16.0
Magnesium Sulphate	105.0
Magnesium Chloride	40.8
Sodium Chloride (common salt)	20.3

ITALIA.

One deep well is reported at Italia. This well is now owned by McLeod Bros. & Airth and was drilled in 1905. It is a 2-inch well and reached a total depth of 430+ feet. It is reported cased 40 feet and to have a head of 30 feet above the surface.

KING'S FERRY.

Kings Ferry is located on the St. Marys River, about 30 miles up the river from Fernandina. One deep well owned by W. J. Carlton is reported from Kings Ferry. This well is two inches in diameter and about 400 feet deep and was drilled in 1909 by D. C. Stafford. The pressure of this well could not be ascertained but it furnishes a strong flow and was reported to rise more than 31 feet above the surface in a one-inch pipe.

LESSIE.

A deep well at Lessie, owned by J. R. Wilson & Company and drilled by D. C. Stafford, is reported to have a depth of 450 feet. It is a two-inch well and furnishes an abundant supply of water.

LOFTON.

The well of J. W. Rodgers at Lofton was bored in 1906 and is reported to have a depth of 510 feet. It is two inches in diameter and gives a good flow, but the height to which the water would rise above the surface was not learned The water from the well is used for general domestic purposes and to supply the turpentine still.

DUVAL COUNTY.

LOCATION AND SURFACE FEATURES.

Duval County joins Nassau County on the south, and is separated from it by the Nassau River and its tributary, Thomas Creek. The St. Johns River flows through Duval County. The surface drainage from this county is carried off largely through these rivers and their tributaries.

The surface is in general flat or but slightly rolling. The surface elevation rises gradually from sea level. The highest elevation reached is found in the southwestern part of the county, where the "Trail Ridge" forms part of the boundary. A narrow strip along this part of the county exceeds 100 feet in elevation. With this exception practically all parts of this county lie below the 100-foot contour line, while much of the area lies below the 25-foot contour line.

The elevations in Nassau and Duval Counties have been obtained from various sources. An important line of levels extending from Trout Creek across Nassau and Duval Counties in a southwesterly direction, made during the summer of 1909, in connection with a preliminary survey for a ship canal across Florida, were kindly made available for this purpose in the office of the

United States Engineer at Jacksonville. Similar surveys made by the same office in 1879 supplied elevations from Fernandina

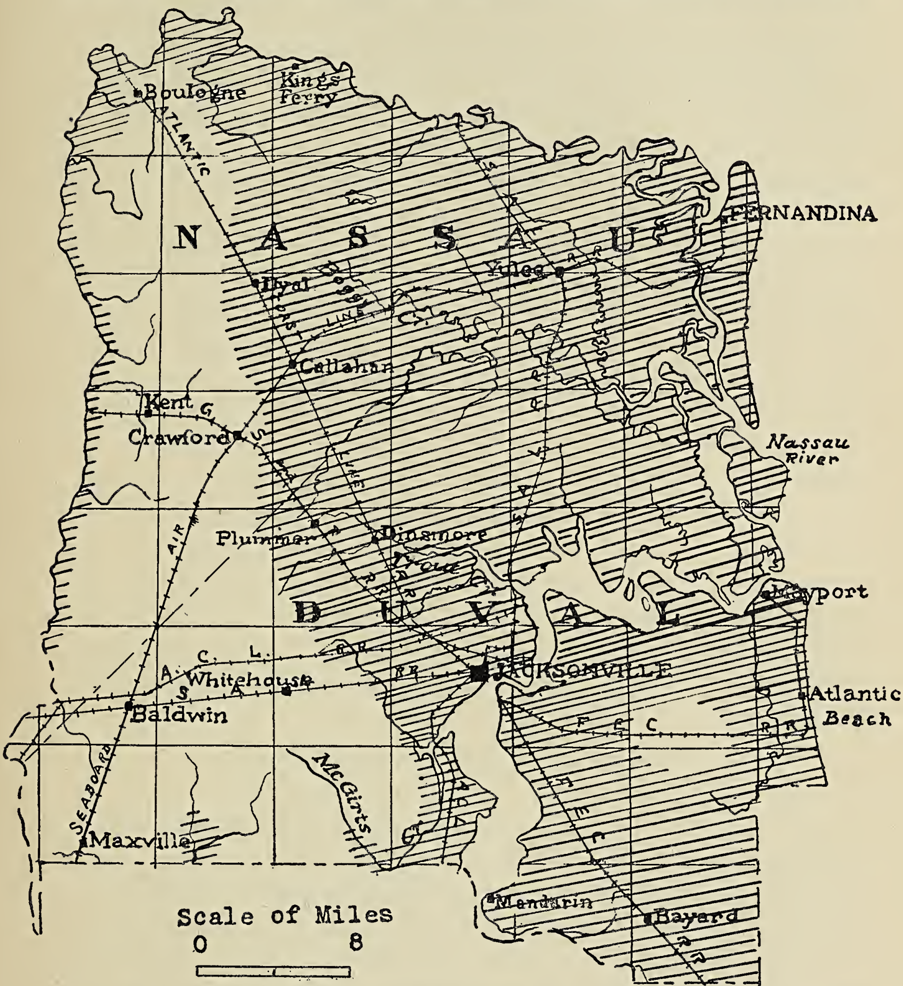

Fig. 6.—Map of flowing area of Nassau and Duval Counties. The area in which flowing wells can be obtained is indicated by shading.

to Maxville and at various points along the St. Marys River.* In addition much information as to elevations has been obtained

*Annual Report of the Chief of Engineers for 1880, pp. 973-1010.

from the profiles of the several railroads crossing this section, particularly the Seaboard Air Line from Jacksonville to Maxville, the Florida East Coast from Jacksonville to Mayport and the Atlantic Coast Line from Jacksonville to the St. Marys River.

From Jacksonville westward the rise in elevation, as shown by the profile of the Seaboard Air Line Railway, is very gradual to a point three miles west of Jacksonville where an elevation of 27 feet is reached. From this summit the elevation drops off slightly, the elevation of Cedar Creek being 17 feet. Beyond Cedar Creek the elevation rises more rapidly. Marietta station is approximately 60 feet above sea. The summit of this rise is reached two miles west of Marietta where the elevation is 94 feet. White House station is 82 feet above sea Beyond McGirts Creek one and one-half miles an elevation of 91 feet is reached. From this point there is a very gradual slope to Baldwin, this latter place being 86 feet above sea. South from Baldwin the contour rises in general, reaching an elevation of 93 feet at Maxville and 100 feet one-half mile beyond the county line.

The line of levels run by United States Engineers extends from Trout Creek, passing just to the south of Brandy Branch station, or Bryceville postoffice. The summit elevation in Nassau and Duval Counties along this line occurs about four miles northeast of Brandy Branch, where an elevation of 90 feet is recorded.

WATER-BEARING FORMATIONS.

The deeper wells in Duval County reach and terminate in the Vicksburg Limestone. This is known to be the case at Jacksonville, at which place the Vicksburg is reached at approximately five hundred feet from the surface. The wells at Jacksonville, the deepest of which reach a total depth of something over a thousand feet, do not, so far as the records show, pass entirely through the Vicksburg.

The formations lying above the Vicksburg are less characteristic lithologically and are not easily differentiated. The surface deposits include both recent and Pleistocene material. During a part of Pleistocene time this section of the State stood at a lower level than at present, permitting the ocean to extend inland some distance beyond the present coast line. Conrad* has re-

*Conrad, T. A., Am. Journ. Sci. (2) 11, 38, 1846.

corded the occurrence of marine shell deposits of post-Pliocene age along the banks of the St. Johns River at an elevation of from ten to fifteen feet above the present high tide. Conrad also reports a similar post-Pliocene deposit about one-half mile from the bank of the river near the ancient village of Hasard. Marl deposits are said to occur near the mouth of the St. Johns River, on the banks of Ft. George Inlet. That the depression of the coast during Pleistocene time was general is indicated by the records from several other localities.

Beneath the Pleistocene, Pliocene deposits probably occur over some parts of the county. The total thickness of the Pleistocene and Pliocene, if both are represented, is, however, not great, as the fossiliferous Miocene limestone was reached at Jacksonville, in the boring at the city well, at a depth of 33 feet.

AREA OF ARTESIAN FLOW IN DUVAL COUNTY.

The area of artesian flow in Duval County is indicated on the accompanying map by shading. As will be observed the flowing area borders the Atlantic coast, Nassau and St. Johns Rivers and extends some distance inland, following each smaller stream and tributary. The wells in western Duval County are non-flowing. A topographic map of this section would assist in determining flowing and non-flowing sections, since the flow is to a large extent correlated with elevation. It is to be borne in mind, however, that artesian water depends primarily upon the structure of the underlying formations and these formations are liable to variations of which there is no surface indication. For this reason, while the map indicates the area of probable flow the exact limits of the area are best determined by drilling.

LOCAL DETAILS.

BALDWIN.

Baldwin is located on the Seaboard Air Line Railway, nineteen miles west of Jacksonville. The elevation is approximately 86 feet above sea. Three wells have been drilled at or near Baldwin. The deepest of these, located at the Atlantic Coast Line Railroad crossing, one-half mile north of Baldwin, is reported to reach a total depth of 580 feet and is cased 511 feet. A second well nearby reaches a depth of 100 feet. A third well located at Baldwin reaches a depth of 92 feet. All of these wells are non-flowing, although the water rises within a few feet of the surface. The distance at which the water stands from the surface in the deep well is not reported beyond the statement that the well is non-flowing.

BAYARD.

Bayard is located on the Florida East Coast Railway, fifteen miles south of Jacksonville. The elevation of this place is approximately 22 feet above sea. Flowing water is obtained at Bayard, one well having been put down for the Carter-Lucas Co. This is a three-inch well, reported to have been drilled to a depth of 280 feet. The water here will rise at least fifteen feet above the surface.

JACKSONVILLE.

The large number of wells occurring at Jacksonville precludes the possibility of listing or describing all. Probably not less than five hundred flowing wells occur in or near this city.

The first flow obtained at Jacksonville, according to the records of the city well, was a light flow from a depth of 487 feet. A large flow, however, is not obtained until the drill enters the Vicksburg limestones, at a depth of about 524 feet. After reaching the Vicksburg the flow increases upon breaking each compact layer. At a depth of 632 feet the flow in the new city well was found to be one million gallons per day. At a depth of 980 feet the same well supplied a flow of two million gallons per day.

The material penetrated in the drilling at Jacksonville, for a depth of about 500 feet, consists largely of clays, sandy clays, and sands with some fossiliferous limestone and some shell deposits. From about 500 to 524 feet the record shows considerable dense hard rock. After penetrating this stratum the limestones of the Vicksburg group are reached.

The water supply for the city of Jacksonville is obtained from artesian wells. At present ten artesian wells are in use. Details as to the depth and construction of these wells will be found in the table of well records Nos. 1 to 10. The log of well No. 6 was given in the Second Annual Report, p. 109. The samples from which this log was made were obtained by Superintendent Ellis by first drilling an eight-inch well, and afterwards reaming it out to a ten-inch well.

The following is the record of the new city well at Jacksonville. Sample of drillings from this well, together with notes on the materials penetrated, were kindly kept by Mr. S. L. Hughes of the Hughes Specialty Well Drilling Company, of Charleston, South Carolina:

Filled ground and sand	0	- 15
Sand with some clay	15	- 33
Sandy limestone, yellowish or light buff in color	33	- 37
Light colored clay marl	37	- 70
Blue sticky clay with black phosphatic pebbles	70	-100
Marls, usually green or olive green in color containing variable amount of sand, and clay. Black phosphatic pebbles together with some shell fragments occur throughout the marl. Occasional thin layers of light colored limestone are reported within this interval. First flow of water at 270 feet 5 gallons per minute	100	-320
Buff clay resembling fuller's earth mixed as seen in the sample, with green sandy marl	320	-340
Greenish and sandy clayey marl	340	-390
Indurated sands or sandstones	390	-396
Greenish sandy marls	396	-415
Light colored limestone	415	-420
Greenish calcareous sandy clay	420	-434
Dark colored hard sand rock	434	-435

Olive green calcareous sandy clay	435 -455
Light sandy marl	455 -455½
Green sandy marl	455½-462
Dark sandy clay	462 -490
Very hard dark or gray sand rock	490 -493
Silicified and very hard shell rock with siliceous phosphatic pebbles. After passing through this rock the flow is increased to 112 gallons per minute, temperature 71 degrees F.	493 -498
Light colored marl	498 -500
Hard rock	500 -506
Light gray sandy calcareous rock with black phosphatic pebbles	506 -510
	Feet.
Light colored fossiliferous limestone (Vicksburg). Upon reaching this formation the flow is increased to 200 gallons per minute. At 625 to 635 feet the harder stratum was drilled through, which flowed 500 gallons per minute, temperature 74 degrees F. At 680 feet the water pressure measured, as shown by the gauge, 12 pounds	510-680
Limestone, prevailing brownish in color, and as a rule harder than above. Occasional thin layers of marl and shell. Slight increase of flow at 780, water pressure at 900 feet 15 pounds; flow about 900 gallons per minute; temperature 74 degrees F.	680-900
Limestone similar in character to above, but as a rule not so hard. Flow at 980 feet, 1,500 to 2,000 gallons per minute	900-980

The Vicksburg Limestone was reached in this well at a depth of about 510 feet. The first 170 feet of the Vicksburg is prevailingly light colored or white and fossiliferous. Below 680 feet the limestone is as a rule brownish in color, compact and harder in texture and not so fossiliferous. The amount of flow, the pressure and the temperature increased as the deeper layers of the Vicksburg Limestone were penetrated.

The formations lying above the Vicksburg Limestone can scarcely be differentiated. The Jacksonville formation, Miocene, is reached at the depth of 33 feet. At about 320 feet some clays resembling fuller's earth were obtained. At from 415 to 420 feet light colored clayey limestones were encountered. With these exceptions the interval from 37 feet to 510 feet consists largely of an olive green sandy marl.

An analysis of the water of the public supply at Jacksonville was made in 1898. Analyst, Albert Leeds, Stevens Institute of Technology. The analysis is as follows:

Constituents.	Grains per U. S. gallon.	Parts per million.
Silica and insoluble matter	0.729	12.497
Alumina	0.047	8.057
Carbonate of lime	3.866	66.274
Sulphate of lime	4.053	69.480
Sulphate of magnesia	2.927	50.177
Sulphate of soda	5.843	100.166
Chlorides of soda	4.811	82.474
Free ammonia	.....	0.143
Albuminoid ammonia	.....	0.044

The following is an analysis of the water from the well of the Florida East Coast Railway, at South Jacksonville. The well is 651 feet deep. The analysis is by the American Water Softener Company, Philadelphia, Pa.

Constituents.	Grains per U. S. gallon.	Parts per million.
Calcium carbonate	.32	5.48
Calcium sulphate	15.00	257.14
Calcium chloride	1.23	21.08
Magnesium carbonate	5.94	101.82
Sodium chloride	0.69	11.82
Free carbon dioxide	0.41	7.02
Iron, aluminum and silica	0.09	1.54
Incrusting solids	22.59	387.26
Non-incrusting solids	0.69	11.82
Total solids	25.90	444.00

The following is a log of this well obtained through Mr. G. A. Miller, as reported by the driller, Mr. H. Walker.

	Feet.
Dark sand	0- 6
Clay	6- 7
White sand	7- 9
Gravel	9- 13

White clay	13- 17
White clay and sand	17- 31
Hard rock, clay and rock	31- 35
Blue clay	35- 50
Rock	50- 56
White clay and sand	56- 89
Sand	89- 90
White clay and sand	90-129
Soft rock	129-130
Blue clay and sand	130-200
Loose sand	200-201
Tough clay and sand	201-310
Sand	310-312
Loose sand	312-355
Clay and sand	355-365
Clay	365-387
Clay and gravel	387-388
Rock	388-396
White clay	396-406
Rock and clay	406-412
Hard rock	412-414
Clay with thin strata of soft rock	414-451
Clay and sand	451-465
Blue clay	465-477
Sand	477-481
Soft sandy rock	481-486
Sand	486-492
Loose sand	492-501
Hard rock	501-510
Soft rock	510-536
Limestone	536-650

MANDARIN.

Mandarin lies within the flowing area which borders the St. Johns River. Several wells have been put down in this section. A well near Mandarin, drilled by H. Walker for J. D. Mead, reached a total depth of 600 feet. This well is cased 377 feet and the water is reported as rising 60 feet above the surface.

MANHATTAN BEACH.

The following is a log of a well drilled at Manhattan Beach by H. VanDorn for the Florida East Coast Railway. This well flows 15,000 gallons per hour through a two-inch pipe. The pressure at the surface is 20.5 pounds. The record has been obtained through Mr. G. A. Miller.

	Feet.
Sand	0- 35
Clay	35- 47
Clay resembling soapstone	47- 90
Clay	90-140
Soft rock	140-155
Clay	155-160
Soft rock	160-170
Sand and clay	170-185
Sand	185-210
Clay	210-275
Rock	275-280
Clay	280-290
Rock	290-292
Sand and clay	292-310
Rock	310-311
Clay	311-320
Sand and clay	320-340
Clay	340-350
Sand	350-357
Clay	357-361
Rock	361-363
Clay	363-369
Rock	369-370
Clay	370-385
Rock	385-387
Sand	387-390
Rock	390-391
Clay	391-395
Rock	395-396
Clay	396-398
Rock	398-404
Water-bearing rock	404-450
Soft rock	450-490
Hard rock	490-520
Water-bearing rock	520-540

Hard and soft rock in thin layers	540-555
Soft rock	555-576
Hard and soft rock in thin layers	576-600

MAXVILLE.

Maxville is located on the Seaboard Air Line Railway, near the southwestern corner of Duval County. The elevation at this point is, according to the profiles of the railroad, about 93 feet above sea. A well drilled at this place in 1902 for Mr. R. V. Douglass is reported to have reached the depth of 650 feet. This well is non-flowing.

MAYPORT.

The following is an analysis of the water of the well of the Florida East Coast Railway at Mayport. The well is 600 feet deep and has a pressure of 22 pounds. Analysis by the American Water Softener Company, Philadelphia, Pa.:

Constituents.	Grains per U. S. gallon.	Parts per million.
Calcium carbonate	3.57	60.20
Calcium sulphate	5.33	91.37
Magnesium carbonate	4.46	76.45
Sodium carbonate	.70	12.00
Sodium chloride	2.45	42.00
Free carbon dioxide	.32	5.48
Iron, aluminum and silica	.33	5.65
Incrusting solids	13.69	234.68
Non-incrusting solids	3.13	53.65
Total solids	18.09	310.11

The following is a log of a well drilled at Mayport by B. S. Partridge for the Florida East Coast Railway. The record has been made available by Mr. G. A. Miller:

	Feet.
Sand and muck	0- 57
Rock	57- 61
Sand	61- 85
Rock	85- 87

Clay	87-160
Rock	160-165
Clay	165-200
Sand	200-240
Clay	240-275
Rock	275-280
Sand	280-350
Rock	350-353
Clay	353-363
Rock	363-366
Clay	366-375
Rock	375-379
Sand	379-400
Clay	400-440
Soft rock	440-447
Soft water-bearing rock	447-627
Hard rock	627-630

ST. JOHNS COUNTY.

LOCATION AND SURFACE FEATURES.

St. Johns County lies in northeastern Florida, bordering the Atlantic Ocean. On the north it joins Duval County and on the south Volusia County. The western boundary is formed by the St. Johns River. The county has a total length of sixty miles. In width it varies from eighteen to twenty-four miles. The total area is approximately 1,000 square miles.

Owing to the location of St. Johns County between the St. Johns River, on the west, and the Atlantic Ocean, on the east, no great variation in elevation is to be expected. It is probable, however, that small areas in the interior of the county lie above the fifty-foot contour. In passing from St. Augustine to Jacksonville, levels made by the Florida East Coast Railway show near the county line an elevation over a small area of 57 feet. The greatest elevation recorded between St. Augustine and Hastings is in the vicinity of Hurds. A line of levels run from the coast at St. Augustine, at the instance of Mr. B. A. Carter, gave for Hurds an elevation of thirty-eight feet. Levels obtained from the U. S. Engineers' Office, Jacksonville, Florida, give, for a point a short distance east of Hurds, a level of thirty-six feet. From East Palatka south information regarding elevation is unfortunately very deficient. From the fact that such wells as have been put down at Dinner Island, Espanola, Bunnell and Dupont, are non-flowing, it is probable that this part of the county is above the twenty-five-foot contour line, and parts of this area may, in fact, approach or exceed the fifty-foot contour. Along the west side of the county bordering the St. Johns River areas varying in width from 3 to 10 or more miles lie below the twenty-five-foot contour line.

WATER-BEARING FORMATIONS.

The Vicksburg Limestone is the chief source of the artesian water supply of St. Johns County, although a small flow is probably obtained before reaching this formation. The Vicksburg Limestone consists of alternating hard and soft fossiliferous strata and is usually easily recognized. At St. Augustine, according to determinations made by Dr. W. H. Dall,* fossils characteristic of this formation were obtained from a depth of 224 feet. At Hastings, 17 miles southwest of St. Augustine, well records indicate that a limestone similar in character to the Vicksburg is reached at a depth of from 175 to 200 feet. At Orange Mills, in Putnam County, 3 miles southwest of Hastings, Orbitoides, apparently representing some member of the Vicksburg group, were obtained at a depth reported at 110 feet. At the time the sample was received the well was drilled to a total depth of only 130 feet. Toward the northern part of St. Johns County the Vicksburg Limestone probably dips deeper, since, at Jacksonville, this formation is first reached at a depth of about 524 feet.

The superficial material in this county is largely Pleistocene and recent sands together with Pleistocene and recent shell deposits. Oscillations of level have affected the surface elevation, and consequently the relative extent of land and water area in this county within comparatively recent time. That this part of the State stood at a lower level during a part of Pleistocene time is evident from the occurrence of marine shell deposits of Pleistocene age at some distance inland and at an elevation of several feet above the present sea level. Oyster banks, probably of Pleistocene age, are exposed along a small drainage ditch on the farm of A. W. Corbett, four miles southwest of St. Augustine, at an elevation of at least 15 to 20 feet above the present sea level. That this depression during Pleistocene time was general for this part of the State is indicated by the evidence already given.

The identification of the formations lying above the Vicksburg limestones and beneath the superficial sands, from well records alone is a matter of difficulty. This interval in St. Johns County is occupied largely by clays, although some sand, shell and rock strata occur.

AREA OF ARTESIAN FLOW IN ST. JOHNS COUNTY.

The areas of flowing and non-flowing wells in St. Johns County are indicated on the accompanying map.

The shaded lines on the map indicate the area in which flowing artesian wells can be obtained in this county. As will be seen from the map the flowing area borders the Atlantic coast and the St. Johns River, and has a width along the coast and also along the St. Johns of from two or three to eight or ten miles. The flowing area extends inland following the streams. So far as present records show, a narrow strip extending north and south through the central part of the county is non-flowing. A fresh water spring is reported to occur in the ocean opposite Matanzas. Springs of this character represent the natural escape of the underground waters into the ocean.

LOCAL DETAILS.

ANASTASIA ISLAND.

A six-inch well, drilled in 1895, at South Beach, on Antastasia Island, reached a total depth of 260 feet. A strong flow of sulphur water was obtained from this well.

*U. S. Geol. Surv. Bull. 84, p. 125, 1892.

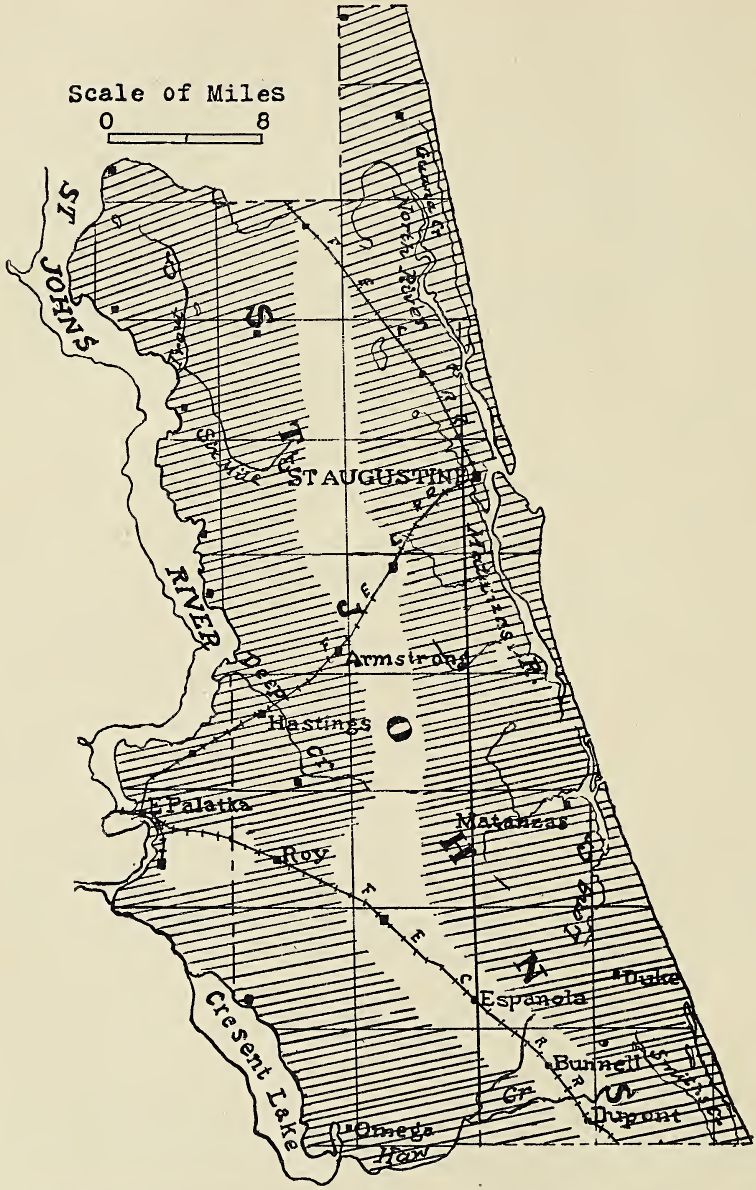

Fig. 7.—Map showing the area of artesian flow in St. Johns County. The area in which flowing wells can be obtained is indicated by shading.

ARMSTRONG.

Flowing wells have been obtained in the vicinity of Armstrong. A four-inch well, drilled in 1908, for J. W. Williams by N. H. Monck, reached a total depth of 200 feet. This well is cased 70 feet and the water is reported to rise 12 feet above the surface.

BUNNELL.

An effort was made in 1909 to obtain a flowing well at Bunnell. A five-inch well was drilled at this place by Mr. N. H. Monck for Messrs. Lambert & Moody. This well was cased to a depth of 130 feet and is reported to have been drilled to a total depth of 300 feet. A flow is not obtained in this well, although the water rises to within about two feet of the surface.

A second well owned by Messrs. Lambert & Moody, drilled by Bellough & Melton in 1910, is 128 feet deep. The following log of this well was supplied by the drillers:

	Feet.
Surface material and sand	0 - 45
Blue clay	45 - 90
Black material looking like gunpowder or pepper	90 -109
Blue clay	109 -119
Shell and sand	119 -124
Blue hard rock	124 -124½
Cavity 6-inch, sand and shell. Water rises to within 1.4 feet of surface	124½-125
Blue hard rock, more water, with same head; drilling stopped in second cavity	125 -128

DINNER ISLAND.

A record of one well has been obtained at Dinner Island. This is a three-inch well drilled by Mr. H. Mervin for Padgett & Company. It has a total depth of 200 feet and does not flow, although the water is reported to rise to within two feet of the surface.

ELKTON.

Flowing wells are obtained at Elkton. A five-inch well drilled by N. H. Monck, in 1908, on the Middleton farm, reached a total depth of 260 feet. The well is cased 100 feet and the principal supply of water comes from a depth of 200 feet. The water is reported to rise five feet above the surface.

ESPANOLA.

A few wells occur in or near Espanola. The wells immediately in the town do not flow. Flowing wells are obtained, however, from one to five miles south, along Haw Creek.

FEDERAL POINT.

Federal Point lies within the flowing area bordering the St. Johns River. A considerable number of wells have been drilled in the vicinity of this place. The material encountered here, to the depth of about 125 feet, consists largely of clays. Water is obtained at a depth of from 200 to 250 feet, the wells terminating in limestone.

The following is a partial log of the well of Messrs. Hubbard and Hart, one-fourth mile northwest of Federal Point. This is a six-inch well drilled by Lloyd Crary in 1889. The well has a total depth of 225 feet and is cased 60 feet. The water is reported to rise twenty feet above the surface or about thirty feet above sea level. The principal supply is obtained at a depth of two hundred feet.

	Feet.
Record incomplete, said to consist largely of clays, bluish in color except where oxidized yellow at surface	0-128
A sample from the depth of 128 feet consists of fragments of dark-colored rock, more or less water worn, including small sharks' teeth, fragments of bones, occasional shining black phosphatic pebbles.....	128-130
Yellowish sandy clays	130-145
Dark fossiliferous rock. Fragments of this rock are of grayish color and contain inclusions of a dark-colored mineral similar in character to rock, found at St. Augustine at a depth of 178 feet. Sharks' teeth and black phosphatic pebbles also occur as well as numerous shell fragments	145-160

A mixed sample contained material similar to above with addition of gray sandy clay	160-168
Buff colored sandy clay	168-180
White granular fossiliferous limestone	180-225

This well probably reaches the Vicksburg group of limestones, as indicated by sample, from the depth of 180 to 225 feet. The material obtained between the depth of 168 and 180 feet may represent the Upper Oligocene, as it has certain lithological resemblances to parts of the Alum Bluff formation. The conglomerate material from 145 to 160 feet together with a part of the overlying clays probably represents the Jacksonville formation of the Miocene.

HASTINGS.

Hastings is in the western part of St. Johns County, and is located on Deep Creek, a tributary to the St. Johns River. The town site is inland about three miles from the river. The elevation at Hastings, at the residence of T. H. Hastings, is, according to the U. S. Coast and Geodetic Survey, 8 feet above sea.

A considerable number of artesian wells have been put down at and in the vicinity of Hastings. Record has been obtained of fifty-one wells within a radius of three miles of the town.

Wells at Hastings are largely used for irrigating purposes. The average depth of the wells now in use is 148 to 272 feet, although some reach a greater depth. Most of the wells are 4 to 6 inches in diameter. The length of casing used in the wells is variable, ranging from 65 to 170 feet.

Aside from the superficial soil and sand the material penetrated at Hastings to a depth of about 170 feet consists largely of clays although some water-bearing sands are reported and a shell stratum at a depth of 60 to 62 feet is specially mentioned.

At a depth of 170 to 180 feet a dark colored, very hard stratum occurs. This rock appears from the well records to be similar in character to the rock found at St. Augustine at a depth of 170 to 180 feet. After passing through this stratum the wells penetrate limestone consisting of alternating hard and soft strata, the flow increasing as each hard stratum is penetrated. This limestone, probably representing the Vicksburg group, has been penetrated at Hastings about 200 feet or to a total depth of 365 feet. feet.

Of the many wells at Hastings it is possible to give an individual record of only a few. The following is a log of the well of F. R. Allen, kindly supplied by the driller, Mr. H. Walker. This is a 6-inch well, located three miles southeast of town. It was drilled in May, 1908, and is used for irrigating purposes.

	Feet.
Yellow clay	0 - 6
Blue clay	6 - 60
Shell stratum	60 - 64
Clay	64 -160
Soft rock	160 -165
Clay	165 -171
Rock supplying small flow	171 -171½
Limestone	171½-183
Shell and limestone	183 -245
Material not reported	245 -300

The following is a partial log of the well of Henry Bugbee taken from the notes kept by I. C. Peck. This is a four-inch well drilled in 1902 and located two and one-half miles south of Hastings. The well has a total depth of 257 feet and is cased 178 feet. It is used for irrigating purposes.

	Feet.
Surface material, soil and sand	0- 6
Mostly clay, some sand at 32 feet. Material from 38 to 70 feet not reported	6-186
Seven feet of very hard rock through which it was possible to drill only a few inches a day	186-193
Porous limestone from which flowing water is obtained	193-208
Soft limestone, flow increasing with depth	208-257

HOLY BRANCH.

Flowing wells are obtained at Holy Branch. A four-inch well drilled in 1908 for Charles Slater by N. H. Monck reached a total depth of 240 feet. This well is cased 200 feet and the water is reported to rise 12 feet above the surface.

The following is a log of the well of Mr. G. A. Beach, supplied by the driller, Mr. Frank Bartlett. This is a 4-inch well, 257 feet deep, and is cased 184 feet:

	Feet.
Surface sand and soil	0 - 6
Red clay	6 - 20
Hardpan, black	20 - 24
White sand	24 - 30
Blue clay and marl	30 - 33
Sand and shell	33 - 53
Blue clay and marl	53 - 59
Shell and sand, water rises to within nine feet of surface	59 - 80
Blue clay and marl	80 -130
Black quicksand, water plentiful	130 -146
Very hard blue marl and clay	146 -180
Black quicksand, water-bearing	180 -186
Blue marl	186 -196
Very hard black flint, water flows	196 -197½
Hard rock, flint and more water	197½-201½
Softer limestone, more water with increase of depth	201½-251

HURDS.

Hurds is located on the Florida East Coast Railway, seven miles southwest of St. Augustine. The elevation at Hurds, according to levels made for Mr. B. A. Carter, is 38 feet above sea. The deepest well recorded at this point is 385 feet. This is a 4-inch well and was drilled in 1906. It was cased to a depth of 160 feet. This well does not flow, although the water rises to within five feet of the surface. The well was drilled for B. A. Carter by I. C. Peck.

MOULTRIE.

Flowing wells are obtained at Moultrie. A six-inch well put down here for the St. Augustine Industrial School reached a total depth of 300 feet. The water at this locality is reported to rise 32 feet above sea level. The surface elevation in the vicinity of Moultrie varies from 0 to about 30 feet above sea.

PICOLATA.

Picolata is in the extreme western portion of St. Johns County, almost due west of St. Augustine, on the St. Johns River. A four-inch well, drilled about the year 1890, is now owned by R. H. Bohn. The depth was reported to be about 300 feet. The pressure of this well was taken January 10, 1910, and was found to be 15 pounds. The elevation of the well is approximately 8 feet above the river. This, together with a pressure of 15 pounds, would give the well a head of 42.65 feet above the level of the water in the St. Johns River.

RIVERDALE.

Riverdale is a settlement along the St. Johns River, in southwestern St. Johns County. At this place several artesian wells have recently been drilled. A well 302 feet deep was sunk in 1909 by Mr. R. C. Walker for the Riverdale Land Company. This is a six-inch well and is cased 107 feet. The well is reported to have a head of 33½ feet above the surface and the surface elevation above the St. Johns River is estimated to be 8 feet, which gives the well a total head of 41½ feet. The first rock encountered was at a depth of 175 feet, and at this depth the water was found to be under sufficient pressure to rise to the surface. An increase in the flow of water was reported at a depth of 190 feet.

Mr. R. C. Walker completed on February 1, 1910, a well for Mr. J. D. Clark. This well is six inches in diameter, 318 feet deep, and is cased 136 feet. At the depth of 174 feet a one-foot stratum of bluish, clayey limestone was encountered. An increase in water is recorded at the depth of 200 feet, from which depth the first flowing water is reported. The well samples indicate that this flow comes from a very hard, bluish colored rock and water-worn small pebbles. Immediately on passing through this stratum, which was 19 feet in thickness, the Vicksburg Limestone was reached, as is shown by the presence of Nummulites. This determination was made from a very complete set of samples of the drillings from this well, kindly saved by the driller, Mr.

R. C. Walker. This limestone was penetrated for nearly 100 feet, the total depth of the well being 318 feet. The following is a log of this well, constructed from the notes and the samples sent in by Mr. Walker:

	Feet.
Surface sand, yellow in color. Soft water	0- 18
Light gray sands	18- 30
Dark gray sands, partly indurated; some clay	30- 44
Shell, sand and gravel	44- 55
Very dark (almost black) marl, similar in appearance to Miocene marls, including shell fragments	55- 63
Light greenish sandy marl	63- 80
Dark green marl, small shark's tooth observed	80-100
Gray sand and shell fragments; water	100-112
Gray sand and shell, water, shark's tooth, also minute black phosphatic pebbles	112-133
Blue clayey marl	133-135
No sample	135-153
Blue marl with inclusions of black phosphatic pebbles	153-174
Blue clayey limestone; water-bearing	174-175
Dark green marl with some black phosphatic pebbles	175-200
Very hard bluish colored rock, and water-worn small pebbles; water commenced to flow upon penetrating this stratum	200-219
Limestone, Vicksburg as indicated by the presence of Nummulites	219-318

ROY.

Roy is located on the Florida East Coast Railway, about six miles inland from the St. Johns River. One deep well is reported from this place. This is a four-inch well drilled by Mr. S. I. Killingsworth for Mr. L. J. Campbell. The well has a total depth of 298 feet and is cased 150 feet. The flow is reported to rise four feet above the surface.

ST. AUGUSTINE.

St. Augustine, the county seat of St. Johns County, is located on Matanzas Bay. An abundance of flowing water is obtained at this place. Probably not less than 100 wells occur in and near

St. Augustine. Of this large number it is possible to mention only a few.

The first considerable flow in and near St. Augustine is obtained at a depth of from 170 to 180 feet after drilling through a five- or ten-foot stratum of dense hard rock. The material penetrated before reaching this hard rock stratum consists largely of sand near the surface, followed by blue clays with some shell and occasional thin layers of rock. A shell stratum often described as "coquina" occurs at a depth of about 60 feet.

The material below the depth of about 180 feet consists of alternating hard and soft strata, largely limestones, with probably occasional flints. The flow of water increases as the limestone is penetrated. The chief large increase of flow occurs at a depth of about 520 feet and most of the wells at St. Augustine terminate at this depth.

Water for the city of St. Augustine is obtained from two artesian wells located about one mile north of the city. Well No. 1 was drilled in 1897 by Mr. Hugh Partridge and had originally a depth of 371 feet. About 1903 this well was deepened to a total depth of 550 feet. The well is 12 inches in diameter for 354 feet; 9 inches for 17 feet, and four inches for 179 feet. It is reported cased to a depth of 100 feet. The head of the water is given as 33 feet above the surface or about 38 feet above sea level. The flow of the well when first drilled in 1897 was 2,396,000 gallons per day (1,664 gallons per minute).

Well No. 2 is a 10-inch well and has a total depth of 500 feet. It is cased about 140 feet. The head of the water is the same as well No. 1 or about 38 feet above sea. The total flow of this well is not recorded. This well was drilled in 1903 by Mr. Horace Walker.

The water system at St. Augustine is now owned by the city. Formerly the city was supplied by five artesian wells, the system then being under private ownership. These wells were located in various parts of the city. They vary in depth from 250 to 500 feet and range from 6 to 8 inches in diameter. The first of these wells was drilled in 1884. They are now in use as private wells.

Several wells have been drilled at St. Augustine to supply water to the Ponce de Leon and other hotels of the Florida East Coast Hotel Company. One of these, commonly known as the Ponce de Leon well, reached a total depth of 1,440 feet, and is the deepest well in St. Johns County. The following log of this well has been made up from records kindly supplied by Messrs. McGuire & McDonald, under whose direction the well was drilled, supplemented by a partial set of samples from the boring. The original intention was to go to a depth of about 3,000 feet in the expectation of obtaining warm water. The well was begun November 27, 1886, and drilling continued until February 24 of the following year. Owing to delay caused by the loss of the drill, boring was finally discontinued at the depth of about 1,440 feet.

	Feet.
Sand. Temperature of the water at 35 feet, 60 degrees F.	0- 35
Sand, with some shell	35- 50
Blue clay	50- 57
Shell	57- 65
Sand	65- 76
Indurated clay and sand	76- 95
Blue clay and black sand, pieces of hard stone. Temperature of the water 72 degrees at 110 feet, 74 degrees at 170 feet. Head 32 feet above sea. Sulphur water, 50 gallons per minute at 170 feet	95- 170
Hard rock. Temperature of water 76 degrees at 177 feet. Flow 350 gallons per minute at 177 feet	170- 177
Limestone. Flow 1,800 gallons per minute at 350 feet	177- 350
Limestone. Temperature of water 76 degrees at 410 feet. Flow of 2,083 gallons per minute at 410 feet	350- 410
Limestone	410- 495
Dense light brown limestone. Temperature of water 79 degrees at 520 feet. Head 42 feet above sea at 520 feet. Flow of 4,860 gallons per minute at 520 feet	495- 520
White "chalk," green clay, dark porous limestone	520- 557
Limestone	557- 675
Hard rock	675- 685
Limestone	685- 770
Limestone, gray to light yellow	770- 960
Thin stratum of hard limestone, followed by limestone similar to above. Temperature of water 80 degrees	

at 1,110 feet. Flow of 6,075 gallons per minute at 1,110 feet	960-1110
Hard rock, said to be sandstone, with some flint	1110-1140
Material not recorded	1140-1170
"Sandstone," followed by limestone. Temperature of water 85 degrees at 1,225 feet	1170-1225
Limestone, as above	1225-1278
"Sandstone." Sample not seen	1278-1293
Fossiliferous limestone	1293-1340
Fossiliferous limestone, easily penetrated. Temperature of water 86 degrees at 1,340 feet	1340-1390
Denser limestone	1390-1440

The following is a log of the well of Mr. W. J. Sherman. This well was drilled by the owner in 1886 and is 210 feet deep. It is two inches in diameter and is cased 110 feet. The head is reported to be 32 feet above sea and the flow about 80 gallons per minute:

	Feet.
Sand	0 - 5
Clay	5 - 6
White quicksand	6 - 11
Clay	11 - 11½
Coarse pebbles and some shells	11½- 43
Coarse gray to greenish sands, water-bearing; slight flow	43 - 45
White plastic clay and fine sand	45 - 90
Greenish clay, very compact	90 -142
Hard rock	142 -143
Greenish clay with a mixture of black sand	143 -172
Hard rock; water rises 32 to 37 feet above sea	172 -180
White chalk rock (probably Vicksburg)	180 -210

SWITZERLAND.

Switzerland is located in the area of artesian flow on the St. Johns River, in the northwestern part of St. Johns County. Wells at this locality reach a depth of from 350 to 500 feet, and the water is reported to rise 29 to 30 feet above the surface.

YELVINGTON.

Records of two wells have been obtained from and near Yelvington. Well No. 1 is located near Yelvington depot and is owned by E. L. Campbell. This well was drilled by Frank Bartlett in 1909 and reached a total depth of 352 feet. It is reported as having 95 feet of four-inch casing. The head of this well was measured December 11, 1909. The water was found to stand at this time 7½ feet below the surface.

Well No. 2 is located one mile west of Yelvington depot. It is a four-inch well and is owned by Campbell & Killingsworth. This well was drilled in 1907 by S. I. Killingsworth and is reported to be 300 feet deep and cased 180 feet. The water is said to stand two feet below the surface.

CLAY COUNTY.

LOCATION AND SURFACE FEATURES.

Clay County has a varied topography. The eastern portion, bordering the St. Johns River, is low and flat and consists largely of open pine woods. Extending westward from the river the elevation rises and the country becomes more rolling. The county is intersected by a number of streams, the largest of which is Black Creek, a tributary to the St. Johns River. This stream is navigable for small boats to or above Middleburg, at which point it divides, forming the north and south forks. The north fork rises in Lake Kingsley, and with its tributaries drains the northwestern part of the county. The south fork rises in Blue Pond and other lakes and drains the central part of the county. In the southwestern part of the county many small lakes occur.

The elevations in this county have been obtained from the levels made by the railroads crossing the county, including the Seaboard Air Line, the Atlantic Coast Line and the Georgia Southern and Florida Railway. In addition levels made during 1909 by the U. S. engineers in connection with a preliminary survey for a ship canal have been available. These levels show that the water level in Lake Kingsley stood at the time the levels were made 170 feet above sea. The measurements of depth show that this lake averages 58 to 60 feet, although one place was found at which the depth exceeded 78 feet, the full length of the sounding line. The country surrounding this lake stands at or about 175 feet above sea. According to the levels made by the Seaboard Air Line Railway the town of Highland, in the northwestern part of the county, stands 210 feet above sea. Newburg and Brooklyn, in the lake region of the southwestern part of the county, have elevations, as recorded by the Georgia Southern and Florida Railway, of 155 and 157 feet, respectively.

WATER-BEARING FORMATIONS.

Most of the flowing wells of Clay County terminate in the Vicksburg Limestone. The first flow at Green Cove Springs, in the eastern part of the county, is obtained at a depth of from 325 to 400 feet.

The Miocene formations underlie much if not all of Clay County. In the pit of Union Brick Company, at Middleburg, the following section was observed:

	Feet.
Loose sand and soil	1
Sandy clays oxidized red	7
Blue sticky clay, comparatively free from sand	10
Light-colored sands	3

The clay exposed in this pit is probably the same as the clays in the clay pit near Jacksonville. Beneath these clays, as indicated by well borings, calcareous and phosphatic Miocene rocks are encountered. This part of the Miocene, the Jacksonville formation, is exposed at many localities along Black Creek and its tributaries. The section exposed at High Bluff, on the south fork of Black Creek, about five miles above Middleburg, has already been given.

Other exposures of this formation were noted at the following localities along the river. At Fowler's Landing, on the south fork of Black Creek, three miles above Middleburg, fifteen feet of the Jacksonville formation is exposed. At Buddington's Landing, one and one-half miles above Middleburg, seventeen feet of the Jacksonville formation is exposed. Hogan's Landing, just below Middleburg, shows twenty-eight feet of the Jacksonville formation. A bluff at the mouth of the south fork shows twenty-five feet of the Jacksonville formation. A bluff on the north bank

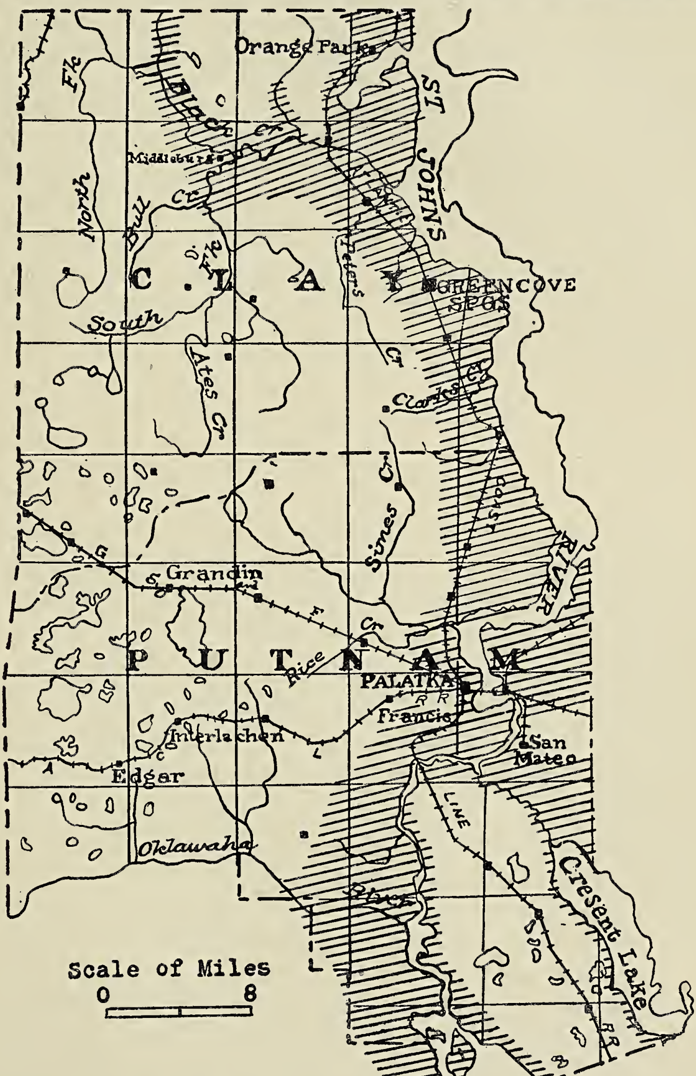

Fig. 8.—Map showing the areas of artesian flow in Clay and Putnam Counties. The area in which flowing wells can be obtained is indicated by shading.

of the north forks, one and one-half miles from Middleburg, shows three feet of the Jacksonville formation.

AREA OF ARTESIAN FLOW IN CLAY COUNTY.

The area of artesian flow in Clay County is confined to that portion bordering the St. Johns River and its tributaries. As has already been stated, upon leaving these streams the elevation soon becomes too great for a flow to be obtained. The location of successful flowing wells, together with the consideration of the elevation, will aid in the determination of the flowing and non-flowing sections in the county. The flowing area in this county is outlined on the accompanying map:

LOCAL DETAILS.

DOCTORS INLET.

A well owned by D. D. Denham and drilled in 1908 by D. C. Stafford is located near Doctors Inlet. This is a four-inch well, 372 feet deep, in which the water is said to rise twelve to fifteen feet above the surface.

A second well, two and a half miles east of Doctors Inlet, was drilled by H. Mervin for Messrs. DeLoach & Edwards in 1907. This is a three-inch well and is 400 feet deep. It is reported cased 120 feet and the water is said to rise twelve feet above the surface. Blue marl or clay from the depth of 198 to 398 feet is reported as encountered in this well. Immediately below this blue marl or clay the first hard rock was struck.

GREEN COVE SPRINGS.

Green Cove Springs, the county seat of Clay County, is supplied with water from two artesian wells. These wells are under private ownership. One is owned by N. B. Ivey, the other by O. A. Buddington. The well owned by Mr. Ivey is 815 feet deep, four inches in diameter, and cased 556 feet. The well is reported to have a head of 23 feet above the surface. The elevation of the well above the St. Johns River is given as 24 feet, thus giving the well a total head of 47 feet above the level of the water in the St. Johns River. The first flow in this well was encountered at a depth of 400 feet.

The following is an analysis of the water from this well drawn January 6, 1910. Analysis made for the State Survey in the office of the State Chemist, A. M. Henry, analyst:

Constituents.	Parts per million.
Silica (SiO_2)	7
Chlorine (Cl)	9
Sulphates (SO_4)	7
Phosphates (PO_4)	0
Carbonates (CO_3)	0
Bicarbonates (HCO_3)	107
Magnesium (Mg)	4
Calcium (Ca)	16
Iron and Alumina (Fe and Al)	Trace
Loss on Ignition	67
Total dissolved solids	155

Aside from the above well, the following two records of wells have been obtained: A well on the property of Mrs. George Halliday (known as the Borden estate), is 825 feet deep and six inches in diameter. The head is reported as 25 feet above the surface. A little southeast of this well is one owned by L. A. Hamilton. This has a reported depth of 785 feet, is six inches in diameter and is cased 100 feet. The head is given as 25 feet above the surface. A well four and one-half miles southwest of Green Cove Springs, drilled by H. Mervin in 1907 for the LaVilla Turpentine Company, is non-flowing. This well contains 128 feet of three-inch casing and 320 feet of two-inch casing. It is 406 feet deep and the water stands 17 feet below the surface. The first rock noted in this well was at a depth of 170 feet.

A well directly east of Green Cove Springs and across the St. Johns River is owned by W. A. Hallows. This well was drilled by N. B. Ivey and is used for irrigation and general domestic purposes. It is 500 feet deep, six inches in diameter and is cased about 200 feet. The water is reported to rise 35 feet above the surface.

Another well owned by N. B. Ivey is located about two miles southwest of Green Cove Springs. This well is used for irrigation and was sunk by the owner in 1907. It is a four-inch well and is reported to be 500 feet deep. At this depth the water is reported to rise five feet above the surface.

HIBERNIA.

One well is reported from Hibernia. This well was commenced July 20, 1885, and was finished in October of the same year. It was drilled by O. H. Wade for F. A. Fleming. The well is 468 feet deep, four inches in diameter and is cased 377 feet. This well when first drilled, in 1885, had a pressure of 23 pounds. Unfortunately, when visited in January, 1910, the pressure could not be obtained. The elevation of the well is about 25 feet above the St. Johns River. A pressure of 23 pounds will cause the water to rise 53.1 feet above the surface, or about 68.1 feet above the St. Johns River. The first water-bearing stratum in this well was reported at a depth of 400 feet, and the first rock noted was at a depth of 120 feet.

The following is an analysis of the water from this well drawn December 17, 1909. Analysis made for the State Survey in the office of the State Chemist, A. M. Henry, analyst:

Constituents.	Parts per million.
Silica (SiO_2)	9
Chlorine (Cl)	7
Sulphates (SO_4)	5
Phosphates (PO_4)	0
Carbonates (CO_3)	0
Bicarbonates (HCO_3)	98
Sodium and potassium (Na and K)	23
Magnesium (Mg)	5
Calcium (Ca)	14
Iron and alumina (Fe and Al)	Trace
Loss of ignition	45
Total dissolved solids	122

LENO.

There are two deep wells at Leno, owned by the Leno Turpentine Company, and drilled in 1903 by H. Mervin. One well, 404 feet deep, is four inches in diameter and the water stood when measured January 6, 1910, 12.5 feet from the surface. The second well is two inches in diameter and 220 feet deep. The water is reported to stand at about the same level.

MAGNOLIA SPRINGS.

Magnolia Springs, a station on the Atlantic Coast Line Railroad, one mile north of Green Cove Springs, takes its name from a small spring located along the western bank of the St. Johns River. A four-inch well owned by O. D. Seavey, proprietor the Magnolia Springs Hotel, was sunk by W. J. Sherman in 1882. This well is said to be 325 feet deep and flows several feet above the surface, although the exact head could not be obtained. This water is bottled and sold as a medicinal and table water. The following analysis shows the mineral constituents. Analysis by C. F. Chandler, Ph. D., School of Mines, Columbia College, New York, N. Y.:

Constituents.	Parts per million.
Sulphate of potash	Trace
Sulphate of lime	21.3
Chloride of sodium	14.4
Carbonate of soda	26.1
Carbonate of lime	40.4
Oxide of iron and alumina	Traces
Silica	31.0
Organic and volatile matter	16.4
	190.4

Two other wells occur on this same property, but a record of these was not obtained. They are both reported to furnish an abundant supply of water and are used for general household purposes.

MIDDLEBURG.

Middleburg lies in the north-central portion of Clay County, just at the point where Black Creek divides, forming the north and south forks. There are several flowing wells in the vicinity of Middleburg. The wells vary in depth from 355 to 498 feet.

The 498-foot well is owned by George A. Chalker and was drilled in 1907 by D. C. Stafford. The well is six inches in diameter at the top and one and a quarter inches at the bottom. The pressure of this well as indicated by the pressure gauge, January 10, 1910, was 18.5 pounds, or a pressure sufficient to cause the water to rise 42.7 feet above the surface. The elevation of the well is approximately 24 feet above the level of the water in Black Creek; thus, with the head of 42.7 feet above the surface, would give the well a total head of 67.7 feet above the water in Black Creek. The temperature of the water at the point of overflow was reported as 72° F. The first rock of which note was made was at a depth of 68 feet.

The well of C. C. Howard, two miles northeast of Middleburg, has a depth of 490 feet. The well was bored by D. C. Stafford in 1907, is cased 80 feet, and is four inches in diameter. The pressure of this well could not be taken, but it is reported to have a head of 21 feet above the surface.

Another well, two and a half miles northwest of Middleburg, was sunk by D. C. Stafford for Messrs. Long & Buddington, in 1907. The exact depth of this well could not be obtained, but it was reported to have a depth of about 370 feet. The well flows and gives an abundant supply of water, but measurement of the head could not be made.

In addition to the above wells is one eight and one-half miles northwest of Middleburg, or six miles southeast of Maxville, on the west bank of Yellow Water Creek, a tributary of the north fork of Black Creek. This well is located in the northwest part of the northwest quarter of the southwest quarter of Section 17, Township 4, Range 24 east. It is owned by Messrs. Long & Buddington, and is said to be 370 feet deep. It is a three-inch well and was drilled in 1907 by D. C. Stafford. The head of this well is reported to be 30 feet above the surface and the first flow encountered was at a depth of 44 feet in a stratum of black pebbles.

PEORIA.

A deep well was put down by Mr. Joseph Doyle at Peoria. This well was drilled to a total depth of 498 feet. The water rises to the surface, giving a slight flow. The well is located about one-half mile west of Peoria station and on the ridge probably 40 or 50 feet above the St. Johns River.

RUSSELL.

One flowing well is reported from Russell. This well is now owned by the Florida Farmers' Land Company and was drilled by L. J. Campbell. The well flows several feet above the surface, but a measurement could not be made and information in regard to the depth and size was not procured. It is used for general drinking purposes.

WALKILL.

A deep well at Walkill, drilled by H. Mervin in 1903 for E. B. Willcoxon & Company, reached a total depth of 352 feet. This well contains 128 feet of three-inch casing and 330 feet of two-inch casing. The water is reported to rise 25 feet above the surface.

WEST TOCOI.

A record of one well has been obtained from West Tocoi. This is a three-inch well, reported to have a depth of 313 feet, and is owned by the R. W. Mattox Company. The head of this well is given as 21 feet above the surface.

WILLIAMS CROSSING.

Messrs. De Loach and Edwards have one deep well at Williams Crossing. This well is 395 feet deep and is three inches in diameter and was sunk by H. Mervin in June, 1907. The pressure of this well, as shown by the pressure gauge, January

6, 1910, was eight and one-half pounds or a pressure sufficient to cause the water to rise 19.6 feet above the surface.

PUTNAM COUNTY.

LOCATION AND SURFACE FEATURES.

Putnam County lies bordering the St. Johns River. On the north it joins Clay County, and on the south Marion and Volusia Counties. The total area of the county is 772 square miles. The elevation increases inland from the St. Johns River. At Florahome, in the northern part of the county, along the line of the Georgia Southern and Florida Railway, an elevation is reached of 150 feet. On the Rochelle branch of the Atlantic Coast Line Railroad an elevation of 105 feet occurs at Interlachen, in the central part of the county. That part of the county bordering the St. Johns River includes palmetto flatwoods and some open flatwoods. Much of the southern and western part of the county is occupied by the lake region, many small, beautiful lakes occurring in this section.

WATER-BEARING FORMATIONS.

The data regarding the formations reached by the wells in Putnam County is very meager, owing to the fact that few well samples have been preserved.

After passing through the superficial sands in this county, calcareous clay and sands are reached, in which are imbedded black phosphatic pebbles and water-worn gravels. From such imperfect information as has been obtained it seems probable that some of the wells terminate in this formation and do not reach the Vicksburg Limestone. The log of a well at Orange Mills, which terminated in loose, clear-grained sand at a depth of 160 feet, is given on a subsequent page. A second well within a half-mile of this well apparently reached the Vicksburg Limestone at or about the depth of 160 feet. Samples from the well of B. F. Dotney, at San Mateo, drilled in 1909, by H. Mervin, show the presence of black phosphatic pebbles as deep at least as 175 or 180 feet. At a depth of 315 feet light-colored calcareous sands were penetrated. It is probable, as these wells seem to indicate, that the Vicksburg Limestone here, as at some other localities, has a very irregular top surface.

AREA OF ARTESIAN FLOW IN PUTNAM COUNTY.

The flowing area of Putnam County includes a relatively narrow strip bordering the St. Johns River and its tributaries. Upon leaving the river the elevation rises and flowing wells are not obtained. The flowing area in this county is indicated by shading on the map.

LOCAL DETAILS.

BOSTWICK.

Flowing wells are obtained at Bostwick. A three-inch well, drilled in 1904 for J. W. Glisson by H. Mervin, reached a total depth of 248 feet. This well is reported cased 60 feet and the water is reported to rise 18 feet above the surface.

Another well three and one-half miles northeast of Bostwick was drilled in 1906. This well is now owned by the R. W. Mattox Company and is used for the general supply around the turpentine camp. It is a three-inch well and reached a total depth of 215 feet.

CRESCENT CITY.

Crescent City lies in southeastern Putnam County, on the western shore of Crescent Lake. Immediately along this western border flowing wells are obtained.

The first flow of water at this locality is obtained from a shell stratum lying from 30 to 60 feet below the surface. Most of the wells at Crescent City terminate at this depth. In some instances this shell stratum is reported absent and in such cases the water is reported as coming from a very fine sand. The water from this depth is usually more or less hard and is impregnated with hydrogen sulphide gas. These wells are reported to have a head of about 15 or 16 feet above the surface.

The second flow in and near Crescent City is obtained at a depth of about 300 to 316 feet. From the immediate vicinity of Crescent Lake westward to the St. Johns River flowing wells are not obtained. The intervening country includes rolling, sandy hills. Surface wells, terminating in the sands and sandy clays furnish an abundant supply of soft water.

Aside from the use of private wells, Crescent City is supplied with water from four artesian wells. The water supply system is under private ownership. Two of the wells are two inches in diameter, while one is six inches in diameter. They are all reported as reaching a depth of approximately 316 feet, and cased about 100 feet. The wells are located on Crescent Lake and have approximately the same elevation. The head is reported 26 feet above the surface or about 27 feet above the level of the water in Crescent Lake. In addition to supplying the town the flow from one two-inch well is used for condensing purposes and for the manufacture of ice. Part of the flow from the other three wells is used for power to run an overshot wheel, which in turn runs a pump, pumping the surplus flow of water to a reservoir or tank where the water is distributed to different parts of the city by gravity.

ORANGE MILLS.

Orange Mills is located on the Florida East Coast Railway, midway between Hastings and East Palatka. The wells in this vicinity are used for the purpose of irrigation. The depth of the wells range from 143 to 200 feet. All of the wells of which record has been obtained are four inches in diameter. The length of casing used in the wells averages 60 feet.

Four wells drilled for J. H. Bahrenberg & Brother by N. H. Monck in December, 1909, gave the following pressure: Well No. 1 is 143 feet deep and is cased 65 feet. The pressure of this well as shown by the pressure gauge December 4, 1909, was 5¾ pounds. Well No. 2 is 160 feet deep and is cased 74 feet. The pressure December 4, 1909, was 5½ pounds. Well No. 3 is 219 feet deep and is cased 54 feet. The pressure of this well on the same day was 5¼ pounds. Well No. 4 is 160 feet deep and is cased 58 feet. This well was not finished at the time the pressure of wells Nos. 1, 2 and 3 was taken. As will be seen from the above records the pressure in the case of these three wells diminished with depth. In this respect the wells are exceptional. The amount of flow of these three wells was not obtained. The following is the record of well No. 4, made from the samples kindly kept by the driller:

	Feet.
Sand	0- 5
Olive green calcareous clay, with black phosphatic pebbles and fragments of shell, and flattened water-worn gravels	5- 40
No sample	40- 45
Similar or somewhat more calcareous green clay or clayey marl. This sample contains occasional fragments of chert	45- 80
This sample contains the black phosphatic water-worn pebbles in greater number than the above sample. Clear quartz grains are numerous. Flattened, water-worn siliceous pebbles up to size 1x½ inches occur	80- 90
In this sample clear quartz grains predominate. These are mixed with gray sand grains. Calcareous gray sand nodules occur, water-worn chert gravels are present, also numerous large, water-worn chert fragments	90-113
No sample	113-115
Loose, clear-grained sand in mass appearing light gray and contains a small amount of calcareous matter in the form of fragments of shell	115-160

PALATKA.

Palatka, the county seat of Putnam County, is located on the St. Johns River, 55 miles south of Jacksonville. The elevation of the Atlantic Coast Line depot, as recorded by the U. S. Coast and Geodetic Survey, is thirteen feet above sea. Records from 35 wells have been obtained from and in the vicinity of Palatka.

The first flowing water encountered at Palatka is obtained from a shell stratum at a depth varying from 30 to 60 feet. A great many wells in the city terminate at this depth. The water from this formation is more or less hard, but is not so strongly impregnated with hydrogen sulphide gas as is the water from the deeper water-bearing formations.

These more shallow wells at one time ceased to flow and pumps had to be resorted to. When the deeper wells were put in, the shallow wells in this vicinity commenced flowing again. As an instance of this, the well now owned by Messrs. L. H. and W. A. Merryday and located in the yard of the Putnam House, may be cited. This is a two-inch well and is 50 feet deep. It is reported as being cased the total depth. The well flowed when first put in, but in subsequent years had ceased to flow. During the year 1908 Mr. H. Mervin drilled a four-inch well for Dr. G. E. Welch about two blocks to the north. This well reached a total depth of 220 feet and is reported cased 120 feet. Immediately on the completion of this well the Merryday well commenced to flow. This seems to indicate that these wells are supplied with water through leakage from the wells reaching the deeper water-bearing strata.

The principal flow in and near Palatka is obtained from a depth of 175 to 250 feet. At this depth an abundance of water is obtained having a head varying from 18 to 26 feet above sea. A measurement was made of the pressure in the well of A. D. Curry, about three-fourths of a mile southwest of Palatka, in December, 1909. The well at this time was found to have a pressure of eleven and one-half pounds. The pressure was taken at the top of the pipe which stands about two feet above the surface of the ground.

A number of wells have been put down across the river and in the vicinity of East Palatka. The elevation of the depot at East Palatka, as given by the Coast and Geodetic Survey, is seventeen feet above sea level. A four-inch well drilled for H. Hanna at this place by N. H. Monck in 1909 reached a depth of 225 feet. It is reported cased 135 feet and the water is reported as rising fifteen feet above the surface. A second well drilled for the Florida East Coast Railway by N. H. Monck in 1909 was drilled to a depth of 256 feet. This is a four-inch well and is reported cased 135 feet. The water is said to rise fifteen feet above the surface.

The following is an analysis of the water from the city well at Palatka. The water was sent in by Dr. E. S. Crill. Analysis made in the office of the Chemist, B. H. Bridges, analyst:

Constituents.	Parts per million.
Silica (SiO_2)	18.0
Chlorine (Cl)	156.0
Sulphates (SO_4)	76.9
Carbonates (CO_3)	7.3
Bicarbonates (HCO_3)	156.1
Magnesium oxide (MgO)	43.3
Calcium oxide (CaO)	97.1
Total solids	531.0

PENIAL.

A three-inch well was drilled at Penial by H. Mervin in 1904. This well is now owned by E. L. Parker and is used for general supply around the turpentine camp. This well reached a total depth of 235 feet and is reported cased 110 feet. The water is reported to rise 16 feet above the surface.

RICE CREEK.

A two-inch well drilled at Rice Creek in 1904 reached a total depth of 175 feet. This well is reported cased 60 feet. It has a small flow of sulphur water, perhaps 12 to 15 gallons a minute. The head as shown by the pressure gauge December 8, 1909, is 25.1 feet above the surface.

RODMAN.

An attempt was made in 1909 to obtain a flowing well at Rodman. Two four-inch wells were drilled by H. Mervin for the Rodman Lumber Company. Well No. 1 reached a total depth of 139 feet and is reported cased 110 feet. Well No. 2 has 110 feet of four-inch casing, 200 feet of three-inch casing and 420 feet of two-inch casing, and was drilled to a total depth of 507 feet. The head did not increase with depth in this well, as is shown by the level of the water in either well, the head being three and one-half feet below the surface.

Approximately one mile east of Rodman a flow is obtained. A well drilled by H. Mervin for J. P. Buie in 1909 at this point has a head of four feet above the surface. It is a three-inch well and has a depth of 270 feet. The flow as measured December 9, 1909, is twelve gallons per minute.

SAN MATEO.

Flowing wells are not obtained at San Mateo, the surface elevation of the town, according to barometic readings, being approximately sixty feet above the St. Johns River. A four-inch well drilled for B. F. Dotney in 1900 by H. Mervin reached a total depth of 365 feet. The water in this well rises to within 48 feet of the surface. A number of flowing wells have been obtained, however, along the river, near San Mateo.

SATSUMA.

No artesian wells are in use at Satsuma. The water used at this place comes from surface sands or clays at a depth varying from 25 to 46 feet. Flowing wells have been obtained along the river west of town.

WELAKA.

Welaka is located on the St. Johns River, about twelve miles south of Palatka. Records of two wells have been obtained at this place. One of these is the well now owned by the Welaka Mineral Water Company, a three-inch well, drilled in 1906. The first water under pressure was encountered at a depth of 160 feet. Below 160 feet the size of the boring was reduced to two inches. and was continued to a total depth of 329 feet, at which depth a highly mineralized water is obtained. The well has 98 feet of three-inch casing and 213 feet of two-inch casing. The elevation of the well above the St. Johns River is reported to be 22 feet. The water in the well comes to within 16 feet of the surface or stands 6 feet above the level of the water in the St. Johns River.

The following is an analysis of the water from this well. Analysis by Robert Spurr Weston, 14 Beacon street, Boston, Mass.:

Constituents.	Parts per million.
Silica	12.00
Alumina	8.57
Iron carbonate	12.00
Calcium chloride	586.32
Calcium sulphate	697.75
Calcium nitrate	Trace
Magnesium bromide	5.14
Magnesium chloride	507.45
Magnesium carbonate	241.72
Sodium chloride	8808.52
Potassium chloride	13.70

A second well at Welaka is owned by Mrs. Franklin Swift and was drilled by H. Mervin in 1909. This is a four-inch well and has a total depth of 151 feet. It is reported to be cased 104 feet and the water is said to stand eight feet below the surface.

WOODBURN.

A well was drilled one and one-half miles northeast of Woodburn in 1905 by H. Mervin for J. E. Edmonson. This is a four-inch well and has a depth of 185 feet. It is reported cased 120 feet and to have a head of five feet above the surface.

ORANGE COUNTY.*

LOCATION AND SURFACE FEATURES.

Orange County lies in South Central Florida, bordering the St. Johns River. This county has an area of 1,250 square miles and presents considerable diversity in soil and topography. The northwestern one-half of the county is included within the lake region of Florida and is dotted with innumerable small and large lakes. This part of the county has a rolling surface topography, the uplands rising considerably above the lakes. The eastern and southeastern part of the county bordering the St. Johns River is of lower elevation and consists largely of pine lands of

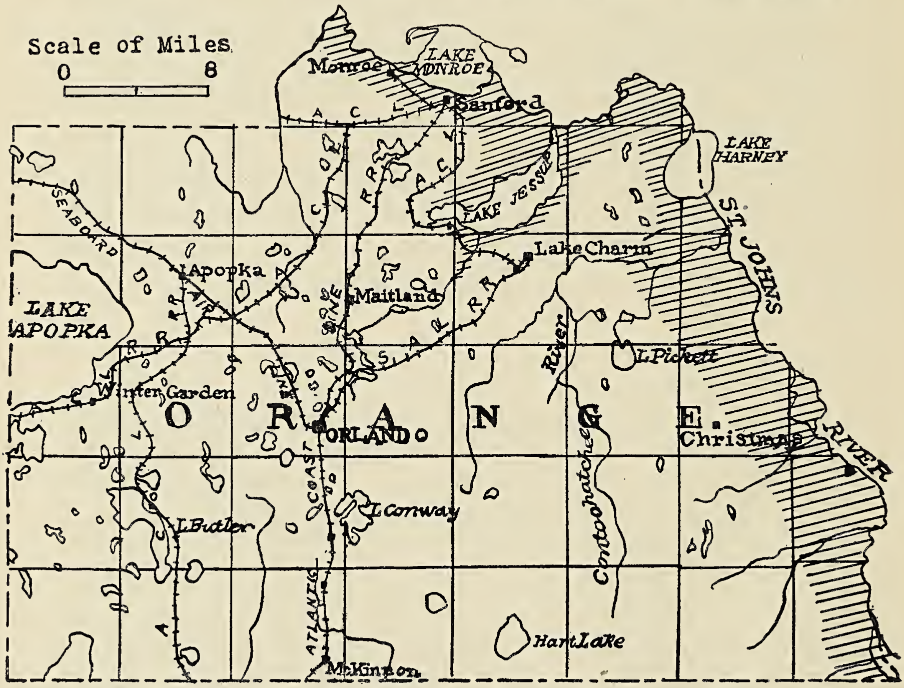

Fig. 9.—Map showing the area of artesian flow in Orange County. The area in which flowing wells can be obtained is indicated by shading.

*Including Seminole County, which was created from Orange County after this paper was set in type.

the palmetto flatwoods type. The surface elevation in this county varies from about 20 feet above the sea in the northern part of the county to elevations of from 100 to 150 feet at points in the interior.

WATER-BEARING FORMATIONS.

The deep wells in Orange County terminate in the Vicksburg Limestone. At Sanford, in the northern part of the county, this formation lies comparatively near the surface, being reached at a depth of from 113 to 125 feet. Owing to the lack of a complete set of well samples the depth at which the formation is to be expected in other parts of the county has not been accurately determined. The formations lying above the Vicksburg have not been fully differentiated. It is probable that the Miocene occurs over the county, as the surface exposure of this formation has been recognized at Rock Springs, in the northwestern part of the county.*

AREA OF ARTESIAN FLOW OF ORANGE COUNTY.

The flowing area of Orange County is confined to a narrow strip bordering the St. Johns River. At Sanford this strip has a width of from three to five miles. Passing inland these low lands quickly give place to the more elevated, rolling lands of the lake region. With the exception of a few wells immediately bordering some of the lakes, flowing wells in this upland section have not been obtained. The flowing area in this county is outlined on the accompanying map.

LOCAL DETAILS.

CHULUOTA.

A two-inch flowing well three miles east of Chuluota is owned by Mr. G. M. Jacobs. The well is 114 feet deep, is cased 75 feet,

*Smith, E. A., On the Geology of Florida. Amer. Journ. Sci. (3) XXI, 292-309, 1881.

and has a head of eight feet above the surface. The water is used for stock.

GENEVA.

There are several non-flowing wells in Geneva, the elevation being too great for a flowing well to be obtained. Mr. H. H. Pattishall has a two-inch well 133 feet deep and cased 85 feet. This well was drilled by the Geo. H. Fernald Company in 1909. The water is said to rise to within 29 feet of the surface.

Mr. J. T. McLain owns a well one and one-half miles north of Geneva. This is a two-inch well and is 135 feet deep. The water is reported to rise to within 31 feet of the surface. The water from this well is hard and is charged with hydrogen sulphide. In addition to the above well Mr. McLain has two wells on Mullet Lake, on the St. Johns River, about four miles slightly west of north from Geneva. Both of the wells furnish salt water impregnated with hydrogen sulphide and are not used. One is seventy-five feet deep and is said to flow two feet above the surface; the other is 135 feet deep and the water is reported to rise within one foot of the surface. The apparent difference in head is due to the difference in the elevation of the two wells.

Mr. W. B. Raulerson owns a two-inch well five miles northwest of Geneva and near the St. Johns River. This well is 76 feet deep and is cased 72 feet and furnishes a small flow of salt water which rises a few inches above the surface. The first flow in the well was encountered at a depth of 70 feet. An increased flow was obtained at 72½ feet. The first water was reported to be more salty than the second, as was indicated when the first flow was cased off. Owing to inability to drill deeper with the light drilling outfit used, the boring was discontinued. Mr. Raulerson states that the water is more salty in seasons of drought than in seasons of normal or heavy rainfall.

A two-inch well owned by Chase & Company, two miles southeast of Geneva, on Lake Harney, is 35 feet deep. This well was sunk by F. B. Bradley and is cased 34 feet. It has a head of four feet above the surface. The water is fresh and is only slightly charged with hydrogen sulphide.

ORLANDO.

Orlando, the county seat of Orange County, lies in the lake region of Florida. The elevation at the depot, as given by the Atlantic Coast Line Railroad, is 111 feet. Several wells have been drilled at Orlando. These are non-flowing wells, the elevation being too great to obtain a flow. The deep wells at this locality are used principally for drainage purposes and for irrigation, the city water supply being obtained from one of the small lakes. A few private wells in and around Orlando are used as a source of water supply.

A well near the north edge of the city owned by Mr. F. A. Lewter, has a total depth of 216 feet and is cased 86 feet. The water is used for general purposes.

A second well at the ice plant is used in cooling pipes in the manufacture of ice. This well is 470 feet deep.

The use of wells to carry off surface waters at this locality was described in the Third Annual Report. One of these drainage wells has developed at intervals the unusual phenomenon of spouting. An account of this well, together with an explanation of its unusual behavior is given in the report referred to, page 72.

OVIEDO.

Oviedo lies on the eastern edge of the lake region of Orange County. The region is sandy and the topography is flat to gently undulating. The country east of Oviedo is of the prevailing flatwoods type bordering the St. Johns River and Lake Jessup, and flowing wells are here obtained at comparatively shallow depths. Both flowing and non-flowing wells occur at Oviedo, depending on the local elevation.

Mr. N. J. Tanner's well, about one-eighth of a mile east of the postoffice at Oviedo, located in a depression, is about 114 feet deep, two inches in diameter, and is cased 75 feet. The water from this well flows just above the surface. It is a hard, sulphur water and is used for irrigating purposes.

The well of Mr. A. J. McCulley is 75 feet deep, two inches in diameter and is cased 70 feet. This well was sunk by the owner in 1907. The water is reported to rise to within 14 feet of the surface. Mr. McCulley owns another two-inch well which is 73 feet deep, and is cased 68 feet. The water in this well is said to rise to within three feet of the surface. This apparent difference in head is due largely to a difference in elevation of the wells.

A two-inch well, 117 feet deep, one and one-quarter miles west of Oviedo, was completed for Mr. D. W. Curry in 1910 by Mr. A. J. McCulley. This well gives a good flow of sulphur water and had, when measured in April, 1910, a pressure of four and one-quarter pounds, the measurement being made about five feet above the ground. The first flow in this well was encountered at a depth of 79 feet.

A well fourteen miles east of Oviedo, on the Econlockhatchee Creek, furnishes a flow of salt water. This well was drilled in 1907 by A. J. McCulley and is 114 feet deep, two inches in diameter, and is cased 75 feet. The first flowing water, which was salty, was found at a depth of 70 feet.

SANFORD.

Probably not less than 1,000 wells occur in and around Sanford. These wells are used for irrigating purposes and obtain flowing artesian water at a comparatively shallow depth, the average being from 125 to 200 feet. Bordering Lakes Monroe and Jessup and the St. Johns River, the wells are more shallow and terminate at a depth of from 66 to 85 feet.

The first flow in the wells at Sanford is encountered at a depth of from 100 to 125 feet, after drilling through a rock more or less hard and penetrating the characteristic "water rock" or the Vicksburg Limestone. In some instances a light flow is obtained above this harder rock immediately overlying the Vicksburg. When such is the case it seems the water comes from a quicksand or sometimes from a stratum of sand and shell. In order to get a sufficient and permanent flow, however, the boring is continued until the Vicksburg Limestone is reached.

In a well owned by Mr. L. E. Morrow, four miles south of Sanford, on the Sanford-Orlando public road, and drilled by Mr. W. E. Holmes in April, 1910, the Vicksburg Limestone was reached at a depth of 113 feet. The first flow was obtained at a depth of 110 feet, coming from a light yellow sand. The following is an approximate log of this well constructed from notes given by the driller and from a partial set of samples kindly saved by him:

	Feet.
Surface soil	0- 5
Yellow sand	5- 40
Shell and sand, water, no flow	40- 60
Sand	60- 91
Shell and sand with shark's teeth	91- 95
Dark blue rock with black phosphatic pebbles	95-100
Very dark rock	100-101
Light yellow sand	101-113
Vicksburg Limestone	113-

The principal supply of water for the city of Sanford is drawn from Lake Ada, about four miles southeast of the city. The soft water from the lake is preferred to the hard, sulphuretted artesian water. However, the city has four artesian wells, which serve as a source of supply when the lake is low. These wells are all four inches in diameter and are reported to have an average depth of 130 feet. Measurements in regard to the volume of flow of these wells could not be obtained.

Several flowing wells occur at Cameron City, on Lake Jessup, about six miles southeast of Sanford. The wells here are of about the same depth as those in and near Sanford and good flows are obtained. The principal use of the water is for irrigating purposes.

At Monroe, a station four miles northwest of Sanford, on the Atlantic Coast Line Railroad, a number of wells have been sunk. According to reports from drillers the artesian conditions here are essentially the same as at Sanford. A well about one-fourth of a mile southwest of the depot was drilled for the Title, Bond and Trust Company by W. E. Holmes & Son. This is a two-inch well, 180 feet deep and cased 120 feet. The pressure of this well April 19, 1910, was eight and one-half pounds, the measurement being made one and one-half feet above the surface. About one-fourth mile beyond the above is a second well. This well indicated a pressure of eight pounds, the measurement in this instance being made three feet above the surface. Unfortunately the total depth of this well could not be learned. A third well about one and one-fourth miles beyond this second well indicated

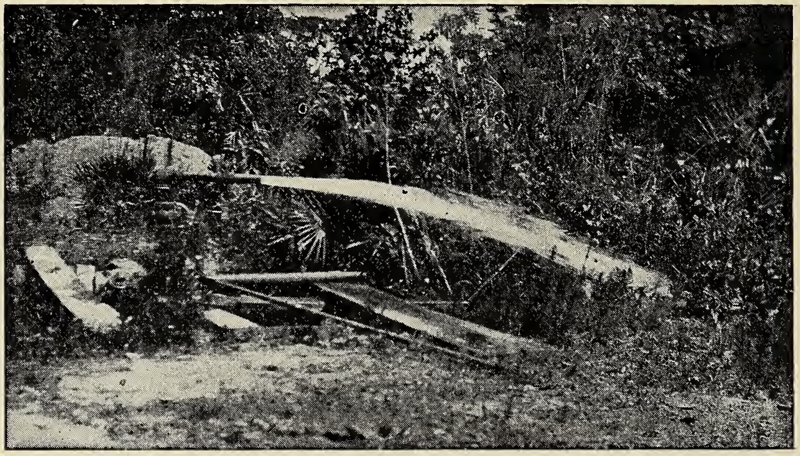

Fig. 10.—Artesian well of E. Hy. Palmer on the west side of Lake Jessup.

a pressure of one pound. This well has a total depth of 201 feet, is two inches in diameter and is cased 154 feet. As will be seen these wells decrease in pressure on leaving the river. This decrease in pressure is due to the increase in elevation. All of the above mentioned wells are along the grade of the now abandoned railroad from Paola to Monroe.

Another well four miles southwest of Sanford and owned by Mr. J. V. Weeden, terminated in the Vicksburg Limestone, as is shown by a mixed sample of the drillings gathered after the well was completed. Unfortunately neither the total depth of the well nor the depth at which the Vicksburg Limestone was reached could be learned. This well is two inches in diameter and furnishes a good flow of water.

The well of Mr. E. Hy. Palmer, seven miles south of Sanford, near the western shore of Lake Jessup, is 75 feet deep and was drilled in 1907. This is a four-inch well and is cased 40 feet. The pressure of this well as indicated by the pressure gauge, April 26, 1910, was nine and one-half pounds, or a pressure sufficient to cause the water to rise 21.9 feet above the point of connection of the gauge, which was three feet above the surface. The well is estimated to be about 12 feet above Lake Jessup, which estimation will give the well a total head of 36 feet and 9 inches above the surface of the lake.

The deepest well at Sanford is the well owned by Mr. J. E. Pace. This well is located just outside of the known flowing area and was sunk in the hopes of obtaining a flow. The well is six inches in diameter to a depth of five hundred feet, below which depth the size of the drill hole was reduced to four inches. It has a total depth of 670 feet and the water rises to within one and one-half feet of the surface. The well is reported cased only 94 feet. A detailed record of the well could not be obtained, but it was stated by Mr. Pace that no apparent increase in head resulted from the increased depth, although no exact measurements regarding this were made.

VOLUSIA COUNTY.

LOCATION AND SURFACE FEATURES.

Volusia County lies between the St. Johns River and the Atlantic Ocean. It joins St. Johns County on the north and Brevard County on the south. The area of the land surface of this county is approximately 1,281 square miles. Much of the eastern part of the county is level and consists largely of palmetto flatwoods. Bordering the Atlantic Ocean, however, is an extensive strip of hammock known as Turnbull Hammock. Back of the hammock is found the line of sand dunes. Bordering the St. Johns River is found some open flatwoods. Running in a general north and south direction through the western part of the county is a ridge including much sandy pine land. Numerous lakes occur in this upland section which forms a part of the lake region of Florida. Elevations above sea level recorded by the Atlantic

Coast Line Railroad which traverses this ridge are as follows: Seville, 52 feet; Pierson, 78 feet.

WATER-BEARING FORMATIONS.

No complete set of well samples having been obtained from any one well in Volusia County the information regarding the underlying formations is very meager. In the city well at DeLand the first water was obtained at a depth of 113 feet after passing through eight feet of clay and entering a twelve-foot shell stratum. The stratum of shell overlies a bed of rock reported to be 24 feet thick. The next rock encountered is at a depth of 237 to 247 feet. At Daytona the Vicksburg Limestone, as shown by the comparatively shallow depths of the wells, lies close to the surface and is presumably reached at from 125 to 150 feet.

AREA OF ARTESIAN FLOW IN VOLUSIA COUNTY.

The area of artesian flow in Volusia County is confined to a strip bordering the Atlantic Ocean on the east and a strip on the west bordering the St. Johns River. This area is indicated on the accompanying map. There are no doubt areas not mapped where flowing wells can be obtained. The area mapped, however, is based on definite information and on well records. In the northern portion of the county flowing wells are obtained as far west as Crescent Lake. This part of the county is flat and of low altitude.

LOCAL DETAILS.

DAYTONA.

Daytona lies in the flowing artesian section in eastern Volusia County, along the western bank of Halifax River. The city is supplied with water from four artesian wells, all of which are six inches in diameter. These wells were drilled in 1909, but in order to obtain an increased flow were deepened in 1910 and now range in depth from 165 to 260 feet. The 260-foot well on April 7, 1910, had a head of 9.3 feet above the surface or approximately 13.3 feet above sea. The wells now furnish an abundant supply of hard sulphuretted water.

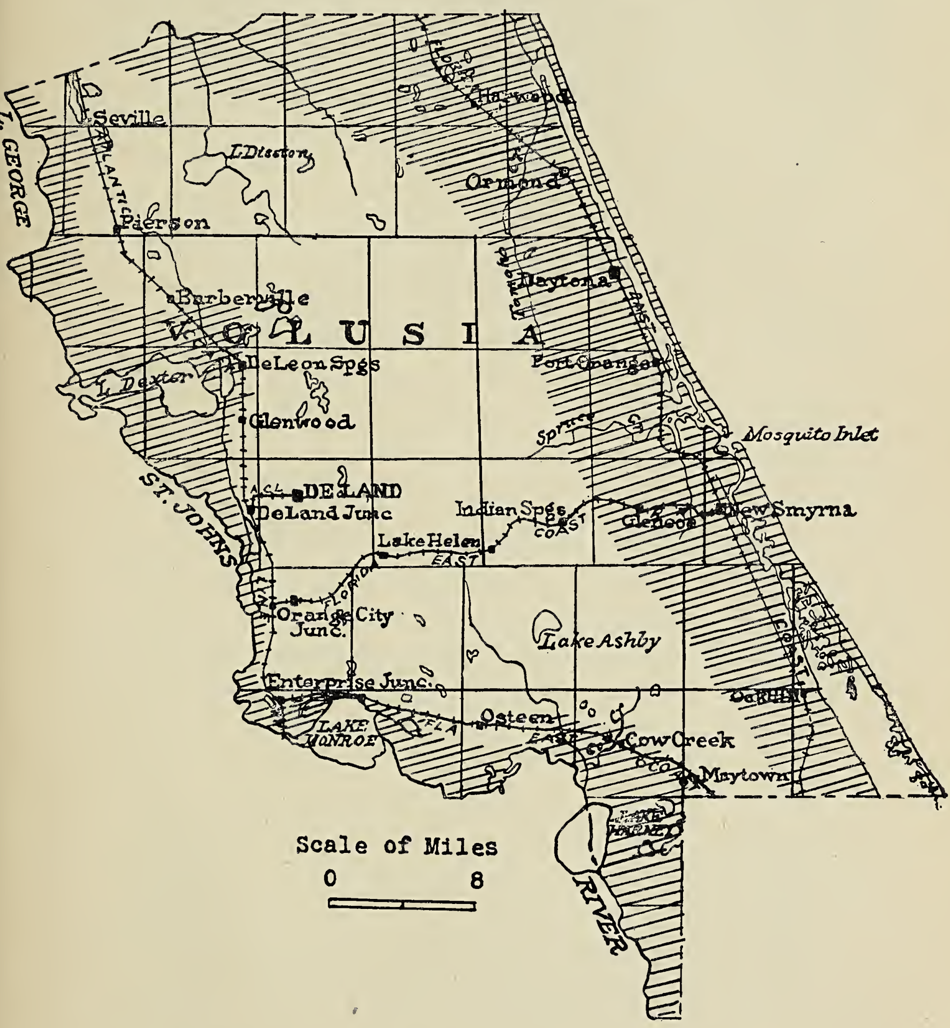

Fig. 11.—Map showing the areas of artesian flow in Volusia County. The areas in which flowing wells can be obtained are indicated by shading.

In addition to the city wells above mentioned numerous private wells occur in and near Daytona. Of these it is possible to list only a few. Mr. Paul Petion owns a two-inch well about two and one-half miles south of the city. The well was drilled by Mr. H. VanDorn in 1910. It is 145 feet deep and is cased 85 feet. The first flowing water is reported to have been encountered at a depth of 85 feet after drilling through about one foot of hard rock.

Messrs. Bellough and Melton completed a two-inch well for Mr. Chas. Lee about two miles southwest of Daytona in April, 1910. This well is 130 feet deep and has a head of five feet above the surface. The first flow is reported from a depth of 88 feet just below a hard rock upon which the casing was landed. The following is a log of this well as given by Mr. Melton:

	Feet.
Dark sandy soil	0- 6
White marl	6- 15
Sand and shell	15- 30
Blue clay	30- 65
Sand and shell	65- 87
Limestone, medium hard. First flow at 88 feet, increase of water with depth	87-130

The following is a log of Mr. H. VanDorn's well. The well is one-half mile west of the postoffice and was completed by Mr. VanDorn in April, 1910. It is a four-inch well, 205 feet deep, and is cased 83 feet:

	Feet.
Dark sandy soil	0- 3
Hardpan	3- 5
White sand	5- 40
Coquina and shell	40- 45
White sand	45- 65
Blue clay	65- 83
Hard rock. Light flow just above this rock	83- 84
Light-colored limestone, with harder and softer layers. Increase of water with increase of depth	84-205

The wells listed are representative of the wells surrounding Daytona. Flowing water is obtained at a comparatively shallow depth. From the above two logs it will be seen that hard rock was encountered at the depth of 87 and 84 feet, respectively. Immediately under this hard rock a softer limestone is reported and in this limestone the first flowing water is obtained. The description of this formation given by the drillers characterizes it as the Vicksburg which is apparently reached in this section at a depth of not more than 125 to 150 feet.

DE LAND.

The city of DeLand, the county seat of Volusia County, lies in the southwestern portion of the county. There are a number of non-flowing artesian wells in and near DeLand. The city is at present supplied by two deep wells located at the pumping station. The six-inch well is 406 feet deep and was sunk in 1895. This well was reduced in diameter in the process of drilling and is cased as follows: Six-inch casing to 100 feet, four-inch casing to 290 feet, two-inch casing to 390 feet. The second well, which was drilled in 1906 by W. F. Hamilton, is ten inches in diameter and is 269 feet deep. At the depth of 191 feet hard rock was encountered upon which the casing was landed. The head of the wells, regardless of the difference in depth, was reported to be 27 feet below the surface in both cases. The following log and analysis of the water from this well were kindly made available by Mr. E. D. McLeod:

	Feet.
Sand	0- 25
Clay	25- 45
Shell	45- 50
Rock	50- 55
Sand	55-105
Clay	105-113
Shell, water-bearing	113-125
Rock	125-149
Sand	149-157
Rock	157-197
Sand and shell	197-237
Rock	237-247

Clay	247-257
Sand	257-265
Rock	265-277
Clay	277-292
Shell and clay	292-372
Rock	372-392
Cavity with water	392-406

The following is an analysis of the water from the six-inch city well at DeLand. Analysis by H. Herzog, Jr., Gainesville, Fla.:

Constituents.	Parts per million.
Total solids	136.29
Residue after ignition (mineral matter)	76.11
Gas and ignition (organic matter)	60.17
Sodium chloride	11.31
Free ammonia	.68
Albuminoid ammonia	.17
Oxygen (consuming power)	1.54
Nitrates	.34
Nitrites	None
Sulphates	2.05
Phosphates	Trace

ENTERPRISE.

Flowing wells are obtained at Enterprise, along the shore of Lake Monroe, and in areas where the elevation does not exceed more than ten or twelve feet above the level of the water in the lake. The depth of the wells in this vicinity ranges from 20 to 200 or more feet, the average depth being between 90 and 110 feet. The water is hard and is charged with hydrogen sulphide, in some instances containing a large amount of salt. A well owned by Mr. William S. Thayer was drilled to a depth of 98 feet. It is two inches in diameter and is cased 45 feet. The estimated elevation of this well is 15 feet above the level of the water in Lake Monroe. The water is reported to rise to within three feet of the surface of the ground. An analysis of the water from this well made in the office of the State Chemist showed it to contain 140 parts total solids to 1,000,000 parts water. The total solids are reported to be composed of calcium carbonate (lime), sodium chloride (common salt), and magnesium sulphate (Epsom salts).

The following is an analysis of the water of the Benson Mineral Spring, located about one-fourth mile west of town, and owned by the Misses Emma and Tina Tucker. Analysis made at Vanderbilt University, Nashville, Tenn., by W. H. Hollenshead:

Constituents.	Parts per million.
Potassium	27.104
Sodium	1805.046
Magnesium	213.047
Calcium	321.619
Iron	.702
Chlorine	3389.640
Bromine	103.206
Carbon dioxide	559.234
Sulphuric acid (radical)	541.132
Silica	16.989
Phosphoric acid (radical)	.702
Boric acid	Heavy trace
Organic matter	Small amount
Hydrogen sulphide	Slight trace

The above are probably combined in the water as follows:

Constituents.	Parts per million.
Potassium sulphate	60.346
Calcium sulphate	720.043
Sodium bromide	133.722
Magnesium chloride	819.787
Sodium phosphate	.994
Iron chloride	1.594
Sodium chloride	4504.371
Calcium chloride	76.701
Calcium bicarbonate	330.928
Silica	16.989
Carbonic acid	379.624
Sodium biborate	Heavy trace
Hydrogen sulphide	Slight trace
Organic matter	Small amount

LAKE HELEN.

Lake Helen lies in the lake region of southern Volusia County. The land here is high, rolling pine woods. The elevation of the depot at Lake Helen, as recorded by the Florida East Coast Railway, is 70 feet. The wells recorded from this place range in depth from 130 to 238 feet. The Bond Sand-Lime Brick Company own several three-inch wells ranging in depth from 130 to 140 feet. The water is reported to rise within 28 feet of the surface. A well for Mr. G. W. Webster was drilled in 1897 by Mr. H. C. Haven. This well is 238 feet, four inches in diameter and cased 158 feet. The first rock is reported at a depth of 78 feet. The principal water supply is obtained from a depth of 210 feet. The water is hard and is only slightly charged with hydrogen sulphide.

NEW SMYRNA.

The artesian conditions at New Smyrna are essentially the same as those given for Daytona. The wells in this vicinity range in depth from 108 to 144 feet. The water is hard and is charged with hydrogen sulphide and is used to a large extent for irrigating purposes.

The following is an analysis of the water from the well of Mr. W. L. Widmeyer, made in the office of the State Chemist, B. H. Bridges, analyst:

Constituents.	Parts per million.
Silica (SiO_2)	27.0
Chlorine (Cl)	836.6
Sulphates (SO_4)	7.8
Carbonates (CO_3)	12.0
Bicarbonates (HCO_3)	209.8
Magnesium oxide (MgO)	108.6
Calcium oxide (CaO)	197.7
Total solids	1980.0

The following is a log of a four-inch well drilled by R. C. Walker for the Florida East Coast Railway. The record is obtained through the courtesy of Mr. G. A. Miller:

	Feet.
Coal cinders (filled land)	0- 5
Coquina rock	5- 14
Sand	14- 16
Sand and shell	16- 42
Blue clay	42- 45
Fine shell	45- 64
Fine shell and sand	64- 80
Coarse shell	80- 91
Rock	91- 92
Clay and shell	92- 96
Hard rock	96-100
Soft white limestone	100-156

The following is a log of a three-inch well drilled by H. Van-Dorn, two miles west of New Smyrna, for the Florida East Coast Railway. The record is obtained through the courtesy of Mr. G. A. Miller:

	Feet
Sand	0 - 16
Rock	16 - 20½
Shell	20½- 24
Clay	24- 40
Rock	40- 42
Clay	42- 44
Rock	44- 46
Clay	46- 79
Rock	79- 81
Shell	81- 85
Rock	85- 87
Rock, bearing salty water	87-103
Rock, bearing fresh water	103-124

OAK HILL.

Oak Hill is eleven miles south of New Smyrna, on the Florida East Coast Railway and about four miles north of the head of Indian River. Several flowing wells occur in the vicinity of this place. These wells are reported to be about 130 feet deep. The water is hard and sulphuretted. Approaching the head of Indian River, some four or five miles south of Oak Hill, flowing wells of brackish water are obtained. Mr. T. J. Murray owns four wells, all near the head of Indian River, which are used for stock. One of these wells was never satisfactorily completed. Two of the wells give a brackish flow while the water from the other well, which is located about one mile south and west of the head of the river, is reported to be fresh. This well, however, is not as deep as the other two wells, being only 82 feet deep and terminating before passing through the "bed" or hard rock which was encountered at that depth. The two brackish wells are reported to have a depth of 110 feet and to have a head of about seven feet above the surface. According to well records this seems to be the northern extent of the shallow brackish flowing wells, fresh water wells being obtained just a few miles to the north. Eastward this salt area presumably extends to the Atlantic Ocean. In 1907 Mr. J. W. Griffis had a well sunk one mile northwest of Shiloh, to a depth of 149 feet. The well at this depth flowed just above the surface and furnished a very strong salt water. The well is now capped and is not used. The character of the artesian water westward in this part of the county is not known, records of wells not having been obtained.

ORANGE CITY.

The Orange City wells vary in depth from 117 to 890 feet. The 890-foot well is owned by Mr. Albert Dickinson and is not used. Salt water was encountered at the depth of 890 feet and the well was plugged up below 660 feet. The depth of the well as now used is 660 feet. The principal use of the artesian wells in this vicinity, aside from general domestic purposes, is that of irrigation, the Orange City Mineral Spring Company, however, have a well 117 feet deep, the water from which is bottled for sale. This is a ten-inch well and is reported cased to a depth of fifteen feet. The water is said to rise to within twenty feet of the surface. The following is an analysis of the water from this well.* Analyst unknown:

Constituents.	Parts per million.
Free ammonia	0.00
Albuminoid ammonia	0.05
Oxygen consumed	1.05
Nitrites	0.00
Nitrates	1.00

ORMOND.

Several deep wells have been sunk at Ormond. These deep wells all furnish a salt water which cannot be used except in some instances where it is used for bathing purposes. A four-inch well was drilled by Mr. H. Walker in 1900 at the Hotel Ormond. This well reached a depth of 752 feet and is cased 360 feet. At a depth of 320 feet salt water was encountered. The water from the well is used for bathing purposes. Another well at the Hotel Ormond reached the same depth. This well is eight inches in diameter and is cased 400 feet, at which depth salt water is reported, continuing to 550 feet. From the depth of 550 feet to the total depth of the well, 752 feet, no water was encountered.

The average depth of the wells surrounding Ormond and vicinity is from 160 to 225 feet. At this depth a hard sulphuretted water is obtained. However, in some instances salt water at this shallow depth is reported. Mrs. A. M. Watson owns a three-inch well which is 180 feet deep and cased 90 feet. The water from this well is not used because it contains salt. This well is the only one of this depth on record that contains salt, other wells of medium depth furnishing an abundant supply of fresh water, which is used for domestic and irrigating purposes. The head of the wells range from eight to nine feet above the surface or about fourteen to fifteen feet above sea.

*U. S. Geological Survey, Bull. 102, p. 263, 1904.

PIERSON.

Pierson is located on the sandy ridge running through the west central portion of Volusia County. The elevation of the depot at this place, as recorded by the Atlantic Coast Line Railroad, is 78 feet. Records of two deep wells occurring here have been obtained. The N. L. Pierson well is three inches in diameter and 150 feet deep. The water is reported to rise to within forty feet of the surface. Its use is general domestic and irrigation purposes. The second well was drilled at the public school house and is used for general drinking purposes.

SEVILLE.

The Atlantic Coast Line Railroad owns four artesian wells at Seville, used for the railroad boiler supplies. One well is four inches in diameter and is reported to be 126 feet deep. The other three wells are two inches in diameter. The exact depth is not known. The water is said to rise to within 18 feet of the surface.

About two miles south of Seville and west of the Atlantic Coast Line Railroad is a flowing artesian well. This well is owned by J. W. Whitner, and was drilled in 1909. This is a two-inch well, 140 feet deep and is cased 90 feet. The elevation at the well, as determined by measurement, is sixteen feet above Lake George. The well on April 25, 1910, as indicated by the pressure gauge, had a pressure of four and one-quarter pounds, equivalent to a head of 9.8 feet above the surface or 25.8 feet above the level of the water in Lake George. The first flowing water was reported at the depth of 80 feet, at which depth hard rock was encountered.

BREVARD COUNTY.

LOCATION AND SURFACE FEATURES.

Brevard County lies between the St. Johns River and the Atlantic Ocean. It has a total length of 66 miles and, including Merritts Island, is about 25 miles wide. It joins Volusia County on the north and St. Lucie County on the south. Aside from the line of sand dunes running parallel with the coast this county is prevailingly of the palmetto flatwoods type of country, although extensive prairie and muck lands occur in the interior of the county. Lake Washington, in the central part of this county, has an elevation of 15.74 feet while Lake Wilmington, the head waters of the St. Johns River, in St. Lucie County, has an elevation of 23.37 feet above mean sea level at Indian River Inlet.*

WATER-BEARING FORMATIONS.

The deep wells in Brevard County enter the Vicksburg Limestone. At Melbourne this limestone, as indicated by well samples kept from the well of Mr. Oliver Gibbs, was reached at the depth of 221 feet. At Cocoa, in the well of Mr. H. Bradford, the Vicksburg Limestone was recognized at a depth not exceeding 190 feet.

AREA OF ARTESIAN FLOW IN BREVARD COUNTY.

Although the interior of this county is but thinly settled and but few wells have been put down, it is probable that the greater part of this county lies within the area of artesian flow. On the high sand dune ridge, which lies out three or four miles from the coast, a flow is not to be expected. This is probably also true of points within the interior of the county, particularly in the southwestern part.

LOCAL DETAILS.

CHESTER SHOALS.

Some fifteen miles from Titusville, through Banana Creek, is the Chester Shoals Life Saving Station and Canaveral Club House. At this club house an artesian well was drilled about 1890. It is a three-inch well and the original depth was 222 feet. The amount of casing used could not be learned. The well in

*Survey made in 1903, under the direction of Captain F. R. Shunk, U. S. Army.

subsequent years decreased in flow, and in order to get a sufficient amount of water for general use it became necessary to deepen the well. In 1905 Captain Alex. Near continued the drilling to 297 feet. The well now gives an abundance of water strongly impregnated with hydrogen sulphide and tasting slightly brackish, although not so much so as to condemn it for general purposes.

CITY POINT.

Flowing wells are obtained along the shore of Indian River at City Point. Between the village on the river and the City Point depot, on the Florida East Coast Railway, there is quite an elevation, evidently an old sand dune. The elevation of this ridge, according to barometric readings, is about fifty feet above the level of the water in the river. A well sunk here some years ago failed to flow, although the water rose to within a few feet of the surface. A well owned by S. Hendry is reported to have a depth of about 160 feet. The elevation of the well is approximately twenty feet above the water in Indian River. The pressure of this well, as indicated by the pressure gauge March 5, 1910. was five pounds, or sufficient pressure to cause the water to rise 11.5 feet above the surface, or approximately 31.5 feet above the river level.

The following is an analysis of the water from this well. Analysis made for the State Survey in the office of the State Chemist, A. M. Henry, analyst:

Constituents.	Parts per million.
Silica (SiO_2)	17.00
Chlorine (Cl)	2248.00
Sulphates (SO_4)	207.00
Phosphates (PO_4)	8.00
Carbonates (CO_3)	0.00
Bicarbonates (HCO_3)	168.00
Sodium and potassium (Na and K)	1174.00
Magnesium (Mg)	116.00
Calcium (Ca)	440.00
Iron and alumina (Fe and Al)	1.00
Loss on ignition	960.00
Total dissolved solids	5053.00

COCOA.

The number of artesian wells in and around Cocoa renders it impossible to specifically mention more than a few representative ones. The artesian wells in this section terminate at a medium depth and are sunk without encountering great difficulty in drilling, thus making the cost comparatively slight. The wells terminate in the Vicksburg Limestone, as indicated by the mixed samples of drillings from the well of H. Bradford, one mile southwest of Cocoa. The water is reported in some instances to contain a trace of salt, but only in a very few cases was it found to be injurious to vegetation.

The well of O. K. Key was sunk by the owner in 1908. It is a three-inch well and has a depth of 202 feet. The well is cased 140 feet. The pressure of the well, as indicated by the gauge, March 10, 1910, was ten pounds, or a head of 23.1 feet above the surface. The elevation of the well above the level of the water in the Indian River, as shown by barometric readings, is 15 feet, thus giving the well a total head of 38.1 feet above the water level in the river. The water has a slight trace of salt and is impregnated with hydrogen sulphide gas.

About one-fourth mile southwest of the city postoffice is the well of the Cocoa Ice Company. This well is reported to have been drilled in 1888. It is a four-inch well, 325 feet deep, and cased about 125 feet. The pressure of this well in 1908 was reported to be twelve and one-quarter pounds. This pressure would give the well a head of 28.2 feet above the surface. The estimated surface elevation is about 10 feet above the river, making a total head of 38.2 feet above the level of the water in Indian River.

An artesian well one mile southeast of Cocoa was completed in February, 1910. This well was drilled by J. A. Coward and is owned by H. Bradford. It is three inches in diameter, 190 feet deep and is cased to a depth of 80 feet. A mixed sample of the drillings taken after the completion of the well indicates that the Vicksburg Limestone was encountered. The exact depth at which this limestone was reached could not be learned. The volume of flow, as measured March 10, 1910, was 60 gallons per minute and the pressure as indicated by the pressure gauge on the same date was five pounds or a pressure sufficient to cause the water to rise 11.5 feet above the surface. The elevation of the well above the level of the water in Indian River, as shown by barometric readings, is 20 feet. This elevation, together with a head of 11.5 feet above the surface, gives the well a total head of 31.5 feet above the river level. The water is the characteristic sulphur water common to most of the artesian wells of the State.

The following is an analysis of the water from this well. Analysis made for the State Survey in the office of the State Chemist, A. M. Henry, analyst:

Constituents.	Parts per million.
Silica (SiO_2)	12
Chlorine (Cl)	1082
Sulphates (SO_4)	201
Phosphates (PO_4)	0
Carbonates (CO_3)	0
Bicarbonates (HCO_3)	152
Sodium and potassium (Na and K)	536
Magnesium (Mg)	77
Calcium (Ca)	167
Iron and alumina (Fe and Al)	4
Loss on ignition	470
Total dissolved solids	2546

EAU GALLIE.

The first artesian well in Eau Gallie was drilled, in 1887, by John McAllister. This well is now owned by George F. Paddison, and is 337 feet deep. It is one and one-fourth inches in diameter and cased 136 feet. The depth to the water rock was reported by the driller, Mr. McAllister, to be 237 feet. The head of this well is given as 42 feet above the surface, or approximately 52 feet above the level of the water in Indian River. Since the completion of the above test well, many wells have been sunk in and around Eau Gallie, varying in depth from 315 to 500 feet. The principal water supply is obtained at a depth of from 230 to 315 feet.

The East Coast Lumber and Supply Company use two artesian wells as a source for power in running a planing mill. They are both six-inch wells and are about 500 feet deep. The pressure of the wells could not be obtained, but they are reported to have a head of 50 feet above the river. The principal use of the surrounding artesian wells is for general domestic purposes and irrigation.

FRONTENAC.

Mr. Josiah Thompson owns an artesian well at Frontenac. This well was reported to be 190 feet deep, and is four inches in diameter. The water is strongly impregnated with salt, and is used for power to pump water from a shallow fresh water well. The pressure of the well could not be obtained, but the head and flow were reported to be very good.

GRANT.

A four-inch well, now owned by Mr. Charles Christiancy, at Grant is the only flowing well in the vicinity. The well is 350 feet deep and is cased 90 feet. It was drilled, in 1896, by Messrs. Near & Taylor. The principal supply of water is said to come from a depth of 256 feet.

MALABAR.

Several deep wells have been sunk at Malabar. They vary from 300 to 390, or more, feet in depth. The principal use of the water is for irrigation purposes.

MELBOURNE.

At Melbourne, a record of several deep wells was obtained. Mr. W. T. Wells owns an artesian well, which was sunk by Capt. Alexander Near in 1898. This well is 389 feet deep and four inches in diameter. The pressure, as shown by the pressure gauge on March 15, 1910, was eleven and one-quarter pounds. The surface elevation was given as about 26 feet above the level of the water in Indian River, and this elevation, together with a pressure of eleven and one-quarter pounds, would give the well a head of 51.9 feet above the river.

The six-inch well of Capt. J. S. Sammis is 400 feet deep and is cased about 73 feet. The pressure of this well was taken on March 15, 1910, but since all connections to the well could not be shut off, the full pressure could not be obtained. The reading, however, was 11 pounds, which was a sufficient pressure to cause the water to rise 25.4 feet above the surface, or about 47.4 feet above the river; the well being about 22 feet above the river.

A three-inch well, owned by Mr. Wm. R. Campbell, near Melbourne is used for power purposes and for irrigation. The water from the well turns an overshot wheel, which runs a pump, pumping water from a surface well. The surface water is soft and is preferred to the hard sulphur water of the deeper well. The well is 385 feet deep and was sunk by Messrs. Near & Taylor in 1895.

A well, one mile west of Melbourne, owned by Mr. H. P. Bowden, is six inches in diameter and is 400 feet deep. The well was sunk by Capt. Alexander Near in 1907. The pressure, as indicated by the pressure gauge March 14, 1910, was 12 pounds, or a head of 27.7 feet above the surface. The surface elevation of the well, shown by barometer, was 22 feet above the water level in Indian River. This would give the well a total head of 49.7 feet above the river. The water from this well, besides being used for general domestic purposes, is used for bathing and for power. Two large concrete bathing pools have been built and the water flows continually into them. The temperature of the water is said to be 77 degrees F. A water wheel, connected near the well, is used to pump water from a shallow, soft water well.

The following is an analysis of the water from this well. Analysis made for the State Survey in the office of the State Chemist, A. M. Henry, analyst:

Constituents.	Parts per million.
Silica (SiO_2)	18
Chlorine (Cl)	573
Sulphates (SO_4)	150
Phosphates (PO_4)	0
Carbonates (CO_3)	0

Bicarbonates (HCO_3)	156
Sodium and potassium (Na and K)	269
Magnesium (Mg)	68
Calcium (Ca)	123
Iron and alumina (Fe and Al)	8
Loss of ignition	375
Total dissolved solids	1555

Mr. M. B. Rhodes' well, near the postoffice, at Melbourne, is 45 feet deep and furnishes a flow, which rises about three feet above the surface. The elevation of the well is about three feet above the water level in Indian River. The well is of interest in that the water flows at such a shallow depth. The materials penetrated in the sinking of this well were approximately as follows:

	Feet.
Sand	0 -10
"Hardpan"	10 -11
Sand, water	11 -20
"Hardpan," water	20 -20½
Sand	20½-35
Sandy, clay, water, flowing 3 feet above the surface of the well	35 -45

The water is soft and very desirable for all domestic purposes.

Another such well as the above is owned by Dr. L. A. Peek. This well is 52 feet deep, one and one-fourth inches in diameter and furnishes a good supply of soft water.

The well owned by Mr. Oliver Gibbs is located at Melbourne Beach, across the Indian River from Melbourne. This is a four-inch well drilled, in 1907, by Capt. Alexander Near. It reached a total depth of 318 feet and is cased 100 feet. The pressure of the well, as indicated by the pressure gauge March 15, 1910, was 17½ pounds. This gives the well a head of 40.4 feet above the surface, or estimating the surface elevation of the well to be 12 feet above the river level, a total head of 52.4 feet above the level of the water in Indian River. From an examination of a mixed sample from the drillings of this well, it is seen that the Vicksburg Limestone is reached. From Mr. Gibb's record made at the time the well was drilled, it would appear that this formation was encountered at a depth of 221 feet. The log, as made out by Mr. Gibbs, is as follows:

	Feet.
Surface sands and soil	0 - 3
Yellow sand	3 - 11
Coquina rock	11 - 21
Fine gray sand	21 - 51
Shell and sand	51 - 56
Hard shell rock	56 -119
Greenish clay	119 -173
Dark colored rock; sharks' teeth	173 -173½
Greenish clay	173½-174¼
Dark colored rock; sharks' teeth	174¼-175
Greenish clay	175 -221
Vicksburg Limestone. Increase of flow with depth. A pressure of 17½ pounds at this depth was shown by the gauge March 15, 1910. Mild sulphur water	221 -318

MERRITTS ISLAND.

From the well records obtained in this locality, it is probable that flowing artesian wells can be obtained at any point on Merritt Island. Record of wells are on file from every postoffice on the island, bordering the Indian River. Also, records have been obtained from Artesia, Cape Canaveral Light House, and Canaveral Club House, on the peninsula, east of the island; good flows being reported from all of these localities. The pressure of two of the wells on the southern end of the island was obtained, one at Lotus and one at Tropic. The well of L. D. Hancock, one mile south of Lotus, has a depth of about 300 feet. The pressure of this well March 12, 1910, was 16 pounds. The elevation of the well, according to barometric readings, is 10 feet. This, together with a pressure of 16 pounds, gives the well a total head of 46.9 feet above the level of the water in Indian River. The following is an analysis of the water from this well. Analysis made for the State Survey in the office of the State Chemist, A. M. Henry, analyst:

Constituents.	Parts per million.
Silica (SiO_2)	12
Chlorine (Cl)	642

Sulphates (SO_4)	178
Phosphates (PO_4)	0
Carbonates (CO_3)	0
Bicarbonates (HCO_3)	149
Sodium and potassium (Na and K)	309
Magnesium (Mg)	63
Calcium (Ca)	132
Iron and alumina (Fe and Al)	3
Loss on ignition	370
Total dissolved solids	1710

At Tropic Mrs. John W. Merrill has two artesian wells, two and three inches respectively. These wells were drilled about 1885. The depth was not learned. The gauge on the two-inch well, March 12, 1910, indicated a pressure of 16½ pounds, or a head of 38.1 feet above the surface, or about 48 feet above the water level in Indian River. The wells are used for general purposes and give an excellent flow of sulphur water.

From the records obtained it appears that the pressure of the wells on the island increases in passing from north to south. At Lotus the pressure was 16 pounds; at Tropic 16½ pounds, and at Melbourne Beach 17½ pounds. No measurements of the pressure of the wells north of Lotus were obtained.

MICCO.

The wells at Micco have, for the most part, been drilled a number of years and, for this reason, no satisfactory records could be obtained. The principal use of the water is for irrigating purposes. One well, drilled in 1908 for Peter Bertleson by J. L. Mobley, was never completed. The well is 3 inches in diameter and is cased 180 feet. At a depth of 300 feet the drill was broken off and was never recovered. A flow coming just over the top of the casing was obtained at this depth.

ROCKLEDGE.

The Rockledge wells vary in depth from 150 to 480 feet. These wells are the principal source of domestic water supply, as well as being used for irrigating purposes. In a few instances the artesian wells are used for power purposes, such as for generating electricity by means of a water turbine. A ten-inch well, drilled in 1893 and now owned by Mr. G. M. Houston, about one and one-half miles south of Rockledge, is used for this purpose. The well has a reported depth of 480 feet. A gauge on the well indicated a pressure of 12½ pounds, March 10, 1910, or a head of 28.8 feet above this point. The gauge was estimated to be ten feet above the level of the water in the river, thus giving the well a total head of 38.8 feet above the river level. The water contains a trace of salt, as is common to the wells in this vicinity.

The well of Mr. H. S. Williams is of particular interest, in that it is the only well in this vicinity, of which a log has been obtained. It was drilled about 1890 and is 304 feet deep. It is three inches in diameter and is cased 130 feet. The following is a log of this well, as reported by Mr. Williams:

	Feet.
Sand and soil	0 - 10
Coquina rock	10 - 30
Sand	30 -100
Sand rock	100 -140
Blue clay	140 -170
Hard flint rock. At this depth water rose to the surface, small stream	170 -173
Rock in layer from 3 to 18 inches thick	173 -269
Hard rock	269 -273
Soft rock	273 -278⅔
Hard rock, good flow of water	278⅔-304⅔

The first flow in the well, as will be seen by consulting the log, was obtained from a depth of 170-173 feet. At this depth 3 feet of hard flint rock was encountered and on penetrating this stratum the first water-bearing formation was reached.

SHARPES.

Several flowing wells occur in and near Sharpes. The water here contains salt to such an extent that it can not be used for irrigation. The well of J. W. Spafford furnished the following record. The well is four inches in diameter and 200 feet deep. It is reported cased only about 40 feet, and to have a head of 10 feet above the surface. The first flow was encountered at 70 feet and it is reported by the driller, Capt. W. H. Sharpes, that neither the head nor the volume increased with the depth. As indicated from the well records and from all obtainable information, only a small amount of casing was used in the wells in this vicinity, and a knowledge as to whether or not fresh water was encountered below the stratum of salt water is, therefore, lacking.

The following is an analysis of the water from the well of J. J. Ollif, Sharpes, Fla. This well is near the Spafford well and approximately one mile north of the Hendry well, at City Point, analysis of which is given on page 234. Analysis made for the State Survey in the office of the State Chemist, A. M. Henry, analyst:

Constituents.	Parts per million.
Silica (SiO_2)	16
Chlorine (Cl)	3120
Sulphates (SO_4)	302
Phosphates (PO_4)	0
Carbonates (CO_3)	0
Bicarbonates (HCO_3)	165
Sodium and potassium (Na and K)	1634
Magnesium (Mg)	286
Calcium (Ca)	262
Iron and alumina (Fe and Al)	4
Loss on ignition	974
Total dissolved solids	6520

TILLMAN.

The only deep well at Tillman, of which record has been obtained, was drilled by John McAllister, in 1890, and is owned by R. A. Conkling. It is 350 feet deep and furnishes an excellent flow of water, which is used for general domestic purposes.

TITUSVILLE.

Titusville, the county seat of Brevard County, is located on the Indian River. Several artesian wells have been sunk at this locality, but up to the present time principally salt water has been obtained. A test well, put down about 1890, was drilled to a total depth of 864 feet. A salt water stratum was reached at a depth of about 100 feet. The well was cased to a depth of about 110 feet, but no attempt was made to case off the salt water. Both the flow and the head is reported to have increased with increase of depth. Several other wells have been subsequently drilled in and near the city. One of these, located at the Dixie Hotel, is said to have been drilled to a depth of about 400 feet. Another, located at the Grand View Hotel, drilled about 1895, is believed to have reached the depth of about 200 feet. Two other wells, one located at the old plant of the Florida Extract Company, the other at the plant of the Titusville Ice Company, were drilled to a depth of 150 and 145 feet, respectively. Salt water was obtained from all of these wells, and in none of them was an attempt made, so far as the records indicate, to go through or to case off the salt water stratum. Fresh water is obtained from shallow driven wells, none of which exceed 100 feet in depth. The water obtained from these wells, as a rule, does not flow. In at least one instance, however, a small flowing fresh-water well has been obtained at a depth of less than 100 feet. The wells, which exceed 100 feet in depth, as stated above, have yielded only salt water.

The following is an analysis of the water of the well of the Titusville Ice Company. Analysis made for the State Survey in the office of the State Chemist, A. M. Henry, analyst:

Constituents.	Parts per million.
Silica (SiO_2)	8
Chlorine (Cl)	11879
Sulphates (SO_4)	547
Phosphates (PO_4)	0
Bicarbonates (HCO_3)	177
Sodium and potassium (Na and K)	6542
Magnesium (Mg)	669
Calcium (Ca)	637
Iron and alumina (Fe and Al)	3
Loss on ignition	1380
Total dissolved solids	23060

VALKARIA.

A record of one deep well, at Valkaria, has been obtained. This well was drilled by Mr. W. J. Nesbitt, in 1892, for Mr. E. A. Svedelius. It is a 3-inch well, 350 feet deep, and is cased to a depth of 90 feet. The water is reported to rise 15 feet or more above the surface. At a depth of 320 feet hard rock was encountered and, immediately below this rock, the first water, under sufficient pressure to cause it to rise to the surface, was obtained.

ST. LUCIE COUNTY.

LOCATION AND SURFACE FEATURES.

St. Lucie County lies south of Brevard County. It is 42 miles long and from 24 to 42 miles in width. Ft. Drum ridge in this county has an elevation of 66.74 feet above the mean sea level.* The eastern part of the county, aside from the line of sand dunes near the coast, consists largely of palmetto flatwoods. Towards the west border the land is more rolling and numerous small lakes occur. Some muck lands are found near the headwaters of the St. Johns River.

WATER-BEARING FORMATIONS.

The wells of this county, as elsewhere along the East Coast, reach the Vicksburg Limestones. These limestones, however, dip in passing to the south and lie at a greater depth in St. Lucie County than in the adjoining counties to the north. The wells of the St. Lucie Ice Company, at Ft. Pierce, are 812 feet deep and, probably, reach the Vicksburg Limestone. The first flow from the wells, at Ft. Pierce, is reported to have been obtained from the depth of 725 to 750 feet.

AREA OF ARTESIAN FLOW OF ST. LUCIE COUNTY.

Owing to the few wells that have been drilled, the area of artesian flow in St. Lucie County is imperfectly determined.

*Survey made in 1903, under the direction of Captain F. R. Shunk, U. S. Army.

Along the East Coast wells are in use as far as the southern line of the county. It is probable that flowing wells can be obtained for some miles inland from the coast.

LOCAL DETAILS.

EDEN.

A four-inch well at Eden, owned by Mr. Chas. Edison, was sunk by Messrs. Fee & Nesbitt and is 870 feet deep. The water is used for general and irrigation purposes. It rises 25 feet above the surface. It is a hard water and is impregnated with hydrogen sulphide.

FT. PIERCE.

Two artesian wells occur at Ft. Pierce, the county seat of St. Lucie County. These are owned by the St. Lucie Ice Company. The wells are reported to have a depth of 812 feet. One is six inches in diameter, the other 2 inches, and both are reported cased 200 feet. The first flow is said to have been obtained from limestone, at a depth of from 725 to 750 feet. The last 100 feet of the well is said to have been through this limestone. The following is an analysis of the water from one of these wells. Analysis by the Geo. W. Lord Company, 2238-2250 North Ninth Street, Philadelphia, Pa., Chester Alsmere, chemist, reported January 18, 1907:

Constituents.	Parts per million.
Organic and volatile matter	51.311
Calcium oxide	70.650
Magnesium oxide	31.939
Sodium oxide	736.846
Sulphur trioxide	241.489
Chlorine	446.737
Carbonic acid (combined)	204.081
Silica	33.979

As will be seen in the above analysis this water contains a high percentage of sodium and chlorine. The water tastes brackish, and is used for cooling purposes in the manufacture of ice. The principal water supply for domestic purposes, in and around Ft. Pierce, is obtained from shallow wells, ranging in depth from 12 to 50 feet.

The following is a record of a well drilled at Ft. Pierce by H. Walker for the Florida East Coast Railway in 1912. The well is 814 feet deep and is cased with eight-inch casing 184 feet and 9 inches, and with six-inch casing 570 feet and 10 inches. The head above the surface is 28 feet and 6 inches. The head above Indian River is 46 feet. The well flows 800 gallons per minute at the surface. The record has been kindly supplied by Mr. G. A. Miller, of the Florida East Coast Railway.

	Feet.
Yellow sand	0- 55
Shell and sand	55- 75
Shell and gravel	75- 85
Shell, sand and clay	85-120
Blue clay and sand	120-135
Soft blue clay and very fine sand	135-145
Blue clay and sand	145-165
Blue clay	165-190
Tough, dry blue clay	190-200
Soft sandy, blue clay	200-250
Hard sandy, blue clay	250-300
Smooth blue clay, no sand	300-400
Blue clay, very tough and sticky	400-460
Yellow clay, with black streaks in it	460-500
Yellow clay, with a few pebbles	500-520
Blue clay, tough and sticky	520-545
Very hard yellow clay	545-555
Blue clay, very sticky	555-585
Yellow clay in hard and soft layers	585-600
Yellow clay, very dry	600-647
Shell and soft rock	647-656
Tough white clay	656-662
Hard white rock	662-676
Soft rock, small flow	676-685
Soft limestone rock, flow increasing very slowly with depth	685-807
Hard rock	807-814

The following is an analysis of the water from this well made by the American Water Softener Company, Philadelphia, Pa.:

Constituents.	Grains per U. S. gallon.	Parts per million.
Calcium carbonate	1.71	29.31
Calcium sulphate	8.34	142.97
Magnesium carbonate	9.26	156.73
Sodium sulphate	18.90	324.00
Sodium chloride	43.50	745.71
Free carbonic acid	1.00	17.14
Iron, aluminum and silica	0.28	4.70
Incrusting solids	19.59	335.83
Non-incrusting solids	62.40	1069.72
Total solids	83.00	1422.86

NARROWS.

Two deep wells are reported from Narrows. One is owned by Mr. F. Foster, the other by Mr. E. L. Gray. These wells were drilled by Mr. W. J. Nesbitt about the year 1892. Both are three inches in diameter and 420 feet deep. The height to which the water would rise above the surface was not obtained, but the wells are reported to have a head of several feet, and to furnish a strong flow of water.

ORCHID.

Mr. S. K. Michael owns an artesian well at Orchid. This well was sunk by Capt. Alexander Near in 1896. It is 480 feet deep, four inches in diameter and is cased 85 feet. The well is reported to have a head of 40 feet above sea, and to furnish an abundant supply of hard, sulphur water.

ROSELAND.

The artesian wells at Roseland have been drilled for a number of years and, for this reason, no very definite information could be obtained. Mr. L. C. Moore owns three wells, located about one and one-half miles north of Roseland, on the point between the Sebastian and Indian Rivers. These wells range in depth from 350 to 453 feet. The water is hard and impregnated with hydrogen sulphide and is used for irrigating and general purposes.

SEBASTIAN.

There are several flowing artesian wells in and near Sebastian. They vary in depth from 365 to 500 feet. At this depth an abundance of hard sulphuretted water is obtained, rising from 16 to 25, or more, feet above the surface. A well owned by Mr. J. A. Groves, drilled by Mr. J. McAllister, was completed in 1896. This well is 460 feet deep, four inches in diameter, and is cased 100 feet. The water is reported to have a head of 16 feet above the surface, the surface elevation being estimated at 25 feet above the level of the water in Indian River. The total head of the well above the river is thus 41 feet. The water is used for general and domestic purposes and for irrigation. A four-inch well, drilled by Capt. Alexander Near, in 1901, owned by the Indian River Cooperage Company, is 365 feet deep. The water is reported to rise 25 or more feet above the surface. The elevation of the depot at Sebastian, according to levels run by the Florida East Coast Railway, is 19 feet. This well has approximately the same elevation as the depot, and this, in addition to head of 25 feet above the surface, gives the well a total head of 44 feet above sea. The well is now abandoned, but, when first sunk, was used for the manufacture of ice.

The Fellsmere Farms Company have recently completed a well, about ten miles west of Sebastian (Sec. 22, T. 31 S., R. 37 E.). The well is four inches in diameter, 370 feet deep, and is cased 146 feet. The head, tested September 23, 1910, by Mr. E. H. Every, manager, was found to be 25 feet above the surface, and the flow 185 gallons per minute.*

The following is the analysis of the water from this well made by the State Chemist:

Constituents.	Parts per million.
Chlorine (Cl)	257
Carbonates (CO_3)	0

*Letter to Capt. R. E. Rose, State Chemist, Sept. 23, 1910.

Bicarbonates (HCO_3)	177
Loss on ignition	245
Total dissolved solids	905

PINELLAS COUNTY.

LOCATION AND SURFACE FEATURES.

Pinellas County lies on the Gulf Coast and includes the peninsula between Tampa Bay and the Gulf of Mexico. The area of the land surface of the county is approximately 260 square miles. The surface is prevailingly level, with a gradual rise in passing inland from the coast. The county is crossed by the Atlantic Coast Line Railroad, and by the Tampa and Gulf Coast Railroad. The elevations recorded by the Atlantic Coast Line Railroad are as follows: Belleair, 49 feet; Clearwater, 29 feet; Dunedin, 13 feet; Largo, 50 feet; St. Petersburg, 20 feet; Tarpon Springs, 14 feet.

WATER-BEARING FORMATIONS.

The deep wells in Pinellas County doubtless terminate in the Vicksburg Limestone.

AREA OF ARTESIAN FLOW.

The flowing area, in this county, includes a narrow strip bordering the coast and extending somewhat north of Dunedin. Flowing wells can probably be obtained along the shore entirely around Tampa Bay. The accompanying map shows the area in this county, in which it is believed that flowing wells can be obtained.

LOCAL DETAILS.

CLEARWATER.

Clearwater is near the center of the county, from north to south. The city water supply, at Clearwater, is taken from a well 250 feet deep. A second well, 270 feet deep, is held in reserve. Both wells are eight inches in diameter and are cased about 30 feet. When not in use the wells flow, but when either well is being pumped the head is reduced, stopping the flow in the other well. The 270-foot well has brackish water.

The Clearwater Ice Factory has three wells, 46, 52 and 80 feet deep. They are all cased 30 feet and the water is reported to stand 26 feet from the surface. These wells are located on high ground, the difference in elevation being probably sufficient to account for the difference in head between these and the city wells.

DUNEDIN.

Flowing wells are obtained along the coast at Dunedin. The wells range in depth from 55 to 120 feet. C. B. Bowden has a six-inch well, 98 feet deep and cased 70 feet, in which the water stands 20 feet from the surface. This well is used as a public supply. T. J. Zimmerman has a well, at this locality, 68 feet deep, in which the water stands 12 feet from the surface. W. C. McLain has a flowing artesian well, about two miles north of Dunedin. This well is 202 feet deep and is estimated to flow 10 gallons a minute. This is the northernmost flowing well in this county.

ESPIRITU SANTO SPRINGS.

The Espiritu Santo Springs, located near the north end of Tampa Bay, include five springs. The following is an analysis of the water from the one known as the drinking spring: Analysis by the N. B. Pratt Laboratory, Atlanta, Georgia:

Constituents.	Grains per U. S. gallon.	Parts per million.
Peroxide of iron and alumina	.1692	2.9007
Sodium chloride	137.8520	2363.2208
Magnesium chloride	25.8768	443.5292
Potassium sulphate	3.4815	59.6854
Calcium sulphate	19.7172	338.0297
Calcium carbonate	12.6145	216.2607
Silica	.9972	17.0958
Total solids by evaporation	254.9165	4370.2629

LARGO.

Several wells have been drilled at Largo. Lewis Johnson has a four-inch well, 200 feet deep, which is used as a public well. Joel McMullen has a well, about eight miles southwest of Largo, 227 feet deep, in which the water stands 15 feet from the surface.

OZONA.

The wells at Ozona are mostly 50 to 60 feet deep. A two-inch well, owned by Wm. Woods, is 80 feet deep and the water stands eight feet below the surface. C. R. C. Smith has a well 106 feet deep, but the water at this depth is said to be salty.

PASS-A-GRILLE.

The following is a log of a four-inch well, 256 feet deep, drilled by J. C. Danielson, and is used as a public well. The well is cased 204 feet and the water rises 14 feet above sea:

	Feet.
White beach sand	0- 3
Shells	3- 7
Fine sand	7- 35
Coquina	35- 41
Quicksand and blue clay	41- 80
Hard blue clay	80-200
Limestone, principal flow from 230 feet	205-256

The following is an analysis of the water from this well. Analysis made in the office of the State Chemist of Florida, A. M. Henry, analyst:

	Milligrams per liter. (Parts per million.)
SiO_2	46.2
Fe and Al	6.2
Ca.	393.8
Mg.	187.0
Na.	611.9
K	10.9
Cl.	1560.2
CO_3	0.0

HCO_3	204.4
SO_4	754.7
PO_4	0.0
Total	3775.3

These may be combined as follows:

KCl.	20.8
NaCl.	1555.3
$MgCl_2$	777.9
$CaCl_2$	25.0
$CaSO_4$	1068.6
$Ca(HCO_3)_2$	271.6
$CaSiO_3$	10.7
SiO_2	39.2
Fe and Al	6.2

PINELLAS PARK.

A six-inch well, drilled at this locality by J. C. Danielson, reached a total depth of 325 feet. The water in the well stands five feet from the surface.

ST. PETERSBURG.

Flowing wells are obtained at St. Petersburg, along the coast, the water rising 10 to 14 feet above sea level. A well near the dock is four inches in diameter and 100 feet deep. The water from this well rises 10 feet above the surface. Another well near the bay, about one mile southeast of St. Petersburg, was drilled 480 feet deep. The water from this well rises about 10 feet above the surface and is salty.

The city supply at St. Petersburg is obtained from one seven-inch and two ten-inch wells, variously reported at 135 and 235 feet deep. These wells are located on the upland, about 31½ feet above the level of the bay. When first drilled, the water is said to have stood 22 feet from the surface, but, after being used for some time, the water level was reduced to 36 feet from the surface. The following is an analysis of the water made by Dearborn Drug and Chemical Works, Chicago, Ill., December 11, 1911:

Constituents.	Grains per U. S. gallon.	Parts per million.
Silica	.934	16.012
Oxides of iron and alumina	.117	2.005
Carbonate of lime	9.900	169.724
Chloride of lime	2.761	47.334
Sulphate of lime	.405	6.943
Carbonate of magnesia	Trace	
Chloride of magnesia	1.993	34.167
Sodium and potassium sulphates	Trace	
Sodium and potassium chlorides	4.964	85.102
Loss, etc.	.183	3.137
Total soluble mineral solids	21.257	364.427
Suspended matter	1.168	20.024
Organic matter	Trace	
Total soluble incrusting solids	16.110	276.188
Total soluble non-incrusting solids	5.147	98.239

The following is analysis of water from one of these wells. Analysis made in the office of the State Chemist, A. M. Henry, analyst:

Well water of 155-foot city well of St. Petersburg, Pinellas County, Florida:

	Milligrams per liter. (Parts per million.)
Silica (SiO_2)	28.5
Iron and alumina (Fe and Al)	0.9
Calcium (Ca)	92.6
Magnesium (Mg)	9.6
Sodium (Na)	...
Potassium (K)	...
Chlorine (Cl)	120.6
Carbonates (CO_3)	0.0
Bicarbonates (HCO_3)	216.6
Sulphates (SO_4)	2.1
Phosphates (PO_4)	1.5
Total	580.00

The following is a log of a six-inch well, 99 feet deep, drilled by J. C. Danielson, and owned by the St. Petersburg Investment Company. The well was drilled in 1912 and is cased 64½ feet.

	Feet.
Casing driven and no record	0 -64½
Hard lime rock	64½-69½
Soft lime rock	69½-71
Close grained lime rock	71 -86
Water-bearing rock	86 -88
Hard lime rock	88 -99

The following is an analysis of the water from this well made by the Bird-Archer Company, 90 West Street, New York City:

Constituents.	Grains per U. S. gallon.	Parts per million.
Organic and volatile matter	4.717	80.867
Sodium chloride	3.244	55.614
Calcium carbonate	9.529	163.364
Magnesium chloride	2.332	39.979
Total solids	19.822	339.826
Free carbonic acid	9.415	161.409

The following is a log of a six-inch well, 155 feet deep, owned and drilled by J. C. Danielson. The well is located on the bay shore, two miles north of St. Petersburg. It is cased 76 feet, and the water rises about three feet above the surface. The flow is estimated at 200 gallons per minute.

	Feet.
Soil	0 - 1½
Dark colored sand	1½- 9
Hard pan	9 - 16
White water-bearing sand	16 - 50
White clay	50 - 60
Water-bearing rock	60 - 66
Light brown, sticky clay	66 - 76
Rock, alternating hard and soft strata	76 -156

The following is a log of a four-inch well, 230 feet deep, drilled by J. C. Danielson for R. S. Hanna, at Maximo Point, five miles southwest of St. Petersburg. The elevation at the well is about seven feet above sea and the water rises six feet above the surface, or a total head of about thirteen feet above sea. The well is cased 86 feet.

	Feet.
Soil	0 - 1
Marl-clay	1 - 2
Rock	2 - 2⅓
Quicksand	2⅓- 72
Blue clay	72 - 76
Limestone	76 -230

The following is an analysis of the water from this well. Analysis made in the office of the State Chemist, A. M. Henry, analyst. Sample taken by H. Gunter, May 14, 1912:

	Milligrams per liter. (Parts per million.)
PO_4	0.0
SiO_2	42.2
SO_4	558.6
CO_3	0.0
HCO_3	180.0
Cl	1117.0
Fe and Al	2.6
Ca	328.6
Mg.	122.8
K	8.8
Na	462.2
O (calculated)	7.8
Total	2830.6

These may be combined as follows:

KCl	24.8
NaCl	1175.2
$MgCl_2$	480.9
$CaCl_2$	46.7
$CaSO_4$	791.7
$Ca(HCO_3)_2$	239.1
$CaSiO_3$	56.9
SiO_2	12.7
Fe and Al	2.6
Total	2830.6

SEMINOLE.

A number of wells have been drilled in the vicinity of Seminole. A four-inch well, owned by Frank Grable, near the locality, drilled by T. J. Zimmerman, reached a depth of 270 feet. The water is reported to stand 16 feet from the surface.

SUTHERLAND.

Several wells have been drilled at Sutherland. Those exceeding about 100 feet in depth are reported to reach salt water. Fresh water is obtained from 50 to 100 feet.

TARPON SPRINGS.

The city supply at Tarpon Springs is obtained from three six-inch wells, 80, 108 and 126 feet deep respectively. The water stands 20 feet from the surface. The Polar Ice Company also have three wells, 82, 90 and 120 feet deep respectively. In the deepest of these salt water was reached at 120 feet, and the well was plugged at 100 feet.

Tarpon Springs, at this locality, comes up in a bayou from Anclote River. Although covered at high tide, the strong boil from the spring can be seen at medium and low tides.

WALL SPRINGS.

A well, drilled at Wall Springs by T. J. Zimmerman for W. W. Clark, reached a total depth of 313 feet. Fresh water was found in this well to a depth of about 90 feet. Below 90 feet the water is brackish. Three lines of casing were used in this well as follows: eight-inch, six-inch and four-inch. The four-inch casing is said to reach 312 feet. The water in the well stands 13 feet from the surface. There are a number of wells that have been drilled at this locality from 50 to 90 feet deep and yield a fresh water.

Wall Spring, at this locality, has an estimated flow of 3,000 gallons per minute. The water from this spring is used for medicinal purposes.

HILLSBORO COUNTY.

LOCATION AND SURFACE FEATURES.

Hillsboro County includes an area of 1,049 square miles. The county is crossed by the Atlantic Coast Line Railroad and by the Seaboard Air Line Railway, and their branches, and by the Tampa Northern Railroad. The elevation rises in passing inland from Tampa Bay and the Gulf. Plant City, near the east line of the county, is reported, by the Atlantic Coast Line Railroad, to be 137 feet above sea level. The level given by the Seaboard Air Line Railway for this locality is 125 feet above sea level. The elevation of other points in this county, along the Seaboard Air Line Railway, is as follows: Brandon, 74 feet; Knights, 117 feet; Turkey Creek, 87 feet. The elevation of points in this county, along the Atlantic Coast Line Railroad, is as follows: Hillsboro, 35 feet; Seffner, 74 feet, and Thonotosassa, 49 feet above sea. The Hillsboro and Alafia Rivers flow across this county and enter Hillsboro Bay.

WATER-BEARING FORMATIONS.

While no complete set of well drillings has been obtained, there is little doubt but that the deep wells of this county terminate in the Vicksburg Limestone. The surface exposures along Tampa Bay and along the Hillsboro River, for some miles above Tampa, are of the Tampa Limestone, Upper Oligocene, which overlies the Vicksburg formation or Lower Oligocene. A full description of the exposures of the Tampa formation in this county, by George C. Matson and F. G. Clapp, will be found in the Second Annual Report of this Survey, pages 84 to 91, 1909.

AREA OF ARTESIAN FLOW.

Flowing artesian wells are, probably, to be obtained entirely around Hillsboro and Tampa Bays. The head is sufficient to bring the water about ten to fifteen feet above sea level, and the wells will usually flow where the rise above sea does not exceed this elevation. The accompanying map shows the area in this county in which flowing wells can be obtained.

LOCAL DETAILS.

PLANT CITY.

The public water supply at Plant City is taken from a well 340 feet deep. This well is cased 260 feet, and the water stands 33 feet from the surface.

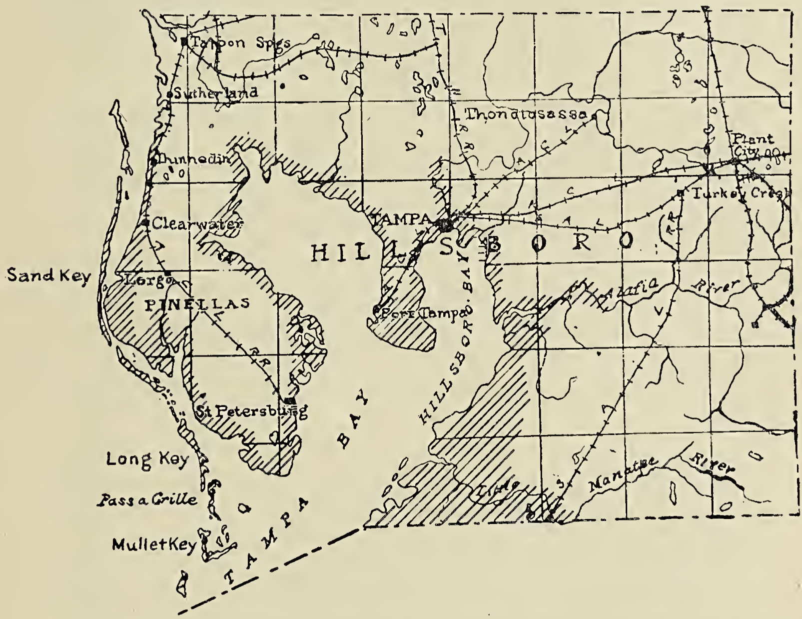

Fig. 13.—Map showing the flowing area in Hillsboro and DeSoto Counties. The area in which flowing wells have been obtained is indicated by shading.

The Plant City Ice and Power Company have a well about 600 feet deep. The water in this well stands 20 feet from the surface.

The following is a log of the well of the Warnell Lumber and Veneer Company, as kept by the drillers, the Hughes Specialty Well Drilling Company. The well is 266½ feet deep and is cased with eight-inch casing to a depth of 105 feet. The water in this well stands 45 feet from the surface.

	Feet.
Sand and clay	1- 20
Sand and dark colored marl	20- 40
Marl and medium hard rock	40-100
Light colored hard rock	100-105
Medium hard rock	105-175
Light colored hard rock	175-190
Shell-bearing medium hard rock	190-215
Soft shell-bearing rock	215-266½

TAMPA.

The water supply for the city of Tampa is obtained from drilled wells, of which there are twenty-eight at present. The wells range in depth from about 200 to 325 feet. Wells at a greater depth, as a rule, reach salty water. The wells are mostly 10 inches in diameter. The casing extends from 52 to 103 feet. The elevation above sea varies from 8 to 15½ feet. The water in these wells will rise 15 to 17 feet above sea level, hence most of the wells flow at the surface. The following is a log of one of the wells taken from the Second Annual Report of this Survey, page 89:

	Feet.
White Pleistocene sand	0- 2
Tough yellow clay with no sand, residual clay	2- 12
Soft limestone, which disintegrates readily, "Tampa limestone"	12- 26
Chert, "Tampa silex bed"	26- 30
Soft limestone, closely resembling that at 12 to 26 feet	30- 36
Tough, plastic, greenish sandy clay	36- 77
Base of the Tampa formation:	
Chert	77- 79
White marl	79- 85
Soft limestone	85- 90
Very light colored hard rock	90-105
Very hard dark yellow limestone	105-111
Gray, porous limestone with some water	111-126
Cherty beds	126-140
Darker limestone.	
Gray plastic clay.	
Hard yellow rock with chert.	
Gray, porous rock, water-bearing.	
Like preceding.	

The following is a log of the well, located at the southwest corner, Lot 2, Block 10, Bouquardez Sub-Division, 233 feet deep:

	Feet.
Sand	0- 8
Clay	8- 12
Hard gray rock	12- 36
Soft gray rock	36- 48
Very hard dark flint	48- 53
Blue clay	53-103
Gray rock with hard streaks	103-124
Dark, hard flint	124-129
White lime rock	129-160
White clay	160-164
Brownish gray rock	164-180
Lime rock	180-233

The following is a log of a well at Ybor City. Northwest quarter, Section 17, Township 29, Range 19, 355 feet deep. Well now abandoned.

	Feet
Sand	0 - 19.4
Gray rock	19.4- 37.6
Tough gray clay	37.6- 41.6
Tough gray clay with streaks of rock	41.6- 48.2
Gray, hard, flinty rock	48.2- 95
Yellow sand rock with a little water	95 - 97
Gray rock, coarse with dark green streaks	97 -109.4
Yellow shell rock	109.4-110.4
Gray hard rock	110.4-223
White sticky clay	223 -228
Gray hard rock	228 -240.5
Soft gray rock, not porous	240.5-315.5
Soft gray rock	315.5-355.5

Four wells at West Tampa, drilled by W. F. Hamilton, formerly used for the public supply, are now used for the manufacture of ice. These wells vary in depth from 360 to 760 feet. One of these is a six-inch well, 360 feet deep, cased 135 feet. Another is a six-inch well, 390 feet deep, cased 93 feet. A third well is 406 feet deep and is cased 90 feet. The fourth well was drilled at a depth of 760 feet and was cased 412 feet. The water from this depth was salty and the well was subsequently filled to about 400 feet. The casing was broken and fresh water admitted at this depth. The water in the wells at this locality is reported to stand at about seven feet from the surface.

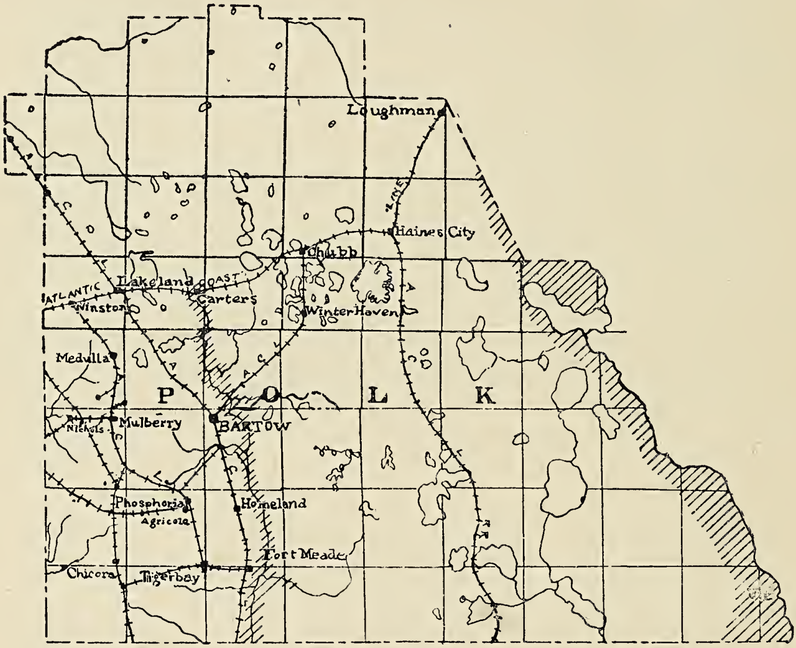

Fig 14.—Map showing of artesian flow in Polk County. The area in which flowing wells have been obtained is indicated by shading.

POLK COUNTY.

LOCATION AND SURFACE FEATURES.

Polk County includes a land area of 1,967 square miles. The Lake Region crosses the central part of this county, and the principal pebble phosphate deposits of the State are found in the western part of the county. The following elevations are recorded along the Atlantic Coast Line Railroad, which crosses the county from east to west and from north to south: Auburndale, 167 feet; Bartow, 115 feet; Bartow Junction, 165 feet; Ft. Meade, 130 feet; Haines City, 157 feet; Homeland, 139 feet; Lakeland, 206 feet.

WATER-BEARING FORMATIONS.

The deep wells of this county reach the Vicksburg Limestone. Some of the more shallow wells, especially in the Lake Region, receive their water supply from formations lying above the Vicksburg.

ARTESIAN WELLS.

Artesian wells are obtained throughout this county. As a rule, however, the surface elevation is such that the wells do not flow at the surface. Some of the deep wells, in the vicinity of Mulberry, flowed when first drilled, but subsequently ceased to flow, owing to the heavy pumping from surrounding wells. Flowing wells may be obtained in the valley of Peace River and in the eastern part of the county, in the valley of the Kissimmee River. In no part of the world, perhaps, is water from deep wells more extensively used than in the pebble phosphate mining section of Polk County. The wells in this section range in depth from 500 to 800 feet. The water rises in the boring to within 20 to 40 feet of the surface, depending upon the elevation. Pumping is chiefly by air lift.

LOCAL DETAILS.

BARTOW.

The city water supply, at Bartow, is taken from a six-inch well, 720 feet deep. The well is reported cased to the bottom. The water stands 24 feet from the surface. Pumping from this well is direct, the pump being lowered in pit to about six feet of the water level.

CARTERS.

Flowing wells have been obtained at Carters. These flowing wells average in depth about 50 feet, and will flow a few feet above the surface.

LAKELAND.

The public water supply of Lakeland is taken from a six-inch well, 489 feet deep, drilled by C. E. Reed in 1904. The well is cased about 350 feet, and the water stands 79 feet from the surface. The well of the Lakeland Refrigerator and Ice Company is reported to be 336 feet deep. The water in this well stands about 100 feet from the surface.

MULBERRY.

The city water supply at Mulberry is taken from an eight-inch well, 385 feet deep. The water stands in this well 21 feet from the surface. The many wells in this locality, used as a source of water supply in phosphate mining, range in depth, as previously stated, from 500 to 800 feet. In size they vary from eight to fourteen inches. The water stands twenty to forty feet from the surface.

OSCEOLA COUNTY.

LOCATION AND SURFACE FEATURES.

Osceola County includes an area of 1827 square miles. Kissimmee River and the chain of lakes from which it takes its origin forms most of the western boundary of this county. The surface elevation of Kissimmee, at the head of Lake Tohopekaliga, according to levels made by the Atlantic Coast Line Railroad, is 63 feet above sea. Campbell, a few miles west of this lake, is 75 feet above sea. St. Cloud, on East Lake Tohopekaliga, is 63 feet above sea. Narcoossee, also on East Lake Tohopekaliga, is 72 feet above sea.

WATER-BEARING FORMATIONS.

Pleistocene shell deposits are found in the valley of the Kissimmee River, this formation having been recognized at a depth of 100 feet in the well of Captain H. Clay Johnson, at Kissimmee. The formations beneath the Pleistocene have not been determined from well samples, but it is probable that the deep

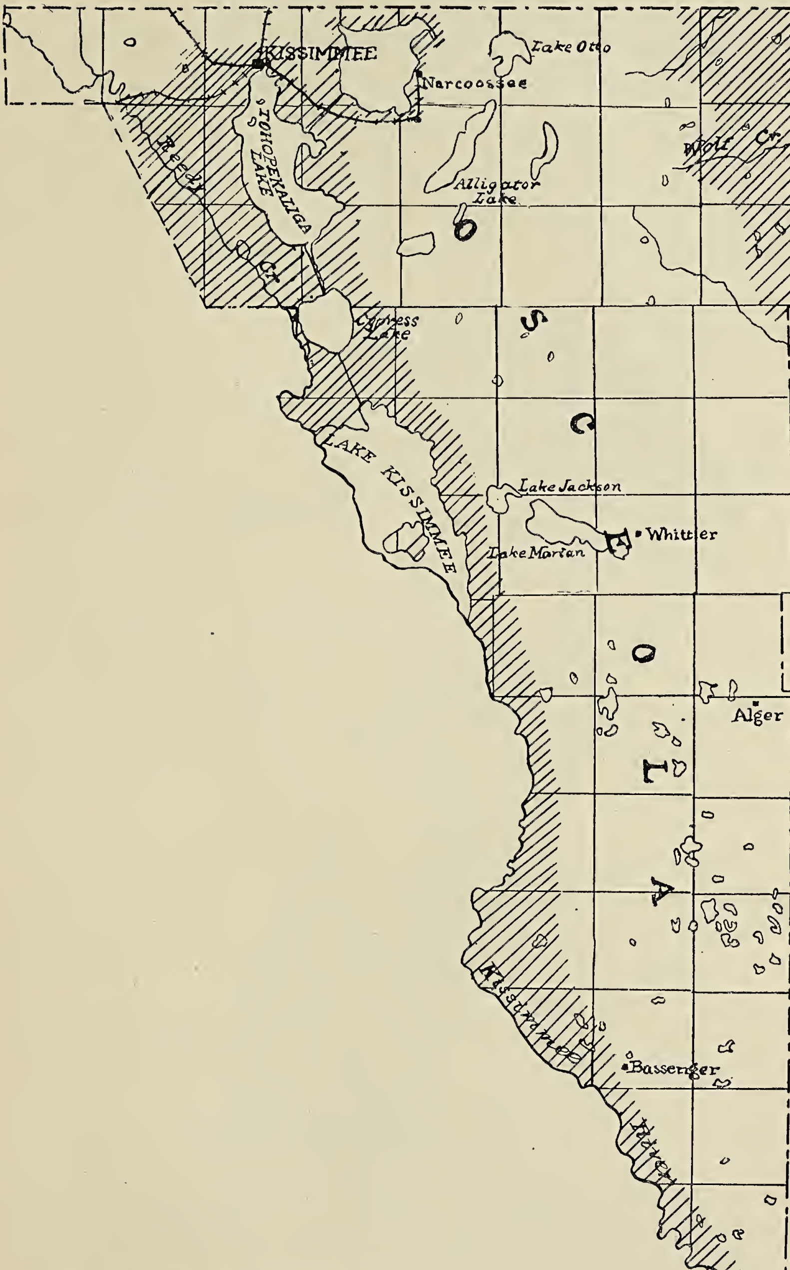

Fig. 15.—Map showing the area of artesian flow in Osceola County. The area in which flowing artesian wells have been obtained is indicated by shading.

wells in this county reach and obtain their chief supply from the Vicksburg Limestone.

AREA OF ARTESIAN FLOW.

Flowing artesian wells are obtained in this county in the valley of the Kissimmee River. It is probable, also, that flowing artesian wells can be obtained in the extreme northeastern part

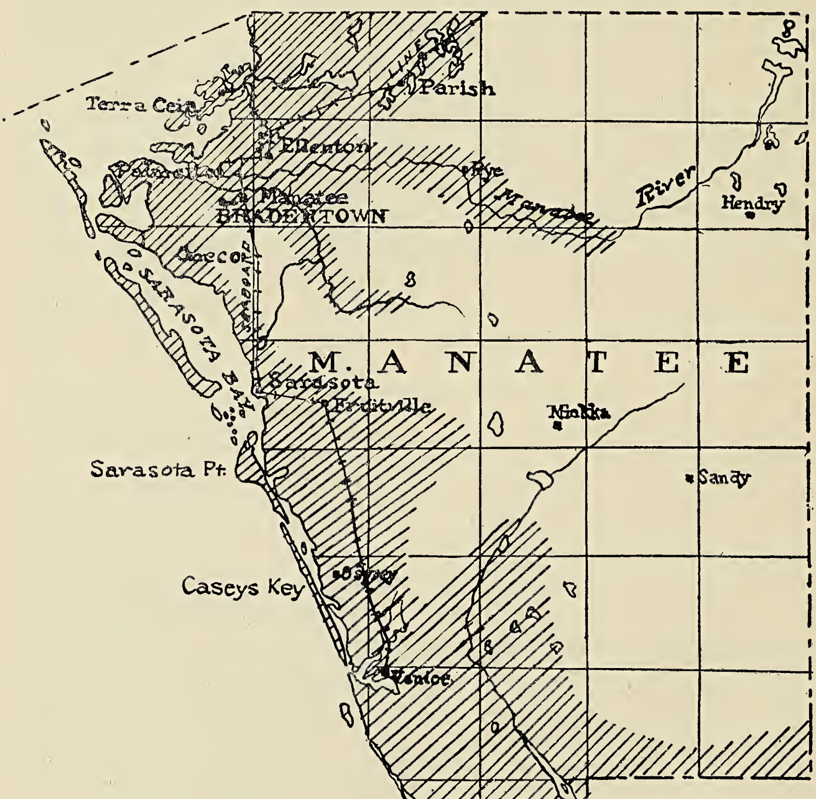

Fig. 16.—Map showing the area of artesian flow in Manatee County. The area in which flowing artesian wells have been obtained is indicated by shading.

of the county, near the St. Johns River. The artesian pressure in the wells in the Kissimmee River valley is sufficient to bring the water from 3 to 7 feet above the surface. These flowing wells vary in depth from less than 100 to 500 and 600 feet.

LOCAL DETAILS.

KISSIMMEE.

Numerous artesian wells have been drilled in and near Kissimmee. These vary in depth from less than one hundred to several hundred feet. The height to which the water will rise above the surface varies from one to three or four feet. The well of the Kissimmee Ice Factory is reported to be 309 feet deep. The water in this well will rise four feet above the surface. The well of H. W. Thurman, at the Granada Hotel, is 341 feet deep and flows at the surface, supplying water for a bathing pool and other domestic purposes. The well of F. Vans Agnew, two miles southeast of Kissimmee, used for domestic and irrigation purposes, is 300 feet deep and yields a strong flow of water at the surface. Many other wells have been drilled for stock, irrigation and domestic purposes in the Kissimmee River valley, and the number is being rapidly increased.

NARCOOSSEE.

Several wells have been drilled at Narcoossee. These vary in depth from 200 to 415 feet. These wells are non-flowing, the elevation here being somewhat greater than at Kissimmee.

MANATEE COUNTY.

LOCATION AND SURFACE FEATURES.

Manatee County lies, bordering the Gulf Coast, between Tampa Bay and Charlotte Harbor. The county includes an area of 1,275 square miles. The principal streams of the county are the Manatee River, which flows across the county from east to west, and enters Tampa Bay and the Myakka River, which flows to the south and enters Charlotte Harbor. It is probable that the northeastern part of the county, near the headwaters of these streams, reaches an elevation of 100 feet above sea. From this part of the county the elevation falls off gradually toward the coast.

WATER-BEARING FORMATIONS.

The deep wells of Manatee County are believed to enter the Vicksburg Limestone. The more shallow wells terminate in the sands and clays before reaching this formation.

AREA OF ARTESIAN FLOW.

Flowing artesian wells are obtained in Manatee County, along the coast and, for some distance inland, along the Manatee and the Myakka Rivers and other streams. The flowing artesian wells along the Manatee River, where a great many have been drilled, vary in depth from 200 to 600 feet. At Sarasota, on Sarasota Bay, flowing water is obtained at 360 feet.

LOCAL DETAILS.

BRADENTOWN.

The city water supply at Bradentown is obtained from artesian wells, which vary in depth from 410 to 528 feet. The water from these wells will rise about thirteen feet above the surface, equivalent to a head of about twenty-nine feet above sea level. Numerous other wells have been drilled in and near Bradentown, which vary in depth from 200 to 600 feet.

MANATEE.

Numerous artesian wells have been drilled in and around Manatee for household use, irrigation and other purposes. The well of the Excelsior Ice Company, at this locality, is 540 feet deep, although a first flow was obtained at a depth of 360 feet. Mr. C. H. Davis has a four-and-one-half-inch well, 510 feet deep, cased 150 feet. This well, when measured May 21, 1910, showed a pressure of eight pounds at the surface, which is equivalent to a head of eighteen and one-half feet above the surface. Another well at this locality, having a depth of 529 feet, cased 260 feet, owned by Mr. Tallant, was found, on the same date, to have a pressure of seven and one-half pounds, or a head above the surface of seventeen and three-tenths feet. The relative elevation of these two wells was not determined, but the surface elevation at the Tallant well is estimated at about six feet above sea.

PALMETTO.

The city water supply at Palmetto is taken from artesian wells. In addition to the city supply, several artesian wells have been drilled at this locality. These vary in depth from 370 to 600 feet. The water is reported to rise 20 to 25 feet above the surface.

SARASOTA.

The well from which the public water supply is taken at Sarasota is reported to have a depth of 450 feet. The water rises about twenty feet above the surface. Other wells drilled at this locality vary in depth from 360 to 400 feet. A flowing well, drilled on Sarasota Key, is reported to be 252 feet deep. The water from this well rises 15 feet above the surface.

DESOTO COUNTY.

LOCATION AND SURFACE FEATURES.

DeSoto County has an area of 3,755 square miles, and extends from the Gulf of Mexico to Lake Okeechobee and the Kissimmee River. The Lake Region extends into the north central part of this county. It is probable that local areas are found in the Lake Region of this county which exceed 150 feet in elevation. From these high lands the slope is gradual to the Gulf and to Lake Okeechobee and to the Kissimmee and the Caloosahatchee Rivers. The following elevations are recorded along the Atlantic

Coast Line Railroad, which crosses the county from north to south: Arcadia, 56 feet; Bowling Green, 116 feet; Ft. Ogden, 37 feet; Nocatee, 38 feet; Wauchula, 107 feet; Zolfo Springs, 61 feet.

WATER-BEARING FORMATIONS.

As elsewhere in Southern Florida, the deep wells obtain their water supply from limestones of the Vicksburg formation.

AREA OF ARTESIAN FLOW.

DeSoto County includes a considerable area, in which flowing artesian wells can be obtained. This flowing area surrounds Charlotte Harbor and in the valley of the Peace River extends entirely across the county. Flowing wells are also obtained along the Caloosahatchee River to Lake Okeechobee. It is also believed that flowing artesian wells may be expected along the west border of Lake Okeechobee and in the valley of the Kissimmee River,

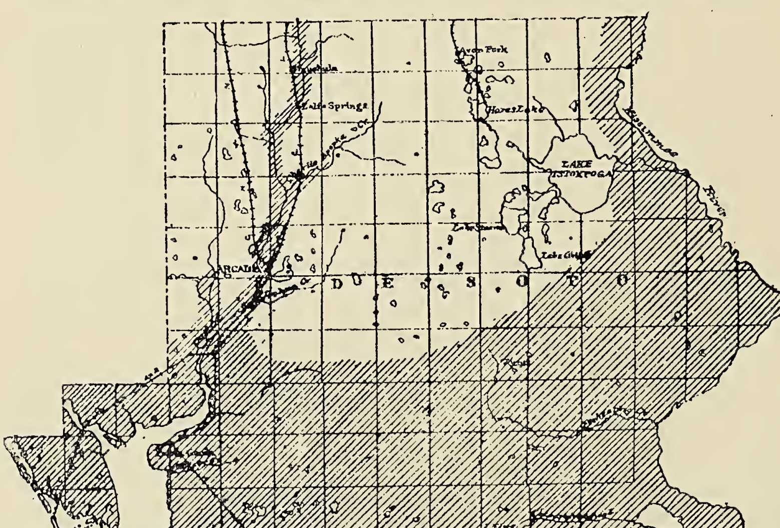

Fig. 17.—Map showing the area of artesian flow in DeSoto County. The area in which flowing artesian wells have been obtained is indicated by shading.

along the east border of this county. The deep wells at Punta Gorda show a pressure of 20 pounds or more, indicating a head of 45 to 50 feet above sea. In the interior of the county, where the elevation is greater, the rise of the artesian water above the surface is correspondingly less. The accompanying map shows approximately the area of artesian flow in the county. It is probable that flowing wells can be obtained over a somewhat larger area than is here indicated. Owing to the fact that no topographic map has been made of this county, and comparatively few wells have been drilled, it is impossible to closely outline the flowing area.

LOCAL DETAILS.

ARCADIA.

The city water supply at Arcadia is taken from an eight-inch well, 375 feet deep. The elevation at Arcadia is given by the Atlantic Coast Line Railroad as 56 feet above sea, and the water in the city well is reported to rise to within one foot of the surface. A number of other wells are reported from the vicinity of Arcadia ranging in depth from 215 to 380 feet. The water from these wells rises to within one to seven feet of the surface. In the valley of the Peace River, near Arcadia, flowing wells are obtained, the water rising from seven to ten feet above the surface.

FT. OGDEN.

The surface elevation at the depot at Ft. Ogden is given as 37 feet above sea. A well, 280 feet deep, located one-half mile west of Ft. Ogden, and belonging to Carr & Williams, flows six or more feet above the surface. The second well, 289 feet deep, belonging to Russell & Windsor, is said to flow 14 feet above sea.

NOCATEE.

Flowing wells are obtained at Nocatee. A well of the DeSoto Fruit Company, one-half mile east of Nocatee, 355 feet deep, flows eight feet above the surface. The well of the Nocatee Fruit

Company, a few miles east of Nocatee, 300 feet deep, also flows eight feet above the ground.

PUNTA GORDA.

The city water supply at Punta Gorda is taken from a six-inch well, 484 feet deep. The well is cased 240 feet. The water from this well is reported to rise about 40 feet above the surface. An eight-inch well, owned by the DeSoto Manufacturing Company, is 430 feet deep. Water from this well is reported to rise about 50 feet above the surface. Numerous other artesian wells have been drilled in and near Punta Gorda, varying in depth from 265 to 600 feet.

PALM BEACH COUNTY.

LOCATION AND SURFACE FEATURES.

Palm Beach County extends from the Atlantic Ocean to Lake Okeechobee, and includes an area of 2,809 square miles. The western part of the county extends into the Everglades of Florida.

WATER-BEARING FORMATIONS.

Samples obtained by N. H. Darton, many years ago, from the well of C. I. Craigin, at Palm Beach, afford practically the only information available regarding the deeper formations of this county. The Vicksburg Limestone is believed to have been reached in this well between 915 and 1,000 feet. The material above this level was scarcely determinable, although apparently the Miocene and, presumably, other formations are represented. The limestone, lying near the surface in the eastern part of this county, is of Pleistocene age, and is known as the Palm Beach Limestone.*

*Second Annual Report, Florida Geol. Surv., p. 209, 1909.

AREA OF ARTESIAN FLOW.

Flowing artesian wells have been obtained in Palm Beach County, along the coast as far south as Palm Beach. The depth to the Vicksburg Limestone, which is the chief water-bearing formation, increases in passing south to east, owing to the dip of the formation in that direction. The Vicksburg at Palm Beach is reached, as previously stated, between 915 and 1,000 feet. In the northern and western parts of the county this formation may be expected at a lesser depth, and it is probable that flowing artesian wells may, ultimately, be obtained throughout all of the northern and much of the western parts of Palm Beach County.

LOCAL DETAILS.

GOMEZ.

A well drilled at Gomez in 1900, by John McAllister, is reported to have reached a depth of 1,200 feet. This is a four-inch well and is cased 300 feet. The water, which is slightly brackish, is reported to flow 20 feet above the surface.

HOBE SOUND.

A well near Hobe Sound, belonging to T. A. Snider, and drilled in 1895 by Near & Taylor, reached a depth of 1,100 feet. This is a four-inch well and the water, which is slightly salty, is reported to rise 12 feet above the surface.

PALM BEACH.

The following is a log of the artesian well of C. I. Cragin, two and one-fourth miles north of Palm Beach. The well is 1,212 feet deep, four inches in diameter and is cased 846 feet. The original four-inch casing having rusted out, is now replaced by a line of 2½-inch casing. At the depth of 1,140 feet the four-inch bore hole was reduced to three inches, making the well three inches in diameter from the depth of 1,140 to the bottom of the well, 1,212 feet. The well was commenced in 1889 and finished in 1890 by J. A. Durst, driller:

Feet from surface.	Character of material.
0 - 5	..Surface soil.
5 - 7	..Rock.
7 - 8	..First sand.
8 - 36	..Mostly fine coquina rock.
36 - 57.2	..Quicksand and sharp pieces of stone.
57.2 - 58	..First really hard rock.
58 - 76.10	..Coquina, alternating with sandy strata.
76.10 - 78	..Hard rock.
78 - 78.6	..Very hard flint.
78.6 - 84	..Sand, white and solid, but not hard.
84 - 96	..Quicksand bed, mixed with bits of coarser material.
96 - 96.6	..Flint rock, thin.
96.6 - 97	..Fine sand.
97 - 148	..Quicksand bed.
148 - 151	..Solid limestone.
151 - 169.6	..Soft gray limestone.
169.6 - 170	..Hard rock.
170 - 171	..Shell stratum.
171 - 171.3	..Very hard sandstone.
171.3 - 175	..Sandstone.
175 - 185	..Alternately hard and soft limestone.
185 - 190	..Straw colored sandstone.
190 - 238	..Drab colored solid sandstone, gradually deepening in its color to a final blue at 230 feet, with small delicate shells throughout.
238 - 238.8	..Bed of small dainty shells. Water level is 3 feet 4 inches below wooden curb.
238.6 - 248	..Very hard drilling, required to move casing in these alternations. Water level above 20 inches (near 242 feet). Very active quicksand.
248 - 250	..Took out loads of quicksand.
250 - 262	..Sand. Water in this sand ran slowly out of pipe at 3 feet 6 inches above ground.
262 - 263	..Coquina.
263 - 300	..Broken shell and sand, more shell (white and pulverized), the last few feet. Water level just above ground level.
300 - 301.6	..Rock, water stands 2 feet 4 inches above curb in this stand.
301.6 - 303.6	..Brown clay, first seen in this well.
303.6 - 310	..Sand.
310 - 312.4	..Blue sandstone.

312.4 - 312.10..Blue sand, shells and pieces of rotten sticks.
312.10- 315.2 ..Blue sandstone.
315.2 - 320 ..Sand, water in this sand stands 3 feet above wooden curb.
320 - 321 ..Blue sandstone.
321 - 340 ..Fine shell and sand, coarser broken shell toward bottom.
340 - 340.3 ..Rock.
340.3 - 350 ..Coarse broken shell, blue pebbles and pieces of coquina, water 2 feet above curb, runs freely at 1 foot above.
350 - 357 ..Yellow sandstone, water 2 feet above curb.
357 - 359 ..Broken shell, pebbles, pieces of coquina.
359 - 373 ..Pulverized shell.
373 - 374 ..Gray limestone, with some broken shell lying immediately beneath, water stands 2 feet 4 inches above on penetrating this rock.
374 - 392 ..Pulverized shell, water stands at level of wooden curb.
392 - 400 ..Alternations of rock and blue marl.
400 - 409 ..Blue marl.
409 - 432 ..Alternations of blue marl and sand which afforded the greatest flow to date and the first fresh water below 49 feet.
432 - 507 ..Blue marl.
507 - 510 ..Coquina.
510 - 542 ..Proportion of sand in the marl increases very much.
542 - 571 ..Quicksand, below casing, can not drill at all. Proportion of sand in the marl increases.
571 - 614 ..Marly sand. Head of water from 9 to 11 feet above ground. Water rises so as to dribble from a height of 11½ feet.
614 - 618 ..Quicksand bed.
618 - 618.6 ..Rock.
618.6 - 640 ..Sand or sandstone.
640 - 707 ..Lighter colored and runs to greenish marly sand all through here. At depth 678-688 more sand, water from 690-700, very many tiny spiral shells.
707 - 710 ..Brown, coarse material.
710 - 794.6 ..Sand with enough marl with it to give a green color to the slush as ejected.
794.6 - 809 ..Loose sand full of black specks and tiny bivalve and spiral shells.

809 - 826	..Blue marl full of black specks.
826 - 828	..Sand.
828 - 834	..Sandstone.
834 - 839	..Very fine, tough clay, thoroughly impervious.
839 - 860	..Fine grained coquina, get dribble of water at depth of about 844 feet 4 inches, casing driven to depth of 846 feet, tight in rock.
860 - 867	..Solid hard limestone.
867 - 874	..Fine clay, devoid of grit.
874 - 876	..Hard rock.
876 - 878	..Lots of black specks here.
878 - 902	..Clays, sandy and lots of black specks, no water.
902 - 905	..Dark sand bed; here the water supply is 115,000 gallons per diem.
905 - 917.6	..Thin block of stone 909 feet, about. This is the lowest sand bed with thin block of limestone at intervals. Water comes from between these thin flakes of limestone.
917.6 - 917.9	..Limestone.
917.9 - 923	..Coralline.
923 - 961	..Hard limestone rock at 923, solid rock nearly 39 feet.
961 - 973	..Gritty marl.
973 - 990.6	..Solid rock.
990.6 -1009	..Sandy marl, full of tiny spirals.
1009 -1012	..Limestone.
1012 -1023	..Yellow sandstone.
1023 -1025	..Hard rock.
1025 -1088	..Rock, first of the regular water strata. Alternating hard and soft strata. Increase of water with depth. At depth of 1042 feet 270,000 gallons, 1057 feet 300,000 gallons, 1075 feet 350,000 gallons; water strata found at frequent intervals.
1088 -1110	..Gray limestone.
1110 -1116	..Gray limestone interspersed with water strata, but the flow increases but slightly. At 1160 feet flow total 400,000 gallons.
1116 -1174	..Solid gray limestone.
1174 -1175	..Blue limestone.
1175 -1193	..All solid.
1193 -1195.6	..Blue limestone (?).
1195.6 -1196	..Six inches water stratum.
1196 -1212	..Mostly gray limestone, with some hard and some water strata, flow increases but little.

The following is an analysis of the water from this well. Analysis made in the office of the State Chemist, A. M. Henry, analyst.

Colorless, odorless, slightly salty taste, no sediment.

	Milligrams per liter.
SiO_2	17
Cl	1337
SO_4	431
PO_4	3
CO_3	0
HCO_3	195
Na and K	835
Mg	112
Ca	102
Fe and Al	2
Loss on ignition	357
Total dissolved solids	3000

WEST JUPITER.

The following is an analysis of the water from Weybrecht's well, at West Jupiter, 57 feet deep. Analysis by the American Water Softener Company, Philadelphia, Pa., July 23, 1908.

	Grains per U. S. gallon.	Parts per million.
Total solids	62.50	1071.49
Calcium carbonate	15.75	270.01
Calcium sulphate	3.13	53.56
Calcium chloride	2.47	42.34
Magnesium carbonate	5.86	100.46
Sodium chloride	30.40	521.17
Free carbonic acid	1.22	29.48
Iron, alumina and silica	1.68	28.80
Incrusting solids	28.89	495.28
Non-incrusting solids	30.40	521.17

YAMATO.

The following is a log of a well at Yamato, drilled by the Florida East Coast Railway. The well is cased 65 feet and the water stands nine feet below the surface.

	Feet.
Sand	0 -24
Yellow clay	24 -34
Sand and shell	34 -40
Rock	40 -41
Gravel	41 -45
Rock	45 -46½
Gravel and rock	46½-61½
Quicksand	61½-65
Rock	65 -67
Sand	67 -74
Rock	75 -88

The following is an analysis of the water from this well made by the American Water Softener Company, Philadelphia, Pa., November 3, 1909:

	Grains per U. S. gallon.	Parts per million.
Calcium carbonate	7.22	123.77
Calcium sulphate	0.54	9.25
Calcium chloride	0.78	13.38
Magnesium carbonate	0.73	12.51
Sodium chloride	0.81	13.78
Free carbonic acid	0.56	9.60
Iron, alumina and silica	0.23	3.94
Incrusting solids	9.50	162.87
Non-incrusting solids	0.81	13.78

LEE COUNTY.

LOCATION AND SURFACE FEATURES.

Lee County lies bordering the Gulf of Mexico and extends inland to Lake Okeechobee. The area of the county is 4,641 square miles. The surface elevation in the northeastern part of the county approximates 25 feet above sea level. No topographic map has been made of the county, but the surface is prevailingly level with, in general, a slope toward the coast.

WATER-BEARING FORMATIONS.

The artesian wells in this county are believed to obtain their chief supply from the Vicksburg formation.

AREA OF ARTESIAN FLOW.

Flowing wells have been obtained over an extensive area throughout the interior of Lee County, as well as along the Caloosahatchee River, along the northern border of the county. It is believed that almost the whole of this county may be included in the artesian flow area.

LOCAL DETAILS.

BOCA GRANDE.

Three deep wells have been drilled at Boca Grande, on Gasparilla Island. The first of these, drilled in 1910, is located 200 feet north of Boca Grande station, and was drilled by G. H. Southard. This well is 1,030 feet deep and is reported cased 800 feet. The well yields a heavy flow of salty water. The second deep well at this locality, drilled in 1911 by F. S. Gilbert, is located 600 feet south of Boca Grande station. This well is 1,220 feet deep and yields a flow of 450 gallons per minute of salty water. The temperature of the water at 1,220 feet was 89 degrees Fahrenheit. The driller, F. S. Gilbert, reports that he cased twenty-two times in drilling this well, the casing being driven and pulled at each show of water in order to test for fresh water. The well, as completed, was cased with six-inch casing to a depth of 1,200 feet. The third well, also drilled by F. S. Gilbert, is located 2,700 feet north of the station. This well is 1,812 feet deep and is cased 1,500 feet. The water is salty. The temperature was 90 degrees Fahrenheit at 1,800 feet. The flow from these wells rises about fifteen feet above sea level. These wells enter the Vicksburg Limestone, and the deepest of the wells apparently does not pass through the Vicksburg Limestone.

FT. MYERS.

The public water supply at Ft. Myers is taken from drilled wells, of which three are in use at present. Three additional wells are available as a reserve supply. These latter vary in depth from

487 to 587 feet. The water from these wells will rise about 45 feet above the surface. A well near Ft. Myers, belonging to Thomas A. Edison, reaches a depth of 648 feet. The water from this well will rise about 45 feet above the surface. Many additional wells have been drilled in and around Ft. Myers; these vary in depth from 400 to 960 feet. The water from these deep wells rises 40 to 50 feet above the surface.

LABELLE.

Flowing wells are obtained at Labelle and elsewhere, along the Caloosahatchee River. D. G. McCormick & Company have a flowing well, about a mile north of the east end of Lake Flirt (T. 42, R. 30, S. 19). This is a three-inch well, 490 feet deep. The well is cased 450 feet and the water is reported to rise 40 feet above the surface. The strong flow reported for this well indicates that flowing wells may be expected over a considerable area, north of the Caloosahatchee River and west of Lake Okeechobee.

THE KEYS.

A number of wells have been drilled on the keys in Lee County. Those at Boca Grande, on Gasparilla Island, have already been described. Two wells are reported to have been drilled on Sanibel Island. One of these belonging to F. P. Bailey, reached a depth of 500 or 600 feet. The second well, belonging to Harry Bailey, is 500 feet deep. The water from both of these wells is said to be brackish. On Useppa Island a fresh water well was obtained by W. H. Towles, at a depth of 250 to 300 feet. A second well on this island, reaching a depth of 400 feet, was said to have been somewhat brackish.

Two wells are reported from St. James Island. One of these is 184 feet deep, the other is 344 feet deep. Both yield fresh water. A well on Bucks Key reaches a depth of 600 feet. The water in this well is reported to rise 20 feet above the surface.

DADE COUNTY.

LOCATION AND SURFACE FEATURES.

Dade County lies in Southern Florida, bordering the Atlantic Coast. The county includes an area of 2,305 square miles. The western part of the county reaches into the Everglades of Florida. East of the Everglades the surface formation is chiefly the Miami Oolitic Limestone.

WATER-BEARING FORMATIONS.

The limestones exposed at the surface, in Dade County, are of Pleistocene age and it is probable that most of the wells terminate without passing through these Pleistocene formations. The deepest well recorded in Dade County is a well drilled recently at Homestead by the Florida East Coast Railway. This well reached a depth of 300 feet, but the age of the formation in which it terminated was not determined.

ARTESIAN WELLS.

The water in the wells at the city waterworks, at Miami, rises to within fourteen inches of the surface level and flows into the collecting basin excavated for that purpose. The possibility of getting flowing artesian water from the Vicksburg Limestone, which lies at a depth of several hundred feet, has not been tested by deep borings.

LOCAL DETAILS.

DANIA.

A well has been drilled at Dania by the Florida East Coast Railway, to a depth of 54 feet. The following is an analysis of the water from this well made by the American Water Softener Company, Philadelphia, Pa., November 3, 1909:

	Grains per U. S. gallon.	Parts per million.
Total solids	17.50	300.01
Calcium carbonate	13.70	234.87
Magnesium carbonate	.77	13.20
Sodium chloride	2.56	43.88
Sodium carbonate	.07	1.20
Free carbonic acid	1.56	26.74
Iron, alumina and silica	.09	1.54
Incrusting solids	14.56	249.61
Non-incrusting solids	2.63	45.08

An analysis of the second sample of water from this well, made by the Dearborn Drug and Chemical Works, Chicago, Ill., July 2, 1910, is as follows:

	Grains per U. S. gallon.	Parts per million.
Silica	.327	5.506
Oxide of iron and alumina	.140	2.400
Carbonate of lime	13.058	233.865
Sulphate of lime	None	None
Carbonate of magnesia	.433	7.423
Sodium and potassium sulphates	.212	3.634
Sodium and potassium chlorides	2.380	40.802
Sodium and potassium carbonates	.369	6.326
Loss, etc.	.307	5.263
Total mineral solids	17.286	296.350
Organic matter	Trace	Trace
Total incrusting solids	13.958	239.294
Total non-incrusting solids	3.328	57.054

The following is a log of the well at Dania, obtained through the courtesy of Mr. G. A. Miller of the Florida East Coast Railway:

	Feet.
Sand	0- 6
Hard pan	6- 8
Shell and rock	8-20
White rock	20-24
Shell, coarse sand and water	24-31
Rock	31-35
Sand and shell	35-40
Rock	40-42

Sand and shell	42-52
Gravel	52-54
Hard rock	54-59½

HOMESTEAD.

An experimental well was drilled at Homestead by the Florida East Coast Railway to a depth of 320 feet. The following is the analysis of the water from this well, at the depth of 16, 46, 66 and 320 feet. Analyses by the American Water Softener Company, Philadelphia, Pa.

No. 1, sample of water from the depth of 16 feet:

	Grains per U. S. gallon.	Parts per million.
Total solids	13.60	233.15
Calcium carbonate	9.85	168.85
Calcium sulphate	0.22	3.77
Calcium chloride	1.42	24.34
Calcium nitrate	0.48	8.22
Magnesium carbonate	0.91	15.59
Iron, alumina and silica	0.90	15.42
Incrusting solids	13.52	221.77

No. 2, sample of water from the depth of 45 feet. May 25, 1911:

	Grains per U. S. gallon.	Parts per million.
Total solids	13.50	185.24
Calcium carbonate	10.14	173.83
Calcium sulphate	0.22	3.77
Calcium chloride	1.32	22.62
Magnesium carbonate	0.45	7.71
Sodium chloride	0.66	11.31
Free carbon dioxide	0.90	15.42
Iron, alumina and silica	0.19	3.25
Incrusting solids	12.32	211.21
Non-incrusting solids	0.66	11.31

No. 3, sample of water from depth of 66 feet. June 29, 1911:

	Grains per U. S. gallon.	Parts per million.
Total solids	14.00	240.01
Calcium carbonate	10.80	185.15
Calcium sulphate	0.39	6.68
Calcium chloride	0.77	13.20
Calcium nitrate	0.39	6.68
Magnesium carbonate	0.39	6.68
Free carbon dioxide	0.53	9.08
Iron, alumina and silica	0.89	15.25
Incrusting solids	13.63	233.67

No. 4, sample of water from the depth of 320 feet. August 4, 1911:

	Grains per U. S. gallon.	Parts per million.
Total solids	57.40	984.05
Calcium carbonate	5.08	87.09
Magnesium carbonate	3.34	57.26
Sodium carbonate	14.35	246.01
Sodium sulphate	15.76	270.18
Sodium chloride	15.76	270.18
Free carbon dioxide	0.26	4.45
Iron, alumina and silica	0.25	4.28
Incrusting solids	8.76	150.18
Non-incrusting solids	45.87	786.39

The water at the depth of 320 feet being unsuited for boiler use, the well was plugged and a more shallow water is being used.

The following is a log of this well, supplied by Mr. G. A. Miller, of the Florida East Coast Railway:

	Feet.
Soft rock	0 - 10
Hard rock	20 - 30
Medium hard rock	30 - 40
Hard rock	40 - 50
Medium hard rock	50 - 55½
Hard rock	55½- 58½

Sand	58½- 59
Soft rock with sand pockets	59 - 62
Loose rock and sand	62 - 66
Sand	66 - 81
Loose sand and rock	81 - 84
Marl	84 - 84¼
Sand	84¼- 92
Marl and shell	92 -115
Gray clay with small amount of fine sand	115 -160
Clay and marl	160 -167
Marl containing a small quantity sand and shell. Sand increasing with depth	167 -197
Marl or soft chalky rock	197 -204
Tough slate colored clay	204 -217
Marl containing sand, shell and gravel	217 -232
Marl or soft chalk-like rock	232 -237
Marl and sand	237 -240
Slate colored clay	240 -268
Clay	268 -294
Marl and clay	294 -298

MIAMI.

The public water supply at Miami is taken from seven wells, located on the north side of Miami River, about one and one-half miles west of the city. The principal supply of fresh water in these wells is obtained at a depth of about 85 feet, although some water is reported at 30 and at 80 feet. The water rises to within 14 inches of the surface and flows into a receiving basin. At 90 feet, in well number 7, recently drilled, salt water was reached. This well was plugged and fresh water admitted from above. The following notes were made from occasional samples from one of these wells. The samples were kept by the Florida East Coast Hotel Company:

	Depth from which sample was obtained. Feet.
Oolitic limestone	0- 3
Non-oolitic granular rock, including some clear grains of silica	24-28
Limestone, fossils, mostly dissolved out and replaced by calcite crystals	28-32
Limestone, compact and partly crystallized	64-66
Hard limestone with few fossils	66-76
Limestone, fossils, mostly dissolved out, leaving cavities; also a number of rounded or flattened pebbles	76-88
Hard limestone, including some water-worn pebbles	88-99

The following is an analysis of the water from the Miami wells. Analysis by the American Water Softener Company, Philadelphia, Pa.:

	Grains per U. S. gallon.	Parts per million.
Total solids	17.50	300.01
Calcium carbonate	12.68	217.38
Calcium sulphate	0.21	3.60
Calcium chloride	0.83	14.22
Magnesium carbonate	0.59	10.11
Sodium chloride	2.20	37.71
Free carbon dioxide	0.60	10.28
Iron, alumina and silica	0.18	3.08
Incrusting solids	14.99	156.98
Non-incrusting solids	2.20	37.71

MONROE COUNTY.

LOCATION AND SURFACE FEATURES.

Monroe County lies along the Gulf Coast, at the extreme southern end of Florida. The area of the land surface, including the numerous keys, is about 1,125 square miles.

WATER-BEARING FORMATIONS.

The Key Largo Coralline Limestone and the Key West Oolitic Limestone make up the surface formations along the keys. On the mainland the Lostman's River Limestone lies near the surface. The deep wells at Key West reach the Vicksburg Limestone.

ARTESIAN WELLS.

No flowing artesian wells have been reported from Monroe County. It is probable, however, that flowing wells could be obtained in the northern part of the county and along the Gulf Coast. Several wells have been drilled on the keys, along the line of the Florida East Coast Railway. None of these, however, have been successful in obtaining either flowing or fresh water.

LOCAL DETAILS.

KEY VACA.

Two deep wells have been drilled by the Florida East Coast Railway at Marathon, on Key Vaca. One of these wells reached a depth of 425 feet, the other 700 feet. The following is a combined record of these two wells by Samuel Sanford, who was in charge of the drilling. The log is republished from the Second Annual Report of this Survey, page 205:

	Feet.
Reef rock	0-105
Hard to soft white limestone, with much white marl	105-148
Soft white limestone with shell casts	148-150
Medium hard white limestone, shell casts and shell fragments	150-155
Soft white limestone with quartz grains, proportion of quartz increasing with depth, shell fragments and casts	155-176
Medium fine quartz-sand containing numerous irregular nodules, with yellowish marly sand at 210 to 215 feet.	176-230
Quartz sand in a varying proportion of limy mud, sand grains, colorless mud, yellowish to dark green; streaks and beds of friable sandstone containing shell casts; bed of oyster shells at 240 feet	230-300
Quartz sands or beds of soft, friable sandstone, containtaining shell casts; streaks of dark green, limy clay, 306-310 feet; beds of shells, few determinable fossils, probably Miocene, 378-390	300-400

Quartz sands as below 230 feet, beds of soft friable sandstone with shell casts; gravel bed with much worn pebbles up to 40 mm. long; tough green, limy clay at 407 to 410 feet	400-435
Quartz sands with little sandstone, tough, dark clay in occasional streaks	435-700

KEY WEST.

Two deep wells have been drilled at Key West. The first of these, drilled in 1895, is reported to have reached a depth of 2,000 feet. The water obtained from this well was too salty for drinking purposes, but is used for fire protection. The following is a log of this well, taken from the Second Annual Report of this Survey, page 206, abbreviated from the detailed description given by E. O. Hovey, of samples from this well:

	Feet.
Yellowish oolite	0- 25
White yellowish or light gray limestone, with oolitic lumps	50- 175
Fine white lime-sand rock	175- 200
White, porous oolitic and sandy limestone	200- 275
White, more or less solid limestone	300- 375
Friable soft gray lime-sand rock	400- 675
Yellowish to brownish lime-sand rock, *Orbitoides,* 800 to 850 feet	700-1075
Light gray, partly dense and partly porous limestone	1100-1175
Gray lime-sand rock	1200-1350
Yellowish gray lime-sand rock, with some porous limestone	1375-1450
Lime-sand rock, varying in color and compactness, with strata of dense limestone	1475-1975
Yellowish to light brownish-gray limestone, rather solid, with porous portions	1975-2000

A second deep well was drilled at this locality by J. T. Brown for S. O. Johnson. This well is 1,010 feet deep and reached salty water. Occasional samples of the drillings from this well to a depth of 540 feet were forwarded to the Florida State Geological Survey. Below 540 feet only one sample was received, which was submitted as representing the material from 800 to 1,010 feet. The following partial log is made up from these occasional samples:

Character of rock.	Depth from which the sample was taken. Feet.
Oolitic limestone with shell fragments. In color the oolitic grains vary from light to pinkish. The sample contains little or no quartz sand	30
Soft limestone powdered very fine, not so conspicuously oolitic as last sample	50
Oolite, light and pinkish oolite grains	70
Light colored oolitic limestone with fragments of shells	80
Oolitic limestone with fragments of shell. Oolite grains vary in color, from light to pinkish	100
From 100 to 210 feet no fine material was brought up by the drill. A salty sulphur water was reached at this depth, and the fine material carried away apparently in the water. The coarse pieces brought up in this distance were as follows:	
Piece of coral and limestone, consisting of fragments of shells and other organisms, also pieces of dark-colored limestones	135
Pieces of hard crystallized limestone and fragment of coral	150
Rough white limestone pieces with shell fragments, also pieces of limestone made up of a mass of shell fragments; also colitic limestone	175
Oolitic limestone with shells and shell fragments, also rough white limestone and partially crystallized limestone	200
Rough white limestone with shell fragments, partially crystallized	210
Rough white limestone with shell fragments	260
Oolite grains light and pinkish in color; also pieces of rough limestone	270
Mass of calcium crystals, stained brownish yellow	325
Rough light-colored limestone pieces with fragments of shells and of corals	340
Rough light-colored limestone pieces with fragments of shells, corals, worm tubes, and light and pinkish oolite with admixture of greenish-gray calcarous material	350
Greenish-gray calcareous sand, with occasional oolite grains imbedded, but no fossils and no siliceous sand	370
Light-colored limestone with fossils and pieces of typical oolite	380

Gray calcareous sand with slight admixture of siliceous sand..	390
Same gray calcareous sand with some pieces of impure light-colored limestone and with one calcite crystal............	400
Same as above, gray calcareous sand, with some light-colored limestone	425
Light, rough limestone with fossils and typical oolite........	450
Gray calcareous sand and light limestone....................	475
Same gray calcareous sand with light-colored limestone......	515
Same gray calcareous sand with fine siliceous sand............	530
Same as above	540

The sample submitted, as representing the material from 800 to 1,010 feet, is limestone, apparently of the Vicksburg formation.

PRODUCTION OF PHOSPHATE ROCK IN FLORIDA DURING 1912.

E. H. Sellards.

The production of phosphate rock in Florida which has steadily increased during the past several years shows, according to statistics collected by the State Geological Survey, a further increase during 1912. The output for 1911 was 2,494,572 long tons, while during 1912 the output, as reported to the State Geological Survey by the producers, was 2,579,865 long tons, an increase of nearly one hundred thousand tons. The increase occurred in both the hard rock and pebble mines. It was greatest, however, in the hard rock mines, this being the reverse of the preceding few years during which the increase had been most rapid in the pebble mines. Thirty companies in all were engaged in mining phosphate in Florida during 1912. Of these fourteen companies were mining hard rock phosphate while sixteen companies were mining pebble phosphate.

The foreign shipments of phosphate rock from Florida during 1912 amounted to 1,203,005 tons. The amount consigned for domestic shipment, as reported by the producers, was 1,219,927 tons. It thus appears that approximately one-half of the phosphate mined in Florida is used in the United States. Hard rock phosphate is said to have sold at the mines during 1912 at about $6.00 per ton. Pebble phosphate sold at the mines at $2.75 to $4.50 per ton, depending upon the grade.

HARD ROCK PHOSPHATE.

Notwithstanding a season of unprecedented rain the mining of hard rock phosphate progressed actively during 1912, resulting in a decided increase in production over the preceding year. The production of hard rock during 1911 in Florida was 474,094 tons while during 1912 there was mined 536,379 tons. The removal of overburden by hydraulics is becoming very general in the hard rock section and has been an important factor in the increased production of rock. Electric lighting and power has made it possible to introduce day and night shifts in the Withlacoochee River mines, one or two plants near Dunnellon having been so operated during 1912. The total number of plants mining hard rock phosphate at the beginning of 1912 was forty-three. Some of these worked out deposits or for other reasons closed down, while several new plants opened up. Forty plants were operating in the hard rock section at the close of the year.

The domestic shipments of hard rock phosphate during 1912 amounted to 15,425 tons, of which 10,449 tons were consigned for use in Florida. The amount of hard rock consigned for export, as reported by the producers, was 473,639 tons, as against 462,072 tons during 1911. The amount of hard rock phosphate actually loaded for shipment during 1912 at the various ports was 470,354 tons.

PEBBLE PHOSPHATE.

The production of pebble phosphate during 1912 shows a slight increase over that of 1911. The output of pebble for 1911 was 2,020,478 tons, while during 1912 the output was 2,043,486 tons. The number of plants engaged in mining pebble phosphate in Florida during 1912 was sixteen, although several mines are frequently worked from one plant. The overburden from the pebble rock is removed by steam shovel or by hydraulics. The rock itself is mined by hydraulics or by steam shovel. Many of the pebble mines run day and night shifts.

The amount of pebble phosphate consigned during 1912 for domestic use, as reported by the producers, was 1,204,502 tons, of which 32,425 tons were consigned for use in Florida. The amount of pebble rock consigned for export during 1912, as reported by the producers, was 682,232 tons. The amount of phosphate actually loaded and cleared for shipments through the several ports during the calendar year 1912, as reported in the American Fertilizer, January 25, 1913, was 732,651 tons, from which it appears probable that a small amount of phosphate sold by the producers to parties in the United States and hence reported by them as domestic shipments, was subsequently exported. The amount of phosphate actually loaded at the ports is used in giving the total exports. The statistics on the production of phosphate rock have been obtained direct from the producers and are complete for all plants operated in Florida.

PHOSPHATE COMPANIES OPERATING IN FLORIDA DURING 1912.

Amalgamated Phosphate Co.	25 S. Calvert St., Baltimore, Md., and Chicora, Fla.
Armour Fertilizer Works	Bartow, Fla.
Peter B. and Robert S. Bradley	92 State St., Boston, Mass., and Floral City, Fla.
J. Buttgenbach & Co.	Holder, Fla.
Camp Phosphate Co.	Ocala and Dunnellon, Fla.
Central Phosphate Co.	Dutton, Fla.
Charleston, S. C., Mining and Manufacturing Co.	Charleston, S. C., and Ft. Meade, Fla.
Compagnie Generale des Phosphates de la Floride	Paris, France, and Pembroke, Fla.
Coronet Phosphate Co.	Lakeland, Fla., and 99 John St., New York.
Cummer Lumber Co.	Jacksonville and Newberry, Fla.
The Dominion Phosphate Co.	Bartow, Fla.
The Dunnellon Phosphate Co.	Rockwell, Fla.
Dutton Phosphate Co.	Gainesville, Fla.
Florida Mining Co.	165 Broadway, New York, and Mulberry, Fla.
Florida Phosphate Mining Corporation	Norfolk, Va., and Bartow, Fla.
Franklin Phosphate Co.	Newberry, Fla.
Holder Phosphate Co.	Ocala and Inverness, Fla.
International Phosphate Co.	27 State St., Boston, Mass., and Ft. Meade, Fla.
Interstate Chemical Corporation	Charleston, S. C., and Bowling Green, Fla.
Istachatta Phosphate Co.	Istachatta, Fla.
Mutual Mining Co.	Savannah, Ga., and Newberry, Fla.
Palmetto Phosphate Co.	Baltimore, Md., and Tiger Bay, Fla.
The Phosphate Mining Co.	55 Johns St., New York, and Nichols, Fla.
Pierce Phosphate Co.	2 Rector St., New York, and Pierce, Fla.
Prairie Pebble Phosphate Co.	165 Broadway, New York, and Mulberry, Fla.
Schilman & Bene	Ocala, Fla.
The Southern Phosphate Development Co.	Ocala and Inverness, Fla.
Standard Phosphate Co.	Christina, Fla.
State Phosphate Co.	Bartow, Fla.
T. A. Thompson	Neals, Fla.

SUMMARY OF PRODUCTION AND SHIPMENT OF FLORIDA PHOSPHATE FOR THE YEARS 1908, 1909, 1910, 1911 AND 1912 (Long Tons).

	1908	1909	1910	1911	1912
HARD ROCK:					
Production	768,011	527,582	392,088	474,094	536,379
Exported	631,001	496,645	461,353	462,072	470,354
Domestic	9,900	17,456	18,745	16,723	15,425
Total shipments	640,901	514,101	480,098	478,795	485,779
PEBBLE ROCK:					
Production	1,150,000	1,334,569	1,637,709	2,020,478	2,043,486
Exported	470,270	509,341	606,110	703,589	732,651
Domestic	421,781	819,701	995,728	1,274,056	1,204,502
Total shipments	892,051	1,329,042	1,601,838	1,977,645	1,937,153
PEBBLE ROCK AND HARD ROCK COMBINED:					
Production	1,918,011	1,862,151	2,029,797	2,494,572	2,579,865
Exported	1,101,271	1,005,986	1,067,463	1,165,661	1,203,005
Domestic	431,681	837,157	1,014,473	1,290,779	1,219,927
Total shipments	1,532,952	1,843,143	2,081,936	2,456,440	2,422,932

Total phosphate produced 1908 to 1912 inclusive	10,884,396 tons
Total phosphate exported 1908 to 1912 inclusive	5,543,386 tons
Total domestic shipments 1908 to 1912 inclusive	4,794,017 tons
Total recorded shipments 1908 to 1912 inclusive	10,337,403 tons
Total amount of phosphate produced in Florida from the beginning of mining in 1888 to 1912 inclusive	23,280,127 tons

STATISTICS ON PUBLIC ROADS.

E. H. Sellards.

A report on roads and road materials of Florida, including statistics, was published by the State Geological Survey in 1911. The accompanying tabulated statement is issued to supplement that report and to complete the statistics to the close of 1912. While the statistics in regard to mileage and cost of construction are necessarily approximate, yet the data are sufficiently accurate to give in a general way the present condition of road building in the State. The information has been supplied chiefly by courtesy of the county officials of the several counties.

At the close of 1912 the total mileage of improved roads in Florida was approximately 2,848 miles. Of this number 857.8 miles are surfaced with marl or crushed stone; 1,408.75 are surfaced with sand-clay; 218 miles are surfaced with shell; 5.2 miles with cement; 26.5 miles with gravel; .4 mile with asphalt and 8.5 miles with brick.

In addition to the funds available from regular and special taxes, the following counties have issued bonds during the past two years for road improvement: Alachua, $40,000; Columbia, $40,000; Dade, $250,000; Jackson, $100,000; St. Johns, $30,000; Walton, $70,000. The following counties had previously issued bonds: Duval, $1,000,000; Hillsboro, $400,000; Manatee, $250,000; Nassau, $60,000; Palm Beach, $200,000; Putnam, $155,000, and St. Lucie, $200,000. The total expenditure on public roads in Florida from all sources exceeds one million dollars per annum.

STATISTICS ON PUBLIC ROADS COLLECTED BY THE STATE GEOLOGICAL SURVEY, 1912

COUNTY	Area of land surface (Square miles)	Population (Census 1910)	Total assessed valuation of property	ROAD REVENUES			Improved roads. mileage, dimensions and cost, exclusive of graded dirt roads				Estimated value of county road equipment	Total expenditures on roads and bridges, 1912, exclusive of statute labor
				Road tax, regular and special (mills)	Approximate income from road tax, regular and special	Bond Issues	Surfaced roads: asphalt(*a*); brick(*b*); cement(*c*); gravel (*g*); marl and crushed stone (*m*); straw(*st*); sand-clay(*sc*); shell(*sh*); lime rock(*lr*)	Width of road (feet)	Thickness of surfacing material at center (inches)	Cost per mile		
Alachua	1,283	34,305	$6,854,711	3	$21,000.00	$ 40,000.00	126 s.c.	12	8	$1,000.00	$ 9,000.00	$ 37,500.00
Baker	585	4,805	1,545,321	3	4,600.00	....	¼ s.c	......	......	....	250.00	5,000.00
Bradford	552	14,090	2,711,089	4	11,000.00	....	7 st. 1½ s.c.	......	6	....	600.00	11,000.00
Brevard	972	4,717	2,707,892	3 reg. 10 spec.	15,435.42	....	32 m. 15 sh.	9	6	1,820.00	1,700.00	11,159.46
Calhoun	1,067	7,465	1,980,267	3 spec.	2,568.50	....	....	......	......	....	....	....
Citrus	612	6,731	1,958,300	7	13,000.00	....	41 m. 25 s.c. 12 lr.	10-12 12	7- 8 8	750.00 1,000.00	10,000.00	16,000.00
Clay	622	6,116	1,904,611	3 reg. 3 spec.	10,700.00	....	½ s.c. 3 sh.	15 20	8 6	1,000,00 1,500.00	200.00	30,000.00
Columbia	792	17,689	2,950,379	5	12,180.00	40,000.00	1 m. 1 s.c.	......	......	700.00	2,000.00	35,000.00
Dade	2,305	11,933	7,658,155	5 reg. 5 spec.	76,613.56	250,000.00	245 m.	16	8	1,800.00	25.000.00	59,762.65
DeSoto	3,755	14,200	5,745,133	8	44,000.00	....	15 s.c.	......	......	....	1,500.00	....
Duval	822	75,163	25,252,101	....	....	1,000,000.00	18.1 m. 33.1 sh. 5.2 c. 8.5 b. .4 a. 6.5 g.	16-18 15-16 15 15 15 20	12-14 14 .... 12	....	10,500.00	....
Escambia	668	38,029	12,406,349	....	33,775.26	....	4 g. 230 s.c.	10 20-25	12 6	9,000.00 600.00	11,000.00	....
Franklin	731	5,201	1,401,896	none	none	....	30 sh.	......	......	....	750.00	2,000.00
Gadsden	500	22,198	2,150.708	6	12,500.00	....	81 s.c.	30	......	450.00	11,000.00	....
Hamilton	508	11,825	1,971,227	2½	8,000.00	....	4 s.c.	30	8	350.00	....	15,000.00
Hernando	475	4,997	1,535,036	4 reg. 3 spec.	10,745.26	....	....	......	......	....	....	....
Hillsboro	1,052	*78,374	16,207,246	....	67,154.40	400,000.00	75 m. 25 s.c. 37 sh.	 12	 8	5,000.00 .... 3,800.00	5,000.00	....
Holmes	435	11,557	1,573,078	2	2,500.00	....	....	......	......	....	300.00	3,000.00
Jackson	963	29,821	3,947,944	2	7,895.89	100,000.00	57½ s.c.	......	......	683.33	26,126.00	41.000.00
Jefferson	593	17,210	2,410.010	11	25,000.00	....	75 s.c.	22 30	....	200.00 500.00	8,000.00	20,000.00

Lafayette	1,202	6,710	$2,593,597	....	$4,625.63	....	4 s.c.	....	....	....	....	....
Lake	1,128	9,509	3,344,103	7	23,000.00	....	70 s.c. 107 st.	9	6	$ 500.00 40.00	$ 500.00	....
Lee	4,641	6,294	3,026,244	10	30,000.000	....	20 m. 10 sh.	10 15	8	1,500.00 6,500.00	5,000.00	$25,000.00
Leon	730	19,427	3,592,000	7	25,144.00	....	150 s.c.	30	....	$100.00-$500.00	20,000.00	29,508.26
Levy	1,133	10,361	2,949,510	1	3,000.00	....	3 s.c. 4 sh.	 12	....	....	25.00	....
Liberty	725	4,700	1,318,025	4	5,272.30	....	....	....	....	....	125.00	....
Madison	693	16,919	2,927,570	5	14,000.00	....	41 sc.	....	....	275.00	7,000.00	14,000.00
Manatee	1,275	9,550	3,898,060	4	15,592.24	$250,000.00	2 m.	12	8	2,000.00	....	....
Marion	1,640	26,941	5,712,713	5	28,000.00	....	97 m 150 s.c.	10	....	2,300.00	5,000.00	....
Monroe	1,125	21,563	3,054,014	....	....	....	3.2 m.	30	....	3,800.00	500.00	1,200.00
Nassau	645	10,525	3,022,193	3	9,000 00	60,000.00	25 sh.	15	6- 8	5,000.00	2,000.00	12,000.00
Orange	1,315	19,107	6,948,798	8	50,000.00	Bond Issue Sanford Dist. $200,000.00	16 m. 42 st. 90 s.c.	10-16 10 10-12	8 8 18	2,000.00 40.00 1,000.00	7,000.00	3,500.00
Osceola	1,827	5,507	3,675,978	6	21,000.00	....	15 m.	....	....	1,500.00	2,000.00	21,000.00
Palm Beach	2,809	5,577	7,054,445	12	70,500.00	200,000.00	139½ m. 6½ sh.	9	....	2,500.00 3,000.00	6,500.00	76,800.00
Pasco	750	7,502	2,371,040	8	18,968.00	....	4 m. 14 st. 8 s.c.	12 6 10	6 3 6	4,500.00 40.00 1,000.00	200.00	16,648.00
Polk	1,967	24,148	9,361,451	8	74,891.61	....	18 m. 55 st. 54 s.c.	12 12 10	6 6	1,500.00 40.00 800.00	4,000.00	....
Pinellas	257	†	4,854,228	....	....	....	....	....	....	....	....	....
Putnam	722	13,096	3,170,630	4¼	13,000.00	155,000.00	8 st. 14 g. 65 s.c. 12½ sh.	..... 9	..... 9-10	1,200.00	4,000.00	20,000.00
Santa Rosa	1,528	14,897	4,369,604	3	14,000.00	....	72 s.c.	30	....	500.00	3,000.00	16,000.00
St. Johns	960	13,208	4,314,575	5½	23,783.76	Warrants $30,000.00	2 g. 12 st. 27 sh.	12 6 15	..... 12 12	3,500.00 150.00 3,000.00	200.00	20,000.00
St. Lucie	1,368	4,075	3,614,049	10	28,000.00	200,000.00	18 m. 15 sh.	9 9	8 8	2,500.00 2,000.00	....	50,000.00
Sumter	599	6,696	2,333,116	3½	10,000.00	....	6 m. 3 st. 30 s.c.	12 12	14 14	800.00 ..... 700.00	200 00	10,000.00
Suwannee	689	18,603	2,989,707	3	9,000.00	....	8 m. 40 s.c.	....	....	....	500.00	....
Taylor	1,100	7,103	2,595,389	none	none	....	3 m.	20	6	5,180.00	....	2,610.60
Volusia	1,281	16,510	7,039,038	6	42,000.00	....	85 m. 75 st.	8-10 8	6	2,750 00 35.00	....	45,000.00
Wakulla	601	4,802	930,784	....	....	....	....	....	....	....	....	....
Walton	1,384	16,460	3,575,111	2	8,000.00	Bond Issue Dist. 1 70,000.00	60 s.c.	12	....	990.00	5,000.00	15,000.00
Washington	1,425	16,403	3,380,093	5	16,000.00	....	30 s.c.	12	....	800.00	2,000.00	20,000.00

*Including Pinellas County. †Included with Hillsboro County.

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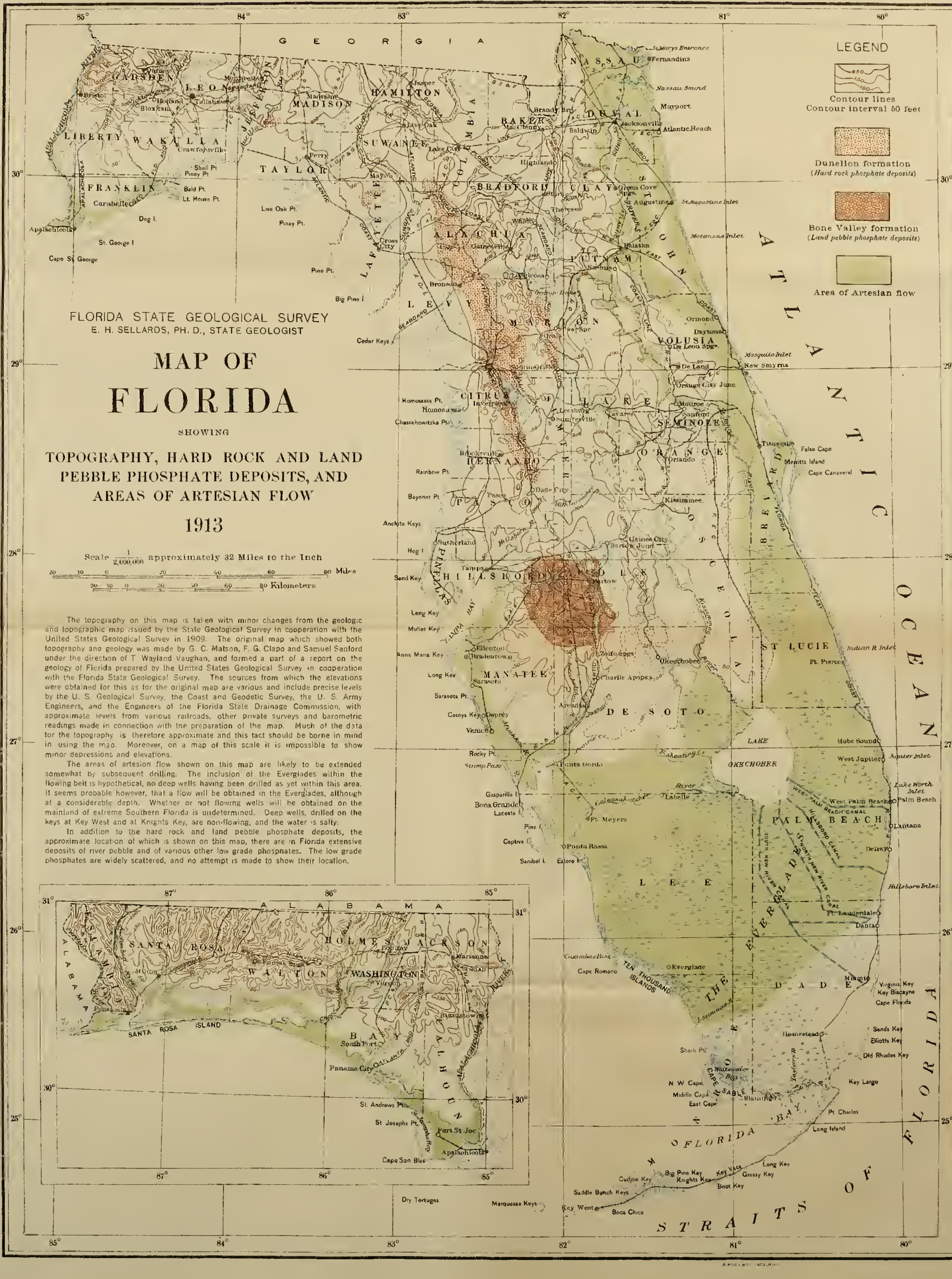

FLORIDA STATE GEOLOGICAL SURVEY
E. H. SELLARDS, PH. D., STATE GEOLOGIST

MAP OF FLORIDA

SHOWING

TOPOGRAPHY, HARD ROCK AND LAND PEBBLE PHOSPHATE DEPOSITS, AND AREAS OF ARTESIAN FLOW

1913

Scale $\frac{1}{2,000,000}$ approximately 32 Miles to the Inch

The topography on this map is taken with minor changes from the geologic and topographic map issued by the State Geological Survey in cooperation with the United States Geological Survey in 1909. The original map which showed both topography and geology was made by G. C. Matson, F. G. Clapo and Samuel Sanford under the direction of T Wayland Vaughan, and formed a part of a report on the geology of Florida prepared by the United States Geological Survey in cooperation with the Florida State Geological Survey. The sources from which the elevations were obtained for this as for the original map are various and include precise levels by the U. S. Geological Survey, the Coast and Geodetic Survey, the U. S. Army Engineers, and the Engineers of the Florida State Drainage Commission, with approximate levels from various railroads, other private surveys and barometric readings made in connection with the preparation of the map. Much of the data for the topography is therefore approximate and this fact should be borne in mind in using the map. Moreover, on a map of this scale it is impossible to show minor depressions and elevations.

The areas of artesion flow shown on this map are likely to be extended somewhat by subsequent drilling. The inclusion of the Everglades within the flowing belt is hypothetical, no deep wells having been drilled as yet within this area. It seems probable however, that a flow will be obtained in the Everglades, although at a considerable depth. Whether or not flowing wells will be obtained on the mainland of extreme Southern Florida is undetermined. Deep wells, drilled on the keys at Key West and at Knights Key, are non-flowing, and the water is salty.

In addition to the hard rock and land pebble phosphate deposits, the approximate location of which is shown on this map, there are in Florida extensive deposits of river pebble and of various other low grade phosphates. The low grade phosphates are widely scattered, and no attempt is made to show their location.