LETTER OF TRANSMITTAL.

To His Excellency, Hon. Albert W. Gilchrist,
Governor of Florida.

Sir:—In accordance with the Survey Law I submit herewith a report of the progress of investigations made by the Geological Survey for the year ending June 30, 1910. The work of the Survey has progressed actively during the past year. This report contains papers on the phosphate deposits, the peat deposits, the lakes and the artesian water supply.

In connection with the report on water supply I would respectfully call attention to the evidence of the loss of flow in some of the artesian wells, and to the danger of a material reduction in the artesian supply in some localities, if the waste of water is not prohibited by law.

The generous interest you have taken in the work of the State Survey is appreciated.

Very respectfully,

E. H. Sellards.
State Geologist.

Tallahassee, Florida,
October 1, 1910.
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ERRATA.

Page 46, explanation of Pl. 9, for “Two views of” read view of.
Page 48, footnote, for “plate 10” read plate 15.
Page 50, second line from bottom of page, for “340” read 840.
FLORIDA STATE GEOLOGICAL SURVEY.
E. H. SELLARDS, STATE GEOLOGIST

ADMINISTRATIVE REPORT.

The members of the State Survey during the past year have been, in addition to the State Geologist, Mr. Herman Gunter and Dr. R. M. Harper. The chemical analyses necessary to the work of the State Survey are made by the State Chemist.

Mr. Gunter has assisted in the preparation of the paper on the artesian water supply of Eastern Florida. In addition he has had charge of cataloging and recording the Survey collections.

Dr. Harper has prepared a preliminary paper on the peat resources of the State. The fuel tests of peat samples, in connection with this work, were made in the fuel testing laboratory of the United States Geological Survey.

In addition to the necessary correspondence and administrative work of the office, the State Geologist has prepared papers on the phosphate deposits, on certain variable lakes, and on the artesian water supply.

PUBLICATIONS ISSUED.

The Second Annual Report covering the operations of the Survey to June 30, 1909, was issued during the year. This report contains: (1) Administrative Report; (2) a preliminary report on the Geology of Florida with special reference to the stratigraphy including a topographic and geologic map of Florida prepared in co-operation with the United States Geological Survey; (3) the topography and geology of Southern Florida; (4) mineral industries; (5) the fuller's earth deposits of Gadsden County with notes on similar deposits found elsewhere in the State.

DISTRIBUTION OF REPORTS.

The reports issued by the Survey are distributed upon request to citizens, and to city and other public libraries. The results of the survey thus become permanently available to those interested in the geology and mineral resources of the State.
The following is a list of the publications issued by the State Geological Survey and now available for distribution:

1 First Annual Report, 1908.
   This report contains: (1) Administrative Report; (2) a sketch of the geology of Florida; (3) a chapter on mineral industries, including phosphate, kaolin or ball clay, brick making clays, fullers earth, peat, lime and cement, and road making materials; (4) a bibliography of publications on Florida geology with a review of the more important papers published previous to the organization of the present Geological Survey.

2 Second Annual Report. (Contents given above.)

3 Third Annual Report. (This volume.)

   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, sink-holes, 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.

5 Circular No. 1. An approximate mapping of the areas of artesian flow in Florida. 1908.

The reports of the State Survey may be obtained without cost by addressing, The State Geologist, Tallahassee, Fla.

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, judging from the experience of similar surveys in other States, to contribute not so much to sensational or sudden development of great mineral deposits as 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 landowners. A knowledge of the mineral deposits which may lie beneath the surface is likewise necessary to a correct valuation of land. The relation of the State 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 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 constitute a part of the regularly planned operations of the Survey.

RELATION OF THE STATE SURVEY TO OTHER ORGANIZATIONS.

U. S. Geological Survey:—Co-operation with the National Geological Survey was arranged soon after the organization of the State Survey. During 1907-1908 this co-operative work was de-
voted chiefly to an investigation of the general geology and stratigraphy of the State and the underground water supply. Bulletin No. 1 published in 1908 formed a part of the results of this co-operative work. A special report on the stratigraphy of the State forming a second part of this co-operative work was published in the Second Annual Report in 1909.

During the present year co-operation has been continued in the investigation of the peat deposits. Numerous peat samples in connection with this work, have been tested during the year in the peat testing plant of the National Survey. These tests form a part of and are included in the report on peat deposits. Through this generous co-operation on the part of the National Survey the State Survey is able to publish at this time a much more complete report on the peat resources of the State than would otherwise have been possible. The constant co-operation and advice in connection with this work given by Professor Charles A. Davis, in charge of peat investigations for the National Geological Survey, is especially appreciated.

The State Department of Agriculture:—The Survey law provides that analytical work necessary to the investigations of the Survey shall be done by the State Chemist. The Survey is thus brought into co-operative relation with the Division of Chemistry of the Department of Agriculture and in so far as the work of the Survey contributes to agricultural interests, to the Department of Agriculture as a whole.

The State Agricultural Experiment Station:—In its study of the water supply in relation to agriculture, of soils in their geological relations, and in other ways, the work of the State Survey may be expected to supplement certain lines of work of the State Experiment Stations, the two organizations being of mutual aid to each other.

THE SURVEY LIBRARY.

A well-equipped reference library is essential to the best results and an effort is being made to bring together those publications which are necessary to the immediate and future work of the Survey. The Survey library now contains more than 1,500 volumes. These include the reports of the several State Geological Surveys; the Annual Reports, Bulletins, Monographs, Professional Papers, Water Supply and Irrigation Papers, and other publications of the National Geological Survey; the reports of the Canadian, and a few other foreign Geological Surveys; and many miscellaneous volumes and papers on geological subjects. Additions to the Survey library will be appreciated.
EXHIBITION OF GEOLOGICAL MATERIAL.

The Survey law provides for the exhibition of geological material. The space available for this purpose is unfortunately as yet very limited. A part of one room has, however, been used for this purpose. Three cases have been built, designed to serve the double purpose of storage and exhibition, the lower part of the case being adapted to the purpose of storing material. In making the collections a systematic plan has been followed to secure a representation of the rocks, minerals, and fossils of each formation in the State. The collections will be added to as opportunity permits.

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 following suggestions are offered for the guidance of those submitting samples:
1. The exact location of all samples should be given. This should be carefully written out in full and placed on the inside of the package.
2. The statement accompanying the samples should give the conditions under which the specimen occurs, whether an isolated fragment or part of a larger mass or deposit.
3. Each package should be addressed to the Florida State Geological Survey, Tallahassee. The name and address of the sender should be plainly written on the outside.
4. Transportation charges, whether by mail, express or freight, should in all cases be prepaid.

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 co-operation 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.
The total appropriation for the State Geological Survey is $7,500 per annum. With the exception of the salary of the State Geologist the amount of which is fixed by statute, all Survey accounts are paid upon warrants issued by the Comptroller as per itemized vouchers approved by the Governor. The following is a list of the expenses of the Survey for the year ending June 30, 1910. 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.

July, 1909.

Overcharge for preceding year ........................................ $ 117.22
Herman Gunter, Assistant, salary July, 1909 .......................... 75.00
Engineering and Mining Journal, publications ........................ 5.19

August, 1909.

Herman Gunter, Assistant, salary, August, 1909 ...................... 75.00
Andrus & Church, pamphlet cases ..................................... 11.80

September 1909.

E. H. Sellards, salary for quarter ending Sept. 30, 1909 .......... 625.00
E. H. Sellards, expenses, July, August and September, 1909 .... 48.94
Herman Gunter, Asst., expenses ($13.05), salary ($100.00), October 113.05
Child Bros., book case and repairs .................................. 26.00
John McDougall, postage ............................................. 50.00
Maurice Joyce Engraving Co., engraving ............................... 20.07

October, 1909.

E. H. Sellards, expenses, October, 1909 ............................. 48.41
Herman Gunter, expenses (30.20) salary (100.00) October ........ 130.20

November 1909.

E. H. Sellards, expenses, November, 1909 ........................... 60.71
Herman Gunter, Asst., expenses (79.69) salary (100.00) Nov... 179.69
Yaeger-Bethel Hardware Company, camp supplies ..................... 54.12

December 1909.

E. H. Sellards, salary for quarter ending Dec., 1909 ............ 625.00
E. H. Sellards, expenses, December, 1909 .......................... 36.05
Herman Gunter, Asst., expenses ($86.80), salary ($100.00), Dec... 180.30
Nellie Mathes, stenographer, salary, one-half month .......... 30.00
H. & W. B. Drew Co., supplies ..................................... 10.61
Academy Natural Sciences, publications ............................. 20.00
Engineering and Mining Journal, subscription ..................... 5.00
American Journal of Science, subscription .......................... 6.00
Dan Allen, drayage ................................................... 3.81
Seaboard Air Line Railway, freight .................................. 33.95

January 1910.

E. H. Sellards, expenses January, 1910 ............................. 79.45
Herman Gunter, Asst., expenses (86.35) salary (100.00) Jan.... 186.35
Nellie Mathes, stenographer, salary, one-half month .......... 30.00
The Record Company, printing ...................................... 678.35
ADMINISTRATIVE REPORT.

Andrew B. Graham Co., engraving ........................................ 330.00
John McDougall, postage .................................................. 125.00
Dan Allen, drayage ....................................................... 7.43
Southern Express Company .................................................. 4.32
Ware Brothers, subscription ............................................... 5.00

February, 1910.
E. H. Sellards, expenses, February, 1910 ............................. 66.30
Herman Gunter, Asst., expenses (87.41) salary (100.00) Feb. .. 187.41
Nellie Mathes, stenographer, salary, two-thirds month .......... 40.00
John McDougall, postage and envelopes ................................ 100.00
H. & W. B. Drew Co., supplies ......................................... 10.18

March, 1910.
E. H. Sellards, salary for the quarter ending March, 1910 .... 625.00
E. H. Sellards, expenses, March, 1910 ................................ 127.79
Herman Gunter, Asst., expenses ($123.60), salary ($100.00) .... 223.60
Nellie Mathes, stenographer, salary, two-thirds month ........ 40.00
Southern Express Company .................................................
D. R. Cox Furniture Co., supplies ......................................
S. B. Hubbard & Co., supplies .......................................... 2.99
H. & W. B. Drew Co., supplies ......................................... 15.70

April, 1910.
E. H. Sellards, expenses, April, 1910 ................................ 163.59
Herman Gunter, Asst., expenses ($112.20), salary ($100.00), April. 212.29
Nellie Mathes, stenographer, two-thirds month ................. 40.00
John McDougall, postage ................................................
Duval Harness Co., field supplies .................................... 6.00
H. Dunod & Pinat, publications ........................................ 4.43
T. J. Appleyard, printing ................................................ 7.00

May, 1910.
E. H. Sellards, expenses, May, 1910 ................................ 100.59
Herman Gunter, Asst., expenses ($82.95), salary (100.00) .... 182.95
R. M. Harper, Asst., expenses ($36.09), salary $100.00) ....... 136.09
Nellie Mathes, stenographer, salary, two-thirds month ....... 40.00
Knight Crockery and Furniture Co., supplies ..................... 10.20

June, 1910.
E. H. Sellards, salary for the quarter ending June 30, 1910 .... 625.00
E. H. Sellards, expenses June, 1910 ................................ 5.44
Herman Gunter, salary June, $100.00 ................................ 100.00
R. M. Harper, salary June, $100.00 ................................ 100.00
Nellie Mathes, salary June 1910 .................................... 6.50
T. J. Appleyard, printing ................................................ 12.80
Andrus & Church, pamphlet cases ..................................... 11.80
Economic Publishing Co, publications ................................ 3.00
University of Chicago Press, publications ........................ 3.00
T. B. Byrd & Co., sample jars ......................................... 3.60
H. & W. B. Drew Co., supplies ......................................... 5.46

Total expenditures ........................................................ 7,313.03
Balance available .......................................................... 186.97

$7,500.00
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A PRELIMINARY PAPER ON THE FLORIDA PHOSPHATE DEPOSITS

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THE HARD ROCK PHOSPHATE.—DUNNELLON FORMATION.

The area of hard rock phosphate at present productive, lies in the western part of central peninsular Florida and extends as a narrow strip parallel with the gulf coast in a general north and south direction from southern Suwannee and Columbia Counties to Hernando County, a distance of one hundred miles. Mining has been carried on continuously in this section since 1888. Seventy-four plants under the ownership of twenty mining companies operated in this section during 1909. These plants were distributed as follows: Suwannee County, one; Columbia County, three; Alachua County, twenty-two; Marion County, twelve; Citrus County, thirty-four; Hernando County, two. Owing to the depressed condition of the phosphate market a number of these plants closed either temporarily or permanently early in the year while many others closed before the end of the year. At the beginning of 1910, the number of plants in actual operation was thirty-seven. These plants were distributed as follows: Suwannee and Columbia Counties, one plant each; Alachua County, fourteen plants; Marion County, eight plants; Citrus County, twelve plants; Hernando County, one plant. 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 notes are based on observations of the exposures made at these and at the many other plants that have operated in this section during the past several years.

LITHOLOGIC DESCRIPTION.

The phosphate-bearing formation as developed in this section includes a mixture of materials from various sources and of the most diverse character, further complicated by pronounced
chemical activity within the formation itself. Although exceedingly variable from place to place 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.

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 the sands is variable. They are also more or less calcareous in places. 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.

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.

Flint boulders occur locally in this formation in some abundance, and occasionally phosphate pits which 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 are occasionally filled with water. Others are solid, compact and of a bluish color throughout. Fossils or casts of fossils occur frequently within the boulders. Limestone inclusions from the underlying formations 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. Such an exposure of a true pebble conglomerate may be seen in one of the pits of plant No. 5 of the Cummer Lumber Company about one mile southwest of Newberry. The matrix at this exposure consists of more or less water-worn fragments of varying sizes 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 found are mostly contained in the limestone inclusions which come largely from the underlying Vicksburg limestones. The vertebrate remains occurring in the phosphate include among others, shark teeth, manatee, turtle and mastodon remains.

Phosphate rock, although the constituent of special economic interest, nevertheless makes up a relatively small part of the formation. The phosphate in this section occurs as fragmentary rock, boulder rock, plate rock or pebble. 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. In general the phosphate rock obtained from the matrix of the grade demanded by the market will not exceed ten to twenty percent of the whole. The workable deposits of phosphate lying within this formation or representing locally a phase of 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 of some acres in extent, elsewhere a deposit appearing equally promising on the surface, may be found to be in reality of very limited extent. As to location, depth from the surface, extent into the ground, lateral extent, quantity and quality, the hard rock phosphate deposits conform to no rule. The desired information regarding location, character and extent of deposits is to be obtained only by extensive 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 No. 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. Gray sands surrounding the phosphate rock may be observed as previously stated in practically every pit throughout the phosphate section. As a rule the phosphate rock extends to and rests upon the underlying limestone. This relation, however, is by no means invariable as gray sands were observed underlying the phosphate rock at several localities. Gray sands above
the phosphate are ordinarily of frequent occurrence both in pits
and in prospect holes.

MATERIALS LYING ABOVE THE PHOSPHATE.

A superficial deposit of pale yellow incoherent sand occurs
generally throughout the phosphate section. The thickness of
this sand varies exceedingly. Five to fifteen feet may be given
as an average as seen in the pits, although a thickness of as much
as thirty feet has been observed. The character and manner of
occurrence of these sands leads the writer to the belief that they
may be residual in origin.

These incoherent sands rest in some localities upon a red clay-
ey sand stratum known to the miners as "hardpan." This
sand stratum contains sufficient clay to give it coherence and
stands usually as a vertical wall in mining. This stratum is fre-
quently absent, and when present varies greatly in thickness.
The top surface of this red sand stratum presents irregularities
which might be taken to mark an unconformity between this for-
mation and the incoherent sands above. Such irregularities as
occur in the top surface, however, present rounded depressions,
rather than sharp irregularities. Moreover the top surface of
the red sands frequently conforms to the surface contour. Both
the superficial sands and the red sands are, as far as the writer
has observed, non-fossiliferous.

RELATION OF THE PHOSPHATE-BEARING FORMATION TO THE
UNDERLYING FORMATIONS.

The phosphate-bearing formation rests in this section, where-
ever observed, upon the Vicksburg limestones. In the northern part
of the section the pits are ordinarily worked out to the limestone,
affording favorable opportunity for observing the contact. The
top surface of the limestone is strikingly irregular, the rock pro-
jecting as rounded peaks. The numerous shells and other inver-
tebrate fossils of which the limestone is largely made up are eroded
off plane with the surface of the limestone. Passing to the south
the limestone lies as a rule at a greater distance beneath the sur-
face, and frequently is not reached by the ordinary processes of
mining. It is occasionally reached, however, and wherever seen,
throughout this entire section the relation between the phosphate
formation and the limestone is the same, that is, the phosphate-
bearing formation lies upon and fills up irregularities in the top sur-
face of the limestone. (Pl. 2, Fig. 1 and Pl. 5)
LOCAL DETAILS.

SUWANNEE COUNTY.

The southern and southeastern part of Suwannee County has produced some phosphate although only one mine was in operation in this county during 1909. 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, 2 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 Ocala 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 actual operation at the close of 1909.

At plant No. 2 of the Dutton Phosphate Company 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 Ocala 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.”

The phosphate matrix in this exposure as in Dutton No. 10, grades below into yellow phosphatic clay. The overburden at this pit is not removed as it is found practicable to allow the entire overburden to be taken up with the phosphate and to pass through the washer.

In the pit of the Fort White Hard Rock Company one-half mile southeast of Ft. White, the foundation rock, as is usual in this section, is the Ocala 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 or 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, twenty-two plants having operated in this county during 1909.

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 \( \frac{1}{2} \) to 2 feet thick is seen interbedded with the phosphate rock.

The incline leading to a new pit being opened up by M. C. and T. A. Thompson near Neal gave the following section:

Pale yellow incoherent sands............................ 5 to 10 feet
Red clayey sands........................................ 5 to 10 feet
Gray phosphatic sands (exposed)................. 7 to 10 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 not in use. 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. In general clay lenses in the phosphate matrix are most frequent in the upper part of the formation.

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. (Pl. 5.) Circular depressions similar in appearance to pot holes or to "natural wells" are frequent in this section. These through subsidence 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 below 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 below water level are often removed by solution; above this level they are 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 removed by solution. The stratification lines in the plate rock are frequently much curved and distorted owing to this irregular subsidence. (Pl. 2, Fig. 3.)

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 small amount of boulder rock. In other words the mechanically transported rock in this section predominates over the rock formed chemically in situ. 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 dips in passing to the south, and 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 determined.

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 only occasionally seen in the pits in this section. It is, however, frequently reached in the dredge operations below the water level. The surface of the limestone wherever seen projects as rounded peaks similar in character to the conditions further north. 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 of the Istachatta Phosphate Company, the water level is within a few feet of the surface and the phosphate formation is entirely submerged. Only the pale 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.
THICKNESS.

The phosphate-bearing formation is exceedingly variable in thickness. In general it is of reduced thickness in the northern part of the area. In Suwannee, Columbia, Alachua and northern Marion Counties, the formation may reach a thickness of from 30 to 50 feet, although in places it is much reduced or even absent. The maximum thickness of the formation is probably found in southern Marion County and in Citrus County. Drillings made by the Dunnellon Phosphate Company along the Withlacoochee River indicate a thickness of from 60 to 70 feet on the particular tract of land being prospected. Similar drillings by the J. Buttgenbach Company gave in one instance for the phosphate formation along the river, a thickness of about 75 feet.

Extensive prospecting carried on by the Southern Phosphate Development Company near Inverness, indicated for the phosphate formation a thickness of 50 to 100 feet; 70 feet being a fair average for the particular deposits prospected. It is probable that the depth may in places approach 200 feet, although this maximum thickness is probably only local.

SOURCE OF MATERIALS.

The very complex and mixed character of the material making up the phosphate-bearing formation has already been mentioned. The determination of the source or sources of all this material is a problem of no little difficulty. A part of the material is of chemical origin formed in situ. This applies particularly, in the writers' opinion, to boulder phosphate rock and to flint boulders.

Of the limestone inclusions some constitute a part of the formation as originally accumulated: others doubtless represent less soluble remnants left behind as the surrounding limestone dissolved permitting the phosphate stratum to subside and enclose them.

The gray sands find their closest resemblance lithologically to the sands of the Alum Bluff formation. Indeed as developed locally at many places one scarcely finds characters on which to distinguish the gray phosphatic sands of this formation from the similar gray phosphatic sands of the Alum Bluff formation, as seen at the type locality on the Apalachicola River. That these sands are residual from the Alum Bluff formation seems probable although the possibility of their origin from some of the later formations must be admitted. That they remain as residual from the Vicksburg Limestone the writer cannot believe.
The source of the dark colored water worn flint pebbles and of the pebble conglomerate occasionally observed especially in the northern part of the field is at present scarcely more than conjectural. So far as the writer's observations have extended, materials of this character occur more frequently in the Miocene than in any other of the formations of the State. The presence of mastodon remains indicates admixture of Pliocene material from some source.

The origin of the phosphate is perhaps the most difficult problem connected with these and, in fact, with phosphate deposits in general. In the case of the Florida deposits the writer is inclined to the view that the phosphoric acid has been very gradually concentrated from various formations in which it exists in only very small quantities. Enrichment by the addition of phosphoric acid is a well known process. Many instances have come to light of shells originally calcareous now completely phosphatized, the phosphoric acid having replaced the carbonic acid. In many instances the shape and markings of the shell are retained. The bones imbedded in the phosphate also are more or less completely phosphatized. The formation of the phosphate boulders in situ seems evident. The plate and fragmental rock represent boulders formed during a preceding stage and subsequently broken, more or less transported and finally deposited in their present position. The pebble phosphate found among the rock phosphate is probably largely water worn detritus mechanically accumulated.

CONDITIONS OF DEPOSITION.

The variable and mixed character of the formation, the frequent clay lenses, the faint tendency to stratification, the occasional local accumulation of loose or conglomerate material indicate to the writer that the material accumulated in shallow water with conflicting currents. Much of the material may indeed have been scarcely at all transported being residual from formations that have decayed in place. The local accumulation of pebble conglomerate, however, as well as the local occurrence of clay lenses implies conflicting currents in comparatively shallow water. The faint tendency to stratification leads to the same conclusions. Such stratification as existed, however, has been much distorted by the settling of the formation as the underlying limestone was removed by solution. The conditions of deposition do not, in the writer's opinion, necessarily indicate complete resubmergence of this area, although such may have been the case. It is extremely probable that the formations which have gone to decay
in this section include, aside from the Vicksburg limestones of Lower Oligocene age, Upper Oligocene formations of the Apalachicola group, Marine Miocene formations, and more or less of Pliocene or later materials since all of these formations occur in position in the adjacent and uneroded high-lands to the northeast. In the course of the decay and lowering of the general land surface there is naturally more or less shifting of material attended probably by the formation of temporary small lakes and streams. It is possible that the conditions thus arising may have been sufficient to account for the mixed condition of the materials, the tendency to stratification in places and other evidence of action by water without the necessity of assuming a complete resubmergence. On this point, however, the writer feels that evidence has not been accumulated to form a final opinion.

FORMATION NAME.

It is thus apparent that the formation contains a mixture of material largely residual from several formations from as early as the Lower Oligocene and as late at least as the Pliocene, further complicated by subsequent chemical action within the formation itself. The residual material moreover has been reworked and in places transported and redeposited. The term Dunnellon formation is suggested for these deposits since they were first found and are best developed in the vicinity of Dunnellon, Florida.

EXPLANATION OF PLATE 1.

Fig. 1. Phosphate washer for hard rock phosphate in use at pit No. 3, Cummer Phosphate Company, Alachua County.

Fig. 2. Drill for prospection 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.

Fig. 3. View of incline to pit, in the Croom mine of the Buttgenbach Phosphate Company.
EXPLANATION OF PLATE 2.

Fig. 1.—View in pit No. 25 of Central Phosphate Company in Alachua County, showing irregular top surface of the Vicksburg Limestone (Ocala formation) after removal of the phosphate deposit. The limestone here as elsewhere in the phosphate section projects as peaks.

Fig. 2.—View showing the irregular top surface of the Miami oolitic limestone, Dade County, after the removal of the superficial sands. Photo by R M. Harper.

Fig. 3.—View in the plate rock phosphate pit at Anthony, showing the laminated structure of the plate rock deposit. The solution of the underlying limestone has permitted subsidence of the phosphate deposit, the folding being due to irregular subsidence.
EXPLANATION OF PLATE 3.

Fig. 1.—View in pit No. 5, Prairie Pebble Phosphate Company, Mulberry, showing overburden of land pebble phosphate. The contact between the light-colored incoherent sand and the somewhat indurated sand is well marked. The overburden in this pit is being removed by hydraulics.

Fig. 2.—View in pit of Florida Mining Company, showing a place where the overburden beneath the superficial sand is indurated, making it necessary to resort to blasting.

Fig. 3.—View in pit of the Pierce Phosphate Company, Pierce, Fla., showing an abrupt break in the pebble phosphate stratum. The break is seen near the right side of the picture, where slickensides have developed as the overburden slid down past the phosphate stratum.
EXPLANATION OF PLATE 4.

Fig. 1.—View in pit of Pierce Phosphate Company, showing the irregular top surface of the bed rock (Arcadia marl) after the removal of the phosphate stratum. Phosphate plant in the background.

Fig. 2.—View in the pit of the Coronet Phosphate Company, Lakeland, Fla. Unconformity between the coarse phosphate above and the finer pebble phosphate below. This unconformity, although imperfectly shown in the photograph, is well marked at this locality. The material above is a coarse conglomerate, that beneath is fine pebble imbedded in clay.

Fig. 3.—View in pit of Standard Phosphate Company, showing irregular line of contact, apparent unconformity, between the loose surface sand and the more indurated sand beneath.
VIEW IN THE PLATE ROCK PHOSPHATE MINE AT ANTHONY, SHOWING THE VERY IRREGULAR TOP SURFACE OF THE LIMESTONE AFTER REMOVAL OF THE PHOSPHATE. PHOTOGRAPH SUPPLIED BY P. JUMEAU.
THE LAND PEBBLE PHOSPHATE—BONE VALLEY FORMATION.

LITHOLOGIC DESCRIPTION.

The land pebble formation to which Matson and Clapp applied the term "Bone Valley Beds" was briefly described in the Second Annual Report. This formation includes a lower phosphate bearing member and an upper sand or sandstone member. The lower member of the formation contains the workable phosphate deposits. The upper member forms the overburden which must be removed in mining.

The phosphate bearing member of this formation is more or less definitely stratified, the stratification line being frequently continuous along the full length of the pit, a distance of a half mile or more. Elsewhere the stratification is irregular and cross bedding is evident.

Although variable from place to place this part of the formation has an average thickness of from 8 to 12 feet; its maximum thickness is possibly 18 or 20 feet. The matrix in which the phosphate pebble is imbedded consists largely of clay, sand and soft phosphate. The pebble phosphate makes up in the workable deposits some ten to twenty-five per cent. of the whole. This member shows certain characteristics which are fairly persistent. The lower 2% to 3 feet is usually olive green in color, and contains pebble imbedded in clay. The next 3 to 5 feet is frequently dark blue in color although oxidizing on exposure to drab or yellow. The upper 2 to 4 feet of this member differs much particularly in the northern part of the area from that which lies below. This upper part contains coarser material and has a higher percentage of pebble phosphate in proportion to the matrix. The break between the coarser material at the top and the more clayey material beneath is particularly well marked as seen in the pit of the Coro- net Phosphate Company in Hillsboro County (Pl. 4, Fig 2.) The break is here so abrupt as to constitute a distinct unconformity. The line of contact is marked by the presence of water worn corals, bone fragments and very coarse conglomerate of phosphate pebbles. Passing to the south the contact line becomes less marked, the conglomerate character of the upper part largely disappearing at the south end of the phosphate area.

The indurated sand above the phosphate has an average thickness of from 10 to 14 feet. Its maximum thickness, however, is much greater. On the other hand owing to decay and erosion these sands are in places much reduced and may be locally entirely
absent, the phosphate lying at the surface. Usually the sand contains sufficient admixture of clay to give it coherence. Under these conditions it oxidizes red near the surface. While this is the prevailing phase of the sand it is nevertheless subject to considerable variation from place to place. Not infrequently the sand is firmly cemented forming the so called "hardpan" which gives much trouble in prospecting and frequently necessitates blasting in mining. (Plate 3, Fig. 2.) In places the sand has a calcareous or phosphatic cement. Locally it varies also to an indurated rock with innumerable small cavities which gives a vesicular appearance to the mass. A sample of this rock was found to contain 15.56% phosphoric acid (equivalent to 33.97% tri-calcium phosphate).

The phosphate bearing member contains vertebrate remains including both marine and land animals. Most of the bones are more or less rolled and water worn although occasional whole skeletons are found. In the sands above the phosphate, fossils are rare. The writer has obtained, however, through the kindness of Mr. M. A. Waldo, Manager of the Dominion Phosphate Company a single tooth of the mastodon preserved as a cast in the phosphatic sands of the overburden. Aside from a few casts near the bottom of the phosphate bed invertebrates have not been found in this formation.

MATERIALS LYING ABOVE THE PHOSPHATE FORMATION.

As in the case of the hard rock section the surface material consists of incoherent pale yellow sand. The depth of this sand is variable, ranging from four to ten or more feet. A very definite and often irregular line separates these loose sands from the formation beneath. (Pl. 3, Figs. 1 and 2, and Pl. 4, Fig. 3.) This line Matson interprets as an evident unconformity.* This may be true although the fact must not be overlooked that seeming unconformities in materials lying near the surface may in reality represent only lines of decay. The writer is inclined to regard the loose surface sands in this section as residual, the irregular line representing the line of complete disintegration of the original sandy formation. A similar explanation has been offered previously by the writer for the surface sands of Gadsden County† as well as for the sands overlying the hard rock phosphate formation. (ante P. 24.)

RELATION TO THE UNDERLYING FORMATION—ARCADIA MARL.

The land pebble formation rests upon a pale yellow phosphatic marl, referred to by the miners as "bed rock". The relation is apparently as stated by Matson, that of unconformity. This is observed in the pit of the Pierce Phosphate Company, six miles south of Mulberry. The marl as exposed in this pit has a very roughly eroded surface. (Pl. 4. Fig. 1.) The phosphate matrix fills these irregularities. The "bed rock" although varying in character is found to underlie the phosphate wherever observed in Hillsboro, Polk and Desoto Counties. The marl beneath the phosphate is probably of Pliocene age.

In 1892 Dall applied the term Arcadia marl to a marl exposed on Mares Creek, six miles above Arcadia.* This marl Dall regarded as slightly older than the Caloosahatchee marl. Matson is of the opinion that the Arcadia marl may be only a phase of the Caloosahatchee marl. The exposure on Mares Creek examined by the writer occurs at and near the mouth of the creek. The marl as seen here has in lithologic character no very striking resemblance to the Caloosahatchee marl but is lithologically very similar to the marls seen at numerous places elsewhere on Peace Creek and underlying the Bone Valley formation. From the continuity of exposures and similarity in character it seems probable that the "bed rock" of the land pebble phosphate is the Arcadia marl.

LOCAL DETAILS.

HILLSBORO COUNTY.

The northernmost plant in the land pebble section is that of the Coronet Phosphate Company located in Hillsboro County three miles southeast of Plant City. The following sections were observed in pits Nos. 1 and 2 of this plant.

SECTION IN PIT NO. 1, CORONET PHOSPHATE COMPANY.

Pale yellow incoherent sand................................. 4 feet
Gray indurated sand......................................... 4 feet
Conglomerate of phosphate pebble, bone fragments, water
worn flints and pebbles..................................... 1 to 1½ feet
Buff yellow and olive green clay.......................... 2 to 5 feet
Yellow clay and marl, "bed rock" at bottom of pit.

SECTION IN PIT NO. 2, CORONET PHOSPHATE COMPANY.

Incoherent sand.............................................. 6 feet
Indurated sands grading at base into a conglomerate of phos-

phate pebble, bone fragments, water worn flints and coral. 3.4 feet
Buff yellow and olive green clay matrix in which phosphate pebble is embedded. 5 feet

The superficial pale yellow sand is of fine texture and is non-fossiliferous. The indurated gray sand is also non-fossiliferous in the upper part. Towards the base, however, this sand grades into the conglomerate previously mentioned, the lower one to one and one-half feet being a very rich phosphate conglomerate.

The break between the phosphate pebble conglomerate and the underlying phosphate matrix is very abrupt, representing a local unconformity. (Pl. 4, Fig. 2.) Aside from the phosphate there is found in this conglomerate lying along the line of contact a considerable amount of coral occurring as water worn fragments, some of which weigh as much as 8 or 10 pounds. The larger corals usually lie immediately upon the contact line. Water worn flint pebbles of one or two pounds in weight, also occur together with fragments of bone.

The phosphate stratum lying beneath this unconformity is chiefly of bluish color which upon exposure oxidizes to a light buff yellow. Occasional bones and flint pebbles are found also in this part of the formation. The water worn corals, however, were not observed below the unconformity. That part of the phosphate matrix below the unconformity contains also many rounded pieces of soft phosphate while that above the unconformity contains hard pebble rock only.

POLK COUNTY.

A pit operated by the Standard Phosphate Company near Medulla is notable for the extreme irregularity in the stratification of the phosphate bearing member. The strata here are observed to dip at an angle of as much as 45 degrees from the horizontal. The bed rock which consists of the usual yellow clay marl is likewise irregular and is observed to rise as much as fourteen feet in a horizontal distance of 50 feet.

In the pit of the Medulla Phosphate Company at Christina, the following section was observed:

| Incoherent pale yellow sand | 2 to 5 feet |
| Gray sand, iron stained near surface | 8 feet |
| Phosphate bearing matrix | 15 to 20 feet |
| Yellow clayey marl, "bed rock" (exposed) | 4 feet |

In Pit No. 3 of the Prairie Pebble Phosphate Company, near Mulberry the following section was observed:
Incoherent sand ............................... 2 to 4 feet
Indurated gray sand grading below into phosphate matrix 12 to 16 feet
Workable phosphate stratum .......................... 10 to 12 feet
Yellow clay marl, “bed rock” (exposed) .................. 5 feet

The upper 5 or 6 feet of the sand of this section contain some clay and are stained red by iron oxide. At the base the sands pass gradually into the pebble rock conglomerate. Beneath the pebble rock conglomerate the matrix is more clayey while near the base the clays of the matrix are olive green in color. The conglomerate as seen in this pit differs from that seen in the pit of the Coronet Phosphate Company in the absence of corals along the contact line.

The relation between the phosphate bearing formation and the underlying marl or limestone is well seen in the pit of the Pierce Phosphate Company, six miles south of Mulberry. The marl exposed in this pit, as previously stated, has a very roughly eroded surface. (Pl. 4, Fig. 1.) The phosphate matrix fills these irregularities. At this pit there is observed in places below the workable phosphate matrix one to three feet of material consisting of quartz sand intimately mixed with small black phosphatic pebbles. An old stream channel crosses this pit. In the bed of the stream is fine loose, more or less stratified dark colored sand. This stream where examined has cut down to the coarse part of the phosphate matrix and at one point almost cut out this coarse part of the matrix, that is it has cut through the sand and the upper part of the phosphate formation. This stream occupies approximately the bed of an existing stream and probably indicates that conditions were such formerly as to permit the stream to cut its bed deeper than now, the channel subsequently having been aggraded. Near by in the same pit is a sudden dip in the sand overburden. (Pl. 3, Fig. 3.) The point of break gives very much the character of a sink hole.

CONDITION OF DEPOSITION.

In attempting to determine the condition under which the land pebble phosphate formation accumulated, the characteristics of the formation itself should be borne clearly in mind. The formation is more or less definitely stratified. The stratification, however, is irregular, and cross bedding and local sand deposits occur. The phosphate bearing part of the formation is highly fossiliferous containing both land and marine vertebrates. Most of these fossil bones are more or less eroded and water worn, indicating that they have been rolled or washed before reaching their final resting place. Occasionally, however, a complete skeleton occurs. Water worn bones of both the land and marine vertebrae could
have as suggested by Matson*, washed into this deposit from some pre-existing formation. This can not apply, however, to the occasional complete skeletons that are found in these deposits. It is probable that the formation accumulated in comparatively shallow water. That the water was not deep is evident from the irregularity of the stratification and from the occasional cross bedding. Also that the place of accumulation was not far removed from land is indicated by the comparatively coarse material and by the presence of numerous bones of land animals.

CHANGE OF CONDITIONS DURING DEPOSITION.

The land pebble phosphate formation, as previously stated, is not of uniform character throughout, indicating that the conditions varied from time to time during the accumulation of the material. The earliest phase of the formation observed consists of clear quartz grains and very small black pebble phosphate forming a stratum one to four feet in thickness. This material occurs only locally and is non-workable, the phosphate pebble being too small to separate from the sand. This phase of the formation may be observed in the pit of the Pierce Phosphate Company, six miles south of Mulberry. The formation divides itself into the workable phosphate stratum and the indurated sands forming a part of the overburden previously described. Stratigraphically the most pronounced break in the formation is that which occurs within the phosphate stratum itself, particularly in the northern part of the phosphate field, where the pebble phosphate conglomerate rests upon the underlying clayey phosphate matrix. This conglomerate grades above very gradually into the overlying gray sands. A change in condition in deposition is clearly indicated. This change probably indicates elevation of the land to the north. Following this elevation there was brought in first the coarse phosphatic material accompanied by the flint and corals, and later the sands which make up the upper member of the formation.

STATE AND GOVERNMENT LANDS IN THE PHOSPHATE SECTION.

Both the State and the National Governments still own lands in the phosphate sections of the State. All State lands have been withdrawn from sale by order of the Internal Improvement Board until properly classified.

The President, by executive order has withdrawn during the year 27,400 acres of Government land in the phosphate section of Florida.

Thirty-six companies in all were engaged in mining phosphate in Florida during all or part of the year 1909. Of these twenty companies operated in the hard rock section. Of this number, however, not more than fourteen were actually producing phosphate during any considerable part of the year, others being temporarily closed or preparing for subsequent operations. In the land pebble district sixteen companies were engaged in mining phosphate during all or a part of the year.

List of companies operating during all or part of 1909:

<table>
<thead>
<tr>
<th>Names</th>
<th>Office</th>
<th>Mines</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Armour Fertilizer Co.</td>
<td>Fort Meade</td>
<td>Pebble</td>
</tr>
<tr>
<td>2. Bradley, Peter B. and Robert S.</td>
<td>Floral City</td>
<td>Hard Rock</td>
</tr>
<tr>
<td>5. Campagnic Gcnerale des Phosphate</td>
<td>Anthony</td>
<td>Plate Rock</td>
</tr>
<tr>
<td>7. Central Phosphate Co.</td>
<td>Newberry</td>
<td>Hard Rock</td>
</tr>
<tr>
<td>8. Coronet Phosphate Co.</td>
<td>Lakeland</td>
<td>Pebble</td>
</tr>
<tr>
<td>10. Dominion Phosphate Co.</td>
<td>Bartow</td>
<td>Pebble</td>
</tr>
<tr>
<td>11. Dennis &amp; Blanton</td>
<td>Gainesville</td>
<td>Hard Rock</td>
</tr>
<tr>
<td>12. Dunnellon Phosphate Co.</td>
<td>Rockwell</td>
<td>Hard Rock</td>
</tr>
<tr>
<td>14. Florida Mining Co.</td>
<td>Mulberry</td>
<td>Pebble</td>
</tr>
<tr>
<td>15. Fla. Phosphate Mining Corpo'n</td>
<td>Norfolk, Va</td>
<td>Pebble</td>
</tr>
<tr>
<td>16. Franklin Phosphate Co.</td>
<td>Newberry</td>
<td>Hard Rock</td>
</tr>
<tr>
<td>18. Germofert Mining Co.</td>
<td>Charleston, S. C.</td>
<td>Pebble</td>
</tr>
<tr>
<td>19. Holder Phosphate Co.</td>
<td>Ocala</td>
<td>Hard Rock</td>
</tr>
<tr>
<td>20. International Phosphate Co.</td>
<td>Ft. Meade</td>
<td>Pebble</td>
</tr>
<tr>
<td>21. Istachatta Phosphate Co.</td>
<td>Istachatta</td>
<td>Hard Rock</td>
</tr>
<tr>
<td>22. John McDowell</td>
<td>Newberry</td>
<td>Hard Rock</td>
</tr>
<tr>
<td>23. Medulla Phosphate Co.</td>
<td>Christina</td>
<td>Pebble</td>
</tr>
<tr>
<td>26. Phosphate Mining Co.</td>
<td>New York</td>
<td>Pebble</td>
</tr>
<tr>
<td>27. Pierce Phosphate Co.</td>
<td>New York</td>
<td>Pebble</td>
</tr>
<tr>
<td>29. Schilman &amp; Bene</td>
<td>Ocala</td>
<td>Hard Rock</td>
</tr>
<tr>
<td>30. Southern Phosphate Develop-</td>
<td>Ocala</td>
<td>Hard Rock</td>
</tr>
<tr>
<td>31. State Phosphate Co.</td>
<td>Bartow</td>
<td>Pebble</td>
</tr>
<tr>
<td>32. Standard Phosphate Co.</td>
<td>Christina</td>
<td>Pebble</td>
</tr>
<tr>
<td>33. Thompson, M. C. &amp; T. A.</td>
<td>Willeford</td>
<td>Hard Rock</td>
</tr>
<tr>
<td>34. Tilghman Phosphate Co.</td>
<td>Bowling Green</td>
<td>Pebble</td>
</tr>
<tr>
<td>35. Union Phosphate Co.</td>
<td>Tioga</td>
<td>Hard Rock</td>
</tr>
<tr>
<td>36. Williams Phosphate Co.</td>
<td>Inverness</td>
<td>Hard Rock</td>
</tr>
</tbody>
</table>
THE PRODUCTION OF PHOSPHATE DURING 1909.

The total production of phosphate in Florida for the year 1909 shows a slight decrease over that of the preceding year. The total production for 1908, exclusive of river pebble, was 1,918,011 long tons. Including river pebble the total production for 1908 was 1,950,961 long tons, while for the year 1909 the total production was 1,862,151 long tons. The decrease in production occurred entirely within the hard rock section, the output of land pebble having actually increased.

The shipment of phosphate for the year 1909 practically equaled the production both of hard rock and of land pebble. Hard rock shipments amounting to 514,101 long tons have been reported as against the production of 527,582 long tons. For the pebble rock, shipments have been reported amounting to 1,329,102 long tons against the production of 1,334,569 long tons.

The phosphate market continued very much depressed during the year. Hard rock phosphate was reported to have been sold as low as from $5 to $6 per ton f. o. b. at mines, while land pebble was sold from $2.75 to $4.25 per ton f. o. b. at mines.

HARD ROCK PHOSPHATE.

The production of hard rock phosphate during 1909 shows a decided falling off from that of the preceding year, the output having been curtailed by the operators on account of the low prices. The amount mined during 1908 was 768,011 long tons, while for the year 1909 the total production reported is 527,582 long tons, a decrease of about 240,000 tons, or about 30 per cent.

As in former years practically all of the hard rock phosphate shipped, was consigned to foreign markets. The total amount of hard rock phosphate consigned for use in the United States during 1909 was 17,456 long tons. Of this amount 13,726 tons were used in Florida. The amount exported during 1909 was 496,645 long tons.

PEBBLE PHOSPHATE.

While the production of hard rock phosphate was reduced during 1909, the output of pebble was increased. The amount of pebble rock mined in 1908 was approximately 1,150,000 long tons. For the year 1909 the total production of pebble phosphate was 1,334,569 long tons, an increase of over 150,000 tons.

Shipments listed by the "American Fertilizer" show that the total pebble rock exported during 1909 was 509,341 long tons.
THE FLORIDA PHOSPHATE DEPOSITS.

The amount consigned for use within the United States as reported by the operators was 819,761 long tons.

The mining of pebble rock on Peace River discontinued during the latter part of 1908 was not resumed during 1909. A small shipment of 3,215 tons of this rock during 1909, mined in 1908, is included in the total domestic shipments of pebble rock as given above.

SUMMARY OF PRODUCTION AND SHIPMENTS FOR THE YEAR 1909.

<table>
<thead>
<tr>
<th></th>
<th>PRODUCTION</th>
<th>Consigned for Use in the U. S.</th>
<th>EXPORTED</th>
<th>Total Shipments</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1908</td>
<td>1909</td>
<td>1908</td>
<td>1909</td>
</tr>
<tr>
<td>Hard Rock</td>
<td>689,011</td>
<td>527,582</td>
<td>9,900</td>
<td>17,455</td>
</tr>
<tr>
<td>Pebble Rock</td>
<td>1,334,361</td>
<td>819,761</td>
<td>421,761</td>
<td>819,761</td>
</tr>
<tr>
<td>Totals</td>
<td>1,918,082</td>
<td>1,847,343</td>
<td>521,661</td>
<td>997,216</td>
</tr>
</tbody>
</table>

COMPARATIVE TABLE OF PRODUCTION AND SHIPMENT OF FLORIDA PHOSPHATE FOR THE YEARS 1908 AND 1909. (LONG TONS.)

<table>
<thead>
<tr>
<th></th>
<th>PRODUCTION</th>
<th>Consigned for Use in the U. S.</th>
<th>EXPORTED</th>
<th>Total Shipments</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1908</td>
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<td>1,918,082</td>
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<td>997,216</td>
</tr>
</tbody>
</table>
SOME FLORIDA LAKES AND LAKE BASINS

BY E. H. SELLARDS.
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SOME FLORIDA LAKES AND LAKE BASINS.

E. H. SELLARDS.

INTRODUCTION.

Florida is justly celebrated for the number and beauty of its lakes. These lakes vary in size from the small ponds which scarcely exceed a few rods in circumference to the great Okeechobee, the surface area of which exceeds 700 square miles. Okeechobee is in fact noteworthy as being, with the exception of Lake Michigan, the largest fresh water lake lying wholly within the United States. In depth the Florida lakes are likewise variable, and in fact the depth is frequently in inverse ratio to the size. Many of the large lakes are comparatively shallow, while some of the small lakes are deep. This is particularly true of the small sink-hole lakes, some of which, while not exceeding a few rods in circumference have a depth of one to two hundred or more feet. In origin and history of development the Florida lakes are as variable as in other characteristics.

The lakes described in this paper include only a few of the many Florida lakes and represent a type peculiar in character and in manner of development. They are fresh water lakes, often of considerable size, although usually relatively shallow as compared to their areal extent. Moreover they are variable in character. Under normal conditions they are clear water lakes abounding in fish and the favorite haunt of the wild duck. They have as a rule no surface outlet, yet from many of them the water has at times disappeared in a manner seemingly inexplicable. In most instances the lakes thus disappearing have refilled slowly. Some of them, however, have remained dry a number of years. A correct understanding of these lakes together with the origin and development of the basins which they occupy is necessarily based on a study of the geologic formations which underlie them.

The fall of 1909 offered an exceptionally favorable time for investigating lakes of this character. The prolonged dry weather of the past few years had reduced these lakes to a low stage offering an opportunity of examining the soil and vegetation as well as the geologic structure of their basins. At the Tallahassee station in Leon County, near which several of these lakes are located, the rainfall at the close of 1909 had been below normal as shown by the weather bureau records for two years in succession. At the Gainesville station in Alachua County, the rainfall had been
below normal during the preceding four years and at the Lake City station the rainfall had been below normal for at least three years in succession and apparently, from some imperfect records, had not reached normal during the preceding seven years.

Under these circumstances it was deemed advisable to make use of the favorable opportunity during the fall of 1909 for investigating the geology of these lake basins.

Attempts have been made to drain some of these lakes as the land is more or less valuable for agricultural purposes. In some instances drainage operations have been delayed owing to legal difficulties arising from the variable character of the lakes. The lake basins claimed by the State under the title of swamp and overflowed lands were likewise claimed by abutting property owners under the privilege of riparian rights. A recent decision of the State Supreme Court vests the title of the lands in question with the State, not, however, as swamp and overflowed land but as navigable water.

LOCATION OF LAKES.

The lakes described in this paper occur in the upland section of the interior of Florida. In general they may be said to occur in a belt extending with interruptions from the Ocklocknee River east and south paralleling the Gulf of Mexico to Hernando and Pasco Counties. The largest and best known examples are found in Leon, Jefferson, Columbia and Alachua Counties. Smaller but no less typical lakes of this type occur in Madison, Suwannee, Marion, Levy, Orange, Hernando and probably some other counties adjacent to those mentioned. West of the Apalachicola River small lakes of similar character occur in Jackson County and possibly also in Holmes County.* The lakes selected for description as illustrating this type include Lakes Iamonia, Jackson, and Lafayette, in Leon County; Lake Miccosukee in Jefferson County: Alligator Lake in Columbia County; Alachua Lake in Alachua County; and Ocheesee Lake in Jackson County. The belt of country through which these lakes occur, although now broken up through natural processes of erosion into several more or less well defined sub-divisions, was probably at one time continuous.

CHARACTERISTICS.

The leading characteristics of these lakes have been mentioned. They do not occur along the coast nor in the level low lying parts

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*For location of counties, see map plate 10, following page 121.
of the state. On the contrary they are on the uplands, and occur in sections having a hilly or rolling topography. Sinks or openings occur through which the water escapes into the underlying formations. These sinks are located ordinarily at the foot of a steep bluff bordering the lake. Around the main sink one finds ordinarily other sinks of more recent formation indicating the manner and direction of enlargement of the basin. The sinks through which the water escapes are variable in depth but reach in all cases to underlying limestones. A channel as a rule leads back from this sink across the lake bottom representing the main channel of flow of water to the sink. Aside from this channel the bottom of the lake is relatively flat and level, although slight local depressions occur involving in some instances differences of level, of ten to fifteen feet. The soil in the lake basins varies considerably. In some of the lakes—those which seldom go dry—there is an accumulation of muck or peat formed largely from pond lilies and other aquatic vegetation. Local depressions in the lake often have an accumulation of this material amounting to several feet. Some of the other lakes which frequently go dry have little or no muck except in depressions which hold water even in dry seasons. Beneath the muck is usually found light colored sand washed and blown from the neighboring highlands. This sand may be several feet deep in places, elsewhere it is largely absent. Ordinarily a sandy clay occurs beneath the sand.

When these lakes dry up the water is commonly reported as running out very suddenly. This, however, is usually not the case. As long as the lake has sufficient water to cover the entire basin the lowering of the water surface proceeds very slowly. Subsequently when the total surface area of the lake becomes much restricted the lowering of the water surface proceeds much more rapidly. This leads to the statement that the water of the lake disappeared suddenly while as a matter of fact in many cases the water escapes through the sink no faster and indeed hardly so fast during the dry season as it had been escaping when the lake was full during the season of normal rainfall. It is true, however, that new sinks occasionally form in the bottom of the lake. In the case of the formation of new sinks the rate of escape of the water is increased.

ORIGIN AND HISTORY OF DEVELOPMENT.

The origin of these lake basins is a part of the history of development of the general topography of the region. In this development both mechanical erosion and erosion by solution have
had a part. The land surface when first elevated above sea was evidently much more nearly level than at present. Upon being lifted above sea level irregularities in topography rapidly develop.

Upon being lifted above sea level, irregularities in topography rapidly develop. A first step in the process of erosion is the development of stream channels and valleys, largely through mechanical erosion. In addition to mechanical erosion, erosion by solution due to underground water is likewise in process especially in sections underlaid by limestones.

As illustrating the efficiency of underground water as an eroding agent, the writer in a previous report computed the rate of erosion by solution in the sections of the state underlaid by limestones. The estimate of the rate of solution given below is taken from that report.

Solution is the most apparent, and geologically the most important result of underground water circulation. Rain water, while passing through the air, takes into solution a small amount of CO₂ gas. To this is added organic and mineral acids taken up while passing through the soil. Increased pressure, as the water descends into the earth, enables the water to hold in solution greater quantities of gases, acids and salts, all of which greatly increase the dissolving power of the water.

That underground water is efficient as a solvent is evident from the analyses of well and spring waters. Rain water entering the earth with almost no solids in solution, returns to the surface through springs and wells with a load of mineral solids in solution determined by the length of time it has been in the ground, the distance traveled, and the character of the rocks and minerals with which it comes in contact.

The mineral matter thus taken into solution is carried along with water, and, while some of it is re-deposited, a large amount is removed annually.

An estimate of the total mineral solids thus removed is difficult. A conception of the largeness of the amount removed is obtained from a consideration of some of the individual springs.

The water of Silver Springs contains, as shown by analysis, 274 parts solids per million parts water. Otherwise expressed, each million pounds of water is carrying with it 274 pounds of solids in solution. Silver Spring is estimated to flow a little more than three million pounds of water per minute (368,913 gallons). The interior of Florida is thus being carried into the ocean through Silver Springs at the rate of more than 340 pounds per minute, or about six hundred tons per day.

*Fla. Geol. Survey Bulletin No. 1, pp. 46, 47, 48, 1908
The total solids removed in solution through six other springs of central Florida, expressed in tabular form, gives the following results:

<table>
<thead>
<tr>
<th>Name of Spring</th>
<th>County</th>
<th>Total solids (parts per million†)</th>
<th>Est. flow (gals. per min.)</th>
<th>Solids removed lbs. per day.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Blue</td>
<td>Marion</td>
<td>112.1</td>
<td>349,166</td>
<td>469,698</td>
</tr>
<tr>
<td>Blue</td>
<td>Levy</td>
<td>196.8</td>
<td>25,000</td>
<td>59,010</td>
</tr>
<tr>
<td>Ichetucknee</td>
<td>Columbia</td>
<td>211.6</td>
<td>180,000</td>
<td>457,056</td>
</tr>
<tr>
<td>Newland</td>
<td>Suwannee</td>
<td>233.5</td>
<td>75,000</td>
<td>210,150</td>
</tr>
<tr>
<td>Weekiwachee</td>
<td>Hernando</td>
<td>227.8</td>
<td>100,000</td>
<td>273,360</td>
</tr>
<tr>
<td>White Sulphur</td>
<td>Hamilton</td>
<td>166.6</td>
<td>32,400</td>
<td>64,774</td>
</tr>
<tr>
<td>Suwannee</td>
<td>Suwannee</td>
<td>332.7</td>
<td>19,747</td>
<td>78,816</td>
</tr>
</tbody>
</table>

As the basis of an estimate of the total solids removed annually from the interior, let it be assumed, (1) that the average total solids in spring water amount to as much as 219 parts per million, this average being obtained from eight of the typical large springs of central Florida; (2) that the annual escape of the underground water approximates the annual in-take, amounting, as previously estimated to 460,536,689 gallons per square mile. Upon these estimates the mineral solids removed amount to a little more than four hundred tons annually per square mile.

Of the minerals thus removed, calcium carbonate or limestone greatly predominates, exceeding the combined weight of all other minerals. From the analyses it appears that magnesium carbonate, magnesium and calcium sulphates are present in variable, although usually limited, quantities. Chlorides are normally present in small amount, although occasionally, as in the case of Perrian Spring, they are exceptionally high. Silica is present in amounts varying from 5.10 to 25.5 parts per million. Traces of phosphoric acid and of iron and alumina are usually present.

The several undetermined factors which enter into the above estimates of mineral solids removed make it difficult to formulate a concrete statement of the rate of lowering of the general surface level. Nevertheless, such statements are desired and have a comparative value. Assuming for the rock removed, most of which is

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*For 340 in the second line from the bottom on the preceding page read 840.
†Organic matter is deducted from the total solids as given for Suwannee Sulphur and White Sulphur Springs. The organic matter occurring in the other springs is of small amounts and was not separately determined. Analyses of the water of these springs were given in Bulletin No. 1, pp. 72-75, 1908.
limestone, an average specific gravity of 2.5, a layer one foot thick over one square mile should weigh about two and one-sixth million tons. The calculated rate of removal of this rock is about four hundred tons per square mile per year. From these estimates it would appear that the surface level of the central peninsular section of Florida is being lowered by solution at the rate of a foot in five or six thousand years.

With due allowance for a wide margin of error in the above estimates it is still evident that a very great amount of mineral solids is being removed annually in solution. The first effect of solution in limestone is to develop cavities through the rock along the line of ready flow of underground water. These cavities gradually enlarge until the overlying material, no longer able to support its own weight, caves in, forming a sink.

The formation of a sink is a first step in the development of the many basins large and small occupied by these temporary lakes. A sink usually retains connection with the underlying limestone for some time after its formation and water entering the sink escapes into the limestone. Under these circumstances more or less of the material lying immediately around the sink is carried by surface wash through the sink. Moreover the large amount of water entering through the sink results in rapid solution in the limestone of that immediate vicinity. The result is frequently the formation of other sinks in close proximity to the first. As old sinks become clogged or partly filled, new sinks form by this process continually enlarging the basin.

Not infrequently a sink forms in or near the bed of a stream. When this occurs the lower course of the stream, or a part of it, may be reversed. Where many sinks form in succession or through a long period of time the valley of the stream is thereby enlarged and is frequently carried to a level lower than the original outlet. Lakes Iamonia and Lafayette in Leon County and Alachua Lake in Alachua County are illustrations of basins of this type.

RELATION OF THE LAKE BASINS TO THE LEVEL OF PERMANENT UNDERGROUND WATER.

It is important to note the relation of these lake basins to the permanent underground water level of the formation into which they drain. It is a well established fact that solution by under-
ground water goes on more rapidly above the level of permanent underground water than below this level. The term “belt of weathering” is commonly applied to that part of the earth’s crust lying above the underground water level; while the term “belt of cementation” is applied to that part lying immediately below this level. According to Van Hise “the most characteristic reaction of the belt of weathering is solution. In contrast with this the most characteristic reaction in the belt of cementation is deposition in the openings of the rocks.”* The rapid solution in the belt of weathering is due to a number of causes. First of all the water in this part of the earth’s crust moves freely, while in the belt of cementation the water often moves very slowly. Moreover water is capable under given conditions of carrying a definite amount of mineral solids in solution and as the water from the surface enters the earth with little or no load, until it becomes saturated it takes materials into solution readily.

In accordance with this principle it is found that the largest of these basins are, as a rule, reduced practically to the level of underground water. Many of the smaller basins, it is true, have not reached the permanent water level, and stand at varying heights above that level. The relation of the basins to the underground water has a practical bearing and will be referred to again in connection with methods of drainage of the lakes.

DESCRIPTIONS OF TYPICAL LAKES.

LAKE IAMONIA.

Lake Iamonia lies near the north line of Leon County. The lake basin is irregular in outline, but has an average width of from one to one and one-half miles. The total length of the lake is from twelve to thirteen miles. At its west end the lake basin connects with the swamp of the Ocklocknee River. During flood seasons the river overflows into the lake. Similarly a high stage in the lake results in an overflow into the river. Small tributary streams enter the lake from both the north and the south side as well as from the east end. The tributaries are small flat-bottomed streams which are dry, except during the rainy season. The lake fluctuates much according to the rainfall. The lake basin when full covers an area of about 6500 acres. Except at the west end, where

it joins the Ocklocknee River, the lake is largely surrounded by the red clay hills characteristic of this part of the State. These hills rise to an elevation of from 50 to 75 feet above the level of the lake.

![Sketch map showing the location of lakes Iamonia, Jackson, Lafayette and Miccosukee in Leon and Jefferson Counties.]

The sink through which the water escapes from this lake occurs along the north border. When visited May 7, 1910, the sink was practically dry, having only a small amount of water in the bottom. Limestone rock, probably of Upper Oligocene age, is exposed near the bottom of the sink, the water escaping through or under these rocks. Above the limestone partly decayed sandy clays occur. These contain few fossils, although oyster shells were found in abundance at one locality. The total depth of the sink below the general level of the lake is not less than 50 feet. The sink occurs, as is usual in this type of lake, facing an abrupt bluff 30 feet or more in height. A considerable number of sinks occur around the border of the lake especially in the vicinity of the one large sink which receives the drainage of the lake. The formation of these sinks is doubtless due, as previously stated, to the fact that the water entering the drainage sink spreads laterally in the underlying limestone and dissolves the rock rapidly. The result is the formation by subsidence of numerous sinks adjacent to the drainage sink. The presence of these sinks also indicates the manner of enlargement of the lake basin, and indicates in each case the direction of most rapid enlargement at the present time. At other times the enlarge-
ment by solution and subsidence may have been most active in some other locality or direction or part of the lake basin. This lake only occasionally goes entirely dry and as a result a covering of muck or peat occurs over the greater part of the bottom of the lake. This deposit of muck reaches a considerable thickness in such natural depressions as occur over the lake bottom. Beneath the muck is usually found a deposit of light colored sand and beneath this is the red sandy clay.

The fact that the Ocklocknee River at flood stage flows into this lake makes any attempt at drainage doubtful of success. An effort which proved unsuccessful was made at one time to prevent the river water from entering the lake by means of a dam. It seemed to be the views of the party constructing the dam that if the water of the Ocklocknee River could be kept out the sink would carry off the water from the lake. This, however, is not probable, since in the several other lakes to be described the sinks have not proved sufficient to carry off the water except in times of greatly reduced rainfall. Lake Iamonia basin represents apparently a stream valley lowered by solution and enlarged laterally by subsidence through the formation of sinks. Originally a small stream tributary to the Ocklocknee River flowed through this section. In this part of the county soluble limestones occur at no great distance from the surface, and in the course of the natural processes of erosion the stream approached sufficiently near this limestone to permit of the formation of sinks and the escape of the water of the stream through the sinks. The enlargement of the valley to its present size has proceeded through the formation and partial filling of successive sinks. As each sink forms, it carries down to or below the lake level, a certain small area of land. Moreover the water passing through the bottom of the sink carries with it more or less detrital material so that the surrounding area is somewhat lowered by wash through the sink. In the course of time other sinks form, while the older sinks become clogged and usually partly fill up. The direction of active enlargement of each lake can be determined from the location of the recent sinks. As previously remarked this rapid enlargement is usually around the sink which is at present actively receiving the drainage.
Lake Jackson lies near the western border of Leon County within one and a half or two miles of the Ocklocknee River. This lake is irregular in shape, and has a total area of about 4,500 acres. The boundaries of the basin are sharply marked by the surrounding highlands which rise 75 to 100 feet above the level of the lake. Several sinks occur in the southern half of the lake. The largest of these, known locally as the "lime sink," is located well out in the basin and in the angle between the north and east arms. (See map). An opening in the bottom of this sink in May, 1907, permitted the water to run out, leaving the sink dry, and also draining the lake or such part of it as was connected with the sinks. An indefinitely defined broad depression or slough extends to the south-east from the lime sink. Several water holes representing old sinks occur along the line of this depression. A new sink occurred along the bottom of the depression about one mile south-east of the lime sink in June, 1907. A compact limestone showed in the bottom of this sink at a depth of about 25 feet from the surface. At the time this sink formed the lake was low, a part of the water having been carried off through the opening which had formed in the lime sink a month earlier. All the water that could reach the new sink was carried off in the course of two or three days, leaving the lake dry except for occasional water holes. When examined in September, 1909, a small open sink was found in the slough which carried away all of the water that reached it from the surrounding parts of the lake.
The surface soil in the basin is quite generally a gray sand darkened by admixture of organic matter. In the lower parts of the lake, quite generally covered by water, more or less muck or peat occurs formed from the accumulation of aquatic vegetation. Sand lighter in color and lacking the organic matter occurs at a depth of 1 1/2 or 2 feet to 3 or 4 feet. Beneath this sand is the usual red sandy clay.

This lake as already mentioned became dry, or nearly so, in the early spring of 1907. It was partly filled by the summer rains of the same year, but became dry or nearly so again during the summer of 1909. The accompanying photograph of this lake was taken July 5, 1909 and shows an unusually low water stage of the lake for that season of the year. (Pl. 7, Fig.1).

LAKE LAFAYETTE.

Lafayette Basin or Lake Lafayette lies in the eastern part of Leon County between Tallahassee and Chaires. The basin begins three and one half miles east of Tallahassee, and extends to within one mile of Chaires, having a total length of about five and one-half miles, and a width of one-half to one mile. An arm of the lake extends north from near the east end of the lake. The bottom of the basin is nearly level with the exception of occasional slight depressions. The tributaries to the lake are flat-bottomed streams with relatively broad valleys and no well defined channel. The soil in these stream valleys is a sandy loam, and the streams are ordinarily dry, carrying water only during the rainy season.

A drainage sink in this basin occurs near the west end of the lake along the northern border (See Fig. 3). The sink when measured in September, 1909, was found to have a total depth of 75 feet. The sink is found, as is usual in this type of lake basin, facing a prominent bluff. A second sink is formed beyond the lake border, thus indicating the enlargement of the lake basin in that direction by subsidence, due to underground solution. This new sink is one hundred yards or more in circumference, and when formed carried down to the lake level, land which stood fifty feet or more above the lake and was being used previous to the subsidence as a cemetery.

That part of the lake basin which surrounds the sink lies at a slightly lower level than the more remote parts of the basin and is the first to be submerged at the approach of the rainy season. This area is entirely devoid of trees, and during the dry season becomes a prairie. The greater part of the basin lying to the south of the railroad is thickly set with small cypress trees.
The soil in the basin is prevailingly a gray sand usually darkened by the presence of organic matter. At a depth of from one to two feet the amount of organic matter is reduced, the sand being lighter in color. Sandy clays are reached as a rule at a depth of from two and a half to three feet.

During a season of normal rainfall this basin is occupied by a lake having a total area of approximately two thousand acres. Following a period of prolonged drought the basin becomes entirely dry, water remaining only at the sink. In times of excessive rainfall the lake overflows at the east end, the water discharged reaching streams tributary to the St. Marks River.

![Fig. 3.—Lake Lafayette.](image)

This basin has much the character of an elongated valley. The general course of the streams of this part of the county, the shape of the basin and particularly the topography of the surrounding country indicate that the drainage of this section was originally through these streams into the St. Marks River. The formation of sinks diverted the drainage to a subterranean course, the west end of the basin having been reduced to a level somewhat lower than the east end. The further enlargement of the basin is being carried on through the formation of sinks along the border. The largest of the newly formed sinks is found near the present drainage sink.

**LAKE MICCOSUKEE**

Miccosukee Basin or Lake Miccosukee lies between Leon and Jefferson Counties, the west border of the lake forming the county line. A small arm of the lake, however, near the north end reaches into Leon County.
Miccosukee Basin has a total area of about 5,000 acres. In its northern part the basin is bordered by sharply defined bluffs, which rise from 50 to 75 or 100 feet above the lake bottom. Farther south these bluffs fall back and give place to a gradual rise of elevation from the lake border. At the south end bluffs are lacking. A drain known as Miccosukee drain enters from the east side. This drain consists of a low, swampy area from one-fourth to three-fourths mile in width. This swamp land supports a thick growth of hardwood trees.

When full, Miccosukee Basin is covered with water to a depth of from 2 to 5 feet. Toward the south end around the border of the lake grass and button bushes project above the water even when the lake is full.

The sink of Lake Miccosukee is located near the north-west corner (see Fig. 4). The sink is bordered by a bluff having an elevation of from 75 to 100 feet. Landslides along the border of the sink show recent enlargements of the basin. Numerous sinks occur along the border of the lake at this locality, showing enlargement of the lake basin through subsidence. The greatest depth of water found in the sink when examined September 7, 1909, was 38 feet. A channel leads back from this sink across the prairie in a south-easterly direction. This channel has cut to a depth of from twenty to twenty-five feet. Followed back from the sink the channel is of gradually reduced depth finally at a distance of about two miles merging into the general level of the lake bottom. When examined September 8, 1909, this stream was carrying water into the sink at a rate estimated to be 200 gallons per minute. Notwithstanding the inflow from the stream the water in the sink was being gradually lowered. Heavy rains occurred in this vicinity on September 21, 1909, and this stream when seen two days later was carrying approximately 7,000 gallons of water per minute. At this time the sink was being rapidly filled, having filled several feet during the two preceding days. From these observations it appears that the opening at the bottom of this sink permits the escape of water at a rate in excess of 200 gallons per minute, but much less than 7,000 gallons per minute. From the behavior of the sink it is probable that not more than 1,000 gallons of water are escaping per minute, and the rate of escape may be much less.

The principal escape of water from Lake Miccosukee when the lake is full is through a drain which leads out from the south end of the lake and enters a sink about two and one-fourth miles from the south end of the lake. This sink is formed in a light colored limestone of Upper Oligocene age, probably representing the Chat-
Fig. 4.—Lake Miccosukee.
tahoochee formation or the Tampa formation. The drain from the lake as it approaches the sink passes through a narrow gorge cut in this limestone.

About one-half mile farther south (Sec. 14) another sink is found. This third sink receives the flow from Mill Creek, a small stream draining considerable territory lying south of the Seaboard Air Line Railway and east of Lloyds.

During a season of excessive rains these sinks are unable to carry away the water. Under these conditions the overflow from Lake Miccosukee as well as from Mill Creek ultimately finds its escape by flowing to the south-west past Lloyds to the St. Marks River.

The surface in Miccosukee Basin is covered with muck to a varying depth. Borings put down near the north end of the basin, out from the margin of the drain, indicated the presence of muck for a depth of from six inches to one foot. Beneath the muck in this part of the basin was found a gray sand. This sand is underlaid, at a variable depth, by the usual red sandy clay. At the south end of the lake the sand is largely absent, the muck which is from one to three or more feet deep resting, so far as observed, directly upon the red clay.

Lake Miccosukee probably represents a basin developed by solution near the headwaters of streams originally tributary to the St. Marks River. Previous to the formation of Miccosukee Basin the drainage of this part of the country doubtless passed through small streams, to the south past the present village of Lloyds, thence to the Gulf through the St. Marks River. The lake basin since its formation has enlarged to the north-west, the lowest part of the basin now being found near the sink in the north-west corner.

Mill Creek which now enters from the south and disappears through a sink a few miles north of Lloyds illustrates the reversal of flow of a stream due to the formation of a sink. This stream, previous to the formation of the sink, flowed south-west to the St. Marks River. At the present time it flows north and enters the sink. At times of excessive rainfall the sink is unable to carry off the water and the stream under these conditions flows in its earlier course to the St. Marks River.

ALLIGATOR LAKE.

Alligator Lake lies in the central part of Columbia County, from one and a half to two miles southeast of Lake City. The lake basin has a total area of about 1,000 acres. Numerous smaller lakes occur to the west and north of this large lake. The sur-
rounding country is in general level or rolling and lies at an elevation approximating 200 feet above sea. The basin along its western side is bordered by a bluff which rises to an elevation of from 50 to 75 feet above the level of the lake. Along the eastern and southeastern side the basin passes gradually into low lying swampy hammock land, or cypress swamp. The sink of Alligator Lake occurs along the southwestern border. The escape of water at the present time is through this sink. In the country bordering the lake around this sink numerous other sinks occur. The lake is said to overflow at high water stage to the south through a small stream known as Clay Hole Branch.

A soil boring put down fifty yards from the edge of the basin along its southwest border gave the following section:

- Black muck with admixture of clay: 1 ft.
- Yellow sand loam: 1/2 ft.
- Fine light gray sand: 1 1/2 ft.

A pit made by Mr. Greer in his garden near the border of the lake gave the following section:

- Brownish colored imperfectly decayed vegetable matter (peat): 1 ft.
- Black muck with admixture of sand and clay: 2 ft.
- Red very sandy clay: 1 ft.

It is reported that at the time of the early settlements in Columbia County, 1835 or thereabouts, Alligator Basin was a prairie or savanna and was used at that time by the Indians as pasture land. The lake was dry in the fall of 1891, and again in the fall of 1899 or 1900. It was dry again during the winter and spring of 1909, but was partly filled by rains during the following summer.

Approximately complete records of rainfall are available at the Lake City station for the year 1897 and succeeding years. The rainfall for the year 1899, at which time the lake became dry, was much below normal, amounting for the year to only 30.49 inches. The next period of unusually low rainfall was the year 1908. During this year the rainfall amounted to only 29.83. The rainfall during the year 1909 was likewise slightly below normal, amounting at Lake City to 49.68 inches.

ALACHUA LAKE.

Alachua Lake or Paynes Prairie is the central and largest of the several lake basins of southeastern Alachua County. This basin is about eight miles long and varies in width from one and a half
to four miles. It contains about twelve thousand acres. Low divides scarcely exceeding ten feet in elevation separate this basin from Kanapaha and other prairies on the west and from Levy, Ledwith, and numerous smaller lakes on the south, and from Newnans Lake on the northeast. The total area embraced within these various basins is not less than fifty square miles. For a map of this section the reader may consult the Arredondo topographic sheet of the U. S. Geological Survey.

When dry or nearly so, this basin supports a dense growth of grasses and weeds. On the more elevated and dryer parts dog-fennel prevails, growing to a height of eight or ten feet, while on the lower and wetter parts of the basin maiden cane abounds.

The principal stream entering this basin is a creek flowing from Newnans Lake. This creek enters at the east side of the basin and flows west and northwest to the sink.

The "sink" of Alachua Basin is located in the northeast border. Two sinks occur here. The waters from these sinks enter the Vicksburg Limestone. The sinks are partly surrounded by bluffs rising to an elevation of thirty or forty feet above the general level of the basin. Numerous sinks occur along the border of the lake showing enlargement of the lake basin in this direction. The stream entering the more westerly of the two sinks was carrying water when examined in October, 1907, at an estimated rate of 20,000 gallons per minute. At this time the water level in the sink was only 2.01 feet above the general level of water in the Vicksburg Limestone as shown by the Gainesville city well,* indicating that the sink was carrying water at its full capacity or nearly so.

In November, 1909, the water in the sink stood approximately one and one-half feet above the level of the water in the surrounding limestone.

During seasons of heavy rainfall the stream draining from Newnans Lake and other smaller streams carry water so rapidly that the water is unable to escape through the sink as rapidly as it flows in. Under these conditions the basin fills, becoming temporarily a lake. It is probable also that the drainage sink becomes more or less completely clogged at times retarding the escape of water, and in this case the prairie may continue as a lake through a succession of years.

Variation in this lake has been more or less perfectly recorded since the time of the earliest settlements in this section. When

* Bull No. 1, Fla. Geol. Survey., p. 60, 1908.
visited by Bartram in 1776 this basin was known as “Alachua savannah” and served as grazing ground for stock belonging to the Indians.* The basin was visited by James Pierce in 1824 and was dry at that time. The water in the basin is said by W. W. Cameron who lives near its margin to have been very low in 1861. When visited by Dr. E. A. Smith in 1880 the basin was comparatively full, forming a lake. The basin in fact is reported to have continued as a lake from 1871 or 1873 to 1891. In the fall of 1891 the basin became dry, and, with the exception of temporary overflows has been dry much of time since that date. It is possible that the higher water stage in the basin during the years from 1871 to 1891 was due to partial clogging of the sink. The records of rainfall during these years for this section is unfortunately lacking.

The following account of the disappearance of Alachua Lake appeared in the Providence Journal for September 14, 1891. The account is given with some omissions as quoted by Dr. W. H. Dall in Bull, 84, U. S. Geol. Survey p. 94, 1892.

“A curious spectacle was to be seen on the outskirts of Gainesville, Florida, recently. Alachua Lake * * * is no more. On its banks were lying thousands of dead fish * * * and the atmosphere was heavy with noxious gases. Men and boys were there in throngs with hoes and rakes, dragging to shore hundreds of fish which had sought the pools for refuge. The waters were fairly alive with their struggles for existence. Except for a small stream known as Payne's Creek flowing from Newnan's Lake into the Sink, the two main basins of the Sink, and a few stagnant pools, no water is now to be seen where a few years ago steamers were ploughing their way. This is the second time since 1823 that a similar occurrence has taken place. At that time the bed of the lake was a large prairie—Payne's Prairie—having in it a body of water called the Sink and a small creek. In 1868 heavy rains filled up the prairie, but the water disappeared after a short time and the prairie was again dry land. In 1873, after a series of heavy rains, the Sink overflowed and the creek swelled to the dimensions of a lake. During several years the waters increased till a larger lake was formed, and for fully fifteen years sufficient depth of water stood over the prairie to allow of small steamers. During the last two years, however, the waters have been gradually lowering, and about four weeks ago they commenced going down with surprising rapidity, the lake falling about eight feet in ten days, until now nothing is left of Alachua Lake but the memory of it. The Sink is considered the cause of this change. There is evidently an underground passage connected, and for some reason not understood, this underground passage has been acting as a drain until all the water in the lake has been drawn off.”

In this account the fact is noted as is usually the case that after the lake became somewhat restricted the water seemed to escape.

Miccocoukee basin, low water stage, 1909. This view is taken at the sink near the northwestern side of the lake.
EXPLANATION OF PLATE 7.

Fig. 1.—Lake Jackson. View taken from the north end of the lake. Photograph by R. M. Harper.

Fig. 2.—Alligator Lake. View taken from the bluff overlooking the lake. Photograph by A. M. Henry.
EXPLANATION OF PLATE 8.

Fig. 1.—The sink of Lake Lafayette.

Fig. 2.—Paynes Prairie at low water stage. View from the sink. Photograph by E. Peck Greene.

Fig. 3.—Paynes Prairie at low water stage. Photograph by R. M. Harper.
Spouting well near Orlando. Photograph by T. P. Robinson.
with great rapidity. The rapid lowering of the surface is due, however, as previously stated, not to greater rapidity in the escape of the water, but to the fact that the total surface area of the lake became greatly restricted so that the escape of a given amount of water lowered the surface much more rapidly.

The following remarks regarding the lake appeared in the Washington Evening Star of September 19, 1891. This quotation is also from Dr. Dall's report.

"The Star recently printed an account of the disappearance of Alachua Lake in Florida, a lake that was so well established that a steamboat line was maintained on it. A U.S. Geological Survey party has been engaged at work in that region. A member of this party, Mr. Hersey Munroe, who is now in the city, gave an interesting account of the lake, or rather the ex-lake, to a Star reporter. "Alachua Lake," said Mr. Munroe, "is situated in north latitude 29° 35' and west longitude 82° 20' in Alachua County, Fla., and 2 miles south of Gainesville, the county seat. The lake was formerly a prairie, known as Alachua prairie before the Seminole War during 1835-37. It has since been named Payne's Prairie, after King Payne, an old Seminole chief of an early day. The prairie was a great grazing spot for the Indians' cattle and later was used for a like purpose and for tillage by the whites, some fine crops of corn and cotton being grown. The prairie lands are immense meadows, covered by the finest grass, interspersed with clumps of beautiful oak trees and palmettoes. These lands are subject to inundation during the summer season. Hatchet Creek rises 3 miles north of Gainesville and flows in every direction of the compass for a distance of 10 miles, emptying into Newnans Lake, a beautiful sheet of water covering 10 square miles.

"HOW THE LAKE WAS FORMED.

"The overflow from Newnans Lake forms a large creek named Prairie Creek, which wended its way through Paynes Prairie to Alachua Sink, one of the curiosities of the State. There the waters found their way into a subterranean passage. Visitors, to have their curiosity gratified by seeing what the effect would be to have logs thrown into the sink, were the probable cause of the overflow of Paynes Prairie. The logs would float out to the center of the sink, whirl around in a circle and suddenly disappear. This choking of the outlet to the waters of Prairie Creek caused the overflow and made a sheet of water sufficient to float small steamers and other crafts.

"One steamer in particular had a splendid freight traffic, during the vegetable season carrying shipments of vegetables from its wharf on Chacala pond across Alachua Lake to the mouth of Sweetwater branch, the nearest point to Gainesville, the principal place for shipment north. After the overflow and the forming of a lake it was christened Alachua Lake. This name has been decided upon by the United States Board on Geographic Names. Alachua Lake is 8 miles long, east and west, and in one place 4 miles in width, north and south, covers 16,000 acres, and the average depth is from 2 to 14 feet.

"LOWER FOR SEVERAL YEARS.

"For several years the lake has been gradually lowering. The elevation of the water above sea level as given by the Savannah, Florida and Western Rail-
road some years ago is 64 feet. By accurate levels run by one of the topographical parties of the Geological Survey working in this section during the winter of 1890-91 the elevation of the water was found to be 58 feet, thus showing that the lake had been changing elevation; and about two weeks ago I was informed that Alachua Lake had disappeared entirely, that only small pools remained and the usual amount immediately around the sink."

The early geological history of that section of Alachua County now occupied by these larger basins and lakes was apparently as follows: Originally the surface runoff from southeastern Alachua County made its way through Orange Creek and the Ocklawaha River into the St. Johns River. These streams were then heading back in the plateau region of Alachua County, and were fed both by the surface runoff and by the numerous small springs issuing from the clays and sands of the Apalachicola group underlying the

Fig. 5.—Sketch map of Hogtown Prairie and surroundings, illustrating a stage in the development of a solution basis. From the Arredondo topographic sheet, U. S. Geol. Survey. The 60-foot contour line borders the prairie.
plateau. In the course of time the streams cut down to or nearly to the underlying Vicksburg Limestone. The result of the close approach to this limestone was the formation of sinks due to solution in the limestone. After the formation of the sinks it became possible for the water to pass through the sinks and find its escape by subterranean drainage. This process of solution and subsidence continued through long intervals of time has resulted in the formation of these numerous basins. Some of these basins have been carried to a level equal to or below their original outlet through Orange Creek.

Basins may be seen at the present time in varying stages of development. In the plateau itself no basins are found. Even here, however, are found occasional sinks, the first evident effect of the reduction by solution. An illustration of a partially developed basin may be found in Sanchez Prairie near Hague. The country surrounding this small basin stands at a level of about 180 feet. The basin itself occupying an area of a few hundred acres is reduced to an elevation of about 100 feet above sea. Hogtown Prairie near Gainesville (Text figure 5) represents a more advanced basin. Hogtown Creek probably originally flowed through Alachua Basin, thence to the St. Johns River through Orange Creek. The formation of the sink, however, permitted a subterranean escape and around this sink is formed Hogtown Prairie, now separated from Paynes Prairie by elevations amounting to twenty or thirty feet.

OCHEESEE LAKE.

Of the few lakes occurring in Jackson County Ocheesee Lake is perhaps the largest. This lake lies in the southeastern part of the county extending from near Grand Ridge in a southeasterly direction to within three or four miles of the Apalachicola River. The total length of the lake is six or seven miles. In breadth it varies from a few rods to possibly three-fourths of a mile. At the northwest end the surrounding country rises very gradually. The southwest part of the lake, however, is surrounded by red sandy hills which rise from 75 to 100 feet above the bottom of the lake. The lake is perhaps best described in this instance as a swamp, the greater part of the lake bottom being occupied by a growth of cypress. Near the east end open water occurs over an area of about 100 acres. The water sinks into the Chattahoochee Limestone at the south-east end of the lake.

The history of the development of this lake is very clear. Originally the drainage from this part of the county passed by
a surface stream to the Apalachicola River. At a distance of three or four miles from the river, this stream, after cutting its channel some depth, reached the Chattahoochee Limestone. When this formation was reached the water passed into the earth, the drainage becoming subterranean. Subsequent erosion carried the basin to its present level.

**METHODS OF DRAINAGE.**

Two methods of draining basins of this type may be considered. (1) drainage by surface ditching to some stream or other outlet lying at a lower level: or (2) drainage into the underlying water bearing formation.

**DRAINAGE BY SURFACE DITCHING.**

Surface ditching usually suggests itself as the more natural method of drainage, and it is often inferred in the absence of definite information that the lakes lie at a higher level than near-by streams. This is not always the case, and such an assumption may lead to a very costly error. A lake or prairie of this type a few miles southeast of Citra was connected many years ago by canal at considerable expense with a tributary of the Ocklawaha River. Upon completion of the canal it was found that the lake basin was at a lower level than the stream bed. The peculiar method of formation of these lake basins by solution, as previously explained, carries them frequently to a lower level than the stream which served in earlier stages as an outlet. Lake Iamonia as previously stated lies practically on a level with the Ocklocknee River, and receives the overflow of that river during high water stages. Alachua Lake basin lies, as shown by the topographic map, at practically the same level as Orange Lake and the headwaters of Orange Creek which served formerly as the outlet.

**DRAINAGE INTO THE UNDERLYING FORMATIONS BY WELLS.**

Drainage into the underlying formations takes place naturally through the sinks already existing. Artificial drainage consists either in enlarging the sinks, or in making artificial openings in the form of dug or drilled wells through to the water bearing formation. In either case the principle is the same. The underlying limestone is porous and cavernous, and is filled with water to a definite although slightly variable line or level known as the permanent underground water level.
Solution in the limestone occurs both above and below the water line, but chiefly above. As solution continues the overlying material is no longer able to support its own weight and caves in, forming a sink or natural opening from the surface to the limestone. As long as this sink remains open, water passes through and escapes readily into the limestone. Drilled or dug wells serve as artificial openings to the same formation. Wells drilled into this limestone will serve either as supply wells from which water may be pumped or as drainage wells into which water may be conducted. It is generally the case that a well entering this formation that can not be appreciably affected by pumping, will also conduct water readily. If the openings at the mouth of the well are sufficiently free to permit ready flow to the well when being pumped, they are, conversely, sufficiently open to allow the water to spread rapidly from the well when used as a drainage well. The amount of water held in the pores and cavities of the limestone is so great that the water level is not appreciably affected either by the water removed when a well is being pumped, or by the water added when a well or sink is used for drainage purposes.

Attempts to enlarge existing sinks or to re-open sinks that have become clogged have usually proved futile. It is doubtless true that the opening through sinks is a more or less winding channel and to re-open this when clogged with debris is difficult.

Better success has been obtained by dug or drilled wells. Where the underlying porous formation into which the well is to be drained lies near the surface, dug wells can be used to advantage and may be preferable. Dr. H. Bjiystra has used this method in draining a small lake or “prairie” on his farm near Brooksville, Florida. At this locality the cavernous limestone lies near the surface and is reached by relatively shallow wells. The one difficulty experienced as reported by Dr. Bjiystra is the fact that during the summer rainy season in one or two instances the rainfall has been so heavy within a short space of time that the wells were unable to carry away the water as fast as it fell, the result being temporary overflow of the farm and serious injury to growing crops. It is probable that this danger can be removed in this instance by digging additional wells.

Drilled or bored wells have been in some instances notably successful. An advantage in the drilled well is that it can be put down to any required depth. When properly cased and screened drilled wells are permanent. The effectiveness of the well is dependent upon the structure of the formation penetrated. If the water-conducting power of the formation reached by the well is
slight a limit is thereby placed on the effectiveness of the well. Unless the flow of water at the bottom of the well is free the in-take of water is necessarily limited.

Assuming free movement of the water at the bottom of the well, the rapidity of in-take and hence the efficiency of the well is influenced by (a) size of well; (b) construction of well; (c) depth of water above the mouth of the pipe; (d) distance from the top of the pipe to the underground water level.*

(a) The capacity of a drain pipe increases rapidly with increased diameter. The area of the section of the pipe is proportionate to the square of the diameter. Thus the area of the cross section of a 12-inch well is nine times that of a 4-inch well. Moreover, for a given velocity the friction of movement is less in a large than in a small pipe.

(b) The construction of a well also affects its rapidity of in-take. When the pipe is cut off squarely at the top according to the usual custom, the full capacity of the well is not realized. The rapidity of in-take may be appreciably increased by the use of a flared or bell-shaped mouth at the top of the pipe.

(c) If the underground water level lies some distance from the surface and if there is free discharge at the bottom of the well, siphonage or draft-tube action increases the rate of flow. When the distance from the top of the pipe to the underground water level is 33 feet or over, the maximum possible draft-tube head of 32.8 feet may be available.

(d) The influence of the depth of water above the mouth of the pipe is as follows: Assuming that the water flows into the pipe as through an orifice, the in-take at the mouth of the pipe will be proportionate to the square root of the depth of the water above the mouth of the pipe.

The velocity of flow in the drainage well may be measured by means of Pitot's tube. This is a bent tube one arm of which is graduated, used to determine the velocity of running water. To make the measurement insert the tube vertically in the top of the pipe, the short end projecting upward and having its mouth a few inches below the top of the drain pipe. The velocity of flow in the pipe is expressed within close limits by the following formula in which \( h \) is the height in inches to which the water rises in the long arm above the surface of the lake.*

\[
V = \sqrt{\frac{64.324}{12} h} = 2.32 \sqrt{h}
\]

SOME FLORIDA LAKES AND LAKE BASINS.

The flow in cubic feet per second into the well will be

\[ Q = 0.0055 \, d^2 \sqrt{h} \]

nearly

\[ \frac{V}{80} \]

In this formula \( Q \) represents the flow in cubic feet per second; \( d \) is the inside diameter of the pipe in inches, and \( h \) the height in inches to which the water rises in the long arm above the surface of the lake. \( V \) is the velocity of flow.

A notably successful instance of drainage by wells where the interests of a municipality were involved occurred at Orlando, Florida, and was given in Bulletin No. 1, as follows:

"A very considerable land area south and east of Orlando, embracing possibly fourteen square miles, lies in an irregular basin with many lakes, marshes, and ponds. The overflow from this area originally drained to and disappeared through a natural sink about one mile east of the city. This sink became clogged in April, 1904. Unsuccessful efforts were made to re-open this sink, first by removing hyacinths accumulated around the opening, and later by the use of dynamite. In the meantime, heavy and continued rains formed a lake around the sink, overflowing the surrounding lands. In August, 1904, efforts were made to dispose of the water through drainage wells. The first well put down was a two-inch test well. The well reached a porous stratum and was thought to justify the expense of a larger and deeper well. Difficulty and delay were experienced in the drilling, but by August, 1905, two wells, one eight-inch and one twelve-inch, put down at the side and near the original sink, had been completed. Two other wells were started and abandoned owing to the difficulties in drilling. The two successful wells were running at full capacity. It was thought probable that the two wells already put down would prove sufficient. Heavy rains followed, and by January, 1906, a considerable area, including some cultivated ground, was flooded, practically all county roads leading into Orlando from the east were partly under water and impassable. The colored settlement known as Jones-town in the suburbs of Orlando was partly under water and uninhabitable; the water was approaching the city of Orlando itself and the situation was becoming alarming. Levels taken by the county authorities indicated that drainage through surface canals was impossible or impracticable. Two additional twelve-inch wells were bored in November and December of 1906. The effect of these was evident at once, the lake beginning to fall. By February a third twelve-inch well had been completed, making in all one eight—
inch well and four twelve-inch wells running at this time. By the end of March the water had returned practically to its normal level and has since been kept under control.

"Four of these drainage wells are located near the original sink and have a uniform depth of 140 feet, a cavity several feet in diameter having been reached at that depth. The fifth well is located one-half mile west of the sink, and terminates in a porous stratum at a depth of 340 feet."

Since the completion of these wells by the city a number of other drainage wells have been put down by individuals, used largely to reclaim trucking and farming lands.

One of these drainage wells near Orlando developed recently the unusual phenomenon of spouting. The well is located three miles north of Orlando on land belonging to Charles T. Myers. It was drilled in 1907 jointly by Mr. Myers and Messrs. McNeal and Davis, the latter gentlemen having the property leased for farming purposes. The well is twelve inches in diameter and has a total depth of 260 feet, and is cased 60 feet. It is located at the edge of a small lake. The level of permanent underground water at this locality is 33 feet from the surface. Trucking is carried on around the border of the lake and the well is intended, by carrying off the surplus water, to prevent the lake from rising above a given level, since to do so would flood the farming land. The well is similar in character to the other drainage wells of this locality and, as in the case of most of the other wells, terminates in a cavity in the limestone.

The well was first seen by the writer October 4, 1910. At this time the water of the lake stood a few inches above the level of the pipe and the well was receiving water at much less than its full carrying capacity. At intervals of a few minutes the well would reverse itself and spout, throwing a column of water into the air. The spouting comes on gradually. First the well ceases to receive water and begins bubbling; the column of water follows rising with considerable force to a height of twenty feet or more above the surface, the spout occurring with tolerable regularity at intervals of four minutes. Mr. R. D. Unis, who has charge of the farm, states, however, that the intervals between spouts vary from two to fifteen minutes, being probably influenced by varying conditions under which the water enters the well. (Pl. 9).

Although drilled about three years ago and receiving water more or less constantly since that time the phenomenon of spouting developed for the first time on September 26, 1910, the first spouting having occurred about eight o'clock on the morning of that
day. The well continued spouting without interruption for a little more than a week and until shut off by the owner.

Various fanciful theories have been advanced to account for the spouting, including supposed occurrence of gas and oil, and the supposed influence of recently formed sinks in the interior of the State. The true explanation is evidently much more simple. At the present stage of the lake the well is receiving water at less than its full carrying capacity and as the water enters the vertical pipe it forms a suction carrying a large amount of air into the well, which doubtless collects in a chamber or cavity along the side or at the bottom of the well. As the well continues receiving water the air accumulates under pressure in this chamber until ultimately the pressure under which the air is confined is sufficient to overcome the weight of the overlying water and hence rushes out with considerable force carrying the column of water with it.

The fact that the well when first drilled did not spout and afterwards began spouting doubtless indicates that the essential conditions were subsequently developed either by caving or by other changes in the underground conditions.

The spouting of the well is therefore on the principle of the air-lift pump in which air under pressure is conveyed into the well through a special tube for that purpose and being liberated in the well lifts a column of water to the surface. In this spouting well, however, the air pressure is developed within the well. This well may, therefore, be classed as a self pumping well.

When partly shut off so that only a limited amount of water enters, the air taken into the well is able to return to the surface freely. Under these conditions spouting ceases. It is probable that if an elbow is placed on the well, allowing the water to enter laterally instead of vertically, the amount of air taken into the well will be so far reduced that the spouting will cease. Likewise when the lake rises so that the water stands several feet above the top of the pipe entering the well it is to be expected that the spouting will cease, since the pipe will then be carrying water at its full capacity, and little or no air under these conditions entering the well.*

The drainage wells are themselves remarkable and found in such perfection only under geological conditions similar to those existing in Florida. Of the many peculiarities of these wells,

*Since the above was written very heavy rains attending the storm of October 17, 1910, caused the lake to rise 18 or 20 inches, and Mr. Unis writes that when the water rose in the lake the well ceased spouting. A similar well at Albany, Georgia, is reported by McCallie. Science, XXIV, p. 694, 1906.
however, that of spouting is certainly the most striking and remarkable.

In considering the use of wells for drainage purposes the relation of the lake basin to the underground water level should first be definitely determined. The effectiveness of the well is reduced as the water level is approached, and it is of course obvious that the water in the lake can in no case be carried below the underground water level. Many of the larger lake basins are known to lie very close to the water level. If the lake basin lies as low as the permanent water level it is obvious that the water in the lake can not be drained by wells, moreover since the effectiveness of the well is affected by the near approach to the water level, it is hardly practicable to reduce the water in the lake quite to the permanent underground water level. It must also be borne in mind that while the underground water is a permanent supply the water level or water line is not stationary, but varies with the seasons. The amount of variation for the locality concerned should be determined.

The fact that a lake basin stands somewhat above the water line at the close of a long dry season is not proof that it will be found to stand above the water line after a season of heavy rainfall. In some sections of the state the range of variation of the water line has been found to be as much as ten feet, and may in some instances exceed that amount.

The relation between the level of the lake basin and the underground water has been determined for a few of the lakes. Measurements of Alachua Lake were made in 1907 and again in 1909. When measured in October, 1907, the water level in Alachua Lake was found to be 2.01 feet above the level of the underground water of the Vicksburg Limestone formation as determined from the Gainesville City well.* When measured in November, 1909, the water in the sink stood approximately 1.4 feet above the water level in the limestone as indicated by the city well. At the time these measurements were made the lake was at a low water stage. The underground water level was likewise at a low stage. From these measurements it appears that Alachua Lake during the dry seasons at least is lowered by natural drainage through the sink to or practically to the underground water level. During the rainy season the water in the lake doubtless rises above this level, although it must be borne in mind that the water line also rises during the rainy season. It is evident, therefore, that the difference between the water level in the lake and the underground water line is great-

*For a record of this well, see Bull. No. 1, pp. 30 and 88-89, 1908.
est during the rainy season when the lake is receiving a large amount of surface drainage.

Approximate measurements of the water level in Alligator Lake near Lake City have also been made. This is one of the smaller basins and the measurements indicate that the level of the water in the lake stands appreciably above the underground water level. In this instance the measurements of the water level and the lake level were made at different seasons of the year and the results can be only approximately compared. The data on this lake are as follows: Levels made by Professor N. H. Cox, on June 19, 1903, showed that the water in Alligator Lake stood 94.22 feet below the Union Depot at Lake City.

The lake at the time the levels were made was at medium full stage. The water of the Lake City public well located near, and on about the same level as the depot was found at the time the well was completed in 1907 to stand 134 feet from the surface. Allowing for any correction that it might be necessary to make owing to the fact that the measurements of lake level and ground water level were not made at the same time it would still seem that the lake basin in this instance stands somewhat above the water level. The drainage of this lake by wells should be possible provided the underlying limestone at this locality proves to be sufficiently porous and cavernous to conduct water readily.

SUMMARY.

The basins of the temporary lakes have their origin in erosion by solution and by mechanical wash. Some of them appear to represent the enlarged valleys of what was originally a small stream. Sinks form along these streams diverting the course of the water into the underlying limestones. Other basins originate from sinks in no way connected with stream valleys. The origin of the sink was due primarily to solution in the limestone. After the sink is formed the general level of the surrounding area is lowered somewhat by mechanical wash, the material being carried into the sink. Subsequently other sinks form in the immediate vicinity. The formation of these new sinks is due also to solution. The large amount of water which entered the limestone from the first sink facilitates solution and results in the formation of additional sinks. The continuance of this process through a long period of time results in the development of the large basins occupied by these lakes. From their manner of development it follows that the steepest bluffs as a rule are those immediately facing the active sinks. Likewise for reasons already given new sinks occur most frequently in the area immediately surrounding the active sink.
It is doubtless true that some of the lakes, especially the smaller ones, could be drained by surface ditching. Any attempt at drainage should be preceded, however, by the preparation of a carefully made topographic map of the region, or at least sufficient exact leveling should be made to determine definitely the relation of the lake basin to the proposed outlet, and to the intervening country.

While some of these lakes can be drained by bored wells it is not to be assumed that all can be so drained. As has been shown some of these lake basins, especially the larger ones, have been lowered by solution practically to the permanent underground water level. Before attempting drainage by wells definite data should be obtained as to the relation between the level of the lake basin and the underground water level of that locality. This information can often be obtained by running a line of levels from the lake to a near by deep well and comparing the level of water in the lake with the level at which the water stands in the well. If necessary, test wells may be drilled before undertaking large wells. Such lakes as have been lowered by natural drainage actually to the underground water level can of course be lowered no further by wells.
THE ARTESIAN WATER SUPPLY OF EASTERN FLORIDA

BY E. H. SELLARDS AND HERMAN GUNDER.
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THE ARTESIAN WATER SUPPLY OF EASTERN 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. This paper, the second of the series to be published by the State Survey, extends the study of the water supply to the counties of eastern 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. De Witt Webb, J. W. Wiggins, H. Van Dorn and W. D. Holcomb. 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.

Most 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 general discussion and introductory chapters of this paper were written by the senior author. The account of the public, city and private supplies and of individual wells was written chiefly by the junior author.
THE AREA TREATED.

The area considered in detail in this report includes the following counties: Nassau, Duval, Clay, St. Johns, Putnam, Volusia, Orange, Brevard and St. Lucie. This section borders the Atlantic Coast for a distance of 250 miles, and comprises the principal artesian area of the east coast.

While central Florida, described in the preceding paper on water supply* is prevailingly a limestone country, having limestone formations at or near the surface, this eastern section of the State is prevailingly a section free from limestones. These differences, due primarily to differences in geologic structure, have given rise to marked differences in the topography, drainage, soils and water supply of the two sections.

GEOLOGY.

A knowledge of the geologic structure is essential to a clear understanding of the underground water conditions. The prevailingly level country of East 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 this part of the State.

The geologic periods in eastern Florida in the order of occurrence are: 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 eastern 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, as described in the preceding paper on water supply, these limestones are frequently exposed at the surface. Passing to the east from central Florida they dip beneath the surface and while nowhere exposed at the surface in eastern Florida, are reached by all deeper wells. It is in fact from these limestones that the principal water supply of eastern 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 first one or two hundred feet is of light color. This 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 through this limestone one or two hundred feet 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 approaching the Atlantic, 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 7 1/2 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 a maximum of approximately 1,000 feet is recorded at Palm Beach. While the occurrence of this formation is thus known in a general way the data are as yet imperfect.

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 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 preceding 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

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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 near-by shallow well.
weathers to a sticky blue clay. The Chattahoochee Limestone is
difficult to recognize in well samples. Fossils in this formation are
comparatively rare and such as occur are preserved as casts and are
largely destroyed in drilling. In surface exposures it may be recog-
nized by its lithologic characters 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 fullers 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.
The wide distribution of this group in West and South Florida leads
one to believe that it is likely to occur very generally underlying East
Florida.

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 un-
determined, 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 ex-
posed 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 Middle-
burg:

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 oxidized yellow...........16 feet
Bluish fossiliferous marl .................................. 4 feet

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 Putman 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.

PLEISTOCENE.

The marine Pleistocene deposits have been recognized at several localities in eastern Florida. Messrs. Matson 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 east 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 east coast also probably belong to the Pleistocene.

EARTH MOVEMENTS DURING THE 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 Railroad 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. Marys 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. 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 St. Lucie, Brevard and St. Johns 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. 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 by the Seaboard Air Line Railway, elevations exceeding 200 feet.

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. Marys 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.

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. The palmetto flatwoods is the prevailing type of country throughout the southern part of this area. 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.

THE LAKE REGION.

The lake region is a term that has come to be applied in Florida to a characteristic type of topography. The term does not refer merely to a section in which lakes occur, but is restricted in usage to apply to a section in which a particular type of lakes occur. The lake region consists of irregularly placed hills which descend abruptly to circular lakes. The soil is prevailingly sandy and well drained. There are few if any surface streams, and the lakes have, as a rule, no surface outlet.

The lake region type of topography occurs in those parts of the State in which soluble limestones, although buried to a considerable depth beneath other formations, nevertheless lie sufficiently near the surface to affect the topography. In that part of the State in which limestones lie at or very near the surface large lakes rarely occur, although sink holes are frequent, some of which may contain water forming small sink hole lakes. On the other hand where the soluble limestones are so completely buried beneath other formations as to have no effect on the topography lakes of this type do not occur.
The typical lakes of the lake region are more or less circular in outline, have sandy and often steep sloping sides with no limestone rock exposed at the surface, and having no evident subterranean outlet. Their origin is doubtless due to solution, although owing to the considerable thickness of other formations the limestone is seldom observed. After the formation of the lake basin the accumulation of sands and clays has effectively concealed whatever limestones may have been exposed by the original subsidence. Any subterranean outlet that may have existed has likewise become clogged in the same way. Typical lakes of the lake region do not run dry at intervals through subterranean passages.

The lake region apparently represents a stage in the lowering of the land surface through solution.

In sections where the limestone occurs nearer the surface a slightly different type of lake occurs. As examples of this second type may be mentioned Alachua Lake in Alachua County; Alligator Lake in Columbia County; Lake Miccosukee in Jefferson County, and Lakes Jackson, Lafayette and Tamonia in Leon County. These lakes have been described in a preceding paper in this volume.

CLIMATE.

The counties of Florida covered by this report lie bordering the Atlantic Ocean 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 250 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 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 Jacksonville in the northern part of the State there is little or no danger of frost before the latter part of October. The earliest killing frost recorded, at this station, is November 12, 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.

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.

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; Aug-

ust 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.*

The prevailing winds in the fall and winter in eastern Florida are from the northeast. During the late spring and summer the prevailing winds at Jacksonville are from the southwest. Farther south at New Smyrna the prevailing winds during the summer are from the southeast.

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 pre-existent 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. (Pl. 12, Fig. 2).

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 tannic or organic

SOIL TYPES.

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 12.—SOIL TYPES.

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 Co.

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.
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. Prairie as the term is used in Florida refers to lands overflowed during a part of the year. The soil consists usually 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.—Calcereous 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 calcereous soils are desirable, particularly for vegetable growing.
EXPLANATION OF PLATE 14.—SOIL TYPES.

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.
acids 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. (Pl. 11).

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. Some of the highly successful celery farms of the State are of this type.

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. (Pl. 12, Fig. 3).

Prairie lands: The word "prairie" as used in Florida is applied to open lands devoid of trees. The native growth is largely grasses. The Florida prairies are without exception lands that are overflowed during the rainy season, the absence of trees being due, in part at least, to the flooded condition of the land during a part of the year. Many of the prairies, however, are entirely dry during the dry season. The soil of these prairies varies. Those prairies which become entirely dry during the dry season have as a rule a top soil consisting of sand, the organic matter having been largely bleached out by the sun during the dry season. Those prairies which only occasionally become dry, or are dry ordinarily only a brief season, have more or less organic matter lying upon or mixed with the sand. As a rule the prairies occupy a basin depressed below the level of the surrounding country. Some of the prairies, especially those having a muck top soil, if successfully drained would probably furnish desirable farming lands. Other prairies have merely sand lying upon "Hardpan" and are of little or no value for farming purposes. (Pl. 13, Fig. 2).

Muck lands: The term "muck soils" is applied in ordinary usage to lands on which organic matter from decay of vegetation
bas 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. (Pl. 13, Fig. 1).

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. The accompanying illustration (Pl. 14, Fig. 3), shows clay soils formed from the decay of impure limestones. The residual material here consists of a sticky clay relatively impervious to water and lacking in organic matter.

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. (Pl. 13, Fig. 3).

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 hard wood 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. (Pl. 12, Fig. 1).

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. (Pl. 14, Figs. 1-2)

River swamp: The river swamp lands support a dense growth of hard wood 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. To clear such
lands, however, is very expensive and there is at present practically no demand for them.

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 average rainfall at Jacksonville for the 33 years ending with 1904, was 53.21 inches, annually; at Jupiter it was for the 17 years ending with 1904, 59.19 inches annually. The area covered by this report lies in that part of the State supplied with

*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.
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 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 eastern 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. A mantle of sand, forming the surface

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*Deduced from the U. S. Weather Reports. Precipitation: Average, Greatest and Least Monthly Amounts, from the Establishment of Stations to the End of 1904. Wm. B. Stockman.
deposit, is almost universally present. This sand receives and stores 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

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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.
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.

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:*

(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 1150 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.*

DEPTIl 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 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 (H₂S) 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 following paper on peat deposits in this volume. The amount of sulphur in the Florida peat in the dried samples varies from less than 1% to over 4%.

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.† H₂S is also found escaping from sewer drains and cesspools, and is formed during the decomposition both of animal and vegetable substances. The H₂S 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 H₂S.‡ The reaction in this

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*Bulletin 43, Florida State Experiment Station, pp. 653, 657, 659, 1897.
†Ostwald, Principles of Inorganic Chemistry, page 274, 1904.
case probably results from reducing properties of decaying organic matter, the sulphates being first reduced to sulphides according to the following reaction: \( \text{Na}_2\text{S}_4\text{O}_4 + \text{C}_2 \rightarrow 2\text{CO}_2 + \text{Na}_2\text{S} \). The sulphide is then acted upon by the carbonic acid to form \( \text{H}_2\text{S} \) as follows: \( \text{Na}_2\text{S} + \text{H}_2\text{CO}_3 \rightarrow \text{H}_2\text{S} + \text{Na}_2\text{CO}_3 \). The reaction of organic matter upon the sulphides is regarded by Van Hise as another important source of \( \text{H}_2\text{S} \) 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 \( \text{H}_2\text{S} \) 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 \( \text{H}_2\text{S} \). 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 earth upon pyrite or marcasite produces sodium sulphide. The reaction given by him is as follows: (l. c. page 1107).

\[
8\text{FeS}_2 + 15\text{Na}_2\text{CO}_3 = 4\text{Fe}_2\text{O}_3 + 14\text{Na}_2\text{S} + \text{Na}_2\text{S}_2\text{O}_3 + 15\text{CO}_2.
\]

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).

\[
3\text{FeS}_2 + 4\text{H}_2\text{O} + 4\text{O} = \text{Fe}_3\text{O}_4 + 4\text{H}_2\text{S} + 2\text{SO}_2.
\]

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

†Inorganic Chemistry. International Library of Technology. Sec. 12, p. 11.
The oxidizing processes are the most rapid near the surface, especially above the underground water level, and H$_2$S derived from this source probably supplies relatively shallow, rather than deep waters.

The formation of H$_2$S 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.

**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$_2$S + O = H$_2$O + S. It is thus possible that H$_2$S 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$_2$S 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.

**AMOUNT OF HYDROGEN SULPHIDE INFLUENCED BY PRESSURE.**

The quantity of H$_2$S 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$_2$S 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 their water "artesian water." The first meaning of "artesian well" was

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*L. c., page 70.*
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 near by. 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.

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-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 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 sort-
ing 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 sandgrains, 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 illustrated by the following sketch taken from the report of M. L.

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![Diagram](image-url)
Fuller.* It is possible that some of the small local flows obtained in the lake region of interior Florida are due to similar conditions.

Fig. 8.—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.

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. 9.—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 recog-

nized 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 FLORIDA.

As explained in the chapter on geology the principal artesian reservoir of the eastern part of Florida is the Vicksburg 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 Messers McGuire and MacDonald, 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 2083 gallons. At 520 feet the flow had increased to 4860 gallons. At 1110 feet the flow was 6075 gallons. The well was continued to a total depth of 1440 feet. The record of the well however, contains no mention of increased flow below 1110 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 like-
wise 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 1440 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.

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 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

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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 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
### TABLE SHOWING PROGRESSIVE LOSS OF FLOW OF ARTESIAN WELLS
#### RECORD OF JACKSONVILLE CITY WELLS, 1885-1904

<table>
<thead>
<tr>
<th>Number of Well</th>
<th>Size of Well in inches</th>
<th>Date When Completed</th>
<th>Flow of Well When Completed. Gallons in 24 hours</th>
<th>1886</th>
<th>1888</th>
<th>1889</th>
<th>1891 May 30</th>
<th>1892 Nov. 1st</th>
<th>1893 Jan. 1st</th>
<th>1894 Jan. 1st</th>
<th>1895</th>
<th>1896</th>
<th>1897</th>
<th>1898</th>
<th>1899 April</th>
<th>1900</th>
<th>1901</th>
<th>1902 Jan.</th>
<th>1902 Nov. 29</th>
<th>1903</th>
<th>1904 Apr. 1</th>
<th>1904 Oct. 26</th>
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<tr>
<td>1</td>
<td>6</td>
<td>Nov. 1885, Dec. 1885</td>
<td>864,000</td>
<td>864,000</td>
<td>790,800</td>
<td>568,073</td>
<td>309,096</td>
<td>254,384</td>
<td>243,000</td>
<td>221,016</td>
<td>200,232</td>
<td>188,568</td>
<td>1108,080</td>
<td>881,280</td>
<td>602,014</td>
<td>419,980</td>
<td>2287,164</td>
<td>1710,720</td>
<td>1710,720</td>
<td>1031,800</td>
<td>1181,800</td>
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<td>2</td>
<td>6</td>
<td>Dec. 1886, Feb. 1887</td>
<td>1,354,320</td>
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<td>3</td>
<td>10</td>
<td>1889, Aug. 1889</td>
<td>2,795,639</td>
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<td>4</td>
<td>10</td>
<td>1889, Aug. 1889</td>
<td>651,500</td>
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<td>5</td>
<td>8</td>
<td>Apr. 1899</td>
<td>651,500</td>
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</table>

**Total Flow:**
2,160,000, 1,967,010, 4,737,210, 17,602,360, 2,066,964, 1,276,231, 1,891,192, 2,857,108, 2,922,037, 2,476,056, 2,449,8, 2,784,176, 2,639,917, 3,933,917, 3,706,347, 3,079,290, 3,179,296, 4,012,340, 3,385,369

**Loss in Flow:**
192,960, 193,482, 1,373,490, 257,250, 130,248, 382,024, 137,024, 299,4, 1 446,383, 226,810, 50,356, 144,520, 587,093, 229,660, 627,057, 0, 46,050, 352,740

**Gain by New Well:**
2,770,170, 1,064,969, 531,320, 1,290,000, 248,760
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 uninterrupted 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 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 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 b, then from this point strictly horizontally to the center of the stream—b to c. 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 centre 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 ⅜ 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.

"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
FLORIDA STATE GEOLOGICAL SURVEY
E. H. SELLARDS, State Geologist.

MAP OF
FLORIDA

SHOWING APPROXIMATELY THE AREAS IN WHICH FLOWING ARTESIAN WELLS CAN BE OBTAINED.

By
E. H. SELLARDS and H. GUNTER
1910

THE AREAS OF ARTESIAN FLOW ARE INDICATED BY SHADING.
THREE PRINCIPAL AREAS OCCUR AS FOLLOWS:
THE ATLANTIC COAST AREA.
THE SOUTHERN GULF COAST AREA.
THE WESTERN GULF COAST AREA.
A FEW ISOLATED FLOWING WELLS IN OTHER PARTS OF THE STATE ARE INDICATED BY CIRCLES.
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 differences 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.

“\(\text{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}

<table>
<thead>
<tr>
<th>I. Flow from Vertical Pipes</th>
<th>II. Flow from Horizontal Pipes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Discharge in Gallons per Minute by Respective Pipes of Diameter given in Inches.</td>
<td>Flow in Gallons per Minute for Pipes—</td>
</tr>
<tr>
<td>Height of Jet</td>
<td>Through 1 inch in Diam.</td>
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<td>Height of Jet</td>
<td>6 in. level.</td>
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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, revised from a similar map published in Bulletin No. 1, 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 a map on a small scale can not indicate local elevations which affect flow. 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. 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 is described in detail in the subsequent pages of this report. This flowing 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 1000 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 reached a depth of 2000 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 2340 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 investigations of the flowing area of the Southern Gulf Coast have not been completed, and it is possible to indicate only approximately the limits of this area. Flowing wells have been obtained in areas of low elevation at Tampa, St. Petersburg and elsewhere along the 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 De Soto 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. 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. In both of these wells the water reached at a great depth is found to be too salty for use.

The Western Gulf Coast area begins at Carrabelle in Franklin County and probably extends without interruption to the western line of the State. This area, however, is very imperfectly known. 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, 1030 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 1000 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 minute. 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.

At Perry in Taylor County flowing water has been obtained recently at a depth of 1199 feet. The water from this well, however, is too salty for use. The total dissolved solids in this water as shown by analysis made by the State Chemist is 5650 parts per million parts water. The chlorine alone amounts to 590 parts per million parts water. A similar deep well near Crystal River in Citrus County was reported with an analysis of the water in the bulletin on the water supply of central Florida published in 1908.

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 1250 feet.
DISCUSSION BY COUNTIES

NASSAU COUNTY.

LOCATION AND SURFACE FEATURES.

Nassau County lies bordering the Atlantic Ocean in extreme northeastern Florida. The St. Marys River, taking its source in Okefinokee 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 is 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 (Pl. 14, Fig. 3), is as follows:

- Sticky blue clay with some soil ......................... 5 feet
- Impure limestone ........................................... 5 feet

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

- Sticky blue clay with some soil at top .................... 2 feet
- Calcareous clay resembling fullers earth .................... 2 feet
- White chalky material ....................................... 1 foot
- Clay resembling fullers earth ............................... 2 feet

Going down the river from King's Ferry no rock or shell exposures are seen until Reed's Bluff near Crandall is reached. This bluff, which lies on the Florida side of the St. Marys 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:

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

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.

Rose’s 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:

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

AREA OF ARTESIAN FLOW IN NASSAU COUNTY.

The 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, (p. 135) 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 410 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. P. Wells and 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 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:

<table>
<thead>
<tr>
<th>Layer</th>
<th>Feet</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sand</td>
<td>0-2</td>
</tr>
<tr>
<td>Red clay</td>
<td>2-10</td>
</tr>
<tr>
<td>Blue clay and sand</td>
<td>10-45</td>
</tr>
</tbody>
</table>
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 and 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 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 the well subsequently became filled with sand and 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 Water works.

<table>
<thead>
<tr>
<th>Date</th>
<th>Flow of well</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Gallons per day</td>
</tr>
<tr>
<td>1890</td>
<td>1,152,000</td>
</tr>
<tr>
<td>1902</td>
<td>641,832</td>
</tr>
<tr>
<td>1904</td>
<td>495,408</td>
</tr>
<tr>
<td>1905</td>
<td>449,564</td>
</tr>
<tr>
<td>1907</td>
<td>425,952</td>
</tr>
<tr>
<td>1909</td>
<td>408,000</td>
</tr>
</tbody>
</table>

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:

<table>
<thead>
<tr>
<th>Feet.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sand</td>
</tr>
<tr>
<td>Medium hard rock</td>
</tr>
<tr>
<td>Sand and clay</td>
</tr>
<tr>
<td>Clay</td>
</tr>
<tr>
<td>Sand</td>
</tr>
<tr>
<td>Green clay</td>
</tr>
<tr>
<td>Rock</td>
</tr>
<tr>
<td>Blue clay</td>
</tr>
<tr>
<td>Limestone termed “bed rock” with alternating hard and soft strata</td>
</tr>
</tbody>
</table>

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 20 1/2 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.

<table>
<thead>
<tr>
<th>Feet.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Muck</td>
</tr>
<tr>
<td>Hardpan. A small flow just below this</td>
</tr>
<tr>
<td>Sand</td>
</tr>
<tr>
<td>Blue clay. A good flow of water reported</td>
</tr>
<tr>
<td>Sand</td>
</tr>
<tr>
<td>Coarse sand and black pebbles</td>
</tr>
<tr>
<td>Hard rock</td>
</tr>
<tr>
<td>Limestone hard and soft strata. Increase of flow upon breaking through each hard stratum</td>
</tr>
</tbody>
</table>

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.
THE ARTESIAN WATER SUPPLY OF EASTERN FLORIDA.

Constituents. Parts per million.
Silica, (SiO₂) ........................................ 24.0
Chlorine, (Cl) ........................................ 30.0
Sulphates, (SO₄) .................................... 133.0
Phosphates, (PO₄) .................................... 0.0
Carbonates, (CO₃) .................................... 0.0
Bicarbonates, (HCO₃) ................................ 195.0
Sodium and Potassium (Na & K) ....................... 30.0
Magnesium (Mg) ...................................... 13.0
Calcium (Ca) .......................................... 55.9
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 Mil.
Free Ammonia ........................................ None
Albuminoid Ammonia ................................. Slight Trace
Nitrites ............................................... None
Nitrites ............................................... Slight Trace
Chlorine ........................................... 20.40
Total Solids ....................................... 192.01
Organic and Volatile Solids ......................... 30.00
Hardness (CaCO₃) ................................... 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. Griffling 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.

<table>
<thead>
<tr>
<th>Constituent</th>
<th>Parts per million</th>
</tr>
</thead>
<tbody>
<tr>
<td>Organic Matter</td>
<td>37.0</td>
</tr>
<tr>
<td>Silica</td>
<td>36.0</td>
</tr>
<tr>
<td>Calcium Carbonate (Lime 91. parts per mil.)</td>
<td>151.0</td>
</tr>
<tr>
<td>Calcium Sulphate</td>
<td>16.0</td>
</tr>
<tr>
<td>Magnesium Sulphate</td>
<td>105.0</td>
</tr>
<tr>
<td>Magnesium Chloride</td>
<td>40.8</td>
</tr>
<tr>
<td>Sodium Chloride (common salt)</td>
<td>20.3</td>
</tr>
</tbody>
</table>

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.

KINGS FERRY.

King's 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 King's 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 and 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 Engineers at Jacksonville. Similar surveys made by the same office in 1879 supplied elevations from Fernandina to Maxville and at various points along the St. Marys River. In addition much information as to elevations has been obtained 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 Jackson-
ville, 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 recorded 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 Cotter-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 the 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 on page 117. 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. Samples 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.

<table>
<thead>
<tr>
<th>Material Description</th>
<th>Feet</th>
</tr>
</thead>
<tbody>
<tr>
<td>Filled ground and sand</td>
<td>0 - 15</td>
</tr>
<tr>
<td>Sand with some clay</td>
<td>15 - 33</td>
</tr>
<tr>
<td>Sandy limestone, yellowish or light buff in color</td>
<td>33 - 37</td>
</tr>
<tr>
<td>Light colored clayey marl</td>
<td>37 - 70</td>
</tr>
<tr>
<td>Blue sticky clay with black phosphatic pebbles</td>
<td>70 - 100</td>
</tr>
<tr>
<td>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 ft. 5 gallons per minute</td>
<td>100 - 320</td>
</tr>
<tr>
<td>Buff clay resembling fullers earth mixed as seen in the sample with green sandy marl</td>
<td>320 - 340</td>
</tr>
<tr>
<td>Greenish and sandy clayey marl</td>
<td>340 - 390</td>
</tr>
<tr>
<td>Indurated sands or sandstones</td>
<td>390 - 396</td>
</tr>
<tr>
<td>Greenish sandy marls</td>
<td>396 - 415</td>
</tr>
<tr>
<td>Light colored limestone</td>
<td>415 - 420</td>
</tr>
<tr>
<td>Greenish calcareous sandy clay</td>
<td>420 - 434</td>
</tr>
<tr>
<td>Dark colored hard sand rock</td>
<td>434 - 435</td>
</tr>
<tr>
<td>Olive green calcareous sandy clay</td>
<td>435 - 435</td>
</tr>
<tr>
<td>Light sandy marl</td>
<td>455 - 455½</td>
</tr>
<tr>
<td>Green sandy marl</td>
<td>455½ - 462</td>
</tr>
<tr>
<td>Dark sandy clay</td>
<td>462 - 490</td>
</tr>
<tr>
<td>Very hard dark or gray sand rock</td>
<td>490 - 493</td>
</tr>
<tr>
<td>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.</td>
<td>493 - 498</td>
</tr>
<tr>
<td>Light colored marl</td>
<td>498 - 500</td>
</tr>
<tr>
<td>Hard rock</td>
<td>500 - 506</td>
</tr>
<tr>
<td>Light gray sandy calcareous rock with black phosphatic pebbles</td>
<td>506 - 510</td>
</tr>
</tbody>
</table>
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 .

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.

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.

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 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:

<table>
<thead>
<tr>
<th>Constituents</th>
<th>Grains per U. S. Gallon</th>
<th>Parts per million</th>
</tr>
</thead>
<tbody>
<tr>
<td>Silica and insoluble matter</td>
<td>0.729</td>
<td>12.497</td>
</tr>
<tr>
<td>Alumina</td>
<td>0.047</td>
<td>8.057</td>
</tr>
<tr>
<td>Carbonate of lime</td>
<td>3.866</td>
<td>66.274</td>
</tr>
<tr>
<td>Sulphate of lime</td>
<td>4.053</td>
<td>69.480</td>
</tr>
<tr>
<td>Sulphate of magnesia</td>
<td>2.927</td>
<td>50.177</td>
</tr>
<tr>
<td>Sulphate of soda</td>
<td>5.843</td>
<td>100.166</td>
</tr>
<tr>
<td>Chlorides of soda</td>
<td>4.811</td>
<td>82.474</td>
</tr>
<tr>
<td>Free ammonia</td>
<td>0.143</td>
<td>0.0044</td>
</tr>
<tr>
<td>Albuminoid ammonia</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
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.

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.

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 1000 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 east 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, 4 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 given elsewhere (pp. 91-93).

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.

Fig. 12.—Map showing the area of artesian flow in St. Johns County. The area in which flowing wells can be obtained is indicated by shading.
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 Anastasia Island reached a total depth of 260 feet. A strong flow of sulphur water was obtained from this well.

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 and 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 and Moody, drilled by Bellough and Melton in 1910 is 128 feet deep. The following log of this well was supplied by the drillers.
THE ARTESIAN WATER SUPPLY OF EASTERN FLORIDA.

145 Feet.

Surface material 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 and 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.

ESPAROLA.

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.

Record incomplete, said to consist largely of clays, bluish in color except where oxidized yellow at the 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 to 130
Yellowish sandy clays ........................................130 to 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 to 160
A mixed sample contained material similar to above with addition of gray sandy clay ........................................160 to 168
Buff colored sandy clay ......................................168 to 180
White granular fossiliferous limestone ......................180 to 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 at about 200 feet or to a total depth of 365 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 3 miles southeast of town. It was drilled in May, 1908 and is used for irrigating purposes.

<table>
<thead>
<tr>
<th>Feet</th>
<th>Yellow clay</th>
<th>Blue clay</th>
<th>Shell stratum</th>
<th>Clay</th>
<th>Soft rock</th>
<th>Clay</th>
<th>Rock supplying small flow</th>
<th>Limestone</th>
<th>Shell and limestone</th>
<th>Material not reported</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0 - 6</td>
<td>6 - 60</td>
<td>60 - 64</td>
<td>64</td>
<td>160 - 165</td>
<td>165</td>
<td>171 - 171 1/2</td>
<td>171 1/2 - 183</td>
<td>183 - 245</td>
<td>245 - 300</td>
</tr>
</tbody>
</table>

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.

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

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.

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

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 5 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 33 1/2 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 41 1/2 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.

<table>
<thead>
<tr>
<th>Feet</th>
<th>Surface sand, yellow in color. Soft water</th>
<th>Light gray sands</th>
<th>Dark gray sands, partly indurated; some clay</th>
<th>Shell, sand and gravel</th>
<th>Very dark (almost black), marl, similar in appearance to Miocene marls, including shell fragments</th>
<th>Light greenish sandy marl</th>
<th>Dark green marl, small shark's tooth observed</th>
<th>Gray sand and shell fragments; water</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-18</td>
<td>........................................</td>
<td>18-30</td>
<td>30-44</td>
<td>44-55</td>
<td>55-63</td>
<td>63-80</td>
<td>80-100</td>
<td>100-112</td>
</tr>
</tbody>
</table>
Gray sand and shell, water, shark's tooth, also minute black phosphatic pebbles .......................................112-133
Blue clayey marl ..................................................133-135
No sample ................................................................135-135
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 Num-mulites ............................................................219-318

ROY.

Roy is located on the Florida East Coast Railway about 6 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 208 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 to 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 to-
THE ARTESIAN WATER SUPPLY OF EASTERN FLORIDA.

The 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, (1664 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 1440 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. MacGuire and 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 3000 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 1440 feet.

<table>
<thead>
<tr>
<th>Sand. Temperature of the water at 35 feet, 62° F.</th>
<th>Feet.</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-35</td>
<td></td>
</tr>
<tr>
<td>Sand, with some shell</td>
<td>35-50</td>
</tr>
<tr>
<td>Blue clay</td>
<td>50-57</td>
</tr>
<tr>
<td>Shell</td>
<td>57-65</td>
</tr>
<tr>
<td>Sand</td>
<td>65-76</td>
</tr>
<tr>
<td>Indurated clay and sand</td>
<td>76-95</td>
</tr>
<tr>
<td>Blue clay and black sand, pieces of hard stone</td>
<td></td>
</tr>
<tr>
<td>Temperature of water 72° at 110 feet, 74° at 170 feet. Head 32 feet above sea. Sulphur water, 50 gallons per minute at 170 feet.</td>
<td>95-170</td>
</tr>
<tr>
<td>Hard rock. Temperature of water 76° at 177 feet. Flow 350 gallons per minute at 177 feet</td>
<td>170-177</td>
</tr>
<tr>
<td>Limestone. Flow 1800 gallons per minute at 350 feet</td>
<td>177-350</td>
</tr>
<tr>
<td>Limestone. Temperature of water 76° at 410 feet. Flow of 2025 gallons per minute at 410 feet</td>
<td>350-410</td>
</tr>
</tbody>
</table>
Limestone ................................................................. 410-490
Dense light brown limestone. Temperature of water 79° 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° at 1,110 feet. Flow
of 6,075 gallons per minute at 1,110 feet ....................... 960-1,110
Hard rock, said to be sandstone, with some flint............ 1,110-1,140
Material not recorded ............................................. 1,140-1,170
"Sandstone," followed by limestone. Temperature of water 85°
at 1,225 feet .......................................................... 1,170-1,225
Limestone as above ................................................... 1,225-1,278
"Sandstone." Sample not seen ................................... 1,278-1,293
Fossiliferous limestone ............................................. 1,293-1,340
Fossiliferous limestone, easily penetrated. Temperature of
water 86° at 1,340 feet ................................................. 1,340-1,390
Denser limestone ....................................................... 1,390-1,440

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.

<table>
<thead>
<tr>
<th>Feet.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sand</td>
</tr>
<tr>
<td>Clay</td>
</tr>
<tr>
<td>White quicksand</td>
</tr>
<tr>
<td>Clay</td>
</tr>
<tr>
<td>Coarse pebbles and some shells</td>
</tr>
<tr>
<td>Coarse gray to greenish sands, water-bearing; slight flow</td>
</tr>
<tr>
<td>White plastic clay and fine sand</td>
</tr>
<tr>
<td>Greenish clay, very compact</td>
</tr>
<tr>
<td>Hard rock</td>
</tr>
<tr>
<td>Greenish clay with a mixture of black sand</td>
</tr>
<tr>
<td>Hard rock; water rises 32 to 37 feet above sea</td>
</tr>
<tr>
<td>White chalk rock (probably Vicksburg)</td>
</tr>
</tbody>
</table>

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.
THE ARTESSIAN WATER SUPPLY OF EASTERN FLORIDA.

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 and 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:

<table>
<thead>
<tr>
<th>Layer Description</th>
<th>Feet</th>
</tr>
</thead>
<tbody>
<tr>
<td>Loose sand and soil</td>
<td>1</td>
</tr>
<tr>
<td>Sandy clays oxidized red</td>
<td>7</td>
</tr>
<tr>
<td>Blue sticky clay, comparatively free from sand</td>
<td>10</td>
</tr>
<tr>
<td>Light-colored sands</td>
<td>3</td>
</tr>
</tbody>
</table>

The clay exposed in this pit is probably the same as the clays in the clay pit near Jacksonville (p. 90). 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 of the north fork 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.

Fig. 13.—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.
LOCAL DETAILS

DOCTORS INLET.

A well owned by D. D. Denham and drilled in 1908 by D. C. Stafford is located near Doctor's 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 Doctor's 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 44 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:

<table>
<thead>
<tr>
<th>Constituents</th>
<th>Parts per Million</th>
</tr>
</thead>
<tbody>
<tr>
<td>Silica (SiO2)</td>
<td>7.</td>
</tr>
<tr>
<td>Chlorine (Cl)</td>
<td>9.</td>
</tr>
<tr>
<td>Sulphates (SO4)</td>
<td>7.</td>
</tr>
<tr>
<td>Phosphates (PO4)</td>
<td>0.</td>
</tr>
<tr>
<td>Carbonates (CO3)</td>
<td>0.</td>
</tr>
<tr>
<td>Bicarbonates (HCO3)</td>
<td>107.</td>
</tr>
<tr>
<td>Sodium and Potassium (Na &amp; K)</td>
<td>14.</td>
</tr>
<tr>
<td>Magnesium (Mg)</td>
<td>4.</td>
</tr>
<tr>
<td>Calcium (Ca)</td>
<td>16.</td>
</tr>
<tr>
<td>Iron and Alumina (Fe &amp; Al)</td>
<td>Trace.</td>
</tr>
<tr>
<td>Loss on Ignition</td>
<td>67.</td>
</tr>
<tr>
<td>Total dissolved Solids</td>
<td>155.</td>
</tr>
</tbody>
</table>

Aside from the above well, the following two records of wells have been obtained: A well on the property of Mrs. George Hal-
HOLIDAY (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 43.1 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:

<table>
<thead>
<tr>
<th>Constituents</th>
<th>Parts per Million</th>
</tr>
</thead>
<tbody>
<tr>
<td>Silica (SiO₂)</td>
<td>9.</td>
</tr>
<tr>
<td>Chlorine (Cl)</td>
<td>7.</td>
</tr>
<tr>
<td>Sulphates (SO₄)</td>
<td>5.</td>
</tr>
<tr>
<td>Phosphates (PO₄)</td>
<td>6.</td>
</tr>
</tbody>
</table>
Constituents.  Parts per Million.
Carb-nates (CO₃) ........................................ 0.
Bicarbonates (HCO₃) .................................... 98.
Sodium and Potassium (Na & K) ......................... 23.
Magnesium (Mg) ........................................ 5.
Calcium (Ca) ........................................... 14.
Iron and Alumina (Fe & Al) ............................. Trace.
Loss on 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 ..................................... 49.4
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 and 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 and 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
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 & 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. (Fig. 13, p. 155).

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 or 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 pressures. 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 57/4 pounds. Well No. 2 is 160 feet deep and is cased 74 feet. The pressure December 4, 1909, was 51/2 pounds. Well No. 3 is 219 feet deep and is cased 54 feet. The pressure of this well on the same day was five and one-quarter 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.

<table>
<thead>
<tr>
<th>Feet.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sand .................................................................</td>
</tr>
<tr>
<td>Olive green calcareous clay with black phosphatic pebbles and fragments of shell and flattened water-worn gravels</td>
</tr>
<tr>
<td>No sample .........................................................</td>
</tr>
<tr>
<td>Similar or somewhat more calcareous green clay or clayey marl. This sample contains occasional fragments of chert</td>
</tr>
<tr>
<td>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 1 x 1/2 inches occur</td>
</tr>
<tr>
<td>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</td>
</tr>
<tr>
<td>No sample .........................................................</td>
</tr>
<tr>
<td>Loose clear-grained sand in mass appearing light gray and contains a small amount of calcareous matter in the form of fragments of shell</td>
</tr>
</tbody>
</table>

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 Geo-
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 State Chemist, B. H. Bridges, analyst.
Constituents. 

<table>
<thead>
<tr>
<th>Constituent</th>
<th>Parts per Million</th>
</tr>
</thead>
<tbody>
<tr>
<td>Silica (SiO₂)</td>
<td>18.0</td>
</tr>
<tr>
<td>Chlorine (Cl)</td>
<td>156.0</td>
</tr>
<tr>
<td>Sulphates (SO₄)</td>
<td>76.9</td>
</tr>
<tr>
<td>Carbonates (CO₃)</td>
<td>7.3</td>
</tr>
<tr>
<td>Bicarbonates (HCO₃)</td>
<td>156.1</td>
</tr>
<tr>
<td>Magnesium Oxide (MgO)</td>
<td>43.3</td>
</tr>
<tr>
<td>Calcium Oxide (CaO)</td>
<td>97.1</td>
</tr>
<tr>
<td>Total Solids</td>
<td>531.0</td>
</tr>
</tbody>
</table>

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. Butie 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 barometric readings being ap-
proximately sixty feet above the St. Johns River. A four-inch well drilled for B. F. Dotney, in 1909 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 north 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.

<table>
<thead>
<tr>
<th>Constituents</th>
<th>Parts per Million</th>
</tr>
</thead>
<tbody>
<tr>
<td>Silica</td>
<td>12.00</td>
</tr>
<tr>
<td>Alumina</td>
<td>8.57</td>
</tr>
<tr>
<td>Iron carbonate</td>
<td>12.00</td>
</tr>
<tr>
<td>Calcium chloride</td>
<td>586.32</td>
</tr>
<tr>
<td>Calcium sulphate</td>
<td>607.75</td>
</tr>
<tr>
<td>Calcium nitrate</td>
<td>Trace</td>
</tr>
<tr>
<td>Magnesium bromide</td>
<td>5.14</td>
</tr>
<tr>
<td>Magnesium chloride</td>
<td>507.45</td>
</tr>
<tr>
<td>Magnesium carbonate</td>
<td>241.72</td>
</tr>
<tr>
<td>Sodium chloride</td>
<td>8868.52</td>
</tr>
<tr>
<td>Potassium chloride</td>
<td>13.70</td>
</tr>
</tbody>
</table>

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 1250 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 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 (p. 167).

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, 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. Pattshall 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 to 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 seventy-two and one-half 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 and for the disposal of sewage, 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. Letter, 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 bored wells for the disposal of sewage has been discussed in the preceding paper on water supply. The practice is regarded as unsanitary.
unhealthful, and as a source of danger to the city and surrounding communities.

The use of wells to carry off surface waters at this locality has been described in the preceding paper of this report (pp. 72-75).

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 flat-woods 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:

<table>
<thead>
<tr>
<th>Feet</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Surface soil</td>
<td>0-5</td>
</tr>
<tr>
<td>Yellow sand</td>
<td>5-40</td>
</tr>
<tr>
<td>Shell and sand, water, no flow</td>
<td>40-60</td>
</tr>
<tr>
<td>Sand</td>
<td>60-91</td>
</tr>
<tr>
<td>Shell and sand with sharks' teeth</td>
<td>91-95</td>
</tr>
<tr>
<td>Dark blue rock with black phosphatic pebbles</td>
<td>95-100</td>
</tr>
<tr>
<td>Very hard rock</td>
<td>100-101</td>
</tr>
<tr>
<td>Light yellow sand</td>
<td>101-113</td>
</tr>
<tr>
<td>Vicksburg Limestone</td>
<td>113-</td>
</tr>
</tbody>
</table>

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 of 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 and 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 a pressure of

Fig. 15.—Artesian well of E. Hy. Palmer on the west side of Lake Jessup.

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. Weedon, 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. H. 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 1281 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 under-
lying 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.

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. Van-Dorn 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 follow-
ing is a log of this well as given by Mr. Melton:

<table>
<thead>
<tr>
<th>Material</th>
<th>Depth Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dark sandy soil</td>
<td>0-6</td>
</tr>
<tr>
<td>White marl</td>
<td>6-15</td>
</tr>
<tr>
<td>Sand and shell</td>
<td>15-30</td>
</tr>
<tr>
<td>Blue clay</td>
<td>30-65</td>
</tr>
<tr>
<td>Sand and shell</td>
<td>65-87</td>
</tr>
<tr>
<td>Limestone, medium hard</td>
<td>87-139</td>
</tr>
</tbody>
</table>

Limestone, medium hard. First flow at 88 feet, increase of water with depth.

Fig. 16.—Map showing the areas of artesian flow in Volusia County. The areas in which flowing wells can be obtained are indicated by shading.
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.

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

**Constituents.**

<table>
<thead>
<tr>
<th>Constituent</th>
<th>Parts per Million.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total solids</td>
<td>136.29</td>
</tr>
<tr>
<td>Residue after ignition (mineral matter)</td>
<td>76.11</td>
</tr>
<tr>
<td>Gas and ignition (organic matter)</td>
<td>60.17</td>
</tr>
<tr>
<td>Sodium chloride</td>
<td>11.31</td>
</tr>
<tr>
<td>Free ammonia</td>
<td>6.8</td>
</tr>
<tr>
<td>Albuminoid ammonia</td>
<td>1.7</td>
</tr>
<tr>
<td>Oxygen (consuming power)</td>
<td>1.54</td>
</tr>
<tr>
<td>Nitrates</td>
<td>0.34</td>
</tr>
<tr>
<td>Nitrites</td>
<td>None</td>
</tr>
<tr>
<td>Sulphates</td>
<td>2.05</td>
</tr>
<tr>
<td>Phosphates</td>
<td>Trace</td>
</tr>
</tbody>
</table>

**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, Tennessee, by W. H. Hollenshead.

<table>
<thead>
<tr>
<th>Constituents</th>
<th>Parts per million</th>
</tr>
</thead>
<tbody>
<tr>
<td>Potassium</td>
<td>27.104</td>
</tr>
<tr>
<td>Sodium</td>
<td>1805.046</td>
</tr>
<tr>
<td>Magnesium</td>
<td>213.047</td>
</tr>
<tr>
<td>Calcium</td>
<td>321.619</td>
</tr>
<tr>
<td>Iron</td>
<td>7.02</td>
</tr>
<tr>
<td>Chlorine</td>
<td>3389.640</td>
</tr>
<tr>
<td>Bromine</td>
<td>103.206</td>
</tr>
<tr>
<td>Carbon dioxide</td>
<td>559.234</td>
</tr>
<tr>
<td>Sulphuric acid (radical)</td>
<td>541.132</td>
</tr>
<tr>
<td>Silica</td>
<td>16.989</td>
</tr>
<tr>
<td>Phosphoric acid (radical)</td>
<td>7.02</td>
</tr>
<tr>
<td>Boric acid</td>
<td>Heavy Trace</td>
</tr>
<tr>
<td>Organic matter</td>
<td>Small Amount</td>
</tr>
<tr>
<td>Hydrogen sulphide</td>
<td>Slight Trace</td>
</tr>
</tbody>
</table>

The above are probably combined in the water as follows:

<table>
<thead>
<tr>
<th>Constituents</th>
<th>Parts per million</th>
</tr>
</thead>
<tbody>
<tr>
<td>Potassium sulphate</td>
<td>60.346</td>
</tr>
<tr>
<td>Calcium sulphate</td>
<td>720.043</td>
</tr>
<tr>
<td>Sodium bromide</td>
<td>133.722</td>
</tr>
<tr>
<td>Magnesium chloride</td>
<td>819.787</td>
</tr>
<tr>
<td>Sodium phosphate</td>
<td>994</td>
</tr>
<tr>
<td>Iron chloride</td>
<td>1.594</td>
</tr>
<tr>
<td>Sodium chloride</td>
<td>4504.371</td>
</tr>
<tr>
<td>Calcium chloride</td>
<td>76.701</td>
</tr>
<tr>
<td>Calcium bicarbonate</td>
<td>330.928</td>
</tr>
<tr>
<td>Silica</td>
<td>16.989</td>
</tr>
<tr>
<td>Carbonic acid</td>
<td>379.634</td>
</tr>
<tr>
<td>Sodium biborate</td>
<td>Heavy Trace</td>
</tr>
<tr>
<td>Hydrogen sulphide</td>
<td>Slight Trace</td>
</tr>
<tr>
<td>Organic matter</td>
<td>Small Amount</td>
</tr>
</tbody>
</table>

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
THE ARTESIAN WATER SUPPLY OF EASTERN FLORIDA.

179

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.

<table>
<thead>
<tr>
<th>Constituents</th>
<th>Parts per Million</th>
</tr>
</thead>
<tbody>
<tr>
<td>Silica (SiO2)</td>
<td>27.0</td>
</tr>
<tr>
<td>Chlorine (Cl)</td>
<td>836.6</td>
</tr>
<tr>
<td>Sulphates (SO4)</td>
<td>7.8</td>
</tr>
<tr>
<td>Carbonates (CO3)</td>
<td>12.0</td>
</tr>
<tr>
<td>Bicarbonates (HCO3)</td>
<td>299.8</td>
</tr>
<tr>
<td>Magnesium Oxide (MgO)</td>
<td>108.6</td>
</tr>
<tr>
<td>Calcium Oxide (CaO)</td>
<td>197.7</td>
</tr>
<tr>
<td>Total Solids</td>
<td>1980.0</td>
</tr>
</tbody>
</table>

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.

<table>
<thead>
<tr>
<th>Constituents</th>
<th>Parts per Million</th>
</tr>
</thead>
<tbody>
<tr>
<td>Free ammonia</td>
<td>0.00</td>
</tr>
<tr>
<td>Albuminoid ammonia</td>
<td>0.05</td>
</tr>
<tr>
<td>Oxygen consumed</td>
<td>1.05</td>
</tr>
<tr>
<td>Nitrites</td>
<td>0.00</td>
</tr>
<tr>
<td>Nitrates</td>
<td>1.00</td>
</tr>
</tbody>
</table>

ORMOND.

Several deep wells have been sunk at Ormond. These deep wells all furnish a salt water which can not be used except in some in-

---

stances 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 reaches 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.

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. 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 mostly between the St. Johns River and the Atlantic Ocean. It has a total length of 66 miles and including Merritt’s 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.

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

<table>
<thead>
<tr>
<th>Constituents</th>
<th>Parts per Million</th>
</tr>
</thead>
<tbody>
<tr>
<td>Silica (SiO2)</td>
<td>17.00</td>
</tr>
<tr>
<td>Chlorine (Cl)</td>
<td>2248.00</td>
</tr>
<tr>
<td>Sulphates (SO4)</td>
<td>207.00</td>
</tr>
<tr>
<td>Phosphates (PO4)</td>
<td>8.00</td>
</tr>
<tr>
<td>Carbonates (CO3)</td>
<td>0.00</td>
</tr>
<tr>
<td>Bicarbonates (HCO3)</td>
<td>168.00</td>
</tr>
<tr>
<td>Sodium and Potassium (Na &amp; K)</td>
<td>1174.00</td>
</tr>
<tr>
<td>Magnesium (Mg)</td>
<td>116.00</td>
</tr>
<tr>
<td>Calcium (Ca)</td>
<td>440.00</td>
</tr>
<tr>
<td>Iron and Alumina (Fe &amp; Al)</td>
<td>1.00</td>
</tr>
<tr>
<td>Loss on ignition</td>
<td>960.00</td>
</tr>
<tr>
<td>Total dissolved solids</td>
<td>5053.00</td>
</tr>
</tbody>
</table>
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 pressure 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.

<table>
<thead>
<tr>
<th>Constituents</th>
<th>Parts per Million</th>
</tr>
</thead>
<tbody>
<tr>
<td>Silica (SiO₂)</td>
<td>12.</td>
</tr>
<tr>
<td>Chlorine (Cl)</td>
<td>1,082.</td>
</tr>
<tr>
<td>Sulphates (SO₄)</td>
<td>201.</td>
</tr>
<tr>
<td>Phosphates (PO₄)</td>
<td>0.</td>
</tr>
<tr>
<td>Carbonates (CO₃)</td>
<td>0.</td>
</tr>
<tr>
<td>Bicarbonates (HCO₃)</td>
<td>152.</td>
</tr>
<tr>
<td>Sodium and Potassium (Na &amp; K)</td>
<td>536.</td>
</tr>
<tr>
<td>Magnesium (Mg)</td>
<td>77.</td>
</tr>
<tr>
<td>Calcium (Ca)</td>
<td>167.</td>
</tr>
<tr>
<td>Iron and Alumina (Fe &amp; Al)</td>
<td>4.</td>
</tr>
<tr>
<td>Loss on ignition</td>
<td>470.</td>
</tr>
<tr>
<td>Total dissolved solids</td>
<td>2,546.</td>
</tr>
</tbody>
</table>

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 & 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 and 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 and 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. (Pl. 10, Fig. 2).

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.

<table>
<thead>
<tr>
<th>Constituents</th>
<th>Parts per Million</th>
</tr>
</thead>
<tbody>
<tr>
<td>Silica (SiO2)</td>
<td>18</td>
</tr>
<tr>
<td>Chlorine (Cl)</td>
<td>573</td>
</tr>
<tr>
<td>Sulphates (SO4)</td>
<td>150</td>
</tr>
<tr>
<td>Phosphates (PO4)</td>
<td>0</td>
</tr>
<tr>
<td>Carbonates (CO3)</td>
<td>0</td>
</tr>
<tr>
<td>Bicarbonates (HCO3)</td>
<td>156</td>
</tr>
<tr>
<td>Sodium and Potassium (Na &amp; K)</td>
<td>269</td>
</tr>
<tr>
<td>Magnesium (Mg)</td>
<td>68</td>
</tr>
<tr>
<td>Calcium (Ca)</td>
<td>123</td>
</tr>
<tr>
<td>Iron and Alumina (Fe &amp; A)</td>
<td>8</td>
</tr>
<tr>
<td>Loss on Ignition</td>
<td>375</td>
</tr>
<tr>
<td>Total dissolved solids</td>
<td>1,555</td>
</tr>
</tbody>
</table>

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:

<table>
<thead>
<tr>
<th>Feet.</th>
<th>0</th>
<th>10</th>
<th>11</th>
<th>20</th>
<th>20½-35</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sand</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&quot;Hardpan&quot;</td>
<td>10</td>
<td>11</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sand, water</td>
<td>11</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&quot;Hardpan,&quot; water</td>
<td>20</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sand</td>
<td>20½-35</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sandy clay, water, flowing 3 feet above the surface of the well.</td>
<td>35</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The water is soft and very desirable for all domestic purposes. Another such well as the above is one 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. Gibbs' 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:

<table>
<thead>
<tr>
<th>Feet.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Surface sands and soil</td>
</tr>
<tr>
<td>Yellow sand</td>
</tr>
<tr>
<td>Coquina rock</td>
</tr>
<tr>
<td>Fine gray sand</td>
</tr>
<tr>
<td>Shell and sand</td>
</tr>
<tr>
<td>Hard shell rock</td>
</tr>
<tr>
<td>Greenish clay</td>
</tr>
<tr>
<td>Dark colored rock; sharks' teeth</td>
</tr>
<tr>
<td>Greenish clay</td>
</tr>
<tr>
<td>Dark colored rock; sharks' teeth</td>
</tr>
<tr>
<td>Greenish clay</td>
</tr>
<tr>
<td>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.</td>
</tr>
</tbody>
</table>

MERRITTS ISLAND.

From the well records obtained in this locality it is probable that flowing artesian wells can be obtained at any point on Merritts 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, 1 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.
THE ARTESIAN WATER SUPPLY OF EASTERN FLORIDA.

<table>
<thead>
<tr>
<th>Constituents</th>
<th>Parts per million</th>
</tr>
</thead>
<tbody>
<tr>
<td>Silica (SiO₂)</td>
<td>12.</td>
</tr>
<tr>
<td>Chlorine (Cl)</td>
<td>642.</td>
</tr>
<tr>
<td>Sulphates (SO₄)</td>
<td>178.</td>
</tr>
<tr>
<td>Phosphates (PO₄)</td>
<td>0.</td>
</tr>
<tr>
<td>Carbonates (CO₃)</td>
<td>0.</td>
</tr>
<tr>
<td>Bicarbonates (HCO₃)</td>
<td>149.</td>
</tr>
<tr>
<td>Sodium and Potassium (Na &amp; K)</td>
<td>399.</td>
</tr>
<tr>
<td>Magnesium (Mg)</td>
<td>65.</td>
</tr>
<tr>
<td>Calcium (Ca)</td>
<td>132.</td>
</tr>
<tr>
<td>Iron and Alumina (Fe &amp; Al)</td>
<td>3.</td>
</tr>
<tr>
<td>Loss on ignition</td>
<td>370.</td>
</tr>
<tr>
<td>Total dissolved solids</td>
<td>1,710.</td>
</tr>
</tbody>
</table>

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 well 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:

<table>
<thead>
<tr>
<th>Feet</th>
<th>Sand and soil</th>
<th>Coquina rock</th>
<th>Sand</th>
<th>Sand rock</th>
<th>Blue clay</th>
<th>Hard flint rock</th>
<th>Small stream</th>
<th>Rock in layer from 3 to 18 inches thick</th>
<th>Hard rock</th>
<th>Soft rock</th>
<th>Hard rock, good flow of water</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0</td>
<td>10</td>
<td>30</td>
<td>100</td>
<td>140</td>
<td>170</td>
<td>170</td>
<td>173</td>
<td>269</td>
<td>273</td>
<td>278 2-3</td>
</tr>
</tbody>
</table>

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 cannot 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, Sharpe's, 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 183. Analysis made for the State Survey in the office of the State Chemist, A. M. Henry, analyst.

Constituents. Parts per million.
Silica (SiO2) ........................................... 16.
Chlorine (Cl) ........................................... 3,120.
Sulphates (SO4) ...................................... 302.
Phosphates (PO4) ....................................... 0.
Carbonates (CO3) ........................................ 0.
Bicarbonates (HCO3) .................................... 165.
Sodium and Potassium (Na & K) ...................... 1,634.
Magnesium (Mg) ....................................... 286.
Calcium (Ca) ........................................... 262.
Iron and Alumina (Fe & Al) ........................... 4.
Loss on ignition ......................................... 974.
Total dissolved solids ................................ 6,520.

TILLMAN.

The only deep well at Tillman of which record has been obtained was drilled by John Mc Allister 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:

<table>
<thead>
<tr>
<th>Constituents</th>
<th>Parts per million</th>
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<tbody>
<tr>
<td>Silica (SiO₂)</td>
<td>8</td>
</tr>
<tr>
<td>Chlorine (Cl)</td>
<td>11,879</td>
</tr>
<tr>
<td>Sulphates (SO₄)</td>
<td>547</td>
</tr>
<tr>
<td>Phosphates (PO₄)</td>
<td>0</td>
</tr>
<tr>
<td>Bicarbonates (HCO₃)</td>
<td>177</td>
</tr>
<tr>
<td>Sodium and Potassium (Na &amp; K)</td>
<td>6,542</td>
</tr>
<tr>
<td>Magnesium (Mg)</td>
<td>669</td>
</tr>
<tr>
<td>Calcium (Ca)</td>
<td>637</td>
</tr>
<tr>
<td>Iron and Alumina (Fe &amp; Al)</td>
<td>3</td>
</tr>
<tr>
<td>Loss on ignition</td>
<td>1,380</td>
</tr>
<tr>
<td>Total dissolved solids</td>
<td>23,060</td>
</tr>
</tbody>
</table>

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 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.

*Survey made in 1903, under the direction of Captain F. R. Shunk, U. S. Army.
THE ARTESIAN WATER SUPPLY OF EASTERN FLORIDA.

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. 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 and Nesbitt and is 807 feet deep. The water is used for general and irrigating 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 9th St., Philadelphia, Pa., Chester Alsmere, Chemist, Reported Jan. 18, 1907.
### Constituents

<table>
<thead>
<tr>
<th>Constituent</th>
<th>Parts per million</th>
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</thead>
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<tr>
<td>Organic and volatile matter</td>
<td>51.311</td>
</tr>
<tr>
<td>Calcium oxide</td>
<td>70.650</td>
</tr>
<tr>
<td>Magnesium oxide</td>
<td>31.939</td>
</tr>
<tr>
<td>Sodium oxide</td>
<td>736.846</td>
</tr>
<tr>
<td>Sulphur trioxide</td>
<td>241.489</td>
</tr>
<tr>
<td>Chlorine</td>
<td>416.737</td>
</tr>
<tr>
<td>Carbonic acid (combined)</td>
<td>204.081</td>
</tr>
<tr>
<td>Silica</td>
<td>33.979</td>
</tr>
</tbody>
</table>

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.

### 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.

<table>
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<th>Constituents</th>
<th>Parts per million</th>
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<tr>
<td>Chlorine (Cl)</td>
<td>257</td>
</tr>
<tr>
<td>Carbonates (CO₃)</td>
<td>0</td>
</tr>
<tr>
<td>Bicarbonates (HCO₃)</td>
<td>177</td>
</tr>
<tr>
<td>Loss on ignition</td>
<td>245</td>
</tr>
<tr>
<td>Total dissolved solids</td>
<td>905</td>
</tr>
</tbody>
</table>

PRELIMINARY REPORT
ON THE
PEAT DEPOSITS OF FLORIDA.

ROLAND M. HARPER.
INTRODUCTION

The following report on peat deposits has been prepared by the State Geological Survey in co-operation with the United States Geological Survey. The aim of the report has been to supply a reliable although necessarily brief account of the peat deposits of the State. It has not been practicable to report separately upon each one of the very many peat bogs of the State since to do so would far exceed the limits available for this report. The objects were rather to determine the character of the peat, to distinguish between the better and the inferior deposits, and to indicate the parts of the State in which peat may be expected to be found. The more detailed work of locating and describing individual bogs will follow as the peat industry grows, creating a demand for such information.

The amount of time and funds that it was possible for the State Survey to devote to the investigation of peat was limited and it is only through fortunate circumstances that the report can be issued at this time. Dr. Harper, the author, has given unsparingly of his time, and the results embodied in the paper represent not only the information accumulated while in the employ of the State, but in addition he has included many supplementary observations obtained in connection with other investigations, all of which he has freely contributed. The photographs in this paper and several of those in the preceding papers of this report have also been contributed by Dr. Harper.

The report contains the analyses of fifty-three samples of peat. Forty-six of these analyses have been made in the fuel testing laboratory of the United States Geological Survey. In accordance with an agreement for co-operative work between the State and the National Surveys, these samples were collected and the field notes regarding the deposits made at the expense of the State Survey. In return the fuel tests and analyses were made by the National Survey. These analyses are included in the report and have added very materially to its value. Dr. Charles A. Davis, in charge of the peat investigations of the United States Geological Survey, has been particularly considerate and helpful in furthering the peat investigations.

It is desirable to call attention at this time to the importance of peat and to the vastness of the deposits in this State. Large deposits are found over a considerable area of the State, and the quality as shown by the fuel tests and analyses, is well up to, if not above the average. The manner of occurrence is such as to permit of
excavating at a minimum expense. It is true that the development of the peat industry has progressed slowly, especially in America where other fuels are abundant. In Florida the chief fuel supply originally was wood. At the present time, however, wood, except to those living in the country, is becoming an expensive fuel, and must become more and more expensive in the future. Coal is not found in the State, and must be imported for fuel from the coal-producing states, involving heavy freight charges. As a fuel, peat must ultimately become of value. Nor should the possibility of the use of peat as a source of power be overlooked. The prevailing general flatness of the country, while advantageous for agricultural purposes, has deprived the state of the large water power vouchsafed to the more mountainous states, and it is to be hoped that ultimately the peat deposits may be made to supply the power that nature has otherwise failed to afford the State. In view of these and the various other purposes mentioned in the report for which peat is or may be used, it is evident that the peat deposits must in time become a valuable resource to the State.

E. H. Sellards,
State Geologist.
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FLORIDA STATE GEOLOGICAL SURVEY
E. H. SELLARDS, State Geologist

MAP OF
FLORIDA
SHOWING
GEOGRAPHICAL DIVISIONS
DESCRIBED IN REPORT ON PEAT
BY
ROLAND M. HARPER
1910

Boundaries well defined
Boundaries vague or unexplored
Boundaries of minor importance

REGIONS
1. West Florida coast region.
2. West Florida pine hills.
3. West Florida limestone region.
4. Middle Florida hammock belt.
5. Lime-bank region.
6. Middle Florida flatwoods.
7. Gulf hammock region.
8. Lake region.
10. East coast strip.
11. South Florida flatwoods
    (including Everglades).
12. Miami limestone region.
13. Coast fringe.

SCALE OF MILES
0 10 20 30
PRELIMINARY REPORT ON THE PEAT DEPOSITS OF FLORIDA.

ROLAND M. HARPER.

PREFACE.

In the preparation of this report the writer has spent only about twelve months in the employ of the Survey, and as a considerable part of that time was necessarily taken up with office work, it was not possible to devote more than a few days, on the average, to the exploration of each county. Under these circumstances it has obviously not been possible to discuss the peat resources of each county in detail, or to describe many individual deposits. Still less has it been feasible to make any quantitative estimates, or to study the structure and development of each type of peat deposit. Every county in the State has been visited, however, and samples of peat have been collected in sixteen.

At some future time, when the population of Florida is considerably denser than at present, it may be found expedient to have the peat bogs of the State, or of certain counties, sounded, measured, analyzed, counted and mapped by an engineer, for strictly commercial purposes, or studied in a thoroughly scientific manner, regardless of economic considerations, by an ecologist; or both. But now while so much of Florida is still comparatively unexplored, and the peat industry in America is still in its infancy, such detailed studies are hardly desirable. The present report is the work of one whose specialty is traveling rapidly and jotting down impressions, without stopping to make measurements or delve into minute details.

Instead of discussing single counties, townships, or swamps, as several peat investigators in more thickly settled or geographically homogeneous states have done, I have attempted first to subdivide the State into natural divisions, each of which is essentially uniform in one or several respects, and to sketch briefly the peat situation in each. I have then essayed a classification of the peat deposits of the State, based primarily on the color, depth, fluctuations, etc., of water, and secondarily on their vegetation. As
the swamps of Florida are probably far more diversified than those
of any other state or country the schemes of classification employed
by northern and European writers have been of very little service
in this connection. The present tentative classification is based on
over a year's work in Florida, and a still longer time spent in neigh­
boring territory, but it is doubtless still far from perfect. It
is altogether likely that many important peat deposits, and perhaps
even whole types of peat deposits, have been overlooked, or very in­
adequately treated.

The language used in the following pages may not be quite
scientific enough to suit some scientists, but they should bear in
mind that this report is designed primarily for the use of the
citizens of the State, the great majority of whom cannot be ex­
pected to be familiar with scientific terms. On the other hand, the
citizens should be reminded that the use of some technicalities is
unavoidable, especially in the names of plants. For a great many
plants have to be mentioned which are unknown to the average
citizen, and it would not be possible to describe them so that he
could recognize them, or to eliminate all the other technicalities,
without increasing the bulk of the report many times. A technical
term is in most cases nothing but a device for expressing a complex
idea in a single word, or else a name for an idea which does not
exist outside of a certain science, profession, or trade. Not only
the scientist, but the engineer, the printer, the carpenter, the sailor,
and even the farmer, all use many words which are meaningless to
the uninitiated.

In my travels over the State I have received valuable informa­
tion and assistance from many of the best citizens, and at the same
time have formed numerous friendships which I hope will be last­
ing. I am under special obligations first to Dr. E. H. Sellards, State
Geologist, for giving me my first opportunity to explore this most
interesting state. Among those who have taken pains to assist
me, or shown an intelligent interest in my work, the following
deserve to be specially mentioned:—

Prof P. H. Rolfs, Director of the State Experiment Station;
Prof. A. W. Blair, Chemist of the same institution; Mr. Robert
Ranson of St. Augustine, the pioneer peat man of Florida; Capt.
R. E. Rose, State Chemist; Mr. A. M. Henry, one of his assistants,
whose intimate knowledge of the geography of some parts of Mid­
dle and East Florida has been useful to me; Dr. T. R. Baker, of
Rollins College; Hon. H. W. Bishop, of Eustis; Dr. E. S. Crill,
of Palatka; Dr. John Gifford, of Cocoanut Grove; Mr. T. L.
Mead, of Lake Charm; Mr. Chas T. Simpson, of Little River;
Mr. J. S. Kirk, of the Tavares & Gulf R. R.; Mr. W. J. Krome, constructing engineer of the Florida East Coast Ry.; and Mr. H. P. Savage, who was in charge of the Everglades drainage operations west of Fort Lauderdale at the time of my visit in April, 1909. Most of these gentlemen, it happens, are of that numerous class who have come from other states to Florida, and attracted by its many natural advantages have become permanent residents.

Outside of Florida I have received most valuable advice from Dr. Chas. A. Davis of the U. S. Geological Survey (lately transferred to the newly created Bureau of Mines), who is perhaps the foremost authority on peat in America at the present time. He has helped me most generously in personal consultation in New York and Washington, and by a somewhat voluminous correspondence; and I have drawn freely for ideas upon his published reports on the peat of Michigan, Maine, and North Carolina, particularly the first named.

Prof. C. S. Sargent, director of the Arnold Arboretum, by sending me to remote corners of Florida in search of rare trees, during three weeks in the spring of 1909 and two months in the spring of 1910, has given me opportunity to see some interesting peat deposits which I might have missed otherwise, particularly at the south end of the Everglades and the mouth of the Suwannee River.

Mr. Bryant Walker, of Detroit, Mich., a recognized authority on fresh-water shells, has furnished a list of shells found in peat near Lake Panasoffkee.

Prof. M. L. Fernald, of the Gray Herbarium, Harvard University, has identified a few of the peat-forming plants by comparison with the large collections at that institution, much better than I could by the descriptions to which I had access in Tallahassee.

Dr. J. H. Barnhart, librarian of the New York Botanical Garden, has kindly looked up for me a number of references which could not be supplied by the library of the Survey.
GENERAL DISCUSSION.

DEFINITION OF PEAT.

Peat is a substance formed by the slow decomposition of vegetable matter in the presence of abundant water. The substance of all plants is chiefly made up of three elements, carbon, hydrogen and oxygen, and this when immersed in water for an indefinite period gradually loses its gaseous constituents, hydrogen and oxygen, until ultimately what is left is mostly carbon. Peat may be regarded as an initial stage in the formation of coal; for coal is supposed to have once been peat, and to have acquired its rock-like consistency by being subjected to pressure from overlying subsequently deposited strata, together with heat from the interior of the earth, for thousands if not millions of years.

Peat, being formed only under water or in very wet places, is in the natural state completely saturated, sometimes containing ten times as much water as solid matter; and it does not part with this water very readily. When thoroughly air-dried, peat contains from about 5 to 25% of water (these figures depending partly on the physical and chemical properties of the peat itself and partly on the climate in which the drying takes place), and even when pressed and dried artificially it still contains at least 1 or 2%.

Peat that has been thoroughly macerated while wet, and not allowed to freeze and thaw repeatedly, will, after drying beyond a certain rather indefinite point, become comparatively firm and hard, and never again absorb enough water to become plastic. The reason for this is not well understood, but it is supposed to be due to certain physical and chemical changes that take place. In this respect peat is somewhat analogous to clay, which, as everyone knows, can be made plastic again by mixing with water after it has been partly dried, but not after burning.

Besides carbon and water, peat always contains small quantities of nitrogen, sulphur, and various other gaseous and volatile substances which are found in plant juices and tissues, and more or less mineral matter, which appears as ash after a sample is burned. Some of this mineral matter, has been an integral part of the plants themselves, and some has been merely suspended or dissolved in the water in which the plants grew, without being taken up by them. In very shallow peat deposits the mineral matter may represent merely a sort of mechanical admixture of the underlying soil; or in dry climates or seasons considerable quantities of it may be brought
into the peat deposit in the form of dust. Peat containing over 25% of mineral matter (which is commonly spoken of as ash) is not worth much for fuel and certain other purposes.

In texture, peat is more or less fibrous, being least so in the oldest and most thoroughly decomposed samples, which are rather plastic and look much like mud. The color is always some shade of brown, varying from light brown (this usually in fresh or imperfectly decomposed peat) to nearly black.

The principal use of peat, like that of coal, is for fuel. This and some of its numerous other uses will be discussed in some detail in a subsequent chapter.

The term muck is often used more or less interchangeably with peat. When a distinction is made between them the former is usually applied to peat which is dark colored and thoroughly decomposed, especially if it contains a large proportion of ash, or is used as a soil to grow crops in. When regarded as synonymous, peat is the more classical term, and muck the one more used by the masses.

Humus is another substance, sometimes confused with peat. But there is one essential difference between them. Humus is formed by the slow decay of vegetable matter in places where it is exposed to the air most of the time, which allows a part of the carbon to oxidize,* and thus increases the concentration of some of the other constituents of the plant, such as lime, potash, nitrogen, etc., correspondingly. Typical humus is rarely more than a few inches deep, while peat often has a depth of many feet. Another difference between peat and humus is that the former always contains certain organic acids which prevent the growth of bacteria and fungi.† (These, however, disappear or become considerably changed when peat is subjected to extensive aeration, as described below).

It should not be inferred from all this however that a sharp line can always be drawn between peat and humus. Although the extremes are distinct enough, they often grade imperceptibly into each other, either vertically or horizontally. Vertical intergradation occurs where the upper layers of a peat deposit become exposed to the air by being built up above the ground-water level, by the climate becoming drier, or by any one of several other causes; and hor-

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*A certain amount of shade and moisture is necessary for the formation of humus, however, for the carbon would be completely oxidized in very dry or sunny places, or where fires are frequent.

†The reader who is sufficiently interested can find a pretty full discussion of humus formation in Chapter 8 of Hilgard's "Soils," 1906.
horizontal intergradation is found wherever a swamp or marsh is bordered by a hammock or a wooded slope. Peat can also be more or less completely transformed into humus by taking it out of the water (or draining the water away from it) and stirring, pulverizing, composting or cultivating it so as to aerate it thoroughly, until finally—after a few years perhaps—enough of the carbon oxidizes away, and the acids disappear, for it to be called humus.

CONDITIONS NECESSARY FOR PEAT FORMATION.

True peat requires for its formation either a permanent body of water or a soil which is saturated with water most of the time, especially in warm weather. The water must not be too deep—for very few plants are able to grow in deep water—or too much agitated by currents, waves or tides, it must not fluctuate in level much, and it must not contain too much salt, mud, or other mineral substances.

The most familiar example of permanent water is the ocean; but in its deeper parts there is no vegetation except a few microscopic forms, and on all unprotected shores the waves effectually prevent the accumulation of peat. Extensive marshes form in sheltered bays, lagoons, etc., connected with the ocean, but salt marsh peat, for various reasons, one of which is the large amount of sediment constantly brought down by rivers, generally contains too much mineral matter to be of much value.

Permanent water is also furnished by most rivers, but many of these are too swift or too muddy, or vary too much in level, for the formation of good peat. Conditions are somewhat better in the estuaries at the mouths of rivers—especially those rivers which are not muddy—near enough to the sea to have little current and to be little affected by floods and droughts, and far enough from it to have hardly any tide or salt water.

Large lakes are often too deep in the middle, and their margins too much disturbed by waves, like the ocean; and shallow ponds usually dry up at some season of the year and allow the vegetable debris which may accumulate in them in the wet season to oxidize; but between these extremes is the happy mean. Small lakes, or shallow bays or coves of larger ones; permanent ponds, and shaded springy places, such as the swamps at the heads of streams, offer some of the best conditions for peat.

It goes without saying that peat formation also demands certain climatic conditions. The climate must of course not be so cold that no vegetation will grow, or so dry that there are no per-
manent streams or bodies or fresh water. Furthermore, the sea­sonal distribution of the rainfall should be such as to pretty well balance the evaporation, otherwise the lakes and streams would fluctuate too much.

GENERAL DISTRIBUTION OF PEAT.

Peat is most abundant in regions of immature topography, i. e., where processes of erosion and sedimentation have been at work a comparatively short time, for it is in such regions that bodies of still, clear water are most numerous. Lakes, ponds, swamps, bogs, etc., in whatever manner they may originate, are comparative­ly short-lived, geologically speaking, for they are almost sure sooner or later to be either filled with sediment washed down from adjacent slopes, or drained by the gradual deepening of the channels leading out of them, or both. Regions of mature topography have no lakes or ponds, and the valleys are typically steep and nar­row, with swift streams in them, toward their heads, and broad and level lower down. The lower courses of the streams are usu­ally sluggish enough, but they are apt to fluctuate too much or carry too much mud for the formation of peat.

In the eastern United States there are two extensive regions characterized by immature topography, namely, the glaciated region and the coastal plain. The glaciated region, which lies mostly north of the latitude of New York City, is believed to have been cov­ered many thousand years ago with a slowly moving ice-sheet, or aggregation of glaciers, which scooped out innumerable irregular depressions (determined largely by the location and character of the rocks and ridges) in the surface, deposited dams of rock and gravel across many of the valleys, and changed the face of the earth in other ways. After the ice retreated northward and the climate became warmer again these depressions quickly filled with water, forming the beautiful lakes for which some of the northern states are noted. The time elapsed since the glacial period—only an insignificant fraction of geological time—has been too short for stream erosion to have much effect on this region, especially as the soil left by the ice-sheet is very largely sand and gravel, which resists erosion pretty well.* Many of the smaller lakes of this region have long since become filled with excellent peat, and the process is still going on actively in others. Similar conditions are found in Europe, mostly north of latitude 45°, and to a lesser extent in some other parts of the world.

*In this connection see H. F. Cleland, Science II. 32: 82-83. July 15, 1910.
A coastal plain is a region which has been elevated above sea-level a comparatively short time, and has not developed any mountains either by folding or erosion, its strata being comparatively level, and elevated only a few hundred feet at the most. By far the largest and most typical coastal plain in the world is that of the southeastern United States, which extends from New York to Texas or beyond, and covers about 200,000 square miles, including all of Florida and Louisiana, nearly all of Mississippi, over half of the Carolinas, Georgia and Alabama, and parts of several other states, even as far inland as southern Illinois. Most of this region is believed to have been under water at about the same time the glaciated region was covered with ice, and it has been very little eroded since then, on account of its prevailing low elevation and sandy soils. The coastal plain contains many lakes and ponds, formed in very different ways from those in the glaciated region, but just as well adapted to the accumulation of peat. Estuaries too are numerous in the coastal plain, not so much on account of its topographic immaturity as for the simple reason that it borders the coast.

Within these regions of immature topography there are of course places where climatic or other conditions do not favor the formation of peat. For example, in the United States west of about the 95th meridian the climate is almost too dry for peat, both in the glaciated region* and in the coastal plain. On the other hand, there are other parts of the world where the climate compels (as one might say) the formation of peat, although the topography does not favor it.

For example, the island of Anticosti, in the Gulf of St. Lawrence, is said by Twenhofel* to be made up mostly of flat terraces which are almost completely covered with peat, and he attributes the abundance of peat to the cool, wet, foggy climate. Darwin on his voyage around the world in the first half of the 19th century found peat exceptionally abundant in Tierra del Fuego and the

*A report on the peat of Iowa recently published in the Annual Report of the Iowa Geological Survey for 1908 brings out some interesting facts. Out of about 300 samples of peat analyzed, none had less than 15% of ash when perfectly dry, and the average was over 25%. This state of affairs is doubtless correlated with the rather dry climate (the average annual rainfall for Iowa being about 31 inches). A large part of the mineral matter probably comes to the peat in the form of dust, for Iowa is said to be especially subject to strong westerly winds, which bring large quantities of dust from the arid regions farther west as well as from cultivated fields near by.

Falkland Islands,* where climatic conditions are somewhat similar to those of Anticosti.

The belief seems to be quite prevalent, even among scientists and authors of textbooks, that peat is chiefly confined to cool climates. This idea doubtless originated in Europe, where peat was first studied; because Europe has no coastal plain to speak of, and glaciated topography is confined to the northern and cooler parts of the continent. In this country the coastal plain has been singularly neglected by peat investigators and most other classes of scientists (most of whom live in or near the glaciated region), so that the European notions about peat have continued to flourish, much like some of the weather proverbs which were brought over from Europe by our ancestors and are still in circulation, regardless of the fact that they do not fit American conditions very well.

High temperature alone would hardly prevent the formation of peat where the humidity and topography were favorable, and the scarcity of peat in the humid tropics, where vegetation is noted for its luxuriance, can probably be explained on topographic grounds.

*See in this connection Jour. Geol. 16: 585. 1908.
PEAT IN FLORIDA.

Conditions in Florida are almost ideal for the formation of peat. The topography of the state is decidedly immature, there being very few evidences of recent surface erosion, especially on the peninsula. There are many times more lakes in Florida than in all other coastal plain states combined, and most of these lakes, quite unlike those of the glaciated region, seem to have been formed by the solution of underlying limestone (never by the damming up of streams by drift), and have no streams carrying sediment into them. Most of the streams carry no appreciable quantity of sediment, anyway, and there is only one river in the State which is very muddy all the time. The very long coast line (considerably over 1000 miles in length), and the general flatness of the country near the coast, favor the development of estuaries. The St. Johns River, for instance, is an estuary for a distance of about 100 miles from its mouth.

The soil being mostly sand, very little of the rain runs off as it falls; most of it soaking into the ground immediately, to reappear gradually in swamps in the lowlands, or in large springs in the more calcareous portions of the state. For this reason the streams which rise within the state do not fluctuate much, and are consequently bordered by peat deposits in many places.

Finally, the rainfall is ample, and so distributed through the seasons that most of it falls during the warmest months, thus balancing the evaporation to a considerable extent. To illustrate this point, the statistics of the average monthly and annual temperature and rainfall at Eustis, Lake County, are subjoined. Eustis is near the geographical center of the State, and the figures for it are probably as typical for the whole State as those of any other one station which might be selected. The following statistics, covering a period of 13 years, from 1890 to 1903, are taken from Bulletin Q of the U. S. Weather Bureau, published in 1906.

<table>
<thead>
<tr>
<th>MONTHS</th>
<th>Jan</th>
<th>Feb</th>
<th>Mar</th>
<th>Apr</th>
<th>May</th>
<th>June</th>
<th>July</th>
<th>Aug</th>
<th>Sep</th>
<th>Oct</th>
<th>Nov</th>
<th>Dec</th>
<th>Annual</th>
</tr>
</thead>
<tbody>
<tr>
<td>MEAN TEMPERATURE—(degrees Fahrenheit)</td>
<td>58°</td>
<td>61°</td>
<td>67°</td>
<td>70°</td>
<td>77°</td>
<td>81°</td>
<td>88°</td>
<td>80°</td>
<td>73°</td>
<td>66°</td>
<td>60°</td>
<td>57°</td>
<td>72°</td>
</tr>
<tr>
<td>TOTAL RAINFALL—(inches)</td>
<td>3.1</td>
<td>3.3</td>
<td>2.9</td>
<td>2.0</td>
<td>3.6</td>
<td>6.4</td>
<td>6.6</td>
<td>5.8</td>
<td>0.3</td>
<td>1.1</td>
<td>2.2</td>
<td>2.2</td>
<td>49.6</td>
</tr>
</tbody>
</table>

It will be noticed that over half the total rainfall comes in the four warmest months, June to September. This is approximately true throughout Florida, and in many other parts of the eastern United States where pine forests prevail.
NATURAL DIVISIONS OF THE STATE.

As peat is by no means universally distributed in Florida, its occurrence will be better understood if the geography of the State is described first. The geography of Florida is much more complex than any one who has not been in the State can possibly realize. There is probably not a more diversified state in the Union, except California, and that owes much of its diversity to its large size, its high mountain ranges, and its many different climates. Florida with only about one-third the area of California, a maximum elevation above sea-level of scarcely more than 300 feet, and not much diversity in climate, has a great many more different kinds of native trees than any other state, and its other productions are correspondingly varied.

PRINCIPLES OF CLASSIFICATION.

The task of dividing Florida into natural geographical regions is by no means an easy one, and very few serious attempts to do it have been made. The method of classification used will depend somewhat on the previous experience of the geographer, and what it is he is studying the distribution of. For instance, to a botanist a certain narrow strip along the upper Apalachicola River is very important, for it contains two trees not found anywhere else in the world, and several other plants not found elsewhere in Florida; but this strip does not differ notably in its peat resources from adjoining regions, and it is too narrow for any estimates to be made of its population. Again, to the geologist the Everglades differs from the country east and west of it only in being a few inches or feet lower, and therefore inundated most of the time; but this region is very important to the botanist on account of its interesting vegetation, and of very little interest to the forester and statistician on account of the absence of trees, population and crops. Also, a geological map of Florida, showing the distribution of the rocks, which are in most places buried deep under sand or clay, would differ considerably from a soil map, and that in turn from a temperature map, etc.

The classification here adopted is based primarily on the two features which chiefly make up a natural landscape; namely, topography and vegetation. The distribution and movements of surface water, and the character of the soil, all of which are intimately connected with topography, are also taken into consideration. In applying such a classification to the State of Florida we are con-
fronted at the outset with what appears to be a serious difficulty; namely such prominent features as lakes, hammocks,* flatwoods, prairies, lime-sinks, scrub, etc., are widely scattered over the state, in what might seem at first to be inextricable confusion. But by careful study it is possible to locate a well-defined lake region, a lime-sink region, two or three hammock regions, several flatwoods regions, etc.

Before defining these regions it will be well to explain in a few words the geological structure of Florida. The entire State is underlaid by limestone, of various ages from Vicksburg to Recent, and that is covered in most places by several feet of clay (mostly Pliocene) or sand (mostly Pleistocene) or both. The character of the country at any particular place is determined principally by the amount of clay or sand on top of the limestone, the elevation above sea-level, the time elapsed since it last emerged from beneath the sea, and the average depth of the ground-water below the surface. (These characters in turn are all more or less dependent on each other, in various intricate ways).

The map accompanying this report (plate 16) divides the State into about twenty geographical divisions of varying rank, some of them more distinct than others. Some which are very small, or imperfectly understood, or which contain little or no peat, are shown merely for the sake of completeness, and for suggestions to future explorers, and will not be described in the text.

It is scarcely necessary to remark that this map is only a preliminary one, and future investigations may change it considerably. For some of the boundaries are rather vague at the best, and even where they are very distinct their location has been verified only at a comparatively few points (such as where they are crossed by railroads), and guessed at the rest of the way. Moreover, there will always be differences of opinion as to how far the process of subdivision should be carried, as is the case in nearly all classifications of things.

*Many residents of other states who have written about Florida have attempted to define "hammock" (a term which is used in Florida more than in all the rest of the world), but most of them have missed the mark by trying to correlate it with soil. A hammock is nothing more nor less than a certain type of vegetation: namely, a comparatively dense growth of trees other than pines, in comparatively dry soil (or at least not wet enough to be called a swamp), in a region where open pine forests predominate. The ground in such places is always covered with more or less humus derived from the trees, but immediately under the humus the soil may be either sand, clay, marl or limestone. An intermediate condition between hammock and swamp is often called low hammock. The desirability of hammock land for agricultural purposes is due primarily to its humus.
The order in which the several regions are described below is necessarily somewhat arbitrary, for they cannot very well be classified by age like geological formations, and they do not form parallel bands like climatic zones. But as far as possible the westernmost ones will be taken up first and the southernmost last. For each of the major divisions the topography, vegetation and other prominent features will now be briefly sketched, and the character and extent of the peat deposits described in a general way.

WEST FLORIDA COAST REGION.

This extends from about the mouth of the Ocklocknee River westward beyond the limits of the State, forming a belt only a few miles wide. Its dominant features are narrow beaches, islands or peninsulas parallel with the general shore-line, with sounds, bays or estuaries behind them, and ancient (stationary) dunes on the edge of the mainland, or on some of the peninsulas. The soil is practically all sand (overlaid in a few places by recent alluvium, etc.), and there is no clay or limestone near enough to the surface to have any perceptible effect. Long-leaf pine (*Pinus palustris*) and spruce pine (*Pinus clausa*) are characteristic trees.

Peat of good quality but rather limited quantity occurs in numerous hollows among the old dunes, characterized by a dense growth of tyty bushes and other evergreens. Larger peat deposits are found in the estuaries of the Blackwater, Apalachicola, and other rivers, but these contain such a high percentage of mineral matter as to be almost worthless.

Analyses of peat from this region can be found in a subsequent chapter, under localities numbered 7, 36, 37 and 38.

WEST FLORIDA PINE HILLS.

The region thus designated covers most of West Florida, passing northeastward into the Altamaha Grit region* of Georgia, and westward into the "Grand Gulf" region of Alabama and Mississippi. It is a non-calcareous region, with sandy soil and clay subsoil throughout. There is doubtless limestone under it, as in all other parts of Florida, but so far below the surface in most places as to have very little effect on the topography, which

*For definition and description of this region see Annals N. Y. Acad. Sciences, vol. 17, part 1. 1906.
is approximately that which would be produced by normal erosion; lakes, ponds, and big springs being scarce. The surface varies from nearly flat near the coast to quite hilly in the interior, especially in Walton County, where elevations of nearly 300 feet are known. (In Gadsden County there is a small area over 300 feet above sea-level, which is the highest recorded elevation in the state.) The uplands are mostly covered with long-leaf pine forests, containing a large proportion of black-jack oak (*Quercus Catesbii*), and the bottoms of the valleys are occupied by narrow creek and branch swamps.

All conditions are here favorable to the formation of peat, except the topography. Lakes being scarce, and the valleys mostly narrow, there is no room for extensive accumulations of peat. Fairly good peat occurs however in some dense tity swamps (locality No. 39), and some of the estuaries mentioned under the preceding region might almost as well be regarded as belonging to this one.

**WEST FLORIDA LIMESTONE REGION.**

As here treated this is chiefly confined to Holmes and Jackson Counties, but embraces quite a variety of scenery, from sandy open pine forests with cypress ponds to red clay hills and limestone outcrops with dense hardwood forests. The limestone (representing various Oligocene horizons) crops out extensively in the vicinity of the Chipola River, and its influence is shown elsewhere in the numerous ponds in the pine woods, and in a few big springs. A considerable part of the drainage is subterranean, and consequently surface streams are much less frequent than in the region last described.

On account of the scarcity of streams and lakes, and the shallowness of the cypress ponds, nearly all of which dry up in the spring, the quantity of peat in this region is insignificant. For various other reasons not so well understood, peat does not seem to form so readily in calcareous as in non-calcareous regions, other things being equal.

**MIDDLE FLORIDA HAMMOCK BELT.**

(*Plates 7, 8, 27.2. Figs. 1-5, 19*)

Beginning on the west in Liberty County, this extends approximately parallel with the Gulf coast about to Ocala, with an outlying area of similar character centering around Brooksville. It is an even more diversified region than the preceding, embracing
red or brown loam hills, sandy and calcareous hammocks, flat pine woods, prairies, lakes, sink-holes, waterfalls, caves, and other curiosities. The flat pine woods are very similar to those of East Florida (described a few pages farther on), but are readily distinguished by the fact that they are always lower than the adjacent loamy hills, while those of East Florida are higher. In elevation above sea-level this region ranges from over 200 feet in some places along its northern edge to about 50 feet near some of the lakes and rivers.

Streams are not rare in some parts, but there is considerable subterranean drainage besides. There are quite a number of streams which rise near the northern and eastern edges of this belt, flow across it toward the Gulf, and disappear into the ground near the lower edge. The topography of the region is complex, and difficult to describe in general terms, but by considering a small part of the area at a time some of the more striking features can be pointed out.

In Gadsden County the topography is just about what would be produced by normal erosion, there being plenty of valleys and streams and no lakes or sinks. The red hills, with many ponds and few streams, and forests composed of hardwoods and short-leaf pines, culminate in the northern half of Leon County, and extend eastward with diminishing relief through Jefferson and part of Madison. South of the Santa Fe River the red clay is scarcer, and in Marion County the belt under consideration is reduced to a ridge of high hammock, with sandy soil, limestone near the surface, and neither streams nor lakes.

Many if not most of the lakes in this region are of a peculiar type (unknown outside of Florida), flat-bottomed, with one or more sink-holes at or near their edges, by means of which the water is kept drained off most of the time, especially during the dry season.* Such lakes when dry are commonly known as prairies, though they have little in common with the large flatwoods prairies of South Florida, except that they are treeless and subject to inundation at more or less regular intervals.

Conditions are not very favorable for peat in the Middle Florida hammock belt, on account of the paucity of streams and the frequent emptying of the lakes. There are, however, various kinds of swamps, some of which contain pretty good peat; and many of the lake-bottoms (or prairies) are dotted with saucer-

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*This type of lake or prairie is discussed by Dr. Sellards in a paper preceding this.
shaped depressions a few acres in extent, which hold water long enough for a little peat to form.

Analyses of peat from this region will be found in the table of analyses, under localities numbered 2, 20 and 42.

LIME-SINK REGION.

This extends from a few miles north of the middle of the straight line which divides Georgia from Florida, southward to Hernando County at least, with disconnected areas in Leon and Marion Counties. South of Hernando County it seems to pass gradually into the South Florida flatwoods (described farther on). Typically it is a region of rolling sandy pine woods with very little underbrush, with many approximately circular depressions or sinks, and very few streams or well-defined valleys. In the northern portion most of the depressions are perfectly dry, but farther south, where the altitude is less, some of them dip below the groundwater level and contain ponds or lakes. Near the few rivers which traverse the region large limestone springs are rather common.

Clay seems to be absent from a large part of the lime-sink region, especially southward; and neither the sand nor the limestone offers much hindrance to the passage of water, which explains why most of the drainage is subterranean, and water is not seen at any considerable elevation above sea-level. This region is of interest geologically as containing all the hard-rock phosphate deposits in Florida which have been worked up to the present time.

In a country with so little surface water, peat is of course scarce. Some samples collected near Inverness and Istachatta (localities 16 and 17) might be regarded as belonging to this region, though they are very close to the edge of another region which will be described below.

MIDDLE FLORIDA FLATWOODS.

(PLATE 23.2)

Under this name are mapped three disconnected areas, all lying within 35 miles of the Gulf coast, north of latitude 29°. This can be described briefly as a region of flat pine woods, with shallow ponds, most of which contain a dense growth of trees and shrubs, making a type of topography and vegetation commonly known as "bays." (San Pedro Bay, a very large bay or aggregation of bays, in Madison, Taylor and Lafayette Counties, popularly supposed to be impenetrable, is in the very heart of this region.) There are a few sluggish streams, most of them hardly
large enough to be called creeks, and probably no lakes. The soil is everywhere sand, and the ground-water is so near the surface that very little of the land is cultivated. The population is consequently sparse, and wells and other excavations so rare that it is not easy to make a general statement as to what underlies the sand. On the shores of Apalachicola Bay can be seen low bluffs of hardpan, a substance which looks like black sandstone but can be easily crumbled in the fingers,* and this probably underlies much of this region (and parts of some of the other flatwoods regions) at no great depth. The limestone which is supposed to form the foundation of all Florida is not near enough to the surface in the Middle Florida flatwoods to have any marked effect on the vegetation.

The innumerable bays and ponds all contain some peat, but on account of the flatness of the country it is so shallow (hardly ever more than a foot or two in thickness) that it will probably be a long time before it can be utilized with profit. No samples have been taken from this region.

GULF HAMMOCK REGION.

(PLATES 17.2, 20.2, 21)

Between St. Mark's on the west and Tarpon Springs on the south, within about 15 miles of the coast, the country is mostly flat, damp and sandy as in the region just described, but differs from that in having limestone everywhere near the surface, and often cropping out. The greater part of Sumter County seems to be also of this character. The whole region, including the Sumter County portion, seems to be less than 75 feet above sea-level.

This is a somewhat more diversified region than the adjacent flatwoods above described, as it contains many low hammocks (of which the great Gulf Hammock of Levy County is typical), a few lakes, and some areas of undulating dry sandy pine land (especially in Taylor County), hardly distinguishable from that of the lime-sink region. Although long-leaf pine is the most abundant tree here, as in most other parts of Florida, there is a considerable variety of hardwoods in the hammocks and swamps.

The coast of the Gulf hammock region is unique. Islands and beaches are practically absent from it, but the ocean bottom slopes so gradually (only a foot or two to the mile in most places) that large waves cannot approach the shore, and the effect is much the

*An analysis of this material can be found in the chapter on fossil peat.
same as if there was a barrier beach a few miles out. This whole coast is bordered by marshes a mile or two in width.

For a flat and calcareous region, this contains considerable peat, around lakes, rivers and estuaries. Descriptions of two of the interesting peat localities of this region (Hog Island and Panas-offkee) and analyses of peat from one of them, will be found in subsequent pages.

LAKE REGION.

(PLATES 9, 12, 24-26, 27.1. FIGS. 20, 23, 26)

This is peculiar to Florida, and occupies the “backbone” of the peninsula for a distance of some 200 miles, with a maximum width of about 50 miles in the latitude of Leesburg and Sanford. Its topography is much like that of the lime-sink region on a large scale. There are plenty of rounded hills and depressions, sometimes giving differences of elevation of over 100 feet within half a mile, but very few streams or valleys. Near the center of the region, particularly in the southern part of Lake County, some of the hills probably rise to a little over 200 feet above sea-level.*

The depressions are nearly all occupied by permanent lakes, of which there are many thousands in the region, varying in size from a few acres to over 50 square miles, and presumably deeper in proportion to area than those in most other parts of the state. The smaller ones are generally nearly circular, but the larger ones are more irregular in outline, as can be seen from a good map.

The surface is nearly everywhere sand, underlaid at a depth of several feet by a pinkish or mottled clay, which in some places is pure enough to be an important source of kaolin, and in others is gritty, and makes an excellent road-surfacing material. Limestone or marl is seen in only a few places, such as around springs and at certain points on the St. Johns River; but the vegetation of most of the low hammocks (which are usually found in the neighborhood of the larger lakes) seems to indicate that there is some calcareous material not far from the surface in such places. The topography is probably due at least in part to the dissolving away of limestone long ago, though there are doubtless other factors connected with it which are not so well understood.

*Elevations of four or five hundred feet have been claimed for points in Lake County by seemingly reliable people, but these estimates are probably not based on actual measurements. No topographic map of any part of this region has ever been published, far as known to the writer.
The prevailing vegetation of the lake region is of the “high pine land” type. Scattered through the region, usually but not always on snow-white sand, and apparently not bearing any constant topographic relation to the high pine land, is a very different type of vegetation known as “scrub,” consisting chiefly of spruce pines and small evergreen oaks. This is very characteristic of the lake region, but not confined to it, being found also on the old dunes near the coasts of East and West Florida, and in a few other parts of the State. High and low hammocks, saw-grass marshes and cypress swamps, are common in the vicinity of the larger lakes.

The country for a few miles on either side of the St. Johns River is mostly of the flatwoods type, and might perhaps be justly regarded as a distinct subdivision; but it happens that most of the lakes along this river are within what is here mapped as the lake region, and probably no serious error will result from including this part of the St. Johns valley with the country on either side of it.

The lakes of this region having no subterranean outlets, and being located among sandy hills which retain water somewhat in the manner of a sponge, do not vary much in level with the seasons. In the smaller lakes, therefore, and in the shallower parts of the larger lakes, conditions are ideal for the formation of peat. It would not be much of an exaggeration to say that peat of excellent quality can be found in every square mile of the lake region. The various classes of swamps, bogs, marshes, etc., in this region will be described in the next chapter, and analyses will be found farther on, under localities 3, 4, 12 to 15, 18, 19, 22, 23.

The climate data given on page 215 are for a station in the heart of this region.

**EAST FLORIDA FLATWOODS.**

*(PLATES 14.3, 15.1, 23.1, 28. FIG. 24)*

An area of about 4000 square miles in the northeastern corner of the State is comparatively flat, but with considerable elevation at distances of 40 miles or more from the coast. Near the rivers, and along the western edge, there has been enough erosion to give the region somewhat the character of a dissected table-land, but over the greater part of the area streams and valleys have never had a chance to develop to any appreciable extent, and the surface is dotted with countless shallow cypress ponds, nearly all of which dry up in the spring, like those of West Florida. Lakes are not very characteristic of this region, but there are several shallow but permanent ones in the western part, particularly in Columbia, Baker,
Bradford and Alachua Counties. The western edge of the region is about 200 feet above sea-level (and everywhere higher than the hammock belt which borders it), and along the eastern edge of Baker and Bradford Counties there is a similar elevation along a remarkable topographic feature which has never yet been explained, known locally as Trail Ridge.* About a dozen miles east of this, and parallel to it, there appears to be a smaller ridge, which is not easily detected without the aid of surveying instruments, but is pronounced enough to send the St. Marys River about 30 miles to the northward before it cuts through and takes a direct course for the coast.

The soil of the East Florida flatwoods is nearly everywhere from one to several feet of sand, resting on clay. In nearly all the cuts through Trail Ridge, however, both in Georgia and Florida, can be seen immediately under the sand a blackish hardpan much like that described above as occurring near Apalachicola. And east of the small ridge just mentioned many of the creeks must have cut their channels down through the clay, if the occurrence of lime-loving plants is any indication. Limestone or shell marl is said to be exposed in a few places along the St. Johns River and some of its larger tributaries in this region.

The most conspicuous features of the vegetation in these flatwoods, as in most others in Florida, are long-leaf pine and saw-palmetto. From nearly every point can also be seen pond cypress and slash pine in the cypress ponds, and sweet gum and black gum in swamps.

The cypress ponds contain no appreciable quantities of peat, for the reasons previously given; but the St. Johns River is an estuary for its whole course through this region, and besides it is never muddy; consequently there are some important peat deposits along it and some of the connecting waters. As this river is at the same time an important highway of commerce, conditions are very favorable to the economic development of peat along it, which has already been worked in at least three different counties. Some of these workable deposits will be described in detail in a subsequent chapter, and analyses will be found farther on, under localities 6 and 8, and miscellaneous Nos. 2 to 5.

*For a map and description of part of this ridge see Popular Science Monthly 74: 601-604. "June" (really published in May) 1909.
EAST COAST STRIP.

(PLATES 13.3, 14.1, 14.2, 17.1, FIG. 25)

From the northern boundary of the State to Cape Florida, a distance of over 350 miles, the east coast of Florida slopes off rapidly into the Atlantic Ocean, and the waves beat upon it with full force, throwing up barrier beaches in the manner common to most wave-washed sandy coasts. The sand has been further shifted by the wind and piled up into dunes, and the coast seems to have slowly risen or fallen, or both, for a distance of several or many feet vertically, in the last few thousand years. The result of these operations of Nature on our coast is in general a remarkably smooth and straight strip of beach and active dunes, averaging perhaps a mile in width, and back of that a lagoon about twice as wide, salt in some places and nearly fresh in others (according to the distance from the nearest inlet, etc.), and sometimes filled with marsh. Next to that is often a line of old stationary dunes with sand almost as white as snow, sometimes resting directly on the mainland and sometimes separated from it by a narrow lagoon of fresh water, or a fresh marsh. Then begin the flatwoods.

Where the water of these lagoons is fresh enough, conditions are favorable for the formation of peat, for such places, like estuaries, are obviously not subject to much disturbance by wind, tides and floods. Although I have not personally examined this region as carefully as I have some of the others, I am assured by Mr. Robert Ranson, who has been studying Florida peat for a dozen years or more, that there are large quantities of good peat along the east coast.

SOUTH FLORIDA FLATWOODS.

(PLATES 11.2, 13.1, 13.2, FIG. 21)

Three of the regions already described, namely, the lime-sink region, the lake region, and the East Florida flatwoods, if traced southward beyond the middle of the peninsula, seem to pass by imperceptible gradations into a region but slightly elevated above the sea, and consequently very flat, which may be called for convenience the South Florida flatwoods. Like the other divisions of the state, it is not altogether homogeneous. Some parts are more calcareous than others, some have more streams than lakes, and some more lakes than streams; and some are well wooded and some are treeless. But the facilities for traveling through this vast thinly settled region are as yet so limited that it is out of the question to attempt to subdivide it geographically at present.
The soil is nearly everywhere sand, where it is not covered by still more recent deposits, such as peat. Clay seems to be absent, and the limestone is often close to the surface, or barely exposed, as in the Gulf hammock region. Long-leaf pine is the prevailing tree as far south as Brevard and DeSoto Counties, and south of that it is replaced by a related species (Pinus Caribaea).* Saw-palmetto is the prevailing undergrowth nearly everywhere. The whole region is dotted with prairies of all sizes, from a few acres to several thousand square miles (if the Everglades be regarded as a prairie) in extent.

This region has been too little explored scientifically to warrant any definite statement about the quantity of peat it may contain, but there are certainly many shallow deposits in and around some of the prairies, lakes and estuaries. The northern part of the Everglades, which is the most extensive (through not the deepest) deposit of peat in Florida, if not the largest in the United States, may be regarded as belonging to this region. Descriptions of this and a few other interesting South Florida peat localities will be found in the following pages, and analyses under localities 11, 21, 28 and 80.

MIAMI LIMESTONE REGION.

(PLATES 2, 18, FIGS. 27, 28)

From the vicinity of Fort Lauderdale there extends southwestward a belt of honeycombed limestone rock† of Pleistocene age, with a maximum elevation of about 20 feet above sea-level, forming a part of the rim of the Everglades. North of the latitude of Cocoanut Grove this rock is covered with sand, at first only a few inches deep, or merely filling the holes in the rock, but becoming deeper northward. Southward of the point named, the rock is almost bare of anything but vegetation and a small quantity of humus, except in the vicinity of Homestead, where there are small areas in which the interstices of the rock are filled with a sort of reddish clay.

*For notes on the distribution of this tree in Florida see Tenth Census U. S., vol. 6, p. 207, and agricultural map facing p. 187. (It is there called “pitch pine”).

†Several botanical writers in recent years have called this “coral rock,” or “coralline limestone,” its honeycombed appearance probably leading them to imagine that it was an ancient coral reef like the upper Keys (which will be described farther on); but geologists have known for years that it is nothing of the kind. It does contain a few corals among its fossils, like many other limestones, but these corals form only a minute fraction of the whole mass, and they are not reef-building species, anyway. All this was brought out pretty clearly by Mr. Sanford in the second annual report of this Survey.
which however has no connection with the Pliocene clay of northern Florida. The same rock extends out into the southern part of the Everglades to an undetermined distance.

Strange to say, the Miami limestone, unlike nearly all other limestones, seems to have very little effect on vegetation. The drier parts of it are covered with forests of pine (Pinus Caribaea) with a dense undergrowth of saw-palmetto, essentially similar in aspect to the forests of the southern part of the South Florida flatwoods; and the parts subject to occasional inundation are treeless, like the prairies in the region just named. The upland forest sometimes known as the Biscayne pineland, which has a maximum width of about ten miles, is dotted with hammocks varying in extent from one to several hundred acres, in which the trees are nearly all of tropical species, but probably not necessarily lime-loving.

The water-level in the Everglades fluctuates considerably with the seasons, so that there are large areas around the edges which are dry in spring and inundated in fall, like the ponds and shallow lakes of northern Florida.* In this part, however, there are many depressions which are permanently wet, and peat accumulates in these in the same way as in the deeper holes in the prairies of the Middle Florida hammock region. Some estuarine peat is also found along the Miami River and other streams.

Analyses of peat from this region will be found under localities 24 to 27.

COAST PRAIRIE.

Bordering the Biscayne pineland from Cocoanut Grove south-westward, and extending all the way to the coast, which is nowhere more than ten or twelve miles away, is a flat prairie so slightly elevated above the sea that it must be inundated by salt water in times of storms or exceptionally high tides. It is dotted with clumps of bushes and small trees like the southern part of the Everglades, and by some botanists it has been considered a part of the Everglades. There are various minor differences in vegetation between the coast prairie and the Everglades, however, (as might be expected from their different relations to salt water), and one very marked difference in aspect. Everywhere in the coast prairie except within a mile or two of the pine land there are millions of

*For a popular account of some explorations at the south end of the Everglades in the dry season, with references to some earlier literature on the same region, see Florida Review (Jacksonville) 4:44-55. 147-157. July and August, 1910.
mangrove bushes reaching a uniform height of three or four feet, and these are entirely absent from the Everglades.

The peat resources of the coast prairie have not been investigated, but are probably insignificant.

**THE KEYS.**

The Keys, a curved line of narrow rocky islands extending from Soldier Key (just south of Cape Florida or Key Biscayne) to Key West, long ago attracted the attention of geologists and other naturalists, and a good deal of more or less accurate information about them has been published. It does not seem to have been generally known until a few years ago, though, that they can be divided into two distinct groups.*

Those lying northeast of Bahia Honda channel (sometimes distinguished as the upper Keys) are generally long and narrow in a direction parallel to the general trend of the coast line, and composed of a limestone in which large fossil corals are extremely abundant. Fresh water, pines, saw-grass, saw-palmetto, and even the cabbage palmetto seem to be absent from these keys, and the vegetation is chiefly made up of a large variety of tropical hardwoods and palms, growing in dense hammocks.

I have not yet visited the lower keys, but a glance at the map suffices to show that they are larger and more irregularly shaped than the upper ones, and from the accounts of Mr. Sanford and several people that I have talked with they must resemble the Miami limestone region in many ways. The highest recorded elevation on any of the keys, according to Sanford, is 18 feet, and the greater part of their area is considerably less than half as high as that.

One might travel the whole length of the Keys without noticing any peat, but there seems to be a good deal of it in certain channels and coves protected from the waves. It is formed chiefly by the mangrove, and is said to occur on both the upper and lower keys. An analysis of mangrove peat from the upper keys can be found farther on, under miscellaneous No. 7.

CLASSIFICATION OF FLORIDA PEAT DEPOSITS.

Florida undoubtedly has a greater variety of swamps, bogs, marshes, and other places where peat accumulates, than any other state or equal area in North America (if not in the world), and it is an extremely difficult matter to classify them. They are related to each other in so many different ways that it is almost impossible to decide what characters should be used for primary subdivisions and what for secondary ones. The problem is still further complicated by the fact that many if not most of them have their vegetation arranged in zones (which usually correspond approximately to the depth of the solid ground below the surface of the water or peat). While in any one deposit the zones might be pretty sharply defined, no two are exactly alike in this respect, and another deposit of essentially the same character might have quite a different series of vegetation zones, owing to slight differences in size, or depth, or age, or some more obscure factor, or merely to the fact that certain plants happened to get established in one bog and not in another of the same kind.

In the present classification attention is first directed to the nature of the water, i. e., to the substances dissolved or suspended in it. The surface waters of Florida can be divided into four principal classes, namely, salt, muddy, calcareous and swamp water. These of course intergrade more or less, but this does not cause much confusion, for wherever two of these kinds of water come together it nearly always happens that they are so unequal in volume that one is soon swallowed up, as it were, by the other.

Swamp water, which characterizes most of our peat deposits, can be further classified as flowing, seeping and stagnant, and the stagnant water according to its depth and fluctuations, and the amount of vegetation in it.

A few peat deposits which do not seem to fit very well into any particular class will be treated by themselves, as exceptions.

The swamps, bogs, etc., described in the succeeding pages may be classified about as follows. Those enclosed in brackets are only briefly mentioned, without their vegetation being described.
Salt water
    Marine marshes
    Mangrove swamps
Muddy water
    Alluvial
    Estuarine
Calcereous water
Swamp water
    On calcereous rock or soil
        [Creek swamps, etc.]
    Estuary of Suwannee River (Hog Island)
    Estuaries of Dade County
Non-calcereous
    Flowing
        Alluvial
        Estuarine
            West Florida
            East Florida.
    Seeping
        [Creek and branch swamps]
    Swamps bordering Escambia Bay
    Tyty swamps of Walton County
    Gum swamps of Leon County
    Slash-pine bogs
    Non-alluvial swamps of lake region
    Non-alluvial swamps of DeSoto County
Stagnant, or nearly so
    Drying up in spring
        [Drained by sinks]
        Without outlets
            [Shallow lakes and prairies]
            Cypress ponds
            [Gum and mayhaw ponds]
            Bays
    Permanent open water
        Small lakes
        Edges of large lakes
        Saw-grass marshes, etc
        Cypress swamps
        [Shallow lakes of East Florida]
        Fresh lagoons of the east coast
        Completely filled with vegetation (the bays and saw-grass
        marshes might also come under this head)
    Peat prairies of lake region
    Marshy prairies of Middle Florida
    Everglades (central portion)

This table includes some types of swamps which contain little
or no peat, and are described merely for comparison with other
kinds and to make the classification more complete. It does not
however include the exceptional or specially interesting peat de-
posits, which are described immediately after the typical ones.
In describing each type of swamp or other peat deposit the plants growing in it are listed, for the vegetation is always the most important feature of such places, and as a rule the peat has been formed from essentially the same species of plants which are now growing on or near it. Our oldest peat (leaving out of consideration the fossil peat which is buried under several feet of sand, etc.) is probably not more than a few thousand years old, and the vegetation of Florida as a whole has probably not changed much in that length of time, though of course there have been many changes in local details, as the peat deposits increase in area or depth.

In most of the following lists the plants are divided into trees, shrubs, herbs and mosses, and the species in each of these groups arranged as nearly as possible in order of abundance, the most abundant or conspicuous ones always being mentioned first. Those seen only once or twice in any one kind of swamp are usually omitted, for there is always a possibility that such plants do not properly belong to the habitat in question, or that they have been wrongly identified; and, furthermore, rare plants are not of much significance in quantitative studies of vegetation. It is scarcely necessary to remark that all of these lists are more or less incomplete or otherwise defective, because of the limited time which I have had for field work, and the fact that most of it was done in the winter and spring months, while many of the plants can be indentified with certainty only in late summer or fall.

In listing the plants the use of technical names is necessary, for the reasons stated in the preface. Common names, where known, are also inserted, to save the non-botanical reader the trouble of looking up each technical name in the index and then in the systematic catalogue of plants, where the same common names are given again.

**MARINE MARSHES AND SWAMPS.**

*(PLATES 17, 18)*

Wherever there are shallow bays or lagoons of salt water, protected from waves, extensive deposits of peat or muck are formed by a type of vegetation quite distinct from that of fresh water. In temperate regions the great bulk of the salt water vegetation is composed of herbs, forming marshes, while in the tropics woody plants are much more numerous in such places, and we find swamps instead. Both types are pretty well represented in Florida, the marshes in the northern parts of the state and the swamps southward.
SALT MARSHES.

Fig. 1.—Salt marshes near Mayport (Duval County), looking northeastward toward mouth of St. Johns River. Grass in foreground all *Spartina glabra*. Low dunes with *Sabal Palmetto* in distance. May 13, 1909.

Fig. 2.—Salt marshes on east side of Way Key, about half a mile north of Cedar Keys station (Levy County), showing archipelago-like character and oyster-shell foundation characteristic of marshes in this vicinity. The bushes are *Avicennia nitida* (black mangrove). April 26, 1909.
MANGROVE SWAMPS.

Fig. 1.—Mangrove swamp on Biscayne Bay near Lemon City (Dade County), from the seaward side. April 3, 1909.

Fig. 2.—Interior of same swamp, looking out toward the bay. Leaning trunk of Conocarpus at right. July 31, 1910.
Fig. 1.—Alluvial swamp of Apalachicola River in northern part of Liberty County, taken in early spring when the trees were all leafless. The small leaning tree in the foreground is *Ilex decidua*, and the larger ones are mostly Liquidambar (sweet gum). March 8, 1909.

Fig. 2.—Looking down muddy bayou in midst of estuarine swamps and marshes of Apalachicola River about 7 miles north of Apalachicola (Franklin County). The trees are mostly *Taxodium distichum* (cypress), with some *Juniperus* (cedar). *Nymphaea fluviatilis* floating in foreground, *Scirpus validus* at water’s edge, and *Cladium* (saw-grass) next to it. April 24, 1910.
Fig. 1.—Looking up Wakulla River from upper bridge a few miles below Wakulla Spring (Wakulla County), showing Taxodium distichum (cypress), Tillandsia usneoides (moss), Sagittaria lancifolia, etc. April 9, 1910.

Fig. 2.—Head of Homosassa River, looking downstream from railroad trestle about a mile northeast of Homosassa (Citrus County). May 23, 1909.
The salt marshes of northern Florida are not very extensive—usually not more than a mile in width—and they differ very little from those of adjoining states. The following list of salt marsh plants is compiled from notes made along the coast in the vicinity of Fernandina, Mayport, New Smyrna, Titusville, Fort Myers, Punta Gorda, Cedar Keys, and Apalachicola.

**SHRUBS**

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<tr>
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<th>Description</th>
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<tbody>
<tr>
<td>Avicennia nitida</td>
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<tr>
<td>Iva frutescens</td>
<td></td>
</tr>
<tr>
<td>Laguncularia racemosa</td>
<td>white mangrove or buttonwood</td>
</tr>
</tbody>
</table>

**HERBS**

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<tr>
<th>Name</th>
<th>Description</th>
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</thead>
<tbody>
<tr>
<td>Spartina glabra</td>
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</tr>
<tr>
<td>Juncus Roemerianus</td>
<td>rush</td>
</tr>
<tr>
<td>Batis maritima</td>
<td></td>
</tr>
<tr>
<td>Salicornia ambigu</td>
<td></td>
</tr>
</tbody>
</table>

North of latitude 29° the bulk of the salt marsh vegetation consists of the first two herbs named, the second usually in less salty situations than the first. Southward the mangroves and buttonwoods become more and more prevalent, until by the time latitude 26° is reached the marshes are completely replaced by mangrove swamps.

The following plants have been noticed in a mangrove swamp on Biscayne Bay near Lemon City, which is probably fairly typical of all such places in South Florida:

**TREES**

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<th>Description</th>
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<tbody>
<tr>
<td>Rhizophora</td>
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</tr>
<tr>
<td>Conocarpus erectus</td>
<td>buttonwood</td>
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**WOODY VINES**

<table>
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<th>Name</th>
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</tr>
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<tbody>
<tr>
<td>Dalbergia Brownei</td>
<td></td>
</tr>
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</table>

**HERBS**

<table>
<thead>
<tr>
<th>Name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acrostichum aureum</td>
<td>(a fern)</td>
</tr>
<tr>
<td>Hymenocallis</td>
<td>(spider-lily)</td>
</tr>
</tbody>
</table>

Salt marsh peat or muck contains too much mineral matter to be of any value for fuel, and it is usually very shallow besides. That of mangrove swamps is probably purer and deeper, on the average, though we have as yet little accurate information about it. (See analysis under miscellaneous No. 7.) In some parts of the world salt marshes are diked and ditched and thereby made available for cultivation, but this is an expensive process, profitable only where the population is dense enough to put high values on every class of land.
SWAMPS WITH MUDDY WATER.

Most Florida streams flow their whole length through sandy or rocky regions, and thus have no chance to become muddy. But the Apalachicola River, which has its sources among the red clay hills of Middle Georgia, is always muddy, and the Choctawhatchee and Escambia, which rise in the Eocene hills of southern Alabama, are quite muddy at times, especially in recent years since so much of the forest around their headwaters has been destroyed to make room for crops. The Ocklocknee and Suwannee have some clayey land in their drainage basins, and may become a little turbid at times, but the amount of mud carried by them in the course of the year is insignificant.

All muddy streams are subject to considerable fluctuation, and the vegetation along their banks is quite different from that which borders the more steady streams. Towards their mouths, however, the fluctuations become less and less, for it is obviously impossible for any river, no matter how swollen, to change the level of the ocean appreciably. Although we are at present unable to explain it, there is a marked difference between the vegetation of alluvial and that of estuarine swamps, even on the same stream.

ALLUVIAL SWAMPS.

(PLATE 19.1)

The subjoined list of alluvial swamp plants is compiled from notes taken along the Apalachicola River in Jackson, Gadsden and Liberty Counties, within a few miles of River Junction and Apalaga. (I have seen very little of the swamps of the Escambia and Choctawhatchee Rivers, but I have no doubt that in most respects they are intermediate between the Escambia and some of the smaller rivers which flow southward across Middle Florida, such as the Ocklocknee).

TREES

*Taxodium distichum* (cypress)  
*Nyssa uniflora* (tupelo gum) (mostly in sloughs)  
*Salix nigra* (willow) (mostly on banks)  
*Platanus occidentalis* (sycamore)  
*Crataegus viridis* (red haw)

*Populus deltoides* (cottonwood)  
*Hicoria aquatica* (swamp hickory)  
*Gleditschia aquatica* (locust)  
*Carpinus Caroliniana* (ironwood)  
*Ulmus Americana?* (elm)  
*Celtis Mississippiensis?* (hackberry)  
*Fraxinus Americana?* (ash)  
*Acer saccharinum* (maple) (mostly on banks)  
*Betula nigra* (birch) (mostly on banks)

*Quercus nigra* (water oak) (mostly in slightly drier spots)  
*Quercus lyrata* (swamp post oak)  
*Liquidambar Styraciflua* (sweet gum)  
*Planea aquatica*  
*Quercus lyrata* (swamp post oak)
PRELIMINARY REPORT ON PEAT.

SMALL TREES OR LARGE SHRUBS

*Ilex decidua*

**Viburnum obovatum**

Adelia acuminata

SHRUBS AND VINES

*Rhus radicans* (poison ivy)

**Sebastiana ligustrina** (in drier spots)

*Sabal glabra* (palmetto)

**Phoradendron flavescens** (mistletoe)

HERBS

*Tillandsia usneoides* (Spanish moss)

**Senecio lobatus**

These swamps contain no peat, but they are mentioned here simply to illustrate one extreme of the swamp series, and for comparison with some of the other kinds.

ESTUARINE SWAMPS.

APALACHICOLA RIVER.

(PLATE 19.2, FIG. 17)

The Apalachicola River near its mouth expands into a delta several miles wide, traversed by a number of crooked channels or bayous, some of which have distinctive names (East River, St. Mark's River, etc.). Between these channels are thousands of acres of typical estuarine swamps and marshes, which were practically impenetrable until about four years ago, when the Apalachicola Northern R. R. was built across them, with a trestle five miles long.

The soil of this delta is a soft mud of great depth. I have been told that when the railroad trestle was being built some piles were driven to a depth of 170 feet without reaching a firm foundation. (This probably indicates that the land has sunk that amount with reference to the sea in the last few thousand years, for the river could never have washed out the solid sand or rock to any considerable depth below sea-level). It had been the intention of the railroad builders to drive the piles to a firm foundation and space the bents 15 feet apart in the usual manner, but the great depth of the alluvium necessitated a change of plans. Ordinary 60-foot piles were then used, and the bents placed eight feet apart most of the distance, which was found to give sufficient support to the
trestle in the swamp areas. In one or two of the marsh areas, however, I noticed bents every four feet, which doubtless indicates that the mud was unusually soft there.

Fig. 17.—Scene in heart of estuarine swamp of Apalachicola River, about 5 miles north of Apalachicola (Franklin County), looking at right angles to railroad right-of-way from trestle. Shows Taxodium distichum (cypress), Nyssa biflora (black gum), Magnolia glauca (bay), and Sabal Palmetto (cabbage palmetto), among other things. April 24, 1910.

Most of the plants in the following list were noted from the trestle on April 24, 1910, when I walked the whole length of it.
PRELIMINARY REPORT ON PEAT.

TREES

*Taxodium distichum* (cypress)
*Sabal Palmetto* (cabbage palmetto)
*Nyssa biflora* (black gum)
*Magnolia glauca* (bay)
*Acer rubrum* (maple)

*Salix longipes*? (willow)
*Nyssa Ogeche* (tupelo gum)
*Fraxinus profunda*? (ash)
*Ulmus Floridana* (elm)
*Juniperus Virginiana* (cedar)

SHRUBS AND VINES

*Hypericum fasciculatum*?
*Alnus rugosa* (alder)
*Amorpha fruticosa*
*Sabal glabra* (palmetto)
*Cephalanthus occidentalis* (button-bush)

*Myrica cerifera* (myrtle)
*Parthenocissus quinquefolia* (Virginia creeper)
*Rhus radicans* (poison ivy)

HERBS

*Cladium effusum* (saw-grass)
*Sagittaria lancifolia*
*Nymphaca fluviatilis* (bonnets) (in bayous)
*Tillandsia usneoides* (Spanish moss) (on trees)
*Osmunda regalis* (a fern)
*Scirpus validus* (bulrush)
*Saururus cernuus*
*Zizania aquatica*? (wild rice)

*Typha latifolia* (cat-tail)
*Phragmites communis* (reed grass)
*Pontederia cordata* (wampee)
*Pelantia Virginica*
*Scirpus Olneyi*?
*Iris versicolor* (blue flag)
*Carex impressa*
*Carex stipata*
*Juncus effusus* (rush)

This vegetation is by no means homogeneous. It is divided pretty sharply into alternate strips or patches of swamp and marsh, and the plants of the two kinds of places (shady and sunny) could have been separated pretty well in the list if the matter had been of sufficient importance to justify it. The marshes contain a few small scattered cypress and willow trees, *Hypericum* and *Cephalanthus* bushes, and most of the herbs listed above, while the swamps contain all the species of trees, most of the shrubs, and a few of the herbs, such as *Tillandsia*, *Osmunda*, *Saururus* and *Carex*.

The alluvium of course contains a considerable quantity of organic matter, from the decay of the plants which have grown there in centuries past, but it can hardly be called peat, on account of the large amount of mud present. It is quite likely that this mass of sediment has a decided stratified structure, with some layers more peaty than others. No samples of it have been taken, but judging from the analogy of other estuarine peat to be mentioned below, this must contain as much as 90% of mineral matter, on the average.
Although the Choctawhatchee River, unlike the Apalachicola, rises in the coastal plain, its head-waters are in the red clay hills of the Eocene region of Alabama, and it seems to be always more or less muddy, though naturally considerably less so than the Apalachicola.

On Sept. 22, 1910, I went in a launch from the head of Choctawhatchee Bay about twelve miles up the river, and for about half this distance the swamps seemed to be essentially estuarine, and not very different from those of the Apalachicola at corresponding distances from its mouth. The following plants were noted at least twice in the first half dozen miles or so.

<table>
<thead>
<tr>
<th>TREES</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Taxodium distichum (cypress)</td>
<td>Liquidambar Styraciflua (sweet gum)</td>
</tr>
<tr>
<td>Magnolia glauca (bay)</td>
<td>Nyssa biflora (black gum)</td>
</tr>
<tr>
<td>Nyssa Ogeche (tupelo gum)</td>
<td>Juniperus Virginiana (cedar)</td>
</tr>
<tr>
<td>Acer rubrum (maple)</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>SHRUBS</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Cyrilla racemiflora (tyty)</td>
<td>Sabal glabra (palmetto)</td>
</tr>
<tr>
<td>Alnus rugosa (alder)</td>
<td>Myrica cerifera (myrtle)</td>
</tr>
<tr>
<td>Amorpha fruticosa</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>HERBS</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Scirpus validus (bulrush)</td>
<td>Pontederia cordata (wampee)</td>
</tr>
<tr>
<td>Phragmites communis (reed grass)</td>
<td>Zizania aquatica (wild rice)</td>
</tr>
<tr>
<td>Cladium effusum (saw-grass)</td>
<td>Dryopteris Thelypteris (a fern)</td>
</tr>
<tr>
<td>Tillandsia usneoides (Spanish moss) (on trees)</td>
<td>Nymphaea fluviatilis (bonnets)</td>
</tr>
</tbody>
</table>

Most of the herbs are confined to strips of marsh a few feet wide bordering the water. The peat was not investigated, but it is doubtless very impure.
Limestone, whether in the soil or in the water, nearly always has a marked effect on vegetation, many species of plants being peculiar to calcareous habitats, or entirely absent from them, and others much commoner or rarer in such places than elsewhere. In Florida limestone occurs in all sorts of relations to soil and topography, and the opportunities for studying its effects on vegetation are unsurpassed.

This State is noted for its many large limestone springs with beautiful bluish-tinged transparent streams issuing from them. These are numerous in the Gulf hammock region, fairly common in the West Florida limestone region and the lime-sink region of the peninsula, and occasional in several other regions. Some of our calcareous streams have steep banks, and no place for peat to accumulate, but others, especially in the flat Gulf hammock region, are bordered by extensive swamps. The fluctuations of calcareous streams are very much less than those of muddy streams.*

The plants listed below were observed either along Spring Creek (a few miles east of Marianna) in Jackson County, or in or near the Gulf hammock region, or both.

**TREES**

- Taxodium distichum (cypress)
- Acer rubrum (maple)
- Liquidambar Styraciflua (sweet gum)
- Magnolia glauca (bay)
- Carpinus Caroliniana (ironwood)
- Ulmus Floridana (elm)
- Quercus nigra (water oak)
- Celtis sp. (hackberry)
- Fraxinus Caroliniana? (ash)
- Fraxinus sp.
- Sabal Palmetto (cabbage palmetto)
- Quercus Michauxii (swamp chestnut oak)
- Pinus Taeda (short-leaf pine)
- Juniperus Virginiana (cedar)

**SMALL TREES**

- Ilex Cassine (swamp holly)
- Salix longipes? (willow)
- Viburnum obovatum

*According to U. S. Geol. Surv. Water Supply Paper No. 242, pp. 132-135, the outlet of Silver Spring fluctuated only 1.65 feet during 1907. At a stage a little above the mean it was discharging 608 cubic feet a second. During the same year the Suwannee River at White Springs (where it is essentially non-calcareous) fluctuated 18.9 feet, with a discharge varying from 18 to 8760 cubic feet a second.
SHRUBS AND WOODY VINES

*Myrica cerifera* (myrtle)  
*Cornus stricta*?  
*Decumaria barbara* (a vine)  
*Itea Virginica*  
*Rhus radicans* (poison ivy)  
*Berchemia scandens* (rattan vine)

HERBS

*Tillandsia usneoides* (Spanish moss) (on trees)  
*Sagittaria natans* (submerged or nearly so)  
*Cladium effersum* (saw-grass)  
*Pontederia cordata* (wampee)  
*Senecio lobatus*  
*Lemma sp.* (duckweed) (floating)  
*Rhynchospora milacea*

*Sabal glabra* (palmetto)  
*Cephalanthus occidentalis* (button bush.)  
*Rhipidophyllum Hystrix* (needle palm)

Several of these herbs, such as *Pontederia, Cladium, Panicum, Phragmites, Scirpus*, and the two *Sagittaria* species, grow right in the water, where it is one to several feet deep, while some of the trees grow out toward the edges of the swamps, on little or no peat; but there are all gradations between in the matter of location.

Peat in such places is usually rather shallow, though Jones, Tharp & Belden, in their soil survey of Jefferson County, (published in 1908 by the U. S. Department of Agriculture), mention the occurrence of several feet of peat along the Wacissa River in the southern or uninhabited part of that county. I have not taken any samples of this kind of peat, but it is probably too full of tree roots and stumps to be worked with profit at present.

A few peat localities with more or less calcareous water, but differing from the above topographically or otherwise, will be described farther on, among the exceptions.
SWAMP WATER.

The water of most streams, lakes, ponds, swamps and fresh marshes in Florida, as in the coastal plain generally (and to a considerable extent in the glaciated region as well), contains organic matter both in suspension and solution, which gives it a brownish color. Such water in a glass looks like very weak coffee, or in a deep stream or lake, especially if the bottom is dark, like strong coffee, or it may even be compared in blackness to ink. Some of the dissolved organic matter is of the nature of vegetable acids, and this kind of water always has an acid reaction, and it is often perceptibly sour to the taste.

SWAMP WATER ON CALCAREOUS SOIL.

CREEK SWAMPS, ETC.

Although most coffee-colored streams flow over beds of sand, there are many places in Florida where such streams have limestone or marl near enough to the surface to have a decided effect on the vegetation without the limestone itself being visible. Such places are usually in small streams with shallow swamps, and are of no importance as sources of peat, but they are of scientific interest because to any one not a botanist they would hardly seem to differ from strictly non-calcareous swamps. Moreover, they might be of some assistance to a geologist in helping him to locate beds of limestone or marl in regions where outcrops are scarce, as in the East Florida flatwoods.

These swamps with invisible calcareous foundations are rather common within a few miles of the St. Johns River and southwest of Kissimmee, where I have seen many of them while traveling by rail, but I have been in very few of them. The following list is made up from observations in Jefferson, Duval and Clay Counties, and about the head-waters of Peace River in Polk County.

**TREES**

*Taxodium distichum* (cypress)  
*Acer rubrum* (maple)  
*Fraxinus profunda*? (ash)  
*Nyssa biflora* (black gum)  
*Ilex Cassine* (swamp holly)  
*Liquidambar Styraciflua* (sweet gum)  
*Quercus sp.* (similar to *Q nigra* but with narrower leaves)  
*Quercus nigra* (water oak)  
*Persea tubescens*?  
*Persea Borbonia* (red bay)  
*Fraxinus Caroliniana* (ash)  
*Juniperus Virginiana* (cedar)  
*Pinus Taeda* (short-leaf pine)  
*Ulmus Americana*? (elm)  
*Carpinus Caroliniana* (ironwood)
SHRUBS AND WOODY VINES

*Myrica cerifera* (myrtle)  
*Itea Virginica*  
*Rhus radicans* (poison ivy)  
*Berchemia scandens* (rattan vine)  
*Phoradendron flavescens* (mistletoe)  
*Viburnum obovatum*

*Coriopsis striata?  
*Rosa Carolina?* (wild rose)  
*Rubus sp.* (blackberry)  
*Sabal glabra* (palmetto)  
*Baccharis halimifolia*  
*Amorpha fruticosa*  
*Aster Carolinianus*

HERBS

*Tillandsia usneoides* (Spanish moss)  
*Tillandsia* (various other species)  
*(air-plants)*  
*Saururus cernuus*  
*Rhynchospora miliciae*  
*Pontederia cordata* (wampee)  
*Cladium effusum* (saw-grass)  
*Nymphaea macrophylla* (bonnets)  
*(in stream)*  
*Thalia divaricata?  
*Iris versicolor?* (blue flag)  
*Mikania scandens* (a vine)  
*Sagittaria lancifolia*  
*Peltandra Virginica*  
*Samolus floribundus*  
*Hydrocotyle verticillata*  
*Sabbatia calycina*  
*Osmunda regalis* (a fern)  
*Canna flaccida* (wild canna)

This aggregation of plants resembles that of the swamps with calcareous water more than it does that of the strictly non-calcareous swamps.

ESTUARY OF THE SUWANEE RIVER.

(PLATE 21)

The Suwannee River takes its rise in Okefinokee Swamp and other swamps in the sandy pine woods of Southeast Georgia, and until it passes White Springs it is a typical non-calcareous coffee-colored stream. In the remainder of its course quite a number of limestone springs discharge into it, which are said to make it quite clear at times.* I have, however, crossed it at seven different places.

*William Bartram, who visited the Suwannee River (then known as the Little St. Juan) in the latter part of the 18th century, probably about where the northern corner of Levy County now is, spoke of it as “the pellucid river,” saying of it among other things:— “The waters are the clearest and purest of any river I ever saw, transmitting distinctly the natural form and appearance of the objects moving in the transparent floods, or reposing on the silvery bed.” (See the first edition of his Travels, pp. 224-226, 1791; or part 2, chapter 7, of any edition.) But Florida scenery seems to have wonderfully stimulated his imagination—as it has that of many another writer since his day—and his descriptions of this state are unfortunately less reliable than those of other states mentioned in the same volume. It is possible, however, that for some reason this river carries relatively less calcareous water now than it did in Bartram’s time.
in Florida, mostly in the dry season, without noticing any variation in its color; and as in its lower courses it has cut a channel through limestone, it may without serious error be regarded as a case of swamp water on calcareous rock.

The estuarine swamps and marshes at the mouth of this river are quite interesting, and in some respects unique. A mile or two from the coast the river divides, enclosing between its arms an island a few thousand acres in extent, known as Hog Island. The coastward edge of this island is marsh, similar in general appearance to the salt marshes elsewhere along the Gulf hammock coast, but with hardly a trace of salt water vegetation. The explanation of this rather anomalous occurrence of fresh water vegetation immediately on the borders of the Gulf of Mexico, without the protection of any sort of barrier beach, is probably to be found in the extreme shallowness of the water. According to the U. S. Coast Survey charts, there are places in the immediate vicinity where the Gulf has a depth of only a foot or two, and several miles out where it is only five feet deep. Under these conditions the fresh water which is continually pouring out of the two mouths of the river must make the salt water very dilute for some distance in every direction.

Going up either mouth of the river, small trees, of every kind mentioned in the following list except perhaps the last two, soon begin to appear in the marshes, gradually become larger and denser until in the inland half of the island they form a compact forest. There is practically no dry land on the island, the soil being all peat or muck, so that it is not a very easy place to explore. On April 15, 1910, I went around it in a launch, penetrated into the interior on foot a short distance in two or three places, and identified the following plants:

**TREES**

- *Sabal Palmetto* (cabbage palmetto)
- *Taxodium distichum* (cypress)
- *Magnolia glauca* (bay)
- *Fraxinus profunda* (ash)
- *Nyssa biflora* (black gum)
- *Acer rubrum* (maple)
- *Juniperus Virginiana* (cedar)
- *Persea pubescens* (red bay)

**SHRUBS AND WOODY VINES**

- *Myrica cerifera* (myrtle)
- *Rhus radicans* (poison ivy)
- *Phoradendron flavescens* (mistletoe)
- *Itea Virginica*
- *Cornus stricta?*
- *Parthenocissus quinquefolia* (Virginia creeper)
- *Baccharis halimifolia*
- *Aster Carolinianus*
HERBS

Sagittaria lancifolia
Cladium effusum (saw-grass)
Phragmites communis (reed grass)
Juncus Roemerianus (rush)
Orontium aquaticum
Senecio lobatus
Rumex verticillatus
Tillandsia usneoides (Spanish moss)
Scirpus validus (bulrush)
Nymphaea macrophylla (bonnets) (in stream)
Piaropus crassipes (water hyacinth) (floating)

Saururus cernus
Zizania aquatica? (wild rice)
Iris versicolor (blue flag)
Isoetes flaccida?
Rhynchospora corniculata
Scirpus lineatus?
Vicia acutifolia? (vetch)
Carex alata
Carex stipata?
Rhynchospora miliaea
Peltandra Virginica
Cicuta Curtissii

This list of plants has a good deal in common with that of the Apalachicola estuaries, although the two places differ greatly in the chemical composition of their soil and water. I did not make any examination of the peat, but I would not expect it to be very deep, and the parts that are full of trees will doubtless escape utilization for a long time to come.

ESTUARIES OF DADE COUNTY.

On the east side of Dade County there are quite a number of short rivers running from the Everglades to the coast, which, like the Suwannee River, seem to be coffee-colored all or nearly all the time, but must carry some calcium carbonate in solution, too. Also like the Suwannee, they have cut channels in limestone rock, and are of the nature of estuaries for a few miles from their mouths. These are of interest as being almost the southernmost estuaries in the United States, and having a somewhat tropical vegetation. They have not been examined very carefully. Most of the plants in the following list were noted in going up New River from Fort Lauderdale to the Everglades on April 12, 1909, and the remainder on the Miami River about two miles from its mouth a few days earlier.

TREES

Acer rubrum (maple) (New River)
Taxodium distichum (cypress)
Taxodium imbricarium?

Sabal Palmetto (cabbage palmetto)
Persea pubescens (red bay)
Ilex Cassine (swamp holly)
The peat was examined at the Miami River locality mentioned, and found to be about four feet deep, with streaks or patches of marl at various depths. Further information about it can be found in the table of analyses, under locality no. 27.
The alluvial swamps of coffee-colored streams differ from those of muddy rivers in being sandy instead of muddy (so that one can walk about in them with little discomfort when the water is low), but resemble them in containing little or no peat, and to a considerable extent in the character of the vegetation.

The following species have been observed between high and low water marks along the Ocklocknee River in Leon County, the Fenholloway near Hampton Springs, the Suwannee near Bradford, and Peace Creek or River near Arcadia.

**TREES**

- *Fraxinus Caroliniana* (ash)
- *Taxodium distichum* (cypress)
- *Carpinus Caroliniana* (ironwood)
- *Pinus Taeda* (short-leaf pine)
- *Crataegus viridis* (red haw)
- *Planera aquatica*
- *Ulmus Floridana?* (elm)
- *Salix nigra* (willow)
- *Acer rubrum tridens* (maple)
- *Sabal Palmetto* (cabbage palmetto).
- *Gleditschia aquatica* (locust)
- *Betula nigra* (birch) (on banks)
- *Ilex opaca* (holly) (in drier spots)
- *Pinus glabra* (spruce pine) (in drier spots)
- *Liquidambar Styraciflua* (sweet gum)
- *Quercus lyrata* (swamp post oak)
- *Quercus nigra* (water oak) (also a variety? with narrower leaves)
- *Nyssa Ogeche* (tupelo gum)
- *Bumelia lycioides*
- *Persea Borbonia* (red bay)
- *Ulmus alata* (elm)
- *Quercus Virginiana* (live oak)
- *Celtis sp.* (hackberry)
- *Hicoria aquatica* (swamp hickory)

**SMALL TREES OR LARGE SHRUBS**

- *Viburnum ebovatum*
- *Cornus stricta?*
- *Cyrilla racemiflora* (tyty)
- *Crataegus oestivalis* (mayhaw)
- *Ilex decidua*
- *Adelia acuminata*
- *Crataegus apiifolia* (and a few other haws)

**SHRUBS AND VINES**

- *Sebastiana ligustrina*
- *Berchemia scandens* (rattan vine)
- *Cephalanthus occidentalis* (button bush)
- *Vaccinium vitis-idaea* (blueberry)
- *Bignonia crassicaulis* (cross-vine)
- *Myrica cerifera* (myrtle)
- *Serenoa serrulata* (saw-palmetto)
- *Gelsemium sempervirens* (yellow jessamine)
- *Tecoma radicans* (cow-itch vine)
- *Styrax Americana*
- *Sageretia minutiflora*
- *Rhus radicans* (poison ivy)
- *Amelopsis arborea* (a vine)
- *Vitis rotundifolia* (muscadine)
- *Hypericum galioides*
- *Phoradendron flavescens* (mistletoe)
PRELIMINARY REPORT ON PEAT.

HERBS

*Tillandsia usneoides* (Spanish moss)

*Polypodium polypodioides* (a fern) (on trees)

*Dichondra Carolinensis*

*Tillandsia sps.* (air-plants)

*Calophanes sp.*

*Salvia lyrata*

MOSSES, ETC

*Brachelyma robustum*

*Porella pinnata*

Some of these plants are species which seem to be pretty fond of limestone—and there is a little of that in the water of all these streams—but probably none absolutely require it. The above list probably resembles that for the swamps of the upper Apalachicola River more than any other mentioned herein, although the order of relative abundance is somewhat different, and there seem to be a good many more vines in these swamps than in the muddy ones. This similarity of vegetation, like that between the estuaries of the Apalachicola and Suwannee Rivers, already pointed out, seems to indicate once more that the amount of fluctuation of the water-level is more important to some plants than the chemical properties of the soil or water.

The upper St. John's River is also a fluctuating stream with essentially non-calcareous water, but the vegetation bordering it, except where there are swamps fed by seepage from the land, is mostly of the prairie type (i.e., mostly herbs), and it would hardly be proper to correlate it with this. And as it forms no peat it may as well be omitted for the present.
In Escambia and Santa Rosa Counties, along the fresh-water bayous near Pensacola and about the mouth of the Blackwater River and some of its tributaries near Milton, where the water is strictly non-calcareous and never muddy, the following plants are found:

**TREES**

- Magnolia glauca (bay)
- Chamaecyparis thyoides (juniper)
- Cliftonia monophylla (tyty)
- Taxodium imbricarium (cypress)
- Nyssa biflora (black gum)
- Pinus Elliottii (slash pine)
- Ilex Cassine (swamp holly)
- Persea pubescens (red bay)
- Osmanthus Americanus (wild olive)

**SHRUBS AND VINES**

- Smilax laurifolia (bamboo vine)
- Myrica cerifera (myrtle)
- Pieris nitida
- Hypericum fasciculatum?
- Ilex coriacea
- Smilax Walteri
- Pieris phillyreifolia
- Gaylussacia hirtella
- Ilex glabra (gallberry)
- Sabal glabra (palmetto)
- Myrica inodora
- Azalea viscosa (swamp honeysuckle)
- Cyrilla racemiflora (tyty)
- Viburnum nudum (possum haw)

**HERBS**

- Cladium effusum (saw-grass)
- Tillandsia usneoides (Spanish moss)
- Sarracenia Drummondii (pitcher-plant)
- Mesadenia sulcata
- Eriocaulon decangulare
- Castalia odorata (white water-lily)
- Polygala cymosa
- Rhynchospora Tracyi
- Macranthera fuchsioides
- Orontium aquaticum
- Baldwinia uniflora
- Sagittaria lancifolia
- Pontederia cordata (wamppee)
- Juncus Roemerianus (rush)
- Dichromena latifolia
- Mayaca sp.
- Osmunda regalis (a fern)
- Nymphaea sagittifolia (bonnets) (in stream)
- Monniera Caroliniana
- Proserpinaca pectinata
- Eriocaulon compressum
- Xyris sp.
- Osmunda cinnamomea (a fern)
- Fuirena scirpoidea
- Eleocharis cellulosa
- Cyperus Haspan
- Lophiola aurea
- Peltandra Virginica
Fig. 1.—Marshes at southeastern corner of Hog Island (Levy County), at coastward limit of trees. *Sabal Palmetto* and *Taxodium distichum* (cypress) at left, *Piaropus* (water-hyacinth), *Fraxinus* (ash), etc., at right. April 15, 1910.

Fig. 2.—Swampy east side of Hog Island, from eastern branch of Suwannee River. April 15, 1910.
ESTUARINE SWAMPS OF WEST FLORIDA.

Fig. 1.—Looking upstream from foot-bridge through swamp of Blackwater River opposite Milton, Santa Rosa County. Shows *Pinus Elliottii*, *Hypericum fasciculatum*, *Cladium*, etc. June 22, 1909.

Fig. 2.—Looking downstream from same point (in one of the treeless strips), showing *Pinus Elliottii*, *Taxodium imbricarium*, *Chamaecyparis*, *Cladium*, *Castalia*, etc. June 22, 1909.
Fig. 1.—Cypress pond in East Florida flatwoods northeast of Bellamy, Alachua County. The trees are Taxodium imbricarium (cypress) and Pinus Elliottii (slash pine). July 17, 1909.

Fig. 2.—Small bay in Middle Florida flatwoods about 2½ miles north of Fanlew (Jefferson County), with Taxodium imbricarium (cypress), Cyrilla parvisulph (tyty), Ilex myrtifolia (yaupon), etc. March 20, 1910.
SMALL LAKES.

Fig. 1.—View of a small lake near Ellsworth Junction (Lake County), showing bordering fringe of *Serenoa* (saw-palmetto) and *Ilex glabra* (gallberry), and long-leaf pine saplings encroaching on it. Feb. 20, 1909.

Fig. 2.—Northwest shore of Lake Milton, about 5 miles south of Tavares (Lake County), showing zonal arrangement of peat-forming vegetation. *Spartina Bakeri* (a large grass) in the foreground. Other marsh vegetation mostly *Cladium* (saw-grass). Feb. 20, 1909.
As in the case of the Apalachicola River estuary, many of these herbs are confined to irregular treeless strips, or marshes (see plate 22), but it would hardly be worth while to describe the marsh and swamp areas separately.

In the swamp of the Blackwater River near Milton the peat is as much as 20 feet deep, which probably indicates a comparatively recent subsidence of that amount, as in the case of the mud-filled estuary of the Apalachicola River. Furthermore, peat would hardly form at a depth of 20 feet below sea-level (though in this case one cannot be sure that the lower layers are not the remains of logs which drifted down the river and sank in centuries past). To all external appearances the peat at this locality is of very good quality, except that it has sandy layers in it, probably representing seasons of excessive floods. But even the best samples (see analyses under locality no. 7) were more than half mineral matter, and therefore utterly unfit for fuel.

**ESCAMBIA AND YELLOW RIVERS.**

The tributaries of the Escambia River flow through about as much red clay country in the coastal plain of Alabama as do those of the Choctawhatchee, and the Yellow River, although a smaller stream, must carry mud at times, to judge from its name and the character of the country about its head-waters; but I have never seen either of these as muddy as the Choctawhatchee usually is, and the vegetation of their estuaries resembles that of the Blackwater River just described much more than anything else I have seen, so that it will be convenient, if not strictly accurate, to discuss it here.

A few minutes was spent at the mouth of each of these rivers the latter part of September, 1910, and the following plants noted:

**TREES**

*Taxodium imbricatum* (pond cypress)  
*Nyssa biflora* (black gum)  
*Pinus Elliottii* (slash pine)  
*Magnolia glauca* (bay)

**SHRUBS**

*Fraxinus Caroliniana* (ash)  
*Smilax laurifolia* (bamboo vine)  
*Hypericum fasciculatum*
HERBS

*Coreopsis angustifolia*  
*Lophiola aurea*

*Cladium effusum* (saw-grass)  
*Zizania aquatica* (wild rice)

*Typha latifolia* (cat-tail)  
*Cyperus virens*

*Oxypolis filiformis*  
*Eriocaulon* sp.

*Pontederia cordata* (wampee)  
*Phragmites communis* (reed grass)

*Juncus Roemerianus* (rush)  
*Cyperus Haspan."

*Fuirena scirpoidea*  
*Sagittaria lancifolia"

*Panicum virgatum* (a grass)  
*Ludwigia alata"

*Boltonia diffusa*  
*Iris versicolor* (blue flag)

*Castalia odorata* (white water-lily)  
*Juncus polycephalus* (rush)

*Mesadenia sulcata*  
*Polygala cymosa"

*Eryngium virgatum*  
*Nymphaea fluviatilis* (bonnets)

*Rhynchospora corniculata*  
*Myriophyllum* sp.

Just about half the species noted in each of the two swamps (which are only 12 miles apart in a straight line) were common to both.

Right at the mouths of these rivers the marshes with shrubs and herbs are more extensive than the wooded swamps, but in going up stream one would doubtless soon find the proportions reversed.

The peat is several feet deep in the Escambia estuaries (its depth was not investigated at the mouth of the Yellow River), but probably still more impure than in the case of the Blackwater, and therefore of little value.

EAST FLORIDA.

The only fresh-water estuary in East Florida, besides the St. Marys River (which I have not examined on the Florida side) and a few creeks south of it, is that of the St. Johns River. The tides ascend this remarkable stream about to Lake George, giving it something like 100 miles of estuary. The following plants which I have seen in the river swamps between Palatka and the railroad bridge about five miles south of there are probably fairly typical of this whole lower portion of the St. Johns.

TREES

*Sabal Palmetto* (cabbage palmetto)  
*Fraxinus* sp. (ash)

*Acer rubrum* (maple)  
*Taxodium distichum* (cypress)

*Magnolia glauca* (bay)  
*Quercus nigra* (water oak)

*Liquidambar Styraciflua* (sweet gum)  
*Persea pubescens* (red bay)

*Ilex Cassine?* (swamp holly)

SHRUBS AND VINES

*Myrica cerifera* (myrtle)  
*Berchemia scandens* (rattan vine)

*Sabal glabra* (palmetto)  
*Amorpha fruticosa"

*Smilax laurifolia* (bamboo vine)
HERBS

* Tillandsia usneoides* (Spanish moss)  
* Osmunda regalis* (a fern)  
* Saururus cernuus*  
* Vallisneria spiralis* (eel-grass) (under water)  
* Lorinscria arcola* (a fern)  
* Piaropus crassipes* (water hyacinth) (introduced)  
* Rhynchospora corniculata*  
* Centella repanda*

About a mile south of Palatka the peat is about 20 feet deep at the water's edge, and of course of very good quality, because the St. Johns River is never muddy. (See analysis under locality No. 8.) In such an accessible locality it ought to be valuable.

About a mile north of Palatka the river is bordered in part by saw-grass marshes, and a plant for the manufacture of fertilizer filler from peat has recently been erected there. Similar marshes probably occur at many other places below Palatka, but I have not had opportunity to examine any of them. There are extensive peat deposits on two tributaries of the lower St. Johns, namely, Julington Creek and Crescent Lake, which might also be classed as estuarine, but they are so unique and interesting in some ways that discussion of them will be deferred to a subsequent chapter.

NON-CALCAREOUS SEEPING SWAMPS.

Wherever the bottom of a valley dips slightly below the general ground-water level the water slowly oozes out and flows away, and certain plants which prefer a perpetually saturated soil establish themselves. In Florida such places are practically immune from the fires which periodically sweep through the pine forests, and a comparatively dense growth of trees and shrubs is the result. The decaying wood and leaves from these keeps forming peat, the thickness of which is limited only by the nature of the surrounding topography and the height to which the ground-water level can be raised by capillary attraction. In the final stage of such a swamp the upper layers of peat would be dry enough for the process of humification to set in, and the vegetation would approach the hammock type. It is quite likely that many of our low hammocks have had just such a history.

The seeping swamps of Florida are of many different types. The commonest are those of branches and small creeks, which are frequent in nearly all parts of the state, but need not be described here, as they are too shallow to be considered as sources of peat. A few of the other types, with deeper peat, will now be described separately.
SWAMPS BORDERING ESCAMBIA BAY.

The west side of Escambia Bay, in the county of the same name, from the mouth of the Escambia River for eight or ten miles southward, is bordered by bluffs of coarse pinkish sand, mottled clay, etc. (probably of Pliocene age), which are over 100 feet high in many places. For about half their length these bluffs rise almost from the water's edge, in the manner of typical sea-cliffs, and are nearly bare of vegetation. In some places, however, especially where the line of bluffs is concave, the action of the waves and currents has been such as to build barrier beaches and cuspatre forelands a few hundred feet or yards out from the bluffs. Where this is the case the bluffs are usually covered with dense vegetation of the sandy hammock type, and the water seeping out from them has given rise to non-alluvial swamps between bluff and beach.

On Sept. 20, 1910, I made a brief examination of such a swamp between Gaberonne and Bohemia, about six miles northeast of Pensacola. It is nearly a mile long, and crescent-shaped, the beach being slightly concave and the bluffs still more so. Its soil is designated as "Portsmouth sand" on the U. S. soil map of Escambia County, but it is really mostly peat, with a depth of at least four feet in some places.

The following plants were observed here.

**TREES**

- *Pinus Elliottii* (slash pine)
- *Magnolia glauca* (bay)
- *Nyssa biflora* (black gum)
- *Acer rubrum* (maple)

**SHRUBS AND VINE**

- *Myrica cerifera* (myrtle)
- *Cyrilla racemiflora* (tyty)
- *Smilax laurifolia* (bamboo vine)
- *Vitis rotundifolia* (muscadine)
- *Decodon verticillatus*
- *Rhus Vernix* (poison sumac)

**HERBS**

- *Panicum gibbum* (a grass)
- *Osmunda regalis* (a fern)
- *Jussicaea suffrutescens* (in open places, introduced)
- *Panicum verrucosum* (a grass)
- *Boehmeria cylintrica*
- *Bidens coronata*
- *Eupatorium serotinum* (introduced?)
- *Carex glaucescens*
- *Sagittaria latifolia* (arrowhead)
- *Triadenum Virginicum*
- *Cladium effusum* (saw-grass)
- *Scutellaria sp.*
Sphagnum sp. Trypethelium cruentum (a red lichen) (on trees)

No samples of this peat were taken, but it is certainly full of logs, and probably rather sandy besides.

TYTY SWAMPS OF WALTON COUNTY.

(Fig. 18)

In a sort of "steep-head" just northwest of DeFuniak Springs there is a dense tyty swamp with steep sandy pine-covered slopes around its head. Its vegetation consists almost entirely of slender tyty bushes (Cliftonia), growing very close together and about 25 feet tall. Around the edges there is quite a variety of sandy bog plants, forming a fringe which is probably gradually creeping

Fig. 18.—Interior of dense tyty swamp just northwest of DeFuniak Springs (Walton County) showing nothing but Cliftonia. June 24, 1909. (Locality No. 39).
up the slopes as the swamp increases in depth by the accumulation of peat. About 100 feet in from the edge of this swamp the peat was found to be ten feet deep, and of fair quality. (See analysis under locality 39.) The area of the swamp was not determined, but it covers a good many acres, and there are doubtless other places of the same kind in the same general region.

GUM SWAMPS OF LEON COUNTY.

(FIG. 19)

A few miles west and south of Tallahassee, just where the red hills merge into the lower and more sandy country of the Middle Florida hammock belt, there are some non-alluvial swamps of a somewhat different type from anything seen elsewhere. Some people call them bays, probably on account of the numerous bushes in them, though the bushes are much less conspicuous than in typical bays, being here completely overshadowed by the tall trees (which are mostly black gums). An interesting feature of these swamps is that nearly all the species of plants in them are found also in the great Dismal Swamp of Virginia and North Carolina. The reason for this is not obvious, as there is not much similarity in the climate of the two places, and still less in the nature of the surrounding country. The plants which have been identified in these swamps are about as follows:

<table>
<thead>
<tr>
<th>TREES</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nyssa biflora (black gum)</td>
</tr>
<tr>
<td>Magnolia glauca (bay)</td>
</tr>
<tr>
<td>Taxodium distichum? (cypress)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>SHRUBS AND VINES</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pieris nitida</td>
</tr>
<tr>
<td>Itea Virginica</td>
</tr>
<tr>
<td>Leucothoe racemosa</td>
</tr>
<tr>
<td>Smilax laurifolia (bamboo vine)</td>
</tr>
<tr>
<td>Cyrilla racemiflora (tyty) (toward edges)</td>
</tr>
<tr>
<td>Phoradendron flavescens (mistle-toe)</td>
</tr>
<tr>
<td>Vaccinium virgatum? (blueberry)</td>
</tr>
<tr>
<td>Cholisma ligustrina</td>
</tr>
<tr>
<td>Clethra alnifolia</td>
</tr>
<tr>
<td>Aronia arbutifolia</td>
</tr>
<tr>
<td>Cephalanthus occidentalis (button bush)</td>
</tr>
<tr>
<td>Pieris phillyreifolia</td>
</tr>
<tr>
<td>Rhus radicans (poison ivy)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>HERBS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tillandsia usneoides (Spanish moss)</td>
</tr>
<tr>
<td>Utricularia inflata, etc.</td>
</tr>
<tr>
<td>Saururus cernus</td>
</tr>
<tr>
<td>Triadenum petiolatum</td>
</tr>
<tr>
<td>Polypodium polypodioides (a fern) (on trees)</td>
</tr>
<tr>
<td>Lorineria arcelata (a fern)</td>
</tr>
<tr>
<td>Boehmeria cylindrica</td>
</tr>
<tr>
<td>Lemna sp.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>MOSSES, ETC.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pallavicinia Lyellii</td>
</tr>
<tr>
<td>Leucobryum glaucum</td>
</tr>
</tbody>
</table>
The swamp of this type which was examined most thoroughly (about 5 miles W. N. W. of Tallahassee) covers about 200 acres, and the peat is at least six feet deep in the middle, but full of logs, as seems to be the case in nearly all our seepage swamps. Analyses of this peat will be found under locality No. 2.

Fig. 19.—Interior of gum swamp about 5 miles W.N.W. of Tallahassee, Leon County. Trees mostly *Nyssa biflora* (black gum, leafless at this time), with a few small specimens of *Magnolia glauca* (bay). Feb. 27, 1909. (Locality No. 2).
SLASH PINE BOGS, OR BAYS

(FIG. 20)

In various parts of Florida, as well as in adjoining states, there are extensive sphagnous bays in which the slash pine is the dominant tree, probably exceeding in bulk all the rest of the vegetation. Considerable areas in Okefenokee Swamp* and along the St. Marys River, just across the line in Georgia, are of this character, and in this state I have seen such bays in Nassau, Lake, Polk and Hills-

borough Counties. The large and almost impenetrable Bay Swamp, in the northern part of Columbia and Baker Counties, which is mentioned in a few descriptions of Florida, but rarely shown on maps, probably consists at least in part of this type of vegetation. These bays are generally in comparatively level sandy country, but how they are formed is still a mystery. They bear considerable resemblance to the pocosins of eastern North Carolina, but those, too, are not well understood.

The following list of plants is compiled from one slash-pine bog between Ellsworth Junction and Astatula in Lake County, two between Auburndale and Carter’s, in Polk County, and one about two miles west of Plant City, Hillsborough County:

**TALL TREES**

*Pinus Elliottii* (slash pine)

**MEDIUM-SIZED TREES.**

*Nyssa biflora* (black gum)  
*Acer rubrum* (maple)

**SMALL TREES**

*Magnolia glauca* (bay)

**SHRUBS AND VINES**

*Smilax laurifolia* (bamboo vine)  
*Viburnum nudum* (possum haw)  
*Vitis rotundifolia* (muscadine)  
*Pieris nitida*  

**HERBS**

*Anchistea Virginica* (a fern)  
*Erianthus sp.* (a large grass)  
*Osmunda cinnamomea* (a fern)  
*Gyrotheca tinctoria* (paint-root)  
*Xyris fimбриata*  
*Ludwigia lanceolata*  
*Osmunda regalis* (a fern)  
*Cladium effusum* (saw-grass)

**MOSSES**

*Sphagnum* (perhaps several species)

The trees, shrubs and vines often grow very densely, making such places almost impenetrable. The herbs are relatively inconspicuous, and the *Sphagnum* carpets the ground everywhere. Samples of peat were taken from a bog of this kind about two miles west of Auburndale (locality No. 8). At the point tested it was about ten feet deep, with a bottom of very sticky black mud. This place (and perhaps most others of the same kind) seems to be subjected to occasional fires, which do great damage to the broad-leaved trees and shrubs—especially the bays—but not much to the pines.
Scattered all through the lake region are many non-alluvial swamps—or bays, as they might be called—usually located between high pine land and some of the lake marshes which will be described later. Most of their water probably seeps out the sandy hills of the pine land. The vegetation of such places is about as follows:

**TREES**
- Magnolia glauca (bay)
- Gordonia Lasianthus (bay)
- Acer rubrum (maple)
- Ilex Cassine (swamp holly)
- Pinus Elliottii (slash pine)
- Persea pubescens (red bay)

**SHRUBS AND VINES**
- Myrica cerifera (myrtle)
- Smilax laurifolia (bamboo vine)
- Pieris nitida
- Cephalanthus occidentalis (button bush)
- Itea Virginica
- Rhus radicans (poison ivy)

**HERBS**
- Blechnum serrulatum (a fern)
- Osmunda cinnamomea (a fern)
- Osmunda regalis (a fern)
- Anchistea Virginica (a fern)
- Saururus cernnus
- Lorinseria areolata (a fern)
- Tillandsia usneoides (Spanish moss)
- Dryopteris unita (a fern)

**MOSSES, ETC.**
- Sphagnum spp.
- Pallavicinia Lyellii

It is interesting to note that all but one of the trees and half the shrubs in this list are evergreen, and all but two of the herbs are ferns. I have found somewhat similar conditions in certain swamps in South Georgia* whose water the sun never shines on from the time it falls as rain until after it leaves the swamp.

The peat in these swamps is often several feet deep, but as they are located in a region where there is plenty of treeless peat, much more easily worked, they are not likely to be of much importance in the near future, and I have taken no samples from them.

**NON-ALLUVIAL SWAMPS OF DESOTO COUNTY.**

(FIG. 2I)

From half a mile to a mile east of the Peace River, on land gently sloping toward it, for several miles north and south of Arcadia, one can see from either the A. C. L. or the C. H. & N. R. R. (for these two railroads are almost in sight of each other for

several miles, and the swamps in question mostly lie between them), at intervals of half a mile or less, a number of non-alluvial swamps approximately circular in shape and a few hundred feet in diameter. They appear to be correlated with small seepage springs, perhaps caused by some impervious stratum which comes to the surface on this gentle slope. There may even be more than one such stratum, for a few instances were noticed where there were two of these circular swamps a short distance apart, one a little higher up the slope than the other and connected by a small stream.

These swamps are too shallow to be of any special importance for peat, the greatest depth found only being three feet; but they are so unique and well-defined that a description will not be out of place here. The dominant trees are black gums and bays, about 60 feet tall, and between the swamp and the surrounding nearly flat pine lands there is usually a narrow strip of sandy bog. The following list is compiled from notes taken in several such swamps between Arcadia and Nocatee on Feb. 17, 1909.

**TREES**

- *Nyssa biflora* (black gum)
- *Magnolia glauca* (bay)
- *Acer rubrum* (maple)
- *Ilex Cassine* (swamp holly)
- *Persea pubescens* (red bay)
- *Gordonia Lasianthus* (bay)
- *Pinus Elliottii* (slash pine)
- *Ulmus sp.* (elm)
SHRUBS AND VINES

Vitis rotundifolia (muscadine)  Phoradendron flavescens (mistletoe)
Myrica cerifera (myrtle)  Itea Virginica
Viburnum nudum (possum haw)  Rhus radicans (poison ivy)
Smilax laurifolia (bamboo vine)  
Parthenocissus quinquefolia (Virginia creeper)

HERBS

Blechnum serrulatum (a fern)  Osmunda cinnamomea (a fern)
Tillandsia sps. (air-plants)  Dryopteris unita (a fern)
Saururus cernuus  Hydrocotyle sp.
Peltandra sagittifolia?  Mayaca Aubleti
Peltandra Virginica  Nephrolepis exaltata (sword fern)
Arisaema triphyllum (Indian turnip)  Osmunda regalis (a fern)

MOSSES, ETC.

Sphagnum cuspidatum (and others)  Pallavicinia Lyellii
Thuidium sp.

This list of plants does not differ very much from that of the lake region swamps just described. The interior of such a swamp is decidedly less tropical in appearance than one might expect in latitude 27°15'. The various Tillandsias, and the three ferns which are not known north of Florida, are about the only suggestions of tropical conditions, most of the other plants being just as common four or five hundred miles farther north. Several of the species, such as Nyssa, Gordonia, Pinus Elliottii, Viburnum, Phoradendron and Arisaema, are here just about at their southern limits.

A sample of peat from about a foot below the surface in one of these swamps (locality No. 21) was very coarse, but of pretty good quality otherwise.
STAGNANT WATER.

Strictly speaking, there is no such thing as stagnant water in Florida, for the water in the ground is slowly but constantly circulating, and that in ponds and lakes of course still more so. But the term stagnant is here applied to all water (not already provided for in the foregoing pages) which has no perceptible current; and this includes all the lakes, even those which are parts of the Ocklawaha and St. Johns River systems and have considerable streams issuing from them.

Lakes and ponds may be either evanescent (intermittent) or permanent. The most conspicuous examples of the former type are the large shallow lakes of the Middle Florida hammock belt. Most of these are flat-bottomed, with sink-holes at or near their edges which keep them drained most of the time.* Even where there are no well-defined sinks the shallowness of such lakes permits them to dry out between rainy seasons. All such places have been favorite pastures for cattle ever since the country was first settled, and this kind of treatment has brought in so many weeds (especially dog-fennel, *Eupatorium capillifolium*, and a grass, *Anastrophus paspaloides*) and damaged the original vegetation so much that it would be a very difficult matter to reconstruct it now.

Some of these shallow lakes, or prairies as the driest ones are called, contain small saucer-like depressions a foot or more below the general surface, and these may retain water long enough to allow some peat to form, as already stated in the description of the Middle Florida hammock belt. Some small lakes and ponds with concave bottoms, mostly in this same hammock belt or in the lime-sink region, also contain a little peat, but it is usually very shallow and mixed with a good deal of sand.

In many places on the peninsula, especially in flat pine woods where limestone is near the surface, from about Sumter County southward, there are prairies not connected with sinks or streams, varying in size from a few acres to several thousand acres. These are nearly flat, depressed a few inches below the surrounding pine woods, and flooded in the wet season. The smaller ones are commonly circular or nearly so. These prairies are very characteristic of South Florida, and probably have no counterpart anywhere else. Except for the Everglades, which might be regarded as a very large prairie (and will be described farther on), they contain little or no peat; and they are scattered over such a wide territory.

*This type of lake basin has been pretty fully discussed by Dr. Sellards in a preceding paper of this volume (pages 43-75)
and vary so much in appearance, that it is hardly worth while to attempt any general statements about their vegetation, except that grasses and other plants with very narrow leaves always make up the bulk of the vegetation where it is undisturbed. Just why these places are treeless is one of the numerous unsolved problems of Florida geography.

In the northern part of the state shallow depressions in the pine woods almost invariably contain a rather dense growth of trees, as in the cypress, gum, and mayhaw ponds, or more bushes than trees, in which case they are known as bays.

CYPRESS PONDS.

(PLATE 23.1)

Cypress ponds are very abundant in the West Florida limestone region and East Florida flatwoods, and frequent in the northern parts of the Gulf hammock region and South Florida flatwoods, but rare in the lake region and south of latitude 28°. They are of various sizes and shapes, but usually approximately circular or slightly elliptical and from one to a hundred acres in extent. In wet weather the water in them may be as much as three feet deep in the middle, while in late spring they are usually dry or nearly so, and it is not an uncommon occurrence for fire to burn through them as it does through the surrounding pine forests. This being the case they are of no importance as sources of peat, but they are of considerable scientific interest as representing a distinct and not very widely distributed (only from South Carolina to Mississippi) type of vegetation.

I have not closely examined any of the cypress ponds of the Gulf hammock region except in winter, but they do not seem to differ much from those in other parts of the state. The following list is made up from notes taken in Jackson, Columbia, Baker, Duval, Clay, Bradford, Alachua, Putnam, St. John's, Orange, Osceola and Pasco Counties.

TREES

Taxodium imbricarium (pond cypress)  Nyssa biflora (black gum)
Pinus Elliottii (slash pine)  Gordonia Lasianthus (bay)
Magnolia glauca (bay)

SMALL TREES OR LARGE SHRUBS

Ilex myrtifolia (yupon)  Ilex Cassine (swamp holly)
Nyssa Ogeche (tupelo gum)  Cyrilla racemiflora (tyty)
Myrica cerifera (myrtle)
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SHRUBS AND WOODY VINES

Hypericum fasciculatum
Smilax laurifolia (bamboo vine)
Hypericum myrtifolium
Pieris nitida
Pieris phillyreifolia
Phoradendron flavescens (mistletoe) (mostly on black gum)

Leucothoe racemosa
Stillingia aquatica
Smilax Walteri
Itea Virginica

HERBS

Anchistea Virginica (a fern)
Tillandsia usneoides (Spanish moss)
Panicum hemitomon (maiden cane)
Polygala cymosa
Eriocaulon decangulare
Dichromena latifolia
Pluchea bifrons
Eriocaulon compressum
Oxypolis filiformis
Aristida palustris (a grass)
Centella repanda
Gerardia linifolia
Ipomoea sagittata (morning-glory)
Tillandsia recurvata (air-plant)
Sabbatia decandra
Pontederia cordata (wampee)
Gyrotheca tinctoria (paint root)
Erigeron vernus
Leptopoda Helianthem
Xyris sp.
Proserpinaca pectinata
Rhexia stricta
Scleria Baldwwii
Cladium effusum (saw-grass)
Rhynchospora axillaris
Ludwigia linifolia
Manisuris Chapmani (a grass)

Asclepias lanceolata (milkweed)
Gratiola ramosa
Tillandsia tenuifolia (air-plant)
Chondrophyra nudata
Lycopus sp.
Panicum erectifolium (a grass)
Rhynchospora corniculata
Panicum agrostoides? (a grass)
Erianthus sp. (a grass)
Andropogon sp. (broom-sedge)
Drosera capillaris
Osmunda cinnamomea (a fern)
Scleria sp.
Monniera Caroliniana
Castalia odorata (white water-lily)
Coreopsis nudata
Ludwigia pilosa
Triadenum Virginicum
Lobelia paludosa
Aster Chapmani
Rhynchospora Tracyi
Panicum sp.
Mesosphaerum radiatum
Mesadenia lanceolata
Panicum tenerum (a grass)
Carex Walteriana?
Fuirena brevijeta

MOSSES

Sphagnum sp.
Sphagnum macrophyllum.

The two trees first mentioned, pond cypress and slash pine, usually exceed in bulk all the rest of the vegetation of these ponds; but there are ponds—usually rather small ones—in which the third species, black gum, is the most abundant and almost the only tree. From Washington County on the west to Suwannee County
on the east one also occasionally sees small shallow ponds characterized by an abundance of mayhaw, *Crataegus aestivalis*, a small tree which does not seem to grow in cypress ponds at all. Both gum and mayhaw ponds seem to occur in more clayey regions than most cypress ponds.

**BAYS.**

(PLATE 23.2. FIG. 22)

Closely related to the cypress ponds are the bays, which seem to differ chiefly, as far as environmental conditions are concerned, in being situated on deeper sand (cypress ponds generally have clay, sometimes rock, under them within a very few feet of the surface) and having less fluctuation of water-level. For some reason not fully understood, the soil and water seem to be more acid than in the cypress ponds, and the vegetation comprises more small trees and shrubs than large trees.

Bays are especially characteristic of the Middle Florida flat-woods (e.g., San Pedro Bay), and they are also common in the West Florida coast region, and occasional elsewhere in the northern parts of the state. The following list of bay plants is compiled from notes taken in Franklin, Gadsden, Leon, Wakulla, Jefferson, Taylor, Lafayette, Alachua and Levy Counties.

**TREES**

- *Taxodium imbricarium* (pond cypress)
- *Pinus Elliottii* (slash pine)
- *Pinus serotina* (black pine)
- *Magnolia glauca* (bay)

- *Nyssa biflora* (black gum)
- *Persea pubescens* (red bay)
- *Acer rubrum* (maple)
- *Gordonia Lasianthus* (bay)

**SMALL TREES OR LARGE SHRUBS**

- *Cyrilla parvifolia* (tyty)
- *Ilex myrtifolia* (yupon)
- *Cliftonia monophylla* (tyty)

- *Cyrilla racemiflora* (tyty)
- *Ilex Cassine* (swamp holly)
- *Myrica cerifera* (myrtle)

**SHRUBS, ETC.**

- *Smilax laurifolia* (bamboo vine)
- *Pieris nitida*
- *Pieris phillyreifolia*
- *Hypericum fasciculatum*
- *Crookea microsepala*
- *Ilex glabra* (gallberry)
- *Serenoa serrulata* (saw-palmetto)

- *Leucothoe racemosa*
- *Smilax Walteri*
- *Clethra alnifolia*
- *Aronia arbutifolia*
- *Azalea viscosa?* (swamp honeysuckle)
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HERBS

Anchistea Virginica (a fern)  Ludwigia lanceolata
Tillandsia usneoides (Spanish moss)  Bartonia verna
Pentederia cordata (wampee)  Utricularia cornuta
Eriocaulon compressum  Rhynchospora leptorrhyncha
Polygala cymosa  Xyris sp.
Xyris fimbriata  Centella repanda
Panicum hemitomon (maiden cane)  Osmunda cinnamomea (a fern)
Castalia odorata (white water-lily)  Eriocaulon decangulare
Syngonanthus flavidulus  Lyco podium alopecuroides
Sarracenia psittacina (pitcher plant)  Drosera capillaris

MOSSES

Sphagnum ssp.  Lophiola aurea

Fig. 22.—Deep tyty bay, treeless in middle, about a mile north of Carrabelle, Franklin County. June 10, 1909. (Locality No. 37).

The bays in the flatwoods hardly ever contain more than a foot or two of peat, and that is of course full of woody roots; but those of the West Florida coast region are deeper, one near Carrabelle (fig. 22) being at least ten feet deep, and treeless in the middle. Analyses of peat from three bays on St. James Island, Franklin County, will be found under localities 36 to 38.
PERMANENT OPEN WATER.

We now come to the most important class of peat deposits, namely, those associated with permanent lakes. The lakes of the lake region can be divided somewhat arbitrarily into two classes, small and large. Most of the small lakes are less than half a mile in diameter, approximately circular, with sandy bottoms and no outlets; and on account of their small size they never have large waves on them. The large lakes are a mile or more in diameter, irregularly shaped, and usually connected with streams, and in many cases the vegetation around them seems to indicate a slight influence of limestone either in soil or water or both. Very few measurements of the depth of these lakes have been made, but the slope of the surrounding pine hills seems to continue some distance below the surface without much change, instead of red hills passing abruptly into flat lake-bottoms as in the prairie-like lakes of the Middle Florida hammock belt.

Both kinds of lakes fluctuate perhaps a foot or so with the seasons, and their level varies also from one year to another, probably with variations in the annual rainfall. Just at present most of the lakes seem to be a few feet lower than they were a decade or two ago, for many of the smaller ones have a fringe of saplings of long-leaf pine (a tree which demands dry soil) around them, a little below what was evidently once high-water mark. (See plate 24I.)

SMALL LAKES.

(PLATE 24)

The vegetation in and around the small lakes is usually arranged in more or less perfect concentric zones, corresponding to the depth of the water, or the distance above it on the shore. The boundaries between them are very ill-defined, however, for there seems to be in most cases a complete gradation from the bonnets, etc., in deep water to the pines around the shores.

The maximum depth at which vegetation can grow in our lakes has not been investigated, but it does not take many feet of coffee-colored water to shut off the sun's light entirely, and all flowering plants, ferns, mosses, etc., need light to grow. In the depths of the lakes there may be algae, diatoms, bacteria, and other low forms of plant life, but plants which send up green leaves to the surface do not usually grow in more than five or six feet of water.

In the middle of lakes which do not exceed this depth, or around the edges of open water in the deeper ones, one or both of two
plants of the water-lily family, *Castalia odorata* and *Nymphaea macrophylla*, can usually be found. These may grow in water only a few inches deep, but in that case they are usually stunted. In slightly shallower water the following herbs are characteristic: *Pontederia cordata* (wampee), *Sagittaria lancifolia*, *Panicum hemitomon* (maiden cane).

A little nearer the shore, where the peat is exposed at low water, but still always wet, small trees of *Magnolia glauca* (bay), or such shrubs as *Hypericum fasciculatum* and *Cephalanthes* (button bush), are often found, but the vegetation is usually all herbaceous, as follows:

* Sagittaria lancifolia  
* Panicum hemitomon (maiden cane)  
* Eriocaulon compressum  
* Pontederia cordata (wampee)  
* Fuirena scirpoidea  
* Cyperus strigosus?  
* Xyris sp.  
* Lachnocalon sp.  
* Erianthus sp. (a tall grass)  
* Cladium efigsum (saw-grass)  
* Drosera capillaris?  
* Hydrocotyle umbellata  
* Gyrotheca tinctoria (paint-root)  
* Amphotocarpum sp.? (a grass)  
* Lycopodium Chatmani  
* Centella repana

A little higher up, on sandy shores which are inundated at high water, but exposed most of the time, may be found the following. (In this list and the one just above, it has not been possible to arrange the species as strictly in order of abundance as elsewhere in this report, on account of the difficulty of determining the limits of the zones.)

**TREES**
(all of them rare)

* Pinus Elliottii* (slash pine)  
* Ilex Cassine* (swamp holly)  
* Nyssa biflora* (black gum)  
* Magnolia glauca* (bay)  
* Gordonia Lasianthus* (bay)  
* Taxodium imbricarium* (pond cypress)

**SHRUBS**
(not common)

* Myrica cerifera* (myrtle)  
* Hypericum fasciculatum*  
* Hypericum myrtifolium  
* Hypericum opacum
HERBS

Drosera capillaris
Spartina Bakeri (a large grass)
Juncus scirpoides compositus (a rush)
Lachnocaulon glabrum
Lachnocaulon Bevrichianum
Ludwigia suffruticosa
Eleocharis Baldwinii
Utricularia subulata
Xyris Baldwiniana
Xyris sp.
Hydrocotyle sp.
Anchistea Virginica (a fern)

Solidago fistulosa (golden-rod)
Anastrophus paspaloides (a grass)
Eriocaulon decangulare
Pluchea bifrons
Sabbatia grandiflora
Panicum erectifolium? (a grass)
Rhynchospora fusca
Rhynchospora axillaris
Rhynchospora fuscicularis?
Bartonia verna
Centella repanda
Triadenum Virginicium

At the very limit of high water are sometimes found Pinus Caribaea or small saplings of Pinus palustris (long-leaf pine), a few shrubs, such as Pieris nitida, Serenoa (saw-palmetto), Ilex glabra (gallberry), Vaccinium sp. (huckleberry) and Cyrilla sp. (tyty), and one or more of the following herbs: Spartina Bakeri, Aristida spiciformis, Juncus scirpoides compositus, and Rhynchospora fusca. Often this sort of vegetation makes a belt of low scrub a good many yards in width, in which Pinus Caribaea, Serenoa, Pieris nitida, Ilex glabra and Aristida spiciformis are the prevailing plants. But where the shores are comparatively steep there is usually a well-marked fringe of saw-palmetto just above high-water mark (see plate 24.1), and immediately back of it the characteristic high pine land with long-leaf pine, turkey oaks, wire-grass, etc. The plants of the various zones above described all tend to migrate toward the center of the lake as the peat accumulates, and when the lake is completely filled, and thus converted into a peat prairie (which will be described later), some of the same species which grew on sandy shores are found well out toward the middle, on several feet of peat.

The peat around small lakes which are not completely filled is usually too shallow to be of much importance, but it is of pretty good quality, being almost free from mineral matter and woody roots and stems. Analyses of this kind of peat will be found in the table under localities 12, 13 and 22.
The formation of peat in the large lakes of the lake region is complicated by the fact that all exposed shores are constantly washed by the waves. Very few plants can grow in such places, and the debris from those which do grow is carried by the water to quieter or deeper parts of the lake. The only visible accumulation of peat around the large lakes therefore is in sheltered coves or bays. In time the waves gradually build beaches of sand across the mouths of such bays, converting them into separate lakes, and making the main lake more and more circular in form.

Fig. 23.—Looking north across Lake Alfred, near Bartow Junction (Chubb P. O.), Polk County. Fringe of Panicum hemitomon (maiden cane) and Nymphaea macrophylla (bonnets) a few yards off the sandy shore and parallel with it. May 18, 1910.

On wave-washed shores some of the following herbs often form a thin fringe in a foot or two of water, out beyond where the waves break upon the sand. (See fig. 23.)

- Panicum hemitomon (maiden cane)
- Pontederia cordata (wampee)
- Nymphaea macrophylla (bonnets)
- Fuirena scirpoidea
- Sagittaria lancifolia
- Panicum geminatum (a grass)
- Potamogeton sp.
- Monniera Caroliniana
- Cladium effusum (saw-grass)
- Eleocharis interstincta
- Hydrocotyle Benariensis?
- Cyperus sp.
- Psilocarya sp.
On the sandy shores, just above the reach of the waves, the ordinary or river cypress, *Taxodium distichum*, is sometimes found, together with *Spartina Bakeri*, *Juncus scirpoides compositus*, or *Ludwigia suffruticosa*.

In the sheltered coves, which have not yet been closed up by sand-bars, the following plants grow in the deepest parts, in or near the open water.

- *Nymphaea macrophylla* (bonnets)
- *Vallisneria spiralis* (eel-grass) (under water)
- *Cladium effusum* (saw grass)
- *Pontederia cordata* (wamppee)
- *Castalia odorata* (white water-lily)
- *Sagittaria lancifolia*
- *Hydrocotyle Bonariensis?*
- *Castalia odorata gigantea*
- *Panicum geminatum* (a grass)
- *Panicum hemitomon* (maiden cane)
- *Lemma sp.*
- *Typha latifolia* (cat-tail)
- *Cicuta Curtissii*
- *Sambucus Canadensis* (elder)
- *Scirpus Cubensis* (introduced)
- *Habenaria repens* (an orchid)
- *Jussiaea Peruviana* (introduced)
- *Acnida australis* (careless)
- *Carex comosa*
- *Scirpus validus* (bulrush)
- *Cyperus Haspan*
- *Ceratophyllum demersum* (under water)
- *Utricularia sp.* (floating)
- *Panicum gibbum* (a grass)

In the marshes back from the water’s edge, on top of several feet of peat, the following herbs are found. (Plate 26).

- *Cladium effusum* (saw-grass)
- *Sagittaria lancifolia*
- *Acnida australis* (careless)
- *Spartina Bakeri* (a large grass)
- *Erianthus sp.* (a tall grass)
- *Pontederia cordata* (wamppee)
- *Triadenum Virginicum*
- *Gerardia linifolia*
- *Polygonum hirsutum?*
- *Hydrocotyle sp.*
- *Isnardia sp.*
- *Jussiaea Peruviana* (introduced)
- *Eupatorium capillifolium* (dog-fennel)
- *Andropogon glomeratus*? (a grass)
- *Ludwigia alata*
- *Eupatorium serotinum*
- *Solidago fistulosa* (golden-rod)
- *Castalia odorata* (white water-lily) (stunted)

In these marshes, which often cover hundreds of acres, the saw-grass is usually more abundant than all other vegetation combined. The peat is sometimes ten feet deep or more, and the upper layers are apt to be rather coarse and fibrous, perhaps because saw-grass does not decay as readily as some other plants. Analyses will be found under localities 18, 19, and 23.
The saw-grass marshes just described are bordered in many places by vast dense moss-garlanded cypress swamps. Just what determines whether saw-grass or cypress shall predominate in a given area of lake peat is not obvious, but the transition from marsh to swamp is usually very abrupt, and marked by a narrow belt of small willows (Salix longipes?). The principal vegetation of these cypress swamps is about as follows.

**TREES**

- *Taxodium distichum* (cypress)
- *Acer rubrum* (maple)
- *Magnolia glauca* (bay)
- *Fraxinus profunda* (ash)
- *Liquidambar Styraciflua* (sweet gum)
- *Nyssa biflora* (black gum)

**SMALL TREES AND SHRUBS**

- *Sambucus Canadensis* (elder)
- *Ilex Cassine* (swamp holly)
- *Cornus stricta*?
- *Cephalanthus occidentalis* (button-bush)
- *Baccharis halimifolia*
- *Rubus sp.* (blackberry)
- *Decodon verticillatus*

**HERBS**

- *Tillandsia usneoides* (Spanish moss)
- *Saururus cernuus*
- *Osmunda regalis* (a fern)
- *Ipomoea sp.* (moonflower)
- *Sagittaria lanciflora*
- *Hydrocotyle sp.*
- *Lycopus sp.*

Some of the plants in this list are believed to be rather partial to limestone. Somewhat similar swamps are found along the St. Johns River near Astor, Sanford, and elsewhere, in the lake region but not associated with saw-grass marshes.

The peat in the cypress swamps is of course open to the same objection as that of other swamps, namely, it is full of logs and woody roots. As cypress is one of the most durable woods known, and at the same time one of the largest of our trees, logs of it might not completely decay for hundreds of years. It might even be profitable, when living cypress trees are considerably scarcer than they are now, to dig out the buried cypress logs from these swamps and use them for shingles, posts, etc., as has been done to a considerable extent with buried juniper (Chamaecyparis) logs in Dismal Swamp and southern New Jersey.
Outside of the lake region, especially in the flatwoods of East and South Florida, and particularly in Bradford, Alachua, Brevard and Osceola Counties, are many large irregular lakes which although permanent must be comparatively shallow (judging from the flatness of the country around them). Examples of this class are Lake Butler, Sampson’s Lake, Santa Fe Lake, Lakes Tohopekaliga and East Tohopekaliga, and probably Lakes Kissimmee, Istokpoga and Okeechobee, which I have not seen. None of these

have been studied sufficiently to be described here, but they are not believed to be very important as sources of peat. An analysis of peat from near East Tohopekaliga Lake (which, however, has been tampered with considerably) will be found in the table under locality no. 11.
Some of the lagoons of the east coast strip, when far enough from inlets to have fresh water all the time, must contain considerable peat. The only fresh lagoon of this kind which I have examined (and that only superficially) is Clear Lake, about a mile west of West Palm Beach. The following herbs were noticed in it on April 13, 1909.

![Clear Lake, a fresh water lagoon about a mile west of West Palm Beach, looking south from Okeechobee Road. April 13, 1909.](image)

*Cladium effusum* (saw-grass)  *Rhynchospora corniculata*

*Pontederia cordata* (wampee)  *Nymphaea macrophylla* (bonnets)

*Sagittaria lancifolia*  *Limnanthemum aquaticum*

*Castalia odorata* (white water-lily)  *Eleocharis cellulosa* (round grass)

*Panicum hemitomon* (maiden cane)  *Crinum Americanum*

No examination was made of the peat.
Whenever a small lake is completely filled with peat it becomes a prairie; and such prairies when dry and firm enough to support a dense growth of broom-sedge do not look very different from old fields, especially in winter and early spring when the water is low and most of the herbage is dead. At such times one can walk across them without much trouble, and it would be hard for a person going into one of these places for the first time to realize that he might be standing on 15 or 20 feet of exceptionally pure peat. The smallest peat prairies are often among the deepest, for they are commonly situated among rather steep hills, whose slopes continue without much change some distance below the surface of the peat. Besides the smaller lakes there are some, especially in Putnam and Polk Counties, which are half a mile or more in diameter and only about half filled with peat, which has essentially the same vegetation on it as that in the completely filled lakes. The difference between the peat prairies bordering the medium-sized lakes of Putnam and Polk Counties and the saw-grass marshes among the large lakes in the central part of the lake region (already described) is probably correlated with the fact that the smaller lakes are strictly non-calcareous, and not connected with streams; while wherever saw-grass grows there seems to be usually a pretty good chance of finding limestone not very far below it.

The following plants have been found in non-calcareous peat prairies in various counties of the lake region.

**SMALL TREES**

*Magnolia glauca* (bay)  
*Persea pubescens* (red bay)  
*Ilex Cassine* (swamp holly)  
*Gordonia Lasianthus* (bay)

**SHRUBS AND VINES**

*Smilax laurifolia* (bamboo vine)  
*Vitis rotundifolia* (muscadine)  
*Hypericum fasciculatum*  
*Ilex glabra* (gallberry)  
*Smilax sp.*  
*Pieris nitida*  
*Cholisma ligistrina*  
*Cephlanthus occidentalis* (button bush)  
*Vaccinium sp.* (buckleberry)
HERBS

Panicum hemitomon (maiden cane)
Eriocaulon compressum
Andropogon sp. (broom-sedge)
Lycopodium Chapmani
Pontederia cordata (wampee)
Drosera capillaris
Spartina Bakeri (a large grass)
Anchistea Virginica (a fern)
Eupatorium capillifolium (dog-fennel)
Castalia odorata (white water-lily)
Centella repanda
Osmunda cinnamomea (a fern)
Rhynchospora axillaris
Fuirena scirpoidea
Solidago fistulosa (golden-rods)
Amphicarpum sp. (a grass)
Sagittaria lancifolia
Erianthus sp. (a tall grass)
Cladium effusum (saw-grass)
Eleocharis interstincta
Rhynchospora Tracyi
Triadenum Virginicum
Bartonia verna
Gyrotheca tinctoria (paint-root)
Rhynchospora fascicularis
Syngonanthus flavidulus
Tillandsia usneoides (Spanish moss)
Tillandsia recurvata (air-plant)
Gerardia linifolia
Osmunda regalis (a fern)
Lorinseria areolata (a fern)
Dryopteris Thelypteris (a fern)

MOSSES

Sphagnum sp.

The trees, vines and air-plants and nearly all the shrubs and ferns grow in dense clumps which are a very characteristic feature of the larger peat prairies. (See illustration.) The location of these clumps seems to have little to do with the depth of the peat under them, and in fact I have not been able to discover any striking correlation between the depth of various parts of these prairies (whose solid sandy bottoms are sometimes very irregular) and the vegetation on the surface, except that the saw-grass and a few other plants seem to be confined to the wettest places. It will be noticed that nearly all the plants mentioned a few pages back as characteristic of sandy shores of small lakes occur also in these peat prairies.

The peat of the prairies of course contains a few woody roots and little or no sediment, and it is just about the purest peat we have. (See analyses under localities 4, 13, 15, 29 and 41, and miscellaneous No. 1). One sample from Lake County (No. 29.11) showed only 1½% of ash, which is the purest peat of which we have any record. Depths of 6 or 8 feet in these prairies are common, and some exceed 20 feet (which is considerably more than is needed to work with a dredge to the greatest advantage). Where samples have been taken from different depths in the same prairie those from near the surface usually show more mineral matter than those
from several feet down, a condition which is not easily explained. One peat prairie of particular interest will be described in some detail under the head of exceptions.

**MARSHY PRAIRIES OF MIDDLE FLORIDA.**

(PLATE 27.2)

In the northern part of the Middle Florida hammock belt, especially in Madison County, and to a lesser extent in Leon, are a number of marshy prairies of various sizes and shapes, which bear a striking resemblance to those in Okefinokee Swamp, Georgia,* though they are surrounded by loamy hills, quite different from the flat sandy pine woods around Okefinokee.

In the largest prairie of this kind that I have seen, which covers several hundred acres between Greenville and Madison, there is a dense border of pond cypress, heavily festooned with Spanish moss, and more or less undergrowth of vines and bushes. Next to the prairie the trees are usually considerably smaller than they are in the midst of the cypress belt, and they are bordered by a dense growth of a small weak shrub, *Decodon*, and a fern, *Anchistea*. Small clumps of similar vegetation, sometimes with only one or two trees in them, are scattered over the surface of the prairie, as the accompanying illustration shows.

The vegetation of these prairies and their bordering fringe of timber is about as follows:

<table>
<thead>
<tr>
<th>TREES</th>
<th></th>
<th>SHRUBS</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Taxodium imbricarium</em> (pond cypress) (very abundant)</td>
<td><em>Nyssa biflora</em> (black gum) (rather scarce)</td>
<td><em>Decodon verticillatus</em></td>
<td><em>Leucothoe racemosa</em></td>
</tr>
<tr>
<td><em>Pieris nitida</em></td>
<td></td>
<td><em>Clethra alnifolia</em></td>
<td></td>
</tr>
<tr>
<td><em>Smilax Walteri</em></td>
<td></td>
<td><em>Smilax usnoides</em> (Spanish moss) (on trees)</td>
<td></td>
</tr>
<tr>
<td><em>Clertbra alnifolia</em></td>
<td></td>
<td><em>Panicum hemitomon</em> (maiden cane)</td>
<td></td>
</tr>
<tr>
<td><em>Castalia odorata</em> (white water-lily)</td>
<td></td>
<td><em>Tillandsia usnoides</em> (Spanish moss) (on trees)</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>HERBS</th>
<th></th>
<th>MOSSES</th>
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</tr>
</thead>
<tbody>
<tr>
<td><em>Ponederia cordata</em> (wampee)</td>
<td></td>
<td><em>Sphagnum</em> sp.</td>
<td></td>
</tr>
<tr>
<td><em>Sagittaria lancifolia</em></td>
<td></td>
<td><em>Nympheha orbiculata</em> (bonnets)</td>
<td></td>
</tr>
<tr>
<td><em>Hydrocotyle sp</em></td>
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<tr>
<td><em>Eleocharis interstincta</em></td>
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As one can easily imagine from the illustration, the shrubs are chiefly confined to the timber and the herbs to the open prairie. As far out as I could conveniently go in the largest of these prairies (which was very boggy) on May 24, 1910, the peat was about five feet deep, resting on a sandy bottom. In the middle it is doubtless deeper. A sample from about a foot and a half below the surface (locality 42) was coarse, brown, fibrous, and not much decomposed, containing many living roots of herbs, as if the peat was accumulating pretty rapidly.

THE EVERGLADES.

(PLATE 13.1)

On April 12, 1909, I went up New River, in Dade County, to its head, about six miles from the railroad station at Fort Lauderdale, and then northwestward in one of the Everglades canals to the dredge, which at that time had reached a point about seven miles from the head of the river or edge of the ‘Glades. From the top of this dredge, about 25 feet above the water, a splendid view of the very heart of the Everglades could be had. Not a tree was in sight, at least to the westward and northward, and the whole landscape consisted of a vast saw-grass marsh with scattered bushes, not aggregated in clumps as in the south coast prairie or the peat prairie already described. The western horizon appeared as a perfect straight line. (A photograph taken by Mr. Gunter near the same place is published elsewhere in this volume.) At this time the marshes were flooded, as a result of a very heavy rain the day before (over 4 inches having fallen at Miami on the 11th), but a few days earlier one might perhaps have been able to walk about in this part of the Everglades without much difficulty.

The plants observed in the vicinity of the dredge are as follows:

**SHRUBS**

Myrica cerifera (myrtle)  
Cephalanthus occidentalis (button bush)  
*Ilex Cassine* (swamp holly)

**HERBS**

Cladium effusum (saw-grass)  
Oxypolis filiformis  
Hymenocallis sp.? (spider-lily)  
Rhynchospora corniculata  
Osmunda regalis (a fern)  
Peltandra Virginica  
*Nymphaea macrophylla* (bonnets)
This list is of course not complete, but it probably represents the bulk of the vegetation of the heart of the far-famed and "mysterious" Everglades. None of the species are particularly tropical (for they all range at least as far north as Georgia, and two or three of them even to Canada), or even rare.

I did not have time to make a careful study of the peat here, but I was told that it averages about ten feet deep, resting sometimes on sand and sometimes on limestone.* A sample of it from about a foot below the surface was taken near the canal about half way between the dredge and the mouth of the river (locality No. 28). This, although it shows up pretty well in the analysis, may not be a fair sample of this, the largest peat deposit in the State. Farther out in the Everglades the proportion of mineral matter might be a little less.

*A somewhat hypothetical section of the peat and underlying formations in this part of the Everglades, by Samuel Sanford, was published in the second annual report of this Survey, page 193.
LOCALITIES OF SPECIAL INTEREST.

LAKE PANASOFFKEE AND VICINITY.

Around Lake Panasoffkee, in Sumter County, there are extensive deposits of peat of considerable depth, which ought to be valuable. The water of this lake, unlike other Florida lakes, comes mostly from limestone springs, and is quite clear; and the vegetation around it differs considerably from that around the large lakes of the lake region.

The deeper parts of the deposit, next to the open water, are covered with marsh vegetation, as usual, and between the marsh and the dry land is a large dense cypress swamp, traversed by several sluggish channels or bayous. The following plants were noted within a mile or so of Panasoffkee station, at the south end of the lake, on April 22 and 23, 1909, and May 16, 1910.

LARGE TREES

*Taxodium distichum* (cypress)

MEDIUM-SIZED TREES

*Fraxinus profunda?* (ash)  *Fraxinus Caroliniana?* (ash)

*Acer rubrum* (maple)

SMALL TREES

*Salix longipes?* (willow)

SHRUBS AND VINES

*Cornus stricta?*

*Ita Virginica*

*Cephalanthus occidentalis* (button bush)

*Sambucus Canadensis* (elder) (introduced?)

HERBS

*Cladium effusum* (saw-grass)

*Tillandsia usneoides* (Spanish moss)

*Hydrocotyle Bonariensis?*

*Cicuta Curtissi*

*Rhynchospora corniculata*

*Eupatorium serotinum*

*Sagittaria lancifolia*

*Piaropus crassipes* (water hyacinth) (introduced)

*Pistia spathulata* (water lettuce) (floating in bayous)

*Hydrocotyle verticillata*

*Berchemia scandens* (rattan vine)

*Ampelopsis arborea*

*Rhus radicans* (poison ivy)

*Aster Carolinianus*

*Saururus cernuus*

*Osmunda regalis* (a fern)

*Pontederia cordata* (wampee)

*Echinocloa Crus-galli?* (a grass)

*Carex stipata*

*Scirpus validus* (bulrush)

*Carex alata*

*Rumex verticillatus*

*Nymphaea macrophylla* (bounets)
The Cladium, Eupatorium and Sagittaria are especially characteristic of the marshes bordering the lake, while most of the other herbs grow along the bayous in the swamp. Most of the plants in this list have already been mentioned as characteristic of calcareous swamps.

The peat in the marsh, as far out as I was able to go, was about 20 feet deep, which is considerably above the average. In the swamp at the point tested, which was where the railroad crosses one of the bayous, the peat was so full of logs that it was difficult to push a sounding instrument into it very far, but it seems to be at least 12 feet deep.

In both swamp and marsh the peat is brown, moderately coarse, with a slight sulphurous odor. A most interesting feature of this peat is that it contains numerous univalve shells (a fact which was discovered by Dr. Sellards about four years ago). The shells are especially abundant in the bayous, at depths exceeding four feet.

A small sample of this material from 6 feet below the surface of the water (which was only a few inches deep) in one of the bayous, collected April 23, 1909, was examined by Dr. W. H. Dall of the U. S. National Museum, with the assistance of Dr. H. A. Pilsbry of the Philadelphia Academy of Natural Sciences, and a list of 15 shells, including one new species, found in it was published by Dr. Dall in The Nautilus for May, 1910. On May 16, 1910, I collected a larger quantity of peat from the same spot, at a depth of 4 to 5 feet, and in this the following species have been identified by Bryant Walker, Esq., of Detroit, Mich.

- Amnicola angustina Pilsbry
- Amnicola Floridana Frarel?
- Amnicola Harperi Dall
- Amnicola Sancti-Johannis Pilsbry
- Amnicola sp.
- Amnicola sp.
- Ampullaria sp. (very young)
- Ancylus obscurus Hald.
- Gillia Wetherbyi Dall?
- Goniobasis catenaria Say (G. pap. illosa Anth.)
- Lymnaea columella Say
- Paludestrina acquiscostata Pilsbry
- Paludestrina monas Pilsbry
- Physa Cubensis Pfr.
- Pisidium sp.
- Planorbis Alabamensis avus Pilsbry
- Planorbis dilatatus Gld.
- Planorbis parvus Say
- Planorbis trivolvis Say
- Planorbis tumidus Pfr.
- Polygyra sp.
- Succinea sp.
- Vertigo ovata Say
- Vivipara Georgiana Lea?
- Vivipara Haleana Lea

All or nearly all of these are said to be found still living in Florida, so that their presence in this peat deposit does not indicate
Fig. 1.—South end of Lake Eustis (Lake County), showing scattered Panicum hemitomon (maiden cane) in water in foreground, and edge of cypress swamp at right. Feb. 8, 1909.

Fig. 2.—Marshy margin of Lake Apopka near West Apopka (Lake County), showing Pontederia in left foreground, Castalia at right, Sagittaria lancifolia, etc. May 20, 1909.
SAW-GRASS MARSHES OF LAKE REGION.

Fig. 1.—Large saw-grass marsh bordering Lake Harris, looking north from about a mile east of Eldorado, Lake County. Pine land in distance, over a mile away. *Aeluropus* (careless) conspicuous at right. Feb. 9, 1909. (Locality No. 18.)

Fig. 2.—Saw-grass marsh and cypress swamp bordering Lake Harris about 2 miles south of Leesburg, looking southwest. *Spartina Bakeri* (grass) in foreground. May 21, 1909.
PEAT PRAIRIES.

Fig. 1.—Peat prairie covering several hundred acres (locality No. 41), about a mile northwest of Haines City, Polk County. Clump of Magnolia glauca (bay) at left. Pine land in background. May 18, 1910.

Fig. 2.—Large marshy prairie about 5 miles east of Greenville, Madison County (locality No. 42). Trees all Taxodium imbricarium (pond cypress). May 24, 1910.
Marshes on east side of Crescent Lake (St. Johns County), looking a little south of east from a point about 30 feet from the ground in a cypress tree. *Pinus Elliottii* (slash pine) at right, bordering the lake. Other trees mostly *Taxodium imbricarium* (pond cypress), bushes mostly *Myrica cerifera* (myrtle), and herbaceous vegetation mostly *Cladium* (saw-grass).
any different climate for the time when the peat was formed (a few hundred years ago, perhaps) from that which prevails today.

Analyses of the Panasoffkee peat will be found in the table, under localities 31 and 32.

HELENA RUN.

(Fig. 26)

On May 21, 1909, in walking from Leesburg to Okahumpka and back, I crossed a sluggish stream flowing into the west end of Lake Harris (which is connected with the Ocklawaha River), and was surprised to see that its water, instead of being coffee-colored as is usual in the lake region, was clear (like that of Lake Panasoffkee just described), which in peninsular Florida is a pretty good sign of calcareous water. Later in the day I was informed by an old resident of the neighborhood that this water comes from a limestone spring a few miles to the southwestward (Bug Spring, near Okahumpka), but that in wet seasons when the lake is high this stream (Helena Run) flows the other way, and its waters find their way into the Gulf by way of the Withlacoochee River.

The calcareous eastward-flowing stage of this run must be the usual one, for there are quite a number of lime-loving plants along it, and the general aspect of the vegetation is very similar
to that in the swamps of Lake Panasoffkee, which is about twelve miles due west of the locality under consideration. The swamps bordering the run contain the following plants:

**TREES**

*Taxodium distichum* (cypress)  
*Acer rubrum* (maple)  
*Fraxinus profunda?* (ash)

**SHRUBS**

*Itea Virginica*  
*Cephalanthus occidentalis* (button bush)

**HERBS**

*Rhynchospora corniculata*  
*Boehmeria cylindrica*  
*Hydrocotyle verticillata*  
*Erechtites hieracifolia* (introduced?)  
*Carex stipata*  
*Mikania scandens* (a vine)  
*Hydrocotyle Bonariensis?*  
*Somolus floribundus*  
*Tillandsia usneoides* (Spanish moss)

In and along the run were noticed the following, all herbs:

*Nymphaea macrophylla* (bonnets)  
*Hydrocotyle Bonariensis?*  
*Ceratophyllum demersum*  
*Sagittaria lancifolia*  
*Pistia stratiotes* (water lettuce)  
*Lemna sp.*  
*Pontederia cordata* (wampee)  
*Cicuta Curtissii*  
*Echinochloa Crus-galli?* (a grass)  
*Carex comosa*  
*Sagittaria latifolia*

The peat seemed to be only about three feet deep in the swamp, and was of course full of logs, as in most other swamps. An analysis will be found under locality No. 35.

**SLOUGH WEST OF LAKE IAMONIA.**

One other stream which flows two ways is worth mentioning. At the west end of Lake Iamonia, in the northern part of Leon County, there is a swampy slough connecting the lake with the Ocklocknee River, a mile or two away. This slough has no water at all in it a large part of the time, but it is said that in wet weather a current sometimes flows from the lake into the river and sometimes vice versa, according to which is the higher. Lake Iamonia is one of those flat-bottomed sink-hole lakes surrounded by red hills, mentioned on preceding pages. As the headwaters of the Ocklocknee River are in Georgia (where its name is spelled Ochlock-
nee), about fifty miles away, it doubtless sometimes happens that the precipitation up there differs enough from that around the lake to set up a current through the slough in one direction or the other.

The vegetation of this slough, as might be expected, differs a little from that of either river-swamps or stagnant swamps. The following plants were noticed in it on July 5, 1909:

**TREES**

- *Nyssa uniflora* (tupelo gum)
- *Taxodium distichum* (cypress)
- *Nyssa biflora* (black gum)

**SHRUBS**

- *Hypericum galicoides?*
- *Rhus radicans* (poison ivy)

**HERBS**

- *Lorinseria areolata* (a fern)
- *Dulichium arundinaceum*
- *Osmunda cinnamomea* (a fern)
- *Tillandsia usneoides* (Spanish moss)
- *Commelina hirtella*
- *Saururus cernuus*
- *Osmunda regalis* (a fern)

**MOSSES**

- *Sphagnum sp.*

-- *Hydrocotyle verticillata*
-- *Carex pululina?*
-- *Rhynchospora corniculata*
-- *Carex Louisianica*
-- *Boehmeria cylindrica*
-- *Triadenum petiolatum*

No search was made for peat here, but it cannot amount to much in a swamp which is dry a large part of the time.
There are several streams and other bodies of water in Florida (besides Helena Run, just described) which in dry weather, when they are fed chiefly by springs, are clear and bluish, but become coffee-colored in wet weather when the swamps and marshes are full of water.*

Most of these are of no particular interest as sources of peat, but there is one which deserves to be described on account of its uniqueness, namely, the south end of the Everglades. In the middle of the Everglades, as already pointed out, the bottom is said to be mostly sand, and the water is probably blackish all or nearly all the time, as in most of our swamps. But at the south end, in the Miami limestone region, there is no sand, and the water which stands in pools and pot-holes or circulates in subterranean channels is decidedly calcareous in the dry season, as shown by its clearness, and by the whitish incrustation that it leaves all over the ground and the bases of plant stems as it dries up.†

*An interesting case of this in Taylor County deserves to be mentioned here. In January, 1909, I saw in the southern edge of the town of Perry what appeared to be a limestone spring with a small bluish creek issuing from it, and as far as I followed the creek there were lime-loving plants growing in it and in the swamps bordering it. In March, 1910, I revisited the place and was surprised to find the water coming out of the same hole in the ground dark brown, like typical swamp water. On inquiry I was told that this hole in the ground was not a true spring, but the outlet of the subterranean portion of one of several streams which have their source in San Pedro Bay, a few miles to the northeastward; and that the bay was then overflowing as a result of unusually heavy rains the month before, which accounted for the color of the water. This creek must be calcareous most of the time, though, otherwise the vegetation in it (Ceratophyllum, etc.), would not be so distinctly calciphile.

Ichetucknee Spring, in the southwestern part of Columbia County, seems to be another case of the same kind. B. M. Hall (in U. S. Geol. Surv. Water Supply & Irrigation Paper No. 102, p. 275, 1904), says of this spring:—"The water of the spring has a decided amber color, probably due to surface swamp drainage coming into it." He does not mention the date of his visit, but it must have been shortly after a rainy spell. Every time I have crossed the creek which flows from this spring (Feb. 4 and April 27, 1909, April 17, 1910) it has appeared to be a typical blue limestone stream.

†This incrustation is not brittle as it would be if it was wholly inorganic, but is a soft, slightly coherent material somewhat resembling damp wood-ashes. It probably contains a considerable proportion of vegetable matter (such as algae), which gives it a somewhat fibrous consistency.
In shallow pools which contain water even in the dry season (known locally as "gator-holes") or in sloughs, there is a deposit of blackish peat which must also be highly charged with lime, as its analysis gives about the same results as that of the ash material.

The following plants were observed in the Everglades within sight of Paradise Key (Royal Palm Hammock) in the latter part of March, 1909, and near the head of the Miami River early in April:

**SMALL TREES OR SHRUBS**

- *Anona glabra* (custard-apple)
- *Salix longipes*? (willow)
- *Cephalanthus occidentalis* (button bush)
- *Persea pubescens*? (red bay)
- *Magnolia glauca* (bay)
- *Chrysobalanus icaco* (cocoa plum)
HERBS

Cladium effusum (saw-grass)

Phragmites communis (reed grass)
(mostly in sloughs)

Nymphaea macrophylla (bonnets)
(in 'gator-holes)

Sagittaria lancifolia

Spartina Bakeri (a grass)

Eleocharis cellulosa (round grass)
(in sloughs)

Monniera Caroliniana

Pontederia cordata (wampee)
(mostly in 'gator-holes)

Peltandra Virginica (mostly in 'gator-holes)

Crinum Americanum

Centella repanda

Schoenus nigricans

Rhynchospora Tracyi

Typha latifolia (cat-tail)

Petomogeton sp.

Oxypolis filiformis

Cassytha filiformis

Aeschynomene pratensis

Asclepias lanceolata (milkweed)

The shrubs (all of which become trees in more sheltered situations) are chiefly confined to the immediate vicinity of the 'gator-holes, where they form small clumps, or oases, which are a charac-

Fig. 28.—Scene in Everglades about a mile west of head of Miami River, Dade County (locality No. 26). Vegetation mostly Phragmites (reed grass). April 9, 1909.

teristic feature of the landscape of the southern part of the Everglades. (They seem to be absent from the middle and northern portions, where the rock is deeper below the surface.) Several of the herbs prefer the same spots, as indicated in the above list.

Analyses of peat from this region will be found under localities 24 to 26.
TRIBUTARIES OF THE LOWER ST. JOHNS.

On the estuarine part of the St. Johns River and its tributaries there are some interesting peat deposits which are quite unlike each other or anything else I have seen. Two of them are much deeper than the average, are situated on navigable waters, and have been worked to some extent.

JULINGTON CREEK.

The first is at the confluence of Davis and Julington Creeks at the southern edge of Duval County, about five miles west of Bayard on the Florida East Coast Railway. At this point each creek is bordered on one side by a narrow strip of cypress swamp, but between them there is an open marsh covering about 200 acres, passing gradually into pine land eastward. On Dec. 18, 1908, the following herbs were observed in this marsh:

- *Spartina Bakeri* (a large grass)
- *Erianthus sp.* (a tall grass)
- *Cladium effusum* (saw-grass)
- *Osmunda regalis* (a fern)
- *Sagittaria lancifolia*
- *Andropogon sp.* (broom-sedge)
- *Rhynchospora caduca?*
- *Eryngium praecentum?*

The grass *Spartina Bakeri*, although it is common around many of the best peat deposits in Florida, does not usually occur in great quantity; but at this place it is more abundant than all the other vegetation combined. Besides the plants above listed, *Pontederia cordata* grows along the water edges of the marsh, but is now almost choked out by its near relative the water hyacinth. *Ceratophyllum demersum* grows beneath the surface of the water, and a few shrubs and small trees, such as *Acer rubrum* (maple), *Ulmus sp.* (elm), *Myrica cerifera* (myrtle), and *Baccharis halimifolia*, are scattered along the banks of the creeks.

The peat here has a decided sulphurous odor, and over 10% of ash, but this does not materially affect its value for either fuel or fertilizer purposes. (See analyses under locality No. 6 and miscellaneous Nos. 2 to 5.) It is said to have a maximum depth of about 30 feet, and to contain rotten wood in its lower portions. This possibly indicates that at some former period, a few thousand years ago, perhaps, when the land stood higher than it does now, this place was a swamp. Just why it should be treeless now, when the other sides of both creeks are well wooded, is not obvious. In South Florida treeless wet places are very common, perhaps because there are not many trees down that way which will grow in water; but in this latitude (a little north of 30°) fresh marshes are rather unusual.
In 1907-8 this peat was exploited by the Florida Peat Fuel & Construction Co., of Jacksonville, of which Mr. Robert Ranson was the leading spirit. Canals were dug through the marsh from the creek to the dry land, where the necessary buildings and machinery for the manufacture of peat fuel and fertilizer filler were erected. The creek being navigable, the product was shipped by water to Jacksonville. Operations were suspended when the main building was partly destroyed by fire in August, 1908.

Crescent Lake

(Plate 28)

Crescent Lake (formerly known as Dunn's Lake), which forms part of the boundary between Putnam and St. Johns Counties, is about 12 miles long and 3 or 4 wide, and connected by Dunn's Creek, a navigable stream, with the St. Johns River a few miles above (south of) Palatka. Its also forms part of the boundary between the lake region and the East Florida flatwoods. The east side of the lake is bordered by a flat, damp, sandy region, uninhabited for miles, while on the west side, at least at Crescent City, the typical high pine land of the lake region rises abruptly from its shores. (The small lake just west of Crescent City is said to be about 50 feet higher than Crescent Lake, though scarcely half a mile from it.)

Just about opposite Crescent City, on the St. Johns County side, there begins a marsh a few hundred feet wide, which is said to extend southward along the lake for several miles. The vegetation is mostly herbaceous, and the trees and shrubs are not abundant enough to seriously interfere with dredging operations (as can be seen from the accompanying illustration). The following plants were observed there on May 15, 1909.

**TREES**

- *Taxodium imbricarium* (pond cypress)
- *Pinus elliottii* (slash pine) (near lake)

**SHRUBS**

- *Myrica cerifera* (myrtle)
- *Cephalanthus occidentalis* (button bush)
There is evidently some peculiarity about the water or underlying soil of this marsh, for several of the herbs listed are species which seem most at home in brackish marshes, and a few also like calcareous places, like the southern end of the Everglades. On the land side the marsh is bordered in part by a low hammock with many calciphile plants; and scattered over the surface of the marsh are a good many shells of the water-snail, *Ampullaria*, which is common in the Everglades, and occurs in various other limestone regions, even as far north as Wakulla and Jackson Counties. But on the water side there is a fringe of slash pine, *Pinus Elliottii*, which has little use for limestone, and all the cypresses on the marsh are of the pond instead of the river species, which seems strange. The water from a flowing artesian well 60 or 70 feet deep near the edge of the marsh seems to contain salt, lime, and sulphur, among other things, to judge by its taste.

The peat is said to be over 20 feet deep in some places, and it has a peculiar pungent odor a little different from anything else I have seen. At the time of my visit the Crescent Mfg. Co., also under Mr. Ranson's direction, had just erected a plant at the north end of the marsh for the manufacture of fertilizer filler.
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**TREES**

*Pinus serotina* (black pine)  
*Magnolia glauca* (bay)  
*Gordonia Lasianthus* (bay)  
*Persea pubescens* (red bay)

**SHRUBS**

*Aralia spinosa* (prickly ash) (mostly near the edge)  
*Smilax laurifolia* (bamboo vine)

**HERBS**

*Osmunda cinnamomea* (a fern)

The width of this part of the swamp is about 200 yards, and at that distance from the edge the peat is about 8 feet deep. At the time of my visit, in January, 1909, the swamp seemed to have been burned over within a year or two, which had lowered the surface of the peat a few inches, and also allowed blackberry briers and a few other weeds to come in. Some parts of it had also been ditched and cultivated to some extent. Analyses of peat from this locality (No. 8.2) show it to contain only about half as much ash and sulphur as that from nearer the river, and its fuel value is higher.

**THE “INFUSORIAL EARTH” BOG.**

About 3 miles east of Tavares, on the north side of Lake Dora, is a bog covering nearly 100 acres, of the peat prairie type already described, which on the surface looks like many other small filled lakes in the same region. But it differs from all others that I have seen in the composition of the ash of the upper layers of the peat. A chunk from near the surface contains so much mineral matter that when dry it has a grayish color, instead of the usual black or dark brown. This mineral matter has been found to consist mostly of the shell of diatoms, and when such peat is burned the diatoms remain as a very fine and light white powder, having much the appearance of flour. (The uses of this material will be mentioned in a subsequent chapter.)

A ditch about six feet deep, leading through a low ridge of scrub to the eastward, has altered conditions to the extent of keeping the average water-Level a foot or so below the surface of the peat, when it was originally no doubt a little above the surface.

According to Hon. H. W. Bishop of Eustis, who was formerly interested in this property, the ditch was dug about 1896 by a man who intended to raise tobacco on the drained peat. In this he was
not successful, but in the course of the work he accidentally discovered what a peculiar ash the peat left when burned. He brought a sample of this to Mr. Bishop, who began to investigate its possibilities, with the result that about 1901 a plant for the manufacture of "infusorial earth" was erected on the northern edge of this peat prairie, a few hundred feet from the Sanford & Lake Eustis division of what is now the Atlantic Coast Line R. R. The peat was dug out by hand to a depth of about a foot, conveyed by machinery up an incline to the top of the building, and there dumped into a machine which pressed out most of the water. From this it was taken to a shed and spread out to dry, and afterwards burned in a suitable furnace. The product was at first sent to England to use in the manufacture of scouring soap.

When I visited the place in the winter of 1908-9 the plant had been idle for a few years, but in the spring of 1909 the property was purchased from Mr. Bishop and his associates by the American Diatomite Co., of New York, who put in several thousand dollars worth of new buildings and machinery, it is said.

At only a short distance from the margin of this bog I could not reach bottom with 18 feet of sounding-rod, and Mr. Bishop informs me that the maximum depth is about 35 feet.

Some of the "infusorial earth" from this locality was submitted by Dr. Davis to Dr. Albert Mann, of the Bureau of Plant Industry, U. S. Department of Agriculture, who identified in it the following species of diatoms:

- Navicula firma tumescens Grunow
- Navicula seriata Breb.
- Navicula major Kuetzing
- Eunotia major (W. Smith) Rab.
- Melosira sp. (very small and rare)

He notes that the deposit is remarkable for the purity of the diatoms, the paucity of forms, and the absence of round forms. All are living fresh-water species.

Analyses of the peat can be found in the table of analyses, under locality No. 4. There are some references to this place in the first annual report of this Survey, page 39, and the second annual report, pages 158 and 244.
The water hyacinth, *Piaropus* (formerly *Eichhornia*, once *Pontederia*) *crassipes*, a beautiful ornamental aquatic plant, native of South America, began to escape from cultivation and make itself a nuisance in Florida about twenty years ago. It thrives in our lakes and estuaries probably almost as well as in its native haunts, and for a time it threatened to close the St. Johns River to navigation.* For some reason not altogether obvious, it is much less troublesome now than formerly having apparently reached a state of equilibrium. It has some redeeming features too. It is undeniably a beautiful plant when in bloom, cows like to eat it, and finally, it may be an important source of peat.

For it grows pretty rapidly, and in just the places which are best adapted for the formation of peat. It is never found in salt or swift water, in ponds which dry up completely, or in streams subject to great fluctuations; and not often in muddy or calcareous water. Its favorite habitat is permanent ponds, lakes and estuaries, sometimes floating on the water, and sometimes taking root on mucky or peaty shores, but in either case constantly decaying and producing peat.

The Withlacoochee River near Istachatta, at the northeastern corner of Hernando County, (and doubtless elsewhere) was in January, 1909, completely covered from shore to shore with a dense mass of water hyacinth, and I was told that a man could take a couple of planks of sufficient size and with their aid walk across the river on the plants. In the edge of the river I noticed some logs partly submerged, which could not have been there many years, and on top of them a few inches of peat, evidently formed mostly from the hyacinths. Associated with the water hyacinth in this river, and partly supported by it, I noticed *Decodon verticillatus*, a weak herb-like shrub, and the following aquatic herbs.

*An interesting account of its status in Florida, written by Dr. H. J. Webber about the time it was at its worst, can be found in Bulletin 18 of the Division of Botany, U. S. Department of Agriculture, published in 1897.

At various times in the last ten years the U. S. Army engineers have conducted experiments in Florida, mostly on the St. Johns River, with a view to exterminating the water hyacinth, sometimes by mechanical and sometimes by chemical means. (See Reports of the Chief of Engineers, 1899: 276-277, 1612-1613; 1900: 315, 1985; 1901: 1746-1749; 1903: 1184-1186; 1904: 1712-1713; 1905: 1318; 1906: 330-331, 1234-1239; especially the last.) Spraying with poisonous liquids was found to be most effective, but had the serious drawback of poisoning cattle which fed on the plants.
Habenaria repens, an orchid with inconspicuous greenish flowers, is sometimes found in similar places,* but I did not happen to see any of it here. Several of these plants are also natives of tropical America, and they may associate with the water hyacinth in its native haunts. They have all probably been in this country longer than the water hyacinth has, though.

Although one can travel for several days in Florida without seeing any water hyacinth, it is found in some very isolated and unexpected places. The peat sample from a shallow depression in Choocochattee Prairie, Hernando Co. (No. 20.11), a locality several miles from any river or permanent lake, was composed mostly of this plant.

*See Plant World 6: 165. 1903.
FOSSIL PEAT.

Peat has doubtless been forming in some parts of the world almost ever since vegetable life began, a period presumably of many millions of years. The peat of the Carboniferous period is now our anthracite and bituminous coal, a material without which the stupendous industrial developments of the past hundred years would have been impossible. Smaller amounts of true coal are also found in Triassic and Cretaceous strata. Next in importance of the pre-historic peat deposits is the lignite of the Tertiary period, a sort of imperfect coal which is used for fuel, etc., in many parts of the world where it is more easily obtained than real coal. All the rocks in Florida which have been reached by artesian borings are of later formations than the so-called Lignitic, and all the fossil or buried peat which is known in this State, with one or two unimportant or little-understood exceptions, is comparatively recent, probably not older than Pliocene.

Fig. 29.—Ledge of black hardpan on shore of bay about a mile west of Apalachicola, Franklin County. April 24, 1910.

As long ago as 1827 Col. J. L. Williams noted the occurrence of a stratum of peat-like substance, containing cypress and cedar stumps, a short distance below the surface sands on the peninsula between Pensacola Bay and Santa Rosa Sound.* Well-drillers in various parts of Florida and elsewhere in the coastal plain frequently report finding logs buried at various depths, which prob-

* See Smith, Tenth Census U. S. 6:223. 1884.
ably indicate ancient peat deposits.* In June, 1909, a resident of Enterprise, Volusia Co., sent to the State Chemist for analysis a sample of black plastic material which looked like good peat (but was found to contain only about 33% of vegetable matter) which he stated to have been brought up from 50 feet below the surface in driving a well near that place.

On the shores of Apalachicola Bay for several miles west of Apalachicola there crops out beneath a few feet of Pleistocene sand, a dark brown, almost black substance which is worn by the waves into rock-like shapes, and at a little distance looks like rock. (Fig. 29). But it is only slightly indurated, and a lump of it can easily be pulverized in one's fingers. The dark color is due to carbonaceous material (and not to iron, as one might suppose at first glance), as shown by the following analysis of a small sample of the material, made by A. M. Henry, assistant state chemist. (This analysis is made on a moisture-free basis).

<table>
<thead>
<tr>
<th></th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Silica</td>
<td>95.62</td>
</tr>
<tr>
<td>Volatile or combustible matter</td>
<td>3.33</td>
</tr>
<tr>
<td>Undetermined (mostly clay)</td>
<td>1.05</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>100.00</strong></td>
</tr>
</tbody>
</table>

Scattered through this deposit are the remains of stumps (which should not be confused with the more modern stumps which are common on the same coast, where they have been exposed by the gradual encroachment of the sea upon the land), all of which seems to indicate that this is an ancient swamp deposit of some kind, though why it should be so highly charged with silica is not obvious. Its depth is not known, as the base of it does not seem to be exposed.

Material of similar appearance and presumably similar composition seems to underlie the whole of the Trial Ridge of East Florida and Southeast Georgia, as stated on page 225. The "hardpan" which is said to underlie parts of the South Florida flatwoods, a few feet below the sandy surface, may be of similar nature. It is interesting to note that all such land is very little used for agricultural purposes at present.

The most interesting fossil peat deposit which has come to the notice of the writer is in Santa Rosa County, about ½ mile north of Milton, where modern gullies have exposed a section which may be described about as follows. (See fig. 30).

*See second annual report of this Survey, p. 153. 1909.
The yellowish sand (No. 2) seems to be identical with much of the material exposed in the splendid bluffs on the west side.

Fig. 30.—Fossil peat locality about a half mile north of Milton, Santa Rosa County. The umbrella is sticking in one of the stumps, and a root of another can be seen projecting from the bank near the center of the picture. June 22, 1909.
of Escambia Bay, a few miles farther west, which in turn are
doubtless of the same age as those on Perdido and Mobile Bays in
Baldwin County, Alabama, which Dr. Eugene A. Smith regards
as representing the Grand Gulf formation.* The logs and stumps
in Nos. 3 and 4 seem to represent both pine and cypress,† and the
whole appearance of the place suggests the remains of a cypress
pond or bay. The gray color of the lowest stratum is doubtless
due to the effect of the vegetable acids on the iron compounds in the
soil, as can be observed under almost any modern bog or swamp
that is shallow enough to dig through.

*See his report on the Underground Water Resources of Alabama, plates
18 and 19. 1907.
†Mr. Edward W. Berry, while doing paleobotanical work for the U. S. Geo-
logical Survey, visited this locality with me on Sept. 19 and 20, 1910, and made
collections of the fossil plants, but up to the present writing he has not had op-
portunity to study them carefully.
ANALYSES OF FLORIDA PEAT SAMPLES.

The subjoined table shows the percentage of water, mineral matter, volatile combustible matter, fixed carbon, sulphur, and (in a few cases) nitrogen, and the fuel value, of the samples of Florida peat collected by the writer in 1908-1910 and analyzed in the peat laboratory of the U. S. Geological Survey at Pittsburgh, Pa., mostly under the direction of Dr. F. M. Stanton.

In the number assigned to each sample the figures before the decimal point indicate the consecutive number of the locality, the first figure after the decimal point the number of the hole from which the sample was taken, and the last figure the number of the sample from that hole. In most cases only one sample from each swamp or bog was taken, on account of the limited time available. For the same reason nearly half the samples were dug out by hand from a depth of about a foot. The deeper ones were taken with a sampling instrument devised by Dr. Chas. A. Davis, consisting of a number of sections of half-inch iron pipe which could be screwed together, one of them with a short transverse handle at one end, and a brass cylinder nearly an inch in diameter and about nine inches long, which could be screwed to the pipes and pushed down to any desired depth, and then filled with peat from that depth by an ingenious mechanism. This cylinder had to be filled a good many times to obtain a sufficient quantity of peat for analysis, and in practice each sample was made up from several taken from the same depth within a few feet of each other.

The next column after the name of the locality gives the depth from which the sample was taken, and the last column on the first page the maximum depth of peat found in each deposit. In a few cases where this depth was given me by other persons the figures are put in parentheses.

The moisture percentage is taken from air-dry samples, and the other determinations were made after the water was eliminated by heating slightly above the boiling point (not enough to decompose or volatilize the peat). The ash was not analyzed, but it is probably chiefly silica in most cases, though in the samples from Panasoffkee, Helena Run, and the south end of the Everglades it must be mostly lime. The reason for determining the sulphur (which is done more generally for coal than for peat) is that an excess of it would have a corrosive effect on the iron parts of fire-boxes, and might also be objectionable if the peat was made into illuminating gas. The percentage of nitrogen gives some indication of the value of the peat for agricultural purposes.
The ash, fixed carbon and volatile matter (other than water) together add up to 100% in each case. The sulphur and nitrogen are part of the volatile matter determined separately. The percentages of ash and fixed carbon added together give the amount of coke which may be obtained from each sample, for in the process of coking enough heat is used to drive off all the other ingredients.

The fuel value is given in "British thermal units" per pound. A British thermal unit is the quantity of heat required to raise the temperature of a pound of water one degree Fahrenheit, or, to be more precise, from 60° to 51° F. If the fuel value is given as 10,000 B. T. U., for instance, this means that a pound of the material if burned under the most favorable conditions could be made to raise the temperature of 5 tons of water 1°, or 1 ton 5°, etc.
<table>
<thead>
<tr>
<th>No.</th>
<th>COUNTY</th>
<th>LOCALITY</th>
<th>Depth of sample</th>
<th>Maximum depth</th>
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<td>2.12</td>
<td>Leon</td>
<td>Gum swamp 5 miles W.N.W. of Tallahassee</td>
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<td>6</td>
</tr>
<tr>
<td>2.21</td>
<td>“</td>
<td>“</td>
<td>1</td>
<td>6</td>
</tr>
<tr>
<td>4.11</td>
<td>Lake</td>
<td>Peat prairie 3 miles east of Tavares</td>
<td>15</td>
<td>(35)</td>
</tr>
<tr>
<td>4.12</td>
<td>“</td>
<td>(“infusorial earth” bog)</td>
<td>1</td>
<td>—</td>
</tr>
<tr>
<td>6.11</td>
<td>Duval</td>
<td>Confluence of Davis and Julington Creeks</td>
<td>12</td>
<td>(30)</td>
</tr>
<tr>
<td>6.21</td>
<td>“</td>
<td>Dry lump from bank of canal</td>
<td>?</td>
<td>—</td>
</tr>
<tr>
<td>7.11</td>
<td>Santa Rosa</td>
<td>Blackwater River swamp near Milton</td>
<td>8</td>
<td>(20)</td>
</tr>
<tr>
<td>7.12</td>
<td>“</td>
<td>“</td>
<td>4</td>
<td>—</td>
</tr>
<tr>
<td>8.11</td>
<td>Putnam</td>
<td>River-swamp 1 m. S. of Palatka, near water</td>
<td>8</td>
<td>20</td>
</tr>
<tr>
<td>8.21</td>
<td>“</td>
<td>Same, about half-way back to dry land</td>
<td>4</td>
<td>10</td>
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<td>Osceola</td>
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<td>10</td>
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<td>Polk</td>
<td>Small lake near Florence Villa</td>
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<td>2</td>
</tr>
<tr>
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<td>“</td>
<td>Bog or peat prairie bordering Lake Marianna</td>
<td>8</td>
<td>20+</td>
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<td>13.12</td>
<td>“</td>
<td>“</td>
<td>1</td>
<td>—</td>
</tr>
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<td>“</td>
<td>Slash-pine bog 2 miles west of Auburndale</td>
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<td>Citrus</td>
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<td>“</td>
<td>“</td>
<td>1</td>
<td>—</td>
</tr>
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<td>“</td>
<td>10</td>
<td>78</td>
</tr>
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<td>19.12</td>
<td>“</td>
<td>“</td>
<td>1</td>
<td>—</td>
</tr>
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<td>Hernando</td>
<td>Do. Dry lump from bank of canal</td>
<td>?</td>
<td>—</td>
</tr>
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<td>“</td>
<td>“</td>
<td>1</td>
<td>3</td>
</tr>
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<td>Desoto</td>
<td>Non-alluvial swamp near Nocatee</td>
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<td>3</td>
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<td>Lake</td>
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<td>1</td>
<td>2+</td>
</tr>
<tr>
<td>23.11</td>
<td>“</td>
<td>Marshes at west end of Lake Dora</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td>23.21</td>
<td>“</td>
<td>“</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>24.11</td>
<td>“</td>
<td>'Gator-hole in Everglades, near Paradise Key</td>
<td>2</td>
<td>4</td>
</tr>
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<td>25.11</td>
<td>“</td>
<td>Marly Everglades soil, near same place</td>
<td>1</td>
<td>—</td>
</tr>
<tr>
<td>26.11</td>
<td>“</td>
<td>Everglades, near head of Miami River</td>
<td>2</td>
<td>5</td>
</tr>
<tr>
<td>27.11</td>
<td>“</td>
<td>Marshes of Miami R. about 2 m. from its mouth</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td>28.11</td>
<td>“</td>
<td>Everglades 9 or 10 m. N.W. of Ft. Lauderdale</td>
<td>1</td>
<td>(15)</td>
</tr>
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<td>29.11</td>
<td>“</td>
<td>Small peat prairie near Clermont</td>
<td>6</td>
<td>10</td>
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<td>29.12</td>
<td>“</td>
<td>“</td>
<td>1</td>
<td>—</td>
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<td>Manatee</td>
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<td>4</td>
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<td>“</td>
<td>“</td>
<td>4</td>
<td>—</td>
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<td>32.11</td>
<td>“</td>
<td>Bayou in cypress swamp near same place</td>
<td>6</td>
<td>12</td>
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<tr>
<td>34.11</td>
<td>Lake</td>
<td>Marshes of Lake Apopka, near Montverde</td>
<td>8</td>
<td>10+</td>
</tr>
<tr>
<td>34.12</td>
<td>“</td>
<td>“</td>
<td>1</td>
<td>—</td>
</tr>
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<td>35.11</td>
<td>“</td>
<td>Along Helena Run, west of Lake Harris</td>
<td>1</td>
<td>3</td>
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<tr>
<td>36.11</td>
<td>Franklin</td>
<td>Tyty bay about 2 miles N.E. of Lanark</td>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td>37.11</td>
<td>“</td>
<td>Deep tyty bay about 1 m. N. of Carrabelle</td>
<td>4</td>
<td>10+</td>
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<tr>
<td>38.11</td>
<td>“</td>
<td>Large tyty bay about 1-2 m. N. of Carrabelle</td>
<td>4</td>
<td>12+</td>
</tr>
<tr>
<td>39.11</td>
<td>Walton</td>
<td>Dense tyty swamp just N.W. of DeFuniakSprs.</td>
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<td>10</td>
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<td>Large peat prairie 1 m. N.W. of Haines City</td>
<td>4</td>
<td>8</td>
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<tr>
<td>42.11</td>
<td>Madison</td>
<td>Large marshy prairies 5 m. E. of Greenville</td>
<td>1</td>
<td>1-2</td>
</tr>
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<td>6.7</td>
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<td>36.2 55.9</td>
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<td>32.8 59.0</td>
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<td>3.5</td>
<td>63.5</td>
<td>13.0 23.5</td>
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ADDITIONAL INFORMATION ABOUT SOME OF THE LOCALITIES IN THE ABOVE TABLE.

4. For description of this locality see page 290.
6. For description of this locality see page 287.
8. For description of this locality see pages 250-251, 289-290.
11. This place was partly drained by the lowering of the large lakes near Kissimmee in the '80's, and once cultivated in pineapples, but has been abandoned for years. In its present condition the peat could easily be dug out by hand, but it is almost too impure for fuel.
13. Peat mixed with sand below 15 feet. Vegetation on surface very similar to that at locality No. 4, but no diatoms have been found in this peat.
14. This bog or bay is about ¼ mile wide, and probably still greater in length. At the point examined the bottom was of black sticky clay, instead of the usual sand.
15. A very accessible locality, covering several hundred acres, dry enough at the time of my visit (in January, 1909) so that cattle could walk all over it. The peat is of good quality, except for containing a good many logs, but the quantity would be difficult to estimate, on account of the irregularity of the bottom. The depth varies from over 20 feet to almost nothing, without definite relation to the surface vegetation or to the distance from the margin.
16. This peat looks almost like coarse sawdust and small chips, has no plasticity, and the water is easily squeezed out. Being thickly overgrown with large cypress trees, it could not be easily dug out, but its fuel value is remarkably high.
17. Very accessible, but quantity too small to be of any importance.
18. Covers several hundred acres (see plate 26.1), and is close to a railroad. This peat is too coarse for a satisfactory fuel, but might be valuable for fiber.
19. Similar to the preceding, and still more accessible, but smaller in extent.
20. Peat composed largely of water hyacinth. Too shallow and remote from transportation to be of any value.
21. For description of this locality see pages 258-260.
22. Good peat, but too shallow to be worth much.
23. An extensive deposit, favorably located, but rather shallow and impure.
30. Vegetation partly destroyed by ditching. Peat too shallow and impure for fuel, better for agricultural purposes. Many
deposits somewhat similar to this are cultivated in Hillsborough County.

31, 32. For description of this locality see pages 279-281.

34. A good crop of corn was growing on this peat deposit. Peat black and fine on top (probably on account of being aerated and cultivated for several years), but coarser and dark brown a few feet below the surface.

35. For description of this locality see pages 281-282.

36. This bay was only about 50 feet in diameter, but there are plenty of larger ones, probably with just as good peat, in the immediate vicinity, and close to the railroad.

37. See illustration, fig. 22. A very good deposit for local use.

38. Similar to the preceding, a little better if anything, for it is drier and firmer, also nearer town.

41. Several hundred acres of excellent peat, right on a railroad.

42. Several hundred acres of coarse fibrous peat, right on a railroads, but remote from habitations. (These last two localities are illustrated on plate 27.)

MISCELLANEOUS ANALYSES.

A few analyses of Florida peat have been obtained from other sources, as follows:

1. Small peat prairie about two miles northwest of Orlando, Orange County. The peat here seems to be at least 15 feet deep, and a few years ago a good deal of it was excavated to a depth of about 8 feet, put through a briquetting machine on the spot, and when dry taken to town and used for fuel in the light, water and ice plant. Analyses taken from U. S. Geol. Surv. Mineral Resources for 1905, p. 1321, and Bulletin 290, p. 77. In these publications the fixed carbon and volatile matter were given only for air-dry peat, but I have re-computed these two factors on a water-free basis, so that they can be compared with the table above.

2 to 5. Marsh at confluence of Davis and Julington Creeks, Duval County, already described. Samples collected by Robert Ranson in May, 1908, from various depths (of which the records are not now available), analyzed by the U. S. Geological Survey, and results communicated to the writer by Dr. Chas. A. Davis.

6. Average of 26 samples from various points in the vicinity of the St. Johns River, analyzed for Robert Ranson, and communicated by him. His figures were for air-dry peat, but I have re-computed them on a water-free basis, except the fuel value.
7. Mangrove peat from along east side of Snake Creek, which is the channel between Windly’s Island and Plamation Key (or Long Island), Monroe County, near 437 mile-post on Florida East Coast Ry. Taken from about 3 feet below the surface, in mangrove swamp, whose vegetation is mostly Rhizophora Mangle (red mangrove). Peat reddish brown, very coarse and fibrous. Collected in September, 1910, under direction of W. J. Krome, Constructing Engineer of the F. E. C. Ry. Extension, at our request. Analysis by E. Peck Greene, assistant state chemist.

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NOTES ON THE SIGNIFICANCE OF SOME OF THE ANALYSES.

It would seem from the figures given that most of our peat contains only about half as much water when air-dry as does the better known material from the glaciated region of Europe and the northern parts of this continent. Too much stress should not be laid on this, however, for the water-content shown probably depends nearly as much on the condition of the air at Pittsburgh at the time the analyses were being made as it does on the nature of the peat itself. (All the samples which show more than 10% of water were collected in April, May or June, and analyzed a month or two later, when the air of the room in which the tests were made was presumably more humid than in winter, on account of artificial heat not being used.) Nevertheless, it is probably safe to say that the Florida peat dries out as well as that from any other part of the world, if not better.

The purest peat is No. 29.11, which has only 1.5% of ash. Other samples with less than 5% are Nos. 13.11, 15.11, 29.12, 37.11, 41.11 and 42.11, all of which are from peat prairies or similar situations. (Locality No. 37 I have called a tyty bay, but it is treeless in the middle, and therefore has the characters of a peat prairie).

The proportion of volatile matter to fixed carbon is nearly 3 to 1 in No. 19.11, a coarse saw-grass peat. In nearly every case
where it is over 2 to 1 the peat is coarse and imperfectly decomposed. It runs below 1½ to 1 both in good black plastic peat and in some very impure samples, which might be better designated as muck.

The sulphur runs highest in estuarine peat, especially in that from Julington Creek (Nos. 6.21 and miscellaneous Nos. 2-5), and is pretty high in calcareous peat and that from Madison County. There is probably not enough of it to be objectionable in any of our samples, however. It is lowest in the samples from small filled lakes, bays, etc. No. 36.11 contains the least sulphur in proportion to other volatile matter, and No. 39.11 is a close second in that respect. (Both of these happen to be from tyty bays.)

The nitrogen determinations unfortunately are too few to warrant much generalization, but in other parts of the world the nitrogen content of peat is rarely less than 1% or more than 3%, and the same seems to hold true in Florida, as far as our information goes.

In fuel value our peat compares very well with that in other parts of the world. According to Davis, 5,760 B. T. U. per pound is a good average for wood, 8,500 for pressed peat, and 14,000 for anthracite coal. The average of the 53 determinations given in the above tables is 8,341; but if Mr. Ranson's 26 samples combined (miscellaneous No. 6) had been counted separately the average would have been 8,833. Most of our samples (counting miscellaneous No. 6 as only one again) exceed 9,050 B. T. U., two thirds of them exceed 8,500 (Davis's average), and three fourths of them exceed 8,341 (our average).

The highest fuel value is as a rule in the purest peat. No. 29.11 (the purest) is best in that respect, though No. 16.11, with 15.5% of ash, and no plasticity (and therefore not adapted to be made into briquettes), stands very high in the list. It should be borne in mind that the fuel value given in these tables is on a water-free basis, which is never realized in practice, for peat as used always contains some water, which reduces its fuel value. But the analyses are usually expressed in this way to eliminate differences due to variations in atmospheric humidity.
UTILIZATION OF PEAT.

Peat can be and has been put to a remarkable variety of uses, ranging all the way from its use in place as a soil for growing crops in, to the extraction of ammonia, alcohol, and other products from it by complicated chemical processes. Some of its uses are based on its physical properties, some on chemical properties, and some on both. New ways of using it are frequently discovered, but those which have not passed beyond the experimental stage hardly need to be mentioned here. The more important uses to which peat is put after being removed from the place where it is formed may be classified as follows:

Based on physical properties
   - Non-conductor of heat or sound
   - Fiber for paper, pasteboard, etc.
   - Blocks for paving and building purposes.

Based on chemical properties
   - Preservative
   - Source of dye, ammonia, alcohol, etc.
   - Fuel
     - Air-dried
     - Pressed
     - Coke
     - Gas

Based on both physical and chemical properties
   - Absorbent and disinfectant
   - Fertilizer
   - Fertilizer filler.

All these uses have been discussed at considerable length in several recent state and government publications, particularly those on the peat of Maine, New York, New Jersey and Michigan (see bibliography), which can be obtained without much trouble by any one who is sufficiently interested; and it is hardly worth while to repeat much of what has already been said on the subject. The uses of peat which are likely to be of most interest to the people of Florida at the present time or in the near future are as fiber, fuel, fertilizer filler, and agricultural soil.

Peat has not been used very extensively for fiber in this country as yet, but there are in Florida, especially in the saw-grass marshes, vast quantities of coarse fibrous peat which probably cannot readily be pressed into briquettes for fuel or ground up for fertilizer filler, but ought to be well adapted for non-conducting material or the manufacture of pasteboard and similar substances.

The simplest use of peat as fuel consists in merely digging it out in lumps or blocks with a spade and exposing it to sun and wind
for a few weeks, or until it is dry enough to burn. This is the way
in which it is used chiefly by the peasants of Europe, in districts
where other fuel is scarce and labor is cheap. But air-dried peat
is rather bulky and friable, and while it is burning a good deal of
its fuel value is wasted in evaporating the 10% or more of water
which it always contains even after being dried for an indefinite
period. If, however, the Florida peat is less retentive of water
than that from most other parts of the world, as the analyses seem
to indicate, the last-named objection would not have so much force
here.

In order to produce peat fuel economically on a large scale it
must be compressed by machinery before drying, or after partial
drying. This diminishes all three of the objections just mentioned.
The amount of water can be still further reduced by the application
of heat before, during, or after compression, but obviously there
is a limit to the amount of heat which can be profitably applied to
a substance which is itself to be used only as a source of heat. To
expel all the water would require nearly as much heat as the
finished product would produce by its combustion, for peat retains
the last drops of water with great tenacity.

Numerous types of machinery have been devised for preparing
peat fuel for the market, and they have been described in some of
the reports previously mentioned, particularly that of Davis on
Michigan peat. In most of them, or at least in the best known
ones, the peat as it comes from the bog is first macerated so as to
break up the vegetable tissues and thus facilitate the escape of the
water, and then squeezed between rollers and pressed into moulds,
somewhat as clay is treated in the process of brick-making. The
blocks are then dried in a shed or other suitable place, and in a few
days or weeks they are ready for use.

Those who have used pressed peat as fuel are almost unanimous
in testifying that it is very satisfactory, especially for domestic pur-
poses. It is said to be clean and easily kindled, to burn steadily,
with considerable heat, and little or no smoke, sparks, soot or cin-
ders, and to be well adapted to both grates and stoves. In short,
its fuel properties are just about intermediate between those of
wood and coal.

For industrial uses it has in some places been found advanta-
geous to subject peat to a process of destructive distillation in iron
retorts, separating it into gas and coke, just as is done every day
with coal. This has the special advantage of simplifying the prob-
lem of transportation, for peat at its best is too bulky to be carried
far with profit, while the gas can be piped for miles and burned
wherever it is needed. The coke remaining in the retorts is an excellent fuel, too, said to be almost as good as anthracite coal.

A peat gas plant requires a larger investment than a peat briquetting mill, and in order to be profitable it must of course be located near a supply of peat large enough to last for many years. There are, however, quite a number of towns in Florida (Palatka and Lakeland, for example) where conditions seem to be favorable for an enterprise of this kind.

Still another method of utilizing peat as a source of power is to convert its heat into electricity, through the medium of either steam or gas engines, right at the bog, and transmitting the electricity to neighboring cities or wherever it is wanted.

Peat is sometimes used as a fertilizer, by applying it directly to soils which are deficient in organic matter. For this purpose fresh peat should not be used, for it is too sour, not to mention other disadvantages. A better way is to let it lie exposed to the weather for a year or so before applying it to the soil, at the same time pulverizing it so that it will not be all hard lumps. This weathering process increases the availability of the nitrogen it contains, and makes it more and more like humus, as explained briefly in the introductory chapter of this report. The humification can be considerably accelerated by mixing the peat thoroughly with barn-yard manure, for this contains bacteria which help to break up the peat, while the peat at the same time absorbs from the manure ammonia and other plant foods which might otherwise be lost.

In Florida there has been more capital invested in plants for the manufacture of fertilizer filler than in any other peat industry. Two of these have already been described on pages 287-289, and another briefly mentioned. All of these being situated on navigable waters, the first step in each case was to build a dredge and cut a canal from the water to the dry land where the buildings were erected.* The peat excavated by the dredge from along the canal and its branches is carried on lighters to a dock, from which a belt conveys it to a “pug mill” similar to those used in mixing brick clay, which mixes and macerates it and lets some of the water escape. Then by an ingenious device of Mr. Ranson’s, which need not be described in detail here, the peat is spread about eight inches deep over an area of several thousand square feet, to dry in the sun. No protection from rain is provided, but rain is infrequent in Florida in the winter and spring months, and in average

*For this description of the process of making fertilizer filler I am chiefly indebted to Mr. Robert Ranson, who designed all three of the plants under consideration.
weather the moisture content of the peat will diminish to 25% in about two weeks.

It is then taken up from the ground and stored under shelter until wanted for grinding. After grinding to a coarse powder it is passed through the drier, which consists of an iron tube about 40 feet long and 5 feet in diameter, slightly inclined, and kept slowly rotating by suitable machinery, while the flames of a furnace are conducted through it. The damp freshly-ground peat is poured in at the upper end, and in half an hour or less comes out at the lower end with less than 10% of moisture (which is the maximum accepted by the fertilizer manufacturers). The driers most commonly used have only a single tube, but Mr. Ranson has lately found many advantages in using one with an inner and outer tube, which makes the gases from the furnace traverse the whole length of the drier twice, and keeps the outer shell from becoming red-hot as it usually does in the single-tube apparatus.

Ground peat as a filler has several advantages over other substances used to dilute commercial fertilizers, such as sand, ground slag, coal waste, etc., because it is organic matter, and cannot injure the soil as some of these other substances do, and it contains nitrogen, a valuable plant food. But much of this nitrogen is in such combinations that it does not become available to plants until after a few years of weathering, and in many states there are legal obstacles in the way of counting such nitrogen in the guaranteed analysis of fertilizers.

Another circumstance which tends to retard the use of peat as a source of nitrogen, is the comparatively recent discovery of a cheap method of extracting nitrogen from the atmosphere and combining it with calcium carbide to form calcium cyanamide, which has proved to be a valuable fertilizing material. However, it is possible by chemical processes to separate nitrogen from peat in a form available to plants, and it is altogether probable that future inventions and improvements will cheapen these processes so that peat nitrogen can compete successfully with that derived from other sources.

For a more elaborate discussion of the use of peat as a fertilizing material see the articles by Haskins, cited in the bibliography.
PEAT AS AN AGRICULTURAL SOIL.

The question of the utilization of peat or muck as a soil to grow crops in belongs to an agricultural rather than to a geological report, and will not be gone into very deeply here. It has been discussed repeatedly in many experiment station bulletins and similar publications which the interested reader can easily find; and I will only undertake to point out a few of the fundamental principles.

Excellent crops have undoubtedly been grown on peat in many parts of the world, but there have also been many failures, due to imperfect understanding of the conditions, which are very different from those of true or mineral soils. Any one undertaking developments of this kind without previous experience would therefore do well to proceed cautiously.

Many people seem to think that an extensive peat deposit, consisting as it does of vegetable debris which has been accumulating for centuries, should make a wonderfully fertile soil when drained; and as such places are often treeless, the expense of clearing, an important item in some fertile soils, is done away with from the start. In Florida, attention has recently been focused upon the Everglades as a possible addition to the agricultural area of the State, partly because of its enormous extent and unique and more or less mysterious character, and partly because it is situated in a latitude almost free from frost.

Considering the last point first, a tropical climate is by no means essential to successful agriculture. If it was, the farmers in temperate regions could not compete with those in the tropics, and northern Florida would be inhabited only by lumber and turpentine men, stockmen, phosphate miners, etc. As it is, every climate has its advantages and disadvantages, and where there is no frost, weeds, insects, and other pests have a much better show than in cooler climates.

Again, peat, unlike humus or ordinary soil, contains very little plant food. Its nitrogen is largely inert, as already explained, and it is usually sour and very deficient in other ingredients which nearly all crops need, such as lime, phosphoric acid, and potash. The natural fertility of a soil (i. e., without fertilizers) is indicated by the native vegetation better than anything else, as Dr. Hilgard* has repeatedly pointed out, and the vegetation growing on peat is nearly always of a character signifying acidity and sterility of soil.

The early settlers of the eastern United States quickly selected and appropriated the richest soils, which they located with unmerring

*See bibliography.
judgment by means of the oak, hickory, beech and maple forests of the northern and middle states, the sweet gum and white oak bottoms of Georgia, Alabama and Mississippi, the hammock vegetation of Florida, etc. (Examination of a land-office map of Florida will show that the old Spanish grants, especially those away from navigable waters, nearly all include a large proportion of hammock land). As the population increased there soon came a time when there was not enough very rich soil to go around, and poorer and poorer soils gradually had to be brought under cultivation. The improvement of agricultural methods and transportation facilities, the selection of more prolific varieties of plants, or, if nothing else, the price of farm produce, always keeps pace with the extension of the cultivated area, however, so that the farmer who cultivates the poorest soil can always make both ends meet in the long run. (According to political economy this is bound to be the case, for obviously no one would continue very long at farming or any other business if he lost money by it; and there are always just enough successful farmers to feed and clothe the world.)

The purpose of the preceding paragraph is merely to show that no one need imagine that our peat deposits and other swamps are newly-discovered mines of agricultural wealth, capable of enriching all who succeed in getting a slice of them. Our forefathers knew good land when they saw it, and any land which they left uncultivated simply was not worth cultivating when the population was sparse. Comparisons are sometimes made (by promoters) between our Everglades and the valley of the Nile, but these are very misleading, for the two regions have little in common except latitude and water, and the water differs greatly in amount, movements, fluctuations, and substances suspended or dissolved in it; characters which I have already shown to be of fundamental importance in classifying swamps. (Equally misleading is the term "delta" often applied to the country between Sanford and Lake Jessup.)

There is, however, another factor to be considered in connection with these and other agricultural problems, namely, fertilizers. The use of commercial fertilizers, which has grown rapidly in the last few decades, has made the original fertility of soil less important than formerly, and enabled the farmer on new poor sandy land to raise just as good crops as the one on old rich clay land. This being the case, not so much attention is now paid to the chemical nature of the soil, and ease of cultivation is the prime requisite.

At the present time almost any soil which is not too hilly or too rocky or too wet or too remote from markets, or impregnated with
injurious substances (as in the alkali soils of the West), can be cultivated with profit, and this is the fundamental reason for the modern demand for the drainage of swamps, marshes, etc. The principal physical drawback about peat soils is of course that they are saturated with water; and as agriculture began and has had its greatest development on dry land, human ingenuity has as yet devised very few crops adapted for growing in water.

In many cases the water can be removed by drainage without much expense, and after the acidity of the peat is corrected by weathering or the application of lime or manure, the proper fertilizers can be applied and crops raised in the usual manner. Peat has the advantage of being very easily tilled, and never suffering from drought. It shrinks considerably in drying, however, and this has to be taken into consideration in making plans for draining it by ditching.

Some peat which is unavailable for fuel on account of being too shallow or too impure, or both, is for the same reasons all the better adapted for cultivation. Most of the peat deposits or "muck lands" which have been cultivated in Florida are of just this character, shallow and sandy. Other things being equal, calcareous peat ought to be better for agricultural purposes than typical sour peat. One advantage possessed by the Everglades is that they are everywhere underlaid by limestone, which is just the proper thing for correcting acidity; and at many places toward the south end there seem to be all gradations between peat and marl, which ought to afford the right combinations for quite a variety of crops. Not all crops are adapted to peat soils, but it would be beyond the scope of this report to make any recommendations along that line.
ASSOCIATED PRODUCTS.

Most peat deposits contain other things besides peat, which deserve to be considered in estimating the probable profits to be derived from any contemplated peat utilization project.

A peat deposit which has been worked for its diatoms ("infusorial earth") alone has been described on page 290. This material is used as a non-conducting covering for steam-pipes, as a polishing powder, and as an ingredient of dynamite. Deposits containing diatoms in such abundance must be rather rare. According to Parsons (see bibliography) there are two such deposits in the state of New York.

The numerous shells in the peat around Lake Panasoffkee (see page 280) might be of some importance if this peat was used in the manufacture of fertilizer filler.

Marl of a composition well suited to the manufacture of Portland cement has been found associated with peat bogs in Michigan and a few other states in the glaciated region,* and bog iron ore was formerly the basis of an important industry in the coastal plain of New Jersey. No special search has been made for these materials in Florida, but it is quite likely that they could be found; especially the former, on account of the abundance of limestone in this state.

The sphagnum (peat moss) which is so abundant in many northern and European peat bogs is used in some places for stable litter and bedding, very extensively for packing cuttings and nursery stock to protect them from cold and dryness, and for several other purposes. Sphagnum is not very abundant in Florida, but there may be a few places in the state, such as some of our bays, slash-pine bogs, and non-alluvial swamps, where it could be collected profitably.

A kind of coarse hay, more suitable for bedding than for fodder, is cut from many northern salt marshes.

Most of the trees which characterize many of our peat deposits are of some value for their wood or sundry other products. Below is a list, with common names and economic properties (if known) of the kinds of trees which I have seen growing on peat in Florida. Their distribution within and without the state is given in the catalogue of peat-forming plants a little farther on.

It is interesting to note that the plants which form the best peat furnish neither food nor medicine for man or beast, with very few exceptions.†

†According to Dr. Hilgard (Soils, pp. 495, 512) bog plants are commonly characterized by having small seeds.
Avicennia nitida Jacq. Black Mangrove.

Osmanthus Americanus (L.) B. & H. Wild Olive.

Fraxinus Caroliniana, Mill., F. profunda Bush, and perhaps other species. Ash.

The wood of various species of ash is used for chairs, hats, agricultural implements, etc., and the bark has some slight medicinal properties.

Nyssa Ogeeche, Marsh. Tupelo Gum or Ogeechee Lime

The flowers are an important source of honey and the fruit is used in some places for preserves.


Wood light and tough, good for baskets, crates, bowls, flooring, etc. Also an important honey plant.

Nyssa biflora, Walt. Black Gum.

Wood almost impossible to split, therefore used for bee-gums, small cart-wheels, mauls, rollers, etc.

Rhizophora Mangle, L. (Red) Mangrove.

An important protector for muddy shores. Bark used in tanning.

Cnesterus erectus, Jacq. Buttonwood.

The wood of this makes excellent fuel, and a good deal of it is shipped into Key West from the mainland for that purpose. The bark is said to be bitter and astringent, and to be used in medicine and in tanning.

Persea rubescens, (Pursh) Sarg. Red or Sweet Bay.

Wood good for cabinet-making and interior finish, but very little used.

Gordonia Lasianthus, L. (Red or Tan) Bay.

The wood ought to be good for cabinet-making. The bark is said to have formerly been used for tanning.

Acer rubrum, L. Red Maple.

Planted for shade in the North. Wood used for chairs, gun-stocks, cabinet-making, etc.

Ilex Cassine, L. Swamp Holly.

Ilex myrtifolia, Walt. Yaupon or Yupon.

The wood of these two small trees is white and close-grained, and ought to be useful for making various small articles, but it is little known or used. The last is sometimes used for decorative purposes in fall and winter, when it is covered with berries.

Cliftonia monophylla, (Lam.) Britton. Tyty.

Wood somewhat similar to the preceding, and also said to make excellent fuel. The flowers are an important source of honey in March.


Bark astringent. The flowers yield a great deal of honey in early summer.
Liquidambar Styraciflua, L. Sweet Gum.
Planted for ornament in northern parks. Wood used for furniture and a few other purposes. Bark medicinal.

Magnolia glauca, L. (White) Bay.
Cultivated for ornament in the North. Wood good for broom handles, etc., but little used. Bark medicinal.

Anona glabra, L. Custard Apple.

Ulmus Floridana, Chapm. (and perhaps other species) Elm.
The wood of most of the elms is hard and tough, and used for chairbacks, bicycle rims, etc. Several of them are planted for shade-trees.

Quercus nigra, L. Water Oak.
A common shade-tree in the South. Wood not good for much except fuel.

Carpinus Caroliniana, Walt. Ironwood.
Wood hard and heavy, good for levers, tool-handles, etc., but little used.

Salix longipes, Anders.? Willow.

Myrica cerifera, L. Myrtle.
Sometimes cultivated for ornament. The berries furnish wax.

Sabal Palmetto, (Walt.) R. & S. Cabbage Palmetto.
Cultivated for ornament all over Florida, and in a few places in other states. Trunks often used for piles in salt water, because they are not attacked by the teredo. The terminal bud ("cabbage") is edible.

Juniperus Virginiana, L. (Red) Cedar.
A common shade-tree around old-settlements. Wood used for posts, boat-ribs, pencils, etc.

Chamaecyparis thyoides, (L.) B. S. P. Juniper.
Wood very durable, used for poles, buckets, shingles, etc.

Planted to some extent in northern parks. Wood very durable, used for canoes, poles, piles, shingles, barrels, sash, doors, blinds, etc.

Wood used for poles, piles, cross-ties, shingles, etc.

Pinus Elliotii, Engelm. Slash Pine.
An important source of lumber and turpentine, almost equal to its better known relative the long-leaf pine.

Pinus serotina, Mx. Black Pine.
Wood very similar to that of the short-leaf pine, but little used, because there is always long-leaf pine to be had near by, and that is much better in every way.
CATALOGUE OF THE PRINCIPAL PEAT-FORMING PLANTS OF FLORIDA.

INTRODUCTORY STATEMENT.

The following catalogue includes only those species of plants which have been seen by the writer at least once in permanent water or on several inches or feet of peat, and therefore in a position to form peat as they decay. (Many of them are found also in other habitats, such as low pine lands and sandy lake shores; but those species mentioned in the foregoing pages as growing only in alluvial swamps, cypress ponds, etc., where there is no peat, are excluded). It is of course far from complete, for the reasons given elsewhere, and also because during the field work quite a number of species were encountered which I did not recognize at first sight, generally because they belonged to difficult groups; and when working on peat I was not usually prepared for collecting botanical specimens for subsequent identification. I have probably identified the genus correctly in nearly every case, and the species in the great majority of cases; and where I was not sure of the specific identity of a plant I have either omitted the specific name entirely or added an interrogation point. With all its shortcomings, however, this is probably the longest list of peat-forming plants ever published for a single state or country.

The species are grouped into genera and families in the usual manner, and arranged in what is essentially the Engler & Prantl sequence, except that it is reversed, so as to bring the highest plants first and the comparatively little-known and inconspicuous mosses, etc., last.

Under each species is given first its technical name (usually the same as in Small's Flora of the Southeastern United States, 1903), and common name or names, if it has any,* then its observed distribution in Florida, with special reference to peat deposits, and finally its general distribution; the last primarily to show the relation of our peat flora to that of other parts of the world.

*As I have not as yet made extensive inquiries into the common names used for plants in Florida, I have employed in most cases names which are current in South Georgia, where I spent a few years before coming to Florida. Such names ought to be familiar to most Floridians, for many of them have lived in the neighboring state. (According to the census of 1900 nearly 11% of the inhabitants—and of course a still larger proportion of the adult inhabitants—of Florida were born in Georgia.) The most careful investigation, however, would probably not discover bona-fide common names for more than half of the peat-forming plants, for they grow in comparatively inaccessible places, and very few of them (except the trees) have any useful properties, so that the people have had little occasion for giving them names.
Senecio lobatus Pers.
In alluvial and calcareous swamps in the northern parts of the state. Contributes slightly to the formation of peat at the mouth of the Suwannee River, if not elsewhere.
Widely distributed in the southeastern United States, mostly in the coastal plain.

Mesadenia sulcata (Fernald) Small
In sandy non-alluvial or non-calcareous swamps in most if not all of the counties in West Florida. Grows on deep but impure peat in the estuarine swamps near Milton and Pensacola.
Otherwise known only in a few places in Southwest Georgia.

Mesadenia diversifolia (T. & G.) Greene
In calcareous swamps in Jackson and Levy Counties.
Also in two or three extreme southwestern counties in Georgia.

Erechthites hieracifolia (L.) Raf. Fireweed.
Grows in damp "new ground" of various kinds, especially in swamps and damp woods which have just been cleared or drained or burned over; or even in natural swamps when the water is very low, especially if calcareous. I have noticed it on peat at Panasoffkee, Helena Run, and in a partly drained small prairie near Manatee. It seems to occur in nearly all parts of the State.
Ranges throughout Eastern North America, but usually in unnatural places.

Baldwinia uniflora Nutt.
In the northern parts of the State, mostly in low pine land, but also flourishing on many feet of peat in the estuarine swamps of the Blackwater River.
North Carolina to Louisiana, in the coastal plain.

Bidens coronata (L.) Fisch. (Coreopsis aurea Ait.)
Mostly in estuarine swamps and marshes, in Escambia, Santa Rosa and Walton Counties. (Prof. A. S. Hitchcock has reported it from various places on the peninsula, but I have not been down that way in the fall, when it blooms.)
Virginia to Louisiana, in the coastal plain.

Coreopsis angustifolia Ait.
In estuarine marshes of the Escambia River, in wet pine lands in Walton County, around mayhaw ponds near Chipley, etc.
North Carolina to Texas (?), in the coastal plain.

Pluchea imbricata (Kearney) Nash
Mostly in shallow ponds, but also in small peat prairies between Grandin and Interlachen and near Rochelle.
Western South Carolina to central Florida, in the coastal plain.
Baccharis halimifolia L.

Edges of salt marshes, also in a few somewhat calcareous swamps in the interior (near Pickett, Duval Co., and Sunnyside, Lake Co.) Not abundant. Occurs as a weed in low grounds around Tallahassee. Massachusetts to Texas, mostly along the coast.

Aster Carolinianus Walt.

Mostly in calcareous and estuarine swamps. Seen near Pickett and Panasoffkee, on the Suwannee, St. Marks, Sopchoppy and Apalachicola Rivers, and near the north end of Biscayne Bay. South Carolina to Florida, in the coastal plain.

Boltonia diffusa Ell.

In estuarine marshes of the Escambia and Yellow Rivers, and around mayhaw ponds near Chipley, and cypress ponds near Tallahassee. South Carolina to Florida, Illinois and Texas, in the coastal plain.

Solidago fistulosa Mill. Goldenrod.

Chiefly on edges of non-alluvial swamps, in sandy prairies, and in the drier portions of peat prairies. As it blooms in fall, I have not identified it very often, but I have seen it in Walton, Lake, Osceola and DeSoto Counties at least.

New Jersey to Louisiana, in the coastal plain.

Mikania scandens (L.) Willd.

Mostly in calcareous swamps; widely distributed over the State, but not abundant. Contributes to the formation of peat along Helena Run, if not elsewhere.

Massachusetts to Indiana, Florida and Texas. Also in the West Indies.

Eupatorium serotinum Mx.

Mostly in saw-grass marshes; not common. Escambia, Santa Rosa, Duval, Sumter and Lake Counties. (In other states it seems to prefer river-bottoms.) Maryland (?) to Iowa, South Florida and Mexico.

Eupatorium capillifolium (Lam.) Small. Dog-fennel.

Abundant in drained marshes and in prairies and lakes which are dry most of the year so that cattle can graze in them, especially in the Middle Florida hammock belt, the southern part of Sumter County, and the northern part of Osceola. It is supposed to be native, but it never seems to grow in places which have not been tampered with in some way. Where it grew before the country was settled is a mystery.

Delaware (?) to Florida and Louisiana, mostly in the coastal plain.

Iva frutescens L.

In and around salt marshes. Frequent at least as far south as Fort Myers, but not abundant.

Virginia to Texas, along the coast.
CAPRIFOLIACEAE. Honeysuckle Family.

Viburnum obovatum Walt.

Usually in river and creek swamps where either the water or soil is calcareous, and there is very little peat. Extends southward to DeSoto County, westward to the Apalachicola River, and northeastward in the coastal plain to North Carolina and perhaps Virginia.

Viburnum nudum L. Possum Haw.

In non-alluvial or non-calcareous swamps. Escambia, Santa Rosa (estuaries), Walton, Hillsborough, Polk and DeSoto Counties, and doubtless at many intervening points.

Long Island to Louisiana, mostly in the coastal plain.

Sambucus Canadensis L. Elder.

In rich damp soil of various kinds, sometimes in drained marshes, etc., like Erechtites, but often apparently indigenous. Probably grows in every county in Florida. In South Florida it becomes a small evergreen tree, and blooms every month in the year, or nearly so.

Nearly throughout temperate North America east of the Rocky Mountains, but natural range and habitat uncertain.

Rubiaceae. Madder Family.


Common throughout the State, in fresh-water swamps and ponds of various kinds, where the water fluctuates a foot or more with the seasons, leaving the soil exposed a good deal of the time. It therefore avoids the sour non-alluvial swamps and bays, and prefers mucky or muddy places.

Nearly throughout the Eastern United States, and in the West Indies.

Diodia Virginiana L.

In a shallow peat prairie near Rochelle, Alachua Co. Not rare in damp places of various kinds, often as a weed.

New Jersey to Texas, mostly in the coastal plain.

Bignoniaceae. Cross-vine Family.

Crescentia cucurbitina L. Calabash Tree

In a mangrove swamp near Lemon City, Dade Co. Also in low hammocks in the same general region.

South Florida to Venezuela.

Utricularia.

Most of these are not in condition for identification in winter and spring, when the peat deposits of Florida are most conveniently examined. They commonly float in permanent stagnant coffee-colored water, in places where they
are protected from waves by the smallness of the pond or cove, or by other aquatic vegetation. About a dozen species have been reported from Florida.

\[ U. \text{ subulata} \] L. is common on sandy shores of small lakes (and probably also occurs in peat prairies), and \[ U. \text{ cornuta} \] L. in a deep open tyty bay near Carrabelle and on moist sandy slopes in the pine woods in the southeastern part of Jackson County.

### SCROPHULARIACEAE. Figwort Family.

**Gerardia linifolia** L.

Cypress ponds, peat prairies, saw-grass marshes, etc.; not common. Jackson, Leon, Lake, Osceola and DeSoto Counties. Delaware to Florida, in the coastal plain.

**Macranthera fuchsioides** (Nutt.) Torr.

In estuarine swamps near Milton, Santa Rosa Co.; sometimes over ten feet tall. Also in branch-swamps in Walton and Washington Counties. Rare. Southwest Georgia to Louisiana, in the coastal plain.

**Gratiola ramosa** Walt.

Edges of shallow ponds, peat prairies, etc. Wakulla, Osceola, and doubtless many other counties. South Carolina to Florida, in the coastal plain.

**Monniera Caroliniana** (Walt.) Kuntze

In still water of various kinds, from the estuaries of Santa Rosa County and the cypress ponds of Jackson County to the large lakes of Leon and Lake Counties, the marshes of Crescent Lake, and the south end of the Everglades. (In other states it seems to be chiefly confined to small ponds.) Maryland (?) to Louisiana, in the coastal plain.

### LABIATAE. Mint Family.

**Lycopus pubens** Britton?

In a cypress swamp near Leesburg. The same or another species grows in cypress ponds in the East Florida flatwoods, and in gum swamps near Tallahassee. They are doubtless common enough in other parts of the state, but I have not been able to identify them because they bloom in the fall.

### VERBENACEAE. Verbena Family.

**Avicennia nitida** Jacq. Black Mangrove.

A common shrub in salt marshes as far north as Cedar Keys and New Smyrna at least. On the coasts of South Florida it becomes a considerable tree, and must contribute more or less to the peat of the mangrove swamps. Coast of Mississippi to the Bahamas and Brazil. (Not yet known in Middle and West Florida and Alabama, however.)
Lippia sp.

In marshy places which are a little calcareous or brackish, and dry a good deal of the time. Grows on several feet of peat in the marshes of Crescent Lake, and in mineral soil in the prairies around Lakes Monroe and Harney, the southern edge of the Everglades, etc.

**HYDROPHYLLACEAE.**

*Nama corymbosa* (Macbride) Kuntze

In a saw-grass marsh at the south end of Lake Eustis, and in a small shallow prairie in the pine woods near Lemon City. (Also collected near Sanford by Nash, and near Fort Myers by Hitchcock.)

South Carolina to Florida, in the coastal plain.

**CUSCUTACEAE.**

*Cuscuta compacta* Juss. Love Vine.

On shrubs of various kinds, in and around bays, tyty swamps, etc., in the northern counties, mostly north of latitude 30°.

Rather widely distributed in the Eastern United States.

**CONVOLVULACEAE.** Morning-glory Family.

*Ipomoea sagittata* Poir. Morning-glory.

In low grounds which are a little calcareous or brackish. Frequent in depressions in the flatwoods of St. Johns County. Occurs also in the marshes of Crescent Lake, in the same county, on several feet of peat, and in a small prairie near Lemon City, and doubtless in many other more or less similar places.

North Carolina to Texas, in the coastal plain. Also reported from Spain and Cuba.

**ASCLEPIADACEAE.** Milkweed Family.

*Asclepias lanceolata* L.

In fresh marshes of various kinds, or occasionally in low pine lands. Widely distributed, but nowhere abundant, rarely more than two or three specimens being visible at once. Santa Rosa, St. Johns and Dade Counties.

New Jersey to Texas, in the coastal plain.

**APOCYNACEAE.** Dogbane Family.

*Rhabdadenia biflora* (Jacq.) Muell. Arg. (*Echites paludosa* A. DC.)

A woody vine, observed in a mangrove swamp near Lemon City, Dade Co South Florida and the West Indies.

**GENTIANACEAE.** Gentian Family.

*Limnanthemum aquaticum* (Walt.) Britton

In sour estuaries, permanent ponds, shallow lakes, and very wet peat prairies. Walton, Leon, Jefferson, Sumter, Lake, Osceola and Palm Beach Counties.
What looks like a small form of it, but may be another species, \textit{L. lacunosum} (Vent.) Griseb., grows in the estuaries near Milton and in a peat prairie near Lakeland.

\textit{L. aquaticum} is confined to the coastal plain, and \textit{L. lacunosum} to the glaciated region and coastal plain.

**Bartonia verna** (Mx.) Muhl.

Low pine land, margins of small lakes and bays, and in the drier parts of peat prairies; widely distributed over the state, blooming in midwinter.

North Carolina to Mississippi, in the coastal plain.

**Sabbatia foliosa** Fernald

Estuarine swamps near Milton.

South Carolina to Alabama, in the coastal plain.

**Sabbatia calycina** (Lam.) Heller

In swamps with calcareous soil or water and very little peat. Jackson and Duval Counties.

North Carolina to Cuba, Arkansas and Texas.

**OLEACEAE.** Olive Family.

**Osmanthus Americanus** (L.) B. & H. Wild Olive.

In estuarine swamps near Milton. More common on bluffs and in hammocks; widely distributed in the northern half of the state.

North Carolina to central Florida and Louisiana, almost confined to the coastal plain.

**Fraxinus Caroliniana** Mill.

Ash.

What I take to be this species (though I may have confused one or two others with it) grows in swamps of various kinds, in Escambia, Santa Rosa, Wakulla, Duval, Sumter and several other counties, but rarely if ever on good peat. In the estuaries of the Escambia and Yellow Rivers a shrubby form of it only a few feet tall, but bearing fruit, is common.

Virginia to Texas, mostly in the coastal plain.

**Fraxinus profunda** Bush.

Ash.

In calcareous and estuarine swamps. Franklin, Jefferson, Duval, Putnam, Levy, Hernando, Sumter, Lake and Osceola Counties. (Our specimens differ from current descriptions in having the leaves smooth on both sides, but they have been identified as \textit{F. profunda} by Prof. C. S. Sargent).

Range not well known. Said to occur also in Pennsylvania, Missouri and Georgia

**THEOPHRASTACEAE.** Jacquinia Family.

**Rapaneca Guyanensis** Aubl. \textit{(Myrsine Rapaneca R. & S.)}

In a slough on the north side of Paradise Key in the Everglades, Dade Co. Also in a non-alluvial swamp a few miles west of West Palm Beach. More common in the hammocks of the Miami limestone region.

Florida to Paraguay.
PRIMULACEAE. Primrose Family.

Samolus floribundus HBK.

This little plant seems to be nearly always a sign of limestone not far below the surface, or in the water. It grows on several feet of peat along Helena Run, and in shallow calcareous swamps in various other parts of the State.

Said to be distributed from Newfoundland to South America, but evidently absent over large areas.

VACCINIACEAE. Huckleberry Family.

Vaccinium virgatum Ait.? Huckleberry. Blueberry.

Non-alluvial swamps, bays, sandy river-bottoms, etc., from DeSoto County northward. (Perhaps several closely related species).

Widely distributed in the Southeastern United States.

Gaylussacia hirtella (Ait. f.) Klotzsch

In estuarine swamps near Milton; sometimes 6 feet tall.
Grows also in southern Alabama, and perhaps in other states.

ERICACEAE. Heath Family.

Cholisma ligustrina (L.) Britton. (Also spelled Xolisma.)

In and around non-alluvial swamps, from DeSoto County northward; not very common.

Widely distributed in the Eastern United States.

Pieris nitida (Bartr.) B. & H. Hurrah Bush.

In sour non-alluvial and non-calcareous swamps, bays, etc., where the water level does not vary more than a few inches throughout the year. Also in low scrub and sandy shores of lakes, above high-water mark. Common as far south as Polk County.

Virginia to Louisiana, in the coastal plain.

Pieris phillyreifolia (Hook.) DC.

In bays, cypress ponds, etc., or in almost any place where pond cypress grows. Usually climbs cypress trees by creeping up between the inner and outer bark, sometimes to a height of 30 feet or more, and sending out branches with leaves and flowers every few feet. More rarely on tyty or juniper. Frequent in nearly all the counties west of the Suwannee River.

Okefinokee Swamp to Mobile Bay.

Leucothoe racemosa (L.) Gray

Chiefly in bays. Franklin, Leon, Jefferson, Madison and Bradford Counties.

Widely distributed in the Eastern United States, but most frequent in the coastal plain.
Azalea viscosa L. Swamp Honeysuckle.

Sandy branch-swamps, non-alluvial swamps, bays, etc., from Hillsborough County northward. Contributes to peat formation in the estuarine swamps of Santa Rosa County, if not elsewhere.

General distribution much like that of the preceding.

CLETHRACEAE.

Clethra alnifolia L.

Bays, non-alluvial swamps, low pine lands, etc., from about lat. 30° northward. Escambia, Walton, Jackson, Leon, Wakulla, Jefferson, Madison and Clay Counties.

Maine to Louisiana, in the glaciated region and coastal plain.

UMBELLIFERAЕ. Parsley Family.

Oxypolis filiformis (Walt.) Britton

In cypress ponds, prairies, Everglades, etc., mostly in open places where the water varies with the seasons from nothing to a few inches in depth, and has little or no current. Contributes to peat formation in the estuaries of West Florida and in the Everglades northwest of Fort Lauderdale and Miami.

North Carolina to Louisiana, in the coastal plain.

Cicuta Curtissii C. & R.

Mostly in large fresh marshes and in somewhat calcareous swamps. Hog Island, Panasoffkee, Helena Run, Lake Apopka, etc. (In other states it usually grows in small marshes and non-calcareaous—but sometimes muddy—swamps).

Virginia to Louisiana.

Eryngium virgatum Lam.

Estuarine marshes, wet pine lands, etc. Escambia, Walton and Jackson Counties.

Western North Carolina to northern Florida and Texas.

Centella repanda (Pers.) Small

Common all over the State, in shallow ponds, prairies, and various other places which are dry about half the time. Often in calcareous soils, and not usually on peat; but it helps form peat in open tyty bays near Carrabelle, in some of the smaller peat prairies of the lake region, and in the St. Johns River swamp near Palatka.

Maryland to Texas, in the coastal plain. Also in the tropics.

Hydrocotyle verticillata Thunb.

In calcareous swamps near Pickett, Panasoffkee, and Helena Run.

Massachusetts to Mexico. Also in the tropics.
Hydrocotyle Bonariensis Lam.?

Usually floating in still deep water, especially if calcareous. Noticed in the estuaries of Santa Rosa County, in the Withlacoochee, Homosassa and Panasoffkee Rivers and Helena Run, in the St. Johns River swamps near Astor, and in Lakes Griffin, Harris, Dora and Apopka.

Probably introduced from the tropics.

Hydrocotyle umbellata L.

Peat prairies, sandy prairies, shores of small lakes, etc. Leon, Madison, Alachua, Lake, Polk, Hillsborough, and doubtless many other counties.

Widely distributed in the Eastern United States and tropical America.

ARALIACEAE. Ginseng Family.

Aralia spinosa L. Prickly Ash.

Usually in hammocks or on bluffs, but grows on a few feet of peat in the St. Johns River swamp near Palatka, and probably elsewhere.

Widely distributed in the Eastern United States between latitudes 29° and 40°.

CORNACEAE. Dogwood Family.

Cornus stricta Lam.

Chiefly in calcareous swamps, sloughs and low hammocks, from DeSoto County northward. Sometimes on several feet of peat, but such peat is generally impure, or full of logs, or both.

Virginia to Mississippi.

Nyssa Ogeche Marsh. Tupelo Gum or Ogeechee Lime.

North of latitude 30°, in swamps and sloughs of various kinds, mostly where the water is non-calcareous and fluctuates about two feet. Rather common from the Tallahassee meridian west to the mouth of the Choctawhatchee River. Becomes a medium-sized tree in the estuarine swamps of the Choctawhatchee and Apalachicola Rivers. (It does not seem to grow above the reach of the tides on the latter river or any of its tributaries.) Farther east, near the St. Marys River, it is a small tree or large shrub, and grows often around ponds.

Extreme southern South Carolina to West Florida.


In swamps and sloughs, affecting more muddy or calcareous situations than the preceding, and flourishing especially in alluvial swamps. Known in Florida only from Leon and Wakulla Counties on the east to the Choctawhatchee River on the west. Rarely if ever on good peat.

Virginia to Florida, Illinois and Texas, mostly in the coastal plain.

Nyssa biflora Walt. Black Gum.

In non-alluvial swamps, shallow ponds, etc., but not averse to a little lime. Common in all the northern tier of counties, and extending as far south as DeSoto County. Seems to be rare in the lake region and east of there.

Maryland to Texas, mostly in the coastal plain.
HALORRHAGIDACEAE.

Myriophyllum sp.

In the estuaries of the Blackwater and Escambia Rivers, in Lake Stanley, Walton County, and in the Big Spring of Jackson County. (Perhaps more than one species).

Proserpinaca pectinata Lam.

In the estuaries near Milton, and in wet peat prairies near Rochelle and Kissimmee. Also in shallow ponds in various other parts of the state. Massachusetts to Texas, in the coastal plain.

MELASTOMACEAE.

Rhexia.

All the species in Florida, 8 or 10 in number, are bog plants, and at least one of them grows in peat prairies. They seem to be rare or wanting in South Florida, although the family to which they belong is mainly tropical.

ONAGRACEAE. Evening-primrose Family.

Jussiaea Peruviana L.

In saw-grass marshes, ditches, etc., often where the water is a little calcareous. Ranges from Lake County southward. Introduced from tropical America.

Jussiaea suffruticosa L.

In open marshy places near Escambia Bay, between Gaberonne and Bohemia, Escambia County. Introduced from tropical America.

Jussiaea leptocarpa Nutt.

In open marshy or miry places, especially where partly drained or otherwise tampered with. Grows among the water-hyacinths in the Withlacoochee River near Istachatta. Pretty widely distributed over the State, but not common. Probably introduced from tropical America.

Ludwigia lanceolata Ell.


Ludwigia alata Ell.

Marshes at the mouths of the Escambia and Blackwater Rivers, and at the south end of Lake Eustis. Probably also in brackish marshes nearer the coast. North Carolina to Louisiana and Missouri, in the coastal plain, mostly near the coast.
Isnardia natans (Ell.) Small.

Abundant in saw-grass marshes at the south end of Lake Eustis. Also occurs in sloughs and 'gator-holes in the southern part of the Everglades. North Carolina to Mexico, in the coastal plain.

RHIZOPHORACEAE. Mangrove Family.

Rhizophora Mangle L. (Red) Mangrove. (Plate 18.)

A very characteristic small tree of tropical coasts, one of the very few in the United States which will grow right in salt water. Said to have formerly extended as far north as New Smyrna and Cedar Keys, but I have not seen it even as far north as Tampa. (It has probably been killed back by some of the severe freezes of recent years.) In the coast prairie of Dade County, where salt water rarely comes, shrubby specimens about three feet high make a rather dense growth over thousands of acres. On the shores of Biscayne Bay and on some of the Keys it becomes a medium-sized tree, and seems to form considerable peat. In the vicinity of the Ten Thousand Islands of Monroe County it grows 60 feet high, according to Sanford (Fla. Geol. Surv., 2nd Ann. Rep., p. 194).

Widely distributed on the coasts of tropical America.

COMBRETACEAE.

Laguncularia racemosa Gaert. White Mangrove or Buttonwood.

Common near salt water in South Florida, with much the same range and habitat as Rhizophora, but less abundant than the other, except toward its northern limit.

Coasts of tropical America and western Africa.

Conocarpus erectus Jacq. Buttonwood. (Plate 18.)

With the preceding, and often growing farther from salt water, as along the Miami River and at the south end of the Everglades and the inland edge of the coast prairie. Grows on peat in mangrove swamps near Lemon City and elsewhere.

Coasts of tropical America and western Africa.

LYTHRACEAE. Loosestrife Family.

Decodon verticillatus (L.) Ell.

In swamps in Escambia and Walton Counties, in marshy prairies in Madison and Polk Counties, in a cypress swamp near Leesburg, and among the water-hyacinths in the Withlacoochee River near Istachatta; usually on a few feet of peat. Rather rare in Florida.

Massachusetts to Minnesota, Florida and Louisiana, mostly in the glaciated region and coastal plain.
Persea pubescens (Pursh) Sarg. Red or Sweet Bay.

Mostly in sour non-alluvial swamps, but sometimes in more or less calcareous situations, as in a creek swamp near Pickett (Duval Co.), and around 'gator holes at the south end of the Everglades. Often on deep peat, as in clumps of trees in peat prairies. Seems to require soil which is perpetually moist but never overflowed. Widely distributed over the State.

North Carolina to Mississippi; almost confined to the coastal plain.

VIOLACEAE. Violet Family.

Viola primulifolia L. White Violet.

In some of the estuarine swamps near Milton, and around non-alluvial swamps in DeSoto County. Being distinctly a bog plant, it probably grows on peat in many other places in Florida.

Widely distributed in the Eastern United States, at least north of latitude 27°.

THEACEAE. Camellia or Tea Family.

Gordonia Lasianthus L. (Red or Tan) Bay.

Non-alluvial swamps, bays, etc., especially in the East Florida flatwoods and the lake region. Rare west of the Suwannee River. Escambia (small and rare), Madison, Bradford, Clay, Putnam, St. John's, Lake, Orange, Brevard, Polk, Hillsborough and DeSoto Counties.

North Carolina to Mississippi, in the coastal plain.

HYPERICACEAE. St. John's-wort Family.


In soil which is perpetually moistened by fresh water and usually not shaded, as in saw-grass marshes, peat prairies, and sandy and sphagnous bogs. Not abundant. Escambia, Leon, Bradford, Alachua, Lake, Polk and Hillsborough Counties.

Widely distributed in the glaciated region and coastal plain of Eastern North America, but not in the older parts of the continent.

*The attempts of the government orthographers and their followers to shorten the name of this county to "St. John" are not justified by local usage. The name of the county is the same as that of the river which forms part of its western boundary.

†There is a strong tendency on the part of the American public to shorten this (and other names similarly formed) by leaving off the last three letters, but "Hillsborough" is still official, and preferred by the newspapers of the county and state.
Triadenum petiolatum (Walt.) Britton

On rotten logs, etc., in gum swamp about two miles south of Tallahassee. Also in the slough west of Lake Iamonia. New Jersey to Florida, Missouri and Louisiana, almost confined to the coastal plain.

Hypericum fasciculatum Lam. (Plate 22.1)

Common around small or medium-sized ponds, lakes, bays, prairies, etc., and in the treeless portions of estuarine swamps. Extends south to Palm Beach County, but is rare south of latitude 28°. Usually in damp sand, but sometimes on a few feet of peat.

The form in the estuaries of West Florida has larger leaves than the average, and may be H. galioides Lam. In low pine lands and low scrub in the lake region is the other extreme, a plant smaller in every way, which is probably H. aspalathoides Willd. But there seems to be a perfect gradation between the two extremes, and I have never been able to separate the three forms satisfactorily.

Typical H. fasciculatum is supposed to range from North Carolina to Texas, in the coastal plain.


Common in and around bays and in low pine land, in Middle Florida, from Gadsden County to Lafayette, but chiefly in the flatwoods region. Confined to Middle Florida, or nearly so.

VITACEAE. Grape Family.

Parthenocissus quinquefolia (L.) Planch. Virginia Creeper.

Mostly in hammocks, but also in rather dense swamps, whose vegetation is approaching the stage in which one may begin to class it as low hammock. Widely distributed over the State, growing on peat in Santa Rosa, Franklin, Levy, Hillsborough, DeSoto and other counties.

Widely distributed in Eastern North America. Said to occur also in the Bahamas and Cuba.

Ampelopsis arborea (L.) Rusby (Cissus stans Pers.; Vitis bipinnata T. & G.)

Mostly in calcareous swamps and rich soil; not common. Grows on more or less peat near Panasoffkee and Tarpon Springs. Virginia to Cuba, Illinois and Mexico, mostly in the coastal plain.


In hammocks and mature swamps, like Parthenocissus. Frequent in clumps of small trees in peat prairies. Common from DeSoto County northward; noticed on peat in Santa Rosa, Bradford, Lake, Polk and DeSoto Counties. Widely distributed in the Southeastern United States.
RHAMNACEAE. Buckthorn Family.

Berchemia scandens (Hill) Trel. Rattan Vine.

Very characteristic of calcareous swamps, low hammocks, etc. Wakulla, Jefferson, Duval, Putnam, Levy, Sumter and Orange Counties. Not observed in the southern half of the state.

Virginia to Florida, Missouri and Texas, mostly in the coastal plain and Appalachian valley.

ACERACEAE. Maple Family.

Acer rubrum L. Red Maple.

Common in both calcareous and non-alluvial swamps, down to about latitude 26° (New River). Not usually on the best kind of peat. (In the adjoining states it seems to avoid limestone.) The variety tridens grows in the swamps of some of the medium-sized rivers which rise and fall a few feet but are rarely or never muddy, particularly the Suwannee.

Nearly throughout temperate Eastern North America.

AQUIFOLIACEAE. Holly Family.

Ilex Cassine L. Swamp Holly.

Nearly throughout the state, in swamps whose water-level varies but a few inches during the year. (This excludes it from alluvial swamps and salt marshes, but it seems to grow equally well in calcareous and non-calcareous swamps.) It often grows on several feet of peat, as for instance in the clumps of small trees in peat prairies.

Virginia to Louisiana in the coastal plain, usually not more than fifty miles inland.

Ilex myrtifolia Walt. Yaupon or Yupon.

Common in shallow bays and cypress ponds north of latitude 30°, all the way across the State. Rarely if ever on peat deep enough to have any commercial value.

North Carolina to Louisiana, in the coastal plain.

Ilex coriacea (Pursh) Chapm.

In estuarine swamps near Milton, and in bays, etc., in Escambia, Walton, Holmes and Jefferson Counties.

Virginia to Louisiana, mostly in the coastal plain.

Ilex glabra (L.) Gray. Gallberry.

Common in low pine lands and about high-water mark on sandy shores of small lakes, in the northern half of the State. Also on peat in the estuarine swamps of Santa Rosa County, and in small peat prairies in Franklin and Lake Counties.

Nova Scotia to Louisiana, mostly in the coastal plain.
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CYRILLACEAE. Tyty* Family.

Cliftonia monophylla (Lam.) Britton. (C. ligustrina (Willd.) Spreng.) Tyty (FIG. 18.)

In bays, estuaries, etc., in which the water is sour (this excludes the Escambia, Choctawhatchee, Apalachicola and Suwannee estuaries, and all calcareous swamps) and without noticeable fluctuations. Common in nearly all the counties from Jefferson westward. (It probably also occurs in some places near the St. Marys River, like Nyssa Ogeche, but certainly not on the peninsula).

Extreme southern South Carolina to Louisiana, in the coastal plain.

Cyrilla racemiflora L. Tyty.

In somewhat similar situations to the preceding, but preferring richer soil, shallower peat, and water which is less sour and less constant in level, as in the swamps of branches and small creeks. Frequent in most of the counties north of latitude 30°. Also extends south to Alachua and perhaps even to Lake County.

Virginia to Texas, almost confined to the coastal plain.

Cyrilla parvifolia Raf. Tyty.

Almost confined to the bays of Middle Florida, from Franklin County to Lafayette. Within this range it occurs in several different regions, but is most characteristic of the flatwoods. It is often associated with Cliftonia. What seems to be the same thing grows on the shores of Lake Stanley in Walton County, and Lake Minneahaha in Lake County.

Not known elsewhere. Perhaps intergrades with C. racemiflora, from which it differs chiefly in having smaller and more persistent leaves. In large specimens a slight difference in the bark is also noticeable.

ANACARDIACEAE. Sumac Family.

Rhus radicans L. Poison Oak or Ivy.

In hammocks, rich swamps, etc., much like the Virginia creeper (with which it is sometimes confused by the uninitiated). Occurs on a few feet of peat in Santa Rosa, Franklin, Wakulla, Levy, Sumter, Polk and other counties; but as it nearly always grows on trees, such peat is not very good, being full of logs.

Widely distributed in the Eastern United States, in one form or another.

POLYGALACEAE.

Polygala cymosa Walt.

Very characteristic of cypress ponds, even as far south as Palm Beach County. Also occasionally on peat in estuarine swamps (Santa Rosa Co.), bays (Wakulla and Alachua Cos.), and wet prairies.

North Carolina to Louisiana, in the coastal plain. Also in Delaware.

*Also spelled “tietie,” “tighteye,” and “titi.”
Polygala lutea L.

Frequent in sandy bogs of various kinds, in the northern half of the State. Also in several feet of peat in an open tyty bay (or prairie) in the West Florida coast region near Carrabelle.

Long Island to Louisiana, in the coastal plain.

LEGUMINOSAE. Pea Family.

Vicia acutifolia Ell. Vetch.

In and near low hammocks in the Gulf hammock region (Taylor Co.), and on peat on Hog Island at the mouth of the Suwannee River, Levy Co.

Coastal plain of Georgia, Florida and Alabama, mostly near the coast.

Aeschynomene pratensis Small

In sloughs, etc., at the southern edge of the Everglades and in the coast prairie near by, on impure peat or marl.

Not known elsewhere.

Amorpha fruticosa L.

On river-banks and in more or less calcareous swamps. Washington, Franklin, Suwannee, Duval, Putnam and Orange Counties. On fairly good peat in the St. Johns River swamp near Palatka.

Widely but irregularly distributed in the Eastern United States.


A weed in rather rich damp soil, occasionally on peat that has been partly drained or trampled over by cattle. Seems to be commonest in the Middle Florida hammock belt.

South Carolina to Texas, in the coastal plain. Probably introduced from the tropics.

Dalbergia Brownei (Pers.) Kuntze. (Ecastophyllum Brownei Pers.)

In a mangrove swamp near Lemon City, Dade Co. Also in Brickell's Hammock, near Miami, and doubtless elsewhere in that vicinity.

South Florida and tropical America.

ROSACEAE. Rose Family.

Chrysobalanus Icaco L. Cocoa Plum.

A large shrub very characteristic of various kinds of swampy places in South Florida, such as the clumps of small trees in the southern edge of the Everglades and the adjacent coast prairie, along streams running out of the Everglades, etc. I have not seen it farther north than Palm Beach County.

South Florida, tropical America and western Africa.
Aronia arbutifolia (L.) Pers.

Sandy bogs, bays and non-alluvial swamps of various kinds, but rarely on good deep peat. Extends as far south as DeSoto County, but is not very common in Florida.

Widely distributed in Eastern North America, mostly in the glaciated region and coastal plain.

Rosa Carolina L.? Wild Rose.

Chiefly in and around calcareous swamps; hardly on good peat. Franklin. Wakulla, Duval and Levy Counties.

Said to range northward to Quebec and Minnesota.

HAMAMELIDACEAE. Witch-Hazel Family.

Liquidambar Styraciflua L. Sweet Gum.* (PLATE 19.1.)

In various habitats, but preferring hammocks, especially low hammocks. Grows also on some well-wooded and essentially mature peat deposits, especially where the soil or water is a little calcareous. In this it resembles Parthenocissus, Berchemia, and several other plants already mentioned. Common as far south as DeSoto County.

Connecticut to Mexico, mostly less than 1000 feet above sea-level.

SAXIFRAGACEAE.

Itea Virginica L.

In moderately rich or calcareous swamps; sometimes on a few feet of peat. Frequent from DeSoto County northward.

New Jersey to Arkansas, most abundant in the coastal plain.

Decumaria barbara L.

In wet woods and springy swamps, often where the water is calcareous. (Outside of Florida it seems to have no use for lime, though.) Frequent north of latitude 30°.

Virginia to Louisiana, outside of the mountains.

SARRACENIACEAE. Pitcher-Plant Family.

Sarracenia Drummondii Croom†

Common in sandy bogs, etc., from Liberty and Franklin Counties westward. Reaches its best development in the estuarine swamps of Santa Rosa County, where it grows nearly four feet tall.

Southwest Georgia to southeastern Mississippi.

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*Also called “red gum” by government foresters and Mississippi valley lumbermen, especially in recent years.

†This handsome and striking plant was described about three-quarters of a century ago by Hardy B. Croom, a noted botanist of that day, who was also the discoverer of two evergreen trees, Torreya (now Tumius) taxifolia and Taxus Floridana, which grow wild only on the east side of the Apalachicola River, as far as known, and of several other rare southern plants. His home was in eastern North Carolina, but he spent a considerable part of the last years of his life near Tallahassee, where one of his brothers had a plantation. An appropriately inscribed monument in front of the Episcopal church in Tallahassee testifies to the high esteem in which he was held by his neighbors in Florida.
Sarracenia psittacina Mx.

Often with the preceding, and ranging farther east. Grows on shallow peat in some of the bays in the flatwoods of Jefferson County. Georgia to Louisiana, in the coastal plain.

Sarracenia purpurea L.

Sometimes with the two preceding, but less common than either in Florida. Grows on shallow peat at the edges of estuarine swamps in Santa Rosa County. Widely but very irregularly distributed in temperate Eastern North America, almost confined to the glaciated region and coastal plain.

DROSERACEAE. Sundew Family.

Drosera capillaris Poir. (D. brevifolia Pursh?)

Sandy bogs, low pine lands, lake shores, etc.; common. Sometimes in bays (Leon and Jefferson Counties) and peat prairies (Lake and Polk Counties.) Not observed in the neighborhood of the Everglades.

Virginia (?) to Louisiana, in the coastal plain.

NYMPHAEACEAE. Water-lily Family.

Castalia odorata (Dryand.) Woodv. & Wood. White Water-lily.

(Water-lily Family.

Castalia odorata (Dryand.) Woodv. & Wood. White Water-lily.

(Water-lily Family.

Widely distributed in the northern half or two-thirds of the State, in permanent coffee-colored water not more than a few feet deep, either stagnant or gently flowing. (Stunted forms are often found in shallow depressions of peat prairies, where the water is never more than a few inches deep, and sometimes dries up completely.) This, like most of the other members of the family, is one of the pioneers in peat formation, such plants as the Virginia creeper and sweet gum representing the other extreme, or culmination of the series.

The variety gigantea, or latifolia, a form with considerably larger leaves, but probably not sharply distinguished from the typical plant, grows in permanent lakes, etc., in Franklin, Leon, Lake and Palm Beach Counties.

C. odorata is widely distributed in the glaciated region and coastal plain, while the variety is known only in Florida and the southern edge of Georgia.

Nymphaea orbiculata Small

In shallow lakes, marshy prairies, etc., in Middle Florida. Leon, Madison and Lafayette Counties, especially the first named.

Not known elsewhere, except in a few neighboring counties in Georgia.

Nymphaea macrophylla Small. Bonnieels. (Figs. 23, 26, 27.)

Common throughout the peninsula, in all kinds of fresh water (except muddy, which does not occur there), if not too deep, too shallow, or too shaded. Extends northwestward to the vicinity of Aucilla, Jefferson County.

Not known outside of Florida, except in a small lake in Georgia a few miles north of Hamilton County.

In creeks, rivers and estuaries from Franklin and Jackson Counties westward; not rare in West Florida. Has no objection to muddy water, and probably does not enter very largely into the composition of peat.

The range of this species is not well understood yet, but it is common in South Georgia, and probably extends northeastern to North Carolina and northwestern to the vicinity of Birmingham, Ala.

Nymphaea sagittifolia Walt.

Rather common in estuaries around Milton. Not known elsewhere in Florida, or in either of the adjoining states, but it is common near the boundary between North and South Carolina, in the coastal plain.


Grows in several of the lakes of Leon County. Also in a pool near Waldo, where it is doubtless introduced. Said to be common in Alligator Lake, Columbia County.

Widely, but very irregularly distributed in the glaciated region and coastal plain.

Brasenia purpurea (Mx.) Caspary

In several lakes and ponds in Leon County, and doubtless in some other counties in Middle Florida. It is very apt to turn up in artificial or accidental ponds as well as in natural ones.

Widely distributed in our glaciated region and coastal plain; also reported from various other parts of the world.

Cabomba Caroliniana pulcherrima Harper (Bull. Torrey Bot. Club 30: 328 1903.)

In a small estuarine creek about two miles northwest of Apalachicola. Collected by Rugel in 1843 in Lake Iamonia, Leon Co., and found by the writer in Decatur County, Georgia, in 1901.

MAGNOLIACEAE. Magnolia Family.

Magnolia glauca L. (White) Bay. (Plate 27.1. Figs. 19, 21.)

Common nearly all over the State, in swamps whose water fluctuates very little, or in soil which is always moist but never inundated. It avoids alluvial swamps and seems to prefer sour swamps, but is often found in muddy estuarine swamps, calcareous swamps, and even in low hammocks. (In other states it seems to shun limestone.) It is the most abundant tree in non-alluvial swamps in the lake region, and in clumps on peat prairies.

Long Island to Texas, mostly in the coastal plain.
ANONACEAE. Pawpaw or Custard-apple Family.

Anona glabra L. Pond or Custard Apple.

A sub-tropical fresh-water swamp plant, common around 'gator-holes in the Everglades, along the streams running out of the 'Glades, etc. It forms some peat, but generally grows in places which are not well adapted for large accumulations of it.

South Florida and the West Indies.

CERATOPHYLLACEAE.

Ceratophyllum demersum L.

Chiefly confined to gently flowing calcareous water, such as the runs of large limestone springs. Grows entirely submerged. I have noticed it in Holmes, Wakulla, Duval, Citrus, Lake and Orange Counties.

Widely distributed in the northern hemisphere.

BATIDACEAE.

Batis maritima L. Salt-water Pursley.

In shallow salt marshes, etc., along the whole length of the Florida coast, wherever conditions permit the formation of such marshes. Commonly on bare sand or rock, where no peat forms.

Georgia to Venezuela, along the coast.

AMARANTACEAE.

Acnida australis Gray. Careless. (Plate 26.1)

In large fresh or brackish marshes, especially where the water or soil is a little calcareous, as in the Everglades and some of the saw-grass marshes of the lake region. Not abundant. Sumter, Lake, Orange and Dade Counties.

Southeast Georgia (?) to the West Indies and Mexico, mostly near the coast.

CHENOPODIACEAE. Goosefoot Family.

Salicornia ambigua Mx. Samphire.

Has just about the same habitat and local distribution as Batis. Massachusetts to Texas, along the coast.

POLYGONACEAE. Buckwheat Family.

Coccolobis uvifera Jacq. Sea Grape.

A characteristic tropical shore plant, growing usually on rock or sand, but occasionally also on peat in mangrove swamps. Dade and Monroe Counties.

South Florida to Brazil.

Polygonum hirsutum Walt.

Abundant in saw-grass marshes near Eldorado, Lake County.

South Carolina to Florida.
Rumex verticillatus L.

Along comparatively large streams whose surface fluctuates very little, because of the nearness either of the ocean or of some large spring, or both. Seems to be commonest in calcareous regions, perhaps mostly because the rivers in such regions are fed largely by big springs. Franklin, Wakulla, Levy, Sumter and Putnam Counties.

Widely distributed in the Eastern United States.

LORANTHACEAE. Mistletoe Family.

Phoradendron flavescens (Pursh) Nutt. Mistletoe.

Common from DeSoto County northward, on various hardwood trees, especially on Nyssa biflora, the swamp black gum. Although it grows high above the ground, when it is in a swamp it must contribute to the formation of peat.

Widely distributed in the Eastern United States outside of the glaciated region and higher mountains.

ULMACEAE. Elm Family.

Ulmus Floridana Chapm. Elm.


Range not well understood. Probably chiefly confined to Southwest Georgia and northern and central Florida.

URTICACEAE. Nettle Family.

Boehmeria cylindrica (L.) Willd.

In damp muddy or calcareous soils, sometimes on peat, as on Hog Island and along Helena Run. Also in Escambia and Leon Counties. Not common in Florida.

Widely distributed in the Eastern United States.

CUPULIFERA. Oak Family.

Quercus nigra L. Water Oak.

Common in clayey or calcareous swamps, low hammocks, and other damp rich places of various kinds, from about latitude 28° northward. Occasionally on several feet of peat, as in the St. Johns River swamp near Palatka.

A form with narrower leaves, perhaps a distinct species, is common in low hammocks and calcareous swamps, especially in the Gulf hammock region.

Widely distributed in the Eastern United States south of latitude 39° and within a few hundred feet of sea-level, much like Liquidambar.

BETULACEAE. Birch Family.

Alnus rugosa (DuRoi) Koch. Alder.

In branch and creek swamps, usually in comparatively rich (or at least not very sour) soil, from Alachua County northward. Seen on peat only in the
estuarine swamps of the Choctawhatchee and Apalachicola Rivers (and that is very poor peat).

Nearly throughout the Eastern United States between latitudes 30° and 43°.

**Carpinus Caroliniana Walt. Ironwood.**

In low hammocks, etc., from Hernando County northward. Occasionally in calcareous swamps with shallow or poor peat, as in Wakulla, Jefferson and Duval Counties.

Widely distributed in the Eastern United States and southern Canada.

**SALICACEAE. Willow Family.**

**Salix longipes Anders.** Willow.

In swamps and ponds whose water does not flow very swiftly (if at all) or fluctuate much; especially in calcareous regions. Frequent from Wakulla County to the south end of the Everglades, particularly in the Gulf hammock region.

*S. nigra* Marsh., the common (or black) willow, grows in alluvial swamps in Middle and West Florida, but probably never on peat.

**MYRICACEAE. Bayberry Family.**

**Myrica cerifera** L. Myrtle.

Common nearly throughout the State, in hammocks (especially low hammocks) and in swamps which are rarely or never inundated. It seems to be the commonest woody plant in the middle of the Everglades. Enters very largely into peat formation, but like other woody plants, it does not make the best peat.

Delaware to Texas, in the coastal plain. Also in the West Indies.

**Myrica Carolinensis** Mill.

In sandy bogs and non-alluvial swamps west of the Tallahassee meridian (perhaps also in a few of the northeastern counties); rather rare. Contributes some to the formation of peat in a tyty swamp near Defuniak Springs.

Nova Scotia to Lake Erie, northern Florida and eastern Louisiana; almost confined to the glaciated region and coastal plain.

**Myrica inodora** Bartr.

In about the same habitats as the preceding, from Wakulla County westward; nowhere abundant. Grows on peat in the estuaries of Santa Rosa County and in some tyty bays in Walton and Franklin Counties.

Middle Florida to southeastern Mississippi.

**LEITNERIACEAE.**

**Leitneria Floridana** Chapm.

In the Apalachicola estuaries and in a few other damp places in that neighborhood; very rare. Never on good peat.

Known also in a few places in the coastal plain of Missouri and Texas.
SAURURACEAE. Lizard's-tail Family.

Saururus cernuus L.

Rather common in swamps and ponds where the water-level varies from about a foot above the surface to an inch or so below. Oftener in muddy or calcareous than in sour swamps. Sometimes in open marshes, but oftener in the shade of trees, and therefore not usually on good peat. Extends southward to DeSoto County at least.

Widely but irregularly distributed in the Eastern United States.
Epidendrum conopseum R. Br. Air-plant.

Epiphytic on the trunks of trees in the swamps bordering Lake Panasoffkee, and doubtless in many other swamps which contain poor (because woody) peat. More frequent on magnolias in hammocks. South Carolina to Mississippi, in the coastal plain.

Habenaria repens Nutt.

Floating or nearly so in the marshes at the southwest corner of Lake Minneola, and in Hicks’s Prairie, Lake County. South Carolina (?) to Louisiana, in the coastal plain. Also in tropical America.*

CANNACEAE. Canna Family.

Thalia divaricata Chapm.

In calcareous swamps and marshes, and in some of the 'gator-holes in the Everglades. Polk and Dade Counties. Not known outside of Florida.

IRIDACEAE. Iris Family.

Iris versicolor L.? Blue Flag.

Chiefly in calcareous swamps, on impure peat or almost none. Franklin, Wakulla, Jefferson, Levy, Duval, Hernando and Polk Counties. Widely distributed in temperate Eastern North America, mostly in the glaciated region and coastal plain.

AMARYLLIDACEAE. Amaryllis Family.

Hymenocallis sp. Spider Lily.

An unidentified species (or perhaps more than one) grows in more or less calcareous swamps in Sumter, Dade and various other counties.

Crinum Americanum L.

In marshes, prairies, Everglades, etc., especially in calcareous places. Santa Rosa, Franklin, Citrus, St. Johns, Palm Beach and Dade Counties. Georgia to Texas, in the coastal plain. Also in Cuba and Mexico.

HAEMODORACEAE.

Gyrotheca tinctoria (Walt.) Sal. Paint-root.

In peat prairies, slash-pine bogs, etc., generally on pretty good peat (unless it is too shallow). Rather rare. Franklin, Jefferson, Putnam, St. Johns, Lake, Orange and Polk Counties.

Massachusetts to Mississippi, in the coastal plain. Also in the West Indies?.

*See Rusby, Jour. N. Y. Bot. Gard. 7: 112-115. f. 3. 1906.
Lophiola aurea Ker

Low pine lands, sandy bogs, estuarine swamps, edges of tyty bays, etc., from Franklin and Jackson Counties westward; not common.

New Jersey to Mississippi, in the coastal plain.

SMILACACEAE. Smilax Family.

Smilax laurifolia L. Bamboo Vine.

As in the case of Magnolia glauca and several other woody plants, this prefers bogs and swamps whose water-level fluctuates very little, such as non-alluvial swamps, bays, and clumps in peat prairies. It tolerates calcareous water (in Florida, not so much in other states), but has no use for mud or salt. Common in nearly all the counties north of the Everglades, and is not unknown in Dade County.

New Jersey to Louisiana, mostly in the coastal plain.

Smilax Walteri Pursh.

In somewhat richer or more calcareous swamps than the preceding; less common. Escambia, Santa Rosa, Jackson, Wakulla, Jefferson, Madison and Levy Counties.

New Jersey to Louisiana, in the coastal plain.

JUNCACEAE. Rush Family.

Juncus trigonocarpus, Steud.

Sandy bogs and estuarine swamps in West Florida. On peat in Escambia County.

South Carolina to Mississippi; almost confined to the coastal plain.

Juncus polycephalus Mx.

Estuarine swamps of Escambia and Santa Rosa Counties.

North Carolina to Texas, in the coastal plain.


Low pine lands, low scrub, sandy shores of lakes, etc. Occasionally out in the water or on the edge of peat. Not rare in the central parts of the State. Putnam, Lake, Orange, Osceola, and several other counties.

North Carolina to Mississippi, in the coastal plain.

Juncus Roemerianus Scheele

In brackish marshes all along the coast. Also occasionally a few miles inland, in low pine land (Wakulla Co.) or in estuarine swamps (Santa Rosa Co. and Hog Island).

New Jersey to Texas, along the coast.
Juncus effusus L.

In comparatively rich low grounds, usually as a sort of weed in damp pastures, ditches, etc. Grows on very impure peat in Leon and Franklin Counties.

Widely distributed in all temperate regions, in one form or another. Our plant has recently been described by Fernald & Wiegand (Rhodora 12: 90-92, 1910) as var. sulcatus, and said to range from New Brunswick to Texas, mostly in the coastal plain.

BROMELIACEAE. Pineapple Family.

Tillandsia usneoides L. (Long or Spanish) Moss. (Figs. 24, 26.)

Abundant in nearly every county in Florida, epiphytic on all kinds of trees that have branches (this excludes the palms), usually near water or limestone, or both. It hardly ever comes nearer to the ground than five or six feet. As it grows in nearly all our swamps, it must contribute largely to the formation of peat, but of course it is not found in the best peat deposits, because those are treeless.

Virginia to Texas, almost confined to the coastal plain. Also in the West Indies.

Tillandsia spp. Air-plants. (Fig. 21.)

The farther south one goes in Florida, the larger and more numerous the species of Tillandsia become. Only one besides T. usneoides crosses the northern boundary of the State, or extends as far west as Wakulla County, but in the southernmost counties there are about a dozen. Their favorite habitat is hammocks, but several of them, such as T. tenuifolia, recurvata, fasciculata, Balbisiana and utriculata, grow also in swamps, and therefore help to form peat.

PONTEDERIACEAE. Pickerel-weed Family.

Piaropus crassipes (Mart.) Britton. Water Hyacinth.

In permanent or nearly permanent (usually coffee-colored) quiet fresh water, in lakes, estuaries, prairie holes, etc., sometimes floating and sometimes (where the water is very shallow) tightly attached to the bottom. Escaped from cultivation near Palatka about twenty years ago, and now pretty widely distributed over Florida, especially in the central portion. Abundant along the St. Johns and Withlacoochee Rivers and in the edges of some of the larger lakes. In the last decade of the 19th century it threatened to choke up some of the navigable streams, but now one hears very few complaints about it. It is certainly a handsome plant, and it seems to form peat pretty rapidly, too, as explained on page 292.

Native of South America; naturalized in Florida, Louisiana, Texas, and perhaps a few other southern states.

Pontederia cordata L. Wampee. Blue Water-lily. (Plate 25.2.)

Grows in places where the water-level fluctuates from about the surface of the ground to a few inches above. Therefore avoids alluvial swamps, where the water gets too high and too low, non-alluvial swamps, where it does not fluctuate.
PRELIMINARY REPORT ON PEAT.

enough, and shallow cypress ponds, which get too dry in spring. Common in small lakes, permanent cypress ponds, the wetter parts of peat prairies, etc. Probably occurs in every county in the State. After the water-lilies this is one of the pioneers in the formation of good peat.

Nearly throughout the glaciated region and coastal plain of temperate Eastern North America. Also reported from Central and South America.

ERIOCAULACEAE.


In wet pine lands, sandy bogs, bays, estuarine swamps (with sour water), peat prairies, etc. Common in the northern half of the State.
New Jersey to Texas, mostly in the coastal plain.

Eriocaulon compressum Lam.

In fresh marshes, peat prairies, cypress ponds, shores of small lakes, etc.; never in running water. Often on several feet of good peat. Rather common from DeSoto County northward.
New Jersey to Texas, in the coastal plain.

Syngonanthus flavidulus (Mx.) Ruhl.

Low pine lands or flatwoods, shores of small lakes, drier parts of peat prairies, etc. Common as far south as Fort Myers and Fort Lauderdale.
North Carolina to Alabama, in the coastal plain.

Lachnocaulon Beyrichianum Sporleder

Shores of small lakes and occasionally a little way out on peat, in Putnam, Lake, and other counties, mostly in the lake region.
Southeast Georgia to central Florida.

XYRIDACEAE. Yellow-eyed Grass Family.

Xyris fimbriata Ell.

Bays, shallow ponds, estuarine swamps, etc., sometimes on several feet of peat. Santa Rosa, Leon, Jefferson, and other northern counties.
New Jersey (?) to Louisiana, in the coastal plain.
Two or three other species which have not been identified (for they bloom mostly in late summer) grow in similar places, and on shores of small lakes.

MAYACACEAE.

Mayaca Aubleti Mx. (and perhaps M. fluviatilis Aubl., if that is a distinct species.)

In estuarine swamps near Milton, and non-alluvial swamps near Arcadia. Also in wet pine lands in West Florida and around ponds near Tallahassee.
Virginia to Texas, in the coastal plain.
LEMNACEAE. Duckweed Family.

**Lemna sp.**

Floats on water, generally in sluggish calcareous streams, where there is enough other vegetation to keep it from drifting out to sea faster than it grows. Leon, Wakulla, Jefferson, Citrus and Lake Counties.

ARACEAE. Arum Family.


**Peltandra Virginica** Raf.

In various marshy, marly or muddy places, widely distributed over the State, even to the south end of the Everglades. Not usually on good peat. Widely distributed in the Eastern United States, outside of the mountains.

**Peltandra sagittaefolia** (Mx.) Morong.

In bays and non-alluvial swamps; rare. Escambia, Walton, Alachua, Lake, and perhaps DeSoto County. North Carolina to Mississippi, in the coastal plain.

**Orontium aquaticum** L.

In permanent gently flowing water, neither muddy nor calcareous, especially in estuaries at the mouths of the Blackwater and Suwannee Rivers. Massachusetts to Florida, Missouri and Texas, mostly in the coastal plain.

**Pistia spathulata** Mx. Water Lettuce.

Floating in gently flowing, usually calcareous, never muddy, water. Lake, Sumter, Hernando and DeSoto Counties. Florida, Texas, and tropical America.

PALMAE. Palm Family.

**Sabal Palmetto** (Walt.) R. & S. Cabbage Palmetto.

(Plates 17, 21. Fig. 17.)

In various habitats, especially in low hammocks, where there is marl near the surface, and on borders of salt marshes. Follows the coast as far west as Washington County, and occurs in all the interior counties as far north as the southern edge of Alachua and Suwannee. Rarely more than 50 feet and perhaps never more than 100 feet above sea-level. Grows on several feet of peat in some of the St. Johns River swamps. Cape Hatteras to St. Andrews Bay, within 60 miles of the coast. (Probably not more than 25 miles inland in Georgia, or 10 miles inland in the Carolinas).
Sabal glabra (Mill.) Sarg. Palmetto.

In swamps, usually either muddy or calcareous. Occurs in most of the counties north of latitude 28°, but is not abundant in Florida. Grows on several feet of peat near Palatka, if not elsewhere.
North Carolina to Texas, in the coastal plain.

Rhapidophyllum Hystrix (Pursh) W. & D. Needle Palm.

In low, especially calcareous, hammocks, from Hernando and Orange Counties northward. Also on poor peat near the head of the Wacissa River in Jefferson County, and perhaps elsewhere.
Coastal plain of Georgia, Florida and Alabama.

Cyperaceae. Sedge Family.

Carex alata Torr.

In muddy or calcareous estuarine swamps, etc. Franklin, Levy and Sumter Counties.
Widely distributed in the glaciated region and coastal plain.

Carex Crus-corvi ShuttI.

Estuarine swamps of the Apalachicola River; not common.
Virginia to Minnesota, Florida and Texas.

Carex stipata Muhl.

In estuarine, muddy, or calcareous swamps, often with C. tribuloides. Franklin, Levy, Sumter and Lake Counties.
Widely distributed in the Eastern United States. Also reported from Japan.

Carex glaucescens Ell.

On a few feet of peat in non-alluvial swamp between Gaberonne and Bohemia, Escambia Co. Also in small branch-swamps, etc., in various other places in the northernmost counties.
South Carolina to Florida and Mississippi, mostly in the coastal plain.

Carex Walteriana Bailey

In a bay about two miles north of Greenville, Madison Co. Also in Jackson and Franklin Counties; and probably in many other places with shallow sour stagnant water.
Long Island to northern Florida, in the coastal plain.


Estuarine swamps of the Apalachicola River; not common.
Ohio to Kansas, Georgia and Texas, mostly in the coastal plain. Until recently confused with the European C. riparia Curtis and the northern C. lacustris Willd.
Carex comosa Boott  
In the calcareous swamps bordering Lake Panasoffkee and Helena Run, and in the edge of Lake Apopka near West Apopka. (Accompanied by Cicutia Curtissii at each place.)  
Said to range northward to Nova Scotia and Washington.

Carex turgescens Torr.?  
Estuarine swamps near Milton.  
North Carolina to Louisiana, in the coastal plain.

Rhynchospora ciliaris (Mx.) Mohr  
In bays in the flatwoods of Jefferson County, and in flat pine woods and other damp sandy places in many other counties in the northern half of the State.  
North Carolina to Mississippi, in the coastal plain.

Rhynchospora miliacea (Lam.) Gray  
Especially characteristic of calcareous swamps and low hammocks; rarely if ever on good peat. Wakulla, Jefferson, Duval, Levy, Orange and Polk Counties.  
North Carolina (?) to Louisiana, in the coastal plain. Also in the West Indies.

Rhynchospora fascicularis (Mx.) Vahl  
In dryish peat prairies and on the margins thereof. Franklin, Alachua, Putnam and Polk Counties.  
North Carolina to Louisiana, in the coastal plain.

Rhynchospora leptorrhyncha Sauv.  
Abundant in an open tyty bay or peat prairie about a mile north of Carrabelle. Also reported from Duval County.  
Also in South Georgia and western Cuba.

Rhynchospora axillaris (Lam.) Britton  
Peat prairies and margins of small lakes in Lake County. Also in cypress ponds and branch-swamps in various other parts of the State.  
Long Island to Louisiana, in the coastal plain.

Rhynchospora Tracyi Britton  
Peat prairies, estuarine marshes, Everglades, etc. Abundant where it grows, but not at all common. Santa Rosa, Polk and Dade Counties.  
South Florida to Southwest Georgia and southern Mississippi.

Rhynchospora corniculata (Lam.) Gray  
Fresh marshes and swamps of various kinds, especially calcareous. Widely distributed over the State, but not abundant.  
Delaware to Missouri, Florida and Texas, mostly in the coastal plain.

Very abundant in nearly all large fresh marshes, such as the Everglades. Also turns up rather unexpectedly in various small shallow ponds, and even in low pine lands, in which cases I take it to indicate limestone near the surface. Grows in every county, with the possible exception of a few of the northernmost ones, such as Holmes, Gadsden and Hamilton. Rarely more than 100 feet above sea-level. Forms vast quantities of peat, which is not usually of the best quality for briquetting, etc., because it is apt to be rather coarse and fibrous.

Virginia to Texas, in the lower parts of the coastal plain (rarely more than 100 feet above sea-level). Also in the West Indies.

Dichromena latifolia Baldw

Wet pine lands, shallow ponds, etc., in the northern half of the State, especially in the East Florida flatwoods. Also on shallow peat in estuarine marshes in Santa Rosa County.

North Carolina to Texas, in the coastal plain.

Dichromena colorata (L.) Hitchcock

In brackish, calcareous, and estuarine marshes, prairies, Everglades, etc. Widely distributed over the State (not yet observed in West Florida), but not abundant.

New Jersey to Texas, in the coastal plain. Also from Bermuda to Brazil.

Psilocarya sp.

In Hicks's Prairie (a wet saw-grass marsh) northeast of Eustis, and in shallow water in Lake Dora near Tavares.

Fimbristylis spadicea (L.) Vahl

In brackish marshes a few miles west of Apalachicola (doubtless in many other places near the coast), in the peat marsh bordering Crescent Lake, in the sandy prairies bordering Lake Harney, and in narrow marshes along the Miami River about two miles from its mouth.

Virginia to Brazil, mostly along the coast.

Eleocharis interstincta (Vahl) R. & S.

In boggy places where the water-level fluctuates from the surface of the ground to a foot or so above, and has no current: as in some ponds and the wetter peat prairies. Rather rare. Often accompanied by Pontederia. Walton, Leon, Madison, Sumter, Lake and Polk Counties.

Massachusetts to Michigan, in the glaciated region; south to Florida and Mexico in the coastal plain. Also reported from the West Indies.

Eleocharis Robbinsii Oakes

Shallow margin of Lake Stanley, Walton County.

New Brunswick to Michigan, in the glaciated region. Also in a few places in the coastal plain of North Carolina, Georgia and Florida.

In shallow water which is permanent or nearly so and has a gentle current. Estuarine marshes between Milton and Bagdad; Clear Lake, back of West Palm Beach; and in sloughs at the southern and southeastern edges of the Everglades.

Florida to Mexico; also in the West Indies.

All the species of *Eleocharis* are moisture-loving plants, and a few others which have not been identified occur in bays, marshes, lakes, etc. Two especially are very abundant in the Crescent Lake marsh.

Scirpus Cubensis Poeppig & Kunth

Floating with water-hyacinths, etc., in the Withlacoochee River near Ichsta-chatta and at the southwestern corner of Lake Minneola, near Clermont.

Introduced from the tropics.

Scirpus lineatus Mx.? (PLATE 19-2)

In springy places at the edge of the Apalachicola River swamp in Jackson County, and in the swamps of Hog Island at the mouth of the Suwannee River.

Widely but irregularly distributed in the Eastern United States.

Scirpus validus Vahl


Widely distributed in temperate North America. By some authors united with the European *S. lacustris* L.

Four or five other species of *Scirpus* occur in wet places in Florida, and may contribute to the formation of peat.

Fuirena scirpoidea Mx.

Frequent on margins of lakes, sometimes in the water and sometimes on shore. Also in peat prairies, estuarine marshes, etc., and more rarely in low pine lands. Escambia, Santa Rosa, Wakulla, Clay, Lake, Polk and Dade Counties.

Southeast Georgia to Louisiana, in the coastal plain.

Dulichium aundinaceum (L.) Britton

In a creek-swamp near Milton, also in bays, in Leon, Jefferson and Madison Counties, always in sour water.

Nearly throughout the glaciated region and coastal plain; also in the mountains of Maryland, Kentucky and Alabama.

Cyperus Haspan L.

In fresh marshes near Escambia, Milton, Crescent Lake and West Apopka.

Virginia to Texas, in the coastal plain. Also in the tropics.
Cyperus virens Mx.

Estuarine swamps or marshes of the Escambia and Apalachicola Rivers.
North Carolina to Central America.

GRAMINEAE. Grass Family.

Phragmites communis Trin. Reed-grass.

In large fresh marshes, such as the Everglades, and along estuaries and lakes, especially where the water is a little calcareous. Escambia, Walton, Washington, Franklin, Levy, Citrus, Lake and Dade Counties.
Widely distributed in the North Temperate Zone.

Spartina Bakeri Merrill. (Plates 24.2, 26.2.)

Grows just about high-water mark on the borders of lakes, open ponds, marshes, peat prairies, etc. Occasionally abundant well out on prairies and marshes, on several feet of peat (especially in the Julington Creek and Crescent Lake marshes, described on pages 287-289, and scattered over the southern portion of the Everglades. Pretty widely distributed over peninsular Florida. Franklin, Duval, St. Johns, Putnam, Volusia, Lake, Orange, Osceola, Polk and Dade Counties.

Found once by the writer near Brunswick, Ga. Otherwise not known outside of Florida.

Spartina glabra Muhl. (Plate 17.)

Abundant in salt marshes in the northern half of the State. Franklin, Nassau, Duval, St. Johns, Levy and Volusia Counties.
Maine to Texas, along the coast.
S. juncea (Mx.) Ell. occasionally grows with it, or in the drier parts of the same marshes, near Cedar Keys at least. It is said to range from Newfoundland to Texas.

Homalocenchrus hexandrus (Sw.) Kuntze

In shallow water, Hicks's Prairie, Lake County.
Eastern North Carolina to Argentina, etc.

Zizania aquatica L. Wild Rice.

Estuaries of the Escambia, Blackwater, Choctawhatchee, Apalachicola and Suwannee Rivers.
New Brunswick to Manitoba, in the glaciated region, south in the coastal plain to Texas. Also reported from Eastern Asia.

Chaetochloa magna (Griseb.) Scribn. (Swamp Millet).

In marshes and prairies which have been ditched or otherwise tampered with. Lake, Manatee and Dade Counties.
Introduced from the West Indies.
Panicum gibbum Ell.

In swamps of various kinds in Escambia, Santa Rosa and Walton Counties, and on shallow margin of Lake Harris near Eldorado, Lake County. Rather rare.

New Jersey and Missouri to Guiana.

Panicum virgatum L.

In estuarine marshes of the Escambia and Yellow Rivers, and on the borders of the Julington Creek marsh described on page 287. Widely distributed in the Eastern United States.

Panicum verrucosum Muhl.

In non-alluvial swamps in Escambia and Jackson Counties. Massachusetts to Indiana, Florida and Texas, mostly in the coastal plain.

Panicum erectifolium Nash

Grassy prairies in Osceola and DeSoto Counties. Also in cypress ponds, etc. North Carolina to Louisiana, in the coastal plain. Also in western Cuba.

Panicum hemitomon Schult. (P. digitarioides Carpenter). Maiden Cane.

Very characteristic of shallow water of lake margins, especially in the lake region: Also in other stagnant water, such as cypress ponds and the wetter parts of peat prairies; often with Pontederia. Walton, Franklin, Leon, Madison, Putnam, St. Johns, Volusia, Lake, Sumter, Polk and Palm Beach Counties. Contributes abundantly to the formation of some of our best peat.

New Jersey to Texas, in the coastal plain.

Panicum geminatum Forsk.

In large lakes, sluggish calcareous streams, etc., usually in water a foot or more in depth. Citrus, Sumter (pond near Wildwood), Lake (Lakes Griffin, Harris and Dora), and Dade (sloughs at south end of the Everglades). Florida, Texas, tropical America, Egypt, Asia and Australia.

Echinochloa Crus-Galli (L.) Beauv.?

In bayous in the calcareous swamps of Lake Panasoffkee and Helena Run. In all temperate and warmer regions of the earth, in one form or another.

Amphicarpum Floridanum Chapm.?

Dryish peat prairies in Lake and Polk Counties; not common. Not known outside of Florida.

Paspalum mucronatum Muhl. P. fluitans Kunth.

Floating with water-hyacinths in the Withlacoochee River near Istachatta. Virginia to Florida, Illinois and Texas, in the coastal plain. Also in tropical America.
Andropogon sp. (perhaps several of them). Broom-sedge.

Common in dryish peat prairies, etc., in Duval, Putnam, Alachua, Lake, Orange, Osceola, Polk and DeSoto Counties. (Most of them bloom in the fall, so that I have not been able to identify them).

Erianthus sp. (perhaps two or three. These, too, bloom in the fall).

In saw-grass marshes, slash-pine bogs, cypress ponds, etc.; not common. Jackson, Leon, Duval, Lake, Orange and Polk Counties.

HYDROCHARITACEAE. Frog's-bit Family.

Limnobium Spongia (Bosc.) L. C. Rich.

In calcareous streams in Jefferson County, and in pools in a non-alluvial swamp about two miles south of Leesburg. Doubtless in many other places, mostly in permanent water.

Ontario to Florida and Louisiana, mostly near the coast.

Vallisneria spiralis L. Eel-grass.

All submerged but the pistillate flowers, in the St. Johns River near Palatka (and doubtless many other places), and in Lakes Harris and Apopka. Doubtless grows on the outer edge of many peat deposits that are advancing into large lakes and estuaries.

Widely distributed in temperate regions where there are large bodies of still fresh (or even slightly brackish) water, as in our glaciated region and coastal plain.

ALISMACEAE. Water-plantain Family.

Sagittaria latifolia Willd. Arrowhead.

In wet muddy or marly places; not common in Florida. Escambia, Leon, Madison, Lake (Helena Run) and Dade (head of Miami River) Counties.

Widely distributed in temperate North America.

Sagittaria lancifolia L. Wampee?

Very characteristic of saw-grass marshes, lake margins, wet prairies, and various other kinds of exposed wet places, especially where there is limestone in the water or near the surface. Widely distributed over the State, perhaps in every county which has considerable areas below the 100-foot contour.

Delaware to Central America, usually within 50 miles of the coast.

Sagittaria natans Mx.

Chiefly in calcareous springs and streams; all submerged but the flowers. Jackson, Wakulla and Citrus Counties. Lee County (Hitchcock).

South Carolina to Alabama, in the coastal plain.
Potamogeton sp. (probably several of them). Pondweed.

In Lake Iamonia, Lake Lafayette, Lake Dora, the St. Marks River, and various other quiet waters. There is one species in the southern part of the Everglades and the adjacent coast prairies which is probably different from any of those farther north.

**TYPHACEAE.** Cat-tail Family.

**Sparganium sp.**

Around a pond about three miles northeast of Tallahassee, and in the Waccasassa River, Levy County.

**Typha latifolia L.** Cat-tail.

Lake margins, estuaries, large fresh marshes, etc.; not common. Escambia, Santa Rosa, Walton, Franklin, Citrus, Lake and Dade Counties.

Widely distributed in the north temperate zone, but absent over large areas.

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**CONIFERAE.** Pine Family.

**Juniperus Virginiana L.** (Red) Cedar.

Mostly in low calcareous hammocks, but occasionally on poor peat, as at the mouths of the Choctawhatchee, Apalachicola and Suwannee Rivers, and on the borders of salt marshes near Titusville. Most frequent in the Gulf hammock region, but not very abundant anywhere in Florida.

Widely but irregularly distributed in temperate Eastern North America, mostly in limestone regions.

**Chamaecyparis thyoides** (L.) BSP. Juniper.

In sour, or at least decidedly non-calcareous, swamps in the West Florida pine hill region from Liberty County westward. Abundant on peat (often 15 or 20 feet of it) in the estuarine swamps of the Blackwater River and its tributaries in Santa Rosa County.

Maine to Louisiana, in the glaciated region and coastal plain; but rare in some of the intervening states, especially in Georgia.

**Taxodium distichum** (L.) Richard. (River) Cypress.

(Plates 20.1, 21.1, 25.1, 26.2. Figs. 17, 26.)

Chiefly in alluvial or calcareous swamps. Widely distributed over the State, perhaps in every county. Abundant among the large lakes and saw-grass marshes of central Florida. Not usually on good peat.

Delaware to Florida, Indiana and Texas, almost confined to the coastal plain.
Taxodium imbricarium (Nutt.) Harper. (Pond) Cypress.

(Plates 22.2, 23, 27.2, 28. Fig. 24.)

Abundant in cypress ponds, bays, non-alluvial swamps, etc., in all the counties north of latitude 29°, with the possible exception of Marion. Farther south it is more scattered, being quite uncommon in the lake region. It is abundant, however, in Pasco and Hillsborough Counties and the northern parts of Osceola and Brevard, and I have seen it in a few places in Lake, Orange, Palm Beach and Dade. It grows on deep but impure peat in the estuarine swamps of Santa Rosa County.

North Carolina to Louisiana, in the coastal plain.

Pinus Elliottii Engelm. Slash Pine.

(Plates 22.1, 23.1, 28. Fig. 20.)

Very common in bays in Middle Florida and in cypress ponds in East Florida, and in various kinds of non-alluvial swamps, sphagnous bogs, and wet pine lands, as far south as DeSoto County. Not abundant in West Florida. Never in permanent water. Grows on several feet of peat in the estuaries of Santa Rosa County and the slash-pine bogs of Lake, Polk and Hillsborough, but elsewhere usually in sand.

South Carolina to Mississippi, in the coastal plain.

Pinus serotina Mx. Black Pine.

In sour sandy swamps, bays, etc., from Walton County on the west to the northern parts of Brevard and Osceola on the south; avoiding distinctly calcareous regions like the West Florida limestone region, the lime-sink or phosphate region, and the Gulf hammock region. Grows on several feet of peat in the landward part of the river swamp near Palatka, and in shallow peat in many of the Middle Florida bays, but elsewhere usually in sand. Although it has no use for limestone, it is often found pretty close to places where there seems to be marl near the surface, especially in the northern edge of the South Florida flatwoods, and near the St. Johns River. Perhaps the reason for this is to be sought in some peculiarity of the water supply in such places.

Extends northeastward to Virginia in the coastal plain, and has recently been found in southern New Jersey.
ISOETACEAE. Quillwort Family.

*Isoetes flaccida* Shutt.

In the swamps of Hog Island, at the mouth of the Suwannee River, South Georgia and Florida.

LYCOPODIACEAE. Club-moss Family.

*Lycopodium alopecuroides* L. Ground-pine.

In estuarine swamps of Bayou Texar, Escambia County, and in bays between Capitola and Fanlew, in Leon and Jefferson Counties. Commoner in sandy bogs, especially in West Florida.

Long Island to Mississippi, mostly in the coastal plain.

*Lycopodium Chapmani* Underw.

Abundant on rather dry peat prairies and sandy shores of small lakes in Lake and Polk Counties. Reported from Lee and Dade Counties by Mr. A. A. Eaton.

Massachusetts to Louisiana, in the coastal plain.

SALVINIACEAE.

*Azolla Caroliniana* Willd.

Floating in ditches in the Julington Creek marsh, among the water-hyacinths in the Withlacoochee River near Istachatta, and near the head of the Wacissa River in Jefferson County.

Widely distributed in temperate North America, mostly near the coast.

FILICES. Ferns.

*Nephrolepis exaltata* (L.) Schott Sword or Boston Fern.

In non-alluvial swamps near Arcadia, DeSoto Co. Also in tropical hammocks in Dade County.

South Florida and tropical America.

*Dryopteris unita* (L.) Kuntze

In non-alluvial swamps with rather shallow peat. Lake, Orange, Polk and DeSoto Counties.

South Florida and the West Indies.

*Dryopteris Thelypteris* (L.) Gray

In calcareous swamps, nearly mature peat bogs, etc., in Hernando, Sumter and Lake Counties. Also in the estuarine swamps of the Choctawhatchee River.

Widely distributed in temperate Eastern North America, at least in the glaciated region and coastal plain.
Lorinseria areolata (L.) Presl

In non-alluvial and chiefly non-calcareous swamps, sometimes on a few feet of peat; not rare. Jackson, Gadsden, Leon, Jefferson, Bradford, Putnam, Lake, Orange, and several other counties.

Widely distributed in the Eastern United States.

Anchistea Virginica (L.) Presl

Always in wet places, but never in permanent or flowing or calcareous water. Abundant in cypress ponds, bays, slash-pine bogs, etc., and in the shade of clumps of small trees on peat prairies, as far south as Hillsborough and Polk Counties. (Mr. A. A. Eaton has reported it as far south as Fort Myers and Fort Lauderdale.)

Nova Scotia to Michigan in the glaciated region, south to Florida and Texas in the coastal plain. Also in a few places among the lower mountains of Georgia and Alabama.

Blechnum serrulatum Mx.

In non-alluvial swamps, frequent from Lake County to the south end of the Everglades.

Also in tropical America.

Polypodium polypodioides (L.) Hitchcock. (P. inceanum Sw.)

A common epiphyte in swamps and hammocks nearly all over the State; ultimately passing into either peat or humus with the tree on which it grows.

Widely distributed in the Southeastern United States and tropical America.

Acrostichum aureum L.

Common on the borders of salt and brackish marshes, mangrove swamps, etc., in South Florida. Reported by Prof. Hitchcock as far north as Hernando County. (There are said to be two species of Acrostichum in Florida, but I have not learned to distinguish them.)

South Florida and the tropics.

Ceratopteris thalictroides Brong. Floating Fern.

Among water-hyacinths in the Withlacoochee River near Istachatta; rare. Said to occur also on the upper St. Johns River.

Florida, Louisiana, and the tropics.

Osmunda cinnamomea L. Cinnamon Fern.

In sandy bogs, low pine lands, non-alluvial swamps, etc., and among trees in peat prairies. Common in the northern half of the State, and extending at least as far south as Arcadia (and even to Monroe County, according to A. A. Eaton).

Nearly throughout the Eastern United States and adjacent Canada. Also reported from the West Indies, South America, Eastern Asia, etc.

Osmunda regalis L.

Often with the preceding, but usually in richer or more calcareous places. Probably grows in every county in Florida, but is not abundant.

Said to be as cosmopolitan as the preceding; but some authors consider the American plant a distinct species from the European one.
MUSCI. Mosses.

Thuidium sp.
In non-alluvial swamps in Leon, Lake and DeSoto Counties. Also in damp woods of various other kinds.

Leucobryum glaucum (L.) Schimp.
In a gum swamp about five miles west-northwest of Tallahassee.

Sphagnum macrophyllum Berth.
In shallow bays in Jefferson County, etc.
New Jersey to Alabama, in the coastal plain.

Sphagnum sps. Peat Mosses.
Several other species occur in various parts of Florida, mostly in non-alluvial swamps, slash-pine bogs, bays, and other wet shaded non-calcareous places. They are most common northward, and I have not noticed any farther south than DeSoto County.

HEPATICAE. Liverworts.

Pallavicinia Lyellii (Hook.)
On the ground and roots of trees in non-alluvial swamps in Leon, Lake, Polk and DeSoto Counties; not rare.
(Many other liverworts, as well as mosses, grow on trunks of trees in swamps of all kinds, but they contribute such an infinitesimal share to peat formation that they are hardly worth mentioning in a treatise of this kind.)

CHARACEAE.

Chara sp.
Entirely submerged in estuaries of the Blackwater River, Santa Rosa County. Something very similar grows in Ponce de Leon Spring, Holmes County, and doubtless in many other deep bodies of fresh water.
Some statistics of more or less interest may be deduced from the foregoing list of plants. In the first place, just about 40% of the angiosperms are monocotyledons. (The proportion for the whole world, counting plants of uplands and lowlands both, seems to be about 20%. For North America alone the figures are probably a little higher.) This accords well with the prevailing belief that monocotyledons are especially characteristic of new regions and wet places.

Of 235 native species whose ranges are pretty well known, about 57% are confined to the coastal plain, at least as far as their distribution on the North American continent is concerned. This 57%, however, includes quite a number which do not approach the fall-line (inland boundary of the coastal plain) at all, some of them being confined to the immediate vicinity of the coast because they require salt water, and others to South Florida because they require a warm climate. Many of the latter are equally at home in the West Indies, where there is no coastal plain. About 8% grow both in the glaciated region and coastal plain, but are not known in the intervening Metamorphic and Paleozoic regions. About 16% occur both in the coastal plain and the highlands, but not as far north as the glaciated region. Some of these, however, are very rare outside of the coastal plain, having been seen only once or twice in the metamorphic region of Georgia or Alabama (where this region has its southernmost extension). About 19% are widely distributed in the eastern United States, being found in the glaciated region and coastal plain and many places between.

Considering now their distribution outside of the United States, about 21% (of these same 235) are found in the West Indies or elsewhere in the American tropics, but not in the Old World. About 3% occur in Europe or Asia but not in tropical America, and 5% are essentially cosmopolitan. The remaining 71% are confined to North America, as far as known.
BIBLIOGRAPHY.

This is divided into two parts; the first including works relating to peat of other states or peat in general, and the second, those relating to the geography or peat resources of Florida.

Much more extensive bibliographies than this, which will be useful to any one who wishes to go into the subject deeply, can be found in several of the works named in the first list. Most of the older books cited by other writers on peat have not been accessible to me, however, and this list does not aim to be complete, but merely to give references to a few of the more important recent papers on the subject. Those relating exclusively to peat machinery or methods of utilization are not mentioned.

The second list includes titles of nearly everything that has been published (outside of newspapers and other ephemeral publications) on Florida peat, as well as several important works of a geographical nature which have been consulted in preparing the descriptions of the natural divisions of the state. (A few of the papers in the first list also contain incidental references to Florida.) Many other more or less geographical titles can be found in the bibliography of Florida geology by Dr. Sellards, in the first annual report of this Survey.

For the benefit of readers who may not be familiar with modern methods of bibliographic citation a brief explanation of the system used will not be out of place. In the case of magazine articles, the title is followed by the name of the magazine (often abbreviated), the volume number—or year for annual publications with no separate volume number—in Arabic; a colon; the first and last pages of the article, connected by a short dash or hyphen (even if the article occupies only two pages); the numbers of the illustrations, if any (pl. meaning plates and f. figures in the text); and finally the date (giving the real date when known, which is often different from the alleged date, especially in State and government publications and in magazines). In a few cases (Science for example) where a magazine has changed hands and taken a new start, with new volume numbers, a series number has to be used, and this is placed before the volume number, in Roman figures, followed by a period.* This is the only use made of Roman numerals in this

*The volumes of the American Journal of Science are divided into series of 50 each, but as this division is purely arbitrary, and the volumes are numbered from the beginning as well as in series, there seems to be no sufficient reason for citing the series numbers, as nearly everybody has been doing for the last 60 years or so.
system, except where prefatory pages numbered with such figures have to be cited.

The system just described is essentially that used by most American botanists (outside of New England) at the present time, and its advantages over the awkward and antiquated methods of using Roman volume numbers, parentheses, the abbreviation pp., etc. and sandwiching dates in between volume and page numbers, as still practiced by several other classes of scientists, ought to be self-evident.

Bulletins, monographs, and annual reports of geological surveys, proceedings of learned societies, etc., are treated in about the same way. Where a work cited forms a volume by itself the total number of pages and illustrations—instead of the first and last—and the city where published are usually given.

The names of authors are arranged alphabetically, and where two or more papers by the same author are mentioned these are arranged chronologically.

GENERAL WORKS.

ASHLEY, G. H. The maximum rate of deposition of coal. Econ. Geol. 2: 34-47. f. 2-6. 1907.

Contains valuable data on the rate of accumulation of peat.


An interesting study of the development of a peat bog, which has some bearing on Florida problems.


Contains many analyses and a bibliography of Iowa peat (the latter compiled by J. H. Lees). Although the author makes no record of the fact, summer is the wet season in Iowa, as in Florida, and this has doubtless favored the accumulation of peat in a comparatively dry climate.


Contains a brief mention of Florida peat, among other things.


Notes on peat on pages 645-648, 663-666.
Contains valuable notes on the formation of bogs.

Besides covering the subject of Michigan peat, this is the most extensive work on peat in general which has appeared in this country in recent years. By order of the state geologist, nearly all the plants mentioned in this report are given "English names," which in the case of many of the rarer species are merely translations of the technical names, and therefore meaningless to the non-botanical reader. The work contains an extensive bibliography, though most of the citations give no page numbers.


This is one of the very few papers devoted to coastal plain peat.

Doubtless the most accurate account of salt marsh formation yet published. The general principles ought to apply almost as well in northern Florida.

Davis, C. A. See also Bastin & Davis.

Früh, J., & Schröter, C. Die Moore der Schweiz, mit Berücksichtigung der gesamten Moorfrage. xviii+751 pp., 4 plates, 45 figs., and map. Bern, 1904. (Not seen).
Reviewed by Ganong in Science II. 21: 424-425. Mar. 17, 1907. This is said to be one of the most comprehensive works on peat there is, by two of the foremost European authorities on the subject.


PRELIMINARY REPORT ON PEAT.


KÜMMEL, H. B. The peat deposits of New Jersey. Econ. Geol. 2: 24-33, f. 1. 1907. Essentially a resume of the report of Parmelee & McCourt, mentioned below.


PAMMEL, L. H. Flora of northern Iowa peat bogs. Iowa Geol. Surv. 19: 735-777, f. 106-117. *1909* (1910). (Also reprinted, with the addition of a 7-page index, as Contr. Bot. Dept. Iowa State Coll. No. 40). Contains list of 255 native and introduced Iowa bog and marsh plants, with a considerable number from other states interpolated; also a bibliography, with many of the dates lacking. It is interesting to note that according to the list of plants there are no Ericaceae and no Sphagnum in the Iowa bogs. One of the causes of this state of affairs is probably the predominantly calcareous soil of Iowa.


A pretty good paper, though chiefly compiled from various earlier non-botanical publications. Contains a bibliography, with most of the titles incomplete.


Contains a rudimentary classification of swamps, which has been copied faithfully, without any attempt to improve on it, by many subsequent writers.

Swamp soils and marine marshes discussed on pages 311-320.


One might suppose from reading this otherwise excellent paper that there were a great many more species of bog plants in the glaciated region than in the coastal plain, and very few in Florida; which is decidedly not the case.

A description of a case of peat formation determined by climatic rather than topographic conditions, with references to similar phenomena in other parts of the world.


For further description of this locality see paper by Chrysler, cited above.
FLORIDA.


The plates include several photographs of the Everglades, probably the first ever published, at least in scientific literature. Some of them are rather poor, but they were doubtless taken under considerable difficulties.


This is probably the most comprehensive of all the numerous magazine articles on Florida which have been published in recent years. Contains several views of the Everglades.


Relates mostly to Florida peat, from near Orlando.


Describes the author's peat plant near Orlando.


Contains many notes on topography and speculations on geographical history.


Lists 15 species of recent shells from peat near Lake Panasoffkee.

[ELLISOT, H. S., compiler.] Florida. A pamphlet descriptive of its history, topography, climate, soil, resources and natural advantages, in general and by counties. Prepared in the interest of immigration by the Department of Agriculture. 591 pages and several half-tone plates. Tallahassee, 1904.

A little-known book, of which only about 1,000 copies were printed. Contains considerable geographical information which is not found elsewhere. Unfortunately, the county descriptions in most cases were prepared by persons each of whom was trying to prove his own county the best in the State, and this naturally gives rise to some extravagant statements.


Contains some interesting geographical information, but is marred by numerous errors, which are almost unavoidable in such compilations.

FLORIDA GEOLOGICAL SURVEY—THIRD ANNUAL REPORT.

Contains valuable information about the topography of Middle and East Florida, Bay Swamp, Saint Pedro Bay, etc.


GRISWOLD, L. S. See AGASSIZ.

Contains valuable data as to altitudes in South Florida, etc.


Contains brief sketch of the phytogeography of the vicinity of Fort Myers.

Analyses and tests of peat from near Orlando.


Taken for the most part from the preceding and from an article by Dix & MacGonigle in the Century for February, 1905. The author makes some errors in discussing the geology and botany, but points out that the limestone between the Everglades and Biscayne Bay is not coral, which is very true.

Contains valuable notes on the plant geography of the lake region, in the vicinity of Eustis.

A valuable compendium of information, impartial and for the most part accurate. Descriptions of the counties, with map of each, on pages 1-102.


Notes on Everglades peat on pages 193 and 228.


Peat and diatomaceous earth discussed on pages 37-39.


Peat and diatomaceous earth discussed on pages 243-245.


This is in many ways the best geographical description of Florida ever published. The geology and soils of the whole State are described in a general way, and the geographical features of each county are discussed separately. The contents of the most important previous publications on Florida are also summarized.


Contains a great deal of interesting geographical information, surprisingly accurate for that early date. Includes a classification of soils and vegetation, with the following divisions:—Flat pine lands, undulating pine lands, low hammock, high hammock, oak and hickory lands, scrub lands, pine land savannas, hammock savannas, river swamps, cypress swamps, fresh marshes and salt marshes. (This is more complete than some which have been published during the present century.)


Williams, J. L. A view of West Florida, embracing its geography, topography, &c., with an appendix, treating of its antiquities, land titles, and canals, and containing a map, exhibiting a chart of the coast, a plan of Pensacola, and the entrance of the harbour. 178 pp. and folded map. Philadelphia, 1827.

A remarkable work for that time, full of valuable information of all kinds. The trees, shrubs, herbs, vines, grasses, etc., of swamps and marshes are listed on pages 53-62, with both technical and common names. ("West Florida" at that time extended east to the Suwannee River, thus including what is now called Middle Florida.) The same author ten years later published a more comprehensive work, entitled "The Territory of Florida," which I have not seen.

INDEX OF PLANT NAMES.

This includes the technical and common names of plants mentioned in this volume (nearly all of which are in the peat report), and of the plant families listed in the catalogue of peat-forming plants which occupies pages 316 to 357. Common names are here enclosed in quotations, to enable the non-botanical reader to pick them out more readily, and the few synonyms of technical names are italicized. Numbers in parentheses indicate pages where certain plants are inadvertently mentioned under different names.

The last number given for each species is in most cases that of the page of the catalogue where its distribution within and without the State is summed up. Species which are not mentioned beyond page 316 (there are about 110 in this category) are not regarded as peat-forming plants, but are described as occurring in various situations which are not permanently saturated with water. About 30 species whose names occur only in the catalogue have been seen on peat in Florida only once or twice, and are for that reason not mentioned in the habitat lists in the first half of the report. The genuine peat plants comprise about 245 species. Of these, those which are not mentioned more than once before page 313 are as a rule comparatively rare and unimportant in the swamps, bogs and marshes of this State. Conversely, the most abundant or conspicuous or characteristic peat-forming plants are mentioned oftenest.

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